Elbow River at McLean Creek Dam (MC1) Environmental Impact Screening Report

Section 6.0 – Physical Environment

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Alberta Transportation

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TABLE OF CONTENTS

List of Tables

List of Figures

6.0 PHYSICAL ENVIRONMENT

6.1 ATMOSPHERIC ENVIRONMENT

This section presents potential environmental effects to the Atmospheric Environment from the proposed Elbow River at McLean Creek Dam (MC1) Option (MC1, Option, or MC1 Option). Atmospheric Environment refers to the air quality, climate, and noise conditions in the MC1 Option area.

The assessments presented in this section are linked to the assessments presented in the following sections:

- Section 7.2 Wildlife and Wildlife Habitat
- Section 8.1 Land Use and Management
- Section 8.3 Public Health and Safety

6.1.1 SCOPE OF ASSESSMENT

This section reviews the scope of the assessment for Atmospheric Environment, and includes relevant regulatory framework, data sources, Valued Components (VCs), measurable parameters, and assessment boundaries. The assessment of MC1-related effects on the Atmospheric Environment relies on information compiled through the review of publicly available literature, results of past studies completed for the MC1 Option, and current engineering design information from Opus Stewart Weir (Opus).

6.1.1.1 Regulatory Framework

This section provides an overview of the relevant regulatory framework and requirements for potential MC1-related effects to Atmospheric Environment as summarized in **Table 6.1-1**.

Where appropriate, air quality considerations follow guidance from the Alberta Environment and Sustainable Resource Development's *Air Quality Model Guideline* (AESRD 2013). In addition to general air quality modelling guidelines, ambient air quality criteria are developed by environmental and health authorities to consider the influence of various air contaminants on humans, wildlife, vegetation, and aesthetic qualities. The assessment of MC1-related changes in air contaminants considered in this EIA are based on these criteria and include total particulate matter (TSP), particulate matter less than 2.5 microns ($PM_{2.5}$), nitrogen oxides (NO_X), sulphur dioxide (SO_2), and carbon monoxide (CO), which are collectively known as criteria air contaminants (CACs). Alberta ambient air quality objectives (AAQOs) and Canadian Ambient Air Quality Standards (CAAQSs) for these CACs are summarized in **Table 6.1-2**.

Climate change considerations follow guidance from *Incorporating Climate Change Considerations in Environmental Assessment: General Guidance for Practitioners* (CEA Agency 2003) and supports the Alberta's climate change framework described in the *Climate Change and Emissions Management Act*, SA

2003, c. 16-7. Climate change is assessed by considering emissions of greenhouse gases (GHGs), a group of gases in the atmosphere that contribute to climate change. The three primary GHGs, and those considered in this assessment, are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). There are no emission criteria for GHGs, but there are federal and provincial reporting requirements. Facilities emitting more than 50,000 tonnes of GHGs, expressed as carbon dioxide equivalent (CO_2e), are required to submit a report under Environment Canada's Greenhouse Gas Emissions Reporting Program. Facilities in Alberta emitting more than 50,000 tonnes of GHGs are also required to submit reports under AESRD's Specified Gas Reporting Regulation (Province of Alberta 2003).

There are currently no directly applicable regulations in Alberta that are relevant to the assessment of MC1-related effects on noise conditions; however, relevant guidance from the Alberta Energy Regulator's *Directive 038: Noise Control* (AER 2007) for energy facilities is considered. Directive 038 does not define any noise limits for construction activities, but it requires noise-reducing measures to be implemented for these activities. This directive was referenced to determine existing noise levels for the Baseline Case and to identify mitigation requirements for the Option. Health Canada's *Guidance for Evaluating Human Health Impacts in Environmental Assessment: Noise* (Health Canada 2017) provides mitigation noise levels for short term construction activities and percent highly annoyed thresholds to support MC1 effects assessments, as summarized in **Table 6.1-3**.

The noise thresholds shown in **Table 6.1-3** represent mitigation noise levels (MNL), or the noise levels above which mitigation measures should be implemented. These noise threshold limits vary based on the duration of construction. The limits for short-term construction (i.e., for timeframes of less than one year) are based on day-night average sound levels. The limits for longer-term construction (i.e., periods of one year or more) are based on the level of high annoyance (percent highly annoyed), an aggregate indicator of assorted potential noise effects at the community level that may not be measurable when considered separately.

Table 6.1-1 Summary of Applicable Regulatory and Policy Framework for Atmospheric Environment

Name	Jurisdiction	Description
Incorporating Climate Change Considerations in Environmental Assessment: General Guidance for Practitioners (CEA Agency 2003)	Federal	This guidance document provides general guidance for incorporating climate change considerations in environmental assessments.
Air Quality Management System	Federal	This air quality management system represents a comprehensive approach for reducing air pollution in Canada, including the development of air quality standards under CEPA, 1999.
Climate Change and Emissions Management Act	Provincial	This legislation provides the framework for the implementation of Alberta's action plan on climate change.

Name	Jurisdiction	Description
Air Quality Model Guideline (AESRD 2013)	Provincial	This document provides guidance for assessing air quality impacts from operations and proposed operations that require an EPEA approval.
Alberta Ambient Air Quality Objectives and Guidelines Summary (AEP 2016a)	Provincial	This document provides air quality objectives developed under the EPEA to protect Alberta's air quality.
Directive 038: Noise Control (AER 2007)	Provincial	This noise control reference directive provides noise control requirements for operations under the jurisdiction of the Alberta Energy and Utilities Board as well as general background information and the approach for dealing with noise issues.
Guidance for Evaluating Human Health Impacts in Environmental Assessment: Noise (Health Canada 2017)	Federal	This guidance document provides human health-focused requirements to facilitate the preparation and review of environmental assessments.

Notes: EPEA = Environmental Protection and Enhancement Act, CEPA = Canadian Environmental Protection Act

Table 6.1-2 Ambient Air Quality Criteria

Contaminant	Averaging Period	Alberta AAQO (µg/m³)	CAAQS (µg/m³)
TSP	24-hour	100	-
	Annual (Geometric Mean)	60	
$PM_{2.5}$	24-hour	30	27 to 28[a]
	Annual	-	8.8 to 10[b]
NO_2	1-hour	300	-
	Annual	45	
SO_2	1-hour	450	170 to 183[c]
	24-hour	125	-
	30-day	30	-
	Annual	20	10 to 13[d]
CO	1-hour	15,000	-
	8-hour	6,000	

Source: AEP 2016a, CCME 2017

Notes: µg – microgram; m^3 – cubic metre

Footnotes:

a) Based on the three-year average of the annual 98th percentile of daily 24-hour average concentrations. The CAAQS of 27 µg/m³ will be effective in 2020.
b) Based on the three-year average of the annual average concentrations. The CAAQS of 8.8 µg/m³ will be effective in 2020.
c) Based on the three-year average of the annual 99th percentile of daily maximum 1-hour average concentrations. The CAAQS of 183 µg/m³ will be effective in 2020 and the CAAQS of 170 µg/m³ will be effective in 2025.
d) The CAAQS of 13 µg/m³ will be effective in 2020 and the CAAQS of 10 µg/m³ will be effective in 2025.

Table 6.1-3 Summary of Construction Noise Criteria

Name	Duration	Criteria
Short-term Construction	Less than 1 year	47 dBA basic MNL for quiet suburban areas, 47 dBA plus 10 dBA correction (i.e. total 57 dBA MNL) for construction periods less than 2 months, 30 dBA nighttime noise level for sleep disturbance (45 dBA for residential areas)
Long-term Construction	1 year or more	6.5% highly annoyed, 30 dBA nighttime noise level for sleep disturbance (45 dBA for residential areas)

Notes: dBA - A-weighted decibel
Source: Health Canada 2017

6.1.1.2 Data Sources

Data sources for the assessment of Atmospheric Environment included MC1-specific data, government databases, as well as scientific literature such as journal publications and white papers. As the MC1 Option is still in the conceptual stage of design, detailed Option information such as the equipment to be used and the amount of material handling and other activities (e.g. bulldozing, drilling, blasting) expected has not yet been developed. The assessment of Atmospheric Environment therefore largely relies on information, regarding equipment and key construction activities, that was used to support the air and noise assessments conducted for the Site C Clean Energy Project, as the project components and sources of air and noise emissions are similar to those expected for the MC1 Option. The following data sources were reviewed:

- Alberta Environment and Parks air data (AEP 2016b)
- National Pollutant Release Inventory (Environment and Climate Change Canada 2016a)
- Government of Canada Historical Climate Data (Government of Canada 2016)
- National Inventory Report 1990 – 2015: Greenhouse Gas Sources and Sinks in Canada – Executive Summary (Environment and Climate Change Canada 2017a)
- Site C Clean Energy Project Environmental Impact Statement (EIS) (BC Hydro 2013).

Data limitations are recognized in the representativeness of the historical air quality and climate data used to depict the Baseline Case, the representativeness of the Site C Clean Energy Project to provide a basis for estimating MC1-related emissions and resulting air quality impacts, and the accuracy of the MC1-specific data used to estimate emissions. These data limitations do not impede the ability to assess high-level effects of the MC1 Option on the Atmospheric Environment, but should be taken into account when considering specific assessment results. If the Option proceeds, a refined assessment would be conducted based on detailed design and construction information. This refined assessment would include a full inventory of MC1-related air and noise emissions as well as a detailed modelling exercise, in line with atmospheric assessments for other EIAs.

6.1.1.3 Valued Components

The Atmospheric Environment may interact directly with MC1-related activities. MC1-related activities may result in emissions of CACs, which are linked to health effects, as well as emissions of GHGs, which contribute to regional climate change. MC1-related activities may also result in changes of overall noise levels and low frequency noise (LFN) in the MC1 Option area. The list of VCs for Atmospheric Environment is provided in **Table 6.1-4**.

Table 6.1-4 Summary of Selected Valued Components for Atmospheric Environment

Valued Component	Interaction
Air Quality	MC1-related activities may result in emissions of CACs and contribute to changes in air quality in the MC1 Option area.
Climate and Climate Change	MC1-related activities may result in emissions of GHGs and contribute to climate change.
Noise	MC1-related activities may result in changes of noise levels and LFN in the MC1 Option area.

6.1.1.4 Measurable Parameters

Measurable parameters are quantitative or qualitative measures used to describe existing conditions and trends and evaluate potential MC1-related effects to the VCs. The measurable parameters selected for Air Quality, Climate and Climate Change, and Noise are shown in **Table 6.1-5**. Potential adverse effects arising from MC1 Option interactions are discussed in more detail in **Section 6.1.3**.

Table 6.1-5 Measurable Parameters for Atmospheric Environment

Selected VC	Potential Option Effects	Measurable Parameter
Air Quality	Increased emissions and ambient concentrations of CACs	MC1-related emissions of TSP, $PM_{2.5}$, NO_X[a], SO_2, and CO Ambient concentrations of TSP, $PM_{2.5}$, NO_2, SO_2, and CO
Climate and Climate Change	Increased emissions of GHGs	Emissions of CO_2, CH_4, and N_2O
Noise	Change in overall noise levels and LFN	A-weighted sound pressure level (dBA) and LFN

Footnote: a) Option emissions of NOX comprise nitric oxide (NO) and nitrogen dioxide (NO2). The primary emission is in the form of NO, with reactions in the atmosphere resulting in the conversion of NO to NO_2. Potential health effects, and therefore ambient air quality criteria, are associated with NO_2. Correspondingly, the measurable parameter for Air Quality includes emissions of NO_X but ambient concentrations of NO_2.

6.1.1.5 Assessment Boundaries

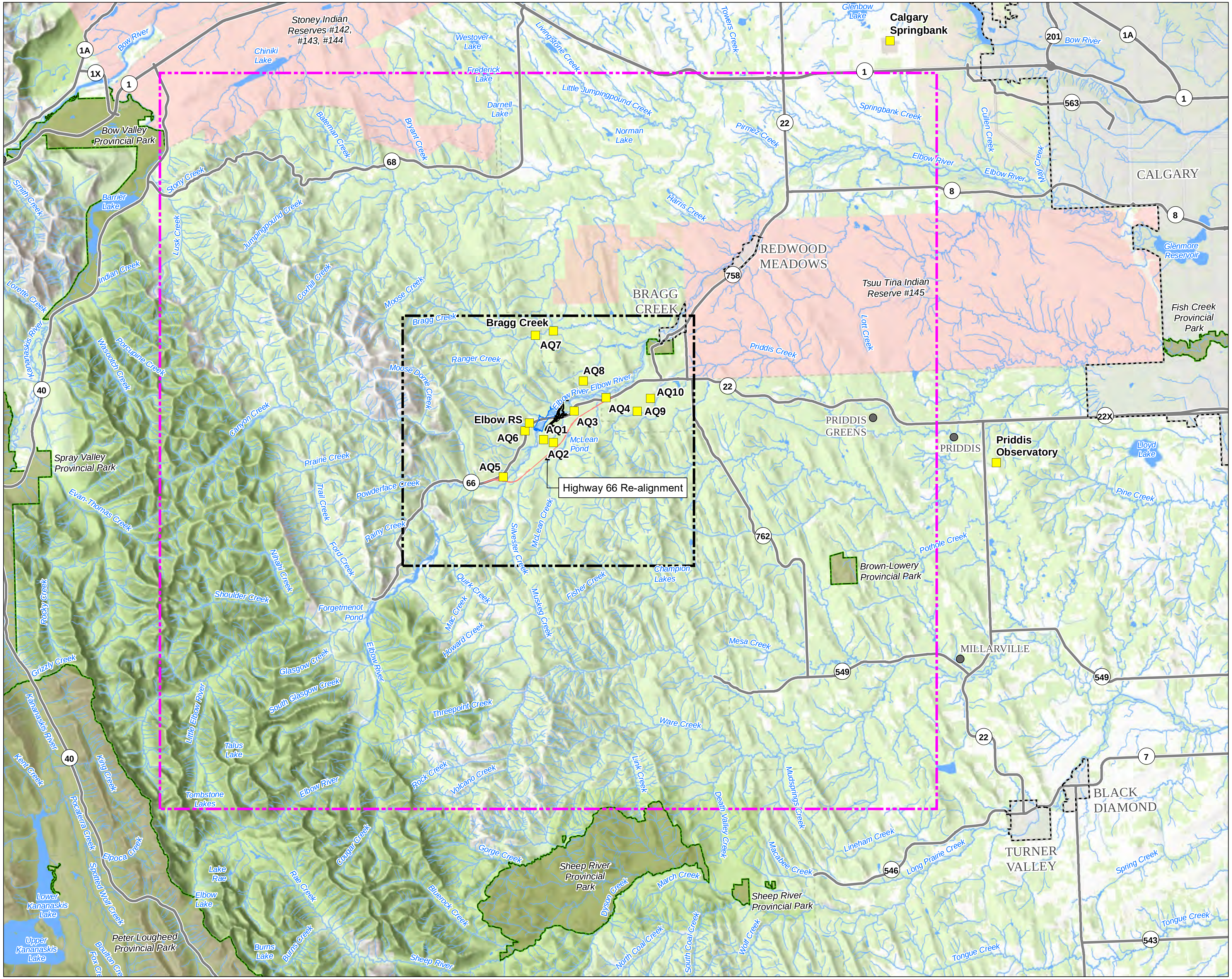
Spatial Boundaries

Spatial boundaries for the assessment of Atmospheric Environment are described in **Table 6.1-6**. The Local Assessment Area (LAA) encompasses the maximum geographical area where the MC1 Option is expected to interact with, and potentially affect Atmospheric Environment. The Regional Assessment Area (RAA), which encompasses the LAA, is established to provide a regional context for the assessment of MC1-related effects. The RAA also encompasses the area where the residual effects of the MC1 Option are likely to interact with the residual effects of other past, present, or future projects or activities to result in cumulative effects.

The LAA for the Air Quality VC is defined as a rectangular area extending at least 5 kilometres (km) from the MC1 footprint, and the RAA for the Air Quality VC is defined as a rectangular area extending at least 20 km from the MC1 footprint, as illustrated in **Figure 6.1-1**. The LAA and RAA for the Noise VC are defined as the area encompassing the MC1 footprint and a 2-km and 5-km buffer, respectively, as illustrated in **Figure 6.1-2**. The LAA's and RAA's for Air Quality and Noise were selected based on standard industry practice for the types of MC1-related air and noise emissions expected. Beyond these areas, MC1-related effects are expected to dissipate to baseline levels. Climate change is global in nature, and therefore an LAA is not applicable for the Climate and Climate Change VC. Two RAAs are defined for Climate and Climate Change: the province of Alberta and Canada, in accordance with boundaries for GHG management.

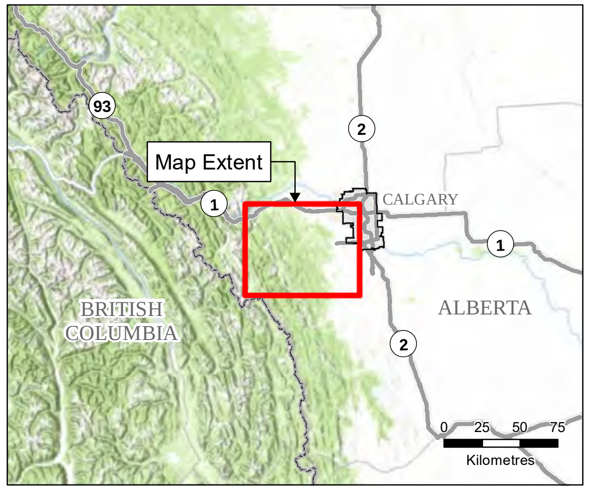
Table 6.1-6 Spatial Boundary Definitions for Atmospheric Environment

Spatial Boundary	Description of Assessment Area
Local Assessment Area	Air Quality: rectangular area extending 5 km from MC1 footprint Noise: MC1 footprint plus 2-km buffer Climate and Climate Change: not applicable
Regional Assessment Area	Air Quality: rectangular area extending 20 km from the MC1 footprint. Noise: MC1 footprint plus 5-km buffer Climate and Climate Change: Alberta and Canada



Elbow River at McLean Creek Dam (MC1)

Air Quality Local Assessment Area and Regional Assessment Area



Legend

- Air Quality Sensitive Receptor Location
- Air Quality Local Assessment Area
- Air Quality Regional Assessment Area
- MC1 Dam
- Highway 66 Re-alignment
- Permanent Pond
- Hamlet
- Highway
- Reserve
- Provincial Park
- Urban Area
- Watercourse
- Waterbody

Notes

1. This map is not intended to be a "stand-alone" document, but a visual aid of the information contained within the referenced Report. It is intended to be used in conjunction with the scope of services and limitations described therein.

Sources

- Basedata: Government of Alberta
- Dam and flood details: Opus International Consultants Limited, 2017
- Borrow Areas: Hatch Ltd., 2017
- Background Image: ESRI World Topographic Map
- Inset Maps: ESRI World Topographic Map

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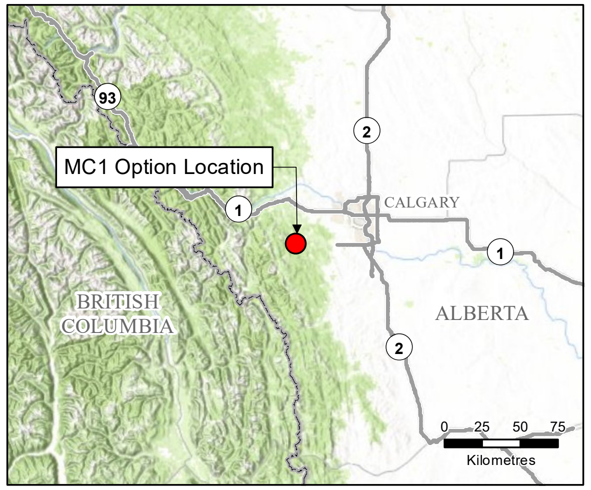
Elbow River at McLean Creek Dam (MC1)

Noise Local Assessment Area and Regional Assessment Area



Legend

- Noise Local Assessment Area
- Noise Regional Assessment Area
- Noise Receptor Location
- MC1 Dam
- Highway 66 Re-alignment
- 2013 Flood Event (1424.1m)
- Borrow Area
- Laydown Area/Disturbed Area
- Permanent Pond
- Highway
- Reserve
- Hemlet of Bragg Creek
- Provincial Park or Recreational Area
- Existing Park Infrastructure to be Removed

Notes

1. All locations and features should be considered approximate and are to be used for discussion purposes only.
2. This map is not intended to be a "stand-alone" document, but a visual aid of the information contained within the referenced Report. It is intended to be used in conjunction with the scope of services and limitations described therein.

