8. ASSESSMENT OF SURFACE WATER AND AQUATIC RESOURCES EFFECTS

8.1 INTRODUCTION

Surface water is a critical component of the biological and physical environment and is protected under both provincial (e.g., *Environmental Management Act* [2004], *Mines Act* [1996]) and federal (e.g., *Canada Water Act* [1985]) legislation. In this chapter, the potential effects of the proposed Murray River Coal Project (the Project) on surface water and aquatic resources are assessed. A pre-development baseline was conducted to allow for the prediction, assessment, mitigation and management of potential Project-related effects and was incorporated into mine and mine waste management planning. The baseline study reports and data (2010 to 2014) are located in Appendices 8-A to 8-D.

Surface water hydrology is a key component of the physical and biological environment because it is linked to other ecosystem components, including surface water quality, fish and fish habitat, and aquatic resources. From a water resource perspective, an understanding of the surface water runoff characteristics within and downstream of the Project area is critical to support an environmental effects assessment as well as to contribute to engineering analysis and the design of water management features. The timing and magnitude of surface water flows have implications for water quantity and quality, and consequently for the organisms that inhabit waterbodies and riparian zones.

Water quality constitutes the physical, chemical, biological, and aesthetic characteristics of water which are, in turn, determined by a variety of regional and local factors including rock weathering, surface transport, biological activity, and anthropogenic influences. The chemical compositions of water and sediment will co-vary, with factors such as pH and temperature driving a dynamic and reversible exchange of elements and molecules between the water column and the underlying sedimentary materials.

Aquatic resources refer to the biological communities residing within the water column and sedimentary system compartments of the freshwater environment. These communities include primary producers (organisms that photosynthesize to produce their own energy and form the base of the food web) and secondary producers (organisms that feed on primary producers and on each other). Phytoplankton and periphyton are primary producers that live in the water column and on submerged surfaces, respectively, and perform the key biogeochemical process of producing organic matter from inorganic nutrients and carbon by photosynthesis. As primary producers, phytoplankton and periphyton are important food sources for grazers, and benthic invertebrates (which, in turn, are consumed by fish), and therefore comprise the base of lake and stream food webs, ultimately driving ecosystem bioenergetics.

Phytoplankton and periphyton also affect water chemistry through their interactions with the carbon, nitrogen, and phosphorus biogeochemical cycles and can be significant sinks and sources of organic carbon and nutrients (Wetzel 2001). Because of their short life cycles, phytoplankton and periphyton are among the first organisms to respond to environmental change, and can exhibit taxon-specific responses to stressors, making them good indicators of current environmental conditions. Periphyton community composition is also used as an indicator of biotic integrity and ecosystem health (Hill et al. 2000).

Secondary producers constitute benthic invertebrate communities (benthos) and represent a critical link between primary producer communities and higher trophic levels in aquatic ecosystems. Benthos have diets that include algae, bacteria, and detritus and are also an important food source for fish. Benthos are also widely used as indicators of environmental conditions and change due to their close contact with benthic substrates, they are abundant and sessile, and have a wide range of environmental tolerances that are often taxon-specific (Hilsenhoff 1988; Poulton et al. 1995).

Changes of water and sediment quality can affect the diversity, abundance and activities of primary and secondary producer communities. Such effects to aquatic resources may cascade to higher trophic levels that depend directly or indirectly on primary and secondary producer communities to survive, including birds, amphibians and fish. Other roles served by aquatic resources include nutrient and organic matter cycling, photosynthesis, the stabilization of substrata and providing habitat for other organisms. Further, due to their limited mobility and life history characteristics (e.g., living on or in sediment) aquatic communities are closely linked to the physical features of their habitat and, as such, are useful for detecting potential shifts or disturbances of sediment quality, water quality, and aquatic habitat in general.

Surface water and aquatic resources effects have linkages with other Valued Components (VCs) and these effects are primarily assessed in the following chapters:

- Chapter 9, Assessment of Fish and Fish Habitat Effects;
- Chapter 12, Assessment of Wetlands Effects;
- Chapter 13, Assessment of Wildlife Effects; and
- Chapter 18, Assessment of Health Effects.

8.2 Regulatory and Policy Framework

This section provides an overview of the relevant provincial and federal statutory framework, guidance documents, and policies related to potential Project-related surface water and aquatic resources effects (summarized in Table 8.2-1).

8.3 Regional Overview

The Murray River Coal Project is located in the Central Canadian Rocky Mountains ecoregion of British Columbia (BC), within the upper Peace River watershed near the community of Tumbler Ridge. The area is characterized by hills and low mountains with broad valleys incised by rivers and streams. Mature forests of hybrid spruce and lodgepole pine typically dominate the landscape. The Project is located within the Peace River Coalfield (PRC) which encompasses two main coal-bearing units: the Gates Formation and the Gething Formation.

Table 8.2-1. Surface Water Legislation, Regulations, Policy, Standards, and Guidelines

Name	Year	Type	Level of Government	Description
BC *Water Act*	1996	Act	Provincial	Under the BC *Water Act*, the ownership of water is vested in the Crown; the act provides statutes governing the allocation of water licences and controls the use of freshwater in the province of British Columbia. The Act also includes explicit environmental protection for waters flowing in a stream, lake, or other surface body of water.
Canada Water Act	1985	Act	Federal	Management of the water resources including research and the planning and implementation of programs relating to the conservation, development and utilization of water resources.
Environmental Management Act	2004	Act	Provincial	Prohibits pollution of the environment and requires authorization to introduce waste into the environment for "prescribed" industries, trades, businesses, operations and activities.
Fisheries Act	2012	Act	National	The Fisheries Protection Policy Statement (DFO 2013) supports changes made to the Fisheries Act (1985) in 2012. The changes to the *Fisheries Act* include a prohibition against causing serious harm to fish that are part of or support a commercial, recreational, or Aboriginal fishery (Section 35 of the *Fisheries Act*); provisions for flow and passage (Sections 20 and 21 of the *Fisheries Act*); and a framework for regulatory decision-making (Sections 6 and 6.1 of the *Fisheries Act*). These provisions guide the Minister's decision-making process in order to provide for sustainable and productive fisheries. Section 36(3) of the Act states "no person shall deposit or permit the deposit of a deleterious substance of any type in water frequented by fish."
Mines Act	1996	Act	Provincial	The BC *Mines Act* and its associated Health, Safety and Reclamation Code for Mines (the Code; BC MEMPR 2008) in BC require mines to have programs for the environmental protection of land and watercourses throughout mine life, including plans for prediction and prevention of metal leaching and acid rock drainage, and prevention of erosion and sediment release. Watercourses are required to be reclaimed, and the Ministry of Energy and Mines has the authority to require monitoring and/or remediation programs to protect watercourses and water quality.

(continued)

Table 8.2-1. Surface Water Legislation, Regulations, Policy, Standards, and Guidelines (continued)

Name	Year	Type	Level of Government	Description
BC Water Quality Guidelines (Approved and Working)	2014	Guideline	Provincial	Water quality criteria are defined as maximum or minimum physical, chemical, or biological characteristics of water, biota or sediment; and are applicable province wide. The guidelines are intended to prevent detrimental effects on water quality or aquatic life, under specified environmental conditions. Guidelines for drinking water supply and wildlife water supply.
CCME Water Quality Guidelines	2014	Guideline	National	Environmental Quality Guidelines (EQGs) are intended to protect, sustain, and enhance the quality of the Canadian environment. Each jurisdiction determines the degree to which it will adopt CCME recommendations and EQGs should not be regarded as blanket values for national environmental quality; users of EQGs consider local conditions and other supporting information (e.g., site-specific background concentrations of naturally occurring substances) during the implementation. Science-based site-specific criteria, guidelines, objectives, or standards may, therefore, differ from the Canadian EQGs.
CCME Sediment Quality Guidelines	2014	Guideline	National	Environmental Quality Guidelines (EQGs) are intended to protect, sustain, and enhance the quality of the Canadian environment. Each jurisdiction determines the degree to which it will adopt CCME recommendations and EQGs should not be regarded as blanket values for national environmental quality; users of EQGs consider local conditions and other supporting information (e.g., site-specific background concentrations of naturally occurring substances) during Project implementation. Science-based site-specific criteria, guidelines, objectives, or standards may, therefore, differ from the Canadian EQGs.
Guidelines for Canadian Drinking Water Quality	2012	Guideline	National	Guidelines established based on current, published scientific research related to health effects, aesthetic effects, and operational considerations. Criteria include exposure leads to adverse health effects in humans, frequently detected in Canadian drinking water supplies and could be detected at level that is of possible human health significance.
Policy for Metal Leaching and Acid Rock Drainage at Minesites in British Columbia	1998	Policy	Provincial	Outlines determining the potential for metal leaching and acid rock drainage, and measures to prevent or reduce its occurrence to satisfy conditions of the *Mines Act*.

(continued)

Table 8.2-1. Surface Water Legislation, Regulations, Policy, Standards, and Guidelines (completed)

Name	Year	Type	Level of Government	Description
Guidelines for Metal Leaching and Acid Rock Drainage in British Columbia	1998	Guidelines	Provincial	Describes generic requirements and outlines common errors, omissions and constraints. Assist mines in developing comprehensive proposals that include the necessary documentation and consideration of risk for sound environmental management.
Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials	2009	Guidelines	National	Guidance on the strengths and potential limitations of different procedures, analyses, tests and criteria used to predict future drainage chemistry.
Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators	2012	Guidelines	Provincial	Outline and define the baseline study requirements and information considerations necessary to propose a mineral development project in BC. Covers information requirements for surficial hydrology, water quality (physical and chemical parameters), aquatic sediments, tissue residues and aquatic life.

The Project area climate is influenced by moist air from the Pacific, and drier continental air from Alberta and the arctic. Mean air temperatures are usually lowest in December and peak in July. The surrounding mountains act as barriers to clouds and strongly influence precipitation, with precipitation usually highest in June and July. Snow cover typically lasts from mid to late October until late April/early May.

The Murray River is a moderate-gradient system stretching 200 km from its origin at Upper Blue Lake to its confluence with the Pine River on the Peace Lowlands to the northeast. The Murray River flows north through the Project area into the Pine River, which in turns empties into the Peace River. The Peace River watershed flows into the Slave River, which is a tributary of the Mackenzie River watershed. Within the Project area, the Murray River has a number of small tributaries that drain the surrounding hills and mountains. Downstream of the Project, major Murray River tributaries include Flatbed Creek, Wolverine River and Bullmoose Creek.

The Murray River provides important fish habitat for a number of species that support local fisheries. The Murray River contains a number of fish populations, and common native species include Arctic Grayling, Bull Trout, Mountain Whitefish and Slimy Sculpin. Non-native sport-fish that have been introduced to the Murray River include Brook Trout, Rainbow Trout and Westslope Cutthroat Trout.

There has been some development in the area, including other mines, forestry, seismic lines, roads, transmission lines, oil, gas and hydroelectric developments. Downstream of the Project is the community of Tumbler Ridge, which draws its drinking water from a groundwater well. The Tumbler Ridge sewage outfall discharges into the Murray River upstream of the confluence with the Wolverine River.

8.4 HISTORICAL ACTIVITIES

Several historic and current human activities are within close proximity to the proposed Project Area. These include mining exploration and production, oil and gas, forestry, tourism/recreation and hunting/trapping. The legacy contribution of these historical and current activities to environmental quality has been captured during baseline studies undertaken for the proposed Project (Section 8.5).

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

The Bullmoose Coal Mine operated from 1983 to 2003, located north of the Wolverine River and downstream of the Murray River Coal Project. It was the largest open pit coal mine at the time, producing about 3 million tons of metallurgical coal. The 1.7-million-tonne-per-year operation consisted of an open-pit mine, a plant facility in the Bullmoose Creek valley below the mine, and a separate rail loadout facility on the B.C. Rail branchline.

Previous exploration in the area included seismic lines and drilling for oil and gas wells which helped target areas for coal exploration. Twelve forest licenses exist within the baseline study area; three of these are held by the proponent. Large portions of the baseline study area have been recently harvested to remove pine-beetle affected timber.

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

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

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

8.5 BASELINE STUDIES

8.5.1 Baseline Study Area

The Murray River flows north through the Project area and eventually joins the Pine River. The Murray River Watershed encompasses a number of major and minor tributaries. Downstream of the Project area the larger tributaries include the Wolverine River, Bullmoose Creek and Flatbed Creek. Within the baseline study area, several small tributaries feed into the Murray River that are associated with the proposed Project infrastructure. On the west bank near the Shaft and Decline sites, this includes Twenty Creek and M20 Creek (Camp Creek) and on the east bank by the Coal Processing Plant Site, M17A Creek, M17B Creek, M19A Creek and M19 Creek drain into the Murray River. To characterize the Project area, baseline surface water quantity, surface water quality, and aquatic resources were assessed upstream and downstream of the proposed surface facilities near these waterbodies. The baseline study area was intended to encompass an area beyond which effects of the Project would not be anticipated.

8.5.2 Surface Water Quantity

8.5.2.1 Data Sources

This section describes background surface water quantity conditions relevant to the Project based on available regional Water Survey of Canada (WSC) data as well as Project-specific water quantity data collected in 2011, 2012, and 2013. Detailed reporting and analysis is provided in Appendix 8-A. These data were supplemented by winter flow measurements in 2014 (Appendix 8-I).

The Murray River in the Southern Rocky Mountain Foothills hydrologic zone (British Columbia Hydrologic Zone 7; ILMB 2009; Obedkoff 2000; Obedkoff 2003). The zone is characterized by a continental climate with low precipitation, moderately warm summers, and cold winters. Data from eight regional WSC stations from Zone 7 were reviewed (Appendix 8-A), including two located on the Murray River (07FB002 and 07FB006), and two on eastern tributaries to the Murray River (07FB005 and 07FB009).

Project-specific monitoring involved establishing a hydrometric station on Murray River, and six hydrometric stations on smaller tributary streams of Murray River immediately adjacent to planned Project infrastructure (Figure 8.5-1, Table 8.5-1).

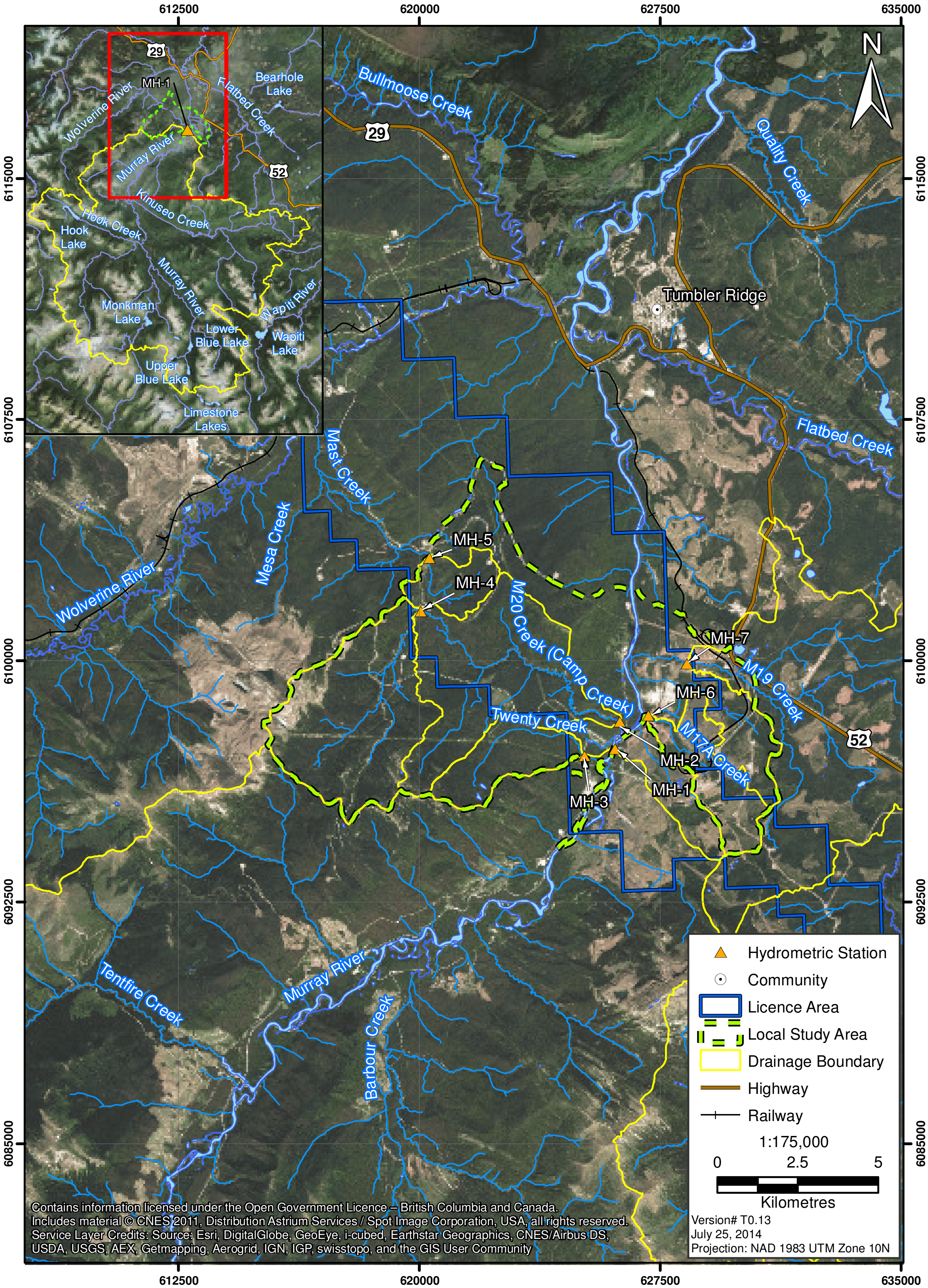
8.5.2.2 Methods

The main objectives of the hydrology baseline program were to:

- Identify the drainage basins and channels that will be affected by the Project to determine the hydrometric monitoring sites for collecting flow data;
- review historical data relevant to the Project;
- establish and monitor project-specific hydrometric stations to augment historical datasets, particularly for smaller watersheds;
- generate daily discharges and annual hydrographs for each hydrometric station;

Figure 8.5-1

Project Hydrometric Station Locations and Watersheds



- calculate hydrological indices related to annual runoff, seasonal runoff distribution, monthly flow rates, and peak and low flows; and
- conduct frequency and regional analyses on the historical hydrological data to analyze the regional hydrological characteristics of the Project-related region.

Table 8.5-1. Project Specific Hydrometric Monitoring Network

Hydrometric Station	Location	UTM Coordinates[a]		Drainage Area (km^2)	Median Elevation (masl)	Period of Operation[b]	Status
		Easting	Northing				
MH-1	Murray River	626,091	6,097,291	2,242	1,323	Jan 2011-Nov 2012	Inactive
MH-2	Lower Camp Creek	626,256	6,097,951	43	1,230	May 2011-Nov 2013	Active
MH-3	Twenty Creek	625,519	6,096,897	7	1,126	May 2011-Nov 2012	Inactive
MH-4	Upper Camp Creek	620,078	6,101,730	21	1,351	May 2011-Nov 2012	Inactive
MH-5	Mast Creek	620,306	6,103,205	4	1,199	May 2011-Nov 2012	Inactive
MH-6	Mile 17 Creek	627,134	6,098,319	7	918	Sep 2012-Nov 2013	Active
MH-7	Mile 19 Creek	628,335	6,099,938	52	998	Sep 2012-Nov 2013	Active

Notes:
[a] *NAD83, Zone 10N*
[b] *Stations demobilized for winter to prevent ice damage.*

The methods in baseline studies followed guidelines described in the Application Information Requirements and EIS Guidelines (CEAA 2012), provincial hydrometric standards (RISC 2009), and provincial hydrometeorologic baseline guidelines (BC_MOE 2012).

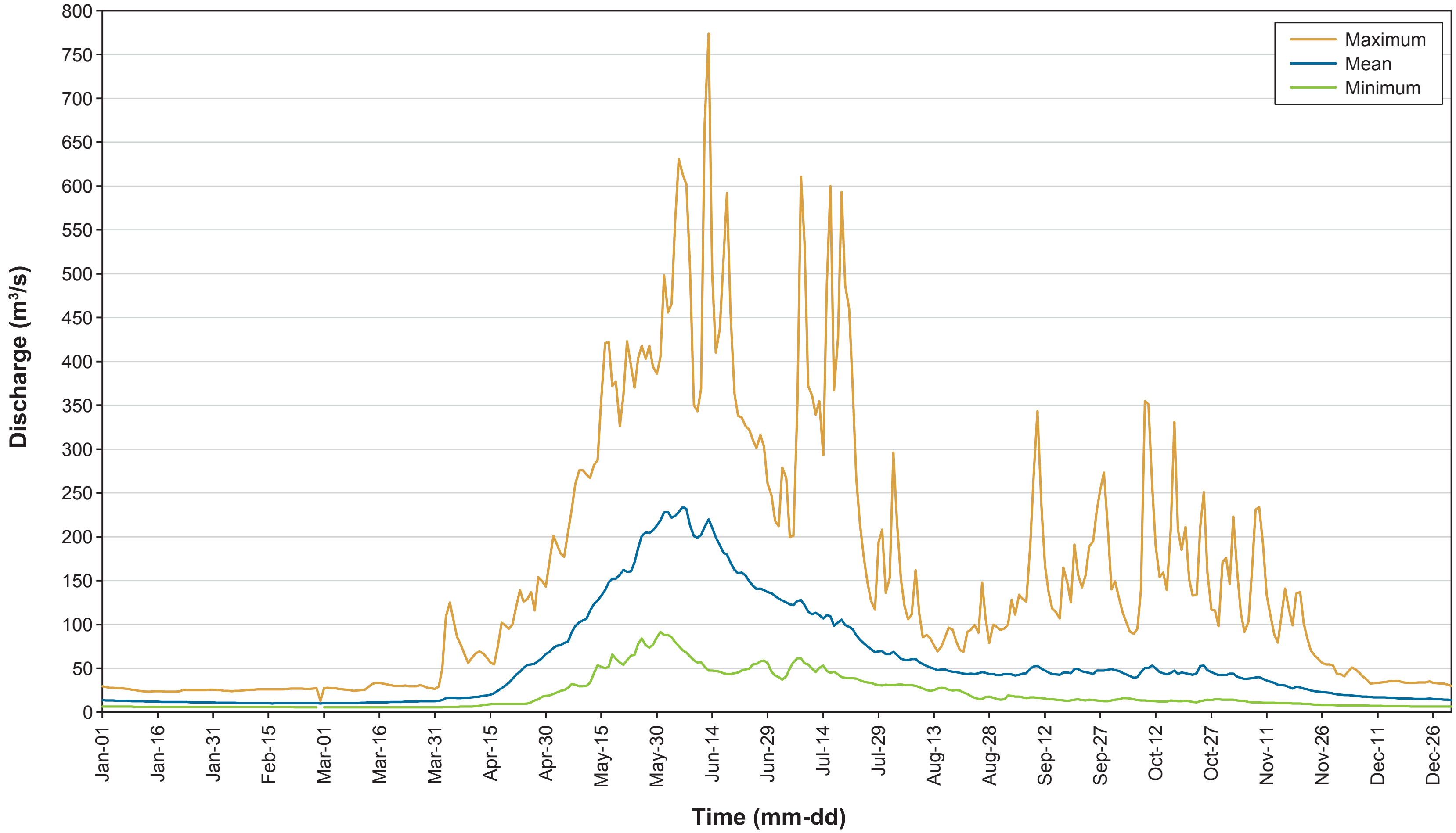
8.5.2.3 Characterization of Surface Water Quantity Baseline Conditions

The climate of the region is a major control on its hydrologic characteristics. Streamflow tends to peak between May and July, driven by snowmelt in May and rainfall in June and July. Low flows occur during the winter and early spring. Many streams, especially in smaller catchments, have almost no flow from November to March. Drainage basins in northeastern British Columbia typically exhibit characteristics of both snowmelt (nival) and rainfall (pluvial) hydrologic regimes (Figure 8.5-2). These are referred to as mixed-regime or hybrid-regime basins (Eaton and Moore 2010). Glacial contributions to runoff are minimal or nonexistent in the Rocky Mountain foothills.

A summary of all Project-specific data collected is provided below; monthly runoff is presented for 2011 through 2013 in Figures 8.5-3 and 8.5-4, and hydrologic indices are summarized in Table 8.5-2 and Table 8.5-3. Descriptions of hydrologic conditions from each of the Project-specific hydrometric stations are provided in the following sections.

Figure 8.5-2

Typical Annual Discharge Hydrographs of the Rocky Mountain Foothills



Note: based on the 1977 – 2010 records of Water Survey of Canada Station Murray River Above Wolverine (07FB006).

Table 8.5-2. Summary Hydrologic Indices for Hydrometric Stations in the Project Area, 2011-2013

Hydrometric Station	Year	Total Annual Runoff (mm)	Peak Annual Discharge (m^3/s)		June-September Low Flows (m^3/s)	
			Instantaneous	Daily	Seven-Day	Daily
MH-1	2011	924	479.0	412.0	28.99	25.86
MH-1	2012	810	426.0	375.0	17.25	15.96
MH-1	2013	*777*	n/d[a]	334.0	19.52	17.23
MH-2	2011	319	12.3	7.1	0.04	0.04
MH-2	2012	305	8.1	6.1	0.01	0.00
MH-2	2013	*353*	7.0	5.6	0.06	0.05
MH-3	2011	n/a[b]	n/a[b]	n/a[b]	n/a[b]	n/a[b]
MH-3	2012	135	0.5	0.4	0.00	0.00
MH-4	2011	401	4.3	2.6	0.03	0.03
MH-4	2012	341	3.9	2.7	0.02	0.02
MH-5	2011	433	0.9	0.8	0.01	0.01
MH-5	2012	134	0.2	0.2	0.00	0.00
MH-6	2013	*193*	0.9	0.7	0.00	0.00
MH-7	2013	*187*	6.1	5.4	0.00	0.00

[a] *Synthetic streamflows were generated for MH-1 based on to WSC hydrometric stations on the Murray River (07FB002 and 07FB006)*
[b] *Hydrologic indices for MH-3 in 2011 are not available due to an incomplete dataset.*
Note: Estimated values are italicized

Murray River (MH-1)

At 2,242 km², this is the largest monitored catchment in the Project area by almost two orders of magnitude. The channel of Murray River at the gauging site is about 80 to 90 m wide. At times of low flow, side and mid-channel bars are exposed.

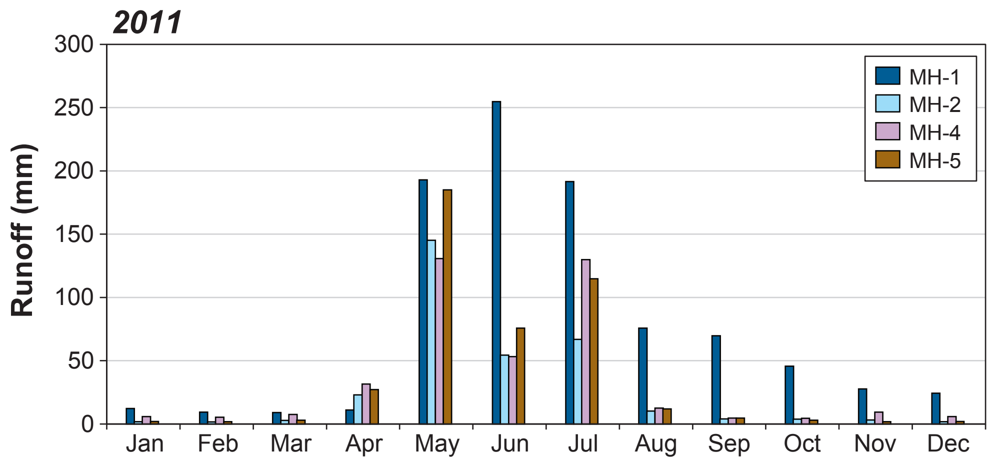
Instantaneous peak flow was 479 m^3/s and 426 m^3/s in 2011 and 2012. These high-magnitude flows reflect the large upstream drainage area. Total annual runoff was also the greatest of any in the Project area in 2011, 2012 and 2013: 924 mm, 810 mm and 777 mm. This large amount of runoff is likely due to the high elevations located in the headwaters of this catchment, and consequent orographic enhancement of precipitation. The watershed also has a large proportion of windward-facing slopes, where increased snow deposition is likely to occur. June to September low flows occurred in mid-to-late September when the seven-day low flow ranged between 17 m^3/s and 29 m^3/s.

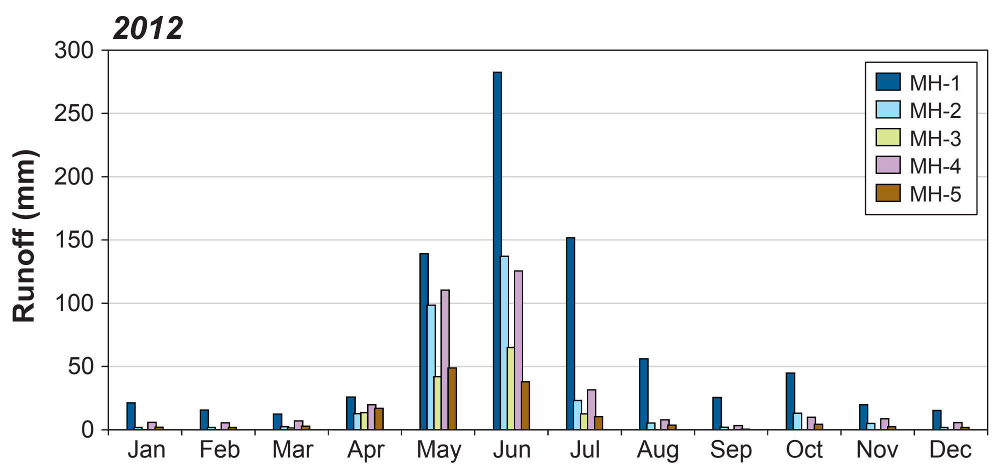
M20 (Camp) Creek (MH-2)

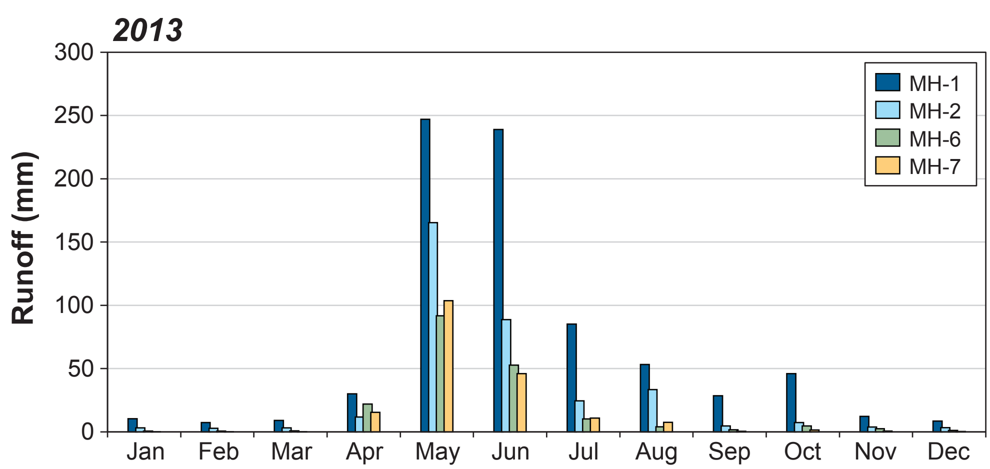
MH-2 is located on M20 Creek, several hundred metres upstream of the confluence with the Murray River. The channel is about 4 to 8 m wide at the gauging site / monitoring station. The upstream drainage area above the monitoring station is 43 km². This is a high energy stream with a gravel-cobble bed. Fallen logs across the channel are the dominant source of pool and riffle formation.

Figure 8.5-3

Monthly Runoff, in Millimetres, at the Project Area Hydrometric Stations, 2011 to 2013







Monthly Runoff, in Millimetres, at the Project Area Hydrometric Stations, 2011 to 2013

ERM

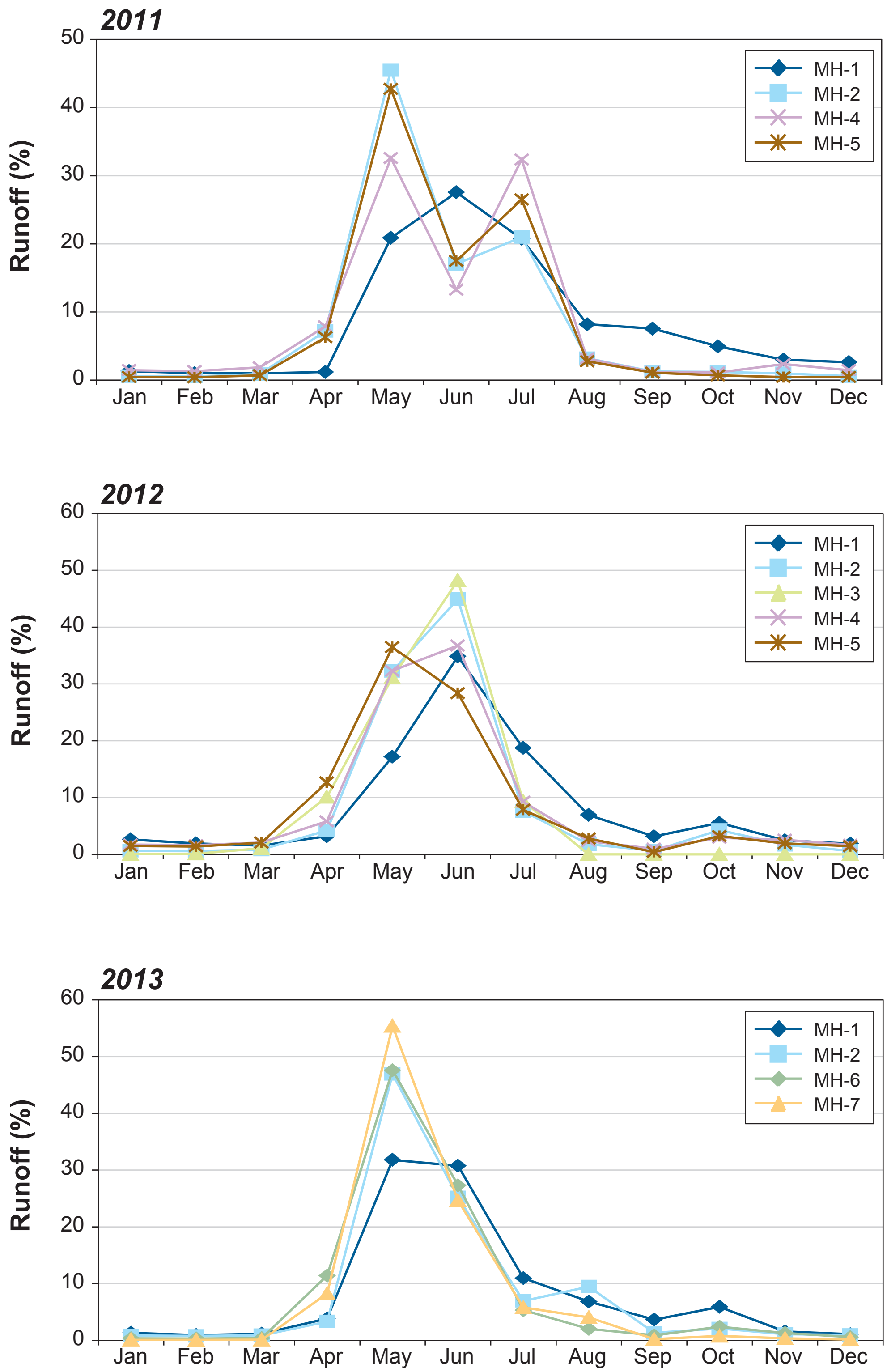


Table 8.5-3. 2011-2013 Annual and Monthly Runoff for Hydrometric Stations in the Project Area (Runoff Presented in Millimetres)

Hydrometric Station	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
MH-1	2011	*12*	*9*	*9*	11	193	255	192	76	70	46	*28*	*24*	924
	2012	*21*	*16*	*12*	26	139	282	152	56	26	45	*20*	*15*	810
	2013	*10*	*7*	*9*	*30*	*247*	*239*	*85*	*53*	*29*	*46*	*12*	*9*	*777*
	Mean	15	11	10	22	193	259	143	62	41	46	20	16	837
MH-2	2011	*2*	*2*	*3*	23	145	54	67	10	4	4	*3*	*2*	*319*
	2012	*2*	*2*	*3*	*13*	98	137	23	5	2	13	*5*	*2*	*305*
	2013	*3*	*3*	*3*	*12*	173	82	25	33	5	7	*4*	*3*	*353*
	Mean	2	2	3	16	139	91	38	16	4	8	4	2	326
MH-3	2012	*0*	*0*	*1*	*14*	*42*	*65*	*13*	0	0	0	0	0	*135*
MH-4	2011	*6*	*5*	*7*	32	131	53	130	13	5	4	*9*	*6*	*401*
	2012	*6*	*5*	*7*	*20*	110	126	32	8	3	10	*9*	*6*	*341*
	Mean	*6*	*5*	*7*	*26*	121	89	81	10	4	7	*9*	*6*	*371*
MH-5	2011	*2*	*2*	*3*	27	185	76	115	12	5	3	*2*	*2*	*433*
	2012	*2*	*2*	*3*	*17*	49	38	10	4	1	4	*3*	*2*	*134*
	Mean	*2*	*2*	*3*	*22*	117	57	63	8	3	4	*2*	*2*	*283*
MH-6	2013	*1*	*1*	*1*	*22*	92	53	10	4	2	5	*2*	*1*	*193*
MH-7	2013	*0*	*0*	*0*	*15*	104	46	11	8	0	1	*1*	*0*	*187*

Note: Estimated values are italicized.

Total annual runoff at MH-2 was 319 mm in 2011, 305 mm in 2012 and 353 mm in 2013. Peak instantaneous flow was 12.3 m^3/s in 2011, 8.1 m^3/s in 2012 and 7.0 m^3/s in 2013. Flow at the site almost ceased at the end of September in each of the monitored years, with seven-day low flows reaching between 0.01 and 0.06 m^3/s.

Twenty Creek (MH-3)

MH-3 is located on Twenty Creek, about 500 m from where it drains into Murray River. At only 7 km^2, the upstream watershed area is small. The station location changed between 2011 and 2012, but both channel widths vary between about 5 to 8 metres, and the channel has a riffle-pool morphology resulting from fallen trees in the channel. Annual runoff in 2011 is not known due to insufficient data collection, but was 135 mm in 2012: one of the lowest measured runoffs of the Project area. Peak instantaneous flow was only 0.5 m^3/s, and the stream ceased flowing in July 2012 and likely remained dry for the remainder of the hydrologic year.

Upper M20 Creek (MH-4)

The MH-4 channel is located on Upper M20 Creek, and is about 4 to 6 metres wide. Its upstream watershed area is 21 km^2. It is a high energy stream with a gravel-cobble bed, consisting of a riffle-pool morphology resulting from large woody debris obstructions. Peak instantaneous flow was 4.3 m^3/s in 2011, and 3.9 m^3/s in 2012. Total annual runoff was 401 mm and 341 mm for both years of monitoring. Flow at the site almost ceased in September in each of the monitored years, with seven-day low flows reaching between 0.02 and 0.03 m^3/s.

Mast Creek (MH-5)

This hydrometric station is located on upper Mast Creek, and its upstream watershed area is the smallest monitored in the Project area, at only 4 km^2. The channel is only 2 to 2.5 m wide, but is incised about a half metre into underlying unconsolidated sediment. It is a small low energy stream with a silty bed. Total annual runoff was 433 m is 2011, but only 134 mm in 2012. Peak instantaneous flow was 0.9 m^3/s in 2011 and 0.2 m^3/s in 2012. Seven-day low flows were less than 0.01 m^3/s.

M17A Creek (MH-6)

The MH-6 watershed is also quite small, at only 7 km^2. It is located on M17A Creek. The channel width was only about four metres in the autumn of 2012, a period of low flow. The channel is deeply incised, and its bed is composed of cobbles and bedrock. The station is very close (< 100 m) from where M17A Creek drains into Murray River. This station was installed at the end of the 2012 monitoring season and only 2013 data are available. Total annual runoff was 193 mm and peak instantaneous flow was 0.9 m^3/s. Flows ceased in September, seven-day low flows were less than 0.01 m^3/s.

M19 Creek (MH-7)

At 52 km^2, this hydrometric station on M19 Creek has the second largest watershed area of any monitored stream in the Project area. The channel is deeply incised into a ravine, and has a cobble and bedrock bed. The stream has a bedrock-dominated morphology, with sections of pools and riffles between bedrock steps. This station is about 1.5 km above where M19 Creek drains into Murray River. The station is the highest elevation of any Project-specific station (about 840 masl). The channel was about six metres wide in the autumn of 2012, a period of low flow. Since this station was installed at the end of the 2012 monitoring season, only 2013 data are available. In 2013 total annual runoff was 187 mm and peak instantaneous flow was 6.1 m^3/s. Flows ceased in September, seven-day low flows were less than 0.01 m^3/s.

Return Period Calculations

Calculation of return periods at Project-specific hydrometric stations was accomplished using regional WSC hydrometric stations. However, significant climatic and physiographic variability exists between the regional and local stations. In particular, Project-specific watersheds are much smaller than most regional stations. Estimation of return periods for peak flow and seven-day low flow produced reasonable values for all monitored stations. Estimation of annual runoff for the larger monitored watersheds (MH-1, MH-2) also produced reasonable return periods. However, the smaller watersheds are significantly physiographically and hydroclimatically different from regional stations; therefore, annual runoff return period estimates for small watersheds (MH-3, MH-4, MH-5) are not presented here. Details of return period calculation are presented in Appendix 8-A; results are presented in Tables 8.5-4 through 8.5-7.

Table 8.5-4. Predicted Return Period Runoff and 2011-2013 Annual Runoff (mm) for Project Hydrometric Stations

Hydrometric Station	Watershed Area (km²)	Median Elevation (m)	Annual Runoff (mm) at Various Recurrence Intervals for Hydrometric Station MH-1											Monitored Runoff (mm)		
			Wet					Mean	Dry							
			100	50	20	10	5	2	5	10	20	50	100	2011	2012	2013
MH-1	2,242	1,323	1,212	1,155	1,071	1,003	914	764	624	558	506	452	418	924	810	777[a]
MH-2	43	1,230	777	695	584	500	409	276	182	144	118	95	81	319	305	353

[a] *Estimated from WSC Station 07FB002 as described in Section 4.3.1.(ERM Rescan 2014)*

Table 8.5-5. Peak Instantaneous Discharges (m³/s) at Various Recurrence Intervals for Project Area Hydrometric Stations

Hydrometric Station	Drainage Area (km²)	Peak Instantaneous Discharge (m³/s) at Various Recurrence Intervals (Years)							Initial or Adjusted Coefficient	Monitored Peak Instantaneous Q (m³/s)		
		200	100	50	20	10	5	2		2011	2012	2013
MH-1	2,242	1,134	988	856	699	590	488	356	Adjusted	479	426	n/d
MH-2	43	145.8	99.0	66.3	37.8	23.8	14.3	7.1	Adjusted	12.3	8.1	7.0
MH-3	7	49.3	29.3	17.1	8.0	4.3	2.1	0.7	Initial	n/d	0.5	n/d
MH-4	21	100.7	65.4	41.8	22.3	13.4	7.5	3.5	Adjusted	4.3	3.9	n/d
MH-5	4	38.3	22.1	12.5	5.6	2.9	1.4	0.4	Initial	0.9	0.2	n/d
MH-6	7	58.4	35.5	21.2	10.3	5.7	3.0	1.2	Adjusted	n/d	n/d	0.9
MH-7	52	161.7	111.2	75.4	43.8	28.0	17.1	8.7	Adjusted	n/d	n/d	6.1

Table 8.5-6. Estimated Summer (June-September) Seven-Day Low Flows (m^3/s) for Project Hydrometric Stations

Hydrometric Station	Watershed Area (km^2)	Median Elevation (m)	7-Day Low Flow (m^3/s) at Various Recurrence Intervals for Project Area Hydrometric Stations				Monitored 7-day Low Flow (m^3/s)		
			2	5	10	20	2011	2012	2013
MH-1	2,242	1,323	25.10	17.40	14.10	11.60	28.99	17.25	19.52[a]
MH-2	43	1,230	0.04	0.02	0.01	0.00	0.04	0.01	0.06
MH-3	7	1,126	0.00	0.00	0.00	0.00	n/d	0.00	n/d
MH-4	21	1,351	0.02	0.01	0.00	0.00	0.03	0.02	n/d
MH-5	4	1,199	0.02	0.01	0.00	0.00	0.01	0.00	n/d
MH-6	7	918	0.04	0.00	0.00	0.00	n/d	n/d	0.00
MH-7	52	998	0.06	0.02	0.01	0.01	n/d	n/d	0.00

Note:
[a] *Estimated from WSC Station 07FB002*

Table 8.5-7. Estimated Annual Seven-Day Low Flows (m^3/s) for Project Hydrometric Stations

Hydrometric Station	Watershed Area (km^2)	Median Elevation (m)	7-Day Low Flow (m^3/s) at Various Recurrence intervals for Project Area Hydrometric Stations				Monitored 7-day low flow (m^3/s)[a]		
			2	5	10	20	2011	2012	2013
MH-1	2,242	1,323	*7.30*	*6.05*	*5.59*	*5.28*	*6.98*	*9.52*	*4.32*[b]
MH-2	43	1,230	*0.002*	*0.002*	*0.005*	*0.001*	*0.03*	*0.01*	*0.05*
MH-3	7	1,126	*0.000*	*0.000*	*0.000*	*0.000*	*n/d*	*n/d*	*0*
MH-4	21	1,351	*0.005*	*0.001*	*0.000*	*0.000*	*0.03*	*0.02*	*n/d*
MH-5	4	1,199	*0.000*	*0.000*	*0.000*	*0.000*	*0.02*	*0.00*	*n/d*
MH-6	7	918	*0.005*	*0.001*	*0.000*	*0.000*	*n/d*	*n/d*	*0.00*
MH-7	52	998	*0.009*	*0.003*	*0.003*	*0.001*	*n/d*	*n/d*	*0.00*

Note:
[a] *Annual low flows occur in winter, when pressure transducers were removed. Flows were estimated as described in Appendix 8-A.*
[b] *Estimated from WSC Station 07FB002.*
Estimated values are italicized.

8.5.3 Surface Water Quality

8.5.3.1 Data Sources

Baseline surface water quality data have been collected for the Project since May 2010. Data presented in this section are drawn from the following sources:

- Murray River Coal Project: 2010 to 2012 Aquatic Resources Baseline Report (Appendix 8-B); and
- Murray River Coal Project: 2010 to 2014 Surface Water Quality and Aquatic Resources Data (Appendix 8-C).

These data are compiled in Appendix 8-C, which supersedes the raw data presented in Appendices 8-B and 8-C.

8.5.3.2 Methods

Sampling Locations

To characterize the baseline surface water quality of the Project area, sites were sampled upstream and downstream of the proposed surface facilities on the east bank tributaries, west bank tributaries, and the Murray River. Sites were assigned to one of the following three categories to aid in the interpretation of the baseline data:

1. Shaft/Decline Sites (west bank): Twenty Creek and M20 (Camp) Creek. Club Creek as reference station.
2. Coal Processing Site (east bank): M17A Creek, M17B Creek, M19A Creek and M19 Creek. M19-01 as an upstream reference station.
3. Receiving Environment: Murray River. MR-REF as an upstream reference station of all mining influences.

A summary of the baseline surface water quality sampling sites and their rationale for inclusion is presented in Table 8.5-8 (see Figure 8.6-1 for a map of the study area). The frequency of baseline surface water quality sampling is summarized in Table 8.5-9. Baseline water quality data were collected at six wetlands within the study area and are presented in Appendix 8-C.

Shaft/Decline Sites (West Bank)

Baseline surface water quality characterization of the west bank focused on sampling upstream and downstream of Shaft and Decline Sites, and accounting for inputs from the Hermann mine.

Twenty Creek was sampled both upstream (TC-01) and downstream (TC-02) of the Decline Site. To account for Hermann Mine activities, M20 Creek (Camp Creek) was sampled downstream of the Hermann Mine and upstream of Project activities (M20-03). M20 Creek was also sampled downstream of a natural sediment source and upstream of the bulk sample site (M20-05), and both upstream (M20-06) and downstream (M20-04) of the proposed Shaft Site.

A Murray River reference stream was established on Club Creek (REFST), over 10 km upstream of the Project and other major developments in the area. Club Creek drains a watershed similar in size to that of M20 Creek, and is located outside of any potential fugitive dust deposition from the Project.

Coal Processing Site (East Bank)

The main Project infrastructure on the east bank is the Coal Processing Site. Several S creeks in the vicinity of this infrastructure were sampled to characterize the baseline surface water quality. This included several sites downstream of the Coal Processing Site, including M17A Creek (M17A), M17 Creek (M17-02), M19A Creek (M19A) and M19 Creek (M19-02). In addition, an upstream reference station was established for M19 Creek (M19-01).

Table 8.5-8. Surface Water Quality and Aquatic Resources Baseline Sites, Murray River Coal Project, 2010 to 2014

Site	Waterbody	Water Quality		Aquatic Resources	Location and Rationale
		Easting	Northing		
Shaft/Decline Sites					
REFST	Club Creek	611594	6080688	x	Reference station upstream of all mining influences and potential Project effects
TC-01	Twenty Creek	622268	6097326		Upstream of the Project's proposed west surface facilities
TC-02	Twenty Creek	625474	6096907		Downstream of the Project's proposed west surface facilities
M20-03	M20 (Camp) Creek	619921	6101621	x	Upstream of the Project's proposed west surface facilities and downstream of Hermann Mine activities
M20-05	M20 (Camp) Creek	621555	6100170	x	Downstream of a natural sediment source within the Project's western footprint
		621661	6099951		Aquatic resources sampling location moved to ensure representative samples could be collected.
M20-06	M20 (Camp) Creek	626293	6098024	x	Upstream of the proposed sediment pond discharge pipe
M20-04	M20 (Camp) Creek	626318	6097879	x	Downstream of the Project's west footprint
		626265	6097901		Location moved upstream of bridge in October 2010, aquatic resources sampling location followed in 2011
Coal Processing Site					
M17A	M17A Creek	627137	6098378		Small tributary directly connected to Murray River south of CCR facility
M17-02	M17 Creek	627050	6098340	x	Downstream of the Project's proposed east surface facilities
M19A	M19A Creek	627302	6099308		Small tributary directly connected to Murray River within the CCR facility
M19-01	M19 Creek	630433	6099185	x	Reference station upstream of the Project's proposed east surface facilities
M19-02	M19 Creek	627283	6100044	x	Downstream of the Project's proposed east surface facilities
Receiving Environment					
MR-REF	Murray River	614254	6086757	x	Reference station upstream of all mining influences and potential Project effects
MR1	Murray River	618539	6090459		Downstream of Canary Creek confluence. Station to monitor the potential effects from Hermann Mine activities
MR2	Murray River	620487	6091416		Downstream of South Hermann Creek confluence. Station to monitor the potential effects from Hermann Mine activities
MR9	Murray River	624025	6093603	x	Downstream of M14 Creek confluence and all Hermann Mine activity. Near-field reference station upstream of potential effects from the Project
		624332	6094213		Water quality sampling location moved ~600 m downstream in 2011 to allow complete mixing of M14 Creek water
MR3	Murray River	626058	6097363	x	Immediately upstream of M20 Creek
		625911	6097042		Aquatic resources sampling location moved to ensure representative samples could be collected.
MR4	Murray River	626486	6097796	x	Immediately downstream of M20 Creek
MR7	Murray River	626471	6100097	x	Downstream of Project's proposed west footprint; adjacent to proposed east footprint. Upstream of M19 Creek
MR7B	Murray River	626730	6101011	x	Downstream of the Project's proposed footprint (Shaft/Decline Sites and Coal Processing Plant Site).
MR8	Murray River	626615	6105516		Mid-field downstream monitoring station
MR6	Murray River	625502	6109058	x	Far-field downstream monitoring station, upstream of Flatbed Creek and Tumbler Ridge
MR10	Murray River	629420	6116790		Far-field downstream monitoring station, downstream of Wolverine River, Flatbed Creek and sewage discharge from Tumbler Ridge

UTM zone 10U

Site name (2010 report name): M20-05 (M20-U/S), M20-04 (M20-D/S), MR9 (MR3), MR3 (MR4) and MR4 (MR5).

Aquatic resources sampling location moved to ensure representative samples could be collected.

Table 8.5-9. Surface Water Quality Baseline Sampling Program, 2010 to 2014

	2010								2011												2012												2013												2014			
Site	May	June	July	August	September	October	November	December	January	February	March	April	May	June	July	August	September	October	November	December	January	February	March	April	May	June	July	August	September	October	November	December	January	February	March	April	May	June	July	August	September	October	November	December	January	February	March	Total
Shaft/Decline Sites																																																
REFST	1	2	1	1		1		1	1	1	1	1	3	3	1	1	1	1	1	1	1	1	1	1	2	4	2	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	54
TC-01													1	1	1	1	1	1	1	1				1	1	1	1										1	1	1	1	1							17
TC-02	1											1	1	1	1	1	1	1	1					1	1	1											1	1	1	1	1							17
M20-03										1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	37
M20-05		1	1			1		1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	41
M20-06																														1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
M20-04	1	1	1	1		1		1	1	1	1	1	3	2	1	1	1	1	1	1	1	1	1	1	2	4	2	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	53
Coal Processing Site																																																
M17A																																				1	2	3	1	1	1	1		1	1	1	1	14
M17-02																														1		1	1	1	2	1	2	3	1	1	1	1	1	1	1	1	1	21
M19A																																			1	1	2	3	1	1	1	1	1	1	1	1	1	16
M19-01																											1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	20
M19-02																											1	1				1	1	1	1	1	2	3	1	1	1	1	1	1	1	1	1	21
Receiving Environment																																																
MR-REF	2	2	1	2		1		1	1	1	1	1	3	3	1	1	1	1	1	1	1	1	1	1	2	4	2	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	56
MR1	1	2				1			1																																							5
MR2	1	2				1			1																																							5
MR9	1	2				1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	2	3	1	1	1	1	1	1	2	1	1	46
MR3	2	2	1	1		1		1	1	1	1	1	3	3	1	1	1	1	1	1	1	1	1	1	2	4	2	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	56
MR4	2	1	1	1		1		1	1	1	1	1	3	2	1	1	1	1	1	1	1	1	1	1	2	4	2	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	54
MR7										1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																					18
MR7B																												1		1	1	1	1	1	1	1	2	3	1	1	1	1	1	1	2	1	1	23
MR8										1	1			1	1	1	1	1	1	1	1	1	1	1	1		1																					15
MR6	2	2	1	1		1		1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	46
MR10											1			1			1			1			1			1						1			1		1			1			1				1	12

Values represent the number of dates sampled

Receiving Environment (Murray River)

The surface water quality baseline characterization included 11 sites along the Murray River which will receive inputs from several tributary streams associated with the Project. A reference site (MR-REF) was established on the Murray River over 10 km upstream of the Project and upstream of potential effects from Hermann Mine activities. Sites MR1 and MR2 were established on the Murray River downstream of two tributary streams that drain the proposed Hermann Mine (which was granted an EA certificate in 2006). Further downstream MR9 was established which is upstream of all Project activities and downstream of any influences from the Hermann Mine and will be a reference station for the Project. If or when the Hermann Mine becomes operational, MR9 would be downstream of these activities and act as a control for Hermann Mine effects.

On the Murray River, MR3 and MR4 are respectively located upstream and downstream of M20 Creek, which will be the receiving environment for the sediment pond discharge pipe associated with the Shaft Site on the west bank. Further downstream on the Murray River, MR7 is adjacent to the Coal Processing Site on the east bank and MR7B is slightly downstream of this infrastructure. MR8 is downstream of all Project infrastructure and will serve as a mid-field downstream monitoring station for the Project. Far-field downstream sites include MR6 and MR10. MR6 is approximately 12 km downstream of the Project and upstream of the Wolverine River and Flatbed Creek confluences. MR10 is located approximately 20 km downstream of the Project and is also downstream of the Tumbler Ridge sewage outflow, Wolverine, Trend/Roman, Hermann and Quintette mining activities.

Surface Water Quality Sampling

Surface water quality sampling methodologies are described in detail in the baseline reports (Appendices 8-B and 8-C). Water quality samples were collected as single replicates in clean, pre-labelled bottles. Field personnel wore nitrile gloves, faced upstream and submerged the sample bottles until they were full. Samples were packed as required and stored in a dark, cool place until shipment. Samples collected from May to August 2010 and February 2011 to March 2014, were analyzed by ALS Environmental Ltd. (ALS) in Burnaby, BC. In October 2010, December 2010, and January 2011 water samples were analyzed by CARO Analytical Services in Richmond, BC. The quality assurance and quality control (QA/QC) program for the baseline included the use of chain of custody (COCs) forms, sample blanks, and sample replication as discussed in Appendices 8-B and 8-C. Surface water quality samples were compared to available federal and BC guidelines for the protection of freshwater aquatic life (CCME 2014a, BC MOE 2014; Table 8.5-10), drinking water (Health Canada 2012, BC MOE 2014; Table 8.5-11), and wildlife water supply (BC MOE 2014; Table 8.5-12).

8.5.3.3 Characterization of Surface Water Quality Baseline Conditions

Surface water quality baseline data collected for the Project is available in Appendix 8-C. QA/QC information including data for blanks and duplicates is presented in Appendix 8-C and the baseline reports (Appendices 8-B and 8-C).

In general, water quality in the Project area was closely tied to seasonal fluctuations of water flow. During the winter low flow (November to March), streams had elevated alkalinity, conductivity, hardness, anions (chloride, fluoride and sulphate) and some metals (total boron, molybdenum, selenium, and uranium).

Table 8.5-10. Federal and Provincial Water Quality Guidelines for the Protection of Freshwater Aquatic Life

Parameter	CCME Guideline for the Protection of Freshwater Aquatic Life[a]	BC Water Quality Guidelines[b]
Physical Tests		
pH	6.5 to 9.0	6.5 to 9.0
Total Suspended Solids	Dependent on background levels[c]	Dependent on background levels[k]
Turbidity (NTU)	Dependent on background levels[d]	Dependent on background levels[l]
Anions		
Chloride (Cl)	640 short-term; 120 long-term	600 maximum; 150 30-day
Fluoride (F)	0.12[e]	Hardness dependent[m]
Sulphate (SO_4)		Hardness dependent[n]
Nutrients		
Ammonia, Total (as N)	pH- and temperature-dependent	
Nitrate (as N)	124 short-term; 3 long-term	32.8 maximum; 3.0 30-day
Nitrite (as N)	0.06	Chloride dependent[o]
Phosphorus (P)-Total	Trigger ranges[f]	
Cyanides		
Cyanide, Weak Acid Dissociable		0.01 maximum; 0.005 30-day
Cyanide, Free	0.005	
Organic / Inorganic Carbon		
Total Organic Carbon		Dependent on background levels[p]
Dissolved Organic Carbon		Dependent on background levels[p]
Total Metals		
Aluminum (Al)	0.005 if pH < 6.5; 0.1 if pH ≥ 6.5	
Antimony (Sb)		0.02[w]
Arsenic (As)	0.005	0.005
Barium (Ba)		5 maximum; 1 30-day [w]
Beryllium (Be)		0.0053[w]
Boron (B)	29 short-term; 1.5 long-term	1.2
Cadmium (Cd)	Hardness dependent[g]	Hardness dependent[w,x]
Chromium (Cr)	0.001 (Cr(VI)); 0.0089 (Cr(III)[e])	
Cobalt (Co)		0.11 maximum; 0.004 30-day
Copper (Cu)	Hardness dependent[h]	Hardness dependent[q]
Iron (Fe)	0.3	1
Lead (Pb)	Hardness dependent[i]	Hardness dependent[r]

(continued)

Table 8.5-10. Federal and Provincial Water Quality Guidelines for the Protection of Freshwater Aquatic Life (completed)

Parameter	CCME Guideline for the Protection of Freshwater Aquatic Life[a]	BC Water Quality Guidelines[b]
Lithium (Li)		0.87 maximum; 0.096 chronic [w]
Manganese (Mn)		Hardness dependent[s]
Mercury (Hg)	0.000026	0.00002 when MeHg = 0.5% THg
Molybdenum (Mo)	0.073[e]	2 maximum; ≤1 30-day
Nickel (Ni)	Hardness dependent[j]	Hardness dependent [w,y]
Selenium (Se)	0.001	0.002
Silver (Ag)	0.0001	Hardness dependent[t]
Thallium (Tl)	0.0008	0.0003 objective; 0.0008 30-day [w]
Uranium (U)	0.033 short-term; 0.015 long-term	0.3 maximum; 0.5 objective [w]
Vanadium (V)		0.006[w]
Zinc (Zn)	0.03	Hardness dependent[u]
Dissolved Metals		
Aluminum (Al)		pH-dependent[v]
Iron (Fe)		0.35

Notes:

[a] *Canadian water quality guideline for the protection of freshwater aquatic life, Canadian Council of Ministers of the Environment, accessed June 2014; all units are in mg/L unless otherwise noted.*

[b] *British Columbia guideline for the protection of freshwater aquatic life, accessed June 2014.*

[c] *TSS - in clear flow, maximum increase of 25 mg/L from background levels for short-term exposure (e.g. 24 h period). Maximum average increase of 5 mg/L from background levels for long-term exposure (e.g. 30 d period). In high flow, maximum increase of 25 mg/L from background levels between 25-250 mg/L. If background is ≥250 mg/L, TSS should not increase more than 10% of background levels.*

[d] *Turbidity - in clear flow maximum increase of 8 NTUs from background levels for short-term exposure (e.g. 24 h period). Maximum average increase of 2 NTUs from background levels for a long-term exposure (e.g. 30 d period). In high flow, maximum increase of 8 NTUs from background levels between 8 to 80 NTUs. If background is > 80 NTUs, turbidity should not increase more than 10%.*

[e] *Interim guideline.*

[f] *Phosphorus - trigger ranges: <0.004 mg/L ultra-oligotrophic; 0.004-0.01 mg/L oligotrophic; 0.01-0.02 mg/L mesotrophic; 0.02-0.035 mg/L meso-eutrophic; 0.035-0.1 mg/L eutrophic; >0.1 mg/L hyper-eutrophic.*

[g] *Cadmium - short-term cadmium concentration =* $10^{1.016[\log(hardness)]-1.71}$ */ 1000 mg/L. If hardness is <5.3 mg/L, the guideline is 0.00011 mg/L; if hardness is >360 mg/L, the guideline is 0.0077 mg/L. Long-term cadmium concentration =* $10^{0.83[\log(hardness)]-2.46}$ */ 1000 mg/L. If hardness is <17 mg/L, the guideline is 0.00004 mg/L; if hardness is >280 mg/L, the guideline is 0.00037 mg/L.*

[h] *Copper - copper concentration =* $e^{0.8545[\ln(hardness)]-1.465}$ ** 0.0002 mg/L. If hardness is <82 mg/L, the guideline is 0.002 mg/L; if hardness is >180 mg/L, the guideline is 0.004 mg/L. If water hardness is not known, the guideline is 0.002 mg/L.*

Notes (cont'd):

[i] *Lead - lead concentration = $e^{1.273[\ln(hardness)]-4.705}$ / 1000 mg/L. If hardness is ≤60 mg/L, the guideline is 0.001 mg/L; if hardness is >180 mg/L, the guideline is 0.007 mg/L. If water hardness is not known, the guideline is 0.001 mg/L.*

[j] *Nickel - nickel concentration = $e^{0.76[\ln(hardness)]+1.06}$ / 1000 mg/L. If hardness is ≤60 mg/L, the guideline is 0.025 mg/L; if hardness is >180 mg/L, the guideline is 0.15 mg/L. If water hardness is not known, the guideline is 0.025 mg/L.*

[k] *TSS - in clear waters, change from background for 24-h period is 25 mg/L and 5 mg/L for 30-day period; if background is 25-100 mg/L then change from background of 10 mg/L; if background > 100 mg/L then change from background of 10%.*

[l] *Turbidity - in clear waters, change from background for 24-h period is 8 NTU and 2 NTU for 30-day period; if background is 8-50 NTU then change from background is 5 NTU; if background > 50 NTU then change from background of 10%.*

[m] *Fluoride - if hardness (as $CaCO_3$) is 10 mg/L the maximum concentration is 0.4 mg/L; otherwise LC_{50} = -51.73 + 92.57 $\log_{10}$ (hardness) * 0.01 mg/L.*

[n] *Sulphate - if hardness is very soft (0-30 mg/L) the guideline is 128 mg/L; if soft to moderately soft (31-75 mg/L) then 218 mg/L; if moderately soft/hard to hard (76-180 mg/L) then 309 mg/L; if very hard (181-250 mg/L) then 429 mg/L; if hardness >250 mg/L then the guideline needs to be determined based on site water.*

[o] *Nitrite - maximum guideline: if chloride <2 mg/L the guideline is 0.06 mg/L, if chloride 2-4 mg/L then 0.12 mg/L, if chloride 4-6 mg/L then 0.18 mg/L, if chloride 6-8 mg/L then 0.24 mg/L, if chloride 8-10 mg/L then 0.3 mg/L and if chloride >10 mg/L then 0.6 mg/L. 30-day guideline: if chloride <2 mg/L the guideline is 0.02 mg/L, if chloride 2-4 mg/L then 0.04 mg/L, if chloride 4-6 mg/L then 0.06 mg/L, if chloride 6-8 mg/L then 0.08 mg/L, if chloride 8-10 mg/L then 0.1 mg/L and if chloride >10 mg/L then 0.2 mg/L.*

[p] *Organic carbon (total and dissolved) - the 30-day median ± 20% of the median background concentration.*

[q] *Copper - the maximum concentration is 0.094(hardness)+2 / 1000 mg/L. If average water hardness (as $CaCO_3$) ≤ 50 mg/L the 30-day mean is ≤ 0.002 mg/L; if average water hardness is > 50 mg/L the 30-day mean is ≤ 0.00004(mean hardness) mg/L.*

[r] *Lead - if hardness (as $CaCO_3$) is ≤ 8 mg/L the maximum concentration is 0.003 mg/L; if hardness is > 8 mg/L the maximum concentration is $e^{1.273\ln(hardness)-1.460}$ / 1000 mg/L and the 30-day mean is 3.31+$e^{1.273\ln(mean[hardness])-4.704}$ / 1000 mg/L.*

[s] *Manganese - manganese concentration maximum = 0.01102(hardness)+0.54 mg/L and the 30-day mean concentration = 0.0044(hardness)+0.605 mg/L.*

[t] *Silver - if hardness is ≤ 100 mg/L the maximum concentration is 0.0001 mg/L and the 30-day mean is 0.00005 mg/L; if hardness > 100 mg/L the maximum concentration is 0.003 mg/L and the 30-day mean is 0.0015 mg/L.*

[u] *Zinc - 30-day mean concentration = 7.5 + 0.75(hardness - 90) / 1000 mg/L; maximum concentration = 33 + 0.75(hardness - 90) / 1000 mg/L.*

[v] *Dissolved aluminum - if pH ≥ 6.5 the maximum concentration is 0.1 mg/L and the 30-day mean is 0.05 mg/L; if pH < 6.5 the maximum concentration is $e^{(1.209 - 2.426pH + 0.286 K)}$ mg/L where K = $(pH)^2$ and the 30-day mean is $e^{1.6 - 3.327 (median\ pH) + 0.402 K)}$ mg/L where K = $(median\ pH)^2$.*

[w] *Working guideline*

[x] *Cadium - $10^{0.86(\log(hardness)-3.2}$ / 1000 mg/L.*

[y] *Nickel - If hardness is ≤60 mg/L, the guideline is 0.025 mg/L; if hardness is 60-120 mg/L, the guideline is 0.065 mg/L; if hardness is 120-180 mg/L, the guideline is 0.11 mg/L; if hardness >180 mg/L, the guideline is 0.15 mg/L.*

Table 8.5-11. Federal and Provincial Water Quality Guidelines for Drinking Water

Parameter	Health Canada[a]	British Columbia[b]
Physical Tests		
Colour	15[c]	15
pH	6.5 - 8.5	6.5 - 8.5
Total Dissolved Solids	500[c]	
Turbidity (NTU)	0.1	Background dependent[e]
Anions		
Chloride (Cl)	250[c]	250
Fluoride (F)	1.5	maximum 1.5; 30-day 1
Sulphate (SO_4)	500[c]	500
Nutrients		
Nitrate (as N)	10	-
Nitrite (as N)	1	1
Cyanides		
Cyanide, Total	0.2	
Cyanide, Strong-acid dissociable + Thiocyanate		0.2
Total Metals		
Aluminum (Al)	0.1[d]	-
Antimony	0.006	-
Arsenic (As)	0.01	0.025[f]
Barium (Ba)	1	-
Boron (B)	5	5
Cadmium (Cd)	0.005	-
Chromium (Cr)	0.05	-
Copper (Cu)	1[c]	0.5
Iron (Fe)	0.3[c]	-
Lead (Pb)	0.01	0.05
Manganese (Mn)	0.05[c]	-
Mercury (Hg)	0.001	0.001
Molybdenum (Mo)		0.25
Selenium (Se)	0.01	0.01
Sodium (Na)	200[c]	-
Uranium (U)	0.02	-
Zinc (Zn)	5[c]	5
Dissolved Metals		
Aluminum (Al)		0.2

Notes:
- Indicates no applicable guideline.
[a] *Health Canada guidelines for drinking water quality, accessed May 2014. All units in mg/L unless otherwise noted.*
[b] *British Columbia guideline for drinking water supply, accessed May 2014.*
[c] *Aesthetic objective*
[d] *Operational guidance value*
[e] *Raw drinking water with treatment to remove particulates: change from background of 5 NTU when background is ≤50 NTU; change from background of 10% when background is >50 NTU.*
Raw drinking water without treatment to remove particulates: change from background of 1 NTU when background is ≤5 NTU; change from background of 5 NTU at any time.
[f] *Interim guideline.*

Table 8.5-12. Provincial Water Quality Guidelines for Wildlife Water Supply

Parameter	Maximum	30-Day Mean
Total Metals		
Aluminum (Al)	5	
Arsenic (As)	0.025*	
Boron (B)	5	
Copper (Cu)	0.3	
Lead (Pb)	0.1	
Mercury (Hg)		0.00002 if MeHg = 0.5% THg 0.00001 if MeHg = 1.0% of THg 0.00000125 if MeHg = 8.0% of THg
Molybdenum (Mo)	0.05	
Selenium (Se)	0.002	

All units in mg/L
** interim guideline*
MeHg = methyl mercury; THg = total mercury

In contrast during freshet (typically May), increased stream flows elevated suspended sediments (total suspended solids (TSS) and turbidity), which was associated with elevated nutrients (total nitrogen, total Kjeldahl nitrogen (TKN), phosphorus), total organic carbon (TOC) and metal concentrations. The increased concentrations likely reflect the increased runoff and re-suspension of sediments during freshet and the associated particle-bound nutrients, TOC and metals.

