



**Riversdale Resources
Grassy Mountain Coal Project:
Surface Water Quality
Assessment Report**

August 2016

Prepared for:

Benga Mining Limited
Blairmore, Alberta

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RIVERSDALE RESOURCES GRASSY MOUNTAIN COAL PROJECT: SURFACE WATER QUALITY ASSESSMENT REPORT

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1.0 INTRODUCTION

Benga Mining Limited (Benga), a wholly-owned subsidiary of Riversdale Resources Limited (Riversdale), is proposing to construct and operate the Grassy Mountain Coal Project (the Project), an open-pit metallurgical coal mine at Grassy Mountain, near the Crowsnest Pass, approximately 7 km north of Blairmore in south-west Alberta ([Figure 1](#)).

The project's proposed production capacity would be a maximum of 4.5 million tonnes of clean coal per year, over a mine life of 24 years. The mine permit area (MPA) straddles the watersheds of Blairmore Creek and Gold Creek, both tributaries of the Crowsnest River. Together, these tributaries represent approximately 20% of the watershed area of the Crowsnest River.

This report presents an Environmental Impact Assessment (EIA) of the Project with regard to surface water quality. This report was prepared by Hatfield Consultants Partnership (Hatfield) for Benga as a component of an integrated formal application for the Project. A baseline environmental study was completed to support EIA for the Project. The objective of this water quality assessment was to summarize baseline surface water quality and assess potential impacts to surface water quality for the Project based on outputs of water quality models built by SRK Consulting Inc. (see Appendix 10B in the Application for details [Benga 2016]). Seasonal water quality data collected in 2013, 2014, 2015, and 2016, and available historical data are included in this report. The Water Quality section of the EIA addresses all relevant EIA Terms of Reference (TOR; AER 2015), which require evaluating the Project's effects on surface water quality.

1.1 TERMS OF REFERENCE

The format and contents of this EIA report are guided by the Final Terms of Reference (ToR) (AER 2015) and CEAA Guidance for the preparation of EIA Report for the Project (CEAA 2012). While these two documents outline the format and contents for the entire regulatory application and EIA (i.e., all environmental disciplines), this report addresses only the specific components that are relevant to surface water quality and summarized in [Table 1](#) and [Table 2](#).

Table 1 Terms of Reference sections applicable to this assessment (from AER 2015).

Section 4.4 Surface Water Quality	Report Section
4.4.1 Baseline Information	Section 3.2
[A] Describe the baseline water quality of watercourses and waterbodies. Discuss the effects of seasonal variations, flow and other factors on water quality.	Section 3.2.3, 3.2.5
4.4.2 Impact Assessment	Section 4
[A] Identify Project components that may influence or impact surface water quality.	Section 2.1
[B] Describe the potential impacts of the Project on surface water quality:	Section 4
a. discuss any changes in water quality resulting from the Project that may exceed the <i>Surface Water Quality Guidelines for Use in Alberta</i> or the <i>Canadian Water Quality Guidelines</i> ;	Sections 4.1.1.3, 4.2.1.3, 4.6, Table 18
b. discuss seasonal variation and potential impacts on surface water quality;	Section 4.1.1.3, Table 15

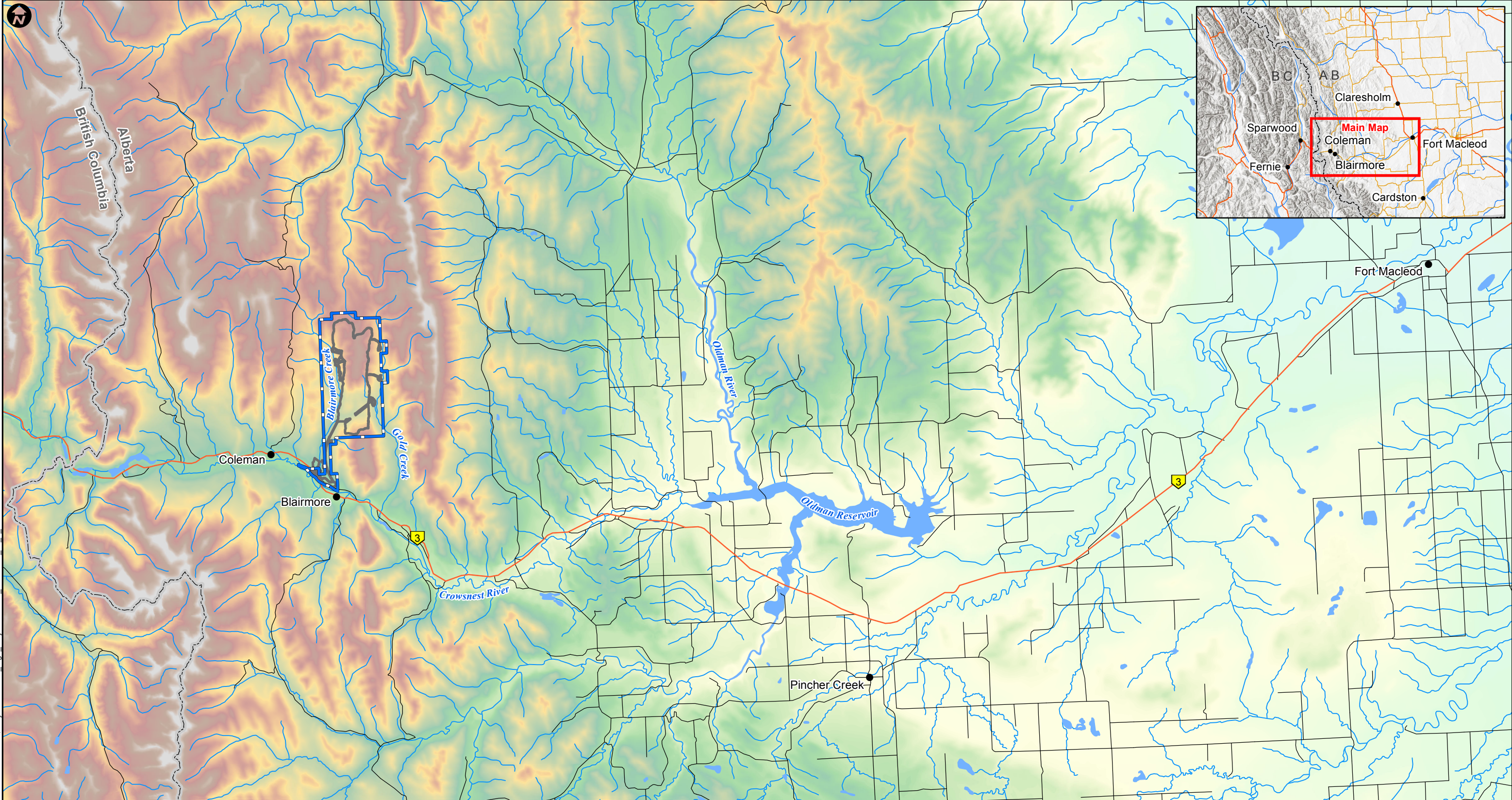
c. assess the potential project-related and cumulative impacts of acidifying and other air emissions on surface water quality;	Section 4.5
d. discuss the effects of changes in surface runoff or groundwater discharge on water quality in surface waterbodies.	Section 4.1.1.3, 4.6
Section 6.0 Traditional Ecological Knowledge and Land Use	
[B] Describe how TEK and TLU information was incorporated into the project design and development, technical components of the EIA, the conservation and reclamation plan, monitoring and mitigation plans.	Section 3.2.2
Section 9.0 Mitigation Measures	
[B] Identify those mitigation measures that will be implemented for each associated impact and provide rationale for their selection.	Section 4.1.1.2, 4.2.1.2, 4.3.1.2, 4.4.1.2
[C] Discuss the effectiveness of the proposed mitigation.	4.1.1.2, 4.1.1.4, 4.2.1.2, 4.2.1.4, 4.3.1.2, 4.3.1.4, 4.4.1.2, 4.4.1.4
Section 10.0 Residual Impacts	
[A] Describe the residual impacts of the Project following implementation of the Proponent's mitigation measures and the Proponent's plans to manage those residual impacts.	Section 4.1.1.4, 4.2.1.4, 4.3.1.4, 4.4.1.4
Section 11.0 Monitoring	
	Section 5.0

Table 2 **CEAA Guidance for the preparation of environmental impact assessment sections applicable to surface water quality (from CEAA 2012).**

CEAA Sections	Report Section
1.4 Regulatory Framework and the Role of the Government	Section 1.2
- Regional, provincial and/or national objectives, standards or guidelines that have been used by the proponent to assist in the evaluation of any predicted environmental effects.	
5 ABORIGINAL ENGAGEMENT AND CONCERNS	Section 3.1.2, 3.2.2, 3.2.5
- Where and how Aboriginal traditional knowledge was incorporated into the environmental effects assessment (including baseline conditions and effects analysis for VCs) and the consideration of potential adverse impacts on potential or established Aboriginal or Treaty rights and related mitigation measures	
6.1. Project Setting and Baseline Conditions	Section 3
6.1.4. (Groundwater and) Surface Water	
- Monitoring protocol for collection of existing groundwater and surface water data;	Section 3.1.3.2
- Seasonal surface water quality, including analytical results (e.g., water temperature, turbidity, pH, dissolved oxygen profile, and contaminants of concern) and interpretation, for representative tributaries and water bodies, including all sites to receive mine effluents or runoff.	Section 3.2.3
- Sediment quality analysis for key sites likely to receive mine effluents.	Section 3.2.3
6.2.2. Predicted Changes to (Groundwater and) Surface Water	
- Changes to turbidity, oxygen level, water temperature, ice regime, water quality.	Sections 4.1.1.3, 4.2.1.3, 4.3.1.3, 4.4.1.3, 4.5.1.3
- Changes in surface water quality and sediment quality associated with any mine effluent or releases of surface runoff.	Section 4.1.1.3, 4.2.1.3, 4.6, Table 18

- Pit water chemistry during operation and post-closure, and pit closure management measures (e.g., flooding). This will include geochemical modelling of pit water quality in the post-closure period.	Section 4.1.1.3
- Surface and seepage water quality from the waste rock dumps, tailings/waste rock impoundment facility, stockpiles, and other infrastructure during operation and post-closure.	Section 4.1.1.3
- Changes in water quality and sediments due to contaminants of concern in potentially affected waterbodies and associated tributaries.	Section 4.1.1.3
6.4. Mitigation	Sections 4.1.1.2, 4.2.1.2, 4.3.1.2, 4.4.1.2
6.5. Significance of Residual Effects	
- Magnitude, duration, frequency, reversibility, ecological and social context, and existence of environmental standards, guidelines, or objectives for assessing the impact.	Sections 4.4.1.4, 4.2.1.4, 4.3.1.4, 4.4.1.4, 4.5.1.4; Table 18
6.6.3. Cumulative Effects Assessment	
For “Surface water quality in the Crowsnest River, Gold Creek, Blairmore Creek, and associated tributaries”:	
- Identify and provide a rationale for the valued components that will constitute the focus of the cumulative effects assessment, emphasizing this assessment on the VCs most likely to be affected by the Project and other projects and activities.	Section 4.1.3, 4.2.3, 4.3.3, 4.4.3, 4.5.2
- Identify and justify the spatial and temporal boundaries for the cumulative effect assessment for each VC selected.	Section 2.3, 2.4
- Identify the sources of potential cumulative effects. Specify other projects or activities.	Section 2.5, 4.1.3, 4.2.3, 4.3.3, 4.4.3, 4.5.2
- Describe the mitigation measures that are technically and economically feasible.	Sections 4.1.1.2, 4.2.1.2, 4.3.1.2, 4.4.1.2
- Determine the significance of the cumulative effects.	Table 18
- Develop a follow-up program to verify the accuracy of the assessment or to dispel the uncertainty concerning the effectiveness of mitigation measures for certain cumulative effects.	Section 5.0
8. Follow-up and Monitoring Program	5.0

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LEGEND

- City/Town
- Primary Highway
- Secondary Highway
- Watercourse
- Waterbody
- Provincial Boundary
- Mine Permit Boundary
- Project Footprint

Elevation (m)

3076

862

PROJECT

 **GRASSY MOUNTAIN COAL PROJECT**

TITLE

OVERVIEW OF PROJECT LOCATION

NOTES

Data Sources: Government of Canada, Government of Alberta
Datum/Projection: UTM NAD 83 Zone 11

0 5 10 20

Kilometres


MILLENNIUM
EMS Solutions Ltd.

PROJECT: 7779

DRAWN BY: AS

CHECKED BY:

DATE: AUGUST 03, 2016

FIGURE

1

Document Path: K:\Data\Project\MEMS7779A_MXD\SurfaceWaterQuality\MEMS7779_Fig1_ProjectLocation_20160803_v0.3_AnS.mxd

1.2 GOVERNMENT REGULATION AND POLICY

This report was prepared with consideration of the following key government laws, regulations, and standards:

- *Alberta Environmental Protection and Enhancement Act (EPEA)*, with associated regulations and amendments in force;
- *Alberta Water Act (1999)*, with associated regulations and amendments in force;
- *Canadian Environmental Assessment Act 2012*;
- Surface Water Quality Guidelines for Use in Alberta (AEP 2014) which also included the Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines (CWQG) (CCME 1999 with updates); and
- Guidelines for the Preparation of an Environmental Impact Statement, pursuant to the *Canadian Environmental Assessment Act 2012*.

2.0 SCOPE OF ENVIRONMENTAL ASSESSMENT

2.1 POTENTIAL WATER QUALITY ISSUES

The Project has the potential to affect surface water quality via a number of impact pathways related to project activities during construction, operation, and reclamation phases. Specific activities that may influence the surface water quality include:

- **Construction:** soil stripping and logging, development of a water management and dewatering system, and building haul roads and stream crossings;
- **Operations:** pit dewatering, surface and groundwater runoff, leaching of overburden rock, leaks and spills, domestic wastewater, use of explosives; and
- **Reclamation:** abandonment of open pit workings, surface and rock disposal area recontouring, and abandonment of roads and water management systems.

In addition, there is the potential for acidification effects associated with the release of air emissions from the Project and other regional developments.

Each of these activities will potentially influence the natural drainage, infiltration, runoff, and soil erosion of the existing pre-disturbed Project area, which can influence surface water quality. Therefore, water management is required for all phases of the Mine. The main objective of the water management plan is to control total suspended solids and other constituents of water quality (e.g., metals) before release of the affected water to natural watercourses (Benga 2016 – Section C.5 Water Management).

During the construction, operation and closure phases, surface water runoff from mining areas, haul roads, overburden disposal areas and any other disturbed areas as well as groundwater runoff from the pit will be collected and directed to six sedimentation ponds (plant site sedimentation pond [PSSP], southwest surge pond [SWSP], west sedimentation pond [WSP], east sedimentation pond [ESP], northeast sedimentation pond [NESP] and loadout sedimentation pond [LSP]) for removal of total suspended solids (TSS) and release to Blairmore Creek and Gold Creek. During operations, mine-affected water from external rock disposal areas will be collected in three surge ponds (raw water pond

[RWP], southeast surge pond [SESP], and northwest surge pond [NWSP]). These surge ponds will pump water to three anaerobic saturated zones (SZ1, SZ2, and SZ3) designed to reduce downstream releases of selenium and inorganic nitrogen. These water management features are shown in [Figure 2](#). The backfilled open pit will be sequenced to provide these anaerobic saturated fill zones. Selenium and nitrate/nitrite will be removed through microbial activities that will be enhanced by labile carbon sources. Finally, water from the saturated zones will be treated in a water treatment plant, if necessary, to reduce elevated metals and released into Blairmore Creek.

Based on the project activities and mine plan, the following potential water quality issues were identified:

- Release of process-related water that does not meet surface water quality guidelines to natural watercourses;
- Use of nitrogen-based explosives;
- Accidental leaks and spills of hydrocarbons, chemicals and waste products used and stored within the Project footprint;
- Generation of domestic wastewater from camp operations; and
- Acidifying/air emission effects.

These water quality issues are assessed in [Section 4.0](#) of this document.

2.2 CHARACTERIZATION OF SURFACE WATER QUALITY

2.2.1 Variables Considered to Characterize Water Quality

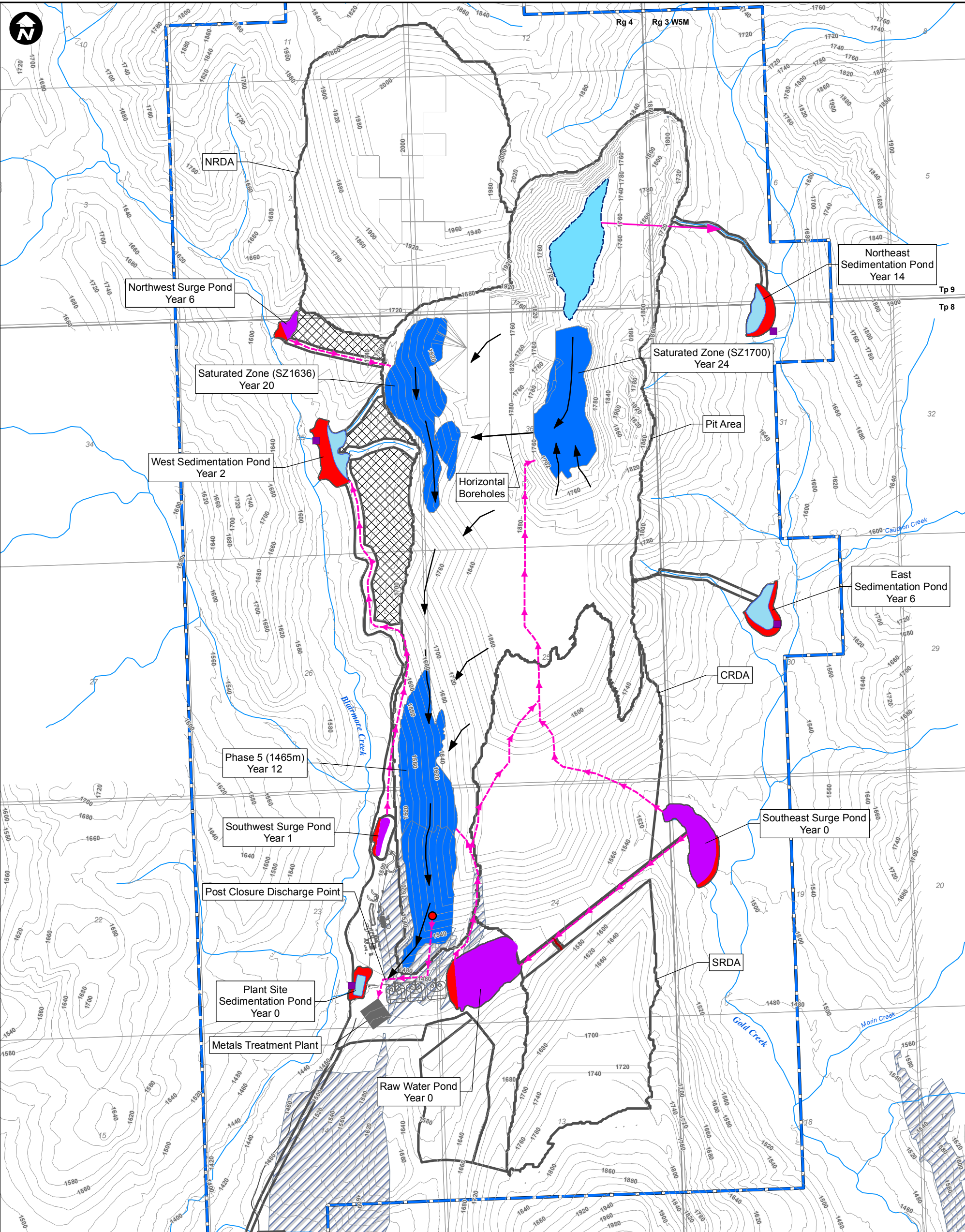
The selection of surface water quality variables considered in this report was guided by a review of:

- Water quality variables used in the environmental assessments for the similar mines in the region (e.g., Luscar 1999, MEMS 2005);
- Requirements of the ToR (AER 2015) and Guidance Document for this EIA (CEAA 2012);
- Water quality variables that have regulatory concern, as indicated by environmental quality guidelines;
- Water quality concerns and issues raised during the public consultation conducted during the preparation of this EIA; and
- Various water quality variables required for interpretation of effects on other aquatic components.

The surface water quality has been identified as the Valued Component (VC) and the following are the potential issues that have been considered:

- Release of process related water to natural watercourses
- Use of nitrogen-based explosives
- Accidental leaks and spills
- Domestic wastewater
- Acidifying/air emission effects

The surface water quality variables, analytical methods and detection limits, and water quality guidelines used in this assessment are presented in [Table 3](#).



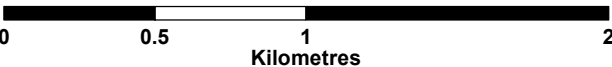
LEGEND		PROJECT		 GRASSY MOUNTAIN COAL PROJECT			
TITLE		WATER MANAGEMENT FEATURES					
NOTES		AltaLIS, 2016; Deswik, 2016; Golder 2016; MEMS, 2016; NRCAN, 2015; Riversdale, 2016 Datum/Projection: UTM NAD 83 Zone 11				PROJECT: 14-00201-01 DRAWN BY: CP/SL CHECKED BY: DM DATE: AUGUST 3, 2016	
						FIGURE 2	

Table 3 List of water quality variables, analytical methods and detection limits and regulatory guidelines.

Variables	Methods	Units	Detection Limits	AEP Guideline 2014	
				Long Term	Short Term
Field Measured Variables					
Temperature	Multi-meter probe	°C	-	Narrative	Narrative
Dissolved Oxygen	Winkler titration	mg/L	-	6.5 (Minimum)	5 (Minimum)
Specific Conductivity	Multi-meter probe	µS/cm	-	-	-
pH	Multi-meter probe	pH	-	6.5-9.0	-
Conventional Variables					
Turbidity	APHA 2130 B-Nephelometer	NTU	0.1	Narrative	Narrative
Dissolved Organic Carbon	APHA 5310 B-Instrumental	mg/L	1	-	-
Total Organic Carbon	APHA 5310 B-Instrumental	mg/L	1	-	-
Colour	APHA 2120	C.U.	5	20% increase	
Total Hardness	APHA 1030E		1	-	-
Total Alkalinity	APHA 4500-H, 2510, 2320	mg/L	5	>20	-
Specific Conductivity	APHA 4500H,2510,2320	µS/cm	3	-	-
Total Dissolved Solids	APHA 2540 C	mg/L	10	-	-
Total Suspended Solids	APHA 2540 D-Gravimetric	mg/L	3/4/6	Narrative	Narrative
Major Ions					
Chloride	APHA 2120	mg/L	0.1/0.5	120	640
Calcium	APHA 3030 B&E / EPA SW-846 6020A	mg/L	0.5	-	-
Magnesium	APHA 3030 B&E / EPA SW-846 6020A	mg/L	0.1	-	-
Potassium	APHA 3030 B&E / EPA SW-846 6020A	mg/L	0.5	-	-
Sodium	APHA 3030 B&E / EPA SW-846 6020A	mg/L	1	-	-
Bicarbonate	APHA 4500-H, 2510, 2320	mg/L	5	-	-
Carbonate	APHA 4500-H, 2510, 2320	mg/L	0.5/5	-	-
Hydroxide	APHA 4500-H, 2510, 2320	mg/L	0.5/5	-	-
Sulphate	APHA 4110 B-ION CHROMATOGRAPHY	mg/L	0.5	309 at hardness 180 mg/L (Hard Water)	
Sulphide	APHA 4500 -S E-Auto-Colorimetry	mg/L	0.0015/0.002	0.0019	-

Table 3 (Cont'd.)

Variables	Methods	Units	Detection Limits	AEP Guideline 2014	
				Long Term	Short Term
Major Nutrients					
Total Ammonia as N	APHA 4500 NH3-NITROGEN (AMMONIA)	mg/L	0.05	pH and temperature dep.	
Nitrate and Nitrite as N	Calculation	mg/L	0.005	-	-
Nitrite as N	APHA 4110 B-ION CHROMATOGRAPHY	mg/L	0.05	0.02 (with <2 mg/L Cl)	0.06 (with <2 mg/L Cl)
Nitrate as N	APHA 4110 B-ION CHROMATOGRAPHY	mg/L	0.05	3	124
Total Phosphorus	APHA 4500-P PHOSPHORUS	mg/L	0.001	-	-
Dissolved Phosphorus	APHA 4500-P PHOSPHORUS	mg/L	0.001	-	-
Total Kjeldahl Nitrogen	APHA 4500-NORG (TKN)	mg/L	0.2	-	-
Biochemical Oxygen Demand	APHA 5210 B-5 day Incub.-O2 electrode	mg/L	2	-	-
Total Metals					
Aluminum	APHA 3030 B&E / EPA SW-846 6020A	µg/L	3	-	-
Antimony	APHA 3030 B&E / EPA SW-846 6020A	µg/L	0.1	-	-
Arsenic	APHA 3030 B&E / EPA SW-846 6020A	µg/L	0.1	5	-
Barium	APHA 3030 B&E / EPA SW-846 6020A	µg/L	0.05	-	-
Beryllium	APHA 3030 B&E / EPA SW-846 6020A	µg/L	0.5	-	-
Bismuth	APHA 3030 B&E / EPA SW-846 6020A	µg/L	0.05	-	-
Boron	APHA 3030 B&E / EPA SW-846 6020A	mg/L	0.01	1.5	29
Cadmium	APHA 3030 B&E / EPA SW-846 6020A	µg/L	0.01	0.26 at hardness 180 mg/L	3.8 at hardness 180 mg/L
Chromium (III+VI)	APHA 3030 B&E / EPA SW-846 6020A	µg/L	0.1	9.9	-
Cobalt	APHA 3030 B&E / EPA SW-846 6020A	µg/L	0.1	2.5	-
Copper	APHA 3030 B&E / EPA SW-846 6020A	µg/L	0.1	7	28 at hardness 180 mg/L
Iron	APHA 3030 B&E / EPA SW-846 6020A	µg/L	10	-	-
Lead	APHA 3030 B&E / EPA SW-846 6020A	µg/L	0.05	6.7 at hardness 180 mg/L	-
Lithium	APHA 3030 B&E / EPA SW-846 6020A	µg/L	5	-	-
Manganese	APHA 3030 B&E / EPA SW-846 6020A	µg/L	0.05	-	-

Table 3 (Cont'd.)

Variables	Methods	Units	Detection Limits	AEP Draft Guideline 2014	
				Long Term	Short Term
Mercury	EPA 1631 REV. E	µg/L	0.0005	0.005	0.013
Molybdenum	APHA 3030 B&E / EPA SW-846 6020A	µg/L	0.05	73	-
Nickel	APHA 3030 B&E / EPA SW-846 6020A	µg/L	0.1	86 at hardness 180 mg/L	770 at hardness 180 mg/L
Selenium	APHA 3030 B&E / EPA SW-846 6020A	µg/L	0.1	Proposed site-specific objective (Section 2.2.2) (Appendix A-1)	
Silver	APHA 3030 B&E / EPA SW-846 6020A	µg/L	0.01	0.1	-
Thallium	APHA 3030 B&E / EPA SW-846 6020A	µg/L	0.05	0.8	-
Tin	APHA 3030 B&E / EPA SW-846 6020A	µg/L	0.1	-	-
Titanium	APHA 3030 B&E / EPA SW-846 6020A	µg/L	0.3	-	-
Uranium	APHA 3030 B&E / EPA SW-846 6020A	µg/L	0.01	15	33
Vanadium	APHA 3030 B&E / EPA SW-846 6020A	µg/L	0.1	-	-
Zinc	APHA 3030 B&E / EPA SW-846 6020A	µg/L	3	30	-
Dissolved Metals					
Aluminum	APHA 3030 B&E / EPA SW-846 6020A	µg/L	1	50 (pH>6.5)	100 (pH>6.5)
Antimony	APHA 3030 B&E / EPA SW-846 6020A	µg/L	0.1	-	-
Arsenic	APHA 3030 B&E / EPA SW-846 6020A	µg/L	0.1	-	-
Barium	APHA 3030 B&E / EPA SW-846 6020A	µg/L	0.05	-	-
Beryllium	APHA 3030 B&E / EPA SW-846 6020A	µg/L	0.5	-	-
Bismuth	APHA 3030 B&E / EPA SW-846 6020A	µg/L	0.05	-	-
Boron	APHA 3030 B&E / EPA SW-846 6020A	µg/L	10	-	-
Cadmium	APHA 3030 B&E / EPA SW-846 6020A	µg/L	0.01	-	-
Chromium (III+VI)	APHA 3030 B&E / EPA SW-846 6020A	µg/L	0.1	-	-
Cobalt	APHA 3030 B&E / EPA SW-846 6020A	µg/L	0.1	-	-
Copper	APHA 3030 B&E / EPA SW-846 6020A	µg/L	0.1	-	-
Iron	APHA 3030 B&E / EPA SW-846 6020A	µg/L	10	300	-
Lead	APHA 3030 B&E / EPA SW-846 6020A	µg/L	0.05	-	-
Lithium	APHA 3030 B&E / EPA SW-846 6020A	µg/L	3	-	-

Table 3 (Cont'd.)

Variables	Methods	Units	Detection Limits	AEP Draft Guideline 2014	
				Long Term	Short Term
Manganese	APHA 3030 B&E / EPA SW-846 6020A	µg/L	0.05	-	-
Molybdenum	APHA 3030 B&E / EPA SW-846 6020A	µg/L	0.05	-	-
Nickel	APHA 3030 B&E / EPA SW-846 6020A	µg/L	0.1	-	-
Selenium	APHA 3030 B&E / EPA SW-846 6020A	µg/L	0.1	-	-
Silicon	APHA 3030 B&E / EPA SW-846 6020A	µg/L	50	-	-
Silver	APHA 3030 B&E / EPA SW-846 6020A	µg/L	0.01	-	-
Thallium	APHA 3030 B&E / EPA SW-846 6020A	µg/L	0.05	-	-
Tin	APHA 3030 B&E / EPA SW-846 6020A	µg/L	0.1	-	-
Titanium	APHA 3030 B&E / EPA SW-846 6020A	µg/L	0.3	-	-
Uranium	APHA 3030 B&E / EPA SW-846 6020A	µg/L	0.01	-	-
Vanadium	APHA 3030 B&E / EPA SW-846 6020A	µg/L	0.1	-	-
Zinc	APHA 3030 B&E / EPA SW-846 6020A	µg/L	1	-	-
General Organics					
Hydrocarbons, recoverable	APHA 5520 C-Tetra CI Ext Infrared	mg/L	1	-	-
Naphthenic Acids	By FTIR	mg/L	1	-	-
Phenols (4AAP)	AB ENV.06537-COLORIMETRIC	mg/L	0.001	4	-
F1(C6-C10)	EPA 5030/8015& 8260-P&T GC-MS/FID	mg/L	0.1	0.15	-
F1-BTEX	EPA 5030/8015& 8260-P&T GC-MS/FID	mg/L	0.1	-	-
F2 (C10-C16)	EPA 3511/ CCME PHC CWS GC-FID	mg/L	0.25	0.11	-
F3 (C16-C34)	EPA 3511/ CCME PHC CWS GC-FID	mg/L	0.25	-	-
F4 (C34-C50)	EPA 3511/ CCME PHC CWS GC-FID	mg/L	0.25	-	-
Benzene	SW 846 8260-GC-MS	µg/L	1	40	-
Ethylbenzene	SW 846 8260-GC-MS	µg/L	1	90	-
Toluene	SW 846 8260-GC-MS	µg/L	1	0.5	-
Xylene (m & p)	SW 846 8260-GC-MS	µg/L	1	30	-
Xylene (o)	SW 846 8260-GC-MS	µg/L	1	-	-

Table 3 (Cont'd.)

Variables	Methods	Units	Detection Limits	AEP Draft Guideline 2014	
				Long Term	Short Term
Polycyclic Aromatic Hydrocarbons (PAHs)					
1-Methylnaphthalene	EPA 3510/8270-GC/MS	µg/L	0.01	-	-
2-methylnaphthalene	EPA 3510/8270-GC/MS	µg/L	0.01	-	-
Acenaphthene	EPA 3510/8270-GC/MS	µg/L	0.01	5.8	-
Acenaphthylene	EPA 3510/8270-GC/MS	µg/L	0.01	-	-
Acridine	EPA 3510/8270-GC/MS	µg/L	0.01	4.4	-
Anthracene	EPA 3510/8270-GC/MS	µg/L	0.01	0.012	-
Benz(a)anthracene	EPA 3510/8270-GC/MS	µg/L	0.01	0.018	-
Benzo(a)pyrene	EPA 3510/8270-GC/MS	µg/L	0.01	0.015	-
Benzo(e)pyrene	EPA 3510/8270-GC/MS	µg/L	0.01	-	-
Benzo(g,h,i)perylene	EPA 3510/8270-GC/MS	µg/L	0.01	-	-
Benzo(k)fluoranthene	EPA 3510/8270-GC/MS	µg/L	0.01	-	-
Benzo[b+j]fluoranthene	EPA 3510/8270-GC/MS	µg/L	0.01	-	-
Biphenyl	EPA 3510/8270-GC/MS	µg/L	0.01	-	-
Chrysene	EPA 3510/8270-GC/MS	µg/L	0.01	-	-
Dibenz(a,h)anthracene	EPA 3510/8270-GC/MS	µg/L	0.01	-	-
Dibenzothiophene	EPA 3510/8270-GC/MS	µg/L	0.01	-	-
Fluoranthene	EPA 3510/8270-GC/MS	µg/L	0.01	0.04	-
Fluorene	EPA 3510/8270-GC/MS	µg/L	0.01	3	-
Indeno(1,2,3-c,d)pyrene	EPA 3510/8270-GC/MS	µg/L	0.01	-	-
Naphthalene	EPA 3510/8270-GC/MS	µg/L	0.05	1	-
Perylene	EPA 3510/8270-GC/MS	µg/L	0.01	-	-
Phenanthrene	EPA 3510/8270-GC/MS	µg/L	0.01	0.4	-
Pyrene	EPA 3510/8270-GC/MS	µg/L	0.01	0.025	-
Quinoline	EPA 3510/8270-GC/MS	µg/L	0.01	3.4	-
Retene	EPA 3510/8270-GC/MS	µg/L	0.01	-	-

2.2.2 Water Quality Measurement Endpoints

The measurement endpoints for water quality variables used in this report are as follows:

- Concentration of water quality variables relative to water quality guideline values to support a viable aquatic ecosystem;
- Frequency of exceedance of surface water quality guideline values; and
- The most recent Environmental Quality Guidelines for Alberta Surface Waters (AEP 2014) were used, which also generally encompass previously-developed CCME Guidelines for the Protection of Aquatic Life (CCME 1999).

For hardness-dependent guidelines, median hardness concentration in the baseline studies was used in determining the appropriate guideline value. Surface water quality guidelines used in this assessment are presented in [Table 3](#).

Selenium in surface waters was identified as an important potential issue for this Project. Therefore, a site-specific objective for selenium for the protection of aquatic life has been developed linked to concentrations of sulphate, which at higher concentrations modifies and attenuates the uptake of selenium present as selenate (Williams et al. 1994; Lo et al. 2012). This study draws upon the recently updated British Columbia guideline (BCMOE 2013), and used site water and varying concentrations of dissolved selenium and sulphate to evaluate uptake of selenium into the aquatic food chain through two species of periphytic algae (*Pseudokirchneriella subcapitata* and *Scenedesmus acutus*) and, with derived Se-objective values used to predict likely effects of selenium on aquatic biota in local creek waters. Periphyton samples also were collected in the LSA and analyzed for selenium as well as other metals to establish baseline metal contents of periphyton in the Project area. Detailed procedures for developing the site-specific selenium objective are presented in [Appendix A1](#). The final equation proposed for calculating a site-specific Se objective for local receiving waters is given below and tabulated relative to varying sulphate concentrations in [Table 4](#).

The proposed site-specific objective for selenium in site waters (mg/L total Se) = $0.000594 \times \text{Sulphate (mg/L)}^{0.46}$.

Table 4 Proposed site-specific selenium objective, relative to sulphate concentrations.

Sulphate Concentration (mg/L)	Total Selenium Objective (mg/L Se)
10	0.0017
20	0.0024
50	0.0036
100	0.0049
200	0.0068
300	0.0082
400	0.0093

2.3 STUDY AREAS

Grassy Mountain straddles the watersheds of Blairmore Creek and Gold Creek, which are tributaries of the Crowsnest River, which itself is a tributary to the Old Man River. Based on the proposed activities and the topography in the area, local and regional study areas were defined as outlined below.

2.3.1 Local Study Area

The Local Study Area (LSA) for aquatic resources was defined based on the lease area and local drainage basins, and encompasses the area where Project activities have the potential to directly affect water quality, hydrology, and fish and aquatic habitat. As the majority of the MPA is located within the watersheds of Blairmore Creek and Gold Creek, the entire watershed of both creeks is included in the LSA (Figure 3). The total areas of the LSA watershed are approximately 11,300 ha.

2.3.2 Regional Study Area

The regional study area (RSA) was defined on the basis of potential effects of construction and operation of the Project on flows, water levels and water quality in regional water courses, including potential surface water/groundwater interactions. Taken together, Blairmore Creek and Gold Creek represent approximately 16% of the watershed area of the Crowsnest River (Figure 3). Project effects have the potential to interact with other projects within the Crowsnest River watershed and therefore the entire Crowsnest River watershed is included in the RSA for evaluation of potential cumulative effects.

2.4 TEMPORAL CONSIDERATIONS

The temporal considerations for the water quality EIA are based on the Project description and schedule (Benga 2016 - Section C.1.3) and include unique conditions that may affect water quality. The Project mine life is approximately 24 years (2019 to 2043) excluding pre-mining (2017 to 2019) and closure (2034 to 2050).

2.5 ASSESSMENT CASES

Three development scenarios addressed in the surface water quality assessment are the Baseline Case, the Application Case and the Planned Development Case (PDC).

Baseline Case

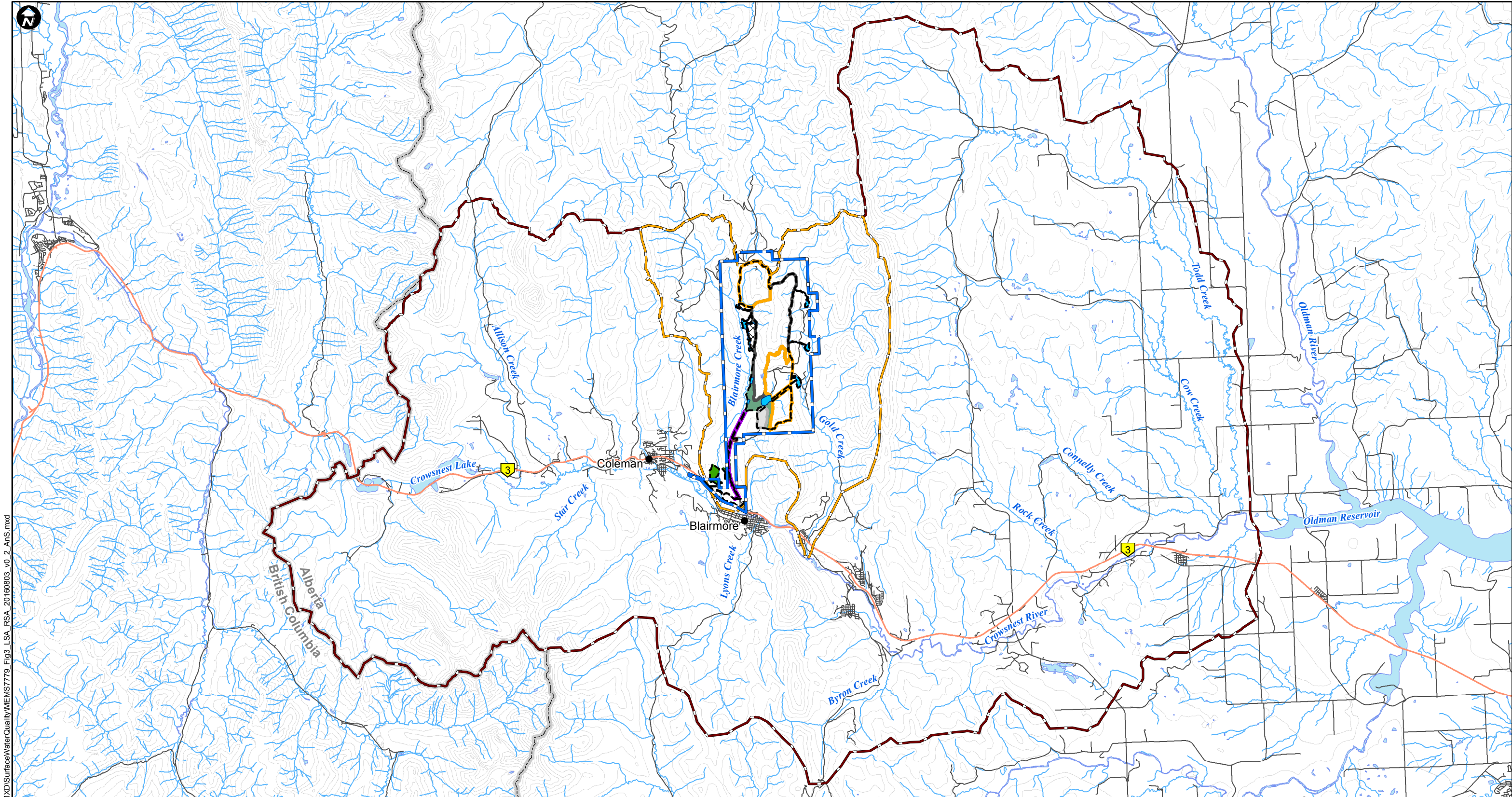
The Baseline Case describes environmental conditions without the Project, but including effects of other existing and approved projects or activities (Benga 2016 - Table D.2.4-2). For the purposes of this environmental assessment, it was assumed that any effects of the existing projects that define the Baseline Case for surface water quality were accurately reflected in data gathered to establish the baseline conditions and other existing projects will not cause any larger or different effects on surface water quality in the future than currently occur.

Application Case

The Application Case describes the Baseline Case with the effects of the Project added. The Application Case adds the residual environmental impacts of the Project to existing environmental conditions in the study areas.

Planned Development Case/Cumulative Effects Assessment

The Planned Development Case (PDC) describes the Application Case with the effects of planned developments added. Planned developments include any projects or activities publicly disclosed up to six months prior to the submission of this application. It involves cumulative environmental effects assessment resulting from designated project as well as other planned development projects. For this Project, the PDC includes Teck Coal Limited's Coal Mountain Phase 2, Elkview Baldy Ridge Extension and Michel Creek Coking Coal Project, Crown's four timber operations, ATCO's Castle Rock Ridge to Chapel Rock Transmission Project, and Alberta Transportation's Highway 3 Realignment project.



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LEGEND			PROJECT		 GRASSY MOUNTAIN COAL PROJECT			
			TITLE		LOCAL AND REGIONAL STUDY AREAS		PROJECT: 7779	
			NOTES		Data Sources: Government of Canada, Government of Alberta Datum/Projection: UTM NAD 83 Zone 11		DRAWN BY: AS	
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2.6 ASSESSMENT METHODS

2.6.1 Collection of Baseline Information

Baseline surveys including traditional knowledge and resource use in the LSA and RSA were completed for water quality and presented in [Section 3.0](#) of this report.

2.6.2 Identification of Impact Pathways

The assessment of potential effects of the Project on water quality is completed with consideration of the following two key questions, which frame the relationships between the Project and the potential environmental effects:

- **Application Case:** What effects could existing and approved developments and the Project have on water quality?
- **Planned Development Case:** What effects could existing and approved developments, the Project, and planned developments have on water quality?

Key questions were addressed using the following procedure:

- Describing the mitigation measures that will be implemented to minimize the effect of Project activities on water quality;
- Identifying the pathways of various Project activities with the key issues and determining whether the pathways are valid;
- Where pathways are found to be valid, conducting effects analyses to quantify the effects on water quality;
- Classifying the residual effects and defining the environmental consequence; and
- Describing monitoring programs that will be implemented to monitor the effects, so that existing mitigation measures can be adjusted or additional measures can be undertaken, if warranted.

2.6.3 Effects Analysis

Potential effects of the Project on surface water quality were evaluated both qualitatively and quantitatively. The qualitative analyses presented are based on other EIA components, monitoring programs, scientific literature and professional judgment. Results from other EIA components were evaluated in terms of their potential to cause changes in surface water quality. The quantitative analysis presented is based on the results of water quality modelling undertaken for the LSA (i.e., Blairmore and Gold creeks) and the RSA (i.e., Crowsnest River). Results of the effects analysis were used to classify residual impacts ([Section 2.6.4](#)).

The prediction confidence for the water quality assessment was determined based on:

- The conservativeness of assumptions and quality of data used for modelling and/or assessment, which would lead to a higher level of confidence;
- Sources of uncertainty; and
- Observed performance of assumed mitigation measures for similar operations.

2.6.4 Residual Effects Classification

The purpose of the residual impacts classification is to describe the residual effects from the Project on water quality using a scale of common words (rather than numbers and units). The definitions for these scales are ecologically or logically based on the characteristics of the water quality and the associated assessment endpoint, although the use of professional judgment is inevitable in some cases. The classification of impacts is based on the criteria presented in [Table 5](#).

Environmental significance is used to identify predicted impacts that have sufficient magnitude, duration, and geographic extent to cause fundamental changes to surface water quality. Significance is determined by the risk to desired water quality. The following two criteria are followed to evaluate the residual effects:

- **Not significant** – impacts are measurable but are not likely to deteriorate water quality to an extent expected to have a significant adverse effect on aquatic life; and
- **Significant** – impacts are measurable and likely to affect water quality to an extent that eventually has an irreversible effect on aquatic life.

These lower and upper bounds on the determination of significance are relatively straightforward to apply. It is the area between these bounds where ecological principles and professional judgment are applied to determine the significance.

Table 5 Evaluation criteria for assessing the environmental impact.

Criteria	Criteria Definition	
Magnitude	Nil	No change from background conditions anticipated after mitigation.
	Low	Disturbance predicted to be somewhat above typical background conditions, but well within established or accepted protective standards and normal socio-economic fluctuations, or to cause no detectable change in ecological, social or economic parameters.
	Moderate	Disturbance predicted to be considerably above background conditions but within scientific and socio-economic effects thresholds, or to cause a detectable change in ecological, social or economic parameters within range of natural variability.
	High	Disturbance predicted to exceed established criteria or scientific and socio-economic effects thresholds associated with potential adverse effect, or to cause a detectable change in ecological, social or economic parameters beyond the range of natural variability.
Geographic Extent	Local	Effects occurring mainly within or close proximity to the proposed development area.
	Regional	Effects extending outside of the project boundary to regional surroundings.
	Provincial	Effects extending outside of the regional surroundings, but within provincial boundary.
	National	Effects extending outside of the provincial surroundings, but within national boundary.
	Global	Effects extending outside of national boundary.

Table 5 (Cont'd.)

Criteria	Criteria Definition	
Duration	Short	Effects occurring within development phase.
	Long	Effects occurring after development and during operation of facility.
	Extended	Effects occurring after facility closes but diminishing with time.
	Residual	Effects persisting after facility closes for a long period of time.
Frequency	Continuous	Effects occurring continually over assessment periods.
	Isolated	Effects confined to a specified period (e.g., construction).
	Periodic	Effects occurring intermittently but repeatedly over assessment period (e.g., routine maintenance activities).
	Occasional	Effects occurring intermittently and sporadically over assessment period.
Reversibility	Reversible in short-term	Effects which are reversible and diminish upon cessation of activities.
	Reversible in long-term	Effects which remain after cessation of activities but diminish with time.
	Irreversible - Rare	Effects which are not reversible and do not diminish upon cessation of activities and do not diminish with time.
Project Contribution	Neutral	No net benefit or loss to the resource, communities, region or province.
	Positive	Net benefit to the resource, community, region or province.
	Negative	Net loss to the resource, community, region or province.
Confidence Rating	Low	Based on incomplete understanding of cause-effect relationships and incomplete data pertinent to study area.
	Moderate	Based on good understanding of cause-effect relationships using data from elsewhere or incompletely understood cause-effect relationship using data pertinent to study area.
	High	Based on good understanding of cause-effect relationships and data pertinent to study.
Probability of Occurrence Ecological Context	Low	Unlikely
	Medium	Possible or probable
	High	Certain
Significance	Not significant	Effects are predicted to be within the range of natural variability and below guideline or threshold levels
	Significant	Effects of the Project are predicted to cause irreversible changes to the sustainability or integrity of a population or resource

3.0 BASELINE CASE

3.1 METHODS

3.1.1 Existing Information

Existing information for the LSA and RSA was obtained through a Water Data System (WDS) request to Alberta Environment and Parks (AEP). Additional information also was obtained from other baseline reports and online resources. Available water quality data in the local and regional study areas included the Crowsnest River sampled at above Bellevue Mine, above Blairmore, above Coleman, above Lundbreck falls, at upstream of Connelly Creek, and at the mouth of Crowsnest Lake, from 1974 to 2008. These historical data sometimes had few QA/QC issues, including higher analytical detection limits than the water quality guideline values, as flagged in the summary table ([Table 7](#)).

3.1.2 Traditional Knowledge

Traditional knowledge and traditional use surveys with members of Treaty 7 First Nations were conducted as part of Project preparation. Information from these surveys was integrated with existing information and with the results of additional field programs to inform the water quality assessment. Four Treaty 7 First Nations communities have provided traditional knowledge reports: the Tsuut'ina Nation, the Piikani Nation, the Kainai Nation, and the Siksika Nation. Water quality related information is extracted from these reports and presented in Section 3.2.2.

3.1.3 Field Sampling

3.1.3.1 Locations and Timing of Sampling

Detailed sampling locations and timings are presented in [Table 6](#) and [Figure 4](#). Seasonal surface water samples were collected from the following stations in the LSA and RSA:

- three Blairmore Creek mainstem stations;
- two tributary stations to Blairmore Creek;
- two Gold Creek mainstem stations;
- six tributary stations to Gold Creek;
- one reference station at Caudron Creek;
- three stations at end-pit lakes created by historical coal mines; and
- three Crowsnest River mainstem stations (within RSA)

Water quality baseline programs were started in May 2013 and continued until May 2016. Two sampling events occurred in July 2013 in order to capture high water conditions, following a flood event at the beginning of the month, and at the end of the month to represent post-flood conditions. Not all sampling stations were sampled in every sampling programs due to changes in the proposed mine plan over time. Efforts were made to collect additional samples to include tributaries that became relevant to the assessment through apparent during mine-footprint revisions issued by Benga's engineering team.

Sampling seasons were defined as follows:

- **Spring:** April, May;
- **Summer:** June, July, August;
- **Fall:** September, October; and
- **Winter:** November, December, January, February, March.

To account for potential interactions between surface and ground water in the Project site, groundwater samples were collected from LSA and presented in Benga 2016 – Section E.3 Hydrogeology.

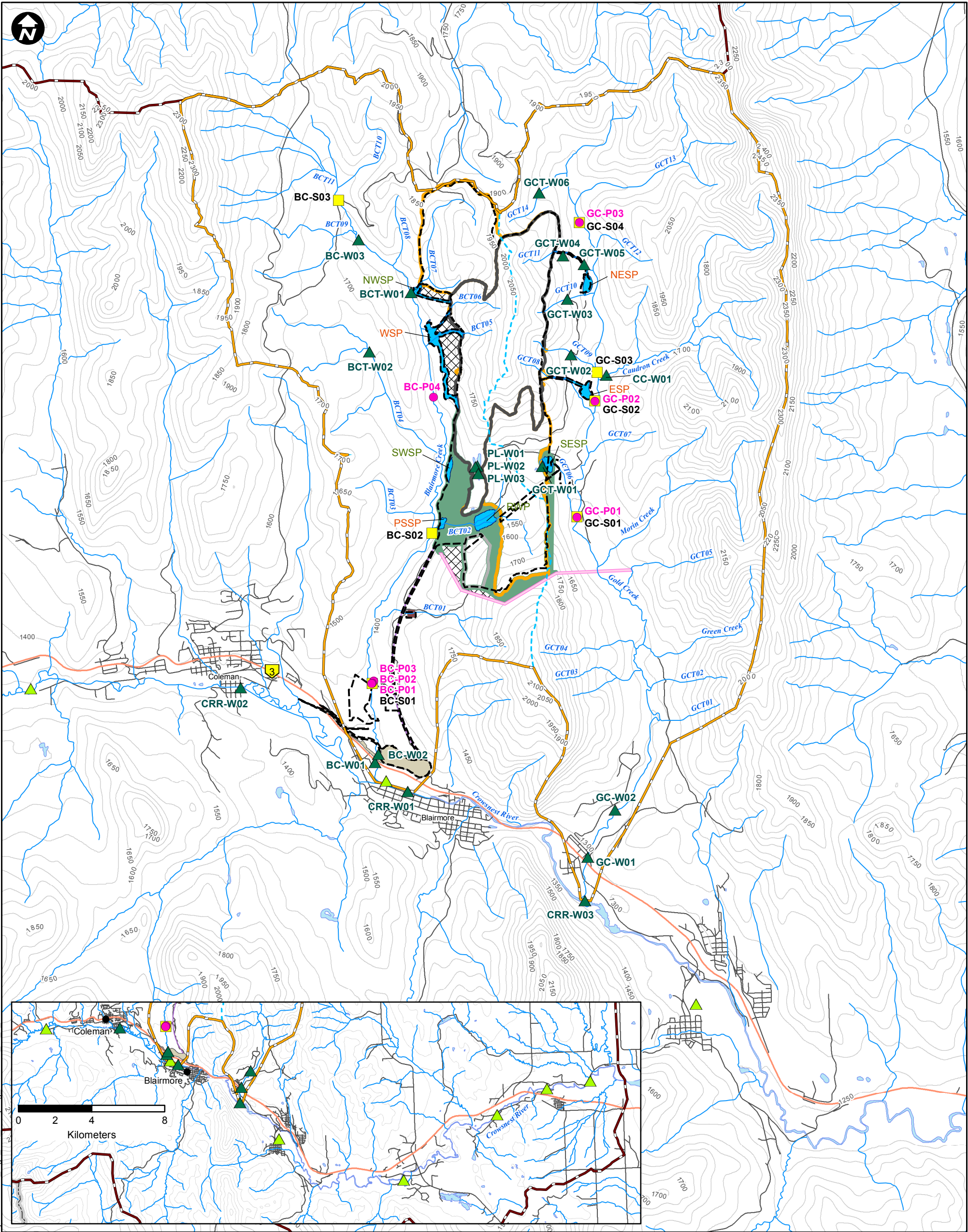
Sediment samples were collected from three stations at Blairmore Creek and four stations at Gold Creek during June 2016 ([Table 6](#), [Figure 4](#)). Periphyton samples were also collected from the same stations at both creeks but one sample at Gold Creek was insufficient for lab analysis.

Table 6 **Water quality, sediment and periphyton sampling locations, May 2013 to June 2016.**

Site ID	River/Creek Details	Easting UTM	Northing UTM	Sampling Dates
Local Study Areas				
Water Samples				
BC-W01	Blairmore Creek downstream	683624	5499170	May, July, September 2013; August 2014; March 2016
BC-W02	Blairmore Creek downstream	683692	5499327	July, October 2014; January 2015; March 2016
BC-W03	Blairmore Creek upstream (reference site)	683309	5509186	May, July, September 2013; April, August 2014; March 2016
BCT-W01	Blairmore Creek Tributary	684319	5508172	February, June 2015
BCT-W02	Unnamed Tributary to Blairmore Creek	683515	5507040	May, July, September 2013; April, August 2014
GC-W01	Gold Creek	687705	5497354	July, September 2013; April, August, 2014; March 2016
GC-W02	Gold Creek	688225	5498257	July, October 2014; January 2015
GCT-W01	Gold Creek Tributary	686831	5504843	June 2015; March 2016
GCT-W02	Gold Creek Tributary	687385	5506986	June 2015; March 2016
GCT-W03	Gold Creek Tributary	687313	5508049	June 2015; March 2016
GCT-W04	Gold Creek Tributary	687230	5508881	June 2015
GCT-W05	Gold Creek Tributary	687629	5508713	June 2015
GCT-W06	Gold Creek Tributary	686772	5510087	June 2015
CC-W01	Caudron Creek (reference site)	688057	5506590	March, May 2016
PL-W01	Northeast Pit Lake	685586	5504847	July, October 2014; February 2015
PL-W02	Northwest Pit Lake	685552	5504831	July, October 2014; February 2015
PL-W03	Southeast Pit Lake	685604	5504710	July, October 2014; February 2015
Sediment Samples				
BC-S01	Blairmore Creek downstream	683572	5500682	June 2016
BC-S02	Blairmore Creek downstream	684713	5503561	June 2016
BC-S03	Blairmore Creek upstream	682926	5509941	June 2016
GC-S01	Gold Creek downstream	687495	5503869	June 2016
GC-S02	Gold Creek downstream	687836	5506093	June 2016
GC-S03	Gold Creek downstream	687883	5506644	June 2016
GC-S04	Gold Creek upstream	687542	5509518	June 2016

Table 6 (Cont'd.)

Site ID	River/Creek Details	Easting UTM	Northing UTM	Sampling Dates
Local Study Areas (Cont'd.)				
Periphyton Samples				
BC-P01	Blairmore Creek downstream	683559	5500680	June 2016
BC-P02	Blairmore Creek downstream	683569	5500688	June 2016
BC-P03	Blairmore Creek downstream	683598	5500728	June 2016
BC-P04	Blairmore Creek upstream	684746	5506172	June 2016
GC-P01	Gold Creek downstream	687495	5503869	June 2016
GC-P02	Gold Creek downstream	687836	5506093	June 2016
GC-P03	Gold Creek upstream	687542	5509518	June 2016
Regional Study Areas				
Water Samples				
CRR-W01	Crowsnest River (downstream of BC confluence)	684254	5498614	May, July, September 2013; April, August 2014; March 2016
CRR-W02	Crowsnest River (upstream of BC confluence)	681055	5500602	May, July, September 2013; April, August 2014; March 2016
CRR-W03	Crowsnest River (downstream of GC confluence)	687648	5496523	July, October 2014; January 2015



LEGEND

Baseline Surface Water Station

Baseline Sediment Station

Baseline Periphyton Station

Historical Surface Water Station

Primary Highway

Road

50 m Contour

Watershed Boundary

Watercourse

Waterbody

Local Study Area

Regional Study Area

Project Footprint

Coal Handling Processing Plant and Infrastructure

Ultimate Pit Extent

Ultimate Dump Extent

Topsoil Storage

Construction Camp

Ponds and Ditches

Proposed Pipeline ROW

Access and Conveyor

Railway Loop

Non-Disturbed Area

PROJECT

RIVERSDALE GRASSY MOUNTAIN
RESOURCES COAL PROJECT

TITLE

WATER QUALITY SAMPLING LOCATIONS

NOTES

Data Sources: Government of Canada, Government of Alberta
Datum/Projection: UTM NAD 83 Zone 11

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FIGURE

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3.1.3.2 Sampling Methods

Sampling locations were identified using GPS coordinates and Alberta Forestry, Lands and Wildlife Resource Access Maps, and accessed by trucks, ATV, or foot. *In situ* measurements of water temperature, pH, and specific conductivity were conducted from just below the water surface using a hand-held Hanna multi-meter probe (model 98129). Dissolved oxygen (DO) was measured using a portable Winkler-titration kit (Lamotte 5860).

For laboratory analyses, grab samples were collected from each station by submerging each sample bottle to a depth of approximately 10 to 30 cm. Sample bottles were uncapped, filled and recapped at depth with the exception of total hydrocarbons (oil and grease) and BTEX, which were collected from the water surface to ensure capture of any floating hydrocarbons, and to ensure that the pre-charged preservative remained in the bottle. Sufficient Quality Assurance/Quality Control (QA/QC) samples were collected to represent at least 10% of all surface water samples. Three types of QA/QC samples were collected as part of the surface water quality QA/QC program which included trip blanks, field blanks and field duplicates:

- **Trip Blanks** were prepared by the analytical laboratory prior to sampling and kept sealed for the duration of the sampling trip. These were used to evaluate potential contamination from the sample container and efficacy of storage conditions. Eight trip blanks were collected and analyzed in the entire water quality programs;
- **Field Blanks** were prepared in the field by filling a complete sample bottle set with de-ionized water provided by the analytical lab. Field blanks were used to assess potential contamination of samples during collection, handling and transport. Nine field blanks were collected and analyzed in the entire water quality programs; and
- **Field Duplicates** were prepared in the field by filling a second complete set of sample bottles congruently with the standard field sample set. These bottles were submitted to the lab using “dummy” station codes and used to assess lab testing methods and provided an assessment of the homogeneity of sampled water. Eight sets of field duplicates were collected and analyzed in the entire water quality programs.

Detailed QA/QC procedures and results are presented in [Appendix A2](#).

All water samples were collected, preserved and shipped according to protocols specified by analytical laboratories. Samples collected for analysis of most dissolved fractions were delivered unfiltered and unpreserved to the analytical laboratory within 24 hours of sample collection, following laboratory direction.