Sources

- Basedata: Government of Alberta, 2017
- Preferred Road Option and Disturbed Areas: Opus International Consultants Limited, 2017
- Dam Details: Hatch Ltd., 2017
- Aerial Imagery: SPOT 1.5 m, 2016
- Inset Basemap: ESRI Topographic Basemap

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Populated areas within the Air Quality VC LAA and RAA include the Town of Bragg Creek, approximately 10 km northeast of the MC1 Option, and the Townsite of Redwood Meadows, approximately 15 km northeast of MC1 (RAA only). Sensitive air quality (AQ) receptors were identified within the LAA for assessment of MC1-related effects on air quality, and are presented as follows:

- Proposed construction camp (AQ1)
- McLean Creek Campground (AQ2)
- Easter Seals Camp Horizon (AQ3)
- Gooseberry Campground (AQ4)
- Paddy’s Flat Campground (AQ5)
- Station Flats Day Use Area (AQ6)
- West Bragg Creek Day Use Area (AQ7)
- Nearest residence in Highlands neighbourhood of Bragg Creek (AQ8)
- Private residence (AQ9)
- Private residence (AQ10).

A number of noise receptors (NRs) were also identified at residential and recreational areas nearest to the MC1 Option. These receptors are located near the main construction area and highway alignment, and are described as follows:

Near Main Construction Area:

- Easter Seals Camp Horizon (NR1)
- Construction Camp/McLean Creek Campground (NR2)
- McLean Creek Campground (NR3)
- Station Flats Day Use Area (NR4)
- Private Residence (NR5)
- Private Residence (NR6)
- Private Residence (NR7)

Near Highway Alignment:

- McLean Creek Campground (HNR1)
- Private Residence (HNR2)
- Paddy's Flat Campground (HNR3)
- Gooseberry Campground (HNR4).

Receptors NR1 to NR7 designate receptors near the main MC1 construction site, and receptors HNR1 to HNR4 designate receptors near the preferred road option for the re-alignment of Highway 66. Since the proposed construction camp is located within a noise area source, it is represented by NR2, located just outside the noise area source.

Due to the proximity of the Allen Bill Pond Day Use Area to construction activities, it was assumed that this recreational area would be closed, and was not identified as a sensitive receptor for the MC1 effects assessment. Likewise, parks infrastructure to be relocated during the Construction phase were not identified as sensitive receptors.

Temporal Boundaries

The temporal boundaries of the MC1 Option consist of the Construction, and the Operation and Maintenance phases of the Option, which are described in **Section 3.0 MC1 Option Description**.

Administrative Boundaries

No administrative boundaries (e.g., political, economic, or social issues, as well as fiscal or other resourcing issues constraining the assessment of potential effects of the Option) were identified for the assessment of potential MC1-related effects on Atmospheric Environment.

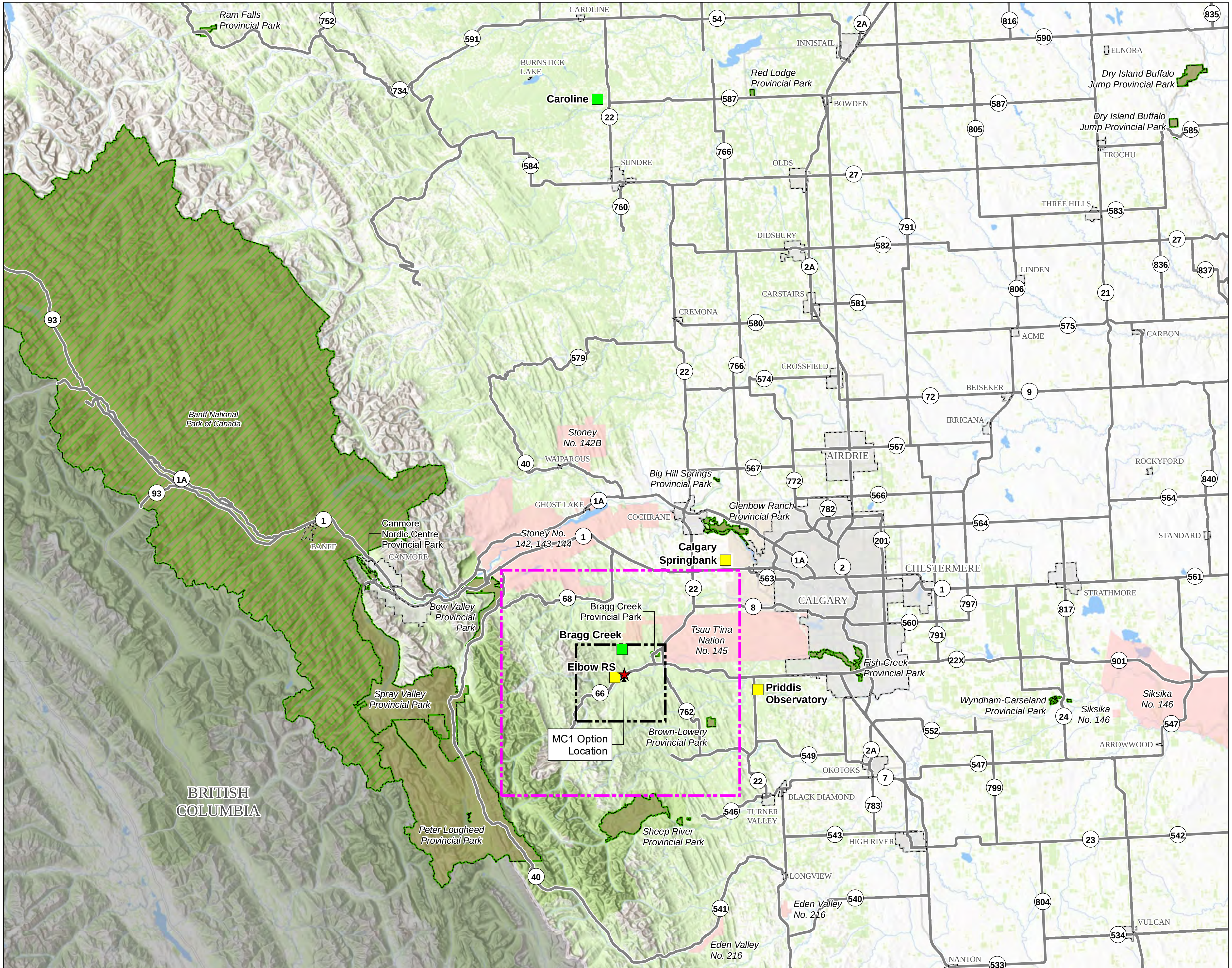
Technical Boundaries

Data limitations are discussed in **Section 6.3.1.2**. No other technical boundaries were identified for the assessment of potential MC1-related effects on Atmospheric Environment.

6.1.2 BASELINE CASE

The Baseline Case for Atmospheric Environment is presented for the RAAs and LAAs using data compiled from the sources listed in **Section 6.3.1.2**. Baseline air quality is characterized using emission data from Environment and Climate Change Canada's 2015 National Pollutant Release Inventory (2016a) as well as historical air quality monitoring data from the Alberta Environment and Parks Air Data Warehouse (AEP 2016b). Baseline climate is characterized using weather and climate normal data from the Government of Canada (Government of Canada 2016) as well as GHG emission data from Environment Canada's national GHG inventory (Environment Canada 2016b). Baseline noise is characterized as per guidance from Directive 038 (AER 2007).

The locations of monitoring stations used to characterize baseline air quality and climate are shown in **Figure 6.1-3.**



Elbow River at McLean Creek Dam (MC1)

Location of Monitoring Stations for Baseline Air Quality and Climate

Legend

- Baseline Air Quality Station
- Baseline Climate Station
- Air Quality Local Assessment Area
- Air Quality Regional Assessment Area
- MC1 Option Location
- Highway
- Reserve
- National Park
- Provincial Park
- Urban Area

Notes

1. This map is not intended to be a "stand-alone" document, but a visual aid of the information contained within the referenced Report. It is intended to be used in conjunction with the scope of services and limitations described therein.

Sources

- Basedata: Government of Alberta
- Background Image: ESRI World Topographic Map
- Inset Maps: ESRI World Topographic Map

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6.1.2.1 Air Quality

Existing air quality in the LAA and RAA for the Air Quality VC is influenced by industrial and agricultural activity in the area, vehicle traffic along Highway 66, residential emissions in the Town of Bragg Creek and the Townsite of Redwood Meadows, and naturally occurring emissions. Industrial sources include three oil and gas facilities (listed in **Table 6.1-7**) approximately 3 km to 4 km west and northwest of the MC1 footprint within the LAA, and four additional oil and gas facilities in the RAA. Existing emissions from these industrial facilities in the Air Quality VC LAA and RAA were obtained from Environment and Climate Change Canada's 2015 National Pollutant Release Inventory (2016a) and summarized in **Table 6.1-7**.

Table 6.1-7 Existing Industrial Emissions in the Assessment Areas for Air Quality

Assessment Area	Facility	2015 Emissions (tonnes)				
		TSP[a]	$PM_{2.5}$	NO_X	SO_2	CO
LAA	Shell Canada Moose Mountain Compressor Station	1.8	1.8	209	NR	703
	Husky Oil McLean Creek North Compressor Station	NR	NR	46	NR	30
	Husky Oil McLean Creek Dehy	1.1	1.1	36	136	26
Total Emissions in LAA		**2.9**	**2.9**	**291**	**136**	**759**
RAA	Husky Oil Moose Mountain North Battery	0.6	0.6	21	132	NR
	Shell Canada Jumping Pound Complex	NR	NR	NR	NR	NR
	Shell Canada Jumping Pound Well Site Compressor	NR	NR	25	NR	NR
	Pengrowth Energy Quirk Creek Gas Plant	NR	NR	NR	NR	NR
Total Emissions in RAA Outside of LAA		*0.6*	*0.6*	*46*	*132*	*0*
Total Emissions in RAA		**3.5**	**3.5**	**337**	**268**	**759**

Source: Environment and Climate Change Canada 2016a
Notes: NR = not reported
Footnote: a) TSP emissions were not reported, and are assumed to be equal to reported $PM_{2.5}$ emissions.

Existing air emissions in the LAA and RAA from non-industrial sources are not available; however, given the types of emission sources and activities in the areas, it is expected that much of the TSP and $PM_{2.5}$ emissions would be from wind-blown dust from dry riverbeds, vehicle and road dust emissions along Highway 66, and residential emissions in the Town of Bragg Creek and the Townsite of Redwood Meadows. Emissions of NO_X, SO_2, and CO are predominantly a result of fuel combustion from industrial activities, vehicles, and residential sources, with a small amount from naturally occurring emissions such as vegetation and soils.

Existing air quality in the LAA and RAA is also characterized using historical air quality monitoring data from the Calgary Regional Airshed Zone passive monitoring network, housed in the Alberta Environment and Parks Air Data Warehouse (AEP 2016b). The nearest monitoring station is Bragg Creek, located approximately 5 km north of the MC1 Option, which measures NO_2, SO_2 and ozone. Five years of NO_2 and SO_2 data for the 2011 to 2015 period from the Bragg Creek station were reviewed. A summary of the data is presented in **Table 6.1-8**. Passive monitoring data represent average concentrations over the exposure period of approximately one month, and provide long-term average conditions in the area. Such data do not provide information on maximum short-term concentrations that may be experienced. In general, average concentrations of NO_2 and SO_2 in the LAA and RAA are low, well below the annual NO_2 and SO_2 Alberta AAQOs of 45 micrograms per cubic metre (µg/m^3) and 20 µg/m^3, respectively. The maximum observed SO_2 concentration was equal to the annual CAAQS of 10 µg/m^3, effective in 2025.

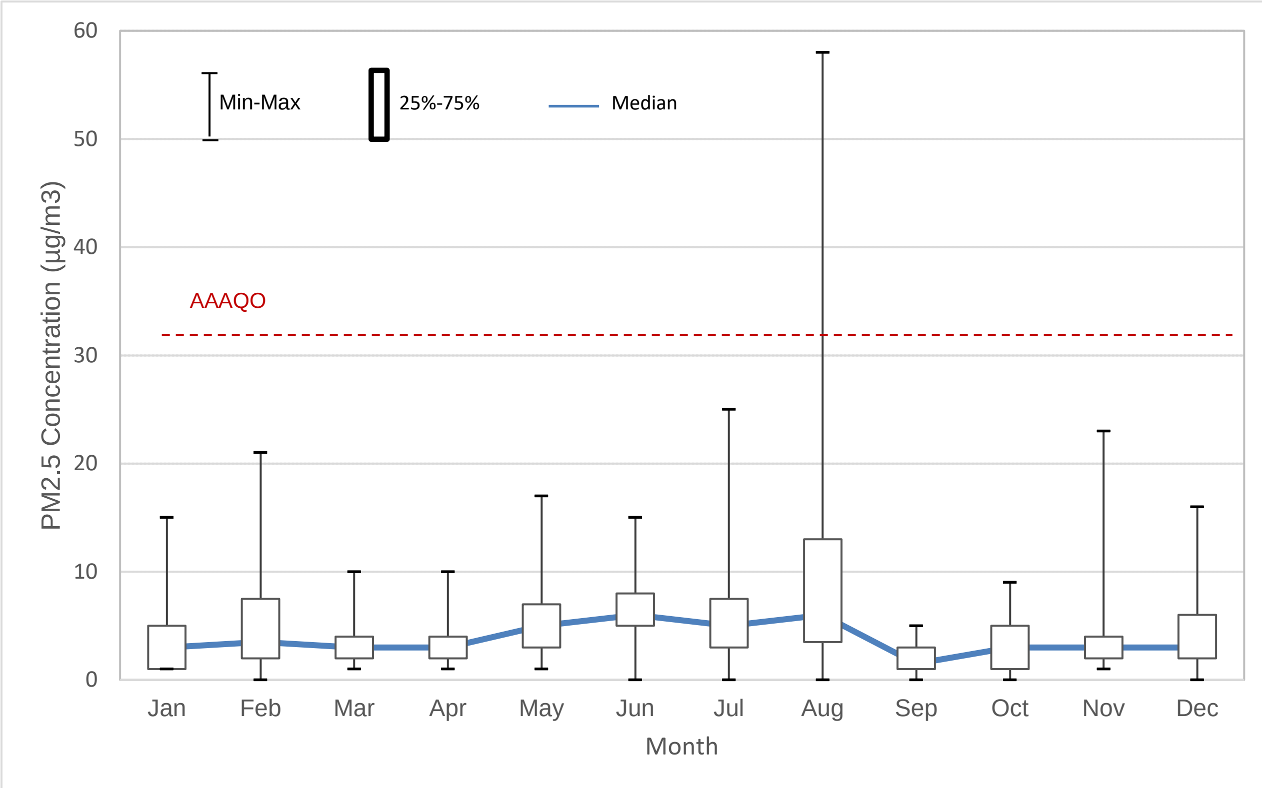
Table 6.1-8 Summary of Nitrogen Dioxide and Sulphur Dioxide Concentrations at Bragg Creek Station

Contaminant	Maximum Concentration (µg/m^3)	Percentile Concentrations (µg/m^3)					
		99th	98th[h]	95th	90th	75th	50th
NO_2	2.8	2.5	2.3	1.9	1.5	0.9	0.6
SO_2	10.2	6.7	3.1	1.6	1.6	1.2	0.9

Source: Table developed from AEP 2016b.

The only monitoring stations measuring particulate matter in the Calgary Regional Airshed Zone are located within the Calgary urban and industrial core. Particulate matter monitoring data from these stations are not deemed to be representative of existing air quality in the LAA and RAA as they may be unduly influenced by nearby residential, industrial, and vehicle traffic emissions not present in the LAA and RAA. Existing particulate matter concentrations were instead characterized using historical $PM_{2.5}$ monitoring data from the Caroline station, which is located approximately 115 km north of the MC1 Option area in a similar remote agricultural setting, surrounded by several oil and gas facilities within a 5-km radius. One year of $PM_{2.5}$ data for 2015 from the Caroline station was reviewed and presented in **Figure 6.1-4**. Daily 24-hour average $PM_{2.5}$ concentrations tend to be highest in the summer months (May to August), and twice exceeded the Alberta AAQO of 30 µg/m^3 in August 2015. The 98th percentile of daily $PM_{2.5}$ concentrations was 22 µg/m^3, less than the CAAQSs.

There are no representative monitoring stations measuring CO in Alberta. Carbon monoxide is typically measured within urban areas. For more remote areas such as the LAA and RAA for the Air Quality VC, existing ambient CO concentrations is considered low. A baseline concentration of zero was selected for use in the MC1 Option effects assessment.



Source: Figure developed from AEP 2016b.

Figure 6.1-4 Summary of Particulate Matter Concentrations at Caroline Station

Background concentrations are developed based on the historical air quality monitoring data to provide context for the MC1 Option's effects assessment while representing the contribution of existing sources in the MC1 Option area to air quality in the Application Case. Typically, a single value is chosen as background, which is assumed to apply at all times and at all locations within the LAA and RAA for the Air Quality VC. As per the Alberta Environment and Sustainable Resource Development's Air Quality Model Guideline (AESRD 2013), the background $PM_{2.5}$ concentration is based on the maximum concentration after removing the top 10 percent (%) of the 2015 hourly data from the Caroline station. Background TSP concentrations are estimated to be 3.3 times the background $PM_{2.5}$ concentrations (Lall et al. 2004). Background NO_2 and SO_2 concentrations are based on the maximum (for the one-hour averaging period) and average (for the annual averaging period) observed concentrations in the 2015 passive monitoring data from Bragg Creek. Due to the lack of representative air quality monitoring data for CO, the background CO concentrations are assumed to be zero. A summary of the background concentrations is provided in **Table 6.1-9**.

Table 6.1-9 Background Air Quality Concentrations

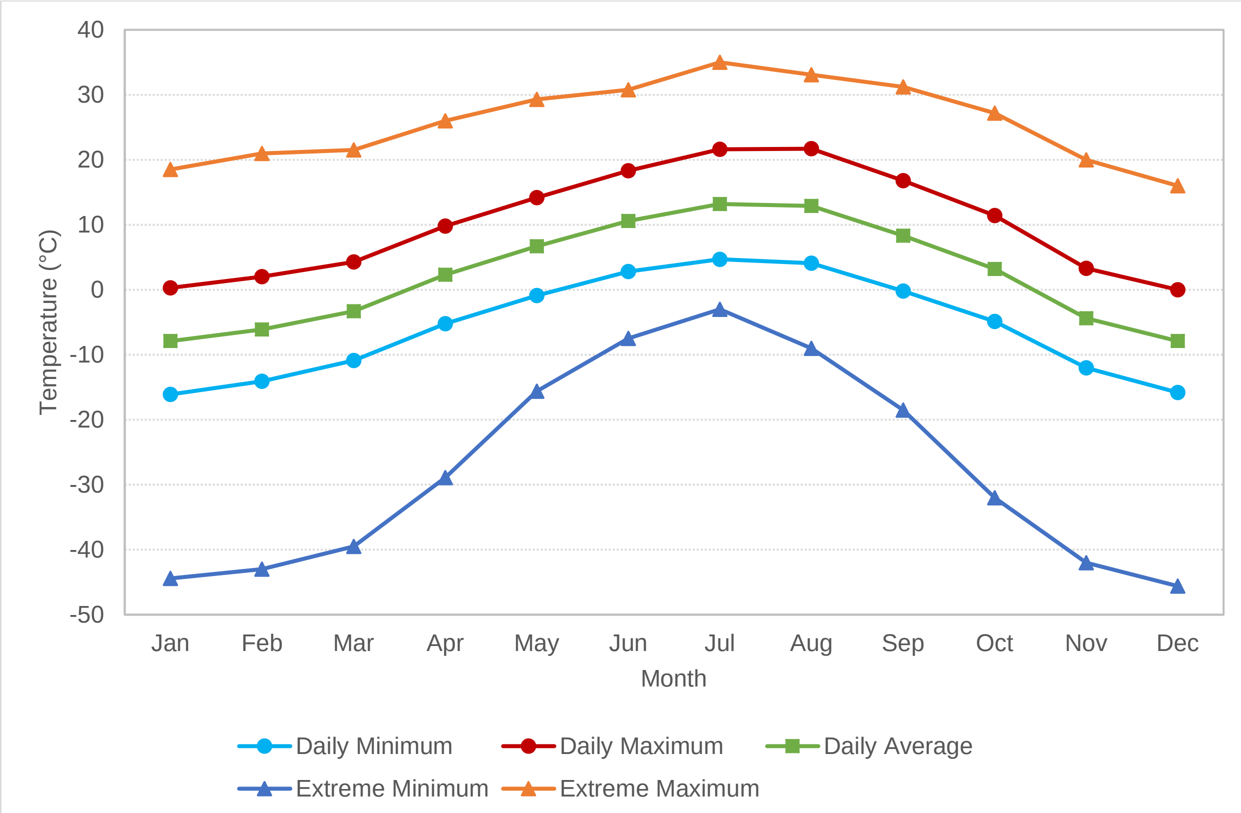
Contaminant	Averaging Period	Background Concentration (μg/m^3)
TSP	24-hour	33
	Annual	12
$PM_{2.5}$	24-hour	10
	Annual	3.7
NO_2	1-hour	2.8
	Annual	0.8
SO_2	1-hour	10
	Annual	1.1
CO	1-hour	0

Source: Table developed from AEP 2016b.