Shaft/Decline Sites (West Bank)

West bank streams associated with the Shaft/Decline Sites had slightly alkaline pH (median range: 8.12-8.34 pH), with moderately hard to very hard water (median range: 65-196 mg $CaCO_3$/L; Durfor and Becker 1964), and were well buffered against acid inputs (median alkalinity >40 mg $CaCO_3$/L; Saffran and Trew 1996). Spatially, west bank streams were more clear (lower TSS and turbidity) at upstream and reference sites (REFST, TC-01 and M20-03), compared to downstream sites adjacent to the Shaft/Decline Sites (Table 8.5-13). Temporally, TSS, turbidity, nutrient and metal concentrations were elevated during freshet in streams on the west bank. Trophic status of west bank streams was also temporally variable, ranging from ultra-oligotrophic in winter (total phosphorus <0.004 mg P/L) to hyper-eutrophic during freshet (total phosphorus >0.1 mg P/L). While nutrient concentrations were not as high in west bank sites as streams on the east bank (by the Coal Processing Site), nutrient concentrations at west bank sites were elevated compared to the Murray River (Table 8.5-13).

M20 Creek both upstream and downstream of the proposed Shaft Site (M20-06 and M20-04, respectively) had elevated metal concentrations compared to other Project area sites. M20 Creek proximal to the proposed Shaft Site had elevated aluminum (total and dissolved), total arsenic, cadmium, chromium, cobalt, copper, iron, lead, nickel, and zinc (Table 8.5-13). Total selenium concentrations were also elevated in M20 Creek compared to other Project area sites; however, concentrations were higher at upstream sites closer to the Hermann Mine (Table 8.5-13). Total molybdenum concentrations increased downstream in M20 Creek, but were highest in REFST compared to other Project area sites. The majority of surface water quality samples for all baseline study area sites were below detection limits for total mercury (97% of samples), and therefore are not discussed in the sections below.

Table 8.5-13. Surface Water Quality Summary, 2010 to 2014

Parameter	pH		Conductivity (µS/cm)		Hardness (as $CaCO_3$)		Total Suspended Solids		Turbidity (NTU)		Alkalinity, Total (as $CaCO_3$)		Ammonia, Total (as N)	
Stat	Median	95^{th} P	Median	95^{th} P	Median	95^{th} P	Median	95^{th} P	Median	95^{th} P	Median	95^{th} P	Median	95^{th} P
Shaft/Decline Sites														
REFST	8.30	8.41	331	401	179	216	1.5	44.7	0.8	15.9	150	177	0.0025	0.0100
TC-01	8.17	8.25	129	188	65	90	1.5	23.2	2.5	12.6	73	99	0.0025	0.0105
TC-02	8.12	8.26	227	377	118	198	5.8	748.4	6.4	386.0	116	204	0.0087	0.0234
M20-03	8.26	8.37	401	432	192	211	1.5	28.9	0.8	17.6	163	174	0.0025	0.0080
M20-05	8.31	8.42	395	422	193	217	8.3	127.0	7.0	129.1	164	181	0.0025	0.0119
M20-06	8.34	8.42	400	433	196	217	8.4	82.2	21.3	126.2	167	185	0.0025	0.0111
M20-04	8.30	8.46	386	431	182	211	19.5	767.0	43.5	660.9	161	182	0.0025	0.0198
Coal Processing Site														
M17A	8.37	8.44	648	892	366	517	6.5	47.4	1.6	19.7	269	322	0.0040	0.0085
M17-02	8.39	8.45	684	949	383	529	8.9	57.7	5.4	43.7	263	296	0.0025	0.0101
M19A	8.36	8.46	805	1,083	452	634	3.3	22.6	0.9	5.9	261	335	0.0025	0.0084
M19-01	8.26	8.36	308	349	159	181	1.5	9.4	0.8	3.2	158	186	0.0025	0.0083
M19-02	8.24	8.33	347	395	182	199	1.5	7.8	0.8	6.0	176	212	0.0025	0.0084
Receiving Environment														
MR-REF	8.24	8.33	207	312	108	164	5.9	64.0	2.5	30.3	111	156	0.0025	0.0104
MR1	8.22	8.26	182	262	98	126	8.2	58.2	5.7	28.1	95	138	0.0025	0.0089
MR2	8.20	8.28	182	267	97	128	8.2	65.2	5.6	27.5	94	139	0.0025	0.0089
MR9	8.20	8.30	240	313	122	162	4.4	41.2	3.9	36.2	123	159	0.0025	0.0086
MR3	8.23	8.32	213	326	108	170	5.7	102.1	3.8	41.2	111	160	0.0025	0.0077
MR4	8.24	8.32	221	332	114	169	8.7	134.7	5.1	84.1	117	164	0.0025	0.0104
MR7	8.24	8.31	254	351	130	188	7.4	165.4	7.5	68.7	128	168	0.0025	0.0205
MR7B	8.24	8.31	259	319	142	172	4.3	20.8	2.9	12.7	133	165	0.0025	0.0025
MR8	8.22	8.34	260	342	125	184	4.2	69.3	3.1	25.4	129	167	0.0025	0.0179
MR6	8.21	8.29	239	346	128	183	4.1	126.4	2.8	53.9	123	171	0.0025	0.0108
MR10	8.24	8.33	330	377	171	201	1.5	72.1	3.0	42.6	155	176	0.0111	0.0234

Values represent mg/L unless otherwise noted.

(continued)

Values below the detection limit were replaced with half the detection limit for calculations.

P = percentile

Table 8.5-13. Surface Water Quality Summary, 2010 to 2014 (continued)

Parameter	Chloride (Cl)		Fluoride (F)		Sulphate (SO_4)		Total Nitrogen		Total Kjeldahl Nitrogen		Nitrate (as N)		Nitrite (as N)	
Stat	Median	95th P	Median	95th P	Median	95th P	Median	95th P	Median	95th P	Median	95th P	Median	95th P
Shaft/Decline Sites														
REFST	0.25	0.25	0.07	0.11	34.30	56.36	0.12	0.27	0.04	0.19	0.0700	0.1310	0.0005	0.0008
TC-01	0.25	0.25	0.08	0.09	3.23	4.55	0.24	0.44	0.16	0.29	0.0603	0.2670	0.0005	0.0005
TC-02	0.25	1.04	0.08	0.09	8.46	17.10	0.25	1.27	0.23	1.15	0.0080	0.1470	0.0005	0.0011
M20-03	0.57	0.81	0.08	0.09	58.80	79.76	0.16	0.29	0.07	0.21	0.0860	0.1340	0.0005	0.0006
M20-05	0.57	0.80	0.08	0.09	51.25	68.60	0.17	0.45	0.08	0.35	0.0708	0.1301	0.0005	0.0005
M20-06	0.91	1.48	0.11	0.14	52.45	65.82	0.20	0.27	0.10	0.24	0.0875	0.1382	0.0005	0.0005
M20-04	1.01	2.01	0.11	0.15	45.70	62.10	0.20	0.75	0.13	0.68	0.0643	0.1336	0.0005	0.0008
Coal Processing Site														
M17A	1.25	2.50	0.10	0.23	137.50	220.60	0.31	0.43	0.27	0.39	0.0204	0.1290	0.0025	0.0050
M17-02	3.19	17.40	0.13	0.26	131.00	286.00	0.35	0.48	0.23	0.36	0.0591	0.3380	0.0025	0.0050
M19A	2.50	2.73	0.10	0.20	215.50	359.50	0.28	0.39	0.25	0.38	0.0303	0.1383	0.0050	0.0050
M19-01	2.57	6.39	0.08	0.09	9.20	15.51	0.32	0.45	0.23	0.41	0.0816	0.1402	0.0005	0.0006
M19-02	2.54	9.70	0.08	0.09	8.44	13.30	0.39	0.47	0.22	0.45	0.0860	0.2370	0.0005	0.0005
Receiving Environment														
MR-REF	0.51	1.80	0.04	0.06	7.47	17.19	0.13	0.27	0.06	0.19	0.0642	0.1123	0.0005	0.0022
MR1	0.25	1.24	0.03	0.05	4.31	14.55	0.12	0.13	0.05	0.08	0.0668	0.0879	0.0008	0.0044
MR2	0.25	1.14	0.03	0.05	4.29	14.21	0.14	0.15	0.07	0.09	0.0666	0.0886	0.0005	0.0043
MR9	0.60	1.67	0.04	0.06	9.66	16.57	0.12	0.20	0.03	0.13	0.0732	0.1164	0.0005	0.0005
MR3	0.61	1.98	0.04	0.06	9.35	21.18	0.12	0.26	0.05	0.17	0.0669	0.1082	0.0005	0.0010
MR4	0.66	2.16	0.04	0.06	11.20	22.66	0.13	0.45	0.06	0.36	0.0694	0.1160	0.0005	0.0027
MR7	0.84	1.91	0.04	0.06	11.33	30.17	0.11	0.27	0.05	0.24	0.0599	0.0999	0.0005	0.0005
MR7B	1.17	2.09	0.05	0.06	16.50	24.11	0.13	0.21	0.05	0.11	0.0801	0.1127	0.0005	0.0005
MR8	0.78	2.92	0.04	0.06	12.35	21.83	0.14	0.25	0.03	0.20	0.0574	0.1147	0.0005	0.0005
MR6	0.77	1.99	0.04	0.06	12.30	24.46	0.12	0.26	0.05	0.21	0.0688	0.1094	0.0005	0.0007
MR10	1.46	2.31	0.05	0.06	27.20	36.22	0.26	0.31	0.08	0.15	0.1805	0.2736	0.0005	0.0015

Values represent mg/L unless otherwise noted.

(continued)

Values below the detection limit were replaced with half the detection limit for calculations.

Table 8.5-13. Surface Water Quality Summary, 2010 to 2014 (continued)

Parameter	Total Phosphorus		Cyanide, Total		Cyanide, WAD		Total Organic Carbon		Total Aluminum (Al)		Total Antimony (Sb)		Total Arsenic (As)	
Stat	Median	95^{th} P	Median	95^{th} P	Median	95^{th} P	Median	95^{th} P	Median	95^{th} P	Median	95^{th} P	Median	95^{th} P
Shaft/Decline Sites														
REFST	0.008	0.072	0.0005	0.0050	0.0005	0.0010	1.62	4.63	0.028	0.540	0.00011	0.00022	0.00017	0.00102
TC-01	0.009	0.035	0.0033	0.0091	0.0005	0.0013	5.96	12.44	0.087	0.768	0.00005	0.00005	0.00018	0.00034
TC-02	0.021	0.557	0.0031	0.0275	0.0005	0.0014	7.37	26.30	0.234	8.004	0.00005	0.00031	0.00031	0.00607
M20-03	0.005	0.036	0.0005	0.0072	0.0005	0.0007	2.40	6.88	0.018	0.895	0.00005	0.00012	0.00014	0.00040
M20-05	0.012	0.146	0.0005	0.0072	0.0005	0.0011	2.64	10.07	0.235	3.470	0.00005	0.00026	0.00025	0.00240
M20-06	0.022	0.125	0.0005	0.0005	0.0005	0.0005	3.19	8.68	0.742	3.048	0.00012	0.00022	0.00041	0.00115
M20-04	0.043	0.509	0.0005	0.0093	0.0005	0.0010	4.00	18.25	1.297	10.460	0.00015	0.00048	0.00050	0.00621
Coal Processing Site														
M17A	0.009	0.031	0.0005	0.0005	0.0005	0.0005	9.76	12.62	0.079	0.687	0.00020	0.00024	0.00030	0.00054
M17-02	0.014	0.061	0.0005	0.0005	0.0005	0.0005	6.43	13.80	0.130	1.570	0.00018	0.00022	0.00032	0.00078
M19A	0.009	0.036	0.0005	0.0005	0.0005	0.0005	7.22	12.23	0.028	0.199	0.00005	0.00007	0.00026	0.00041
M19-01	0.005	0.012	0.0005	0.0005	0.0005	0.0005	8.98	16.05	0.016	0.112	0.00005	0.00012	0.00026	0.00033
M19-02	0.004	0.015	0.0005	0.0005	0.0005	0.0005	8.29	17.50	0.010	0.156	0.00005	0.00010	0.00023	0.00035
Receiving Environment														
MR-REF	0.008	0.080	0.0010	0.0050	0.0005	0.0010	1.62	4.38	0.097	0.953	0.00005	0.00032	0.00017	0.00088
MR1	0.012	0.062	0.0031	0.0048	0.0010	0.0010	1.55	2.77	0.189	1.114	0.00005	0.00041	0.00025	0.00211
MR2	0.012	0.053	0.0036	0.0050	0.0010	0.0010	1.75	3.32	0.190	1.139	0.00005	0.00041	0.00025	0.00211
MR9	0.005	0.050	0.0005	0.0040	0.0005	0.0010	1.58	3.18	0.119	1.202	0.00005	0.00016	0.00018	0.00067
MR3	0.006	0.091	0.0005	0.0050	0.0005	0.0010	1.75	4.28	0.113	1.520	0.00005	0.00014	0.00020	0.00102
MR4	0.010	0.125	0.0005	0.0050	0.0005	0.0010	1.68	6.13	0.179	2.501	0.00005	0.00021	0.00026	0.00176
MR7	0.010	0.083	0.0019	0.0049	0.0005	0.0010	2.04	4.88	0.211	2.405	0.00005	0.00014	0.00020	0.00122
MR7B	0.005	0.023	0.0005	0.0005	0.0005	0.0005	1.46	3.06	0.098	0.352	0.00005	0.00017	0.00018	0.00034
MR8	0.006	0.073	0.0016	0.0032	0.0005	0.0010	2.04	3.34	0.110	0.854	0.00005	0.00017	0.00016	0.00043
MR6	0.006	0.104	0.0005	0.0050	0.0005	0.0010	1.63	3.87	0.088	1.855	0.00005	0.00031	0.00021	0.00144
MR10	0.008	0.070	0.0005	0.0024	0.0005	0.0008	2.17	4.85	0.055	1.247	0.00005	0.00013	0.00021	0.00066

Values represent mg/L unless otherwise noted. *(continued)*

Values below the detection limit were replaced with half the detection limit for calculations.

Table 8.5-13. Surface Water Quality Summary, 2010 to 2014 (continued)

Parameter	Total Barium (Ba)		Total Beryllium (Be)		Total Boron (B)		Total Cadmium (Cd)		Total Chromium (Cr)		Total Cobalt (Co)		Total Copper (Cu)	
Stat	Median	95^{th} P	Median	95^{th} P	Median	95^{th} P	Median	95^{th} P	Median	95^{th} P	Median	95^{th} P	Median	95^{th} P
Shaft/Decline Sites														
REFST	0.039	0.072	0.00005	0.00025	0.005	0.015	0.000028	0.000095	0.00028	0.00250	0.00005	0.00031	0.0003	0.0011
TC-01	0.122	0.150	0.00005	0.00025	0.005	0.012	0.000016	0.000052	0.00031	0.00136	0.00005	0.00032	0.0007	0.0015
TC-02	0.183	0.577	0.00005	0.00054	0.011	0.017	0.000029	0.000572	0.00057	0.01229	0.00023	0.00674	0.0013	0.0174
M20-03	0.203	0.227	0.00005	0.00025	0.010	0.014	0.000011	0.000047	0.00017	0.00129	0.00005	0.00044	0.0003	0.0014
M20-05	0.211	0.241	0.00005	0.00025	0.011	0.016	0.000025	0.000252	0.00052	0.00560	0.00012	0.00159	0.0007	0.0053
M20-06	0.182	0.192	0.00005	0.00013	0.013	0.017	0.000045	0.000140	0.00116	0.00437	0.00039	0.00151	0.0016	0.0044
M20-04	0.179	0.454	0.00005	0.00058	0.015	0.022	0.000059	0.000754	0.00210	0.01724	0.00063	0.00776	0.0026	0.0212
Coal Processing Site														
M17A	0.125	0.159	0.00005	0.00005	0.013	0.016	0.000016	0.000052	0.00023	0.00107	0.00005	0.00054	0.0010	0.0021
M17-02	0.118	0.133	0.00005	0.00005	0.017	0.024	0.000025	0.000076	0.00036	0.00226	0.00013	0.00073	0.0011	0.0033
M19A	0.141	0.192	0.00005	0.00005	0.014	0.018	0.000014	0.000027	0.00016	0.00040	0.00005	0.00028	0.0006	0.0009
M19-01	0.144	0.157	0.00005	0.00005	0.005	0.013	0.000005	0.000020	0.00013	0.00035	0.00005	0.00013	0.0008	0.0013
M19-02	0.142	0.167	0.00005	0.00005	0.005	0.015	0.000014	0.000020	0.00011	0.00040	0.00005	0.00012	0.0008	0.0010
Receiving Environment														
MR-REF	0.044	0.069	0.00005	0.00025	0.010	0.018	0.000018	0.000100	0.00029	0.00230	0.00005	0.00057	0.0003	0.0018
MR1	0.035	0.073	0.00025	0.00045	0.008	0.018	0.000020	0.000073	0.00072	0.00237	0.00017	0.00059	0.0007	0.0016
MR2	0.036	0.075	0.00025	0.00045	0.005	0.018	0.000025	0.000078	0.00090	0.00238	0.00019	0.00062	0.0010	0.0017
MR9	0.053	0.076	0.00005	0.00025	0.011	0.016	0.000016	0.000052	0.00034	0.00248	0.00005	0.00045	0.0005	0.0023
MR3	0.053	0.078	0.00005	0.00025	0.011	0.017	0.000019	0.000107	0.00035	0.00262	0.00009	0.00095	0.0006	0.0027
MR4	0.060	0.102	0.00005	0.00025	0.011	0.017	0.000024	0.000130	0.00057	0.00365	0.00014	0.00129	0.0008	0.0048
MR7	0.065	0.112	0.00005	0.00025	0.012	0.015	0.000020	0.000130	0.00046	0.00349	0.00012	0.00153	0.0007	0.0037
MR7B	0.055	0.071	0.00005	0.00005	0.010	0.014	0.000015	0.000038	0.00027	0.00068	0.00005	0.00020	0.0003	0.0010
MR8	0.056	0.077	0.00005	0.00025	0.011	0.015	0.000018	0.000055	0.00037	0.00131	0.00005	0.00048	0.0006	0.0016
MR6	0.063	0.096	0.00005	0.00025	0.011	0.017	0.000018	0.000085	0.00033	0.00292	0.00005	0.00111	0.0005	0.0033
MR10	0.085	0.103	0.00005	0.00025	0.012	0.013	0.000013	0.000080	0.00026	0.00205	0.00005	0.00065	0.0006	0.0023

Values represent mg/L unless otherwise noted.

(continued)

Values below the detection limit were replaced with half the detection limit for calculations.

Table 8.5-13. Surface Water Quality Summary, 2010 to 2014 (continued)

Parameter	Total Iron (Fe)		Total Lead (Pb)		Total Lithium (Li)		Total Manganese (Mn)		Total Mercury (Hg)		Total Molybdenum (Mo)		Total Nickel (Ni)	
Stat	Median	95th P	Median	95th P	Median	95th P	Median	95th P	Median	95th P	Median	95th P	Median	95th P
Shaft/Decline Sites														
REFST	0.033	0.741	0.000025	0.000500	0.00250	0.00462	0.0008	0.0114	0.000005	0.000012	0.00359	0.00439	0.0007	0.0025
TC-01	0.087	0.770	0.000051	0.000393	0.00189	0.00250	0.0013	0.0126	0.000005	0.000005	0.00022	0.00031	0.0011	0.0023
TC-02	0.627	14.480	0.000159	0.009056	0.00266	0.00974	0.0247	0.2352	0.000005	0.000058	0.00032	0.00094	0.0019	0.0224
M20-03	0.099	0.810	0.000025	0.000480	0.00541	0.00657	0.0119	0.0305	0.000005	0.000005	0.00045	0.00052	0.0005	0.0024
M20-05	0.237	3.720	0.000136	0.002110	0.00530	0.00690	0.0053	0.0772	0.000005	0.000021	0.00048	0.00063	0.0008	0.0071
M20-06	0.522	2.999	0.000265	0.001581	0.01004	0.01275	0.0105	0.0490	0.000005	0.000006	0.00064	0.00075	0.0026	0.0071
M20-04	1.090	18.660	0.000585	0.010270	0.00980	0.01630	0.0201	0.3104	0.000005	0.000066	0.00067	0.00129	0.0038	0.0280
Coal Processing Site														
M17A	0.136	1.130	0.000061	0.000565	0.00796	0.01198	0.0059	0.0341	0.000005	0.000005	0.00126	0.00152	0.0016	0.0028
M17-02	0.192	1.730	0.000112	0.000907	0.01190	0.02320	0.0044	0.0253	0.000005	0.000005	0.00121	0.00144	0.0023	0.0049
M19A	0.046	0.403	0.000025	0.000232	0.00957	0.01153	0.0030	0.0204	0.000005	0.000005	0.00030	0.00036	0.0012	0.0017
M19-01	0.076	0.256	0.000025	0.000119	0.00289	0.00342	0.0040	0.0091	0.000005	0.000005	0.00025	0.00032	0.0009	0.0013
M19-02	0.015	0.247	0.000025	0.000115	0.00298	0.00357	0.0011	0.0085	0.000005	0.000005	0.00026	0.00032	0.0008	0.0022
Receiving Environment														
MR-REF	0.191	1.570	0.000114	0.001045	0.00250	0.00697	0.0073	0.0520	0.000005	0.000017	0.00061	0.00100	0.0005	0.0024
MR1	0.280	1.307	0.000200	0.000748	0.00250	0.00602	0.0080	0.0371	0.000005	0.000085	0.00054	0.00123	0.0010	0.0020
MR2	0.290	1.369	0.000239	0.000800	0.00250	0.00570	0.0089	0.0390	0.000005	0.000085	0.00053	0.00132	0.0010	0.0022
MR9	0.213	1.060	0.000112	0.000600	0.00343	0.00709	0.0093	0.0232	0.000005	0.000005	0.00070	0.00092	0.0005	0.0020
MR3	0.221	2.245	0.000134	0.001185	0.00315	0.00841	0.0106	0.0525	0.000005	0.000010	0.00061	0.00095	0.0006	0.0034
MR4	0.298	3.127	0.000157	0.001654	0.00374	0.00824	0.0127	0.0678	0.000005	0.000018	0.00064	0.00090	0.0008	0.0043
MR7	0.318	3.502	0.000140	0.002430	0.00450	0.00832	0.0157	0.0869	0.000005	0.000005	0.00070	0.00091	0.0007	0.0046
MR7B	0.176	0.594	0.000095	0.000301	0.00463	0.00858	0.0087	0.0186	0.000005	0.000005	0.00076	0.00090	0.0003	0.0010
MR8	0.220	1.097	0.000096	0.000616	0.00369	0.00697	0.0109	0.0286	0.000005	0.000005	0.00067	0.00092	0.0005	0.0016
MR6	0.231	2.585	0.000111	0.001412	0.00378	0.00776	0.0095	0.0604	0.000005	0.000020	0.00063	0.00089	0.0005	0.0035
MR10	0.159	1.608	0.000088	0.000854	0.00546	0.00833	0.0081	0.0281	0.000005	0.000005	0.00086	0.00105	0.0006	0.0028

Values represent mg/L unless otherwise noted.

(continued)

Values below the detection limit were replaced with half the detection limit for calculations.

Table 8.5-13. Surface Water Quality Summary, 2010 to 2014 (continued)

Parameter	Total Potassium (K)		Total Selenium (Se)		Total Silver (Ag)		Total Thallium (Tl)		Total Uranium (U)		Total Vanadium (V)		Total Zinc (Zn)	
Stat	Median	95th P	Median	95th P	Median	95th P	Median	95th P	Median	95th P	Median	95th P	Median	95th P
Shaft/Decline Sites														
REFST	0.349	0.559	0.00068	0.00118	0.000005	0.000051	0.000015	0.000067	0.00068	0.00091	0.0015	0.0050	0.0015	0.0088
TC-01	0.342	0.440	0.00014	0.00016	0.000005	0.000029	0.000005	0.000050	0.00008	0.00021	0.0005	0.0022	0.0015	0.0053
TC-02	0.570	2.448	0.00018	0.00063	0.000005	0.000241	0.000005	0.000212	0.00017	0.00096	0.0005	0.0268	0.0041	0.0789
M20-03	0.552	0.750	0.00155	0.00272	0.000005	0.000023	0.000005	0.000050	0.00053	0.00064	0.0005	0.0026	0.0015	0.0065
M20-05	0.650	1.620	0.00128	0.00281	0.000005	0.000109	0.000005	0.000100	0.00053	0.00066	0.0005	0.0126	0.0030	0.0235
M20-06	0.834	1.493	0.00120	0.00158	0.000005	0.000043	0.000017	0.000069	0.00057	0.00068	0.0026	0.0097	0.0067	0.0206
M20-04	1.040	3.195	0.00112	0.00250	0.000013	0.000250	0.000049	0.000301	0.00058	0.00103	0.0045	0.0378	0.0094	0.0894
Coal Processing Site														
M17A	0.833	1.132	0.00058	0.00190	0.000005	0.000016	0.000005	0.000021	0.00175	0.00275	0.0005	0.0026	0.0015	0.0062
M17-02	1.420	1.720	0.00109	0.00253	0.000005	0.000019	0.000005	0.000047	0.00197	0.00439	0.0005	0.0052	0.0015	0.0119
M19A	1.075	1.278	0.00044	0.00066	0.000005	0.000011	0.000005	0.000007	0.00101	0.00180	0.0005	0.0007	0.0015	0.0038
M19-01	0.489	0.656	0.00013	0.00017	0.000005	0.000005	0.000005	0.000005	0.00020	0.00029	0.0005	0.0005	0.0015	0.0037
M19-02	0.513	0.710	0.00019	0.00030	0.000005	0.000013	0.000005	0.000010	0.00024	0.00040	0.0005	0.0010	0.0015	0.0065
Receiving Environment														
MR-REF	0.380	0.719	0.00018	0.00043	0.000005	0.000044	0.000010	0.000057	0.00020	0.00033	0.0005	0.0050	0.0015	0.0148
MR1	0.381	0.671	0.00010	0.00208	0.000010	0.000205	0.000050	0.000306	0.00017	0.00046	0.0011	0.0049	0.0030	0.0175
MR2	0.375	0.684	0.00010	0.00208	0.000011	0.000205	0.000050	0.000322	0.00017	0.00048	0.0012	0.0050	0.0020	0.0176
MR9	0.430	0.816	0.00021	0.00032	0.000005	0.000039	0.000005	0.000050	0.00024	0.00031	0.0005	0.0047	0.0015	0.0176
MR3	0.426	0.818	0.00021	0.00036	0.000005	0.000029	0.000012	0.000050	0.00022	0.00035	0.0005	0.0053	0.0020	0.0132
MR4	0.490	1.175	0.00025	0.00049	0.000005	0.000067	0.000016	0.000070	0.00025	0.00037	0.0005	0.0085	0.0034	0.0205
MR7	0.474	1.043	0.00023	0.00036	0.000005	0.000024	0.000015	0.000063	0.00026	0.00038	0.0005	0.0076	0.0035	0.0140
MR7B	0.423	0.517	0.00021	0.00031	0.000005	0.000005	0.000005	0.000012	0.00028	0.00035	0.0005	0.0015	0.0015	0.0049
MR8	0.454	0.638	0.00022	0.00027	0.000005	0.000007	0.000005	0.000050	0.00024	0.00035	0.0005	0.0030	0.0015	0.0073
MR6	0.471	0.941	0.00022	0.00065	0.000005	0.000046	0.000005	0.000050	0.00026	0.00036	0.0005	0.0057	0.0016	0.0138
MR10	0.555	0.938	0.00050	0.00061	0.000005	0.000018	0.000009	0.000050	0.00035	0.00043	0.0005	0.0049	0.0033	0.0093

Values represent mg/L unless otherwise noted.

(continued)

Values below the detection limit were replaced with half the detection limit for calculations.

Table 8.5-13. Surface Water Quality Summary, 2010 to 2014 (completed)

Parameter	Dissolved Aluminum (Al)		Dissolved Iron (Fe)	
Stat	Median	95th P	Median	95th P
Shaft/Decline Sites				
REFST	0.002	0.025	0.015	0.050
TC-01	0.027	0.136	0.041	0.184
TC-02	0.021	0.226	0.102	0.553
M20-03	0.002	0.033	0.034	0.074
M20-05	0.003	0.057	0.015	0.073
M20-06	0.018	0.039	0.015	0.071
M20-04	0.025	0.154	0.015	0.177
Coal Processing Site				
M17A	0.003	0.007	0.015	0.045
M17-02	0.002	0.011	0.015	0.053
M19A	0.002	0.003	0.015	0.021
M19-01	0.005	0.020	0.049	0.142
M19-02	0.003	0.014	0.015	0.088
Receiving Environment				
MR-REF	0.006	0.025	0.015	0.049
MR1	0.016	0.023	0.023	0.049
MR2	0.016	0.023	0.032	0.049
MR9	0.005	0.022	0.015	0.052
MR3	0.006	0.025	0.015	0.051
MR4	0.006	0.048	0.015	0.059
MR7	0.007	0.053	0.015	0.061
MR7B	0.002	0.017	0.015	0.047
MR8	0.004	0.013	0.015	0.020
MR6	0.004	0.025	0.037	0.137
MR10	0.005	0.021	0.015	0.045

Values represent mg/L unless otherwise noted.

Values below the detection limit were replaced with half the detection limit for calculations.

Total aluminum, cadmium, chromium, and iron concentrations were commonly above guidelines in the Project area, and concentrations were particularly high in west bank streams near the Shaft/Decline Sites (TC-02 and M20-04; Tables 8.5-14 to 8.5-16). West bank streams were above more guidelines than other baseline study area sites (including pH, fluoride, cyanide, dissolved aluminum and iron, total arsenic, barium, cobalt, copper, lead, mercury, nickel, selenium, silver, vanadium, and zinc). Guideline exceedances were typically most common during freshet and greatest at the mouth of the streams by Shaft/Decline Sites (TC-02 and M20-04).

Coal Processing Site (East Bank)

Streams on the east bank of the Murray River near the proposed Coal Processing Site had slightly alkaline pH (median range: 8.24-8.39 pH) and water was fairly clear (median TSS <10 mg/L; median turbidity <6 NTU). East bank creeks in general had hard to very hard water, were well buffered against acid inputs (high alkalinity), and total phosphorus levels indicated the tropic status ranged from ultra-oligotrophic in winter to eutrophic (0.035-0.1 mg P/L) during freshet (Table 8.5-13). M19 Creek had lower conductivity, hardness, alkalinity and sulphate compared to other streams near the Coal Processing Site.

Streams adjacent to the Coal Processing Site had elevated concentrations of nutrients (total nitrogen, TKN) compared to other Project area sites, and nitrogen was primarily organic (high TKN and low ammonia levels; Table 8.5-13). TOC concentrations were also elevated in east bank streams (median range: 6.43-9.76 mg/L) compared to other Project area sites (medians <7.5 mg/L).

Of the sampled Project area sites, streams near the Coal Processing Site typically had the lowest metal concentrations (Table 8.5-13). Elevated molybdenum, selenium and uranium in M17A, M17-02 and M19A streams were exceptions, and concentrations were typically highest during winter low flow.

In addition to total aluminum, cadmium, chromium, and iron which were commonly above guidelines in the Project area, water quality at sites on the east bank of the Murray River was above guidelines for pH, fluoride, sulphate, total mercury, total selenium and dissolved iron (Tables 8.5-14 to 8.5-16). These parameters were also sporadically above guidelines in other Project area sites. Overall, sites by the Coal Processing Site had the fewest number of guideline exceedances and sites usually exceeded by the lowest factor.

Receiving Environment (Murray River)

The Murray River had slightly alkaline pH (median range: 8.20-8.24 pH), moderately hard to hard (median range: 97-171 mg $CaCO_3$/L), clear water that was well buffered against acid inputs (alkalinity >40 mg $CaCO_3$/L), as was observed in the Murray River tributaries in the baseline study area (Table 8.5-13). As with the tributaries, sulphate was the dominant anion in the Murray River. Nitrogen (total nitrogen, TKN, and nitrate) and TOC concentrations were lower in the Murray River compared to its tributaries. Total phosphorus levels displayed seasonal patterns, with the tropic status being elevated during high flow in freshet (eutrophic to hyper-eutrophic) and low during winter low-flow months (ultra-oligotrophic to oligotrophic), as was observed in the tributary streams.

Similar to its tributary streams, the Murray River had elevated TSS, turbidity and metals during freshet; however, these increases were less prominent compared to the west bank tributaries associated with the Shaft/Decline Sites. Murray River metal concentrations were usually within the range of its tributary streams, with concentrations being higher in the west bank tributaries and lower in the east bank tributaries (Table 8.5-13).

MR4 (downstream of M20 Creek and the Shaft/Decline Sites) and MR7 (downstream of the proposed Coal Processing Site) had slightly elevated concentrations of many metals compared to other Murray River sites, particularly during freshet. However, further downstream at MR7B and MR8 concentrations were consistent with other Murray River sites (Table 8.5-13).

As was true for the tributaries, water quality of the Murray River was frequently above guidelines for total aluminum, cadmium, chromium, and iron (Tables 8.5-14 to 8.5-16). The pH, fluoride, cyanide, total copper, mercury, silver, vanadium, zinc, and dissolved aluminum concentrations were also sporadically above guidelines in the Murray River. While total selenium levels were above guidelines in Murray River tributaries, the Murray River had no samples above guidelines for total selenium.

8.5.4 Aquatic Resources

8.5.4.1 Data Sources

Data presented in this section are drawn from the following sources:

- Murray River Coal Project: 2010 to 2012 Aquatic Resources Baseline Report (Appendix 8-B);
- Murray River Coal Project: 2010 to 2014 Surface Water Quality and Aquatic Resources Data (Appendix 8-C); and
- HD Mining: Aquatic Life Baseline 2013 (Appendix 8-D).

These data are compiled in Appendix 8-C, which supersedes the raw data presented in Appendices 8-B and 8-D.

8.5.4.2 Methods

<u>Sampling Locations</u>

The aquatic resources baseline program was designed to overlap with the surface water quality program and shares many of the same sites (Table 8.5-8; see Figure 8.6-1). Baseline aquatic resources were characterized for seven sites along the Murray River, as well as Murray River tributary streams on the west bank (five sites) and the east bank (three sites). Aquatic resources baseline information has been collected in August annually since 2010. A summary of the aquatic resources sampling program is presented in Table 8.5-17. S descriptions and rationale are described in Section 8.5.3.2 as well as Table 8.5-8. Aquatic resources sampling methodologies are described in detail in the baseline reports (Appendices 8-B and 8-D), and are briefly summarized below. As with the surface water quality baseline setting, the aquatic resources setting is discussed in relation to the Project infrastructure to aid with interpretation of the data:

Table 8.5-14. BC and CCME Water Quality for the Protection of Freshwater Aquatic Life Guideline Screening, 2010 to 2014

Parameter		pH		Total Phosphorus	Fluoride		Cyanide, Total		Total Aluminum (Al)		Dissolved Aluminum (Al)			
Jurisdiction		CCME = BC		CCME	CCME		CCME		CCME		BC			
Guideline		9.0			0.12		0.005 (free)		0.1		30-day Hardness dependent		Maximum Hardness dependent	
Site	Samples	Factor	Percent	Trigger ranges	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent
Shaft/Decline Sites														
REFST	54	-	0%	Oligotrophic - Hyper-eutrophic	-	0%	1.4	4%	5.3	31%	1.3	2%	-	0%
TC-01	17	-	0%	Oligotrophic - Eutrophic	-	0%	1.6	29%	4.3	41%	2.3	35%	1.8	12%
TC-02	17	-	0%	Oligotrophic - Hyper-eutrophic	-	0%	3.1	35%	32.0	59%	3.3	29%	3.1	12%
M20-03	37	-	0%	Ultra-oligotrophic - Eutrophic	-	0%	1.8	11%	4.9	27%	2.2	3%	1.1	3%
M20-05	41	-	0%	Oligotrophic - Hyper-eutrophic	-	0%	2.0	10%	9.1	90%	1.8	7%	1.1	5%
M20-06	18	-	0%	Mesotrophic - Hyper-eutrophic	1.1	39%	-	0%	12.2	100%	-	0%	-	0%
M20-04	53	-	0%	Mesotrophic - Hyper-eutrophic	1.1	31%	1.9	13%	28.2	98%	2.5	30%	1.6	17%
Coal Processing Site														
M17A	14	-	0%	Ultra-oligotrophic - Eutrophic	1.8	21%	-	0%	4.4	29%	-	0%	-	0%
M17-02	21	-	0%	Ultra-oligotrophic - Eutrophic	1.3	57%	-	0%	5.1	67%	-	0%	-	0%
M19A	16	-	0%	Oligotrophic - Eutrophic	1.9	13%	-	0%	2.2	13%	-	0%	-	0%
M19-01	20	-	0%	Ultra-oligotrophic - Mesotrophic	-	0%	-	0%	1.9	10%	-	0%	-	0%
M19-02	21	-	0%	Ultra-oligotrophic - Eutrophic	1.7	5%	-	0%	3.7	10%	-	0%	-	0%
Receiving Environment														
MR-REF	56	1.3	2%	Ultra-oligotrophic - Hyper-eutrophic	1.7	2%	1.2	4%	4.5	50%	1.1	2%	-	0%
MR1	5	-	0%	Oligotrophic - Eutrophic	-	0%	-	0%	4.9	80%	-	0%	-	0%
MR2	5	-	0%	Oligotrophic - Eutrophic	-	0%	-	0%	5.0	80%	-	0%	-	0%
MR9	45	-	0%	Ultra-oligotrophic - Hyper-eutrophic	-	0%	1.4	2%	4.9	56%	-	0%	-	0%
MR3	56	-	0%	Ultra-oligotrophic - Hyper-eutrophic	-	0%	1.3	4%	6.1	54%	-	0%	-	0%
MR4	54	-	0%	Ultra-oligotrophic - Hyper-eutrophic	-	0%	1.7	4%	10.6	59%	1.5	4%	-	0%
MR7	18	-	0%	Ultra-oligotrophic - Hyper-eutrophic	-	0%	2.0	6%	9.4	61%	1.2	11%	-	0%
MR7B	23	-	0%	Ultra-oligotrophic - Meso-eutrophic	-	0%	-	0%	2.2	48%	-	0%	-	0%
MR8	15	-	0%	Ultra-oligotrophic - Eutrophic	-	0%	-	0%	5.2	53%	-	0%	-	0%
MR6	46	-	0%	Ultra-oligotrophic - Hyper-eutrophic	1.2	2%	1.8	4%	7.8	46%	1.2	2%	-	0%
MR10	12	-	0%	Ultra-oligotrophic - Eutrophic	-	0%	-	0%	7.9	42%	-	0%	-	0%

Values represent mg/L unless otherwise noted.

(continued)

Values below the detection limit were replaced with half the detection limit for calculations.

Parameters were only screened against CCME guidelines if BC guidelines were not available.

Only parameters above guidelines are included in table.

Detection limits for chromium, mercury, selenium and silver were above guidelines in samples analyzed at CARO (October 2010, December 2010 and January 2011). Samples below detection limits were excluded from calculations.

Factor represents the average factor samples above guidelines were higher than guideline concentrations.

Percent (%) represents percentage of samples collected at each site that were higher than available guidelines.

Table 8.5-14. BC and CCME Water Quality for the Protection of Freshwater Aquatic Life Guideline Screening, 2010 to 2014 (continued)

Parameter		Total Arsenic (As)		Total Barium (Ba)		Total Cadmium (Cd)		Total Chromium (Cr)				Total Cobalt (Co)		Total Copper (Cu)			
Jurisdiction		BC		BC		BC		CCME = BC				BC		BC			
Guideline				30-day				Cr(VI)		Cr(III)		30-day		30-day		Maximum	
		0.005		1		Hardness dependent		0.001		0.0089		0.004		Hardness dependent		Hardness dependent	
Site	Samples	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent
Shaft/Decline Sites																	
REFST	54	-	0%	-	0%	2.1	28%	2.1	12%	-	0%	-	0%	-	0%	-	0%
TC-01	17	-	0%	-	0%	2.9	29%	1.3	18%	-	0%	-	0%	-	0%	-	0%
TC-02	17	3.8	6%	1.7	6%	17.5	35%	8.2	35%	3.9	6%	5.1	6%	9.3	18%	4.1	12%
M20-03	37	-	0%	-	0%	2.0	11%	1.5	11%	-	0%	-	0%	-	0%	-	0%
M20-05	41	-	0%	-	0%	4.2	27%	3.7	30%	-	0%	-	0%	1.6	12%	-	0%
M20-06	18	-	0%	-	0%	3.7	28%	2.6	61%	-	0%	-	0%	2.4	6%	-	0%
M20-04	53	1.3	8%	-	0%	8.2	49%	4.9	85%	1.6	15%	1.9	9%	3.1	26%	1.6	13%
Coal Processing Site																	
M17A	14	-	0%	-	0%	-	0%	1.6	7%	-	0%	-	0%	-	0%	-	0%
M17-02	21	-	0%	-	0%	1.2	5%	1.9	24%	-	0%	-	0%	-	0%	-	0%
M19A	16	-	0%	-	0%	-	0%	-	0%	-	0%	-	0%	-	0%	-	0%
M19-01	20	-	0%	-	0%	-	0%	-	0%	-	0%	-	0%	-	0%	-	0%
M19-02	21	-	0%	-	0%	1.3	5%	1.1	5%	-	0%	-	0%	-	0%	-	0%
Receiving Environment																	
MR-REF	56	-	0%	-	0%	2.1	21%	1.9	13%	-	0%	-	0%	-	0%	-	0%
MR1	5	-	0%	-	0%	1.8	40%	1.9	25%	-	0%	-	0%	-	0%	-	0%
MR2	5	-	0%	-	0%	1.9	40%	1.9	25%	-	0%	-	0%	-	0%	-	0%
MR9	45	-	0%	-	0%	2.0	20%	2.1	16%	-	0%	-	0%	1.2	4%	-	0%
MR3	56	-	0%	-	0%	2.3	29%	1.8	26%	-	0%	-	0%	1.1	2%	-	0%
MR4	54	-	0%	-	0%	3.1	33%	2.5	40%	-	0%	-	0%	1.9	9%	1.3	2%
MR7	18	-	0%	-	0%	3.0	33%	2.6	28%	-	0%	-	0%	1.2	11%	-	0%
MR7B	23	-	0%	-	0%	1.3	9%	-	0%	-	0%	-	0%	-	0%	-	0%
MR8	15	-	0%	-	0%	2.3	13%	1.5	13%	-	0%	-	0%	-	0%	-	0%
MR6	46	-	0%	-	0%	2.4	24%	2.0	27%	-	0%	-	0%	1.0	7%	-	0%
MR10	12	-	0%	-	0%	2.2	25%	1.7	25%	-	0%	-	0%	-	0%	-	0%

Values represent mg/L unless otherwise noted. *(continued)*

Values below the detection limit were replaced with half the detection limit for calculations.

Parameters were only screened against CCME guidelines if BC guidelines were not available.

Only parameters above guidelines are included in table.

Detection limits for chromium, mercury, selenium and silver were above guidelines in samples analyzed at CARO (October 2010, December 2010 and January 2011). Samples below detection limits were excluded from calculations.

Factor represents the average factor samples above guidelines were higher than guideline concentrations.

Percent (%) represents percentage of samples collected at each site that were higher than available guidelines.

Table 8.5-14. BC and CCME Water Quality for the Protection of Freshwater Aquatic Life Guideline Screening, 2010 to 2014 (continued)

Parameter		Total Iron (Fe)		Dissolved Iron (Fe)		Total Lead (Pb)		Total Mercury (Hg)		Total Nickel (Ni)		Total Selenium (Se)				Total Silver (Ag)			
Jurisdiction		BC		BC		BC		BC		BC		BC				BC			
Guideline		1		0.35		30-day Hardness dependent		0.00002 (MeHg=0.5% THg)		Hardness dependent		Guideline 0.002		Alert Concentration 0.001		30-day Hardness dependent		Maximum Hardness dependent	
Site	Samples	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent
Shaft/Decline Sites																			
REFST	54	2.8	4%	-	0%	-	0%	-	0%	-	0%	-	0%	1.2	4%	-	0%	-	0%
TC-01	17	-	0%	-	0%	-	0%	-	0%	-	0%	-	0%	-	-	-	0%	-	0%
TC-02	17	11.1	29%	1.5	18%	6.0	6%	3.6	12%	2.5	6%	-	0%	1.6	6%	8.1	12%	4.0	12%
M20-03	37	1.6	3%	-	0%	-	0%	-	0%	-	0%	1.2	27%	1.7	84%	-	0%	-	0%
M20-05	41	3.8	20%	-	0%	-	0%	1.1	3%	-	0%	1.3	17%	1.6	83%	1.6	8%	1.1	3%
M20-06	18	2.8	28%	-	0%	-	0%	-	0%	-	0%	-	0%	1.3	83%	1.8	6%	-	0%
M20-04	53	6.2	51%	5.9	2%	1.5	9%	2.3	12%	-	0%	1.3	10%	1.5	67%	2.5	16%	1.7	8%
Coal Processing Site																			
M17A	14	1.8	7%	-	0%	-	0%	-	0%	-	0%	1.2	7%	2.0	14%	-	0%	-	0%
M17-02	21	1.7	14%	-	0%	-	0%	-	0%	-	0%	1.2	19%	1.6	71%	-	0%	-	0%
M19A	16	-	0%	-	0%	-	0%	-	0%	-	0%	-	0%	-	-	-	0%	-	0%
M19-01	20	-	0%	1.8	5%	-	0%	-	0%	-	0%	-	0%	-	-	-	0%	-	0%
M19-02	21	-	0%	-	0%	-	0%	10.6	5%	-	0%	2.5	5%	5.1	5%	-	0%	-	0%
Receiving Environment																			
MR-REF	56	1.9	11%	-	0%	-	0%	-	0%	-	0%	-	0%	-	-	-	0%	-	0%
MR1	5	1.5	20%	-	0%	-	0%	-	0%	-	0%	-	0%	-	-	-	0%	-	0%
MR2	5	1.6	20%	-	0%	-	0%	-	0%	-	0%	-	0%	-	-	-	0%	-	0%
MR9	45	2.4	7%	-	0%	-	0%	-	0%	-	0%	-	0%	-	-	-	0%	-	0%
MR3	56	2.3	11%	-	0%	-	0%	-	0%	-	0%	-	0%	-	-	-	0%	-	0%
MR4	54	2.7	22%	-	0%	-	0%	-	0%	-	0%	-	0%	-	-	1.4	4%	-	0%
MR7	18	3.2	17%	-	0%	-	0%	-	0%	-	0%	-	0%	-	-	1.1	6%	-	0%
MR7B	23	-	0%	-	0%	-	0%	-	0%	-	0%	-	0%	-	-	-	0%	-	0%
MR8	15	1.8	7%	-	0%	-	0%	-	0%	-	0%	-	0%	-	-	-	0%	-	0%
MR6	46	2.3	13%	-	0%	-	0%	-	0%	-	0%	-	0%	-	-	-	0%	-	0%
MR10	12	1.7	17%	-	0%	-	0%	-	0%	-	0%	-	0%	-	-	-	0%	-	0%

Values represent mg/L unless otherwise noted.

(continued)

Values below the detection limit were replaced with half the detection limit for calculations.

Parameters were only screened against CCME guidelines if BC guidelines were not available.

Only parameters above guidelines are included in table.

Detection limits for chromium, mercury, selenium and silver were above guidelines in samples analyzed at CARO (October 2010, December 2010 and January 2011). Samples below detection limits were excluded from calculations.

Factor represents the average factor samples above guidelines were higher than guideline concentrations.

Percent (%) represents percentage of samples collected at each site that were higher than available guidelines.

Table 8.5-14. BC and CCME Water Quality for the Protection of Freshwater Aquatic Life Guideline Screening, 2010 to 2014 (completed)

Parameter		Total Vanadium (V)		Total Zinc (Zn)			
Jurisdiction		BC		BC		BC	
Guideline		0.006		30-day Hardness dependent		Maximum Hardness dependent	
Site	Samples	Factor	Percent	Factor	Percent	Factor	Percent
Shaft/Decline Sites							
REFST	54	1.9	4%	-	0%	-	0%
TC-01	17	-	0%	-	0%	-	0%
TC-02	17	7.5	12%	9.5	24%	4.1	12%
M20-03	37	-	0%	1.3	3%	-	0%
M20-05	41	2.0	17%	2.7	10%	1.1	2%
M20-06	18	1.6	28%	4.3	6%	-	0%
M20-04	53	3.1	42%	4.5	25%	1.7	15%
Coal Processing Site							
M17A	14	-	0%	-	0%	-	0%
M17-02	21	-	0%	-	0%	-	0%
M19A	16	-	0%	-	0%	-	0%
M19-01	20	-	0%	-	0%	-	0%
M19-02	21	-	0%	-	0%	-	0%
Receiving Environment							
MR-REF	56	1.4	2%	-	0%	-	0%
MR1	5	-	0%	-	0%	-	0%
MR2	5	-	0%	-	0%	-	0%
MR9	45	1.8	2%	1.1	2%	-	0%
MR3	56	1.3	4%	1.4	2%	-	0%
MR4	54	1.5	15%	1.6	11%	-	0%
MR7	18	1.6	11%	1.6	11%	-	0%
MR7B	23	-	0%	-	0%	-	0%
MR8	15	-	0%	-	0%	-	0%
MR6	46	1.7	4%	1.2	4%	-	0%
MR10	12	1.0	8%	1.1	8%	-	0%

Values represent mg/L unless otherwise noted.

Values below the detection limit were replaced with half the detection limit for calculations.

Parameters were only screened against CCME guidelines if BC guidelines were not available.

Only parameters above guidelines are included in table.

Detection limits for chromium, mercury, selenium and silver were above guidelines in samples analyzed at CARO (October 2010, December 2010 and January 2011). Samples below detection limits were excluded from calculations.

Factor represents the average factor samples above guidelines were higher than guideline concentrations.

Percent (%) represents percentage of samples collected at each site that were higher than available guidelines.

Table 8.5-15. BC and Health Canada Drinking Water Quality Guideline Screening, 2010 to 2014

Parameter Jurisdiction Guideline		pH Health Canada 8.5		Sulphate Health Canada = BC 500		Total Aluminum (Al) Health Canada 0.1		Dissolved Aluminum (Al) BC 0.2		Total Arsenic (As) Health Canada 0.01		Total Barium (Ba) Health Canada 1		Total Iron (Fe) Health Canada 0.3		Total Lead (Pb) Health Canada 0.01	
Site	Samples	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent
Shaft/Decline Sites																	
REFST	54	-	0%	-	0%	5.3	31%	-	0%	-	0%	-	0%	3.2	20%	-	0%
TC-01	17	-	0%	-	0%	4.3	41%	1.3	6%	-	0%	-	0%	2.2	24%	-	0%
TC-02	17	-	0%	-	0%	32.0	59%	2.2	6%	1.9	6%	1.7	6%	18.1	65%	2.8	6%
M20-03	37	-	0%	-	0%	4.9	27%	-	0%	-	0%	-	0%	2.5	16%	-	0%
M20-05	41	-	0%	-	0%	9.1	90%	-	0%	-	0%	-	0%	7.0	41%	-	0%
M20-06	18	-	0%	-	0%	12.2	100%	-	0%	-	0%	-	0%	3.9	94%	-	0%
M20-04	53	1.0	4%	-	0%	28.2	98%	1.3	4%	-	0%	-	0%	12.0	94%	1.1	6%
Coal Processing Site																	
M17A	14	-	0%	-	0%	4.4	29%	-	0%	-	0%	-	0%	4.3	14%	-	0%
M17-02	21	1.0	5%	-	0%	5.1	67%	-	0%	-	0%	-	0%	3.7	29%	-	0%
M19A	16	-	0%	-	0%	2.2	13%	-	0%	-	0%	-	0%	1.4	13%	-	0%
M19-01	20	-	0%	-	0%	1.9	10%	-	0%	-	0%	-	0%	1.3	5%	-	0%
M19-02	21	-	0%	1.8	5%	3.7	10%	-	0%	-	0%	-	0%	3.1	5%	-	0%
Receiving Environment																	
MR-REF	56	1.4	2%	-	0%	4.5	50%	-	0%	-	0%	-	0%	3.1	32%	-	0%
MR1	5	-	0%	-	0%	4.9	80%	-	0%	-	0%	-	0%	3.2	40%	-	0%
MR2	5	-	0%	-	0%	5.0	80%	-	0%	-	0%	-	0%	3.3	40%	-	0%
MR9	45	-	0%	-	0%	4.8	57%	-	0%	-	0%	-	0%	3.1	30%	-	0%
MR3	56	-	0%	-	0%	6.1	54%	-	0%	-	0%	-	0%	3.5	39%	-	0%
MR4	54	-	0%	-	0%	10.6	59%	-	0%	-	0%	-	0%	5.1	50%	-	0%
MR7	18	-	0%	-	0%	9.4	61%	-	0%	-	0%	-	0%	5.0	50%	-	0%
MR7B	23	-	0%	-	0%	2.2	48%	-	0%	-	0%	-	0%	1.9	13%	-	0%
MR8	15	-	0%	-	0%	5.2	53%	-	0%	-	0%	-	0%	2.3	47%	-	0%
MR6	46	-	0%	-	0%	7.8	46%	-	0%	-	0%	-	0%	3.9	39%	-	0%
MR10	12	-	0%	-	0%	7.9	42%	-	0%	-	0%	-	0%	3.4	42%	-	0%

Values represent mg/L unless otherwise noted.

Values below the detection limit were replaced with half the detection limit for calculations.

Only parameters above guidelines are included in table.

Detection limits for chromium, mercury, selenium and silver were above guidelines in samples analyzed at CARO (October 2010, December 2010 and January 2011). Samples below detection limits were excluded from calculations.

Parameters were not screened against aesthetic objectives.

Table 8.5-16. BC Water Quality for the Protection of Wildlife Water Supply Guideline Screening, 2010 to 2014

Parameter		Total Aluminum (Al)		Total Mercury (Hg)				Total Selenium (Se)	
Guideline		Maximum 5		30-day 0.00002		30-day 0.00001		Maximum 0.002	
Site	Samples	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent
Shaft/Decline Sites									
REFST	54	-	0%	-	0%	-	0%	-	0%
TC-01	17	-	0%	-	0%	-	0%	-	0%
TC-02	17	4.4	6%	3.6	12%	7.2	12%	-	0%
M20-03	37	-	0%	-	0%	-	0%	1.2	27%
M20-05	41	1.1	2%	1.1	3%	1.8	8%	1.3	17%
M20-06	18	-	0%	-	0%	1.1	6%	-	0%
M20-04	53	1.7	17%	2.3	12%	3.3	20%	1.3	10%
Coal Processing Site									
M17A	14	-	0%	-	0%	-	0%	1.2	7%
M17-02	21	-	0%	-	0%	-	0%	1.2	19%
M19A	16	-	0%	-	0%	-	0%	-	0%
M19-01	20	-	0%	-	0%	-	0%	-	0%
M19-02	21	-	0%	10.6	5%	21.1	5%	2.5	5%
Receiving Environment									
MR-REF	56	-	0%	-	0%	1.4	2%	-	0%
MR1	5	-	0%	-	0%	-	0%	-	0%
MR2	5	-	0%	-	0%	-	0%	-	0%
MR9	45	-	0%	-	0%	-	0%	-	0%
MR3	56	-	0%	-	0%	-	0%	-	0%
MR4	54	1.0	2%	-	0%	1.4	2%	-	0%
MR7	18	-	0%	-	0%	-	0%	-	0%
MR7B	23	-	0%	-	0%	-	0%	-	0%
MR8	15	-	0%	-	0%	-	0%	-	0%
MR6	46	-	0%	-	0%	-	0%	-	0%
MR10	12	-	0%	-	0%	-	0%	-	0%

Values represent mg/L unless otherwise noted.

Values below the detection limit were replaced with half the detection limit for calculations.

Only parameters above guidelines are included in table.

Detection limits for chromium, mercury, selenium and silver were above guidelines in samples analyzed at CARO (October 2010, December 2010 and January 2011). Samples below detection limits were excluded from calculations.

Detection limits for all mercury samples were higher than the BC guideline when MeHg = 8.0% of THg (0.00000125 mg/L).

Table 8.5-17. Aquatic Resources Baseline Sampling Program, 2010 to 2013

	Water Toxicity	Sediment Quality				Periphyton								Benthic Invertebrates				Tissue Metals						
						Biomass (chl *a*)				Taxonomy				Hess	Kick net (CABIN)			Periphyton			Benthic Invertebrates			
Site	2010	2010	2011	2012	2013	2010	2011	2012	2013	2010	2011	2012	2013	2010	2011	2012	2013	2011	2012	2013	2010	2011	2012	2013
Shaft/Decline Sites																								
REFST		3				3				3				5										
M20-03			2				6				6				3			3				1		
M20-05			6				6				3				3			2				1		
M20-06				1	3			6	6			3	3			3	3		1	1			1	1
M20-04		3	1	1	3	3	6	6	6	3	3	3	3	5	3	3	3	1	1	1		2	1	1
Coal Processing Site																								
M17-02				1	4			6	6			3	3			3	3		1	1			1	1
M19-01				4	4			6	6			3	3			3	3		4	1			2	1
M19-02				1	4			6	6			4	3			3	3		2	1			1	1
Receiving Environment																								
MR-REF	1	3			4	3			6	3				5			3			4	1			1
MR9			1	1	4		6	6	6		3	3	3		4	3	3	1	1	1		1	1	1
MR3		3		5	4	3		6	6	3		3	3	5		3	3		1	1	1		1	1
MR4	1	3	1	2	4	3	6	6	6	3	3	3	3	5	3	3	3	1	1	1		1	1	1
MR7							6				3				3			1				1		
MR7B				1	4			6	6			3	3			3	3		1	1			1	1
MR6		3		1	4	3		6	6	3		3	3	5		3	3		1	1	1		1	1

Values represent the number of samples (including replicates and field splits).

1. Shaft/Decline Sites (west bank): Twenty Creek and M20 (Camp) Creek. Club Creek as reference station.
2. Coal Processing Site (east bank): M17 Creek and M19 Creek. M19-01 as an upstream reference station.
3. Receiving Environment: Murray River. MR-REF as an upstream reference station of all mining influences.

Water Toxicity Bioassays

Toxicity bioassays were conducted on important primary, secondary, and tertiary producers in the Project area in 2010. This included the Rainbow trout (*Oncorhynchus mykiss*), the common water flea (*Daphnia magna*), a freshwater microcrustacean (*Ceriodaphnia dubia*), a green alga (*Pseudokirchneriella subcapitata*), and an aquatic macrophyte (duckweed; *Lemna minor*). Water for bioassays was collected in clean containers concurrently with surface water quality samples.

Sediment Quality Sampling

Sediment samples were collected using a plastic spoon and bowl (for metal analyses) or metal spoon and bowl (for PAH analyses). Each sample was a composite of several scoops that were homogenized and transferred into clean, pre-labelled Whirl-Pak bags. Sample bags were sealed with no air bubbles and kept cool in the dark until analysis. Replicates were collected from separate and distinct areas of the site. Samples were shipped to ALS (Burnaby, BC) for analysis in 2010 and to Maxxam Analytics (Burnaby, BC) in 2011 to 2013.

Sediment quality results were compared to CCME and BC sediment quality guidelines for the protection of freshwater aquatic life (CCME 2014b; BC MOE 2006; Table 8.5-18). The CCME sediment guidelines include the interim sediment quality guidelines (ISQG) and the probable effect levels (PEL). A sediment parameter concentration below the ISQG is not expected to be associated with any adverse biological effects, while concentrations above the PEL are expected to be frequently associated with adverse biological effects. BC sediment quality guidelines are analogous to the ISQG and PEL, and consist of a Lowest Effect Level (LEL) and Severe Effect Level (SEL).

Periphyton Sampling

Each periphyton sample was collected from a randomly selected rock from a representative area of the stream. A circular template was placed on the selected rock and the area within the template was scraped free of periphyton and rinsed into a plastic sample jar.

Periphyton biomass samples (as chlorophyll *a* [chl *a*]) were filtered through a 0.45 µm pore size membrane, frozen, and sent to ALS (2010) and Maxxam (2011 to 2013) for analysis. Periphyton taxonomy samples were preserved with Lugol's solution, and shipped to Fraser Environmental Services in Surrey, BC (2010), EcoAnalysts Inc. in Moscow, ID (2011 and 2012) and Biologica in Victoria, BC (2013) for identification and enumeration. Periphyton results were standardized to the area sampled however the area sampled has varied; therefore, richness and diversity metrics should be interpreted with caution.

Table 8.5-18. Federal and Provincial Sediment Quality Guidelines for the Protection of Freshwater Aquatic Life

	CCME Guideline[a]		BC Guideline[b]		
Parameter	ISQG[c]	PEL[d]	No Effect	LEL[e]	SEL[f]
Metals					
Arsenic (As)	5.90	17		5.90	17
Cadmium (Cd)	0.6	3.5		0.6	3.5
Chromium (Cr)	37.3	90		37.3	90
Copper (Cu)	35.7	197		35.7	197
Iron (Fe)				21,200	43,766
Lead (Pb)	35	91.3		35	91.3
Manganese (Mn)				460	1,100
Mercury (Hg)	0.170	0.486		0.170	0.486
Nickel (Ni)				16	75
Selenium (Se)				2	
Silver (Ag)				0.5	
Zinc (Zn)	123	315		123	315
Polycyclic Aromatic Hydrocarbons (PAHs)				4[i]	35[h,i]
Low Molecular Weight (≤ 3 benzene rings)			0.1[i]		
Acenaphthene[g]	0.00671	0.0889		0.15[j]	
Acenaphthylene[g]	0.00587	0.128			
Acridene				1[j]	
Anthracene[g]	0.0469	0.245		0.6[j]	
Fluorene[g]	0.0212	0.144		0.2[j]	
Naphthalene[g]	0.0346	0.391		0.01[j]	
2-Methylnaphthalene[g]	0.0202	0.201			
Phenanthrene	0.0419	0.515		0.04[j]	
High Molecular Weight (> 3 benzene rings)			1[i]		
Benz(a)anthracene	0.0317	0.385		0.2[j]	
Benzo(a)pyrene	0.0319	0.782		0.06[j]	
Benzofluoranthene			0.3[i]		
Benzo(g,h,i)perylene			0.1[i]	0.17[i]	3.2[i]
Benzo(k)fluoranthene				0.24[i]	13.4[i]
Chrysene	0.0571	0.862			
Dibenz(a,h)anthracene[g]	0.00622	0.135			
Fluoranthene	0.111	2.355		2[j]	
Indeno(1,2,3,c,d)pyrene			0.07[i]	0.2[i]	3.2[i]
Pyrene	0.053	0.875			

Notes:

[a] *Canadian sediment quality guideline for the protection of freshwater aquatic life, Canadian Council of Ministers of the Environment, accessed March 2014; all units are in mg/kg.*

[b] *British Columbia working sediment guideline for the protection of freshwater aquatic life; accessed March 2014.*

[c] *CCME interim sediment guideline.*

[d] *CCME probable effects level.*

[e] *BC lowest effect level based on the screening level concentration.*

[f] *BC severe effect level based on the screening level concentration.*

[g] *CCME guideline provisional; adoption of marine guideline developed using the modified NSTP approach.*

[h] *Medium effect range.*

[i] *Working guideline.*

[j] *Organic carbon dependent. Values shown for 1.0% organic carbon content.*

Benthic Invertebrate Sampling

Two methods were used to collect benthic invertebrates: a 250 µm Hess net (surface area: 0.096 m^2; 2010) and a 400 µm kick net (2011 to 2013). For Hess sampling, the streambed was disturbed for one minute within the Hess sampler, allowing the stream current to rinse the suspended benthos into the cod-end. Hess samples were standardized to the area sampled. Kick net samples were collected based on the Canadian Aquatic Biomonitoring Network (CABIN) protocol (Environment Canada 2012). Samples were preserved with formalin and sent to Cordillera Consulting (Summerland, BC; 2010 and 2013) and EcoAnalysts, Inc. (2011 and 2012) for enumeration and identification.

Tissue Metals Sampling

Tissue metals analysis was performed for periphyton dry weight (2011 to 2013) and benthic invertebrate wet weight (2010 to 2013) in the Project area. Tissue metal samples were collected concurrently with periphyton and benthic invertebrate taxonomy samples. Samples were sent to ALS (2010) and Maxxam Analytics (2011 to 2013).

8.5.4.3 Characterization of Aquatic Resources Baseline Conditions

Aquatic resources baseline data collected for the Project is available in Appendix 8-C. Wetland data were collected in 2010 and are included in the appendices but are not discussed.