Sediment samples were collected using an Ekman grab, after collecting water samples. Each sample was a composite sample, consisting of material from the top 2 to 5 cm of 3 to 5 individual grabs, mixed in a stainless steel pan before filling sample jars. Samples were stored and shipped to the analytical laboratory in coolers containing ice packs. Sediment QC included a duplicate sample from Blairmore Creek and analyzed for the same parameters as creek sediment samples.

Periphyton samples were collected by scraping the rocks with a plastic blade. A transect was established across the station, perpendicular to the direction of flow and five or more rocks were randomly selected at evenly spaced intervals. Rocks that were relatively flat, small enough to lift, and large enough to collect a sufficient sample were kept and brought to the shore. A plastic template with a 4-cm x 4-cm square cut-out was placed over a selected patch of rock that was randomly selected from each station. Typically, the template was placed in the center of the upside face of the rock to ensure consistency among samples. A plastic blade was used to remove periphyton from the area within the 16 cm² area. Scraped materials from rocks were placed in plastic bag labeled with site and date. Samples were stored in the dark with minimal water at 4°C and sent to the lab in coolers with ice packs.

3.1.4 Laboratory Analysis

Water quality samples were analyzed for a full list of water quality variables by ALS Environmental Ltd. (Calgary, AB) except samples collected by Benga (on July, October, 2014 and January, 2015), which were analyzed by Maxxam Analytics (Calgary, AB). Full suite water quality variables included conventional variables, general organics, major ions, nutrients, metals (total and dissolved), hydrocarbons, BTEX and polycyclic aromatic hydrocarbons (PAHs). A complete list of water quality variables, analytical methods and regulatory guidelines is presented in [Table 3](#). Sediment and periphyton samples were analyzed by ALS for only total metals.

3.1.5 Data Analysis

Quality assurance and quality control (QA/QC) procedures were conducted throughout the sample collection, data analysis and reporting components of the Project following procedures described above and as required by Hatfield's ISO9001 certification. These procedures are utilized to ensure that data generated during this monitoring program are of consistently high quality and appropriate to address the objectives of the study.

In situ monitored field data and analytical chemistry data are presented as summary statistics (i.e., minimum, mean, maximum, and total number of sample analyzed) by seasons with AEP guideline exceedances highlighted where applicable. Data were screened against most recent Environmental Quality Guidelines for Alberta Surface Waters (AEP 2014), which includes the CCME Guidelines for the Protection of Aquatic Life ([Table 3](#)). For hardness-dependent guidelines, median hardness concentration of the corresponding station was used in determining the appropriate guideline value. Selenium concentrations were screened against the proposed site-specific water quality objective developed based on sulphate concentrations (Appendix A1).

Sediment quality data were compared to the CCME freshwater Interim Sediment Quality Guidelines (ISQG) for the protection of aquatic life (CCME 2002). For selenium, BC guideline for alert concentration was used (BC MOE 2014). Differences between concentrations measured in duplicate sediment QC sample were considered notable if the RPD value was greater than 20% and concentrations in one or both samples were greater than, or equal to, five times the MDL.

3.1.6 Interpretation of Water Quality Variables

This section describes some major variables that are evaluated to characterize the baseline water quality in the LSA and RSA, and how these variables are indicative of specific aspects of water quality criteria.

pH

The pH is a measure of a buffering capacity in a solution and is expressed as the negative logarithm (-log) of hydrogen ion concentration. The greater the hydrogen ion activity in water, the more acidic it is. Because it is expressed as the -log, the greater the hydrogen ion activity, the lower the pH value, and more acidic the solution is. Solutions with low hydrogen ion activity are alkaline (basic) and have a high pH value. Neutral waters have a pH of 7. Most aquatic organisms can tolerate waters with a pH between 6 and 9, as commonly found in many of the natural surface waters in Canada. Acidic deposition can lower the pH of a waterbody/watercourse. Likewise, during spring freshet, the pH of surface waters can drop to values approximating the pH of precipitation (e.g., 5.1 to 5.4; Schindler 1996).

Dissolved Oxygen

Adequate amounts of dissolved oxygen (DO) are required to support fish and other organisms in aquatic systems (Northern Ecological Monitoring and Assessment Network 2005). The solubility of oxygen depends on the partial pressure of oxygen in the air, water temperature, turbulence, mineral content of the water, and the ability of the water to exchange freely with the atmosphere. McNeely et al. (1979) suggest the typical concentration of DO to be less than 10 mg/L in the surface waters. The solubility of atmospheric oxygen in fresh water ranges from approximately 15 mg/L at 0°C to 8 mg/L at 25°C at sea level (McNeely et al. 1979). Concentrations less than 4 mg/L have been shown to produce detrimental effects on most aquatic organisms (Department of the Environment 1972).

Water Colour

Colour, which often reflects the amount of humic material in water, is measured in True Colour Units (TCU). Filtered water samples are compared to a mixture of platinum (Pt) and cobalt (Co) compounds to determine the degree of colour (1 mg/L Pt is equal to 1 TCU). According to Mitchell and Prepas (1990), a scale of true colour is presented below:

- Clear water: < 4 TCU;
- Coloured water: 4 to 55 TCU; and
- highly coloured water: > 55 TCU.

Colour often displays seasonal variation related to the hydrologic regime (e.g., elevated values during spring melt and summer), and local rainstorm events.

Total Alkalinity

The capacity/quality of water to neutralize its acidity is termed as alkalinity; therefore, this provides an indication of sensitivity of a waterbody to acid deposition or its Acid Neutralizing Capacity (ANC). Saffran and Trew (1996) presented the following scale of surface water sensitivity to acidification based on alkalinity:

- High acid sensitivity: 0 to 10 mg/L CaCO_3 ;
- Moderate sensitivity: > 10 to 20 mg/L CaCO_3 ;
- Low sensitivity: > 20 to 40 mg/L CaCO_3 ; and
- Least sensitivity: > 40 mg/L CaCO_3 .

Total Suspended Solids

The concentration of all solid particles in the water column is referred to as total suspended solids (TSS). Major sources of suspended solids in an aquatic system include soil particles from erosion from agricultural areas and construction sites, erosion of stream substrates, and particulate matter resulting from live plankton and detritus. High TSS values can cause stress to aquatic life depending on both the TSS concentration and the duration of exposure (Newcombe and Jensen 1996). Concentrations of TSS below 25 mg/L are generally not considered harmful to aquatic life (DFO and DOE 1983; EIFAC 1965; U.S. EPA 1973). Aquatic organisms can withstand low levels of TSS for long periods and higher levels for shorter periods (Newcombe and MacDonald 1991). In this report, water courses are characterized as low (< 10 mg/L), moderate (10 to 25 mg/L) and high (> 25 mg/L) TSS levels.

Total Organic Carbon

Total Organic Carbon (TOC) comprises particulate and dissolved organic carbon. Natural waters can have concentrations that vary from 1 to 30 mg/L (McNeely et al. 1979). Most TOC is derived from humic substances, and partly degraded plant and animal materials. In this report, sampling sites are characterized as low (< 5 mg/L), moderate (5-20 mg/L) and high (> 20 mg/L) TOC levels.

Major Ions

Major ion concentrations in surface waters include both anions (CO_3^{2-} , HCO_3^- , Cl^- , F^- , SO_4^{2-} , etc.) and cations (Ca^{+2} , Mg^{+2} , K^+ , Na^+ , etc.), and can be measured by hardness, Total Dissolved Solids (TDS) and specific conductivity.

Total Hardness

Total hardness is the sum of all cation concentrations in a sample, expressed as mg/L equivalent of calcium carbonate (CaCO_3). The toxicity of many metals decreases as hardness increases. Qualitative scale of water hardness is as follows (McNeely et al. 1979):

- Very soft water: 0 to 30 mg/L hardness;
- Soft water: 31 to 60 mg/L;
- Moderately soft water: 61 to 120 mg/L;
- Hard water: 121 to 180 mg/L; and
- Very hard water: > 180 mg/L.

Total Dissolved Solids and Specific Conductivity

Conductivity is a measure of the ability of water to conduct electricity and varies with the concentration of charged particles in the water. Thus, the concentration of total dissolved solids (TDS) and conductivity are strongly related. An increase in hardness also increases conductivity, and vice versa. Descriptive scales for conductivity and TDS in freshwaters are provided below (Hart et al. 1990; Mitchell and Prepas 1990):

- Low: ≤ 100 mg/L TDS or ≤ 165 μ S/cm conductivity;
- Moderate 100 to 500 mg/L TDS or 165 to 830 μ S/cm conductivity; and
- High: > 500 mg/L TDS or > 830 μ S/cm conductivity

Major Nutrients

The main nutrients of concern in most surface waters include nitrogen and phosphorus. Both are required for plant growth but in very low concentrations. Aquatic plants including phytoplankton and periphyton use these nutrients as inorganic nitrogen (e.g., ammonia and nitrate) and phosphorus (e.g., dissolved orthophosphate). Ammonium is more labile in the aquatic environment and metabolically more energy-efficient, given nitrate must be reduced to ammonium before it can be assimilated (Wetzel 2001). Syrett (1981) reported that algae will take up significant quantities of nitrate as a nutrient only when concentrations of ammonium are nearly depleted. Total Kjeldahl Nitrogen (TKN) is a measure of ammonia and organic nitrogen and is an indicator of biologically available nitrogen. The TKN concentrations in rivers that are not influenced by excessive organic inputs typically range from 0.1 to 0.5 mg/L (McNeely et al. 1979). The TKN is characterized as low (< 0.1 mg N/L), moderate (0.1 to 0.5 mg N/L) and high (> 0.5 mg N/L), based on the typically observed range in fresh waters.

Phosphorus is often the limiting nutrient (i.e., the nutrient in shortest supply) in controlling trophic status in freshwaters. Biological productivity of watercourses can be categorized in terms of trophic classification based on Total Phosphorus (TP) concentration as follows (Environment Canada 2004):

- Oligotrophic (nutrient-poor): < 0.025 mg P/L;
- Mesotrophic (containing a moderate level of nutrients): 0.025 to 0.075 mg P/L; and
- Eutrophic (nutrient rich): > 0.075 mg P/L.

Total and Dissolved Metals

Metals naturally occur in surface waters in low concentrations. Aquatic organisms can show effects associated with high metal concentrations; however, the level at which metals are toxic varies highly among metals and is dependent on several factors such as water hardness, DOC, temperature, oxygen demand, aquatic environment, levels of suspended solids present and exposure pathway/organism, etc. The toxicity of selected metals (e.g., cadmium, nickel copper, etc.) generally decreases with increasing water hardness. Usually, most metals are associated with suspended sediments and therefore tend to settle out of the water column, rendering them biologically unavailable.

Organic Compounds

Organic compounds include chemicals consisting of chains or rings of carbon atoms, such as hydrocarbons, phenols, polycyclic aromatic hydrocarbons (PAHs) and naphthenic acids. These

compounds may originate from natural sources (e.g., runoff following forest fires) or may be released from industrial sources (e.g., internal combustion engines, wastewater discharges). Elevated levels of organic compounds may be harmful to aquatic organisms; however, toxicity varies widely by nature of the chemicals. Recoverable hydrocarbons (or mineral oil and grease) provide an estimate of naturally occurring hydrocarbons.

Phenol is a naturally occurring and manufactured chemical that is widely distributed in the environment and has been detected in surface waters, rainwater, sediments, drinking water, groundwater, industrial effluents, urban runoff, and at hazardous waste sites (ATSDR 2008). Phenols may occur naturally in aquatic environments from the decomposition of aquatic and terrestrial vegetation (CCME 1999; Dobbins et al. 1987). Late-successional boreal forests are dominated by plants with high tissue-levels of phenolic compounds, and produce litter containing large quantities of phenolic compounds (Berglund 2004). As vegetation decomposes, soluble phenolic compounds enter the soils as leachate. Over time, this leachate may enter aquatic systems through seepage or as runoff from precipitation and snowmelt, producing elevated concentrations of phenolic compounds. PAHs are a unique class of persistent organic pollutants (POPs), originate from both natural and anthropogenic sources including bituminous geologic formations, forest fires, burning of fossil fuels, oil plants and refineries, diagenesis, biosynthesis, natural inputs of petroleum hydrocarbons and atmospheric deposition (Hites et al. 1980). Some of the PAHs are known to be carcinogenic, making their presence, concentrations, and fate in aquatic ecosystems of public concern (Atwater and Mavinic 1985; EPA 1987; Chung and King 1999).

3.2 RESULTS AND DISCUSSION

This section provides a review of the historical and current baseline results for water quality within the LSA and RSA and metal contents of sediment and periphyton within the LSA. The seasonal water quality statistics for field measured variables, conventional variables, major nutrients and ions, and metals, and how these statistics compare with water quality guidelines are summarized in this section.

A review of QC data for samples collected during baseline surveys is provided in [Appendix A2](#). The QA/QC assessment indicated a high level of accuracy and precision in field sampling and laboratory analyses for the water quality monitoring programs. Therefore, the data generated in the program were of good quality and adequate to address the objectives of this study.

3.2.1 Historical Information in the Local and Regional Study Areas

Historical water quality data collected during 1974 to 2008 are summarized in [Table 7](#) and discussed below.

Field and Conventional Variables

Both field- and lab-measured pH was generally alkaline and remained within the water quality guideline range in all seasons. The Crowsnest River was historically well-oxygenated in all seasons, although DO concentrations were below the minimum requirements of the water quality guideline for the protection of aquatic life on a few occasions.

Concentrations of TDS and specific conductivity were “moderate” with the highest values recorded in winter. Similar seasonal trends were also observed for total hardness and alkalinity. According to

measured alkalinity, the Crowsnest River had the highest capacity to neutralize acidity and therefore less sensitive to acid deposition. Based on median values of hardness, water of the Crowsnest River was classified as “hard” in summer and “very hard” in spring, fall, and winter. TOC concentrations and turbidity levels were low in all seasons.

Major Nutrients and Ions

Concentrations of total ammonia and nitrite in the Crowsnest River were generally below the detection limits. Data indicate that TKN was “moderate”, and concentrations of nitrate and nitrite were always lower than the water quality guideline for the protection of aquatic life except one occasion for nitrite during winter. The TP concentrations indicate that the Crowsnest River was within the “oligotrophic to mesotrophic” range depending on the seasons. Biochemical oxygen demand (BOD) concentration was low, often below the detection limit.

Calcium and magnesium as cations and bicarbonate and sulphate as anions dominated the major ions. Carbonate and hydroxide concentrations were mostly below detection limits in all seasons.

Trace Metals and Organic Compounds

Metal concentrations in the historical data were mostly below analytical detection limits, sometimes the detection limits were higher than the water quality guidelines (e.g., cadmium, copper, and mercury). Out of 19 total metals measured, concentrations of a number of metals had below detection limits including beryllium, cadmium, copper, chromium, cobalt, lead, mercury, molybdenum, and vanadium in spring; mercury and molybdenum in summer; boron, cadmium, mercury, molybdenum, silver, and vanadium in fall; and cadmium, copper, chromium, cobalt, lead, nickel and selenium in winter. Dissolved metals had even higher number of below detection limits, concentrations of barium, iron, manganese, selenium and zinc were above detection limits at least in one sample in all seasons. Few dissolved metals were measured in winter, most of them were below detection limits. The metals that had higher concentrations than water quality guidelines in one or more seasons included total copper in summer, total chromium in spring, summer and fall, total cobalt in summer and fall, total lead in summer and fall, total silver in summer, and total zinc in summer. Total mercury exceeded both chronic and acute water quality guidelines on one occasion in winter (out of 22 samples) near Lundbreck. Dissolved aluminum in fall also exceeded both chronic and acute guidelines in one sample of two.

Concentrations of oil and grease and phenolic compounds in the Crowsnest River were generally low and mostly below detection limits. The concentration of total phenolics was above water quality guideline in one sample (out of 20) in fall, in two samples (out of 26) in summer, and in five samples (out of 40) in winter.

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Table 7 Summary of historical water quality variables in the Crowsnest River, October 1974 to August 2008.

Variables	Units	Regulatory Guidelines	Spring				Summer				Fall				Winter			
			N	Med	Min	Max	N	Med	Min	Max	N	Med	Min	Max	N	Med	Min	Max
Field Measured Variables																		
Temperature	°C	-	32	7.15	1	13.02	85	13.4	4.49	19.4	53	9.07	1.7	15.97	69	0.12	<0.23	7
Dissolved Oxygen (meter)	mg/L	>5-6.5	29	12.26	10.21	14.5	54	10.265	8.78	13.6	34	10.81	8.76	13.09	47	12.5	9.53	14.46
Oxygen dissolved (Winkler)	mg/L	>5-6.5	24	11.25	1.0	13.5	34	10.3	9	11.9	28	10.595	8.8	13.9	49	11.7	1.0	13.9
pH	pH unit	6.5-9	26	8.13	7.4	8.59	52	8.27	6.9	8.63	31	8.22	7.79	8.9	46	7.98	6.9	8.5
Specific Conductivity	µS/cm	-	27	366	281	438	52	330	224	397	33	396	205	439	49	421	294	486
Conventional Variables																		
Total Suspended Solids	mg/L	-	37	14	3	153	68	7.6	<0.4	840	46	5	<0.4	340	53	10	<0.4	107
Total Dissolved Solids	mg/L	-	29	250	180	470	72	240	152	330	48	265	168	410	37	271	220	380
TDS (calculated)	mg/L	-	40	220	155	274	56	184	145	228	70	225	119	280	79	253	164	292
Turbidity	NTU	-	51	5	<0.1	90	83	2.6	0.7	561	58	<1	<0.4	6.2	91	1.5	<0.2	56
Specific Conductivity (lab)	µS/cm	-	53	377	260	488	82	337	253	408	91	380	220	458	93	438	275	512
pH (lab)	pH unit	-	53	8.23	7.8	8.7	82	8.3	7.2	8.7	91	8.3	7.81	8.5	92	8.13	7.48	8.5
Total Hardness (as CaCO ₃)	mg/L	-	42	190	146	238	58	174	140	218	70	198	131	236	67	223	164	253
Total Alkalinity (as CaCO ₃)	mg/L	-	52	156	119	198	82	145	115	175	89	163	112	195	93	168	113	199
Total Organic Carbon (TOC)	mg/L	-	47	1.5	0.4	6.3	76	1.6	0.2	13.2	84	2	0.7	12	82	1	0.5	11
Total Carbon	mg/L	-	25	43	34	53	30	40	29	45	26	43	29	49	38	47	30	57
Major Nutrients																		
Total Ammonia (as N)	mg/L	Narrative	26	<0.01	<0.01	0.19	56	<0.01	<0.01	0.25	35	<0.01	<0.01	<0.05	49	<0.01	<0.01	0.1
Nitrate and Nitrite (as N)	mg/L	-	10	0.0765	0.021	0.154	24	0.134	0.011	0.245	18	0.09	0.012	0.129	35	0.212	0.103	0.608
Nitrite (as N)	mg/L	0.02-0.06	10	<0.003	<0.003	<0.003	24	<0.003	<0.003	0.011	18	<0.003	<0.003	0.005	35	0.004	<0.003	0.085
Nitrate (as N)	mg/L	3-124	10	0.0765	0.018	0.154	22	0.134	0.011	0.245	16	0.086	0.007	0.129	25	0.195	0.103	0.492
Total Kjeldahl Nitrogen	mg/L	-	54	0.26	0.07	1.2	88	0.16	<0.05	3.52	90	0.12	<0.05	0.68	93	<0.2	<0.05	1.1
Dissolved Ortho-phosphate	mg/L	-	24	0.011	<0.002	0.034	35	0.004	<0.002	0.029	57	0.024	<0.002	0.3	40	0.0315	<0.002	0.062
Total Dissolved Phosphorus	mg/L	-	28	0.00515	<0.003	0.019	57	0.0037	<0.003	0.04	33	<0.003	0.0027	0.01	49	0.004	<0.003	0.066
Total Phosphorus	mg/L	-	56	0.035	<0.003	0.2905	86	<0.02	<0.003	0.687	91	0.03	<0.003	0.1	92	0.024	<0.003	0.11
Biochemical Oxygen Demand	mg/L	-	34	1.2	0.9	1.8	44	1	0.7	4.1	33	1.1	0.5	2.3	60	1	0.7	5.5
Major Ions																		
Calcium	mg/L	-	31	54	45	72	58	50	38	62	36	55	37	67	55	61	45	74
Magnesium	mg/L	-	56	13.55	9	18.6	88	11.25	1	16	91	13	8	18	102	15	9	19.6
Potassium	mg/L	-	53	0.59	<0.2	1.13	81	0.52	<0.2	1.2	90	0.6	<0.1	1.4	93	0.7	<0.2	1.9
Sodium	mg/L	-	57	6	<0.5	12	88	4.9	0.8	9	93	6	<0.3	16	103	7.8	0.9	14.6

Table 7 (Cont'd.)

Variables	Units	Guidelines	Spring				Summer				Fall				Winter			
			N	Med	Min	Max	N	Med	Min	Max	N	Med	Min	Max	N	Med	Min	Max
Bicarbonate	mg/L	-	27	185	142	217	51	169	140	203	35	190	150	217	40	209	6	234
Carbonate	mg/L	-	25	<0.5	<0.5	10.6	50	<0.5	<0.5	13.4	32	<0.5	<0.5	7.7	37	<0.5	<0.5	<0.5
Chloride	mg/L	120-640	53	2	<1	5.5	82	1.65	0.9	3.7	91	2	0.5	4.3	93	3	<1	7
Fluoride	mg/L	-	44	0.25	0.16	0.34	67	0.26	0.037	0.34	78	0.27	<0.05	0.36	72	0.31	0.2	0.44
Sulphate	mg/L	309	53	46	21	77	82	33	19	54	91	45	10	67	93	59	10	82
Hydroxide	mg/L	-	10	<0.5	<0.5	<0.5	24	<0.5	<0.5	<0.5	18	<0.5	<0.5	<0.5	25	<0.5	<0.5	<0.5
Total Metals																		
Aluminum	mg/L	-	1	0.59	0.59	0.59	4	0.15	0.04	14.4	6	0.07	0.02	0.31	0	-	-	-
Arsenic	mg/L	0.005	5	0.0004	<0.0002	0.0008	13	0.0003	<0.0002	0.0038	9	0.0003	<0.0002	0.0006	6	0.00045	<0.0002	0.0006
Barium	mg/L	-	2	0.095	0.08	0.11	8	0.07	0.06	0.406	8	0.08	0.06	0.09	4	0.09	0.08	0.09
Beryllium	mg/L	-	1	<0.001	<0.001	<0.001	4	<0.001	0.0007	0.002	2	0.0015	<0.001	0.002	0	-	-	-
Boron	mg/L	1.5-29	0	-	-	-	1	0.03	0.03	0.03	2	<0.01	<0.01	<0.01	0	-	-	-
Cadmium	mg/L	0.00026-0.0038	3	<0.001	<0.0002	<0.001	8	<0.001	<0.0002	0.0011	7	0.0005	<0.0002	<0.001 ^a	9	<0.001 ^a	<0.001 ^a	<0.001 ^a
Copper	mg/L	0.007-0.024	1	<0.001	<0.001	<0.001	4	0.0124	0.012	0.02	4	0.00085	0.0004	<0.001	1	<0.001	<0.001	<0.001
Chromium	mg/L	0.0099	1	0.01	0.01	0.01	4	0.0065	<0.002	0.011	5	0.007	<0.001	0.017	5	<0.001	<0.001	<0.001
Cobalt	mg/L	0.0025	1	<0.001	<0.001	<0.001	3	<0.001	<0.001	0.005	4	0.00065	<0.0003	0.01	1	<0.001	<0.001	<0.001
Iron	mg/L	-	2	0.28	0.1	0.46	4	0.15	0.1	15.1	5	0.04	0.01	0.1	0	-	-	-
Lead	mg/L	0.0067	1	<0.001	<0.001	<0.001	3	<0.001	<0.001	0.0128	5	<0.001	0.0003	0.017	5	<0.001	<0.001	<0.001
Manganese	mg/L	-	2	0.0595	0.019	<0.1	4	0.0105	0.006	0.489	4	0.0035	0.003	0.01	1	0.007	0.007	0.007
Mercury	µg/L	0.005-0.013	13	<0.05 ^a	<0.04 ^a	<0.1 ^a	30	<0.05 ^a	<0.00026	<0.1 ^a	21	<0.05 ^a	<0.0013	<0.1 ^a	22	<0.1 ^a	<0.05 ^a	0.4
Molybdenum	mg/L	0.073	1	<0.003	<0.003	<0.003	4	<0.003	0.0011	<0.003	4	<0.003	<0.003	<0.003	0	-	-	-
Nickel	mg/L	0.086-0.77	1	0.003	0.003	0.003	3	0.002	<0.001	0.0211	4	0.00235	<0.001	0.003	1	<0.001	<0.001	<0.001
Selenium	mg/L	Site-specific	2	0.00025	<0.0002	0.0003	8	0.00055	0.0003	0.0016	8	0.00035	<0.0002	0.0018	1	<0.0002	<0.0002	<0.0002
Silver	mg/L	0.0001	0	-	-	-	1	0.0002	0.0002	0.0002	2	<0.0001	<0.0001	<0.0001	0	-	-	-
Vanadium	mg/L	-	1	<0.002	<0.002	<0.002	4	<0.002	<0.002	0.017	4	<0.002	<0.002	<0.002	0	-	-	-
Zinc	mg/L	0.03	1	0.023	0.023	0.023	3	0.025	0.012	0.0412	6	0.003	0.001	0.013	4	<0.1 ^a	<0.1 ^a	<0.1 ^a
Dissolved Metals																		
Aluminum	mg/L	0.05-0.1	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	2	0.14	<0.01	0.27	0	-	-	-
Arsenic	mg/L	-	2	0.00025	<0.0002	0.0003	1	<0.0002	<0.0002	<0.0002	5	<0.0002	<0.0002	<0.0002	4	<0.0002	<0.0002	0.0003
Barium	mg/L	-	1	0.06	0.06	0.06	1	0.07	0.07	0.07	1	0.08	0.08	0.08	0	-	-	-
Beryllium	mg/L	-	1	<0.001	<0.001	<0.001	1	<0.001	<0.001	<0.001	1	<0.001	<0.001	<0.001	0	-	-	-
Boron	mg/L	-	0	-	-	-	0	-	-	-	2	0.015	<0.01	0.02	0	-	-	-

Table 7 (Cont'd.)

Variables	Units	Guidelines	Spring				Summer				Fall				Winter			
			N	Med	Min	Max	N	Med	Min	Max	N	Med	Min	Max	N	Med	Min	Max
Cadmium	mg/L	-	2	<0.0006	<0.0002	<0.001	1	<0.0002	<0.0002	<0.0002	3	<0.001	<0.0002	<0.001	4	<0.001	<0.001	<0.001
Chromium	mg/L	-	1	0.003	0.003	0.003	1	<0.002	<0.002	<0.002	1	<0.002	<0.002	<0.002	0	-	-	-
Cobalt	mg/L	-	1	<0.001	<0.001	<0.001	1	<0.001	<0.001	<0.001	1	<0.001	<0.001	<0.001	0	-	-	-
Copper	mg/L	-	2	<0.0505	<0.001	<0.1	0	-	-	-	2	<0.0505	<0.001	<0.1	0	-	-	-
Iron	mg/L	0.3	12	<0.01	<0.01	0.02	23	<0.01	<0.01	0.08	19	<0.01	<0.01	0.06	29	<0.01	<0.01	0.03
Lead	mg/L	-	2	<0.0505	<0.001	<0.1	1	<0.001	<0.001	<0.001	2	<0.0505	<0.001	<0.1	0	-	-	-
Manganese	mg/L	-	12	<0.004	<0.001	0.006	23	<0.004	<0.001	0.023	19	<0.004	<0.001	0.005	29	<0.004	<0.001	<0.004
Molybdenum	mg/L	-	1	<0.003	<0.003	<0.003	1	<0.003	<0.003	<0.003	1	<0.003	<0.003	<0.003	0	-	-	-
Nickel	mg/L	-	1	<0.001	<0.001	<0.001	1	<0.001	<0.001	<0.001	1	<0.001	<0.001	<0.001	0	-	-	-
Selenium	mg/L	-	1	0.0002	0.0002	0.0002	1	0.0003	0.0003	0.0003	3	<0.0002	<0.0002	0.0004	0	-	-	-
Vanadium	mg/L	-	1	<0.002	<0.002	<0.002	1	<0.002	<0.002	<0.002	1	<0.002	<0.002	<0.002	0	-	-	-
Zinc	mg/L	-	2	0.057	0.014	<0.1	1	0.014	0.014	0.014	2	0.052	0.004	<0.1	0	-	-	-
Organics																		
Oil and Grease	mg/L	-	9	0.6	<0.2	0.9	15	0.5	<0.2	1.1	10	<0.2	<0.2	<0.2	29	0.7	<0.2	2.6
Phenols	mg/L	0.004	16	<0.002	<0.001	<0.002	26	<0.002	<0.001	0.023	20	0.0015	<0.001	0.007	40	<0.002	<0.001	0.039

Note: **Bold** values indicate water quality guideline exceedance; ^a = analytical detection limits higher than water quality guideline values; - = data not available.

3.2.2 Traditional Knowledge

Information gathered during traditional knowledge and traditional use surveys with members of four Treaty 7 First Nations was integrated with the existing scientific information. Traditional use of aquatic resources within the area is limited and traditional use has mainly been as a source of water for plants and animals.

Water quality was identified as one of the important components by Tsuut'ina participants during ground-truthing efforts on August 12 to 13 and October 27 to 28, 2014. In the words of a Tsuut'ina Nation member,

“if you don't have water, you don't have growth!”

Water determines how vibrant plants will growth and, thus, the quality of wildlife forage. Streams and waterways determine the hunting areas for moose, elk, or deer. Both berries and poplars are known to use a lot of water and thus are indicators of either wet or dry environments or particularly warm or cool years. While ground-truthing in October, it was reported by the Tsuut'ina Nation that the mountain sage did not grow too tall in 2014, which is a sign that it was a dry summer. The Tsuut'ina Nation also observed that some of the streams were not running fast enough this time of the year and commented that this standing water was not drinkable due to having lots of bacteria and moss.

During the workshop on December 2, 2014, several Kainai Elders recommended an emergency preparedness plan in the event of leaks, spills, or other disasters. This plan is to address concerns they have about effects on water quality and species dependent on clean water sources. Several areas in and around Grassy Mountain were identified as good camping locations based on access to water.

Also of importance to the Piikani people is the Oldman River, which features prominently as a source of life, legend, and food.

“Everything from the mountains, to the water... that's why I say the water is so important, because of this water, we have all these other animals to help contribute to these certain powers, given to us by the spirit world to maintain us as the people we are. It connects from the upper, to the ground, to underground.” - Piikani Elder (Breakout Session, June 2014).

He further elaborated that plants are harvested during different parts of the year:

“Right now is spring. All the water is going through it, the fresh air. So, when you go out, you could smell it.”

Traditional Use (TU) site assessment by Siksika Consultation Office (SCO) was undertaken during October 6 and 10, 2014. The community members were concerned that the springs and streams running off Grassy Mountain and hillsides nearby that will be impacted by the Project and likely will become polluted by the mine run-off causing unnecessary deaths of animals. They recommended that a workable, effective mitigation strategy and plan for the protection of the animals and watercourses extant at the site needs to be developed jointly with Siksika SCO and Elders.

3.2.3 Baseline Conditions

Water quality surveys were conducted at five stations within the Blairmore Creek drainage and eight stations within the Gold Creek drainage, and three stations in the Crowsnest River from May 2013 to March 2016. A new station at Caudron Creek (CC-W01) was introduced in 2016 as a reference site for Gold Creek and sampled during winter and spring 2016. Blairmore Creek upstream station, BC-W03 also was proposed to be a reference station for Blairmore Creek during operations.

3.2.3.1 Local Study Area

The LSA included both Blairmore Creek and Gold Creek drainages ([Figure 3](#)). Water quality data in these water courses are summarized in [Table 8](#) (Blairmore Creek) and [Table 9](#) (Gold Creek) and station-wise raw data are presented in [Appendix A3](#). Summary of water quality guideline exceedances is presented in [Table 10](#). Metal contents of sediment and periphyton in the LSA are summarized in [Table 11](#) and [Table 12](#), respectively, and station-wise raw data are presented in [Appendix A3](#).

Table 8 Summary of seasonal of water quality variables at Blairmore Creek drainage, May 2013 to March 2016.

Variables	Units	Guidelines	Spring				Summer				Fall				Winter			
			N	Med	Min	Max	N	Med	Min	Max	N	Med	Min	Max	N	Med	Min	Max
Field Measured Variables																		
Temperature	(°C)		11	4.88	0	9.3	16	12	5.94	17.1	5	7.3	6.4	10.67	5	0.8	0.2	6.6
pH	-	6.5-9.0	9	8.49	7.73	10.01	16	8.08	6.66	8.55	5	8.3	8.23	8.44	5	8.46	8.36	8.65
Dissolved Oxygen	mg/L	>5.0-6.5	11	12.4	9	16.09	17	9.2	7.6	12.64	5	10.40	9.5	18.72	4	10.5	9.5	11.7
Specific Conductivity	μS/cm		10	182	9.3	279	15	242	79	358	5	242	238	354	5	300	149	337
Conventional Variables																		
Colour	TCU	-	5	19.3	<5	33.1	10	11.85	<5	60	3	7.3	<5	14.4	4	<5	<5	<5
Total Suspended Solids (TSS)	mg/L	-	5	<4	<4	<6	11	<4	<2	97	3	<4	<4	<4	4	<3	<3	<3
Turbidity	NTU	-	5	6.34	0.29	8.24	10	1.18	0.29	109	3	1.03	0.36	1.42	4	0.6	0.33	3.22
Total Dissolved Solids (TDS)	mg/L	-	5	124	104	244	11	180	78	238	4	199	124	210	5	180	100	205
TDS (Calculated)	mg/L	-	5	134	104	237	11	176	47.2	207	4	204	136	210	5	180	83.6	214
Specific Conductivity	μS/cm	-	5	254	198	390	11	322	97	391	4	344.5	242	370	5	330	175	338
pH	-	6.5-9.0	5	8.17	8.1	8.25	11	8.31	7.8	8.4	4	8.36	8.3	8.45	5	8.18	8.01	8.26
Total Hardness (as CaCO ₃)	mg/L	-	5	122	95	225	11	161	44	190	4	185	123	200	5	180	73	216
Total Alkalinity (as CaCO ₃)	mg/L	>20	5	131	101	229	11	154	45	209	4	186	133	195	5	152	78	180
Dissolved Organic Carbon	mg/L	-	5	4.3	1.4	6.9	10	3.2	1.1	11.7	3	3	2.9	4.8	4	2.3	1	2.3
Total Organic Carbon	mg/L	-	5	4.2	1.4	7.2	11	3.1	1.2	11.5	4	2.8	2.1	4.6	5	2.3	1.1	2.3
Major Nutrients and BOD																		
Total Ammonia (as N)	mg/L	narrative	5	<0.05	<0.05	<0.05	10	<0.05	<0.05	<0.05	3	<0.05	<0.05	<0.05	4	<0.05	<0.05	<0.05
Nitrate and Nitrite (as N)	mg/L	-	5	<0.071	<0.071	0.074	10	<0.071	<0.054	0.078	3	<0.071	<0.071	<0.071	4	<0.05	<0.05	0.067
Nitrate (as N)	mg/L	3-124	5	<0.05	<0.05	0.074	11	<0.05	0.015	0.078	4	<0.05	0.035	<0.05	5	0.023	<0.02	0.067
Nitrite (as N)	mg/L	0.02-0.06	5	<0.05	<0.05	<0.05	10	<0.05	<0.01	<0.05	4	<0.05	<0.01	<0.05	5	<0.01	<0.01	<0.01
Total Kjeldahl Nitrogen	mg/L	-	5	<0.2	<0.2	0.23	10	<0.2	<0.2	1.08	3	<0.2	<0.2	<0.2	4	<0.2	<0.2	<0.2
Dissolved Phosphorus	mg/L	-	5	0.0052	0.0032	0.0109	10	0.00455	0.0032	0.0366	4	0.00695	0.0018	0.1	4	0.0032	0.0027	0.004
Total Phosphorus	mg/L	-	5	0.011	0.005	0.0162	10	0.0079	0.0047	0.145	3	0.0056	0.0029	0.0128	4	0.00485	0.0024	0.0056
Biochemical Oxygen Demand (BOD)	mg/L	-	5	<2	<2	<2	10	<2	<2	<2	3	<2	<2	<2	4	<2	<2	<2
Major Ions																		
Calcium	mg/L	-	5	37	29	69	11	47	12	58	4	56	37	60	5	54	22.1	65.6
Magnesium	mg/L	-	5	7.23	5.74	12.9	11	9.75	3.53	12.1	4	10.72	7.49	12	5	12	4.43	12.6
Potassium	mg/L	-	5	0.56	0.453	0.6	11	0.74	0.5	0.94	4	0.705	0.56	0.74	5	0.67	0.5	0.79
Sodium	mg/L	-	5	2.68	2.4	7.3	11	4.1	1	5.5	4	5.05	3.7	5.2	5	5.5	4.3	6.8
Bicarbonate	mg/L	-	5	160	123	279	11	188	55.1	241	4	218.5	162	234	5	190	95.4	220
Carbonate	mg/L	-	5	<5	<5	<5	11	<5	0.82	6.8	4	<5	3.2	<5	5	5	0.5	5
Chloride	mg/L	120-640	5	0.4	0.21	0.8	10	0.38	0.14	0.61	4	0.74	0.68	1.5	5	0.51	0.5	1.9
Hydroxide	mg/L	-	5	<5	<5	<5	10	<5	<5	<5	4	<5	<0.5	<5	5	<5	<0.5	<5
Sulphate	mg/L	309	5	8.3	4.6	9.8	11	13.7	4.53	24.5	4	14.2	7.4	22.0	5	18	5.56	19.6
Sulphide	mg/L	0.0019	5	<0.002	<0.002	<0.002	10	<0.002	<0.0015	<0.002	3	<0.002	<0.002	<0.002	4	<0.0015	<0.0015	<0.0015

Table 8 (Cont'd.)

Variables	Units	Guidelines	Spring				Summer				Fall				Winter			
			N	Med	Min	Max	N	Med	Min	Max	N	Med	Min	Max	N	Med	Min	Max
Total Metals																		
Aluminum	mg/L	-	5	0.419	0.0134	0.663	10	0.04255	0.0144	3.13	3	0.0411	0.0089	0.0462	4	0.0275	0.0208	0.0641
Antimony	mg/L	-	5	<0.0004	<0.0001	<0.0004	10	<0.0001	<0.0001	<0.0004	3	<0.0001	<0.0001	0.00015	4	0.0001	0.0001	0.0001
Arsenic	mg/L	0.005	5	<0.0004	0.0002	<0.0004	10	0.000395	0.00021	0.00118	3	0.00034	0.00025	0.00039	4	0.000195	0.00012	0.0002
Barium	mg/L	-	5	0.109	0.0844	0.178	10	0.121	0.0976	0.16	3	0.129	0.117	0.161	4	0.108	0.0424	0.126
Beryllium	mg/L	-	5	<0.001	<0.0005	<0.001	10	<0.0005	0.00015	<0.001	3	<0.0005	<0.0005	<0.0005	4	0.0001	0.0001	0.0005
Boron	mg/L	1.5-29	5	<0.05	<0.011	<0.05	10	<0.013	<0.01	<0.05	3	<0.01	<0.01	0.013	4	0.0125	0.01	0.014
Cadmium	mg/L	0.00026-0.0038	5	<0.00005	<0.00001	<0.00005	10	0.0000155	<0.00001	0.00021	3	0.0000115	<0.00001	0.000013	4	0.0000124	<0.000005	0.0000154
Chromium	mg/L	0.0099	5	<0.005	<0.0001	<0.005	10	<0.000105	<0.0001	<0.005	3	<0.0001	<0.0001	<0.0001	4	<0.0001	<0.0001	<0.0001
Cobalt	mg/L	0.0025	5	<0.002	<0.0001	<0.002	10	<0.00012	<0.0001	<0.002	3	<0.0001	<0.0001	<0.0001	4	<0.0001	<0.0001	<0.0001
Copper	mg/L	0.007-0.028	5	0.0012	0.00031	0.0017	10	0.00074	0.0004	0.00544	3	0.00044	0.00032	0.00053	4	0.000505	<0.0005	0.00053
Iron	mg/L	-	0	-	-	-	7	0.075	0.021	4.07	0	-	-	-	4	0.066	0.018	0.085
Lead	mg/L	0.0067	5	0.00021	<0.00005	0.00029	10	<0.00005	<0.00005	0.00220	3	<0.00005	<0.00005	0.000066	4	<0.00005	<0.00005	<0.00005
Lithium	mg/L	-	5	<0.01	<0.005	<0.01	10	<0.005	<0.0035	<0.01	3	<0.005	<0.005	<0.005	4	0.0032	0.0029	0.005
Manganese	mg/L	-	0	-	-	-	7	0.00329	0.00203	0.0982	0	-	-	-	4	0.005	0.00042	0.005
Mercury	µg/L	0.005-0.013	5	0.0038	<0.0005	0.0045	10	0.001375	0.00065	0.0375	3	0.00124	0.00098	0.00142	4	0.005	0.00085	0.005
Molybdenum	mg/L	0.073	5	<0.005	0.000503	<0.005	10	0.000909	0.0003	<0.005	3	0.000825	0.00063	0.000861	4	0.00083	0.000767	0.00107
Nickel	mg/L	0.086-0.77	5	<0.002	<0.0001	<0.002	10	0.001025	0.00014	0.00557	3	0.00051	0.00027	0.0008	4	0.000575	<0.0001	0.00069
Selenium	mg/L	Site-specific	5	0.00042	0.00026	0.00062	10	0.00045	0.0003	0.00115	3	0.00043	0.00028	0.00048	4	0.0007205	0.00047	0.00091
Silver	mg/L	0.0001	5	<0.0001	<0.00001	<0.0001	10	<0.00001	<0.00001	0.000120	3	0.000033	2.4E-05	0.000048	4	<0.00001	<0.00001	<0.00001
Thallium	mg/L	0.0008	5	<0.0001	<0.00005	<0.0001	10	<0.00005	<0.00005	<0.0001	3	<0.00005	<0.00005	0.000096	4	<0.00001	<0.00001	0.00005
Tin	mg/L	-	5	<0.05	<0.0001	<0.05	10	<0.0001	<0.0001	<0.05	3	0.00028	0.00027	0.0003	4	<0.0001	<0.0001	<0.0001
Titanium	mg/L	-	5	0.0056	<0.0003	0.0124	10	0.0007	<0.0003	0.0447	3	0.00082	<0.0003	0.00088	4	0.00031	0.0003	0.00085
Uranium	mg/L	0.015-0.033	5	0.00029	0.00021	0.000661	10	0.0004405	0.00018	0.00074	3	0.000417	0.00033	0.00062	4	0.000579	0.000186	0.000688
Vanadium	mg/L	-	5	0.0012	0.00023	0.0017	10	0.00046	0.00024	0.00883	3	0.00041	0.0003	0.00042	4	0.0005	0.0005	0.0005
Zinc	mg/L	0.03	5	<0.0046	<0.004	<0.005	10	<0.005	<0.004	0.0188	3	<0.005	<0.005	<0.005	4	0.003	<0.003	0.004
Dissolved Metals																		
Aluminum	mg/L	0.05-0.1	4	0.01465	0.0119	0.0313	11	<0.01	<0.001	0.0417	4	0.00585	0.0011	0.010	4	0.0119	0.0019	0.0195
Antimony	mg/L	-	4	<0.0001	<0.0001	<0.0001	10	<0.0001	<0.0001	<0.0004	4	<0.0001	<0.0001	<0.0006	4	<0.0001	<0.0001	<0.0001
Arsenic	mg/L	-	4	0.00023	0.00017	0.00031	10	0.000305	0.00018	<0.0004	4	0.000265	0.00021	0.00037	4	0.000155	<0.0001	0.00018
Barium	mg/L	-	4	0.1001	0.0777	0.184	11	0.117	0.0512	0.166	4	0.122	0.112	0.157	4	0.1085	0.0413	0.122
Beryllium	mg/L	-	4	<0.0005	<0.0005	<0.0005	10	<0.0005	<0.0001	<0.001	4	<0.0005	<0.0005	<0.001	4	<0.0001	<0.0001	0.0005
Boron	mg/L	-	4	<0.01	<0.01	0.011	10	<0.0145	<0.01	<0.05	4	<0.0125	<0.01	<0.02	4	0.0125	<0.01	0.014
Cadmium	mg/L	-	4	0.0000115	<0.00001	0.000013	11	<0.000014	<0.00001	<0.00005	4	<0.00001	<0.00001	<0.00002	4	0.0000104	<0.000005	0.0000119
Chromium	mg/L	-	4	<0.0001	<0.0001	<0.0001	10	<0.0001	<0.0001	<0.005	4	<0.0001	<0.0001	<0.0001	4	<0.0001	<0.0001	<0.0001
Cobalt	mg/L	-	4	<0.0001	<0.0001	0.00018	10	<0.0001	<0.0001	<0.002	4	<0.0001	<0.0001	<0.0003	4	<0.0001	<0.0001	<0.00011

Table 8 (Cont'd.)

Variables	Units	Guidelines	Spring				Summer				Fall				Winter			
			N	Med	Min	Max	N	Med	Min	Max	N	Med	Min	Max	N	Med	Min	Max
Copper	mg/L	-	4	0.000735	0.00034	0.00105	11	0.00056	0.00017	0.0014	4	0.000395	0.00013	0.00058	4	0.00033	0.00026	0.00041
Iron	mg/L	0.3	5	0.03	0.022	0.031	10	0.0215	<0.01	0.102	4	<0.03	<0.03	<0.06	5	<0.03	<0.03	0.06
Lead	mg/L	-	4	<0.00005	<0.00005	<0.00005	10	<0.00005	<0.00005	<0.0001	4	<0.00005	<0.00005	<0.0002	4	<0.00005	<0.00005	<0.00005
Lithium	mg/L	-	4	<0.005	<0.005	0.0053	10	<0.005	0.0013	0.0062	4	<0.005	<0.005	<0.02	4	0.0033	0.0027	0.005
Manganese	mg/L	-	5	<0.005	0.00121	0.00695	11	<0.005	0.00114	0.0108	4	<0.005	<0.004	<0.005	5	0.005	0.004	0.005
Mercury	µg/L	-	2	<0.0005	<0.0005	<0.0005	1	0.00776	0.00776	0.00776	1	<0.0005	<0.0005	<0.0005	4	<0.005	<0.0006	<0.005
Molybdenum	mg/L	-	4	0.000537	0.0004	0.000558	11	0.000861	0.00017	<0.005	4	0.000787	0.00065	0.000851	4	0.000758	0.000648	0.000891
Nickel	mg/L	-	4	0.000475	0.0003	0.00108	11	0.00105	0.00011	0.0023	4	0.00057	0.00026	0.00073	4	0.00051	<0.0001	0.00056
Selenium	mg/L	-	0	0.00052	0.0004	0.00083	9	0.0005	0.00042	0.00127	4	0.000685	0.00064	0.00076	3	0.000797	0.000491	0.000798
Silver	mg/L	-	4	<0.00001	<0.00001	<0.00001	10	<0.00001	<0.00001	<0.00001	4	<0.00001	<0.00001	<0.00001	4	<0.00001	<0.00001	<0.00001
Thallium	mg/L	-	4	<0.00005	<0.00005	<0.00005	10	<0.00005	<0.00001	<0.0001	4	<0.00005	<0.00005	<0.0002	4	<0.00001	<0.00001	0.00005
Tin	mg/L	-	4	<0.0001	<0.0001	<0.0001	10	<0.0001	<0.0001	<0.05	4	<0.0001	<0.0001	<0.0001	4	<0.0001	<0.0001	<0.0001
Titanium	mg/L	-	4	0.000575	0.00037	0.0008	10	0.00048	<0.0003	0.00569	4	0.00047	<0.0003	<0.001	4	<0.0003	<0.0003	<0.0003
Uranium	mg/L	-	4	0.0002195	0.000177	0.000682	11	0.000401	4.8E-05	0.0006	4	0.000509	0.00032	0.00069	4	0.0005115	0.000145	0.000587
Vanadium	mg/L	-	4	0.000165	<0.0001	0.00021	10	0.000285	0.00014	<0.001	4	0.00016	0.00011	<0.001	4	0.0005	0.00014	0.0005
Zinc	mg/L	-	4	0.003	<0.001	0.0064	10	0.00215	<0.001	<0.005	4	<0.005	<0.003	<0.005	4	0.0037	<0.001	0.0066
General Organics																		
Recoverable Hydrocarbons	mg/L	-	5	<1	<1	<1	9	<1	<1	<1	3	<1	<1	<1	4	<1	<1	<1
Phenols (4AAP)	mg/L	0.004	5	0.0012	<0.001	0.0019	9	<0.001	<0.001	<0.001	4	<0.001	<0.001	<0.002	5	<0.001	<0.001	<0.002
Benzene	mg/L	0.04	5	<0.0005	<0.0005	<0.0005	6	<0.0005	<0.0005	<0.0005	3	<0.0005	<0.0005	<0.0005	4	<0.0005	<0.0005	<0.0005
Ethylbenzene	mg/L	0.09	5	<0.0005	<0.0005	<0.0005	6	<0.0005	<0.0005	<0.0005	3	<0.0005	<0.0005	<0.0005	4	<0.0005	<0.0005	<0.0005
Toluene	mg/L	0.0005	2	<0.0005	<0.0005	<0.0005	6	<0.0005	<0.0005	<0.0005	3	<0.0005	<0.0005	<0.0005	4	<0.0005	<0.0005	<0.0005
o-xylene	mg/L	-	2	<0.0005	<0.0005	<0.0005	6	<0.0005	<0.0005	<0.0005	3	<0.0005	<0.0005	<0.0005	4	<0.0005	<0.0005	<0.0005
m+p-Xylene	mg/L	-	2	<0.0005	<0.0005	<0.0005	6	<0.0005	<0.0005	<0.0005	3	<0.0005	<0.0005	<0.0005	4	<0.0005	<0.0005	<0.0005
Xylenes	mg/L	0.03	2	<0.00071	<0.00071	<0.00071	6	<0.000605	<0.0005	<0.00071	3	<0.0005	<0.0005	<0.0005	4	<0.00071	<0.00071	<0.00071
F1(C6-C10)	mg/L	0.15	2	<0.1	<0.1	<0.1	6	<0.1	<0.1	<0.1	3	<0.1	<0.1	<0.1	4	<0.1	<0.1	<0.1
F1-BTEX	mg/L	-	2	<0.1	<0.1	<0.1	6	<0.1	<0.1	<0.1	3	<0.1	<0.1	<0.1	4	<0.1	<0.1	<0.1
F2 (>C10-C16)	mg/L	0.11	2	<0.25	<0.25	<0.25	3	<0.25	<0.25	<0.25	3	<0.25	<0.25	<0.25	4	<0.1	<0.1	<0.25
F3 (C16-C34)	mg/L	-	2	<0.25	<0.25	<0.25	3	<0.25	<0.25	<0.25	3	<0.25	<0.25	<0.25	4	<0.25	<0.25	<0.25
F4 (C34-C50)	mg/L	-	2	<0.25	<0.25	<0.25	3	<0.25	<0.25	<0.25	3	<0.25	<0.25	<0.25	4	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	2	<0.1	<0.1	0.13	9	<0.1	<0.1	<0.1	3	<0.1	<0.1	<0.1	4	<0.2	<0.1	0.52
Polycyclic Aromatic Hydrocarbons																		
Benzo[a]pyrene	µg/L	0.015	5	-	-	-	0	-	-	-	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01
Acenaphthene	µg/L	5.80	0	-	-	-	0	-	-	-	1	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1
Acenaphthylene	µg/L	-	0	-	-	-	0	-	-	-	1	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1
Acridine	µg/L	4.4	0	-	-	-	0	-	-	-	1	<0.2	<0.2	<0.2	1	<0.2	<0.2	<0.2
Anthracene	µg/L	0.012	0	-	-	-	0	-	-	-	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01
Benzo(a)anthracene	µg/L	0.018	0	-	-	-	0	-	-	-	1	<0.0085	<0.0085	<0.0085	1	<0.0085	<0.0085	<0.0085

Table 8 (Cont'd.)

Variables	Units	Guidelines	Spring				Summer				Fall				Winter			
			N	Med	Min	Max	N	Med	Min	Max	N	Med	Min	Max	N	Med	Min	Max
Benzo(b&j)fluoranthene	µg/L	-	0	-	-	-	0	-	-	-	1	<0.0085	<0.0085	<0.0085	1	<0.0085	<0.0085	<0.0085
Benzo(k)fluoranthene	µg/L	-	0	-	-	-	0	-	-	-	1	<0.0085	<0.0085	<0.0085	1	<0.0085	<0.0085	<0.0085
Benzo(g,h,i)perylene	µg/L	-	0	-	-	-	0	-	-	-	1	<0.0085	<0.0085	<0.0085	1	<0.0085	<0.0085	<0.0085
Benzo(c)phenanthrene	µg/L	-	0	-	-	-	0	-	-	-	1	<0.05	<0.05	<0.05	1	<0.05	<0.05	<0.05
Benzo(a)pyrene	µg/L	0.015	0	-	-	-	0	-	-	-	1	0.0075	0.0075	0.0075	1	0.0075	0.0075	0.0075
Benzo[e]pyrene	µg/L	-	0	-	-	-	0	-	-	-	1	<0.05	<0.05	<0.05	1	<0.05	<0.05	<0.05
Chrysene	µg/L	-	0	-	-	-	0	-	-	-	1	<0.0085	<0.0085	<0.0085	1	<0.0085	<0.0085	<0.0085
Dibenz(a,h)anthracene	µg/L	-	0	-	-	-	0	-	-	-	1	<0.0075	<0.0075	<0.0075	1	<0.0075	<0.0075	<0.0075
Fluoranthene	µg/L	0.04	0	-	-	-	0	-	-	-	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01
Fluorene	µg/L	3	0	-	-	-	0	-	-	-	1	<0.05	<0.05	<0.05	1	<0.05	<0.05	<0.05
Indeno(1,2,3-cd)pyrene	µg/L	-	0	-	-	-	0	-	-	-	1	<0.0085	<0.0085	<0.0085	1	<0.0085	<0.0085	<0.0085
2-Methylnaphthalene	µg/L	-	0	-	-	-	0	-	-	-	1	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1
Naphthalene	µg/L	1	0	-	-	-	0	-	-	-	1	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1
Phenanthrene	µg/L	0.4	0	-	-	-	0	-	-	-	1	<0.05	<0.05	<0.05	1	<0.05	<0.05	<0.05
Perylene	µg/L	-	0	-	-	-	0	-	-	-	1	<0.05	<0.05	<0.05	1	<0.05	<0.05	<0.05
Pyrene	µg/L	0.025	0	-	-	-	0	-	-	-	1	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02
Quinoline	µg/L	3.4	0	-	-	-	0	-	-	-	1	<0.2	<0.2	<0.2	1	<0.2	<0.2	<0.2

Note: **Bold** values indicate water quality guideline exceedance; - = data not available

Table 9 Summary of seasonal water quality variables at Gold Creek drainage, May 2013 to March 2016.

Variables	Units	Guidelines	Spring				Summer				Fall				Winter			
			N	Med	Min	Max	N	Med	Min	Max	N	Med	Min	Max	N	Med	Min	Max
Field Measured Variables																		
Temperature	(°C)		6	3.89	1.8	6.39	12	7.595	3.98	14.92	3	6.6	5.99	7.85	5	2.1	0.9	6.4
pH	-	6.5-9.0	6	8.56	8.35	10.14	12	8.49	6.55	10.52	3	8.3	8.28	8.38	5	7.72	6.84	8.06
Dissolved Oxygen	mg/L	>5.0-6.5	6	13.26	8.1	14.39	12	12.3	8.4	13.65	3	18.34	9.7	20.32	5	11.2	8.6	11.4
Specific Conductivity	µS/cm		5	187	143	304	12	178	39	307	3	213	211	305	5	240	138	429
Conventional Variables																		
Colour	TCU	-	1	<5	<5	<5	8	9	<5	64	1	<5	<5	<5	5	<5	<5	7.3
Total Suspended Solids (TSS)	mg/L	-	1	<6	<6	<6	9	4	1.3	27	1	<4	<4	<4	5	<3	<3	<3
Turbidity	NTU	-	1	0.36	0.36	0.36	8	4.08	0.15	34.1	1	0.26	0.26	0.26	5	5.95	0.14	7.32
Total Dissolved Solids (TDS)	mg/L	-	1	186	186	186	9	145	60	202	2	171	162	180	6	168	93	305
TDS (Calculated)	mg/L	-	1	184	184	184	9	139	34	182	2	180	179	180	6	181	83	312
Specific Conductivity	µS/cm	-	1	309	309	309	9	251	86	335	2	314	308	320	6	304	155	527
pH	-	6.5-9.0	1	8.3	8.3	8.3	9	8.25	7.7	8.46	2	8.40	8.36	8.43	6	8.05	7.89	8.37
Total Hardness (as CaCO ₃)	mg/L	-	1	175	175	175	9	131	30	180	2	174	168	180	6	184	78	307
Total Alkalinity (as CaCO ₃)	mg/L	>20	1	155	155	155	9	112	35	163	2	155	150	159	6	149	57	233
Dissolved Organic Carbon	mg/L	-	1	<1	<1	<1	8	2.55	<1	9	1	1.7	1.7	1.7	5	1.7	<1	2
Total Organic Carbon	mg/L	-	1	<1	<1	<1	9	2.5	<1	10	2	1.07	0.74	1.4	6	1.35	0.79	2.6
Major Nutrients and BOD																		
Total Ammonia (as N)	mg/L	narrative	1	<0.05	<0.05	<0.05	8	<0.05	<0.05	<0.05	1	<0.05	<0.05	<0.05	5	<0.05	<0.05	<0.05
Nitrate and Nitrite (as N)	mg/L	-	1	0.108	0.108	0.108	8	0.052	<0.054	0.116	1	<0.071	<0.071	<0.071	5	0.094	<0.05	0.258
Nitrate (as N)	mg/L	3-124	1	0.108	0.108	0.108	9	<0.05	<0.02	0.116	2	0.055	0.053	0.057	6	0.107	0.047	0.258
Nitrite (as N)	mg/L	0.02-0.06	1	<0.05	<0.05	<0.05	8	<0.01	<0.01	<0.05	2	<0.03	<0.01	<0.05	5	<0.01	<0.01	<0.01
Total Kjeldahl Nitrogen	mg/L	-	1	0.21	0.21	0.21	8	<0.2	<0.2	0.53	1	<0.2	<0.2	<0.2	5	<0.2	<0.2	0.57
Dissolved Phosphorus	mg/L	-	1	0.0019	0.0019	0.0019	8	0.01355	<0.001	0.0279	2	<0.0505	<0.001	<0.1	5	0.0058	0.0014	0.0111
Total Phosphorus	mg/L	-	1	0.0023	0.0023	0.0023	8	0.01825	0.0022	0.0797	1	0.0022	0.0022	0.0022	5	0.0123	0.0027	0.0173
Biochemical Oxygen Demand (BOD)	mg/L	-	1	<2	<2	<2	8	<2	<2	<2	1	<2	<2	<2	5	<2	<2	<2
Major Ions																		
Calcium	mg/L	-	1	51	51	51	9	34	9	52	2	52	50	54	6	54	19.9	92.3
Magnesium	mg/L	-	1	11.6	11.6	11.6	9	8.64	2.12	12	2	10.9	10.7	11	6	12.8	6.81	18.6
Potassium	mg/L	-	1	<0.5	<0.5	<0.5	8	0.50	0.40	0.75	2	<0.4	<0.3	<0.5	6	0.5	0.35	0.99
Sodium	mg/L	-	1	1.8	1.8	1.8	9	1.4	1	2.2	2	1.045	0.79	1.3	5	1.6	1.1	7
Bicarbonate	mg/L	-	1	188	188	188	9	137	42	187	2	180	170	190	6	178.5	69.1	285
Carbonate	mg/L	-	1	<5	<5	<5	9	5	2	6.2	2	3.65	2.3	<5	6	5	1.3	5
Chloride	mg/L	120-640	1	0.48	0.48	0.48	8	0.5	0.27	0.5	2	0.73	0.26	1.2	6	<0.5	<0.5	1.1
Hydroxide	mg/L	-	1	<5	<5	<5	8	<5	<5	<5	2	<2.75	<0.5	<5	5	<5	<5	<5
Sulphate	mg/L	309	1	25.8	25.8	25.8	9	13.7	1.96	28.5	2	22.3	21.6	23	6	26.55	17	53.5
Sulphide	mg/L	0.0019	1	<0.002	<0.002	<0.002	8	<0.0015	<0.002	<0.002	1	<0.002	<0.002	<0.002	4	<0.0015	<0.0015	<0.0015

Table 9 (Cont'd.)