6.1.2.2 Climate and Climate Change

The MC1 Option area is located within a humid continental climate zone, typified by large seasonal temperature differences with warm, humid summers and cold (sometimes severely cold) winters. Climate conditions in the area are described using climate normal data from the Elbow Ranger Station (RS) meteorological station, located approximately 2 km downstream from the MC1 Option.

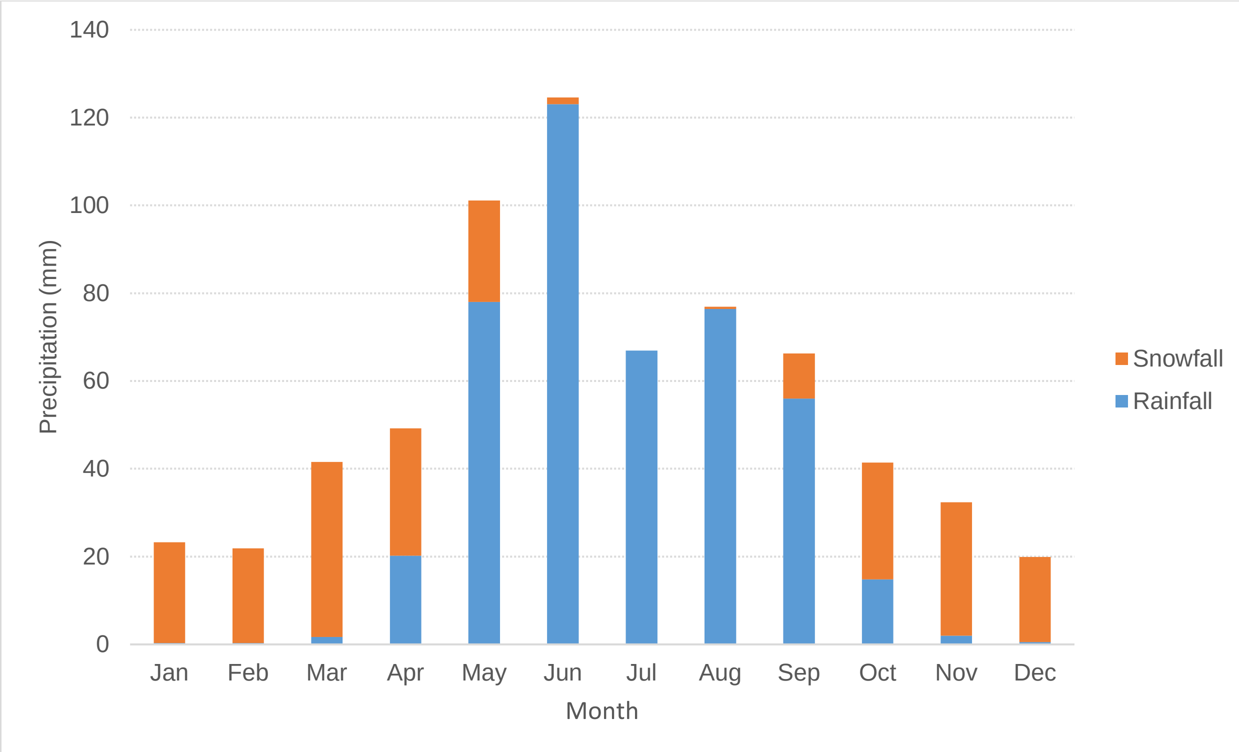
Daily temperature variations, based on 30-year climate normal data from 1981 to 2010 at the Elbow RS meteorological station, are illustrated in **Figure 6.1-5**. Temperatures range from a daily maximum of 22 degrees Celsius (°C) in the summer to an average daily minimum of –16° C in the winter. Extreme temperatures reached a low of –46°C in 1968 and a high of 35°C in 2002.



Source: Figure developed from Government of Canada 2016.

Figure 6.1-5 Monthly Temperature from Elbow Ranger Station Climate Normal Data, 1981 – 2010

The precipitation regime, also based on the 30-year climate normal data at the Elbow RS meteorological station, is illustrated in **Figure 6.1-6**.There is significant rainfall in the MC1 Option area, with an average of 440 millimetres (mm) of rainfall annually. The highest rainfall amounts occur between May and September; thus, natural attenuation of fugitive dust would likely be greatest during these months. Similarly, snow that remains on the surface of a potential source of dust can act as a physical barrier to fugitive dust. An average of 240 centimetres (cm) of snow is received annually, with monthly snowfall amounts greatest from October to November and from March to April.

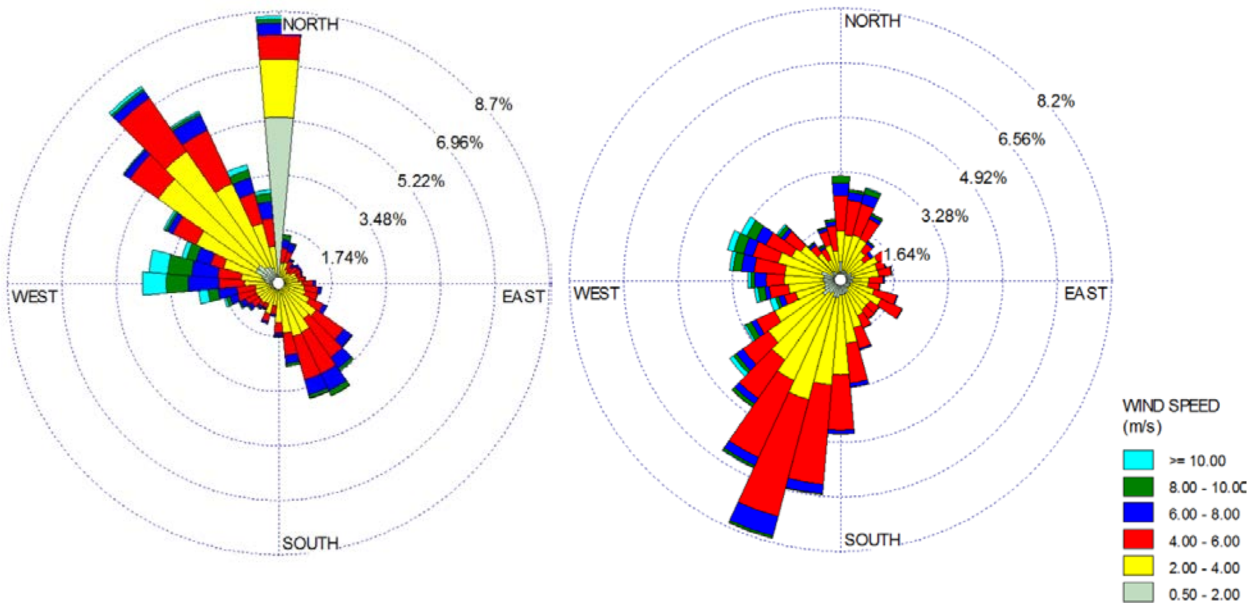


Source: Figure developed from Government of Canada 2016.

Figure 6.1-6 Monthly Precipitation from Elbow Ranger Station Climate Normal Data, 1981 – 2010

Wind is not measured at the Elbow RS meteorological station. The nearest meteorological stations that can provide a depiction of wind patterns in the MC1 Option area are the Calgary Springbank Airport station, approximately 30 km northeast of the Option, and the Priddis Observatory station, approximately 27 km east of the Option. Wind roses based on one year of data in 2015 from the Calgary Springbank Airport and Priddis Observatory stations are illustrated in **Figure 6.1-7**.

The wind patterns at the two stations are very different. The wind rose for Calgary Springbank Airport shows a majority of winds from the north, with secondary winds from the northwest. Conversely, the predominant winds at Priddis Observatory are from the south-southwest. High wind speeds are also more frequently observed at Priddis Observatory than at Calgary Springbank Airport. Wind patterns are strongly dependent on topography and with the relatively complex terrain in the Rocky Mountains Foothills, wind patterns are expected to vary spatially. In the MC1 Option area, winds are expected to follow the river valley, with a predominant wind direction from the southwest.



(a) Calgary Springbank Airport (b) Priddis Observatory

Source: Figure developed from Government of Canada 2016.

Figure 6.1-7 Wind Roses from Calgary Springbank Airport and Priddis Observatory Stations

Existing conditions for assessing MC1-related effects on climate change are characterized by total provincial and federal GHG emissions, taken from Environment Canada's national GHG inventory (Environment Canada 2017a). In 2015, Canada's total GHG emissions were estimated to be 722 million tonnes (Mt) of CO_2e. Of the 722 Mt CO_2e, 274 Mt CO_2e was from Alberta.

6.1.2.3 Noise

The Option is situated in a rural area. Existing noise levels in the LAA and RAA for the Noise VC are primarily influenced by local residential and agricultural activities, as well as vehicle traffic along Highway 66. The nearest industrial facilities are Shell Canada's Moose Mountain Compressor Station and Husky Oil's McLean Creek North Compressor Station. These industrial facilities are located inside the RAA and outside of the LAA.

Existing noise levels are the combination of effects from ambient sound levels (ASLs) described in Directive 038 and effects from other existing industrial facilities, and would vary by location throughout the RAA. Existing noise levels at the noise receptors are summarized in **Table 6.1-10**. As per Directive 038, the rural ASL in Alberta is approximately 35 A-weighted decibels (dBA) at night (10:00 p.m. to 7:00 a.m.) and usually 10 dBA higher than nighttime levels during daytime (7:00 a.m. to 10:00 p.m.). The Directive recommends adjustments to the ASLs based on proximity to roadways and dwelling density. The existing noise levels at the receptors were estimated by using the rural ASL and adjustments recommended in the Directive for each category. Additionally, the effects of existing industrial facilities in the RAA were added to the baseline levels.

Table 6.1-10 Existing Noise Levels at Noise Receptors

Receptor	Receptor Location (UTM Zone 11U)		Baseline Sound Level		Notes
	Easting	Northing	Day (dBA)	Night (dBA)	
NR1	664492	5641960	50	40	Category 2, 1 to 8 dwellings
NR2	663617	5640569	45	35	Category 1, 1 to 8 dwellings
NR3	663062	5640247	48	38	Category 1, 9 to 160 dwellings
NR4	661465	5640733	45	35	Category 1, 1 to 8 dwellings
NR5	665054	5643802	48	38	Category 1, 9 to 160 dwellings
NR6	668397	5641944	45	35	Category 1, 1 to 8 dwellings
NR7	669201	5642738	45	35	Category 1, 1 to 8 dwellings
HNR1	663076	5639574	48	38	Category 1, 9 to 160 dwellings
HNR2	661629	5637977	45	35	Category 1, 1 to 8 dwellings
HNR3	660122	5637885	45	35	Category 1, 1 to 8 dwellings
HNR4	666466	5642786	53	43	Category 2, 9 to 160 dwellings

Source: Table developed from AER 2007.
Note: UTM – Universal Transverse Mercator

6.1.3 APPLICATION CASE

The Application Case describes the effects of the MC1 Option added to the Baseline Case (i.e., assesses potential MC1-related effects). The following sections present potential Option interactions, related effects, and applicable mitigation measures, along with an assessment of residual effects.

6.1.3.1 Potential MC1 Option Interactions

Potential MC1 Option interactions with the Atmospheric Environment, and potential effects of each interaction are presented in **Table 6.1-11**.

Table 6.1-11 Identification of Potential Option Interactions with Atmospheric Environment

Phase	Activity	Air Quality		Climate Change		Noise	
		Interaction	Potential Effect	Interaction	Potential Effect	Interaction	Potential Effect
Construction	Clearing	X	Increased emissions and ambient concentrations of CACs	X	Increased emissions of GHGs	X	Increased noise levels
	Road construction	X	Increased emissions and ambient concentrations of CACs	X	Increased emissions of GHGs	X	Increased noise levels
	Decommissioning and removal of existing provincial parks infrastructure and ranger station	X	Increased emissions and ambient concentrations of CACs	X	Increased emissions of GHGs	X	Increased noise levels
	Dam (cofferdam and earth fill) construction	X	Increased emissions and ambient concentrations of CACs	X	Increased emissions of GHGs	X	Increased noise levels
	Spillway construction	X	Increased emissions and ambient concentrations of CACs	X	Increased emissions of GHGs	X	Increased noise levels
	Rock groin and diversion tunnels construction	X	Increased emissions and ambient concentrations of CACs	X	Increased emissions of GHGs	X	Increased noise levels
	Laydown areas construction and use	X	Increased emissions and ambient concentrations of CACs	X	Increased emissions of GHGs	X	Increased noise levels
	Stockpile development and use	X	Increased emissions and ambient concentrations of CACs	X	Increased emissions of GHGs	X	Increased noise levels
	Borrow and spoil areas development and use	X	Increased emissions and ambient concentrations of CACs	X	Increased emissions of GHGs	X	Increased noise levels
	Realignment of McLean Creek and other small waterbodies	X	Increased emissions and ambient concentrations of CACs	X	Increased emissions of GHGs	X	Increased noise levels
	Realignment of Highway 66	X	Increased emissions and ambient concentrations of CACs	X	Increased emissions of GHGs	X	Increased noise levels
	Storage of water in permanent pond	-	-	X	Increased emissions of GHGs	X	-
	Reclamation	X	Increased emissions and ambient concentrations of CACs	X	Increased emissions of GHGs	X	Increased noise levels

Phase	Activity	Air Quality		Climate Change		Noise	
		Interaction	Potential Effect	Interaction	Potential Effect	Interaction	Potential Effect
Operation and Maintenance	Routine and Flood Operations and Maintenance	X	Increased emissions and ambient concentrations of CACs	X	Increased emissions of GHGs	X	Increased noise levels

Note: X – potential interaction; '- '– no interaction

Air Quality

Activities during the Construction phase are expected to be a source of CAC emissions. Emissions associated with the Construction phase and the resulting impact on ambient concentrations were estimated as described in **Section 6.1.2.1**. The following sources of emissions were included in the emission inventory:

- Dust emissions from stripping of topsoil
- Dust emissions from bulldozing
- Dust emissions from material handling
- Dust emissions from wind erosion and maintenance of stockpiles
- CAC emissions from the use of vehicles and equipment
- Re-entrained road dust emissions from the use of unpaved access roads
- CAC emissions from Highway 66 realignment
- CAC emissions from the burning of wood debris generated from site clearing activities.

Based on the geology in the MC1 Option area, it is expected that much of the required excavation could be undertaken with conventional equipment such as loaders and excavators, and the need for drilling and blasting would be minimal. Drilling and blasting may be required for excavation of the diversion tunnels. Details on drilling and blasting requirements have not been developed yet; therefore, dust emissions from drilling and blasting, as well as CAC and GHG emissions from the use of explosives, were not included in the emission inventory. This is not expected to substantively impact the assessment of overall MC1-related effects.

During the Option's Operation and Maintenance phase, dust emissions may result from wind erosion of exposed reservoir banks. This would mainly occur during periods of high winds and is expected to be a small contributor to overall MC1-related effects on air quality given the reservoir configuration and steep reservoir banks. Operation of vehicles and equipment would occur intermittently during the Operation and Maintenance phase, and would be a source of CAC emissions.

Overall, MC1-related effects on air quality would be bounded by effects during the Construction phase; therefore, the Operation and Maintenance phase was not assessed.

Climate Change

Activities during the Construction phase are expected to be a source of GHG emissions from the use of vehicles and equipment, Highway 66 realignment activities, the burning of wood debris generated from site clearing activities. MC1-related GHG emissions during the Construction phase were estimated to assess MC1-related effects on climate change.

During the Operation and Maintenance phase, GHG emissions would occur intermittently from the operation of vehicles and equipment. Another potential source of GHG emissions is the decay of organic matter in the reservoir following a flood event. These GHG emissions would depend on the amount of flooded vegetation and characteristics of the water, but are expected to be low in magnitude and infrequent. Most vegetation and organic matter in the permanent pond area would be removed prior to inundation and would not be a source of continuous GHG emissions.

Overall, MC1-related effects on climate change would be primarily bounded by effects during the Construction phase; therefore, the Operation and Maintenance phase was not assessed.

Noise

The MC1 Option may affect noise levels in the area during the Construction phase and the Operation and Maintenance phase. The Option phase with the greatest potential to affect noise levels is the Construction phase, when excavation and construction activities, including the operation of vehicles and equipment, would emit sound that may be perceived as noise. During the Operation and Maintenance phase, changes in existing noise levels may occur due to the operation of vehicles and equipment. Since sources of noise during the Operation and Maintenance phase would be limited to short durations after flood events and during routine maintenance where only a small number of vehicles and equipment are required, assessment of MC1-related effects on noise is focused on the Construction phase. The effect during the Operation and Maintenance phase is expected to be less than 3 dBA, which is below the perceptible level of change for noise.

6.1.3.2 Potential Option Effects

This section considers potential adverse MC1-related effects on VCs arising from potential interactions, as identified in **Table 6.1-11**, and in relation to the measurable parameters listed in **Table 6.1-5.** Mitigation measures for each potential effect are described in **Section 6.1.3.3.**

Increased Emissions and Ambient Concentrations of Criteria Air Contaminants

Emissions of CACs were estimated for the Construction phase. Where sufficient MC1-specific data were available, emissions were estimated using published emission factors. Where MC1-specific data were not available at the time of writing, emissions were estimated based on information contained in the Site C Clean Energy Project EIS (BC Hydro 2013), and were adjusted to reflect the MC1 Option. The Site C Clean Energy Project is a large-scale earth fill hydroelectric dam located on the Peace River in northeastern British Columbia. The methodology used in the emission inventory is detailed by emission source below, and is followed by a description of the methodology used to estimate the resulting impact on ambient CAC concentrations in the LAA and RAA for the Air Quality VC.

Stripping

MC1-specific estimates of the amount of stripping required is summarized in **Table 6.1-12** by Option component. The volume of stripping required was converted to a mass basis assuming a density of 90 kilograms per cubic metre (kg/m3) for moist earth (SI Metric 2017). Dust emissions from stripping were estimated using a TSP emission factor from Section 11.9 of the United States Environmental Protection Agency (US EPA) Compilation of Air Pollutant Emission Factors known as AP-42 (US EPA 1998). Emissions of PM2.5 were estimated based on the TSP emissions using particle size multipliers from Section 13.2.4 of AP-42 (US EPA 2006a).

Table 6.1-12 Amount of Stripping Required

Option Component	Volume (m^3)
Main Dam	220,000
Facilities Relocation	33,000

Bulldozing

Dust emissions from bulldozing were estimated for the Site C Clean Energy Project using emission factors from Section 11.9 of AP-42 (US EPA 1998). These emission factors are based on the total hours of bulldozing activity, which is expected to be proportional to the volume of material bulldozed. Dust emissions associated with the Site C Clean Energy Project for the dam site and borrow areas were taken and scaled based on the total volume of construction material required, assuming that the fraction of material bulldozed would be similar between Site C and MC1.