Project area sediments were primarily sand and sites generally had consistent metal and PAH concentrations spatially and temporally. Periphyton communities were variable (biomass and density), diverse (high Simpson's genus diversity) and dominated by diatoms. Benthic invertebrate communities were also diverse, with high richness and common taxa included pollution-sensitive taxa (Ephemeroptera, Plecoptera and Trichoptera) and Chironomidae. Periphyton tissue metals were generally highest in streams associated with the Shaft/Decline Sites (west bank of Murray River) and MR6. Toxicity bioassays found no impact of Murray River site water on survival and reproduction of *C. dubia* or rainbow trout, and water stimulated algae growth (*P. subcapitata*). The water flea *D. magna* had considerably reduced survivorship, and *L. minor* may have been inhibited by water chemistry at MR-REF.

Shaft/Decline Sites (West Bank)

Sediment Quality

Streams sediments on the west bank of the Murray River proximal to the Shaft/Decline Sites were primarily composed of sand and silt and TOC concentrations were variable (Table 8.5-19). Metal concentrations were slightly elevated in west bank sediments compared other Project area sites, including arsenic, cadmium, chromium, selenium, silver, and zinc (Table 8.5-19). These metals (except silver) were also elevated in the surface water quality samples, although the spatial differences were more pronounced in the water quality (see Section 8.5.3). Sediment cadmium and nickel concentrations appear to be naturally elevated in the Project area, and all samples from the west bank of the Murray River were above the BC LEL guideline (Table 8.5-20). Arsenic, chromium, iron, and zinc concentrations in sediments were sporadically above BC and CCME guidelines.

Sediment PAH concentrations were similar across sites and many samples were near or below detection limits (Table 8.5-21). Chrysene, fluorene, 2-methylnaphthalene, naphthalene, phenanthrene and pyrene levels were slightly elevated in M20 Creek, and were also above applicable BC and CCME guidelines (Table 8.5-22).

Periphyton

Periphyton communities in M20 Creek and Club Creek (REFST) were similar to other sampled Project area streams (Table 8.5-23). Stream periphyton biomass was variable, with the upstream site M20-03 being an order of magnitude higher than other M20 Creek sites and REFST. Periphyton densities were also variable; mean densities ranged from 3,735 cells/cm^2 (M20-05) to 12,831 cells/cm^2 (REFST). West bank periphyton communities were dominated by diatoms (67-100%; Bacillariophyceae). Myxophyceae (blue-green algae) and Chlorophyceae (green algae) were common in REFST and M20-04 (2010 only). Simpson's diversity and evenness were high (>0.65) but periphyton genus richness was slightly lower in M20 Creek compared to other Project area sites. *Gomphonema*, *Achnanthes* and *Cymbella* were common genera in M20 Creek and Club Creek periphyton communities (Table 8.5-24). The invasive diatom *Didymosphenia germinata* (a.k.a. didymo or rock snot) was identified in REFST (2010), M20-03 (2011) and M20-04 (2010), and therefore extra precaution should be exercised when working in and around these streams to prevent the spreading of this invasive species.

Benthic Invertebrates

Benthic invertebrate abundance was lower in M20 Creek at upstream sites near the Hermann Mine compared to near the mouth adjacent to the Shaft Site (Table 8.5-25). Benthic invertebrate communities in west bank streams (M20 and Club creeks) were diverse (Simpson's diversity >0.85; Table 8.5-25) and largely composed of Ephemeroptera (mayflies; 19-33%), Plecoptera (stoneflies; 17-30%), Trichoptera (caddisflies; 7-24%) and Chironomidae (Diptera; 4-30%). Ephemeroptera, Plecoptera and Trichoptera (EPT) are pollution sensitive taxa and their presence usually indicates a healthy aquatic environment. Family richness was high, and means ranged from 16 to 211 families/sample, with Heptageniidae and Ephemerellidae being commonly dominant (Table 8.5-26). Family evenness was generally higher in west bank streams compared to other Project area streams.

Tissue Metals

In comparison to other Project area sites, periphyton tissues from M20 Creek had elevated chromium, cobalt, copper, iron, lead, nickel, selenium, silver, and zinc (Table 8.5-27), with the exception of upstream site M20-03 which was similar to other Project area sites. The highest mean periphyton selenium concentration for the Project area was observed just upstream of the proposed shaft site (M20-06; 3.24 mg/kg dw). No spatial patterns were observed for the benthic invertebrate tissue metals, except that benthic invertebrate tissues at the site downstream of the Hermann Mine (M20-03) had elevated concentrations of several metals (Table 8.5-28).

Table 8.5-19. Sediment Quality Summary, 2010 to 2013

Site	Years Sampled	Gravel (%)		Sand (%)		Silt (%)		Clay (%)		Total Organic Carbon		Arsenic (As)		Cadmium (Cd)		Chromium (Cr)		Copper (Cu)		Iron (Fe)	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Shaft/Decline Sites																					
REFST	2010	2.8	-	71.1	-	25.9	-	0.2	-	2.68	-	8.10	-	2.567	-	25.6	-	16.4	-	15,367	-
M20-03	2011	2.5	-	76.5	-	15.0	-	6.0	-	-	-	5.35	-	0.825	-	10.5	-	15.6	-	14,950	-
M20-05	2011	5.3	-	39.8	-	16.5	-	38.7	-	-	-	7.22	-	1.195	-	22.0	-	28.3	-	23,683	-
M20-06	2012, 2013	1.0	0.0	51.7	9.7	37.0	7.0	10.1	2.0	2.00	-	5.35	0.13	0.779	0.100	12.0	1.4	21.6	8.0	16,517	983
M20-04	2010 - 2013	7.8	4.2	55.7	18.3	28.8	17.8	8.1	4.1	1.37	0.03	4.93	0.33	0.676	0.017	20.2	10.3	16.0	2.2	14,392	485
Coal Processing Site																					
M17-02	2012, 2013	2.1	0.8	50.0	0.0	32.4	1.6	15.6	2.6	2.20	-	4.06	0.23	0.689	0.016	13.7	0.2	19.6	3.9	16,175	675
M19-01	2012, 2013	1.6	0.6	66.4	9.6	23.8	5.0	8.8	5.3	2.55	-	3.34	0.26	0.493	0.003	10.7	0.7	16.2	6.0	13,875	1,225
M19-02	2012, 2013	2.9	1.9	48.5	3.5	31.4	5.4	17.8	0.8	2.60	-	3.67	0.06	0.623	0.113	12.1	1.3	18.2	7.8	15,925	775
Receiving Environment																					
MR-REF	2010, 2013	2.5	1.5	59.1	29.8	30.7	23.8	8.2	8.1	0.93	-	6.68	0.69	0.731	0.051	26.1	13.2	16.7	2.3	18,163	2,463
MR9	2011 - 2013	1.0	0.0	55.6	12.4	28.4	2.4	16.1	10.1	1.80	-	5.08	0.40	0.798	0.049	13.9	1.4	16.8	1.3	17,525	2,077
MR3	2010, 2012, 2013	1.3	0.3	65.1	10.5	27.2	7.1	7.2	4.0	1.57	0.43	4.76	0.48	0.745	0.105	13.9	0.6	16.1	2.0	15,233	1,790
MR4	2010 - 2013	1.0	0.6	77.5	9.4	17.7	6.6	4.6	3.1	1.37	0.58	4.70	0.16	0.728	0.070	15.2	3.1	16.2	2.2	14,408	519
MR7B	2012, 2013	1.0	0.0	48.3	5.8	42.8	3.8	9.2	2.0	2.10	-	4.12	0.09	0.773	0.008	11.7	0.2	15.9	2.8	15,088	288
MR6	2010, 2012, 2013	0.7	0.3	63.6	8.7	30.7	4.3	5.5	4.8	1.91	0.09	4.41	0.16	0.707	0.095	16.6	4.1	17.3	4.8	14,197	1,375

Values represent mg/kg unless otherwise noted.

Replicate and split sample values averaged before summary statistics performed.

Values below the detection limit were replaced with half the detection limit

SE = Standard Error

(continued)

Table 8.5-19. Sediment Quality Summary, 2010 to 2013 (completed)

Site	Years Sampled	Lead (Pb)		Manganese (Mn)		Mercury (Hg)		Nickel (Ni)		Selenium (Se)		Silver (Ag)		Zinc (Zn)	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Shaft/Decline Sites															
REFST	2010	9.82	-	208.0	-	0.043	-	39.3	-	1.62	-	0.208	-	142.3	-
M20-03	2011	8.50	-	317.5	-	0.060	-	22.1	-	1.10	-	0.180	-	83.0	-
M20-05	2011	12.75	-	425.2	-	0.072	-	39.9	-	1.22	-	0.225	-	116.2	-
M20-06	2012, 2013	9.64	0.76	297.8	38.2	0.061	0.003	23.4	3.6	0.90	0.31	0.241	0.028	85.2	16.8
M20-04	2010 - 2013	8.24	0.37	252.4	15.9	0.040	0.009	26.3	7.1	0.66	0.09	0.179	0.018	78.3	8.1
Coal Processing Site															
M17-02	2012, 2013	9.17	0.11	266.6	0.6	0.067	0.005	25.7	0.7	0.72	0.01	0.181	0.011	85.2	3.9
M19-01	2012, 2013	7.19	0.35	221.0	9.3	0.043	0.004	17.1	0.8	0.40	0.03	0.159	0.010	62.6	0.6
M19-02	2012, 2013	8.71	1.12	267.1	0.1	0.052	0.012	20.7	3.9	0.69	0.10	0.184	0.015	86.4	5.3
Receiving Environment															
MR-REF	2010, 2013	10.29	1.81	239.9	9.6	0.056	0.031	32.1	4.7	0.76	0.24	0.202	0.060	97.3	7.1
MR9	2011 - 2013	9.66	1.08	304.9	38.9	0.030	0.005	23.6	1.6	0.64	0.25	0.135	0.014	78.3	1.0
MR3	2010, 2012, 2013	8.81	0.88	275.5	36.9	0.036	0.010	22.8	1.6	0.56	0.09	0.166	0.021	81.6	5.4
MR4	2010 - 2013	8.24	0.20	253.8	15.0	0.037	0.005	23.1	1.5	0.67	0.15	0.157	0.009	77.5	1.7
MR7B	2012, 2013	8.14	0.06	260.3	15.3	0.046	0.008	20.8	0.4	0.52	0.01	0.152	0.004	77.0	0.6
MR6	2010, 2012, 2013	7.86	0.63	270.5	37.7	0.036	0.007	22.9	1.6	0.56	0.07	0.148	0.017	74.9	5.4

Values represent mg/kg unless otherwise noted.

Replicate and split sample values averaged before summary statistics performed.

Values below the detection limit were replaced with half the detection limit

SE = Standard Error

Table 8.5-20. BC and CCME Sediment Metal Guideline Screening, 2010 to 2013

Parameter		Arsenic (As)		Cadmium (Cd)		Chromium (Cr)		Iron (Fe)		Nickel (Ni)		Zinc (Zn)	
Jurisdiction		CCME[a] = BC[b]		CCME = BC		CCME = BC		BC		BC		CCME = BC	
Guideline		ISQG[c]		ISQG		ISQG		LEL[e]		LEL		ISQG	
		5.9		0.6		37.3		21,200		16		123	
Site	Samples	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent
Shaft/Decline Sites													
REFST	3	1.4	100%	4.3	100%	-	0%	-	0%	2.5	100%	1.2	100%
M20-03	2	-	0%	1.4	100%	-	0%	-	0%	1.4	100%	-	0%
M20-05	6	1.2	100%	2.0	100%	-	0%	1.1	100%	2.5	100%	-	0%
M20-06	6	-	0%	1.2	100%	-	0%	-	0%	1.4	100%	-	0%
M20-04	9	1.0	13%	1.1	100%	1.4	38%	-	0%	1.9	100%	-	0%
Coal Processing Site													
M17-02	7	-	0%	1.2	100%	-	0%	-	0%	1.6	100%	-	0%
M19-01	13	-	0%	-	0%	-	0%	-	0%	1.1	75%	-	0%
M19-02	7	-	0%	1.2	20%	-	0%	-	0%	1.2	100%	-	0%
Receiving Environment													
MR-REF	9	1.2	86%	1.2	100%	1.7	14%	1.1	14%	2.0	100%	-	0%
MR9	7	1.0	17%	1.3	100%	-	0%	1.1	33%	1.6	100%	-	0%
MR3	18	1.0	17%	1.4	83%	-	0%	-	0%	1.4	100%	-	0%
MR4	13	-	0%	1.3	70%	-	0%	-	0%	1.5	100%	-	0%
MR7B	12	-	0%	1.3	100%	-	0%	-	0%	1.3	100%	-	0%
MR6	11	-	0%	1.3	75%	-	0%	-	0%	1.5	100%	-	0%

Notes:

[a] *Canadian sediment quality guideline for the protection of freshwater aquatic life, Canadian Council of Ministers of the Environment, accessed March 2014; all units are in mg/kg.*

[b] *British Columbia working sediment guideline for the protection of freshwater aquatic life; accessed March 2014.*

[c] *CCME interim sediment guideline.*

[d] *CCME probable effects level.*

[e] *BC lowest effect level based on the screening level concentration.*

Coal Processing Site (East Bank)

Sediment Quality

As with sites on the west bank of the Murray River, east bank sediments by the Coal Processing Site were predominantly sand and silt (Table 8.5-19). TOC concentrations were slightly higher in east bank sediments compared to other Project areas, as was observed for stream water (see Section 8.5.3).

While sediment metal concentrations were generally consistent spatially and temporally across all sites, arsenic, cadmium, and chromium levels were marginally lower in M17 and M19 creeks compared to other Project area sites (Table 8.5-19). Of these, the site upstream of the proposed Coal Processing Site (M19-01) generally had the lowest metal concentrations. M17 and M19 creek sediment quality samples were commonly above BC and CCME guidelines for cadmium and nickel, similar to other Project area sites (Table 8.5-20).

Fluorene, 2-methylnapthalene, naphthalene and phenanthrene were elevated in east bank sediments compared to Murray River samples; however, concentrations were lower than west bank sediments (Table 8.5-21). M17 and M19 creeks sediment samples were commonly above applicable CCME and BC guidelines for 2-methylnaphthalene and phenanthrene and were sporadically above guidelines for naphthalene and chrysene (Table 8.5-22).

Periphyton

As with west bank periphyton communities, east bank communities associated with the Coal Processing Site were variable and diatoms were dominant (Table 8.5-23). East bank mean density, richness and Simpson's diversity were highest in M19 at the mouth of the stream and adjacent to the Coal Processing Site (M19-02). Biomass was twice as high at M17-02 compared to other sites in M17 and M19 creeks. The dominant taxa at each site were *Gomphonema*, *Navicula* and *Cocconeis*. Genus evenness was moderately high (mean range 0.67-0.71 Simpson's evenness; Table 8.5-24).

Benthic Invertebrates

East bank benthic invertebrate communities were similar to west bank communities, having high richness and Simpson's diversity and being primarily composed of EPT and Chironomidae (Table 8.5-25). M17-02 downstream of the Coal Processing Site had the highest mean abundance (14,762 organisms/sample) and family richness (25 families/sample) of all Project area sites. EPT families commonly found in other Project area streams were also found in the east bank. EPT family evenness was moderately high (Table 8.5-26).

Tissue Metals

Periphyton tissue metal concentrations at M17 and M19 creeks by the Coal Processing Site were typically low compared to other Project area sites, except for elevated concentrations of mercury at M19-02 (Table 8.5-27). Metal concentrations were also low in water quality samples from the east bank compared to other areas in the baseline study area (see Section 8.5.3). Benthic invertebrate tissue metal concentrations were within the range of other Project area sites (Table 8.5-28).

Table 8.5-21. Sediment PAH Summary, 2010 to 2013

		Total PAHs		Low Molecular Weight PAHs		Acenaphthene		Acenaphthylene		Anthracene		Fluorene		2-Methylnaphthalene		Naphthalene		Phenanthrene		High Molecular Weight PAHs	
	Years Sampled	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Shaft/Decline Sites																					
M20-03	2011	0.6100	-	0.5700	-	0.0025	-	0.0030	-	0.0020	-	0.0100	-	0.2650	-	0.1500	-	0.1500	-	0.0375	-
M20-05	2011	1.0500	-	0.8150	-	0.0025	-	0.0058	-	0.0020	-	0.0700	-	0.3300	-	0.0767	-	0.3450	-	0.2250	-
M20-06	2012, 2013	0.7850	0.3150	0.6250	0.2650	0.0024	0.0011	0.0043	0.0018	0.0038	0.0013	0.0280	0.0100	0.3000	0.1400	0.0690	0.0180	0.2300	0.1000	0.1350	0.0350
M20-04	2010 - 2013	0.3300	0.0300	0.2700	0.0400	0.0025	0.0000	0.0025	0.0000	0.0035	0.0015	0.0110	0.0010	0.1215	0.0285	0.0280	0.0020	0.1125	0.0175	0.0655	0.0055
Coal Processing Site																					
M17-02	2012, 2013	0.4900	0.1600	0.4000	0.1300	0.0019	0.0006	0.0027	0.0002	0.0038	0.0013	0.0160	0.0030	0.2000	0.0700	0.0665	0.0245	0.1200	0.0400	0.0875	0.0225
M19-01	2012, 2013	0.1220	0.0630	0.0873	0.0503	0.0005	0.0002	0.0005	0.0003	0.0008	0.0003	0.0034	0.0020	0.0321	0.0201	0.0163	0.0103	0.0344	0.0174	0.0349	0.0129
M19-02	2012, 2013	0.4200	0.1300	0.3500	0.1100	0.0026	0.0019	0.0018	0.0007	0.0028	0.0023	0.0150	0.0050	0.1650	0.0650	0.0610	0.0160	0.1055	0.0245	0.0730	0.0160
Receiving Environment																					
MR-REF	2010, 2013	0.1860	0.0460	0.1000	-	0.0025	0.0000	0.0025	0.0000	0.0035	0.0015	0.0050	0.0000	0.0405	0.0115	0.0265	0.0075	0.0845	0.0275	0.0390	-
MR9	2011 - 2013	0.1950	0.0150	0.1500	0.0000	0.0025	0.0000	0.0025	0.0000	0.0035	0.0015	0.0075	0.0025	0.0485	0.0015	0.0295	0.0005	0.0695	0.0005	0.0425	0.0175
MR3	2010, 2012, 2013	0.2800	0.0500	0.2040	0.0440	0.0017	0.0008	0.0019	0.0006	0.0032	0.0019	0.0059	0.0009	0.0695	0.0175	0.0392	0.0102	0.0929	0.0119	0.0754	0.0054
MR4	2010 - 2013	0.1983	0.0495	0.1530	0.0770	0.0022	0.0003	0.0021	0.0004	0.0023	0.0003	0.0064	0.0018	0.0635	0.0222	0.0188	0.0069	0.0775	0.0160	0.0470	0.0030
MR7B	2012, 2013	0.2600	0.0500	0.1917	0.0383	0.0016	0.0009	0.0019	0.0007	0.0028	0.0023	0.0069	0.0019	0.0659	0.0131	0.0362	0.0068	0.0831	0.0119	0.0676	0.0114
MR6	2010, 2012, 2013	0.1920	0.0627	0.1850	0.0650	0.0019	0.0007	0.0021	0.0004	0.0025	0.0013	0.0053	0.0003	0.0523	0.0189	0.0310	0.0137	0.0660	0.0150	0.0550	0.0120

Values represent mg/kg unless otherwise noted.

(continued)

Replicate and split sample values averaged before summary statistics performed.

Values below the detection limit were replaced with half the detection limit

SE = Standard Error

Table 8.5-21. Sediment PAH Summary, 2010 to 2013 (completed)

		Benz(a)anthracene		Benzo(a)pyrene		Benzo(b)fluoranthene		Benzo(b,j)fluoranthene		Benzo(g,h,i)perylene		Benzo(k)fluoranthene		Chrysene		Dibenz(a,h)anthracene		Fluoranthene		Indeno(1,2,3-c,d)pyrene		Pyrene	
	Years Sampled	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Shaft/Decline Sites																							
M20-03	2011	0.0100	-	0.0100	-	-	-	0.0100	-	0.0250	-	0.0100	-	0.0450	-	0.0250	-	0.0100	-	0.0250	-	0.0100	-
M20-05	2011	0.0100	-	0.0100	-	-	-	0.0617	-	0.0250	-	0.0100	-	0.1383	-	0.0250	-	0.0333	-	0.0250	-	0.0533	-
M20-06	2012, 2013	0.0055	0.0005	0.0038	0.0013	0.0230	-	0.0315	0.0085	0.0115	0.0015	0.0038	0.0013	0.0895	0.0205	0.0043	0.0018	0.0150	0.0040	0.0075	0.0025	0.0255	0.0055
M20-04	2010 - 2013	0.0075	0.0025	0.0075	0.0025	0.0180	-	0.0190	0.0010	0.0175	0.0075	0.0075	0.0025	0.0590	0.0010	0.0138	0.0113	0.0075	0.0025	0.0175	0.0075	0.0120	0.0020
Coal Processing Site																							
M17-02	2012, 2013	0.0063	0.0013	0.0038	0.0013	0.0230	-	0.0265	0.0035	0.0105	0.0005	0.0038	0.0013	0.0575	0.0075	0.0043	0.0018	0.0085	0.0035	0.0075	0.0025	0.0175	0.0035
M19-01	2012, 2013	0.0016	0.0005	0.0011	0.0006	0.0068	-	0.0094	0.0026	0.0049	0.0007	0.0008	0.0003	0.0196	0.0056	0.0010	0.0008	0.0034	0.0015	0.0015	0.0005	0.0091	0.0040
M19-02	2012, 2013	0.0042	0.0009	0.0038	0.0012	0.0250	-	0.0195	0.0055	0.0085	0.0015	0.0028	0.0023	0.0425	0.0135	0.0026	0.0000	0.0089	0.0022	0.0055	0.0045	0.0170	0.0050
Receiving Environment																							
MR-REF	2010, 2013	0.0050	0.0000	0.0050	0.0000	0.0280	0.0070	0.0210	-	0.0075	0.0025	0.0050	0.0000	0.0290	0.0090	0.0025	0.0000	0.0050	0.0000	0.0075	0.0025	0.0050	0.0000
MR9	2011 - 2013	0.0075	0.0025	0.0075	0.0025	0.0260	-	0.0180	0.0080	0.0175	0.0075	0.0075	0.0025	0.0385	0.0085	0.0138	0.0113	0.0075	0.0025	0.0175	0.0075	0.0115	0.0015
MR3	2010, 2012, 2013	0.0042	0.0008	0.0033	0.0017	0.0290	-	0.0280	0.0030	0.0071	0.0029	0.0032	0.0019	0.0520	0.0060	0.0029	0.0004	0.0073	0.0023	0.0063	0.0037	0.0148	0.0028
MR4	2010 - 2013	0.0061	0.0020	0.0059	0.0021	0.0143	0.0023	0.0185	0.0015	0.0121	0.0064	0.0059	0.0021	0.0325	0.0118	0.0098	0.0076	0.0066	0.0017	0.0118	0.0066	0.0069	0.0016
MR7B	2012, 2013	0.0044	0.0006	0.0032	0.0018	0.0215	-	0.0240	0.0020	0.0072	0.0028	0.0028	0.0023	0.0458	0.0012	0.0029	0.0004	0.0069	0.0019	0.0055	0.0045	0.0133	0.0018
MR6	2010, 2012, 2013	0.0046	0.0004	0.0037	0.0013	0.0170	0.0040	0.0210	0.0000	0.0063	0.0019	0.0035	0.0015	0.0298	0.0112	0.0026	0.0001	0.0059	0.0009	0.0053	0.0026	0.0077	0.0027

Values represent mg/kg unless otherwise noted.

Replicate and split sample values averaged before summary statistics performed.

Values below the detection limit were replaced with half the detection limit

SE = Standard Error

Table 8.5-22. BC and CCME Sediment PAH Guideline Screening, 2010 to 2013

Parameter		Fluorene		2-Methylnaphthalene[f]				Naphthalene[f]				Phenanthrene				Chrysene		Pyrene	
Jurisdiction		CCME		CCME				CCME		BC[b]		CCME		BC		CCME[a]		CCME	
Guideline		ISQG		ISQG		PEL[d]		ISQG		LEL[e]		ISQG		LEL		ISQG[c]		ISQG	
		0.0212		0.0202		0.201		0.0346		TOC dependent		0.0419		TOC dependent		0.0571		0.053	
Site	Samples	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent	Factor	Percent
Shaft/Decline Sites																			
M20-03	2	-	0%	13.1	100%	1.3	100%	4.3	100%	-	0%	3.6	100%	-	0%	-	0%	-	0%
M20-05	6	3.3	100%	16.3	100%	1.6	100%	2.2	100%	-	0%	8.2	100%	-	0%	2.4	100%	1.1	33%
M20-06	2	1.8	50%	14.9	100%	2.2	50%	2.0	100%	4.4	50%	5.5	100%	4.1	50%	1.6	100%	-	0%
M20-04	2	-	0%	6.0	100%	-	0%	-	0%	-	0%	2.7	100%	-	0%	1.0	100%	-	0%
Coal Processing Site																			
M17-02	2	-	0%	9.9	100%	1.3	50%	1.9	100%	4.1	50%	2.9	100%	1.8	50%	1.1	50%	-	0%
M19-01	5	-	0%	2.6	80%	-	0%	-	0%	-	0%	1.2	80%	-	0%	-	0%	-	0%
M19-02	2	-	0%	8.2	100%	1.1	50%	1.8	100%	1.7	50%	2.5	100%	-	0%	-	0%	-	0%
Receiving Environment																			
MR-REF	2	-	0%	2.0	100%	-	0%	-	0%	-	0%	2.0	100%	-	0%	-	0%	-	0%
MR9	2	-	0%	2.4	100%	-	0%	-	0%	-	0%	1.7	100%	-	0%	-	0%	-	0%
MR3	6	-	0%	4.0	100%	-	0%	1.5	67%	2.5	83%	2.4	100%	1.4	67%	1.0	33%	-	0%
MR4	4	-	0%	2.6	100%	-	0%	-	0%	-	0%	1.7	100%	-	0%	-	0%	-	0%
MR7B	7	-	0%	2.8	100%	-	0%	1.2	29%	2.0	14%	1.8	100%	1.1	14%	-	0%	-	0%
MR6	3	-	0%	2.6	100%	-	0%	1.7	33%	2.9	33%	1.6	100%	1.2	33%	-	0%	-	0%

[a] *Canadian sediment quality guideline for the protection of freshwater aquatic life, Canadian Council of Ministers of the Environment, accessed March 2014; all units are in mg/kg.*

[b] *British Columbia working sediment guideline for the protection of freshwater aquatic life; accessed March 2014.*

[c] *CCME interim sediment guideline.*

[d] *CCME probable effects level.*

[e] *BC lowest effect level based on the screening level concentration.*

[f] *CCME guideline provisional; adoption of marine guideline developed using the modified NSTP approach.*

n/a = data not available

Table 8.5-23. Periphyton Summary, 2010 to 2013

Site	Sample Size		Biomass (chl *a* µg/cm²)		Density (µg/cm²)		Genus Richness		Genus Diversity (Simpson's D)		Genus Evenness (Simpson's E)	
	Biomass	Taxonomy	Mean	Standard Error	Mean	Standard Error	Mean	Standard Error	Mean	Standard Error	Mean	Standard Error
Shaft/Decline Sites												
REFST	3	3	0.29	0.19	12,831	1,391	14.7	0.7	0.90	0.01	0.71	0.07
M20-03	6	6	3.77	0.48	5,308	893	9.5	1.2	0.83	0.03	0.71	0.07
M20-05	6	3	0.36	0.07	3,735	330	5.7	0.9	0.78	0.02	0.83	0.07
M20-06	12	6	0.34	0.08	10,189	1,952	11.8	1.1	0.87	0.00	0.67	0.07
M20-04	21	12	0.24	0.06	8,587	958	10.9	0.8	0.86	0.01	0.71	0.03
Coal Processing Site												
M17-02	12	6	1.20	0.16	8,495	1,433	11.2	1.1	0.87	0.01	0.71	0.04
M19-01	12	6	0.30	0.03	8,605	1,430	10.5	1.2	0.85	0.01	0.70	0.07
M19-02	12	7	0.54	0.06	11,774	2,765	15.3	2.3	0.89	0.01	0.67	0.06
Receiving Environment												
MR-REF	9	3	0.56	0.14	18,841	483	18.0	0.6	0.90	0.01	0.57	0.05
MR9	18	9	0.46	0.10	10,196	2,703	10.8	2.3	0.77	0.08	0.75	0.04
MR3	15	9	0.47	0.09	12,366	2,090	14.4	1.1	0.89	0.01	0.66	0.03
MR4	21	12	0.90	0.27	11,766	2,527	13.4	2.4	0.77	0.08	0.55	0.08
MR7	6	3	4.95	0.71	636	418	2.0	1.0	0.30	0.20	0.14	0.14
MR7B	12	6	0.54	0.15	12,476	3,143	15.8	2.5	0.90	0.01	0.71	0.06
MR6	15	9	0.36	0.04	12,307	1,666	15.4	0.9	0.90	0.00	0.69	0.05

The total area sampled has varied between years, which could increase variation in richness and diversity metrics

Table 8.5-24. Periphyton Dominant Taxa Summary, 2010 to 2013

Site	Class	Genus	Percent
Shaft/Decline Sites			
REFST	Bacillariophyceae	*Cymbella*	15%
	Bacillariophyceae	*Achnanthes*	15%
	Chlorophyceae	*Ulothrix*	12%
M20-03	Bacillariophyceae	*Diatoma*	19%
	Bacillariophyceae	*Gomphonema*	14%
	Bacillariophyceae	*Cymbella*	13%
M20-05	Bacillariophyceae	*Gomphonema*	25%
	Bacillariophyceae	*Reimeria*	21%
	Bacillariophyceae	*Diatoma*	19%
M20-06	Bacillariophyceae	*Gomphonema*	20%
	Bacillariophyceae	*Nitzschia*	12%
	Bacillariophyceae	*Synedra*	9%
M20-04	Bacillariophyceae	*Gomphonema*	16%
	Bacillariophyceae	*Achnanthes*	10%
	Bacillariophyceae	*Navicula*	10%
Coal Processing Site			
M17-02	Bacillariophyceae	*Gomphonema*	13%
	Bacillariophyceae	*Navicula*	11%
	Bacillariophyceae	*Cocconeis*	11%
M19-01	Bacillariophyceae	*Gomphonema*	17%
	Bacillariophyceae	*Navicula*	11%
	Bacillariophyceae	*Cocconeis*	10%
M19-02	Bacillariophyceae	*Gomphonema*	15%
	Bacillariophyceae	*Cocconeis*	9%
	Bacillariophyceae	*Navicula*	9%
Receiving Environment			
MR-REF	Bacillariophyceae	*Cymbella*	20%
	Bacillariophyceae	*Achnanthes*	12%
	Bacillariophyceae	*Gomphonema*	10%
MR9	Bacillariophyceae	*Gomphonema*	16%
	Bacillariophyceae	*Achnanthes*	16%
	Bacillariophyceae	*Synedra*	7%
MR3	Bacillariophyceae	*Cymbella*	11%
	Bacillariophyceae	*Gomphonema*	9%
	Bacillariophyceae	*Fragilaria*	9%
MR4	Bacillariophyceae	*Gomphonema*	22%
	Bacillariophyceae	*Achnanthes*	12%
	Bacillariophyceae	*Cymbella*	9%
MR7	Euglenophyceae	*Euglena*	29%
	Bacillariophyceae	*Achnanthes*	13%
	Bacillariophyceae	*Gomphonema*	13%
MR7B	Bacillariophyceae	*Gomphonema*	11%
	Bacillariophyceae	*Fragilaria*	10%
	Bacillariophyceae	*Navicula*	7%
MR6	Bacillariophyceae	*Cymbella*	10%
	Bacillariophyceae	*Gomphonema*	9%
	Bacillariophyceae	*Navicula*	7%

Table 8.5-25. Benthic Invertebrate Summary, 2010 to 2013

Site	Method	Sample Size	Hess Density / CABIN Abundance		Family Richness				Family Diversity (Simpson's D)				Family Evenness (Simpson's E)			
					Whole Community		EPT		Whole Community		EPT		Whole Community		EPT	
			Mean	Standard Error	Mean	Standard Error	Mean	Standard Error	Mean	Standard Error	Mean	Standard Error	Mean	Standard Error	Mean	Standard Error
Shaft/Decline Sites																
REFST	Hess	5	10,708	1,291	20.2	1.6	12.4	0.5	0.92	0.007	0.87	0.008	0.64	0.027	0.63	0.029
M20-03	CABIN	3	5,799	361	19.0	1.0	12.0	1.0	0.93	0.002	0.89	0.007	0.79	0.035	0.80	0.022
M20-05	CABIN	3	4,879	371	16.3	0.3	11.3	0.3	0.92	0.006	0.88	0.009	0.79	0.048	0.78	0.085
M20-06	CABIN	6	11,368	1,026	20.8	0.8	13.5	0.8	0.90	0.017	0.89	0.010	0.54	0.085	0.68	0.042
M20-04	CABIN	9	11,308	1,959	20.9	1.4	13.2	0.9	0.92	0.006	0.88	0.010	0.63	0.037	0.68	0.037
	Hess	5	9,228	628	19.6	0.5	12.2	0.2	0.92	0.003	0.88	0.004	0.66	0.031	0.69	0.025
Coal Processing Site																
M17-02	CABIN	6	14,762	724	25.0	1.1	13.0	0.9	0.91	0.015	0.89	0.014	0.50	0.086	0.74	0.057
M19-01	CABIN	6	11,700	1,264	23.0	0.4	13.7	0.6	0.91	0.011	0.88	0.010	0.51	0.064	0.65	0.046
M19-02	CABIN	6	10,937	1,038	19.5	1.0	12.0	0.7	0.88	0.019	0.87	0.007	0.48	0.055	0.66	0.049
Receiving Environment																
MR-REF	CABIN	3	10,413	1,540	16.3	0.3	10.7	0.3	0.90	0.013	0.85	0.028	0.62	0.067	0.66	0.088
	Hess	5	8,765	840	17.2	1.8	8.6	0.7	0.91	0.008	0.83	0.010	0.67	0.048	0.69	0.054
MR9	CABIN	10	6,056	1,921	15.5	2.0	8.9	1.0	0.79	0.086	0.73	0.082	0.52	0.044	0.59	0.043
MR3	CABIN	6	7,751	1,994	18.0	1.5	10.0	1.0	0.87	0.026	0.79	0.045	0.52	0.064	0.55	0.053
	Hess	5	9,992	763	19.8	1.9	10.8	0.9	0.93	0.008	0.88	0.008	0.73	0.036	0.76	0.041
MR4	CABIN	9	8,267	1,449	21.9	1.4	10.8	0.7	0.90	0.007	0.84	0.017	0.48	0.032	0.60	0.023
	Hess	5	8,975	696	20.2	1.7	10.6	1.1	0.93	0.003	0.86	0.005	0.74	0.056	0.71	0.056
MR7	CABIN	3	2,619	293	13.0	2.5	4.0	1.5	0.85	0.028	0.26	0.251	0.57	0.085	0.48	0.076
MR7B	CABIN	6	10,148	917	23.3	1.1	12.7	0.6	0.91	0.005	0.84	0.010	0.51	0.036	0.52	0.022
MR6	CABIN	6	11,852	1,318	22.7	1.1	12.8	0.5	0.91	0.011	0.86	0.016	0.54	0.072	0.62	0.070
	Hess	5	9,053	1,246	22.0	1.5	10.4	0.8	0.93	0.006	0.85	0.013	0.66	0.037	0.68	0.041

EPT = Ephemeroptera, Plecoptera and Trichoptera

Hess density values represent organisms/m^2; CABIN abundance represents organisms/sample

Table 8.5-26. Benthic Invertebrate Dominant Taxa Summary, 2010 to 2013

Site	Method	Order	Family	Percent
Shaft/Decline Sites				
REFST	Hess	Ephemeroptera	Ephemerellidae	12%
		Ephemeroptera	Heptageniidae	10%
		Ephemeroptera	Baetidae	9%
M20-03	CABIN	Diptera	Chironomidae	8%
		Ephemeroptera	Ephemerellidae	7%
		Plecoptera	Nemouridae	7%
M20-05	CABIN	Trichoptera	Hydropsychidae	9%
		Diptera	Chironomidae	9%
		Plecoptera	Perlodidae	8%
M20-06	CABIN	Diptera	Chironomidae	19%
		Ephemeroptera	Heptageniidae	9%
		Plecoptera	Nemouridae	8%
M20-04	CABIN	Diptera	Chironomidae	13%
		Ephemeroptera	Heptageniidae	10%
		Plecoptera	Nemouridae	8%
	Hess	Ephemeroptera	Heptageniidae	11%
		Ephemeroptera	Baetidae	11%
		Ephemeroptera	Ephemerellidae	9%
Coal Processing Site				
M17-02	CABIN	Diptera	Chironomidae	21%
		Coleoptera	Elmidae	5%
		Diptera	Empididae	5%
M19-01	CABIN	Diptera	Chironomidae	19%
		Ephemeroptera	Heptageniidae	9%
		Plecoptera	Nemouridae	6%
M19-02	CABIN	Diptera	Chironomidae	23%
		Plecoptera	Perlodidae	8%
		Ephemeroptera	Baetidae	8%
Receiving Environment				
MR-REF	CABIN	Ephemeroptera	Ephemerellidae	17%
		Ephemeroptera	Baetidae	11%
		Plecoptera	Perlodidae	10%
	Hess	Ephemeroptera	Ephemerellidae	13%
		Ephemeroptera	Baetidae	12%
		Plecoptera	Perlodidae	10%
MR9	CABIN	Ephemeroptera	Ameletidae	17%
		Diptera	Chironomidae	9%
		Plecoptera	Capniidae	9%
MR3	CABIN	Diptera	Chironomidae	21%
		Ephemeroptera	Ephemerellidae	9%
		Plecoptera	Chloroperlidae	8%
	Hess	Ephemeroptera	Baetidae	13%
		Ephemeroptera	Ephemerellidae	8%
		Ephemeroptera	Heptageniidae	7%

(continued)

Table 8.5-26. Benthic Invertebrate Dominant Taxa Summary, 2010 to 2013 (completed)

Site	Method	Order	Family	Percent
Receiving Environment (cont'd)				
MR4	CABIN	Diptera	Chironomidae	20%
		Ephemeroptera	Ephemerellidae	8%
		Plecoptera	Perlodidae	8%
	Hess	Ephemeroptera	Ephemerellidae	8%
		Ephemeroptera	Baetidae	8%
		Diptera	Empididae	7%
MR7	CABIN	Diptera	Chironomidae	14%
		Trombidiformes	Lebertiidae	14%
		Trombidiformes	Hygrobatidae	11%
MR7B	CABIN	Ephemeroptera	Ephemerellidae	15%
		Diptera	Chironomidae	13%
		Plecoptera	Perlodidae	8%
MR6	CABIN	Diptera	Chironomidae	13%
		Ephemeroptera	Ephemerellidae	10%
		Trichoptera	Hydropsychidae	8%
	Hess	Ephemeroptera	Baetidae	10%
		Plecoptera	Chloroperlidae	9%
		Ephemeroptera	Ephemerellidae	9%

Table 8.5-27. Periphyton Tissue Metals Summary, 2011 to 2013

		Moisture (%)		Aluminum (Al)		Antimony (Sb)		Arsenic (As)		Barium (Ba)		Beryllium (Be)		Bismuth (Bi)		Boron (B)		Cadmium (Cd)		Calcium (Ca)		Chromium (Cr)	
Site	Years Sampled	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Shaft/Decline Sites																							
M20-03	2011	-	-	2,437	-	0.155	-	3.540	-	324.0	-	0.233	-	0.050	-	4.7	-	0.74	-	10,693	-	5.33	-
M20-05	2011	-	-	5,290	-	0.269	-	5.365	-	506.0	-	0.400	-	0.100	-	4.5	-	1.10	-	50,200	-	12.10	-
M20-06	2012, 2013	100.0	-	7,005	485	0.352	0.013	5.125	0.155	452.0	31.0	0.495	0.015	0.108	0.033	10.9	3.9	0.93	0.00	55,350	1,250	12.05	1.35
M20-04	2011 - 2013	100.0	-	5,400	1,015	0.264	0.095	4.793	0.486	425.3	96.5	0.400	0.051	0.103	0.029	9.0	4.3	0.72	0.15	31,567	8,907	10.20	1.41
Coal Processing Site																							
M17-02	2012, 2013	100.0	-	5,495	245	0.220	0.008	3.725	0.085	505.0	149.0	0.355	0.035	0.080	0.030	9.3	0.3	0.95	0.19	88,450	16,550	9.69	0.01
M19-01	2012, 2013	100.0	-	3,140	190	0.205	0.036	4.870	0.130	259.0	21.0	0.271	0.029	0.066	0.016	8.4	2.8	0.50	0.00	39,250	27,350	6.30	1.00
M19-02	2012, 2013	100.0	-	3,490	1,481	0.208	0.078	3.557	0.976	163.8	53.7	0.280	0.121	0.073	0.023	67.9	61.1	0.77	0.08	18,567	4,013	6.45	2.71
Receiving Environment																							
MR-REF	2013	99.3	-	5,253	-	0.228	-	6.225	-	221.0	-	0.393	-	0.158	-	21.8	-	0.68	-	35,400	-	8.79	-
MR9	2011 - 2013	99.0	-	6,047	670	0.197	0.021	5.327	0.503	137.3	12.3	0.340	0.021	0.100	0.029	7.3	3.0	0.65	0.01	58,367	2,918	11.19	0.91
MR3	2012, 2013	100.0	-	6,225	485	0.219	0.042	5.920	0.700	145.5	4.5	0.390	0.020	0.105	0.005	7.2	1.0	0.52	0.00	45,900	4,100	11.23	1.38
MR4	2011 - 2013	99.0	-	5,243	208	0.224	0.013	5.723	0.439	202.7	13.0	0.333	0.020	0.103	0.003	4.7	1.0	0.78	0.09	36,400	2,227	10.08	0.36
MR7	2011	-	-	3,150	-	0.124	-	4.110	-	135.0	-	0.200	-	0.050	-	5.0	-	0.79	-	14,700	-	12.40	-
MR7B	2012, 2013	99.0	-	4,740	280	0.332	0.149	6.780	1.650	183.5	14.5	0.360	0.030	0.050	0.000	6.1	1.2	1.24	0.38	55,650	2,850	9.74	1.16
MR6	2012, 2013	100.0	-	6,935	185	0.278	0.020	11.435	5.965	294.0	83.0	0.455	0.015	0.130	0.000	16.4	4.4	2.05	1.22	46,550	5,950	12.30	1.20

Values represent mg/kg dry weight unless otherwise noted.

(continued)

Replicate and split sample values averaged before summary statistics performed.

Values below the detection limit were replaced with half the detection limit

SE = Standard Error

Table 8.5-27. Periphyton Tissue Metals Summary, 2011 to 2013 (continued)

		Cobalt (Co)		Copper (Cu)		Iron (Fe)		Lead (Pb)		Magnesium (Mg)		Manganese (Mn)		Mercury (Hg)		Molybdenum (Mo)		Nickel (Ni)		Phosphorus (P)		Potassium (K)	
Site	Years Sampled	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Shaft/Decline Sites																							
M20-03	2011	4.63	-	9.34	-	9,717	-	4.33	-	1,833	-	1,256	-	0.0667	-	0.69	-	15.57	-	795	-	596	-
M20-05	2011	8.55	-	16.00	-	17,250	-	9.81	-	15,000	-	783	-	0.0650	-	1.41	-	27.85	-	1,074	-	1,129	-
M20-06	2012, 2013	15.15	0.55	19.75	3.55	17,200	900	9.82	0.59	15,450	4,550	556	134	0.0635	0.0015	1.19	0.08	28.05	2.95	1,195	65	1,945	265
M20-04	2011 - 2013	13.20	6.17	16.93	3.70	14,633	2,348	7.78	0.73	8,433	1,391	499	281	0.0573	0.0066	1.02	0.14	25.60	5.33	1,080	200	1,526	291
Coal Processing Site																							
M17-02	2012, 2013	5.65	1.12	13.65	0.15	11,250	750	7.06	1.14	7,845	115	351	75	0.0465	0.0035	0.75	0.06	22.70	1.20	1,025	5	1,495	95
M19-01	2012, 2013	5.11	0.35	8.97	0.19	13,975	1,375	5.75	0.24	8,045	4,405	739	353	0.0458	0.0043	1.00	0.16	15.01	0.19	1,042	158	938	71
M19-02	2012, 2013	4.67	2.20	13.90	1.66	10,733	4,791	5.84	2.86	5,160	535	312	95	0.0960	0.0255	0.93	0.36	14.68	5.99	1,413	564	6,807	5,697
Receiving Environment																							
MR-REF	2013	7.94	-	13.37	-	16,608	-	9.28	-	13,170	-	822	-	0.0398	-	1.48	-	21.00	-	1,153	-	2,475	-
MR9	2011 - 2013	7.13	0.51	12.03	0.48	15,567	1,241	8.58	0.50	18,033	769	593	71	0.0337	0.0019	1.11	0.08	20.40	0.51	1,027	18	1,082	172
MR3	2012, 2013	6.76	0.20	10.85	0.35	16,150	150	8.64	0.65	15,450	650	525	87	0.0370	0.0060	1.19	0.01	19.20	0.50	1,041	60	1,315	195
MR4	2011 - 2013	8.83	1.79	13.27	1.05	14,967	371	8.62	0.89	13,933	1,485	788	227	0.0600	0.0158	1.06	0.06	20.97	2.31	1,116	98	1,116	210
MR7	2011	3.74	-	11.10	-	8,980	-	5.07	-	7,010	-	117	-	0.0500	-	0.53	-	15.60	-	1,020	-	722	-
MR7B	2012, 2013	11.62	3.98	10.97	1.13	16,050	1,950	7.67	0.77	16,850	3,350	1,755	935	0.0455	0.0115	1.50	0.55	25.20	4.50	993	47	1,050	221
MR6	2012, 2013	18.20	7.70	14.80	0.10	20,450	3,450	9.35	0.36	13,750	2,850	3,229	2,281	0.0425	0.0015	1.54	0.31	40.60	19.60	968	62	1,420	80

Values represent mg/kg dry weight unless otherwise noted.

(continued)

Replicate and split sample values averaged before summary statistics performed.

Values below the detection limit were replaced with half the detection limit

SE = Standard Error

Table 8.5-27. Periphyton Tissue Metals Summary, 2011 to 2013 (completed)

		Selenium (Se)		Silver (Ag)		Sodium (Na)		Strontium (Sr)		Thallium (Tl)		Tin (Sn)		Titanium (Ti)		Uranium (U)		Vanadium (V)		Zinc (Zn)	
Site	Years Sampled	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Shaft/Decline Sites																					
M20-03	2011	2.00	-	0.157	-	110.0	-	37.6	-	0.078	-	0.117	-	6.7	-	0.449	-	10.6	-	63.4	-
M20-05	2011	1.42	-	0.455	-	297.5	-	86.4	-	0.186	-	0.300	-	58.0	-	0.766	-	23.5	-	125.0	-
M20-06	2012, 2013	3.24	1.04	0.989	0.772	154.0	38.0	95.7	5.3	0.232	0.012	0.525	0.045	40.5	17.7	0.712	0.010	25.8	3.8	172.5	67.5
M20-04	2011 - 2013	1.71	0.51	1.075	0.800	138.7	49.9	67.0	17.3	0.175	0.020	0.410	0.107	34.8	20.4	0.627	0.080	20.2	3.5	162.6	66.3
Coal Processing Site																					
M17-02	2012, 2013	1.50	0.08	0.218	0.120	142.5	31.5	123.5	19.5	0.183	0.013	0.270	0.040	37.7	9.5	0.710	0.105	19.1	0.9	84.1	19.0
M19-01	2012, 2013	1.03	0.08	0.449	0.255	86.3	16.3	78.1	20.1	0.100	0.012	0.351	0.131	18.7	13.3	0.584	0.190	15.9	0.5	107.1	39.9
M19-02	2012, 2013	1.25	0.07	0.222	0.151	266.7	175.3	45.4	13.8	0.098	0.038	0.177	0.072	12.2	2.4	0.362	0.126	12.3	3.9	91.6	17.8
Receiving Environment																					
MR-REF	2013	0.91	-	0.123	-	78.5	-	235.2	-	0.239	-	0.265	-	34.7	-	0.828	-	21.8	-	123.5	-
MR9	2011 - 2013	0.57	0.10	0.137	0.047	75.3	5.0	100.2	14.9	0.188	0.001	0.193	0.018	49.1	17.4	0.815	0.030	22.7	2.4	65.8	5.1
MR3	2012, 2013	0.54	0.06	0.108	0.009	77.5	2.5	90.1	28.0	0.188	0.012	0.270	0.050	46.1	14.8	0.924	0.052	24.3	3.5	63.6	1.5
MR4	2011 - 2013	0.73	0.08	0.221	0.105	67.3	0.9	71.5	14.0	0.173	0.015	0.237	0.033	30.9	9.0	0.750	0.042	20.3	0.4	83.0	14.6
MR7	2011	0.73	-	0.560	-	36.0	-	20.9	-	0.087	-	0.100	-	6.0	-	0.389	-	13.8	-	111.0	-
MR7B	2012, 2013	0.80	0.18	0.121	0.019	76.0	10.0	89.6	6.1	0.191	0.023	0.380	0.250	21.7	7.1	0.880	0.086	24.2	4.1	74.9	11.6
MR6	2012, 2013	1.07	0.09	0.251	0.151	80.0	2.0	128.5	50.5	0.217	0.017	0.280	0.050	40.7	15.2	0.788	0.091	28.8	5.2	103.0	2.0

Values represent mg/kg dry weight unless otherwise noted.

Replicate and split sample values averaged before summary statistics performed.

Values below the detection limit were replaced with half the detection limit

SE = Standard Error

Table 8.5-28. Benthic Invertebrate Tissue Metals Summary, 2010 to 2013

		Moisture (%)		Aluminum (Al)		Antimony (Sb)		Arsenic (As)		Barium (Ba)		Beryllium (Be)		Bismuth (Bi)		Boron (B)		Cadmium (Cd)		Calcium (Ca)		Chromium (Cr)	
Site	Years Sampled	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Shaft/Decline Sites																							
M20-03	2011	-	-	267	-	0.035	-	0.460	-	27.2	-	0.040	-	0.010	-	2.5	-	0.27	-	2,110	-	0.64	-
M20-05	2011	-	-	118	-	0.015	-	0.080	-	13.2	-	0.010	-	0.010	-	3.0	-	0.22	-	1,580	-	0.22	-
M20-06	2012, 2013	-	-	166	53	0.015	0.003	0.091	0.011	11.7	2.5	0.015	0.005	0.015	0.005	0.3	0.1	0.45	0.07	1,200	170	0.29	0.07
M20-04	2011 - 2013	-	-	171	53	0.017	0.003	0.115	0.035	12.6	1.1	0.023	0.011	0.023	0.011	1.3	1.1	0.39	0.15	1,302	156	0.33	0.11
Coal Processing Site																							
M17-02	2012, 2013	-	-	157	126	0.016	0.005	0.125	0.083	9.9	1.1	0.013	0.003	0.013	0.003	0.3	0.1	0.39	0.25	907	544	0.28	0.21
M19-01	2012, 2013	-	-	216	97	0.013	0.001	0.198	0.023	13.6	4.7	0.013	0.003	0.013	0.003	0.3	0.1	0.76	0.55	1,698	203	0.42	0.15
M19-02	2012, 2013	-	-	155	40	0.013	0.000	0.150	0.032	10.7	1.6	0.010	0.000	0.010	0.000	0.3	0.1	0.34	0.06	1,170	60	0.31	0.07
Receiving Environment																							
MR-REF	2010, 2013	93.9	-	99	14	0.013	0.002	0.124	0.056	15.5	12.9	0.030	0.020	0.013	0.003	1.2	-	0.55	0.10	1,217	674	0.21	0.02
MR9	2011 - 2013	-	-	157	48	0.018	0.006	0.122	0.049	13.4	6.3	0.068	0.017	0.068	0.017	1.4	0.3	0.44	0.10	1,700	391	0.25	0.08
MR3	2010, 2012, 2013	90.3	-	248	126	0.030	0.027	0.341	0.172	13.4	8.2	0.033	0.012	0.022	0.009	1.2	1.0	0.81	0.55	1,829	1,260	0.51	0.25
MR4	2011 - 2013	-	-	190	60	0.020	0.003	0.149	0.018	9.7	2.2	0.043	0.013	0.043	0.013	2.0	1.0	0.85	0.25	2,030	219	0.40	0.11
MR7	2011	-	-	355	-	0.049	-	0.340	-	9.2	-	0.050	-	0.050	-	7.0	-	0.25	-	1,860	-	0.60	-
MR7B	2012, 2013	-	-	62	35	0.009	0.005	0.093	0.033	3.6	1.6	0.010	0.000	0.010	0.000	0.5	0.3	0.59	0.24	941	329	0.12	0.07
MR6	2010, 2012, 2013	91.9	-	108	27	0.012	0.002	0.110	0.015	7.2	0.7	0.025	0.013	0.013	0.002	0.3	0.1	0.43	0.11	1,310	326	0.20	0.04

Values represent mg/kg wet weight unless otherwise noted.

(continued)

Replicate and split sample values averaged before summary statistics performed.

Values below the detection limit were replaced with half the detection limit

SE = Standard Error

Table 8.5-28. Benthic Invertebrate Tissue Metals Summary, 2010 to 2013 (continued)

		Cobalt (Co)		Copper (Cu)		Iron (Fe)		Lead (Pb)		Lithium (Li)		Magnesium (Mg)		Manganese (Mn)		Mercury.ICPMS		Mercury.CVAA		Molybdenum (Mo)		Nickel (Ni)	
Site	Years Sampled	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Shaft/Decline Sites																							
M20-03	2011	0.71	-	3.04	-	1,940	-	0.48	-	-	-	318	-	117.0	-	-	-	0.0070	-	0.17	-	2.59	-
M20-05	2011	0.17	-	2.01	-	263	-	0.21	-	-	-	278	-	20.3	-	-	-	0.0110	-	0.08	-	0.64	-
M20-06	2012, 2013	1.14	0.31	5.06	1.22	283	14	0.22	0.03	-	-	461	15	26.3	10.9	0.0064	0.0041	0.0070	-	0.11	0.00	0.83	0.11
M20-04	2011 - 2013	1.03	0.57	4.19	1.54	315	86	0.24	0.04	-	-	356	121	26.1	3.2	0.0048	0.0008	0.0153	0.0123	0.10	0.01	1.13	0.10
Coal Processing Site																							
M17-02	2012, 2013	0.28	0.16	4.89	1.04	335	241	0.20	0.14	-	-	587	22	22.7	1.5	0.0038	0.0028	0.0048	-	0.14	0.02	0.77	0.36
M19-01	2012, 2013	0.36	0.18	4.83	2.30	677	22	0.29	0.01	-	-	524	17	30.9	12.2	0.0131	0.0087	0.0176	-	0.14	0.01	0.78	0.08
M19-02	2012, 2013	0.23	0.04	4.21	0.04	431	32	0.22	0.03	-	-	314	84	14.1	0.1	0.0083	0.0004	0.0060	-	0.12	0.03	0.74	0.08
Receiving Environment																							
MR-REF	2010, 2013	0.33	0.14	3.66	1.42	378	-	0.12	0.05	0.12	-	357	224	37.6	28.7	0.0026	0.0006	-	-	0.08	0.04	0.46	0.16
MR9	2011 - 2013	0.27	0.10	3.76	1.53	341	125	0.21	0.07	-	-	404	77	30.6	18.6	0.0115	0.0075	0.0289	0.0211	0.11	0.01	0.70	0.37
MR3	2010, 2012, 2013	0.76	0.27	4.77	0.86	999	551	0.36	0.21	0.37	-	457	226	36.7	19.5	0.0032	0.0004	0.0010	-	0.13	0.08	1.42	0.84
MR4	2011 - 2013	0.46	0.16	5.02	1.27	442	90	0.27	0.05	-	-	541	120	32.9	9.7	0.0125	0.0095	0.0103	0.0047	0.18	0.03	0.81	0.13
MR7	2011	0.53	-	1.60	-	958	-	0.57	-	-	-	744	-	21.9	-	-	-	0.0300	-	0.23	-	1.72	-
MR7B	2012, 2013	0.23	0.01	6.37	0.12	227	162	0.11	0.06	-	-	383	98	26.6	9.9	0.0019	0.0009	0.0010	-	0.14	0.08	0.41	0.13
MR6	2010, 2012, 2013	0.31	0.06	6.43	1.35	248	77	0.14	0.02	0.18	-	451	143	31.5	3.2	0.0037	0.0007	0.0010	-	0.08	0.01	0.52	0.08

Values represent mg/kg wet weight unless otherwise noted.

(continued)

Replicate and split sample values averaged before summary statistics performed.

Values below the detection limit were replaced with half the detection limit

SE = Standard Error

Table 8.5-28. Benthic Invertebrate Tissue Metals Summary, 2010 to 2013 (completed)

		Phosphorus (P)		Potassium (K)		Selenium (Se)		Silver (Ag)		Sodium (Na)		Strontium (Sr)		Thallium (Tl)		Tin (Sn)		Titanium (Ti)		Uranium (U)		Vanadium (V)		Zinc (Zn)	
Site	**Years Sampled**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Shaft/Decline Sites																									
M20-03	2011	745	-	67	-	0.57	-	0.034	-	18.0	-	6.1	-	0.008	-	0.030	-	1.3	-	0.117	-	1.7	-	29.7	-
M20-05	2011	801	-	43	-	0.57	-	0.011	-	7.0	-	5.1	-	0.005	-	0.010	-	1.5	-	0.034	-	0.5	-	22.2	-
M20-06	2012, 2013	1,295	85	238	135	1.15	0.02	0.021	0.003	94.4	60.7	3.1	0.5	0.005	0.004	0.085	0.029	2.8	1.1	0.022	0.001	0.6	0.2	52.2	0.3
M20-04	2011 - 2013	1,041	308	408	337	0.85	0.30	0.019	0.005	183.9	141.2	3.3	0.6	0.007	0.003	0.047	0.022	3.3	0.9	0.028	0.004	0.6	0.2	39.7	7.5
Coal Processing Site																									
M17-02	2012, 2013	1,345	165	688	210	0.90	0.12	0.018	0.006	281.0	91.0	1.9	1.0	0.007	0.007	0.013	0.003	2.7	1.9	0.033	0.016	0.6	0.5	51.3	1.7
M19-01	2012, 2013	1,122	134	155	93	0.65	0.06	0.020	0.006	40.7	29.5	3.0	0.1	0.005	0.005	0.035	0.025	3.7	2.8	0.028	0.003	0.9	0.3	34.7	8.7
M19-02	2012, 2013	1,130	30	182	140	0.98	0.19	0.025	0.001	62.9	51.1	2.6	0.5	0.003	0.003	0.125	0.115	1.7	0.5	0.020	0.003	0.6	0.2	33.8	4.1
Receiving Environment																									
MR-REF	2010, 2013	1,660	-	604	-	0.44	0.21	0.023	-	173.0	-	3.0	1.8	0.006	0.001	0.134	0.124	2.3	-	0.024	0.003	0.4	0.1	59.5	35.8
MR9	2011 - 2013	1,101	574	163	65	0.39	0.16	0.024	0.003	42.8	21.0	4.6	0.7	0.007	0.002	0.068	0.017	3.2	0.9	0.027	0.012	0.6	0.3	35.6	8.6
MR3	2010, 2012, 2013	817	364	373	250	0.41	0.11	0.019	0.017	299.7	290.4	5.4	4.4	0.015	0.003	0.092	0.060	3.8	3.7	0.043	0.027	1.4	0.7	28.8	8.7
MR4	2011 - 2013	1,297	163	135	66	0.67	0.17	0.020	0.004	33.8	22.7	4.3	0.4	0.009	0.003	0.320	0.290	4.4	2.2	0.026	0.006	0.7	0.2	48.2	15.1
MR7	2011	154	-	117	-	0.13	-	0.010	-	5.0	-	2.8	-	0.014	-	0.050	-	7.0	-	0.067	-	1.7	-	8.5	-
MR7B	2012, 2013	1,185	115	107	19	0.65	0.06	0.038	0.000	49.9	19.3	1.9	0.4	0.001	0.001	0.010	0.000	0.8	0.3	0.009	0.005	0.2	0.1	66.1	1.3
MR6	2010, 2012, 2013	1,765	35	463	76	0.69	0.20	0.056	0.029	155.5	14.5	2.8	0.7	0.003	0.001	0.127	0.059	1.4	0.3	0.023	0.008	0.4	0.1	76.6	22.4

Values represent mg/kg wet weight unless otherwise noted.

Replicate and split sample values averaged before summary statistics performed.

Values below the detection limit were replaced with half the detection limit

SE = Standard Error

Receiving Environment (Murray River)

Water Toxicity

The results of water toxicity bioassays are presented in detail in the report generated by Nautilus Environmental (note that MR4 is labeled with its 2010 name, MR5) in the baseline report (Appendix 8-B).

Overall, the toxicity bioassays found no impact of MR-REF and MR4 site water on survival and reproduction of *Ceriodaphnia dubia* or rainbow trout (Appendix 8-B). However, the water flea *Daphnia magna* had considerably reduced survivorship when site water was present at any concentration (Appendix 8-B). The *D. magna* LC_{50} (lethal concentration for 50% of the sample) was less than 6.25% site water for both sites.

The duck weed *Lemna minor* may have been inhibited by water chemistry at MR-REF, although there was no evidence of this at the downstream MR4 site (Appendix 8-B). The water chemistry at both sites stimulated the growth of the microalgae *Pseudokirchneriella subcapitata* (Appendix 8-B).

Sediment Quality

Sand was the primary constituent of Murray River sediments, followed by silt, as was the case for other Project area sites (Table 8.5-19). TOC concentrations were lowest in Murray River sediments, as was observed for water quality (see Section 8.5.3).

Sediment metal concentrations in the Murray River were generally within the range its tributary streams (Table 8.5-19). As with its tributary streams, the majority of Murray River sediments were above CCME and BC guidelines for cadmium and nickel (Table 8.5-20). Arsenic, chromium, and iron concentrations were sporadically above guidelines in the Murray River, as was true for its tributaries M20 Creek and Club Creek on the west bank.

PAH levels were generally low and similar across all sites; however, Murray River sediments had lower concentrations of fluorene, 2-methylnapthalene, naphthalene and phenanthrene compared to its tributary streams (Table 8.5-21). All Murray River sediment samples were above the CCME ISQG for 2-methylnaphthalene and phrenanthrene, which was also common in the tributary streams (Table 8.5-22). Naphthalene and chrysene concentrations were also sporadically above applicable CCME and BC guidelines in Murray River sediments.

Periphyton

Murray River periphyton communities were largely composed of diatoms and were diverse (high Simpson's diversity), as was found in its tributaries (Table 8.5-23). The Murray River upstream reference site MR-REF had the highest mean density (18,841 cells/cm^2), genus richness (18 genera) and diversity (0.90 Simpson's diversity) of all sites. In contrast, the Murray River just below the M20 confluence (MR7) had the lowest density, genus richness, diversity and evenness in the Project area, but the highest mean biomass (4.95 chl *a* µg/cm^2).*Gomphonema*, *Achnanthes*, *Cymbella* and *Navicula* were common periphyton genera in Murray River sites, and were also commonly found in its tributary streams (Table 8.5-24). *Didymosphenia germinata* was found at MR-REF, MR3, MR4 and MR6 in 2010, and MR4 in 2013. Extra caution should be taken at these sites to ensure that this invasive species does not spread to other Project area sites.

Benthic Invertebrates

Murray River benthic invertebrate communities were very similar to the west and east banks tributary streams, except MR7 (Table 8.5-25). Abundance was similar across sites, and family richness (mean range: 13.0-23.3 families/sample) and diversity were high (>0.75 Simpson's diversity). The Murray River had moderately high family evenness (Simpson's evenness), as was found in the tributary streams. EPTs and Chironomidae were common, with an abundance of EPT families such as Ephemerellidae, Baetidae and Perlodidae (Table 8.5-26). As was observed for periphyton communities, the MR7 benthic invertebrate community was inconsistent with other Murray River sites. The MR7 community had the lowest mean abundance, richness (whole community and EPT) and diversity (EPT) of all Project area sites.

Tissue Metals

Murray River periphyton tissue metal concentrations were generally low compared to M20 Creek (Shaft/Decline Sites), with the exception of MR6 (Table 8.5-27). MR6, which is one of two Murray River far-field monitoring stations, had the highest observed mean periphyton tissue concentrations for arsenic, cadmium, cobalt, iron, manganese, molybdenum, and nickel. In contrast, MR6 had some of the lowest observed metal concentrations in benthic invertebrate tissues (Table 8.5-28). Selenium tissue concentrations were lowest in Murray River periphyton compared to east and west bank sites, which had a maximum site mean of 1.07 mg/kg dw.

8.6 ESTABLISHING THE SCOPE OF THE EFFECTS ASSESSMENT FOR SURFACE WATER AND AQUATIC RESOURCES

This section includes a description of the scoping process used to identify potentially affected Valued Components (VCs), select assessment boundaries, and identify the potential effects of the Project that are likely to arise from the Project's interaction with a VC. Scoping is fundamental to focusing the Application/EIS on those issues where there is the greatest potential to cause significant adverse effects.

8.6.1 Selecting Valued Components

Valued components are components of the natural and human environment that are considered to be of scientific, ecological, economic, social, cultural, or heritage importance (CEAA 2006; EAO 2013). To be included in the Application/EIS, there must be a perceived likelihood that the VC will be affected by the proposed Project. Valued components are scoped into the environmental assessment based on issues raised during consultation on the AIR and EIS Guidelines with Aboriginal communities, government agencies, the public, and stakeholders. Consideration of certain VCs may also be a legislated requirement, or known to be a concern because of previous project experience.

8.6.1.1 Summary of Valued Components Selected for Assessment

Surface water, sediment quality, and aquatic resources (Table 8.6-1) were identified as key components of the bio-physical environment. Valued component selection was guided by the Murray River Coal Project AIR (BC EAO 2013) and the EIS Guidelines (CEAA 2012). No identified surface water or aquatic resources VCs were excluded from the assessment.

Table 8.6-1. Surface Water Valued Components Included in the Effects Assessment

Valued Components	Identified by*			Rationale for Inclusion
	AG	G	P/S	
Surface Water	X	X	X	linked to other ecosystem components, fish and fish habitat, wildlife, wetlands, and human health
Sediment Quality	X	X	X	
Aquatic Resources	X	X	X	

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

The proposed Project has the potential to affect surface water during Construction, Operation, Decommissioning and Reclamation, and Post-closure. Through a review of relevant regulations and guidelines, scientific literature, other recent Application/EIS documents in BC, as well as professional experience and judgement, surface water was selected for inclusion as a single VC, rather than assessing individual physical or chemical components.

Surface water quantity and quality were identified as two key sub-components of the surface water VC. Surface water quantity is a key sub-component of the surface water VC because it is linked to other ecosystem components, including surface water quality, fish and fish habitat, aquatic resources, terrestrial ecosystems, wetlands, navigation, and land use. Based on the natural flow regime paradigm, flow indices are vital elements of aquatic environmental health (Poff et al. 1997; Poff et al. 2010). The assessment of changes to surface water quantity is evaluated using "indicators" that are relevant, practical, measurable, responsive, accurate, and predictable metrics to measure the condition and trend of surface water quantity. These indicators include average annual and monthly flows, peak flows, and low flows.

Surface water quality is also a key sub-component of the surface water VC as it is linked to other important ecosystem components including fish and fish habitat, aquatic resources (primary and secondary producers), sediment quality, terrestrial ecosystems, wildlife, and human health. Indicators of surface water quality include concentrations of total and dissolved metals, nutrients, major ions, and TSS. The BC Ministry of the Environment (MOE) noted that the following water quality parameters are of particular concern for coal mines: selenium, sulphate, nitrate, cadmium, total dissolved solids, hardness, total suspended solids (TSS), and turbidity. Other parameters of interest to BC MOE include cobalt, chromium, nickel, zinc, and lithium (Gerrard 2014, pers. comm.). For water management ponds that may be accessed by wildlife or discharged to the downstream receiving environment (i.e., sites within the water balance and predictive water quality models) indicators are defined as quantitatively identified chemicals of potential concern (COPC; Section 8.8).