Variables	Units	Guidelines	Spring				Summer				Fall				Winter			
			N	Med	Min	Max	N	Med	Min	Max	N	Med	Min	Max	N	Med	Min	Max
Total Metals																		
Aluminum	mg/L	-	1	0.0458	0.0458	0.0458	8	0.11665	0.0065	1.2	1	0.0051	0.0051	0.0051	5	0.0367	0.004	0.211
Antimony	mg/L	-	1	<0.0001	<0.0001	<0.0001	8	<0.0001	<0.0001	<0.0001	1	0.00038	0.00038	0.00038	5	<0.0001	<0.0001	<0.0001
Arsenic	mg/L	0.005	1	0.00016	0.00016	0.00016	8	0.00023	0.00015	0.00063	1	0.00043	0.00043	0.00043	5	0.00014	0.00012	0.00021
Barium	mg/L	-	1	0.0519	0.0519	0.0519	8	0.05895	0.0556	0.115	1	0.0561	0.0561	0.0561	5	0.0697	0.0468	0.109
Beryllium	mg/L	-	1	<0.0005	<0.0005	<0.0005	8	<0.0005	<0.0001	<0.0005	1	<0.0005	<0.0005	<0.0005	5	<0.0001	<0.0001	<0.0001
Boron	mg/L	1.5-29	1	<0.01	<0.01	<0.01	8	<0.01	<0.01	0.02	1	<0.01	<0.01	<0.01	5	<0.01	<0.01	0.032
Cadmium	mg/L	0.00026-0.0038	1	<0.00001	<0.00001	<0.00001	8	0.0000234	0.0000086	0.000116	1	0.00003	0.00003	0.00003	5	0.000012	0.000006	0.000023
Chromium	mg/L	0.0099	1	0.0002	0.0002	0.0002	8	0.000255	0.00014	0.00165	1	0.0002	0.0002	0.0002	5	0.00013	<0.0001	0.00022
Cobalt	mg/L	0.0025	1	<0.0001	<0.0001	<0.0001	8	0.000135	<0.0001	0.00055	1	<0.0001	<0.0001	<0.0001	5	0.0001	<0.0001	0.00026
Copper	mg/L	0.007-0.028	1	0.00025	0.00025	0.00025	8	0.000895	0.00024	0.00306	1	0.0003	0.0003	0.0003	5	<0.0005	<0.0005	0.00074
Iron	mg/L	-	0	-	-	-	7	0.157	<0.01	1.11	0	-	-	-	5	0.037	<0.03	0.195
Lead	mg/L	0.0067	1	<0.00005	<0.00005	<0.00005	8	0.0001415	<0.00005	0.000959	1	0.000182	0.000182	0.000182	5	<0.00005	<0.00005	0.00014
Lithium	mg/L	-	1	<0.005	<0.005	<0.005	8	0.00345	<0.001	0.0054	1	<0.005	<0.005	<0.005	5	0.0017	<0.001	0.013
Manganese	mg/L	-	0	-	-	-	7	0.005	0.000753	0.0396	0	-	-	-	5	<0.005	<0.005	0.0355
Mercury	µg/L	0.005-0.013	1	<0.0005	<0.0005	<0.0005	8	0.00294	0.00067	0.0201	1	0.00067	0.00067	0.00067	5	<0.005	<0.005	<0.005
Molybdenum	mg/L	0.073	1	0.000782	0.000782	0.000782	8	0.00068	0.000288	0.000821	1	0.000827	0.000827	0.000827	5	0.000789	0.00034	0.00105
Nickel	mg/L	0.086-0.77	1	0.00029	0.00029	0.00029	8	0.00073	0.00026	0.00284	1	0.00032	0.00032	0.00032	5	<0.0005	<0.0005	0.0007
Selenium	mg/L	Site-specific	1	0.00093	0.00093	0.00093	8	0.0007	0.000389	0.00758	1	0.00112	0.00112	0.00112	5	0.00289	0.00089	0.00904
Silver	mg/L	0.0001	1	<0.00001	<0.00001	<0.00001	8	<0.00001	<0.00001	0.000075	1	0.000082	0.000082	0.000082	5	<0.00001	<0.00001	0.000012
Thallium	mg/L	0.0008	1	<0.00005	<0.00005	<0.00005	8	0.000021	<0.00001	<0.00005	1	0.00044	0.00044	0.00044	5	<0.00001	<0.00001	<0.00001
Tin	mg/L	-	1	<0.0001	<0.0001	<0.0001	8	<0.0001	<0.0001	<0.0001	1	0.0004	0.0004	0.0004	5	<0.0001	<0.0001	<0.0001
Titanium	mg/L	-	1	0.00071	0.00071	0.00071	8	0.001295	<0.0003	0.0209	1	<0.0003	<0.0003	<0.0003	5	0.00034	0.0003	0.00237
Uranium	mg/L	0.015-0.033	1	0.000445	0.000445	0.000445	8	0.000225	0.000077	0.000461	1	0.000376	0.000376	0.000376	5	0.000424	0.00005	0.000659
Vanadium	mg/L	-	1	0.00033	0.00033	0.00033	8	0.000685	0.00027	0.00387	1	0.00048	0.00048	0.00048	5	<0.0005	<0.0005	0.00065
Zinc	mg/L	0.03	1	<0.005	<0.005	<0.005	8	0.004	<0.003	0.0093	1	<0.005	<0.005	<0.005	5	<0.003	<0.003	<0.003
Dissolved Metals																		
Aluminum	mg/L	0.05-0.1	1	0.0033	0.0033	0.0033	9	0.0181	<0.001	0.338	2	<0.002	<0.001	<0.003	5	0.0107	<0.001	0.0547
Antimony	mg/L	-	1	<0.0001	<0.0001	<0.0001	8	<0.0001	<0.0001	0.00011	2	0.00035	<0.0001	0.0006	5	<0.0001	<0.0001	<0.0001
Arsenic	mg/L	-	1	0.00012	0.00012	0.00012	8	0.00015	<0.0001	0.00028	2	0.00016	0.00012	<0.0002	5	0.00012	0.00011	0.00013
Barium	mg/L	-	1	0.0517	0.0517	0.0517	9	0.0594	0.0353	0.101	2	0.0527	0.052	0.0534	5	0.0708	0.0461	0.109
Beryllium	mg/L	-	1	<0.0005	<0.0005	<0.0005	8	0.0001	<0.0001	<0.0005	2	<0.00075	<0.0005	<0.001	5	<0.0001	<0.0001	<0.0001
Boron	mg/L	-	1	<0.01	<0.01	<0.01	8	<0.01	<0.01	0.018	2	<0.015	<0.01	<0.02	5	<0.01	<0.01	0.033
Cadmium	mg/L	-	1	<0.00001	<0.00001	<0.00001	9	0.0000125	0.0000053	0.000043	2	<0.000015	<0.00001	<0.00002	5	0.0000058	0.000005	0.0000316
Chromium	mg/L	-	1	0.00014	0.00014	0.00014	8	<0.0001	<0.0001	0.00053	2	0.000555	0.00011	<0.001	5	<0.0001	<0.0001	<0.0001
Cobalt	mg/L	-	1	<0.0001	<0.0001	<0.0001	9	<0.0001	<0.0001	0.0004	2	<0.0002	<0.0001	<0.0003	5	0.00011	<0.0001	0.00014
Copper	mg/L	-	1	0.00018	0.00018	0.00018	9	0.00035	0.00012	0.00153	2	0.000185	<0.0001	0.00027	5	<0.0002	<0.0002	0.00055

Table 9 (Cont'd.)

Variables	Units	Guidelines	Spring				Summer				Fall				Winter			
			N	Med	Min	Max	N	Med	Min	Max	N	Med	Min	Max	N	Med	Min	Max
Iron	mg/L	0.3	1	<0.03	<0.03	<0.03	8	0.032	<0.01	0.259	2	<0.045	<0.03	<0.06	5	0.03	0.03	0.064
Lead	mg/L	-	1	<0.00005	<0.00005	<0.00005	8	<0.00005	<0.00005	0.000187	2	<0.000125	<0.00005	<0.0002	5	<0.00005	<0.00005	0.000089
Lithium	mg/L	-	1	<0.005	<0.005	<0.005	8	0.00315	<0.001	0.0056	2	<0.0125	<0.005	<0.02	5	0.0017	<0.001	0.0137
Manganese	mg/L	-	1	<0.005	<0.005	<0.005	8	0.005	0.000407	<0.005	2	<0.0045	<0.004	<0.005	5	<0.005	<0.005	0.0332
Mercury	µg/L	-	1	<0.0005	<0.0005	<0.0005	6	0.00168	0.00091	0.0082	1	<0.0005	<0.0005	<0.0005	5	<0.005	<0.005	<0.005
Molybdenum	mg/L	-	1	0.000765	0.000765	0.000765	9	0.000657	0.000226	0.000693	2	0.0007255	0.00072	0.000731	5	0.000701	0.000246	0.000943
Nickel	mg/L	-	1	0.00017	0.00017	0.00017	8	0.00051	0.00016	0.00113	2	0.00034	0.00018	<0.0005	5	<0.0005	<0.0005	0.00059
Selenium	mg/L	Site-specific	1	0.0011	0.0011	0.0011	9	0.00066	0.000376	0.00753	2	0.0007	0.00064	0.00076	5	0.0031	0.00105	0.00967
Silver	mg/L	-	1	<0.00001	<0.00001	<0.00001	8	<0.00001	<0.00001	0.000018	2	<0.000055	<0.00001	<0.0001	5	<0.00001	<0.00001	<0.00001
Thallium	mg/L	-	1	<0.00005	<0.00005	<0.00005	8	<0.00001	<0.00001	<0.00005	2	<0.000125	<0.00005	<0.0002	5	<0.00001	<0.00001	<0.00001
Tin	mg/L	-	1	<0.0001	<0.0001	<0.0001	8	<0.0001	<0.0001	<0.0001	2	<0.00055	<0.0001	<0.001	5	<0.0001	<0.0001	<0.0001
Titanium	mg/L	-	1	<0.0003	<0.0003	<0.0003	8	0.00105	<0.0003	0.000018	2	<0.00065	<0.0003	<0.001	5	<0.0003	<0.0003	0.00258
Uranium	mg/L	-	1	0.000449	0.000449	0.000449	9	0.000246	0.000037	0.00045	2	0.0003645	0.000349	0.00038	5	0.000359	0.000073	0.000525
Vanadium	mg/L	-	1	0.0002	0.0002	0.0002	8	0.0005	0.00019	0.00123	2	0.00058	0.00016	<0.001	5	<0.0005	<0.0005	<0.0005
Zinc	mg/L	-	1	<0.005	<0.005	<0.005	9	0.001	<0.001	0.64	2	<0.004	<0.003	<0.005	4	0.00355	<0.001	0.0049
General Organics																		
Recoverable Hydrocarbons	mg/L	-	1	<1	<1	<1	2	<1	<1	<1	1	<1	<1	<1	5	<1	<1	<1
Phenols (4AAP)	mg/L	0.004	1	<0.001	<0.001	<0.001	2	<0.001	<0.001	<0.001	2	<0.0015	<0.001	<0.002	5	<0.001	<0.001	<0.001
Benzene	mg/L	0.04	1	<0.0005	<0.0005	<0.0005	2	<0.0005	<0.0005	<0.0005	1	<0.0005	<0.0005	<0.0005	5	<0.0005	<0.0005	<0.0005
Ethylbenzene	mg/L	0.09	1	<0.0005	<0.0005	<0.0005	2	<0.0005	<0.0005	<0.0005	1	<0.0005	<0.0005	<0.0005	5	<0.0005	<0.0005	<0.0005
Toluene	mg/L	0.0005	1	<0.0005	<0.0005	<0.0005	2	<0.0005	<0.0005	<0.0005	1	<0.0005	<0.0005	<0.0005	5	<0.0005	<0.0005	<0.0005
o-xylene	mg/L	-	1	<0.0005	<0.0005	<0.0005	2	<0.0005	<0.0005	<0.0005	1	<0.0005	<0.0005	<0.0005	5	<0.0005	<0.0005	<0.0005
m+p-Xylene	mg/L	-	1	<0.0005	<0.0005	<0.0005	2	<0.0005	<0.0005	<0.0005	1	<0.0005	<0.0005	<0.0005	5	<0.0005	<0.0005	<0.0005
Xylenes	mg/L	0.03	1	<0.00071	<0.00071	<0.00071	2	<0.000605	<0.0005	<0.00071	1	<0.0005	<0.0005	<0.0005	5	<0.00071	<0.00071	<0.00071
F1(C6-C10)	mg/L	0.15	1	<0.1	<0.1	<0.1	2	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1	5	<0.1	<0.1	<0.1
F1-BTEX	mg/L	-	1	<0.1	<0.1	<0.1	2	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1	5	<0.1	<0.1	<0.1
F2 (>C10-C16)	mg/L	0.11	1	<0.25	<0.25	<0.25	1	<0.25	<0.25	<0.25	1	<0.25	<0.25	<0.25	5	<0.1	<0.1	<0.1
F3 (C16-C34)	mg/L	-	1	<0.25	<0.25	<0.25	1	<0.25	<0.25	<0.25	1	<0.25	<0.25	<0.25	5	<0.25	<0.25	<0.25
F4 (C34-C50)	mg/L	-	1	<0.25	<0.25	<0.25	1	<0.25	<0.25	<0.25	1	<0.25	<0.25	<0.25	5	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	1	<0.1	<0.1	<0.1	2	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1	5	0.24	<0.1	0.26
Polycyclic Aromatic Hydrocarbons																		
Benzo[a]pyrene	µg/L	0.015	0	-	-	-	0	-	-	-	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01
Acenaphthene	µg/L	5.80	0	-	-	-	0	-	-	-	1	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1
Acenaphthylene	µg/L	-	0	-	-	-	0	-	-	-	1	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1
Acridine	µg/L	4.4	0	-	-	-	0	-	-	-	1	<0.2	<0.2	<0.2	1	<0.2	<0.2	<0.2
Anthracene	µg/L	0.012	0	-	-	-	0	-	-	-	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01
Benzo(a)anthracene	µg/L	0.018	0	-	-	-	0	-	-	-	1	<0.0085	<0.0085	<0.0085	1	<0.0085	<0.0085	<0.0085

Table 9 (Cont’d.)

Variables	Units	Guidelines	Spring				Summer				Fall				Winter			
			N	Med	Min	Max	N	Med	Min	Max	N	Med	Min	Max	N	Med	Min	Max
Benzo(b&j)fluoranthene	µg/L	-	0	-	-	-	0	-	-	-	1	<0.0085	<0.0085	<0.0085	1	<0.0085	<0.0085	<0.0085
Benzo(k)fluoranthene	µg/L	-	0	-	-	-	0	-	-	-	1	<0.0085	<0.0085	<0.0085	1	<0.0085	<0.0085	<0.0085
Benzo(g,h,i)perylene	µg/L	-	0	-	-	-	0	-	-	-	1	<0.0085	<0.0085	<0.0085	1	<0.0085	<0.0085	<0.0085
Benzo(c)phenanthrene	µg/L	-	0	-	-	-	0	-	-	-	1	<0.05	<0.05	<0.05	1	<0.05	<0.05	<0.05
Benzo(a)pyrene	µg/L	0.015	0	-	-	-	0	-	-	-	1	<0.0075	<0.0075	<0.0075	1	<0.0075	<0.0075	0.0075
Benzo[e]pyrene	µg/L	-	0	-	-	-	0	-	-	-	1	<0.05	<0.05	<0.05	1	<0.05	<0.05	<0.05
Chrysene	µg/L	-	0	-	-	-	0	-	-	-	1	<0.0085	<0.0085	<0.0085	1	<0.0085	<0.0085	<0.0085
Dibenz(a,h)anthracene	µg/L	-	0	-	-	-	0	-	-	-	1	<0.0075	<0.0075	<0.0075	1	<0.0075	<0.0075	<0.0075
Fluoranthene	µg/L	0.04	0	-	-	-	0	-	-	-	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01
Fluorene	µg/L	3	0	-	-	-	0	-	-	-	1	<0.05	<0.05	<0.05	1	<0.05	<0.05	<0.05
Indeno(1,2,3-cd)pyrene	µg/L	-	0	-	-	-	0	-	-	-	1	<0.0085	<0.0085	<0.0085	1	<0.0085	<0.0085	<0.0085
2-Methylnaphthalene	µg/L	-	0	-	-	-	0	-	-	-	1	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1
Naphthalene	µg/L	1	0	-	-	-	0	-	-	-	1	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1
Phenanthrene	µg/L	0.4	0	-	-	-	0	-	-	-	1	<0.05	<0.05	<0.05	1	<0.05	<0.05	<0.05
Perylene	µg/L	-	0	-	-	-	0	-	-	-	1	<0.05	<0.05	<0.05	1	<0.05	<0.05	<0.05
Pyrene	µg/L	0.025	0	-	-	-	0	-	-	-	1	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02
Quinoline	µg/L	3.4	0	-	-	-	0	-	-	-	1	<0.2	<0.2	<0.2	1	<0.2	<0.2	<0.2

Note: **Bold** values indicate water quality guideline exceedance; - = data not available

Table 10 Percent exceedances (number of samples exceeded guidelines/total number of samples) of water and sediment quality guidelines in the LSA and RSA in the Grassy Mountain mine site, May 2013 to June 2016.

Variables	Blairmore Creek				Gold Creek				Crowsnest River			
	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
Water Samples												
Field pH	11% (1/9)	-	-	-	25% (1/4)	25% (3/12)	-	-	13% (1/8)	-	-	-
Sulphide	-	-	-	-	-	-	-	-	-	17% (1/6)	50% (1/2)	-
Total Mercury	-	20% (2/10)	-	-	-	25% (2/8)	-	-	-	-	-	-
Total/Dissolved Selenium	-	-	-	-	-	25% (2/8)	-	40% (2/5)	-	-	-	-
Dissolved Aluminum	-	-	-	-	-	11% (1/9)	-	20% (1/5)	-	-	-	-
Sediment Samples												
Total Arsenic	-	100% (4/4)	-	-	-	50% (2/4)	-	-	-	-	-	-
Total Cadmium	-	50% (2/4)	-	-	-	50% (2/4)	-	-	-	-	-	-
Total Selenium	-	-	-	-	-	25% (1/4)	-	-	-	-	-	-
Total Zinc	-	25% (1/4)	-	-	-	25% (1/4)	-	-	-	-	-	-

= no exceedances/data not available

Blairmore Creek and its Tributaries

Water quality samples were collected from three mainstem stations and two tributaries to Blairmore Creek (Figure 4) as part of the baseline field program during May 2013 to March 2016. Water quality data summarized by variables group and seasons are presented in Table 8 and discussed below.

Field and Conventional Variables

Both field- and lab-measured pH was alkaline and remained within the water quality guideline range in all seasons; however, two lab measured pH values were slightly acidic range during summer and one pH value during spring exceeded upper bound of water quality guideline. DO concentrations always were within the requirements for water quality guidelines for the protection of aquatic life. TSS levels were below detection limits in all seasons except summer, where a high TSS concentration (97 mg/L) was recorded at an unnamed tributary to Blairmore Creek. Similar trends also were reflected for colour, turbidity, and TOC concentrations at this station on the same date but they were “low” ranges (see Section 3.1.6 for definition) in the other seasons. There were considerable discrepancies between field- and lab-measured specific conductivity. Field-measured data may be more reliable given they are measured immediately, whereas lab measurement involves hold time requirements. Therefore field-measured data were used for evaluation. Concentrations of TDS and specific conductivity were in “moderate” range (see Section 3.1.6 for definition) in all seasons. Median concentrations of total hardness were slightly higher in winter and fall (hard water) than in summer and spring (relatively soft water). Total alkalinity indicated Blairmore Creek as a “least sensitive” (see Section 3.1.6 for definition) water course to acid deposition. There were no water quality guideline exceedances for field and conventional variables except one field measured pH value during spring.

Major Nutrients and Ions

Concentrations of total ammonia and nitrite were below the detection limits in all seasons. Concentrations of nitrate were detected in seven samples out of 25 samples; however no samples exceeded the water quality guideline for the protection of aquatic life. Out of 22 samples analyzed, TKN concentrations were detected in five samples which remained “moderate” in range. The TP concentrations ranged from 0.0024 to 0.145 mg/L with the highest value recorded at the Blairmore Creek tributary station. Based on median concentrations of limited data, the Blairmore Creek watershed can be regarded as “oligotrophic” (see Section 3.1.6 for definition) in all seasons. BOD concentrations were below the detection limit at all seasons.

Calcium was the dominant cation, followed by magnesium and sodium. Bicarbonate followed by sulphate dominated among anions. Carbonate, hydroxide and sulphide concentrations were mostly below detection limits in all seasons.

Trace Metals and Organic Compounds

Out of 25 metals measured, 13 total metals and eight dissolved metals in spring, seven total metals and 11 dissolved metals in summer, five total metals and 17 dissolved metals in fall, and 15 total metals and 16 dissolved metals in winter were below the detection limits in all samples analyzed. Total mercury exceeded chronic water quality guideline in two samples and acute guideline in one sample out of 10 samples analyzed during summer. All these exceedances occurred at tributary stations (BCT-W01 and BCT-W02).

A range of organic variables including hydrocarbons, naphthenic acids, phenolics, volatile organics, and PAHs were analyzed but all of them were below detection limits except phenols in four samples out of 23 analyzed. However, phenol concentrations were below the water quality guideline for the protection of aquatic life.

Metal Contents in Sediment and Periphyton

Sediment quality data collected at four stations of Blairmore Creek are summarized in [Table 11](#), with the raw data presented in [Appendix A3](#). Metals concentrations measured above the CCME interim sediment quality guidelines for the protection of freshwater life included arsenic (100% of samples), cadmium (50%), and zinc (25%) ([Table 10](#)).

Metal contents of periphyton at Blairmore Creek are summarized in [Table 12](#), with the raw data presented in [Appendix A3](#). Most of the metals were detectable in periphyton except bismuth and tin. Selenium content ranged between 1.7 mg/kg (upstream station) and 9.66 mg/kg (downstream station) with a median concentration of 4.95 mg/kg (dry weight basis). Mercury concentration ranged from 0.032 to 0.073 mg/kg with a median concentration of 0.039 mg/kg.

Gold Creek and its Tributaries

Water quality samples were collected from two mainstem stations and six tributary stations to Gold Creek ([Figure 4](#)) as part of the baseline field program during May 2013 to March 2016. Water quality data summarized by seasons are presented in [Table 9](#) and discussed below.

Field and Conventional Variables

Both field- and lab-measured pH was in alkaline range in all seasons and the maximum field measured pH in spring and summer exceeded the upper bound of the water quality guideline in one sample of four in spring and three samples of 12 in summer. However, no guideline exceedances occurred during fall and winter. DO concentrations were always higher in all seasons with over-saturated concentrations in fall. Levels of specific conductivity were higher in fall and winter than in spring and summer.

Colour and TSS levels were mostly below detection limits in spring fall, and winter but very high in summer. Turbidity and TOC concentrations had the similar seasonal trend as TSS. Concentrations of TDS and specific conductivity were in “moderate” range (see [Section 3.1.6](#) for definition) in all seasons. Higher total hardness and alkalinity in all seasons indicates Gold Creek contains “hard” water with high acid neutralizing capacity (see [Section 3.1.6](#) for definition).

Major Nutrients and Ions

Concentrations of total ammonia and nitrite at Gold Creek were below the detection limits in all seasons. Out of 15 samples analyzed, TKN concentrations were detected in two samples in both summer and winter, and one sample in spring. Concentrations of nitrate were below detection limit in three samples of total 18 in summer. None of the nitrate concentrations exceeded the water quality guideline for the protection of aquatic life. TP concentrations ranged from 0.0023 to 0.08 mg/L with the highest value recorded in summer, and likely indicating the presence of P-containing particulate minerals. Based on median concentrations of limited data, the Gold Creek can be classified as “oligotrophic” in all seasons. BOD concentrations were below the detection limit in all seasons.

Calcium was the dominant cation followed by magnesium. Bicarbonate and sulphate were dominant anions. Carbonate, chloride, hydroxide, and sulphide concentrations were mostly below detection limits in all seasons.

Trace Metals and Organic Compounds

Out of 25 metals measured, 12 total metals and 15 dissolved metals in spring, four total and dissolved metals in summer, six total metals and 18 dissolved metals in fall, and seven total and eight dissolved metals in winter were below the detection limits in all samples analyzed. Concentrations of total and dissolved mercury, total and dissolved selenium, and dissolved aluminum were above the relevant water quality guidelines/objective for the protection of aquatic life. Total mercury exceeded both chronic and acute guidelines in two samples at Gold Creek tributaries (GCT-W05 and GCT-W06) out of eight samples collected in summer. Dissolved mercury also exceeded chronic guideline in the same stations during summer. Both total and dissolved selenium exceeded the proposed site-specific objective in two samples at Gold Creek tributaries (GCT-W03 and GCT-W05) out of eight collected in summer and in two samples at Gold Creek tributaries (GCT-W02 and GCT-W03) out of five in winter. Dissolved aluminum exceeded water quality guideline in one sample (at GCT-W05) out of nine in summer and in one sample (GCT-W02) out of five in winter.

A range of organic variables including hydrocarbons, naphthenic acids, phenolics, volatile organics, and PAHs were analyzed but all of them were below detection limits.

Metal Contents in Sediment and Periphyton

Sediment quality data collected at four stations of Gold Creek are summarized in [Table 11](#), with the raw data presented in [Appendix A3](#). Metals concentrations measured above the CCME interim

quality guidelines for the protection of freshwater life included arsenic (50% of samples), cadmium (50%), and zinc (25%) ([Table 10](#)). Selenium concentration was higher than BC alert concentration of 2 mg/kg in one of four samples.

Metal content of periphyton from Gold Creek is summarized in [Table 12](#), with raw data presented in [Appendix A3](#). Most metals were detectable in periphyton except bismuth and tin. Overall, metal content of periphyton was lower in Gold Creek than in Blairmore Creek. Selenium content ranged from 1.71 mg/kg at upstream station to 3.15 mg/kg at downstream station with a median concentration of 1.98 mg/kg (dry weight basis). Mercury concentration ranged from 0.006 to 0.042 mg/kg with a median concentration of 0.008 mg/kg.

Table 11 **Summary of total metal concentrations (dry weight basis) in sediment at Blairmore Creek and Gold Creek, June, 2016.**

Variables	Units	Detection Limit	Sediment Guidelines		Blairmore Creek				Gold Creek			
			ISQG	PEL	N	Med	Min	Max	N	Med	Min	Max
Aluminum	mg/kg	50	-	-	4	14,150	12,900	18,400	4	10,635	4,240	19,600
Antimony	mg/kg	0.10	-	-	4	0.56	0.53	0.60	4	0.59	0.21	0.67
Arsenic	mg/kg	0.10	5.9	17	4	8.91	7.94	9.30	4	5.64	2.13	8.46
Barium	mg/kg	0.50	-	-	4	368	354	390	4	181	72	304
Beryllium	mg/kg	0.10	-	-	4	1.12	0.97	1.16	4	0.62	0.27	1.00
Bismuth	mg/kg	0.20	-	-	4	<0.20	<0.20	<0.20	4	<0.20	<0.20	<0.20
Boron	mg/kg	5.0	-	-	4	5.60	5.20	6.70	4	7.60	6.50	8.80
Cadmium	mg/kg	0.020	0.6	3.5	4	0.757	0.488	1.380	4	0.596	0.492	0.809
Calcium	mg/kg	50	-	-	4	23,250	5,820	29,200	4	40,900	12,200	56,000
Chromium	mg/kg	0.50	37.3	90	4	17.8	16.3	21.9	4	15.3	8.0	25.4
Cobalt	mg/kg	0.10	-	-	4	12.7	12.0	18.6	4	6.9	2.6	12.8
Copper	mg/kg	0.50	35.7	197	4	25.6	25.0	27.6	4	18.1	9.4	35.5
Iron	mg/kg	50	-	-	4	24,900	23,800	28,500	4	17,650	6,520	35,000
Lead	mg/kg	0.50	35	91.3	4	13.6	10.1	15.0	4	8.8	3.2	13.6
Lithium	mg/kg	2.0	-	-	4	14.9	13.7	21.1	4	12.1	8.7	22.4
Magnesium	mg/kg	20	-	-	4	4,745	4,100	5,850	4	11,400	8,050	13,400
Manganese	mg/kg	1.0	-	-	4	594	532	852	4	300	89	500
Mercury	mg/kg	0.0050	0.17	0.486	4	0.031	0.025	0.033	4	0.036	0.032	0.160
Molybdenum	mg/kg	0.10	-	-	4	1.005	0.870	1.230	4	1.565	1.110	2.080
Nickel	mg/kg	0.50	-	-	4	29.9	27.3	39.9	4	22.0	11.6	38.5
Phosphorus	mg/kg	50	-	-	4	679	616	972	4	635	600	902
Potassium	mg/kg	100	-	-	4	1,975	1,680	2,150	4	1,630	890	2,670
Selenium	mg/kg	0.20	2*	-	4	0.86	0.70	0.96	4	1.11	0.56	4.92
Silver	mg/kg	0.10	-	-	4	0.11	0.11	0.12	2	0.12	0.11	0.12
Sodium	mg/kg	50	-	-	4	131	93	143	4	85	65	99
Strontium	mg/kg	0.50	-	-	4	112	54	170	4	43	33	58
Thallium	mg/kg	0.050	-	-	4	0.184	0.149	0.194	4	0.147	0.079	0.222
Tin	mg/kg	2.0	-	-	4	<2.0	<2.0	<2.0	4	<2.0	<2.0	<2.0
Titanium	mg/kg	1.0	-	-	4	103	64	143	4	45	12	65
Uranium	mg/kg	0.050	-	-	4	0.752	0.687	0.872	4	0.700	0.541	2.430
Vanadium	mg/kg	0.20	-	-	4	39.4	38.3	47.5	4	32.6	16.3	47.2
Zinc	mg/kg	2.0	123	315	4	111	103	158	4	80	72	133
Zirconium	mg/kg	1.0	-	-	4	1.3	1.2	1.6	4	1.3	1.3	1.3

Notes: * Alert concentration, British Columbia; bold values indicate guideline exceedances; - = not available

Table 12 **Summary of total metal concentrations (dry weight basis) in periphyton at Blairmore Creek and Gold Creek, June, 2016.**

Variables	Detection Limit	Units	Blairmore Creek				Gold Creek			
			N	Med	Min	Max	N	Med	Min	Max
Aluminum	50	mg/kg	4	12,541	7,018	20,795	3	4,660	2,790	13,600
Antimony	0.10	mg/kg	4	0.37	0.27	0.66	3	0.23	0.16	0.55
Arsenic	0.10	mg/kg	4	7.62	4.37	11.70	3	3.68	2.95	6.06
Barium	0.50	mg/kg	4	949	345	2,080	3	163	78	238
Beryllium	0.10	mg/kg	4	1.01	0.61	2.09	3	0.24	0.14	0.67
Bismuth	0.20	mg/kg	4	<0.20	<0.20	0.23	3	<0.20	<0.20	<0.20
Boron	5.0	mg/kg	4	47	23	125	3	7.8	<5	99.4
Cadmium	0.020	mg/kg	4	2.85	0.60	5.41	3	0.36	0.26	0.77
Calcium	50	mg/kg	4	580,962	103,311	1,307,339	3	27,300	12,100	155,000
Chromium	0.50	mg/kg	4	14.61	6.83	22.17	3	7.83	5.26	17.60
Cobalt	0.10	mg/kg	4	16.96	5.15	33.33	3	2.83	2.58	8.35
Copper	0.50	mg/kg	4	23.82	13.25	43.12	3	8.37	5.90	25.80
Iron	50	mg/kg	4	18,067	9,976	29,511	3	6,000	5,120	22,100
Lead	0.50	mg/kg	4	9.06	5.33	16.67	3	3.87	2.25	9.22
Lithium	2.0	mg/kg	4	13.59	7.10	24.46	3	7.80	3.30	16.30
Magnesium	20	mg/kg	4	8,707	4,852	18,960	3	7,080	5,620	13,300
Manganese	1.0	mg/kg	4	1,102	245	2,018	3	303	137	356
Mercury	0.0050	mg/kg	4	0.039	0.032	0.073	3	0.008	0.006	0.042
Molybdenum	0.10	mg/kg	4	1.41	0.87	2.11	3	0.58	0.33	1.56
Nickel	0.50	mg/kg	4	34.70	20.55	63.46	3	10.50	9.06	26.30
Phosphorus	50	mg/kg	4	2,008	1,655	2,859	3	1,360	1,090	1,600
Potassium	100	mg/kg	4	4,493	2,982	6,468	3	2,110	1,610	6,040
Selenium	0.20	mg/kg	4	4.95	1.70	9.66	3	1.98	1.71	3.15
Silver	0.10	mg/kg	2	0.144	0.106	0.182	1	0.12	0.12	0.12
Sodium	50	mg/kg	4	654	426	869	3	148	129	224
Strontium	0.50	mg/kg	4	1,074	239	2,187	3	32	30	177
Thallium	0.050	mg/kg	4	0.210	0.135	0.381	3	0.085	0.062	0.142
Tin	2.0	mg/kg	4	<2.0	<2.0	<2.0	3	<2.0	<2.0	<2.0
Titanium	1.0	mg/kg	4	327	123	353	3	48	37	58
Uranium	0.050	mg/kg	4	0.86	0.57	1.64	3	0.37	0.31	0.46
Vanadium	0.20	mg/kg	4	47	20	67	3	13	9	33
Zinc	2.0	mg/kg	4	159	60	266	3	66	65	98
Zirconium	1.0	mg/kg	4	9.06	5.07	14.42	3	1.1	<1.0	2.0

Reference Sites

Two reference stations, Blairmore Creek upstream (BC-W03) and Caudron Creek (CC-W01) were identified as potential reference stations for Blairmore Creek and Gold Creek, respectively. Seasonal water quality data for BC-W03 collected during May 2013 to March 2016 and for CC-W01 collected during March and May 2016 are presented in [Appendix A3](#). Concentrations of most of the water quality variables in reference stations were more or less similar to the respective future impacted stations indicating their suitability as reference stations for the water quality effects monitoring program. Baseline data collection from these reference stations will be continued and compared with the data from affected downstream stations during operation and reclamation phases of the Mine.

Historical End-Pit Lakes

Water quality samples were collected from three historical end-pit lake stations ([Figure 4](#)) as part of the baseline field program during July and October 2014 and February 2016. Water quality data summarized by seasons are presented in [Table 13](#) and discussed below. Station-wise raw data are presented in [Appendix A3](#).

Conventional Variables

Similar to creek water, pH in end-pit lakes was alkaline in all seasons at all stations. Concentrations of TDS and specific conductivity were generally higher than in creek water. Total hardness and alkalinity had similar trends.

Major Nutrients and Ions

Concentrations of nitrite and nitrate were measured in winter and fall and were mostly below the detection limits. Total phosphorus concentrations measured only in winter indicated end-pit lakes as “oligotrophic” (see [Section 3.1.6](#) for definition). Calcium was the dominant cation at all stations followed by magnesium. Bicarbonate and sulphate were the dominant anions.

Trace Metals and Organic Compounds

A total of 25 metals were measured in end-pit lake samples, total metals during winter only and dissolved metals during summer, fall and winter. Concentrations of total metals were below water quality guidelines for the protection of aquatic life. Concentrations of all organic compounds were below analytical detection limits.

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Table 13 Summary of seasonal water quality variables in end-pit lakes, July 2014 to February 2015.

Variables	Units	Guidelines	Summer				Fall				Winter			
			N	Med	Min	Max	N	Med	Min	Max	N	Med	Min	Max
Conventional Variables														
Colour	TCU	20% increase	0	-	-	-	0	-	-	-	4	<5	<5	<5
Total Suspended Solids	mg/L	-	2	6.7	1.3	12.0	0	-	-	-	4	<3	<3	<3
Total Dissolved Solids	mg/L	-	3	200	200	220	3	260	260	300	0	-	-	-
TDS (Calculated)	mg/L	-	3	240	220	250	3	280	240	300	4	285	171	309
Turbidity	NTU	-	0	-	-	-	0	-	-	-	4	0.97	0.41	3.23
Specific Conductivity	µS/cm	-	3	410	410	470	3	510	450	510	4	520	340	558
pH	-	6.5-9.0	3	8.38	8.32	8.55	3	8.25	8.21	8.41	4	8.3	8.26	8.37
Total Hardness (as CaCO ₃)	mg/L	-	3	230	230	260	3	280	250	280	4	299	169	331
Total Alkalinity (as CaCO ₃)	mg/L	>20	3	160	130	190	3	180	140	220	4	225	166	251
Dissolved Organic Carbon	mg/L	-	0	-	-	-	0	-	-	-	4	1.9	1.3	2.0
Total Organic Carbon	mg/L	-	3	1.4	1.2	2.4	3	1.5	1.4	2.4	4	2	1.4	2.1
Major Nutrients and BOD														
Total Ammonia (as N)	mg/L	temp and pH dependent	0	-	-	-	0	-	-	-	4	<0.05	<0.05	<0.05
Nitrate and Nitrite (as N)	mg/L	-	0	-	-	-	0	-	-	-	4	<0.05	<0.05	<0.05
Nitrate (as N)	mg/L	3-124	0	-	-	-	3	<0.01	<0.01	<0.01	4	0.022	<0.02	0.026
Nitrite (as N)	mg/L	0.02-0.06	0	-	-	-	3	<0.01	<0.01	<0.01	4	<0.01	<0.01	<0.01
Total Kjeldahl Nitrogen	mg/L	-	0	-	-	-	0	-	-	-	4	<0.2	<0.2	<0.2
Dissolved Phosphorus	mg/L	-	0	-	-	-	3	<0.1	<0.1	<0.1	4	0.0029	0.0017	0.0054
Total Phosphorus	mg/L	-	0	-	-	-	0	-	-	-	4	0.0081	0.006	0.0105
Biochemical Oxygen Demand	mg/L	-	0	-	-	-	0	-	-	-	4	<2	<2	<2
Major Ions														
Calcium	mg/L	-	3	44	40	48	3	55	47	57	4	47	34	54
Magnesium	mg/L	-	3	28	27	40	3	33	27	40	4	42	21	52
Potassium	mg/L	-	3	1	0.83	1.4	3	1.2	1.2	1.7	4	1.68	1.48	1.93
Sodium	mg/L	-	2	1.72	0.54	2.9	3	<0.5	<0.5	2.9	4	3.65	<1	4.1
Bicarbonate	mg/L	-	3	190	150	220	3	230	180	270	4	269	202	300
Carbonate	mg/L	-	2	5.1	2.9	7.3	3	<0.5	<0.5	2.9	4	<5	<5	5.6
Chloride	mg/L	120-640	0	-	-	-	3	1.2	<1	1.3	4	<0.5	<0.5	<0.5
Hydroxide	mg/L	-	0	-	-	-	3	<0.5	<0.5	<0.5	4	<5	<5	<5
Sulphate	mg/L	429	3	51	50	87	3	49	47	120	4	53	12	54
Sulphide (as S)	mg/L	0.0019	0	-	-	-	0	-	-	-	4	<0.0015	<0.0015	<0.0015
Total Metals														
Aluminum	mg/L	-	0	-	-	-	0	-	-	-	4	0.0067	0.0048	0.0327
Antimony	mg/L	-	0	-	-	-	0	-	-	-	4	0.00025	0.00019	0.00028
Arsenic	mg/L	0.005	0	-	-	-	0	-	-	-	4	0.000445	0.0004	0.00049
Barium	mg/L	-	0	-	-	-	0	-	-	-	4	0.1505	0.145	0.166
Beryllium	mg/L	-	0	-	-	-	0	-	-	-	4	<0.0005	<0.0005	<0.0005
Boron	mg/L	1.5	0	-	-	-	0	-	-	-	4	0.0625	0.028	0.087
Cadmium	mg/L	0.00022-0.0032	0	-	-	-	0	-	-	-	4	0.0000225	0.000012	0.000034
Chromium	mg/L	0.0099	0	-	-	-	0	-	-	-	4	0.000105	<0.0001	0.00014
Cobalt	mg/L	0.0025	0	-	-	-	0	-	-	-	4	<0.0001	<0.0001	0.00041
Copper	mg/L	0.007-0.024	0	-	-	-	0	-	-	-	4	0.00073	0.00054	0.00108
Iron	mg/L	-	0	-	-	-	0	-	-	-	4	0.021	<0.01	0.093

Note: **Bold** values indicate water quality guideline exceedance; - = data not available.

Table 13 (Cont’d.)

Variables	Units	Guidelines	Summer				Fall				Winter			
			N	Med	Min	Max	N	Med	Min	Max	N	Med	Min	Max
Total Metals (Cont'd.)														
Lead	mg/L	0.0053	0	-	-	-	0	-	-	-	4	<0.00005	<0.00005	0.000107
Lithium	mg/L	-	0	-	-	-	0	-	-	-	4	0.01675	0.0098	0.0216
Manganese	mg/L	-	0	-	-	-	0	-	-	-	4	0.004065	0.00087	0.0518
Mercury	µg/L	0.005-0.013	0	-	-	-	0	-	-	-	4	0.000625	0.00054	0.00204
Molybdenum	mg/L	0.073	0	-	-	-	0	-	-	-	4	0.00164	0.00107	0.00192
Nickel	mg/L	0.074-0.66	0	-	-	-	0	-	-	-	4	0.001575	0.00126	0.00205
Selenium	mg/L	site-specific	0	-	-	-	0	-	-	-	4	0.0004	0.00023	0.00179
Silver	mg/L	0.00001	0	-	-	-	0	-	-	-	4	<0.00001	<0.00001	<0.00001
Thallium	mg/L	0.0008	0	-	-	-	0	-	-	-	4	<0.00005	<0.00005	<0.00005
Tin	mg/L	-	0	-	-	-	0	-	-	-	4	<0.0001	<0.0001	<0.0001
Titanium	mg/L	-	0	-	-	-	0	-	-	-	4	<0.0003	<0.0003	<0.0003
Uranium	mg/L	0.015-0.033	0	-	-	-	0	-	-	-	4	0.0007855	0.00043	0.000942
Vanadium	mg/L	-	0	-	-	-	0	-	-	-	4	<0.0005	<0.0005	<0.0005
Zinc	mg/L	0.03	0	-	-	-	0	-	-	-	4	0.0111	0.0052	0.0158
Dissolved Metals														
Aluminum	mg/L	0.05-0.1	3	0.017	0.0033	0.028	3	0.0044	<0.003	0.0069	4	0.0011	<0.001	0.0027
Antimony	mg/L	-	0	-	-	-	3	<0.0006	<0.0006	<0.0006	4	0.00022	0.00016	0.00026
Arsenic	mg/L	0.005	2	0.000275	0.00026	0.00029	3	0.00024	<0.0002	0.00036	4	0.000405	0.00038	0.00046
Barium	mg/L	-	3	0.13	0.07	0.13	3	0.14	0.08	0.14	4	0.15	0.14	0.16
Beryllium	mg/L	-	0	-	-	-	3	<0.001	<0.001	<0.001	4	<0.0005	<0.0005	<0.0005
Boron	mg/L	1.5	2	0.048	0.026	0.07	3	0.033	0.025	0.072	4	0.062	0.029	0.085
Cadmium	mg/L	0.00022-0.0032*	3	0.000028	0.0000068	0.000029	3	<0.00002	<0.00002	<0.00002	4	0.000016	<0.00001	0.000025
Chromium	mg/L	0.001	0	-	-	-	3	<0.001	<0.001	<0.001	4	<0.0001	<0.0001	<0.0001
Cobalt	mg/L	0.0025	0	-	-	-	3	<0.0003	<0.0003	<0.0003	4	<0.0001	<0.0001	0.00027
Copper	mg/L	0.007-0.024*	3	0.00053	0.00052	0.00097	3	0.00052	0.00048	0.00074	4	0.000585	0.00041	0.0008
Iron	mg/L	0.3	0	-	-	-	3	0.062	<0.06	0.066	4	<0.03	<0.03	<0.03
Lead	mg/L	0.0053*	0	-	-	-	3	<0.0002	<0.0002	<0.0002	4	<0.00005	<0.00005	<0.00005
Lithium	mg/L	-	1	0.024	0.024	0.024	3	0.025	<0.02	0.033	4	0.0171	0.01	0.0218
Manganese	mg/L	-	1	0.017	0.017	0.017	3	<0.004	<0.004	0.019	4	0.00515	<0.005	0.0376
Molybdenum	mg/L	0.073	3	0.0012	0.00038	0.0018	3	0.0014	0.00038	0.0018	4	0.001445	0.000973	0.00167
Nickel	mg/L	0.074-0.66	3	0.0019	0.0012	0.0024	3	0.0015	0.001	0.0017	4	0.00138	0.00109	0.00166
Selenium	mg/L	site-specific	3	0.00222	0.00054	0.00222	2	0.00104	0.00098	0.0011	2	0.00012	<0.0002	0.0022
Silver	mg/L	0.0001	0	-	-	-	3	<0.0001	<0.0001	<0.0001	4	<0.00001	<0.00001	<0.00001
Strontium	mg/L	-	3	0.076	0.072	0.2	3	0.095	0.079	0.22	0	-	-	-
Thallium	mg/L	0.0008	0	-	-	-	3	<0.0002	<0.0002	<0.0002	4	<0.00005	<0.00005	<0.00005
Tin	mg/L	-	0	-	-	-	3	<0.001	<0.001	<0.001	4	<0.0001	<0.0001	<0.0001
Titanium	mg/L	-	0	-	-	-	3	<0.001	<0.001	<0.001	4	<0.0003	<0.0003	<0.0003
Uranium	mg/L	0.015-0.033	3	0.00065	0.00027	0.00094	3	0.00066	0.00025	0.00092	4	0.000676	0.000375	0.000814
Vanadium	mg/L	-	0	-	-	-	3	<0.001	<0.001	<0.001	4	0.000145	<0.0001	0.00017
Zinc	mg/L	0.03	0	-	-	-	3	<0.003	<0.003	<0.003	4	0.01045	<0.005	0.0159

Note: **Bold** values indicate water quality guideline exceedance; - = data not available.

Table 13 (Cont’d.)

Variables	Units	Guidelines	Summer				Fall				Winter			
			N	Med	Min	Max	N	Med	Min	Max	N	Med	Min	Max
General Organics														
Recoverable Hydrocarbons	mg/L	-	0	-	-	-	0	-	-	-	4	<1	<1	<1
Phenols (4AAP)	mg/L	0.004	0	-	-	-	3	<0.002	<0.002	<0.002	4	<0.001	<0.001	<0.001
Benzene	mg/L	0.04	0	-	-	-	0	-	-	-	4	<0.0005	<0.0005	<0.0005
Ethylbenzene	mg/L	0.09	0	-	-	-	0	-	-	-	4	<0.0005	<0.0005	<0.0005
Toluene	mg/L	0.0005	0	-	-	-	0	-	-	-	4	<0.0005	<0.0005	<0.0005
o-xylene	mg/L	-	0	-	-	-	0	-	-	-	4	<0.0005	<0.0005	<0.0005
m+p-Xylene	mg/L	-	0	-	-	-	0	-	-	-	4	<0.0005	<0.0005	<0.0005
Xylenes	mg/L	0.03	0	-	-	-	0	-	-	-	4	<0.00071	<0.00071	<0.00071
F1(C6-C10)	mg/L	0.15	0	-	-	-	0	-	-	-	4	<0.1	<0.1	<0.1
F1-BTEX	mg/L	-	0	-	-	-	0	-	-	-	4	<0.1	<0.1	<0.1
F2 (>C10-C16)	mg/L	0.11	0	-	-	-	0	-	-	-	4	<0.25	<0.25	<0.25
F3 (C16-C34)	mg/L	-	0	-	-	-	0	-	-	-	4	<0.25	<0.25	<0.25
F4 (C34-C50)	mg/L	-	0	-	-	-	0	-	-	-	4	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	0	-	-	-	0	-	-	-	4	<0.1	<0.1	<0.1
Polycyclic Aromatic Hydrocarbons			0	-	-	-	0	-	-	-	0	-	-	-
Benzo[a]pyrene	µg/L	0.015	0	-	-	-	3	<0.01	<0.01	<0.01	0	-	-	-
Acenaphthene	µg/L	5.80	0	-	-	-	3	<0.1	<0.1	<0.1	0	-	-	-
Acenaphthylene	µg/L	-	0	-	-	-	3	<0.1	<0.1	<0.1	0	-	-	-
Acridine	µg/L	4.4	0	-	-	-	3	<0.2	<0.2	<0.2	0	-	-	-
Anthracene	µg/L	0.012	0	-	-	-	3	<0.01	<0.01	<0.01	0	-	-	-
Benzo(a)anthracene	µg/L	0.018	0	-	-	-	3	<0.0085	<0.0085	<0.0085	0	-	-	-
Benzo(b&j)fluoranthene	µg/L	-	0	-	-	-	3	<0.0085	<0.0085	<0.0085	0	-	-	-
Benzo(k)fluoranthene	µg/L	-	0	-	-	-	3	<0.0085	<0.0085	<0.0085	0	-	-	-
Benzo(g,h,i)perylene	µg/L	-	0	-	-	-	3	<0.0085	<0.0085	<0.0085	0	-	-	-
Benzo(c)phenanthrene	µg/L	-	0	-	-	-	3	<0.05	<0.05	<0.05	0	-	-	-
Benzo(a)pyrene	µg/L	0.015	0	-	-	-	3	<0.0075	<0.0075	<0.0075	0	-	-	-
Benzo[e]pyrene	µg/L	-	0	-	-	-	3	<0.05	<0.05	<0.05	0	-	-	-
Chrysene	µg/L	-	0	-	-	-	3	<0.0085	<0.0085	<0.0085	0	-	-	-
Dibenz(a,h)anthracene	µg/L	-	0	-	-	-	3	<0.0075	<0.0075	<0.0075	0	-	-	-
Fluoranthene	µg/L	0.04	0	-	-	-	3	<0.01	<0.01	<0.01	0	-	-	-
Fluorene	µg/L	3	0	-	-	-	3	<0.05	<0.05	<0.05	0	-	-	-
Indeno(1,2,3-cd)pyrene	µg/L	-	0	-	-	-	3	<0.0085	<0.0085	<0.0085	0	-	-	-
2-Methylnaphthalene	µg/L	-	0	-	-	-	3	<0.1	<0.1	<0.1	0	-	-	-
Naphthalene	µg/L	1	0	-	-	-	3	<0.1	<0.1	<0.1	0	-	-	-
Phenanthrene	µg/L	0.4	0	-	-	-	3	<0.05	<0.05	<0.05	0	-	-	-
Perylene	µg/L	-	0	-	-	-	3	<0.05	<0.05	<0.05	0	-	-	-
Pyrene	µg/L	0.025	0	-	-	-	3	0.02	0.02	0.02	0	-	-	-
Quinoline	µg/L	3.4	0	-	-	-	3	<0.2	<0.2	<0.2	0	-	-	-

Note: **Bold** values indicate water quality guideline exceedance; - = data not available.

3.2.3.2 Regional Study Area

The RSA included the Crowsnest River and its watersheds ([Figure 4](#)). A total of 17 water quality samples were collected from three mainstem stations in the Crowsnest River covering both upstream, downstream and project areas as part of the regional baseline field program during May 2013 to March 2016. Raw data are provided in Appendix A3 and summarized by seasons in [Table 14](#).

Field and Conventional Variables

Both field- and lab-measured pH were generally alkaline in all seasons; field pH in spring 2014 exceeded the upper bound of the water quality guideline in one sample out of eight samples measured but this may reflect measurement error, given no other higher pH observations were made any location. DO concentrations were higher than minimum requirement for the protection of aquatic life in all seasons. Consistent with LSA stations, levels of specific conductivity were relatively higher in fall and winter than in spring and summer.

Colour levels were below detection limits in all seasons except two samples during summer. TSS and turbidity levels were higher in spring than in other seasons (mostly below detection limits). TOC concentrations was comprised of mainly DOC and remained within “low” range (see [Section 3.1.6](#) for definition). Concentrations of TDS and specific conductivity were in “moderate” range (see [Section 3.1.6](#) for definition) in all seasons. Levels of total hardness and alkalinity were higher in fall and winter than in spring and summer and indicate “hard” water river with high acid neutralizing capacity (see [Section 3.1.6](#) for definition) during all seasons.

Major Nutrients and Ions

Concentrations of total ammonia and nitrite in the Crowsnest River were below the detection limits in all seasons except one sample for total ammonia in summer. Out of 14 samples analyzed, TKN concentrations were detected in two samples in spring and one in summer. Concentrations of nitrate were detected in all samples except one in fall but none of them exceeded the water quality guideline for the protection of aquatic life. The TP concentrations ranged from 0.0047 to 0.0231 mg/L with the highest value recorded in summer and the lowest in winter. Based on median concentrations, the Crowsnest River can be classified as “oligotrophic” (see [Section 3.1.6](#) for definition) in all seasons. BOD concentrations were below the detection limit in all seasons.

Calcium and magnesium were dominant cations and bicarbonate and sulphate were dominant anions in the Crowsnest River. Carbonate and hydroxide concentrations were below detection limits in all seasons except one sample for carbonate in summer. Sulphide concentrations exceeded water quality guidelines in one sample of six in summer and one sample of two in fall.

Trace Metals and Organic Compounds

Out of 25 metals measured, 16 total metals and eight dissolved metals in spring, 15 total metals and 17 dissolved metals in summer, 10 total metals and 17 dissolved metals in fall, and nine total and 15 dissolved metals in winter were below the detection limits. No metals exceeded water quality guidelines for the protection of aquatic life.

A range of organic variables including hydrocarbons, naphthenic acids, phenolics, volatile organics, and PAHs were analyzed but all of them were below detection limits.

Table 14 Summary of seasonal of water quality variables in the Crowsnest River, May 2013 to March 2016.

Variables	Units	Guidelines	Spring				Summer				Fall				Winter			
			N	Med	Min	Max	N	Med	Min	Max	N	Med	Min	Max	N	Med	Min	Max
Field Measured Variables																		
Temperature	(°C)	-	8	5.00	2.5	9	10	12.57	6	17.1	4	8.57	8	11.2	2	4.7	4.2	5.2
pH	-	6.5-9.0	8	8.4	8.16	9.82	10	7.46	6.17	8.5	4	8.31	8.18	8.32	2	7.88	7.36	8.39
Dissolved Oxygen	mg/L	>5.0-6.5	8	12.34	9	13.96	11	10.42	8.4	12.07	4	12.48	9.4	17.92	2	10.35	10.3	10.4
Specific Conductivity	µS/cm	-	7	242	153	425	10	267	157	348	4	306	263	354	2	359	357	361
Conventional Variables																		
Colour	TCU	-	4	<5	<5	<5	6	<5	<5	6.9	2	<5	<5	<5	2	<5	<5	<5
Total Suspended Solids (TSS)	mg/L	-	4	6.5	4	11.8	7	4	<3	6	2	<4	<4	<4	2	<3	<3	<3
Turbidity	NTU	-	4	3.81	0.44	4.24	6	1.74	1.01	7.66	2	1.17	1.14	1.2	2	1.3	0.95	1.65
Total Dissolved Solids (TDS)	mg/L	-	4	221	142	271	7	200	176	219	3	204	198	220	3	230	200	255
TDS (Calculated)	mg/L	-	4	221	175	266	7	190	169	209	3	215	213	220	3	260	210	267
Specific Conductivity (lab)	µS/cm	-	4	367	301	420	7	337	306	353	3	353	346	400	3	406	370	409
pH (lab)	-	6.5-9.0	4	8.21	8.20	8.24	7	8.26	8.22	8.44	3	8.23	8.17	8.29	3	8.09	8.08	8.11
Total Hardness (as CaCO ₃)	mg/L	-	4	200	164	231	7	163	149	180	3	190	182	210	3	253	200	256
Total Alkalinity (as CaCO ₃)	mg/L	>20	4	163	138	185	7	151	142	166	3	159	150	166	3	177	140	180
Dissolved Organic Carbon	mg/L	-	4	1.4	1.0	1.9	6	1.6	1.0	2	2	2.0	1.8	2.1	2	1.2	1	1.4
Total Organic Carbon	mg/L	-	4	1.5	1.0	1.9	7	1.4	1.0	1.7	3	1.6	1.0	1.8	3	1.2	1	2.1
Major Nutrients and BOD																		
Total Ammonia (as N)	mg/L	narrative	4	<0.05	<0.05	<0.05	6	<0.05	<0.05	0.056	2	<0.05	<0.05	<0.05	2	<0.05	<0.05	<0.05
Nitrate and Nitrite (as N)	mg/L	-	4	0.14	<0.071	0.214	6	0.113	0.091	0.128	2	0.1165	0.106	0.127	2	0.1505	0.142	0.159
Nitrate (as N)	mg/L	3-124	4	0.14	0.07	0.214	7	0.116	0.091	0.17	3	0.106	<0.01	0.127	3	0.159	0.142	0.22
Nitrite (as N)	mg/L	0.02-0.06	4	<0.05	<0.05	<0.05	6	<0.05	<0.02	<0.05	3	<0.05	<0.01	<0.05	3	<0.01	<0.01	<0.01
Total Kjeldahl Nitrogen	mg/L	-	4	0.23	<0.2	0.26	6	<0.2	<0.2	0.25	2	<0.2	<0.2	<0.2	2	<0.2	<0.2	<0.2
Dissolved Phosphorus	mg/L	-	4	0.0029	<0.001	0.008	6	0.0018	0.0015	0.0035	3	<0.001	<0.001	<0.1	2	0.0029	0.0024	0.0034
Total Phosphorus	mg/L	-	4	0.01025	0.0049	0.0122	6	0.0066	0.0051	0.0231	2	0.00575	0.0055	0.006	2	0.0059	0.0047	0.0071
Biochemical Oxygen Demand (BOD)	mg/L	-	4	<2	<2	<2	6	<2	<2	<2	2	<2	<2	<2	2	<2	<2	<2
Major Ions																		
Calcium	mg/L	-	4	59	51	67	7	51	44	53	3	56	54	61	3	76.4	59	76.8
Magnesium	mg/L	-	4	12.75	9.56	15.2	7	10.8	9.5	11.3	3	12	11.5	13	3	15.1	14	15.6
Potassium	mg/L	-	4	0.591	0.399	0.79	6	0.5	0.485	0.54	3	0.5	0.5	0.53	3	0.63	0.62	0.71
Sodium	mg/L	-	4	5.435	2.88	7.9	7	4.37	3.4	5.2	3	4.6	4.6	4.7	3	8	5.3	8.1
Bicarbonate	mg/L	-	4	198	169	225	7	182	174	195	3	195	190	202	3	216	170	220
Carbonate	mg/L	-	4	<5	<5	<5	6	<5	<5	10.5	3	<5	<0.5	<5	3	<5	<0.5	<5
Chloride	mg/L	120-640	4	2.58	1.14	4.88	7	1.72	1.3	1.9	3	2.2	2.1	3.3	3	2.72	2.62	3.9
Hydroxide	mg/L	-	4	<5	<5	<5	6	<5	<5	<5	3	<5	<0.5	<5	3	<5	<0.5	<5
Sulphate	mg/L	309-429	4	42.4	25.2	59.9	7	31.8	23.3	41.7	3	44	40.5	46	3	48.8	40	56.1
Sulphide	mg/L	0.0019	4	<0.002	<0.002	<0.002	6	<0.002	<0.0015	0.0029	2	0.003	<0.002	0.004	2	<0.0015	<0.0015	<0.0015

Table 14 (Cont'd.)