The amount of construction material required for the MC1 Option is summarized in **Table 6.1-13**. The specific materials required for the MC1 Option were grouped into three generic categories for comparison to the Site C Clean Energy Project:

- Till: material with a maximum particle size of approximately 150 mm and a silt content (i.e., fines less than 0.075 mm) of 20%
- Gravel: granular material with a maximum size of approximately 200 mm and a silt content of 5%
- Riprap: hard, sound, and durable rock with a maximum size of approximately 250 mm and a minimum size of 40 mm.

For the MC1 Option, till and gravel would be expected to be obtained from nearby borrow sources. Rock rip-rap would be brought in from off-site. For the Site C Clean Energy Project, till and gravel were obtained from excavated materials at the dam site and a borrow area known as the 85th Avenue Industrial Lands, while rip-rap was obtained from a borrow area known as West Pine Quarry. Since rip-rap for the MC1 Option would be brought in and not obtained from a borrow source, bulldozing emissions were estimated based on emissions at the dam site and the 85th Avenue Industrial Lands; bulldozing emissions at West Pine Quarry were not considered.

The bulldozing emission factors are dependent on material silt and moisture content. The scaled emissions were therefore adjusted to account for differences in material silt content, as the MC1 Option would be expected to use a larger proportion of till, which has a much higher silt content than gravel and rip-rap. Moisture contents of the construction materials were not available; therefore, an adjustment to account for differences in material moisture content was not performed.

Table 6.1-13 Amount of Construction Material Required

Material	Category	Volume Required (m^3)				
		Main Dam	Service Spillway	Diversion Tunnel	Auxiliary Spillway	Facilities Relocation
Impervious Fill	Till	742,000	-	-	-	-
Granular Fill and Bedding Gravel	Gravel	2,789,000	50,900	-	27,900	220,000
Rock Riprap	Riprap	122,000	-	1,600	7,400	-
Concrete Aggregates[a]	Gravel	-	30,900	31,345	10,350	72,646

Footnote: a) Concrete aggregates are estimated as 75% by volume of total reinforced concrete

Material Handling

Material handling activities include loading and unloading of construction material at the Option site and nearby borrow sources. Dust emissions from material handling for the Site C Clean Energy Project were estimated using emission factors from Section 13.2.4 of AP-42 (US EPA 2006a). These emission factors are based on the mass of material handled, and depend on wind speed and material moisture content. Material handling emissions associated with the Site C Clean Energy Project for the dam site and the 85th Avenue Industrial Lands were taken and scaled based on the mass of construction material required. These material handling emissions are assumed to include emissions from the transfers of sand and aggregate at the concrete batch plant as these emissions were not reported elsewhere. As described above, material handling emissions at West Pine Quarry were not considered as rip-rap would be brought in from off-site. The volume of material required for the MC1 Option, shown in **Table 6.1-13**, was converted to a mass basis using material densities assumed for the Site C Clean Energy Project (BC Hydro 2013).

This methodology assumes that the wind speed and material moisture content will be the same between the two projects. A comparison of the wind rose for the Site C dam site and the wind roses in **Figure 6.1-7** suggest that average wind speeds at the MC1 Option site may be slightly higher. Detailed information regarding material moisture contents was not available and thus a comparison was not made.

Stockpile Wind Erosion

Dust emissions from wind erosion of stockpiles for the Site C Clean Energy Project were estimated using the methodology published by the Western Regional Air Partnership (WRAP 2006). This methodology is based on the stockpile surface area and material silt content, and depends on the frequency of wind speeds greater than 5.4 metres per second (m/s) and the number of days with at least 0.0254 cm of precipitation.

Stockpile wind erosion emissions at the Site C dam site and the 85th Avenue Industrial Lands were taken and scaled based on the volume of till and gravel required (**Table 6.1-13**). The size of rip-rap is expected to be sufficiently large such that there would be negligible wind erosion of rip-rap stockpiles. Furthermore, it is expected that rip-rap would be brought in to the dam site as needed, and the need for stockpiling rip-rap would be minimal.

These scaled emissions were then adjusted to account for material silt content and the number of days with at least 0.0254 cm of precipitation. The weighted average silt content for till and gravel was estimated using the silt contents described above (20% for till, 5% for gravel). The number of days with at least 0.0254 cm of precipitation was obtained from 1981 to 2010 climate normal data at the Elbow RS meteorological station (Government of Canada 2016).

This methodology assumes that stockpiling practices would be similar between the two projects; therefore, stockpile surface areas would be proportional to the volume of construction material required.

Vehicles and Equipment

The number of haul truck trips required to transport the volume of construction material shown in **Table 6.1-13** was estimated assuming a typical haul truck capacity of 15 cubic metres (m^3). An average one-way haulage distance of 11 km was assumed for till and gravel based on the locations of identified borrow areas. Rip-rap would be brought in from off-site locations, and a haulage distance of 88 km was assumed based on the distance along Highway 66 between the earth fill dam and the junction with Highway 22. The total hours of haul truck operation were then estimated based on an average vehicle speed of 30 km per hour (km/h) along site access roads and an average vehicle speed of 100 km/h along Highway 66.

Exhaust CAC emissions from haul trucks were estimated using the methodology from the US EPA NONROAD model (US EPA 2010). An engine power rating of 329 horsepower (hp) was assumed, based on manufacturer specifications for the Caterpillar 730 dump truck (Ritchie Specs 2017). Vehicle age was estimated based on a model year of 2010, as assumed for the Site C Clean Energy Project (BC Hydro 2013). Emissions of SO_2 are dependent on fuel sulphur content and a maximum sulphur content of 15 parts per million was used, in accordance with Canada's Sulphur in Diesel Fuel Regulation (Environment and Climate Change Canada 2017b).

Details on other non-road equipment required for the Construction phase have not been developed yet; therefore, equipment emissions associated with the Site C Clean Energy Project for the dam site and the 85th Avenue Industrial Lands were taken and scaled based on the volume of construction material required. As discussed above, rip-rap would be brought in from off-site locations, and equipment emissions for West Pine Quarry were not considered. This methodology assumes that the types and sizes of non-road equipment such as bulldozers, excavators, and loaders would be similar for the two projects.

Re-Entrained Road Dust

Haul trucks would travel along unpaved site access roads and along Highway 66, resulting in the re-entrainment of road dust particles. Unpaved road dust emissions were estimated using the equation for industrial roads in Section 13.2.2 of AP-42 (US EPA 2006b):

$$E = 281.9\,k\left(\frac{s}{12}\right)^{a}\left(\frac{W}{3}\right)^{b}$$

Where:

E = emission factor (gram per vehicle-kilometre-travelled)

k, a, b = empirical constants (**Table 6.1-14**)

s = surface material silt content (%)

W = mean vehicle weight (tons)

Table 6.1-14 Empirical Constants for Unpaved Roads

Constant	TSP	$PM_{2.5}$
k	4.9	0.15
a	0.7	0.9
b	0.45	0.45

Source: US EPA 2006b

A default surface material silt content of 8.3% was assumed for haul roads at stone quarrying and processing sites.

Paved road dust emissions along Highway 66 were estimated using the equation in Section 13.2.1 of AP-42 (US EPA 2011):

$$E = 281.9\, k(sL)^{0.91}(W)^{1.02}$$

Where:

E = emission factor (gram per vehicle-kilometre-travelled)

k = empirical constants (**Table 6.1-15**)

sL = road surface silt loading (g/m^2)

W = mean vehicle weight (tons)

Table 6.1-15 Empirical Constants for Paved Roads

Constant	TSP	$PM_{2.5}$
k	0.011	0.00054

Source: US EPA 2011

The annual average daily traffic in 2015 along Highway 66 is estimated to be 1,078 vehicles (Alberta Transportation 2015), and the Option is expected to result in an addition of up to 5 rip-rap haul trucks per day (i.e. 5,077 trucks over the 33-month construction period for the main dam). A default road surface silt loading of 0.2 g/m2 was therefore assumed for roads with an average daily traffic between 500 and 5,000.

A mean vehicle weight of 53 tons was estimated for till and gravel haul trucks, and a mean vehicle weight of 52 tons was estimated for rip-rap trucks, based on the empty truck weight of a Caterpillar 730 dump truck (Ritchie Specs 2017), an average haul truck capacity of 15 m^3, and material densities assumed for the Site C Clean Energy Project (BC Hydro 2013).

An average control efficiency of 75% was assumed to account for watering activities and precipitation. This is further discussed in **Section 6.1.3.3**.

Highway 66 Realignment

The reservoir would cover a portion of the existing Highway 66, including a bridge crossing on the Elbow River. A 10.5-km portion of Highway 66 would therefore need to be re-aligned. Highway realignment activities may include transport and handling of aggregate materials for asphalt production, operation of a mobile asphalt batch plant, grading and paving. These activities would result in emissions of CACs.

Details regarding highway realignment activities have not been developed yet; therefore, emissions associated with road infrastructure for the Site C Clean Energy Project were taken and scaled based on the length of highway to be realigned. This methodology assumes that highway realignment activities, the transport distance of aggregate materials, as well as specifications of the mobile asphalt batch plant, would be similar for the two projects. Road infrastructure for the Site C Clean Energy Project included the realignment of a portion of Highway 29 in northern British Columbia, including a bridge crossing, as well as the construction of site access roads, one of which was indicated to be paved. Estimated emissions for the MC1 Option are thus expected to be conservative, since they are based on emissions predictions from the Site C Clean Energy Project. Furthermore, the asphalt batch plant used for Site C was fuelled by waste oil; the use of a different fuel for the MC1 Option may result in reduced emissions.

Burning of Wood Debris

The Construction phase would require site clearing, including removal of vegetation. Wood debris generated from site clearing may be open-burned, which would result in emissions of CACs. The amount of burning required for the Mc1 Option would be estimated during later stages of Option planning and design; therefore, burning emissions associated with the Site C Clean Energy Project were taken and scaled based on the area of land to be cleared. This methodology assumes that the amount of vegetation per hectare of land to be cleared, as well as the fraction of salvageable wood (both merchantable and non-merchantable), would be the same for the two projects.

MC1 Construction CAC Emissions

A summary of total estimated CAC emissions over the duration of the Construction phase is provided in **Table 6.1-16**. The largest contributors to CAC emissions associated with the Construction phase are the realignment of Highway 66, construction of the main dam, and burning of debris generated by site clearing.

Table 6.1-16 Summary of Total Estimated Criteria Air Contaminant Emissions from Option Construction

MC1 Component	Total Emissions (tonnes)				
	TSP	$PM_{2.5}$	NO_X	SO_2	CO
Main Dam	582	56	227	0.4	100
Service Spillway	10	1.0	5.1	0.008	2.2
Diversion Tunnel	4.0	0.4	2.0	0.003	0.9
Auxiliary Spillway	5.2	0.5	2.9	0.004	1.3
Facilities Relocation	28	2.6	14	0.02	6.0
Highway 66 Realignment	1,530	326	1,059	984	2,275
Burning of Wood Debris	55	35	17	0.4	427
Total MC1 Construction	**2,214**	**422**	**1,327**	**984**	**2,812**

MC1 construction is expected to start in May 2019 and last until January 2023. The worst-case year in terms of air quality is expected to be the period from December 2019 to November 2020, when the realignment of Highway 66 occurs and overlaps with the construction of all other MC1 components. **Table 6.1-17** provides a summary of CAC emissions from the worst-case year of the Construction phase, and compares these emissions to existing industrial emissions in the LAA and RAA for Air Quality. It is important to note that existing industrial emissions in the Air Quality LAA and RAA are only a fraction of total existing emissions in the areas, since there would also be emissions from vehicles along Highway 66, residential sources within the Town of Bragg Creek, and the Townsite of Redwood Meadows, as well as naturally occurring emissions. Emissions from burning are not included in **Table 6.1-17** as this activity is not defined in the proposed construction schedule.

MC1-related emissions during construction are expected to be greater than existing emissions in the Air Quality RAA and LAA (compare **Table 6.1-7** and **Table 6.1-17**). Existing emissions in **Table 6.1-17** include only emissions from industrial sources, however, and may not reflect total existing emissions. The largest source of MC1-related emissions is highway realignment. Total suspended particulate would primarily derive from re-entrained road dust along paved roads (i.e., Highway 66) during transport of aggregate materials for asphalt production. All other CACs would primarily be from the operation of the mobile asphalt batch plant. As discussed above, the estimated emissions from highway realignment may be conservative.

Table 6.1-17 Summary of Estimated Criteria Air Contaminant Emissions from MC1 Construction Worst-Case Year (December 2019 to November 2020)

Emission Source	Emissions (tonnes)				
	TSP	$PM_{2.5}$	NO_X	SO_2	CO
Stripping	0.2	0.01	-	-	-
Bulldozing	59	6.2	-	-	-
Material Handling	0.8	0.06	-	-	-
Stockpile Wind Erosion	15	1.1	-	-	-
Vehicles and Equipment	5.6	5.4	63	0.1	28
Re-Entrained Road Dust	74	2.1	-	-	-
Realignment of Highway 66	1,020	217	706	656	1,517
Total Worst-Case Year Emissions	**1,174**	**232**	**769**	**656**	**1,545**
Existing Emissions in LAA	*2.9*	*2.9*	*291*	*136*	*759*
Existing Emissions in RAA	*3.5*	*3.5*	*337*	*268*	*759*

Impact on Ambient Concentrations

Typically, dispersion modelling is conducted to estimate the impact of MC1-related emissions on ambient CAC concentrations. Due to the lack of MC1-specific information for the MC1 Option, the impact of estimated emissions from the Construction phase of the MC1 Option was estimated by considering the dispersion modelling results from the Site C Clean Energy Project.

Emissions from the construction of the Site C dam site area and associated activities at the borrow sources were modelled using the CALMET/CALPUFF dispersion modelling system (BC Hydro 2013). Modelled emissions for the Site C Clean Energy Project are compared to the worst-case year Construction-phase emissions for the MC1 Option in **Table 6.1-18**. Emissions from re-entrained road dust, highway realignment, and burning of debris are not included as these emissions were not modelled for the Site C Clean Energy Project. Limitations associated with this approach are discussed below. Emissions for the MC1 Option are approximately 10% to 20% of emissions for the Site C Clean Energy Project.

Table 6.1-18 Comparison of Modelled Emissions from the Site C Clean Energy Project to MC1 Option – Worst-Case Year of Construction (December 2019 to November 2020)

Project	Emissions (tonnes)				
	TSP	$PM_{2.5}$	NO_X	SO_2	CO
Site C Clean Energy Project	593	66	334	0.7	193
MC1 Option	80	13	63	0.1	28
MC1 Emissions as Fraction of Site C Emissions	0.1	0.2	0.2	0.1	0.1

Dispersion modelling results for the Site C Clean Energy Project were presented in the form of isopleth maps depicting maximum predicted concentrations in the model domain, except 24-hour $PM_{2.5}$, which was presented as the 98th percentile predicted concentrations for comparison with the British Columbia AAQO. The maximum extent of each isopleth was estimated from the maps and scaled to estimate the potential extent of air quality impacts associated with the worst-case year of the Construction phase for the MC1 Option. The concentration level of each isopleth was adjusted to reflect the background concentrations in the Air Quality LAA and RAA, as summarized in **Table 6.1-9**. For NO_2 and SO_2, isopleth maps were only presented for the one-hour averaging period in the Site C Clean Energy Project EIS. EIS Annual concentrations for these contaminants were estimated using averaging time conversion factors from the Ontario Ministry of the Environment and Climate Change (Ontario MOECC 2009).

The estimated ambient concentrations as a function of distance from the emission sources are illustrated in **Figure 6.1-8** to **Figure 6.1-16.** Ambient concentrations are expected to decrease rapidly with distance for all contaminants.

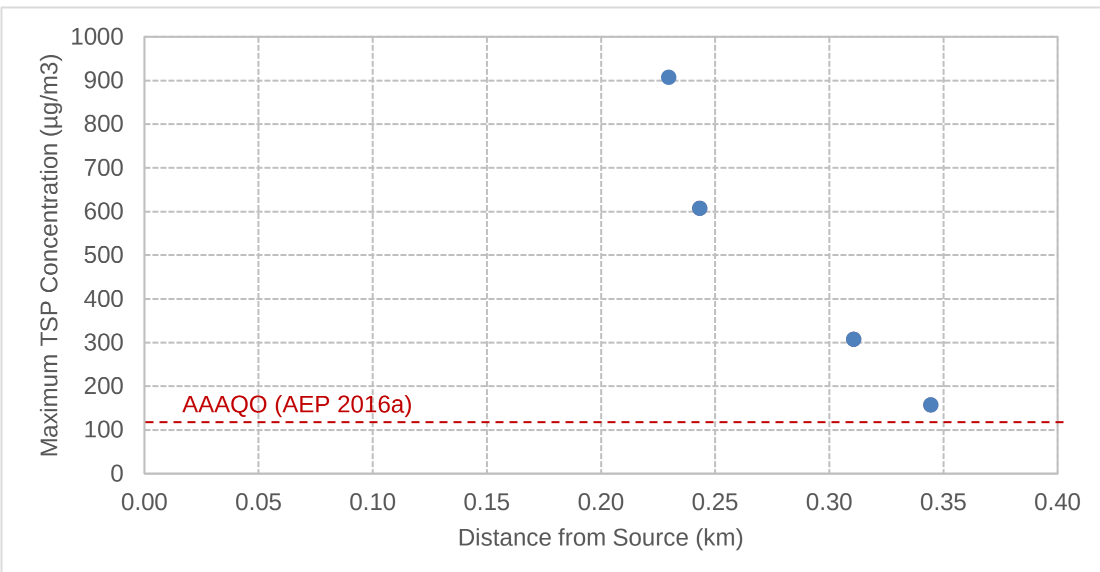


Figure 6.1-8 Maximum 24-hour Total Suspended Particulate Concentration as a Function of Distance from Emission Sources

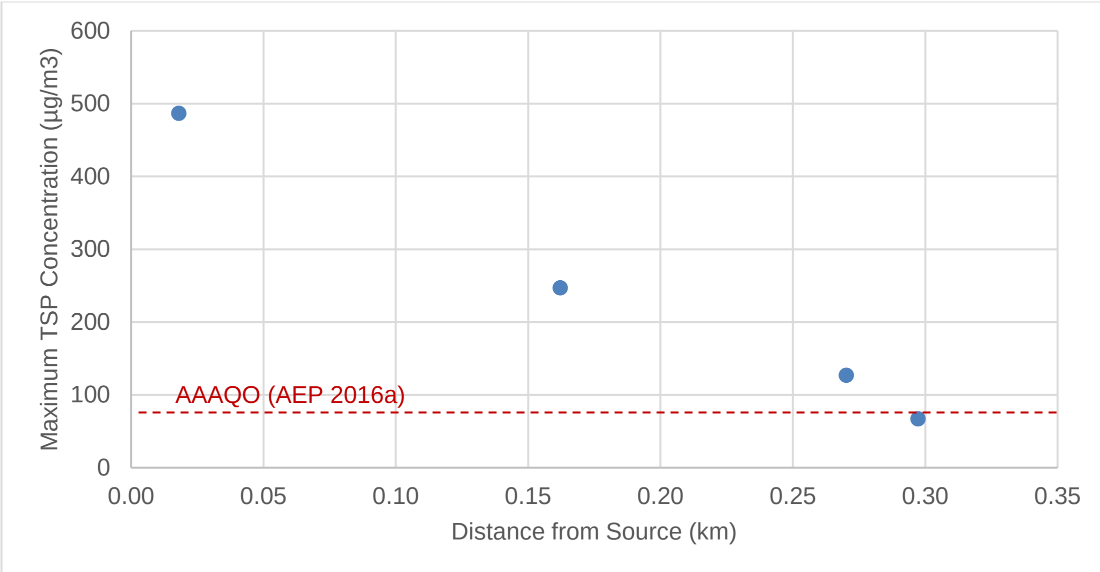


Figure 6.1-9 Maximum Annual Total Suspended Particulate Concentration as a Function of Distance from Emission Sources