Sediment quality was identified as a VC because of the intimate interactions stream sediments have with water quality and benthic invertebrates; indicators of sediment quality include particle size, nutrients and metal concentrations. Sediment and water quality tend to co-vary, as metals and organic compounds shift between particulate matter and dissolved components. Further, sediments represent a compartment in the aquatic ecosystem that may accumulate substantial quantities of metals and organic compounds due to the high surface area of sediment particles, favourable redox conditions, and low oxygen concentrations. Given the close association of benthic invertebrates with stream substrates for habitat, shifts in sediment quality may alter benthic invertebrate community density, composition, and tissue residue levels. Feeding methods may affect some benthic invertebrate taxa if sediments are ingested. Shifts in benthic invertebrate communities and the bioaccumulation of metals can have important implications for higher trophic levels because they are an important food source for fish, birds, and amphibians

Aquatic resources were identified as a VC because these organisms are fundamental components for aquatic ecosystem functioning, processing available nutrients, and providing the biomass to support higher trophic levels. Benthic community assemblages also stabilize substrata and serve as a habitat for many other organisms. Aquatic organisms have limited mobility and life history characteristics (e.g., living on or in sediment); therefore, aquatic communities are closely linked to the physical features of their habitat and, as such, are useful for detecting potential shifts or disturbances of sediment quality, water quality, and aquatic habitat.

Aquatic resources were defined, through a review of relevant regulations, guidelines, scientific literature, and the application of professional experience and judgment, as the biological communities residing in the pelagic (water column) and benthic habitats of waterbodies. These biological communities comprise the following components:

- primary producers, which are the photosynthetic plants and algae that form the base of the aquatic food web;
- secondary producers, which are aquatic invertebrates that are the crucial link in the food web between primary production and higher trophic levels; and
- higher trophic levels, which are fish and other vertebrates living in the higher levels of the food web. The higher trophic levels are considered in other assessment chapters and not considered further in this assessment.

8.6.2 Selecting Assessment Boundaries

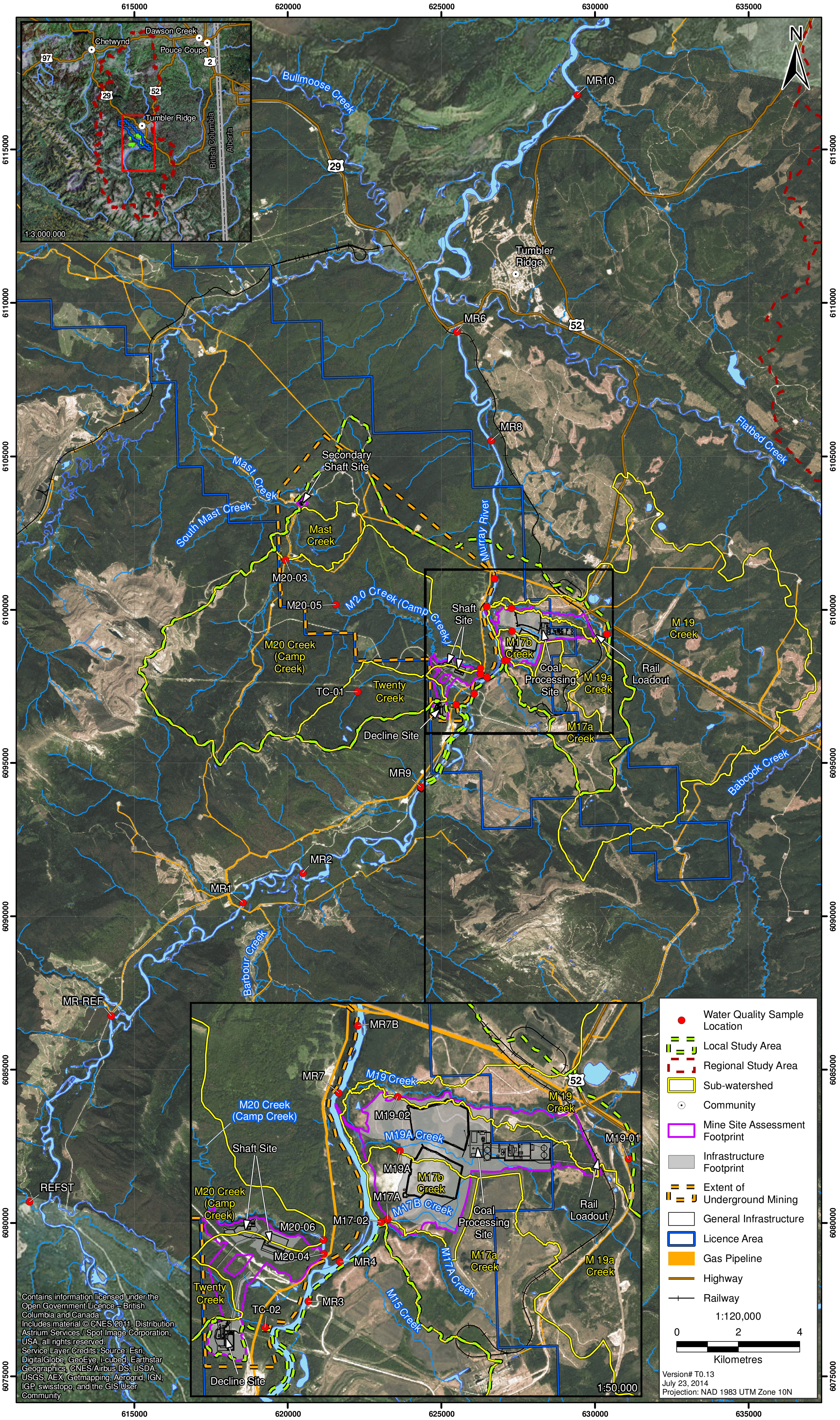
Assessment boundaries define the maximum limit within which the effects assessment is conducted. They encompass the areas within, and times during which, the Project is expected to interact with identified VCs, as well as the constraints that may be placed on the assessment of those interactions due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

8.6.2.1 Spatial Boundaries

Spatial boundaries reflect the location of the Project components and consider watersheds over a range of spatial scales from local (i.e., immediately upstream of the Mine Site Assessment Footprint) to regional (i.e., the Murray River watershed). The spatial boundaries have been divided into a Local Study Area (LSA) and a Regional Study Area (RSA), discussed below and presented in Figure 8.6-1.

Figure 8.6-1

Local and Regional Study Areas



Local Study Area

The LSA was selected to focus on the Mine Site Assessment Footprint and a larger, localized area of direct Project influence (Figure 8.6-1).

The LSA incorporates the sub-watersheds on the east and west bank of the Murray River that may be potentially affected by the Shaft Site, the Decline Site, and the Coal Processing Site. Sub-watersheds included in the LSA include M20, Twenty, M17A, M17B, and M19A creeks. To assess potential localized effects on the headwaters of Mast Creek, and on M19 Creek, the LSA boundaries deviate from the sub-watershed boundaries and are focussed on the area most likely to be directly influenced by the Secondary Shaft Site (Mast Creek) and the Coal Processing Site (M19 Creek, downstream of monitoring site M19-01). The LSA incorporates the Murray River between water quality baseline site MR9 (upstream of all proposed Project activities) and MR7 (downstream of all Project discharges; Figure 8.6-1). The downstream boundary of the LSA was selected to be the point downstream where the predicted effects fall within the range of natural variability.

Regional Study Area

The RSA is intended to encompass an area beyond which effects of the Project would not be expected. The RSA is aligned with the Murray River watershed boundaries (Figure 8.6-1).

8.6.2.2 Temporal Boundaries

Surface water, sediment quality, and aquatic resources VCs can potentially be affected throughout the life of the mine, encompassing Construction, Operation, Decommissioning and Reclamation, and Post-closure. The temporal boundaries of the Project include the following:

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

8.6.2.3 Administrative Boundaries

No administrative boundaries were applied to the surface water, sediment quality, and aquatic resources effects assessment.

8.6.2.4 Technical Boundaries

No technical boundaries were applied to the surface water, sediment quality, and aquatic resources effects assessment.

8.6.3 Identifying Potential Effects on Surface Water, Sediment Quality, and Aquatic Resources

The purpose of this section is to identify the potential effects that can result from the interaction of the Project components and activities with the VCs selected in Section 8.6.1 within the boundaries selected in Section 8.6.2. The potential effects were identified through professional experience with other mining project Applications/EIS' in BC and through consultation with the Working Group through the pre-application phase. Effects to surface water, sediment quality, and aquatic resources could potentially occur during all phases of the Project. Components and activities for each temporal phase are discussed to describe the pathways that can lead to effects on surface water, sediment quality, and aquatic resources VCs (Table 8.6-2; Sections 8.6.3.1 to 8.6.3.4). Note that the potential for spills and accidents involving large quantities of petroleum products or other chemicals are not considered here as these are related to occurrences of low likelihood outside of normal operating conditions. These are instead addressed in Chapter 21 (Accidents and Malfunctions) as well as in the Spill Response Plan (Section 24.18).

Key effects were identified as those that warrant further consideration and assessment. Interactions of Project activities with the potential for negligible or minor expected adverse effects that require implementation of best practices or standard mitigation and management measures were not further considered in the effects assessment.

8.6.3.1 Identifying Potential Effects on Surface Water

The following sections identify the potential effects to the surface water VC from activities in each Project phase.

Potential effects on the surface water VC include:

- Changes in surface water quantity; and
- Changes in surface water quality.

In general, the Project has the potential to change surface water quantity by:

- changing the timing, volume, and peak and minimum flows (e.g., dewatering of underground works, altering natural flow pathways, and water withdrawals and discharges); and
- affecting natural stream morphology and sediment transport, if changes are evidenced from changes to the hydrological flow regime.

In general, the Project has the potential to change surface water quality by:

- releasing effluent potentially affected by metal leaching/acid rock drainage (ML/ARD) to the receiving environment;
- erosion and sedimentation during site clearing, construction, and maintenance activities;
- seepage and releasing effluent by exfiltration to ground (surface water-groundwater interactions);

Table 8.6-2. Ranking Potential Effects On Surface Water and Aquatic Resources

	Project Activities	Potential Effects on Surface Water: Change in Surface Water Quantity	Potential Effects on Surface Water: Change in Surface Water Quality	Potential Effects on Sediment Quality: Change in Sediment Quality	Potential Effects on Aquatic Resources: Change in Surface Water Quantity	Potential Effects on Aquatic Resources: Change in Surface Water Quality	Potential Effects on Aquatic Resources: Change in Sediment Quality	Potential Effects on Aquatic Resources: Habitat Loss
Construction	**Underground Mine**							
	Construction of the Production Decline (2 headings - surface and underground)	M	L	L	M	L	L	L
	Haul of waste rock from Production Decline portal to North Site	L	L	L	L	L	L	L
	Ventilation during construction	L	L	L	L	L	L	L
	Development mining of underground service bays, sumps, conveyor headings, etc.	M	L	L	M	L	L	L
	Construct underground conveyor system	L	L	L	L	L	L	L
	Coal Processing Site							
	Surface Preparation							
	Establish site drainage and water management	H	L	L	H	L	L	L
	Site clearing and stripping (CPP site, CCR #1)	M	L	L	M	L	L	L
	Soil salvage for reclamation	L	L	L	L	L	L	L
	Upgrade access roads, parking and laydown areas	L	L	L	L	L	L	L
	Heavy machinery use	L	L	L	L	L	L	L
	Buildings and Services							
	Install domestic water system	M	L	L	M	L	L	L
	Install sanitary sewer system	M	L	L	M	L	L	L
	Install natural gas and electricity distribution network	L	L	L	L	L	L	L
	Construct main fuel station	L	L	L	L	L	L	L
	Construct buildings (e.g., maintenance, administration, warehouse)	M	L	L	M	L	L	L
	Construct raw coal and clean coal stockpile areas	M	L	L	M	L	L	L
	Construct coal preparation plant buildings and install/commission equipment	M	L	L	M	L	L	L
	Construct surface conveyor system	L	L	L	L	L	L	L
	Construct rail load-out facilities	L	L	L	L	L	L	L
	Shaft Site							
	Upgrades to infrastructure within existing site	L	L	L	L	L	L	L
	Addition of waste rock within existing storage area	L	L	L	L	L	L	L
	Management of runoff from waste rock pile and release to receiving environment (M20 Creek)	H	M	M	H	M	M	L
	Decline Site							
	Upgrades to infrastructure within existing site	L	L	L	L	L	L	L
	Management of water from underground activities and release by exfiltration to ground	H	M	M	H	M	M	L
	Traffic and Transportation							
	Transportation of materials to and from site	L	L	L	L	L	L	L
	Recycling and solid waste disposal	L	L	L	L	L	L	L
	Shuttling workforce to and from site	L	L	L	L	L	L	L
	Workforce and Administration							
	Hiring and management of workforce	L	L	L	L	L	L	L
	Taxes, contracts, and purchases	L	L	L	L	L	L	L

(continued)

Table 8.6-2. Ranking Potential Effects On Surface Water and Aquatic Resources (continued)

	Project Activities	Potential Effects on Surface Water: Change in Surface Water Quantity	Potential Effects on Surface Water: Change in Surface Water Quality	Potential Effects on Sediment Quality: Change in Sediment Quality	Potential Effects on Aquatic Resources: Change in Surface Water Quantity	Potential Effects on Aquatic Resources: Change in Surface Water Quality	Potential Effects on Aquatic Resources: Change in Sediment Quality	Potential Effects on Aquatic Resources: Habitat Loss
Operations	**Underground Mine**							
	Longwall panel mining, and development mining	M	L	L	M	L	L	L
	Ventilation from underground	L	L	L	L	L	L	L
	Methane management	L	L	L	L	L	L	L
	Secondary shaft construction	L	L	L	L	L	L	L
	Underground seepage collection and water management	H	L	L	H	L	L	L
	Surface subsidence	M	L	L	M	L	L	L
	Coal Processing Site							
	Coal Processing Plant							
	Stockpiles of raw coal	M	L	L	M	L	L	L
	Operation of coal preparation plant and conveyor system	H	L	L	H	L	L	L
	Stockpiles of clean coal and middlings	M	L	L	M	L	L	L
	Operation of rail loadout	L	L	L	L	L	L	L
	CCR							
	CCR Pile development	H	M	M	H	M	M	L
	Site clearing and stripping (expansion of CCR #1, construction of CCR #2)	M	L	L	M	L	L	L
	Seepage collection system	H	M	M	H	M	M	L
	Water Management							
	Management of water brought to surface from underground	H	L	L	H	L	L	L
	Management of seepage from CCR	H	L	L	H	L	L	L
	Management of other site contact water	M	L	L	M	L	L	L
	Maintenance of site ditching and water management infrastructure	H	L	L	H	L	L	L
	Release of excess contact water to receiving environment	M	H	H	M	H	H	L
	Shaft Site							
	Maintenance of infrastructure within existing site	L	L	L	L	L	L	L
	Progressive reclamation of waste rock pile	L	L	L	L	L	L	L
	Management of runoff from waste rock pile and release to receiving environment (M20 Creek)	M	H	H	M	H	H	L
	Decline Site							
	Maintenance of infrastructure within existing site	L	L	L	L	L	L	L
	Secondary Shafts Site							
	Site preparation and construction of shafts	M	L	L	M	L	L	L
	Maintenance of infrastructure within existing site	L	L	L	L	L	L	L
	Utilities, Power, and Waste Handling							
	Electrical power use	L	L	L	L	L	L	L
	Natural gas use	L	L	L	L	L	L	L
	Domestic water use	M	L	L	M	L	L	L
	Domestic sewage handling	L	L	L	L	L	L	L
	Recycling and solid waste disposal	L	L	L	L	L	L	L

(continued)

Table 8.6-2. Ranking Potential Effects On Surface Water and Aquatic Resources (completed)

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

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

- direct release of effluent to the receiving environment (Murray River); and
- nutrient loading from explosives use; and
- dust deposition.

Construction

During Construction (three years), activities with the potential to affect surface water quantity and surface water quality will include:

- the establishment of water management structures (e.g., embankments, sedimentation ponds, water treatment facilities, and groundwater wells), and site drainage, including a system of diversion channels to divert contact and non-contact water;
- erosion and sedimentation during site clearing and grubbing;
- erosion and sedimentation during excavation and foundation preparation;
- erosion and sedimentation during construction of buildings and processing facilities;
- release of effluent from the Shaft Site sedimentation pond to the receiving environment (M20 Creek); and
- release of effluent from the Decline Site sedimentation pond by exfiltration to ground with seepage to Murray River.

Operation

During Operations (25 years), activities with the potential to affect surface water quantity and surface water quality will include:

- underground and surface water management;
- surface subsidence effects on water quantity;
- activities associated with operation of coal stockpiles and coal processing;
- erosion and sedimentation during site clearing and grubbing at CCR piles, excavation and foundation preparation at CCR piles, and during maintenance of Project infrastructure;
- seepage loss from CCR piles to M19A and M19 creeks;
- release of effluent from the Shaft Site sedimentation pond to the receiving environment (M20 Creek); and
- release of effluent from the Coal Processing Site to the receiving environment (Murray River).

Decommissioning and Reclamation

During Decommissioning and Reclamation (three years), activities with the potential to affect surface water quantity and surface water quality will include:

- surface water management;
- erosion and sedimentation during facility tear down, removal, and reclamation;

- erosion and sedimentation during excavation and foundation preparation;
- seepage loss from CCR piles to M19A and M19 creeks;
- seepage from the waste rock facility to M20 Creek; and
- release of effluent from the Coal Processing Site by exfiltration to ground with seepage to Murray River.

Post-closure

Post-closure will last until long-term environmental objectives are achieved (currently estimated to be 30 years). Surface water and groundwater monitoring will take place during this phase.

Activities with the potential to affect surface water in Post-closure will include:

- surface water management;
- seepage loss from CCR piles to M19A and M19 creeks;
- seepage from the waste rock facility to M20 Creek; and
- release of effluent from the Coal Processing Site by exfiltration to ground with seepage to Murray River.

Potential Effects Excluded in the Effects Assessment

The following effects on the surface water VC are not further considered in the effects assessment in order to focus the assessment on key effects:

Erosion and Sedimentation

The Erosion and Sediment Control Plan (Section 24.6) describes the guidelines that HD Mining will adhere to in order to minimize erosion and sediment loss during the life of the Project. Erosion control Best Management Practices (BMPs) and sediment control measures are designed to mitigate adverse effects due to erosion and sedimentation.

Effluent discharge will be required to meet permit limits under the *Environmental Management Act*, which are expected to include a limit for total suspended solids (TSS) that is protective of water quality and freshwater aquatic life. Given implementation of the Erosion and Sediment Control Plan and expected permit limits for effluent discharges, the likelihood of an adverse effect on surface water due to erosion and sedimentation is considered to be low. The effect of erosion and sedimentation was therefore not considered further.

Dust Deposition

The Air Quality Management Plan (Section 24.2) describes the guidelines that HD Mining will adhere to in order to minimize emissions and fugitive dust during the life of the Project. Air quality modelling without considering dust control mitigation, indicated that the maximum 30-day deposition will be 2.3 $mg/dm^2/day$, of which 1.2 $mg/dm^2/day$ is attributed to the background dustfall.

Given that mitigation measures, such as road and stockpile watering, would significantly reduce the amount of fugitive dust, an adverse effect on surface water due to dust deposition is considered to be low. Effects of dust deposition were; therefore, not considered further.

Nutrient Loading

Most mining, including the main tunnel systems, will be within the coal seams, where use of explosives is not necessary. Small amounts of explosives may be required when constructing the Production Decline, excavating rock tunnels, and when mining between coal seams. The Explosives and Nitrogen Management Plan (Section 24.9) describes the guidelines that HD Mining will adhere to in order to minimize nutrient loading from the transportation, storage, and use of explosives required for the Project. A qualified and experienced local contracting company, with good performance history, will be used and an explosives management plan will be developed and reviewed.

Given the infrequent explosives use for mining, the likelihood of an adverse effect on surface water quality due to nutrient loading associated with explosives (e.g., nitrogen) is considered low. As such, the effects of nutrient loading from explosives will not be considered further.

8.6.3.2 Identifying Potential Effects on Sediment Quality

The following sections identify the potential effects to sediment quality from activities in each Project phase. Many of the potential effects identified for surface water are also concerns for sediment quality.

Potential effects on the sediment quality VC include:

- changes in sediment quality.

The assessment of effects on sediment quality is linked to the assessment of surface water effects (Section 8.6.3.1). In general, the Project has the potential to change sediment quality by:

- change in water quantity that affects natural stream morphology and sediment transport;
- change in water quality, such as releasing effluent potentially affected by ML/ARD to the receiving environment; and
- change in surface water quality as a result of erosion and sedimentation that leads to a change in particle size distribution of sediments.

<u>Potential Effects Excluded in the Effects Assessment</u>

The potential effects identified for surface water are as described in Section 8.6.3.1. As described in Section 8.6.3.1, standard BMPs will be applied to mitigate potential effects of erosion and sedimentation; therefore, this potential effect will not be further considered for sediment quality.

8.6.3.3 Identifying Potential Effects on Aquatic Resources

The following sections identify the potential effects to aquatic resources from activities in each Project phase. Potential effects on the aquatic resources VC may occur as a result of:

- changes in water quantity (Section 8.6.3.1);
- changes in water quality (Section 8.6.3.1);
- changes in sediment quality (Section 8.6.3.2); and
- habitat loss.

The Project interactions in each phase that may lead to potential effects to aquatic resources due to changes in surface water (quantity and quality) and sediment quality are as described in Section 8.6.3.1 and 8.6.3.2, respectively.

Potential Effects Excluded in the Effects Assessment

The assessment of effects on aquatic resources is linked to the assessment of surface water and sediment quality effects. The deposition or erosion of sediments could result from surface runoff, stream bank destabilization, and effluent discharge with potential effects on aquatic resources. Sedimentation or erosion of stream sediments can either add or remove fine sediments in interstitial spaces between cobble and boulders (Wood and Armitage 1997), which can affect habitat availability and community biomass, density, and composition for aquatic resources (Wood and Armitage 1997; Roy et al. 2003). In extreme cases, large sediment inputs into streams could smother periphyton and benthic invertebrates. However, as described in Section 8.6.3.1, standard BMPs and an Erosion and Sediment Control Plan will be applied to mitigate potential effects of erosion and sedimentation; therefore, this potential effect will not be further considered for aquatic resources.

In general, Project activities can have the potential to cause habitat loss by removal of riparian vegetation during site clearing, construction, and maintenance activities. However, since no substantive in-stream works are proposed, aquatic habitat loss due to removal of riparian vegetation is unlikely. Therefore, this potential effect is not considered further for aquatic resources.

8.6.3.4 Summary of Potential Effects to be Assessed for Surface Water, Sediment Quality, and Aquatic Resources

Potential effects on surface water, sediment quality and aquatic resources VCs were ranked in Table 8.6-2 to focus the assessment on key effects.

The key effects on the surface water VC include:

- changes in surface water quantity; and
- changes in surface water quality due to:
  - releasing effluent potentially affected by ML/ARD to the receiving environment; and
  - seepage and releasing effluent by exfiltration to ground (surface water-groundwater interactions).

The assessment of effects on sediment quality is linked to the assessment of surface water effects. The key effect on the sediment quality VC is:

- changes in sediment chemistry.

The key effects on the aquatic resources VC may occur due to:

- changes in water quantity;
- changes in water quality; and
- changes in sediment quality.

8.7 EFFECTS ASSESSMENT AND MITIGATION FOR SURFACE WATER, SEDIMENT QUALITY, AND AQUATIC RESOURCES

8.7.1 Key Effects on Surface Water

8.7.1.1 Change in Surface Water Quantity

The Project components and activities have the potential to affect the streamflows in M17B, M19A, M19, and M20 creeks, as well as streamflows in Murray River. Therefore, streamflow assessment points were selected on M17B, M19A, M19, and M20 creeks (at the mouth of these streams), and on Murray River downstream of confluence with M19 Creek. A water balance model (WBM) was developed to estimate effects of the Project on annual and monthly streamflows. Details of the model, including input data, modelling assumptions, calibration, and results are available in Appendix 8-E, Water Balance and Water Quality Modelling Report. GoldSim™ was used to develop the water balance model with monthly time-step input data.

Model inputs, where possible, were based on data collected from baseline studies, field measurements, bulk sample results, engineering designs, and professional knowledge and experience. Where uncertainty existed, a conservative assessment or approach was applied. Details are provided in Appendix 8-E.

Key elements of the water balance model were the underground mine, CPP, CPP pond, CCR piles, Decline pond, and Shaft pond. The main inflows into the water balance model include:

- groundwater inflows into the underground mine;
- diverted and undiverted surface runoff in the Coal Processing, Decline, and Shaft sites;
- precipitation on open water ponds (i.e., CPP pond, Decline pond, and Shaft pond); and
- precipitation on the CCR piles, raw coal stockpile within the Decline Site, and waste rock facility within the Shaft Site.

Outflows or losses include:

- evaporation from open water in the ponds;
- water loss in the underground workings (e.g., spraying) and water loss within the CPP (e.g., evaporation during drying);

- water loss in clean coal and middlings moisture;
- onsite water uses; and
- unforeseen uses.

The base case model scenario represents average climate conditions (average annual precipitation) and moderate estimates for groundwater inflows into the underground mine. The water balance model was calibrated to monthly streamflows measured during baseline studies (Appendices 8-A and 8-E).

To investigate the potential variability in the base case effects assessment, sensitivity scenarios were used. Three climate estimates (i.e., 100-year dry, average, and 100-year wet annual effective precipitation) and three groundwater inflow rates into the underground mine (i.e., high, moderate and low inflows) were considered. The 100-year dry, average, and 100-year wet annual effective precipitation estimates are 57, 190, and 530 mm, respectively (Appendix 8-E). The low, moderate, and high groundwater inflow estimates are 1,890, 6,000, and 12,750 m^3/day, respectively (Appendix 8-E). These model inputs generate nine different combinations (the base case and eight sensitivity scenarios):

- **Base Case Scenario**: Average Annual Precipitation and Moderate Groundwater Inflows into the Mine
- **Sensitivity Scenario #1**: Average Annual Precipitation and High Groundwater Inflows into the Mine
- **Sensitivity Scenario #2**: Average Annual Precipitation and Low Groundwater Seepage
- **Sensitivity Scenario #3**: 100-Year Wet Annual Precipitation and Moderate Groundwater Inflows into the Mine
- **Sensitivity Scenario #4**: 100-Year Wet Annual Precipitation and High Groundwater Inflows into the Mine
- **Sensitivity Scenario #5**: 100-Year Wet Annual Precipitation and Low Groundwater Inflows into the Mine
- **Sensitivity Scenario #6**: 100-Year Dry Annual Precipitation and Moderate Groundwater Inflows into the Mine
- **Sensitivity Scenario #7**: 100-Year Dry Annual Precipitation and High Groundwater Inflows into the Mine
- **Sensitivity Scenario #8**: 100-Year Dry Annual Precipitation and Low Groundwater Inflows into the Mine.

The model estimated monthly flows at baseline conditions, as well as flows during Construction, Operation, Decommissioning, and Post-closure of the Project under the nine aforementioned scenarios. These results were used to estimate the effects of the Project on annual and monthly flows, and annual low flows (Section 8.8.1.1).

Streamflows in the Project area have little fluctuation during February, which represents the lowest monthly flow in a year (Appendix 8-A, 2011-2013 Hydrology Baseline Report). Therefore, in this assessment, monthly flows in February were used to represent the annual low-flow indicator of streamflows.

Potential changes in annual peak flows were used as a proxy for potential changes in stream morphology. Because the WBM is set up based on monthly water quantity data, it may not reliably estimate the effects of the Project on peak flows. The magnitude and timing of peak flows within a watershed are a function of three parameters. These are the:

- magnitude and timing of a storm, as well as snowmelt, events;
- catchment area of the watershed; and
- runoff coefficient within the watershed.

Among these three parameters, the last two are more likely to potentially be affected by the Project. The catchment area and runoff coefficient of the watersheds will be impacted due to the Project. The runoff coefficient within the disturbed area of the Project will be changed due to surface disturbance. In addition, contact water from such disturbed areas is planned to be collected and stored the CPP pond, or be used in the CPP. These changes were considered in estimating the effects of the Project on peak flows (Section 8.8.1.1).

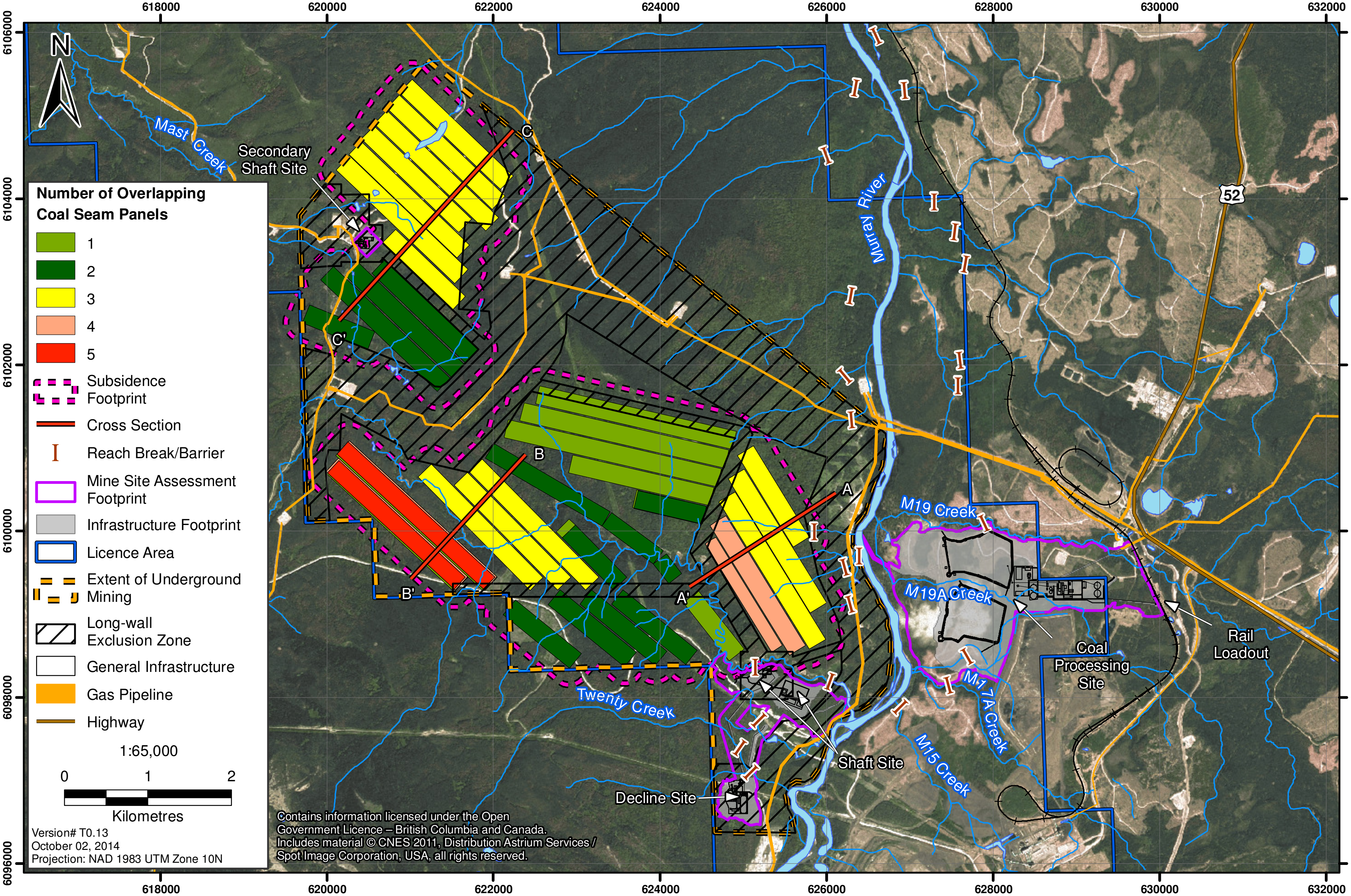
Due to the inherent data and modelling uncertainty in hydrologic studies, it is reasonable to account for at least a 5% error in streamflow estimates. Therefore, it was assumed that any streamflow change of less than 5%, compared to the baseline flows, could be an artifact of data and/or modelling uncertainty; therefore, it was considered a negligible change.

Quantified effects of the Project on surface water quantity (Section 8.8.1.1) do not include the subsidence effects. The subsidence processes associated with the planned longwall mining operations in the Project may impact the ground surface and water bodies in the M20 Creek watershed. HD Mining has conducted a subsidence study according to the proposed mining plan to assess the possible subsidence impacts (Appendix 3-C). Subsidence predictions are made along three major cross-sections where largest impact will be observed.

Mining of all the coal seams in Block II will cause the highest surface movements and deformations within the mine property. In this area, the overburden depth over each of the coal seams is smallest, the possible mining heights are largest, and mining will be conducted in all of the five coal seams. In this section, the subsidence prediction was made along a cross-section B-B′ covering the panels mined in the area (Figure 8.7-1; Appendix 3-C).

Based on the subsidence predictions, the highest tensile strains are expected at the edges of the panels. Areas of high strain may create cracks in the ground surface that could potentially drain surface water bodies. Streamflows at M20 Creek could be affected by the subsidence process, particularly in areas where panel edges intersect the stream. Two processes may reduce these effects. These are:

Figure 8.7-1
Subsidence Assessment Cross Sections



1. Mining in the different coal seams will be conducted over a significant period of time (25 years), the ground surface may self-heal some of the disturbance between the mining stages (Appendix 3-C).
2. Surface water that drains into the cracks will emerge further downstream.

Given the above processes, effects of subsidence on streamflows at downstream reaches of M20 Creek are expected to be diminished. No effects, beyond the natural flow variability, are expected in Murray River.

Given these complexities, accurate quantification of the subsidence effects on streamflows at M20 Creek would require further monitoring and studies. If reduced flows are evident during any stage of the monitoring program, appropriate mitigation measures will be implemented.

8.7.1.2 Change in Surface Water Quality

In support of the environmental assessment, quantitative modelling was completed to predict key effects on surface water. Two water quality modelling approaches were used to assess the potential for change to surface water quality.

The primary objective of water quality modelling for the Project was to predict the concentrations of total and dissolved metals, nutrients, and anions within the Project footprint and in the surrounding surface waters that will receive direct effluent discharge and/or seepage from Project components.

To assess chemical loadings to the receiving environment, water quality predictions were developed for the Project using GoldSim. A summary of the model approach, assumptions, and sensitivity analyses are provided in the following sections. Full details are provided in Appendix 8-E, Murray River Coal Project: Water Balance and Water Quality Model Report.

The GoldSim water balance and water quality model incorporated water management, Project design, and baseline geochemistry, hydrology, and surface water quality inputs to characterize the potential change in surface water quality due to release of effluent and seepage loss during all Project phases as identified in Section 8.6.3.1.

To assess mixing of effluent discharge into Murray River from the Coal Processing Site, a MIKE3 hydrodynamic model was developed. The results of the mixing model were used to identify the optimal effluent discharge location. A summary of the model approach, assumptions, and sensitivity analyses are provided in the following sections. Full details are provided in Appendix 8-F, Mixing Associated with Discharge of an Effluent to Murray River at Low Flow Conditions.

The MIKE3 mixing model evaluated four potential discharge locations with a nominal effluent discharge rate of 100 L/s under low-flow conditions in the Murray River (5 m^3/s) that are equivalent to a 7-day low flow with a 10-year return period (7Q10).

GoldSim Water Quality Model

Approach and Assumptions

The base case water quality model was used to assess effects on the surface water VC. The results are based on the average annual precipitation, moderate groundwater inflows into the underground mine, and expected case geochemical source terms (Appendix 8-E). Water quality and quantity data used as model inputs inherently have a degree of uncertainty. Therefore, sensitivity analysis was conducted on model inputs to evaluate input parameters that contribute to uncertainty in predictive results, and therefore, uncertainty in the effects assessment. The water quality model scenarios presented in Table 8.7-1 were selected to evaluate the uncertainty associated with 1) variability in climate conditions, 2) underground inflow rates, 3) geochemical source terms, and 4) groundwater quality.

The water quality model for the Project was developed using a mass balance calculation approach in GoldSim to model the volume and flow of water and the concentrations and transport of chemical species as a function of time. GoldSim program was developed to model complex environmental systems and has been extensively and successfully applied to simulate water resource management, mining operation, contaminant transport, and radioactive waste management (GoldSim 2014). GoldSim is a simulation program that includes Project components as "containers" that are made up of "elements." These containers include the formulas, data, conditions, and/or operation criteria for different Project components.

Table 8.7-1. GoldSim Water Quality Model Scenarios

Model Case		Surface Flows	Groundwater Inflows	Surface Water Source Term	Geochemical Source Term	Groundwater Quality Source Term
Base Case		Average Annual Precipitation	Moderate Groundwater Inflows	Median monthly surface water quality	Expected geochemical source terms	Deep groundwater chemistry
Sensitivity Scenarios						
Scenario		**Surface Flows**	**Groundwater Inflows**	**Surface Water Source Term**	**Geochemical Source Term**	
Water Management	1	Average Annual Precipitation	High Groundwater Inflows	Median monthly surface water quality	Expected geochemical source terms	Deep groundwater chemistry
	2	Average Annual Precipitation	Low Groundwater Inflows	Median monthly surface water quality	Expected geochemical source terms	Deep groundwater chemistry
	3	100-Year Wet Annual Precipitation	Moderate Groundwater Inflows	Median monthly surface water quality	Expected geochemical source terms	Deep groundwater chemistry
	4	100-Year Wet Annual Precipitation	High Groundwater Inflows	Median monthly surface water quality	Expected geochemical source terms	Deep groundwater chemistry
	5	100-Year Wet Annual Precipitation	Low Groundwater Inflows	Median monthly surface water quality	Expected geochemical source terms	Deep groundwater chemistry

(continued)

Table 8.7-1. GoldSim Water Quality Model Scenarios (completed)

Sensitivity Scenarios *(cont'd)*						
Scenario		**Surface Flows**	**Groundwater Inflows**	**Surface Water Source Term**	**Geochemical Source Term**	**Groundwater Quality Source Term**
Water Management (cont'd)	6	100-Year Dry Annual Precipitation	Moderate Groundwater Inflows	Median monthly surface water quality	Expected geochemical source terms	Deep groundwater chemistry
	7	100-Year Dry Annual Precipitation	High Groundwater Inflows	Median monthly surface water quality	Expected geochemical source terms	Deep groundwater chemistry
	8	100-Year Dry Annual Precipitation	Low Groundwater Inflows	Median monthly surface water quality	Expected geochemical source terms	Deep groundwater chemistry
Water Chemistry	9	Average Annual Precipitation	Moderate Groundwater Inflows	95th percentile surface water chemistries	Expected geochemical source terms	Deep groundwater chemistry
	10	Average Annual Precipitation	High Groundwater Inflows	95th percentile surface water chemistries	Expected geochemical source terms	Deep groundwater chemistry
	11	Average Annual Precipitation	Low Groundwater Inflows	95th percentile surface water chemistries	Expected geochemical source terms	Deep groundwater chemistry
	12	Average Annual Precipitation	Moderate Groundwater Inflows	Median monthly surface water quality	Upper geochemical source terms	Deep groundwater chemistry
	13	Average Annual Precipitation	High Groundwater Inflows	Median monthly surface water quality	Upper geochemical source terms	Deep groundwater chemistry
	14	Average Annual Precipitation	Low Groundwater Inflows	Median monthly surface water quality	Upper geochemical source terms	Deep groundwater chemistry
Groundwater Sensitivity	15	Average Annual Precipitation	Moderate Groundwater Inflows	Median monthly surface water quality	Expected geochemical source terms	Ten times deep groundwater chemistry
	16	Average Annual Precipitation	High Groundwater Inflows	Median monthly surface water quality	Expected geochemical source terms	Ten times deep groundwater chemistry
	17	Average Annual Precipitation	Low Groundwater Inflows	Median monthly surface water quality	Expected geochemical source terms	Ten times deep groundwater chemistry

The water quality model is based on monthly time steps and contains both contact and non-contact water that reports to Murray River either directly or via a tributary.

Geochemical source terms were developed based on the geochemistry characterization program (Appendices 3-B and 8-E) and were used to represent contact water quality signatures in the water quality model. Non-contact water quality source terms were derived from baseline monitoring for the Project (Appendices 8-B, 8-D, and 8-E).

Mass balance modelling considered inputs (i.e., source terms) from Project-related sources including:

- Waste rock facility;
- CCR North and CCR South piles;
- Coal stockpiles;
- Underground mine dewatering; and
- Water management including diversion of non-contact water.

Water quality predictions were developed for the receiving environment based on additional Project-related chemical loads due to seepage loss and effluent discharge. Results of water quality predictions include management and mitigation measures; that is, results indicating a change in water quality represent a residual effect to the surface water VC. These mitigations are further described in Section 8.7.4.

Results: Effluent Quality

Effluent discharges with the potential to change water quality occur from the Decline and Shaft ponds primarily during Construction and from the CPP pond during Operations. Water quality predictions for individual Project components are presented in Appendix 8-E.

Predicted water quality model results for selected parameters of interest in these ponds are presented in Figures 8.7-2 to 8.7-4. The relative loadings of the various sources contributing to the predicted water quality in the ponds is presented in Appendix 8-E.

Predicted pond water quality is considered to be reasonable for discharge without a requirement for water treatment for chemical parameters.

The GoldSim water quality model assumes full mixing of effluent discharge with the receiving environment. A mixing model with environmentally conservative assumptions was developed to evaluate the validity of assessing change in water quality in Murray River using the GoldSim model results.

<u>MIKE3 Mixing Model</u>

Approach and Assumptions

The MIKE3 numerical model developed by Danish Hydraulic Institute (DHI) was used in the study. MIKE3 is a three-dimensional numerical simulation software which solves Reynolds-averaged Navier-Stokes equations of motion and has been extensively used to study engineering and environmental problems related to marine and freshwater bodies.

Figure 8.7-2

Water Quality Predictions for Decline Pond, Murray River Coal Project

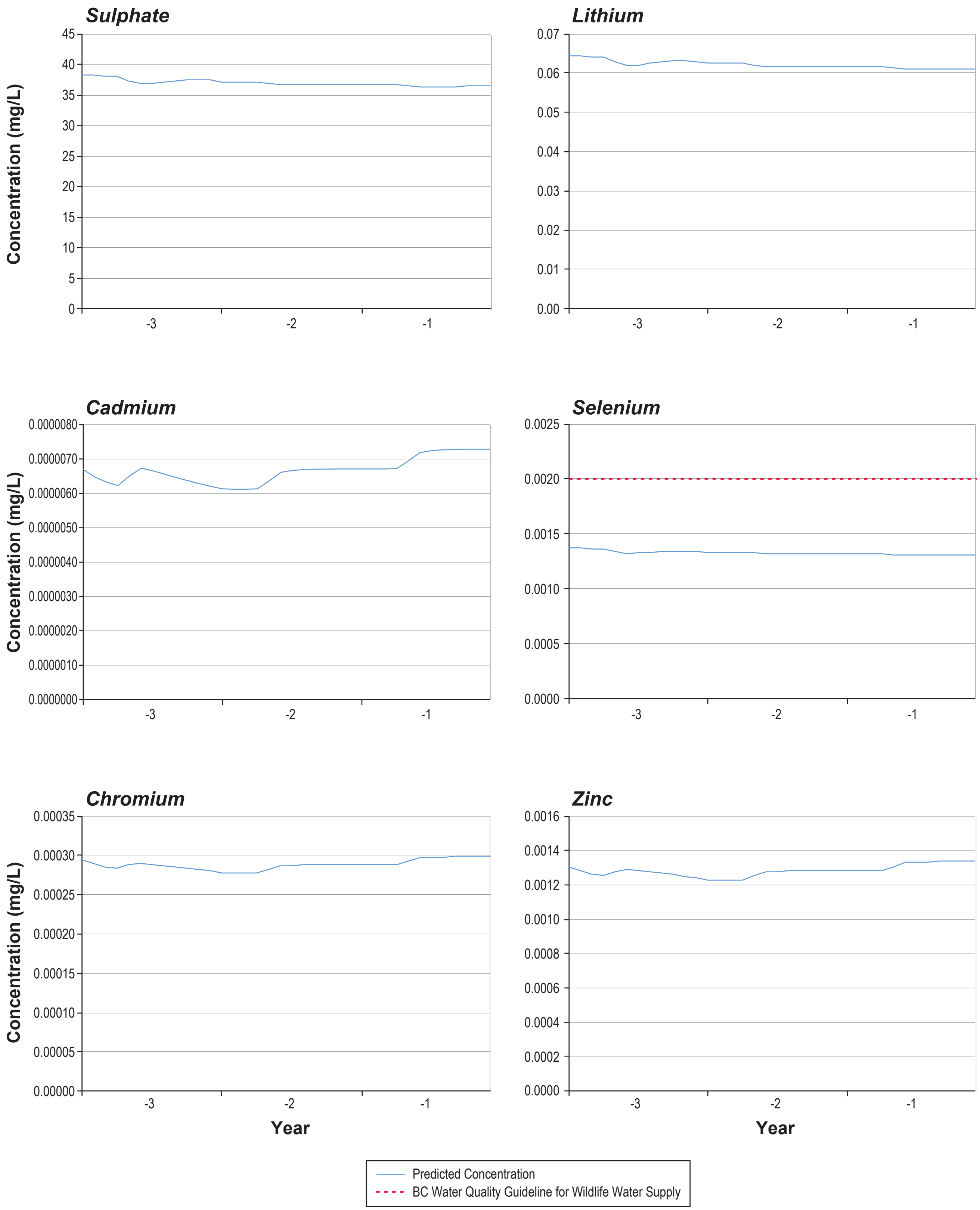


Figure 8.7-3

Water Quality Predictions for Shaft Pond, Murray River Coal Project

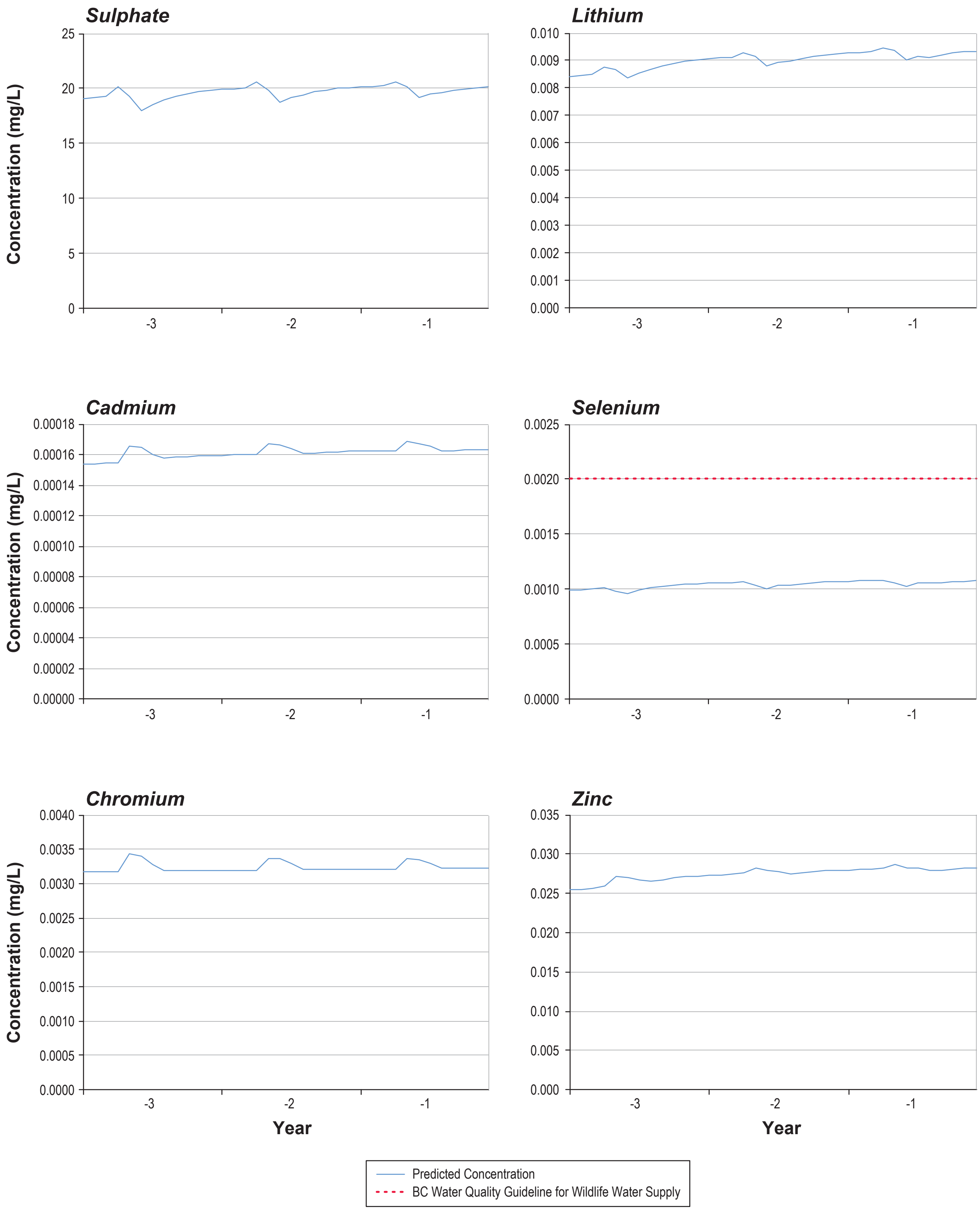
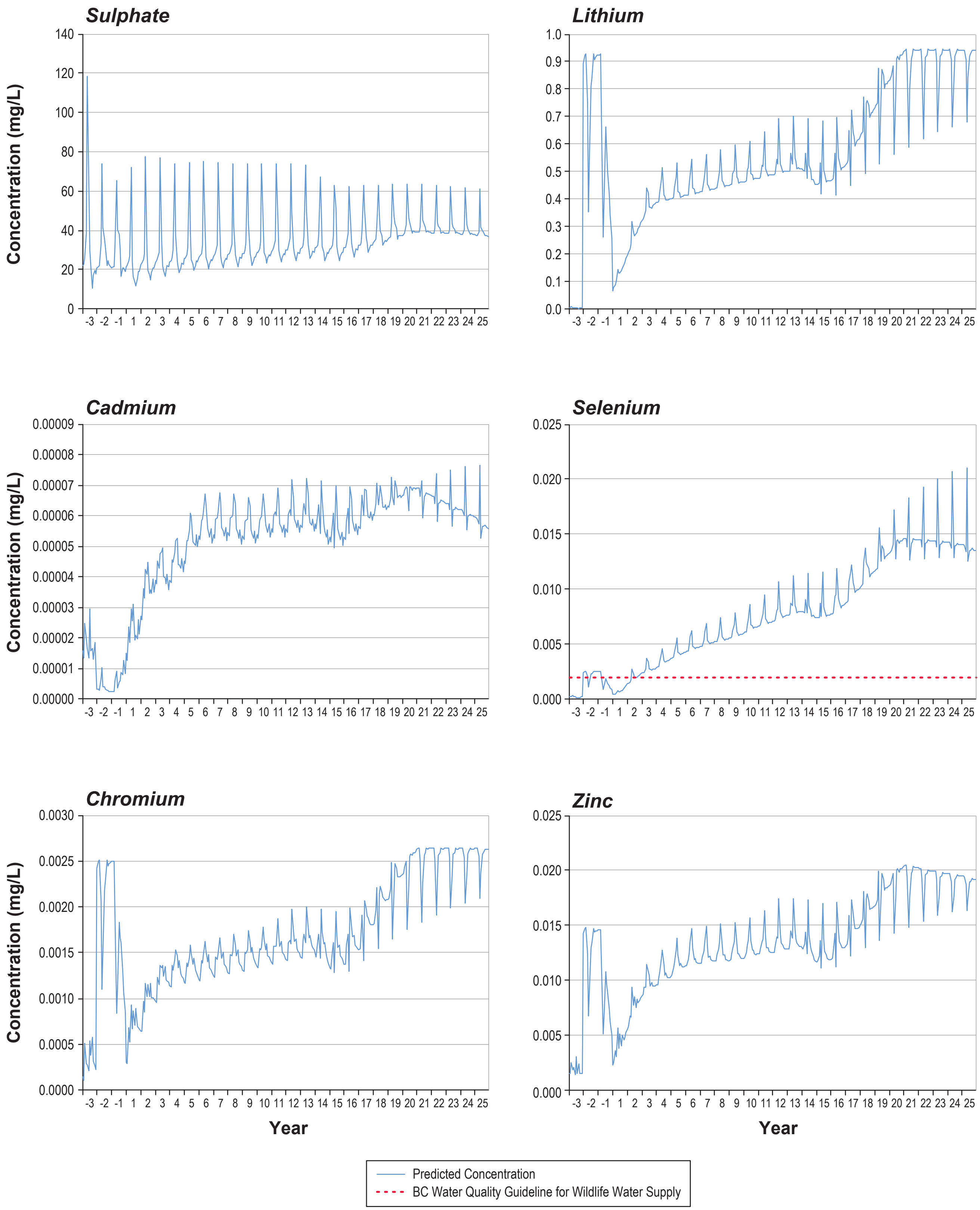


Figure 8.7-4

Water Quality Predictions for CPP Pond, Murray River Coal Project



The conservative model case used to evaluate mixing in the Murray River was selected to correspond to maximum effluent concentrations in the river. These conditions are expected to occur at a low winter flow of 5 m^3/s (5,000 L/s; 7-day low flow with 10 year return period) under a rigid ice cover. It was assumed that the effluent discharge flow rate is 100 L/s (0.1 m^3/s). Water balance base case predictions under average annual precipitation conditions estimate discharge rates ranging from 0 to 56 L/s (0 to 4,829 m^3/day; Appendix 8-E) from the Coal Processing Site to Murray River throughout the life of the Project, with maximum rates realized during Operation.

Numerical simulation of these conditions was undertaken by first calibrating the model using field data of depth and flow (stage and discharge data).

A very low salt concentration was ascribed to the effluent to serve as a passive tracer in the model runs. The effluent salinity was selected as equal to 0.01 PSU, low enough to have a negligible effect on buoyancy in this regime.

Results

The results of the mixing model indicate that optimal mixing occurs at the inner bend of the east bank adjacent to the Coal Processing Site (discharge location 4; Appendix 8-F); therefore, the proposed CPP pond discharge was sited at this location. Under the stream and discharge flow conditions used in the mixing model, effluent concentrations differ by a factor of 2 across the river under equilibrium conditions at 100 m downstream of the point of discharge (Figure 8.7-5). Given the relatively rapid mixing of effluent discharge under the conservative conditions simulated in the MIKE3 model, assessing the change in surface water quality based on the results of the GoldSim model (which assumes complete mixing) is reasonable and appropriate at the environmental assessment stage.

Screening of Contaminants of Potential Concern

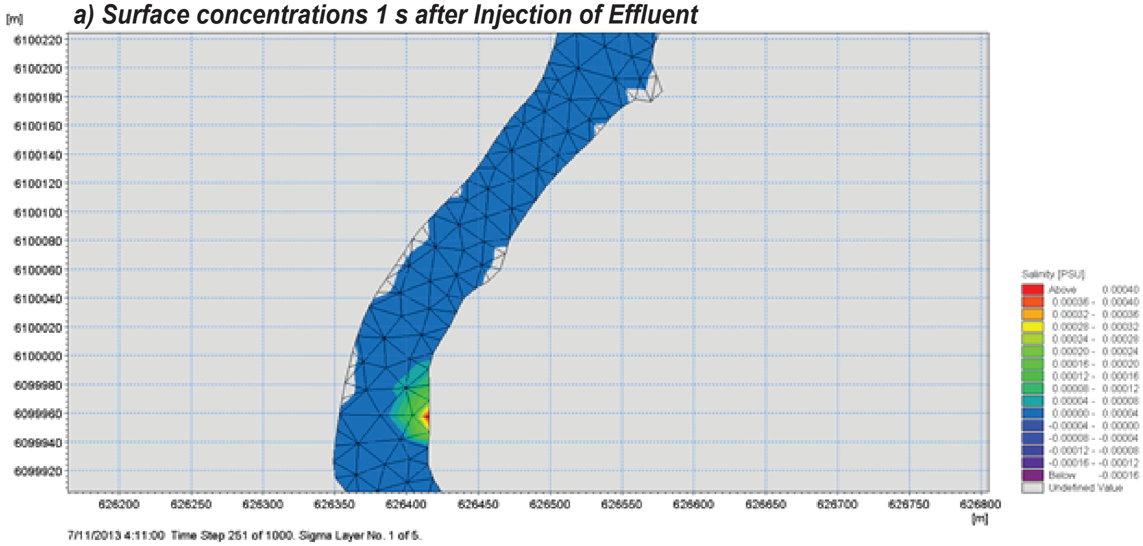
A change in surface water quality parameters was assessed through the consideration of locations where there was the potential for interactions between a VC (e.g., sediment quality, aquatic resources, fish, wetlands, wildlife, and human health) and Project-related water. These locations included the Construction ponds at the Decline Site and the Shaft Site, the Operations pond at the CPP, and the receiving environment in M20, M19A, and M19 creeks and the Murray River in all Project phases.

Project-related effects associated with the ponds are restricted to potential effects to wildlife. The water quality of the ponds is presented in Section 8.8.1.2 and Appendix 8-E; however, the potential effect to wildlife due to pond water quality is assessed in Chapter 13.

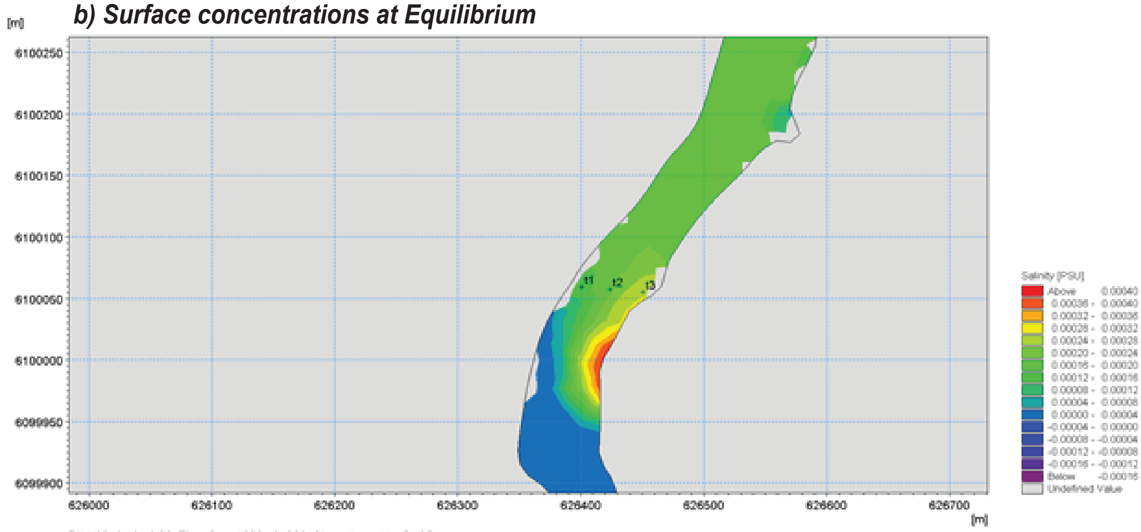
Key changes in surface water quality were identified through the calculation of hazard quotients (HQs) for modelled water quality parameters. In environmental effects assessments, the calculation of HQs can be a useful screening tool for determining the potential for a chemical to cause toxicity in receptors, such as aquatic resources (primary producers, secondary producers, and sediment quality), fish, wildlife species, or human health (US EPA 1998). HQs are most often calculated as a ratio of the concentration of a chemical (either a measured or predicted concentration) compared to the relevant guideline value. A HQ greater than 1.0 may indicate a potential for effects in receptors, while a HQ less than 1.0 is considered to not carry additional risk of toxicity to receptors.

Mixing Associated with Effluent Discharge to Murray River at Low Flow Conditions

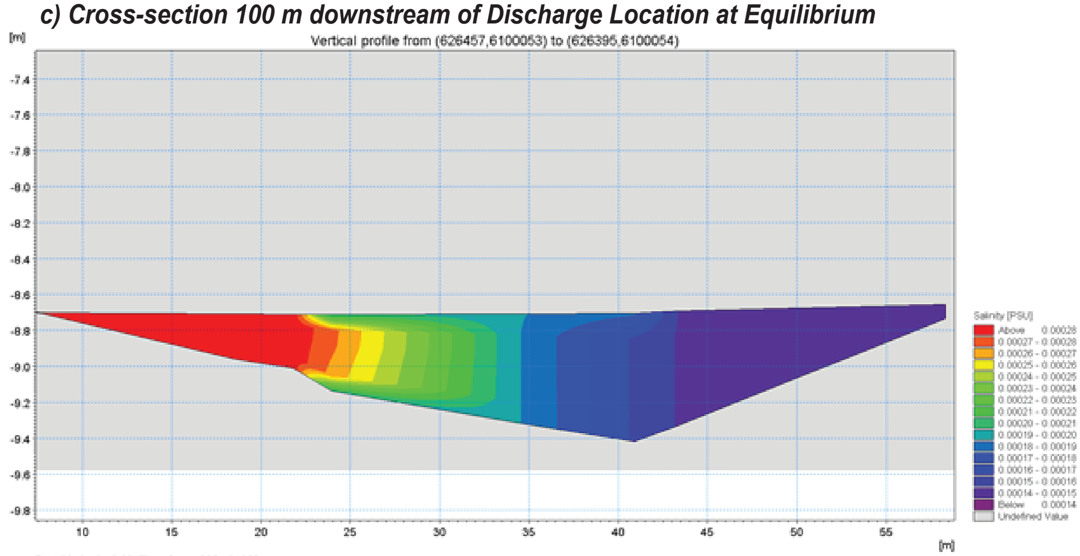
a) Surface concentrations 1 s after Injection of Effluent



b) Surface concentrations at Equilibrium



c) Cross-section 100 m downstream of Discharge Location at Equilibrium



Note: view upstream.

The screening process used for the receiving environment is illustrated in Figure 8.7-6. Monthly water quality predictions for different Project phases were assessed. The screening method considered both maximum and mean predicted values.

The scope of the water quality effects assessment is restricted to parameters with an approved or working BC water quality guideline for the protection of freshwater aquatic life, wildlife, and drinking water.

In the first screening step, HQs were calculated by dividing the predicted monthly mean and maximum concentration of water quality parameters by the appropriate 30-day average or maximum guideline. Water quality parameters with a HQ less than or equal to 1.0 were screened out of the assessment for residual effects, because the guidelines are determined by the BC Ministry of Environment to be protective of the relevant receptors; therefore, there is no potential for adverse effects as a result of a change to water quality. Water quality parameters with a HQ greater than 1.0 relative to the guideline limit were retained for a second screening step. The results of the first screening step for the base case are presented in Appendix 8-G.

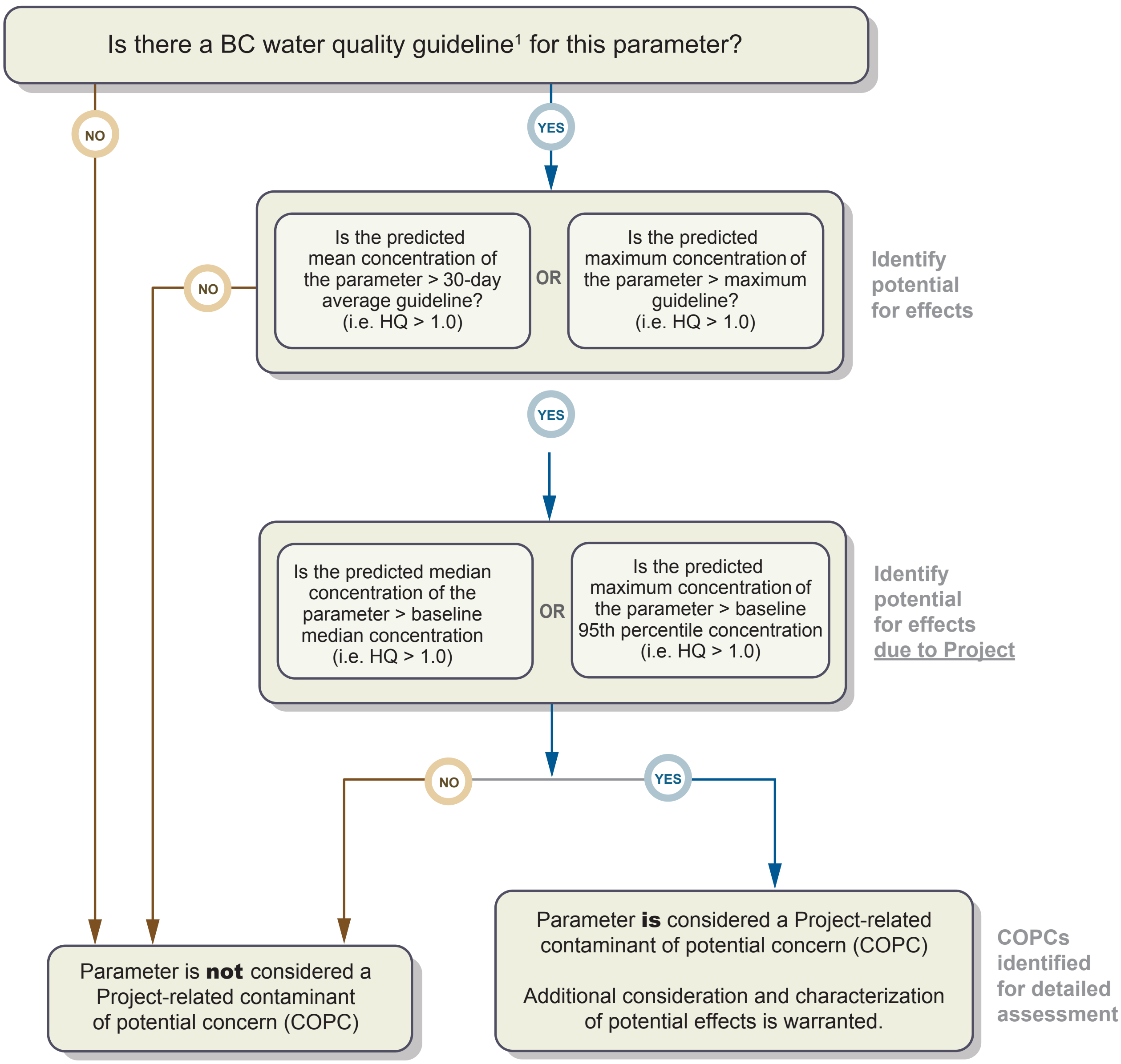
In the second screening step, predicted monthly median and maximum water quality parameters for each Project phase were compared to the monthly median and 95th percentile baseline concentrations (Figure 8.7-6). Predicted median values were compared to baseline median values because baseline median values were used as the model source term for the receiving environment (Appendix 8-E). The comparison of predicted concentrations to baseline concentrations provides a good indicator of the potential for incremental change due to Project-related activities. This step screens out those contaminants where concentrations are at or above guidelines under baseline conditions; naturally occurring guideline exceedances are not a Project-related effect. If the HQ calculated during this screening step was greater than 1.0, the parameter was considered a possible Project-related COPC and retained for further assessment in Section 8.8.1.2. If the final HQ was equal to or less than 1.0, the parameter was not considered a Project-related COPC and was not assessed further.

Pond water quality was only screened against BC water quality guidelines for the protection of wildlife as there is only the potential for interaction between wildlife VCs and pond water quality and there are no relevant baseline data. Identified COPCs for the Decline Site, Shaft Site, and CPP pond are presented in Appendix 8-H. Pond water quality was carried forward to the assessment of effects on wildlife (Chapter 13).