Variables	Units	Guidelines	Spring				Summer				Fall				Winter			
			N	Med	Min	Max	N	Med	Min	Max	N	Med	Min	Max	N	Med	Min	Max
Total Metals																		
Aluminum	mg/L	-	4	0.08335	0.0144	0.199	6	0.05585	0.0227	0.148	2	0.02135	0.019	0.0237	2	0.0256	0.0128	0.0384
Antimony	mg/L	-	4	<0.00025	<0.0001	<0.0004	6	<0.0001	<0.0001	<0.0004	2	<0.0001	<0.0001	<0.0001	2	<0.0001	<0.0001	<0.0001
Arsenic	mg/L	0.005	4	0.00034	0.00024	<0.0004	6	0.00028	0.00025	<0.0004	2	0.00028	0.00028	0.00028	2	0.00024	0.00024	0.00024
Barium	mg/L	-	4	0.0663	0.0566	0.0764	6	0.05775	0.0548	0.0619	2	0.0618	0.0606	0.063	2	0.07165	0.0692	0.0741
Beryllium	mg/L	-	4	<0.00075	<0.0005	<0.001	6	<0.0005	<0.0005	<0.001	2	<0.0005	<0.0005	<0.0005	2	<0.0001	<0.0001	<0.0001
Boron	mg/L	1.5-29	4	<0.0305	<0.01	<0.05	6	<0.01	<0.01	<0.05	2	<0.01	<0.01	<0.01	2	0.011	0.011	0.011
Cadmium	mg/L	0.00026-0.0038	4	<0.00003	<0.00001	<0.00005	6	<0.00001	<0.00001	<0.00005	2	<0.00001	<0.00001	<0.00001	2	0.0000058	<0.000005	0.0000067
Chromium	mg/L	0.0099	4	<0.00257	0.00014	<0.005	6	0.00024	0.00019	<0.005	2	0.00015	0.00015	0.00015	2	0.000155	0.00011	0.0002
Cobalt	mg/L	0.0025	4	<0.00105	<0.0001	<0.002	6	<0.0001	<0.0001	<0.002	2	<0.0001	<0.0001	<0.0001	2	<0.0001	<0.0001	<0.0001
Copper	mg/L	0.007-0.028	4	0.0007	0.00038	<0.001	6	0.00044	0.00025	<0.001	2	0.0004	0.00024	0.00056	2	<0.0005	<0.0005	<0.0005
Iron	mg/L	-	0	-	-	-	4	0.1155	0.059	0.179	0	-	-	-	2	0.075	0.058	0.092
Lead	mg/L	0.0067	4	0.00013	0.000067	0.00021	6	0.000075	<0.00005	0.00022	2	<0.00005	<0.00005	<0.00005	2	0.000051	<0.00005	0.000052
Lithium	mg/L	-	4	0.008	0.0057	<0.01	6	<0.0052	<0.005	<0.01	2	<0.005	<0.005	<0.005	2	0.00555	0.0053	0.0058
Manganese	mg/L	-	0	-	-	-	4	0.009105	0.00689	0.0107	0	-	-	-	2	0.0102	0.0093	0.0111
Mercury	µg/L	0.005-0.013	2	0.000635	<0.0005	0.00077	4	0.001115	0.00066	0.00156	0	-	-	-	2	<0.005	<0.005	<0.005
Molybdenum	mg/L	0.073	4	0.0028355	0.000627	<0.005	6	0.00056	0.000538	<0.005	2	0.000621	0.000621	0.000621	2	0.000611	0.000599	0.000623
Nickel	mg/L	0.086-0.77	4	0.00126	0.00041	<0.002	6	0.00053	0.00042	<0.002	2	0.000465	0.00046	0.00047	2	0.00056	0.00053	0.00059
Selenium	mg/L	Site-specific	4	0.00139	0.0012	0.00156	6	0.00163	0.00142	0.00194	2	0.001515	0.00143	0.0016	2	0.001195	0.00111	0.00128
Silver	mg/L	0.0001	4	<0.000055	<0.00001	<0.0001	6	<0.00001	<0.00001	<0.0001	2	0.0000285	0.000026	0.000031	2	<0.00001	<0.00001	<0.00001
Thallium	mg/L	0.0008	4	<0.000075	<0.00005	<0.0001	6	<0.00005	<0.00005	<0.0001	2	<0.00005	<0.00005	<0.00005	2	<0.00001	<0.00001	<0.00001
Tin	mg/L	-	4	<0.02505	<0.0001	<0.05	6	<0.0001	<0.0001	<0.05	2	0.000285	0.00028	0.00029	2	<0.0001	<0.0001	<0.0001
Titanium	mg/L	-	4	0.000965	<0.0003	0.0026	6	0.00105	<0.0003	0.0031	2	<0.0003	<0.0003	<0.0003	2	0.000385	<0.0003	0.00047
Uranium	mg/L	0.015-0.033	4	0.0004375	0.00037	0.000495	6	0.000372	0.000365	0.000392	2	0.0003745	0.000368	0.000381	2	0.000466	0.000456	0.000477
Vanadium	mg/L	-	4	0.00072	0.00035	<0.001	6	0.00045	0.0004	<0.001	2	0.00046	0.00043	0.00049	2	<0.0005	<0.0005	<0.0005
Zinc	mg/L	0.03	4	<0.0045	<0.004	<0.005	6	<0.005	<0.004	<0.005	2	<0.005	<0.005	<0.005	2	<0.003	<0.003	<0.003
Dissolved Metals																		
Aluminum	mg/L	0.05-0.1	3	0.004	0.0035	0.0274	7	<0.002	<0.001	<0.01	3	<0.001	<0.001	0.0036	2	0.0026	0.0019	0.0033
Antimony	mg/L	-	3	<0.0001	<0.0001	<0.0001	6	<0.0001	<0.0001	<0.0004	3	<0.0001	<0.0001	<0.0006	2	<0.0001	<0.0001	<0.0001
Arsenic	mg/L	-	3	0.00023	0.00021	0.00028	6	0.000255	0.00023	<0.0004	3	0.00022	<0.0002	0.00024	2	0.000195	0.00019	0.0002
Barium	mg/L	-	3	0.0666	0.0557	0.0748	7	0.059	0.0568	0.0604	3	0.0583	0.0583	0.063	2	0.0712	0.0699	0.0725
Beryllium	mg/L	-	3	<0.0005	<0.0005	<0.0005	6	<0.0005	<0.0005	<0.001	3	<0.0005	<0.0005	<0.001	2	<0.0001	<0.0001	<0.0001
Boron	mg/L	-	3	<0.01	<0.01	<0.01	6	<0.01	<0.01	<0.05	3	<0.01	<0.01	<0.02	2	0.0105	<0.01	0.011
Cadmium	mg/L	-	3	<0.00001	<0.00001	0.000011	7	<0.00001	<0.00001	<0.00005	3	<0.00001	<0.00001	<0.00002	2	0.0000005	0.0000005	0.0000005
Chromium	mg/L	-	3	0.00011	0.0001	0.00012	6	<0.000125	<0.0001	<0.005	3	<0.00011	<0.0001	<0.001	2	<0.0001	<0.0001	<0.0001
Cobalt	mg/L	-	3	<0.0001	<0.0001	<0.0001	6	<0.0001	<0.0001	<0.002	3	<0.0001	<0.0001	<0.0003	2	<0.0001	<0.0001	<0.0001
Copper	mg/L	-	3	0.00025	0.00023	0.00035	7	0.00019	<0.0001	0.0012	3	<0.0001	<0.0001	0.00043	2	<0.0002	<0.0002	<0.0002
Iron	mg/L	0.3	2	<0.01	<0.01	0.102	6	<0.01	<0.01	<0.03	3	<0.03	<0.03	<0.06	3	<0.03	<0.03	<0.06

Table 14 (Cont'd.)

Variables	Units	Guidelines	Spring				Summer				Fall				Winter			
			N	Med	Min	Max	N	Med	Min	Max	N	Med	Min	Max	N	Med	Min	Max
Dissolved Metals (Cont'd.)																		
Lead	mg/L	-	3	<0.00005	<0.00005	0.000102	6	<0.00005	<0.00005	<0.0001	3	<0.00005	<0.00005	<0.0002	2	<0.00005	<0.00005	<0.00005
Lithium	mg/L	-	3	<0.005	<0.005	0.006	6	0.005	0.0035	0.0054	3	<0.0051	<0.005	<0.02	2	0.0057	0.0054	0.006
Manganese	mg/L	-	2	0.005235	0.00324	0.0185	7	0.0047	0.00324	<0.005	3	<0.005	<0.004	<0.005	3	0.0068	0.0046	0.0085
Mercury	µg/L	-	2	0.00059	<0.0005	0.00068	0	-	-	-	0	-	-	-	2	<0.005	<0.005	<0.005
Molybdenum	mg/L	-	3	0.000552	0.000515	0.000559	7	0.00054	<0.0005	<0.005	3	0.000602	0.00058	0.00068	2	0.000559	0.000543	0.000575
Nickel	mg/L	-	3	0.0004	0.00035	0.00057	7	0.00043	0.00029	<0.002	3	0.00045	0.00044	<0.0005	2	<0.0005	<0.0005	<0.0005
Selenium	mg/L	-	3	0.00136	0.00128	0.00163	7	0.0017	0.00149	0.00209	3	0.00151	0.0012	0.00169	2	0.001275	0.00117	0.00138
Silicon	mg/L	-	0	-	-	-	1	1.9	1.9	1.9	1	2.1	2.1	2.1	2	<0.00001	<0.00001	<0.00001
Silver	mg/L	-	3	<0.00001	<0.00001	<0.00001	6	<0.00001	<0.00001	<0.0001	3	<0.00001	<0.00001	<0.0001	2	<0.00001	<0.00001	<0.00001
Strontium	mg/L	-	0	-	-	-	1	0.22	0	0.22	1	0.3	0.3	0.3	2	<0.0001	<0.0001	<0.0001
Thallium	mg/L	-	3	<0.00005	<0.00005	<0.00005	6	<0.00005	<0.00005	<0.0001	3	<0.00005	<0.00005	<0.0002	2	<0.0003	<0.0003	<0.0003
Tin	mg/L	-	3	<0.0001	<0.0001	<0.0001	6	<0.0001	<0.0001	<0.05	3	<0.0001	<0.0001	<0.0001	2	0.000415	0.000398	0.000432
Titanium	mg/L	-	3	<0.0003	<0.0003	<0.0003	6	<0.0003	<0.0003	<0.001	3	<0.0003	<0.0003	<0.001	2	<0.0005	<0.0005	<0.0005
Uranium	mg/L	-	3	0.000387	0.000382	0.000505	7	0.00034	0.00032	0.00041	3	0.000361	0.00036	0.00048	2	0.0017	0.0016	0.0018
Vanadium	mg/L	-	3	0.00024	0.00022	0.00028	6	0.000265	0.0002	<0.001	3	0.00021	0.0002	<0.001	2	<0.00005	<0.00005	<0.00005
Zinc	mg/L	-	3	<0.001	<0.001	0.0098	7	<0.0028	<0.001	<0.005	3	<0.005	<0.003	<0.005	2	0.0057	0.0054	0.006
General Organics																		
Recoverable Hydrocarbons	mg/L	-	4	<1	<1	<1	6	<1	<1	<1	2	<1	<1	<1	2	<1	<1	<1
Phenols (4AAP)	mg/L	0.004	4	<0.001	<0.001	<0.001	6	<0.001	<0.001	0.0011	3	<0.001	<0.001	<0.002	3	<0.001	<0.001	<0.002
Benzene	mg/L	0.04	2	<0.0005	<0.0005	<0.0005	4	<0.0005	<0.0005	<0.0005	2	<0.0005	<0.0005	<0.0005	2	<0.0005	<0.0005	<0.0005
Ethylbenzene	mg/L	0.09	2	<0.0005	<0.0005	<0.0005	4	<0.0005	<0.0005	<0.0005	2	<0.0005	<0.0005	<0.0005	2	<0.0005	<0.0005	<0.0005
Toluene	mg/L	0.0005	2	<0.0005	<0.0005	<0.0005	4	<0.0005	<0.0005	<0.0005	2	<0.0005	<0.0005	<0.0005	2	<0.0005	<0.0005	<0.0005
o-xylene	mg/L	-	2	<0.0005	<0.0005	<0.0005	4	<0.0005	<0.0005	<0.0005	2	<0.0005	<0.0005	<0.0005	2	<0.0005	<0.0005	<0.0005
m+p-Xylene	mg/L	-	2	<0.0005	<0.0005	<0.0005	4	<0.0005	<0.0005	<0.0005	2	<0.0005	<0.0005	<0.0005	2	<0.0005	<0.0005	<0.0005
Xylenes	mg/L	0.03	2	<0.00071	<0.00071	<0.00071	4	<0.000605	<0.0005	<0.00071	2	<0.0005	<0.0005	<0.0005	2	<0.0005	<0.0005	<0.0005
F1 (C6-C10)	mg/L	0.15	2	<0.1	<0.1	<0.1	4	<0.1	<0.1	<0.1	2	<0.1	<0.1	<0.1	2	<0.1	<0.1	<0.1
F1-BTEX	mg/L	-	2	<0.1	<0.1	<0.1	4	<0.1	<0.1	<0.1	2	<0.1	<0.1	<0.1	2	<0.1	<0.1	<0.1
F2 (>C10-C16)	mg/L	0.11	2	<0.25	<0.25	<0.25	2	<0.25	<0.25	<0.25	2	<0.25	<0.25	<0.25	2	<0.25	<0.25	<0.25
F3 (C16-C34)	mg/L	-	2	<0.25	<0.25	<0.25	2	<0.25	<0.25	<0.25	2	<0.25	<0.25	<0.25	2	<0.25	<0.25	<0.25
F4 (C34-C50)	mg/L	-	2	<0.25	<0.25	<0.25	2	<0.25	<0.25	<0.25	2	<0.25	<0.25	<0.25	2	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	4	<0.1	<0.1	<0.1	6	<0.1	<0.1	0.69	2	<0.1	<0.1	<0.1	2	<0.295	<0.24	<0.35
Polycyclic Aromatic Hydrocarbons																		
Benzo[a]pyrene	µg/L	0.015	0	-	-	-	0	-	-	-	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01
Acenaphthene	µg/L	5.80	0	-	-	-	0	-	-	-	1	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1
Acenaphthylene	µg/L	-	0	-	-	-	0	-	-	-	1	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1
Acridine	µg/L	4.4	0	-	-	-	0	-	-	-	1	<0.2	<0.2	<0.2	1	<0.2	<0.2	<0.2
Anthracene	µg/L	0.012	0	-	-	-	0	-	-	-	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01

Table 14 (Cont'd.)

Variables	Units	Guidelines	Spring				Summer				Fall				Winter			
			N	Med	Min	Max	N	Med	Min	Max	N	Med	Min	Max	N	Med	Min	Max
Polycyclic Aromatic Hydrocarbons (Cont'd.)																		
Benzo(a)anthracene	µg/L	0.018	0	-	-	-	0	-	-	-	1	<0.0085	<0.0085	<0.0085	1	<0.0085	<0.0085	<0.0085
Benzo(b&j)fluoranthene	µg/L	-	0	-	-	-	0	-	-	-	1	<0.0085	<0.0085	<0.0085	1	<0.0085	<0.0085	<0.0085
Benzo(k)fluoranthene	µg/L	-	0	-	-	-	0	-	-	-	1	<0.0085	<0.0085	<0.0085	1	<0.0085	<0.0085	<0.0085
Benzo(g,h,i)perylene	µg/L	-	0	-	-	-	0	-	-	-	1	<0.0085	<0.0085	<0.0085	1	<0.0085	<0.0085	<0.0085
Benzo(c)phenanthrene	µg/L	-	0	-	-	-	0	-	-	-	1	<0.05	<0.05	<0.05	1	<0.05	<0.05	<0.05
Benzo(a)pyrene	µg/L	0.015	0	-	-	-	0	-	-	-	1	<0.0075	<0.0075	<0.0075	1	<0.0075	<0.0075	<0.0075
Benzo[e]pyrene	µg/L	-	0	-	-	-	0	-	-	-	1	<0.05	<0.05	<0.05	1	<0.05	<0.05	<0.05
Chrysene	µg/L	-	0	-	-	-	0	-	-	-	1	<0.0085	<0.0085	<0.0085	1	<0.0085	<0.0085	<0.0085
Dibenz(a,h)anthracene	µg/L	-	0	-	-	-	0	-	-	-	1	<0.0075	<0.0075	<0.0075	1	<0.0075	<0.0075	<0.0075
Fluoranthene	µg/L	0.04	0	-	-	-	0	-	-	-	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01
Fluorene	µg/L	3	0	-	-	-	0	-	-	-	1	<0.05	<0.05	<0.05	1	<0.05	<0.05	<0.05
Indeno(1,2,3-cd)pyrene	µg/L	-	0	-	-	-	0	-	-	-	1	<0.0085	<0.0085	<0.0085	1	<0.0085	<0.0085	<0.0085
2-Methylnaphthalene	µg/L	-	0	-	-	-	0	-	-	-	1	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1
Naphthalene	µg/L	1	0	-	-	-	0	-	-	-	1	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1
Phenanthrene	µg/L	0.4	0	-	-	-	0	-	-	-	1	<0.05	<0.05	<0.05	1	<0.05	<0.05	<0.05
Perylene	µg/L	-	0	-	-	-	0	-	-	-	1	<0.05	<0.05	<0.05	1	<0.05	<0.05	<0.05
Pyrene	µg/L	0.025	0	-	-	-	0	-	-	-	1	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02
Quinoline	µg/L	3.4	0	-	-	-	0	-	-	-	1	<0.2	<0.2	<0.2	1	<0.2	<0.2	<0.2

3.2.4 Quality Assurance and Quality Control (QA/QC)

Quality assurance and quality control (QA/QC) protocols included procedures incorporated into sample collection, data analysis, and reporting. These procedures were utilized to make sure that the data generated during this monitoring program were of consistently high quality and appropriate to address the objectives of the baseline studies. A detailed QA/QC report is provided in [Appendix A2](#) and summarized below.

Concentrations of all water quality variables (approximately 90 variables) in the nine field blanks assessed were below five times the detection limits except total mercury and dissolved barium and tin. Concentrations of total mercury and dissolved tin in the field blank samples were much higher than in the corresponding watercourse samples collected on the same date indicating that the concentrations in the field blanks were the result of an isolated field or laboratory error. In this case, the corresponding water samples were considered uncontaminated. On the other hand, dissolved barium concentration in the watercourse sample collected on the same date was well above the one observed in the field blank indicating a negligible effect on the quality of the corresponding watercourse data.

Analyte concentrations in all eight travel blanks were below five times the detection limits indicating no potential contamination of the watercourse samples due to transport of the samples.

Several water quality variables showed relative percent difference (RPD) values in duplicate samples, above the QC assessment criterion of 20%. On average, 5% of the total number of variables for duplicate samples exceeded this criterion. This represents a 'high' level of field sampling and analytical precision and does not substantially influence the interpretation of the water quality baseline data.

Sediment quality control results are presented in [Appendix A2](#). One duplicate sample was collected as a part of the June 2016 field program. Only four metals (boron, phosphorus, strontium, and zirconium) out of 33 had a RPD greater than 20% indicating a high level of field sampling and analytical precisions.

3.2.5 Summary

Seasonal water samples were collected from five stations at Blairmore Creek drainage, eight stations at Gold Creek drainage, and three stations in the Crowsnest River during spring 2013 to winter 2016. Available historical water quality data were compiled and traditional knowledge and use of water in the project area were surveyed in three first nations' communities. Water quality data were summarized, tabulated and compared with AEP's water quality guidelines for the protection of aquatic life (AEP 2014).

Participants of Treaty 7 First Nations identified water quality as an important concern regarding the Project, particularly the potential for springs and streams nearby Grassy Mountain might be affected by mine runoff and cause deaths of animals. They recommended an emergency preparedness plan in the event of leaks, spills, and other disasters. They also recommended a workable effective mitigation strategy and plan for the protection of animals and watercourses at the site in consultation with First Nations.

The QC assessment indicates a high level of field sampling and analytical precision for the water quality of the entire baseline programs. Therefore, the data generated in the baseline programs were of acceptable quality and adequate to address the objectives of this study.

Surface waters in the LSA and RSA were generally clear, characterized by low colour, low suspended solids and low organic carbon concentrations. All watercourses were well-oxygenated, and at times observed to be over-saturated. The pH was mostly in alkaline range. Consistently high total hardness and alkalinity levels indicate all sampled watercourses contain hard water creeks/river with low sensitivity to acid deposition. With the exception of a few sulphide concentrations, concentrations of ions were generally low and dominated by calcium and bicarbonate. Surface waters in the LSA and RSA were classified as “low” nutrient concentrations with total ammonia, nitrite, and nitrate concentrations being often below the detection limits. Concentrations of total phosphorus generally suggest the surface waters in the LSA and RSA were within the “oligotrophic” (low) range of aquatic productivity.

Of the 25 metals (both dissolved and particulate forms) measured in the study areas approximately half were below analytical detection limits. Concentrations of detected metals were generally within guidelines, with the exception of total mercury, total selenium, and dissolved aluminum which exceeded water quality guidelines for the protection of aquatic life on some occasions. Total mercury exceeded the guideline in 20% of the samples at Blairmore Creek and 25% of the samples at Gold Creek during summer. Total selenium exceeded the guidelines only at Gold Creek in 25% of the samples during summer. Dissolved aluminum exceeded the guideline in 11% of samples in summer and 25% of total samples in winter at Gold Creek. No guideline exceedances for metals were noted in the Crowsnest River in the baseline data. However, historical data collected in the Crowsnest River indicate that concentrations of total copper, total chromium, total cobalt, total lead total silver, total mercury, and total zinc were higher than water quality guidelines in at least one season. Concentrations of organic compounds were usually below the detection limits at all watercourses and all seasons. Water quality in historical end-pit lakes was similar to creeks and within water quality guidelines.

Metals concentrations in sediments measured above the CCME interim sediment quality guidelines for the protection of freshwater life included arsenic (100% of samples at Blairmore Creek and 50% of samples at Gold Creek), cadmium (50% of samples at both creeks), and zinc (25% of samples at both creeks). Metal contents of periphyton were well detected at both creeks with relative higher concentrations at Blairmore Creek than Gold Creek. Selenium concentrations in periphyton ranged from 1.70 to 9.66 mg/kg at Blairmore Creek and 1.71 to 3.15 mg/kg at Gold Creek with the highest concentrations at downstream stations.

4.0 APPLICATION CASE AND PLANNED DEVELOPMENT CASE FOR SURFACE WATER QUALITY ASSESSMENT

This section assesses the potential effects on surface water quality within the Aquatic Resources RSA and LSA of the Application Case (i.e., construction, operation, decommissioning and reclamation of the Project along with existing and approved developments), and of the Application Case plus the cumulative effects assessment due to other planned development projects (PDC). The assessment is organized as follows:

- Assessment of the validity of the causal relationships linking Project activities to possible changes in surface water quality;
- Specification of mitigation measures to be implemented to prevent or avoid potentially negative environmental consequences of Project activities;
- An analysis of residual effects after the application of mitigation measures; and
- A classification of residual effects using a range of environmental impact assessment criteria.

Conservative assumptions are used throughout the impact assessment to ensure that residual effects are not underestimated.

An effects analysis for valid water quality issues identified in Section 2.1 is described below.

4.1 RELEASE OF PROCESS-RELATED WATER TO NATURAL WATERCOURSES

4.1.1 Local Study Area

4.1.1.1 Validity of Impact Pathways

During construction, suspended sediment inputs to watercourses could result from disturbances of land, creek substrates, and bank sediments during soil stripping and vegetation clearing, building haul roads, development of water management drainage ditches, sedimentation ponds and surge ponds, construction of the rail loop alignment and associated crossing, and surface and groundwater runoff from the pit. Increased sediment concentrations could increase turbidity and concentrations of water quality constituents that bind to and are found in particulate material, such as nutrients, metals or organic compounds. This impact pathway was judged to be valid and related to increased sediment loading and runoff to surface waters and associated changes in surface water quality.

During the operations, the Project will create large volumes of waste rock. Exposure of waste rock to water and air has the potential for acid rock drainage and associated metal leaching and the release of bioaccumulative forms of selenium into the environment (Wayland and Crosley 2006). Selenium is a naturally-occurring metalloid that is essential for metabolic function in vertebrates. However, if present in high enough concentrations in appropriate environmental conditions, it can bioaccumulate to concentrations causing chronic toxicity in aquatic organisms (Chapman 1999). Selenium concentrations also may increase in groundwater that percolates through the rock dumps. Leaching of blasting residues will generate inorganic nitrogen species (ammonia, nitrite, and nitrate) which may enhance primary productivity and in turn cause oxygen depletion. Seepage, acid rock drainage, surface runoff and process

water may also elevate other trace metal concentrations which may cause toxic effects to aquatic life. Surveys of local First Nations also indicated concerns that mine activities would adversely affect surface waters. Therefore, the impact pathways for discharging process water to natural environment are assessed to be valid.

4.1.1.2 Mitigation Measures

The water management strategy aims to minimize water diverted from streams, maximize the separation of clean and contact water, and pump water with high selenium and nitrate concentrations to saturated zones for attenuation. Water collected in the pits during mining will be pumped to ponds for treatment and discharge. Nine ponds are included in the water management system. They are classified as either surge ponds or sedimentation ponds. Sedimentation ponds collect all other runoff and water pumped out of the pits for treatment and release. Surge ponds collect and hold water that is deemed contact water that may contain selenium, and will require further treatment via pumping through the saturated backfill zone.

The Project will implement a range of mitigation measures during construction to effectively prevent Project effects of suspended sediments and associated water quality constituents (e.g. selenium, acidic conditions, and metals) or reduce them to acceptable levels (Benga 2016 – Section C.5 Water Management). A full description of the mitigation is summarized below.

Managing Suspended Sediments:

- A series of collection ditches, sumps, pumps and sedimentation ponds will be established to manage all surface water on the mine site. A total of six sedimentation ponds are proposed to remove total suspended solids and associated constituents in the water before releasing to the environment. Surface water runoff from mining areas, haul roads, overburden disposal areas and any other disturbed areas, as well as groundwater captured in the pit will be directed to sedimentation ponds for treatment. Once suspended solids are settled, supernatant water will be released to Blairmore Creek and Gold Creek;
- Progressive reclamation to reduce the amount of disturbed area at any given time will be applied. During reclamation, permanent plant cover will be established. Soil erosion will be reduced by minimizing the time that reclaimed surfaces are left bare;
- Benga will maintain a 100 m undisturbed buffer zone between development activities and Blairmore Creek and Gold Creek;
- The design and construction of all stream crossings will be done in compliance with the Alberta Code of Practice for Watercourse Crossings and associated guidelines;

Managing Capture of Contact Water:

In order to meet site specific selenium objective, it will be necessary to capture and pump the waste rock seepage to surge ponds and then to saturated zones where selenium can be attenuated. The LSA water quality model (see [Section 4.1.1.3](#)) assumed that the efficiency of contact water capture system will be

Attenuation of Selenium and Inorganic Nitrogen in Saturated Rock Zones:

Specific mitigation measures will be implemented to attenuate and reduce selenium and inorganic nitrogen concentrations in process water before its release to the receiving environment in lower Blairmore Creek.

Surge ponds will receive all potentially mine-affected water draining from external rock-disposal areas. From there, water will be directed to the various anaerobic saturated zones for treatment. The backfilled open pit will be sequenced to provide three anaerobic, saturated fill zones. Three saturated rock zones will be developed during the mine life (SZ1, SZ2, and SZ3). SZ1 will be engineered and constructed to function as a semi-passive bioreactor for selenium attenuation. As pit areas are backfilled, the saturated zone area will be increased. Project-affected water will flow from the newest saturated zone to the oldest one. Discharge from the saturated zones will be from the first saturated zone established, to maximize the residence time of water within the saturated zones. Given enough retention time, dissolved selenium (e.g., selenite) will reduce to elemental selenium and fall out of solution through microbial action in an anoxic environment. In the LSA water quality model, saturated zones are assumed to attenuate 99% of selenium loading. If the total selenium concentration in the upstream of the saturation zone is above 1.5 mg/L prior to attenuation, the downstream concentration of the saturated zone is predicted to be a maximum of 0.015 mg/L Se. The LSA water quality model predicts that up to 95% of the influent nitrate and nitrite loading also will be removed from water routed through saturated backfill zones. These applied attenuation factors assume that a carbon source will be added if required to enhance anaerobic reduction and meet the post-treatment concentrations predicted by the water quality model.

Water Treatment:

Water in the saturation zones is expected to require treatment prior to release to the environment especially due to elevated metal concentrations. The model predicted some metals may exceed guidelines and that a WTP may be required, this will be confirmed with on-site monitoring during operations. The outflow from the saturation zones will be directed to a water treatment plant, if required. The proposed treatment method is aeration, followed by high density sludge (HDS) lime treatment combined with sulphide precipitation of metal. Predicted final effluent characteristics are based on general performance data for typical HDS water treatment plants.

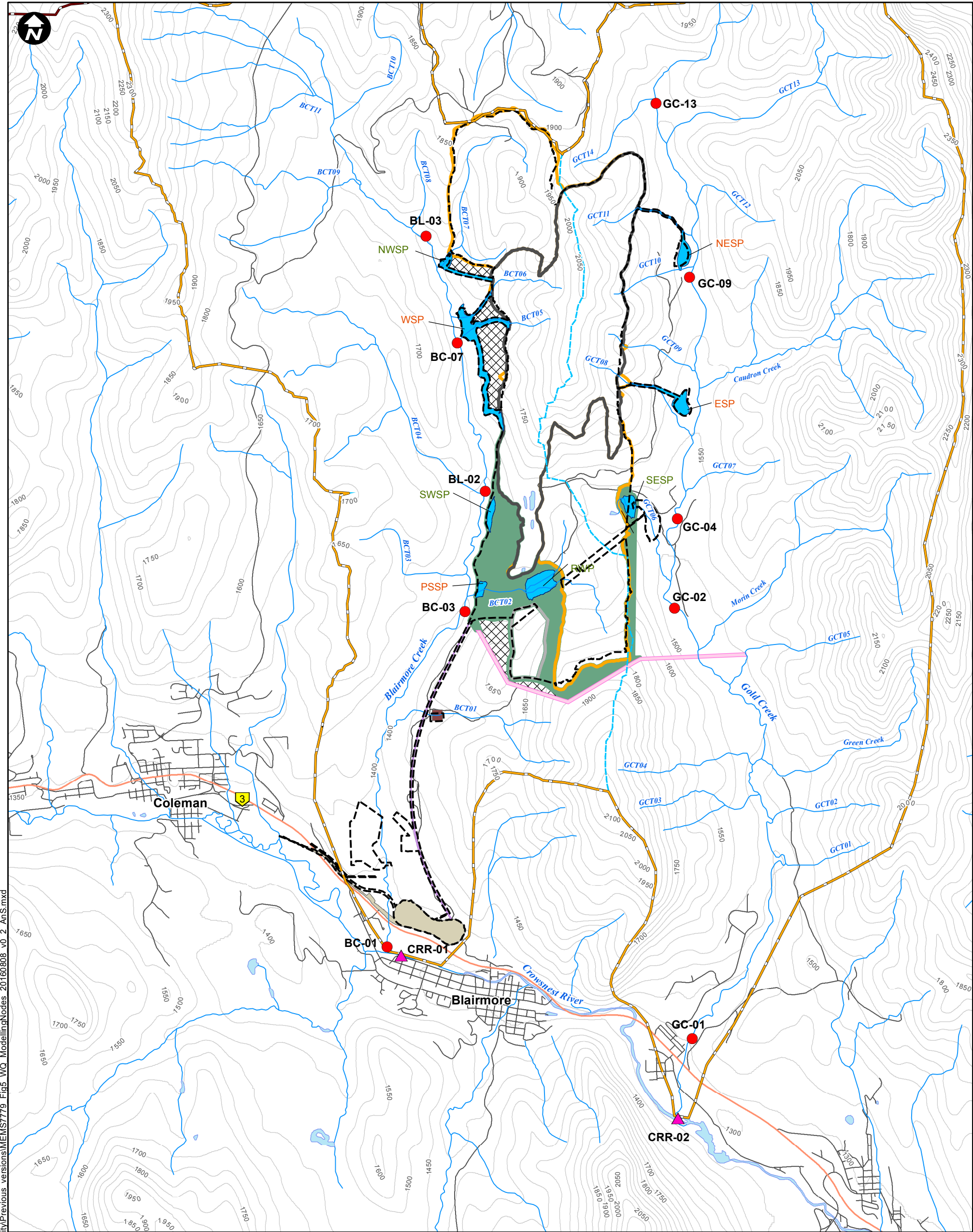
The treated water will be released to natural environment only after water quality testing to prove compliance of water quality guidelines. The water will be released into Blairmore Creek and Gold Creek, which will eventually flow into the Crowsnest River.

Management of Acid-Generating Materials:

Static geochemical characterization results have shown ARD potential that will require management.

- During operations neutralizing the acid generating material by blending with non-acid generating materials or sub-aqueous disposal;
- During mine closure, all acid-generating pit walls will be actively managed by blending with non-acid generating materials. The LSA water quality model assumes that 80% of loadings generated by acidic rock types will be mitigated.

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Modelling node (LSA)

Modelling node (RSA)

Primary Highway

Road

50 m Contour

Watershed Boundary

Watercourse

Waterbody

Local Study Area

Regional Study Area

Project Footprint

Coal Handling Processing Plant and Infrastructure

Ultimate Pit Extent

Ultimate Dump Extent

Topsoil Storage

Construction Camp

Ponds and Ditches

Proposed Pipeline ROW

Access and Conveyor

Railway Loop

Non-Disturbed Area

PROJECT

RIVERSDALE GRASSY MOUNTAIN COAL PROJECT

RESOURCES

TITLE

WATER QUALITY MODELLING NODES

NOTES

Data Sources: Government of Canada, Government of Alberta
Datum/Projection: UTM NAD 83 Zone 11

0124

Kilometres

PROJECT: 7779

DRAWN BY: AS

CHECKED BY: MD

DATE: AUGUST 08, 2016

FIGURE

5

4.1.1.3 Residual Effects Analysis

The hydrology effects analysis concluded that the Project's effects on sediment yields and constituent concentrations in receiving watercourses of the LSA due to construction activities will be small and localized (Benga 2016 - Section C.5). Sediments re-suspended during watercourse crossing construction will originate from native stream substrates, which are assumed to be uncontaminated. Surface water runoff from mining areas, haul roads, overburden disposal areas and any other disturbed areas, as well as groundwater runoff from the pit, will be collected and directed to sedimentation ponds. Once suspended solids are settled there, water will be discharged to the receiving environment. Based on the planned management of construction activities and runoff waters, the controlled release of water from the sedimentation ponds, elevated sediment inputs and surface runoff waters is predicted to have a negligible effect on surface water quality.

To assess the effectiveness of passive (anoxic saturated zones) and active water treatments (water treatment plant), a water balance (stochastic model) and load balance (mechanistic model) were developed for Blairmore and Gold creeks (i.e., the LSA) by SRK Consulting Inc. using GoldSim (version 11.1 GoldSim Technology Group 2014) and applied to predict the effects of process water releases into Blairmore Creek and Gold Creek (Appendix 10B in the Application [Benga 2016]).

The load balance was connected to a water balance that tracked all inputs and outflows. Model water quality inputs included surface water, groundwater, and pit wall and waste rock seepage. Direct precipitation and outflows were accounted for as discharges, evaporation and seepage. Runoff was modelled as a function of precipitation where a runoff coefficient was applied to account for losses such as evaporation and infiltration. Loadings and concentrations were calculated for the mine component, and loading rates were generated for each corresponding inflow of the water balance. The majority of the loading rates were calculated based on the concentrations of source terms, but some also were based on loadings per unit waste volumes. Appendix 10B in the Application (Benga 2016) contains a detailed description of the water quality model; a summary of the model is provided below:

- A total of 39 water quality variables were modelled including metals, major nutrients (ammonia, nitrite, nitrate, and phosphorus), and major ions (calcium, magnesium, potassium, sodium, chloride, and sulphate);
- For loadings and water quality, predictions used hydrology model outputs and median concentrations of source terms, considered to be most likely based on baseline data and site geochemistry;
- Water quality variables were predicted on a daily timescale, with results summarized to monthly averages and annual ranges throughout the pre-mining (year 2017 to 2019), operation (2019 to 2042), closure (2043 to 2050), and post-closure (2050 to 2099) periods of the mine;
- Water quality prediction nodes in the LSA were strategically chosen to best support the environmental project management approval and water license throughout the Project's life cycle (Figure 5):
 - On Blairmore Creek, one upstream control node (BL-03) and four downstream nodes (presented below in upstream-to-downstream order):

- BC-07, downstream of West Sedimentation Pond release;
 - BL-02, downstream of Raw Water Pond release;
 - BC-03, downstream of Saturated Zone Treatment; and
 - BC-01, lower Blairmore Creek at its mouth;
- o On Gold Creek, one upstream control node (GC-13) and four downstream nodes (presented below in upstream-to-downstream order):
 - GC-10, downstream of Northeast Sedimentation Pond release;
 - GC-04, downstream of East Sedimentation Pond release;
 - GC-02, downstream of Southeast Surge Pond; and
 - GC-01, lower Gold Creek at its mouth.

Predicted results were summarized by seasons for all phases of mine cycle and compared against AEP water quality guidelines for the protection of aquatic life (AEP 2014), the proposed site-specific Se objective (see [Section 2.2.2](#)), and for sulphate, published effects thresholds. For hardness-dependent variables, respective calculated hardness levels (based on calcium and magnesium) were used to calculate guideline values.

In addition to the standard-case source terms, the LSA model also was run using worst-case geochemistry source terms (see Appendix 10B in the Application [Benga 2016] for details). These worst-case predictions are not considered to be likely or realistic, but were used as a sensitivity analysis, to assess what additional mitigation could be required to address water quality issues in such a case. Results of this worst-case assessment were considered in the water quality assessment as screening values to identify potential water quality variables of specific concern.

Results of Water Quality Model

A total of 39 variables were modelled, of which 21 variables have published Alberta water quality guidelines. Predicted concentrations of all of these 21 regulated water quality variables during the construction, operation, closure and post-closure periods of the Grassy Mountain Mine fell within published Alberta guidelines (or for Se, the proposed site-specific objective) in Gold Creek. In Blairmore Creek, predicted concentrations of all variables fell within these guidelines or the proposed Se objective except sulphate.

Sulphate concentrations in Blairmore Creek are predicted to increase steadily over mine life to above the maximum published Alberta guideline of 429 mg/L (at 181-250 mg/L hardness) at all modelled locations downstream of the West Sedimentation Pond release (i.e., from BC-07 downstream) ([Figure 6](#)). Sulphate is predicted to remain below the AB guideline during mine life until the mid-to-late 2030s, when it is predicted to exceed this guideline in all seasons until mine closure, after which time concentrations are predicted to decline to a stable, long-term average, which would still remain consistently above this guideline at all modelled locations downstream of the West Sedimentation Pond water release ([Figure 6](#)).

Predicted selenium concentrations in Blairmore Creek throughout all mine phases appear in [Figure 7](#). Predicted selenium concentrations are well below the proposed site-specific water quality objective throughout the modelled period, and mostly below generic Alberta guideline during pre-mining and initial period of operations, increasing through operations until mine closure followed by stable post-closure conditions.

Figure 6 Predicted sulphate concentrations at locations along Blairmore Creek during different mine phases.

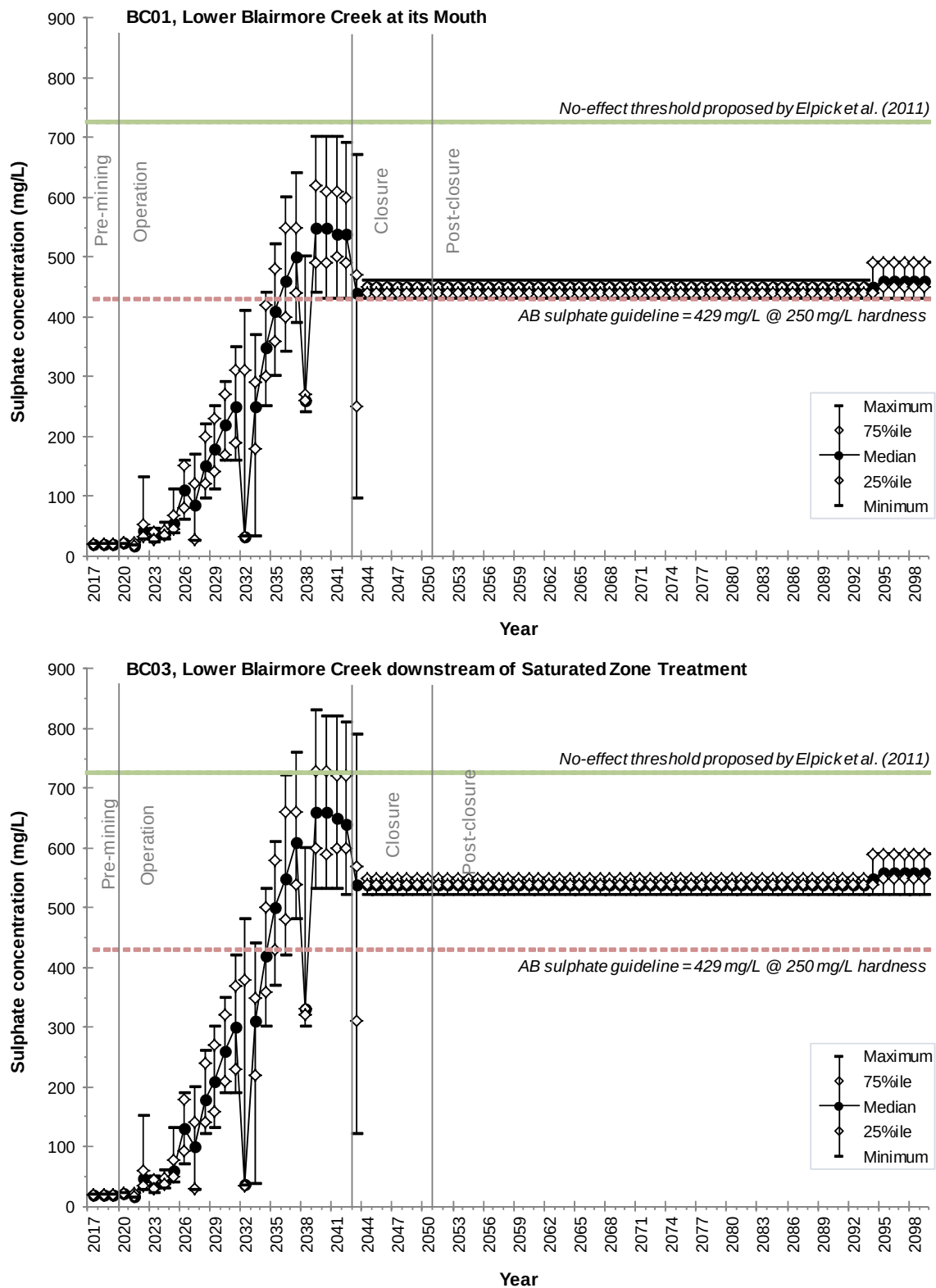


Figure 6 (Cont'd.)

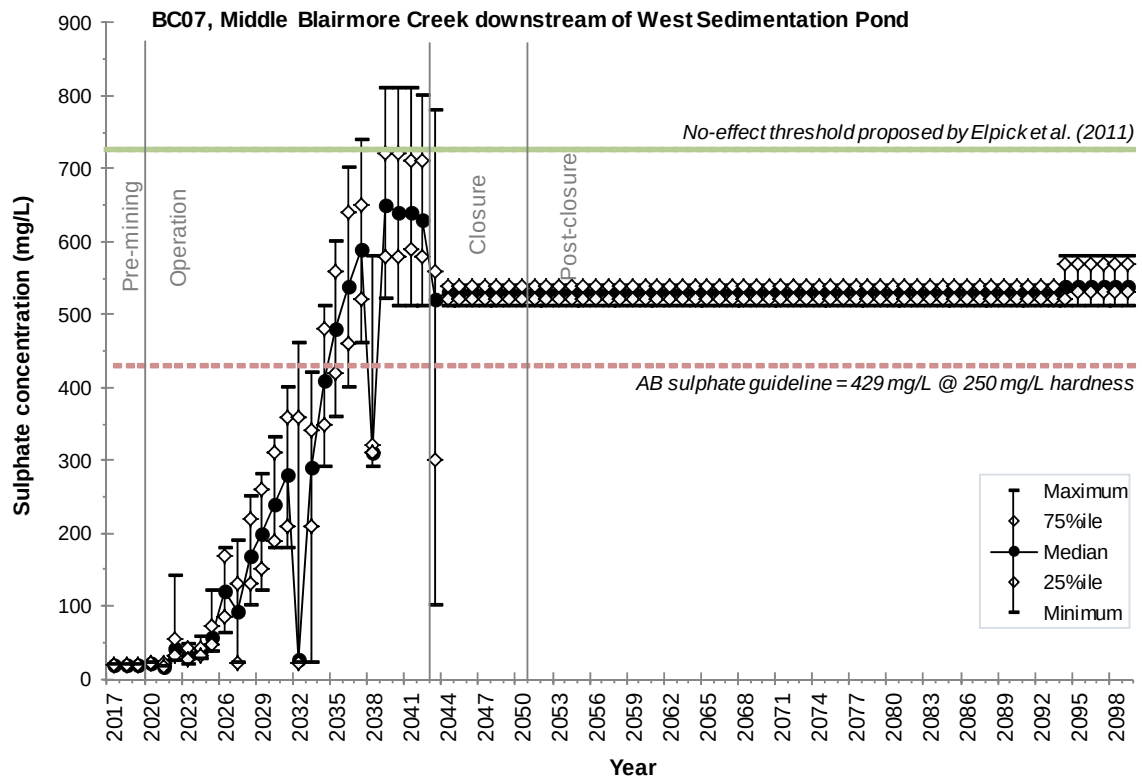
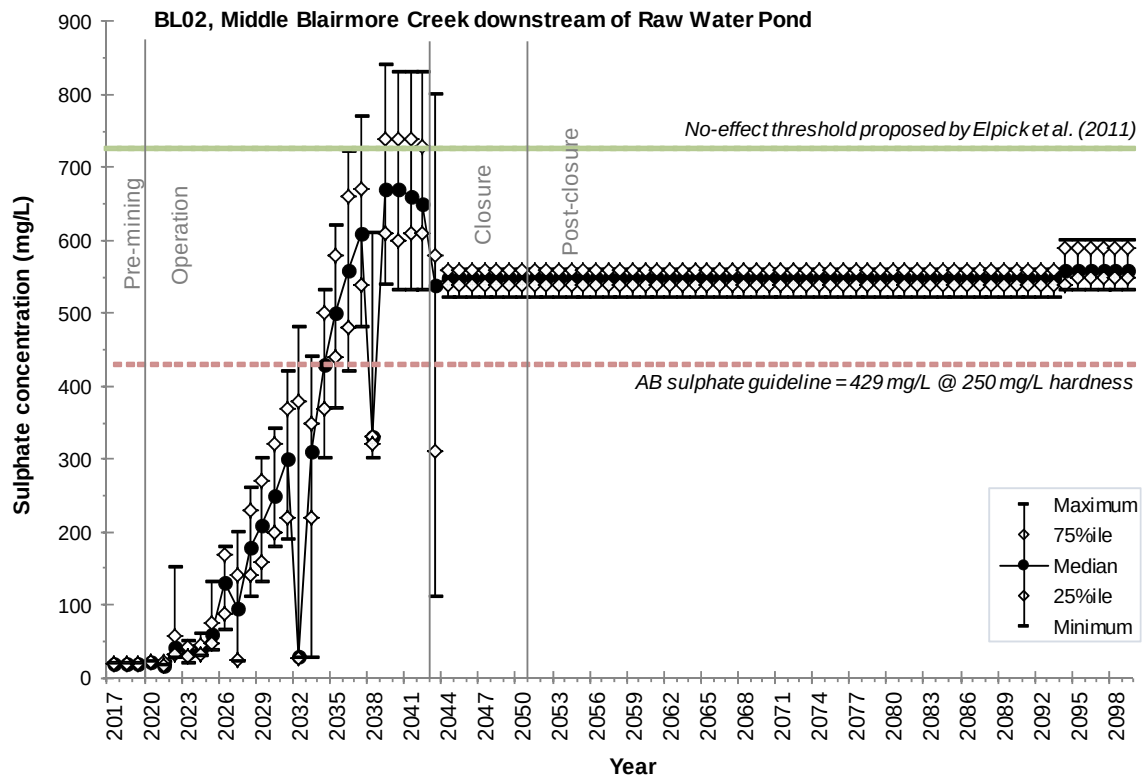


Figure 7 Predicted selenium concentrations at locations along Blairmore Creek during different mine phases.

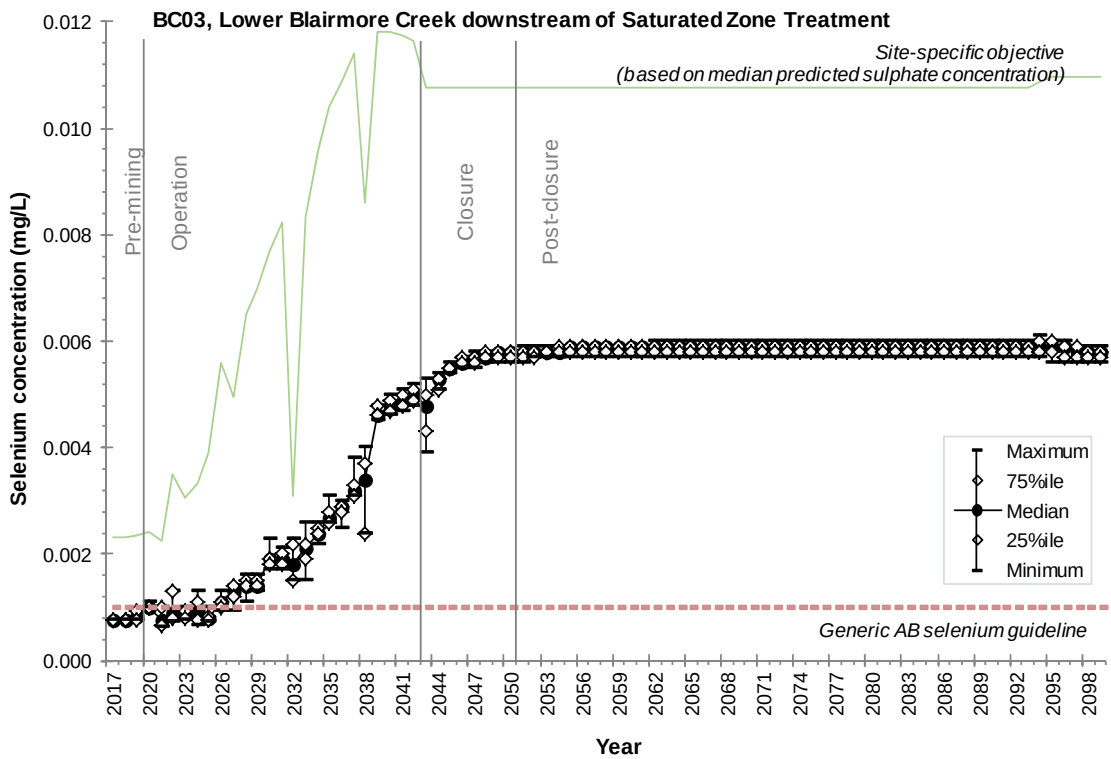
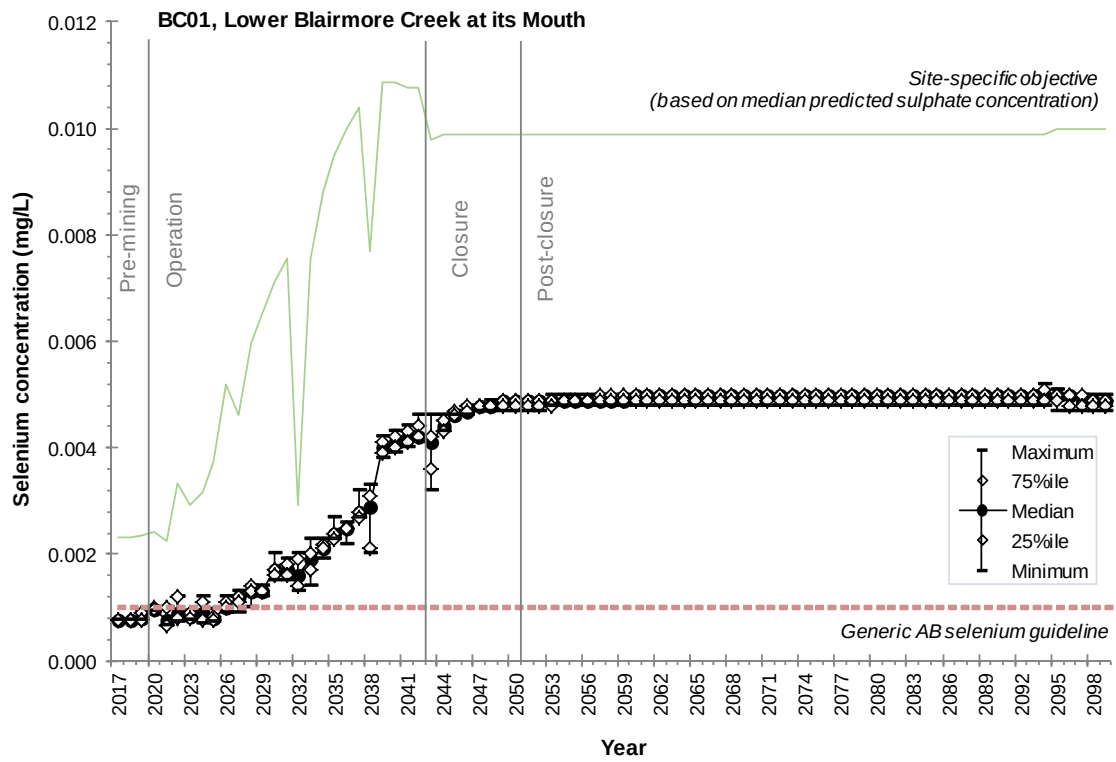
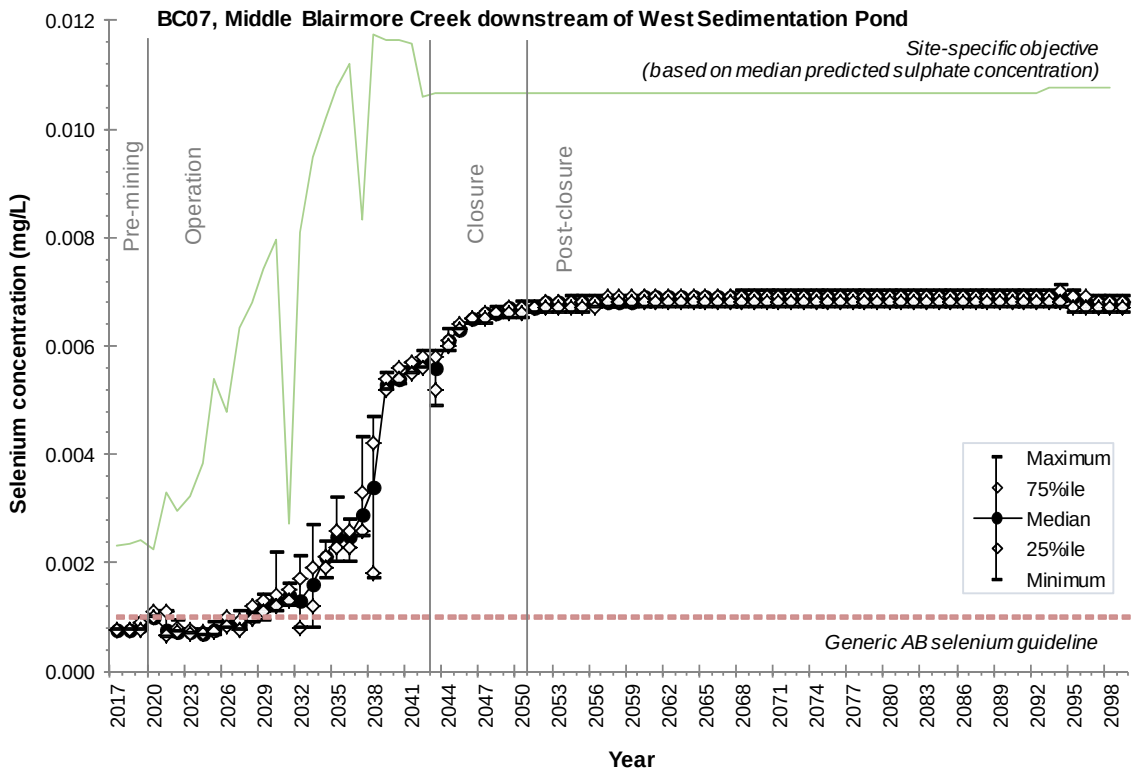
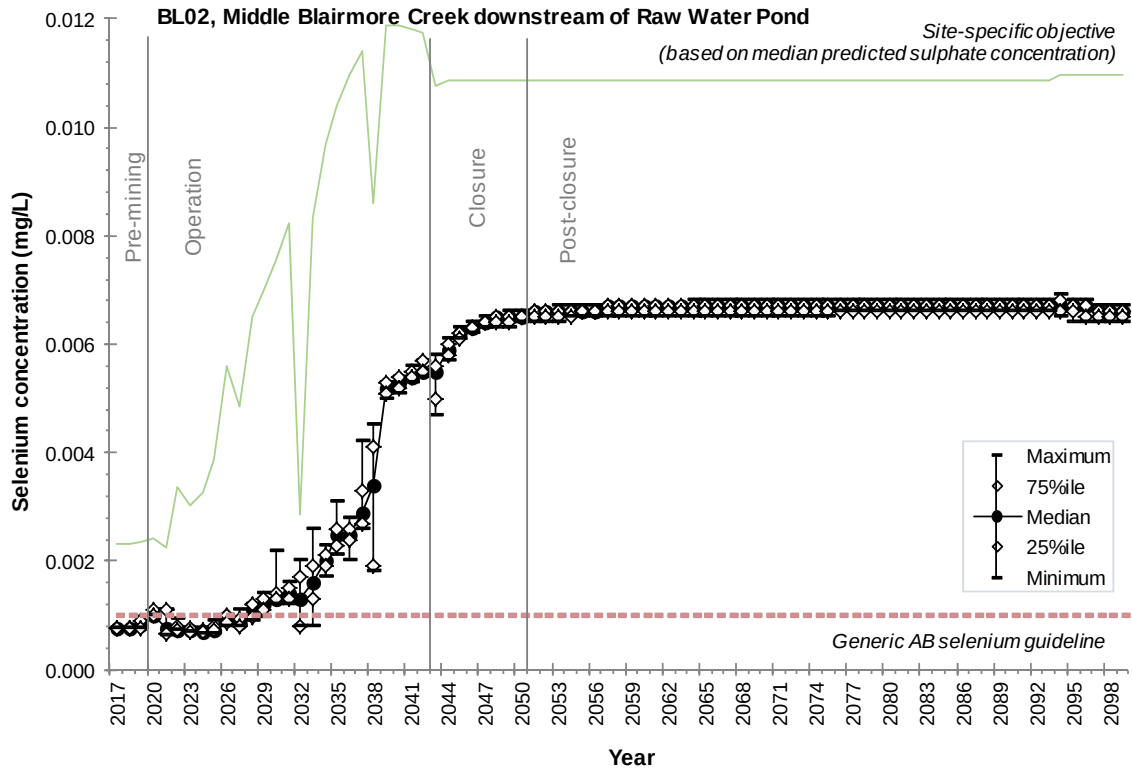


Figure 7 (Cont'd.)



The Alberta guideline for sulphate follows the recently produced British Columbia guideline (Meays and Nordin 2013), and is hardness-based. Generally, the greater the hardness of the receiving water, the greater the sulphate concentration in water that can be tolerated by aquatic life. In part, revision of the BC guideline was driven by new toxicity testing undertaken by Davies and Hall (2007) and Elphick et al. (2011), who assessed sulphate toxicity to various aquatic organisms at a range of hardness. Elphick et al. challenged several aquatic plant, invertebrate and fish species to sulphate concentrations up to 4,000 mg/L sulphate using standard sublethal toxicity tests, at a range of hardnesses up to 250 mg/L. In hard water (i.e., 160 to 250 mg/L), the most sensitive species to sulphate was found to be the daphnid *Ceriodaphnia dubia*, which showed reduced reproduction (IC25) at 1,213 mg/L at 160 mg/L hardness. From a species-sensitivity curve (SSC) developed for all species exposed to sulphate in high-hardness waters, they suggested a safe threshold concentration of sulphate of 725 mg/L, equal to the 5th percentile of the modelled SSC.

This Alberta and BC guideline apply up to hardness of 250 mg/L, above which development of a site-specific objective is recommended, due to potential confounding effects of hardness itself (and the particular ionic composition of waters) on biological responses. Hardness in Blairmore Creek is already high (i.e., to over 200 mg/L in Blairmore Creek and over 300 mg/L in Gold Creek in some seasons; see [Section 3.2.3.1](#)), likely indicating a strong influence of groundwater in these systems. This also suggests that aquatic species and communities in these creeks are adapted to the high hardness conditions present in them.

Water quality in Blairmore Creek is predicted to fall below the Elphick et al. (2011) recommended effect threshold of 725 mg/L for high hardness waters in all years at all locations ([Figure 7](#)). However, maximum concentrations in middle to lower Blairmore Creek (i.e., at BC07, BL02 and BC03) are predicted to exceed this threshold in five of the six final years of mine life. These excursions are predicted to occur specifically in winter, when available dilution from ambient creek flows is lowest. In all other months at BC07 and BC03, sulphate concentrations are predicted to fall below this 725 mg/L threshold. In lower Blairmore Creek at its mouth, sulphate is predicted to fall below this threshold at all times, and to remain near the published Alberta sulphate guideline after mine closure.

Table 15 Seasonal exceedances of sulphate guideline and recommended effect threshold in Blairmore Creek over time.

Nodes	Mine Phase															
	Pre-mining				Operations				Closure				Post-closure			
	Sp	Su	F	W	Sp	Su	F	W	Sp	Su	F	W	Sp	Su	F	W
Blairmore Upper (BL03)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Blairmore Mid (BC07)	-	-	-	-	-*	-*	-*	√	-*	-*	-*	-*	-*	-*	-*	-*
Blairmore Mid (BL02)	-	-	-	-	-*	-*	-*	√	-*	-*	-*	-*	-*	-*	-*	-*
Blairmore Lower (BC03)	-	-	-	-	-*	-*	-*	√	-*	-*	-*	-*	-*	-*	-*	-*
Blairmore Lower (BC01)	-	-	-	-	-*	-*	-*	√	-*	-*	-*	-*	-*	-*	-*	-*

Sp = Spring; Su = Summer; F = Fall; W = Winter;

√ = Exceeds published AB guideline and Elphick et al. (2011) threshold; -* = Does not exceed Elphick et al (2011) threshold but does exceed published AB guideline; - = no exceedance.

4.1.1.4 Residual Effects Classification

Predicted effects of Project-related changes in water quality in the LSA were evaluated using a range of impact rating criteria presented in Table 5, and are summarized in Table 18. After mitigation, the residual effect of the Project on water quality in the LSA is considered to be **not significant**.