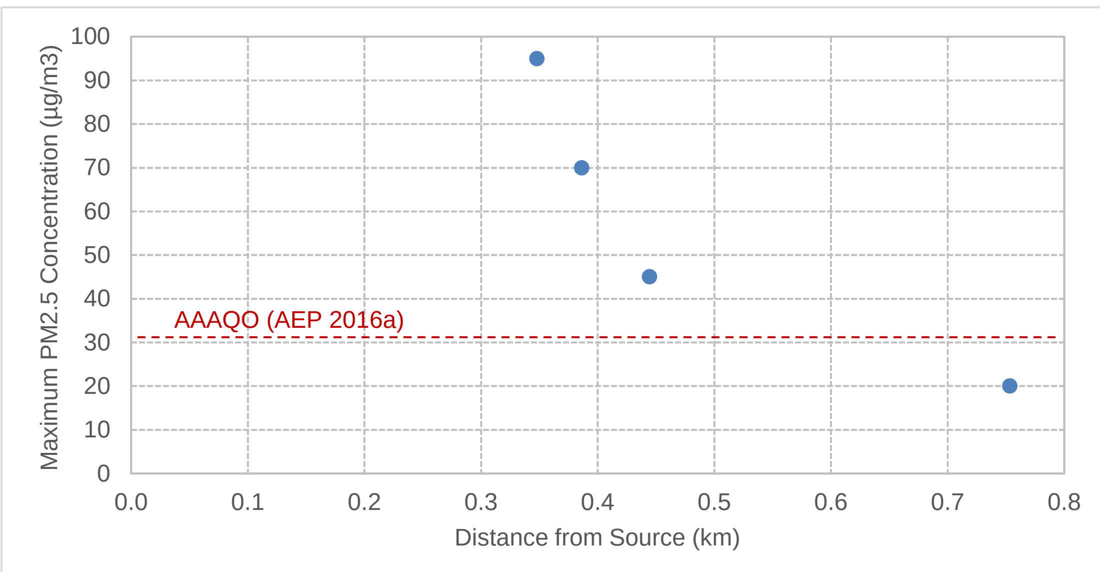


Figure 6.1-10 Ninety-eighth Percentile 24-hour Particulate Matter Concentration as a Function of Distance from Emission Sources

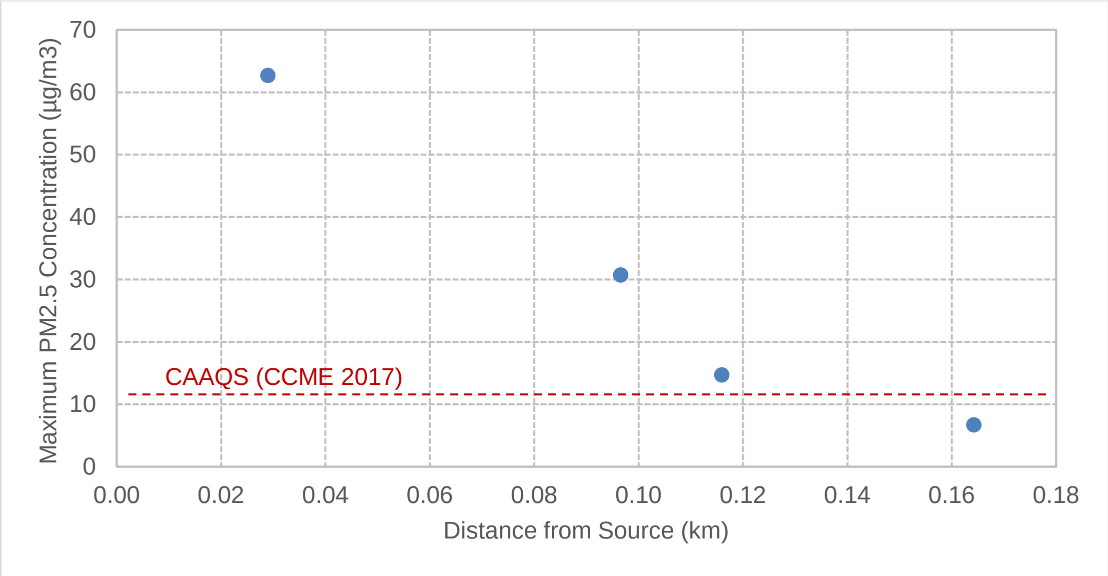


Figure 6.1-11 Maximum Annual Particulate Matter Concentration as a Function of Distance from Emission Sources

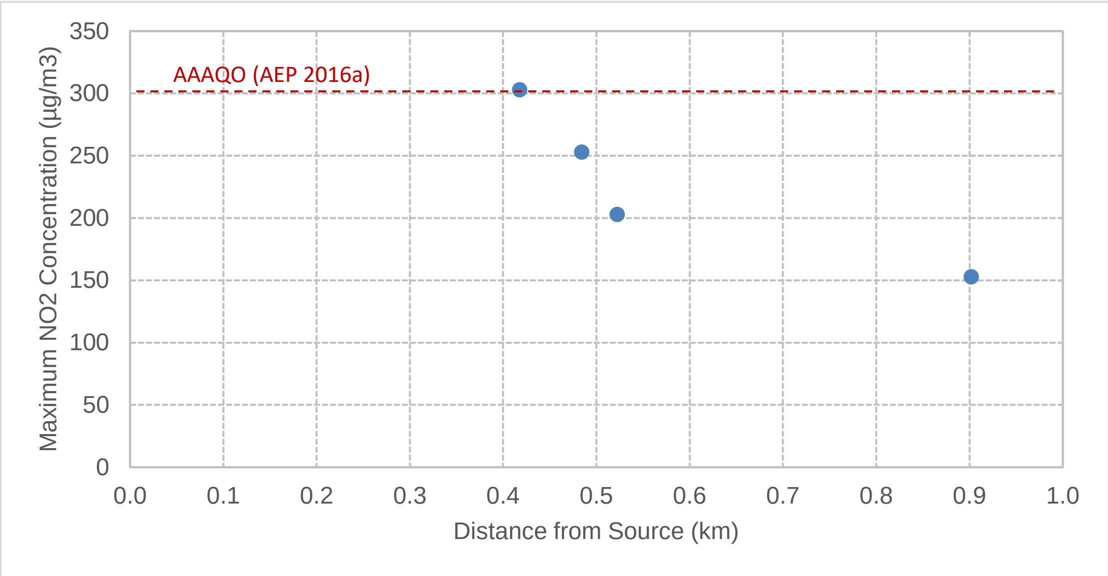


Figure 6.1-12 Maximum 1-hour Nitrogen Dioxide Concentration as a Function of Distance from Emission Sources

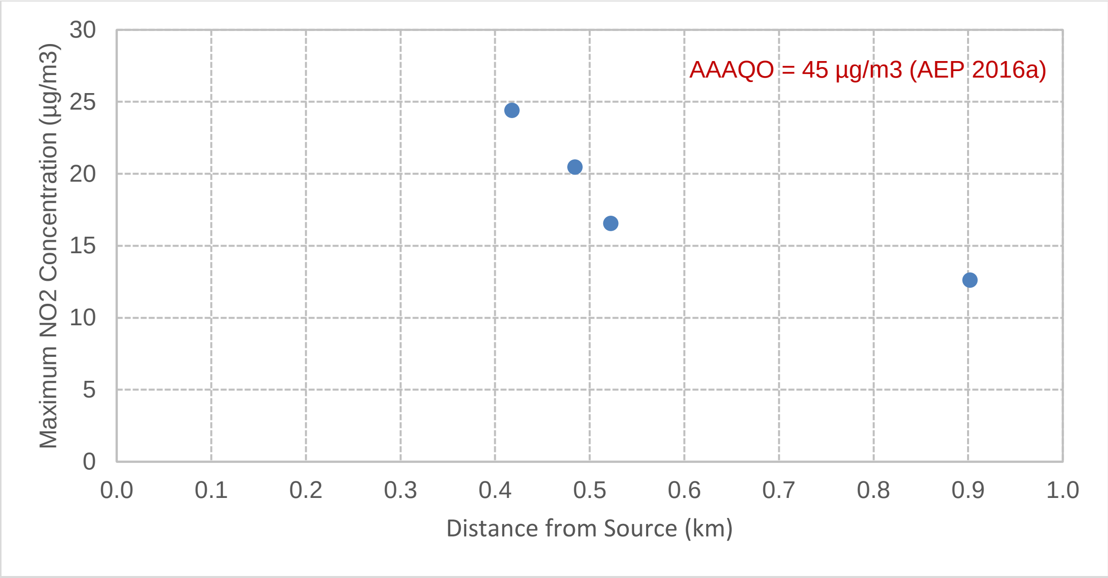


Figure 6.1-13 Maximum Annual Nitrogen Dioxide Concentration as a Function of Distance from Emission Sources

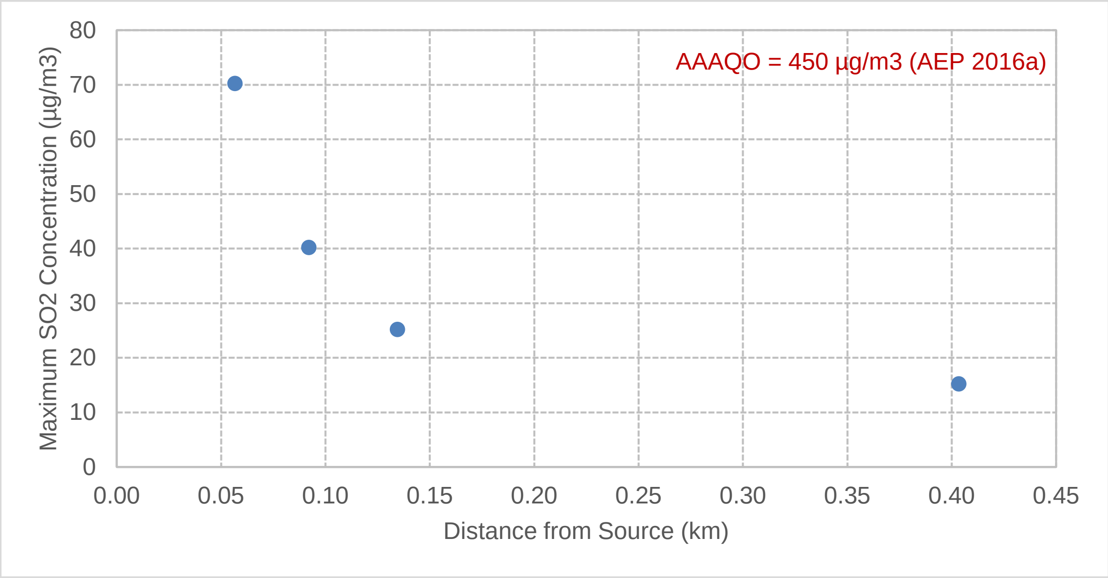


Figure 6.1-14 Maximum 1-hour Sulphur Dioxide Concentration as a Function of Distance from Emission Sources

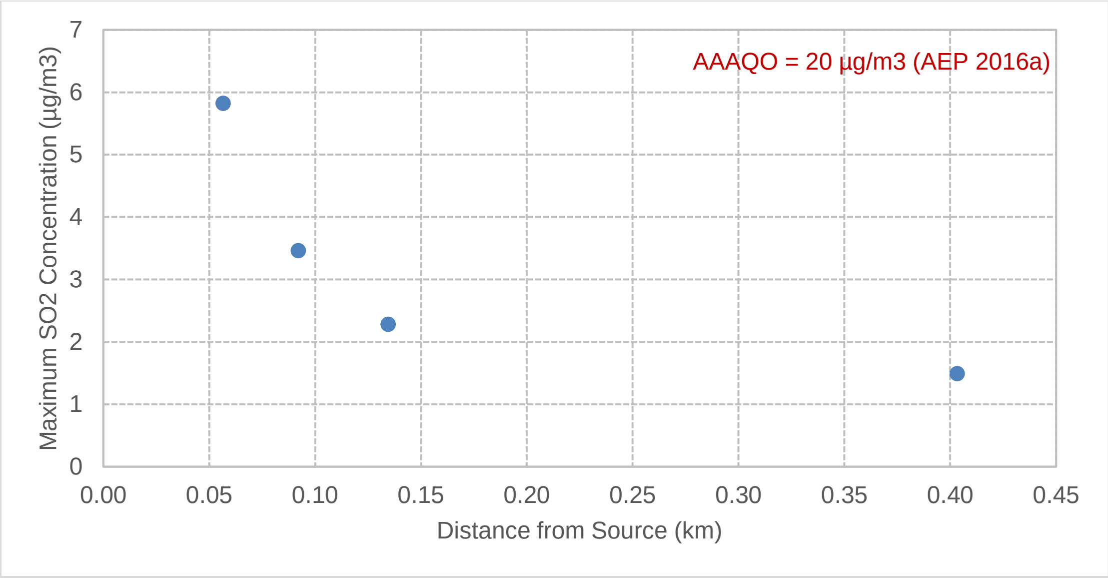


Figure 6.1-15 Maximum Annual Sulphur Dioxide Concentration as a Function of Distance from Emission Sources

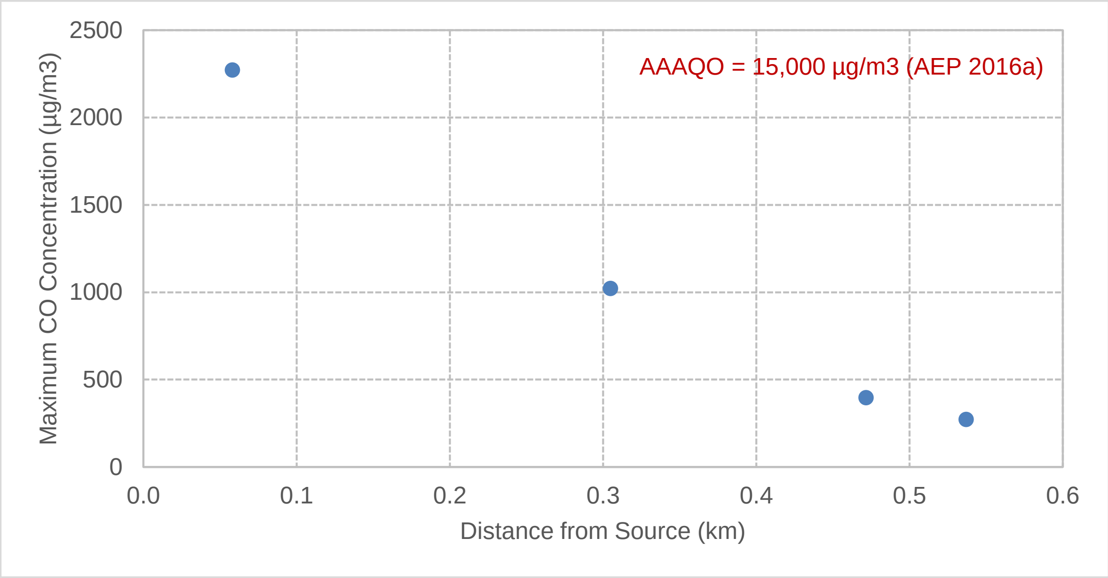
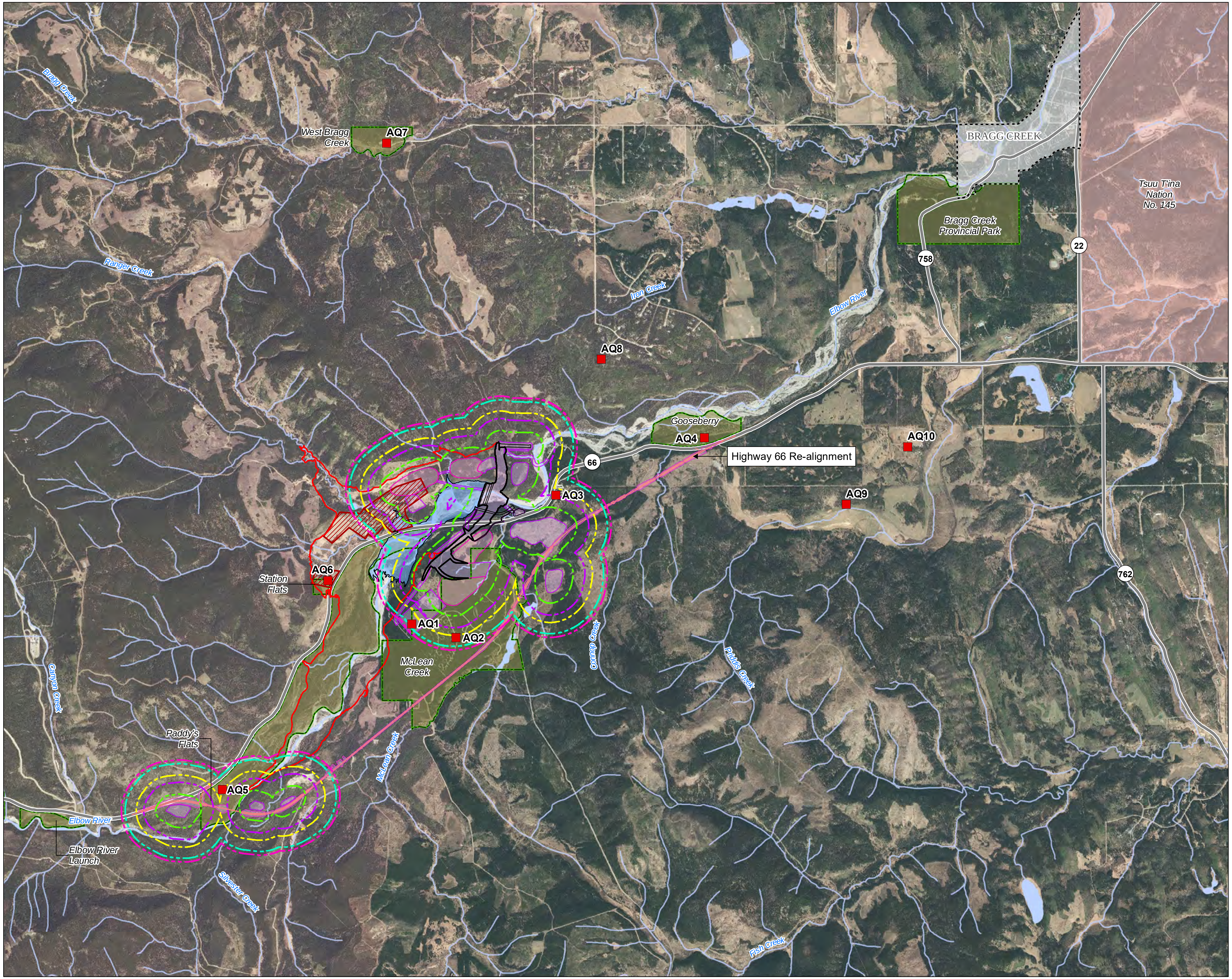


Figure 6.1-16 Maximum 1-Hour Carbon Monoxide Concentration as a Function of Distance from Emission Sources

As shown in **Figure 6.1-8** to **Figure 6.1-16**, the Alberta AAQOs for 24-hour and annual TSP, 24-hour $PM_{2.5}$, and 1-hour NO_2 as well as the CAAQS for annual $PM_{2.5}$ may be exceeded during the worst-case year of the Construction phase. The distance to which exceedances of the ambient air quality criteria may occur would range from approximately 0.14 km for annual $PM_{2.5}$ to approximately 0.6 km for 24-hour $PM_{2.5}$. The aerial extent of potential exceedances of the ambient air quality criteria is shown in **Figure 6.1-17**.



Elbow River at McLean Creek Dam (MC1)

Aerial Extent of Potential Exceedances of Ambient Air Quality Criteria – Worst-Case Year of Construction (December 2019 to November 2020)

Legend

- MC1 Dam
- Highway 66 Re-alignment
- 2013 Flood Event (1424.1m)
- Borrow Area
- Laydown Area/Disturbed Area
- Permanent Pond
- Existing Park Infrastructure to be Removed
- Highway
- Reserve
- Provincial Park or Recreational Area
- Urban Area
- Watercourse
- Waterbody
- Air Quality Sensitive Receptor Location

Potential Exceedances of Ambient Air Quality Criteria

- Annual $PM_{2.5}$
- 1-Hour NO_2
- Annual TSP
- 24-Hour TSP
- 24-Hour $PM_{2.5}$

Notes

1. This map is not intended to be a "stand-alone" document, but a visual aid of the information contained within the referenced Report. It is intended to be used in conjunction with the scope of services and limitations described therein.