Those water quality parameters determined to be Project-related COPCs for the base case model scenario are carried forward to the effects assessments for the following linked VCs:

- Sediment Quality – Section 8.7.2
- Aquatic Resources – Section 8.7.3
- Fish (multiple VCs) – Section 9.8.3
- Wetlands – Section 12.7.1

Screening Process for Selection of Contaminants of Potential Concern (COPC) for Surface Water Quality Assessment, Murray River Coal Project



Notes: COPC = contaminant of potential concern.
HQ = hazard quotient.
[1] Approved and working BC water quality guidelines.

- Wildlife (multiple VCs) – Section 13.6.3.6
- Human Health (Drinking Water) – Section 18.8.1
- Human Health (Country Foods) – Section 18.8.3

By following the COPC screening procedure as outlined above, the assessment of residual effects on the surface water VC due to a change in water quality incorporates water quality parameters that are predicted to increase in concentration above water quality guidelines and above the range of natural variability. The screening procedure thus focuses the residual effects assessment on those parameters with the potential for a Project-related effect. The significance determination on residual effects considers, but is not limited to, factors, such as the sensitivity of potential receptors in the receiving environment, uncertainty in guideline limits (e.g., due to safety factors or the underlying studies used to derive the guidelines), or other Project-specific information (e.g., uncertainty in the predicted concentrations or other factors that may affect the metal concentration or toxicity).

8.7.2 Key Effects on Sediment Quality

8.7.2.1 Change in Sediment Quality

The potential key effect on sediment quality from these Project activities is a change to sediment chemistry. Sediment chemistry can be an indicator of long-term patterns in water quality because sediment particles adsorb water constituents. Fluxes of these constituents are always moving between the water and sediment depending on the environmental conditions.

Stream sediment chemistry could be altered by Project activities due to changes in water quality. Changes in water quality may occur through site contact water and surface runoff discharged into the receiving environment. Site contact water and surface runoff could potentially have elevated metal concentrations from contact with ML/ARD materials, and could elevate stream metal water levels and in turn, sediment concentrations (see section 8.7.1).

Any COPCs that are selected as a result of the screening procedure described in Section 8.7.1.2 for water quality will also be considered as COPCs that could affect sediment quality.

8.7.3 Key Effects on Aquatic Resources

The key effects identified for surface water (Section 8.7.1) and sediment quality (Section 8.7.2) have the potential to affect aquatic resources. If there is no residual effect on surface water (quantity or quality) or sediment quality, there will be no residual effect on aquatic resources due to changes in surface water or sediment quality. Changes to aquatic resources have the potential to affect other VCs, including fish (Chapter 9) and wildlife (e.g., waterfowl; Chapter 13) that use streams for habitat and food.

8.7.3.1 Change in Surface Water Quantity

Changes to stream discharge from the release of effluent into the receiving environment or water uptake for Project activities have the potential to affect aquatic resources through habitat availability and the re-suspension of sediments. Changes in habitat availability for periphyton and benthic invertebrates could occur due to changes to water velocity, wetted area, and change in sediment quality (discussed in Section 8.7.3.3).

Alteration to stream velocity can increase periphyton scouring, thereby reducing primary production and limiting colonization (Biggs and Close 1989). Increased stream velocity could affect benthic invertebrate community composition based on a taxon's ability to cling to the substrate and may also increase drift (Wood and Armitage 1997).

Stream habitat availability may also be changed through stream discharge by reducing the wetted area of a stream. If streamflows are reduced by Project activities, there may be less area available for periphyton and benthic invertebrate communities to occupy in a stream. Decreased wetted area could also potentially reduce habitat heterogeneity; for example, stream margins may contain slightly different habitats, such as riparian vegetation (e.g., exposed roots and woody debris) or pools which are more suitable for certain taxa.

8.7.3.2 Change in Surface Water Quality

The primary potential effect on aquatic resources due to changes in water quality from Project activities is due to the potential for increased concentrations of COPCs. Effluent discharge to the receiving environment has the potential to increase the concentration of water quality parameters that could cause toxicity (either lethal or sub-lethal effects) to aquatic life. Depending on the parameter, sub-lethal effects may include changes in growth, reproduction, physiology, or behaviour.

At the community level, elevated metal concentrations are generally associated with decreased periphyton biomass and communities that are dominated by fewer taxa (Hill et al. 2000; Niyogi et al. 2002). Benthic invertebrate communities respond similarly to elevated metal levels, and decreased abundance, density and richness have been observed (Poulton et al. 1995; Clements et al. 2000). Elevated concentrations of metals can also have cascading effects for the stream ecosystem, as functions like litter breakdown by benthic invertebrates and microbes may become impaired by elevated metals and metal oxides (Niyogi et al. 2001).

A potential parameter of concern for the Project is selenium because it is commonly associated with coal deposits (Yudovich and Ketris 2006), and has been identified as a concern for other coal projects in northeastern BC. Selenium has the potential to bioaccumulate in food webs, and is taken up by periphyton through direct interaction with the water column. For primary producers, reduced algae cell densities are associated with high selenium levels (Fournier et al. 2010; Morlon et al. 2005).

Selenium uptake at higher trophic levels (i.e., benthic invertebrates) is through the diet (Conley et al. 2009; DeBruyn and Chapman 2007). At the individual level for benthic invertebrates, elevated selenium tissue levels have been shown to reduce adult body mass and fecundity in mayflies (Conley et al. 2009). At the community level, elevated selenium concentrations downstream of coal mines have been associated with reduced Ephemeroptera abundance (Frenette 2008).

Generally though, most (non-fish) aquatic life such as bacteria, periphyton, and benthic invertebrates are more tolerant of selenium exposures and can bioaccumulate it without adverse effects (Janz et al.

2009) although there are a few species that are sensitive to selenium toxicity (DeBruyn and Chapman 2007).

As the base of the aquatic food web, effects to periphyton and benthic invertebrates can have consequences for higher trophic levels (e.g., fish and water fowl), not only in terms of selenium uptake (e.g., bioaccumulation), but in terms of the overall production of the community.

8.7.3.3 Change in Sediment Quality

For aquatic resources the key sediment quality effect from Project activities is changes to sediment chemistry. Sediment quality can be affected by the overlying water quality, and increases in metal concentrations in the water may lead to increased partitioning of those metals into sediments or aquatic biota and potential for adverse effects.

Aquatic organisms living on or within sediment can be adversely affected by poor sediment quality. Sediment quality can influence contaminant transfer through bioaccumulation by periphyton or benthic organisms and can affect upper trophic level structure and function in aquatic ecosystems. Increased concentrations of COPCs in sediment, similar to the potential effects to aquatic resources due to changes in water quality, can lead to altered productivity and community structure of aquatic resources.

8.7.4 Mitigation Measures for Surface Water, Sediment Quality, and Aquatic Resources

The Project has been designed to reduce adverse effects by optimizing alternatives, incorporating specific design changes, following best practices, and enhancing project benefits.

Mitigation by design includes a variety of diversion, collection, and storage/settlement structures to manage water for the Project. The primary goals of water management activities are to divert non-contact water, and to collect and reuse contact water in the Coal Preparation Plant. By reusing contact water in the Coal Preparation Plant, the amount of contact water that is discharged to the environment is minimized.

The CCR piles will be constructed on a geomembrane liner to minimize infiltration of contact water to groundwater. Water that infiltrates the CCR North and South piles, during Operation, will be captured in a seepage collection system. The seepage collection system will drain contact water into a collection sump. Contact water in this sump will be preferentially reclaimed and pumped to the Coal Preparation Plant, and excess water, beyond the Coal Preparation Plant water demand, will be pumped into the CPP pond. After reclamation, surface runoff is rerouted to M19A Creek, and infiltrated water will be recharged to groundwater through exfiltration galleries.

Additional mitigation measures to avoid and minimize adverse effects to surface water, sediment quality, and aquatic resources include implementation of the following environmental management plans:

- Water Management Plan (Section 24.6);
- Metal Leaching and Acid Rock Drainage Management Plan (Section 24.7);

- Selenium Management Plan (Section 24.10);
- Erosion and Sediment Control Plan (Section 24.5);
- Subsidence Management Plan (Section 24.15); and
- Air Quality and Dust Control Plan (Section 24.2).

8.7.4.1 Water Management Plan

The Water Management Plan (Section 24.6) describes a range of mitigation measures to reduce or eliminate the potential effects of the Project on surface water quantity and water quality. A summary of these measures during different phases of the Project are presented here.

A variety of diversion, collection, and storage/settlement structures will be developed to manage water for the Project. The primary goals of water management activities are to divert non-contact water, and to collect and reuse contact water in the Coal Preparation Plant. By reusing contact water in the Coal Preparation Plant, the amount of contact water that is discharged to the environment is minimized. Additionally, surface water diversion decreases the potential for erosion and sediment production by limiting the volume of water that enters a work area.

This Water Management Plan addresses the following targeted goals:

- to protect water-related ecologically sensitive sites and resources, and avoid harmful impacts on fish and wildlife habitat;
- to supply and retain water for mine operations;
- to define water-related environmental control structures; and
- to manage water to ensure that any discharges are in compliance with the applicable water quality levels and guidelines.

Water management and erosion prevention and sediment control measures will be implemented soon after Project approvals and before construction/pre-production mining commences. Perimeter water diversion and sediment collection structures will be established as a first step to work activities. In addition to perimeter diversion ditches, small-scale runoff collection measures may be used locally (e.g., temporary sediment fences around the perimeter of stockpiles).

Erosion prevention and sediment control Best Management Practices (BMPs) will be implemented. These include isolation of work areas from surface waters and proper use of structural practices such as sediment traps, geotextile cloth, sediment fences, gravel berms, and straw bales to mitigate and control erosion and sediment.

Water management and sediment control structures will be regularly inspected and maintained. Maintenance procedures will include prompt attention to potential erosion sites, ditch or culvert failure, ditch or culvert blockage, or outside seepage, because such problems could lead to structure failure and sediment transport. Maintenance will also include routine removal of accumulated sediment from ditches and retention structures. The sediment removed will be used as fill or deposited on stockpiles.

8.7.4.2 Metal Leaching and Acid Rock Drainage Management Plan

The ML/ARD Management Plan is designed to minimize chemical loadings to the receiving environment from:

- waste rock, including material excavated or exposed during construction of shafts, declines, and any surface infrastructure;
- raw and processed coal;
- coarse and fine coal rejects; and
- exposed underground mine faces and workings.

The objective of the ML/ARD Management Plan is to minimize adverse effects on regional surface water quality, groundwater quality, and other linked valued components (VCs) due to drainage from geologic materials produced or exposed during any phase of the proposed Project.

Specific targets related to achieving the objective are to:

- achieve compliance with legislation and BC provincial and federal ML/ARD prediction, prevention, and mitigation policies;
- provide general management recommendations to minimize ML/ARD;
- minimize alienation of land and watercourses; and
- achieve receiving environment objectives.

The quality and quantity of effluent and surface and seepage water quality from the waste rock facility, CCR piles, coal stockpiles and other infrastructure during operations and post-closure will be monitored to verify prediction of the water quality modelling.

8.7.4.3 Selenium Management Plan

The objective of the Selenium Management Plan (SeMP) is to identify, characterize, and address potential environmental risks that Se may pose to the aquatic receiving environment of the Project. The framework of the SeMP is designed to meet best practices for environmental and technical performance objectives for the Project, in addition to ensuring statutory requirements are considered and addressed. The framework of the SeMP is supported by four aspects: prediction, prevention, mitigation, and monitoring, that together form an effective strategy to achieve environmental protection. Potential risks due to Se will be adaptively managed based on the results of the proposed monitoring plan to ensure that risks are mitigated before adverse effects occur in the aquatic receiving environment.

Water quality, sediment quality, and aquatic resources in the receiving environment will be monitored as part of the SeMP.

8.7.4.4 Erosion and Sediment Control Plan

The primary objective of the Erosion and Sediment Control Plan is to ensure that through planning and maintenance, best efforts are used to prevent erosion in the first instance. The secondary objective is to implement appropriate sediment control measures in areas where there remains likelihood for erosion to occur.

The following goals are implicit in achieving these objectives:

- conservation of soil quantity and quality in areas that are subject to erosion (e.g., stockpiles and disturbed areas located on slopes);
- minimizing erosion along access roads and in non-vegetated areas around mine infrastructure;
- stabilizing exposed erodible materials; and
- minimizing sediment delivery into watercourses.

Specific BMPs relating to the mitigation and/or minimizing of effects caused by erosion and sedimentation to the aquatic environment include:

- using water diversion structures to direct dirty water from the work zone to a sediment control area;
- installing silt fencing, geotextile cloth, straw bales, berms, or other sediment control structures;
- conducting instream work from the point farthest away from the construction access point and working backward;
- allowing constructed ponds to settle before connecting to the stream;
- storing soil, substrate, removed vegetation, and building materials in stable areas away from the channel;
- ensuring that all rock materials used in the stream are inert (non-acid generating);
- ensuring constructed banks are graded at a stable slope;
- stabilizing excavated materials and areas denuded of vegetation using temporary erosion control blankets, biodegradable mats, planted vegetation, or other erosion control techniques;
- environmental monitoring;
- repairing areas that are potential sediment sources;
- using dust suppression on roads; and
- adhering to appropriate construction operating windows for instream work.

8.7.4.5 Subsidence Management Plan

The Subsidence Management Plan identifies the mitigation measures and monitoring for subsidence in M20 Creek.

If reduced flows in M20 Creek (due to subsidence processes) are evident during any stage of the monitoring program, appropriate mitigation measures will be implemented. These measures may include assessment of effects on fish habitat and implementation of an offsetting plan as required.

8.7.4.6 Air Quality and Dust Control Plan

Mitigation measures to reduce fugitive dust will be implemented. Fugitive dust suppression measures include wetting work areas, roads, and storage piles, installing covers on equipment and loads carried by vehicles, installing windbreaks or fences, and using dust hoods and shields.

8.7.4.7 Summary of Potential for Residual Effects on Surface Water, Sediment Quality, and Aquatic Resources

The following key effects are considered fully mitigated with the implementation of the mitigation measures above; therefore no residual effects are predicted and these effects are not further considered:

- change to sediment quality;
- effects to aquatic resources due to change in sediment quality; and
- habitat loss (aquatic resources).

The following key effects are considered partially mitigated with the implementation of the mitigation measures above; therefore, residual effects are assessed in Section 8.8:

- change to surface water quantity;
- change to surface water quality; and
- effects to aquatic resources due to changes in surface water quantity and surface water quality.

8.8 RESIDUAL EFFECTS ON SURFACE WATER AND AQUATIC RESOURCES

8.8.1 Residual Effects on Surface Water

8.8.1.1 Change in Surface Water Quantity

The key changes to surface water quantity that are predicted to remain after the implementation of mitigation measures are summarized in Table 8.8-1. The WBM simulation results (Appendix 8-E) were used to estimate the effects of the Project on mean annual and monthly flows (Figures 8.8-1 to 8.8-3; Table 8.8-1). The effects on mean annual flows during each phase of the Project under the base case scenario (i.e., average annual precipitation and the moderate groundwater inflows into the mine) are:

- Construction: the mean annual flows are decreased by 5% in M19A Creek, and by less than 1% in all other streams. Mean annual flows in M17B Creek are not affected by the Project during Construction;
- Operation: the mean annual flows are decreased by 10% in M19A Creek, and by 1% in M19 Creek. Changes in mean annual flows are negligible (less than 1%) for M20 Creek and Murray River. No change in the mean annual flows are presented for M17B Creek because the flow change is less than a threshold that was deemed reliable to estimate flows at this stream (i.e., 0.0005 m^3/s);
- Decommissioning and Reclamation: the mean annual flows are increased by 4% in M19A Creek. Expected changes in mean annual flows are negligible for all other streams; and
- Post-closure: the mean annual flows are increased by 4% in M19A Creek. Expected changes in mean annual flows are negligible for all other streams.

The effects on monthly flows during each phase of the Project under the base case scenario (i.e., average annual precipitation and moderate groundwater inflows into the mine) are:

- Construction: monthly flows are decreased in M19A Creek (5%) and M20 Creek (4%). Monthly flows in M17B Creek are not affected by the Project during Construction. Changes in monthly flows are negligible for M19 Creek (less than 1%) and Murray River (less than 0.1%);
- Operation: monthly flows are decreased in M17B Creek (6%), M19A Creek (10%), M19 Creek (1%), and M20 Creek (9%). Changes in Murray River monthly flows are negligible (0.2%);
- Decommissioning and Reclamation: monthly flows are decreased in M17B Creek (11%), increased in M19A Creek (4%), and M20 Creek (9%). Changes in M19 Creek, M20 Creek, and Murray River monthly flows are negligible (0.5% for M19 Creek and less than 0.1% for Murray River); and
- Post-closure: monthly flows are decreased in M17B Creek (11%) and M20 Creek (9%), and increased in M19A Creek (4%). Changes in M19 Creek and Murray River monthly flows are negligible (0.5% for M19 Creek and less than 0.1% for Murray River).

As previously mentioned (Section 8.7.1.1), potential changes in peak flows were used as a proxy for potential changes in stream morphology. The magnitude and timing of peak flows within a watershed are a function of three parameters:

- the magnitude and timing of storms, as well as snowmelt, events;
- the catchment area of the watershed; and
- the runoff coefficient within the watershed.

Among these parameters, the catchment area (Figure 8.8-4 and Table 8.8-2) and runoff coefficient of the watersheds within the Project area will be changed due to the Project infrastructure. The runoff coefficient within the disturbed area of the Project will change (generally increased) due to surface disturbance activities. In addition, contact water from such disturbed areas is planned to be collected in sumps.

Table 8.8-1. Simulated Average Monthly and Annual Streamflows within the Project Area during Different Phases of the Project under the Base Case Scenario (Average Annual Precipitation and Moderate Groundwater Inflows into the Mine)

			January			February			March			April			May		
Assessment Point	ID	Project Phase	Flow (m³/s)	Change from Baseline (m³/s)	Change from Baseline (% of Baseline Flow)	Flow (m³/s)	Change from Baseline (m³/s)	Change from Baseline (% of Baseline Flow)	Flow (m³/s)	Change from Baseline (m³/s)	Change from Baseline (% of Baseline Flow)	Flow (m³/s)	Change from Baseline (m³/s)	Change from Baseline (% of Baseline Flow)	Flow (m³/s)	Change from Baseline (m³/s)	Change from Baseline (% of Baseline Flow)
M19A Creek above confluence with M19 Creek	M19A	Baseline	0.001	n/a	n/a	0.001	n/a	n/a	0.001	n/a	n/a	0.042	n/a	n/a	0.271	n/a	n/a
		Bulk Sample	0.001	0**	n/a**	0.001	0**	n/a**	0.001	0**	n/a**	0.041	0**	n/a**	0.268	-0.003	-1.1%
		Construction	0*	n/a*	n/a**	0*	n/a*	n/a**	0.001	0**	n/a**	0.040	-0.002	-5.1%	0.257	-0.014	-5.1%
		Operation	0*	n/a*	n/a**	0*	n/a*	n/a**	0.001	0**	n/a**	0.038	-0.004	-9.9%	0.244	-0.027	-10.0%
		Decomissioning & Reclamation	0.001	0**	n/a**	0.001	0**	n/a**	0.001	0**	n/a**	0.043	0.002	4.2%	0.282	0.011	4.2%
		Post Closure	0.001	0**	n/a**	0.001	0**	n/a**	0.001	0**	n/a**	0.043	0.002	4.2%	0.282	0.011	4.2%
M19 Creek at the mouth	M19	Baseline	0.004	n/a	n/a	0.004	n/a	n/a	0.005	n/a	n/a	0.362	n/a	n/a	2.347	n/a	n/a
		Bulk Sample	0.004	0**	n/a**	0.004	0**	n/a**	0.005	0**	n/a**	0.361	0**	n/a**	2.344	-0.003	-0.1%
		Construction	0.004	0**	n/a**	0.004	0**	n/a**	0.005	0**	n/a**	0.360	-0.002	-0.6%	2.333	-0.014	-0.6%
		Operation	0.004	0**	n/a**	0.004	0**	n/a**	0.005	0**	n/a**	0.358	-0.004	-1.1%	2.320	-0.027	-1.1%
		Decomissioning & Reclamation	0.004	0**	n/a**	0.004	0**	n/a**	0.005	0**	n/a**	0.364	0.002	0.5%	2.358	0.011	0.5%
		Post Closure	0.004	0**	n/a**	0.004	0**	n/a**	0.005	0**	n/a**	0.364	0.002	0.5%	2.358	0.011	0.5%
M17B Creek at the mouth	M17B	Baseline	0*	n/a	n/a	0*	n/a	n/a	0*	n/a	n/a	0.005	n/a	n/a	0.021	n/a	n/a
		Bulk Sample	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.005	0**	n/a**	0.021	0**	n/a**
		Construction	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.005	0**	n/a**	0.021	0**	n/a**
		Operation	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.005	0**	n/a**	0.020	-0.001	-5.6%
		Decomissioning & Reclamation	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.005	-0.001	-11.3%	0.019	-0.002	-11.3%
		Post Closure	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.005	-0.001	-11.3%	0.019	-0.002	-11.3%
M20 Creek at the mouth	M20	Baseline	0.050	n/a	n/a	0.050	n/a	n/a	0.051	n/a	n/a	0.194	n/a	n/a	2.641	n/a	n/a
		Bulk Sample	0.049	0**	n/a**	0.049	0**	n/a**	0.051	0**	n/a**	0.193	0**	n/a**	2.643	0.002	0.1%
		Construction	0.048	-0.002	-3.4%	0.048	-0.002	-3.5%	0.050	-0.002	-3.4%	0.192	-0.002	-0.9%	2.644	0.004	0.1%
		Operation	0.045	-0.005	-9.2%	0.045	-0.005	-9.2%	0.047	-0.005	-9.0%	0.189	-0.005	-2.4%	2.641	0.001	0.0%
		Decomissioning & Reclamation	0.045	-0.005	-9.2%	0.045	-0.005	-9.2%	0.047	-0.005	-9.0%	0.189	-0.005	-2.4%	2.641	0.001	0.0%
		Post Closure	0.045	-0.005	-9.2%	0.045	-0.005	-9.2%	0.047	-0.005	-9.0%	0.189	-0.005	-2.4%	2.641	0.001	0.0%
Murray River Downstream of confluence with M19 Creek	MR	Baseline	8.78	n/a	n/a	6.82	n/a	n/a	7.69	n/a	n/a	26.57	n/a	n/a	211.52	n/a	n/a
		Bulk Sample	8.78	0**	n/a**	6.82	0**	n/a**	7.69	0**	n/a**	26.57	0**	n/a**	211.52	0**	n/a**
		Construction	8.78	0**	n/a**	6.81	0**	n/a**	7.69	0**	n/a**	26.56	0**	n/a**	211.53	0**	n/a**
		Operation	8.76	-0.01	-0.2%	6.80	-0.01	-0.2%	7.68	-0.01	-0.2%	26.55	-0.01	-0.1%	211.52	0**	n/a**
		Decomissioning & Reclamation	8.78	0**	n/a**	6.82	0**	n/a**	7.69	0**	n/a**	26.57	0**	n/a**	211.54	0.01	0.0%
		Post Closure	8.78	0**	n/a**	6.82	0**	n/a**	7.69	0**	n/a**	26.57	0**	n/a**	211.54	0.02	0.0%

(continued)

Table 8.8-1. Simulated Average Monthly and Annual Streamflows within the Project Area during Different Phases of the Project under the Base Case Scenario (Average Annual Precipitation and Moderate Groundwater Inflows into the Mine) (continued)

Assessment Point	ID	Project Phase	June Flow (m^3/s)	June Change from Baseline (m^3/s)	June Change from Baseline (% of Baseline Flow)	July Flow (m^3/s)	July Change from Baseline (m^3/s)	July Change from Baseline (% of Baseline Flow)	August Flow (m^3/s)	August Change from Baseline (m^3/s)	August Change from Baseline (% of Baseline Flow)	September Flow (m^3/s)	September Change from Baseline (m^3/s)	September Change from Baseline (% of Baseline Flow)	October Flow (m^3/s)	October Change from Baseline (m^3/s)	October Change from Baseline (% of Baseline Flow)
M19A Creek above confluence with M19 Creek	M19A	Baseline	0.124	n/a	n/a	0.028	n/a	n/a	0.020	n/a	n/a	0.001	n/a	n/a	0.004	n/a	n/a
		Bulk Sample	0.123	-0.001	-1.1%	0.028	0**	n/a**	0.020	0**	n/a**	0.001	0**	n/a**	0.004	0**	n/a**
		Construction	0.118	-0.007	-5.2%	0.027	-0.002	-5.3%	0.019	-0.001	-5.4%	0.001	0**	n/a**	0.004	0**	n/a**
		Operation	0.112	-0.012	-10.0%	0.026	-0.003	-10.0%	0.018	-0.002	-10.0%	0.001	0**	n/a**	0.003	0**	n/a**
		Decomissioning & Reclamation	0.130	0.005	4.2%	0.030	0.001	4.2%	0.021	0.001	4.2%	0.001	0**	n/a**	0.004	0**	n/a**
		Post Closure	0.130	0.005	4.2%	0.030	0.001	4.2%	0.021	0.001	4.2%	0.001	0**	n/a**	0.004	0**	n/a**
M19 Creek at the mouth	M19	Baseline	1.079	n/a	n/a	0.246	n/a	n/a	0.172	n/a	n/a	0.010	n/a	n/a	0.034	n/a	n/a
		Bulk Sample	1.077	-0.001	-0.1%	0.246	0**	n/a**	0.172	0**	n/a**	0.010	0**	n/a**	0.034	0**	n/a**
		Construction	1.072	-0.006	-0.6%	0.244	-0.002	-0.6%	0.171	-0.001	-0.6%	0.010	0**	n/a**	0.033	0**	n/a**
		Operation	1.066	-0.012	-1.1%	0.243	-0.003	-1.1%	0.170	-0.002	-1.2%	0.010	0**	n/a**	0.033	0**	n/a**
		Decomissioning & Reclamation	1.084	0.005	0.5%	0.247	0.001	0.5%	0.173	0.001	0.5%	0.010	0**	n/a**	0.034	0**	n/a**
		Post Closure	1.084	0.005	0.5%	0.247	0.001	0.5%	0.173	0.001	0.5%	0.010	0**	n/a**	0.034	0**	n/a**
M17B Creek at the mouth	M17B	Baseline	0.012	n/a	n/a	0.002	n/a	n/a	0.001	n/a	n/a	0*	n/a	n/a	0.001	n/a	n/a
		Bulk Sample	0.012	0**	n/a**	0.002	0**	n/a**	0.001	0**	n/a**	0*	n/a*	n/a*	0.001	0**	n/a**
		Construction	0.012	0**	n/a**	0.002	0**	n/a**	0.001	0**	n/a**	0*	n/a*	n/a*	0.001	0**	n/a**
		Operation	0.012	-0.001	-5.6%	0.002	0**	n/a**	0.001	0**	n/a**	0*	n/a*	n/a*	0.001	0**	n/a**
		Decomissioning & Reclamation	0.011	-0.001	-11.3%	0.002	0**	n/a**	0.001	0**	n/a**	0*	n/a*	n/a*	0.001	0**	n/a**
		Post Closure	0.011	-0.001	-11.3%	0.002	0**	n/a**	0.001	0**	n/a**	0*	n/a*	n/a*	0.001	0**	n/a**
M20 Creek at the mouth	M20	Baseline	1.467	n/a	n/a	0.394	n/a	n/a	0.533	n/a	n/a	0.077	n/a	n/a	0.118	n/a	n/a
		Bulk Sample	1.466	-0.001	0.0%	0.393	-0.001	-0.1%	0.532	-0.001	-0.1%	0.076	-0.001	-0.8%	0.117	-0.001	-0.5%
		Construction	1.465	-0.002	-0.1%	0.392	-0.002	-0.5%	0.531	-0.002	-0.4%	0.075	-0.002	-2.6%	0.116	-0.002	-1.7%
		Operation	1.462	-0.005	-0.3%	0.389	-0.005	-1.2%	0.528	-0.005	-0.9%	0.072	-0.005	-6.1%	0.113	-0.005	-4.0%
		Decomissioning & Reclamation	1.462	-0.005	-0.3%	0.389	-0.005	-1.2%	0.528	-0.005	-0.9%	0.072	-0.005	-6.1%	0.113	-0.005	-4.0%
		Post Closure	1.462	-0.005	-0.3%	0.389	-0.005	-1.2%	0.528	-0.005	-0.9%	0.072	-0.005	-6.1%	0.113	-0.005	-4.0%
Murray River Downstream of confluence with M19 Creek	MR	Baseline	208.94	n/a	n/a	71.85	n/a	n/a	45.15	n/a	n/a	24.73	n/a	n/a	38.62	n/a	n/a
		Bulk Sample	208.94	0**	n/a**	71.85	0**	n/a**	45.15	0**	n/a**	24.73	0**	n/a**	38.62	0**	n/a**
		Construction	208.94	0**	n/a**	71.84	0**	n/a**	45.15	0**	n/a**	24.72	0**	n/a**	38.61	0**	n/a**
		Operation	208.93	-0.01	0.0%	71.83	-0.014	0.0%	45.14	-0.014	0.0%	24.71	-0.014	-0.1%	38.60	-0.014	0.0%
		Decomissioning & Reclamation	208.95	0**	n/a**	71.85	0**	n/a**	45.15	0**	n/a**	24.73	0**	n/a**	38.62	0**	n/a**
		Post Closure	208.95	0**	n/a**	71.85	0**	n/a**	45.15	0**	n/a**	24.73	0**	n/a**	38.62	0**	n/a**

(continued)

Table 8.8-1. Simulated Average Monthly and Annual Streamflows within the Project Area during Different Phases of the Project under the Base Case Scenario (Average Annual Precipitation and Moderate Groundwater Inflows into the Mine) (completed)

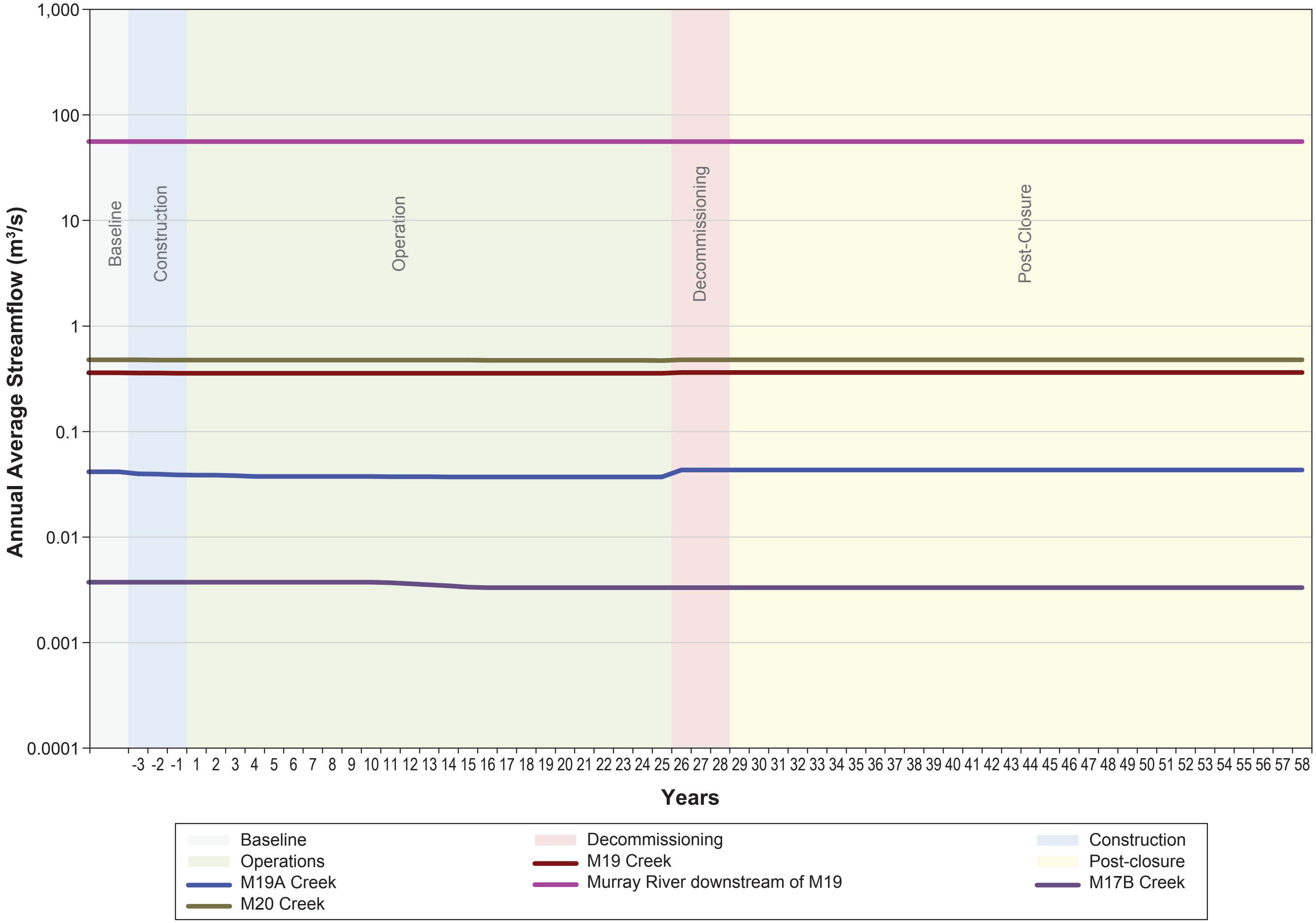
			November			December			Annual		
Assessment Point	ID	Project Phase	Flow (m³/s)	Change from Baseline (m³/s)	Change from Baseline (% of Baseline Flow)	Flow (m³/s)	Change from Baseline (m³/s)	Change from Baseline (% of Baseline Flow)	Flow (m³/s)	Change from Baseline (m³/s)	Change from Baseline (% of Baseline Flow)
M19A Creek above confluence with M19 Creek	M19A	Baseline	0.002	n/a	n/a	0.001	n/a	n/a	0.042	n/a	n/a
		Bulk Sample	0.002	0**	n/a**	0.001	0**	n/a**	0.041	0**	n/a**
		Construction	0.002	0**	n/a**	0.001	0**	n/a**	0.039	-0.002	-5.2%
		Operation	0.002	0**	n/a**	0.001	0**	n/a**	0.037	-0.004	-10.0%
		Decomissioning & Reclamation	0.002	0**	n/a**	0.001	0**	n/a**	0.043	0.002	4.2%
		Post Closure	0.002	0**	n/a**	0.001	0**	n/a**	0.043	0.002	4.2%
M19 Creek at the mouth	M19	Baseline	0.016	n/a	n/a	0.007	n/a	n/a	0.360	n/a	n/a
		Bulk Sample	0.016	0**	n/a**	0.007	0**	n/a**	0.359	0**	n/a**
		Construction	0.015	0**	n/a**	0.007	0**	n/a**	0.358	-0.002	-0.6%
		Operation	0.015	0**	n/a**	0.007	0**	n/a**	0.356	-0.004	-1.1%
		Decomissioning & Reclamation	0.016	0**	n/a**	0.007	0**	n/a**	0.362	0.002	0.5%
		Post Closure	0.016	0**	n/a**	0.007	0**	n/a**	0.362	0.002	0.5%
M17B Creek at the mouth	M17B	Baseline	0.001	n/a	n/a	0*	n/a	n/a	0.004	n/a	n/a
		Bulk Sample	0.001	0**	n/a**	0*	n/a*	n/a*	0.004	0**	n/a**
		Construction	0.001	0**	n/a**	0*	n/a*	n/a*	0.004	0**	n/a**
		Operation	0.001	0**	n/a**	0*	n/a*	n/a*	0.004	0**	n/a**
		Decomissioning & Reclamation	0.001	0**	n/a**	0*	n/a*	n/a*	0.003	0**	n/a**
		Post Closure	0.001	0**	n/a**	0*	n/a*	n/a*	0.003	0**	n/a**
M20 Creek at the mouth	M20	Baseline	0.064	n/a	n/a	0.054	n/a	n/a	0.478	n/a	n/a
		Bulk Sample	0.064	-0.001	-1.1%	0.053	-0.001	-1.3%	0.478	0**	n/a**
		Construction	0.062	-0.002	-3.2%	0.052	-0.002	-3.9%	0.477	-0.001	-0.3%
		Operation	0.060	-0.005	-7.4%	0.049	-0.005	-8.8%	0.474	-0.004	-0.9%
		Decomissioning & Reclamation	0.060	-0.005	-7.4%	0.049	-0.005	-8.8%	0.474	-0.004	-0.9%
		Post Closure	0.060	-0.005	-7.4%	0.049	-0.005	-8.8%	0.474	-0.004	-0.9%
Murray River Downstream of confluence with M19 Creek	MR	Baseline	10.72	n/a	n/a	7.18	n/a	n/a	55.98	n/a	n/a
		Bulk Sample	10.72	0**	n/a**	7.18	0**	n/a**	55.98	0**	n/a**
		Construction	10.71	0**	n/a**	7.17	0**	n/a**	55.98	-0.002	0.0%
		Operation	10.70	-0.014	-0.1%	7.16	-0.013	-0.2%	55.97	-0.013	0.0%
		Decomissioning & Reclamation	10.72	0**	n/a**	7.18	0**	n/a**	55.99	0.002	0.0%
		Post Closure	10.72	0**	n/a**	7.18	0**	n/a**	55.99	0.002	0.0%

** Flows are less than 0.0005 m³/s (less than 0.005 for Murray River)*

*** Flow changes are less than 0.0005 m³/s (less than 0.005 for Murray River)*

Figure 8.8-1

Annual Average Streamflows within the Project Area during Different Phases of the Project under the Base Case Scenario (Average Annual Precipitation and Moderate Groundwater Inflows into the Mine)



Effects of these two processes on the magnitude and timing of the peak flows is expected to have two antagonistic effects. That is, the first process is expected to increase the magnitude of peak flows and decrease the lag time of peak flows, and the second process would decrease the magnitude and increase the lag time. Further, the catchment areas of the M19A Creek and M17B Creek watersheds are expected to change by up to 11% (Table 8.8-2). These changes will be much less in the M19 Creek (1%), M20 Creek (0.0%), and Murray River (0.1%) watersheds (Figure 8.8-4 and Table 8.8-2). Thus, the effects of the Project on peak flows are not expected to be more than the effects on monthly flows, as described above. Therefore, changes in channel morphology and sediment transport are expected to be negligible.

Table 8.8-2. Maximum Change in Sub-catchment Areas during Life of the Project

Watershed	Baseline Catchment Area (km²)	Maximum Catchment Area		Maximum Catchment Area	
		Area (km²)	Change from Baseline (% of Baseline Area)	Area (km²)	Change from Baseline (% of Baseline Area)
M19A Creek	6.9	7.2	4.2%	6.2	-10.7%
M19 Creek	59.7	60.0	0.5%	59.0	-1.2%
M17B Creek	0.6	0.6	0.0%	0.6	-11.3%
M20 Creek	43.0	43.0	0.0%	43.0	0.0%
Murray River*	2359.6	2360.1	0.0%	2358.1	-0.1%

** downstream of confluence with M19 Creek*

Based on the observation of monthly flows at baseline conditions, as well as the predicted monthly flows, February flows represent the lowest monthly flows annually. Further, significant intra-month variations were not expected, nor were observed, in the baseline flows during February (Appendix 8-A). Therefore, the February monthly flows were used as an estimate for low flows during different phases of the Project in this assessment. The WBM simulation results were used to estimate the effects of the Project on low flows (Appendix 8-E). The effects on low flows during each phase of the Project under the base case scenario (i.e., average annual precipitation and the moderate groundwater inflows into the mine) are summarized in Table 8.8-3. These effects include:

- Construction: annual low flows are decreased in M20 Creek (4%). No change in the annual low flow is presented for other streams because either the baseline flows or the flow changes are less than a threshold that was deemed reliable to estimate flows at these streams (i.e., 0.005 m^3/s for Murray River and 0.0005 m^3/s for other streams);
- Operation: annual low flows are decreased in M20 Creek (9%). Changes in annual low flows are negligible for Murray River (0.2%). No change in the annual low flow is presented for other streams because either the baseline flows or the flow changes are less than a threshold that was deemed reliable to estimate flows at these streams (i.e., 0.0005 m^3/s);
- Decommissioning and Reclamation: annual low flows are decreased in M20 Creek (9%). No change in the annual low flow is presented for any other stream because either the baseline flows or the flow changes are less than a threshold that was deemed reliable to estimate flows at these streams (i.e., 0.005 m^3/s for Murray River and 0.0005 m^3/s for other streams); and

Figure 8.8-2

Streamflow Hydrographs during Different Phases of the Project under the Base Case Scenario (Average Annual Precipitation and Moderate Groundwater Inflows into the Mine)

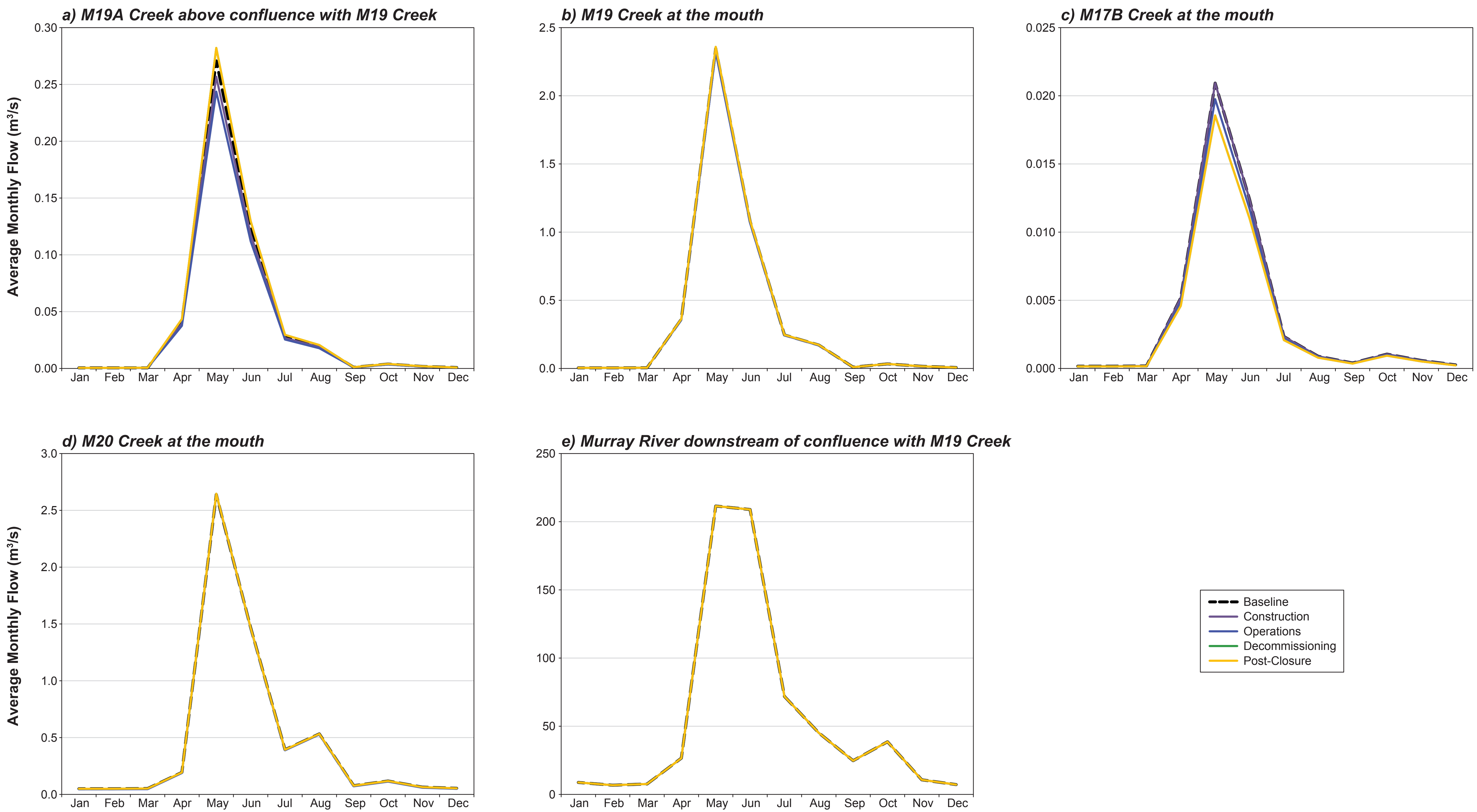


Figure 8.8-3

Simulated Time-series for Discharges and Withdrawals during Different Phases of the Project under the Base Case Scenario

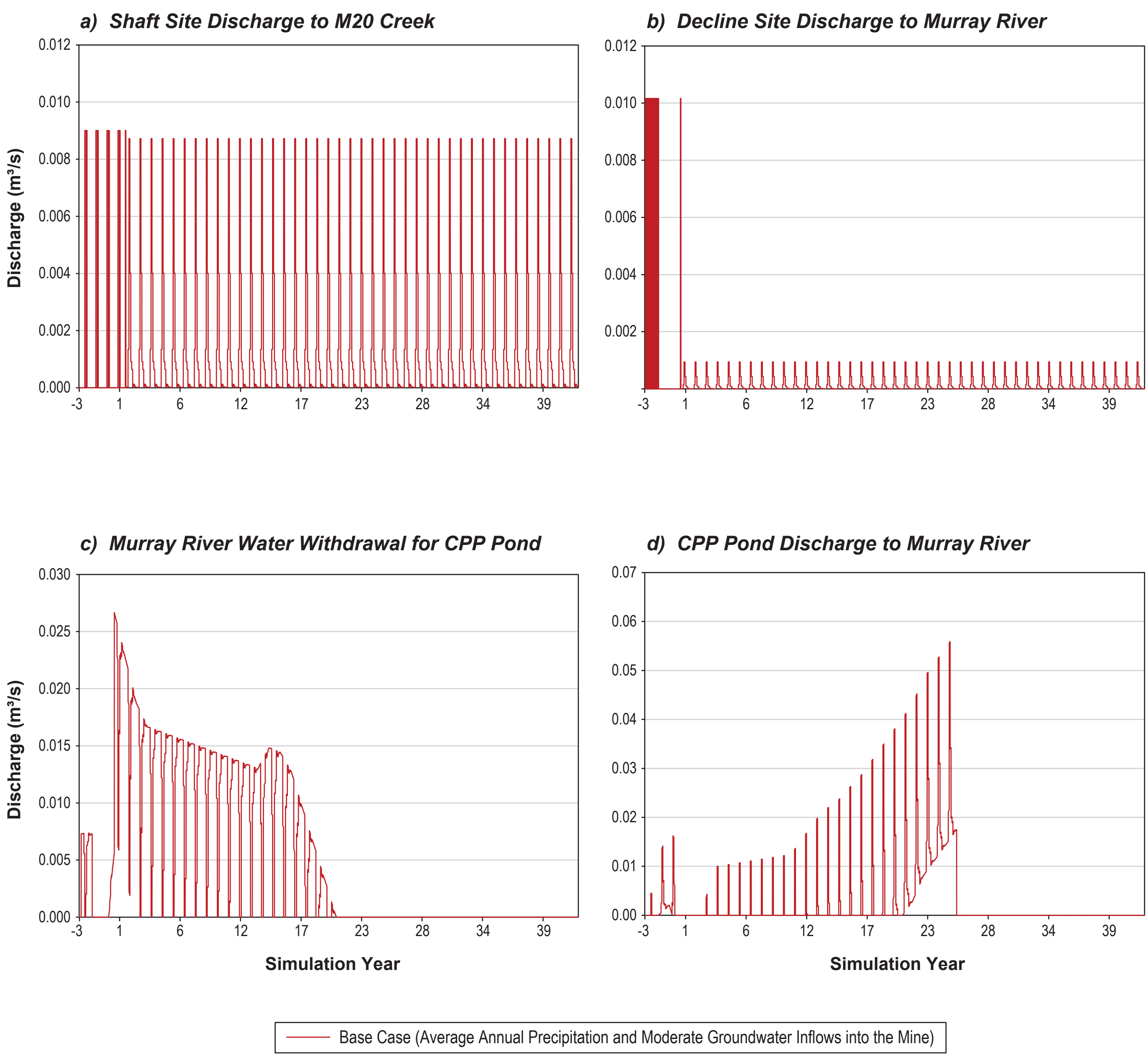


Figure 8.8-4

Sub-catchment Areas during Different Phases of the Project

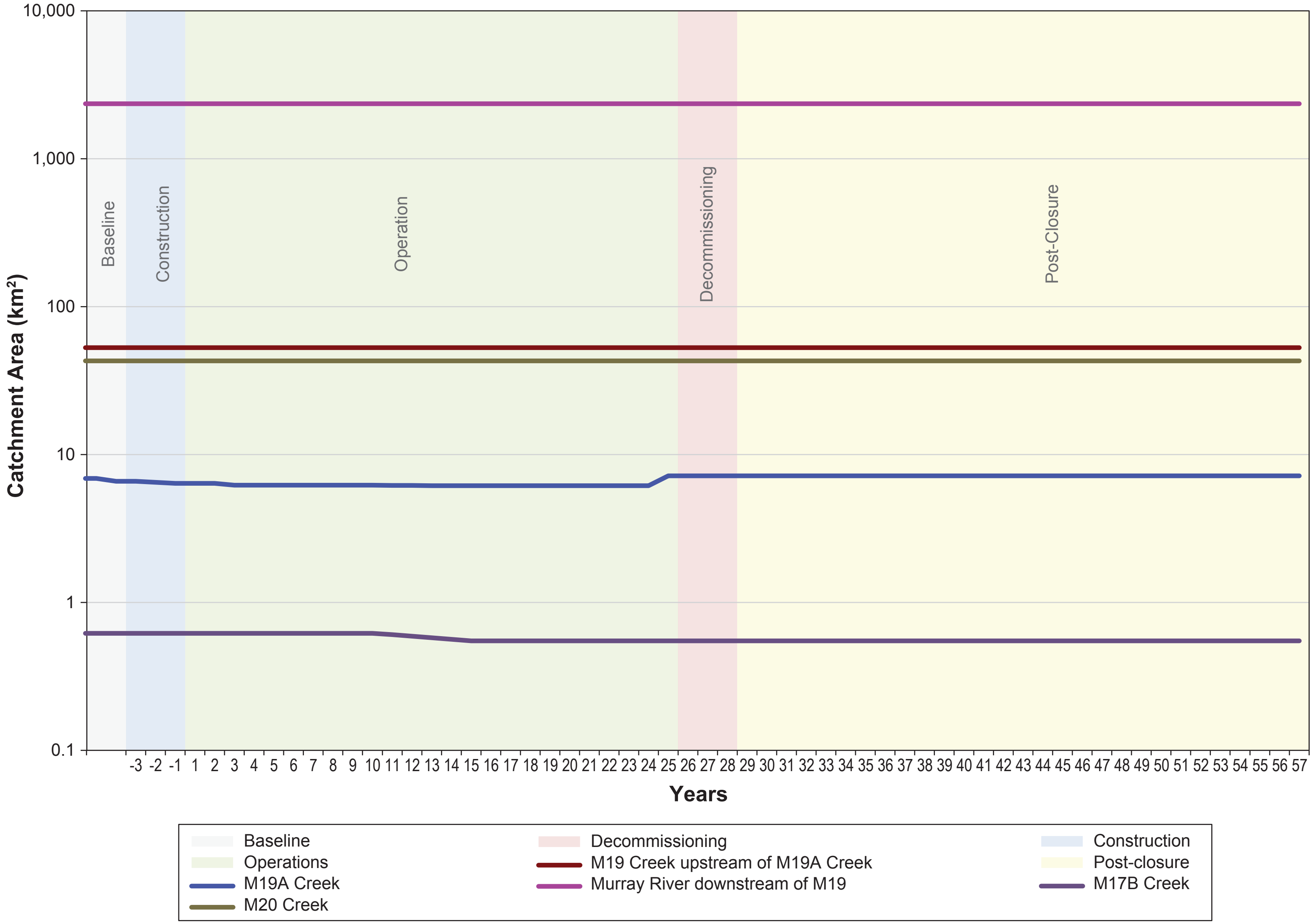


Table 8.8-3. Simulated Average Annual Low Flows within the Project Area during Different Phases of the Project under the Base Case Scenario (Average Annual Precipitation and Moderate Groundwater Inflows into the Underground Mine)

			Construction			Operation			Decommissioning and Reclamation			Post-closure		
Assessment Point	ID	Baseline Flow (m^3/s)	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)
M19A Creek above confluence with M19 Creek	M19A	0.001	0*	n/a*	n/a**	0*	n/a*	n/a**	0.001	0**	n/a**	0.001	0**	n/a**
M19 Creek at the mouth	M19	0.004	0.004	0**	n/a**	0.004	0**	n/a**	0.004	0**	n/a**	0.004	0**	n/a**
M17B Creek at the mouth	M17B	0*	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*
M20 Creek at the mouth	M20	0.050	0.048	-0.002	-3.5%	0.045	-0.005	-9.2%	0.045	-0.005	-9.2%	0.045	-0.005	-9.2%
Murray River Downstream of confluence with M19 Creek	MR	6.82	6.81	0**	n/a**	6.80	-0.01	-0.2%	6.82	0**	n/a**	6.82	0**	n/a**

** Flows are less than 0.0005 m^3/s (less than 0.005 m^3/s for Murray River)*

*** Flow changes are less than 0.0005 m^3/s (less than 0.005 m^3/s for Murray River)*

- Post-closure: annual low flows are decreased in M20 Creek (9%). No change in the annual low flow is presented for any other stream because either the baseline flows or the flow changes are less than a threshold that was deemed reliable to estimate flows at these streams (i.e., 0.005 m^3/s for Murray River and 0.0005 m^3/s for other streams).

Effects of the project on streamflows (i.e., the percentage of annual flow change) are greatest on M20 Creek due to flow reductions as a result of dewatering the underground mine (Appendix 7-B).

Effects of the project on streamflows at most streams are consistent among all sensitivity scenario cases (Tables 8.8-4 to 8.8-8 and Figures 8.8-5 to 8.8-10). The only exception is the streamflow at M20 Creek (Table 8.8-7) where flow reductions under sensitivity scenarios # 6 and 7 are greater than those of other scenarios.

These results indicate that streamflow effects assessment results for all streams (except M20 Creek) would not be influenced by altering the precipitation and groundwater inflow assumptions that were made for the base case scenario.

Differences between the sensitivity analysis results for the M20 Creek streamflows are most pronounced during the low flow months of the year (Table 8.8-7). Annual low flows are decreased by up to 31% in Scenario #6, and up to 53% in Scenario #7. Under the base case scenario conditions, annual low flows in M20 Creek are decreased by 9%.

Anticipated climate change in the Project area is detailed in Chapter 23, Effects of the Environment on the Project. This section summarizes the expected climate change projections pertinent to surface water hydrology.

To evaluate climate change impacts on streamflow, hydrologic modelling results were obtained for the Murray River (Section 23.3.2.3). Modelling results with different greenhouse gas scenarios indicate that the annual runoff in the Murray River watershed, currently 764 mm, is expected to increase to 1100 - 1250 mm by the end of the century (Section 23.3.2.3). This is equivalent of up to 64% increase in annual runoff. Modelling results (Section 23.3.2.3) predicted little change in the magnitude of peak annual flow throughout the century, and anticipated an increase in annual low flow beginning around 2075.

Sensitivity analysis scenarios conducted for this effects assessment, consider wet years with 180% more runoff than that of an average year. That is, sensitivity scenarios # 3, 4, and 5, consider wet years with annual runoff values that are significantly greater than climate change predictions. Therefore, climate change does not alter the effects assessment results.

8.8.1.2 Change in Surface Water Quality

The key changes to surface water quality that are predicted to remain after the implementation of mitigation measures are discussed in the sections below. Water quality predictions (Appendix 8-E) were screened (see Section 8.7.1.2) to determine residual effects on the surface water VC due to a change in water quality. Monthly water quality predictions and comparisons to water quality guidelines for the expected case (base case) are presented in Appendix 8-G.

M20 Creek

The change in M20 Creek water quality due to effluent discharge from the Shaft Site pond during Construction and from Shaft site runoff during Operations, Decommissioning and Reclamation, and Post-closure was assessed by screening water quality predictions for the base case and 17 sensitivity analyses to identify COPC (Table 8.8-9). Screening of parameters against provincial guidelines is presented in Appendix 8-G. COPC were identified for aquatic life for the set of sensitivity analyses associated with 95 percentile background surface water quality, are discussed below. No COPC were identified for drinking water or wildlife.

Aluminum

An increase in aluminum concentrations above guidelines and above background concentrations in M20 Creek was identified in the model cases when background concentrations were modelled as the 95th percentile of background concentrations in Construction, Operations, Decommissioning and Reclamation, and Post-Closure and in Post-Closure under dry surface flow conditions (model cases 6, 7, and 8).

Mass balance modelling typically overestimates aluminum concentrations in circum-neutral environments such as the Shaft site pond and M20 Creek because aluminum is typically controlled through mineral solubility (Stumm and Morgan 1996). Further, the likelihood of background water quality persisting at the 95th percentile of historical observations is low and decreased water contact in the waste rock facility in a dry year has not been considered in the model. Water quality in the Shaft Site pond will be monitored as part of the ML/ARD Management Plan (Section 24.7) and in M20 Creek as part of the Selenium Management Plan (Section 24.10); therefore, any increase in aluminum above the concentrations predicted in the base case model will be identified.

Iron

An increase in iron concentrations above guidelines and above background concentrations in M20 Creek was identified in the model cases when background concentrations were modelled as the 95th percentile of background concentrations in Construction, Operations, Decommissioning and Reclamation, and Post-Closure.

Mass balance modelling typically overestimates iron concentrations in circum-neutral environments such as the Shaft site pond and M20 Creek because iron is highly insoluble at pH > 3.5 (Stumm and Morgan 1996). Water quality in the Shaft Site pond will be monitored as part of the ML/ARD Management Plan (Section 24.7) and in M20 Creek as part of the Selenium Management Plan (Section 24.10); therefore, any increase in iron above the concentrations predicted in the base case model will be identified.

For the reasons discussed above, a change in water quality in M20 Creek due to increased aluminum and iron concentrations is not considered to be a likely Project-related effect; therefore, no residual effect on M20 Creek was determined and effects on surface water due to a change in water quality in M20 Creek will not be considered further in the assessment.