However, given sulphate concentrations are expected to exceed the published Alberta guideline of 429 mg/L late in mine life (i.e., by the mid 2030s), development of a site-specific sulphate objective reflective of predicted hardness (i.e., ~350 mg/L) and ionic composition of Blairmore Creek at this future time is recommended for Blairmore Creek, using site waters for test dilution to reflect the specific ionic composition of Blairmore Creek waters.

4.1.2 Regional Study Area

Results of the LSA water quality model were extended into the RSA (i.e., the Crowsnest River) through development of a simple volumetric-dilution model. Predicted concentrations of selenium and sulphate in the Crowsnest River downstream of Blairmore Creek and Gold Creek were calculated by combining modelled variable concentrations and flow data of Blairmore Creek and Gold Creek, using baseline variable concentrations and flow data of the Crowsnest River. The model used to estimate concentrations downstream mixing zones after complete mixing was as follows:

$$[WQ]_{ds} = \{([WQ]_{BC/GC} \times V_{BC/GC}) + ([WQ]_{CRus} \times V_{CRus})\} / (V_{BC/GC} + V_{CRus})$$

Where:

$[WQ]_{CRds}$ was the predicted variable concentration in the Crowsnest River with the confluence of Blairmore Creek or Gold Creek;

$[WQ]_{BC/GC}$ was the predicted variable concentration in the most downstream nodes of Blairmore Creek or Gold Creek;

$[WQ]_{CRus}$ was the baseline variable concentration in the Crowsnest River upstream of the Blairmore Creek or Gold Creek mixing points;

$V_{BC/GC}$ was the flow rate (m^3/s) of the most downstream node of Blairmore Creek (BC-01) or Gold Creek (GC-01); and

V_{CRus} was the flow rate (m^3/s) of the Crowsnest River upstream of discharge.

Concentrations were estimated on monthly basis to capture seasonal variability for the entire cycle of the mine (2017 to 2099). Historical monthly flow data of the Crowsnest River from 1964 to 2013 were obtained from Water Survey of Canada. For each month, three separate predictions were made of downstream variable concentration, intended to capture approximate conditions in low-flow, high-flow, and typical conditions. These case predictions were made as follows:

- Low-flow case: Minimum of historical flow observed for that month, and highest observed variable concentration for that month (representing lowest flows available for dilution and highest background concentration);

- High-flow case: Maximum of historical flow observed for that month, and lowest observed variable concentration (representing greatest flows available for dilution and lowest background concentration); and
- Typical best-estimate case: Median (50th-percentile) of historical flows and variable concentrations observed for that month (representing most frequently observed upstream conditions).

It should be noted that downstream conditions are expected to be similar to the typical case, and rarely (one in 10 years or less) reflect the high- and low-flow cases.

Results of Water Quality Model

Sulphate and selenium concentrations of typical best-estimate case at Crowsnest River located downstream confluences of Blairmore Creek and Gold Creek are shown in [Figure 8](#) and [Figure 9](#), respectively. Results of volumetric dilution modelling indicated that sulphate and selenium concentrations were below published Alberta guidelines in the RSA, throughout mine construction, operation, closure and post-closure.

Figure 8 Predicted sulphate concentrations in the Crowsnest River, downstream of the confluences of Blairmore and Gold creeks during different mine phases.

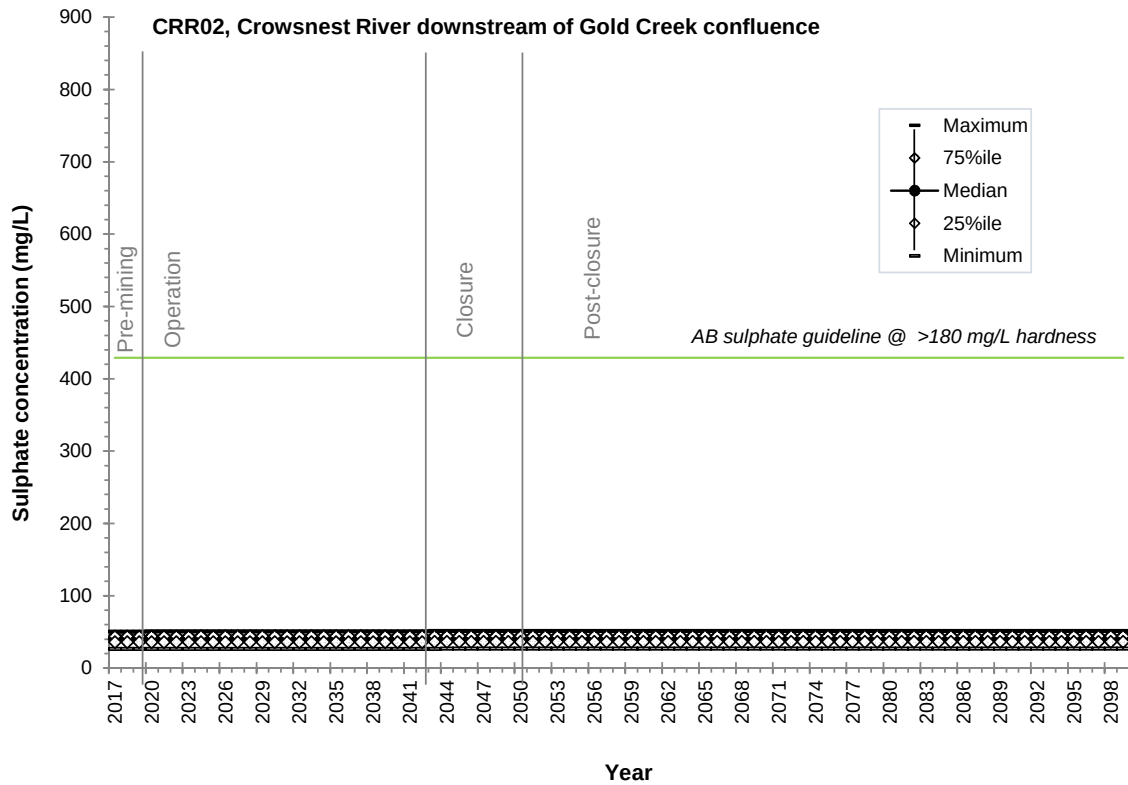
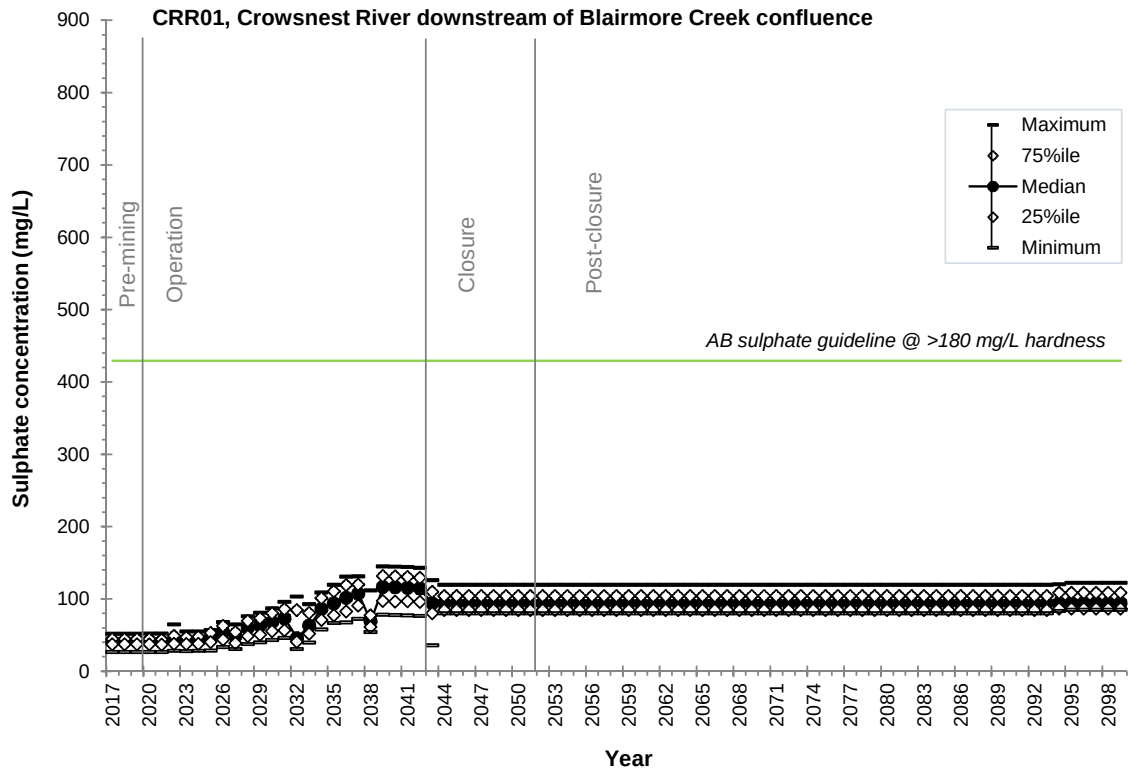
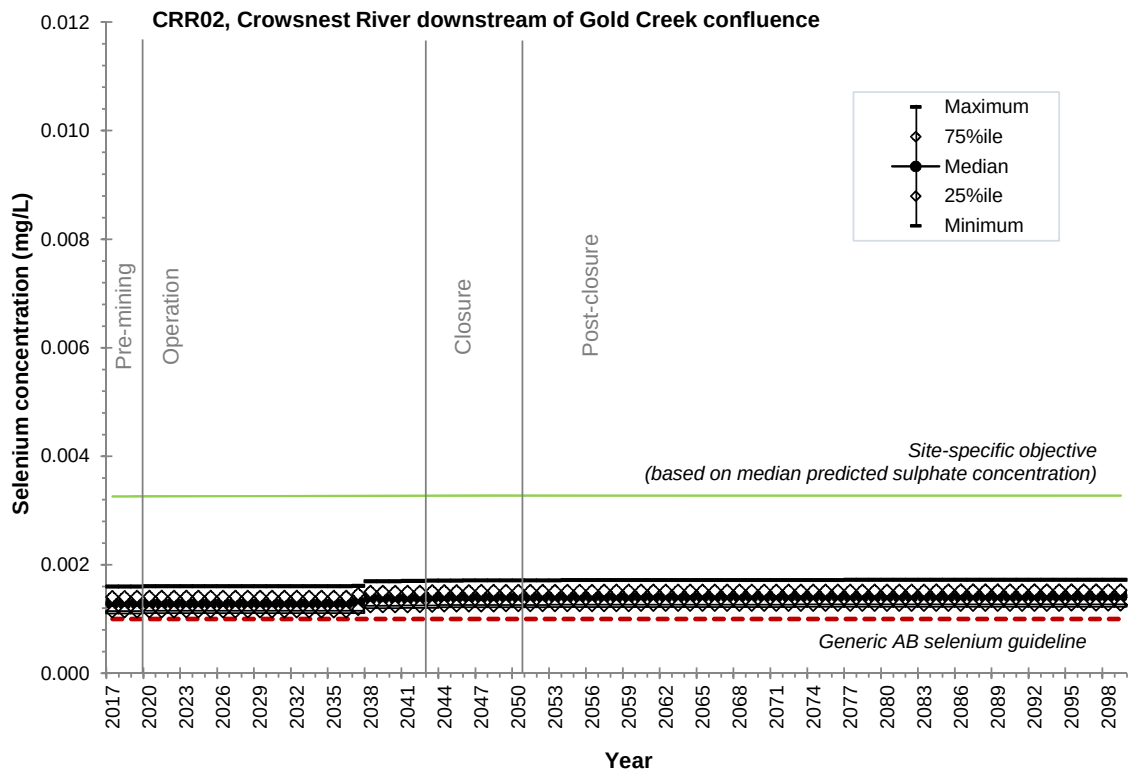
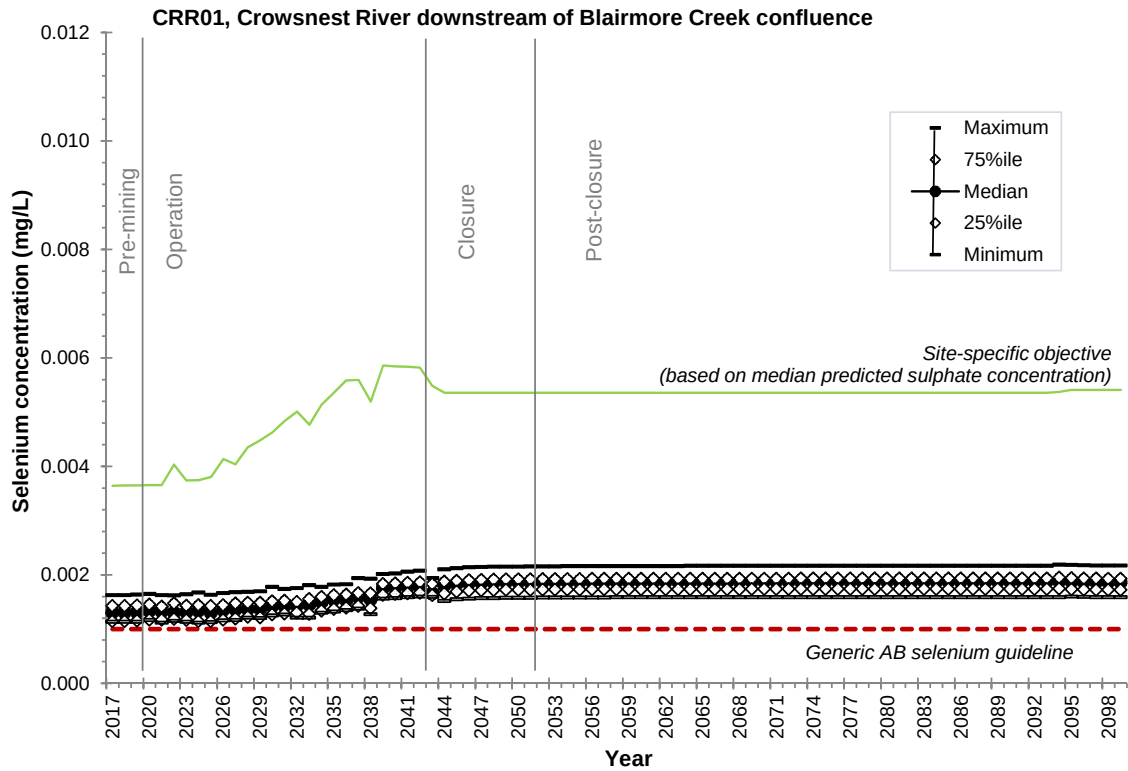


Figure 9 Predicted selenium concentrations in the Crowsnest River, downstream of the confluences of Blairmore and Gold creeks during different mine phases.



4.1.2.1 Residual Effects Classification

The residual effects of the Project for typical case on surface water quality from process water release in the RSA were assessed as ***not significant***.

4.1.3 Planned Development Case/Cumulative Effects Assessment

Because the potential effects of process water discharge on the water quality variables in the LSA and RSA are classified as ***not significant*** for the Application Case, none of the effects of the Project on the same variables will have the potential to overlap with predicted effects from other developments. Therefore, the results of the PDC analysis are identical to those for the Application Case.

4.1.4 Level of Confidence and Uncertainties

The water quality model provides an indication of prediction uncertainties for flows and loadings as follows:

- Site-wide orographic effects were not modelled:
 - An orographic correction was applied to the annual precipitation for catchments in with head water in the Livingstone Mountain Range on the east side of Gold Creek to account for an increase in runoff from those catchments. However, orographic effects on precipitation were not accounted for elsewhere on site;
 - A difference in runoff distribution from catchments at higher elevations. No data are available to resolve the difference in the timing of the runoff from higher elevations and therefore this mechanism was not included in the model.
- Waste rock hydrology was simplified. Runoff from waste rock disposal areas was assumed to accumulate in the waste rock pile, and allowed to seep out once the pile had wet up and field capacity of 10% had been reached. After the storage capacity of the waste rock was reached, runoff from the area responds immediately to changes in precipitation.
- Flows predicted include both interflow in gravel, and surface flow and does not make a distinction between them.

The level of confidence in this assessment of residual effects is ***moderate***. First, there are good baseline data records of source terms (flows and water quality). Second, the assessment was conducted using conservative estimates of flows and concentrations in receiving watercourses.

This water quality model should be used as decision tools rather than absolute predictors of receiving water quality.

Predictions of insignificant effect of sulphate in Blairmore Creek waters in late mine life and in closure should be further validated through sublethal toxicity testing using site waters collected from middle Blairmore Creek in winter, to best represent future times when sulphate concentrations are expected to be highest.

4.2 EFFECTS OF USING NITROGEN-BASED EXPLOSIVES

4.2.1 Local Study Area

4.2.1.1 Validity of Impact Pathways

Explosives containing ammonium nitrate will be used in the blasting program during Project operations. The use of explosives is required to breakup of the overburden material to be removed by shovels and trucks. Broken rock and unconsolidated material will be deposited in piles, or be used to backfill previously mined areas. These rock piles and backfilled areas are potential sources of leaching of nitrogenous substances into surface waters. Assessment of potential water quality effects arising from the use of ammonium nitrate (AN)-based explosives using a generic prediction model developed in the Elk Valley (Ferguson and Leask 1988) has shown that mitigation for leaching of explosives residuals (primarily nitrate) may be needed. Increased ammonia and nitrate will result in increased primary productivity and oxygen depletion, whereas increased nitrite concentration may have toxic effects to aquatic life. Therefore, the pathway of using nitrogen-based explosives to affect surface water quality is valid.

4.2.1.2 Mitigation Measures

Emulsions will be used for wet blasting; ammonium nitrate fuel oil (ANFO) will be used for dry blasting to limit ammonia leaching. Packaged explosives will be kept on-site where required. All runoff from ANFO storage areas, mine pits, and mine rock piles will be contained within the water management system (surge ponds and saturated zones) for removal of nitrogenous species. Addition of labile carbon sources in saturated will enhance the nitrogen removal through microbial activities. Once nitrate and nitrite concentrations are within the guideline compliance, water will be released from sedimentation ponds to Blairmore Creek and Gold Creek.

Aeration is an effective means to reduce nitrite levels in surface waters as well. All surface runoff and pit water will have considerable aeration in the ditches and channels that convey the water from the mine down to the sedimentation ponds (which are at much lower elevations).

4.2.1.3 Residual Effects Analysis

Total ammonia, nitrate and nitrite concentrations were modelled and found below water quality guidelines in the LSA during all mine phases (see [Section 4.2](#)) due to release of mine process water. For this project, an assumption that up to 95% of the influent nitrate and nitrite loading could be removed from water routed through saturated backfill zones. It is expected that any residual reduced form of nitrogen will be converted to less harmful nitrate rapidly upon mixing with well-oxygenated natural waters.

4.2.1.4 Residual Effects Classification

The residual (after mitigation) effects of the use of explosives on surface water quality from are assessed as **not significant** in the LSA:

- **Magnitude: Low;**
- **Geographic Extent: Local,** within the LSA;

- **Duration:** *Short*;
- **Frequency:** *Low*;
- **Reversibility:** *Reversible, short-term*;
- **Project Contribution:** *Negative*;
- **Confidence Rating:** *high*, the mitigation measures to be applied are well-accepted and there is good evidence from previous studies that the effective application of these mitigation measures in accordance with operating procedures will ensure any effects of explosives on surface water quality will be localized and short-term;
- **Probability of Occurrence:** *High*; and
- **Impact Rating:** *Not significant*.

4.2.2 Regional Study Area

Because the potential effects of using nitrogen-based explosives on surface water quality in the LSA are assessed as Not significant for the Application Case, potential effects of the use of nitrogen-based explosives in the Project on surface water quality in the RSA are also assessed as ***Not significant*** for the Application Case.

4.2.3 Planned Development Case

Because the potential effects of using nitrogen-based explosives on surface water quality in the LSA and RSA are classified as ***not significant*** for the Application Case, none of the effects of the Project on the same variables will have the potential to overlap with predicted effects from other developments. Therefore, the results of the PDC analysis are identical to those for the Application Case.

4.2.4 Level of Confidence and Uncertainties

The level of confidence in the assessments concerning the leaching of nitrates from mined areas is ***Moderate*** because the magnitude as well as spatial and temporal patterns of elevated nitrogen as a result of mining and use of nitrogen-based explosives are well-documented (Hackbarth 1999).

4.3 LEAKS AND SPILLS

4.3.1 Local Study Area

4.3.1.1 Validity of Impact Pathways

During construction and operations, there will be a potential for leaks and spills of liquids (e.g., hydrocarbons, chemicals, waste products, etc.) that may affect surface water quality. Participants of First Nations' community surveys also raised this concern. Therefore, the linkage between leaks and spills and changes in water quality is valid.

4.3.1.2 Mitigation Measures

The Project will incorporate design features, management practices and mitigation plans to minimize the potential for spills that might adversely affect surface water quality. Appropriate design features (e.g., berms and containment areas around potential sources), best management practices and emergency spill response plan will be developed and followed. These measures will reduce the potential for spills to reach nearby surface waters. Spills of produced water or other potentially hazardous substances will be cleaned up according to emergency response procedures and regulations (Benga 2016 - Section C.7). Leaks and spills will be reported to AER and AEP as required and cleaned up in a timely manner.

4.3.1.3 Residual Effects Analysis

Given these regulated measures, it is most likely that the environmental effect from leaks and spills will be minimum. Therefore, the overall environmental consequence of leaks and spills on surface water quality is considered to be negligible.

4.3.1.4 Residual Effects Classification

The residual (after mitigation) effects of the accidental leaks and spills on surface water quality from are assessed as ***not significant*** in the LSA:

- **Magnitude: *Moderate***, there will be changes in surface water quality as a result of leaks and spills. However, with the effective application of well-accepted and regulated mitigation measures, these changes are expected to cause a detectable change in water quality;
- **Geographic Extent: *Local***, within the LSA;
- **Duration: *Short***;
- **Frequency: *Low***;
- **Reversibility**: the effect is assessed as ***Reversible, short-term*** because of timely remediation;
- **Project Contribution: *Negative***, there will be some effect of leaks and spills on surface water quality;
- **Confidence Rating: *high***;
- **Probability of Occurrence: *Medium***; and
- **Impact Rating: *Not significant***.

4.3.2 Regional Study Area

Because the potential effects of accidental leaks and spills on water quality in the LSA are assessed Not significant for the Application Case, potential effects of the same on surface water quality in the RSA are also assessed as ***not significant*** for the Application Case.

4.3.3 Planned Development Case

Because the potential effects of accidental leaks and spills on surface water quality in the LSA and RSA are assessed as ***not significant*** for the Application Case, none of the effects of the Project on surface

water quality will have the potential to overlap with predicted effects from other developments. Therefore, the results of the PDC analysis are identical to those for the Application Case. No residual cumulative effect of the Project is anticipated.

4.3.4 Level of Confidence and Uncertainties

The level of confidence in the assessments concerning the leaks and spills is **High**. The mitigation measures to be applied are well-accepted and there is good evidence from previous studies that the effective application of these mitigation measures in accordance with operating procedures will ensure any effects of accidental leaks and spills on surface water quality will be localized and short-term.

4.4 DOMESTIC WASTEWATER RELEASES

4.4.1 Local Study Area

4.4.1.1 Validity of Impact Pathways

With the exception of surface runoff, the only release of wastewater associated with the Project will be domestic wastewater. Domestic wastewater may increase nutrient concentrations resulting in increased primary productivity and oxygen depletion. Treated domestic wastewater from the Project will be tracked away to a treatment facility. Since treated domestic water eventually will be released to surface waters, the linkage between domestic wastewater disposal and the water quality of receiving surface waters is considered to be valid.

4.4.1.2 Mitigation Measures

Domestic wastewater will be collected in storage tanks and brought to the wastewater treatment facility. Treated effluent will be tested to ensure that its quality meets or exceeds the limits for treated wastewater discharge as specified in the EPEA approval.

4.4.1.3 Residual Effect Analysis

Based on the expected level of treatment, the anticipated low amounts of domestic wastewater generated and water treatment, no measurable effects on the water quality of nearby surface waters are predicted from the release of treated domestic wastewater from the Project.

4.4.1.4 Residual Effects Classification

The residual (after mitigation) effects of the domestic wastewater release on surface water quality from are assessed as **not significant** in the LSA:

- **Magnitude:** *Low*;
- **Geographic Extent:** *Local*, within the LSA;
- **Duration:** *Short*;
- **Frequency:** *Low*;
- **Reversibility:** the effect is assessed as **Reversible, short-term** because of timely remediation;

- **Project Contribution:** *Negative*, there will be some effect of domestic wastewater release on surface water quality;
- **Confidence Rating:** *high*;
- **Probability of Occurrence:** *Medium*; and
- **Impact Rating:** *Not significant*.

4.4.2 Regional Study Area

Because the potential effects of domestic wastewater release on water quality in the LSA are assessed not significant for the Application Case, potential effects of the same on surface water quality in the RSA are also assessed as **not significant** for the Application Case.

4.4.3 Planned Development Case

Because the potential effects of domestic wastewater release on surface water quality in the LSA and RSA are assessed as not significant for the Application Case, none of the effects of the Project on surface water quality will have the potential to overlap with predicted effects from other developments. Therefore, the results of the PDC analysis are identical to those for the Application Case. No residual cumulative effect of the Project is anticipated.

4.4.4 Level of Confidence and Uncertainties

The level of confidence in the assessments concerning domestic waste water release is **High**. The mitigation measures to be applied are well-accepted and there is good evidence from previous studies that the effective application of these mitigation measures in accordance with operating procedures will ensure any effects of domestic wastewater release on surface water quality will be localized and short-term.

4.5 ACIDIFYING EFFECTS ON SURFACE WATER QUALITY

4.5.1 Regional Study Area

4.5.1.1 Validity of Impact Pathways

Mining activities have the potential to affect surface water quality through the release of air emissions that result in increased deposition of sulphate and nitrate. Deposition of sulphate and nitrate can lead to a reduction in pH in acid-sensitive watercourses and water bodies, which in turn might alter other aspects of water chemistry (e.g., the solubility of aluminum), ultimately resulting in adverse effects on water quality as well as aquatic life.

The air emissions effects assessment is presented in Benga 2016 - Section E.1. This section summarizes the potential for acidification of local and regional surface waters from Project-related air emissions.

4.5.1.2 Mitigation Measures

No mitigation measures are anticipated.

4.5.1.3 Effects Analysis

Acid Deposition Criteria

Deposition includes both wet and dry processes, and can result in the long-term accumulation of atmospheric emissions in aquatic and terrestrial ecosystems. Wet processes involve the removal of these atmospheric emissions by precipitation. Dry processes involve removal by direct contact with surface features (e.g., vegetation, soils and surface water).

Both wet and dry depositions are expressed as a flux in units of kg/ha/yr. Where more than one acidifying chemical species is considered, the flux is often expressed in keq/ha/yr where 'keq' refers to hydrogen ion equivalents (1 keq = 1 kmol H⁺). The deposition of sulphur and nitrogen compounds to these systems has been associated with changes in water and soil chemistry, and with the acidification of water and soil.

The PAI is used as a deposition measure of acidification and is defined by:

$$\text{PAI} = \sum (\text{SO}_4^{2-}) + \sum (\text{NO}_3^-) - \sum (\text{base cations})$$

Where:

$\sum (\text{SO}_4^{2-})$ = total sulphur compound contribution (i.e., SO₂ and SO₄²⁻), expressed in keq/ha/yr

$\sum (\text{NO}_3^-)$ = total nitrogen compound contribution (i.e., NO, NO₂, HNO₃, and NO₃⁻), expressed in keq/ha/yr

$\sum (\text{base cations})$ = primarily calcium (Ca²⁺) and magnesium (Mg²⁺)

Precursor emissions for PAI include NOX and SO₂. Based on RELAD modelling (Cheng 2009), the PAI deposition was zero in the RSA. The PAI background is 0.10 keq/ha/yr, which was estimated from the closest precipitation station at Kananaskis.

Critical, target, and monitoring loads for management of acid deposition in Alberta were established on the basis of the work of the CASA Target Loading Subgroup (CASA 1999) as updated by Alberta Environment (AENV 2008). The loads were specifically based upon predictions of the Regional Lagrangian Acid Deposition (RELAD) model over 1° latitude by 1° longitude grid cells, and based upon the specific definitions of receptor sensitivity.

According to the receptor sensitivity map that is currently used for acid deposition assessment (AENV 2008, Figure 2), the Project is located in moderately sensitive ecological areas. The management levels adopted by CASA for moderately sensitive grid cells are:

- **Critical Load:** the highest load that will not lead to long-term, harmful changes to a receptor. The trigger level is 0.50 keq/ha/yr for moderately sensitive area.
- **Target load:** the level of deposition that consider the critical load and is practically and politically achievable. The trigger level is 0.45 keq/ha/yr for moderately sensitive areas.
- **Monitoring load:** the level of deposition predicted or estimated by dispersion and deposition models that trigger monitoring and/or research. The trigger level is 0.35 keq/ha/yr for moderately sensitive areas.

Use of the above critical, target, and monitoring loads uncoupled from RELAD modelling, and the definitions of receptor sensitivity (including the 5% level of protection) in a regional or Project-specific application is limited to the use of these values in the identification of areas potentially at risk of becoming acidified. Upon identifying such areas, actions towards confirming the acidification sensitivity of these areas are to be taken, and this may involve the use of models such as CALPUFF (AENV 2008). The provincial acid deposition management framework specifies that an exceedance of a target load at a local scale (e.g., a project EIA) is not to be considered to be an exceedance of an environmental objective.

This assessment includes estimates of the areas above these thresholds, and the CASA monitoring, target and critical loads, based on CALPUFF modelling.

Results

The detailed results of CALPUFF modelling are presented in Benga, 2016 - Section E.1 and summarized below:

The predicted maximum annual PAI at the RSA-MPOI is approximately 0.11 keq/ha/yr in the Baseline case and 0.18 keq/ha/yr in the Application/PDC case (Table 16), both below the threshold of 0.35 keq/ha/yr for moderately sensitive ecological areas. Predicted annual PAI at the MPB was 0.02 keq/ha/yr for Baseline case and 0.04 keq/ha/yr for Application and PDC case, both well below the threshold of 0.35 keq/ha/yr. Outside the MPB, there is no deposition above the threshold of 0.17 keq/ha/yr for sensitive soil.

Predicted maximum annual RSA-MPOIs for PAI in the Baseline case are located near Highway 3 and the community of Blairmore, primarily influenced by regional community and highway emissions.

Table 16 Predicted maximum annual potential acid input.

Parameter	Project Only	Baseline Case	Application/ PDC Case	Application/PDC Case Increase Over Baseline [%]
RSA PAI Deposition (keq/ha/yr)				
Overall Maximum MPOI	0.18	0.11	0.18	66
Mine Permit Boundary (MPB) Maximum	0.04	0.02	0.04	98
RSA PAI Deposition Load Areas (km²) Outside of Mine Permit Boundary				
Sensitive Soil Monitoring Load > 0.17 keq/ha/yr	0	0	0	-

PAI is commonly evaluated in latitude/longitude grid cells to assist in the regional evaluation of potential acidification (Cheng 2009). As the Project encompasses an area less than one 1° by 1° grid cell, only the average deposition within a grid cell encompassing the project was evaluated (Table 17). In this calculation, areas outside the influence of the Project were assumed to have PAI at background levels. The average deposition in the grid cell is 0.03 keq H⁺/ha/yr for Project-only and Application cases, much less than the monitoring level for moderately sensitive ecosystems. Therefore, the impact pathway of acidifying air emissions on water quality is not valid; acidification effects are not expected to occur due to aerial emissions of the Project.

Table 17 Average potential acid input predicted by CALPUFF in 1° by 1° grid cells.

Latitude (°)	Longitude (°)	Project Only Case (keq H ⁺ /ha/yr)	Baseline Case (keq H ⁺ /ha/yr)	Application/PDC Case (keq H ⁺ /ha/yr)	Application/PDC Case Increase Over Baseline (%)
49	114	0.03	0.02	0.03	86

4.5.1.4 Residual Effects Classification

The residual (after mitigation) effects of the acidifying air emissions of the Project on surface water quality are assessed as ***not significant*** in both the LSA and RSA for Application case:

- **Magnitude:** *Low*;
- **Geographic Extent:** *Local*;
- **Duration:** *Medium*;
- **Frequency:** *Continuous*;
- **Reversibility:** *Reversible, short-term*;
- **Project Contribution:** *Negative*;
- **Confidence Rating:** *Moderate*;
- **Probability of Occurrence:** *Medium*; and
- **Impact Rating:** *Not significant*.

4.5.2 Planned Development Case

Because the potential effects of the acidifying air emissions of the Project on surface water quality are assessed as ***not significant*** in both the LSA and RSA for the Application Case, none of the effects of the Project on the same variables will have the potential to overlap with predicted effects from other developments. Therefore, the results of the PDC analysis are identical to those for the Application Case.

4.5.3 Level of Confidence and Uncertainties

The level of confidence in the assessments concerning acidifying effects on surface water quality is Moderate as the predictions have some uncertainties in deposition estimates.

4.6 SUMMARY OF WATER QUALITY ASSESSMENT

The water quality effects assessment is summarized in [Table 18](#). Based on the anticipated management of runoff and controlled release rates from sedimentation ponds, negligible effects are anticipated on water quality from sediment-associated inputs. All process water with elevated selenium, nitrogen species, and other constituents will be treated in surge ponds and saturated zones with sufficient water residence time. All other elevated metal concentrations will be treated in treatment facility before releasing to the environment. All 21 regulated water quality variables were within Alberta water quality

guidelines except for sulphate, which is predicted to exceed Alberta water quality guidelines for the protection of aquatic life.

Site facilities and associated Project components will be constructed to comply with regulatory guidelines and best management practices, to minimize the potential for leaks and spills. Pipelines and storage areas will be inspected and maintained regularly. Emergency spill procedures will be in place for rapid spill containment and clean-up. Therefore, potential effects on water quality from leaks and spills will be minimized.

Facility sewage will be collected and treated in a sewage treatment package plant located on the MIA pad. The treatment plant will treat all sewage produced at the MIA facilities and has been based on an estimated sewage treatment requirement of 30 m³/day. Effluent water quality will be in accordance with relevant regulations as well as appropriate standards. The treatment plant effluent produced will be pumped to the plant site sediment pond (PSSP) located adjacent to the CHPP product stockpiles. Excess sludge will be collected for removal from the package treatment plant by vacuum trucks and disposal off site. Sewage and grey water from the CHPP service buildings will be pumped to the water treatment plant for processing and discharge.

Negligible effects are predicted from treated domestic wastewater releases on water quality of receiving surface waters. To minimize the nitrogen species, packaged explosives will be kept on-site, all runoff from the ammonium nitrate storage areas, mine pits, and mine rock piles will be contained within the water management system and treated in saturated zones. The average acid deposition due to Project air emissions is less than the monitoring level for the moderately sensitive ecosystems, therefore acidification effects are not expected to occur due to aerial emissions of the project.

In conclusion, different water quality issues due to the Project activities would be addressed by applying appropriate mitigation measures. Effects of process-related water release are predicted on sulphate in the receiving surface water environments. The predicted sulphate concentrations were above the range of hardness-dependent sulphate guideline value which is 429 mg/L for a maximum hardness level of 250 mg/L. Therefore, development of a site-specific sulphate objective based on site water hardness is recommended. Water quality model outputs should be considered as information for decision-making rather than representing absolute predictions of receiving water quality; monitoring vigilance is recommended to track and identify any trends in water quality and further refine model predictions.

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Table 18 Summary of surface water quality effects assessment in the Grassy Mountain Coal Project.

Potential Issues	Project Activity	Potential Effects	Proposed Mitigation	Residual Effect	Magnitude	Extent	Duration	Frequency	Reversibility	Significance
Release of process related water that does not meet water quality guidelines to natural watercourses	Construction, operations, closure, and post-closure	Increased turbidity and associated elevated concentrations of constituents, acid rock drainage, leaching, elevated concentrations of metals	Collection of surface runoff to sedimentation ponds; creation of anoxic saturated zones and addition of labile C sources to attenuate Selenium and nitrogen, metal treatment, adhere to EPEA approval	Elevated sulphate concentrations in Blairmore Creek	Low, except sulphate in Blairmore Creek, which is Moderate	Local	Short except for sulphate which is Residual	Occasional	Reversible in Short-term except for sulphate which is Irreversible	Not significant
Use of nitrogen-based explosives	Blasting during mine operations	Higher concentrations of ammonia, nitrite and nitrate	Anoxic saturated zones, addition of labile C sources to attenuate nitrogen species through microbial uptake	No	Low	Local	Short	Low	Reversible in Short-term	Not significant
Accidental leaks and spills	Construction and operations	Elevated concentrations of hydrocarbons, chemicals and waste products	Appropriate design features (e.g., berms and containment areas around potential sources), best management practices and spill response plan	No	Moderate	Local	Short	Low	Reversible in Short-term	Not significant
Domestic wastewater	Construction, operations and closure	Elevated concentrations of nutrients resulting in increased primary productivity and oxygen depletion	Use of storage tanks; wastewater treatment to industrial standard; water quality testing	No	Low	Local	Short	Low	Reversible in Short-term	Not significant
Acidifying/air emission effects	Construction and operations	Increase in acidity	No mitigation anticipated	No	Low	Local	Medium	Continuous	Reversible in Short-term	Not significant

5.0 WATER QUALITY MONITORING

Water quality compliance monitoring will be an integral component of the Project operations. Sedimentation/release ponds will be tested before release to the surrounding environment to verify acceptability of release waters for variables to be defined under the EPEA approval for the Project. A water quality monitoring program will be implemented in natural watercourses both upstream and downstream of the Project to assess any changes in water quality due to treated water release into the natural water system.

Reference locations will be incorporated into the monitoring design, including locations in the mainstems and tributaries of Blairmore and Gold creeks and Crowsnest River upstream of Project influences, as well as potentially reference locations in other similar, nearby creeks flowing to the Crowsnest River or other similar drainages. Where possible and appropriate, reference water quality sampling locations will be co-located with relevant aquatic ecology monitoring locations and/or fish-habitat offsetting and habitat enhancement locations, which will be determined in advance of mine construction.

Recent EPEA approval conditions for similar coal mines require the runoff and wastewater treatment and control system to be monitored for the following parameters:

- TSS;
- Turbidity (NTU);
- pH;
- floating solids;
- nitrate-nitrogen;
- visible foam;
- acute lethality test using rainbow trout (for any ponds within the system using approved floc agents); and
- oil and grease.

Specific monitoring variables may vary depending on the type of pond and approval conditions. The frequency of sampling will vary depending on whether the settling pond is classed as a major or minor pond in the approval. All sedimentation ponds will be equipped to use flocculants to assist with the removal of TSS, and will be classed as major ponds. Flocculants will be field tested for effectiveness and approved by the AER prior to use.

Additional sampling will be conducted of the components of the runoff, wastewater treatment and control system (e.g., sedimentation ponds, surge ponds, saturated backfill zones, groundwater monitoring, Blairmore Creek upstream, Blairmore Creek downstream, Gold Creek upstream, Gold Creek downstream, Crowsnest River upstream, Crowsnest River downstream) on a monthly/quarterly/annual basis for the following variables:

- inorganic variables listed in the Canadian Water Quality Guidelines for the Protection of Aquatic Life, 2003, CCME as amended; and
- flow, nitrate-nitrogen, ammonia, BOD, BTEX, colour, oil and grease, phenols, total phosphorous, sulphate, TDS, temperature, total sulphide, selenium, hardness, TSS.

Compliance monitoring will be reported monthly and all monitoring (including effects monitoring) will be reported in an annual report.

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APPENDICES

Appendix A1

Proposed Site-Specific Water Quality Objective for Selenium



Evaluation of selenium uptake in waters by primary producers associated with the Grassy Mountain coal mine project

DRAFT Report

Report date:
July 22, 2016

Submitted to:

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SIGNATURE PAGE

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This report has been prepared based on data and/or samples provided by our client and the results of this study are for their sole benefit. Any reliance on the data by a third party is at the sole and exclusive risk of that party. The results presented here relate only to the samples tested.

1.0 INTRODUCTION

It is widely recognized that environmental risk associated with selenium is primarily linked to accumulation of organic selenium (as seleno-amino acids) through the food-chain (Young et al., 2010). Consequently, selenium water quality guideline development efforts have increasingly focused on tissue burdens of selenium, rather than measures in other environmental compartments such as water or sediment. For example, both the BC Ministry of Environment (BCMoE) and the U.S. Environmental Protection Agency (USEPA) have issued draft or finalized water quality benchmarks in which the importance of tissue burdens of selenium was emphasized.

Accumulation of selenium into the food-web is primarily modified at the primary producer level, where the bio-concentration of inorganic selenium from water into tissue commonly comprises two or three orders of magnitude, and varies considerably between sites. The bio-concentration factor (often referred to as an Enrichment Function [EF] or the K_d) is calculated by dividing the selenium concentration in biological tissues associated with the base of the food-web (e.g., primary producers such as algae and periphyton) by the concentration in water. Once selenium is incorporated into the food-chain and transformed into seleno-amino acids, transfer between trophic levels in freshwater environments results in selenium concentrations that are generally similar between trophic levels. Consequently, variations in the uptake rate at the base of the food-chain (i.e., from water into primary producers) dominates the potential for differences in accumulation rates between sites (Presser and Luoma, 2010).

The Grassy Mountain project is a planned coal mine located in western Alberta. Water quality predictions for the site have indicated that selenium may exceed the CCME water quality guideline of 1 $\mu\text{g/L}$ for the water column and, consequently, there is an interest in understanding whether increased selenium concentrations would be expected to result in accumulation of selenium in the food-web to concentrations that might pose an environmental risk. Sulphate is also expected to increase concurrently with selenium, and this constituent modifies uptake of selenium, when present as selenate (Williams et al, 1994; Lo et al., 2012), which is the expected form of selenium at the site. Consequently, this study was performed to evaluate uptake of selenium across a range of concentrations of sulphate.

The exposures described in this report provide an evaluation of the estimated site-specific uptake rate of selenium into two algae and a vascular plant under conditions that are anticipated to occur at the site. The accumulation rate of selenium was assessed in original site

water collected from BC-W01, as well as BL-W01 site water after adding different concentrations of major ions associated with future predicted conditions (in particular, calcium, magnesium and sulphate).

The exposure duration used in these tests was relatively short (i.e., 7 days); however, as a result of encompassing exponential growth phase for the algae, the cell density increased by over 3000-fold during the exposure. Because of the nature of the exposure, it is not possible to measure the cells for reaching “steady-state”, since they are continually dividing. Similarly, for duckweed, the fronds multiplied by more than a factor of five relative to the start of the tests. Thus, the vast majority of cells or fronds in the test containers at the end of the exposure were produced using the ionic nutrients (including selenium) that were present in the test solutions. Thus, it is reasonable to assume that the cells are in equilibrium with the surrounding media, including the selenium concentration. Regardless, this test method provides a measure of relative uptake of selenium under differing water quality conditions.

This report expands on a previous Nautilus Environmental report summarizing uptake measurements for selenium associated with a green alga (*Pseudokirchneriella subcapitata*) and duckweed (*Lemna minor*). Results for a second alga, *Scenedesmus acutus*, are also included in this report to address a comment from Environment Canada on the original report that information for an additional algal species, that would be more representative of periphyton communities than *L. minor*, would be helpful to reduce uncertainty.

2.0 METHODS

Water samples were collected from BC-W01 on September 3, 2015 and June 29, 2016. The September 3 sample was used for uptake tests using *P. subcapitata* and *L. minor*, and the June 29 sample was used for uptake tests using *S. acutus*.

The methods used here are based on methodology developed by Lo et al. (2012) for evaluation of the effect of water quality characteristics on uptake of selenium. The selenium-spiked waters were evaluated for uptake using 7-day exposures using two green algae (*P. subcapitata* and *S. acutus*) and duckweed (*L. minor*). The test waters were supplemented with nutrients required for growth of these species, and the exposures conducted in a constant environment room with lighting and temperature regimes which are suitable for culturing these species (Environment Canada 2007a; 2007b). In the case of *P. subcapitata* and *S. acutus*, nutrients were added at four-

fold over the usual culture water in order to achieve sufficient cell growth for subsequent analysis of selenium in the cells. The test exposures were not replicated.

Selenium uptake was evaluated under current conditions and under conditions of elevated ionic strength that are predicted to occur in the environment. Selenium was introduced using sodium selenate, since selenate is expected to be the predominant form of selenium in lotic systems such as this (BC MoE 2014).

Uptake of selenium into algal cells and duckweed was measured in three water types:

- 1) A sample from BC-W01 was tested to evaluate selenium uptake under current conditions.
- 2) An amended site water was created by supplementing BC-W01 water with calcium and magnesium sulphates at a ratio of 1.7:1 Ca:Mg (on a mass basis) to achieve 500 mg/L sulphate in the water (note that the actual sulphate in this water was higher than 500 mg/L as a result of sulphate in the unamended site water, as well as sulphate present in the nutrients that were added). This water was diluted with BC-W01 water using a 0.5-times dilution series to achieve nominal concentrations of 62.5, 125, 250, and 500 mg/L of supplemented SO₄. These dilutions were then each spiked with 5 and 10 µg/L Se.
- 3) A laboratory-prepared water was evaluated after supplementing with a range of selenium concentrations in order to benchmark the results against prior uptake studies conducted in the laboratory.

At the end of the exposures, the tissues were rinsed with selenium-free water. For *P. subcapitata* and *S. acutus*, algal cells were rinsed in deionized water with 15 mg/L sodium bicarbonate to reduce osmotic stress on the cells. The rinsing and centrifugation process was repeated three times. Following the final rinse and decanting of overlaying water, the algal pellet was frozen at -20°C. For *L. minor*, macrophytes were rinsed in deionized water, dabbed dry using Kim-wipes and frozen at -20°C. The concentration of selenium in the tissues was measured by Brooks Rand Labs LLC (Bothell, WA). Samples were digested in a hotblock digestion apparatus (temperature of 95°C) using nitric and hydrogen peroxide and resulting digests were analyzed using inductively coupled plasma dynamic reaction cell mass spectrometry (ICP-DRC-MS). Moisture content in the tissue was measured in a representative subsample and applied to calculate the selenium concentrations on a dry weight basis. Concentrations of sulphate in the

exposure waters were measured at test initiation by CARO Analytical (Edmonton, AB) using ion chromatography.

3.0 RESULTS

Pseudokirchneriella subcapitata

Measured selenium and sulphate concentrations in the exposure waters, selenium concentrations in the *P. subcapitata* algal cells and calculated EF values are summarized in [Table 1](#). The average EF values measured in laboratory water and BC-W01 water were 293 and 192, respectively. The average EF values measured in sulphate-amended BC-W01 waters ranged from 59 to 94. Uptake in BC-W01 water was approximately 34% lower relative to laboratory water, while uptake in sulphate-amended BC-W01 waters ranged from 68 and 51% lower relative to laboratory and BC-W01 waters to 80 and 69% lower, respectively.

Results of uptake tests using *P. subcapitata* in lab water and samples collected from BC-W01 supplemented with major ions are shown in [Figure 1](#). Selenium uptake into algal cells increased in a very consistent manner with increasing waterborne selenium. Linear regression analyses found that waterborne selenium had a significant effect on tissue selenium concentrations ($p < 0.05$). The relationship between tissue selenium and selenium in water was best explained by a power function, which is linear on a log x-axis, log y-axis scale.

Amending the BC-W01 water with sulphate resulted in a two to three-fold decrease in uptake of selenium relative to un-amended BC-W01 water ([Figure 1](#)), demonstrating that the higher ionic strength reduced the selenium bioaccumulation. The EF values decreased with increasing sulphate concentration, as shown in [Figure 2](#).

Lemna minor

Measured selenium and sulphate concentrations in the exposure waters, selenium concentrations in *L. minor* tissue and EF values are summarized in [Table 2](#). Consistent with the results from the algal tests, waterborne selenium exhibited a statistically significant effect ($p < 0.01$) on duckweed selenium tissue concentrations. The average EF values for the laboratory water and BC-W01 were 112 and 70, respectively. The average EF values for the sulphate-amended BC-W01 waters ranged from 36 to 46.

Results of uptake tests using duckweed into BC-W01 and BC-W01 water amended with major ions are shown in [Figure 3](#). Consistent with the effects observed with algae, EF decreased with increasing sulphate when the BC-W01 water was supplemented with major ions ([Figure 4](#)).

Scenedesmus acutus

Measured selenium and sulphate concentrations in the exposure waters, selenium concentrations in the *S. acutus* algal cells and calculated EF values are summarized in [Table 3](#). The average (geometric mean) EF values measured in laboratory water and BC-W01 water were 174 and 175, respectively. The average EF values measured in sulphate-amended BC-W01 waters ranged from 46 to 66. Uptake in BC-W01 water was approximately similar relative to laboratory water, while uptake in sulphate-amended BC-W01 waters ranged from 75 and 63% lower relative to laboratory and BC-W01 waters.

Results of uptake tests using *P. subcapitata* in lab water and samples collected from BC-W01 supplemented with major ions are shown in [Figure 1](#). Selenium uptake into algal cells increased in a very consistent manner with increasing waterborne selenium. Linear regression analyses found that waterborne selenium had a significant effect on tissue selenium concentrations ($p < 0.05$). The relationship between tissue selenium and selenium in water was best explained by a power function, which is linear on a log x-axis, log y-axis scale.

Results of uptake tests using *S. acutus* into BC-W01 and BC-W01 water amended with major ions are shown in [Figure 5](#). Consistent with the effects observed with *P. subcapitata* and *L. minor*, EF decreased with increasing sulphate when the BC-W01 water was supplemented with major ions ([Figure 6](#)).

Table 1. Measured tissue concentrations of selenium in *Pseudokirchneriella subcapitata*, exposed to different levels of selenium and sulphate.

Water	Se (µg/L)	Sulphate (mg/L)	Tissue Se (mg/kg dw)	Enrichment function
Lab	0	23.9	0.021	NC
Lab	1.25	23.9	0.407	326
Lab	2.5	23.9	0.801	320
Lab	5	23.9	1.15	230
Lab	10	23.9	2.97	297
BC-W01	0	44.0	0.21	NC
BC-W01	1.25	44.0	0.399	319
BC-W01	2.5	44.0	0.806	322
BC-W01	5	44.0	0.88	176
BC-W01	10	44.0	1.65	165
BC-W01 amended	5	115	0.528	106
BC-W01 amended	10	115	0.462	83
BC-W01 amended	5	181	0.342	92
BC-W01 amended	10	181	0.349	56
BC-W01 amended	5	327	0.831	68
BC-W01 amended	10	327	0.493	49
BC-W01 amended	5	596	0.669	70
BC-W01 amended	10	596	0.349	67

* NC = not calculable

Figure 1. Uptake of selenium into *Pseudokirchneriella subcapitata* in amended BC-W01 waters compared with laboratory water.

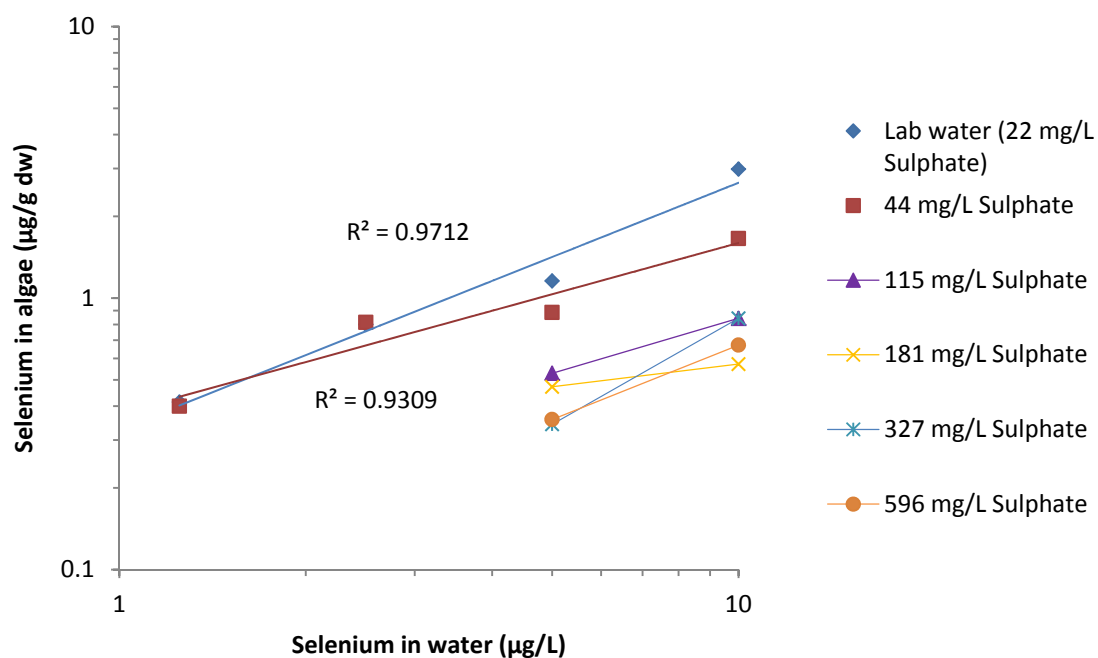


Figure 2. *Pseudokirchneriella subcapitata* enrichment function compared to sulphate concentration in BC-W01 waters amended with magnesium and calcium sulphate.

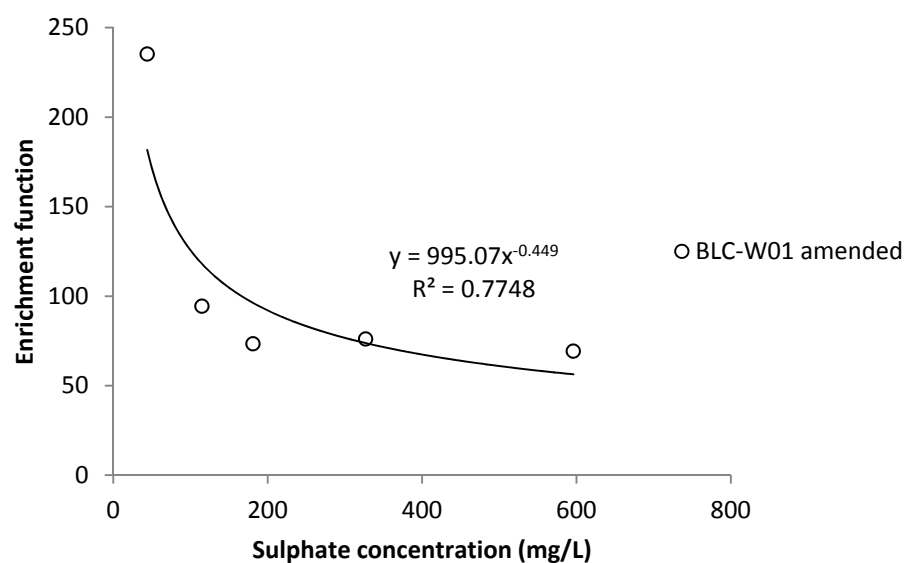


Table 2. Measured tissue concentrations of selenium in *Lemna minor* exposed to different levels of selenium and sulphate.

Water	Se (µg/L)	Sulphate (mg/L)	Tissue Se dry (mg/kg dw)	Enrichment function
Lab	<1	57.2	0.042	NC
Lab	1.25	57.2	0.136	109
Lab	2.5	57.2	0.234	94
Lab	5	57.2	0.46	92
Lab	10	57.2	0.706	71
BC-W01	<1	83.5	0.06	NC
BC-W01	1.25	83.5	0.141	113
BC-W01	2.5	83.5	0.21	84
BC-W01	5	83.5	0.335	67
BC-W01	10	83.5	0.706	71
BC-W01 amended	5	158	0.42	44
BC-W01 amended	10	158	0.236	42
BC-W01 amended	5	235	0.438	47
BC-W01 amended	10	235	0.201	44
BC-W01 amended	5	356	0.322	40
BC-W01 amended	10	356	0.224	32
BC-W01 amended	5	627	0.284	45
BC-W01 amended	10	627	0.438	28

* NC = Not calculable

Figure 3. Uptake of selenium into *Lemna minor* in amended BC-W01 waters compared with laboratory water.

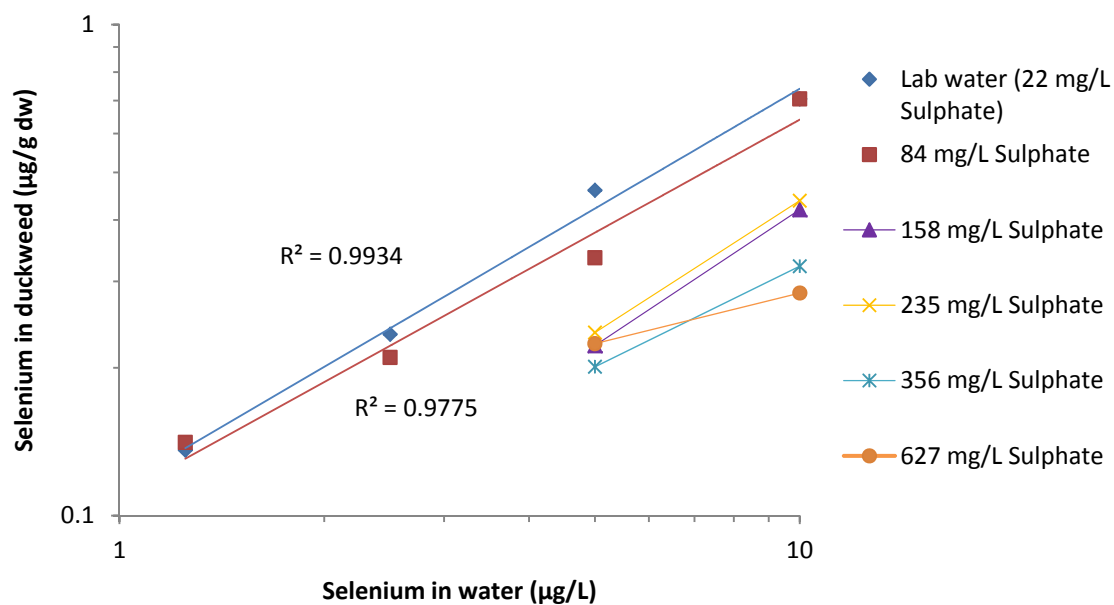


Figure 4. *Lemna minor* enrichment function compared to sulphate concentration in BC-W01 waters amended with magnesium and calcium sulphate.

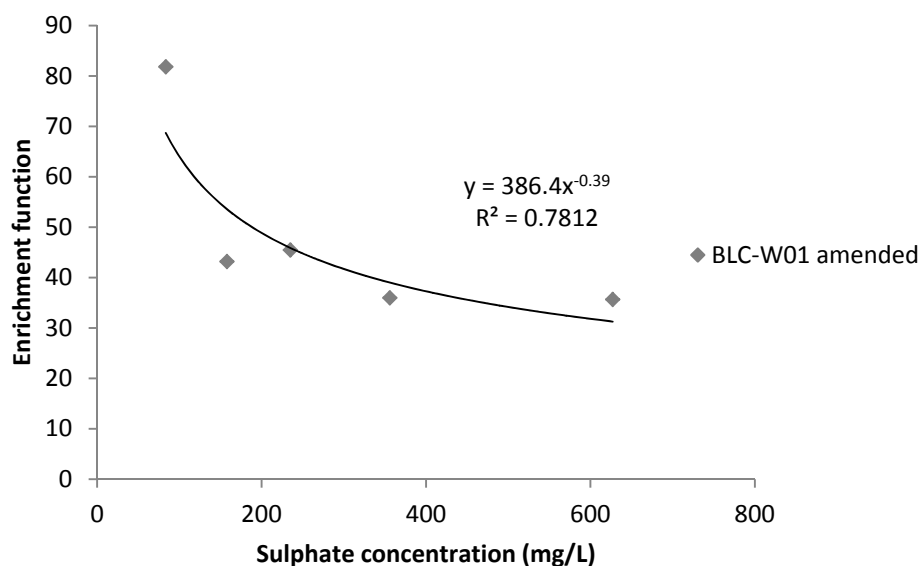


Table 3. Measured tissue concentrations of selenium in *Scenedesmus acutus*, exposed to different levels of selenium and sulphate.

Water	Se (µg/L)	Sulphate (mg/L)	Tissue Se (mg/kg dw)	Enrichment function
Lab	0	24.2	0.027	NC
Lab	1.25	24.2	0.176	141
Lab	2.5	24.2	0.518	207
Lab	5	24.2	0.932	186
Lab	10	24.2	1.689	169
BC-W01	0.1	37.7	0.122	1216
BC-W01	1.25	37.7	0.270	216
BC-W01	2.5	37.7	0.545	218
BC-W01	5	37.7	0.725	145
BC-W01	10	37.7	1.365	136
BC-W01 amended	5	98	0.482	96
BC-W01 amended	10	98	0.455	45
BC-W01 amended	5	158	0.356	71
BC-W01 amended	10	158	0.297	30
BC-W01 amended	5	287	0.360	72
BC-W01 amended	10	287	0.428	43
BC-W01 amended	5	541	0.203	41
BC-W01 amended	10	541	0.514	51

* NC = not calculable

Figure 5. Uptake of selenium into *Scenedesmus acutus* in amended BC-W01 waters compared with laboratory water.