Sources

- Basedata: Government of Alberta, 2017
- Preferred Road Option and Disturbed Areas: Opus International Consultants Limited, 2017
- Dam Details: Hatch Ltd., 2017
- Aerial Imagery: SPOT 1.5 m, 2016

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As shown in **Figure 6.1-17**, ambient air quality criteria may be exceeded at several sensitive receptors, including the proposed construction camp (AQ1), McLean Creek Campground (AQ2), Easter Seals Camp Horizon (AQ3), and Paddy's Flat Campground (AQ5) during the MC1 Option's Construction phase. Ambient air quality criteria are not expected to be exceeded at any private residences.

These potential extents of air quality impacts do not include the effects of re-entrained road dust, highway realignment, and debris burning. As emission factors associated with re-entrained road dust are understood to be overly conservative, it is standard practice not to include these emissions in dispersion modelling. Approximately 60% to 90% of road dust particles remain within 1 metre (m) to 2 m above the ground, and are not considered transportable, since they deposit within several minutes after suspension (Desert Research Institute 2000). The extent of impacts from re-entrained road dust is therefore expected to be small, typically within several hundred metres of the road. Operation of the mobile asphalt batch plant for highway realignment and burning of debris generated from site clearing may affect ambient air quality beyond that estimated above. Mitigation measures outlined in **Section 6.1.3.3** would likely minimize impacts from these sources.

Summary

Overall, MC1-related emissions would be greater than existing emissions in the Air Quality LAA and RAA. There is also the potential for ambient concentrations of TSP, $PM_{2.5}$, and NO_2 to exceed ambient air quality criteria at several sensitive receptors, including the proposed construction camp (AQ1), McLean Creek Campground (AQ2), Easter Seals Camp Horizon (AQ3), and Paddy's Flat Campground (AQ5) during the Construction phase.

Increased Emissions of Greenhouse Gases

Emissions of GHGs were estimated for the Construction phase. Similar to CACs, GHG emissions were estimated using MC1-specific data where available, or scaled using information from the Site C Clean Energy Project EIS (BC Hydro 2013). The methodology used in the emission inventory is detailed by emission source below.

Vehicles and Equipment

Emissions of CO_2 from construction material haul trucks were estimated using the methodology from the US EPA NONROAD model (US EPA 2010) based on the estimated hours of haul truck operation (see discussion of CACs above). Emissions of CH_4 and N_2O were estimated based on the CO_2 emissions using emission factors for non-road diesel from Environment Canada's national GHG inventory (Environment and Climate Change Canada 2015).

Emissions of CO_2 from other non-road equipment were estimated to be 204 times the estimated NO_X emissions. This is based on the final adjusted emission factors based on the methodology from the US EPA

NONROAD model (US EPA 2010) for a generic construction equipment with a model year of 2010 and a rated engine power between 300 hp and 600 hp, which is expected to be representative of most of the construction equipment to be used for the MC1 Option. Emissions of NO_X were selected as the basis of CO_2 estimation because these two contaminants have similar adjustment factors to account for transient operation and deterioration, whereas particulate matter and CO have much higher adjustment factors. Similar to emissions produced by haul trucks, emissions of CH_4 and N_2O from other non-road equipment were estimated based on the CO_2 emissions using emission factors for non-road diesel from Environment Canada's national GHG inventory (Environment and Climate Change Canada 2015).

Highway Realignment

Greenhouse gas emissions from highway realignment includes emissions from vehicles and equipment as well as emissions from the mobile asphalt batch plant. Vehicle- and equipment-based GHG emissions were estimated as discussed above. Emissions of CO_2 from the asphalt plant were estimated to be 1,158 times the estimated NO_X emissions, based on emission factors for the combustion of waste oil in Section 1.11 of AP-42 (US EPA 1996). Emissions of CH_4 and N_2O from the asphalt plant were estimated based on the CO_2 emissions using emission factors for waste oil combustion from The Intergovernmental Panel for Climate Change (IPCC 2006a).

Burning of Wood Debris

Emissions of CO_2, CH_4, and N_2O from debris burning generated during site clearing have been estimated by scaling the estimated NO_X emissions based on the emission factors shown in **Table 6.1-19**. The NO_X emission factor was taken from the Site C Clean Energy Project (BC Hydro 2013) and is representative of open burning of forest residues. The CO_2, CH_4, and N_2O emission factors were taken from IPCC (IPCC 2006b), and are representative of open burning of agricultural residues. Emissions of NO_X were chosen as the basis of GHG estimation because IPCC provides an emission factor of 2.5 grams per kilogram (g/kg) for open burning of agricultural residues, similar to the emission factor of 2.0 g/kg used for the Site C Clean Energy Project. In comparison, IPCC provides an emission factor of 92 g/kg for CO, whereas the emission factor used for Site C, representative of prescribed burning, was 37 g/kg.

Table 6.1-19 Emission Factors for Burning

Pollutant	Emission Factor (g/kg)
NO_X	2.0
CO_2	1,515
CH_4	2.7
N_2O	0.07

Sources: BC Hydro 2013, IPCC 2006b

Summary

A summary of estimated GHG emissions associated with the Construction phase is provided in **Table 6.1-20**. Total GHG emissions are expressed in carbon dioxide equivalents (CO_{2e}), a standard unit used to express the overall effect on climate change. Emissions of CO_2 from biomass burning are shown in the table but are not included in the total GHG emissions, as per convention of GHG inventories, on the basis that renewable resources such as biomass are part of the natural carbon cycle. The total GHG emissions estimated for MC1 Construction are 1,195 kt CO_{2e}, which equates to an average of 326 kt CO_{2e} annually over the 44-month construction period. This estimation represents 0.1% of Alberta's total GHG emissions in 2014 and 0.05% of Canada's total GHG emissions in 2014.

Table 6.1-20 Summary of Total Greenhouse Gas Emissions from MC1 Construction

Emission Source	Total Emissions (tonnes)			
	CO_2	CH_4	N_2O	$CO2_E$
Vehicles and Equipment	51,243	2.9	21	57,559
Highway Realignment	1,105,149	443	69	1,136,938
Burning of Wood Debris	13,089	23	0.6	13,852
Total MC1 Construction[(a)]	**1,156,391**	**469**	**91**	**1,195,260**

Note: (a) Emissions of CO_2 from biomass burning are not included in the total.

Increased Noise Levels

MC1 effects to noise receptors were evaluated by comparing the predicted estimated sound levels to the Health Canada MNLs and to the threshold at which potential nighttime sleep disturbance begins.

The receptors near the main construction area (i.e., NR1-NR7), would be exposed to increased noise levels for more than a year; noise levels at these receptors were evaluated by long-term (≥ 1 year) construction noise approach. This method considers the percent highly annoyed (%HA) at the receptors and the change in %HA is to be less than 6.5%.

The receptors near the highway realignment (i.e., HNR1-HNR4) would be primarily affected by road construction and would be exposed to increased noise levels for less than a year; these receptors were evaluated by short-term (< 1 year) construction noise approach. This method suggests that in the event of day-night sound levels (L_{dn}) at receptors being greater than the calculated MNLs, mitigation measures should be implemented to reduce the levels to below the MNLs.

Further to long-term and short-term noise exposures evaluations, nighttime noise levels for all receptors were compared to the sound levels where sleep disturbance impact are reported to begin. This suggested level can vary depending on the outdoor-to-indoor noise transmission loss but it is an indication of there being a potential impact on sleep. This method suggests bedroom noise levels should be 30 dBA or less and outdoor-to-indoor noise transmission loss is 15 dBA; this method assumes that sleep disturbance impacts at outdoor noise levels of 45 dBA would begin. Some permanent residential areas would meet or exceed the structure transmission loss of 15 dBA, but temporary residential areas such as campgrounds may not have sufficient insulation to have this level achieved. Therefore; this study considers the temporary residential areas without transmission loss.

Noise Sources

Noise sources associated with the Construction phase include heavy equipment such as backhoes, shovels, dozers, loaders and haul trucks. Detailed information regarding construction equipment requirements were not available; therefore, noise sources were estimated based on information from the noise assessment of other similar earth fill dams such as the Site C Clean Energy Project, and adjusted based on the size of the Option. **Table 6.1-21** provides a summary of the noise sources and the sound power levels assumed for the MC1 Option's effects assessment. During a construction project, not all equipment is active at all times; however, this noise study assumes all equipment would be active during the construction day. This conservative approach eliminates the under-estimation of equipment noise levels during construction. Additionally, backup alarms on equipment such as loaders and forklifts were included in the noise assessment, as recommended by Health Canada.

Table 6.1-21 Construction Noise Sources and Sound Power Levels

Equipment	Number of Equipment Pieces	Total Sound Power Level (dBA)
Construction Equipment		
Drilling Rig (Mobile)	2	90.1
Scraper	1	79.0
Roller (18 tonnes)	3	79.5
Light Plant	10	65.5
Haul Truck – Large Size (104 yd^3 / 79.5m^3 CAT 785C)	5	81.0
Haul Truck – Mid-sizes (33 yd^3 / 23.23 m^3)	5	80.6
Front End Loader – Mid-sizeM-s (7 m^3 capacity)	3	77.5
Bulldozer	8	77.6
Grader – Large	1	83.2
Grader	2	74.8
Front End Loader – Large Size (20 m^3 capacity)	2	79.0
Conveyor	1	74.1
Drill	1	73.8
Excavator	5	72.8
Concrete Pump	5	77.8
Shovel	2	89.9
Concrete Mixer Truck	10	80.0
Backhoe (8 tonnes)	2	67.9
Loader	7	89.9
Crusher (Semi-Mobile)	1	90.1
Vibratory Compactor	3	77.7
Asphalt Paver and Tipper	2	83.8
Asphalt Kettle	2	84.8
Support Equipment		
Welder	1	70.5
Generator for Welder	1	71.3
Forklift	1	77.5
Air Compressor	2	89.5
Water Pump	3	85.1
Portable Generator	5	84.8
Crane (110 tonnes)	5	66.5
Hydraulic Piling	2	88.6
Articulated Dump Truck (40 tonnes)	2	88.5
Tree Removal Excavator	3	72.8
Rock Breaker (23 tonnes)	3	93.0

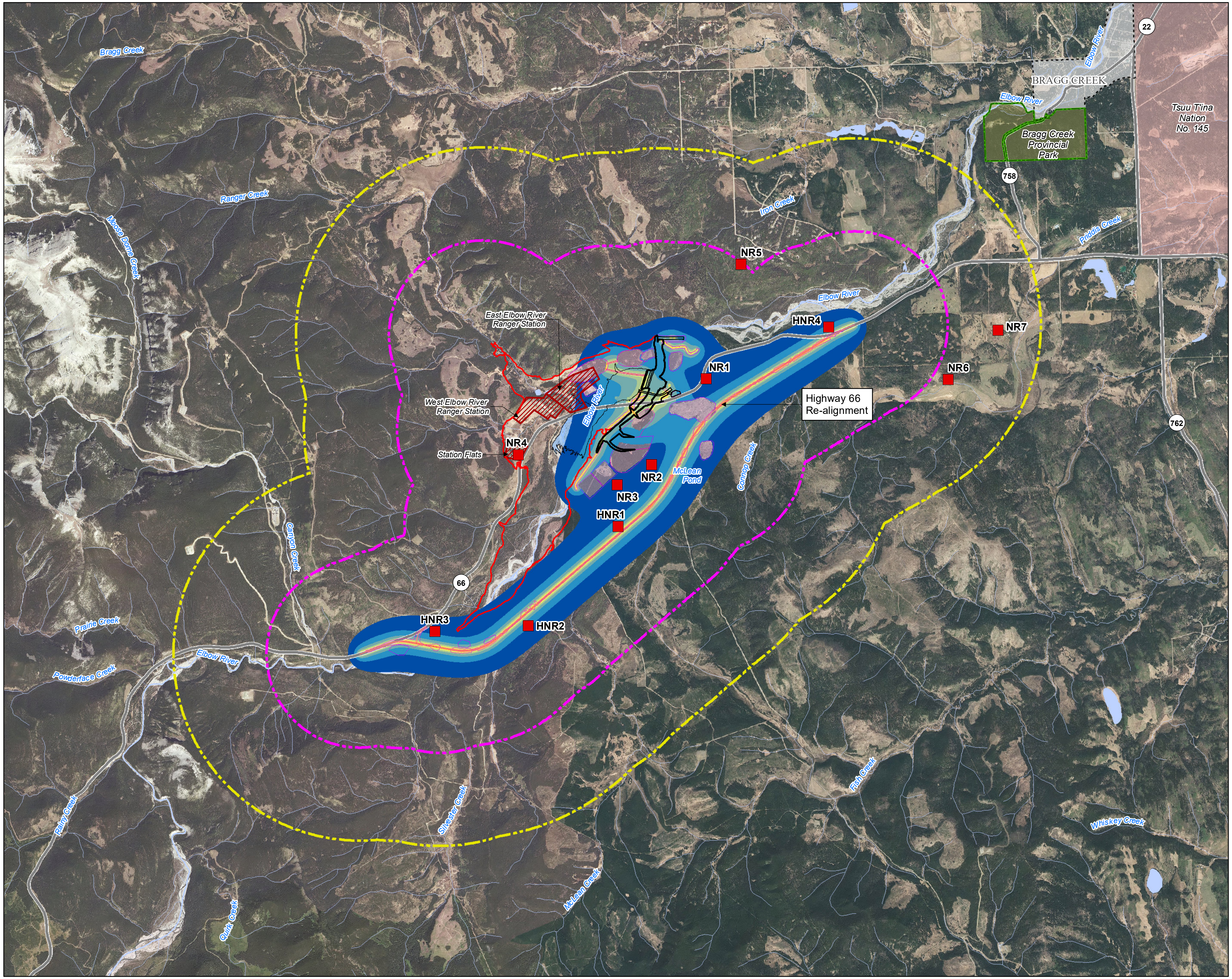
Equipment	Number of Equipment Pieces	Total Sound Power Level (dBA)
Asphalt Plant		
Burner	1	92.5
Dust Collector	1	59.9
Mixing System	2	78.1
Conveyor	1	74.1
Drying Drum	4	73.1
Concrete Plant		
Mixer	1	60.3
Batcher	1	50.6
Conveyor	1	74.1
Heater	1	90.9
Dust Collectors	2	59.9

Note: yd^3 – cubic yards

Noise Predictions

Noise sources and sound power levels from equipment summarized in **Table 6.1-21** were input into the CadnaA noise propagation model (DataKustik 2016) to estimate the noise levels at the noise receptors due to construction activities. The CadnaA model uses the environmental sound propagation calculation methods prescribed by the International Organization for Standardization Standard 9613, which conservatively predicts noise levels under moderately developed temperature inversion and downwind conditions.

An isopleth map of maximum predicted noise levels due to the Construction phase is illustrated in **Figure 6.1-18** . Noise levels would be highest at the dam embankment and along the highway realignment route.



Elbow River at McLean Creek Dam (MC1)

Maximum Noise Levels from MC1 Dam Construction

Legend

- Noise Local Assessment Area
- Noise Regional Assessment Area
- Noise Receptor Location
- MC1 Dam
- Highway 66 Re-alignment
- 2013 Flood Event (1424.1m)
- Borrow Area
- Laydown Area/Disturbed Area
- Permanent Pond
- Existing Park Infrastructure to be Removed
- Highway
- Reserve
- Hamlet of Bragg Creek
- Provincial Park

Maximum Construction Noise Levels (dBA)

- 30 - 35
- 35 - 40
- 40 - 45
- 45 - 50
- 50 - 55
- 55 - 60
- 60 - 65
- 65 - 70
- 70 - 75

Notes

1. All locations and features should be considered approximate and are to be used for discussion purposes only.
2. This map is not intended to be a "stand-alone" document, but a visual aid of the information contained within the referenced Report. It is intended to be used in conjunction with the scope of services and limitations described therein.

Sources

- Basedata: Government of Alberta, 2017
- Preferred Road Option and Disturbed Areas: Opus International Consultants Limited, 2017
- Dam Details: Hatch Ltd., 2017
- Aerial Imagery: SPOT 1.5 m, 2016

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The predicted noise levels due to the Construction phase are added to existing noise levels in **Table 6.1-10** to determine the cumulative noise levels at each receptor. For comparison with Health Canada's MNL in **Table 6.1-3,** the 24-hour day-night sound level (L_{dn}), was calculated based on the 15-hour daytime sound level (L_d) and the 9-hour nighttime sound level (L_n) as follows:

$$L_{dn} = 10\ Log\left[\frac{15 \times 10\left(\frac{L_d}{10}\right) + 9 \times 10\left(\frac{L_n + 10}{10}\right)}{24}\right]$$

The noise predictions at HNR1 (McLean Creek Campground), HNR2 (Private Residence), HNR3 (Paddy's Flat Campground and HNR4 (Gooseberry Campground) along the highway realignment route are shown in **Table 6.1-22**. The highest predicted L_{dn} is 54.2 dBA at HNR4, which is below the MNL of 57 dBA. The MNL of 57 dBA is based on the MNL of 47 dBA for rural areas plus a 10 dBA correction for construction less than two months. The correction factor is applied because the construction activities associated with highway realignment would move along the route quickly such that each receptor would not be affected for longer than two months. However, at HNR3, the highway realignment includes bridge construction which would last longer than two months therefore, the correction does not apply for this receptor.

Table 6.1-22 Predicted Noise Levels at Receptors along Highway Alignment Route

Receptor	Existing Noise Level		Contribution from MC1 Construction		Existing + MC1 Noise Level		L_{dn} (dBA)	MNL[a] (dBA)
	Day (dBA)	Night (dBA)	Day (dBA)	Night[(a)] (dBA)	Day (dBA)	Night (dBA)		
HNR1 (McLean Creek Campground)	48.0	38.0	44.6	44.6	49.6	45.5	52.8	57.0
HNR2 (Private Residence)	45.0	35.0	40.6	40.6	46.3	41.7	49.1	57.0
HNR3 (Paddy's Flat Campground)	45.0	35.0	38.8	38.8	45.9	40.3	48.1	47.0
HNR4 (Gooseberry Campground)	53.0	43.0	41.6	41.6	53.3	45.4	54.2	57.0

Note: Values in bold font exceed the relevant criteria

Footnote: a) MNL = Mitigation Noise Level calculated using HC 2017.

Table 6.1-23 compares the potential sleep disturbance level to the predicted nighttime noise levels at receptors along the highway realignment route. HNR3 (Paddy's Flat Campground) is not included in this table because the predicted Ldn value of 48.1 dBA exceeds Health Canada's MNL guidance threshold of 47 dBA. This receptor would be exposed to noise from bridge construction lasting longer than two months, suggesting that this receptor is not suitable for nighttime accommodation during bridge construction. In addition, bridge construction would involve pile driving and would be a source of additional noise at HNR3. The close proximity of HNR3 to the bridge construction would not allow for effective mitigation measures; therefore, nighttime accommodation at HNR3 is not recommended during the bridge construction and is not carried forward for sleep disturbance assessment.

Table 6.1-23 Comparison of Nighttime Noise Levels along the Highway Alignment Route to Potential Sleep Disturbance Level

Receptor	Existing Option Noise Level	Potential Sleep Disturbance Threshold for Outdoor (dBA)	Potential Exceedance
	Night (dBA)		
HNR1 (McLean Creek Campground)	45.5	30	Yes
HNR2 (Private Residence)	41.7	45	No
HNR4 (Gooseberry Campground)	45.4	30	Yes

Note: Health Canada estimates 15 dBA outdoor to indoor transmission loss; therefore, ambient noise levels in bedrooms should be 45 – 15 = 30 dBA.

The potential for adverse effects on sleep begin when ambient noise levels in bedrooms exceed 30 dBA, or a sudden noise of 45 dBA or greater occurs. With an estimated 15 dBA decrease in outdoor to indoor transmission, as suggested by Health Canada (HC 2017), the outdoor levels should therefore be at or below 45 dBA for ambient outdoor noise and 60 dBA for a sudden noise event. The exceedance of guidance thresholds for sleep disturbance levels suggest that HNR1 and HNR4 (McLean Creek Campground and Gooseberry Campground) may not be suitable for sleeping during the period of highway realignment construction. However, exceedance of the threshold would not be anticipated to last longer than two months at either receptor.