Table 8.8-4. Sensitivity Analysis Scenario Results for Simulated Average Monthly Streamflows at M19A Creek

				January			February			March			April			May		
Scenario	Annual Precipitation	Groundwater Inflows into the Mine	Project Phase	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)
Base Case	Average	Moderate	Baseline	0.001	n/a	n/a	0.001	n/a	n/a	0.001	n/a	n/a	0.042	n/a	n/a	0.271	n/a	n/a
			Bulk Sample	0.001	0**	n/a**	0.001	0**	n/a**	0.001	0**	n/a**	0.041	0**	n/a**	0.268	-0.003	-1.1%
			Construction	0*	n/a*	n/a**	0*	n/a*	n/a**	0.001	0**	n/a**	0.040	-0.002	-5.1%	0.257	-0.014	-5.1%
			Operation	0*	n/a*	n/a**	0*	n/a*	n/a**	0.001	0**	n/a**	0.038	-0.004	-9.9%	0.244	-0.027	-10.0%
			Decomissioning & Reclamation	0.001	0**	n/a**	0.001	0**	n/a**	0.001	0**	n/a**	0.043	0.002	4.2%	0.282	0.011	4.2%
			Post Closure	0.001	0**	n/a**	0.001	0**	n/a**	0.001	0**	n/a**	0.043	0.002	4.2%	0.282	0.011	4.2%
Sensitivity #1	Average	High	Baseline	0.001	n/a	n/a	0.001	n/a	n/a	0.001	n/a	n/a	0.042	n/a	n/a	0.271	n/a	n/a
			Bulk Sample	0.001	0**	n/a**	0.001	0**	n/a**	0.001	0**	n/a**	0.041	0**	n/a**	0.268	-0.003	-1.1%
			Construction	0*	n/a*	n/a**	0*	n/a*	n/a**	0.001	0**	n/a**	0.040	-0.002	-5.1%	0.257	-0.014	-5.1%
			Operation	0*	n/a*	n/a**	0*	n/a*	n/a**	0.001	0**	n/a**	0.038	-0.004	-9.9%	0.244	-0.027	-10.0%
			Decomissioning & Reclamation	0.001	0**	n/a**	0.001	0**	n/a**	0.001	0**	n/a**	0.043	0.002	4.2%	0.282	0.011	4.2%
			Post Closure	0.001	0**	n/a**	0.001	0**	n/a**	0.001	0**	n/a**	0.043	0.002	4.2%	0.282	0.011	4.2%
Sensitivity #2	Average	Low	Baseline	0.001	n/a	n/a	0.001	n/a	n/a	0.001	n/a	n/a	0.042	n/a	n/a	0.271	n/a	n/a
			Bulk Sample	0.001	0**	n/a**	0.001	0**	n/a**	0.001	0**	n/a**	0.041	0**	n/a**	0.268	-0.003	-1.1%
			Construction	0*	n/a*	n/a**	0*	n/a*	n/a**	0.001	0**	n/a**	0.040	-0.002	-5.1%	0.257	-0.014	-5.1%
			Operation	0*	n/a*	n/a**	0*	n/a*	n/a**	0.001	0**	n/a**	0.038	-0.004	-9.9%	0.244	-0.027	-10.0%
			Decomissioning & Reclamation	0.001	0**	n/a**	0.001	0**	n/a**	0.001	0**	n/a**	0.043	0.002	4.2%	0.282	0.011	4.2%
			Post Closure	0.001	0**	n/a**	0.001	0**	n/a**	0.001	0**	n/a**	0.043	0.002	4.2%	0.282	0.011	4.2%
Sensitivity #3	100-Year Wet	Moderate	Baseline	0.001	n/a	n/a	0.001	n/a	n/a	0.002	n/a	n/a	0.117	n/a	n/a	0.758	n/a	n/a
			Bulk Sample	0.001	0**	n/a**	0.001	0**	n/a**	0.002	0**	n/a**	0.116	0**	n/a**	0.750	0**	n/a**
			Construction	0.001	0**	n/a**	0.001	0**	n/a**	0.002	0**	n/a**	0.111	-0.006	-5.1%	0.719	-0.039	-5.1%
			Operation	0.001	0**	n/a**	0.001	0**	n/a**	0.002	0**	n/a**	0.105	-0.012	-9.9%	0.682	-0.075	-10.0%
			Decomissioning & Reclamation	0.002	0**	n/a**	0.002	0**	n/a**	0.002	0**	n/a**	0.122	0.005	4.2%	0.790	0.032	4.2%
			Post Closure	0.002	0**	n/a**	0.002	0**	n/a**	0.002	0**	n/a**	0.122	0.005	4.2%	0.790	0.032	4.2%
Sensitivity #4	100-Year Wet	High	Baseline	0.001	n/a	n/a	0.001	n/a	n/a	0.002	n/a	n/a	0.117	n/a	n/a	0.758	n/a	n/a
			Bulk Sample	0.001	0**	n/a**	0.001	0**	n/a**	0.002	0**	n/a**	0.116	-0.001	-1.1%	0.750	-0.008	-1.1%
			Construction	0.001	0**	n/a**	0.001	0**	n/a**	0.002	0**	n/a**	0.111	-0.006	-5.1%	0.719	-0.039	-5.1%
			Operation	0.001	0**	n/a**	0.001	0**	n/a**	0.002	0**	n/a**	0.105	-0.012	-9.9%	0.682	-0.075	-10.0%
			Decomissioning & Reclamation	0.002	0**	n/a**	0.002	0**	n/a**	0.002	0**	n/a**	0.122	0.005	4.2%	0.790	0.032	4.2%
			Post Closure	0.002	0**	n/a**	0.002	0**	n/a**	0.002	0**	n/a**	0.122	0.005	4.2%	0.790	0.032	4.2%
Sensitivity #5	100-Year Wet	Low	Baseline	0.001	n/a	n/a	0.001	n/a	n/a	0.002	n/a	n/a	0.117	n/a	n/a	0.758	n/a	n/a
			Bulk Sample	0.001	0**	n/a**	0.001	0**	n/a**	0.002	0**	n/a**	0.116	-0.001	-1.1%	0.750	-0.008	-1.1%
			Construction	0.001	0**	n/a**	0.001	0**	n/a**	0.002	0**	n/a**	0.111	-0.006	-5.1%	0.719	-0.039	-5.1%
			Operation	0.001	0**	n/a**	0.001	0**	n/a**	0.002	0**	n/a**	0.105	-0.012	-9.9%	0.682	-0.075	-10.0%
			Decomissioning & Reclamation	0.002	0**	n/a**	0.002	0**	n/a**	0.002	0**	n/a**	0.122	0.005	4.2%	0.790	0.032	4.2%
			Post Closure	0.002	0**	n/a**	0.002	0**	n/a**	0.002	0**	n/a**	0.122	0.005	4.2%	0.790	0.032	4.2%
Sensitivity #6	100-Year Dry	Moderate	Baseline	0*	n/a	n/a	0*	n/a	n/a	0*	n/a	n/a	0.013	n/a	n/a	0.081	n/a	n/a
			Bulk Sample	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.012	0**	n/a**	0.080	-0.001	-1.1%
			Construction	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.012	-0.001	-5.1%	0.077	-0.004	-5.1%
			Operation	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.011	-0.001	-9.9%	0.073	-0.008	-10.0%
			Decomissioning & Reclamation	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.013	0.001	4.2%	0.085	0.003	4.2%
			Post Closure	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.013	0.001	4.2%	0.085	0.003	4.2%
Sensitivity #7	100-Year Dry	High	Baseline	0*	n/a	n/a	0*	n/a	n/a	0*	n/a	n/a	0.013	n/a	n/a	0.081	n/a	n/a
			Bulk Sample	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.012	0**	n/a**	0.080	-0.001	-1.1%
			Construction	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.012	-0.001	-5.1%	0.077	-0.004	-5.1%
			Operation	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.011	-0.001	-9.9%	0.073	-0.008	-10.0%
			Decomissioning & Reclamation	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.013	0.001	4.2%	0.085	0.003	4.2%
			Post Closure	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.013	0.001	4.2%	0.085	0.003	4.2%
Sensitivity #8	100-Year Dry	Low	Baseline	0*	n/a	n/a	0*	n/a	n/a	0*	n/a	n/a	0.013	n/a	n/a	0.081	n/a	n/a
			Bulk Sample	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.012	0**	n/a**	0.080	-0.001	-1.1%
			Construction	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.012	-0.001	-5.1%	0.077	-0.004	-5.1%
			Operation	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.011	-0.001	-9.9%	0.073	-0.008	-10.0%
			Decomissioning & Reclamation	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.013	0.001	4.2%	0.085	0.003	4.2%
			Post Closure	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.013	0.001	4.2%	0.085	0.003	4.2%

(continued)

Table 8.8-4. Sensitivity Analysis Scenario Results for Simulated Average Monthly Streamflows at M19A Creek (continued)

				June			July			August			September			October		
Scenario	Annual Precipitation	Groundwater Inflows into the Mine	Project Phase	Flow (m³/s)	Change from Baseline (m³/s)	Change from Baseline (% of Baseline Flow)	Flow (m³/s)	Change from Baseline (m³/s)	Change from Baseline (% of Baseline Flow)	Flow (m³/s)	Change from Baseline (m³/s)	Change from Baseline (% of Baseline Flow)	Flow (m³/s)	Change from Baseline (m³/s)	Change from Baseline (% of Baseline Flow)	Flow (m³/s)	Change from Baseline (m³/s)	Change from Baseline (% of Baseline Flow)
Base Case	Average	Moderate	Baseline	0.124	n/a	n/a	0.028	n/a	n/a	0.020	n/a	n/a	0.001	n/a	n/a	0.004	n/a	n/a
			Bulk Sample	0.123	-0.001	-1.1%	0.028	0**	n/a**	0.020	0**	n/a**	0.001	0**	n/a**	0.004	0**	n/a**
			Construction	0.118	-0.007	-5.2%	0.027	-0.002	-5.3%	0.019	-0.001	-5.4%	0.001	0**	n/a**	0.004	0**	n/a**
			Operation	0.112	-0.012	-10.0%	0.026	-0.003	-10.0%	0.018	-0.002	-10.0%	0.001	0**	n/a**	0.003	0**	n/a**
			Decomissioning & Reclamation	0.130	0.005	4.2%	0.030	0.001	4.2%	0.021	0.001	4.2%	0.001	0**	n/a**	0.004	0**	n/a**
			Post Closure	0.130	0.005	4.2%	0.030	0.001	4.2%	0.021	0.001	4.2%	0.001	0**	n/a**	0.004	0**	n/a**
Sensitivity #1	Average	High	Baseline	0.124	n/a	n/a	0.028	n/a	n/a	0.020	n/a	n/a	0.001	n/a	n/a	0.004	n/a	n/a
			Bulk Sample	0.123	-0.001	-1.1%	0.028	0**	n/a**	0.020	0**	n/a**	0.001	0**	n/a**	0.004	0**	n/a**
			Construction	0.118	-0.007	-5.2%	0.027	-0.002	-5.3%	0.019	-0.001	-5.4%	0.001	0**	n/a**	0.004	0**	n/a**
			Operation	0.112	-0.012	-10.0%	0.026	-0.003	-10.0%	0.018	-0.002	-10.0%	0.001	0**	n/a**	0.003	0**	n/a**
			Decomissioning & Reclamation	0.130	0.005	4.2%	0.030	0.001	4.2%	0.021	0.001	4.2%	0.001	0**	n/a**	0.004	0**	n/a**
			Post Closure	0.130	0.005	4.2%	0.030	0.001	4.2%	0.021	0.001	4.2%	0.001	0**	n/a**	0.004	0**	n/a**
Sensitivity #2	Average	Low	Baseline	0.124	n/a	n/a	0.028	n/a	n/a	0.020	n/a	n/a	0.001	n/a	n/a	0.004	n/a	n/a
			Bulk Sample	0.123	-0.001	-1.1%	0.028	0**	n/a**	0.020	0**	n/a**	0.001	0**	n/a**	0.004	0**	n/a**
			Construction	0.118	-0.007	-5.2%	0.027	-0.002	-5.3%	0.019	-0.001	-5.4%	0.001	0**	n/a**	0.004	0**	n/a**
			Operation	0.112	-0.012	-10.0%	0.026	-0.003	-10.0%	0.018	-0.002	-10.0%	0.001	0**	n/a**	0.003	0**	n/a**
			Decomissioning & Reclamation	0.130	0.005	4.2%	0.030	0.001	4.2%	0.021	0.001	4.2%	0.001	0**	n/a**	0.004	0**	n/a**
			Post Closure	0.130	0.005	4.2%	0.030	0.001	4.2%	0.021	0.001	4.2%	0.001	0**	n/a**	0.004	0**	n/a**
Sensitivity #3	100-Year Wet	Moderate	Baseline	0.348	n/a	n/a	0.079	n/a	n/a	0.055	n/a	n/a	0.003	n/a	n/a	0.011	n/a	n/a
			Bulk Sample	0.345	0**	n/a**	0.079	0**	n/a**	0.055	0**	n/a**	0.003	0**	n/a**	0.011	0**	n/a**
			Construction	0.330	-0.018	-5.2%	0.075	-0.004	-5.3%	0.053	-0.003	-5.4%	0.003	0**	n/a**	0.010	0**	n/a**
			Operation	0.314	-0.035	-10.0%	0.071	-0.008	-10.0%	0.050	-0.006	-10.0%	0.003	0**	n/a**	0.010	-0.001	-10.0%
			Decomissioning & Reclamation	0.363	0.015	4.2%	0.083	0.003	4.2%	0.058	0.002	4.2%	0.003	0**	n/a**	0.011	0.000	4.2%
			Post Closure	0.363	0.015	4.2%	0.083	0.003	4.2%	0.058	0.002	4.2%	0.003	0**	n/a**	0.011	0.000	4.2%
Sensitivity #4	100-Year Wet	High	Baseline	0.348	n/a	n/a	0.079	n/a	n/a	0.055	n/a	n/a	0.003	n/a	n/a	0.011	n/a	n/a
			Bulk Sample	0.345	-0.004	-1.1%	0.079	-0.001	-1.1%	0.055	-0.001	-1.1%	0.003	0**	n/a**	0.011	0**	n/a**
			Construction	0.330	-0.018	-5.2%	0.075	-0.004	-5.3%	0.053	-0.003	-5.4%	0.003	0**	n/a**	0.010	-0.001	-5.5%
			Operation	0.314	-0.035	-10.0%	0.071	-0.008	-10.0%	0.050	-0.006	-10.0%	0.003	0**	n/a**	0.010	-0.001	-10.0%
			Decomissioning & Reclamation	0.363	0.015	4.2%	0.083	0.003	4.2%	0.058	0.002	4.2%	0.003	0**	n/a**	0.011	0**	n/a**
			Post Closure	0.363	0.015	4.2%	0.083	0.003	4.2%	0.058	0.002	4.2%	0.003	0**	n/a**	0.011	0**	n/a**
Sensitivity #5	100-Year Wet	Low	Baseline	0.348	n/a	n/a	0.079	n/a	n/a	0.055	n/a	n/a	0.003	n/a	n/a	0.011	n/a	n/a
			Bulk Sample	0.345	-0.004	-1.1%	0.079	-0.001	-1.1%	0.055	-0.001	-1.1%	0.003	0**	n/a**	0.011	0**	n/a**
			Construction	0.330	-0.018	-5.2%	0.075	-0.004	-5.3%	0.053	-0.003	-5.4%	0.003	0**	n/a**	0.010	-0.001	-5.5%
			Operation	0.314	-0.035	-10.0%	0.071	-0.008	-10.0%	0.050	-0.006	-10.0%	0.003	0**	n/a**	0.010	-0.001	-10.0%
			Decomissioning & Reclamation	0.363	0.015	4.2%	0.083	0.003	4.2%	0.058	0.002	4.2%	0.003	0**	n/a**	0.011	0**	n/a**
			Post Closure	0.363	0.015	4.2%	0.083	0.003	4.2%	0.058	0.002	4.2%	0.003	0**	n/a**	0.011	0**	n/a**
Sensitivity #6	100-Year Dry	Moderate	Baseline	0.037	n/a	n/a	0.009	n/a	n/a	0.006	n/a	n/a	0*	n/a	n/a	0.001	n/a	n/a
			Bulk Sample	0.037	0**	n/a**	0.008	0**	n/a**	0.006	0**	n/a**	0*	n/a*	n/a*	0.001	0**	n/a**
			Construction	0.035	-0.002	-5.2%	0.008	0**	n/a**	0.006	0**	n/a**	0*	n/a*	n/a*	0.001	0**	n/a**
			Operation	0.034	-0.004	-10.0%	0.008	-0.001	-10.0%	0.005	-0.001	-10.0%	0*	n/a*	n/a*	0.001	0**	n/a**
			Decomissioning & Reclamation	0.039	0.002	4.2%	0.009	0**	n/a**	0.006	0**	n/a**	0*	n/a*	n/a*	0.001	0**	n/a**
			Post Closure	0.039	0.002	4.2%	0.009	0**	n/a**	0.006	0**	n/a**	0*	n/a*	n/a*	0.001	0**	n/a**
Sensitivity #7	100-Year Dry	High	Baseline	0.037	n/a	n/a	0.009	n/a	n/a	0.006	n/a	n/a	0*	n/a	n/a	0.001	n/a	n/a
			Bulk Sample	0.037	0**	n/a**	0.008	0**	n/a**	0.006	0**	n/a**	0*	n/a*	n/a*	0.001	0**	n/a**
			Construction	0.035	-0.002	-5.2%	0.008	0**	n/a**	0.006	0**	n/a**	0*	n/a*	n/a*	0.001	0**	n/a**
			Operation	0.034	-0.004	-10.0%	0.008	-0.001	-10.0%	0.005	-0.001	-10.0%	0*	n/a*	n/a*	0.001	0**	n/a**
			Decomissioning & Reclamation	0.039	0.002	4.2%	0.009	0**	n/a**	0.006	0**	n/a**	0*	n/a*	n/a*	0.001	0**	n/a**
			Post Closure	0.039	0.002	4.2%	0.009	0**	n/a**	0.006	0**	n/a**	0*	n/a*	n/a*	0.001	0**	n/a**
Sensitivity #8	100-Year Dry	Low	Baseline	0.037	n/a	n/a	0.009	n/a	n/a	0.006	n/a	n/a	0*	n/a	n/a	0.001	n/a	n/a
			Bulk Sample	0.037	0**	n/a**	0.008	0**	n/a**	0.006	0**	n/a**	0*	n/a*	n/a*	0.001	0**	n/a**
			Construction	0.035	-0.002	-5.2%	0.008	0**	n/a**	0.006	0**	n/a**	0*	n/a*	n/a*	0.001	0**	n/a**
			Operation	0.034	-0.004	-10.0%	0.008	-0.001	-10.0%	0.005	-0.001	-10.0%	0*	n/a*	n/a*	0.001	0**	n/a**
			Decomissioning & Reclamation	0.039	0.002	4.2%	0.009	0**	n/a**	0.006	0**	n/a**	0*	n/a*	n/a*	0.001	0**	n/a**
			Post Closure	0.039	0.002	4.2%	0.009	0**	n/a**	0.006	0**	n/a**	0*	n/a*	n/a*	0.001	0**	n/a**

(continued)

Table 8.8-4. Sensitivity Analysis Scenario Results for Simulated Average Monthly Streamflows at M19A Creek (completed)

				November			December			Annual		
Scenario	Annual Precipitation	Groundwater Inflows into the Mine	Project Phase	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)
Base Case	Average	Moderate	Baseline	0.002	n/a	n/a	0.001	n/a	n/a	0.04	n/a	n/a
			Bulk Sample	0.002	0**	n/a**	0.001	0**	n/a**	0.04	0**	n/a**
			Construction	0.002	0**	n/a**	0.001	0**	n/a**	0.04	-0.002	-5.2%
			Operation	0.002	0**	n/a**	0.001	0**	n/a**	0.04	-0.004	-10.0%
			Decomissioning & Reclamation	0.002	0**	n/a**	0.001	0**	n/a**	0.04	0.002	4.2%
			Post Closure	0.002	0**	n/a**	0.001	0**	n/a**	0.04	0.002	4.2%
Sensitivity #1	Average	High	Baseline	0.002	n/a	n/a	0.001	n/a	n/a	0.04	n/a	n/a
			Bulk Sample	0.002	0**	n/a**	0.001	0**	n/a**	0.04	0**	n/a**
			Construction	0.002	0**	n/a**	0.001	0**	n/a**	0.04	-0.002	-5.2%
			Operation	0.002	0**	n/a**	0.001	0**	n/a**	0.04	-0.004	-10.0%
			Decomissioning & Reclamation	0.002	0**	n/a**	0.001	0**	n/a**	0.04	0.002	4.2%
			Post Closure	0.002	0**	n/a**	0.001	0**	n/a**	0.04	0.002	4.2%
Sensitivity #2	Average	Low	Baseline	0.002	n/a	n/a	0.001	n/a	n/a	0.04	n/a	n/a
			Bulk Sample	0.002	0**	n/a**	0.001	0**	n/a**	0.04	0**	n/a**
			Construction	0.002	0**	n/a**	0.001	0**	n/a**	0.04	-0.002	-5.2%
			Operation	0.002	0**	n/a**	0.001	0**	n/a**	0.04	-0.004	-10.0%
			Decomissioning & Reclamation	0.002	0**	n/a**	0.001	0**	n/a**	0.04	0.002	4.2%
			Post Closure	0.002	0**	n/a**	0.001	0**	n/a**	0.04	0.002	4.2%
Sensitivity #3	100-Year Wet	Moderate	Baseline	0.005	n/a	n/a	0.002	n/a	n/a	0.12	n/a	n/a
			Bulk Sample	0.005	0**	n/a**	0.002	0**	n/a**	0.11	-0.001	-1.1%
			Construction	0.005	0**	n/a**	0.002	0**	n/a**	0.11	-0.006	-5.2%
			Operation	0.005	0**	n/a**	0.002	0**	n/a**	0.10	-0.012	-10.0%
			Decomissioning & Reclamation	0.005	0**	n/a**	0.002	0**	n/a**	0.12	0.005	4.2%
			Post Closure	0.005	0**	n/a**	0.002	0**	n/a**	0.12	0.005	4.2%
Sensitivity #4	100-Year Wet	High	Baseline	0.005	n/a	n/a	0.002	n/a	n/a	0.12	n/a	n/a
			Bulk Sample	0.005	0**	n/a**	0.002	0**	n/a**	0.11	-0.001	-1.1%
			Construction	0.005	0**	n/a**	0.002	0**	n/a**	0.11	-0.006	-5.2%
			Operation	0.005	-0.001	-10.0%	0.002	0**	n/a**	0.10	-0.012	-10.0%
			Decomissioning & Reclamation	0.005	0**	n/a**	0.002	0**	n/a**	0.12	0.005	4.2%
			Post Closure	0.005	0**	n/a**	0.002	0**	n/a**	0.12	0.005	4.2%
Sensitivity #5	100-Year Wet	Low	Baseline	0.005	n/a	n/a	0.002	n/a	n/a	0.12	n/a	n/a
			Bulk Sample	0.005	0**	n/a**	0.002	0**	n/a**	0.11	-0.001	-1.1%
			Construction	0.005	0**	n/a**	0.002	0**	n/a**	0.11	-0.006	-5.2%
			Operation	0.005	-0.001	-10.0%	0.002	0**	n/a**	0.10	-0.012	-10.0%
			Decomissioning & Reclamation	0.005	0**	n/a**	0.002	0**	n/a**	0.12	0.005	4.2%
			Post Closure	0.005	0**	n/a**	0.002	0**	n/a**	0.12	0.005	4.2%
Sensitivity #6	100-Year Dry	Moderate	Baseline	0.001	n/a	n/a	0*	n/a	n/a	0.01	n/a	n/a
			Bulk Sample	0.001	0**	n/a**	0*	n/a*	n/a*	0.01	0**	n/a**
			Construction	0.001	0**	n/a**	0*	n/a*	n/a*	0.01	-0.001	-5.2%
			Operation	0*	n/a*	n/a**	0*	n/a*	n/a*	0.01	-0.001	-10.0%
			Decomissioning & Reclamation	0.001	0**	n/a**	0*	n/a*	n/a*	0.01	0.001	4.2%
			Post Closure	0.001	0**	n/a**	0*	n/a*	n/a*	0.01	0.001	4.2%
Sensitivity #7	100-Year Dry	High	Baseline	0.001	n/a	n/a	0*	n/a	n/a	0.01	n/a	n/a
			Bulk Sample	0.001	0**	n/a**	0*	n/a*	n/a*	0.01	0**	n/a**
			Construction	0.001	0**	n/a**	0*	n/a*	n/a*	0.01	-0.001	-5.2%
			Operation	0*	n/a*	n/a**	0*	n/a*	n/a*	0.01	-0.001	-10.0%
			Decomissioning & Reclamation	0.001	0**	n/a**	0*	n/a*	n/a*	0.01	0.001	4.2%
			Post Closure	0.001	0**	n/a**	0*	n/a*	n/a*	0.01	0.001	4.2%
Sensitivity #8	100-Year Dry	Low	Baseline	0.001	n/a	n/a	0*	n/a	n/a	0.01	n/a	n/a
			Bulk Sample	0.001	0**	n/a**	0*	n/a*	n/a*	0.01	0**	n/a**
			Construction	0.001	0**	n/a**	0*	n/a*	n/a*	0.01	-0.001	-5.2%
			Operation	0*	n/a*	n/a**	0*	n/a*	n/a*	0.01	-0.001	-10.0%
			Decomissioning & Reclamation	0.001	0**	n/a**	0*	n/a*	n/a*	0.01	0.001	4.2%
			Post Closure	0.001	0**	n/a**	0*	n/a*	n/a*	0.01	0.001	4.2%

** Flows are less than 0.0005 m^3/s*

*** Flow changes are less than 0.0005 m^3/s*

Table 8.8-5. Sensitivity Analysis Scenario Results for Simulated Average Monthly Streamflows at M19 Creek

Scenario	Annual Precipitation	Groundwater Inflows into the Mine	Project Phase	January Flow (m³/s)	January Change from Baseline (m³/s)	January Change from Baseline (% of Baseline Flow)	February Flow (m³/s)	February Change from Baseline (m³/s)	February Change from Baseline (% of Baseline Flow)	March Flow (m³/s)	March Change from Baseline (m³/s)	March Change from Baseline (% of Baseline Flow)	April Flow (m³/s)	April Change from Baseline (m³/s)	April Change from Baseline (% of Baseline Flow)	May Flow (m³/s)	May Change from Baseline (m³/s)	May Change from Baseline (% of Baseline Flow)
Base Case	Average	Moderate	Baseline	0.004	n/a	n/a	0.004	n/a	n/a	0.005	n/a	n/a	0.362	n/a	n/a	2.347	n/a	n/a
			Bulk Sample	0.004	0**	n/a**	0.004	0**	n/a**	0.005	0**	n/a**	0.361	0**	n/a**	2.344	-0.003	-0.1%
			Construction	0.004	0**	n/a**	0.004	0**	n/a**	0.005	0**	n/a**	0.360	-0.002	-0.6%	2.333	-0.014	-0.6%
			Operation	0.004	0**	n/a**	0.004	0**	n/a**	0.005	0**	n/a**	0.358	-0.004	-1.1%	2.320	-0.027	-1.1%
			Decomissioning & Reclamation	0.004	0**	n/a**	0.004	0**	n/a**	0.005	0**	n/a**	0.364	0.002	0.5%	2.358	0.011	0.5%
			Post Closure	0.004	0**	n/a**	0.004	0**	n/a**	0.005	0**	n/a**	0.364	0.002	0.5%	2.358	0.011	0.5%
Sensitivity #1	Average	High	Baseline	0.004	n/a	n/a	0.004	n/a	n/a	0.005	n/a	n/a	0.362	n/a	n/a	2.347	n/a	n/a
			Bulk Sample	0.004	0**	n/a**	0.004	0**	n/a**	0.005	0**	n/a**	0.361	0**	n/a**	2.344	-0.003	-0.1%
			Construction	0.004	0**	n/a**	0.004	0**	n/a**	0.005	0**	n/a**	0.360	-0.002	-0.6%	2.333	-0.014	-0.6%
			Operation	0.004	0**	n/a**	0.004	0**	n/a**	0.005	0**	n/a**	0.358	-0.004	-1.1%	2.320	-0.027	-1.1%
			Decomissioning & Reclamation	0.004	0**	n/a**	0.004	0**	n/a**	0.005	0**	n/a**	0.364	0.002	0.5%	2.358	0.011	0.5%
			Post Closure	0.004	0**	n/a**	0.004	0**	n/a**	0.005	0**	n/a**	0.364	0.002	0.5%	2.358	0.011	0.5%
Sensitivity #2	Average	Low	Baseline	0.004	n/a	n/a	0.004	n/a	n/a	0.005	n/a	n/a	0.362	n/a	n/a	2.347	n/a	n/a
			Bulk Sample	0.004	0**	n/a**	0.004	0**	n/a**	0.005	0**	n/a**	0.361	0**	n/a**	2.344	-0.003	-0.1%
			Construction	0.004	0**	n/a**	0.004	0**	n/a**	0.005	0**	n/a**	0.360	-0.002	-0.6%	2.333	-0.014	-0.6%
			Operation	0.004	0**	n/a**	0.004	0**	n/a**	0.005	0**	n/a**	0.358	-0.004	-1.1%	2.320	-0.027	-1.1%
			Decomissioning & Reclamation	0.004	0**	n/a**	0.004	0**	n/a**	0.005	0**	n/a**	0.364	0.002	0.5%	2.358	0.011	0.5%
			Post Closure	0.004	0**	n/a**	0.004	0**	n/a**	0.005	0**	n/a**	0.364	0.002	0.5%	2.358	0.011	0.5%
Sensitivity #3	100-Year Wet	Moderate	Baseline	0.013	n/a	n/a	0.013	n/a	n/a	0.015	n/a	n/a	1.013	n/a	n/a	6.572	n/a	n/a
			Bulk Sample	0.012	0**	n/a**	0.012	0**	n/a**	0.015	0**	n/a**	1.012	0**	n/a**	6.563	0**	n/a**
			Construction	0.012	0**	n/a**	0.012	0**	n/a**	0.014	0**	n/a**	1.007	-0.006	-0.6%	6.533	-0.039	-0.6%
			Operation	0.012	0**	n/a**	0.012	0**	n/a**	0.014	0**	n/a**	1.001	-0.012	-1.1%	6.496	-0.075	-1.1%
			Decomissioning & Reclamation	0.013	0**	n/a**	0.013	0**	n/a**	0.015	0**	n/a**	1.018	0.005	0.5%	6.604	0.032	0.5%
			Post Closure	0.013	0**	n/a**	0.013	0**	n/a**	0.015	0**	n/a**	1.018	0.005	0.5%	6.604	0.032	0.5%
Sensitivity #4	100-Year Wet	High	Baseline	0.013	n/a	n/a	0.013	n/a	n/a	0.015	n/a	n/a	1.013	n/a	n/a	6.572	n/a	n/a
			Bulk Sample	0.012	0**	n/a**	0.012	0**	n/a**	0.015	0**	n/a**	1.012	-0.001	-0.1%	6.563	-0.008	-0.1%
			Construction	0.012	0**	n/a**	0.012	0**	n/a**	0.014	0**	n/a**	1.007	-0.006	-0.6%	6.533	-0.039	-0.6%
			Operation	0.012	0**	n/a**	0.012	0**	n/a**	0.014	0**	n/a**	1.001	-0.012	-1.1%	6.496	-0.075	-1.1%
			Decomissioning & Reclamation	0.013	0**	n/a**	0.013	0**	n/a**	0.015	0**	n/a**	1.018	0.005	0.5%	6.604	0.032	0.5%
			Post Closure	0.013	0**	n/a**	0.013	0**	n/a**	0.015	0**	n/a**	1.018	0.005	0.5%	6.604	0.032	0.5%
Sensitivity #5	100-Year Wet	Low	Baseline	0.013	n/a	n/a	0.013	n/a	n/a	0.015	n/a	n/a	1.013	n/a	n/a	6.572	n/a	n/a
			Bulk Sample	0.012	0**	n/a**	0.012	0**	n/a**	0.015	0**	n/a**	1.012	-0.001	-0.1%	6.563	-0.008	-0.1%
			Construction	0.012	0**	n/a**	0.012	0**	n/a**	0.014	0**	n/a**	1.007	-0.006	-0.6%	6.533	-0.039	-0.6%
			Operation	0.012	0**	n/a**	0.012	0**	n/a**	0.014	0**	n/a**	1.001	-0.012	-1.1%	6.496	-0.075	-1.1%
			Decomissioning & Reclamation	0.013	0**	n/a**	0.013	0**	n/a**	0.015	0**	n/a**	1.018	0.005	0.5%	6.604	0.032	0.5%
			Post Closure	0.013	0**	n/a**	0.013	0**	n/a**	0.015	0**	n/a**	1.018	0.005	0.5%	6.604	0.032	0.5%
Sensitivity #6	100-Year Dry	Moderate	Baseline	0.001	n/a	n/a	0.001	n/a	n/a	0.002	n/a	n/a	0.109	n/a	n/a	0.704	n/a	n/a
			Bulk Sample	0.001	0**	n/a**	0.001	0**	n/a**	0.002	0**	n/a**	0.108	0**	n/a**	0.703	-0.001	-0.1%
			Construction	0.001	0**	n/a**	0.001	0**	n/a**	0.002	0**	n/a**	0.108	-0.001	-0.6%	0.700	-0.004	-0.6%
			Operation	0.001	0**	n/a**	0.001	0**	n/a**	0.002	0**	n/a**	0.107	-0.001	-1.1%	0.696	-0.008	-1.1%
			Decomissioning & Reclamation	0.001	0**	n/a**	0.001	0**	n/a**	0.002	0**	n/a**	0.109	0.001	0.5%	0.708	0.003	0.5%
			Post Closure	0.001	0**	n/a**	0.001	0**	n/a**	0.002	0**	n/a**	0.109	0.001	0.5%	0.708	0.003	0.5%
Sensitivity #7	100-Year Dry	High	Baseline	0.001	n/a	n/a	0.001	n/a	n/a	0.002	n/a	n/a	0.109	n/a	n/a	0.704	n/a	n/a
			Bulk Sample	0.001	0**	n/a**	0.001	0**	n/a**	0.002	0**	n/a**	0.108	0**	n/a**	0.703	-0.001	-0.1%
			Construction	0.001	0**	n/a**	0.001	0**	n/a**	0.002	0**	n/a**	0.108	-0.001	-0.6%	0.700	-0.004	-0.6%
			Operation	0.001	0**	n/a**	0.001	0**	n/a**	0.002	0**	n/a**	0.107	-0.001	-1.1%	0.696	-0.008	-1.1%
			Decomissioning & Reclamation	0.001	0**	n/a**	0.001	0**	n/a**	0.002	0**	n/a**	0.109	0.001	0.5%	0.708	0.003	0.5%
			Post Closure	0.001	0**	n/a**	0.001	0**	n/a**	0.002	0**	n/a**	0.109	0.001	0.5%	0.708	0.003	0.5%
Sensitivity #8	100-Year Dry	Low	Baseline	0.001	n/a	n/a	0.001	n/a	n/a	0.002	n/a	n/a	0.109	n/a	n/a	0.704	n/a	n/a
			Bulk Sample	0.001	0**	n/a**	0.001	0**	n/a**	0.002	0**	n/a**	0.108	0**	n/a**	0.703	-0.001	-0.1%
			Construction	0.001	0**	n/a**	0.001	0**	n/a**	0.002	0**	n/a**	0.108	-0.001	-0.6%	0.700	-0.004	-0.6%
			Operation	0.001	0**	n/a**	0.001	0**	n/a**	0.002	0**	n/a**	0.107	-0.001	-1.1%	0.696	-0.008	-1.1%
			Decomissioning & Reclamation	0.001	0**	n/a**	0.001	0**	n/a**	0.002	0**	n/a**	0.109	0.001	0.5%	0.708	0.003	0.5%
			Post Closure	0.001	0**	n/a**	0.001	0**	n/a**	0.002	0**	n/a**	0.109	0.001	0.5%	0.708	0.003	0.5%

(continued)

Table 8.8-5. Sensitivity Analysis Scenario Results for Simulated Average Monthly Streamflows at M19 Creek (continued)

				June			July			August			September			October		
Scenario	Annual Precipitation	Groundwater Inflows into the Mine	Project Phase	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)
Base Case	Average	Moderate	Baseline	1.079	n/a	n/a	0.246	n/a	n/a	0.172	n/a	n/a	0.010	n/a	n/a	0.034	n/a	n/a
			Bulk Sample	1.077	-0.001	-0.1%	0.246	0**	n/a**	0.172	0**	n/a**	0.010	0**	n/a**	0.034	0**	n/a**
			Construction	1.072	-0.006	-0.6%	0.244	-0.002	-0.6%	0.171	-0.001	-0.6%	0.010	0**	n/a**	0.033	0**	n/a**
			Operation	1.066	-0.012	-1.1%	0.243	-0.003	-1.1%	0.170	-0.002	-1.2%	0.010	0**	n/a**	0.033	0**	n/a**
			Decomissioning & Reclamation	1.084	0.005	0.5%	0.247	0.001	0.5%	0.173	0.001	0.5%	0.010	0**	n/a**	0.034	0**	n/a**
			Post Closure	1.084	0.005	0.5%	0.247	0.001	0.5%	0.173	0.001	0.5%	0.010	0**	n/a**	0.034	0**	n/a**
Sensitivity #1	Average	High	Baseline	1.079	n/a	n/a	0.246	n/a	n/a	0.172	n/a	n/a	0.010	n/a	n/a	0.034	n/a	n/a
			Bulk Sample	1.077	-0.001	-0.1%	0.246	0**	n/a**	0.172	0**	n/a**	0.010	0**	n/a**	0.034	0**	n/a**
			Construction	1.072	-0.006	-0.6%	0.244	-0.002	-0.6%	0.171	-0.001	-0.6%	0.010	0**	n/a**	0.033	0**	n/a**
			Operation	1.066	-0.012	-1.1%	0.243	-0.003	-1.1%	0.170	-0.002	-1.2%	0.010	0**	n/a**	0.033	0**	n/a**
			Decomissioning & Reclamation	1.084	0.005	0.5%	0.247	0.001	0.5%	0.173	0.001	0.5%	0.010	0**	n/a**	0.034	0**	n/a**
			Post Closure	1.084	0.005	0.5%	0.247	0.001	0.5%	0.173	0.001	0.5%	0.010	0**	n/a**	0.034	0**	n/a**
Sensitivity #2	Average	Low	Baseline	1.079	n/a	n/a	0.246	n/a	n/a	0.172	n/a	n/a	0.010	n/a	n/a	0.034	n/a	n/a
			Bulk Sample	1.077	-0.001	-0.1%	0.246	0**	n/a**	0.172	0**	n/a**	0.010	0**	n/a**	0.034	0**	n/a**
			Construction	1.072	-0.006	-0.6%	0.244	-0.002	-0.6%	0.171	-0.001	-0.6%	0.010	0**	n/a**	0.033	0**	n/a**
			Operation	1.066	-0.012	-1.1%	0.243	-0.003	-1.1%	0.170	-0.002	-1.2%	0.010	0**	n/a**	0.033	0**	n/a**
			Decomissioning & Reclamation	1.084	0.005	0.5%	0.247	0.001	0.5%	0.173	0.001	0.5%	0.010	0**	n/a**	0.034	0**	n/a**
			Post Closure	1.084	0.005	0.5%	0.247	0.001	0.5%	0.173	0.001	0.5%	0.010	0**	n/a**	0.034	0**	n/a**
Sensitivity #3	100-Year Wet	Moderate	Baseline	3.021	n/a	n/a	0.689	n/a	n/a	0.481	n/a	n/a	0.027	n/a	n/a	0.094	n/a	n/a
			Bulk Sample	3.017	0**	n/a**	0.688	0**	n/a**	0.481	0**	n/a**	0.027	0**	n/a**	0.094	0**	n/a**
			Construction	3.003	-0.018	-0.6%	0.684	-0.004	-0.6%	0.478	-0.003	-0.6%	0.027	0**	n/a**	0.093	0**	n/a**
			Operation	2.986	-0.035	-1.1%	0.681	-0.008	-1.1%	0.476	-0.006	-1.2%	0.027	0**	n/a**	0.093	-0.001	-1.2%
			Decomissioning & Reclamation	3.035	0.015	0.5%	0.692	0.003	0.5%	0.484	0.002	0.5%	0.027	0**	n/a**	0.094	0.000	0.5%
			Post Closure	3.035	0.015	0.5%	0.692	0.003	0.5%	0.484	0.002	0.5%	0.027	0**	n/a**	0.094	0.000	0.5%
Sensitivity #4	100-Year Wet	High	Baseline	3.021	n/a	n/a	0.689	n/a	n/a	0.481	n/a	n/a	0.027	n/a	n/a	0.094	n/a	n/a
			Bulk Sample	3.017	-0.004	-0.1%	0.688	-0.001	-0.1%	0.481	-0.001	-0.1%	0.027	0**	n/a**	0.094	0**	n/a**
			Construction	3.003	-0.018	-0.6%	0.684	-0.004	-0.6%	0.478	-0.003	-0.6%	0.027	0**	n/a**	0.093	-0.001	-0.6%
			Operation	2.986	-0.035	-1.1%	0.681	-0.008	-1.1%	0.476	-0.006	-1.2%	0.027	0**	n/a**	0.093	-0.001	-1.2%
			Decomissioning & Reclamation	3.035	0.015	0.5%	0.692	0.003	0.5%	0.484	0.002	0.5%	0.027	0**	n/a**	0.094	0**	n/a**
			Post Closure	3.035	0.015	0.5%	0.692	0.003	0.5%	0.484	0.002	0.5%	0.027	0**	n/a**	0.094	0**	n/a**
Sensitivity #5	100-Year Wet	Low	Baseline	3.021	n/a	n/a	0.689	n/a	n/a	0.481	n/a	n/a	0.027	n/a	n/a	0.094	n/a	n/a
			Bulk Sample	3.017	-0.004	-0.1%	0.688	-0.001	-0.1%	0.481	-0.001	-0.1%	0.027	0**	n/a**	0.094	0**	n/a**
			Construction	3.003	-0.018	-0.6%	0.684	-0.004	-0.6%	0.478	-0.003	-0.6%	0.027	0**	n/a**	0.093	-0.001	-0.6%
			Operation	2.986	-0.035	-1.1%	0.681	-0.008	-1.1%	0.476	-0.006	-1.2%	0.027	0**	n/a**	0.093	-0.001	-1.2%
			Decomissioning & Reclamation	3.035	0.015	0.5%	0.692	0.003	0.5%	0.484	0.002	0.5%	0.027	0**	n/a**	0.094	0**	n/a**
			Post Closure	3.035	0.015	0.5%	0.692	0.003	0.5%	0.484	0.002	0.5%	0.027	0**	n/a**	0.094	0**	n/a**
Sensitivity #6	100-Year Dry	Moderate	Baseline	0.324	n/a	n/a	0.074	n/a	n/a	0.052	n/a	n/a	0.003	n/a	n/a	0.010	n/a	n/a
			Bulk Sample	0.323	0**	n/a**	0.074	0**	n/a**	0.051	0**	n/a**	0.003	0**	n/a**	0.010	0**	n/a**
			Construction	0.322	-0.002	-0.6%	0.073	0**	n/a**	0.051	0**	n/a**	0.003	0**	n/a**	0.010	0**	n/a**
			Operation	0.320	-0.004	-1.1%	0.073	-0.001	-1.1%	0.051	-0.001	-1.2%	0.003	0**	n/a**	0.010	0**	n/a**
			Decomissioning & Reclamation	0.325	0.002	0.5%	0.074	0**	n/a**	0.052	0**	n/a**	0.003	0**	n/a**	0.010	0**	n/a**
			Post Closure	0.325	0.002	0.5%	0.074	0**	n/a**	0.052	0**	n/a**	0.003	0**	n/a**	0.010	0**	n/a**
Sensitivity #7	100-Year Dry	High	Baseline	0.324	n/a	n/a	0.074	n/a	n/a	0.052	n/a	n/a	0.003	n/a	n/a	0.010	n/a	n/a
			Bulk Sample	0.323	0**	n/a**	0.074	0**	n/a**	0.051	0**	n/a**	0.003	0**	n/a**	0.010	0**	n/a**
			Construction	0.322	-0.002	-0.6%	0.073	0**	n/a**	0.051	0**	n/a**	0.003	0**	n/a**	0.010	0**	n/a**
			Operation	0.320	-0.004	-1.1%	0.073	-0.001	-1.1%	0.051	-0.001	-1.2%	0.003	0**	n/a**	0.010	0**	n/a**
			Decomissioning & Reclamation	0.325	0.002	0.5%	0.074	0**	n/a**	0.052	0**	n/a**	0.003	0**	n/a**	0.010	0**	n/a**
			Post Closure	0.325	0.002	0.5%	0.074	0**	n/a**	0.052	0**	n/a**	0.003	0**	n/a**	0.010	0**	n/a**
Sensitivity #8	100-Year Dry	Low	Baseline	0.324	n/a	n/a	0.074	n/a	n/a	0.052	n/a	n/a	0.003	n/a	n/a	0.010	n/a	n/a
			Bulk Sample	0.323	0**	n/a**	0.074	0**	n/a**	0.051	0**	n/a**	0.003	0**	n/a**	0.010	0**	n/a**
			Construction	0.322	-0.002	-0.6%	0.073	0**	n/a**	0.051	0**	n/a**	0.003	0**	n/a**	0.010	0**	n/a**
			Operation	0.320	-0.004	-1.1%	0.073	-0.001	-1.1%	0.051	-0.001	-1.2%	0.003	0**	n/a**	0.010	0**	n/a**
			Decomissioning & Reclamation	0.325	0.002	0.5%	0.074	0**	n/a**	0.052	0**	n/a**	0.003	0**	n/a**	0.010	0**	n/a**
			Post Closure	0.325	0.002	0.5%	0.074	0**	n/a**	0.052	0**	n/a**	0.003	0**	n/a**	0.010	0**	n/a**

(continued)

Table 8.8-5. Sensitivity Analysis Scenario Results for Simulated Average Monthly Streamflows at M19 Creek (completed)

Scenario	Annual Precipitation	Groundwater Inflows into the Mine	Project Phase	November Flow (m^3/s)	November Change from Baseline (m^3/s)	November Change from Baseline (% of Baseline Flow)	December Flow (m^3/s)	December Change from Baseline (m^3/s)	December Change from Baseline (% of Baseline Flow)	Annual Flow (m^3/s)	Annual Change from Baseline (m^3/s)	Annual Change from Baseline (% of Baseline Flow)
Base Case	Average	Moderate	Baseline	0.016	n/a	n/a	0.007	n/a	n/a	0.36	n/a	n/a
			Bulk Sample	0.016	0**	n/a**	0.007	0**	n/a**	0.36	0**	n/a**
			Construction	0.015	0**	n/a**	0.007	0**	n/a**	0.36	-0.002	-0.6%
			Operation	0.015	0**	n/a**	0.007	0**	n/a**	0.36	-0.004	-1.1%
			Decomissioning & Reclamation	0.016	0**	n/a**	0.007	0**	n/a**	0.36	0.002	0.5%
			Post Closure	0.016	0**	n/a**	0.007	0**	n/a**	0.36	0.002	0.5%
Sensitivity #1	Average	High	Baseline	0.016	n/a	n/a	0.007	n/a	n/a	0.36	n/a	n/a
			Bulk Sample	0.016	0**	n/a**	0.007	0**	n/a**	0.36	0**	n/a**
			Construction	0.015	0**	n/a**	0.007	0**	n/a**	0.36	-0.002	-0.6%
			Operation	0.015	0**	n/a**	0.007	0**	n/a**	0.36	-0.004	-1.1%
			Decomissioning & Reclamation	0.016	0**	n/a**	0.007	0**	n/a**	0.36	0.002	0.5%
			Post Closure	0.016	0**	n/a**	0.007	0**	n/a**	0.36	0.002	0.5%
Sensitivity #2	Average	Low	Baseline	0.016	n/a	n/a	0.007	n/a	n/a	0.36	n/a	n/a
			Bulk Sample	0.016	0**	n/a**	0.007	0**	n/a**	0.36	0**	n/a**
			Construction	0.015	0**	n/a**	0.007	0**	n/a**	0.36	-0.002	-0.6%
			Operation	0.015	0**	n/a**	0.007	0**	n/a**	0.36	-0.004	-1.1%
			Decomissioning & Reclamation	0.016	0**	n/a**	0.007	0**	n/a**	0.36	0.002	0.5%
			Post Closure	0.016	0**	n/a**	0.007	0**	n/a**	0.36	0.002	0.5%
Sensitivity #3	100-Year Wet	Moderate	Baseline	0.044	n/a	n/a	0.020	n/a	n/a	1.01	n/a	n/a
			Bulk Sample	0.044	0**	n/a**	0.020	0**	n/a**	1.01	-0.001	-0.1%
			Construction	0.043	0**	n/a**	0.020	0**	n/a**	1.00	-0.006	-0.6%
			Operation	0.043	0**	n/a**	0.020	0**	n/a**	1.00	-0.012	-1.1%
			Decomissioning & Reclamation	0.044	0**	n/a**	0.020	0**	n/a**	1.01	0.005	0.5%
			Post Closure	0.044	0**	n/a**	0.020	0**	n/a**	1.01	0.005	0.5%
Sensitivity #4	100-Year Wet	High	Baseline	0.044	n/a	n/a	0.020	n/a	n/a	1.01	n/a	n/a
			Bulk Sample	0.044	0**	n/a**	0.020	0**	n/a**	1.01	-0.001	-0.1%
			Construction	0.043	0**	n/a**	0.020	0**	n/a**	1.00	-0.006	-0.6%
			Operation	0.043	-0.001	-1.2%	0.020	0**	n/a**	1.00	-0.012	-1.1%
			Decomissioning & Reclamation	0.044	0**	n/a**	0.020	0**	n/a**	1.01	0.005	0.5%
			Post Closure	0.044	0**	n/a**	0.020	0**	n/a**	1.01	0.005	0.5%
Sensitivity #5	100-Year Wet	Low	Baseline	0.044	n/a	n/a	0.020	n/a	n/a	1.01	n/a	n/a
			Bulk Sample	0.044	0**	n/a**	0.020	0**	n/a**	1.01	-0.001	-0.1%
			Construction	0.043	0**	n/a**	0.020	0**	n/a**	1.00	-0.006	-0.6%
			Operation	0.043	-0.001	-1.2%	0.020	0**	n/a**	1.00	-0.012	-1.1%
			Decomissioning & Reclamation	0.044	0**	n/a**	0.020	0**	n/a**	1.01	0.005	0.5%
			Post Closure	0.044	0**	n/a**	0.020	0**	n/a**	1.01	0.005	0.5%
Sensitivity #6	100-Year Dry	Moderate	Baseline	0.005	n/a	n/a	0.002	n/a	n/a	0.11	n/a	n/a
			Bulk Sample	0.005	0**	n/a**	0.002	0**	n/a**	0.11	0**	n/a**
			Construction	0.005	0**	n/a**	0.002	0**	n/a**	0.11	-0.001	-0.6%
			Operation	0.005	0**	n/a**	0.002	0**	n/a**	0.11	-0.001	-1.1%
			Decomissioning & Reclamation	0.005	0**	n/a**	0.002	0**	n/a**	0.11	0.001	0.5%
			Post Closure	0.005	0**	n/a**	0.002	0**	n/a**	0.11	0.001	0.5%
Sensitivity #7	100-Year Dry	High	Baseline	0.005	n/a	n/a	0.002	n/a	n/a	0.11	n/a	n/a
			Bulk Sample	0.005	0**	n/a**	0.002	0**	n/a**	0.11	0**	n/a**
			Construction	0.005	0**	n/a**	0.002	0**	n/a**	0.11	-0.001	-0.6%
			Operation	0.005	0**	n/a**	0.002	0**	n/a**	0.11	-0.001	-1.1%
			Decomissioning & Reclamation	0.005	0**	n/a**	0.002	0**	n/a**	0.11	0.001	0.5%
			Post Closure	0.005	0**	n/a**	0.002	0**	n/a**	0.11	0.001	0.5%
Sensitivity #8	100-Year Dry	Low	Baseline	0.005	n/a	n/a	0.002	n/a	n/a	0.11	n/a	n/a
			Bulk Sample	0.005	0**	n/a**	0.002	0**	n/a**	0.11	0**	n/a**
			Construction	0.005	0**	n/a**	0.002	0**	n/a**	0.11	-0.001	-0.6%
			Operation	0.005	0**	n/a**	0.002	0**	n/a**	0.11	-0.001	-1.1%
			Decomissioning & Reclamation	0.005	0**	n/a**	0.002	0**	n/a**	0.11	0.001	0.5%
			Post Closure	0.005	0**	n/a**	0.002	0**	n/a**	0.11	0.001	0.5%

** Flows are less than 0.0005 m^3/s*

*** Flow changes are less than 0.0005 m^3/s*

Table 8.8-6. Sensitivity Analysis Scenario Results for Simulated Average Monthly Streamflows at M17B Creek

				January			February			March			April			May		
Scenario	Annual Precipitation	Groundwater Inflows into the Mine	Project Phase	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)
Base Case	Average	Moderate	Baseline	0*	n/a	n/a	0*	n/a	n/a	0*	n/a	n/a	0.005	n/a	n/a	0.021	n/a	n/a
			Bulk Sample	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.005	0**	n/a**	0.021	0**	n/a**
			Construction	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.005	0**	n/a**	0.021	0**	n/a**
			Operation	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.005	0**	n/a**	0.020	-0.001	-5.6%
			Decomissioning & Reclamation	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.005	-0.001	-11.3%	0.019	-0.002	-11.3%
			Post Closure	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.005	-0.001	-11.3%	0.019	-0.002	-11.3%
Sensitivity #1	Average	High	Baseline	0*	n/a	n/a	0*	n/a	n/a	0*	n/a	n/a	0.005	n/a	n/a	0.021	n/a	n/a
			Bulk Sample	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.005	0**	n/a**	0.021	0**	n/a**
			Construction	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.005	0**	n/a**	0.021	0**	n/a**
			Operation	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.005	0**	n/a**	0.020	-0.001	-5.6%
			Decomissioning & Reclamation	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.005	-0.001	-11.3%	0.019	-0.002	-11.3%
			Post Closure	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.005	-0.001	-11.3%	0.019	-0.002	-11.3%
Sensitivity #2	Average	Low	Baseline	0*	n/a	n/a	0*	n/a	n/a	0*	n/a	n/a	0.005	n/a	n/a	0.021	n/a	n/a
			Bulk Sample	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.005	0**	n/a**	0.021	0**	n/a**
			Construction	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.005	0**	n/a**	0.021	0**	n/a**
			Operation	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.005	0**	n/a**	0.020	-0.001	-5.6%
			Decomissioning & Reclamation	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.005	-0.001	-11.3%	0.019	-0.002	-11.3%
			Post Closure	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.005	-0.001	-11.3%	0.019	-0.002	-11.3%
Sensitivity #3	100-Year Wet	Moderate	Baseline	0*	n/a	n/a	0*	n/a	n/a	0.001	n/a	n/a	0.015	n/a	n/a	0.059	n/a	n/a
			Bulk Sample	0*	n/a*	n/a*	0*	n/a*	n/a*	0.001	0**	n/a**	0.015	0**	n/a**	0.059	0**	n/a**
			Construction	0*	n/a*	n/a*	0*	n/a*	n/a*	0.001	0**	n/a**	0.015	0**	n/a**	0.059	0**	n/a**
			Operation	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a**	0.014	-0.001	-5.5%	0.055	-0.003	-5.6%
			Decomissioning & Reclamation	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a**	0.013	-0.002	-11.3%	0.052	-0.007	-11.3%
			Post Closure	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a**	0.013	-0.002	-11.3%	0.052	-0.007	-11.3%
Sensitivity #4	100-Year Wet	High	Baseline	0*	n/a	n/a	0*	n/a	n/a	0.001	n/a	n/a	0.015	n/a	n/a	0.059	n/a	n/a
			Bulk Sample	0*	n/a*	n/a*	0*	n/a*	n/a*	0.001	0**	n/a**	0.015	0**	n/a**	0.059	0**	n/a**
			Construction	0*	n/a*	n/a*	0*	n/a*	n/a*	0.001	0**	n/a**	0.015	0**	n/a**	0.059	0**	n/a**
			Operation	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a**	0.014	-0.001	-5.5%	0.055	-0.003	-5.6%
			Decomissioning & Reclamation	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a**	0.013	-0.002	-11.3%	0.052	-0.007	-11.3%
			Post Closure	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a**	0.013	-0.002	-11.3%	0.052	-0.007	-11.3%
Sensitivity #5	100-Year Wet	Low	Baseline	0*	n/a	n/a	0*	n/a	n/a	0.001	n/a	n/a	0.015	n/a	n/a	0.059	n/a	n/a
			Bulk Sample	0*	n/a*	n/a*	0*	n/a*	n/a*	0.001	0**	n/a**	0.015	0**	n/a**	0.059	0**	n/a**
			Construction	0*	n/a*	n/a*	0*	n/a*	n/a*	0.001	0**	n/a**	0.015	0**	n/a**	0.059	0**	n/a**
			Operation	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a**	0.014	-0.001	-5.5%	0.055	-0.003	-5.6%
			Decomissioning & Reclamation	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a**	0.013	-0.002	-11.3%	0.052	-0.007	-11.3%
			Post Closure	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a**	0.013	-0.002	-11.3%	0.052	-0.007	-11.3%
Sensitivity #6	100-Year Dry	Moderate	Baseline	0*	n/a	n/a	0*	n/a	n/a	0*	n/a	n/a	0.002	n/a	n/a	0.006	n/a	n/a
			Bulk Sample	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.002	0**	n/a**	0.006	0**	n/a**
			Construction	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.002	0**	n/a**	0.006	0**	n/a**
			Operation	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.001	0**	n/a**	0.006	0**	n/a**
			Decomissioning & Reclamation	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.001	0**	n/a**	0.006	-0.001	-11.3%
			Post Closure	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.001	0**	n/a**	0.006	-0.001	-11.3%
Sensitivity #7	100-Year Dry	High	Baseline	0*	n/a	n/a	0*	n/a	n/a	0*	n/a	n/a	0.002	n/a	n/a	0.006	n/a	n/a
			Bulk Sample	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.002	0**	n/a**	0.006	0**	n/a**
			Construction	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.002	0**	n/a**	0.006	0**	n/a**
			Operation	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.001	0**	n/a**	0.006	0**	n/a**
			Decomissioning & Reclamation	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.001	0**	n/a**	0.006	-0.001	-11.3%
			Post Closure	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.001	0**	n/a**	0.006	-0.001	-11.3%
Sensitivity #8	100-Year Dry	Low	Baseline	0*	n/a	n/a	0*	n/a	n/a	0*	n/a	n/a	0.002	n/a	n/a	0.006	n/a	n/a
			Bulk Sample	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.002	0**	n/a**	0.006	0**	n/a**
			Construction	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.002	0**	n/a**	0.006	0**	n/a**
			Operation	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.001	0**	n/a**	0.006	0**	n/a**
			Decomissioning & Reclamation	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.001	0**	n/a**	0.006	-0.001	-11.3%
			Post Closure	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*	0.001	0**	n/a**	0.006	-0.001	-11.3%

(continued)

Table 8.8-6. Sensitivity Analysis Scenario Results for Simulated Average Monthly Streamflows at M17B Creek (continued)

				June			July			August			September			October		
Scenario	Annual Precipitation	Groundwater Inflows into the Mine	Project Phase	Flow (m³/s)	Change from Baseline (m³/s)	Change from Baseline (% of Baseline Flow)	Flow (m³/s)	Change from Baseline (m³/s)	Change from Baseline (% of Baseline Flow)	Flow (m³/s)	Change from Baseline (m³/s)	Change from Baseline (% of Baseline Flow)	Flow (m³/s)	Change from Baseline (m³/s)	Change from Baseline (% of Baseline Flow)	Flow (m³/s)	Change from Baseline (m³/s)	Change from Baseline (% of Baseline Flow)
Base Case	Average	Moderate	Baseline	0.012	n/a	n/a	0.002	n/a	n/a	0.001	n/a	n/a	0*	n/a	n/a	0.001	n/a	n/a
			Bulk Sample	0.012	0**	n/a**	0.002	0**	n/a**	0.001	0**	n/a**	0*	n/a*	n/a*	0.001	0**	n/a**
			Construction	0.012	0**	n/a**	0.002	0**	n/a**	0.001	0**	n/a**	0*	n/a*	n/a*	0.001	0**	n/a**
			Operation	0.012	-0.001	-5.6%	0.002	0**	n/a**	0.001	0**	n/a**	0*	n/a*	n/a*	0.001	0**	n/a**
			Decomissioning & Reclamation	0.011	-0.001	-11.3%	0.002	0**	n/a**	0.001	0**	n/a**	0*	n/a*	n/a*	0.001	0**	n/a**
			Post Closure	0.011	-0.001	-11.3%	0.002	0**	n/a**	0.001	0**	n/a**	0*	n/a*	n/a*	0.001	0**	n/a**
Sensitivity #1	Average	High	Baseline	0.012	n/a	n/a	0.002	n/a	n/a	0.001	n/a	n/a	0*	n/a	n/a	0.001	n/a	n/a
			Bulk Sample	0.012	0**	n/a**	0.002	0**	n/a**	0.001	0**	n/a**	0*	n/a*	n/a*	0.001	0**	n/a**
			Construction	0.012	0**	n/a**	0.002	0**	n/a**	0.001	0**	n/a**	0*	n/a*	n/a*	0.001	0**	n/a**
			Operation	0.012	-0.001	-5.6%	0.002	0**	n/a**	0.001	0**	n/a**	0*	n/a*	n/a*	0.001	0**	n/a**
			Decomissioning & Reclamation	0.011	-0.001	-11.3%	0.002	0**	n/a**	0.001	0**	n/a**	0*	n/a*	n/a*	0.001	0**	n/a**
			Post Closure	0.011	-0.001	-11.3%	0.002	0**	n/a**	0.001	0**	n/a**	0*	n/a*	n/a*	0.001	0**	n/a**
Sensitivity #2	Average	Low	Baseline	0.012	n/a	n/a	0.002	n/a	n/a	0.001	n/a	n/a	0*	n/a	n/a	0.001	n/a	n/a
			Bulk Sample	0.012	0**	n/a**	0.002	0**	n/a**	0.001	0**	n/a**	0*	n/a*	n/a*	0.001	0**	n/a**
			Construction	0.012	0**	n/a**	0.002	0**	n/a**	0.001	0**	n/a**	0*	n/a*	n/a*	0.001	0**	n/a**
			Operation	0.012	-0.001	-5.6%	0.002	0**	n/a**	0.001	0**	n/a**	0*	n/a*	n/a*	0.001	0**	n/a**
			Decomissioning & Reclamation	0.011	-0.001	-11.3%	0.002	0**	n/a**	0.001	0**	n/a**	0*	n/a*	n/a*	0.001	0**	n/a**
			Post Closure	0.011	-0.001	-11.3%	0.002	0**	n/a**	0.001	0**	n/a**	0*	n/a*	n/a*	0.001	0**	n/a**
Sensitivity #3	100-Year Wet	Moderate	Baseline	0.035	n/a	n/a	0.007	n/a	n/a	0.003	n/a	n/a	0.001	n/a	n/a	0.003	n/a	n/a
			Bulk Sample	0.035	0**	n/a**	0.007	0**	n/a**	0.003	0**	n/a**	0.001	0**	n/a**	0.003	0**	n/a**
			Construction	0.035	0**	n/a**	0.007	0**	n/a**	0.003	0**	n/a**	0.001	0**	n/a**	0.003	0**	n/a**
			Operation	0.033	-0.002	-5.6%	0.006	0**	n/a**	0.002	0**	n/a**	0.001	0**	n/a**	0.003	0**	n/a**
			Decomissioning & Reclamation	0.031	-0.004	-11.3%	0.006	-0.001	-11.3%	0.002	0**	n/a**	0.001	0**	n/a**	0.003	0**	n/a**
			Post Closure	0.031	-0.004	-11.3%	0.006	-0.001	-11.3%	0.002	0**	n/a**	0.001	0**	n/a**	0.003	0**	n/a**
Sensitivity #4	100-Year Wet	High	Baseline	0.035	n/a	n/a	0.007	n/a	n/a	0.003	n/a	n/a	0.001	n/a	n/a	0.003	n/a	n/a
			Bulk Sample	0.035	0**	n/a**	0.007	0**	n/a**	0.003	0**	n/a**	0.001	0**	n/a**	0.003	0**	n/a**
			Construction	0.035	0**	n/a**	0.007	0**	n/a**	0.003	0**	n/a**	0.001	0**	n/a**	0.003	0**	n/a**
			Operation	0.033	-0.002	-5.6%	0.006	0**	n/a**	0.002	0**	n/a**	0.001	0**	n/a**	0.003	0**	n/a**
			Decomissioning & Reclamation	0.031	-0.004	-11.3%	0.006	-0.001	-11.3%	0.002	0**	n/a**	0.001	0**	n/a**	0.003	0**	n/a**
			Post Closure	0.031	-0.004	-11.3%	0.006	-0.001	-11.3%	0.002	0**	n/a**	0.001	0**	n/a**	0.003	0**	n/a**
Sensitivity #5	100-Year Wet	Low	Baseline	0.035	n/a	n/a	0.007	n/a	n/a	0.003	n/a	n/a	0.001	n/a	n/a	0.003	n/a	n/a
			Bulk Sample	0.035	0**	n/a**	0.007	0**	n/a**	0.003	0**	n/a**	0.001	0**	n/a**	0.003	0**	n/a**
			Construction	0.035	0**	n/a**	0.007	0**	n/a**	0.003	0**	n/a**	0.001	0**	n/a**	0.003	0**	n/a**
			Operation	0.033	-0.002	-5.6%	0.006	0**	n/a**	0.002	0**	n/a**	0.001	0**	n/a**	0.003	0**	n/a**
			Decomissioning & Reclamation	0.031	-0.004	-11.3%	0.006	-0.001	-11.3%	0.002	0**	n/a**	0.001	0**	n/a**	0.003	0**	n/a**
			Post Closure	0.031	-0.004	-11.3%	0.006	-0.001	-11.3%	0.002	0**	n/a**	0.001	0**	n/a**	0.003	0**	n/a**
Sensitivity #6	100-Year Dry	Moderate	Baseline	0.004	n/a	n/a	0.001	n/a	n/a	0*	n/a	n/a	0*	n/a	n/a	0*	n/a	n/a
			Bulk Sample	0.004	0**	n/a**	0.001	0**	n/a**	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*
			Construction	0.004	0**	n/a**	0.001	0**	n/a**	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*
			Operation	0.004	0**	n/a**	0.001	0**	n/a**	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*
			Decomissioning & Reclamation	0.003	0**	n/a**	0.001	0**	n/a**	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*
			Post Closure	0.003	0**	n/a**	0.001	0**	n/a**	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*
Sensitivity #7	100-Year Dry	High	Baseline	0.004	n/a	n/a	0.001	n/a	n/a	0*	n/a	n/a	0*	n/a	n/a	0*	n/a	n/a
			Bulk Sample	0.004	0**	n/a**	0.001	0**	n/a**	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*
			Construction	0.004	0**	n/a**	0.001	0**	n/a**	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*
			Operation	0.004	0**	n/a**	0.001	0**	n/a**	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*
			Decomissioning & Reclamation	0.003	0**	n/a**	0.001	0**	n/a**	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*
			Post Closure	0.003	0**	n/a**	0.001	0**	n/a**	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*
Sensitivity #8	100-Year Dry	Low	Baseline	0.004	n/a	n/a	0.001	n/a	n/a	0*	n/a	n/a	0*	n/a	n/a	0*	n/a	n/a
			Bulk Sample	0.004	0**	n/a**	0.001	0**	n/a**	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*
			Construction	0.004	0**	n/a**	0.001	0**	n/a**	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*
			Operation	0.004	0**	n/a**	0.001	0**	n/a**	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*
			Decomissioning & Reclamation	0.003	0**	n/a**	0.001	0**	n/a**	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*
			Post Closure	0.003	0**	n/a**	0.001	0**	n/a**	0*	n/a*	n/a*	0*	n/a*	n/a*	0*	n/a*	n/a*

(continued)

Table 8.8-6. Sensitivity Analysis Scenario Results for Simulated Average Monthly Streamflows at M17B Creek (completed)

				November			December			Annual		
Scenario	Annual Precipitation	Groundwater Inflows into the Mine	Project Phase	Flow (m³/s)	Change from Baseline (m³/s)	Change from Baseline (% of Baseline Flow)	Flow (m³/s)	Change from Baseline (m³/s)	Change from Baseline (% of Baseline Flow)	Flow (m³/s)	Change from Baseline (m³/s)	Change from Baseline (% of Baseline Flow)
Base Case	Average	Moderate	Baseline	0.001	n/a	n/a	0*	n/a	n/a	0.00	n/a	n/a
			Bulk Sample	0.001	0**	n/a**	0*	n/a*	n/a*	0.00	0**	n/a**
			Construction	0.001	0**	n/a**	0*	n/a*	n/a*	0.00	0**	n/a**
			Operation	0.001	0**	n/a**	0*	n/a*	n/a*	0.00	0**	n/a**
			Decomissioning & Reclamation	0.001	0**	n/a**	0*	n/a*	n/a*	0.00	0**	n/a**
			Post Closure	0.001	0**	n/a**	0*	n/a*	n/a*	0.00	0**	n/a**
Sensitivity #1	Average	High	Baseline	0.001	n/a	n/a	0*	n/a	n/a	0.00	n/a	n/a
			Bulk Sample	0.001	0**	n/a**	0*	n/a*	n/a*	0.00	0**	n/a**
			Construction	0.001	0**	n/a**	0*	n/a*	n/a*	0.00	0**	n/a**
			Operation	0.001	0**	n/a**	0*	n/a*	n/a*	0.00	0**	n/a**
			Decomissioning & Reclamation	0.001	0**	n/a**	0*	n/a*	n/a*	0.00	0**	n/a**
			Post Closure	0.001	0**	n/a**	0*	n/a*	n/a*	0.00	0**	n/a**
Sensitivity #2	Average	Low	Baseline	0.001	n/a	n/a	0*	n/a	n/a	0.00	n/a	n/a
			Bulk Sample	0.001	0**	n/a**	0*	n/a*	n/a*	0.00	0**	n/a**
			Construction	0.001	0**	n/a**	0*	n/a*	n/a*	0.00	0**	n/a**
			Operation	0.001	0**	n/a**	0*	n/a*	n/a*	0.00	0**	n/a**
			Decomissioning & Reclamation	0.001	0**	n/a**	0*	n/a*	n/a*	0.00	0**	n/a**
			Post Closure	0.001	0**	n/a**	0*	n/a*	n/a*	0.00	0**	n/a**
Sensitivity #3	100-Year Wet	Moderate	Baseline	0.002	n/a	n/a	0.001	n/a	n/a	0.01	n/a	n/a
			Bulk Sample	0.002	0**	n/a**	0.001	0**	n/a**	0.01	0**	n/a**
			Construction	0.002	0**	n/a**	0.001	0**	n/a**	0.01	0**	n/a**
			Operation	0.002	0**	n/a**	0.001	0**	n/a**	0.01	-0.001	-5.6%
			Decomissioning & Reclamation	0.001	0**	n/a**	0.001	0**	n/a**	0.01	-0.001	-11.3%
			Post Closure	0.001	0**	n/a**	0.001	0**	n/a**	0.01	-0.001	-11.3%
Sensitivity #4	100-Year Wet	High	Baseline	0.002	n/a	n/a	0.001	n/a	n/a	0.01	n/a	n/a
			Bulk Sample	0.002	0**	n/a**	0.001	0**	n/a**	0.01	0**	n/a**
			Construction	0.002	0**	n/a**	0.001	0**	n/a**	0.01	0**	n/a**
			Operation	0.002	0**	n/a**	0.001	0**	n/a**	0.01	-0.001	-5.6%
			Decomissioning & Reclamation	0.001	0**	n/a**	0.001	0**	n/a**	0.01	-0.001	-11.3%
			Post Closure	0.001	0**	n/a**	0.001	0**	n/a**	0.01	-0.001	-11.3%
Sensitivity #5	100-Year Wet	Low	Baseline	0.002	n/a	n/a	0.001	n/a	n/a	0.01	n/a	n/a
			Bulk Sample	0.002	0**	n/a**	0.001	0**	n/a**	0.01	0**	n/a**
			Construction	0.002	0**	n/a**	0.001	0**	n/a**	0.01	0**	n/a**
			Operation	0.002	0**	n/a**	0.001	0**	n/a**	0.01	-0.001	-5.6%
			Decomissioning & Reclamation	0.001	0**	n/a**	0.001	0**	n/a**	0.01	-0.001	-11.3%
			Post Closure	0.001	0**	n/a**	0.001	0**	n/a**	0.01	-0.001	-11.3%
Sensitivity #6	100-Year Dry	Moderate	Baseline	0*	n/a	n/a	0*	n/a	n/a	0.00	n/a	n/a
			Bulk Sample	0*	n/a*	n/a*	0*	n/a*	n/a*	0.00	0**	n/a**
			Construction	0*	n/a*	n/a*	0*	n/a*	n/a*	0.00	0**	n/a**
			Operation	0*	n/a*	n/a*	0*	n/a*	n/a*	0.00	0**	n/a**
			Decomissioning & Reclamation	0*	n/a*	n/a*	0*	n/a*	n/a*	0.00	0**	n/a**
			Post Closure	0*	n/a*	n/a*	0*	n/a*	n/a*	0.00	0**	n/a**
Sensitivity #7	100-Year Dry	High	Baseline	0*	n/a	n/a	0*	n/a	n/a	0.00	n/a	n/a
			Bulk Sample	0*	n/a*	n/a*	0*	n/a*	n/a*	0.00	0**	n/a**
			Construction	0*	n/a*	n/a*	0*	n/a*	n/a*	0.00	0**	n/a**
			Operation	0*	n/a*	n/a*	0*	n/a*	n/a*	0.00	0**	n/a**
			Decomissioning & Reclamation	0*	n/a*	n/a*	0*	n/a*	n/a*	0.00	0**	n/a**
			Post Closure	0*	n/a*	n/a*	0*	n/a*	n/a*	0.00	0**	n/a**
Sensitivity #8	100-Year Dry	Low	Baseline	0*	n/a	n/a	0*	n/a	n/a	0.00	n/a	n/a
			Bulk Sample	0*	n/a*	n/a*	0*	n/a*	n/a*	0.00	0**	n/a**
			Construction	0*	n/a*	n/a*	0*	n/a*	n/a*	0.00	0**	n/a**
			Operation	0*	n/a*	n/a*	0*	n/a*	n/a*	0.00	0**	n/a**
			Decomissioning & Reclamation	0*	n/a*	n/a*	0*	n/a*	n/a*	0.00	0**	n/a**
			Post Closure	0*	n/a*	n/a*	0*	n/a*	n/a*	0.00	0**	n/a**

** Flows are less than 0.0005 m³/s*

*** Flow changes are less than 0.0005 m³/s*

Table 8.8-7. Sensitivity Analysis Scenario Results for Simulated Average Monthly Streamflows at M20 Creek