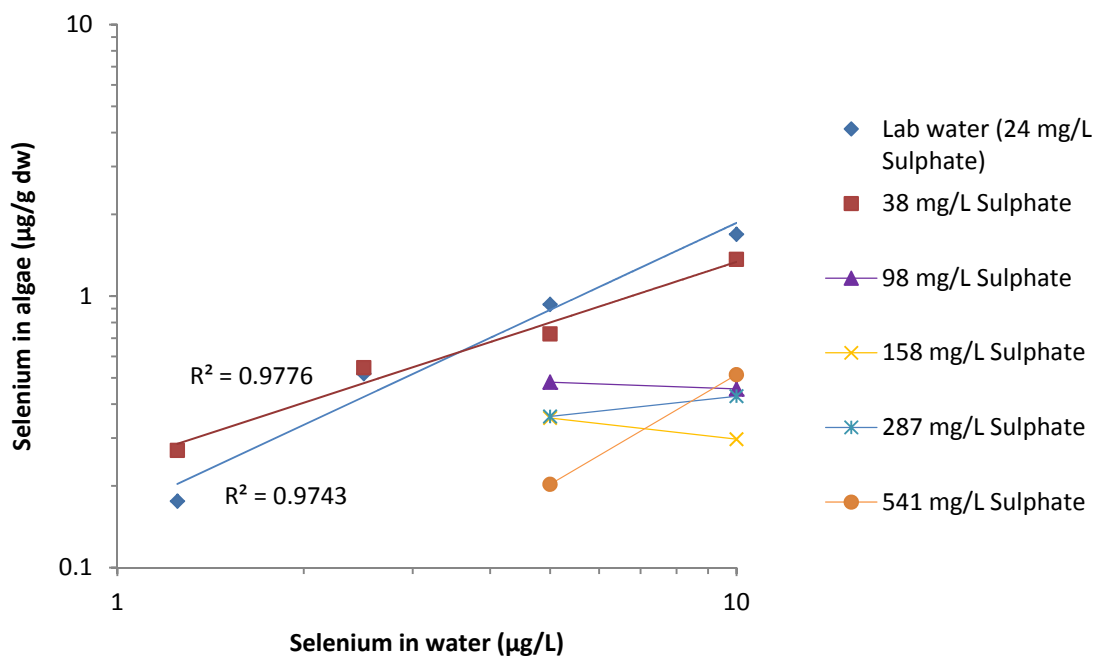
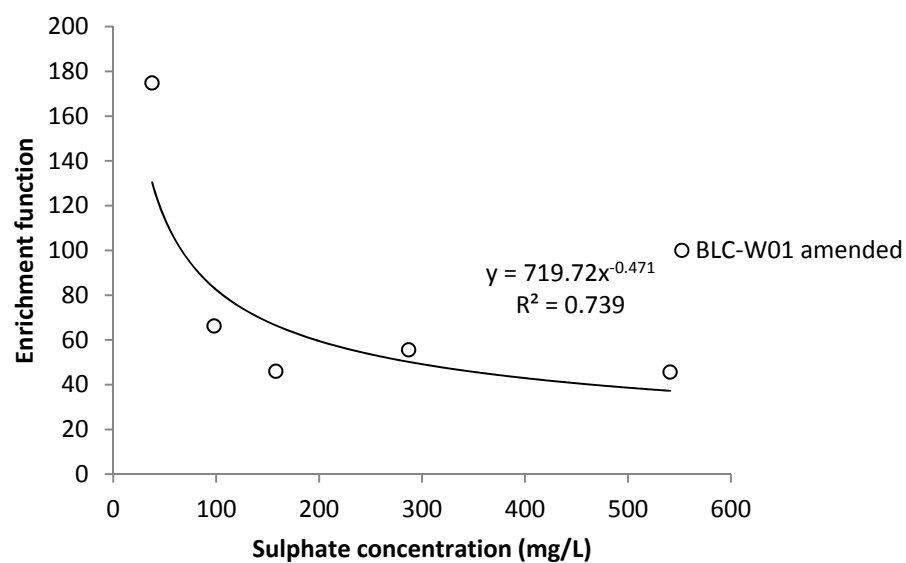


Figure 6. *Scenedesmus acutus* enrichment function compared to sulphate concentration in BC-W01 waters amended with magnesium and calcium sulphate.



4.0 DISCUSSION

The results for amended BC-W01 water, shown in [Figures 2, 4 and 6](#), indicated that higher ionic strength associated with predicted future conditions would be expected to reduce the bioaccumulation rate of selenium of all three species relative to current conditions, likely as a result of interaction between sulphate and selenate, since sulphate has been shown to reduce uptake of selenate into primary producers (Lo et al. 2012; Williams et al. 1994). The slopes of the relationship between sulphate and EF were very similar among species.

It should be noted that the actual site-related EF values may differ from the EF values reported here as a result of differing assemblages of species, seasonal fluctuations etc., and there are limitations to the accuracy of the predictions made here for this factor. However, the tissue selenium concentrations would be expected to change in a manner that is similar to that described here, assuming that sulphate exhibits a consistent relationship among species, which appears to be the case. Presence of selenite or significant depositional areas, where anoxic sediment may occur, in the system would cause a deviation from that described here, since sulphate does not compete with selenite for uptake sites. However, since the receiving environment is a fast-flowing system, these conditions would not be expected.

The slopes of the relationships between sulphate and EF shown in [Figures 2, 4 and 6](#) of -0.449, -0.390, and -0.471, respectively, were pooled to provide a combined slope for the three species using the same approach that is used to pool slopes for hardness-based water quality guidelines (USEPA 1985; [Figure 5](#)). The pooled slope was -0.444 ([Figure 8](#)). This slope can be used to develop a preliminary site-specific water quality objective (SSWQO) that incorporates sulphate as an uptake-modifying factor. Thus, if the current BC selenium water quality guideline of 2 µg/L (water column) and 4 µg/g dry weight (fish tissue) are established as being appropriate under current conditions at BC-W01 (median concentration in summer and fall of ~14 mg/L SO₄), then the preliminary SSWQO can be calculated as follows:

The generic water quality guideline can be presented as follows, where the enrichment and transfer factor (ETF) is a constant (at a given sulphate concentration) reflecting the combination of uptake into primary producers (enrichment function) and trophic transfer factors ($TTF_{\text{invertebrate}}$ and TTF_{fish}):

$$\begin{aligned}\text{Fish-tissue GL [i.e., } 4 \mu\text{g Se/g}] &= \text{Water-based GL [i.e., } 2 \mu\text{g Se/L}] \times \text{ETF} \\ 4 &= 2 \times \text{ETF} \\ \text{ETF} &= 2\end{aligned}$$

The ETF is inversely related to sulphate concentration, with a slope of -0.444. So, under current conditions (i.e., 14 mg/L SO_4):

$$\begin{aligned}\text{ETF} &= \text{constant} \times (\text{sulphate}^{-0.444}) \\ 2 &= \text{constant} \times (14^{-0.444}) \\ \text{constant} &= 6.455 \\ \text{ETF} &= 6.455 \times \text{sulphate}^{-0.444}\end{aligned}$$

Thus, the preliminary SSWQO (in $\mu\text{g/L}$) can be calculated as:

$$\begin{aligned}\text{Water-based SSWQG} &= \text{Fish-based GL} / \text{ETF} \\ &= 4 / (6.455 \times \text{sulphate}^{-0.444}) \\ &= 0.620 / \text{sulphate}^{-0.444} \\ &= 0.620 \times \text{sulphate}^{0.444}\end{aligned}$$

Alternatively, based on the two algal species alone (i.e., excluding the data for *L. minor*), the slope of the relationship was 0.460, which would result in the following:

$$\text{Water-based SSWQG} = 0.594 \times \text{sulphate}^{0.460}$$

Table 4. Example calculations for the preliminary SSWQO.

Sulphate concentration (mg/L)	Preliminary SSWQO using all three species (µg/L Se)	Preliminary SSWQO using two algal species (µg/L Se)
10	1.7	1.7
20	2.3	2.4
50	3.5	3.6
100	4.8	4.9
200	6.5	6.8
300	7.8	8.2
400	8.9	9.3

Figure 7. Normalized *Pseudokirchneriella subcapitata*, *Lemna minor* and *Scenedesmus acutus* enrichment functions compared to normalized sulphate concentration in BC-W01 waters amended with magnesium and calcium sulphate.

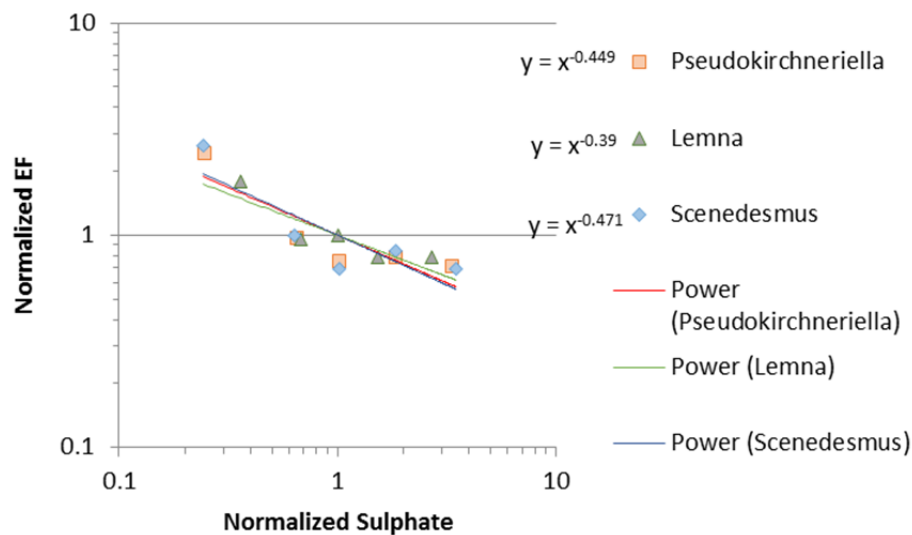
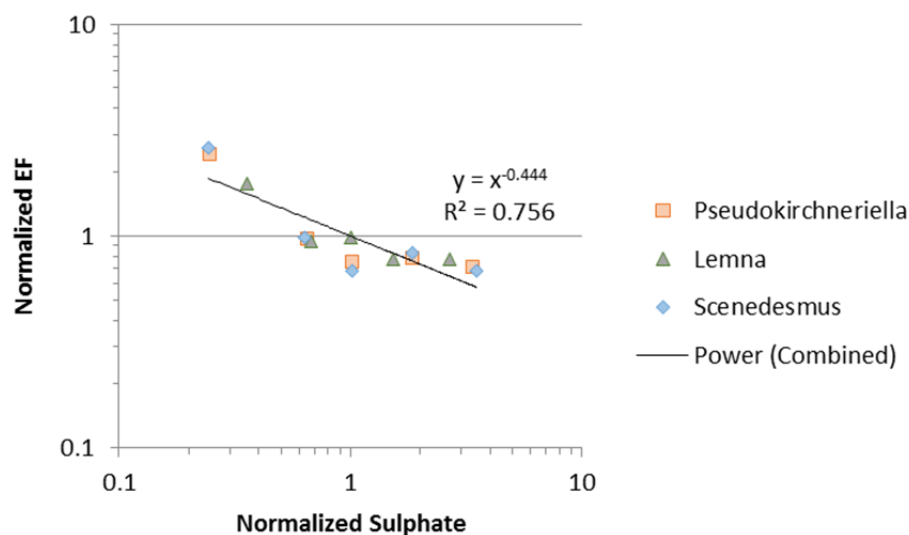


Figure 8. Combined, normalized *Pseudokirchneriella subcapitata*, *Lemna minor* and *Scenedesmus acutus* enrichment functions compared to normalized sulphate concentration in BC-W01 waters amended with magnesium and calcium sulphate.



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APPENDIX A - Chemistry

Appendix A2

QA/QC of Water Quality Data



APPENDIX A2

GRASSY MOUNTAIN COAL MINE BASELINE WATER QUALITY MONITORING QUALITY ASSURANCE AND QUALITY CONTROL REPORT

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A2.1 INTRODUCTION

Quality assurance and quality control (QA/QC) practices are key to data integrity and relevant to all aspects of an environmental study, from sample collection to data analysis and reporting. Quality assurance (Q/A) deals with the management and technical aspects to ensure that the data generated are of consistently high quality. Quality control (QC) is an aspect of QA and includes the procedures used to measure and evaluate data quality, and to take corrective actions when data quality objectives are not met. This appendix describes QA/QC practices applied during the water quality baseline study, evaluates QC data, and describes the implications of QC results to the interpretation of results within the Grassy Mountain Coal Mine Project.

A2.2 QUALITY ASSURANCE

A2.2.1 Field Staff Training and Operations

Field sampling was carried out by Hatfield Consultants field personnel. Hatfield staff are well-trained in standardized field sampling procedures, data recording and equipment operations applicable to water quality sampling. Field work was completed according to approved field work instructions (FWIs) and established Hatfield technical procedures (TPs). FWIs are standardized technical documents that describe exact sampling locations and provide specific sampling instructions, equipment needs and calibration requirements, required technical procedures, sample labelling and shipping protocols, and laboratory contacts. These documents also provide specific guidelines for field record keeping and sample tracking. The TPs are consistent with standard field methods described in the relevant scientific literature (e.g., Environment Canada 1993; APHA 2012) and outline sample collection, preservation, handling, storage, and shipping protocols. Field work was preceded by a pre-field meeting by the field crews and the project manager. In this meeting, the purpose of the field program was discussed, roles of crew members were specified, questions regarding the FWI were addressed, and equipment needs, field logistics and contingency plans were discussed. During field work, field data were recorded on standardized field data sheets, according to established field record-keeping procedures. In addition, field crews checked-in with project manager regularly to provide an update on work completed. Samples were documented and tracked using chain-of-custody forms and receipt of samples by the analytical laboratory were confirmed.

One field crew member was responsible for managing the sample shipping process to ensure that:

- All required samples were collected;
- Chain-of-custody and analytical request forms were accurately completed;
- Proper labelling and documentation procedures were followed; and
- Samples were delivered to the designated lab in a timely manner.

A2.2.2 Laboratory

One member of the project team was designated as the laboratory liaison. To ensure that high quality data were generated, ALS Environmental (Calgary, AB) and Maxxam Analytics (Calgary, AB) were

selected for the laboratory analyses. Both laboratories are accredited by the Canadian Association for Laboratory Accreditation Inc. (CALA). Under CALA's accreditation program, performance evaluation assessments are conducted annually for laboratory procedures, methods and internal quality control.

A2.2.3 Office Operations

Office-related QA included use of appropriately trained personnel for each task and senior review of work products. An appropriate data management system was established and standardized data manipulation/summary tools were used to ensure an organized consistent system of data storage, QC and retrieval.

A2.3 QUALITY CONTROL

A2.3.1 Field Quality Control Procedures

The water quality field QC program consisted of the collection and analysis of travel blanks, field blanks and duplicate samples. The QC samples collected during the field program accounted for approximately 10% of the total number of samples submitted for analysis. These samples were handled, stored and shipped along with field-collected surface water samples, and were submitted “blind” to the analytical laboratories. The QC samples were analyzed for the same set of parameters as the samples collected from surface waters.

Different QC sample types are described below:

- Field blanks consist of de-ionized water provided by the analytical laboratory, which are exposed to the sampling environment at the sample site and handled in the same manner as the surface water samples (e.g., preserved, filtered) collected during the field program. Field blanks are used to detect potential sample contamination during sample collection, handling, shipping, and analysis. Nine field blanks were analyzed under this baseline study;
- Travel blanks (or trip blanks) consist of de-ionized water provided by the analytical laboratory, preserved prior to the sampling trip in the same manner as field-collected samples. Travel blanks remain unopened throughout the duration of the field program and are submitted for laboratory analysis at the end of the field trip. They are used to detect any widespread contamination resulting from the container, preservative or field conditions during transport and storage. Eight travel blanks were analyzed; and
- Duplicate samples (or replicate samples, depending on the number collected) are additional samples collected at the same time and location as surface water samples collected during a field program, using the same sampling methods. They are used to check within-site variation, and the precision of field sampling methods and laboratory analysis. Eight sets of duplicates for water quality and one set for sediment quality were collected and submitted to the laboratory for analysis.

A2.3.2 Initial Laboratory Data Screening

Upon receipt of water quality data from the analytical laboratories, a series of standard checks were performed to identify any potential data quality issues. These allowed potential re-analysis of samples to verify questionable data, or generate data for missing variables. The following data checks were performed:

- Whether all required variables and samples were analyzed;
- Whether data were reported using the appropriate units;
- Whether analyses were done with the appropriate detection limits;
- Field versus laboratory data comparisons for variables with parallel field and laboratory data (pH, specific conductivity);
- Logic checks: presence of zero values, comparisons of TDS and conductivity, hardness and alkalinity, total and dissolved phosphorus, total and dissolved organic carbon, total and dissolved metals, measured and calculated TDS;
- Checking for outliers using graphical methods, and based on expected concentration ranges in the sampled waters;
- Checking blanks for evidence of contamination;
- Checking duplicate samples for evidence of unacceptable variation;
- Checking laboratory QC data (sample temperature and integrity of containers upon receipt, review laboratory qualifiers, holding times, internal duplicates, ion balance, recovery of spiked variables); and
- Checking field-collected data for completeness, and unexpected values and trends.

If results of initial data screening indicated that there were deficiencies or potential data quality issues, the analytical laboratory was contacted and re-analysis of the parameters in question in the affected samples was requested. If data were verified by the analytical laboratory, but remained questionable based on the above evaluation, qualifiers were added to affected concentrations in the project data set for consideration during data summary and analysis, or data were excluded from further analysis (and identified in the report as excluded, with the corresponding reasons).

A2.3.3 Field Quality Control Data Evaluation

Field Blanks and Travel Blanks

Concentrations in field blanks and travel blanks were considered notable if they were greater than or equal to five times the corresponding analytical detection limit (DL). This threshold is based on the Practical Quantitation Limit (PQL) defined by the United States Environmental Protection Agency (US EPA 1985). This criterion was not applied to pH, which is expected to be above the laboratory-reported detection limit in the deionized water used to prepare the blanks.

The implications of notable results in blanks to data quality were evaluated relative to concentrations observed in surface waters sampled during the field programs. The aim of this evaluation was to determine (1) whether contamination was limited to a blank or was also apparent in the corresponding water samples, (2) whether it resulted in a consistent bias, and (3) whether it was severe enough to warrant invalidating the affected data. To address these questions, notable concentrations in blanks were interpreted as follows:

- If the blank had a detectable concentration of a parameter that was higher than those in the corresponding surface water samples, it was assumed that the concentration in the blank was the result of an isolated field or laboratory error. In this case, the corresponding water samples were considered uncontaminated;
- If the detectable concentration in the blank was less than 10% of the typical surface water concentration, the data for the corresponding water samples were considered acceptable for the parameter in question and were included in further analysis;
- If the detectable concentration in the blank was greater than 10% of the typical surface water concentration, but below those in the corresponding water samples, the water samples were considered potentially contaminated and were qualified in the data tables and the project database. Affected data were excluded from further analysis; and
- If two or more blanks had similar notable concentrations of a parameter, which was greater than 10% of the typical surface water concentration, but below those in the corresponding water samples, the results were considered to indicate a consistent analytical bias for that parameter. In this case, the data for the corresponding water samples were adjusted by subtracting the mean concentration in the blanks and the analytical laboratory was contacted to request development of corrective actions.

Duplicate Samples

Differences between concentrations measured in duplicate samples were calculated as the relative percent difference (RPD) for each variable. Before calculating the RPD, concentrations below the detection limit were replaced with the detection limit value in cases when only one of the concentrations for a given variable was detectable. The RPD was calculated using the following formula:

$$\text{RPD} = (|\text{difference in concentration between duplicate samples}| / \text{mean concentration}) \times 100.$$

The RPD value for a given variable was considered notable if:

- It was greater than 20%; and
- Concentration in one or both samples were greater than or equal to five times the DL.

These criteria are consistent with those used by analytical laboratories as part of internal QC procedures for duplicate samples.

The number of parameters with exceedances of the assessment criteria was compared with the total number of parameters analyzed to evaluate analytical precision. Analytical precision was rated as follows:

- High: if less than 10% of the total number of parameters were notably different from one another;
- Moderate: if 10 to 30% of the total number of parameters were notably different from one another; and
- Low: if more than 30% of the total number of parameters were notably different from one another.

A2.3.4 Quality Control Results

Field Blanks

Nine field blanks were collected during the entire water quality baseline programs ([Table A2.1](#)). The results of the field blank analysis suggest that the corresponding surface water samples were largely free of contamination. Out of 90 water quality variables measured for each of the nine field blanks, only three variables were detected at a concentration greater than five times the DL on one occasion only, including total mercury, dissolved barium and dissolved tin. The elevated concentration of total mercury was detected in the field blank collected on April 01, 2014 in the Crowsnest River (CRR-W02), and the elevated concentrations of both dissolved barium and tin were detected in the field blank collected on May 28, 2013 at unnamed tributary to Blairmore Creek (BCT-W02).

The concentrations of total mercury and dissolved tin in the field blank samples were much higher than in the corresponding surface water samples collected on the same date (i.e., < 0.0005 mg/L in the CRR-W02 water sample versus 0.0182 mg/L in the field blank for total mercury and < 0.0001 mg/L in the BCT-W02 water sample versus 0.00119 mg/L in the field blank for dissolved tin). This indicates that the concentrations in the field blanks were the result of an isolated field or laboratory error. In this case, the corresponding water samples were considered uncontaminated. Further, dissolved barium concentration in the BCT-W02 water sample collected on the same date was well above the one observed in the field blank (i.e., 0.0882 mg/L in the BCT-W02 water sample versus 0.000101 mg/L in the field blank for dissolved barium). As a result, possible contamination for this variable had a negligible effect on the quality of the corresponding creek water data.

Travel/Trip Blanks

Eight travel blanks were collected during the entire water quality baseline programs ([Table A2.1](#)). Around 90 water quality variables were measured in each of the field blanks but none of them were detected at a concentration greater than five times the DL. The results of the travel blanks suggest no potential contamination of surface water samples for any water quality variables.

Duplicates

Eight sets of duplicate water samples were collected during the entire water quality baseline programs from BC-W01 (two sets), BC-W03, GC-W01, GCT-W03, CRR-W01 (two sets), and CRR-W02 ([Table A2.2](#)). Among the duplicate samples, notable variations were observed in the concentrations of total suspended solids, specific conductivity, total dissolved solids, total organic carbon, total and dissolved phosphorus, total and dissolved aluminum, total chromium, total and dissolved copper, total mercury, total nickel, total tin, total titanium, total and dissolved vanadium, total zinc, dissolved cadmium, and dissolved uranium. The significant RPD values (> 20% and at least five times the detection limit)

between the sample and duplicate were recorded as the following percentage of the total number of parameters analyzed for each site:

- BC-W01 (sampled on July 03, 2013): 4%;
- BC-W01 (sampled on August 29, 2014): 8%;
- BC-W03 (sampled on July 23, 2013): 2%;
- GC-W01 (sampled on April 01, 2014): 9%;
- GCT-W03 (sampled on June 09, 2015): 5%;
- CRR-W01 (September 24, 2013): 2%;
- CRR-W01 (March 20, 2016): 1%; and
- CRR-W02 (sampled on May 28, 2013): 6%.

All of these sites could be rated as 'high' with respect to field sampling and analytical precision, as the significant RPD values as a percentage of total parameters were less than 10%.

One duplicate sediment sample was collected as a part of the June 2016 field program. Only two variables (phosphorus and strontium) out of 33 had a RPD greater than 20% indicating a high level of field sampling and analytical precisions.

A2.4 CONCLUSION

- Quality assurance and quality control (QA/QC) protocols were performed from sample collection to data analysis and reporting. These procedures were utilized to make sure that the data generated during this baseline monitoring study are of consistent high quality and appropriate to address the objectives of the study;
- None of the water quality variables had potential contamination in the field and travel blanks;
- A number of water quality variables had RPD values for duplicate samples above the QC assessment criterion of 20%. On average, 5% of the total number of variables for duplicate samples exceeded this criterion. This represents a 'high' level of field sampling and analytical precisions and does not significantly influence the interpretation of the collected baseline data;
- Two sediment quality variables had RPD values for duplicate samples above the QC assessment criterion of 20% resulting in 6% of the total number of variables that exceeded this criterion. This represents a 'high' level of field sampling and analytical precisions and does not significantly influence the interpretation of the collected baseline data;
- Therefore, the data generated in the entire water quality baseline programs were of acceptable quality and adequate to address the objectives of this study.

Table A2.1 Quality control results for blank water samples collected during the water quality baseline programs at Grassy Mountain mine site.

Variables	Units	DL	Field Blanks									Travel Blanks								
			BCT-W02	CRR-W02	BC-W03	BCT-W02	CRR-W02	CRR-W1	GCT-W06	GCT-W01	-	-	-	-	-	-	-	-	-	
			28-May-13	3-Jul-13	23-Jul-13	24-Sep-13	4-Apr-14	29-Aug-14	23-Feb-15	9-Jun-15	19-Mar-16	28-May-13	3-Jul-13	23-Jul-13	24-Sep-13	1-Apr-14	23-Feb-15	9-Jun-15	19-Mar-16	
Conventional Variables																				
True Colour	CU	5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	
Total Suspended Solids	mg/L	3,4,6	<4.0	<4.0	<4.0	<4.0	<6.0	<3.0	<3.0	<3.0	<3.0	<4.0	<4.0	<4.0	<4.0	<4.0	<3.0	<3.0	<3.0	
Turbidity	NTU	0.10	<0.10	0.17	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.1	<0.10	<0.10	
Specific Conductivity	µS/cm	3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	
pH	pH	0.10	6.66	6.64	6.90	6.28	6.54	6.36	6.73	6.45	5.89	6.74	6.92	6.91	6.19	6.48	6.34	6.07	6.11	
Total Dissolved Solids	mg/L	10,20	<20	<20	<20	<20	<10	<10	<10	<10	<10	<20	<20	<20	<20	<10	<10	<10	<10	
Total Alkalinity	mg/L	5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	
Total Hardness	mg/L	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	
Dissolved Organic Carbon	mg/L	1.0	<1.0	<1.0	<1.0	<1.0	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	-	<1.0	<1.0	<1.0	
Total Organic Carbon	mg/L	1.0	<1.0	<1.0	<1.0	<1.0	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	-	<1.0	<1.0	<1.0	
Major Nutrients																				
Total Ammonia (as N)	mg/L	0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	
Nitrate and Nitrite (as N)	mg/L	0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.054	<0.020	<0.020	<0.050	<0.071	<0.071	<0.071	<0.071	<0.071	<0.020	<0.020	<0.050	
Nitrate (as N)	mg/L	0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.020	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.020	
Nitrite (as N)	mg/L	0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.020	<0.010	<0.010	<0.010	<0.050	<0.050	<0.050	<0.050	<0.050	<0.010	<0.010	<0.010	
Total Kjeldahl Nitrogen	mg/L	0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	
Dissolved Phosphorus	mg/L	0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.001	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	
Total Phosphorus	mg/L	0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.001	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	
Biochemical Oxygen Demand	mg/L	2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	-	<2.0	<2.0	<2.0	<2.0	<2.0	
Major Ions																				
Calcium	mg/L	0.02/0.1/0.5	<0.10	<0.50	<0.020	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.50	<0.020	<0.10	<0.10	<0.10	<0.10	<0.10	
Magnesium	mg/L	0.005/0.1	<0.10	<0.10	<0.0050	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.0050	<0.10	<0.10	<0.10	<0.10	<0.10	
Potassium	mg/L	0.50	<0.50	<0.50	<0.050	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.050	<0.50	<0.50	<0.50	<0.50	<0.50	
Sodium	mg/L	0.05/1	<1.0	<1.0	<0.050	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.050	<1.0	<1.0	<1.0	<1.0	<1.0	
Bicarbonate	mg/L	5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	
Carbonate	mg/L	5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	
Chloride	mg/L	0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.50	<0.50	<0.50	<0.10	<0.10	<0.10	<0.10	0.11	<0.50	<0.50	<0.50	
Hydroxide	mg/L	5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	
Sulphate	mg/L	0.3/0.5	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.30	<0.30	<0.30	<0.50	<0.50	<0.50	<0.50	<0.50	<0.30	<0.30	<0.30	
Sulphide	mg/L	0.0015/0.002	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0015	<0.0015	0.0029	<0.0015	<0.0020	<0.0020	<0.0020	-	<0.0020	<0.0015	0.0026	<0.0015	
Total Metals																				
Aluminum	mg/L	0.010	<0.010	<0.010	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.010	<0.010	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	
Antimony	mg/L	0.00040	<0.00040	<0.00040	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.0004	<0.00040	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	
Arsenic	mg/L	0.00040	<0.00040	<0.00040	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.0004	<0.00040	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	
Barium	mg/L	0.0030	<0.0030	<0.0030	<0.000050	<0.000050	<0.00005	<0.00005	<0.00010	<0.000050	<0.00005	<0.0030	<0.0030	<0.000050	<0.00005	<0.000050	<0.00010	<0.000050	<0.000050	
Beryllium	mg/L	0.0010	<0.0010	<0.0010	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00010	<0.00010	<0.0010	<0.0010	<0.00050	<0.00050	<0.00050	<0.00050	<0.00010	<0.00010	
Boron	mg/L	0.050	<0.050	<0.050	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.050	<0.050	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	
Cadmium	mg/L	0.000050	<0.00005	<0.00005	<0.000010	<0.000010	<0.00001	<0.00001	<0.00001	<0.000005	<0.000005	<0.00005	<0.00005	<0.00001	<0.00001	<0.00001	<0.00001	<0.000005	<0.000005	
Chromium	mg/L	0.0050	<0.0050	<0.0050	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.0050	<0.0050	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	
Cobalt	mg/L	0.0020	<0.0020	<0.0020	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.0020	<0.0020	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	
Copper	mg/L	0.0010	<0.0010	<0.0010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00050	<0.00050	<0.0010	<0.0010	<0.00010	<0.00010	<0.00010	<0.00050	<0.00050	<0.00050	
Iron	mg/L	0.010	-	<0.010	<0.010	-	-	-	-	<0.030	<0.030	-	<0.010	<0.010	-	-	-	<0.030	<0.030	

Table A2.1 (Cont'd.)

Variables	Units	DL	Field Blanks									Travel Blanks								
			BCT-W02	CRR-W02	BC-W03	BCT-W02	CRR-W02	CRR-W1	GCT-W06	GCT-W01	-	-	-	-	-	-	-	-	-	
			28-May-13	3-Jul-13	23-Jul-13	24-Sep-13	4-Apr-14	29-Aug-14	23-Feb-15	9-Jun-15	19-Mar-16	28-May-13	3-Jul-13	23-Jul-13	24-Sep-13	1-Apr-14	23-Feb-15	9-Jun-15	19-Mar-16	
Total Metals (Cont'd.)																				
Lead	mg/L	0.00010	<0.0001	<0.0001	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.0001	<0.0001	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.000050	
Lithium	mg/L	0.010	<0.010	<0.010	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0010	<0.0010	<0.010	<0.010	<0.0050	<0.0050	<0.0050	<0.0050	<0.0010	<0.0010	
Manganese	mg/L	0.0020	-	<0.0020	<0.000050	-	-	-	<0.00010	<0.0050	<0.0050	-	<0.0020	<0.000050	-	-	<0.00010	<0.0050	<0.0050	
Mercury	µg/L	0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0.0182	<0.00050	<0.00050	<0.00050	<0.0050	<0.0005	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0.00108	<0.0050	
Molybdenum	mg/L	0.0050	<0.005	<0.005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.005	<0.005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.000050	
Nickel	mg/L	0.0020	<0.0020	<0.0020	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00050	<0.00050	<0.0020	<0.0020	<0.00010	<0.00010	<0.00010	<0.00010	<0.00050	<0.00050	
Selenium	mg/L	0.0001	<0.00040	<0.00040	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.000050	<0.00005	<0.0004	<0.00040	<0.00010	<0.00010	<0.00010	<0.00010	<0.000050	<0.000050	
Silver	mg/L	0.00010	<0.0001	<0.0001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.0001	<0.0001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.000010	
Thallium	mg/L	0.00010	<0.0000	<0.0001	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00001	<0.00001	<0.0001	<0.0001	<0.00005	<0.00005	<0.00005	<0.00005	<0.00001	<0.000010	
Tin	mg/L	0.050	<0.050	<0.050	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.050	<0.050	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	
Titanium	mg/L	0.0010	<0.0010	<0.0010	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.0010	<0.0010	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	
Uranium	mg/L	0.00010	<0.0001	<0.0001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.000010	<0.00001	<0.0001	<0.0001	<0.00001	<0.00001	<0.000010	<0.00001	<0.000010	<0.000010	
Vanadium	mg/L	0.0010	<0.0010	<0.0010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00050	<0.00050	<0.00050	<0.0010	<0.0010	<0.00010	<0.00010	<0.00010	<0.00050	<0.00050	<0.00050	
Zinc	mg/L	0.0040	<0.0040	<0.0040	<0.0050	<0.0050	<0.0050	<0.0050	<0.0040	<0.0030	<0.0030	<0.0040	<0.0040	<0.0050	<0.0050	<0.0050	<0.0040	<0.0030	<0.0030	
Dissolved Metals																				
Aluminum	mg/L	0.010	<0.0010	<0.010	<0.0010	<0.0010	-	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	
Antimony	mg/L	0.0004	<0.00010	<0.00040	<0.00010	<0.00010	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.0001	<0.00040	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	
Arsenic	mg/L	0.0001	<0.0001	<0.0004	<0.0001	<0.0001	-	<0.0000	<0.0001	<0.0001	<0.00010	<0.0001	<0.0004	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.00010	
Barium	mg/L	0.003	0.000101	<0.003	<0.00005	<0.00005	-	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.003	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.000050	
Beryllium	mg/L	0.0010	<0.00050	<0.0010	<0.00050	<0.00050	-	<0.00050	<0.00050	<0.00010	<0.00010	<0.0005	<0.0010	<0.00050	<0.00050	<0.00050	<0.00050	<0.00010	<0.00010	
Boron	mg/L	0.050	<0.010	<0.050	<0.010	<0.010	-	<0.010	<0.010	<0.010	<0.010	<0.010	<0.050	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	
Cadmium	mg/L	0.00001	<0.00001	<0.00005	<0.00001	<0.00001	-	<0.00001	<0.00001	<0.000005	<0.000005	<0.00001	<0.00005	<0.00001	<0.00001	<0.00001	<0.00001	<0.000005	<0.000005	
Chromium	mg/L	0.0050	<0.00010	<0.0050	<0.00010	<0.00010	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.0001	<0.0050	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	
Cobalt	mg/L	0.0020	<0.00010	<0.0020	<0.00010	<0.00010	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.0001	<0.0020	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	
Copper	mg/L	0.0010	<0.00010	<0.0010	<0.00010	<0.00010	-	<0.00010	<0.00010	<0.00020	<0.00020	0.00039	<0.0010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00020	<0.00020	
Iron	mg/L	0.010	<0.030	<0.010	<0.010	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.010	<0.010	<0.010	<0.030	<0.030	<0.030	<0.030	
Lead	mg/L	0.0001	<0.00005	<0.0001	<0.00005	<0.00005	-	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.0001	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.000050	
Lithium	mg/L	0.001	<0.0030	<0.0030	<0.0050	<0.0050	-	<0.0050	<0.0050	<0.0010	<0.001	<0.0030	<0.0030	<0.0050	<0.0050	<0.0050	<0.0050	<0.0010	<0.0010	
Manganese	mg/L	0.0020	<0.0050	<0.0020	<0.000050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.005	<0.0050	<0.0020	<0.000050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	
Mercury	µg/L	0.0005	-	-	-	-	<0.0005	-	-	<0.0005	<0.005	-	-	-	-	<0.0005	-	<0.0005	<0.0050	
Molybdenum	mg/L	0.00005	<0.00005	<0.005	<0.00005	<0.00005	-	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.000050	
Nickel	mg/L	0.0001	<0.00010	<0.0020	<0.00010	<0.00010	-	<0.00010	<0.00010	<0.00050	<0.00050	<0.00010	<0.0020	<0.00010	<0.00010	<0.00010	<0.00010	<0.00050	<0.00050	
Selenium	mg/L	0.00005	<0.00010	<0.00040	<0.00010	<0.00010	-	<0.00010	<0.00010	<0.000050	<0.00005	<0.00010	<0.00040	<0.00010	<0.00010	<0.00010	<0.00010	<0.000050	<0.000050	
Silver	mg/L	0.0001	<0.00001	<0.0001	<0.00001	<0.00001	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.0001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.000010	
Thallium	mg/L	0.00005	<0.00005	<0.0001	<0.00005	<0.00005	-	<0.00005	<0.00005	<0.00001	<0.00001	<0.00005	<0.0001	<0.00005	<0.00005	<0.00005	<0.00005	<0.00001	<0.000010	
Tin	mg/L	0.0001/0.05	0.00119	<0.050	<0.00010	<0.00010	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.050	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	
Titanium	mg/L	0.0003	<0.0003	<0.001	<0.0003	<0.0003	-	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.001	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.00030	
Uranium	mg/L	0.00001	<0.00001	<0.0001	<0.00001	<0.00001	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.0001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.000010	
Vanadium	mg/L	0.0001	<0.00010	<0.0010	<0.00010	<0.00010	-	<0.00010	<0.00010	<0.00050	<0.00050	<0.00010	<0.0010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00050	<0.00050	
Zinc	mg/L	0.001	<0.0010	<0.0020	<0.0010	<0.0050	-	<0.0050	<0.0050	<0.0010	<0.0010	<0.0010	<0.0020	<0.0010	<0.0050	<0.0050	<0.0050	0.0011	<0.0010	

Table A2.1 (Cont'd.)

Variables	Units	DL	Field Blanks									Travel Blanks								
			BCT-W02	CRR-W02	BC-W03	BCT-W02	CRR-W02	CRR-W1	GCT-W06	GCT-W01	-	-	-	-	-	-	-	-		
			28-May-13	3-Jul-13	23-Jul-13	24-Sep-13	4-Apr-14	29-Aug-14	23-Feb-15	9-Jun-15	19-Mar-16	28-May-13	3-Jul-13	23-Jul-13	24-Sep-13	1-Apr-14	23-Feb-15	9-Jun-15	19-Mar-16	
Organics																				
Hydrocarbons, Recoverable	mg/L	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	-	<1.0		
Phenols (4AAP)	mg/L	0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	-	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	-	<0.0010		
Benzene	mg/L	0.00050	-	-	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	-	<0.00050	-	-	<0.00050	<0.00050	<0.00050	-	<0.00050		
Ethylbenzene	mg/L	0.00050	-	-	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	-	<0.00050	-	-	<0.00050	<0.00050	<0.00050	-	<0.00050		
Toluene	mg/L	0.00050	-	-	<0.00050	<0.10	<0.00050	<0.00050	<0.10	-	<0.00050	-	-	<0.00050	<0.10	<0.00050	<0.10	<0.00050		
o-xylene	mg/L	0.00050	-	-	<0.00050	<0.10	<0.00050	<0.00050	<0.10	-	<0.00050	-	-	<0.00050	<0.10	<0.00050	<0.10	<0.00050		
m+p-Xylene	mg/L	0.00050	-	-	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	-	<0.00050	-	-	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050		
Xylenes	mg/L	0.00071	-	-	<0.00050	<0.00050	<0.00071	<0.00071	<0.00050	-	<0.00071	-	-	<0.00050	<0.00050	<0.00071	<0.00050	<0.00071		
F1(C6-C10)	mg/L	0.10	-	-	<0.10	<0.00050	<0.10	<0.10	<0.00050	-	<0.10	-	-	<0.10	<0.00050	<0.10	<0.00050	<0.10		
F1-BTEX	mg/L	0.10	-	-	<0.10	<0.00050	<0.10	<0.10	<0.00071	-	<0.10	-	-	<0.10	<0.00050	<0.10	<0.00071	<0.10		
F2 (>C10-C16)	mg/L	0.25	-	-	-	<0.25	<0.25	<0.25	<0.25	-	<0.10	-	-	-	<0.25	<0.25	<0.25	<0.10		
F3 (C16-C34)	mg/L	0.25	-	-	-	<0.25	<0.25	<0.25	<0.25	-	<0.25	-	-	-	<0.25	<0.25	<0.25	<0.25		
F4 (C34-C50)	mg/L	0.25	-	-	-	<0.25	<0.25	<0.25	<0.25	-	<0.25	-	-	-	<0.25	<0.25	<0.25	<0.25		
Naphthenic Acids	mg/L	0.10	<0.10	<0.10	<0.10	<0.10	<0.10	1.44	<0.10	-	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	-	<0.10		

Table A2.2 Quality control results for duplicate water samples collected during the water quality baseline programs at Grassy Mountain mine site.

Variables	Units	DL	3-Jul-13			23-Jul-13			1-Apr-14			29-Aug-14			28-May-13			24-Sep-13			9-Jun-15			20-Mar-16		
			BC-W01	BC-W01 Dup	RPD	BC-W03	BC-W03 Dup	RPD	GC-W01	GC-W01 Dup	RPD	BC-W01	BC-W01 Dup	RPD	CRR-W02	CRR-W02 Dup	RPD	CRR-W01	CRR-W01 Dup	RPD	GCT-W03	GCT-W03 Dup	RPD	CRR-W01	CRR-W01 Dup	RPD
Conventional Variables																										
True Colour	CU	5.0	15.5	15.2	2	6.4	5.9	8	<5.0	<5.0	-	7.7	6.9	11	<5.0	<5.0	-	<5.0	<5.0	-	12.1	12.3	2	<5.0	<5.0	-
Total Suspended Solids	mg/L	4.0	<4.0	<4.0	-	<4.0	<4.0	-	<6.0	<6.0	-	<3.0	<3.0	-	4	7	55	<4.0	<4.0	-	8	9.3	15	<3.0	<3.0	-
Turbidity	NTU	0.10	3.38	3.28	3	0.76	0.75	1	0.36	<0.10	-	1.13	1.07	5	4.24	3.74	13	1.14	1.22	7	6.35	7.31	14	1.65	1.48	10.86
Specific Conductivity	µS/cm	3.0	322	320	1	245	246	0	309	309	0	339	337	1	317	325	2	346	348	1	251	105	82	406	393	3.25
pH	pH	0.10	8.24	8.26	0	8.31	8.33	0	8.30	8.30	0	8.40	8.32	1	8.24	8.25	0	8.23	8.21	0	8.25	8.26	0	8.09	8.15	0.74
Total Dissolved Solids	mg/L	20	184	178	3	128	142	10	186	188	1	218	215	1	142	182	25	198	208	5	160	143	11	230	250	8.33
Total Alkalinity	mg/L	5.0	154	156	1	124	125	1	155	155	0	192	189	2	142	142	0	166	168	1	112	108	4	180	180	0.00
Total Hardness	mg/L	-	161	161	0	112	114	2	175	178	2	183	187	2	164	152	8	182	186	2	131	134	2	253	260	2.73
Dissolved Organic Carbon	mg/L	1.0	4.1	4.1	0	2.4	2.4	0	<1.0	<1.0	-	2.0	1.9	5	1.6	1.6	0	2.1	1.9	10	2.5	2.6	4	1.4	1.3	7.41
Total Organic Carbon	mg/L	1.0	4.2	4.2	0	3.0	2.0	40	<1.0	<1.0	-	2.0	2.2	10	1.5	1.6	6	1.8	1.7	6	2.9	2.9	0	1.2	1.1	8.70
Major Nutrients																										
Total Ammonia (as N)	mg/L	0.050	<0.050	<0.050	-	<0.050	<0.050	-	<0.050	<0.050	-	<0.050	<0.050	-	<0.050	<0.050	-	<0.050	<0.050	-	<0.050	<0.050	-	<0.050	<0.050	-
Nitrate and Nitrite (as N)	mg/L	0.071	<0.071	<0.071	-	<0.071	<0.071	-	0.108	0.109	1	<0.054	<0.054	-	0.081	0.079	3	0.106	0.109	3	0.116	0.123	6	0.142	0.142	0.00
Nitrate (as N)	mg/L	0.050	<0.050	<0.050	-	<0.050	<0.050	-	0.108	0.109	1	<0.050	<0.050	-	0.081	0.079	3	0.106	0.109	3	0.116	0.123	6	0.142	0.142	0.00
Nitrite (as N)	mg/L	0.050	<0.050	<0.050	-	<0.050	<0.050	-	<0.050	<0.050	-	<0.020	<0.020	-	<0.050	<0.050	-	<0.050	<0.050	-	<0.010	<0.010	-	<0.010	<0.010	-
Total Kjeldahl Nitrogen	mg/L	0.20	<0.20	<0.20	-	<0.20	<0.20	-	0.21	<0.20	-	<0.20	<0.20	-	<0.20	<0.20	-	<0.20	<0.20	-	<0.20	<0.20	-	<0.20	<0.20	-
Dissolved Phosphorus	mg/L	0.0010	0.0036	0.0034	6	0.0048	0.0048	0	0.0019	0.0013	38	0.0038	0.0016	81	<0.0010	<0.0010	-	0.0011	<0.0010	-	0.0151	0.0143	5	0.0034	0.0035	2.90
Total Phosphorus	mg/L	0.0010	0.0084	0.0078	7	0.0056	0.0054	4	0.0023	0.0019	19	0.0052	0.0042	21	0.0092	0.0096	4	0.006	0.0059	2	0.0247	0.0245	1	0.0071	0.0055	25.40
Biochemical Oxygen Demand	mg/L	2.0	<2.0	<2.0	-	<2.0	<2.0	-	<2.0	<2.0	-	<2.0	<2.0	-	<2.0	<2.0	-	<2.0	<2.0	-	<2.0	<2.0	-	<2.0	<2.0	-
Major Ions																										
Calcium	mg/L	0.50	47.1	47.4	1	34.9	35.5	2	50.9	51.9	2	54.5	55.8	2	46.6	47.8	3	53.9	54.8	2	33.5	34.3	2	76.4	78.8	3.09
Magnesium	mg/L	0.10	10.5	10.4	1	7.83	8.00	2	11.6	11.8	2	11.3	11.5	2	9.23	9.46	2	11.5	11.9	3	11.4	11.7	3	15.1	15.4	1.97
Potassium	mg/L	0.50	0.83	0.82	1	0.662	0.643	3	<0.50	<0.50	-	0.94	0.92	2	<0.50	<0.50	-	<0.50	0.51	-	0.75	0.83	10	0.62	0.73	16.30
Sodium	mg/L	1.0	3.9	3.8	3	3.56	3.57	0	1.8	1.8	0	5.5	5.5	0	2.7	2.8	4	4.6	4.8	4	1.4	1.5	7	8.0	8.2	2.47
Bicarbonate	mg/L	5.0	188	190	1	151	151	0	188	188	0	218	222	2	173	173	0	202	204	1	137	132	4	220	220	0.00
Carbonate	mg/L	5.0	<5.0	<5.0	-	<5.0	<5.0	-	<5.0	<5.0	-	<5.0	<5.0	-	<5.0	<5.0	-	<5.0	<5.0	-	<5.0	<5.0	-	<5.0	<5.0	-
Chloride	mg/L	0.10	0.34	0.33	3	0.26	0.27	4	0.48	0.47	2	0.51	0.50	2	1.14	1.08	5	2.2	2.22	1	<0.50	<0.50	-	2.72	2.71	0.37
Hydroxide	mg/L	5.0	<5.0	<5.0	-	<5.0	<5.0	-	<5.0	<5.0	-	<5.0	<5.0	-	<5.0	<5.0	-	<5.0	<5.0	-	<5.0	<5.0	-	<5.0	<5.0	-
Sulphate	mg/L	0.50	21.3	21.1	1	7.38	7.32	1	25.8	25.5	1	18.9	18.8	1	29.7	29.4	1	40.5	40.9	1	28.5	28.6	0	48.8	48.9	0.20
Sulphide	mg/L	0.0020	<0.0020	<0.0020	-	<0.0020	<0.0020	-	<0.0020	<0.0020	-	<0.0015	<0.0015	-	<0.0020	<0.0020	-	<0.0020	<0.0020	-	<0.0015	0.0022	-	<0.0015	<0.0015	-
Total Metals																										
Aluminum	mg/L	0.010	0.119	0.099	18	0.0232	0.0253	9	0.0458	0.0075	144	0.0449	0.0535	17	0.141	0.143	1	0.0237	0.0225	5	0.189	0.19	1	0.0384	0.0426	10.37
Antimony	mg/L	0.00040	<0.00040	<0.00040	-	<0.00010	<0.00010	-	<0.00010	<0.00010	-	<0.00010	<0.00010	-	<0.00040	<0.00040	-	<0.00010	<0.00010	-	0.00014	0.00014	0	<0.00010	<0.00010	-
Arsenic	mg/L	0.00040	<0.00040	<0.00040	-	0.00021	0.00018	15	0.00016	0.00014	13	0.00028	0.00027	4	<0.00040	<0.00040	-	0.00028	0.00026	7	0.0003	0.00028	7	0.00024	0.00025	4.08
Barium	mg/L	0.0030	0.110	0.109	1	0.109	0.109	0	0.0519	0.0560	8	0.140	0.122	14	0.0566	0.0579	2	0.063	0.0607	4	0.0976	0.0949	3	0.0741	0.0726	2.04
Beryllium	mg/L	0.0010	<0.0010	<0.0010	-	<0.00050	<0.00050	-	<0.00050	<0.00050	-	<0.00050	<0.00050	-	<0.0010	<0.0010	-	<0.00050	<0.00050	-	<0.00010	<0.00010	-	<0.00010	<0.00010	-
Boron	mg/L	0.050	<0.050	<0.050	-	<0.010	<0.010	-	<0.010	<0.010	-	0.016	0.014	13	<0.050	<0.050	-	<0.010	<0.010	-	0.016	0.015	6	0.011	0.011	0.00
Cadmium	mg/L	0.00005	<0.00005	<0.00005	-	<0.00001	<0.00001	-	<0.00001	<0.00001	-	0.000018	0.000022	20	<0.00005	<0.00005	-	<0.00001	<0.00001	-	0.0000524	0.0000502	4	0.0000067	0.0000066	1.50
Chromium	mg/L	0.0050	<0.0050	<0.0050	-	<0.00010	<0.00010	-	0.00020	0.00016	22	0.00011	0.00011	0	<0.0050	<0.0050	-	0.00015	0.00015	0	0.00026	0.0011	124	0.00020	0.00015	-

Table A2.2 (Cont'd.)

Variables	Units	DL	3-Jul-13			23-Jul-13			1-Apr-14			29-Aug-14			28-May-13			24-Sep-13			9-Jun-15			20-Mar-16		
			BC-W01	BC-W01 Dup	RPD	BC-W03	BC-W03 Dup	RPD	GC-W01	GC-W01 Dup	RPD	BC-W01	BC-W01 Dup	RPD	CRR-W02	CRR-W02 Dup	RPD	CRR-W01	CRR-W01 Dup	RPD	GCT-W03	GCT-W03 Dup	RPD	CRR-W01	CRR-W01 Dup	RPD
Total Metals (Cont'd.)																										
Cobalt	mg/L	0.0020	<0.0020	<0.0020	-	<0.00010	<0.00010	-	<0.00010	<0.00010	-	<0.00010	<0.00010	-	<0.0020	<0.0020	-	<0.00010	<0.00010	-	0.00022	0.00022	0	<0.00010	<0.00010	-
Copper	mg/L	0.0010	<0.0010	<0.0010	-	0.00046	0.00042	9	0.00025	0.00018	33	0.00078	0.00072	8	<0.0010	<0.0010	-	0.00056	0.00021	91	0.00117	0.00122	4	<0.00050	<0.00050	-
Iron	mg/L	0.010	0.251	0.217	15	0.021	0.022	5	-	-	-	-	-	-	-	-	-	-	-	-	0.184	0.188	2	0.092	0.095	3.21
Lead	mg/L	0.00010	<0.00010	<0.00010	-	<0.000050	<0.000050	-	<0.00005	<0.00005	-	<0.00005	<0.000050	-	0.00017	0.00016	6	<0.000050	<0.000050	-	0.000256	0.000255	0	0.000052	0.000056	7.41
Lithium	mg/L	0.010	<0.010	<0.010	-	<0.0050	<0.0050	-	<0.0050	<0.0050	-	<0.0050	<0.0050	-	<0.010	<0.010	-	<0.0050	<0.0050	-	0.0043	0.0042	2	0.0053	0.0052	1.90
Manganese	mg/L	0.0020	0.0141	0.0138	2	0.00203	0.00194	5	-	-	-	-	-	-	-	-	-	-	-	0.005	0.0055	10	0.0111	0.0111	0.00	
Mercury	µg/L	0.00050	0.00194	0.00189	3	0.00113	0.00110	3	<0.00050	<0.00050	-	0.00086	0.00094	9	0.0012	0.0012	0	<0.0010	<0.0010	-	0.00472	0.00372	24	<0.005	<0.005	0.00
Molybdenum	mg/L	0.0050	<0.0050	<0.0050	-	0.000874	0.000857	2	0.000782	0.000757	3	0.000918	0.000878	4	<0.0050	<0.0050	-	0.00062	0.000592	5	0.00077	0.000764	1	0.000599	0.000614	2.47
Nickel	mg/L	0.0020	0.0022	0.0022	0	0.00021	0.00020	5	0.00029	0.00014	70	0.00076	0.00079	4	<0.0020	<0.0020	-	0.00046	0.0004	14	0.00118	0.00116	2	0.00059	0.00058	1.71
Selenium	mg/L	0.00040	0.00069	0.00074	7	0.00049	0.00052	6	0.00093	0.00088	6	0.00041	0.00039	5	0.00156	0.00161	3	0.00143	0.00136	5	0.00758	0.00735	3	0.00111	0.00111	0.00
Silver	mg/L	0.00010	<0.00010	<0.00010	-	<0.000010	<0.000010	-	<0.00001	<0.00001	-	<0.00001	<0.000010	-	<0.00010	<0.00010	-	3.1E-05	0.000028	10	0.000011	0.000011	0	<0.00001	<0.00001	-
Thallium	mg/L	0.00010	<0.00010	<0.00010	-	<0.000050	<0.000050	-	<0.00005	<0.00005	-	<0.00005	<0.000050	-	<0.00010	<0.00010	-	<0.000050	<0.000050	-	0.00001	<0.00001	-	<0.00001	<0.00001	-
Tin	mg/L	0.050	<0.050	<0.050	-	<0.00010	<0.00010	-	<0.00010	<0.00010	-	<0.00010	<0.00010	-	<0.050	<0.050	-	0.00029	0.00023	23	<0.00010	<0.00010	-	<0.00010	<0.00010	-
Titanium	mg/L	0.0010	0.0029	0.0013	76	0.00043	0.00044	2	0.00071	<0.00030	-	0.00067	0.00067	0	0.0016	0.0023	36	<0.00030	<0.00030	-	0.00147	0.00202	32	0.00047	0.00048	2.11
Uranium	mg/L	0.00010	0.00045	0.00045	0	0.00035	0.000369	5	0.000445	0.000421	6	0.000735	0.000684	7	0.00039	0.00038	3	0.00038	0.00037	3	0.000461	0.000449	3	0.000477	0.000471	1.27
Vanadium	mg/L	0.0010	<0.0010	<0.0010	-	0.00031	0.00027	14	0.00033	0.00026	24	0.00046	0.00035	27	<0.0010	<0.0010	-	0.00043	0.00042	2	0.00093	0.00093	0	<0.00050	<0.00050	-
Zinc	mg/L	0.0040	0.0042	0.0052	21	<0.0050	<0.0050	-	<0.0050	<0.0050	-	<0.0050	<0.0050	-	<0.0040	<0.0040	-	<0.0050	<0.0050	-	0.003	<0.0030	-	<0.0030	<0.0030	-
Dissolved Metals																										
Aluminum	mg/L	0.010	<0.010	<0.010	-	0.0011	0.0016	37	0.0033	0.0018	59	0.0150	0.0217	37	0.0035	0.0032	9	<0.0010	0.0024	-	0.0337	0.0317	6	0.0033	0.0033	0.00
Antimony	mg/L	0.00040	<0.00040	<0.00040	-	<0.00010	<0.00010	-	<0.00010	<0.00010	-	<0.00010	<0.00010	-	<0.00010	<0.00010	-	<0.00010	<0.00010	-	0.00011	0.0001	10	<0.00010	<0.00010	-
Arsenic	mg/L	0.00040	<0.00040	<0.00040	-	0.00018	0.00019	5	0.00012	0.00014	15	0.00022	0.00025	13	0.00021	0.00023	9	0.00022	0.00022	0	0.00017	0.00018	6	0.00020	0.00021	4.88
Barium	mg/L	0.0030	0.124	0.124	0	0.111	0.116	4	0.0517	0.0549	6	0.125	0.124	1	0.0557	0.0593	6	0.0583	0.0612	5	0.0905	0.0887	2	0.0725	0.0732	0.96
Beryllium	mg/L	0.0010	<0.0010	<0.0010	-	<0.00050	<0.00050	-	<0.00050	<0.00050	-	<0.00050	<0.00050	-	<0.00050	<0.00050	-	<0.00050	<0.00050	-	<0.00010	<0.00010	-	<0.00010	<0.00010	-
Boron	mg/L	0.050	<0.050	<0.050	-	<0.010	<0.010	-	<0.010	<0.010	-	0.017	0.017	0	<0.010	<0.010	-	<0.010	<0.010	-	0.014	0.014	0	0.010	0.011	9.52
Cadmium	mg/L	0.00005	<0.00005	<0.00005	-	<0.00001	<0.00001	-	<0.00001	<0.00001	-	0.000014	0.00002	35	<0.00001	<0.00001	-	<0.00001	<0.00001	-	0.0000223	0.0000224	0	<0.000005	<0.000005	-
Chromium	mg/L	0.0050	<0.0050	<0.0050	-	<0.00010	<0.00010	-	0.00014	0.00013	7	<0.00010	<0.00010	-	0.0001	<0.00010	-	<0.00010	0.0001	-	<0.00010	<0.00010	-	<0.00010	<0.00010	-
Cobalt	mg/L	0.0020	<0.0020	<0.0020	-	<0.00010	<0.00010	-	<0.00010	<0.00010	-	<0.00010	<0.00010	-	<0.00010	<0.00010	-	<0.00010	<0.00010	-	<0.00010	<0.00010	-	<0.00010	<0.00010	-
Copper	mg/L	0.0010	0.0011	<0.0010	-	0.00023	0.00022	4	0.00018	0.00013	32	0.00047	0.00059	23	0.00023	0.00036	44	<0.00010	<0.00010	-	0.00035	0.00031	12	<0.00020	<0.00020	-
Iron	mg/L	0.010	<0.010	<0.010	-	<0.010	<0.010	-	<0.030	<0.030	-	<0.030	0.053	-	<0.030	<0.030	-	<0.030	<0.030	-	0.034	<0.030	-	<0.030	<0.030	-
Lead	mg/L	0.0001	<0.0001	<0.0001	-	<0.00005	<0.00005	-	<0.00005	<0.00005	-	<0.00005	<0.00005	-	<0.00005	<0.00005	-	<0.000050	<0.00005	-	<0.00005	<0.00005	-	<0.00005	<0.00005	-
Lithium	mg/L	0.0030	0.0039	0.0039	0	<0.0050	<0.0050	-	<0.0050	<0.0050	-	<0.0050	<0.0050	-	<0											

Table A2.2 (Cont’d.)