Percent Highly Annoyed

The %HA for the other sensitive receptors NR1 to NR7 was calculated based on the predicted L_{dn} using the following equation:

$$\%HA = \frac{100}{1 + e^{(10.4 - 0.132 L_{dn})}}$$

Table 6.1-24 shows the predicted %HA at the sensitive receptors. The predicted change in %HA at all receptors is less than 6.5%. As per Health Canada's (2017) Guidance for Evaluating Human Health Impacts in Environmental Assessment: Noise, noise levels at receptors, while not exceeding the change of 6.5%, may exceed levels at which sleep disturbance may occur.

Table 6.1-24 Predicted Noise Levels and Percent Highly Annoyed at Receptors near Main Construction Area

Receptor	Existing Noise Level		Contribution from Construction		Existing+MC1 Noise Level		%HA Baseline Case	% HA Application Case
	Day (dBA)	Night (dBA)	Day (dBA)	Night[(a)] (dBA)	Day (dBA)	Night (dBA)		
NR1 (Easter Seals Camp Horizon)	50	40	36.1	36.1	50.2	41.5	2.0	2.2
NR2 (Construction Camp / McLean Creek Campground)	45	35	37.2	37.2	45.7	39.2	1.0	1.4
NR3 (McLean Creek Campground)	48	38	34.1	34.1	48.2	39.5	1.5	1.7
NR4 (Station Flats Day Use Area)	45	35	21.0	21.0	45.0	35.2	1.0	1.0
NR5 (Private Residence)	48	38	23.9	23.9	48.0	38.2	1.5	1.6
NR6 (Private Residence)	45	35	21.0	21.0	45.0	35.2	1.0	1.0
NR7 (Private Residence)	45	35	22.0	22.0	45.0	35.2	1.0	1.0

Adverse effects on sleeping, described previously, begin when the outdoor levels are 45 dBA for noise sources and 60 dBA for noise events, respectively. The nighttime predicted noise levels for NR1 to NR7 are less than Health Canada's guidance thresholds for outdoor levels (see **Table 6.1-25**).

Table 6.1-25 Comparison of Nighttime Noise Levels at Receptors near Main Construction Area to Potential Sleep Disturbance Level

Receptor	Existing + MC1 Noise Level	Potential Sleep Disturbance Threshold for Outdoor (dBA)	Potential Exceedance
	Night (dBA)		
NR1 (Easter Seals Camp Horizon)	41.5	45	No
NR2 (Construction Camp / McLean Creek Campground)	39.2	45	No
NR3 (McLean Creek Campground)	39.5	45	No
NR4 (Station Flats Day Use Area)	35.2	45	No
NR5 (Private Residence)	38.2	45	No
NR6 (Private Residence)	35.2	45	No
NR7 (Private Residence)	35.2	45	No

Note: Health Canada estimates 15 dBA outdoor to indoor transmission loss; therefore, ambient noise levels in bedrooms should be 45 – 15 = 30 dBA.

Low-frequency Noise (LFN)

As per Directive 038, LFN may be a concern due to a dominant low frequency noise from heavy equipment that may cause annoyance even when A-weighted sound levels are satisfactory at each receptor. Further investigation was therefore conducted to determine the potential for an LFN complaint condition, defined as a difference between C-weighted (dBC) and A-weighted (dBA) levels greater than 20 dB. If the difference is greater than 20 dB, a further investigation or mitigation measures are to be implemented.

Table 6.1-26 presents the predicted noise levels at sensitive receptors NR1 to NR7 in both dBA and dBC decibel units. The difference between overall daytime dBC and dBA values is less than 20 dB at all receptors; therefore, there is no indication of low frequency effects due to Construction-phase activities.

Table 6.1-26 Low-frequency Analysis at Sensitive Receptors

Receptor	Daytime A-Weighted Level (dBA)	Daytime C-Weighted Level (dBC)	Difference (dBC minus dBA)	Difference <20 dB	Nighttime A-Weighted Level (dBA)	Nighttime C-Weighted Level (dBC)	Difference (dBC minus dBA)	Difference <20 dB
NR1 (Easter Seals Camp Horizon)	50.2	53.9	3.7	Yes	41.5	44.6	3.1	Yes
NR2 (Construction Camp / McLean Creek Campground)	45.7	49.1	3.4	Yes	39.2	42.2	2.9	Yes
NR3 (McLean Creek Campground)	48.2	51.8	3.6	Yes	39.5	37.6	2.6	Yes
NR4 (Station Flats Day Use Area)	45.0	48.4	3.3	Yes	35.2	37.8	2.8	Yes
NR5 (Private Residence)	48.0	48.0	3.6	Yes	38.2	41.0	2.6	Yes
NR6 (Private Residence)	45.0	48.4	3.3	Yes	35.2	37.8	2.6	Yes
NR7 (Private Residence)	45.0	48.4	3.3	Yes	35.2	37.8	2.6	Yes

6.1.3.3 Mitigation Measures

Mitigation measures comprise any practical means taken to manage potential adverse effects, and may include applicable standards, guidelines, and best management practices (BMPs) supported by specific guidance documents. Mitigation measures to address potential adverse effects, discussed in **Section 6.1.3.2**, are described below and summarized in **Table 6.1-27.** The final column in the table identifies whether or not there is the potential for a residual effect.

In accordance with Alberta Transportation standard practice, BMPs and standard mitigation measures, including those outlined below to address potential effects to the Atmospheric Environment, would be included in the Environmental Construction Operations (ECO) Plan that would be developed by the contractor prior to the start of construction.

Fugitive Dust Management Measures

Best management practices would be followed to reduce fugitive dust emissions during the Construction phase. Best management practices relevant to the MC1 Option would include:

- Water would be applied to construction materials prior to bulldozing activities.
- Water would be applied to Highway 66 and site access roads during dry weather conditions when hauling activities are underway.
- Track-out of sediment and dirt from the construction site onto site access roads would be prevented. A wheel washing station would be made available to wash any sediment and dirt from haul truck tires prior to their entry onto the main site access roads. Any residual track-out would be cleaned regularly, at least once at the end of each day.
- A minimum freeboard of 7 cm would be maintained when loading haul trucks, and trucks would be covered with tarpaulin or other suitable cover where practical.
- Drills will be equipped with water tanks and rubber skirts.
- Water or polymer-based emulsions would be applied to stabilize soils prior to blasting. Water-filled ampoules would be used in the stemming to reduce dust dispersal.
- Construction activities such as bulldozing and material handling would be temporarily ceased or reduced to a minimal level during periods of high wind speeds (e.g. wind speeds greater than 36 kilometres per hour (km/h) or 10 metres per second (m/s)).

Regular Inspection of Vehicles and Equipment

All vehicles and equipment would be inspected regularly as per manufacturer recommendations. Any deficiencies would be corrected and worn parts replaced promptly to maintain vehicles and equipment in good working order.

This mitigation measure would reduce emissions of CACs, GHGs, and noise from vehicles and equipment used during the Construction phase as well as during the Operations and Maintenance phase.

Selection of Asphalt Plant

Emissions of CACs and GHGs would be considered when selecting a mobile asphalt plant for use during the Construction phase. The selected asphalt plant would meet or exceed the emission limits specified in Alberta's Code of Practice for Asphalt Paving Plants (AEP 2017). Emissions from the asphalt plant can be further reduced by following BMPs. Emissions of particulate matter would be minimized with the use of a baghouse and pre-collector. To minimize emissions of NO_X, SO_2, CO, and GHGs, the asphalt plant would be fuelled by natural gas or propane.

Manage Open Burning

Open burning practices would be managed to reduce impacts on air quality and climate change. At minimum, provincial and local open burning bylaws would be followed. The amount of material burned would be minimized by salvaging as much material as possible (e.g., for mulching, salvageable timber, firewood, biomass fuel, etc.) Vegetative material can also be chipped and used as cover material for site access roads and unused stockpiles. To minimize adverse effects on ambient concentrations, burning would only be conducted when the forecasted ventilation index is good. The ventilation index forecast for the Calgary region can be viewed on Environment Canada's website (Environment and Climate Change Canada 2017c).

Reduce Exposure to Elevated Ambient Concentrations of Criteria Air Contaminants

Exceedances of ambient air quality criteria may occur during the Construction phase at the proposed construction camp, McLean Creek Campground, Easter Seals Camp Horizon, and Paddy's Flat Campground. To reduce exposure to potential air quality effects the McLean Creek Campground, Easter Seals Camp Horizon, and Paddy's Flat Campground would need to be closed during the Construction phase. The proposed construction camp would also need to be relocated outside the aerial extent of exceedances of ambient air quality criteria (i.e., more than 0.6 km away from construction activities).

Clear Loose Sediment on Reservoir Banks

Wind erosion of reservoir banks may result in emissions and ambient concentrations of particulate matter during the MC1 Option's Operation and Maintenance phase. To reduce the potential for wind erosion, any loose sediment remaining on reservoir banks after a flood would be cleared or re-vegetated as soon as practicable.

Noise Management

Best management practices would be followed to reduce noise impacts during the Construction phase. Best management practices relevant to the MC1 Option include:

- Engines would be fitted with muffler systems to reduce noise emissions as deemed feasible.
- Noisy equipment would be attenuated with temporary noise barriers.
- Blasting would be limited to day-time hours and appropriate notice provided.
- HNR1 (McLean Creek Campground) and HNR4 (Gooseberry Campground) may be closed after 10:00 pm during the peak construction period or for day-use only, as predictions indicate sleep disturbance may occur. Alternatively, campground users should be notified of the potential sleep disturbance and to consent to being aware of this potential disturbance before nighttime use. The preliminary construction schedule suggests that each 1 km of roadway would have about one month of full activity therefore the mitigation measures would begin approximately 1 km before and end 1 km after HNR1 and HNR4,
- HNR3 (Paddy's Flat Campground) is exposed to road and bridge construction which would last longer than two months but less than one year. The receptor's close proximity to bridge construction and the additional noise sources (i.e., pile driving) does not allow for effective mitigation measures by design or scheduling and potential sleep disturbance at this location cannot be mitigated effectively. Use of the campground for nighttime accommodation should not be allowed (for day-use only) or the campground users should be notified for potential sleep disturbance to consent before nighttime use.

Table 6.1-27 presents a summary of the potential effects, mitigation measures and residual effects remaining after the application of mitigation measures.

Table 6.1-27 Summary of Potential Effects and Mitigation Measures for Atmospheric Environment

Summary of Potential Effect and Classification	MC1 Components	Contributing MC1 Activities	Proposed Mitigation Measure	Detectable / Measurable Residual Effect
Construction Phase				
Increased emissions and ambient concentrations of CACs	Flood storage reservoir Earth fill dam Borrow and spoil areas Highway 66 relocation Site clearing	Bulldozing of construction material Use of non-road construction equipment Transport of construction materials along Highway 66 and site access roads Operation of mobile asphalt plant Burning of debris generated from site clearing	Fugitive dust management measures Regular inspection of vehicles and equipment Selection of asphalt plant Manage open burning Reduce exposure to elevated ambient concentrations of CACs	Yes
Increased emissions of GHGs	Flood storage reservoir Earth fill dam Borrow and spoil areas Highway 66 relocation Site clearing	Use of non-road construction equipment Operation of mobile asphalt plant Burning of debris generated from site clearing	Regular inspection of vehicles and equipment Selection of asphalt plant Manage open burning	Yes
Increased noise levels	Flood storage reservoir Earth fill dam Borrow and spoil areas Highway 66 relocation	Excavation and construction activities Use of construction equipment and haul trucks Material movement and earth works Operation of temporary asphalt plant Operation of temporary concrete plant	Regular inspection of vehicles and equipment Noise management	Yes
Operation and Maintenance Phase				
Increased emissions and ambient concentrations of CACs	Flood storage reservoir	Use of non-road construction equipment Wind erosion of reservoir banks	Regular inspection of vehicles and equipment Clear loose sediment on reservoir banks	Yes
Increased emissions of GHGs	Flood storage reservoir	Use of non-road construction equipment Decay of organic matter in permanent pond	Regular inspection of vehicles and equipment	Yes
Increased noise levels	Flood storage reservoir	Use of construction equipment and haul trucks	Regular inspection of vehicles and equipment Install muffler system on engines	Yes

6.1.3.4 Residual Effects

Residual effects are MC1-related effects that are anticipated to occur after the application of mitigation measures. This section describes how the residual effects of the Option are characterized and summarized for Atmospheric Environment. The determination of a substantive or non-substantive residual effect includes a characterization including magnitude, regional extent, and duration.

Residual Effects Characteristics

Residual effects are characterized based on the criteria defined in **Table 6.1-28**. The effect characteristics are assessed in the context of the VCs identified for Atmospheric Environment.

Table 6.1-28 Residual Effects Characteristics for Atmospheric Environment

Residual Effect Characteristic	Rating	Definition
Direction	Positive	Net benefit to quality of Atmospheric Environment
	Adverse	Net loss to quality of Atmospheric Environment
Extent	Local	Confined to the area directly disturbed by Option facilities
	Sub-regional	Within the LAA
	Regional	Within the RAA
Magnitude	Negligible	No detectable change relative to existing conditions
	Minor	Air Quality and Noise: Detectable change relative to existing conditions but remains less than 50% of any relevant criteria Climate Change: GHG emissions are less than reporting threshold
	Moderate	Air Quality and Noise: More than 50% but meets all relevant criteria Climate Change: GHG emissions are greater than reporting threshold but less than 1% of provincial totals and less than 0.1% of federal totals.
	Major	Air Quality and Noise: Exceeds relevant criteria Climate Change: GHG emissions are greater than 1% of provincial totals or 0.1% of federal totals
Duration	Short-term	Does not extend beyond MC1 Construction
	Long-term	Effect lasts for the entire life of MC1 Option
Reversibility	Reversible	Effect can be reversed once the activity causing the residual effect ceases
	Not reversible	Effect is permanent
Frequency	Isolated	Effect would likely occur once
	Rare	Effect would be intermittent but not frequent (less than 50% of the time)
	Frequent	Effect would occur more than 50% of the time
Confidence	High	Rating predictions are based on a limited understanding of cause-effect relationships and/or relying on data from elsewhere; data are sourced from projects or activities with a high level of similarity with the MC1 Option

Residual Effect Characteristic	Rating	Definition
	Moderate	Rating predictions are based on a limited understanding of cause-effect relationships and/or relying on data from elsewhere; data are sourced from projects or activities with a moderate level of similarity with the MC1 Option
	Low	Rating predictions are based on a limited understanding of cause-effect relationships and/or relying on data from elsewhere; data are sourced from projects or activities with a low level of similarity with the MC1 Option

Increased Emissions and Ambient Concentrations of Criteria Air Contaminants

The residual effect characteristics ratings for the Air Quality VC is summarized in **Table 6.1-29**. MC1 Option activities would result in increased emissions and ambient concentrations of CACs and therefore the direction is adverse. Exceedances of relevant ambient air quality criteria may occur during the Construction phase; therefore, the magnitude is major. These air quality effects are expected to occur within the LAA, and would be reduced to minimal levels after the Construction phase is complete (i.e., during the Operation and Maintenance phase). Due to the lack of MC1-specific information and the reliance on information from the Site C Clean Energy Project EIS, a project with similar types of air emissions but located in an area with different geology and different meteorology, the confidence level is rated as moderate.

Residual effects to air quality resulting from increased emissions and ambient concentrations of CAC are predicted during MC1's Operations and Maintenance phase. However, if sensitive receptors at which residual effects may occur are closed and/or relocated, there would be limited exposure to residual effects and are therefore considered non-substantive.

Table 6.1-29 Summary of Effect Characteristics Ratings for Increased Emissions and Ambient Concentrations of Criteria Air Contaminants during Construction

Residual Effects Characteristic	Rating	Rationale for Rating
Direction	Adverse	Increased emissions and ambient concentrations of CACs
Extent	Local	Ambient concentrations of CACs are expected to decrease rapidly with distance and not extend beyond the LAA
Magnitude	Major	Potential exceedances of ambient air quality criteria
Duration	Short-term	Magnitude of effect is expected to be minor after MC1 Construction
Reversibility	Reversible	Ambient concentrations of CACs would return to existing levels after contributing activities cease
Frequency	Frequent	Effect would occur through MC1 Construction
Confidence	Moderate	Lack of MC1-specific information. Reliance on project with similar types of air emissions but located in area with different geology and different meteorology.

Increased Emissions of Greenhouse Gases

The residual effect characteristics ratings for the Climate and Climate Change VC during MC1 Construction is summarized in **Table 6.1-30**. MC1 activities would result in increased emissions of GHGs; therefore, the direction is adverse. Since total GHG emissions are greater than federal and provincial reporting thresholds, but expected to be small relative to existing provincial and national emissions, the magnitude is rated as moderate.

Effects on climate and climate change are long-term and regional in nature. Because of the moderate magnitude of emissions of GHGs, the residual effects of the Option on Climate and Climate Change are considered non-substantive. Since MC1-effects assessment relies on information from the Site C Clean Energy Project EIS, a project with similar types of GHG emissions, the confidence level is rated as high.

During the Operations and Maintenance phase GHG emissions would be minimal compared with those during the Construction phase. Thus, increased emissions of GHG during Operations and Maintenance are similarly assessed to be non-substantive.

Table 6.1-30 Summary of Effect Characteristics Ratings for Increased Emissions of Greenhouse Gases during Construction

Residual Effects Characteristic	Rating	Rationale for Rating
Direction	Negative	Increased emissions of GHGs
Extent	Regional	Nature of effect
Magnitude	Moderate	Greater than reporting threshold Small increase relative to existing provincial and national GHG emissions
Duration	Long-term	Nature of effect
Reversibility	Irreversible	Nature of effect
Frequency	Frequent	Effect would occur through MC1 construction
Confidence	High	Lack of MC1-specific information. Reliance on project with similar types of GHG emissions.

Increased Noise Levels

The residual effect characteristics ratings for the Noise VC during the Construction phase is summarized in **Table 6.1-31**. Option activities would result in increased noise levels in the LAA and RAA; therefore, the direction is adverse. Predicted noise levels are well below the Health Canada MNL for highway realignment, and the predicted change in percent annoyed is less than 6.5% for construction of the main (i.e. dam) site; therefore, the magnitude is rated as minor. The construction schedule indicates that construction would take place 24-hours a day, 7 days a week; however, mitigation measures would be implemented and the resultant sleep disturbance is negligible. Noise effects are only expected to occur within the LAA. Because of the low magnitude rating, the residual effects of MC1 on noise during construction are considered non-substantive. Since the MC1-effects assessment relies on information from other projects with similar types of noise emissions, the confidence level is rated high.

During the Operation and Maintenance phase noise effects would be limited as only service vehicles would be in operation. Thus, the effects of increased noise levels during Operations and Maintenance are similarly assessed to be non-substantive.

Table 6.1-31 Summary of Effect Characteristics Ratings for Increased Noise Levels during Construction

Residual Effects Characteristic	Rating	Rationale for Rating
Direction	Adverse	Increased noise levels
Extent	Local	Noise levels are expected to decrease rapidly with distance and not extend beyond the LAA
Magnitude	Minor	Predicted noise levels are well below the MNL
Duration	Short-term	Sources of noise are limited after the Construction phase
Reversibility	Reversible	Noise would return to existing levels after effect ceases
Frequency	Frequent	Effect would occur when Option construction activities are underway
Confidence	High	Lack of MC1-specific information. Reliance on projects with similar types of noise emissions.

6.1.3.5 Summary of Atmospheric Environment Assessment

Based on the determination of no substantive residual effects**,** it is concluded that there is no potential for a substantive residual effect(s) on Atmospheric Environment.

6.1.4 FOLLOW-UP MONITORING FOR ATMOSPHERIC ENVIRONMENT

Based on the information available at the time of writing, ambient concentrations of CACs at private residences in the LAA were predicted to be below ambient air quality criteria. However, the estimation of CAC concentrations does not consider effects of highway realignment activities or open-burning of wood debris generated from site clearing. These activities may result in elevated CAC concentrations beyond the aerial extents estimated in this assessment. Therefore, an air quality monitoring program would be developed to manage air quality during the Construction phase. One continuous monitor would be installed near the location of the sensitive receptor AQ7 to collect ambient concentrations of TSP and $PM_{2.5}$ for the duration of the Construction phase.