				January			February			March			April			May		
Scenario	Annual Precipitation	Groundwater Inflows into the Mine	Project Phase	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)
Base Case	Average	Moderate	Baseline	0.050	n/a	n/a	0.050	n/a	n/a	0.051	n/a	n/a	0.194	n/a	n/a	2.641	n/a	n/a
			Bulk Sample	0.049	0**	n/a**	0.049	0**	n/a**	0.051	0**	n/a**	0.193	0**	n/a**	2.643	0.002	0.1%
			Construction	0.048	-0.002	-3.4%	0.048	-0.002	-3.5%	0.050	-0.002	-3.4%	0.192	-0.002	-0.9%	2.644	0.004	0.1%
			Operation	0.045	-0.005	-9.2%	0.045	-0.005	-9.2%	0.047	-0.005	-9.0%	0.189	-0.005	-2.4%	2.641	0.001	0.0%
			Decommissioning & Reclamation	0.045	-0.005	-9.2%	0.045	-0.005	-9.2%	0.047	-0.005	-9.0%	0.189	-0.005	-2.4%	2.641	0.001	0.0%
			Post Closure	0.045	-0.005	-9.2%	0.045	-0.005	-9.2%	0.047	-0.005	-9.0%	0.189	-0.005	-2.4%	2.641	0.001	0.0%
Sensitivity #1	Average	High	Baseline	0.050	n/a	n/a	0.050	n/a	n/a	0.051	n/a	n/a	0.194	n/a	n/a	2.641	n/a	n/a
			Bulk Sample	0.049	-0.001	-1.1%	0.049	-0.001	-1.3%	0.051	-0.001	-1.3%	0.193	-0.001	-0.4%	2.642	0.002	0.1%
			Construction	0.047	-0.003	-5.9%	0.047	-0.003	-6.0%	0.048	-0.003	-6.0%	0.190	-0.003	-1.6%	2.643	0.002	0.1%
			Operation	0.042	-0.008	-15.9%	0.042	-0.008	-16.0%	0.043	-0.008	-15.5%	0.186	-0.008	-4.1%	2.638	-0.003	-0.1%
			Decommissioning & Reclamation	0.042	-0.008	-15.9%	0.042	-0.008	-16.0%	0.043	-0.008	-15.5%	0.186	-0.008	-4.1%	2.638	-0.003	-0.1%
			Post Closure	0.042	-0.008	-15.9%	0.042	-0.008	-16.0%	0.043	-0.008	-15.5%	0.186	-0.008	-4.1%	2.638	-0.003	-0.1%
Sensitivity #2	Average	Low	Baseline	0.050	n/a	n/a	0.050	n/a	n/a	0.051	n/a	n/a	0.194	n/a	n/a	2.641	n/a	n/a
			Bulk Sample	0.050	0**	n/a**	0.050	0**	n/a**	0.051	0**	n/a**	0.193	0**	n/a**	2.643	0.003	0.1%
			Construction	0.049	0**	n/a**	0.049	0**	n/a**	0.051	0**	n/a**	0.193	0**	n/a**	2.646	0.005	0.2%
			Operation	0.049	-0.001	-2.1%	0.049	-0.001	-2.2%	0.050	-0.001	-2.1%	0.192	-0.001	-0.6%	2.645	0.004	0.2%
			Decommissioning & Reclamation	0.049	-0.001	-2.1%	0.049	-0.001	-2.2%	0.050	-0.001	-2.1%	0.192	-0.001	-0.6%	2.645	0.004	0.2%
			Post Closure	0.049	-0.001	-2.1%	0.049	-0.001	-2.2%	0.050	-0.001	-2.1%	0.192	-0.001	-0.6%	2.645	0.004	0.2%
Sensitivity #3	100-Year Wet	Moderate	Baseline	0.139	n/a	n/a	0.139	n/a	n/a	0.144	n/a	n/a	0.542	n/a	n/a	7.401	n/a	n/a
			Bulk Sample	0.139	0**	n/a**	0.139	0**	n/a**	0.143	0**	n/a**	0.544	0**	n/a**	7.402	0**	n/a**
			Construction	0.138	-0.002	-1.2%	0.137	-0.002	-1.2%	0.142	-0.002	-1.2%	0.544	0.002	0.4%	7.402	0**	n/a**
			Operation	0.135	-0.005	-3.3%	0.135	-0.005	-3.3%	0.139	-0.005	-3.2%	0.541	0.000	-0.1%	7.399	-0.002	0.0%
			Decommissioning & Reclamation	0.135	-0.005	-3.3%	0.135	-0.005	-3.3%	0.139	-0.005	-3.2%	0.541	0.000	-0.1%	7.399	-0.002	0.0%
			Post Closure	0.135	-0.005	-3.3%	0.135	-0.005	-3.3%	0.139	-0.005	-3.2%	0.541	0.000	-0.1%	7.399	-0.002	0.0%
Sensitivity #4	100-Year Wet	High	Baseline	0.139	n/a	n/a	0.139	n/a	n/a	0.144	n/a	n/a	0.542	n/a	n/a	7.401	n/a	n/a
			Bulk Sample	0.139	-0.001	-0.4%	0.139	-0.001	-0.5%	0.143	-0.001	-0.5%	0.543	0.001	0.2%	7.401	0.001	0.0%
			Construction	0.136	-0.003	-2.1%	0.136	-0.003	-2.2%	0.141	-0.003	-2.1%	0.543	0.001	0.2%	7.400	0**	n/a**
			Operation	0.131	-0.008	-5.7%	0.131	-0.008	-5.7%	0.136	-0.008	-5.5%	0.538	-0.004	-0.7%	7.396	-0.005	-0.1%
			Decommissioning & Reclamation	0.131	-0.008	-5.7%	0.131	-0.008	-5.7%	0.136	-0.008	-5.5%	0.538	-0.004	-0.7%	7.396	-0.005	-0.1%
			Post Closure	0.131	-0.008	-5.7%	0.131	-0.008	-5.7%	0.136	-0.008	-5.5%	0.538	-0.004	-0.7%	7.396	-0.005	-0.1%
Sensitivity #5	100-Year Wet	Low	Baseline	0.139	n/a	n/a	0.139	n/a	n/a	0.144	n/a	n/a	0.542	n/a	n/a	7.401	n/a	n/a
			Bulk Sample	0.139	0**	n/a**	0.139	0**	n/a**	0.144	0**	n/a**	0.544	0.002	0.4%	7.402	0.001	0.0%
			Construction	0.139	0**	n/a**	0.139	0**	n/a**	0.143	0**	n/a**	0.546	0.004	0.7%	7.403	0.002	0.0%
			Operation	0.138	-0.001	-0.8%	0.138	-0.001	-0.8%	0.143	-0.001	-0.7%	0.545	0.003	0.6%	7.402	0.002	0.0%
			Decommissioning & Reclamation	0.138	-0.001	-0.8%	0.138	-0.001	-0.8%	0.143	-0.001	-0.7%	0.545	0.003	0.6%	7.402	0.002	0.0%
			Post Closure	0.138	-0.001	-0.8%	0.138	-0.001	-0.8%	0.143	-0.001	-0.7%	0.545	0.003	0.6%	7.402	0.002	0.0%
Sensitivity #6	100-Year Dry	Moderate	Baseline	0.015	n/a	n/a	0.015	n/a	n/a	0.015	n/a	n/a	0.058	n/a	n/a	0.791	n/a	n/a
			Bulk Sample	0.015	0**	n/a**	0.015	0**	n/a**	0.015	0**	n/a**	0.058	0**	n/a**	0.791	0**	n/a**
			Construction	0.013	-0.002	-11.4%	0.013	-0.002	-11.6%	0.014	-0.002	-11.5%	0.056	-0.002	-3.1%	0.792	0.001	0.2%
			Operation	0.010	-0.005	-30.6%	0.010	-0.005	-30.7%	0.011	-0.005	-29.9%	0.054	-0.004	-7.6%	0.789	-0.002	-0.2%
			Decommissioning & Reclamation	0.010	-0.005	-30.6%	0.010	-0.005	-30.7%	0.011	-0.005	-29.9%	0.054	-0.004	-7.6%	0.789	-0.002	-0.2%
			Post Closure	0.010	-0.005	-30.6%	0.010	-0.005	-30.7%	0.011	-0.005	-29.9%	0.054	-0.004	-7.6%	0.789	-0.002	-0.2%
Sensitivity #7	100-Year Dry	High	Baseline	0.015	n/a	n/a	0.015	n/a	n/a	0.015	n/a	n/a	0.058	n/a	n/a	0.791	n/a	n/a
			Bulk Sample	0.014	-0.001	-3.8%	0.014	-0.001	-4.2%	0.015	-0.001	-4.5%	0.057	-0.001	-1.3%	0.791	0**	n/a**
			Construction	0.012	-0.003	-19.7%	0.012	-0.003	-20.1%	0.012	-0.003	-19.9%	0.055	-0.003	-5.4%	0.791	0**	n/a**
			Operation	0.007	-0.008	-53.1%	0.007	-0.008	-53.3%	0.007	-0.008	-51.8%	0.050	-0.008	-13.4%	0.786	-0.005	-0.7%
			Decommissioning & Reclamation	0.007	-0.008	-53.1%	0.007	-0.008	-53.3%	0.007	-0.008	-51.8%	0.050	-0.008	-13.4%	0.786	-0.005	-0.7%
			Post Closure	0.007	-0.008	-53.1%	0.007	-0.008	-53.3%	0.007	-0.008	-51.8%	0.050	-0.008	-13.4%	0.786	-0.005	-0.7%
Sensitivity #8	100-Year Dry	Low	Baseline	0.015	n/a	n/a	0.015	n/a	n/a	0.015	n/a	n/a	0.058	n/a	n/a	0.791	n/a	n/a
			Bulk Sample	0.015	0**	n/a**	0.015	0**	n/a**	0.015	0**	n/a**	0.058	0**	n/a**	0.792	0.001	0.1%
			Construction	0.015	0**	n/a**	0.015	0**	n/a**	0.015	0**	n/a**	0.058	0**	n/a**	0.794	0.003	0.3%
			Operation	0.014	-0.001	-7.1%	0.014	-0.001	-7.2%	0.014	-0.001	-7.0%	0.057	-0.001	-1.5%	0.793	0.002	0.2%
			Decommissioning & Reclamation	0.014	-0.001	-7.1%	0.014	-0.001	-7.2%	0.014	-0.001	-7.0%	0.057	-0.001	-1.5%	0.793	0.002	0.2%
			Post Closure	0.014	-0.001	-7.1%	0.014	-0.001	-7.2%	0.014	-0.001	-7.0%	0.057	-0.001	-1.5%	0.793	0.002	0.2%

(continued)

Table 8.8-7. Sensitivity Analysis Scenario Results for Simulated Average Monthly Streamflows at M20 Creek (continued)

				June			July			August			September			October		
Scenario	Annual Precipitation	Groundwater Inflows into the Mine	Project Phase	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)
Base Case	Average	Moderate	Baseline	1.467	n/a	n/a	0.394	n/a	n/a	0.533	n/a	n/a	0.077	n/a	n/a	0.118	n/a	n/a
			Bulk Sample	1.466	-0.001	0.0%	0.393	-0.001	-0.1%	0.532	-0.001	-0.1%	0.076	-0.001	-0.8%	0.117	-0.001	-0.5%
			Construction	1.465	-0.002	-0.1%	0.392	-0.002	-0.5%	0.531	-0.002	-0.4%	0.075	-0.002	-2.6%	0.116	-0.002	-1.7%
			Operation	1.462	-0.005	-0.3%	0.389	-0.005	-1.2%	0.528	-0.005	-0.9%	0.072	-0.005	-6.1%	0.113	-0.005	-4.0%
			Decommissioning & Reclamation	1.462	-0.005	-0.3%	0.389	-0.005	-1.2%	0.528	-0.005	-0.9%	0.072	-0.005	-6.1%	0.113	-0.005	-4.0%
			Post Closure	1.462	-0.005	-0.3%	0.389	-0.005	-1.2%	0.528	-0.005	-0.9%	0.072	-0.005	-6.1%	0.113	-0.005	-4.0%
Sensitivity #1	Average	High	Baseline	1.467	n/a	n/a	0.394	n/a	n/a	0.533	n/a	n/a	0.077	n/a	n/a	0.118	n/a	n/a
			Bulk Sample	1.466	-0.001	-0.1%	0.393	-0.001	-0.2%	0.532	-0.001	-0.2%	0.076	-0.001	-1.4%	0.117	-0.001	-0.9%
			Construction	1.464	-0.003	-0.2%	0.390	-0.003	-0.8%	0.529	-0.003	-0.6%	0.074	-0.003	-4.5%	0.115	-0.003	-3.0%
			Operation	1.459	-0.008	-0.6%	0.385	-0.008	-2.1%	0.525	-0.008	-1.5%	0.069	-0.008	-10.6%	0.110	-0.008	-6.9%
			Decommissioning & Reclamation	1.459	-0.008	-0.6%	0.385	-0.008	-2.1%	0.525	-0.008	-1.5%	0.069	-0.008	-10.6%	0.110	-0.008	-6.9%
			Post Closure	1.459	-0.008	-0.6%	0.385	-0.008	-2.1%	0.525	-0.008	-1.5%	0.069	-0.008	-10.6%	0.110	-0.008	-6.9%
Sensitivity #2	Average	Low	Baseline	1.467	n/a	n/a	0.394	n/a	n/a	0.533	n/a	n/a	0.077	n/a	n/a	0.118	n/a	n/a
			Bulk Sample	1.467	0**	n/a**	0.393	0**	n/a**	0.533	0**	n/a**	0.077	0**	n/a**	0.118	0**	n/a**
			Construction	1.466	-0.001	0.0%	0.393	0**	n/a**	0.532	0**	n/a**	0.077	0**	n/a**	0.118	0**	n/a**
			Operation	1.466	-0.001	-0.1%	0.392	-0.001	-0.3%	0.532	-0.001	-0.2%	0.076	-0.001	-1.4%	0.117	-0.001	-0.9%
			Decommissioning & Reclamation	1.466	-0.001	-0.1%	0.392	-0.001	-0.3%	0.532	-0.001	-0.2%	0.076	-0.001	-1.4%	0.117	-0.001	-0.9%
			Post Closure	1.466	-0.001	-0.1%	0.392	-0.001	-0.3%	0.532	-0.001	-0.2%	0.076	-0.001	-1.4%	0.117	-0.001	-0.9%
Sensitivity #3	100-Year Wet	Moderate	Baseline	4.108	n/a	n/a	1.104	n/a	n/a	1.492	n/a	n/a	0.216	n/a	n/a	0.330	n/a	n/a
			Bulk Sample	4.107	0**	n/a**	1.103	0**	n/a**	1.491	0**	n/a**	0.215	0**	n/a**	0.330	0**	n/a**
			Construction	4.106	-0.002	0.0%	1.102	-0.002	-0.2%	1.490	-0.002	-0.1%	0.214	-0.002	-0.9%	0.328	-0.002	-0.6%
			Operation	4.103	-0.005	-0.1%	1.099	-0.005	-0.4%	1.487	-0.005	-0.3%	0.211	-0.005	-2.2%	0.326	-0.005	-1.4%
			Decommissioning & Reclamation	4.103	-0.005	-0.1%	1.099	-0.005	-0.4%	1.487	-0.005	-0.3%	0.211	-0.005	-2.2%	0.326	-0.005	-1.4%
			Post Closure	4.103	-0.005	-0.1%	1.099	-0.005	-0.4%	1.487	-0.005	-0.3%	0.211	-0.005	-2.2%	0.326	-0.005	-1.4%
Sensitivity #4	100-Year Wet	High	Baseline	4.108	n/a	n/a	1.104	n/a	n/a	1.492	n/a	n/a	0.216	n/a	n/a	0.330	n/a	n/a
			Bulk Sample	4.107	-0.001	0.0%	1.103	-0.001	-0.1%	1.491	-0.001	-0.1%	0.215	-0.001	-0.5%	0.329	-0.001	-0.3%
			Construction	4.105	-0.003	-0.1%	1.100	-0.003	-0.3%	1.488	-0.003	-0.2%	0.212	-0.003	-1.6%	0.327	-0.003	-1.1%
			Operation	4.100	-0.008	-0.2%	1.096	-0.008	-0.7%	1.484	-0.008	-0.5%	0.208	-0.008	-3.8%	0.322	-0.008	-2.5%
			Decommissioning & Reclamation	4.100	-0.008	-0.2%	1.096	-0.008	-0.7%	1.484	-0.008	-0.5%	0.208	-0.008	-3.8%	0.322	-0.008	-2.5%
			Post Closure	4.100	-0.008	-0.2%	1.096	-0.008	-0.7%	1.484	-0.008	-0.5%	0.208	-0.008	-3.8%	0.322	-0.008	-2.5%
Sensitivity #5	100-Year Wet	Low	Baseline	4.108	n/a	n/a	1.104	n/a	n/a	1.492	n/a	n/a	0.216	n/a	n/a	0.330	n/a	n/a
			Bulk Sample	4.108	0**	n/a**	1.104	0**	n/a**	1.492	0**	n/a**	0.216	0**	n/a**	0.330	0**	n/a**
			Construction	4.107	0**	n/a**	1.103	0**	n/a**	1.491	0**	n/a**	0.215	0**	n/a**	0.330	0**	n/a**
			Operation	4.107	-0.001	0.0%	1.103	-0.001	-0.1%	1.491	-0.001	-0.1%	0.215	-0.001	-0.5%	0.329	-0.001	-0.3%
			Decommissioning & Reclamation	4.107	-0.001	0.0%	1.103	-0.001	-0.1%	1.491	-0.001	-0.1%	0.215	-0.001	-0.5%	0.329	-0.001	-0.3%
			Post Closure	4.107	-0.001	0.0%	1.103	-0.001	-0.1%	1.491	-0.001	-0.1%	0.215	-0.001	-0.5%	0.329	-0.001	-0.3%
Sensitivity #6	100-Year Dry	Moderate	Baseline	0.439	n/a	n/a	0.117	n/a	n/a	0.160	n/a	n/a	0.023	n/a	n/a	0.035	n/a	n/a
			Bulk Sample	0.439	0**	n/a**	0.117	-0.001	-0.5%	0.159	-0.001	-0.4%	0.022	-0.001	-2.6%	0.035	-0.001	-1.8%
			Construction	0.437	-0.002	-0.4%	0.115	-0.002	-1.6%	0.158	-0.002	-1.2%	0.021	-0.002	-8.6%	0.033	-0.002	-5.7%
			Operation	0.435	-0.004	-0.9%	0.113	-0.004	-3.6%	0.155	-0.005	-2.9%	0.018	-0.005	-20.3%	0.031	-0.005	-13.3%
			Decommissioning & Reclamation	0.435	-0.004	-0.9%	0.113	-0.004	-3.6%	0.155	-0.005	-2.9%	0.018	-0.005	-20.3%	0.031	-0.005	-13.3%
			Post Closure	0.435	-0.004	-0.9%	0.113	-0.004	-3.6%	0.155	-0.005	-2.9%	0.018	-0.005	-20.3%	0.031	-0.005	-13.3%
Sensitivity #7	100-Year Dry	High	Baseline	0.439	n/a	n/a	0.117	n/a	n/a	0.160	n/a	n/a	0.023	n/a	n/a	0.035	n/a	n/a
			Bulk Sample	0.439	0**	n/a**	0.116	-0.001	-0.8%	0.159	-0.001	-0.6%	0.022	-0.001	-4.6%	0.034	-0.001	-3.1%
			Construction	0.436	-0.003	-0.7%	0.114	-0.003	-2.8%	0.156	-0.003	-2.1%	0.020	-0.003	-14.9%	0.032	-0.003	-9.9%
			Operation	0.431	-0.008	-1.7%	0.110	-0.008	-6.6%	0.152	-0.008	-5.1%	0.015	-0.008	-35.2%	0.027	-0.008	-23.1%
			Decommissioning & Reclamation	0.431	-0.008	-1.7%	0.110	-0.008	-6.6%	0.152	-0.008	-5.1%	0.015	-0.008	-35.2%	0.027	-0.008	-23.1%
			Post Closure	0.431	-0.008	-1.7%	0.110	-0.008	-6.6%	0.152	-0.008	-5.1%	0.015	-0.008	-35.2%	0.027	-0.008	-23.1%
Sensitivity #8	100-Year Dry	Low	Baseline	0.439	n/a	n/a	0.117	n/a	n/a	0.160	n/a	n/a	0.023	n/a	n/a	0.035	n/a	n/a
			Bulk Sample	0.440	0.001	0.1%	0.117	0**	n/a**	0.160	0**	n/a**	0.023	0**	n/a**	0.035	0**	n/a**
			Construction	0.439	0**	n/a**	0.117	0**	n/a**	0.159	0**	n/a**	0.023	0**	n/a**	0.035	0**	n/a**
			Operation	0.438	-0.001	-0.1%	0.117	-0.001	-0.6%	0.159	-0.001	-0.7%	0.022	-0.001	-4.7%	0.034	-0.001	-3.1%
			Decommissioning & Reclamation	0.438	-0.001	-0.1%	0.117	-0.001	-0.6%	0.159	-0.001	-0.7%	0.022	-0.001	-4.7%	0.034	-0.001	-3.1%
			Post Closure	0.438	-0.001	-0.1%	0.117	-0.001	-0.6%	0.159	-0.001	-0.7%	0.022	-0.001	-4.7%	0.034	-0.001	-3.1%

(continued)

Table 8.8-7. Sensitivity Analysis Scenario Results for Simulated Average Monthly Streamflows at M20 Creek (completed)

				November			December			Annual		
Scenario	Annual Precipitation	Groundwater Inflows into the Mine	Project Phase	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)
Base Case	Average	Moderate	Baseline	0.064	n/a	n/a	0.054	n/a	n/a	0.48	n/a	n/a
			Bulk Sample	0.064	-0.001	-1.1%	0.053	-0.001	-1.3%	0.48	0**	n/a**
			Construction	0.062	-0.002	-3.2%	0.052	-0.002	-3.9%	0.48	-0.001	-0.3%
			Operation	0.060	-0.005	-7.4%	0.049	-0.005	-8.8%	0.47	-0.004	-0.9%
			Decommissioning & Reclamation	0.060	-0.005	-7.4%	0.049	-0.005	-8.8%	0.47	-0.004	-0.9%
			Post Closure	0.060	-0.005	-7.4%	0.049	-0.005	-8.8%	0.47	-0.004	-0.9%
Sensitivity #1	Average	High	Baseline	0.064	n/a	n/a	0.054	n/a	n/a	0.48	n/a	n/a
			Bulk Sample	0.063	-0.001	-1.8%	0.053	-0.001	-2.3%	0.48	-0.001	-0.1%
			Construction	0.061	-0.004	-5.5%	0.051	-0.004	-6.7%	0.48	-0.003	-0.6%
			Operation	0.056	-0.008	-12.7%	0.046	-0.008	-15.2%	0.47	-0.008	-1.6%
			Decommissioning & Reclamation	0.056	-0.008	-12.7%	0.046	-0.008	-15.2%	0.47	-0.008	-1.6%
			Post Closure	0.056	-0.008	-12.7%	0.046	-0.008	-15.2%	0.47	-0.008	-1.6%
Sensitivity #2	Average	Low	Baseline	0.064	n/a	n/a	0.054	n/a	n/a	0.48	n/a	n/a
			Bulk Sample	0.064	0**	n/a**	0.054	0**	n/a**	0.48	0**	n/a**
			Construction	0.064	0**	n/a**	0.054	0**	n/a**	0.48	0**	n/a**
			Operation	0.063	-0.001	-1.7%	0.053	-0.001	-2.0%	0.48	-0.001	-0.1%
			Decommissioning & Reclamation	0.063	-0.001	-1.7%	0.053	-0.001	-2.0%	0.48	-0.001	-0.1%
			Post Closure	0.063	-0.001	-1.7%	0.053	-0.001	-2.0%	0.48	-0.001	-0.1%
Sensitivity #3	100-Year Wet	Moderate	Baseline	0.180	n/a	n/a	0.152	n/a	n/a	1.34	n/a	n/a
			Bulk Sample	0.179	0**	n/a**	0.151	0**	n/a**	1.34	0**	n/a**
			Construction	0.178	-0.002	-1.1%	0.150	-0.002	-1.4%	1.34	-0.001	-0.1%
			Operation	0.175	-0.005	-2.6%	0.147	-0.005	-3.1%	1.34	-0.004	-0.3%
			Decommissioning & Reclamation	0.175	-0.005	-2.6%	0.147	-0.005	-3.1%	1.34	-0.004	-0.3%
			Post Closure	0.175	-0.005	-2.6%	0.147	-0.005	-3.1%	1.34	-0.004	-0.3%
Sensitivity #4	100-Year Wet	High	Baseline	0.180	n/a	n/a	0.152	n/a	n/a	1.34	n/a	n/a
			Bulk Sample	0.179	-0.001	-0.7%	0.150	-0.001	-0.8%	1.34	-0.001	0.0%
			Construction	0.177	-0.004	-2.0%	0.148	-0.004	-2.4%	1.34	-0.003	-0.2%
			Operation	0.172	-0.008	-4.6%	0.143	-0.008	-5.4%	1.33	-0.007	-0.6%
			Decommissioning & Reclamation	0.172	-0.008	-4.6%	0.143	-0.008	-5.4%	1.33	-0.007	-0.6%
			Post Closure	0.172	-0.008	-4.6%	0.143	-0.008	-5.4%	1.33	-0.007	-0.6%
Sensitivity #5	100-Year Wet	Low	Baseline	0.180	n/a	n/a	0.152	n/a	n/a	1.34	n/a	n/a
			Bulk Sample	0.180	0**	n/a**	0.152	0**	n/a**	1.34	0**	n/a**
			Construction	0.180	0**	n/a**	0.151	0**	n/a**	1.34	0**	n/a**
			Operation	0.179	-0.001	-0.6%	0.151	-0.001	-0.7%	1.34	-0.001	0.0%
			Decommissioning & Reclamation	0.179	-0.001	-0.6%	0.151	-0.001	-0.7%	1.34	-0.001	0.0%
			Post Closure	0.179	-0.001	-0.6%	0.151	-0.001	-0.7%	1.34	-0.001	0.0%
Sensitivity #6	100-Year Dry	Moderate	Baseline	0.019	n/a	n/a	0.016	n/a	n/a	0.14	n/a	n/a
			Bulk Sample	0.019	-0.001	-3.5%	0.016	-0.001	-4.4%	0.14	0**	n/a**
			Construction	0.017	-0.002	-10.6%	0.014	-0.002	-12.8%	0.14	-0.002	-1.1%
			Operation	0.015	-0.005	-24.5%	0.012	-0.005	-29.2%	0.14	-0.004	-3.0%
			Decommissioning & Reclamation	0.015	-0.005	-24.5%	0.012	-0.005	-29.2%	0.14	-0.004	-3.0%
			Post Closure	0.015	-0.005	-24.5%	0.012	-0.005	-29.2%	0.14	-0.004	-3.0%
Sensitivity #7	100-Year Dry	High	Baseline	0.019	n/a	n/a	0.016	n/a	n/a	0.14	n/a	n/a
			Bulk Sample	0.018	-0.001	-6.1%	0.015	-0.001	-7.6%	0.14	-0.001	-0.5%
			Construction	0.016	-0.004	-18.4%	0.013	-0.004	-22.3%	0.14	-0.003	-2.1%
			Operation	0.011	-0.008	-42.5%	0.008	-0.008	-50.6%	0.14	-0.008	-5.4%
			Decommissioning & Reclamation	0.011	-0.008	-42.5%	0.008	-0.008	-50.6%	0.14	-0.008	-5.4%
			Post Closure	0.011	-0.008	-42.5%	0.008	-0.008	-50.6%	0.14	-0.008	-5.4%
Sensitivity #8	100-Year Dry	Low	Baseline	0.019	n/a	n/a	0.016	n/a	n/a	0.14	n/a	n/a
			Bulk Sample	0.019	0**	n/a**	0.016	0**	n/a**	0.14	0**	n/a**
			Construction	0.019	0**	n/a**	0.016	0**	n/a**	0.14	0**	n/a**
			Operation	0.018	-0.001	-5.7%	0.015	-0.001	-6.8%	0.14	-0.001	-0.5%
			Decommissioning & Reclamation	0.018	-0.001	-5.7%	0.015	-0.001	-6.8%	0.14	-0.001	-0.5%
			Post Closure	0.018	-0.001	-5.7%	0.015	-0.001	-6.8%	0.14	-0.001	-0.5%

** Flows are less than 0.0005 m^3/s*

*** Flow changes are less than 0.0005 m^3/s*

Table 8.8-8. Sensitivity Analysis Scenario Results for Simulated Average Monthly Streamflows at Murray River

Scenario	Annual Precipitation	Groundwater Inflows into the Mine	Project Phase	January			February			March			April			May		
				Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)
Base Case	Average	Moderate	Baseline	8.78	n/a	n/a	6.82	n/a	n/a	7.69	n/a	n/a	26.57	n/a	n/a	211.52	n/a	n/a
			Bulk Sample	8.78	0**	n/a**	6.82	0**	n/a**	7.69	0**	n/a**	26.57	0**	n/a**	211.52	0**	n/a**
			Construction	8.78	0**	n/a**	6.81	0**	n/a**	7.69	0**	n/a**	26.56	0**	n/a**	211.53	0**	n/a**
			Operation	8.76	-0.01	-0.2%	6.80	-0.01	-0.2%	7.68	-0.01	-0.2%	26.55	-0.01	-0.1%	211.52	0**	n/a**
			Decomissioning & Reclamation	8.78	0**	n/a**	6.82	0**	n/a**	7.69	0**	n/a**	26.57	0**	n/a**	211.54	0.01	0.0%
			Post Closure	8.78	0**	n/a**	6.82	0**	n/a**	7.69	0**	n/a**	26.57	0**	n/a**	211.54	0.02	0.0%
Sensitivity #1	Average	High	Baseline	8.78	n/a	n/a	6.82	n/a	n/a	7.69	n/a	n/a	26.57	n/a	n/a	211.52	n/a	n/a
			Bulk Sample	8.78	0**	n/a**	6.82	0**	n/a**	7.70	0**	n/a**	26.57	0**	n/a**	211.53	0.01	0.0%
			Construction	8.80	0.02	0.2%	6.83	0.02	0.2%	7.71	0.02	0.2%	26.58	0.02	0.1%	211.54	0.02	0.0%
			Operation	8.81	0.03	0.3%	6.85	0.03	0.4%	7.72	0.03	0.4%	26.60	0.03	0.1%	211.56	0.04	0.0%
			Decomissioning & Reclamation	8.78	0**	n/a**	6.82	0**	n/a**	7.69	0**	n/a**	26.57	0**	n/a**	211.54	0.01	0.0%
			Post Closure	8.78	0**	n/a**	6.82	0**	n/a**	7.69	0**	n/a**	26.57	0**	n/a**	211.54	0.01	0.0%
Sensitivity #2	Average	Low	Baseline	8.78	n/a	n/a	6.82	n/a	n/a	7.69	n/a	n/a	26.57	n/a	n/a	211.52	n/a	n/a
			Bulk Sample	8.78	0**	n/a**	6.81	0**	n/a**	7.69	0**	n/a**	26.56	0**	n/a**	211.52	0**	n/a**
			Construction	8.77	-0.01	-0.1%	6.81	-0.01	-0.2%	7.68	-0.01	-0.2%	26.55	-0.01	0.0%	211.51	-0.01	0.0%
			Operation	8.74	-0.04	-0.5%	6.78	-0.04	-0.6%	7.65	-0.04	-0.5%	26.53	-0.04	-0.1%	211.49	-0.03	0.0%
			Decomissioning & Reclamation	8.78	0**	n/a**	6.82	0**	n/a**	7.69	0**	n/a**	26.57	0**	n/a**	211.54	0.01	0.0%
			Post Closure	8.78	0**	n/a**	6.82	0**	n/a**	7.69	0**	n/a**	26.57	0**	n/a**	211.54	0.01	0.0%
Sensitivity #3	100-Year Wet	Moderate	Baseline	24.58	n/a	n/a	19.09	n/a	n/a	21.54	n/a	n/a	74.39	n/a	n/a	592.27	n/a	n/a
			Bulk Sample	24.58	0**	n/a**	19.09	0**	n/a**	21.54	0**	n/a**	74.39	0**	n/a**	592.27	0**	n/a**
			Construction	24.58	0**	n/a**	19.09	0**	n/a**	21.54	0**	n/a**	74.39	0**	n/a**	592.27	0**	n/a**
			Operation	24.57	-0.01	-0.1%	19.07	-0.01	-0.1%	21.53	-0.01	-0.1%	74.38	-0.01	0.0%	592.27	0**	n/a**
			Decomissioning & Reclamation	24.58	0**	n/a**	19.09	0**	n/a**	21.54	0**	n/a**	74.40	0.01	0.0%	592.30	0.03	0.0%
			Post Closure	24.58	0**	n/a**	19.09	0**	n/a**	21.54	0**	n/a**	74.39	0.01	0.0%	592.30	0.03	0.0%
Sensitivity #4	100-Year Wet	High	Baseline	24.58	n/a	n/a	19.09	n/a	n/a	21.54	n/a	n/a	74.39	n/a	n/a	592.27	n/a	n/a
			Bulk Sample	24.58	0**	n/a**	19.09	0**	n/a**	21.54	0**	n/a**	74.39	0.01	0.0%	592.28	0.01	0.0%
			Construction	24.60	0.02	0.1%	19.10	0.02	0.1%	21.56	0.02	0.1%	74.41	0.02	0.0%	592.29	0.02	0.0%
			Operation	24.61	0.03	0.1%	19.12	0.03	0.2%	21.57	0.03	0.1%	74.42	0.04	0.0%	592.32	0.05	0.0%
			Decomissioning & Reclamation	24.58	0**	n/a**	19.09	0**	n/a**	21.54	0**	n/a**	74.39	0.01	0.0%	592.30	0.03	0.0%
			Post Closure	24.58	0**	n/a**	19.09	0**	n/a**	21.54	0**	n/a**	74.40	0.01	0.0%	592.30	0.03	0.0%
Sensitivity #5	100-Year Wet	Low	Baseline	24.58	n/a	n/a	19.09	n/a	n/a	21.54	n/a	n/a	74.39	n/a	n/a	592.27	n/a	n/a
			Bulk Sample	24.58	0**	n/a**	19.08	0**	n/a**	21.54	0**	n/a**	74.39	0**	n/a**	592.27	0**	n/a**
			Construction	24.57	-0.01	0.0%	19.08	-0.01	-0.1%	21.53	-0.01	-0.1%	74.38	-0.01	0.0%	592.26	-0.01	0.0%
			Operation	24.54	-0.04	-0.2%	19.05	-0.04	-0.2%	21.50	-0.04	-0.2%	74.35	-0.03	0.0%	592.25	-0.02	0.0%
			Decomissioning & Reclamation	24.58	0**	n/a**	19.09	0**	n/a**	21.54	0**	n/a**	74.40	0.01	0.0%	592.30	0.03	0.0%
			Post Closure	24.58	0**	n/a**	19.09	0**	n/a**	21.54	0**	n/a**	74.39	0.01	0.0%	592.30	0.03	0.0%
Sensitivity #6	100-Year Dry	Moderate	Baseline	2.63	n/a	n/a	2.05	n/a	n/a	2.31	n/a	n/a	7.97	n/a	n/a	63.46	n/a	n/a
			Bulk Sample	2.63	0**	n/a**	2.04	0**	n/a**	2.31	0**	n/a**	7.97	0**	n/a**	63.46	0**	n/a**
			Construction	2.63	0**	n/a**	2.04	0**	n/a**	2.31	0**	n/a**	7.97	0**	n/a**	63.46	0**	n/a**
			Operation	2.62	-0.01	-0.6%	2.03	-0.01	-0.7%	2.29	-0.01	-0.6%	7.96	-0.01	-0.2%	63.45	-0.01	0.0%
			Decomissioning & Reclamation	2.63	0**	n/a**	2.05	0**	n/a**	2.31	0**	n/a**	7.97	0**	n/a**	63.46	0.01	0.0%
			Post Closure	2.63	0**	n/a**	2.05	0**	n/a**	2.31	0**	n/a**	7.97	0**	n/a**	63.46	0**	n/a**
Sensitivity #7	100-Year Dry	High	Baseline	2.63	n/a	n/a	2.05	n/a	n/a	2.31	n/a	n/a	7.97	n/a	n/a	63.46	n/a	n/a
			Bulk Sample	2.64	0**	n/a**	2.05	0**	n/a**	2.31	0**	n/a**	7.97	0**	n/a**	63.46	0.01	0.0%
			Construction	2.65	0.02	0.7%	2.06	0.02	0.8%	2.32	0.02	0.7%	7.99	0.02	0.2%	63.47	0.02	0.0%
			Operation	2.66	0.03	1.1%	2.07	0.03	1.5%	2.34	0.03	1.3%	8.00	0.03	0.4%	63.49	0.03	0.1%
			Decomissioning & Reclamation	2.63	0**	n/a**	2.05	0**	n/a**	2.31	0**	n/a**	7.97	0**	n/a**	63.46	0.01	0.0%
			Post Closure	2.63	0**	n/a**	2.05	0**	n/a**	2.31	0**	n/a**	7.97	0**	n/a**	63.46	0**	n/a**
Sensitivity #8	100-Year Dry	Low	Baseline	2.63	n/a	n/a	2.05	n/a	n/a	2.31	n/a	n/a	7.97	n/a	n/a	63.46	n/a	n/a
			Bulk Sample	2.63	0**	n/a**	2.04	0**	n/a**	2.31	0**	n/a**	7.97	0**	n/a**	63.45	0**	n/a**
			Construction	2.62	-0.01	-0.4%	2.03	-0.01	-0.6%	2.30	-0.01	-0.5%	7.96	-0.01	-0.2%	63.45	-0.01	0.0%
			Operation	2.59	-0.04	-1.5%	2.00	-0.04	-2.0%	2.27	-0.04	-1.7%	7.93	-0.04	-0.5%	63.42	-0.04	-0.1%
			Decomissioning & Reclamation	2.63	0**	n/a**	2.05	0**	n/a**	2.31	0**	n/a**	7.97	0**	n/a**	63.46	0.01	0.0%
			Post Closure	2.63	0**	n/a**	2.05	0**	n/a**	2.31	0**	n/a**	7.97	0**	n/a**	63.46	0**	n/a**

(continued)

Table 8.8-8. Sensitivity Analysis Scenario Results for Simulated Average Monthly Streamflows at Murray River (continued)

				June			July			August			September			October		
Scenario	Annual Precipitation	Groundwater Inflows into the Mine	Project Phase	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)
Base Case	Average	Moderate	Baseline	208.94	n/a	n/a	71.85	n/a	n/a	45.15	n/a	n/a	24.73	n/a	n/a	38.62	n/a	n/a
			Bulk Sample	208.94	0**	n/a**	71.85	0**	n/a**	45.15	0**	n/a**	24.73	0**	n/a**	38.62	0**	n/a**
			Construction	208.94	0**	n/a**	71.84	0**	n/a**	45.15	0**	n/a**	24.72	0**	n/a**	38.61	0**	n/a**
			Operation	208.93	-0.01	0.0%	71.83	-0.014	0.0%	45.14	-0.014	0.0%	24.71	-0.014	-0.1%	38.60	-0.014	0.0%
			Decomissioning & Reclamation	208.95	0**	n/a**	71.85	0**	n/a**	45.15	0**	n/a**	24.73	0**	n/a**	38.62	0**	n/a**
			Post Closure	208.95	0**	n/a**	71.85	0**	n/a**	45.15	0**	n/a**	24.73	0**	n/a**	38.62	0**	n/a**
Sensitivity #1	Average	High	Baseline	208.94	n/a	n/a	71.85	n/a	n/a	45.15	n/a	n/a	24.73	n/a	n/a	38.62	n/a	n/a
			Bulk Sample	208.95	0.01	0.0%	71.85	0.005	0.0%	45.16	0.005	0.0%	24.73	0.006	0.0%	38.62	0.006	0.0%
			Construction	208.96	0.02	0.0%	71.86	0.016	0.0%	45.17	0.017	0.0%	24.74	0.017	0.1%	38.63	0.017	0.0%
			Operation	208.98	0.03	0.0%	71.88	0.031	0.0%	45.19	0.032	0.1%	24.76	0.032	0.1%	38.65	0.032	0.1%
			Decomissioning & Reclamation	208.95	0**	n/a**	71.85	0**	n/a**	45.15	0**	n/a**	24.73	0**	n/a**	38.62	0**	n/a**
			Post Closure	208.95	0**	n/a**	71.85	0**	n/a**	45.15	0**	n/a**	24.73	0**	n/a**	38.62	0**	n/a**
Sensitivity #2	Average	Low	Baseline	208.94	n/a	n/a	71.85	n/a	n/a	45.15	n/a	n/a	24.73	n/a	n/a	38.62	n/a	n/a
			Bulk Sample	208.94	0**	n/a**	71.84	0**	n/a**	45.15	0**	n/a**	24.72	0**	n/a**	38.61	0**	n/a**
			Construction	208.93	-0.01	0.0%	71.83	-0.014	0.0%	45.14	-0.014	0.0%	24.71	-0.014	-0.1%	38.60	-0.014	0.0%
			Operation	208.90	-0.04	0.0%	71.81	-0.040	-0.1%	45.11	-0.040	-0.1%	24.69	-0.040	-0.2%	38.58	-0.040	-0.1%
			Decomissioning & Reclamation	208.95	0**	n/a**	71.85	0**	n/a**	45.15	0**	n/a**	24.73	0**	n/a**	38.62	0**	n/a**
			Post Closure	208.95	0**	n/a**	71.85	0**	n/a**	45.15	0**	n/a**	24.73	0**	n/a**	38.62	0**	n/a**
Sensitivity #3	100-Year Wet	Moderate	Baseline	585.04	n/a	n/a	201.17	n/a	n/a	126.43	n/a	n/a	69.23	n/a	n/a	108.13	n/a	n/a
			Bulk Sample	585.04	0**	n/a**	201.17	0**	n/a**	126.43	0**	n/a**	69.23	0**	n/a**	108.13	0**	n/a**
			Construction	585.04	0**	n/a**	201.17	0**	n/a**	126.43	0**	n/a**	69.23	0**	n/a**	108.13	0**	n/a**
			Operation	585.03	-0.01	0.0%	201.16	-0.013	0.0%	126.42	-0.013	0.0%	69.22	-0.014	0.0%	108.12	-0.014	0.0%
			Decomissioning & Reclamation	585.05	0.01	0.0%	201.18	0**	n/a**	126.43	0**	n/a**	69.23	0**	n/a**	108.13	0**	n/a**
			Post Closure	585.05	0.01	0.0%	201.18	0**	n/a**	126.43	0**	n/a**	69.23	0**	n/a**	108.13	0**	n/a**
Sensitivity #4	100-Year Wet	High	Baseline	585.04	n/a	n/a	201.17	n/a	n/a	126.43	n/a	n/a	69.23	n/a	n/a	108.13	n/a	n/a
			Bulk Sample	585.05	0.01	0.0%	201.18	0.005	0.0%	126.44	0.005	0.0%	69.24	0.006	0.0%	108.14	0.006	0.0%
			Construction	585.06	0.02	0.0%	201.19	0.016	0.0%	126.45	0.017	0.0%	69.25	0.017	0.0%	108.15	0.017	0.0%
			Operation	585.08	0.04	0.0%	201.21	0.032	0.0%	126.46	0.032	0.0%	69.26	0.032	0.0%	108.16	0.032	0.0%
			Decomissioning & Reclamation	585.05	0.01	0.0%	201.18	0**	n/a**	126.43	0**	n/a**	69.23	0**	n/a**	108.13	0**	n/a**
			Post Closure	585.05	0.01	0.0%	201.18	0**	n/a**	126.43	0**	n/a**	69.23	0**	n/a**	108.13	0**	n/a**
Sensitivity #5	100-Year Wet	Low	Baseline	585.04	n/a	n/a	201.17	n/a	n/a	126.43	n/a	n/a	69.23	n/a	n/a	108.13	n/a	n/a
			Bulk Sample	585.04	0**	n/a**	201.17	0**	n/a**	126.43	0**	n/a**	69.23	0**	n/a**	108.13	0**	n/a**
			Construction	585.03	-0.01	0.0%	201.16	-0.014	0.0%	126.42	-0.014	0.0%	69.22	-0.014	0.0%	108.11	-0.014	0.0%
			Operation	585.01	-0.03	0.0%	201.14	-0.039	0.0%	126.39	-0.039	0.0%	69.19	-0.040	-0.1%	108.09	-0.040	0.0%
			Decomissioning & Reclamation	585.05	0.01	0.0%	201.18	0**	n/a**	126.43	0**	n/a**	69.23	0**	n/a**	108.13	0**	n/a**
			Post Closure	585.05	0.01	0.0%	201.18	0**	n/a**	126.43	0**	n/a**	69.23	0**	n/a**	108.13	0**	n/a**
Sensitivity #6	100-Year Dry	Moderate	Baseline	62.68	n/a	n/a	21.55	n/a	n/a	13.55	n/a	n/a	7.42	n/a	n/a	11.59	n/a	n/a
			Bulk Sample	62.68	0**	n/a**	21.55	0**	n/a**	13.55	0**	n/a**	7.42	0**	n/a**	11.59	0**	n/a**
			Construction	62.68	0**	n/a**	21.55	0**	n/a**	13.54	0**	n/a**	7.41	0**	n/a**	11.58	0**	n/a**
			Operation	62.67	-0.01	0.0%	21.54	-0.014	-0.1%	13.53	-0.014	-0.1%	7.40	-0.014	-0.2%	11.57	-0.014	-0.1%
			Decomissioning & Reclamation	62.68	0**	n/a**	21.55	0**	n/a**	13.55	0**	n/a**	7.42	0**	n/a**	11.59	0**	n/a**
			Post Closure	62.68	0**	n/a**	21.55	0**	n/a**	13.55	0**	n/a**	7.42	0**	n/a**	11.59	0**	n/a**
Sensitivity #7	100-Year Dry	High	Baseline	62.68	n/a	n/a	21.55	n/a	n/a	13.55	n/a	n/a	7.42	n/a	n/a	11.59	n/a	n/a
			Bulk Sample	62.69	0.01	0.0%	21.56	0.005	0.0%	13.55	0.005	0.0%	7.42	0.006	0.1%	11.59	0.006	0.1%
			Construction	62.70	0.02	0.0%	21.57	0.016	0.1%	13.56	0.017	0.1%	7.43	0.017	0.2%	11.60	0.017	0.1%
			Operation	62.71	0.03	0.1%	21.58	0.032	0.1%	13.58	0.031	0.2%	7.45	0.032	0.4%	11.62	0.032	0.3%
			Decomissioning & Reclamation	62.68	0**	n/a**	21.55	0**	n/a**	13.55	0**	n/a**	7.42	0**	n/a**	11.59	0**	n/a**
			Post Closure	62.68	0**	n/a**	21.55	0**	n/a**	13.55	0**	n/a**	7.42	0**	n/a**	11.59	0**	n/a**
Sensitivity #8	100-Year Dry	Low	Baseline	62.68	n/a	n/a	21.55	n/a	n/a	13.55	n/a	n/a	7.42	n/a	n/a	11.59	n/a	n/a
			Bulk Sample	62.68	0**	n/a**	21.55	0**	n/a**	13.54	0**	n/a**	7.41	0**	n/a**	11.58	0**	n/a**
			Construction	62.67	-0.01	0.0%	21.54	-0.014	-0.1%	13.53	-0.014	-0.1%	7.40	-0.014	-0.2%	11.57	-0.014	-0.1%
			Operation	62.64	-0.04	-0.1%	21.51	-0.040	-0.2%	13.51	-0.040	-0.3%	7.38	-0.040	-0.5%	11.55	-0.040	-0.3%
			Decomissioning & Reclamation	62.68	0**	n/a**	21.55	0**	n/a**	13.55	0**	n/a**	7.42	0**	n/a**	11.59	0**	n/a**
			Post Closure	62.68	0**	n/a**	21.55	0**	n/a**	13.55	0**	n/a**	7.42	0**	n/a**	11.59	0**	n/a**

(continued)

Table 8.8-8. Sensitivity Analysis Scenario Results for Simulated Average Monthly Streamflows at Murray River (completed)

				November			December			Annual		
Scenario	Annual Precipitation	Groundwater Inflows into the Mine	Project Phase	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)	Flow (m^3/s)	Change from Baseline (m^3/s)	Change from Baseline (% of Baseline Flow)
Base Case	Average	Moderate	Baseline	10.72	n/a	n/a	7.18	n/a	n/a	55.98	n/a	n/a
			Bulk Sample	10.72	0**	n/a**	7.18	0**	n/a**	55.98	0**	n/a**
			Construction	10.71	0**	n/a**	7.17	0**	n/a**	55.98	-0.002	0.0%
			Operation	10.70	-0.014	-0.1%	7.16	-0.013	-0.2%	55.97	-0.013	0.0%
			Decomissioning & Reclamation	10.72	0**	n/a**	7.18	0**	n/a**	55.99	0.002	0.0%
			Post Closure	10.72	0**	n/a**	7.18	0**	n/a**	55.99	0.002	0.0%
Sensitivity #1	Average	High	Baseline	10.72	n/a	n/a	7.18	n/a	n/a	55.98	n/a	n/a
			Bulk Sample	10.73	0.007	0.1%	7.18	0.008	0.1%	55.99	0.005	0.0%
			Construction	10.74	0.017	0.2%	7.19	0.018	0.2%	56.00	0.017	0.0%
			Operation	10.75	0.032	0.3%	7.21	0.033	0.5%	56.02	0.032	0.1%
			Decomissioning & Reclamation	10.72	0**	n/a**	7.18	0**	n/a**	55.99	0.002	0.0%
			Post Closure	10.72	0**	n/a**	7.18	0**	n/a**	55.99	0.002	0.0%
Sensitivity #2	Average	Low	Baseline	10.72	n/a	n/a	7.18	n/a	n/a	55.98	n/a	n/a
			Bulk Sample	10.71	0**	n/a**	7.17	0**	n/a**	55.98	-0.003	0.0%
			Construction	10.70	-0.015	-0.1%	7.16	-0.015	-0.2%	55.97	-0.013	0.0%
			Operation	10.68	-0.040	-0.4%	7.14	-0.040	-0.6%	55.94	-0.039	-0.1%
			Decomissioning & Reclamation	10.72	0**	n/a**	7.18	0**	n/a**	55.99	0.002	0.0%
			Post Closure	10.72	0**	n/a**	7.18	0**	n/a**	55.99	0.002	0.0%
Sensitivity #3	100-Year Wet	Moderate	Baseline	30.01	n/a	n/a	20.09	n/a	n/a	156.75	n/a	n/a
			Bulk Sample	30.01	0**	n/a**	20.10	0**	n/a**	156.75	0**	n/a**
			Construction	30.01	0**	n/a**	20.09	0**	n/a**	156.75	-0.002	0.0%
			Operation	30.00	-0.014	0.0%	20.08	-0.013	-0.1%	156.74	-0.011	0.0%
			Decomissioning & Reclamation	30.01	0**	n/a**	20.09	0**	n/a**	156.76	0.005	0.0%
			Post Closure	30.01	0**	n/a**	20.09	0**	n/a**	156.76	0.005	0.0%
Sensitivity #4	100-Year Wet	High	Baseline	30.01	n/a	n/a	20.09	n/a	n/a	156.75	n/a	n/a
			Bulk Sample	30.02	0.007	0.0%	20.10	0.008	0.0%	156.76	0.005	0.0%
			Construction	30.03	0.017	0.1%	20.11	0.018	0.1%	156.77	0.018	0.0%
			Operation	30.04	0.032	0.1%	20.13	0.033	0.2%	156.79	0.034	0.0%
			Decomissioning & Reclamation	30.01	0**	n/a**	20.09	0**	n/a**	156.76	0.005	0.0%
			Post Closure	30.01	0**	n/a**	20.09	0**	n/a**	156.76	0.005	0.0%
Sensitivity #5	100-Year Wet	Low	Baseline	30.01	n/a	n/a	20.09	n/a	n/a	156.75	n/a	n/a
			Bulk Sample	30.01	0**	n/a**	20.09	0**	n/a**	156.75	-0.003	0.0%
			Construction	29.99	-0.015	0.0%	20.08	-0.015	-0.1%	156.74	-0.012	0.0%
			Operation	29.97	-0.040	-0.1%	20.05	-0.040	-0.2%	156.72	-0.037	0.0%
			Decomissioning & Reclamation	30.01	0**	n/a**	20.09	0**	n/a**	156.76	0.005	0.0%
			Post Closure	30.01	0**	n/a**	20.09	0**	n/a**	156.76	0.005	0.0%
Sensitivity #6	100-Year Dry	Moderate	Baseline	3.22	n/a	n/a	2.15	n/a	n/a	16.79	n/a	n/a
			Bulk Sample	3.22	0**	n/a**	2.15	0**	n/a**	16.79	0**	n/a**
			Construction	3.21	0**	n/a**	2.15	0**	n/a**	16.79	-0.002	0.0%
			Operation	3.20	-0.014	-0.4%	2.14	-0.013	-0.6%	16.78	-0.014	-0.1%
			Decomissioning & Reclamation	3.22	0**	n/a**	2.15	0**	n/a**	16.80	0.001	0.0%
			Post Closure	3.22	0**	n/a**	2.15	0**	n/a**	16.80	0.001	0.0%
Sensitivity #7	100-Year Dry	High	Baseline	3.22	n/a	n/a	2.15	n/a	n/a	16.79	n/a	n/a
			Bulk Sample	3.22	0.007	0.2%	2.16	0.008	0.4%	16.80	0.005	0.0%
			Construction	3.23	0.017	0.5%	2.17	0.018	0.8%	16.81	0.017	0.1%
			Operation	3.25	0.032	1.0%	2.19	0.033	1.5%	16.83	0.032	0.2%
			Decomissioning & Reclamation	3.22	0**	n/a**	2.15	0**	n/a**	16.80	0.001	0.0%
			Post Closure	3.22	0**	n/a**	2.15	0**	n/a**	16.80	0.001	0.0%
Sensitivity #8	100-Year Dry	Low	Baseline	3.22	n/a	n/a	2.15	n/a	n/a	16.79	n/a	n/a
			Bulk Sample	3.21	0**	n/a**	2.15	0**	n/a**	16.79	0**	n/a**
			Construction	3.20	-0.015	-0.5%	2.14	-0.015	-0.7%	16.78	-0.013	-0.1%
			Operation	3.18	-0.040	-1.2%	2.11	-0.040	-1.9%	16.76	-0.040	-0.2%
			Decomissioning & Reclamation	3.22	0**	n/a**	2.15	0**	n/a**	16.80	0.001	0.0%
			Post Closure	3.22	0**	n/a**	2.15	0**	n/a**	16.80	0.001	0.0%

** Flows are less than 0.005 m^3/s*

*** Flow changes are less than 0.005 m^3/s*

Figure 8.8-5

Sensitivity Analysis Scenario Results for Annual Average Streamflows within the Project Area

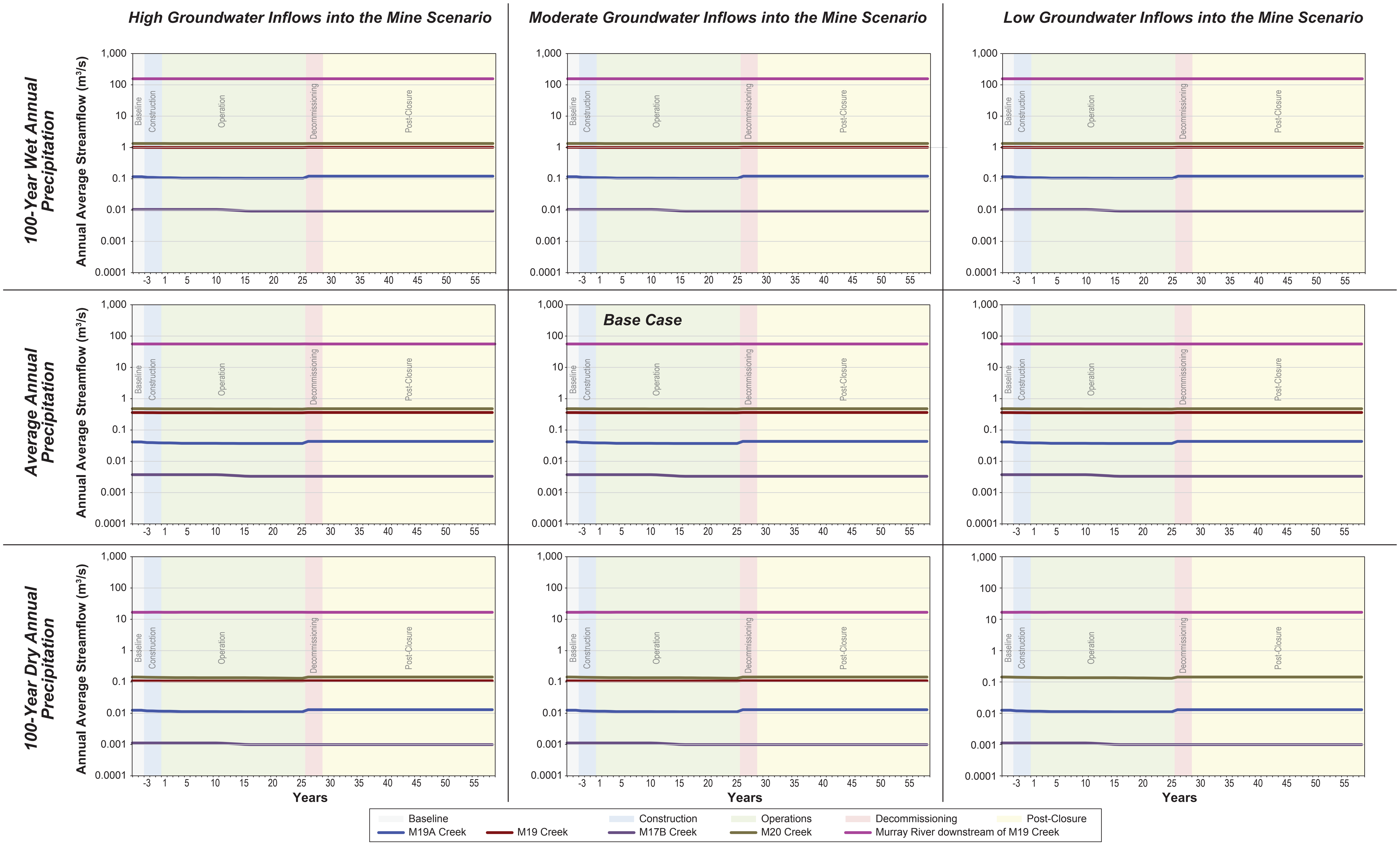


Figure 8.8-6

Sensitivity Analysis Scenario Results for Streamflow Hydrographs at M19A Creek

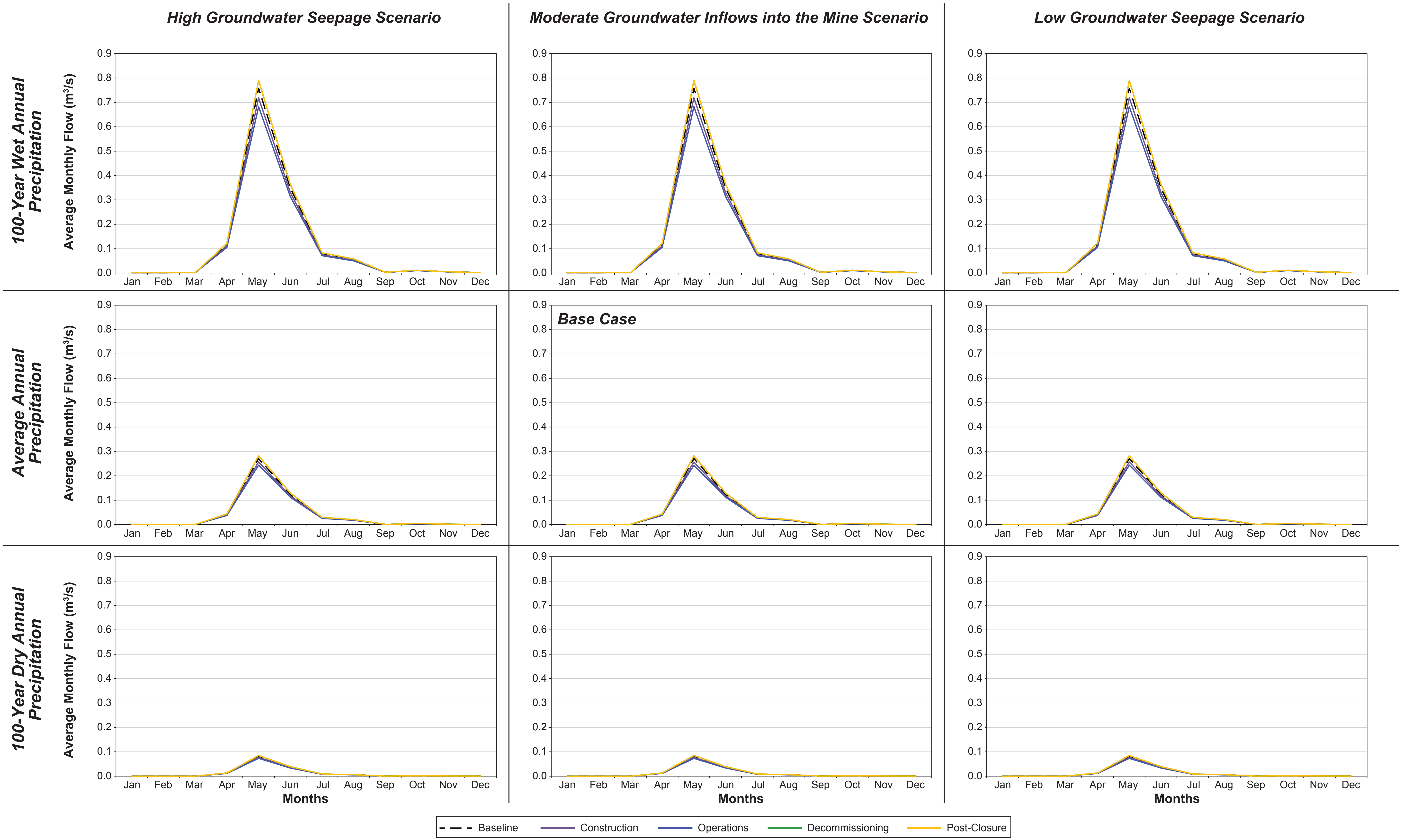


Figure 8.8-7

Sensitivity Analysis Scenario Results for Streamflow Hydrographs at M19 Creek

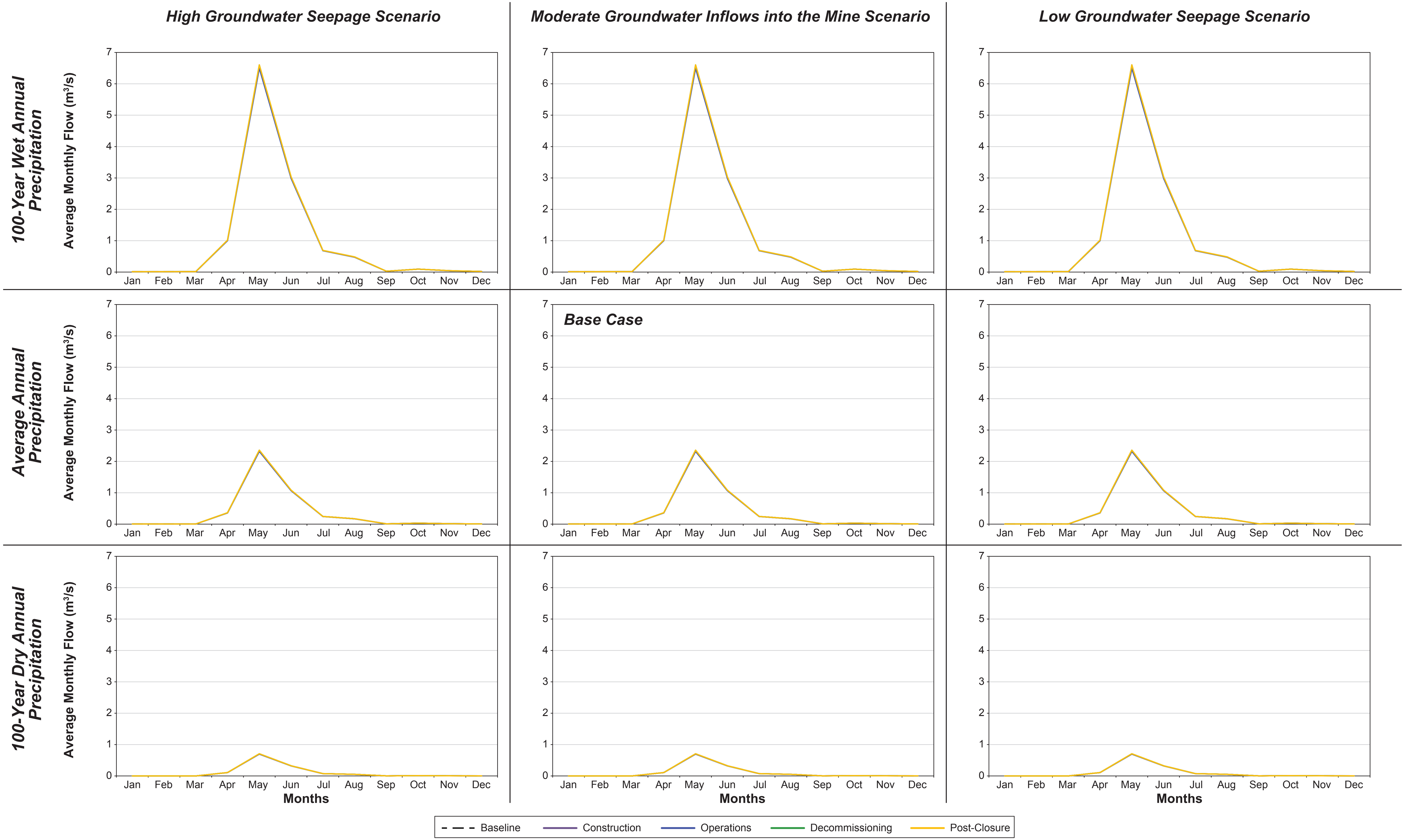


Figure 8.8-8

Sensitivity Analysis Scenario Results for Streamflow Hydrographs at M17B Creek

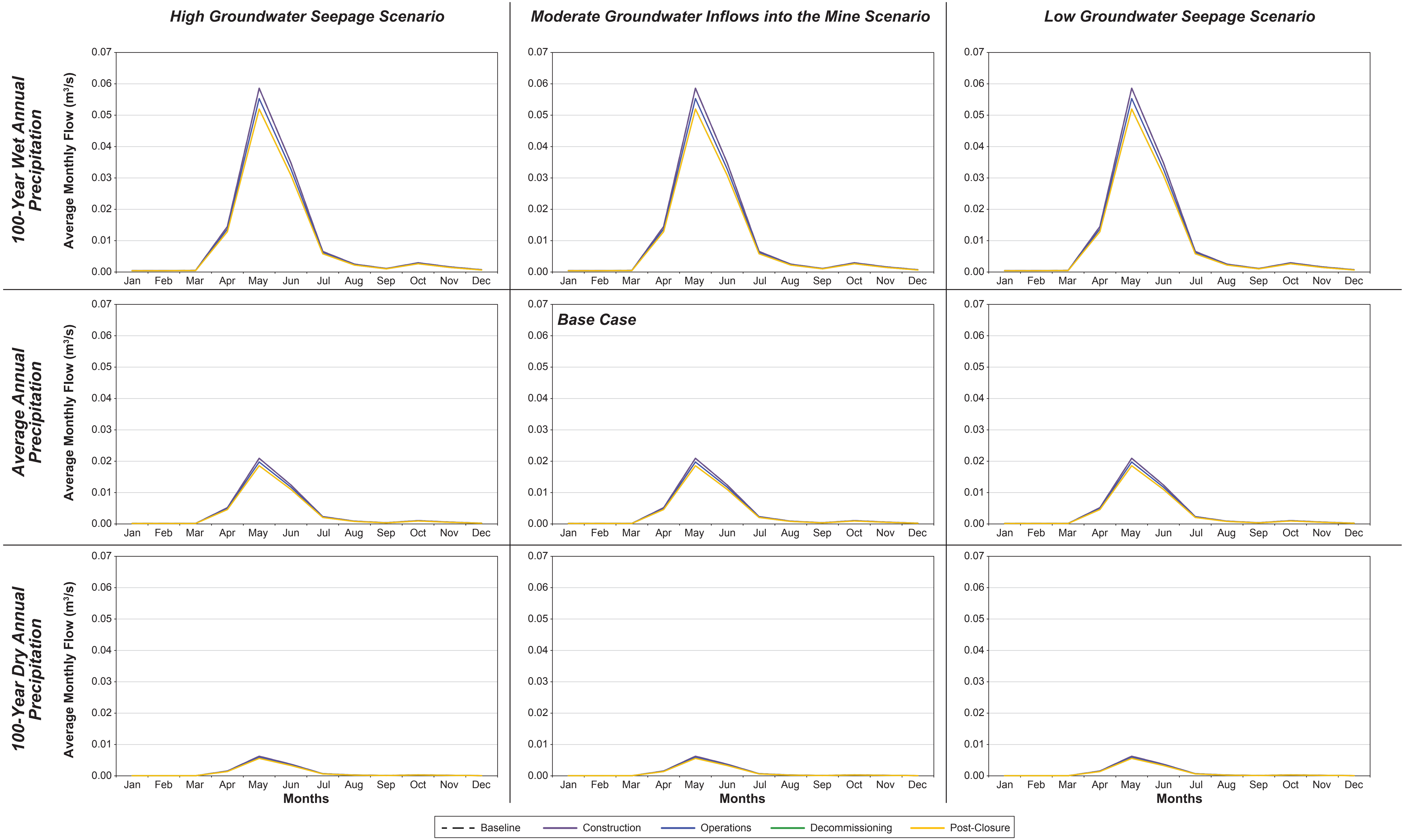


Figure 8.8-9

Sensitivity Analysis Scenario Results for Streamflow Hydrographs at M20 Creek

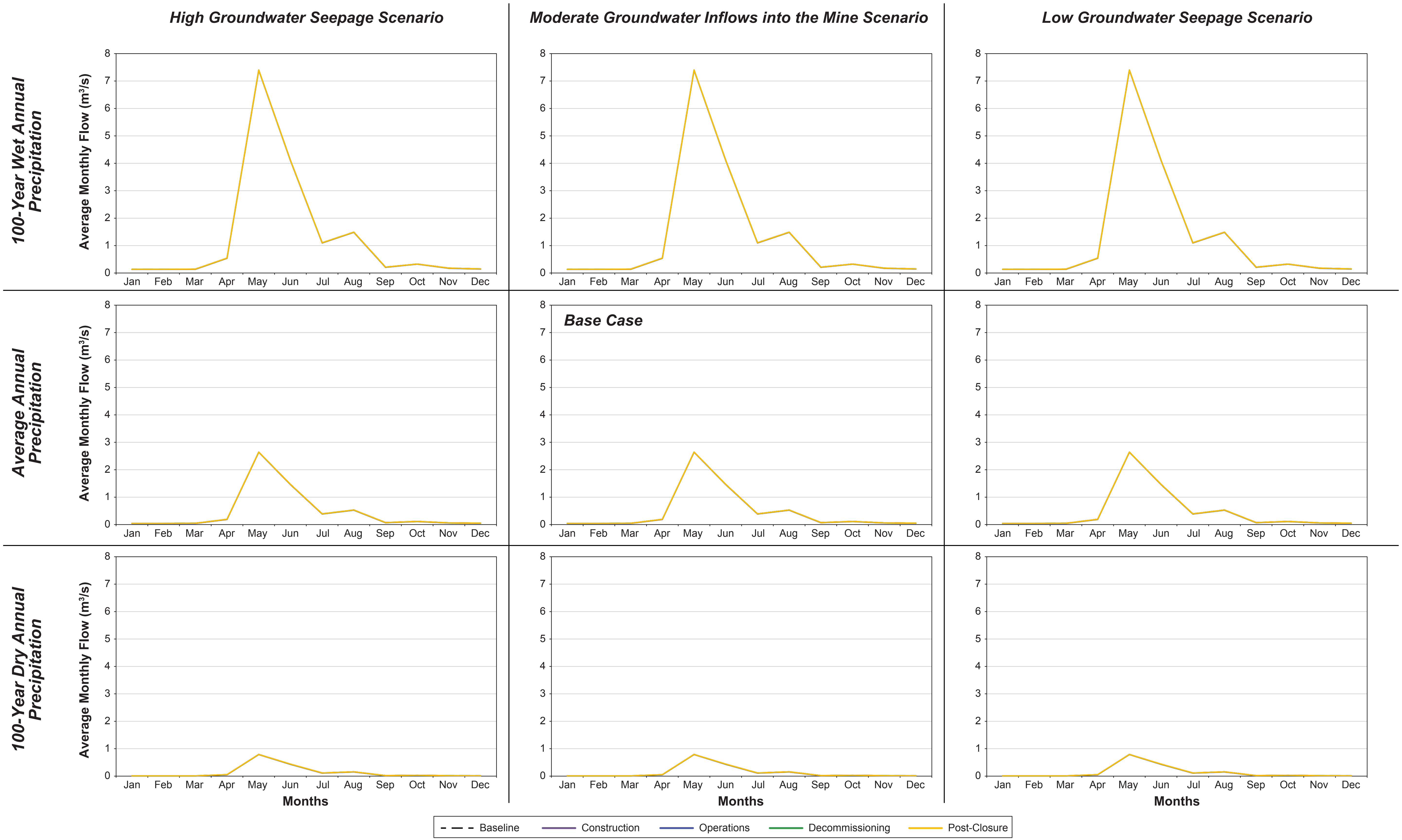


Figure 8.8-10

Sensitivity Analysis Scenario Results for Streamflow Hydrographs at Murray River Downstream of Confluence with M19 Creek

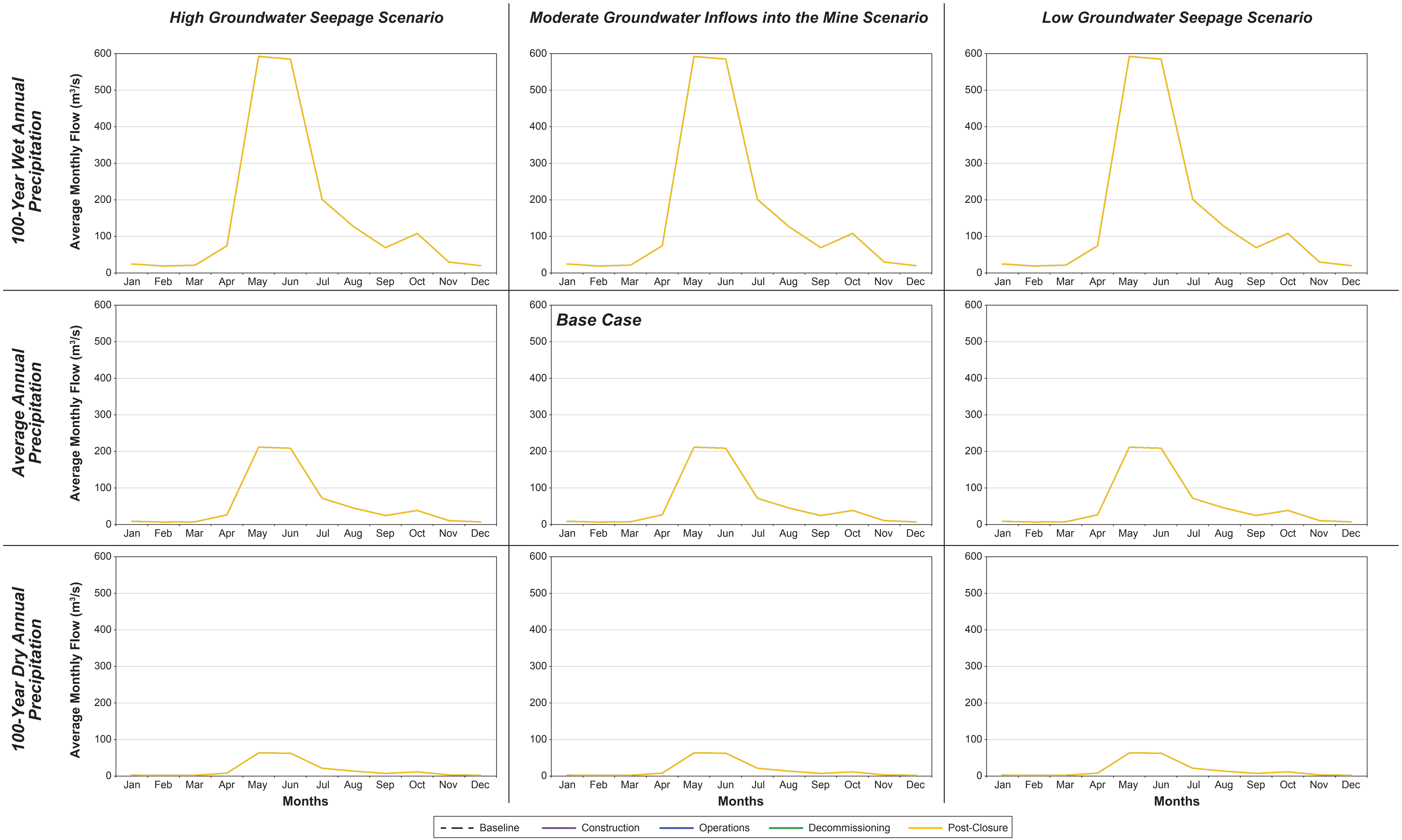


Table 8.8-9. Identified Project-related Contaminants of Potential Concern, M20 Creek

Model Case	Surface Flows	Groundwater Inflows	Stream Chemistry	Geochemistry Source Terms	Groundwater Quality	COPC for Aquatic Life: Construction	COPC for Aquatic Life: Operations	COPC for Aquatic Life: Decommissioning and Post-Closure
Base	average	moderate	median	expected case	baseline	-	-	-
1	average	high	median	expected case	baseline	-	-	-
2	average	low	median	expected case	baseline	-	-	-
3	wet	moderate	median	expected case	baseline	-	-	-
4	wet	high	median	expected case	baseline	-	-	-
5	wet	low	median	expected case	baseline	-	-	-
6	dry	moderate	median	expected case	baseline	-	-	Al[1]
7	dry	high	median	expected case	baseline	-	-	Al[1]
8	dry	low	median	expected case	baseline	-	-	Al[1]
9	average	moderate	95th percentile	expected case	baseline	Al[1], Fe[1]	Al[1], Fe[1]	Al[1], Fe[1]
10	average	high	95th percentile	expected case	baseline	Al[1], Fe[1]	Al[1], Fe[1]	Al[1], Fe[1]
11	average	low	95th percentile	expected case	baseline	Al[1], Fe[1]	Al[1], Fe[1]	Al[1], Fe[1]
12	average	moderate	median	upper case	baseline	-	-	-
13	average	high	median	upper case	baseline	-	-	-
14	average	low	median	upper case	baseline	-	-	-
15	average	moderate	median	expected case	10 times baseline	-	-	-
16	average	high	median	expected case	10 times baseline	-	-	-
17	average	low	median	expected case	10 times baseline	-	-	-

[1] *Dissolved parameter*

M19A Creek

The change in M19A Creek water quality due to seepage loss from CCR North and CCR South piles was assessed by screening water quality predictions to identify COPC (Table 8.8-10). Selenium was identified as a COPC for aquatic life and wildlife for the base case water quality predictions. Mercury was identified as a COPC for aquatic life and wildlife for one set of sensitivity analyses. No COPC were identified for drinking water.