Variables	Units	DL	3-Jul-13			23-Jul-13			1-Apr-14			29-Aug-14			28-May-13			24-Sep-13			9-Jun-15			20-Mar-16		
			BC-W01	BC-W01 Dup	RPD	BC-W03	BC-W03 Dup	RPD	GC-W01	GC-W01 Dup	RPD	BC-W01	BC-W01 Dup	RPD	CRR-W02	CRR-W02 Dup	RPD	CRR-W01	CRR-W01 Dup	RPD	GCT-W03	GCT-W03 Dup	RPD	CRR-W01	CRR-W01 Dup	RPD
Organics																										
Hydrocarbons, Recoverable	mg/L	1.0	<1.0	<1.0	-	<1.0	<1.0	-	<1.0	<1.0	-	<1.0	<1.0	-	<1.0	<1.0	-	<1.0	<1.0	-	-	-	-	<1.0	<1.0	-
Phenols (4AAP)	mg/L	0.0010	<0.0010	<0.0010	-	<0.0010	<0.0010	-	<0.0010	<0.0010	-	<0.0010	<0.0010	-	<0.0010	<0.0010	-	<0.0010	<0.0010	-	-	-	-	<0.0010	<0.0010	-
Benzene	mg/L	0.00050	-	-	-	<0.00050	<0.00050	-	<0.00050	<0.00050	-	<0.00050	<0.00050	-	-	-	-	<0.00050	<0.00050	-	-	-	-	<0.00050	<0.00050	-
Ethylbenzene	mg/L	0.00050	-	-	-	<0.00050	<0.00050	-	<0.00050	<0.00050	-	<0.00050	<0.00050	-	-	-	-	<0.00050	<0.00050	-	-	-	-	<0.00050	<0.00050	-
Toluene	mg/L	0.00050	-	-	-	<0.00050	<0.00050	-	<0.00050	<0.00050	-	<0.00050	<0.00050	-	-	-	-	<0.10	<0.10	-	-	-	-	<0.00050	<0.00050	-
o-xylene	mg/L	0.00050	-	-	-	<0.00050	<0.00050	-	<0.00050	<0.00050	-	<0.00050	<0.00050	-	-	-	-	<0.10	<0.10	-	-	-	-	<0.00050	<0.00050	-
m+p-Xylene	mg/L	0.00050	-	-	-	<0.00050	<0.00050	-	<0.00050	<0.00050	-	<0.00050	<0.00050	-	-	-	-	<0.00050	<0.00050	-	-	-	-	<0.00050	<0.00050	-
Xylenes	mg/L	0.00071	-	-	-	<0.00050	<0.00050	-	<0.00071	<0.00071	-	<0.00071	<0.00071	-	-	-	-	<0.00050	<0.00050	-	-	-	-	<0.00071	<0.00071	-
F1(C6-C10)	mg/L	0.10	-	-	-	<0.10	<0.10	-	<0.10	<0.10	-	<0.10	<0.10	-	-	-	-	<0.00050	<0.00050	-	-	-	-	<0.10	<0.10	-
F1-BTEX	mg/L	0.10	-	-	-	<0.10	<0.10	-	<0.10	<0.10	-	<0.10	<0.10	-	-	-	-	<0.00050	<0.00050	-	-	-	-	<0.10	<0.10	-
F2 (>C10-C16)	mg/L	0.25	-	-	-	-	-		<0.25	<0.25	-	<0.25	<0.25	-	-	-	-	<0.25	<0.25	-	-	-	-	<0.10	<0.10	-
F3 (C16-C34)	mg/L	0.25	-	-	-	-	-		<0.25	<0.25	-	<0.25	<0.25	-	-	-	-	<0.25	<0.25	-	-	-	-	<0.25	<0.25	-
F4 (C34-C50)	mg/L	0.25	-	-	-	-	-		<0.25	<0.25	-	<0.25	<0.25	-	-	-	-	<0.25	<0.25	-	-	-	-	<0.25	<0.25	-
Naphthenic Acids	mg/L	0.10	<0.10	<0.10	-	<0.10	<0.10	-	<0.10	<0.10	-	<0.10	0.15	-	<0.10	<0.10	-	<0.10	<0.10	-	-	-	-	<0.24	<0.37	-
Number of variables with>20% RPD					3			2			8			7			5			2			4			1
Total number of variables analyzed					81			89			91			90			79			90			79			92
Analytical Precision (%)					4			2			9			8			6			2			5			1

Table A2.3 **Quality control results for duplicate sediment samples collected during the water quality baseline program at Grassy Mountain mine site.**

Variables	Units	DL	21-Jun-2016		
			BC-S01	BC-S01 Dup	RPD
Aluminum	mg/kg	50	13,900	14,400	3.5
Antimony	mg/kg	0.10	0.55	0.53	3.7
Arsenic	mg/kg	0.10	9.17	8.64	6.0
Barium	mg/kg	0.50	371	354	4.7
Beryllium	mg/kg	0.10	1.16	1.08	7.1
Bismuth	mg/kg	0.20	<0.20	<0.20	-
Boron	mg/kg	5.0	5.2	6.7	25.2
Cadmium	mg/kg	0.020	0.798	0.716	10.8
Calcium	mg/kg	50	24,300	22,200	9.0
Chromium	mg/kg	0.50	16.6	19.0	13.5
Cobalt	mg/kg	0.10	12.7	12.0	5.7
Copper	mg/kg	0.50	25.5	25.0	2.0
Iron	mg/kg	50	23,800	24,000	0.8
Lead	mg/kg	0.50	13.4	13.8	2.9
Lithium	mg/kg	2.0	14.6	15.2	4.0
Magnesium	mg/kg	20	4,640	4,850	4.4
Manganese	mg/kg	1.0	555	532	4.2
Mercury	mg/kg	0.0050	0.0322	0.0298	7.7
Molybdenum	mg/kg	0.10	1.00	0.87	13.9
Nickel	mg/kg	0.50	28.1	27.3	2.9
Phosphorus	mg/kg	50	630	972	42.7
Potassium	mg/kg	100	1,980	1,970	0.5
Selenium	mg/kg	0.20	0.88	0.83	5.8
Silver	mg/kg	0.10	0.11	0.11	0.0
Sodium	mg/kg	50	141	143	1.4
Strontium	mg/kg	0.50	170	131	25.9
Thallium	mg/kg	0.050	0.186	0.181	2.7
Tin	mg/kg	2.0	<2.0	<2.0	-
Titanium	mg/kg	1.0	105	101	3.9
Uranium	mg/kg	0.050	0.687	0.777	12.3
Vanadium	mg/kg	0.20	39.4	39.4	0.0
Zinc	mg/kg	2.0	114	108	5.4
Zirconium	mg/kg	1.0	1.3	1.6	20.7
Number of variables with >20% RPD					2
Total number of variables analyzed					33
Analytical Precision (%)					6

A2.5 REFERENCES

[APHA] American Public Health Association. 2012. Standard Methods for the Examination of Waste and Wastewater. American Public Health Association. Washington, D.C.

Environment Canada. 1993. Quality Assurance in Water Quality Monitoring Ecosystem Sciences and Evaluation Directorate Conservation and Protection. Ottawa. ON.

[US EPA] United States Environmental Protection Agency. 1985. National Primary Drinking Water Regulations; Volatile Synthetic Organic Chemicals; Proposed Rule; Recommendations for and Documentation of Biological Values for Use in Risk Assessment. U.S. EPA, Environmental Criteria and Assessment Office. Federal Register: 50; EPA/600/6-87/008. Volume 50. Cincinnati, OH. Submitted November 13, 1985.

Appendix A3

Water Quality Raw Data

Table A3.1 Water quality raw data – Blairmore Creek.

		BC-W01	BC-W03	BCT-W02	BC-W01	BC-W01	BC-W03	BC-W03	BCT-W02	BCT-W02	BC-W01	BC-W03	BCT-W02
		2013 May Spring	2013 May Spring	2013 May Spring	2013 July-H High Water	2013 July-R Summer	2013 July High Water	2013 July Summer	2013 July-H High Water	2013 July-R Summer	2013 September Fall	2013 September Fall	2013 September Fall
Date Sampled		5/28/2013 4:54:00 PM	5/27/2013 6:00:00 PM	5/28/2013 10:14:00 AM	7/3/2013 8:30:00 AM	7/24/2013 9:35:00 AM	7/23/2013 3:57:00 PM		7/3/2013 12:10:00 PM	7/23/2013 5:45:00 PM	9/24/2013 10:03:00 AM	9/23/2013 1:45:00 PM	9/23/2013 3:10:00 PM
Analyte	Units												
Conventional Variables													
Colour, True	CU	19.7	19.3	33.1	15.5	8.9	11.8	6.4	46.8	19.3	5	7.3	14.4
Total Suspended Solids	mg/L	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0
Total Dissolved Solids	mg/L	118	104	124	184	238	118	128	152	222	202	124	196
TDS (Calculated)	mg/L	110	104	134	176	207	114	126	119	188	210	136	198
Turbidity	NTU	8.24	6.34	6.16	3.38	0.72	2.58	0.76	10.5	1.23	0.36	1.03	1.42
Conductivity (EC)	µS/cm	205	198	254	322	391	215	245	217	358	352	242	337
pH	pH	8.14	8.1	8.17	8.24	8.4	8.2	8.31	7.98	8.34	8.39	8.3	8.33
Hardness (as CaCO ₃)	mg/L	100	94.8	122	161	180	105	112	103	167	191	123	178
Alkalinity, Total (as CaCO ₃)	mg/L	101	104	131	154	186	113	124	93.6	179	192	133	195
Dissolved Organic Carbon	mg/L	4.5	4.3	6.9	4.1	3.2	3	2.4	11.7	5.1	3	2.9	4.8
Total Organic Carbon	mg/L	4.6	4.2	7.2	4.2	3	2.8	3	11.5	4.8	2.8	2.8	4.6
Major Nutrients													
Ammonia, Total (as N)	mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Nitrate and Nitrite (as N)	mg/L	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071	<0.071
Nitrate (as N)	mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Nitrite (as N)	mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Total Kjeldahl Nitrogen	mg/L	<0.20	<0.20	0.21	<0.20	<0.20	<0.20	<0.20	0.35	<0.20	<0.20	<0.20	<0.20
Phosphorus (P)-Total Dissolved	mg/L	0.0036	0.0032	0.0055	0.0036	0.0043	0.0041	0.0048	0.0187	0.0136	0.0018	0.0034	0.0105
Phosphorus (P)-Total	mg/L	0.0162	0.011	0.0145	0.0084	0.0059	0.0074	0.0056	0.0382	0.0147	0.0029	0.0056	0.0128
Biochemical Oxygen Demand	mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Major Ions													
Calcium (Ca)-Dissolved	mg/L	30.5	28.5	36.9	47.1	58.1	30.3	34.9	31.6	55.8	57.2	36.9	55.1
Magnesium (Mg)-Dissolved	mg/L	5.89	5.74	7.23	10.5	12.1	7.15	7.83	5.94	9.75	11.7	7.49	9.73
Potassium (K)-Dissolved	mg/L	0.556	0.453	0.57	0.83	0.937	0.54	0.662	0.71	0.815	0.74	0.56	0.67
Sodium (Na)-Dissolved	mg/L	2.68	2.4	2.64	3.9	5.28	2.8	3.56	3.3	4.99	5.2	3.7	5
Bicarbonate (HCO ₃)	mg/L	123	127	160	188	219	138	151	114	215	227	162	234
Carbonate (CO ₃)	mg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Chloride (Cl)	mg/L	0.28	0.21	0.4	0.34	0.43	0.19	0.26	0.14	0.36	0.75	0.68	0.72
Hydroxide (OH)	mg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Sulfate (SO ₄)	mg/L	9.76	4.57	7.33	21.3	24.5	5.55	7.38	21.2	13.7	19	7.36	9.45
Sulphide	mg/L	<0.0020	0.002	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Total Metals													
Aluminum (Al)-Total	mg/L	0.663	0.419	0.533	0.119	0.0144	0.088	0.0232	0.667	0.0402	0.0089	0.0411	0.0462
Antimony (Sb)-Total	mg/L	<0.00040	<0.00040	<0.00040	<0.00040	<0.00010	<0.00040	<0.00010	<0.00040	<0.00010	<0.00010	0.00015	<0.00010
Arsenic (As)-Total	mg/L	<0.00040	<0.00040	<0.00040	<0.00040	0.00028	<0.00040	0.00021	0.00063	0.0004	0.00025	0.00034	0.00039
Barium (Ba)-Total	mg/L	0.0844	0.0967	0.109	0.11	0.127	0.0976	0.109	0.139	0.16	0.129	0.117	0.161
Beryllium (Be)-Total	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.00050	<0.0010	<0.00050	<0.0010	<0.00050	<0.00050	<0.00050	<0.00050
Boron (B)-Total	mg/L	<0.050	<0.050	<0.050	<0.050	0.014	<0.050	<0.010	<0.050	0.011	0.013	<0.010	0.01
Cadmium (Cd)-Total	mg/L	<0.000050	<0.000050	<0.000050	<0.000050	0.000013	<0.000050	<0.000010	<0.000050	<0.000010	<0.000010	0.000013	<0.000010
Chromium (Cr)-Total	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.00010	<0.0050	<0.00010	<0.0050	<0.00010	<0.00010	0.00011	<0.00010
Cobalt (Co)-Total	mg/L	<0.0020	<0.0020	<0.0020	<0.0020	0.00014	<0.0020	<0.00010	<0.0020	<0.00010	<0.00010	<0.00010	<0.00010
Copper (Cu)-Total	mg/L	0.0017	0.0013	0.0012	<0.0010	0.00067	<0.0010	0.00046	0.0019	0.0007	0.00053	0.00032	0.00044
Iron (Fe)-Total	mg/L	-	-	-	0.251	0.053	0.075	0.021	0.521	0.038	-	-	-
Lead (Pb)-Total	mg/L	0.00029	0.00022	0.00021	<0.00010	<0.000050	<0.00010	<0.000050	0.00036	<0.000050	<0.000050	0.000066	<0.000050

Table A3.1 (Cont'd.)

		BC-W01	BC-W03	BCT-W02	BC-W01	BC-W01	BC-W03	BC-W03	BCT-W02	BCT-W02	BC-W01	BC-W03	BCT-W02
		2013 May Spring	2013 May Spring	2013 May Spring	2013 July-H High Water	2013 July-R Summer	2013 July High Water	2013 July Summer	2013 July-H High Water	2013 July-R Summer	2013 September Fall	2013 September Fall	2013 September Fall
Date Sampled		5/28/2013 4:54:00 PM	5/27/2013 6:00:00 PM	5/28/2013 10:14:00 AM	7/3/2013 8:30:00 AM	7/24/2013 9:35:00 AM	7/23/2013 3:57:00 PM		7/3/2013 12:10:00 PM	7/23/2013 5:45:00 PM	9/24/2013 10:03:00 AM	9/23/2013 1:45:00 PM	9/23/2013 3:10:00 PM
Analyte	Units												
Total Metals (Cont'd.)													
Lithium (Li)-Total	mg/L	<0.010	<0.010	<0.010	<0.010	<0.0050	<0.010	<0.0050	<0.010	<0.0050	<0.0050	<0.0050	<0.0050
Manganese (Mn)-Total	mg/L	-	-	-	0.0141	0.00329	0.0029	0.00203	0.0085	0.003	-	-	-
Mercury (Hg)-Total	µg/L	0.0045	0.004	0.0038	0.00194	0.00101	0.00183	0.00113	0.00703	0.00162	0.00098	0.00124	0.00142
Molybdenum (Mo)-Total	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	0.0009	<0.0050	0.000874	<0.0050	0.000604	0.000861	0.000825	0.000628
Nickel (Ni)-Total	mg/L	<0.0020	<0.0020	<0.0020	0.0022	0.00127	<0.0020	0.00021	0.0034	0.00078	0.0008	0.00027	0.00051
Selenium (Se)-Total	mg/L	0.00062	0.00042	<0.00040	0.00069	0.00056	0.00043	0.00049	<0.00040	0.0003	0.00043	0.00048	0.00028
Silver (Ag)-Total	mg/L	<0.00010	<0.00010	<0.00010	<0.00010	<0.000010	<0.00010	<0.000010	<0.00010	<0.000010	0.000024	0.000048	0.000033
Thallium (Tl)-Total	mg/L	<0.00010	<0.00010	<0.00010	<0.00010	<0.000050	<0.00010	<0.000050	<0.00010	<0.000050	<0.000050	0.000096	<0.000050
Tin (Sn)-Total	mg/L	<0.050	<0.050	<0.050	<0.050	<0.00010	<0.050	<0.00010	<0.050	<0.00010	0.00027	0.00028	0.0003
Titanium (Ti)-Total	mg/L	0.0124	0.0056	0.0102	0.0029	<0.00030	0.0014	0.00043	0.0099	0.00073	<0.00030	0.00088	0.00082
Uranium (U)-Total	mg/L	0.00029	0.00021	0.00027	0.00045	0.000646	0.00026	0.00035	0.00018	0.000445	0.00062	0.000329	0.000417
Vanadium (V)-Total	mg/L	0.0017	0.0012	0.0014	<0.0010	0.00032	<0.0010	0.00031	0.0017	0.00046	0.0003	0.00041	0.00042
Zinc (Zn)-Total	mg/L	0.0046	<0.0040	<0.0040	0.0042	<0.0050	<0.0040	<0.0050	<0.0040	<0.0050	<0.0050	<0.0050	<0.0050
Dissolved Metals													
Aluminum (Al)-Dissolved	mg/L	0.0134	0.0119	0.0159	<0.010	<0.0010	<0.010	0.0011	0.022	0.0087	0.0011	0.0074	0.01
Antimony (Sb)-Dissolved	mg/L	<0.00010	<0.00010	<0.00010	<0.00040	<0.00010	<0.00040	<0.00010	<0.00040	<0.00010	<0.00010	<0.00010	<0.00010
Arsenic (As)-Dissolved	mg/L	0.0002	0.00017	0.00026	<0.00040	0.00025	<0.00040	0.00018	0.00044	0.00038	0.00022	0.00021	0.00037
Barium (Ba)-Dissolved	mg/L	0.0777	0.0882	0.112	0.124	0.131	0.107	0.111	0.117	0.16	0.124	0.112	0.157
Beryllium (Be)-Dissolved	mg/L	<0.00050	<0.00050	<0.00050	<0.0010	<0.00050	<0.0010	<0.00050	<0.0010	<0.00050	<0.00050	<0.00050	<0.00050
Boron (B)-Dissolved	mg/L	<0.010	<0.010	<0.010	<0.050	0.015	<0.050	<0.010	<0.050	0.013	0.014	<0.010	0.011
Cadmium (Cd)-Dissolved	mg/L	0.000013	<0.000010	<0.000010	<0.000050	<0.000010	<0.000050	<0.000010	<0.000050	<0.000010	<0.000010	<0.000010	<0.000010
Chromium (Cr)-Dissolved	mg/L	<0.00010	<0.00010	<0.00010	<0.0050	<0.00010	<0.0050	<0.00010	<0.0050	<0.00010	<0.00010	<0.00010	<0.00010
Cobalt (Co)-Dissolved	mg/L	0.00018	<0.00010	<0.00010	<0.0020	0.00011	<0.0020	<0.00010	<0.0020	<0.00010	<0.00010	<0.00010	<0.00010
Copper (Cu)-Dissolved	mg/L	0.00105	0.00064	0.00083	0.0011	0.00048	<0.0010	0.00023	0.0014	0.00056	0.00026	0.00013	0.00053
Iron (Fe)-Dissolved	mg/L	0.022	0.023	0.031 *	<0.010	<0.010	<0.010	<0.010	0.061	0.013	<0.030	<0.030	<0.030
Lead (Pb)-Dissolved	mg/L	<0.000050	<0.000050	<0.000050	<0.00010	<0.000050	<0.00010	<0.000050	<0.00010	<0.000050	<0.000050	<0.000050	<0.000050
Lithium (Li)-Dissolved	mg/L	<0.0050	<0.0050	<0.0050	0.0039	<0.0050	<0.0030	<0.0050	0.0062	<0.0050	<0.0050	<0.0050	<0.0050
Manganese (Mn)-Dissolved	mg/L	0.00695 *	0.00146 *	0.00121 *	0.0108	0.00206	<0.0020	0.00114	0.0033	0.00186	<0.0050	<0.0050	<0.0050
Mercury (Hg)-Dissolved	µg/L	-	-	-	-		-		-		-	<0.00050	-
Molybdenum (Mo)-Dissolved	mg/L	0.000558	0.000549	0.0004	<0.0050	0.000861	<0.0050	0.000846	<0.0050	0.000617	0.000851	0.000753	0.000651
Nickel (Ni)-Dissolved	mg/L	0.00108	0.00032	0.00063	0.0021	0.00111	<0.0020	0.00017	0.0023	0.00065	0.00073	0.00026	0.00053
Selenium (Se)-Dissolved	mg/L	0.00064	0.0004	0.00034	0.00083	0.0006	0.00052	0.00052	<0.00040	0.00032	0.00045	0.00042	0.00028
Silver (Ag)-Dissolved	mg/L	<0.000010	<0.000010	<0.000010	<0.00010	<0.000010	<0.00010	<0.000010	<0.00010	<0.000010	<0.000010	<0.000010	<0.000010
Thallium (Tl)-Dissolved	mg/L	<0.000050	<0.000050	<0.000050	<0.00010	<0.000050	<0.00010	<0.000050	<0.00010	<0.000050	<0.000050	<0.000050	<0.000050
Tin (Sn)-Dissolved	mg/L	<0.00010	<0.00010	<0.00010	<0.050	<0.00010	<0.050	<0.00010	<0.050	<0.00010	<0.00010	<0.00010	<0.00010
Titanium (Ti)-Dissolved	mg/L	0.00058	0.00057	0.0008	<0.0010	<0.00030	<0.0010	<0.00030	0.0015	0.00066	<0.00030	<0.00030	0.00064
Uranium (U)-Dissolved	mg/L	0.000236	0.000177	0.000203	0.00043	0.000595	0.00025	0.000323	0.00015	0.000401	0.000605	0.000324	0.000413
Vanadium (V)-Dissolved	mg/L	0.00015	<0.00010	0.00018	<0.0010	0.00022	<0.0010	0.00016	<0.0010	0.00033	0.00013	0.00011	0.00019
Zinc (Zn)-Dissolved	mg/L	0.0064	<0.0010	<0.0010	0.0026	<0.0010	<0.0020	<0.0010	0.0023	<0.0010	<0.0050	<0.0050	<0.0050

Table A3.1 (Cont'd.)

		BC-W01	BC-W03	BCT-W02	BC-W01	BC-W01	BC-W03	BC-W03	BCT-W02	BCT-W02	BC-W01	BC-W03	BCT-W02
		2013 May Spring	2013 May Spring	2013 May Spring	2013 July-H High Water	2013 July-R Summer	2013 July High Water	2013 July Summer	2013 July-H High Water	2013 July-R Summer	2013 September Fall	2013 September Fall	2013 September Fall
Date Sampled		5/28/2013 4:54:00 PM	5/27/2013 6:00:00 PM	5/28/2013 10:14:00 AM	7/3/2013 8:30:00 AM	7/24/2013 9:35:00 AM	7/23/2013 3:57:00 PM		7/3/2013 12:10:00 PM	7/23/2013 5:45:00 PM	9/24/2013 10:03:00 AM	9/23/2013 1:45:00 PM	9/23/2013 3:10:00 PM
Analyte	Units												
General Organics													
Hydrocarbons, Recoverable (I.R.)	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Phenols (4AAP)	mg/L	0.0012	0.0013	0.0019	<0.0010	<0.0010	<0.0010	<0.0010	0.0011	<0.0010	<0.0010	<0.0010	<0.0010
Benzene	mg/L	-	-	-	-	<0.00050	-	<0.00050	-	<0.00050	<0.00050	<0.00050	<0.00050
Ethylbenzene	mg/L	-	-	-	-	<0.00050	-	<0.00050	-	<0.00050	<0.00050	<0.00050	<0.00050
Toluene	mg/L	-	-	-	-	<0.00050	-	<0.00050	-	<0.00050	<0.00050	<0.00050	<0.00050
o-xylene	mg/L	-	-	-	-	<0.00050	-	<0.00050	-	<0.00050	<0.00050	<0.00050	<0.00050
m+p-Xylene	mg/L	-	-	-	-	<0.00050	-	<0.00050	-	<0.00050	<0.00050	<0.00050	<0.00050
Xylenes	mg/L	-	-	-	-	<0.00050	-	<0.00050	-	<0.00050	<0.00050	<0.00050	<0.00050
F1(C6-C10)	mg/L	-	-	-	-	<0.10	-	<0.10	-	<0.10	<0.10	<0.10	<0.10
F1-BTEX	mg/L	-	-	-	-	<0.10	-	<0.10	-	<0.10	<0.10	<0.10	<0.10
F2 (>C10-C16)	mg/L	-	-	-	-	-	-	-	-	-	<0.25	<0.25	<0.25
F3 (C16-C34)	mg/L	-	-	-	-	-	-	-	-	-	<0.25	<0.25	<0.25
F4 (C34-C50)	mg/L	-	-	-	-	-	-	-	-	-	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	<0.10	<0.10	0.13	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Polycyclic Aromatic Hydrocarbons													
Benzo[a]pyrene equivalency	µg/L	-	-	-	-	-	-	-	-	-	-	-	-
Acenaphthene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-
Acenaphthylene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-
Acridine	µg/L	-	-	-	-	-	-	-	-	-	-	-	-
Anthracene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-
Benzo(a)anthracene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-
Benzo(b&j)fluoranthene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-
Benzo(k)fluoranthene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-
Benzo(g,h,i)perylene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-
Benzo(c)phenanthrene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-
Benzo(a)pyrene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-
Benzo[e]pyrene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-
Chrysene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-
Dibenz(a,h)anthracene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-
Fluoranthene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-
Fluorene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-
Indeno(1,2,3-cd)pyrene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-
2-Methylnaphthalene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-
Naphthalene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-
Phenanthrene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-
Perylene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-
Pyrene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-
Quinoline	µg/L	-	-	-	-	-	-	-	-	-	-	-	-

Table A3.1 (Cont'd.)

		BC-W03	BCT-W02	BC-W02	BC-W01	BC-W03	BCT-W02	BC-W02	BC-W02	BCT-W01	BCT-W01	BC-W01	BC-W02	BC-W03
		2014 April Spring	2014 April Spring	2014 July Summer	2014 August Summer	2014 August Summer	2014 August Summer	2014 October Fall	2015 January Winter	2015 Feb Winter	2015 June Summer	2016 March Winter	2016 March Winter	2016 March Winter
Date Sampled		4/3/2014 2:15:00 PM	4/3/2014 11:40:00 AM	2014/07/10	8/29/2014 2:20:00 PM	8/29/2014 3:15:00 PM	8/29/2014 1:30:00 PM	2014/10/23	2015/01/27	2/24/2015 3:10:00 PM	6/10/2015	3/18/2016	3/18/2016	3/19/2016
Analyte	Units													
Conventional Variables														
Colour, True	CU	<5.0	7.1		7.7	<5.0	11.9	-	-	<5.0	59.5	<5.0	<5.0	<5.0
Total Suspended Solids	mg/L	<6.0	<6.0	2.0	<3.0	<3.0	<3.0	-	-	<3.0	96.7	<3.0	<3.0	<3.0
Total Dissolved Solids	mg/L	166	244	180	218	152	216	210	180	100	78	0.72	0.48	3.22
TDS (Calculated)	mg/L	166	237	190	207	143	206	210	180	83.6	47.2	205.0	195.0	170.0
Turbidity	NTU	0.29	0.79		1.13	0.29	0.46			0.33	109	212.0	214.0	167.0
Conductivity (EC)	µS/cm	277	390	340	339	246	344	370	330	175	96.7	338.0	332.0	268.0
pH	pH	8.21	8.25	8.34	8.4	8.2	8.34	8.45	8.26	8.14	7.80	8.2	8.2	8.0
Hardness (as CaCO ₃)	mg/L	155	225	190	183	125	185	200	180	73.4	43.8	215.0	216.0	171.0
Alkalinity, Total (as CaCO ₃)	mg/L	158	229	160	192	140	209	180	150	78.2	45.2	177.0	180.0	152.0
Dissolved Organic Carbon	mg/L	1.4	2.9		2	1.1	3.2			1	7.3	2.3	2.3	2.3
Total Organic Carbon	mg/L	1.4	3	3.1	2	1.2	3.3	2.1	2.3	1.1	11.1	2.3	2.3	2.1
Major Nutrients														
Ammonia, Total (as N)	mg/L	<0.050	<0.050		<0.050	<0.050	<0.050	-	-	<0.050	0.050	<0.050	<0.050	<0.050
Nitrate and Nitrite (as N)	mg/L	0.074	<0.071		<0.054	<0.054	<0.054	-	-	0.067	0.078	<0.050	<0.050	<0.050
Nitrate (as N)	mg/L	0.074	0.069	0.015	<0.050	<0.050	<0.050	0.035	0.039	0.067	0.078	<0.02	<0.02	<0.02
Nitrite (as N)	mg/L	<0.050	<0.050	-	<0.020	<0.020	<0.020	<0.010	<0.010	<0.010	0.010	<0.01	0.01	0.01
Total Kjeldahl Nitrogen	mg/L	<0.20	0.23		<0.20	<0.20	0.24			<0.20	1.08	<0.2	<0.2	<0.2
Phosphorus (P)-Total Dissolved	mg/L	0.0052	0.0109	-	0.0038	0.0032	0.005	<0.10	-	0.0028	0.0366	0.0036	0.0027	0.0040
Phosphorus (P)-Total	mg/L	0.005	0.0106		0.0052	0.0047	0.0105	-	-	0.0024	0.145	0.0049	0.0048	0.0056
Biochemical Oxygen Demand	mg/L	<2.0	<2.0		<2.0	<2.0	<2.0	-	-	<2.0	2.0	<2.0	<2.0	<2.0
Major Ions														
Calcium (Ca)-Dissolved	mg/L	46.5	68.7	58	54.5	36.9	57.6	60	54	22.1	11.7	65.50	65.60	53.00
Magnesium (Mg)-Dissolved	mg/L	9.47	12.9	11	11.3	8.08	10.1	12	12	4.43	3.53	12.60	12.60	9.35
Potassium (K)-Dissolved	mg/L	0.56	0.6	0.82	0.94	0.69	0.74	0.74	0.79	<0.50	0.50	0.67	0.69	0.54
Sodium (Na)-Dissolved	mg/L	5.2	7.3	4.4	5.5	4.1	5.2	5.1	5.2	4.3	1.0	6.70	6.80	5.50
Bicarbonate (HCO ₃)	mg/L	193	279	190	218	171	241	210	190	95.4	55.1	216.00	220.00	185.00
Carbonate (CO ₃)	mg/L	<5.0	<5.0	0.82	<5.0	<5.0	6.8	3.2	<0.50	<5.0	<5.0	<5.0	<5.0	<5.0
Chloride (Cl)	mg/L	0.64	0.8	-	0.51	0.4	0.61	1.5	1.9	<0.50	0.50	0.51	0.51	0.53
Hydroxide (OH)	mg/L	<5.0	<5.0	-	<5.0	<5.0	<5.0	<0.50	<0.50	<5.0	<5.0	<5.0	<5.0	<5.0
Sulfate (SO ₄)	mg/L	8.26	9.07	22	18.9	8.7	6.47	22	18	5.56	4.53	19.60	19.40	7.16
Sulphide	mg/L	<0.0020	<0.0020		<0.0015	<0.0015	<0.0015	-	-	<0.0015	0.0022	<0.0015	<0.0015	<0.0015
Total Metals														
Aluminum (Al)-Total	mg/L	0.0134	0.0349		0.0449	0.0146	0.0237	-	-	0.0208	3.13	0.028	0.027	0.064
Antimony (Sb)-Total	mg/L	<0.00010	<0.00010		<0.00010	<0.00010	<0.00010	-	-	<0.00010	0.00017	<0.00010	<0.00010	<0.00010
Arsenic (As)-Total	mg/L	0.0002	0.0003		0.00028	0.00021	0.00039	-	-	0.00012	0.00118	0.00019	0.00020	0.00020
Barium (Ba)-Total	mg/L	0.136	0.178		0.14	0.115	0.159	-	-	0.0424	0.113	0.1070	0.1090	0.1260
Beryllium (Be)-Total	mg/L	<0.00050	<0.00050		<0.00050	<0.00050	<0.00050	-	-	<0.00050	0.00015	<0.0001	<0.0001	<0.0001
Boron (B)-Total	mg/L	0.011	0.013		0.016	0.01	0.012	-	-	<0.010	0.010	0.014	0.014	0.011
Cadmium (Cd)-Total	mg/L	<0.000010	<0.000010		0.000018	<0.000010	<0.000010	-	-	<0.000010	0.000213	0.000015	0.000015	0.000005
Chromium (Cr)-Total	mg/L	<0.00010	<0.00010		0.00011	<0.00010	<0.00010	-	-	<0.00010	0.00383	<0.0001	<0.0001	<0.0001
Cobalt (Co)-Total	mg/L	<0.00010	<0.00010		<0.00010	<0.00010	<0.00010	-	-	<0.00010	0.00145	<0.0001	<0.0001	<0.0001
Copper (Cu)-Total	mg/L	0.00031	0.00034		0.00078	0.0004	0.00053	-	-	<0.00050	0.00544	0.00051	0.00053	<0.0005
Iron (Fe)-Total	mg/L	-	-	-	-	-	-	-	-	0.018	4.07	0.063	0.069	0.085
Lead (Pb)-Total	mg/L	<0.000050	<0.000050		<0.000050	<0.000050	<0.000050	-	-	<0.000050	0.00220	<0.000050	<0.000050	<0.000050

Table A3.1 (Cont'd.)

		BC-W03	BCT-W02	BC-W02	BC-W01	BC-W03	BCT-W02	BC-W02	BC-W02	BCT-W01	BCT-W01	BC-W01	BC-W02	BC-W03
		2014 April Spring	2014 April Spring	2014 July Summer	2014 August Summer	2014 August Summer	2014 August Summer	2014 October Fall	2015 January Winter	2015 Feb Winter	2015 June Summer	2016 March Winter	2016 March Winter	2016 March Winter
Date Sampled		4/3/2014 2:15:00 PM	4/3/2014 11:40:00 AM	2014/07/10	8/29/2014 2:20:00 PM	8/29/2014 3:15:00 PM	8/29/2014 1:30:00 PM	2014/10/23	2015/01/27	2/24/2015 3:10:00 PM	6/10/2015	3/18/2016	3/18/2016	3/19/2016
Analyte	Units													
Total Metals (Cont'd.)														
Lithium (Li)-Total	mg/L	<0.0050	0.0068		<0.0050	<0.0050	<0.0050	-	-	<0.0050	0.0035	0.0032	0.0032	0.0029
Manganese (Mn)-Total	mg/L							-	-	0.00042	0.0982	<0.0050	<0.0050	<0.0050
Mercury (Hg)-Total	µg/L	<0.0005	0.00051		0.00086	0.00065	0.00108	-	-	0.00085	0.0375	<0.0050	<0.0050	<0.0050
Molybdenum (Mo)-Total	mg/L	0.000931	0.000503		0.000918	0.000936	0.000777	-	-	0.00107	0.000296	0.000824	0.000836	0.000767
Nickel (Ni)-Total	mg/L	<0.00010	0.00027		0.00076	0.00014	0.00039	-	-	<0.00010	0.00557	0.00069	0.00065	<0.0005
Selenium (Se)-Total	mg/L	0.00057	0.00026		0.00041	0.00047	0.00033	-	-	0.00091	0.00115	0.000718	0.000723	0.000470
Silver (Ag)-Total	mg/L	<0.000010	<0.000010		<0.000010	<0.000010	<0.000010	-	-	<0.000010	0.000120	<0.000010	<0.000010	<0.000010
Thallium (Tl)-Total	mg/L	<0.000050	<0.000050		<0.000050	<0.000050	<0.000050	-	-	<0.000050	0.000089	<0.000010	<0.000010	<0.000010
Tin (Sn)-Total	mg/L	<0.00010	<0.00010		<0.00010	<0.00010	<0.00010	-	-	<0.00010	0.00010	<0.000010	<0.000010	<0.000010
Titanium (Ti)-Total	mg/L	<0.00030	0.0011		0.00067	<0.00030	0.0004	-	-	0.00032	0.0447	<0.00030	<0.00030	0.000850
Uranium (U)-Total	mg/L	0.00059	0.000661		0.000735	0.000436	0.000569	-	-	0.000186	0.000226	0.000684	0.000688	0.000474
Vanadium (V)-Total	mg/L	0.00023	0.00028		0.00046	0.00024	0.00036	-	-	<0.00050	0.00883	<0.00050	<0.00050	<0.00050
Zinc (Zn)-Total	mg/L	<0.0050	<0.0050		<0.0050	<0.0050	<0.0050	-	-	<0.0040	0.0188	<0.003	<0.003	<0.003
Dissolved Metals														
Aluminum (Al)-Dissolved	mg/L	-	0.0313	0.041	0.015	0.0033	0.0032	0.0043	-	0.0019	0.0417	0.0123	0.0115	0.0195
Antimony (Sb)-Dissolved	mg/L	-	<0.00010	-	<0.00010	<0.00010	<0.00010	<0.00060	-	<0.00010	0.00010	<0.00010	<0.00010	<0.00010
Arsenic (As)-Dissolved	mg/L	-	0.00031	-	0.00022	0.00019	0.00036	0.00031	-	<0.00010	0.00025	0.00016	0.00015	0.00018
Barium (Ba)-Dissolved	mg/L	-	0.184	0.11	0.125	0.117	0.166	0.12	-	0.0413	0.0512	0.1100	0.1070	0.1220
Beryllium (Be)-Dissolved	mg/L	-	<0.00050	-	<0.00050	<0.00050	<0.00050	<0.0010	-	<0.00050	0.00010	<0.0001	<0.0001	<0.0001
Boron (B)-Dissolved	mg/L	-	0.011	-	0.017	0.011	0.014	<0.020	-	0.011	0.010	0.014	0.014	0.010
Cadmium (Cd)-Dissolved	mg/L	-	<0.000010	0.00002	0.000014	<0.000010	<0.000010	<0.000020	-	<0.000010	0.0000237	0.000012	0.000011	0.000005
Chromium (Cr)-Dissolved	mg/L	-	<0.00010	-	<0.00010	<0.00010	<0.00010	<0.0010	-	<0.00010	0.00014	<0.00010	<0.00010	<0.00010
Cobalt (Co)-Dissolved	mg/L	-	<0.00010	-	<0.00010	<0.00010	<0.00010	<0.00030	-	<0.00010	0.00010	0.000110	<0.00010	<0.00010
Copper (Cu)-Dissolved	mg/L	-	0.00034	0.00098	0.00047	0.00017	0.00033	0.00058	-	0.00027	0.00117	0.00041	0.00039	0.00026
Iron (Fe)-Dissolved	mg/L	<0.03	<0.030	-	<0.030	<0.030	<0.030	<0.060	<0.060	<0.030	0.102	<0.030	<0.030	0.055
Lead (Pb)-Dissolved	mg/L	-	<0.000050	-	<0.000050	<0.000050	<0.000050	<0.00020	-	<0.000050	0.000066	<0.000050	<0.000050	<0.000050
Lithium (Li)-Dissolved	mg/L	-	0.0053	-	<0.0050	<0.0050	<0.0050	<0.020	-	<0.0050	0.0013	0.0033	0.0033	0.0027
Manganese (Mn)-Dissolved	mg/L	<0.0050	<0.0050	0.0097	<0.0050	<0.0050	<0.0050	<0.0040	<0.0040	<0.0050	0.0050	<0.0050	<0.0050	<0.0050
Mercury (Hg)-Dissolved	µg/L	<0.00050	<0.00050		-	-	-			0.00060 *	0.00776	<0.0050	<0.0050	<0.0050
Molybdenum (Mo)-Dissolved	mg/L	-	0.000525	0.00097	0.000856	0.000875	0.000714	0.00082	-	0.000891	0.000174	0.000758	0.000758	0.000648
Nickel (Ni)-Dissolved	mg/L	-	0.0003	0.0015	0.00066	0.00011	0.00029	0.00061	-	<0.00010	0.00105	0.00052	0.00056	0.00050
Selenium (Se)-Dissolved	mg/L	-	0.00033	0.00053	0.00042	0.0005	0.00034	0.00045	-	0.0011	0.00127	0.000798	0.000797	0.000491
Silver (Ag)-Dissolved	mg/L	-	<0.000010	-	<0.000010	<0.000010	<0.000010	<0.00010	-	<0.000010	0.000011	<0.000010	<0.000010	<0.000010
Thallium (Tl)-Dissolved	mg/L	-	<0.000050	-	<0.000050	<0.000050	<0.000050	<0.00020	-	<0.000050	0.000010	<0.000010	<0.000010	<0.000010
Tin (Sn)-Dissolved	mg/L	-	<0.00010	-	<0.00010	<0.00010	<0.00010	<0.0010	-	<0.00010	0.00010	<0.00010	<0.00010	<0.00010
Titanium (Ti)-Dissolved	mg/L	-	0.00037	-	<0.00030	<0.00030	<0.00030	<0.0010	-	<0.00030	0.00569	<0.00030	<0.00030	<0.00030
Uranium (U)-Dissolved	mg/L	-	0.000682	0.00060	0.000596	0.000351	0.000507	0.00069	-	0.000145	0.000048	0.000587	0.000584	0.000439
Vanadium (V)-Dissolved	mg/L	-	0.00021	-	0.00017	0.00014	0.00024	<0.0010	-	0.00014	0.00050	<0.0005	<0.0005	<0.0005
Zinc (Zn)-Dissolved	mg/L	-	<0.0050	-	<0.0050	<0.0050	<0.0050	<0.0030	-	<0.0050	0.0010	0.0010	0.0024	0.0066

Table A3.1 (Cont'd.)

		BC-W03	BCT-W02	BC-W02	BC-W01	BC-W03	BCT-W02	BC-W02	BC-W02	BCT-W01	BCT-W01	BC-W01	BC-W02	BC-W03
		2014 April Spring	2014 April Spring	2014 July Summer	2014 August Summer	2014 August Summer	2014 August Summer	2014 October Fall	2015 January Winter	2015 Feb Winter	2015 June Summer	2016 March Winter	2016 March Winter	2016 March Winter
Date Sampled		4/3/2014 2:15:00 PM	4/3/2014 11:40:00 AM	2014/07/10	8/29/2014 2:20:00 PM	8/29/2014 3:15:00 PM	8/29/2014 1:30:00 PM	2014/10/23	2015/01/27	2/24/2015 3:10:00 PM	6/10/2015	3/18/2016	3/18/2016	3/19/2016
Analyte	Units													
General Organics														
Hydrocarbons, Recoverable (I.R.)	mg/L	<1.0	<1.0		<1.0	<1.0	<1.0	-	-	<1.0	-	<1.0	<1.0	<1.0
Phenols (4AAP)	mg/L	<0.0010	<0.0010	-	<0.0010	<0.0010	<0.0010	<0.0020	<0.0020	<0.0010	-	<0.0010	<0.0010	<0.0010
Benzene	mg/L	<0.00050	<0.00050		<0.00050	<0.00050	<0.00050	-	-	<0.00050	-	<0.00050	<0.00050	<0.00050
Ethylbenzene	mg/L	<0.00050	<0.00050		<0.00050	<0.00050	<0.00050	-	-	<0.00050	-	<0.00050	<0.00050	<0.00050
Toluene	mg/L	<0.00050	<0.00050		<0.00050	<0.00050	<0.00050	-	-	<0.00050	-	<0.00050	<0.00050	<0.00050
o-xylene	mg/L	<0.00050	<0.00050		<0.00050	<0.00050	<0.00050	-	-	<0.00050	-	<0.00050	<0.00050	<0.00050
m+p-Xylene	mg/L	<0.00050	<0.00050		<0.00050	<0.00050	<0.00050	-	-	<0.00050	-	<0.00050	<0.00050	<0.00050
Xylenes	mg/L	<0.00071	<0.00071		<0.00071	<0.00071	<0.00071	-	-	<0.00071	-	<0.00071	<0.00071	<0.00071
F1(C6-C10)	mg/L	<0.10	<0.10		<0.10	<0.10	<0.10	-	-	<0.10	-	<0.10	<0.10	<0.10
F1-BTEX	mg/L	<0.10	<0.10		<0.10	<0.10	<0.10	-	-	<0.10	-	<0.10	<0.10	<0.10
F2 (>C10-C16)	mg/L	<0.25	<0.25		<0.25	<0.25	<0.25	-	-	<0.25	-	<0.1	<0.1	<0.1
F3 (C16-C34)	mg/L	<0.25	<0.25		<0.25	<0.25	<0.25	-	-	<0.25	-	<0.25	<0.25	<0.25
F4 (C34-C50)	mg/L	<0.25	<0.25		<0.25	<0.25	<0.25	-	-	<0.25	-	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	<0.10	<0.10		<0.10	<0.10	<0.10	-	-	<0.10	-	<0.21	<0.19	<0.52
Polycyclic Aromatic Hydrocarbons														
Benzo[a]pyrene equivalency	µg/L	-	-	-	-	-	-	<0.010	<0.010	-	-	-	-	-
Acenaphthene	µg/L	-	-	-	-	-	-	<0.10	<0.10	-	-	-	-	-
Acenaphthylene	µg/L	-	-	-	-	-	-	<0.10	<0.10	-	-	-	-	-
Acridine	µg/L	-	-	-	-	-	-	<0.20	<0.20	-	-	-	-	-
Anthracene	µg/L	-	-	-	-	-	-	<0.010	<0.010	-	-	-	-	-
Benzo(a)anthracene	µg/L	-	-	-	-	-	-	<0.0085	<0.0085	-	-	-	-	-
Benzo(b&j)fluoranthene	µg/L	-	-	-	-	-	-	<0.0085	<0.0085	-	-	-	-	-
Benzo(k)fluoranthene	µg/L	-	-	-	-	-	-	<0.0085	<0.0085	-	-	-	-	-
Benzo(g,h,i)perylene	µg/L	-	-	-	-	-	-	<0.0085	<0.0085	-	-	-	-	-
Benzo(c)phenanthrene	µg/L	-	-	-	-	-	-	<0.050	<0.050	-	-	-	-	-
Benzo(a)pyrene	µg/L	-	-	-	-	-	-	<0.0075	<0.0075	-	-	-	-	-
Benzo[e]pyrene	µg/L	-	-	-	-	-	-	<0.050	<0.050	-	-	-	-	-
Chrysene	µg/L	-	-	-	-	-	-	<0.0085	<0.0085	-	-	-	-	-
Dibenz(a,h)anthracene	µg/L	-	-	-	-	-	-	<0.0075	<0.0075	-	-	-	-	-
Fluoranthene	µg/L	-	-	-	-	-	-	<0.010	<0.010	-	-	-	-	-
Fluorene	µg/L	-	-	-	-	-	-	<0.050	<0.050	-	-	-	-	-
Indeno(1,2,3-cd)pyrene	µg/L	-	-	-	-	-	-	<0.0085	<0.0085	-	-	-	-	-
2-Methylnaphthalene	µg/L	-	-	-	-	-	-	<0.10	<0.10	-	-	-	-	-
Naphthalene	µg/L	-	-	-	-	-	-	<0.10	<0.10	-	-	-	-	-
Phenanthrene	µg/L	-	-	-	-	-	-	<0.050	<0.050	-	-	-	-	-
Perylene	µg/L	-	-	-	-	-	-	<0.050	<0.050	-	-	-	-	-
Pyrene	µg/L	-	-	-	-	-	-	<0.020	<0.020	-	-	-	-	-
Quinoline	µg/L	-	-	-	-	-	-	<0.20	<0.20	-	-	-	-	-

Table A3.2 Water quality raw data – Gold Creek and Caudron Creek.

		GC-W01 2014 April Spring	GC-W01 2013 July-R Summer	GC-W01 2013 September Fall	GC-W02 2014 July Summer	GC-W01 2014 August Summer	GC-W02 2014 October Fall	GC-W02 2015 January Winter	GCT-W01 2015 June Summer	GCT-W02 2015 June Summer	GCT-W03 2015 June Summer	GCT-W04 2015 June Summer	GCT-W05 2015 June Summer	GCT-W-06 2015 June Summer	GCT-W01 2016 March Winter	GCT-W02 2016 March Winter	GCT-W03 2016 March Winter	GCT-W03A 2016 March Winter	GCT-W01 2016 March Winter	CC-W01 2016 March Winter	CC-W01 2016 May Spring
Date Sampled		4/1/2014 6:20:00 PM	7/23/2013 2:27:00 PM	9/23/2013 11:50:00 AM	2014/07/10	8/29/2014 3:30:00 PM	2014/10/23	2015/01/27	6/10/2015	6/10/2015	6/10/2015	6/10/2015	6/10/2015	6/10/2015	3/18/2016	3/19/2016	3/19/2016	3/19/2016	3/18/2016	3/22/2016	5/18/2016
Analyte	Units																				
Conventional Variables																					
Colour, True	CU	<5.0	<5.0	<5.0	-	<5.0	-	-	6.8	11.9	12.1	<5.0	63.9	36.7	7.3	6.3	<5.0	<5.0	<5.0	<5.0	<5.0
Total Suspended Solids	mg/L	<6.0	<4.0	<4.0	1.3	<3.0	-	-	<3.0	14.0	8.0	<3.0	26.7	12.7	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
Total Dissolved Solids	mg/L	186	202	162	160	190	180	180	145	113	160	69	92	60	7.02	7.32	5.95	0.45	0.14	0.49	0.33
TDS (Calculated)	mg/L	184	176	179	170	182	180	200	139	103	143	59.4	59.3	33.6	305	155	93	160	175	140	140 *
Turbidity	NTU	0.36	0.24	0.26	-	0.15	-	-	1.23	7.10	6.35	1.81	34.1	20.6	312	160	83.4	163	199	145	144
Conductivity (EC)	µS/cm	309	335	308	320	299	320	330	256	183	251	121	123	85.5	527	261	155	298	310	258	249
pH	pH	8.3	8.46	8.36	8.37	8.32	8.43	8.37	8.32	8.21	8.25	7.96	7.87	7.67	7.92	7.96	7.89	8.14	8.18	8.06	8.45
Hardness (as CaCO ₃)	mg/L	175	162	168	180	173	180	190	136	92.5	131	44.9	51.9	30.4	307	161	77.7	177	206	150	160
Alkalinity, Total (as CaCO ₃)	mg/L	155	161	159	150	163	150	160	141	90.7	112	62.0	57.7	34.7	233	107	56.7	137	160	120	124
Dissolved Organic Carbon	mg/L	<1.0	<1.0	1.7	-	<1.0	-	-	2.2	2.8	2.5	2.6	9.0	5.8	2.0	1.8	1.7	<1.0	<1.0	<1.0	<1.0
Total Organic Carbon	mg/L	<1.0	<1.0	1.4	1.4	<1.0	0.74	0.79	1.9	2.9	2.9	2.5	10.0	6.1	2.6	1.9	1.7	<1.0	<1.0	<1.0	<1.0
Major Nutrients																					
Ammonia, Total (as N)	mg/L	<0.050	<0.050	<0.050	-	<0.050	-	-	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Nitrate and Nitrite (as N)	mg/L	0.108	<0.071	<0.071	-	<0.054	-	-	0.054	<0.050	0.116	<0.050	<0.050	<0.050	<0.050	0.217	0.258	0.062	0.094	0.15	0.18
Nitrate (as N)	mg/L	0.108	<0.050	0.053	0.053	<0.050	0.057	0.12	0.054	0.036	0.116	0.024	0.034	<0.020	0.047	0.217	0.258	0.062	0.094	0.150	0.18
Nitrite (as N)	mg/L	<0.050	<0.050	<0.050	-	<0.020	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Total Kjeldahl Nitrogen	mg/L	0.21	<0.20	<0.20	-	<0.20	-	-	<0.20	<0.20	<0.20	<0.20	<0.20	0.53	0.27	0.21	0.57	<0.20	<0.20	<0.20	0.27
Phosphorus (P)-Total Dissolved	mg/L	0.0019	0.0015	0.001	-	<0.0010	<0.10	-	0.0137	0.0134	0.0151	0.0032	0.0279	0.0267	0.0058	0.0108	0.0111	0.0014	0.0024	0.0031	0.0027 *
Phosphorus (P)-Total	mg/L	0.0023	0.0022	0.0022	-	0.0045	-	-	0.0121	0.0244	0.0247	0.0060	0.0797	0.0530	0.0151	0.0173	0.0123	0.0031	0.0027	0.0056	0.0037
Biochemical Oxygen Demand	mg/L	<2.0	<2.0	<2.0	-	<2.0	-	-	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Major Ions																					
Calcium (Ca)-Dissolved	mg/L	50.9	50.5	49.8	52	50.7	54	56	40.2	22.9	33.5	13.6	13.3	8.67	92.3	41.4	19.9	52.0	61.7	42.8	46.2
Magnesium (Mg)-Dissolved	mg/L	11.6	11.5	10.7	12	11.2	11	13	8.64	8.57	11.4	2.66	4.55	2.12	18.6	14.1	6.81	11.4	12.6	10.4	10.8
Potassium (K)-Dissolved	mg/L	<0.50	0.404	<0.50	-	<0.50	<0.30	0.35	<0.50	0.68	0.75	<0.50	0.54	<0.50	0.99	0.74	<0.50	<0.50	<0.50	<0.50	<0.50
Sodium (Na)-Dissolved	mg/L	1.8	1.67	1.3	1.2	1.5	0.79	1.6	<1.0	2.2	1.4	2.2	<1.0	<1.0	7.0	1.4	1.1	<1.0	2.0	<1.0	<1.0
Bicarbonate (HCO ₃)	mg/L	188	187	190	170	186	170	190	170	111	137	75.7	70.4	42.4	285	130	69.1	167	195	146	136
Carbonate (CO ₃)	mg/L	<5.0	<5.0	<5.0	2.0	6.2	2.3	1.3	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	7.3
Chloride (Cl)	mg/L	0.48	0.27	0.26	-	0.27	1.2	1.1	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Hydroxide (OH)	mg/L	<5.0	<5.0	<5.0	-	<5.0	<0.50	<0.50	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Sulfate (SO ₄)	mg/L	25.8	20.3	21.6	19	21	23	27	5.60	13.7	28.5	3.68	6.11	1.96	53.5	37.0	20.4	17.0	26.1	19.2	11.7
Sulphide	mg/L	<0.0020	<0.0020	<0.0020	-	<0.0015	-	-	0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	-	<0.0015	<0.0015	<0.0015	<0.0015	0.0018
Total Metals																					
Aluminum (Al)-Total	mg/L	0.0458	0.0065	0.0051	-	0.0078	-	-	0.0590	0.148	0.189	0.0853	1.20	1.19	0.0702	0.211	0.0367	0.0070	0.0040	0.0033	0.0074
Antimony (Sb)-Total	mg/L	<0.00010	<0.00010	0.00038	-	<0.00010	-	-	<0.00010	0.00013	0.00014	<0.00010	0.00015	<0.00010	<0.00010	<0.0001	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Arsenic (As)-Total	mg/L	0.00016	0.00015	0.00043	-	0.00016	-	-	0.00020	0.00026	0.00030	0.00016	0.00063	0.00044	0.00019	0.00021	0.00012	0.00014	0.00014	0.00015	0.00019
Barium (Ba)-Total	mg/L	0.0519	0.0556	0.0561	-	0.0572	-	-	0.0602	0.115	0.0976	0.0405	0.113	0.0577	0.109000	0.079400	0.069700	0.046800	0.054200	0.0277	0.0264
Beryllium (Be)-Total	mg/L	<0.00050	<0.00050	<0.00050	-	<0.00050	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Boron (B)-Total	mg/L	<0.010	<0.010	<0.010	-	<0.010	-	-	<0.010	0.020	0.016	<0.010	<0.010	<0.010	0.032	0.013	<0.010	<0.010	<0.010	<0.010	<0.010
Cadmium (Cd)-Total	mg/L	<0.000010	<0.000010	0.00003	-	<0.000010	-	-	0.0000116	0.0000352	0.0000524	0.0000086	0.000116	0.0000690	0.0000119	0.0000230	0.0000172	0.0000061	0.0000065	<0.0000050	<0.0000050
Chromium (Cr)-Total	mg/L	0.0002	0.00014	0.0002	-	0.00016	-	-	0.00025	0.00033	0.00026	0.00015	0.00165	0.00144	0.00012	0.00022	<0.00010	0.00017	0.00013	0.00020	0.00019
Cobalt (Co)-Total	mg/L	<0.00010	<0.00010	<0.00010	-	<0.00010	-	-	<0.00010	0.00017	0.00022	<0.00010	0.00055	0.00032	0.00026	0.00011	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Copper (Cu)-Total	mg/L	0.00025	0.00024	0.0003	-	0.00025	-	-	0.00057	0.00122	0.00117	0.00062	0.00306	0.00174	<0.00050	0.00074	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Iron (Fe)-Total	mg/L		<0.010	-	-		-	-	0.077	0.157	0.184	0.077	1.11	0.873	0.194	0.195	0.037	<0.030	<0.030	<0.030	<0.030

Table A3.2 (Cont'd.)

		GC-W01 2014 April Spring	GC-W01 2013 July-R Summer	GC-W01 2013 September Fall	GC-W02 2014 July Summer	GC-W01 2014 August Summer	GC-W02 2014 October Fall	GC-W02 2015 January Winter	GCT-W01 2015 June Summer	GCT-W02 2015 June Summer	GCT-W03 2015 June Summer	GCT-W04 2015 June Summer	GCT-W05 2015 June Summer	GCT-W-06 2015 June Summer	GCT-W01 2016 March Winter	GCT-W02 2016 March Winter	GCT-W03 2016 March Winter	GCT-W03A 2016 March Winter	GCT-W01 2016 March Winter	CC-W01 2016 March Winter	CC-W01 2016 May Spring
Date Sampled		4/1/2014 6:20:00 PM	7/23/2013 2:27:00 PM	9/23/2013 11:50:00 AM	2014/07/10	8/29/2014 3:30:00 PM	2014/10/23	2015/01/27	6/10/2015	6/10/2015	6/10/2015	6/10/2015	6/10/2015	6/10/2015	3/18/2016	3/19/2016	3/19/2016	3/19/2016	3/18/2016	3/22/2016	5/18/2016
Analyte	Units																				
Total Metals (Cont'd.)																					
Lead (Pb)-Total	mg/L	<0.000050	<0.000050	0.000182	-	<0.000050	-	-	<0.000050	0.000233	0.000256	<0.000050	0.000959	0.000517	0.000116	0.000139	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Lithium (Li)-Total	mg/L	<0.0050	<0.0050	<0.0050	-	<0.0050	-	-	0.0018	0.0054	0.0043	<0.0010	0.0026	0.0018	0.0130	0.0029	<0.0010	0.0012	0.0017	<0.0010	0.0011
Manganese (Mn)-Total	mg/L		0.000753	-	-		-	-	<0.0050	<0.0050	0.0050	<0.0050	0.0396	0.0142	0.0355	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Mercury (Hg)-Total	ug/L	<0.00050	0.00227	0.00067	-	0.00067	-	-	0.00158	0.00350	0.00472	0.00238	0.0201	0.0122	<0.0050000	<0.0050000	<0.0050000	<0.0050000	<0.0050000	<0.0050	<0.0050
Molybdenum (Mo)-Total	mg/L	0.000782	0.000699	0.000827	-	0.000692	-	-	0.000566	0.000668	0.000770	0.000821	0.000423	0.000288	0.000725	0.000810	0.000342	0.00105	0.000789	0.00119	0.000712
Nickel (Ni)-Total	mg/L	0.00029	0.00026	0.00032	-	0.0003	-	-	<0.00050	0.00096	0.00118	<0.00050	0.00284	0.00182	0.00053	0.00070	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Selenium (Se)-Total	mg/L	0.00093	0.00069	0.00112	-	0.00063	-	-	0.000709	0.00161	0.00758	0.000528	0.00176	0.000389	0.00289	0.00904	0.00449	0.00123	0.000887	0.00116	0.000884
Silver (Ag)-Total	mg/L	<0.000010	<0.000010	0.000082	-	<0.000010	-	-	<0.000010	<0.000010	0.000011	<0.000010	0.000075	0.000071	<0.000010	0.000012	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Thallium (Tl)-Total	mg/L	<0.000050	<0.000050	0.00044	-	<0.000050	-	-	<0.000010	<0.000010	0.000010	<0.000010	0.000043	0.000032	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Tin (Sn)-Total	mg/L	<0.00010	<0.00010	0.0004	-	<0.00010	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Titanium (Ti)-Total	mg/L	0.00071	<0.00030	<0.00030	-	<0.00030	-	-	0.00087	0.00146	0.00147	0.00113	0.0175	0.0209	0.00058	0.00237	0.00034	<0.00030	<0.00030	<0.00030	<0.00030
Uranium (U)-Total	mg/L	0.000445	0.00038	0.000376	-	0.000388	-	-	0.000286	0.000155	0.000461	0.000077	0.000164	0.000120	0.000228	0.000659	0.000052	0.000440	0.000424	0.000482	0.000361
Vanadium (V)-Total	mg/L	0.00033	0.00034	0.00048	-	0.00027	-	-	0.00055	0.00082	0.00093	<0.00050	0.00387	0.00292	<0.00050	0.00065	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Zinc (Zn)-Total	mg/L	<0.0050	<0.0050	<0.0050	-	<0.0050	-	-	<0.0030	<0.0030	0.0030	<0.0030	0.0093	0.0052	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030
Dissolved Metals																					
Aluminum (Al)-Dissolved	mg/L	0.0033	<0.0010	<0.0010	0.0089	0.0013	<0.0030	-	0.0079	0.0331	0.0337	0.0181	0.338	0.0296	0.0107	0.0547	0.0320	<0.0010	<0.0010	<0.0010	0.0011
Antimony (Sb)-Dissolved	mg/L	<0.00010	<0.00010	<0.00010	-	<0.00010	<0.00060	-	<0.00010	<0.00010	0.00011	<0.00010	0.00011	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Arsenic (As)-Dissolved	mg/L	0.00012	0.00013	0.00012	-	0.00015	<0.00020	-	0.00015	0.00015	0.00017	0.00010	0.00028	0.00018	0.00012	0.00013	0.00011	0.00012	0.00013	0.00015	0.00016
Barium (Ba)-Dissolved	mg/L	0.0517	0.0584	0.0534	0.057	0.0653	0.052	-	0.0594	0.101	0.0905	0.0391	0.0839	0.0353	0.109	0.0765	0.0708	0.0461	0.0551	0.0281	0.0276
Beryllium (Be)-Dissolved	mg/L	<0.00050	<0.00050	<0.00050	-	<0.00050	<0.0010	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Boron (B)-Dissolved	mg/L	<0.010	<0.010	<0.010	-	<0.010	<0.020	-	<0.010	0.018	0.014	<0.010	<0.010	<0.010	0.033	0.013	<0.010	<0.010	<0.010	<0.010	<0.010
Cadmium (Cd)-Dissolved	mg/L	<0.000010	<0.000010	<0.000010	0.000043	<0.000010	<0.000020	-	0.0000053	0.0000125	0.0000223	0.0000083	0.0000264	0.0000173	<0.0000050	0.0000131	0.0000316	<0.0000050	0.0000058	<0.0000050	<0.0000050
Chromium (Cr)-Dissolved	mg/L	0.00014	<0.00010	0.00011	-	<0.00010	<0.0010	-	<0.00010	<0.00010	<0.00010	<0.00010	0.00053	0.00011	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00016	0.00012
Cobalt (Co)-Dissolved	mg/L	<0.00010	<0.00010	<0.00010	0.00040	<0.00010	<0.00030	-	<0.00010	<0.00010	<0.00010	<0.00010	0.00012	<0.00010	0.00014	0.00011	0.00011	<0.00010	<0.00010	<0.00010	<0.00010
Copper (Cu)-Dissolved	mg/L	0.00018	0.00012	<0.00010	0.00098	0.00012	0.00027	-	<0.00020	0.00028	0.00035	0.00055	0.00153	0.00051	<0.00020	0.00035	0.00055	<0.00020	<0.00020	<0.00020	<0.00020
Iron (Fe)-Dissolved	mg/L	<0.030	<0.010	<0.030	-	<0.030	<0.060	<0.060	<0.030	0.038	0.034	<0.030	0.259	0.056	<0.030	0.064	0.032	<0.030	<0.030	<0.030	<0.030
Lead (Pb)-Dissolved	mg/L	<0.000050	<0.000050	<0.000050	-	<0.000050	<0.00020	-	<0.000050	<0.000050	<0.000050	<0.000050	0.000187	<0.000050	<0.000050	<0.000050	0.000089	<0.000050	<0.000050	<0.000050	<0.000050
Lithium (Li)-Dissolved	mg/L	<0.0050	<0.0050	<0.0050	-	<0.0050	<0.020	-	0.0019	0.0056	0.0044	<0.0010	0.0017	<0.0010	0.0137	0.0028	0.0010	0.0013	0.0017	0.0016	0.0012
Manganese (Mn)-Dissolved	mg/L	<0.0050	0.000407	<0.0050	-	<0.0050	<0.0040	<0.0040	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.0332	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Mercury (Hg)-Dissolved	ug/L	<0.00050		<0.000050	-	-	-	-	0.00091	0.00182	0.00154	0.00142	0.00820	0.00577	<0.005	<0.005	<0.005	<0.005	<0.005	<0.0050	<0.0050
Molybdenum (Mo)-Dissolved	mg/L	0.000765	0.000657	0.000731	0.00068	0.000674	0.00072	-	0.000498	0.000522	0.000690	0.000693	0.000314	0.000226	0.000664	0.000701	0.000246	0.000943	0.000725	0.00120	0.000676
Nickel (Ni)-Dissolved	mg/L	0.00017	0.00022	0.00018	-	0.00016	<0.00050	-	<0.00050	0.00057	0.00061	<0.00050	0.00113	0.00052	<0.00050	<0.00050	0.00059	<0.00050	<0.00050	<0.00050	<0.00050
Selenium (Se)-Dissolved	mg/L	0.0011	0.00072	0.00076	0.00065	0.00064	0.00064	-	0.000660	0.00151	0.00753	0.000565	0.00200	0.000376	0.00310	0.00967	0.00475	0.00134	0.00105	0.00139	0.00098
Silver (Ag)-Dissolved	mg/L	<0.000010	<0.																		

Table A3.2 (Cont'd.)

		GC-W01 2014 April Spring	GC-W01 2013 July-R Summer	GC-W01 2013 September Fall	GC-W02 2014 July Summer	GC-W01 2014 August Summer	GC-W02 2014 October Fall	GC-W02 2015 January Winter	GCT-W01 2015 June Summer	GCT-W02 2015 June Summer	GCT-W03 2015 June Summer	GCT-W04 2015 June Summer	GCT-W05 2015 June Summer	GCT-W-06 2015 June Summer	GCT-W01 2016 March Winter	GCT-W02 2016 March Winter	GCT-W03 2016 March Winter	GCT-W03A 2016 March Winter	GCT-W01 2016 March Winter	CC-W01 2016 March Winter	CC-W01 2016 May Spring
Date Sampled		4/1/2014 6:20:00 PM	7/23/2013 2:27:00 PM	9/23/2013 11:50:00 AM	2014/07/10	8/29/2014 3:30:00 PM	2014/10/23	2015/01/27	6/10/2015	6/10/2015	6/10/2015	6/10/2015	6/10/2015	6/10/2015	3/18/2016	3/19/2016	3/19/2016	3/19/2016	3/18/2016	3/22/2016	5/18/2016
Analyte	Units																				
General Organics																					
Hydrocarbons, Recoverable (I.R.)	mg/L	<1.0	<1.0	<1.0	-	<1.0	-	-	-	-	-	-	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Phenols (4AAP)	mg/L	<0.0010	<0.0010	<0.0010	-	<0.0010	<0.0020	<0.0020	-	-	-	-	-	-	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Benzene	mg/L	<0.00050	<0.00050	<0.00050	-	<0.00050	-	-	-	-	-	-	-	-	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Ethylbenzene	mg/L	<0.00050	<0.00050	<0.00050	-	<0.00050	-	-	-	-	-	-	-	-	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Toluene	mg/L	<0.00050	<0.00050	<0.00050	-	<0.00050	-	-	-	-	-	-	-	-	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
o-xylene	mg/L	<0.00050	<0.00050	<0.00050	-	<0.00050	-	-	-	-	-	-	-	-	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
m+p-Xylene	mg/L	<0.00050	<0.00050	<0.00050	-	<0.00050	-	-	-	-	-	-	-	-	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Xylenes	mg/L	<0.00071	<0.00050	<0.00050	-	<0.00071	-	-	-	-	-	-	-	-	<0.00071	<0.00071	<0.00071	<0.00071	<0.00071	<0.00071	<0.00071
F1(C6-C10)	mg/L	<0.10	<0.10	<0.10	-	<0.10	-	-	-	-	-	-	-	-	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
F1-BTEX	mg/L	<0.10	<0.10	<0.10	-	<0.10	-	-	-	-	-	-	-	-	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
F2 (>C10-C16)	mg/L	<0.25	-	<0.25	-	<0.25	-	-	-	-	-	-	-	-	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
F3 (C16-C34)	mg/L	<0.25	-	<0.25	-	<0.25	-	-	-	-	-	-	-	-	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25
F4 (C34-C50)	mg/L	<0.25		<0.25	-	<0.25	-	-	-	-	-	-	-	-	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	<0.10	<0.10	<0.10	-	<0.10	-	-	-	-	-	-	-	-	<0.10	<0.26	<0.24	<0.10	<0.26	<0.10	<1.0
Polycyclic Aromatic Hydrocarbons																					
Benzo[a]pyrene equivalency	µg/L	-	-	-	-	-	<0.010	<0.010	-	-	-	-	-	-	-	-	-	-	-	-	-
Acenaphthene	µg/L	-	-	-	-	-	<0.10	<0.10	-	-	-	-	-	-	-	-	-	-	-	-	-
Acenaphthylene	µg/L	-	-	-	-	-	<0.10	<0.10	-	-	-	-	-	-	-	-	-	-	-	-	-
Acridine	µg/L	-	-	-	-	-	<0.20	<0.20	-	-	-	-	-	-	-	-	-	-	-	-	-
Anthracene	µg/L	-	-	-	-	-	<0.010	<0.010	-	-	-	-	-	-	-	-	-	-	-	-	-
Benzo(a)anthracene	µg/L	-	-	-	-	-	<0.0085	<0.0085	-	-	-	-	-	-	-	-	-	-	-	-	-
Benzo(b&j)fluoranthene	µg/L	-	-	-	-	-	<0.0085	<0.0085	-	-	-	-	-	-	-	-	-	-	-	-	-
Benzo(k)fluoranthene	µg/L	-	-	-	-	-	<0.0085	<0.0085	-	-	-	-	-	-	-	-	-	-	-	-	-
Benzo(g,h,i)perylene	µg/L	-	-	-	-	-	<0.0085	<0.0085	-	-	-	-	-	-	-	-	-	-	-	-	-
Benzo(c)phenanthrene	µg/L	-	-	-	-	-	<0.050	<0.050	-	-	-	-	-	-	-	-	-	-	-	-	-
Benzo(a)pyrene	µg/L	-	-	-	-	-	<0.0075	<0.0075	-	-	-	-	-	-	-	-	-	-	-	-	-
Benzo[e]pyrene	µg/L	-	-	-	-	-	<0.050	<0.050	-	-	-	-	-	-	-	-	-	-	-	-	-
Chrysene	µg/L	-	-	-	-	-	<0.0085	<0.0085	-	-	-	-	-	-	-	-	-	-	-	-	-
Dibenz(a,h)anthracene	µg/L	-	-	-	-	-	<0.0075	<0.0075	-	-	-	-	-	-	-	-	-	-	-	-	-
Fluoranthene	µg/L	-	-	-	-	-	<0.010	<0.010	-	-	-	-	-	-	-	-	-	-	-	-	-
Fluorene	µg/L	-	-	-	-	-	<0.050	<0.050	-	-	-	-	-	-	-	-	-	-	-	-	-
Indeno(1,2,3-cd)pyrene	µg/L	-	-	-	-	-	<0.0085	<0.0085	-	-	-	-	-	-	-	-	-	-	-	-	-
2-Methylnaphthalene	µg/L	-	-	-	-	-	<0.10	<0.10	-	-	-	-	-	-	-	-	-	-	-	-	-
Naphthalene	µg/L	-	-	-	-	-	<0.10	<0.10	-	-	-	-	-	-	-	-	-	-	-	-	-
Phenanthrene	µg/L	-	-	-	-	-	<0.050	<0.050	-	-	-	-	-	-	-	-	-	-	-	-	-
Perylene	µg/L	-	-	-	-	-	<0.050	<0.050	-	-	-	-	-	-	-	-	-	-	-	-	-
Pyrene	µg/L	-	-	-	-	-	<0.020	<0.020	-	-	-	-	-	-	-	-	-	-	-	-	-
Quinoline	µg/L	-	-	-	-	-	<0.20	<0.20	-	-	-	-	-	-	-	-	-	-	-	-	-

Table A3.3 Water quality raw data – Crowsnest River.

		CRR-W01	CRR-W02	CRR-W01	CRR-W01	CRR-W02	CRR-W02	CRR-W01	CRR-W02	CRR-W01	CRR-W02	CRR-W03	CRR-W01	CRR-W02	CRR-W03	CRR-W03	CRR-W01	CRR-W02
		2013 May Spring	2013 May Spring	2013 July-H High Water	2013 July-R Summer	2013 July-H High Water	2013 July-R Summer	2013 September Fall	2013 September Fall	2014 April Spring	2014 April Spring	2014 July Summer	2014 August Summer	2014 August Summer	2014 October Fall	2015 January Winter	2016 March Winter	2016 March Winter
Date Sampled		5/28/2013 3:45:00 PM	5/28/2013 2:57:00 PM	7/3/2013 5:15:00 PM	7/24/2013 9:03:00 AM	7/3/2013 4:45:00 PM	7/24/2013 8:30:00 AM	9/24/2013 10:38:00 AM	9/24/2013 9:20:00 AM	4/4/2014 11:40:00 AM	4/4/2014 10:45:00 AM	2014/07/10	8/29/2014 1:40:00 PM	8/29/2014 12:30:00 PM	2014/10/23	2015/01/27	2016/03/20	2016/03/18
Analyte	Units																	
Conventional Variables																		
Colour, True	CU	<5.0	<5.0	5.8	<5.0	6.9	<5.0	<5.0	<5.0	<5.0	<5.0	-	<5.0	<5.0	-	-	<5.0	<5.0
Total Suspended Solids	mg/L	7	4	4	<4.0	6	<4.0	<4.0	<4.0	11.8	<6.0	3.3	<3.0	<3.0	-	-	<3.0	<3.0
Total Dissolved Solids	mg/L	172	142	176	212	176	200	198	204	270	271	180	215	219	220	200	1.65	0.95
TDS (Calculated)	mg/L	175	179	169	188	171	190	213	215	263	266	190	209	209	220	210	230	255
Turbidity	NTU	3.83	4.24	7.66	1.06	7.38	1.08	1.14	1.2	3.78	0.44	-	2.39	1.01	-	-	260	267
Conductivity (EC)	µS/cm	301	317	306	352	307	353	346	353	417	420	340	334	337	400	370	406	409
pH	pH	8.22	8.24	8.26	8.32	8.22	8.27	8.23	8.17	8.2	8.2	8.23	8.44	8.23	8.29	8.11	8.09	8.08
Hardness (as CaCO ₃)	mg/L	170	164	149	161	155	163	182	190	230	231	180	173	177	210	200	253	256
Alkalinity, Total (as CaCO ₃)	mg/L	138	142	144	152	142	151	166	159	185	183	150	166	159	150	140	180	177
Dissolved Organic Carbon	mg/L	1.9	1.6	1.6	2	1.5	1.9	2.1	1.8	1.2	<1.0	-	1	<1.0			1.4	<1.0
Total Organic Carbon	mg/L	1.9	1.5	1.5	1.7	1.4	1.6	1.8	1.6	1.4	<1.0	1.2	1	<1.0	1.0	2.1	1.2	<1.0
Major Nutrients																		
Ammonia, Total (as N)	mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	-	0.056	<0.050	-	-	<0.050	<0.050
Nitrate and Nitrite (as N)	mg/L	<0.071	0.081	0.109	0.11	0.12	0.128	0.106	0.127	0.199	0.214	-	0.091	0.116	-	-	0.142	0.159
Nitrate (as N)	mg/L	0.07	0.081	0.109	0.11	0.12	0.128	0.106	0.127	0.199	0.214	0.17	0.091	0.116	<0.010	0.22	0.142	0.159
Nitrite (as N)	mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	-	<0.020	<0.020	<0.010	<0.010	<0.010	<0.010
Total Kjeldahl Nitrogen	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	0.26	0.25	-	0.25	<0.20			<0.20	<0.20
Phosphorus (P)-Total Dissolved	mg/L	<0.0010	<0.0010	0.0028	0.0015	0.0035	0.0016	0.0011	<0.0010	0.008	0.0048	-	0.002	0.0015	<0.10	-	0.0034	0.0024
Phosphorus (P)-Total	mg/L	0.0122	0.0092	0.0186	0.0051	0.0231	0.0055	0.006	0.0055	0.0113	0.0049	-	0.0063	0.0069	-	-	0.0071	0.0047
Biochemical Oxygen Demand	mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	-	<2.0	<2.0	-	-	<2.0	<2.0
Major Ions																		
Calcium (Ca)-Dissolved	mg/L	50.8	49.9	44.2	51.4	46	50.8	53.9	56.2	67.2	67.4	53	51.3	52.4	61	59	76.4	76.8
Magnesium (Mg)-Dissolved	mg/L	10.5	9.56	9.5	10.8	9.72	10.5	11.5	12	15	15.2	11	11	11.3	13	14	15.1	15.6
Potassium (K)-Dissolved	mg/L	0.492	0.399	<0.50	0.497	<0.50	0.485	<0.50	<0.50	0.79	0.69	-	0.53	0.54	0.53	0.71	0.62	0.63
Sodium (Na)-Dissolved	mg/L	3.27	2.88	3.4	4.51	3.5	4.37	4.6	4.7	7.9	7.6	3.7	5.1	5.2	4.6	5.3	8.0	8.1
Bicarbonate (HCO ₃)	mg/L	169	173	176	183	174	184	202	195	225	223	180	182	195	190	170	220	216
Carbonate (CO ₃)	mg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	-	10.5	<5.0	<0.50	<0.50	<5.0	<5.0
Chloride (Cl)	mg/L	1.16	1.14	1.34	1.72	1.3	1.65	2.2	2.1	4.88	3.99	1.9	1.81	1.87	3.3	3.9	2.72	2.62
Hydroxide (OH)	mg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	-	<5.0	<5.0	<0.50	<0.50	<5.0	<5.0
Sulfate (SO ₄)	mg/L	25.2	29.7	23.3	31.8	24.8	33.8	40.5	44	55.1	59.9	30	39	41.7	46	40	48.8	56.1
Sulphide	mg/L	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	0.004	<0.0020	<0.0020	-	0.0029	<0.0015	-	-	<0.0015	<0.0015
Total Metals																		
Aluminum (Al)-Total	mg/L	0.199	0.141	0.148	0.0256	0.135	0.0227	0.0237	0.019	0.0257	0.0144	-	0.0778	0.0339	-	-	0.0384	0.0128
Antimony (Sb)-Total	mg/L	<0.00040	<0.00040	<0.00040	<0.00010	<0.00040	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	-	<0.00010	<0.00010	-	-	<0.00010	<0.00010
Arsenic (As)-Total	mg/L	<0.00040	<0.00040	<0.00040	0.00028	<0.00040	0.00027	0.00028	0.00028	0.00028	0.00024	-	0.00028	0.00025	-	-	0.00024	0.00024
Barium (Ba)-Total	mg/L	0.0612	0.0566	0.0563	0.0592	0.0562	0.0548	0.063	0.0606	0.0764	0.0714	-	0.0619	0.0595	-	-	0.074100	0.069200
Beryllium (Be)-Total	mg/L	<0.0010	<0.0010	<0.0010	<0.00050	<0.0010	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	-	<0.00050	<0.00050	-	-	<0.00010	<0.00010

Table A3.3 (Cont'd.)

		CRR-W01	CRR-W02	CRR-W01	CRR-W01	CRR-W02	CRR-W02	CRR-W01	CRR-W02	CRR-W01	CRR-W02	CRR-W03	CRR-W01	CRR-W02	CRR-W03	CRR-W03	CRR-W01	CRR-W02
		2013 May Spring	2013 May Spring	2013 July-H High Water	2013 July-R Summer	2013 July-H High Water	2013 July-R Summer	2013 September Fall	2013 September Fall	2014 April Spring	2014 April Spring	2014 July Summer	2014 August Summer	2014 August Summer	2014 October Fall	2015 January Winter	2016 March Winter	2016 March Winter
Date Sampled		5/28/2013 3:45:00 PM	5/28/2013 2:57:00 PM	7/3/2013 5:15:00 PM	7/24/2013 9:03:00 AM	7/3/2013 4:45:00 PM	7/24/2013 8:30:00 AM	9/24/2013 10:38:00 AM	9/24/2013 9:20:00 AM	4/4/2014 11:40:00 AM	4/4/2014 10:45:00 AM	2014/07/10	8/29/2014 1:40:00 PM	8/29/2014 12:30:00 PM	2014/10/23	2015/01/27	2016/03/20	2016/03/18
Analyte	Units																	
Total Metals (Cont'd.)																		
Boron (B)-Total	mg/L	<0.050	<0.050	<0.050	<0.010	<0.050	<0.010	<0.010	<0.010	<0.010	0.011	-	0.01	<0.010	-	-	0.011	0.011
Cadmium (Cd)-Total	mg/L	<0.000050	<0.000050	<0.000050	<0.000010	<0.000050	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	-	<0.000010	<0.000010	-	-	0.0000067	<0.0000050
Chromium (Cr)-Total	mg/L	<0.0050	<0.0050	<0.0050	0.00019	<0.0050	0.00019	0.00015	0.00015	0.00014	0.00014	-	0.00022	0.00026	-	-	0.00020	0.00011
Cobalt (Co)-Total	mg/L	<0.0020	<0.0020	<0.0020	<0.00010	<0.0020	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	-	<0.00010	<0.00010	-	-	<0.00010	<0.00010
Copper (Cu)-Total	mg/L	<0.0010	<0.0010	<0.0010	0.00033	<0.0010	0.00025	0.00056	0.00024	0.0004	0.00038	-	0.00053	0.00035	-	-	<0.00050	<0.00050
Iron (Fe)-Total	mg/L	-	-	0.179	0.059	0.171	0.06	-	-	-	-	-	-	-	-	-	0.092	0.058
Lead (Pb)-Total	mg/L	0.00021	0.00017	0.00022	<0.000050	0.0002	<0.000050	<0.000050	<0.000050	0.00009	0.000067	-	0.000097	0.000053	-	-	0.000052	<0.000050
Lithium (Li)-Total	mg/L	<0.010	<0.010	<0.010	<0.0050	<0.010	<0.0050	<0.0050	<0.0050	0.0057	0.006	-	0.0051	0.0053	-	-	0.0053	0.0058
Manganese (Mn)-Total	mg/L	-	-	0.0106	0.00761	0.0107	0.00689	-	-			-			-	-	0.0111	0.0093
Mercury (Hg)-Total	µg/L	0.0016 *	0.0012 *	0.0015	<0.0010 *	0.00156	<0.0010 *	<0.0010 *	<0.0010 *	0.00077	<0.00050	-	0.00073	0.00066	-	-	<0.005	<0.005
Molybdenum (Mo)-Total	mg/L	<0.0050	<0.0050	<0.0050	0.000538	<0.0050	0.000571	0.000621	0.000621	0.000627	0.000671	-	0.000538	0.000549	-	-	0.000599	0.000623
Nickel (Ni)-Total	mg/L	<0.0020	<0.0020	<0.0020	0.00052	<0.0020	0.00054	0.00046	0.00047	0.00052	0.00041	-	0.00044	0.00042	-	-	0.00059	0.00053
Selenium (Se)-Total	mg/L	0.00141	0.00156	0.00181	0.00158	0.00194	0.00168	0.00143	0.0016	0.0012	0.00137	-	0.00142	0.00157	-	-	0.00111	0.00128
Silver (Ag)-Total	mg/L	<0.00010	<0.00010	<0.00010	<0.000010	<0.00010	<0.000010	0.000031	0.000026	<0.000010	<0.000010	-	<0.000010	<0.000010	-	-	<0.000010	<0.000010
Thallium (Tl)-Total	mg/L	<0.00010	<0.00010	<0.00010	<0.000050	<0.00010	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	-	<0.000050	<0.000050	-	-	<0.000010	<0.000010
Tin (Sn)-Total	mg/L	<0.050	<0.050	<0.050	<0.00010	<0.050	<0.00010	0.00029	0.00028	<0.00010	<0.00010	-	<0.00010	<0.00010	-	-	<0.00010	<0.00010
Titanium (Ti)-Total	mg/L	0.0026	0.0016	0.0019	<0.00030	0.0031	0.00063	<0.00030	<0.00030	0.00033	<0.00030	-	0.00147	0.00031	-	-	0.00047	<0.00030
Uranium (U)-Total	mg/L	0.00037	0.00039	0.00037	0.000365	0.00037	0.000374	0.000381	0.000368	0.000495	0.000485	-	0.000392	0.000385	-	-	0.000477	0.000456
Vanadium (V)-Total	mg/L	<0.0010	<0.0010	<0.0010	0.00043	<0.0010	0.00044	0.00043	0.00049	0.00044	0.00035	-	0.00046	0.0004	-	-	<0.00050	<0.00050
Zinc (Zn)-Total	mg/L	<0.0040	<0.0040	<0.0040	<0.0050	<0.0040	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	-	<0.0050	<0.0050	-	-	<0.0030	<0.0030
Dissolved Metals																		
Aluminum (Al)-Dissolved	mg/L	0.004	0.0035	<0.010	<0.0010	<0.010	<0.0010	<0.0010	<0.0010	0.0274	-	0.0052	0.002	0.0011	0.0036	-	0.0033	0.0019
Antimony (Sb)-Dissolved	mg/L	<0.00010	<0.00010	<0.00040	<0.00010	<0.00040	<0.00010	<0.00010	<0.00010	<0.00010	-	-	<0.00010	<0.00010	<0.00060	-	<0.00010	<0.00010
Arsenic (As)-Dissolved	mg/L	0.00023	0.00021	<0.00040	0.00026	<0.00040	0.00025	0.00022	0.00024	0.00028	-	-	0.00024	0.00023	<0.00020	-	0.00020	0.00019
Barium (Ba)-Dissolved	mg/L	0.0666	0.0557	0.0591	0.0596	0.0576	0.0568	0.0583	0.0583	0.0748	-	0.059	0.0604	0.0568	0.063	-	0.0725	0.0699
Beryllium (Be)-Dissolved	mg/L	<0.00050	<0.00050	<0.0010	<0.00050	<0.0010	<0.00050	<0.00050	<0.00050	<0.00050	-	-	<0.00050	<0.00050	<0.0010	-	<0.00010	<0.00010
Boron (B)-Dissolved	mg/L	<0.010	<0.010	<0.050	<0.010	<0.050	<0.010	<0.010	<0.010	0.01	-	-	<0.010	<0.010	<0.020	-	0.010	0.011
Cadmium (Cd)-Dissolved	mg/L	<0.000010	<0.000010	<0.000050	<0.000010	<0.000050	<0.000010	<0.000010	<0.000010	0.000011	-	0.0000073	<0.000010	<0.000010	<0.000020	-	<0.0000050	<0.0000050
Chromium (Cr)-Dissolved	mg/L	0.00012	0.0001	<0.0050	0.00013	<0.0050	0.00012	<0.00010	0.00011	0.00011	-	-	<0.00010	<0.00010	<0.0010	-	<0.00010	<0.00010
Cobalt (Co)-Dissolved	mg/L	<0.00010	<0.00010	<0.0020	<0.00010	<0.0020	<0.00010	<0.00010	<0.00010	<0.00010	-	-	<0.00010	<0.00010	<0.00030	-	<0.00010	<0.00010
Copper (Cu)-Dissolved	mg/L	0.00035	0.00023	<0.0010	0.00013	<0.0010	0.00019	<0.00010	<0.00010	0.00025	-	0.0012	0.00012	<0.00010	0.00043	-	<0.00020	<0.00020
Iron (Fe)-Dissolved	mg/L	<0.010 *	<0.010 *	<0.010	<0.010	<0.010	<0.010	<0.030	<0.030	0.102	0.043	-	<0.030	<0.030	<0.060	<0.060	<0.030	<0.030
Lead (Pb)-Dissolved	mg/L	<0.000050	<0.000050	<0.00010	<0.000050	<0.00010	<0.000050	<0.000050	<0.000050	0.000102	-	-	<0.000050	<0.000050	<0.00020	-	<0.000050	<0.000050
Lithium (Li)-Dissolved	mg/L	<0.0050	<0.0050	0.0035	<0.0050	0.0038	<0.0050	<0.0050	0.0051	0.006	-	-	0.0052	0.0054	<0.020	-	0.0054	0.0060
Manganese (Mn)-Dissolved	mg/L	0.00377	0.00324	0.0046	0.0035	0.0048	0.00324	<0.0050	<0.0050	0.0185	0.0067	0.0047	<0.0050	<0.0050	<0.0040	0.0046	0.0085	0.0068
Mercury (Hg)-Dissolved	µg/L	-	-	-		-	-	-	-	0.00068	<0.00050	-	-	-	-		<0.005	<0.005
Molybdenum (Mo)-Dissolved	mg/L	0.000559	0.000515	<0.0050	0.000512	<0.0050	0.000539	0.00058	0.000602	0.000552	-	0.00057	0.0005	0.00054	0.00068	-	0.000543	0.000575

Table A3.3 (Cont'd.)

		CRR-W01	CRR-W02	CRR-W01	CRR-W01	CRR-W02	CRR-W02	CRR-W01	CRR-W02	CRR-W01	CRR-W02	CRR-W03	CRR-W01	CRR-W02	CRR-W03	CRR-W03	CRR-W01	CRR-W02
		2013 May Spring	2013 May Spring	2013 July-H High Water	2013 July-R Summer	2013 July-H High Water	2013 July-R Summer	2013 September Fall	2013 September Fall	2014 April Spring	2014 April Spring	2014 July Summer	2014 August Summer	2014 August Summer	2014 October Fall	2015 January Winter	2016 March Winter	2016 March Winter
Date Sampled		5/28/2013 3:45:00 PM	5/28/2013 2:57:00 PM	7/3/2013 5:15:00 PM	7/24/2013 9:03:00 AM	7/3/2013 4:45:00 PM	7/24/2013 8:30:00 AM	9/24/2013 10:38:00 AM	9/24/2013 9:20:00 AM	4/4/2014 11:40:00 AM	4/4/2014 10:45:00 AM	2014/07/10	8/29/2014 1:40:00 PM	8/29/2014 12:30:00 PM	2014/10/23	2015/01/27	2016/03/20	2016/03/18
Analyte	Units																	
Dissolved Metals (Cont'd.)																		
Nickel (Ni)-Dissolved	mg/L	0.0004	0.00035	<0.0020	0.00042	<0.0020	0.00043	0.00044	0.00045	0.00057	-	0.00053	0.00029	0.00035	<0.00050	-	<0.00050	<0.00050
Selenium (Se)-Dissolved	mg/L	0.00136	0.00163	0.00186	0.00167	0.00209	0.0018	0.00151	0.00169	0.00128	-	0.0015	0.00149	0.0017	0.0012	-	0.00117	0.00138
Silver (Ag)-Dissolved	mg/L	<0.000010	<0.000010	<0.00010	<0.000010	<0.00010	<0.000010	<0.000010	<0.000010	<0.000010	-	-	<0.000010	<0.000010	<0.00010	-	<0.000010	<0.000010
Thallium (Tl)-Dissolved	mg/L	<0.000050	<0.000050	<0.00010	<0.000050	<0.00010	<0.000050	<0.000050	<0.000050	<0.000050	-	-	<0.000050	<0.000050	<0.00020	-	<0.000010	<0.000010
Tin (Sn)-Dissolved	mg/L	<0.00010	<0.00010	<0.050	<0.00010	<0.050	<0.00010	<0.00010	<0.00010	<0.00010	-	-	<0.00010	<0.00010	<0.0010	-	<0.00010	<0.00010
Titanium (Ti)-Dissolved	mg/L	<0.00030	<0.00030	<0.0010	<0.00030	<0.0010	<0.00030	<0.00030	<0.00030	<0.00030	-	-	<0.00030	<0.00030	<0.0010	-	<0.00030	<0.00030
Uranium (U)-Dissolved	mg/L	0.000387	0.000382	0.00034	0.000329	0.00035	0.00036	0.00036	0.000361	0.000505	-	0.00041	0.000327	0.00032	0.00048	-	0.000432	0.000398
Vanadium (V)-Dissolved	mg/L	0.00024	0.00022	<0.0010	0.00026	<0.0010	0.00027	0.0002	0.00021	0.00028	-	-	0.0002	0.00023	<0.0010	-	<0.00050	<0.00050
Zinc (Zn)-Dissolved	mg/L	<0.0010	<0.0010	0.0028	<0.0010	<0.0020	<0.0010	<0.0050	<0.0050	0.0098	-	0.0038	<0.0050	<0.0050	<0.0030	-	0.0018	0.0016
General Organics																		
Hydrocarbons, Recoverable (I.R.)	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	-	<1.0	<1.0	-	-	<1.0	<1.0
Phenols (4AAP)	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	0.0011	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	-	<0.0010	<0.0010	<0.0020	<0.0020	<0.0010	<0.0010
Benzene	mg/L	-	-	-	<0.00050	-	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	-	<0.00050	<0.00050	-	-	<0.00050	<0.00050
Ethylbenzene	mg/L	-	-	-	<0.00050	-	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	-	<0.00050	<0.00050	-	-	<0.00050	<0.00050
Toluene	mg/L	-	-	-	<0.00050	-	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	-	<0.00050	<0.00050	-	-	<0.00050	<0.00050
o-xylene	mg/L	-	-	-	<0.00050	-	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	-	<0.00050	<0.00050	-	-	<0.00050	<0.00050
m+p-Xylene	mg/L	-	-	-	<0.00050	-	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	-	<0.00050	<0.00050	-	-	<0.00050	<0.00050
Xylenes	mg/L	-	-	-	<0.00050	-	<0.00050	<0.00050	<0.00050	<0.00071	<0.00071	-	<0.00071	<0.00071	-	-	<0.00071	<0.00071
F1(C6-C10)	mg/L	-	-	-	<0.10	-	<0.10	<0.10	<0.10	<0.10	<0.10	-	<0.10	<0.10	-	-	<0.10	<0.10
F1-BTEX	mg/L	-	-	-	<0.10	-	<0.10	<0.10	<0.10	<0.10	<0.10	-	<0.10	<0.10	-	-	<0.10	<0.10
F2 (>C10-C16)	mg/L	-	-	-	-	-	-	<0.25	<0.25	<0.25	<0.25	-	<0.25	<0.25	-	-	<0.10	<0.10
F3 (C16-C34)	mg/L	-	-	-	-	-	-	<0.25	<0.25	<0.25	<0.25	-	<0.25	<0.25	-	-	<0.25	<0.25
F4 (C34-C50)	mg/L	-	-	-	-	-	-	<0.25	<0.25	<0.25	<0.25	-	<0.25	<0.25	-	-	<0.25	<0.25
Naphthenic Acids	mg/L	<0.10	<0.10	0.69	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	-	<0.10	<0.10	-	-	<0.24	<0.35
Polycyclic Aromatic Hydrocarbons																		
Benzo[a]pyrene equivalency	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.010	<0.010	-	-
Acenaphthene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.10	<0.10	-	-
Acenaphthylene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.10	<0.10	-	-
Acridine	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.20	<0.20	-	-
Anthracene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.010	<0.010	-	-
Benzo(a)anthracene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.0085	<0.0085	-	-
Benzo(b&j)fluoranthene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.0085	<0.0085	-	-
Benzo(k)fluoranthene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.0085	<0.0085	-	-
Benzo(g,h,i)perylene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.0085	<0.0085	-	-
Benzo(c)phenanthrene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.050	<0.050	-	-
Benzo(a)pyrene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.0075	<0.0075	-	-
Benzo[e]pyrene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.050	<0.050	-	-

Table A3.3 (Cont'd.)

		CRR-W01	CRR-W02	CRR-W01	CRR-W01	CRR-W02	CRR-W02	CRR-W01	CRR-W02	CRR-W01	CRR-W02	CRR-W03	CRR-W01	CRR-W02	CRR-W03	CRR-W03	CRR-W01	CRR-W02
		2013 May Spring	2013 May Spring	2013 July-H High Water	2013 July-R Summer	2013 July-H High Water	2013 July-R Summer	2013 September Fall	2013 September Fall	2014 April Spring	2014 April Spring	2014 July Summer	2014 August Summer	2014 August Summer	2014 October Fall	2015 January Winter	2016 March Winter	2016 March Winter
Date Sampled		5/28/2013 3:45:00 PM	5/28/2013 2:57:00 PM	7/3/2013 5:15:00 PM	7/24/2013 9:03:00 AM	7/3/2013 4:45:00 PM	7/24/2013 8:30:00 AM	9/24/2013 10:38:00 AM	9/24/2013 9:20:00 AM	4/4/2014 11:40:00 AM	4/4/2014 10:45:00 AM	2014/07/10	8/29/2014 1:40:00 PM	8/29/2014 12:30:00 PM	2014/10/23	2015/01/27	2016/03/20	2016/03/18
Analyte	Units																	
Polycyclic Aromatic Hydrocarbons (Cont'd.)																		
Chrysene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.0085	<0.0085	-	-
Dibenz(a,h)anthracene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.0075	<0.0075	-	-
Fluoranthene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.010	<0.010	-	-
Fluorene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.050	<0.050	-	-
Indeno(1,2,3-cd)pyrene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.0085	<0.0085	-	-
2-Methylnaphthalene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.10	<0.10	-	-
Naphthalene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.10	<0.10	-	-
Phenanthrene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.050	<0.050	-	-
Perylene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.050	<0.050	-	-
Pyrene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.020	<0.020	-	-
Quinoline	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.20	<0.20	-	-

Table A3.4 Water quality raw data – End Pit Lakes.

		PL-W1	PL-W2	PL-W3	PL-W3	PL-W1	PL-W2	PL-W1	PL-W2	PL-W3	PL-W1A
		2014 July Summer	2014 July Summer	2014 July Summer	2014 October Fall	2014 October Fall	2014 October Fall	2015 Feb Winter	2015 Feb Winter	2015 Feb Winter	2015 Feb Winter
Date Sampled		2014/07/10	2014/07/10	2014/07/10	2014/10/23	2014/10/23	2014/10/23	2/23/2015 4:00:00 PM	2/23/2015 4:00:00 PM	2/23/2015 5:00:00 PM	2/23/2015 3:10:00 PM
Analyte	Units										
Conventional Variables											
Colour, True	CU	-	-	-	-	-	-	<5.0	<5.0	<5.0	<5.0
Total Suspended Solids	mg/L	12	1.3	-	-	-	-	<3.0	<3.0	<3.0	<3.0
Turbidity	NTU	-	-	-	-	-	-	0.73	3.23	1.21	0.41
Total Dissolved Solids	mg/L	220	200	200	260	260	300	240	160	245	275
TDS (Calculated)	mg/L	250	240	220	240	280	300	309	171	263	306
Conductivity (EC)	µS/cm	470	410	410	450	510	510	558	340	481	558
pH	pH	8.55	8.32	8.38	8.21	8.41	8.25	8.32	8.28	8.26	8.37
Hardness (as CaCO ₃)	mg/L	260	230	230	250	280	280	331	169	273	325
Alkalinity, Total (as CaCO ₃)	mg/L	190	130	160	180	220	140	251	166	202	248
Dissolved Organic Carbon	mg/L							2	2	1.3	1.8
Total Organic Carbon	mg/L	2.4	1.2	1.4	1.5	2.4	1.4	2	2.1	1.4	2
Major Nutrients											
Ammonia, Total (as N)	mg/L	-	-	-	-	-	-	<0.050	<0.050	<0.050	<0.050
Nitrate and Nitrite (as N)	mg/L	-	-	-	-	-	-	<0.050	<0.050	<0.050	<0.050
Nitrate (as N)	mg/L	-	-	-	<0.010	<0.010	<0.010	0.026	<0.020	0.024	<0.020
Nitrite (as N)	mg/L	-	-	-	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Total Kjeldahl Nitrogen	mg/L							<0.20	<0.20	<0.20	<0.20
Phosphorus (P)-Total Dissolved	mg/L	-	-	-	<0.10	0.10	<0.10	0.0017	0.0054	0.0039	0.0019
Phosphorus (P)-Total	mg/L	-	-	-	-	-	-	0.0061	0.0105	0.0101	0.006
Biochemical Oxygen Demand	mg/L	-	-	-	-	-	-	<2.0	<2.0	<2.0	<2.0
Major Ions											
Calcium (Ca)-Dissolved	mg/L	40	44	48	55	47	57	47.4	33.6	54.4	46.9
Magnesium (Mg)-Dissolved	mg/L	40	28	27	27	40	33	51.6	20.6	33.4	50.5
Potassium (K)-Dissolved	mg/L	1.4	0.83	1.0	1.2	1.7	1.2	1.93	1.48	1.48	1.87
Sodium (Na)-Dissolved	mg/L	2.9	0.54	-	<0.50	2.9	<0.50	3.7	4.1	<1.0	3.6
Bicarbonate (HCO ₃)	mg/L	220	150	190	230	270	180	300	202	246	291
Carbonate (CO ₃)	mg/L	7.3	-	2.9	<0.50	2.9	<0.50	<5.0	<5.0	<5.0	5.6
Chloride (Cl)	mg/L	-	-	-	1.2	1.3	<1.0	<0.50	<0.50	<0.50	<0.50
Hydroxide (OH)	mg/L	-	-	-	<0.50	<0.50	<0.50	<5.0	<5.0	<5.0	<5.0
Sulfate (SO ₄)	mg/L	51	87	50	47	49	120	54	11.9	52.9	54.1
Sulphide (as S)	mg/L	-	-	-	-	-	-	<0.0015	<0.0015	<0.0015	<0.0015

Table A3.4 (Cont'd.)

		PL-W1	PL-W2	PL-W3	PL-W3	PL-W1	PL-W2	PL-W1	PL-W2	PL-W3	PL-W1A
		2014 July Summer	2014 July Summer	2014 July Summer	2014 October Fall	2014 October Fall	2014 October Fall	2015 Feb Winter	2015 Feb Winter	2015 Feb Winter	2015 Feb Winter
Date Sampled		2014/07/10	2014/07/10	2014/07/10	2014/10/23	2014/10/23	2014/10/23	2/23/2015 4:00:00 PM	2/23/2015 4:00:00 PM	2/23/2015 5:00:00 PM	2/23/2015 3:10:00 PM
Analyte	Units										
Total Metals											
Aluminum (Al)-Total	mg/L	-	-	-	-	-	-	0.0077	0.0327	0.0057	0.0048
Antimony (Sb)-Total	mg/L	-	-	-	-	-	-	0.00028	0.00019	0.00022	0.00028
Arsenic (As)-Total	mg/L	-	-	-	-	-	-	0.00042	0.00049	0.00047	0.0004
Barium (Ba)-Total	mg/L	-	-	-	-	-	-	0.15	0.166	0.145	0.151
Beryllium (Be)-Total	mg/L	-	-	-	-	-	-	<0.00050	<0.00050	<0.00050	<0.00050
Boron (B)-Total	mg/L	-	-	-	-	-	-	0.086	0.039	0.028	0.087
Cadmium (Cd)-Total	mg/L	-	-	-	-	-	-	0.000012	0.000034	0.000033	0.000012
Chromium (Cr)-Total	mg/L	-	-	-	-	-	-	<0.00010	0.00011	0.00014	<0.00010
Cobalt (Co)-Total	mg/L	-	-	-	-	-	-	<0.00010	0.00041	<0.00010	<0.00010
Copper (Cu)-Total	mg/L	-	-	-	-	-	-	0.00068	0.00108	0.00078	0.00054
Iron (Fe)-Total	mg/L	-	-	-	-	-	-	0.02	0.093	0.022	<0.010
Lead (Pb)-Total	mg/L	-	-	-	-	-	-	<0.000050	0.000107	<0.000050	<0.000050
Lithium (Li)-Total	mg/L	-	-	-	-	-	-	0.021	0.0098	0.0125	0.0216
Manganese (Mn)-Total	mg/L	-	-	-	-	-	-	0.00116	0.0518	0.00697	0.00087
Mercury (Hg)-Total	µg/L	-	-	-	-	-	-	0.00065	0.00204	0.0006	0.00054
Molybdenum (Mo)-Total	mg/L	-	-	-	-	-	-	0.00191	0.00107	0.00137	0.00192
Nickel (Ni)-Total	mg/L	-	-	-	-	-	-	0.00129	0.00205	0.00186	0.00126
Selenium (Se)-Total	mg/L	-	-	-	-	-	-	0.0004	0.00023	0.00179	0.0004
Silver (Ag)-Total	mg/L	-	-	-	-	-	-	<0.000010	<0.000010	<0.000010	<0.000010
Thallium (Tl)-Total	mg/L	-	-	-	-	-	-	<0.000050	<0.000050	<0.000050	<0.000050
Tin (Sn)-Total	mg/L	-	-	-	-	-	-	<0.00010	<0.00010	<0.00010	<0.00010
Titanium (Ti)-Total	mg/L	-	-	-	-	-	-	<0.00030	<0.00030	<0.00030	<0.00030
Uranium (U)-Total	mg/L	-	-	-	-	-	-	0.000941	0.00043	0.00063	0.000942
Vanadium (V)-Total	mg/L	-	-	-	-	-	-	<0.00050	<0.00050	<0.00050	<0.00050
Zinc (Zn)-Total	mg/L	-	-	-	-	-	-	0.0158	0.011	0.0112	0.0052
Dissolved Metals											
Aluminum (Al)-Dissolved	mg/L	0.028	0.017	0.0033	0.0069	0.0044	<0.0030	<0.0010	0.0027	<0.0010	0.0012
Antimony (Sb)-Dissolved	mg/L	-	-	-	<0.00060	<0.00060	<0.00060	0.00026	0.00016	0.0002	0.00024
Arsenic (As)-Dissolved	mg/L	0.00026	-	0.00029	0.00036	0.00024	<0.00020	0.00038	0.00043	0.00046	0.00038
Barium (Ba)-Dissolved	mg/L	0.13	0.074	0.13	0.14	0.14	0.076	0.151	0.161	0.14	0.149
Beryllium (Be)-Dissolved	mg/L	-	-	-	<0.0010	<0.0010	<0.0010	<0.00050	<0.00050	<0.00050	<0.00050
Boron (B)-Dissolved	mg/L	0.070	0.026	-	0.025	0.072	0.033	0.085	0.04	0.029	0.084
Cadmium (Cd)-Dissolved	mg/L	6.8E-06	0.000029	0.000028	<0.000020	<0.000020	0.000	<0.000010	0.000025	0.000022	<0.000010
Chromium (Cr)-Dissolved	mg/L	-	-	-	<0.0010	<0.0010	<0.0010	<0.00010	<0.00010	<0.00010	<0.00010
Cobalt (Co)-Dissolved	mg/L	-	-	-	<0.00030	<0.00030	<0.00030	<0.00010	0.00027	<0.00010	<0.00010
Copper (Cu)-Dissolved	mg/L	0.00097	0.00052	0.00053	0.00074	0.00052	0.00048	0.00059	0.0008	0.00058	0.00041

Table A3.4 (Cont'd.)

		PL-W1	PL-W2	PL-W3	PL-W3	PL-W1	PL-W2	PL-W1	PL-W2	PL-W3	PL-W1A
		2014 July Summer	2014 July Summer	2014 July Summer	2014 October Fall	2014 October Fall	2014 October Fall	2015 Feb Winter	2015 Feb Winter	2015 Feb Winter	2015 Feb Winter
Date Sampled		2014/07/10	2014/07/10	2014/07/10	2014/10/23	2014/10/23	2014/10/23	2/23/2015 4:00:00 PM	2/23/2015 4:00:00 PM	2/23/2015 5:00:00 PM	2/23/2015 3:10:00 PM
Analyte	Units										
Dissolved Metals (Cont'd.)											
Iron (Fe)-Dissolved	mg/L	-	-	-	<0.060	0.066	0.062	<0.030	<0.030	<0.030	<0.030
Lead (Pb)-Dissolved	mg/L	-	-	-	<0.00020	<0.00020	<0.00020	<0.000050	<0.000050	<0.000050	<0.000050
Lithium (Li)-Dissolved	mg/L	-	0.024	-	<0.020	0.025	0.033	0.0218	0.01	0.013	0.0212
Manganese (Mn)-Dissolved	mg/L	0.017	-	-	<0.0040	<0.0040	0.019	<0.0050	0.0376	0.0053	<0.0050
Mercury (Hg)-Dissolved	µg/L							<0.00050 *	0.00096 *	<0.00050 *	<0.00050 *
Molybdenum (Mo)-Dissolved	mg/L	0.0018	0.00038	0.0012	0.0014	0.0018	0.00038	0.00165	0.000973	0.00124	0.00167
Nickel (Ni)-Dissolved	mg/L	0.0019	0.0024	0.0012	0.0015	0.0010	0.0017	0.00109	0.00164	0.00166	0.00112
Selenium (Se)-Dissolved	mg/L	0.00222	0.00054	0.00222	0.0011	0.00098	-	0.0022	<0.00020	-	
Silver (Ag)-Dissolved	mg/L	-	-	-	<0.00010	<0.00010	<0.00010	<0.000010	<0.000010	<0.000010	<0.000010
Thallium (Tl)-Dissolved	mg/L	-	-	-	<0.00020	<0.00020	<0.00020	<0.000050	<0.000050	<0.000050	<0.000050
Tin (Sn)-Dissolved	mg/L	-	-	-	<0.0010	<0.0010	<0.0010	<0.00010	<0.00010	<0.00010	<0.00010
Titanium (Ti)-Dissolved	mg/L	-	-	-	<0.0010	<0.0010	<0.0010	<0.00030	<0.00030	<0.00030	<0.00030
Uranium (U)-Dissolved	mg/L	0.00094	0.00027	0.00065	0.00066	0.00092	0.00025	0.000792	0.000375	0.00056	0.000814
Vanadium (V)-Dissolved	mg/L	-	-	-	<0.0010	<0.0010	<0.0010	0.00016	0.00013	0.0001	0.00017
Zinc (Zn)-Dissolved	mg/L	-	-	-	<0.0030	<0.0030	<0.0030	0.0159	0.0089	0.012	<0.0050
General Organics											
Hydrocarbons, Recoverable (I.R.)	mg/L	-	-	-	-	-	-	<1.0	<1.0	<1.0	<1.0
Phenols (4AAP)	mg/L	-	-	-	<0.0020	<0.0020	<0.0020	<0.0010	<0.0010	<0.0010	<0.0010
Benzene	mg/L	-	-	-	-	-	-	<0.00050	<0.00050	<0.00050	<0.00050
Ethylbenzene	mg/L	-	-	-	-	-	-	<0.00050	<0.00050	<0.00050	<0.00050
Toluene	mg/L	-	-	-	-	-	-	<0.00050	<0.00050	<0.00050	<0.00050
o-xylene	mg/L	-	-	-	-	-	-	<0.00050	<0.00050	<0.00050	<0.00050
m+p-Xylene	mg/L	-	-	-	-	-	-	<0.00050	<0.00050	<0.00050	<0.00050
Xylenes	mg/L	-	-	-	-	-	-	<0.00071	<0.00071	<0.00071	<0.00071
F1(C6-C10)	mg/L	-	-	-	-	-	-	<0.10	<0.10	<0.10	<0.10
F1-BTEX	mg/L	-	-	-	-	-	-	<0.10	<0.10	<0.10	<0.10
F2 (>C10-C16)	mg/L	-	-	-	-	-	-	<0.25	<0.25	<0.25	<0.25
F3 (C16-C34)	mg/L	-	-	-	-	-	-	<0.25	<0.25	<0.25	<0.25
F4 (C34-C50)	mg/L	-	-	-	-	-	-	<0.25	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	-	-	-	-	-	<0.10	<0.10	<0.10	<0.10

Table A3.4 (Cont'd.)

		PL-W1	PL-W2	PL-W3	PL-W3	PL-W1	PL-W2	PL-W1	PL-W2	PL-W3	PL-W1A
		2014 July Summer	2014 July Summer	2014 July Summer	2014 October Fall	2014 October Fall	2014 October Fall	2015 Feb Winter	2015 Feb Winter	2015 Feb Winter	2015 Feb Winter
Date Sampled		2014/07/10	2014/07/10	2014/07/10	2014/10/23	2014/10/23	2014/10/23	2/23/2015 4:00:00 PM	2/23/2015 4:00:00 PM	2/23/2015 5:00:00 PM	2/23/2015 3:10:00 PM
Analyte	Units										
Polycyclic Aromatic Hydrocarbons											
Benzo[a]pyrene equivalency	µg/L	-	-	-	<0.010	<0.010	<0.010	-	-	-	-
Acenaphthene	µg/L	-	-	-	<0.10	<0.10	<0.10	-	-	-	-
Acenaphthylene	µg/L	-	-	-	<0.10	<0.10	<0.10	-	-	-	-
Acridine	µg/L	-	-	-	<0.20	<0.20	<0.20	-	-	-	-
Anthracene	µg/L	-	-	-	<0.010	<0.010	<0.010	-	-	-	-
Benzo(a)anthracene	µg/L	-	-	-	<0.0085	<0.0085	<0.0085	-	-	-	-
Benzo(b&j)fluoranthene	µg/L	-	-	-	<0.0085	<0.0085	<0.0085	-	-	-	-
Benzo(k)fluoranthene	µg/L	-	-	-	<0.0085	<0.0085	<0.0085	-	-	-	-
Benzo(g,h,i)perylene	µg/L	-	-	-	<0.0085	<0.0085	<0.0085	-	-	-	-
Benzo(c)phenanthrene	µg/L	-	-	-	<0.050	<0.050	<0.050	-	-	-	-
Benzo(a)pyrene	µg/L	-	-	-	<0.0075	<0.0075	<0.0075	-	-	-	-
Benzo[e]pyrene	µg/L	-	-	-	<0.050	<0.050	<0.050	-	-	-	-
Chrysene	µg/L	-	-	-	<0.0085	<0.0085	<0.0085	-	-	-	-
Dibenz(a,h)anthracene	µg/L	-	-	-	<0.0075	<0.0075	<0.0075	-	-	-	-
Fluoranthene	µg/L	-	-	-	<0.010	<0.010	<0.010	-	-	-	-
Fluorene	µg/L	-	-	-	<0.050	<0.050	<0.050	-	-	-	-
Indeno(1,2,3-cd)pyrene	µg/L	-	-	-	<0.0085	<0.0085	<0.0085	-	-	-	-
2-Methylnaphthalene	µg/L	-	-	-	<0.10	<0.10	<0.10	-	-	-	-
Naphthalene	µg/L	-	-	-	<0.10	<0.10	<0.10	-	-	-	-
Phenanthrene	µg/L	-	-	-	<0.050	<0.050	<0.050	-	-	-	-
Perylene	µg/L	-	-	-	<0.050	<0.050	<0.050	-	-	-	-
Pyrene	µg/L	-	-	-	<0.020	<0.020	<0.020	-	-	-	-
Quinoline	µg/L	-	-	-	<0.20	<0.20	<0.20	-	-	-	-

Table A3.5 Sediment metals raw data – Blairmore Creek and Gold Creek.

Parameter	Lowest Detection Limit	Units	ISQG	PEL	BC-S02	BC-S03	BC-S01	Dup (BC-S01)	GC-S03	GC-S02	GC-S04	GC-S01
					20-Jun-2016	21-Jun-2016	21-Jun-2016	21-Jun-2016	20-Jun-2016	20-Jun-2016	21-Jun-2016	20-Jun-2016
Aluminum (Al)	50	mg/kg			12,900	18,400	13,900	14,400	9,070	4,240	19,600	12,200
Antimony (Sb)	0.10	mg/kg			0.57	0.60	0.55	0.53	0.58	0.21	0.67	0.59
Arsenic (As)	0.10	mg/kg	5.9	17	7.94	9.30	9.17	8.64	5.15	2.13	8.46	6.12
Barium (Ba)	0.50	mg/kg			390	365	371	354	189	72.0	304	173
Beryllium (Be)	0.10	mg/kg			1.15	0.97	1.16	1.08	0.59	0.27	1.00	0.65
Bismuth (Bi)	0.20	mg/kg			<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	0.22	<0.20
Boron (B)	5.0	mg/kg			5.6	<5.0	5.2	6.7	6.5	8.8	6.8	8.4
Cadmium (Cd)	0.020	mg/kg	0.6	3.5	1.38	0.488	0.798	0.716	0.670	0.492	0.809	0.521
Calcium (Ca)	50	mg/kg			29,200	5,820	24,300	22,200	56,000	34,400	12,200	47,400
Chromium (Cr)	0.50	mg/kg	37.3	90	16.3	21.9	16.6	19.0	13.6	8.00	25.4	17.0
Cobalt (Co)	0.10	mg/kg			18.6	12.6	12.7	12.0	6.88	2.62	12.8	6.88
Copper (Cu)	0.50	mg/kg	35.7	197	27.6	25.7	25.5	25.0	19.4	9.35	35.5	16.8
Iron (Fe)	50	mg/kg			25,800	28,500	23,800	24,000	15,800	6,520	35,000	19,500
Lead (Pb)	0.50	mg/kg	35	91.3	10.1	15.0	13.4	13.8	8.45	3.17	13.6	9.18
Lithium (Li)	2.0	mg/kg			13.7	21.1	14.6	15.2	11.1	8.7	22.4	13.1
Magnesium (Mg)	20	mg/kg			5,850	4,100	4,640	4,850	13,400	11,200	8,050	11,600
Manganese (Mn)	1.0	mg/kg			852	633	555	532	304	88.9	500	296
Mercury (Hg)	0.0050	mg/kg	0.17	0.486	0.0333	0.0249	0.0322	0.0298	0.0382	0.0320	0.0347	0.160
Molybdenum (Mo)	0.10	mg/kg			1.01	1.23	1.00	0.87	1.33	1.80	2.08	1.11
Nickel (Ni)	0.50	mg/kg			39.9	31.7	28.1	27.3	21.5	11.6	38.5	22.4
Phosphorus (P)	50	mg/kg			728	616	630	972	645	600	902	624
Potassium (K)	100	mg/kg			1,680	2,150	1,980	1,970	1,370	890	2,670	1,890
Selenium (Se)	0.20	mg/kg	2		0.96	0.70	0.88	0.83	1.43	4.92	0.79	0.56
Silver (Ag)	0.10	mg/kg			0.11	0.12	0.11	0.11	0.12	<0.10	0.11	<0.10
Sodium (Na)	50	mg/kg			120	93	141	143	83	65	99	87
Strontium (Sr)	0.50	mg/kg			92.3	54.0	170	131	57.7	41.1	33.0	45.3
Thallium (Tl)	0.050	mg/kg			0.149	0.194	0.186	0.181	0.133	0.079	0.222	0.160
Tin (Sn)	2.0	mg/kg			<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Titanium (Ti)	1.0	mg/kg			143	64.1	105	101	44.3	12.2	45.9	64.7
Uranium (U)	0.050	mg/kg			0.872	0.727	0.687	0.777	0.741	2.43	0.659	0.541
Vanadium (V)	0.20	mg/kg			38.3	47.5	39.4	39.4	29.1	16.3	47.2	36.1
Zinc (Zn)	2.0	mg/kg	123	315	158	103	114	108	72	74	133	86
Zirconium (Zr)	1.0	mg/kg			1.2	1.2	1.3	1.6	1.3	1.3	1.3	1.3

Table A3.6 Periphyton metals raw data – Blairmore Creek and Gold Creek.

Variables	Detection Limit	Units	BC-P04	BC-P03	BC-P02	BC-P01	GC-P02	GC-P03	GC-P01
			10-Jun-2016	10-Jun-2016	10-Jun-2016	10-Jun-2016	21-Jun-2016	21-Jun-2016	21-Jun-2016
Aluminum (Al)	50	mg/kg	11,416	13,666	20,795	7,018	4,660	13,600	2,790
Antimony (Sb)	0.10	mg/kg	0.27	0.46	0.66	0.28	0.23	0.55	0.16
Arsenic (As)	0.10	mg/kg	4.50	10.74	11.70	4.37	2.95	6.06	3.68
Barium (Ba)	0.50	mg/kg	345	1185	2080	714	163	238	77.8
Beryllium (Be)	0.10	mg/kg	0.61	1.37	2.09	0.65	0.24	0.67	0.14
Bismuth (Bi)	0.20	mg/kg	<0.20	<0.20	0.23	<0.20	<0.20	<0.20	<0.20
Boron (B)	5.0	mg/kg	22.72	56.90	125.23	37.16	99.4	7.8	<5
Cadmium (Cd)	0.020	mg/kg	0.599	3.482	5.413	2.213	0.358	0.765	0.263
Calcium (Ca)	50	mg/kg	103,311	712,221	1,307,339	449,704	155,000	12,100	27,300
Chromium (Cr)	0.50	mg/kg	13.58	15.64	22.17	6.83	7.83	17.6	5.26
Cobalt (Co)	0.10	mg/kg	5.15	20.89	33.33	13.02	2.58	8.35	2.83
Copper (Cu)	0.50	mg/kg	18.61	29.04	43.12	13.25	8.37	25.8	5.90
Iron (Fe)	50	mg/kg	13,927	22,208	29,511	9,976	6,000	22,100	5,120
Lead (Pb)	0.50	mg/kg	7.92	10.20	16.67	5.33	3.87	9.22	2.25
Lithium (Li)	2.0	mg/kg	11.42	15.77	24.46	7.10	7.8	16.3	3.3
Magnesium (Mg)	20	mg/kg	4,852	10,762	18,960	6,651	13,300	5,620	7,080
Manganese (Mn)	1.0	mg/kg	245	1,305	2,018	898	137	356	303
Mercury (Hg)	0.0050	mg/kg	0.0320	0.0460	0.0734	0.0320	0.0062	0.0416	0.0081
Molybdenum (Mo)	0.10	mg/kg	0.87	1.80	2.11	1.02	0.58	1.56	0.33
Nickel (Ni)	0.50	mg/kg	20.55	43.36	63.46	26.04	10.5	26.3	9.06
Phosphorus (P)	50	mg/kg	1,655	2,300	2,859	1,716	1,090	1,360	1,600
Potassium (K)	100	mg/kg	4,361	4,625	6,468	2,982	2,110	6,040	1,610
Selenium (Se)	0.20	mg/kg	1.70	6.14	9.66	3.76	1.98	1.71	3.15
Silver (Ag)	0.10	mg/kg	<0.10	0.11	0.18	<0.10	<0.10	0.12	<0.10
Sodium (Na)	50	mg/kg	426	761	869	548	224	129	148
Strontium (Sr)	0.50	mg/kg	239	1353	2187	795	177	32	30
Thallium (Tl)	0.050	mg/kg	0.172	0.247	0.381	0.135	0.085	0.142	0.062
Tin (Sn)	2.0	mg/kg	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Titanium (Ti)	1.0	mg/kg	339	315	353	123	58	48	37
Uranium (U)	0.050	mg/kg	0.638	1.083	1.636	0.570	0.374	0.460	0.306
Vanadium (V)	0.20	mg/kg	40.5	53.6	67.3	20.4	13.0	32.8	8.50
Zinc (Zn)	2.0	mg/kg	60	202	266	115	66	98	65
Zirconium (Zr)	1.0	mg/kg	7.71	10.41	14.42	5.07	1.1	<1.0	2.0