The predicted water quality for M19A Creek for parameters of interest is presented in Figure 8.8-11.

Selenium

Selenium concentrations are predicted to increase above the BC water quality guidelines for the protection of aquatic life and for wildlife (0.002 mg/L) and above the range of background concentrations during low flows in January, February, and March during Decommissioning and Reclamation and Post-closure.

CCR North and South piles will be constructed on geomembrane liners (Appendix 3-C) to prevent infiltration of contact water to groundwater and minimize selenium loading to the receiving environment. The water quality model conservatively assumed 2% seepage loss through the geomembrane liner (Appendix 3-C; Appendix 8-E). Collected seepage will be directed to seepage collection ponds and water will be preferentially reclaimed to the Coal Processing Plant.

At Decommissioning and Reclamation, reclaim of collected seepage from the CCR piles to the Coal Processing Plant will cease and seepage in the CCR North and South collection ponds will exfiltrate to ground. Groundwater modelling (Appendix 7-B) indicates that groundwater flow paths from the CCR piles will report to M19A Creek.

Elevated selenium concentrations in M19A Creek are predicted under extreme dry climatic conditions (100-year dry year). Concentrations of selenium in CCR seepage are likely over estimated under extreme dry conditions because low infiltration conditions results in lower water contact that was not considered in the scaling factors applied in the water quality model for these sensitivity analyses.

Water quality in the CCR piles' seepage collection ponds will be monitored as part of the ML/ARD Management Plan (Section 24.7) and in M19A Creek as part of the Selenium Management Plan (Section 24.10); therefore, any increase in selenium above the concentrations predicted in the base case model will be identified.

It is important to note that no selenium attenuation or solubility control was applied in the water quality model. Selenium attenuation in CCR piles in the Elk Valley has been observed to be up to 95% and these attenuation factors have been applied to water quality predictions in northeastern BC (SRK 2012; Lorax 2012). Reduced selenium loading in the Elk Valley from CCR and tailings with low oxygen content and high organic carbon content has been attributed to natural biological reduction of selenium to less mobile species (e.g., selenite and SeO_3^{2-}) which more readily sorb to iron and manganese oxides and oxyhydroxides (SAPSM 2010). Therefore, the effects assessment presented here represents a conservative assessment of potential effects to the surface water VC due to increased selenium concentrations.

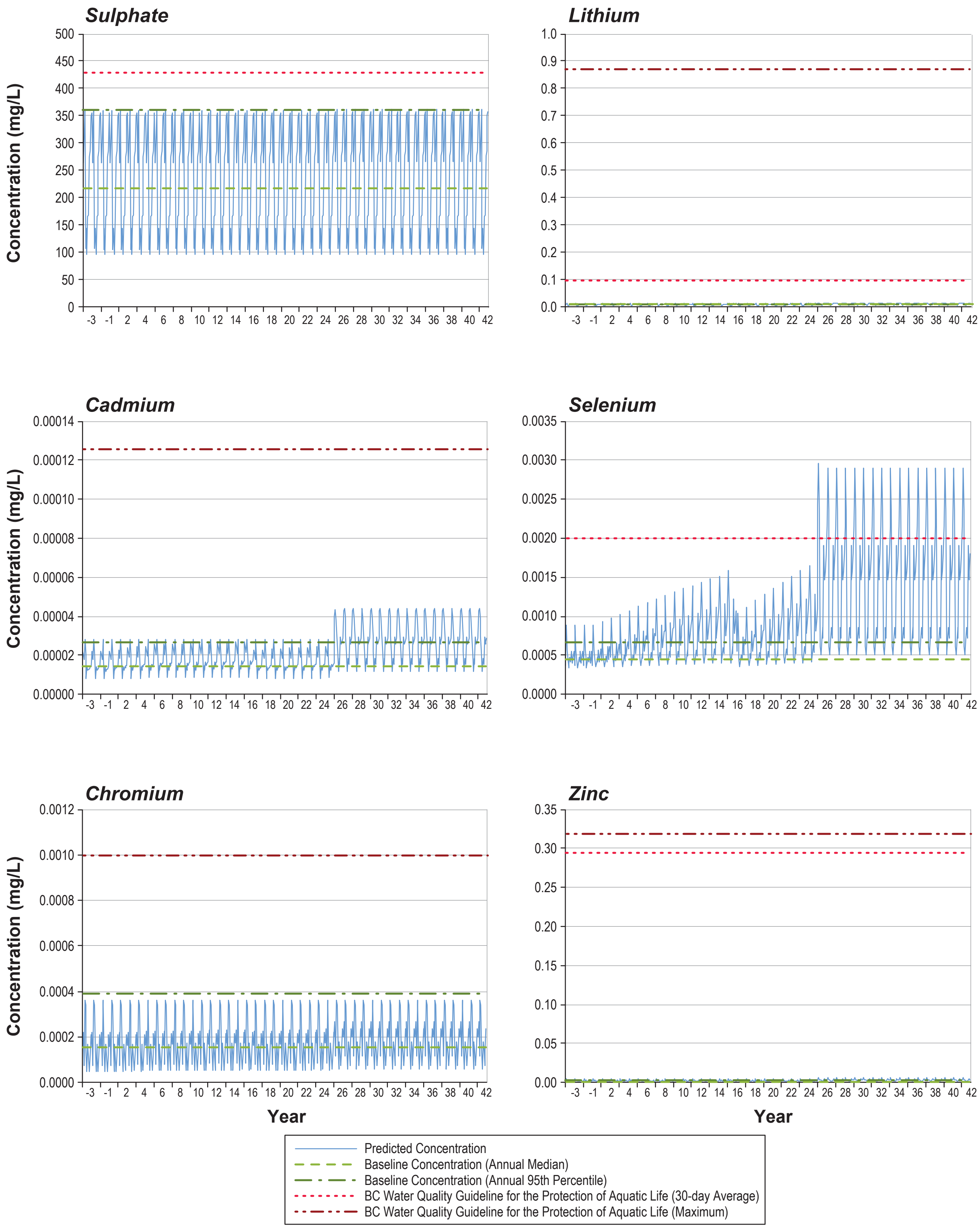
Table 8.8-10. Identified Project-related Contaminants of Potential Concern, M19A Creek

Model Case	Surface Flows	Groundwater Inflows	Stream Chemistry	Geochemistry Source Terms	Groundwater Quality	COPC for Aquatic Life			COPC for Wildlife		
						Construction	Operations	Decommissioning and Post-Closure	Construction	Operations	Decommissioning and Post-Closure
Base	average	moderate	median	expected case	baseline	-	-	Se	-	-	Se
1	average	high	median	expected case	baseline	-	-	Se	-	-	Se
2	average	low	median	expected case	baseline	-	-	Se	-	-	Se
3	wet	moderate	median	expected case	baseline	-	-	-	-	-	-
4	wet	high	median	expected case	baseline	-	-	-	-	-	-
5	wet	low	median	expected case	baseline	-	-	-	-	-	-
6	dry	moderate	median	expected case	baseline	-	Se	Al[1], Se	-	Se	Se
7	dry	high	median	expected case	baseline	-	Se	Al[1], Se	-	Se	Se
8	dry	low	median	expected case	baseline	-	Se	Al[1], Se	-	Se	Se
9	average	moderate	95th percentile	expected case	baseline	-	-	Se	-	-	Se
10	average	high	95th percentile	expected case	baseline	-	-	Se	-	-	Se
11	average	low	95th percentile	expected case	baseline	-	-	Se	-	-	Se
12	average	moderate	median	upper case	baseline	-	-	Al[1], Hg, Se	-	Se	Hg, Se
13	average	high	median	upper case	baseline	-	-	Hg, Se	-	Se	Hg, Se
14	average	low	median	upper case	baseline	-	-	Al[1], Hg, Se	-	Se	Hg, Se
15	average	low	median	expected case	10 times baseline	-	-	Se	-	-	Se
16	average	moderate	median	expected case	10 times baseline	-	-	Se	-	-	Se
17	average	high	median	expected case	10 times baseline	-	-	Se	-	-	Se

[1]*Dissolved parameter*

Figure 8.8-11

Water Quality Predictions for Site M19A, Murray River Coal Project



Note: Annual median hardness values for the site were applied for hardness dependent guidelines.

Long-term selenium leaching from the CCR piles will primarily be minimized by limiting infiltration. The CCR piles will be constructed using "bottom-up" methods allowing for greater compaction and reducing the need for rehandling of material at Decommissioning and Reclamation (Appendix 3-C). At Decommissioning and Reclamation and Post-closure, a low permeability layer consisting of stockpiled fine rejects or tailings material and a topsoil layer will be placed as a cover. The cover will have sufficient water storage for both annual precipitation and snowmelt (Section 3.9.4.1).

A change in water quality in M19A Creek due to increased selenium concentrations is considered to be a potential Project-related effect; therefore, a residual effect on M19A Creek was determined and effects on surface water due to a change in water quality in M19A Creek is further considered in Section 8.9.1.

Aluminum

An increase in aluminum concentrations above guidelines and above background concentrations in M19A Creek was identified in Decommissioning and Reclamation and Post-Closure in model cases with low surface flows or upper case geochemistry source terms.

Mass balance modelling typically overestimates aluminum concentrations in circum-neutral environments such as M19A Creek because aluminum is typically controlled through mineral solubility (Stumm and Morgan 1996). Further, decreased water contact in the CCR piles in a dry year has not been considered in the model. Water quality in the CCR seepage collection ponds will be monitored as part of the ML/ARD Management Plan (Section 24.7) and in M19A Creek as part of the Selenium Management Plan (Section 24.10); therefore, any increase in aluminum above the concentrations predicted in the base case model will be identified.

For the reasons discussed above, a change in water quality in M19A Creek due to increased aluminum concentrations is not considered to be a likely Project-related effect.

Mercury

An increase in total mercury concentrations above guidelines and above background concentrations in M19A Creek was identified in the model cases when upper case geochemistry source terms were applied.

Total mercury is frequently below the detection limit in coal humidity cells used to develop source terms for the water quality model (Appendices 3-B and 8-E). Therefore, mercury concentrations may be inappropriately magnified in the water quality model. Water quality in the CCR seepage collection ponds will be monitored as part of the ML/ARD Management Plan (Section 24.7) and in M19A Creek as part of the Selenium Management Plan (Section 24.10); therefore, any increase in total mercury above the concentrations predicted in the base case model will be identified.

For the reasons discussed above, a change in water quality in M19A Creek due to increased total mercury concentrations is not considered to be a likely Project-related effect; therefore, no residual effect on M19A Creek due to increase mercury concentrations was determined and effects on surface water due to increased mercury in M19A Creek will not be considered further in the assessment.

M19 Creek

The change in M19A Creek water quality due to seepage loss from CCR North and South piles and additional Project-related chemical loading from M19A Creek was assessed by screening water quality predictions to identify COPC. Screening of parameters against provincial guidelines is presented in Appendix 8-G.

No Project-related COPC were identified for M19 Creek for any of the model sensitivity analyses following the screening-level assessment.

Water quality will be monitored in M19 Creek as part of the Selenium Management Plan (Section 24.10); therefore, any increase in concentrations above predictions will be identified.

Water quality predictions indicate that no change to water quality is expected as a result of Project-related activities; therefore, no residual effect on M19 Creek was determined and effects on surface water due to a change in water quality in M19 Creek will not be considered further in the assessment.

Murray River

The change in Murray River water quality due to effluent discharge from the Decline and CPP ponds and additional Project-related chemical loading from M20 and M19 creeks was assessed downstream of all Project-related effluent discharges and seepage pathways at water quality monitoring site MR7 (Figure 8.6-1).

The predicted water quality for Murray River for parameters of interest from various sensitivity analyses is presented in Figures 8.8-12 to 8.8-15. Screening of parameters against provincial guidelines is presented in Appendix 8-G. No Project-related COPC were identified for Murray River for the model sensitivity analyses 1 to 16 following the screening-level assessment. Increasing the concentrations of baseline groundwater quality by ten times to assess uncertainty in baseline groundwater quality source terms for the model did not substantially alter predicted water quality from base case predictions in Murray River, with the exception of lithium which was identified as a COPC for aquatic life for the high inflow rate, ten times groundwater chemistry water quality predictions.

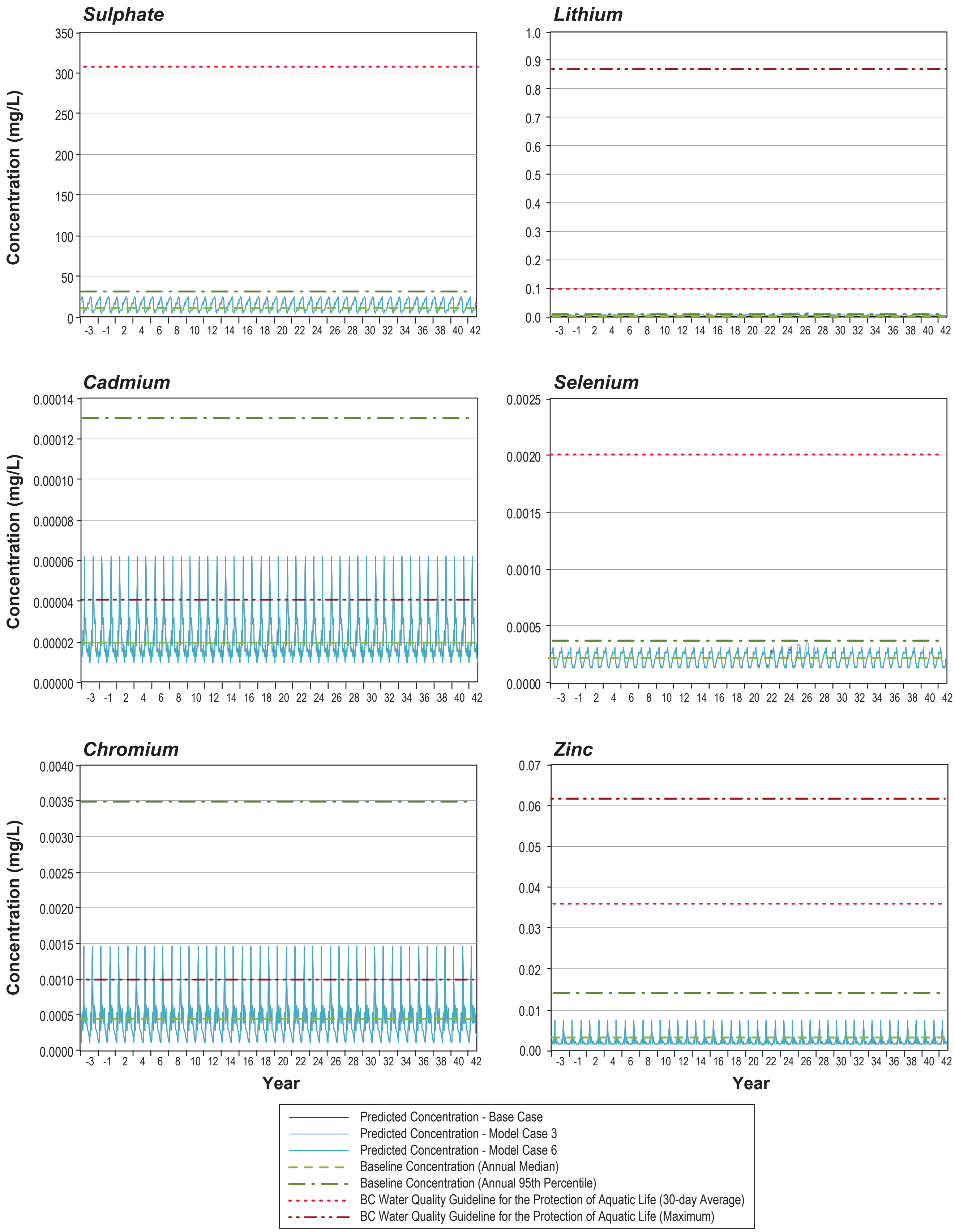
Lithium

An increase in total lithium concentrations above guidelines and above background concentrations in Murray River was identified in the model cases when high groundwater inflow rates, and ten times increased groundwater chemistry source terms were applied. Increased concentrations above the 30-day average water quality guideline are predicted in low flow months from Year 22 to Year 25 only. No concentrations greater than the maximum water quality guideline are predicted.

Underground water will be collected in the CPP pond and water quality in the CPP pond will be monitored as part of the ML/ARD Management Plan (Section 24.7) and in Murray River as part of the Selenium Management Plan (Section 24.10); therefore, any increase in total lithium above the concentrations predicted in the base case model will be identified.

Figure 8.8-12

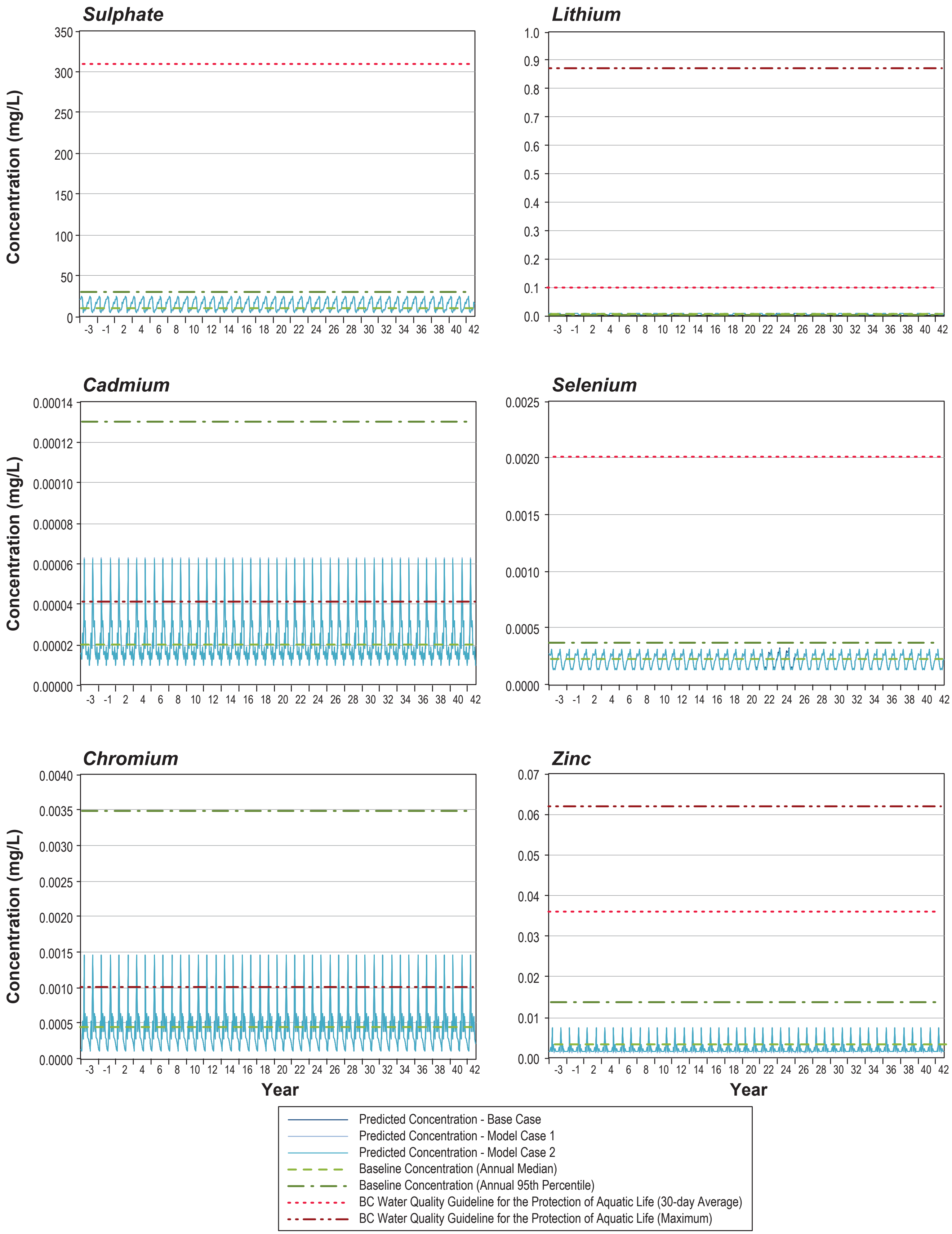
Water Quality Predictions for Site MR7, Varying Annual Precipitation, Murray River Coal Project



Note: Annual median hardness values for the site were applied for hardness dependent guidelines.

Figure 8.8-13

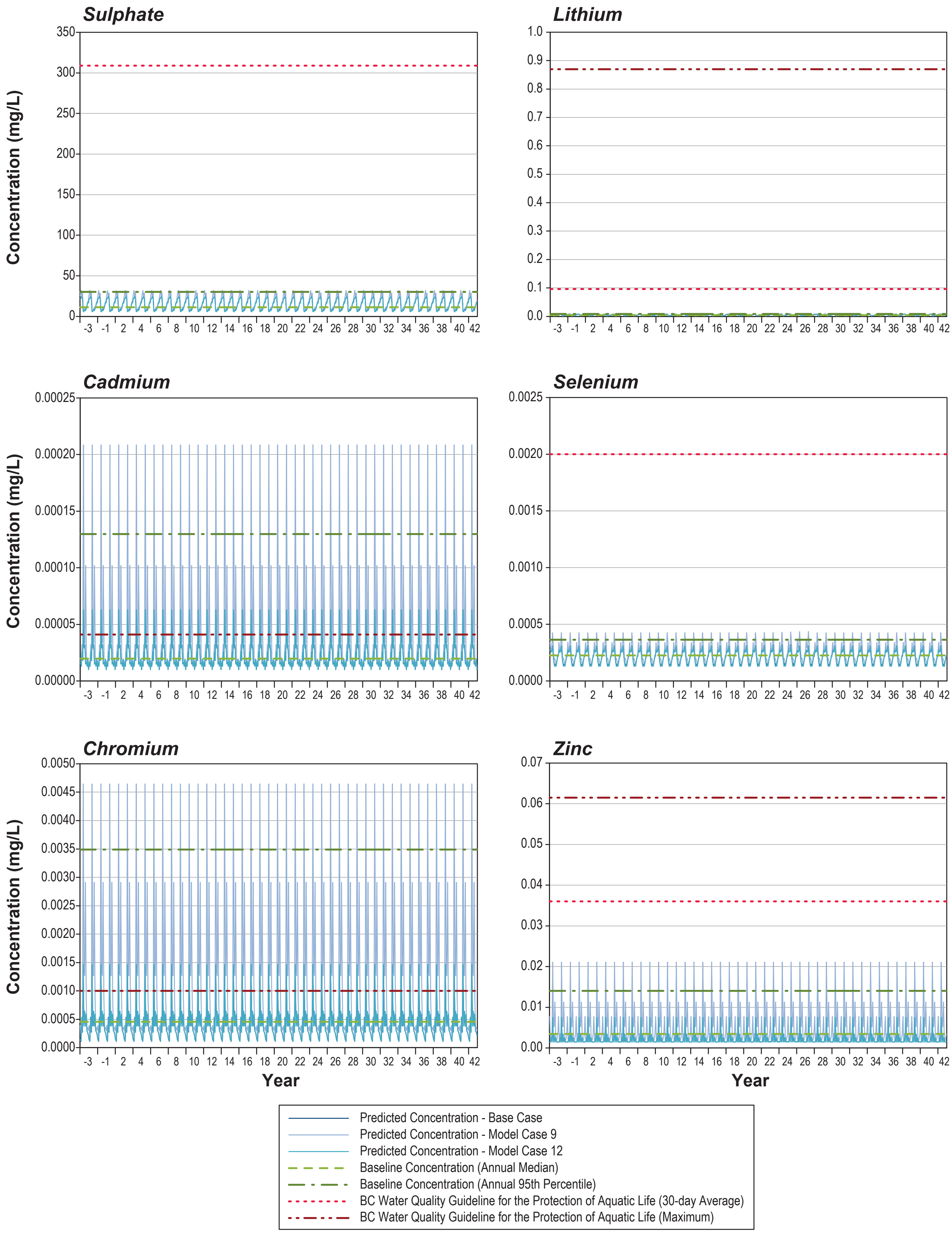
Water Quality Predictions for Site MR7, Varying Groundwater Inflows, Murray River Coal Project



Note: Annual median hardness values for the site were applied for hardness dependent guidelines.

Figure 8.8-14

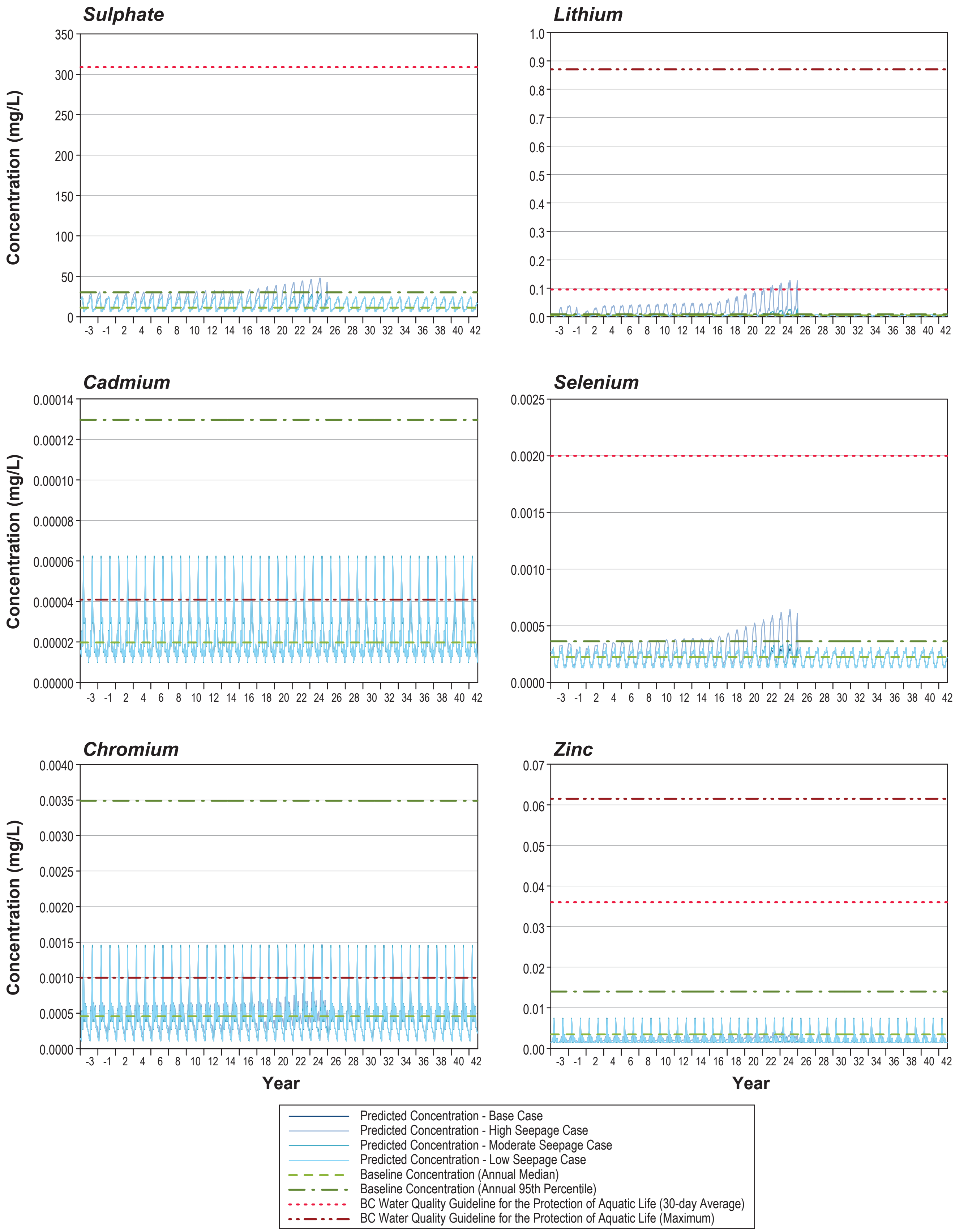
Water Quality Predictions for Site MR7, Varying Chemistry Source Terms, Murray River Coal Project



Note: Annual median hardness values for the site were applied for hardness dependent guidelines.

Figure 8.8-15

Water Quality Predictions for Site MR7, Varying Groundwater Chemistry Source Terms, Murray River Coal Project



Note: Annual median hardness values for the site were applied for hardness dependent guidelines.

For the reasons discussed above, a change in water quality in Murray River due to increased total lithium concentrations is not considered to be a likely Project-related effect; therefore, no residual effect on Murray River due to increased lithium concentrations was determined and effects on surface water due to increased lithium in Murray River will not be considered further in the assessment.

8.8.2 Residual Effects on Sediment Quality

Potential Project-related effects to sediment quality are expected to be successfully mitigated with the management plans proposed in Chapter 24. Project-related changes to sediment quality particle size are anticipated to be mitigated with the Erosion and Sediment Control (Chapter 24.5) management plan. Residual changes to sediment chemistry through Project related changes to water quality are expected to be mitigated with the Water Management Plan (Section 24.6) and ML/ARD Management Plan (Section 24.7).

The increased selenium levels in M19A Creek predicted by the water quality model (Section 8.8.1) are not anticipated to have a residual effect on sediment quality. Concentrations of selenium in the water column are expected to be marginally higher than the BC Water Quality Guideline for Aquatic Life for a short period of time (January to March) during Decommissioning and Reclamation and Post-closure. Changes to water selenium levels may be more pronounced than in stream sediments. In the Elk River Basin (southeastern BC), increases of selenium in stream water associated with coal mines (approximately 100-200 fold increase in Se concentrations compared to water from reference sites) were more apparent than changes to sediment concentrations (approximately five-fold increase; McDonald and Strosher 1998). As such, it is expected that there will be no residual effects on M19A selenium concentrations in sediment.

8.8.3 Residual Effects on Aquatic Resources

8.8.3.1 Change in Surface Water Quantity

Project-related effects from changes to surface water quantity are anticipated to be negligible for aquatic resources. Model results (Section 8.8.1 and Appendix 8-E) indicated that Project-related changes from baseline to stream flow will be low (maximum of 11%). Changes to channel morphology are considered negligible, as Project related changes to catchment area for most sites is minimal (≤1%) and still minor in the highest predicted cases (~11% for M19A and M17B creek catchment areas). Given these small changes to surface water quantity, no Project residual effects are anticipated for aquatic resources due to changes in surface water quantity.

8.8.3.2 Change in Surface Water Quality

Results of the water quality model identified selenium as a COPC for aquatic life (Section 8.8.1.2). It is predicted that M19A Creek will have selenium concentrations greater than the BC MOE water quality guideline for the protection of aquatic life (0.002 mg/L) from January to March during Decommissioning and Reclamation and Post-closure. A change in surface water quality due to increased selenium concentrations in M19A Creek may affect aquatic resources since selenium bioaccumulates in the food web (see Section 8.7.5.2).

Elevated selenium concentrations are predicted to be restricted to M19A Creek, and elevated concentrations downstream in M19 Creek or the Murray River are not predicted (Section 8.8.1.2). Model results indicated that selenium concentrations will be elevated from January to March, which is a period of low activity for both periphyton and benthic invertebrates. Therefore, the timing of elevated selenium concentrations is expected to have limited effects on aquatic resources (as opposed to during high productivity periods in the summer). Aquatic resources are generally more tolerant of selenium exposures and can bioaccumulate it without adverse effects than the more sensitive egg-laying vertebrates (Janz et al. 2009).

As well, changes to water selenium concentrations may be more prominent than in aquatic resources tissues. In the Elk River Basin (southeastern BC), large increases of selenium in stream water due to discharge or activities at coal mines (approximately 100-200 fold increase in Se concentrations compared to water from reference sites) were more apparent than changes to periphyton and benthic invertebrate tissue levels (approximately two to five-fold increase; McDonald and Strosher 1998).

A change in water quality in M19A Creek due to increased selenium concentrations is considered to be a Project-related effect; therefore, a residual effect to aquatic resources due to a change in water quality in M19A Creek was determined and is further considered in Section 8.9.1.

8.8.4 Summary of Residual Effects on Surface Water and Aquatic Resources

Table 8.8-11 provides a summary of the assessment of residual effects on surface water and aquatic resources.

8.9 Characterizing Residual Effects, Significance, Likelihood and Confidence on Surface Water and Aquatic Resources

Residual effects of the Project on surface water identified in Section 8.8 are further characterized and assessed in this section. Residual effects are characterized using standard criteria (i.e., the magnitude, geographic extent, duration, frequency, reversibility, resiliency, and ecological context). Standard ratings (i.e., major, moderate, minor/low, medium, and high) for these characterization criteria are provided in Chapter 5; however, Table 8.9-1 provides a summary of definitions for each characterization criterion, specific to the surface water VC.

Characterization of residual effects, likelihood, significance, and confidence for surface water VCs are presented in Table 8.9-2. The assessment considered results of baseline studies, predictive modelling, feedback received during the pre-Application stage from review participants, relevant legislation/standards, scientific literature, and professional experience and judgement.

8.9.1 Residual Effects Characterization for Surface Water

8.9.1.1 Significance of Residual Effects on Surface Water

<u>Change in Surface Water Quantity</u>

- **Magnitude**: Based on estimated effects of the Project on surface water quantity (Section 8.8.1.1) the magnitude of changes in surface water quantity is **minor** at M17B, M19A, and M20 creeks.

Table 8.8-11. Summary of Residual Effects on Surface Water

Valued Component	Project Phase	Project Component / Physical Activity	Description of Cause-Effect	Description of Mitigation Measure(s)	Description of Residual Effect
Surface Water	Construction, Operations, Decommissioning and Reclamation, Post-Closure	Site water management, release into receiving environment, and sibsidence	- Surface Water Quantity: Site water management activities (diversions, withdrawals, and discharges) could alter the stream hydrologic regime	Water Management Plan	Streamflow changes are predicted at M17B, M19A, and M20 creeks. Flow changes in Murray River are negligible (less than 1% of baseline flows).
Surface Water	Decommissioning and Reclamation, Post-Closure	Seepage loss from CCR piles.	Selenium leaching from CCR piles in exfiltrate to ground with flow paths predicted to discharge to receiving environment	Erosion and Sediment Control Management Plan; Water Management Plan; ML/ARD Management Plan; Selenium Management Plan	Increased selenium concentrations from January to March through Decommissioning and Reclamation and Post-Closure in M19A. No other residual effects on surface water due to a change in water quality are predicted.
Aquatic Resources	Decommissioning and Reclamation, Post-Closure	Seepage loss from CCR piles.	Increased aqueous selenium concentrations from January to March through Decommissioning and Reclamation and Post-Closure in M19A. No other residual effects on surface water due to a change in water quality are predicted.	Erosion and Sediment Control Management Plan; Water Management Plan; ML/ARD Management Plan; Selenium Management Plan	Selenium can biomagnify and bioaccumulate in food webs. Elevated selenium levels can alter aquatic resource community composition, and has been associated with several effects at the individual level (reduced body mass, fecundity and maternal transfer to eggs observed in mayflies). No other residual effects on aquatic resources are predicted.

Table 8.9-1. Definitions of Characterization Criteria for Residual Effects on Surface Water and Aquatic Resources

							Likelihood of Effects	
Magnitude	**Duration**	**Frequency**	**Geographic Extent (Physical/Biophysical)**	**Reversibility**	**Resiliency**	**Ecological Context**	**Probability**	**Confidence Level**
How severe will the effect be?	*How long will the effect last?*	*How often will the effect occur?*	*How far will the effect reach?*	*To what degree is the effect reversible?*	*How resilient is the receiving environment or population?*	*What is the current condition of the ecosystem and how commonly is it represented in the LSA?*	*How likely is the effect to occur?*	*How certain is this analysis?*
Negligible: No or very little detectable change from baseline conditions or below applicable guideline.	**Short-term:** Effect lasts 1 to 5 years.	**Once:** Effect is confined to one discrete period in time during the life of the Project.	**Local:** Effect extends less than 500 m from infrastructure or activity.	**Reversible Short-term:** Effect can be reversed relatively quickly.	**Low:** The receiving environment or population has a low resilience to imposed stresses, and will not easily adapt to the effect.	**Low:** the receptor is considered to have little to no unique attributes or provision of functions is severely degraded.	**High:** It is highly likely that this effect will occur.	**High:** > 80% confidence. There is a good understanding of the cause-effect relationship and all necessary data are available for the Project area. There is a low degree of uncertainty and variation from the predicted effect is expected to be low.
Minor: Differs from the average value for baseline conditions to a small degree or within two times the applicable guideline.	**Medium-term:** Effect lasts 6 to 25 years.	**Sporadic:** Effect an effect that occurs at sporadic or intermittent intervals during any phase of the Project.	**Landscape:** Effect is limited to the LSA or one watershed (i.e., Sub-area).	**Reversible Long-term:** within 20 years of Post Closure.	**Neutral:** The receiving environment or population has a neutral resilience to imposed stresses and may be able to respond and adapt to the effect.	**Neutral:** The receiving environment considered to have some unique attributes and provides most functions that an undisturbed environment would provide.	**Medium:** This effect is likely, but may not occur.	**Medium:** 50 to 80% confidence. The cause-effect relationships are not fully understood, there are a number of unknown external variables, or data for the Project area are incomplete. There is a moderate degree of uncertainty; while results may vary, predictions are relatively confident.
Medium: Differs substantially from the average value for baseline conditions and approaches the limits of natural variation or within five times the applicable guideline.	**Long-term:** Effect lasts between 26 and 50 years.	**Regular:** Effect occurs on a regular basis during the life span of the Project.	**Regional:** Effect extends across the broader region (e.g., RSA, multiple watersheds, etc.).	**Irreversible:** an effect cannot be reversed (i.e., is permanent).	**High:** The receiving environment or population has a high natural resilience to imposed stresses, and can respond and adapt to the effect.	**High:** The receiving environment or population is uncommon and occurs in a natural state and provides functions at a maximum capacity.	**Low:** This effect is unlikely but could occur.	**Low:** < 50% confidence. The cause-effect relationships are poorly understood, there are a number of unknown external variables, and data for the Project area are incomplete. High degree of uncertainty and final results may vary considerably.
Major: Differs substantially from baseline conditions, resulting in a detectable change beyond the range of natural variation or within ten times the applicable guideline.	**Far Future:** Effect lasts more than 50 years.	**Continuous:** Effect occurs constantly during the life of the Project.	**Beyond Regional:** Effect extends beyond the regional scale, and may extend across or beyond the province.					

Table 8.9-2. Characterization of Residual Effects, Significance, Confidence and Likelihood on Surface Water and Aquatic Resources

Residual Effects	Residual Effects Characterization Criteria							Significance of Adverse Residual Effects	Likelihood and Confidence	
	Magnitude (*minor, moderate, major*)	Duration (*short, medium, long, far future*)	Frequency (*once, sporadic, regular, continuous*)	Geographic Extent (*local, landscape, regional, beyond regional*)	Reversibility (*reversible short term; reversible long term; irreversible*)	Resiliency	Context (*low, neutral, high*)	Not significant (*minor, moderate*); Significant (*major*)	Probability (*low, medium, high*)	Confidence (*low, medium, high*)
Surface Water (due to a change in water quantity)	Minor	Far future	Continuous	Local	Reversible long term	Neutral	Neutral	Not significant (minor)	High	Medium
Surface Water (due to a change in water quality)	Minor	Far future	Regular	Local	Reversible long term	Neutral	Low	Not significant (minor)	Medium	Medium
Aquatic Resources (due to a change in water quality)	Minor	Far future	Regular	Local	Reversible long term	High	Low	Not significant (minor)	Medium	High

- **Duration**: Residual effects on flows will be detectable during all proposed Project phases; therefore, the residual effects are considered **far future** in duration.
- **Frequency**: The assessed indicators (i.e., annual, monthly, peak, and low flows) are **continuous** hydrologic indices that would be affected on an on-going basis, though not to the same degree.
- **Geographic Extent**: Effects of the Project on Murray River streamflows, within the LSA, are negligible. Changes in Murray River flows downstream of the LSA (i.e., within the RSA) will be even less, and therefore, are considered negligible. Thus, effects of the Project on surface water quantity are **local** and restricted to M17B, M19A, and M20 creeks.
- **Reversibility**: Effects on streamflows are reversible at the end of the project when mine dewatering ceases (**reversible long-term**).
- **Resiliency:** For surface water quantity, there is not a direct measure of resilience, and therefore a **neutral** resiliency level was selected in Table 8.9.2. Indirect measures, i.e., resilience of downstream fisheries and aquatic resources to surface water quantity changes, are discussed in Chapter 9 and Section 8.9.3.
- **Ecological Context**: For surface water quantity, there is not a direct measure of ecological context, and therefore, a **neutral** level was selected in Table 8.9.2. Indirect measures, i.e., unique attributes of downstream fisheries and aquatic resources, are discussed in Chapter 9 and Section 8.9.3.

The residual effects on surface water quantity due to Project activities are predicted to be **not significant (minor)** (Table 8.9-2). Minor streamflow changes are anticipated to be confined to M17B, M19A, and M20 creeks. Predicted effects at the downstream end of the LSA (i.e., Murray River downstream of confluence with M19 Creek) are negligible.

<u>Change in Surface Water Quality</u>

- **Magnitude**: Increased selenium concentrations in M19A Creek are predicted to be higher than baseline conditions, but within two times the BC MOE guideline for the protection of freshwater aquatic life. Therefore, the magnitude was assessed as **minor.**
- **Duration**: Residual effects on water quality are predicted to begin in Decommissioning and Reclamation and extend into Post-closure; therefore, the duration of the effect is considered **far future.**
- **Frequency**: Increased selenium concentrations occur between January and March annually; therefore, the frequency of the effect is **regular.**
- **Geographic Extent**: The change in water quality is confined to M19A; therefore, the geographic extent is **local.**
- **Reversibility**: Surface water quality effects are **reversible long-term** if leaching rates from the CCR piles decrease over time due to source depletion or armouring of particle surfaces.
- **Resiliency:** The resilience of M19A is assessed as **neutral** as end-receptors including aquatic resources may have some ability to tolerate or adapt to increased selenium concentrations.

- **Ecological Context**: The ecological context of M19A Creek was assessed as **low** because fish were not observed during baseline studies due to a fish barrier (beaver dam) and does not have unique aquatic attributes (see Section 8.9.3).

8.9.1.2 Characterization of Likelihood and Confidence for Residual Effects Conclusions on Surface Water

<u>Change in Surface Water Quantity</u>

- **Probability**: Project activities include underground mine dewatering, disturbance of surface runoff, and water discharge to (and withdrawal from) Murray River. Therefore, the probability changes in streamflows are **high**.
- **Confidence Level**: The confidence in the significance prediction and mitigation measures being followed was rated as **medium** for the residual effect of the Project on streamflows. While uncertainty exists in every prediction of future change, the approach used to assess the effects on water management activities on streamflows (Appendix 8-E) incorporated quantitative data from baseline reports, and is considered as a reliable water balance model. However, a high confidence level was not selected in Table 8.9-2 mainly due to the uncertainty in effects of subsidence on streamflows at M20 Creek.

<u>Change in Surface Water Quality</u>

- **Probability**: Water quality modelling included sensitivity analyses. Based on the understanding of the cause-effect relationship between selenium leaching from the CCR piles and increased selenium concentrations in M19A, the probability of an effect is **high.**
- **Confidence Level**: The confidence in the significance prediction and mitigation measures being followed was rated as **medium** for the residual effect of the Project on water quality. While uncertainty exists in every prediction of future change, the approach used to assess the effects of Project activities on surface water quality (Appendix 8-E) incorporated quantitative data from baseline reports, analytical testing, and calibrated water balance and groundwater models and is considered a reliable water quality model.

8.9.2 Residual Effects Characterization for Sediment Quality

No residual Project effects were identified for sediment quality (Section 8.8.2). As such, no residual effects were carried forward for characterization.

8.9.3 Residual Effects Characterization for Aquatic Resources

8.9.3.1 Significance of Residual Effects Aquatic Resources

<u>Change in Water Quality</u>

The characterization of the residual effects to aquatic resources from changes to water quality (predicted elevated concentrations in M19A Creek) is summarized in Table 8.9-2.

- **Magnitude**: The potential increase of selenium concentrations in aquatic resource tissue is low, because the magnitude of the increase in water was assessed as minor (less than two times the guideline limit) and the effect occurs only periodically. As well, it is expected that the magnitude of change in surface water selenium concentrations will be higher than in benthic invertebrate tissues (McDonald and Strosher 1998). In general, algae and benthic invertebrates have a greater tolerance to elevated selenium concentrations than higher trophic levels (Janz et al. 2009). Given the small deviation of selenium water concentrations from guideline limits and the general higher tolerance of aquatic resources to selenium, the magnitude is considered **minor**.
- **Duration**: Selenium levels in the water column are expected to be elevated for a short period (three months) during Decommissioning and Reclamation (three years) and Post-closure (30 years). As such, the effect is considered **far-future**.
- **Frequency**: Elevated selenium concentrations will be **regular**. Concentrations of selenium in M19A Creek are anticipated to be greater than BC guidelines for aquatic life in low flow months (January to March) during Decommissioning and Reclamation and Post-closure. Selenium concentrations are predicted to be lower than the guidelines at other times of the year during these phases, and at all times during Construction and Operation in M19A Creek.
- **Geographic Extent**: Elevated selenium concentrations are only predicted to occur in M19A Creek. No Project-related exceedances of the guidelines are predicted to occur in the downstream waterways (M19 Creek or the Murray River); therefore, the geographic extent of the effect is considered **local.**
- **Reversibility**: Pulses of elevated selenium water concentrations into aquatic systems can lead to elevated concentrations in the aquatic environment for some time (Hamilton 2004; Conley et al. 2009). However, leaching rates from the CCR piles may decrease over time due to source depletion or armouring of particle surfaces. Given that these small pulses with elevated selenium concentrations will occur regularly, but may decrease over time, the effects are considered **reversible long-term**.
- **Resiliency**: Algae and benthic invertebrates have generally demonstrated a greater tolerance to selenium than higher trophic levels (Janz et al. 2009); however, some taxa may display lower sensitivities (DeBruyn and Chapman 2007). If the habitat (water quality) in M19A Creek is affected by Project activities, it is anticipated that the re-colonization time will be short once conditions return to habitable levels. As such, given the high tolerance of aquatic resources to selenium, the timing of the elevated water concentrations (winter, when aquatic resources are not very active) and their strong ability to recolonize in M19A Creek, aquatic resource resiliency to elevated selenium is considered **high**.
- **Ecological Context**: The aquatic ecosystem on the east bank of the Murray River near the Coal Processing Site exhibits no unique traits. Communities are similar to the west bank and Murray River (Section 8.5.4), and therefore, are concluded to have **low** ecological context.

The residual effect on aquatic resources due to Project activities from changes to surface water quality are predicted to be **not significant (minor**; Table 8.9-2). Minor increases in selenium water concentrations are anticipated to be confined to M19A Creek, during a short time frame (January to March during Decommissioning and Reclamation and Post-closure). Potential effects are estimated to be short-term reversible, and periphyton and benthic invertebrate communities are likely to have a high resiliency.

8.9.3.2 Characterization of Likelihood and Confidence for Residual Effects Conclusions on Aquatic Resources

Increased Selenium Concentrations

- **Probability**: Water quality modelling included sensitivity analyses. While there is good understanding of the cause-effect relationship between selenium leaching from the CCR piles and increased selenium concentrations in M19A, there are uncertainties around the likely effects on aquatic resources. The probability of an effect is **medium.**
- **Confidence Level**: The confidence in the significance prediction and mitigation measures being followed was rated as **medium** for the residual effect of selenium on aquatic resources (Table 8.9-2). While uncertainty exists in every prediction of future change, the approach used to assess the effects on aquatic resources was developed to incorporate quantitative data from baseline reports and literature reviews, as well as predictive water quality modelling. The baseline status of the freshwater receiving environment is well established, the pathways of interactions between the Project and aquatic resources are well understood, and the predictive modelling provides quantitative estimates of the most significant changes in the freshwater environment.

8.10 SUMMARY OF RESIDUAL EFFECTS ASSESSMENT AND SIGNIFICANCE FOR SURFACE WATER AND AQUATIC RESOURCES

Table 8.10-1 provides a summary of the residual effects, mitigation, and significance on surface water and aquatic resources. Identified residual effects were carried forward to the Cumulative Effects Assessment in Section 8.11.

Table 8.10-1. Summary of Residual Effects, Mitigation, and Significance on Surface Water and Aquatic Resources

Residual Effects	Project Phase	Mitigation Measures	Significance
Surface Water			
Change in surface water quantity in M20, M17B, and M19A creeks.	Construction, Operation, Decommissioning and Reclamation, Post-closure	Water Management Plan	Not Significant (minor)
Change in surface water quality (elevated selenium concentrations) in M19A Creek.	Decommissioning and Reclamation, Post-closure	Erosion and Sediment Control Management Plan; Water Management Plan; ML/ARD Management Plan; Selenium Management Plan	Not Significant (minor)
Aquatic Resources			
Change in surface water quality (elevated selenium concentrations) in M19A Creek.	Decommissioning and Reclamation, Post-closure	Erosion and Sediment Control Management Plan; Water Management Plan; ML/ARD Management Plan; Selenium Management Plan	Not Significant (minor)

8.11 CUMULATIVE EFFECTS ASSESSMENT

8.11.1 Introduction

Cumulative effects are the result of a Project-related effect interacting with the effects of other human actions (i.e., anthropogenic developments, projects, or activities) to produce a combined effect. Cumulative effects are assessed in each of the assessment chapters, as required by the BC EAO (2013). A synthesis of these sections is provided in Chapter 21, to address CEA Agency (2012) requirements.

The method for assessing cumulative effects generally follows the same steps as the Project-specific effects assessment, as described in Sections 5.6 to 5.9:

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

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

8.11.2 Establishing the Scope of the Cumulative Effects Assessment

The cumulative effects assessment boundary for surface water and aquatic resources defines the maximum limit within which the assessment is conducted. This encompasses the areas and waterbodies within, and times during which the Project is expected to interact with surface water and aquatic resources, and with other projects and activities. The CEA boundary also considers the constraints that may be placed on the assessment of those interactions due to political, social, and economic realities (administrative boundaries), as well as limitations in predicting or measuring changes (technical boundaries). The definition of these assessment boundaries is an integral part of the cumulative effects assessment, and encompasses possible direct, indirect, and induced effects of the Project on surface water and aquatic resources.

VCs that were included in the surface water and aquatic resources cumulative effects assessment were selected using four criteria following BC EAO (2013):

- there must be a residual environmental effect of the project being proposed;
- the environmental effect must be demonstrated to interact cumulatively with the environmental effects from other projects or activities;

- other projects or activities must be known to have been or will be carried out and are not hypothetical; and
- the cumulative environmental effect must be likely to occur.

Project-related residual effects are not anticipated for sediment quality; therefore, cumulative effects on this VC are not further considered.

A description of past, existing, and proposed projects with the potential to result in cumulative effects on surface water and aquatic resources is presented in the following sections.

8.11.2.1 Spatial Boundaries

Project-related residual effects on surface water due to a change in water quantity were assessed in M20, M17B, and M19A creeks. Therefore, the potential for interaction with surface water quantity effects from other human actions were only considered for M20, M17B, and M19A creeks.

Project-related residual effect on surface water and aquatic resources due to a change in water quality were assessed in M19A Creek. No residual effect on surface water due to a change in water quality was identified in M20 or M19 creeks, and no change in water quality (for any sensitivity analysis) was identified for Murray River. Project design and mitigation (e.g., lined CCR piles) result in relatively small volumes of effluent discharge (< 60 L/s) and minimal seepage loss to the receiving environment.

Therefore, the potential for interaction with surface water quality effects from other human actions was only considered for M19A Creek.

8.11.2.2 Temporal Boundaries

The temporal boundaries for the CEA go beyond the phases of the Project, beginning before major human actions were undertaken in the region, and extending into the future.

The following temporal periods are evaluated as part of the CEA:

- **Past:** 1940 (to capture the early non-Aboriginal human activities in the region) to 2010 (when baseline studies at the Murray River Project began);
- **Present:** 2010 (from the start of the Project baseline studies) to 2014 (completion of the environmental assessment); and
- **Future:** temporal boundaries are stated in each assessment chapter, and vary according to the time estimated for VCs to recover to baseline conditions (taking into account natural cycles of ecosystem change).

The other human actions considered in the CEA (described in Section 5.10.5) fall into the following temporal categories:

- Past (closed) human actions;
- Present (continuing and active) human actions; and

- Future human actions, which may be:
  - **certain actions:** those actions that have received regulatory authorizations but are not as yet built or operating;
  - **reasonably foreseeable actions:** those actions that are currently in some stage of a regulatory authorization process, and for which a general concept is available from which potential cumulative effects may be anticipated; and
  - **hypothetical actions:** those actions that are conjectural but probable, based on best professional judgement of currently available information, including leases, licences, and extrapolations from historical development patterns; the potential cumulative effects of such actions are discussed on a conceptual basis only in this CEA.

8.11.2.3 Administrative and Technical Boundaries

No administrative or technical boundaries were applied to the cumulative effects assessment.

8.11.2.4 Identification of Potential Cumulative Effects

Monitoring and management of cumulative effects on surface water effects in Murray River is of regional interest and importance to federal and provincial regulators, including BC Ministry of Environment, Aboriginal groups, and the public. HD Mining will continue to participate in the NE Murray River Aquatic CEA Framework Steering Committee, including sharing Project-related data.

A review of the interaction between potential Project-related effects and effects of other projects and activities on surface water and aquatic resources was undertaken within the spatial and temporal boundaries identified in sections 8.11.2.1 and 8.11.2.2 and is presented in Table 8.11-1.

Streamflow changes in M20 Creek have the potential to interact with streamflow changes induced by activities related to development of the Hermann Mine. The Hermann Mine is located east of the Project and will discharge into M20 Creek.

No potential interactions with other human actions were identified for Project-related residual effects due to change in water quantity in M17B and M19A creeks; therefore, no potential cumulative effects were identified.

No potential interactions with other human actions were identified for Project-related residual effects due to change in water quality and aquatic resources in M19A Creek; therefore, no potential cumulative effects were identified.

8.11.3 Description of Potential Cumulative Effects and Mitigation

Based on the predictions included in the Hermann Mine Application for an Environmental Assessment Certificate, streamflows at M20 Creek will be increased during the low flow months. The Murray River Project will decrease the low flows at M20 Creek (Section 8.8.1.1). That is, the effects of Murray River Coal and Hermann Mine projects on M20 Creek flows are predicted to be in two opposite directions (decreasing and increasing the low flows, respectively). Therefore, adverse interactions between the two projects are not anticipated and additional mitigation is not required.

8.12 EFFECTS ASSESSMENT CONCLUSIONS FOR SURFACE WATER AND AQUATIC RESOURCES

The potential for Project-related effects to surface water and aquatic resources was assessed by determining the potential for changes in surface water quantity, surface water quality, and sediment quality, and the potential for aquatic habitat loss. Quantitative information was used wherever possible in the assessment and included extensive baseline studies and water quantity and quality modelling.

After considering mitigation measures, residual effects were identified for surface water due to a change in water quantity and water quality, and on aquatic resources due to a change in water quality (Sections 8.8.1 and 8.8.3). No residual effects on sediment quality were identified.

The residual effects on surface water due to a change in water quantity as a result of Project activities are predicted to be **not significant (minor)**. Minor streamflow changes are anticipated to be confined to M17B, M19A, and M20 creeks. Predicted effects at the downstream end of the LSA (i.e., Murray River downstream of confluence with M19 Creek) are negligible.

The residual effects on surface water due to a change in water quality as a result of Project activities are predicted to be **not significant (minor)**. Minor increases in selenium concentrations in M19A Creek under low flow conditions beginning in Decommissioning and Reclamation and extending into Post-closure were identified through predictive water quality modelling. A change in water quality at the downstream end of the LSA (i.e., Murray River downstream of confluence with M19 Creek) was not predicted.

The residual effects on aquatic resources due to a change in water quality as a result of Project activities are predicted to be **not significant (minor)**. There is potential for minor increases in selenium tissue concentrations in aquatic resources in M19A Creek, but it is unlikely that aquatic resources will experience toxicity due to selenium.

Project-related residual effects were carried forward to the cumulative effects assessment. Potential interactions with other human actions were considered in the cumulative effects assessment. No interactions were identified for potential cumulative effects due to a change in water quality in M19A Creek.

Potential cumulative effects on surface water due to a change in surface water quantity in M20 Creek as a result of interaction with the Hermann Mine were identified; however, no adverse effects are expected based on opposing direction of the effect.

Table 8.11-1. Screening for Residual Effects to Interact Cumulatively with Effects of Other Human Actions on Surface Water and Aquatic Resources.

Murray River Coal Project Residual Effect	Potential for Cumulative Effect with Other Human Actions																	
	Time Frame																	
	Past						Present						Future					
	Historic		Recent										Certain					
	Hasler Coal Mine	Sukunka (Bullmoose) Mine	Bullmoose Mine	Dillon Coal Mine	Quintette (Babcock) Mine	Willow Creek Mine	Brule Mine	Trend Mine	Quality Wind Project	Peace Canyon Dam	Wolverine Mine (Perry Creek) and EB Pit	WAC Bennett Dam	Hermann Mine	Quintette Mine	Roman Mine Project	Thunder Mountain Wind Park	Tumbler Ridge Wind Project	Wartenbe Wind Project
Change in surface water quantity in M20, M17B, and M19A creeks.	-	-	-	-	-	-	-	-	-	-	-	-	L	-	-	-	-	-
Change in surface water quality in M19A Creek.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Increase in selenium tissue concentrations in aquatic resources in M19A Creek.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Murray River Coal Project Residual Effect	Potential for Cumulative Effect with Other Human Actions *(cont'd)*																
	Time Frame *(cont'd)*																
	Future *(cont'd)*																
	Reasonably Foreseeable										Hypothetical						
	Echo Hill Mine	Coastal Gaslink Project	Horizon Mine	Meikle Wind Energy Project	Northern Gateway Pipeline	Rocky Creek Energy Project	Site C Clean Energy Project	Sukunka Coal Mine Project	Sundance Wind Project	Wind Energy Project	Babcock Creek Wind Project	Belcourt Saxon Coal Project	Huguenot Mine	Moose Lake Wind Power	Septimus Creek Wind Power Project	Suska Mine	Wapiti River Coal Project
Change in surface water quantity in M20, M17B, and M19A creeks.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Change in surface water quality in M19A Creek.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Increase in selenium tissue concentrations in aquatic resources in M19A Creek.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Notes:

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

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