Meteorological conditions in the vicinity of the MC1 Option area during the Construction phase would be continuously monitored using a weather station connected to a data logger. Results of the monitoring program would provide forecasts that would be used to adjust MC1 construction activities for mitigation measures as necessary.

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6.2 TERRAIN AND SOILS

This section addresses potential MC1-related effects to the Terrain and Soils Valued Component (VC). For the purposes of this assessment, Terrain and Soils comprises surficial geology, topography, soil, as classified by the Canadian System of Soil Classification (Soil Classification Working Group 1998), and geohazards.

The assessments presented in this section are supported by or linked to the assessments presented in the following sections:

- Section 6.3 Hydrogeology
- Section 6.4 Fluvial Geomorphology
- Section 6.5 Water Quality
- Section 7.1 Vegetation and Wetlands
- Section 7.3 Aquatic Environment

6.2.1 SCOPE OF ASSESSMENT

This section reviews the scope of the assessment for Terrain and Soils, and includes the regulatory framework, data sources, measurable parameters, and assessment boundaries relevant for Terrain and Soils. The scope of this assessment relies on information compiled from the review of publicly available literature as well as past and new studies for the Elbow River at McLean Creek Dam (MC1) Option.

6.2.1.1 Regulatory Framework

This section provides an overview of the relevant regulatory framework and requirements for potential MC1-related effects to Terrain and Soils, as summarized in **Table 6.2-1**.

Table 6.2-1 Summary of Applicable Regulatory and Policy Framework for Terrain and Soil

Name	Jurisdiction	Description
Alberta *Soil Conservation Act*	Provincial	The *Soil Conservation Act* imposes a duty upon landholders to take appropriate measures to prevent soil loss or deterioration or to mitigate soil loss/deterioration where it has occurred.

6.2.1.2 Data Sources

Data sources for the assessment of Terrain and Soils include MC1-specific data, data collected for the Springbank Off-stream Reservoir (SR1) Project, government databases, as well as scientific literature such as journal publications and white papers. The following data sources have been reviewed:

- Preliminary Reservoir Terrain Assessment and Watershed Landslide Geohazard Inventory – Draft (BGC 2017)
- Environmental Overview of the Conceptual Elbow River Dam at McLean Creek (AMEC 2015)
- South Saskatchewan Regional Plan 2014-2024 (Alberta Government 2014)
- Surface Geology of Alberta Map 601 (Fenton et al. 2013)
- Natural Regions and Subregions of Alberta (Natural Regions Committee 2006)
- Soils groups of Alberta (Agriculture and Agri-Foods Canada 1995)
- Soil Series Information for Reclamation Planning in Alberta (Pedocan 1993a)
- Soil Series Information for Reclamation Planning in Alberta Volume 2 (Pedocan 1993b)
- Soil Quality Criteria Relative to Disturbance and Reclamation (Soil Quality Criteria Working Group et al. 1987).

Data limitations include the following:

- The assessment relies on a desktop assessment using previously completed studies; a soils and terrain-focused field program was not undertaken.
- Land capability classes are not available for the MC1 Option area. A spatial analysis of extent by land capability rating is not possible at this stage.

6.2.1.3 Valued Components

Terrain stability and soils may interact directly with MC1-related activities (e.g., clearing and grubbing, earthworks, flooding), and, when disturbed, may adversely affect other biophysical components (e.g., vegetation, wildlife, water (quality and quantity) (**Table 6.2-2)**. Information on contaminated sites within the MC1 Option area is included in **Section 3.5** and **Appendix 3 A and 3 B**.

Table 6.2-2 Valued Components for Terrain and Soils

Valued Components	Interaction
Terrain and Soils	MC1-related activities have the potential to change soil quality and quantity, slope stability and topography, as well as increase erosion and cause effects due to inundation and sediment deposition.

6.2.1.4 Measurable Parameters

Measurable parameters are quantitative or qualitative measures used to describe existing conditions and trends, and evaluate potential MC1-related effects on the VCs. The measurable parameters selected for the Terrain and Soils VC are shown in **Table 6.2-3**.

Table 6.2-3 Measurable Parameters for Terrain and Soils

Selected VC	Potential MC1-related Effects	Measurable Parameter
Terrain and Soils	Change in soil quantity	Area (ha) of surface disturbance during construction and operation by soil type
	Change in soil quality	Area (ha) reclaimed following construction
	Increased erosion risk	Area (ha) of exposed soil during construction and operation
	Change in topography	Area (ha) of borrow pits and dam during construction and operation
	Decrease in slope stability (change in geohazard)	Qualitative assessment for slope failure events based on geotechnical report (BGC 2017)
	Effects due to inundation and sediment deposition	Area (ha) that would have been flooded during the 2013 flood event

6.2.1.5 Assessment Boundaries

Spatial Boundaries

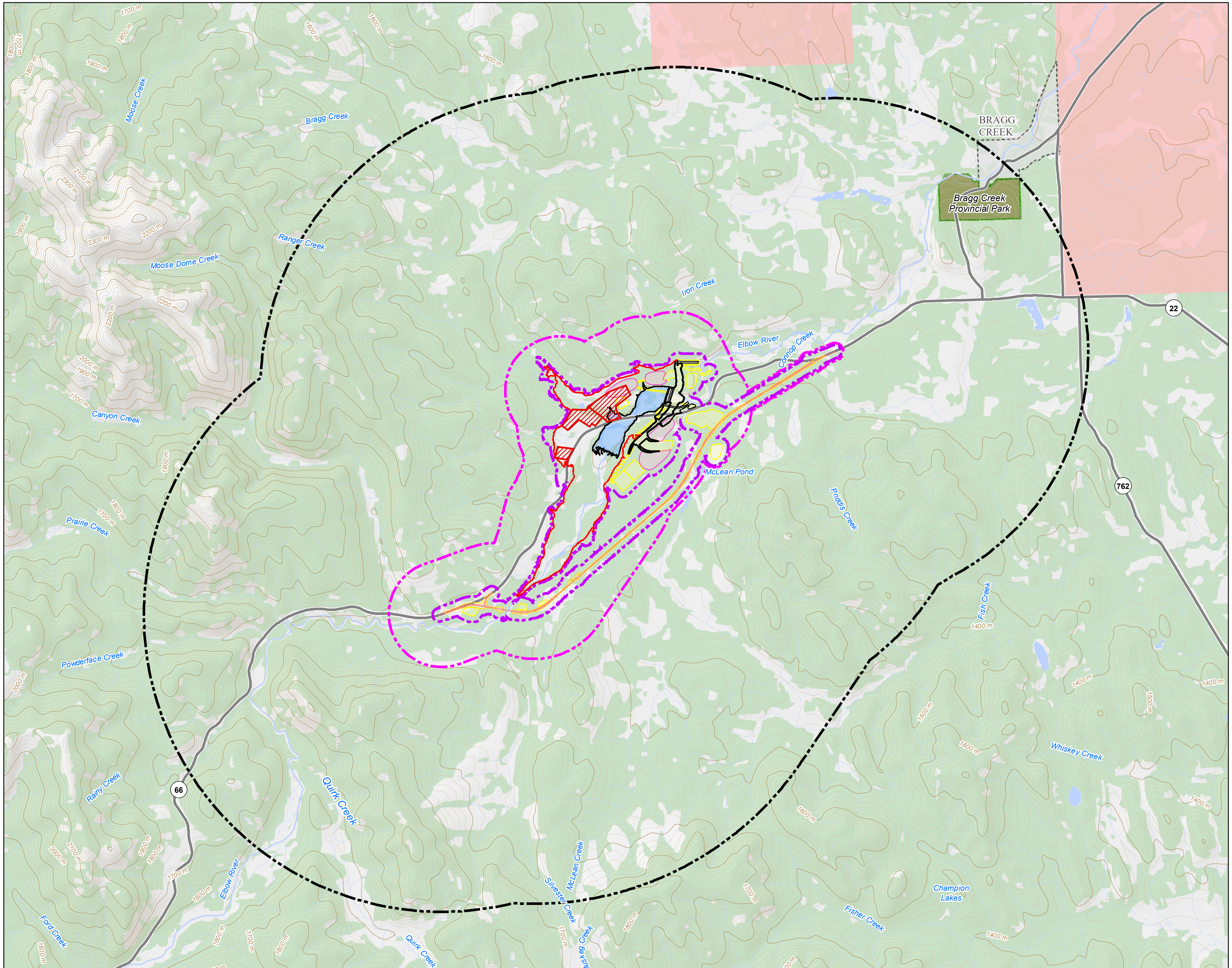
Spatial boundaries for the assessment of the Terrain and Soils VC are defined in **Table 6.2-4** and shown on **Figure 6.2-1**. The Local Assessment Area (LAA) encompasses the maximum geographical area where the Option would likely interact with, and potentially have a direct or indirect effect on Terrain and Soils. The Regional Assessment Area (RAA), which encompasses the LAA, is established to provide a regional context for the assessment of MC1-related effects. The RAA also encompasses the area where the residual effects of the Option would be likely to interact with the residual effects of other past, present or future projects or activities to result in a cumulative effect or effects. The MC1 Option area covers an area of 326 ha, the LAA covers an area of 2,665 ha, and the RAA covers an area of 23,430 ha.

Table 6.2-4 Spatial Boundary Definitions for Terrain and Soils Valued Component

Spatial Boundary	Description of Assessment Area
MC1 Option area	Area directly affected by the proposed works, related relocations and new constructions, a buffer area and the reservoir.
Local Assessment Area	Based on the AMEC 2015 study area and extended to include additional MC1 components (the highway realignment and one area) with a 100 m buffer.
Regional Assessment Area	The LAA plus a 5-km buffer (for a total buffer of approximately 6 km).

Elbow River at McLean Creek Dam (MC1)

Terrain and Soils Local Assessment Area and Regional Assessment Area



Legend

- MC1 Area
- Soils and Terrain Local Assessment Area
- Soils and Terrain Regional Assessment Area
- 2013 Flood Event (1424.1m)
- MC1 Dam
- Highway 66 Re-alignment
- Borrow Area
- Laydown Area/Disturbed Area
- Permanent Pond
- Existing Park Infrastructure to be Removed
- Major Contour (m)
- Minor Contour (m)
- Highway
- Reserve
- Provincial Park
- Watercourse
- Waterbody

Notes

1. All locations and features should be considered approximate and are to be used for discussion purposes only.
2. This map is not intended to be a "stand-alone" document, but a visual aid of the information contained within the referenced Report. It is intended to be used in conjunction with the scope of services and limitations described therein.

Sources

- Basedata: Government of Alberta, 2017
- Preferred Road Option and Disturbed Areas: Opus International Consultants Limited, 2017
- Dam Details: Hatch Ltd., 2017
- Inset Basemap: ESRI Topographic Basemap

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Alberta Transportation

Temporal Boundaries

The temporal boundaries of the Option consist of the Construction, and the Operation and Maintenance phases of the MC1 Option, which are described in **Section 3.0 Option Description**.

Temporal boundaries for the Terrain and Soils VC, within the Operation and Maintenance phase of the Option, include the periods of inundation that would occur during the peak spring flood risk period, which typically occurs in May and June. Duration of the inundation period would depend on flood volumes, but is anticipated to range between three days (1:20 year flood) to nine days (flood event equivalent to 2013 flood) (see **Section 3.0 Option Description**).

Administrative Boundaries

No administrative boundaries (e.g., political, economic, or social issues, as well as fiscal or other resourcing issues that may constrain the assessment of potential effects of the Option) were identified for the assessment of potential MC1-related effects on Terrain and Soils.

Technical Boundaries

Data compiled to support the Terrain and Soils assessment was based on a review of existing information, including mapping of soil units (AMEC 2015). These various data sources come with inherent technical limitations which form the basis of the technical boundaries for this assessment (e.g., completing field surveys in areas that are safely accessible). The identification of soil map units provides a level of detail necessary to support a high-level assessment of effects, as well as reclamation planning. Soil mapping was not conducted specifically for this Option; however, it was undertaken as part of the AMEC 2015 study. While the Option team has not ground-truthed the AMEC 2015 data, it is assumed that the AMEC 2015 data is sufficient to support the conclusions presented in this environmental assessment.

A soil survey intensity level (SIL) 2 is required for the MC1 Option area pursuant to Alberta guidance for full EIAs (AEP 2013). This EIA relies on a SIL 3 survey completed in the area by AMEC (2015). A SIL 2 would require an additional 100 soil inspection points, and at least one soil inspection in over 90 percent (%) of delineations; boundaries checked in the field along most of their length in open country, or less than 10% in woodland; and approximately 2 ha to 30 ha represented by each inspection.

The Terrain and Soils LAA was set to the AMEC 2015 study area (with minor modification to accommodate additional MC1 infrastructure) in order to provide meaningful information on soil mapping units and terrain units and is considered to be of an appropriate size to capture MC1-related effects on terrain and soils.

Such limitations have been offset using a conservative approach to the identification of potential effects. This approach, for the MC1 Option, involves the establishment of a 100-metre (m) buffer around proposed infrastructure, which provides an over-estimation of potential MC1-related effects.

6.2.2 BASELINE CASE

This section presents the Baseline Case for the RAA and LAA, using data compiled from the sources listed in **Section 6.2.1.2**. Information on the surficial geology and topography are presented, as well as the soil types and distribution, and a summary is provided of the wind and erosion risks for soils.

The Rocky Mountain Natural Region spans an elevation range from approximately 825 m to over 3,600 m (Natural Regions Committee 2006), and runs along the continental divide and is characterized by grasslands, shrubs and forest, and alpine areas above the treeline (Government of Alberta 2014). The MC1 Option area spans an elevation range from approximately 1,380 m to 1,428 m, and is located within the Montane Natural Subregion of the Rocky Mountain Natural Region, which is characterized by mountains and foothills separated by deep glacial valleys. Vegetation in the Montane Natural Subregion comprises a mix of grasslands and deciduous-coniferous forests on southern and western aspects, and primarily coniferous forests on northerly aspects and higher elevations (Natural Regions Committee 2006). Colluvial and morainal parent materials on mountain and hillslopes support lodgepole pine (*Pinus contorta*), Douglas-fir (*Pseudotsuga menziesii*), and trembling aspen (*Populus tremuloides*) (AMEC 2015).

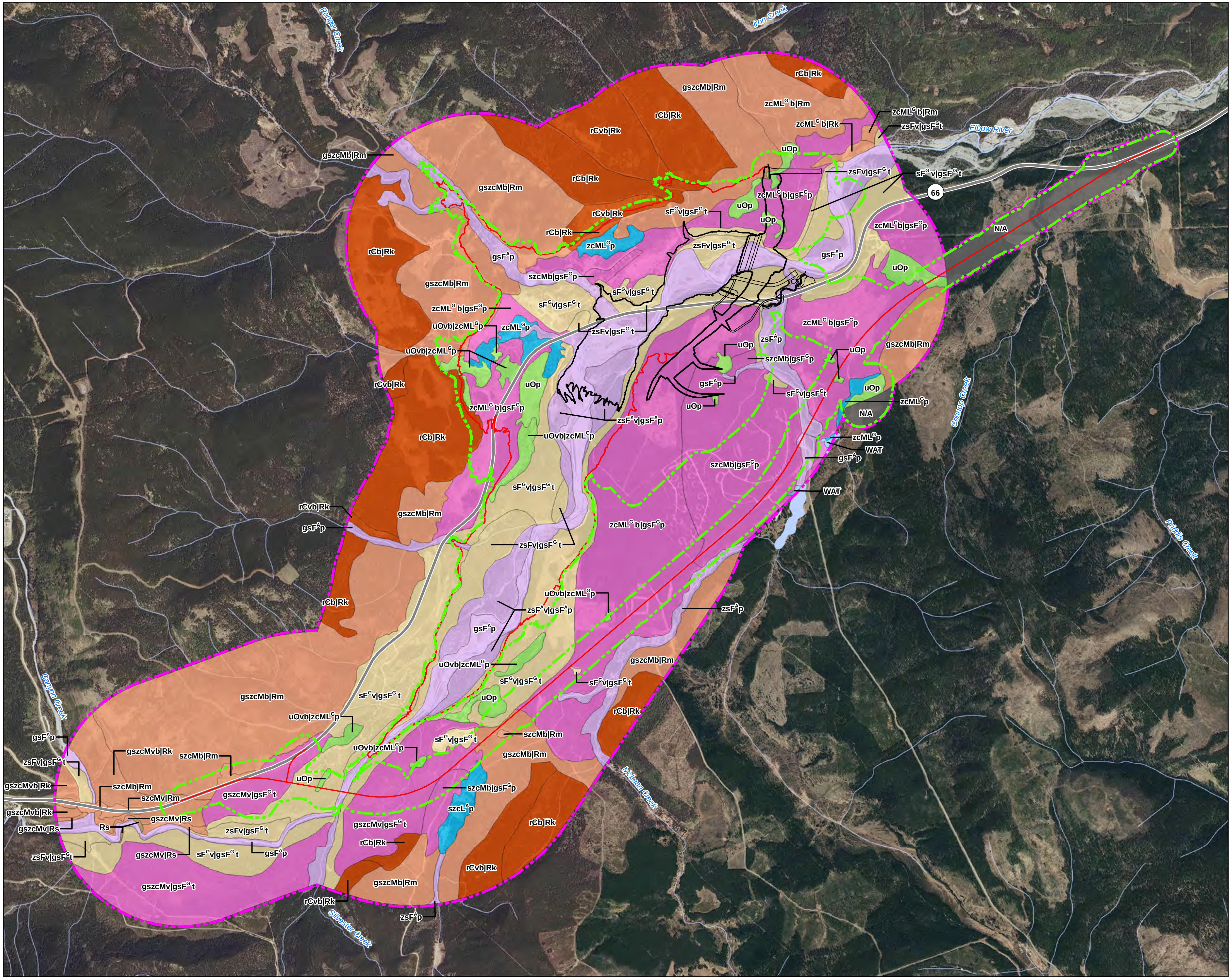
Within the MC1 Option area, previous disturbances, both anthropogenic and natural, are evident to varying extents. There are several parks facilities including the McLean Creek Campground and Station Flats. Natural disturbances include floods, most recently from the 2013 flood which removed Allen Bill Pond.

6.2.2.1 Surficial Geology and Terrain

Surficial materials in the Montane Natural Subregion are mainly medium textured, weakly calcareous tills; however, these deposits are quite thin in steeper areas, and textures tend to be variable (Natural Regions Committee 2006). The Montane Natural Subregion is underlain by Cretaceous and Tertiary sedimentary rocks, and, while bedrock exposures do occur, glacial till deposits, fluvial deposits along river valleys, and occasionally highly calcareous, wind-deposited materials are prevalent (Natural Regions Committee 2006). In major river valleys, where rivers have dissected the glacial till, fluvial and glaciofluvial sands and gravels form level to gently undulating terraces on valley bottoms; till and colluvial deposits of variable textures occur on lower slopes (Natural Regions Committee 2006). Valley slopes contain thin deposits of glacial till, and higher elevations are covered by a thin veneer of bedrock and till-derived soil and rock-creep colluvium above bedrock (AMEC 2015).

Within the RAA, the glacial till deposits have been dissected by the Elbow River and tributaries. The surficial geology is typical of the location; glacial and fluvial deposits are common. Generally, the recent fluvial deposits along the Elbow River are bounded by glaciofluvial terraces, in turn bounded by morainal and glaciolacustrine deposits over bedrock and glaciofluvial deposits. Higher elevations tend to be colluvium over bedrock. (Fenton et al. 2013).

Terrain units, which identify surficial materials, landforms and geomorphological process, were mapped for the LAA following the *Terrain Classification System for British Columbia* Version 2 (Howes and Kenk 1997; AMEC 2015) (**Figure 6.2-2)**. The distribution of the terrain units is summarized in **Table 6.2-5**. Areas that were not mapped by AMEC (2015) are not included in the table calculations. This includes an area of approximately 59 ha (2% of the LAA), which is mainly associated with the Highway 66 relocation and a small part of a borrow area south of the Highway 66 realignment (see **Figure 6.2-2)**. The majority of the LAA is mapped as morainal and glaciolacustrine veneers and blankets over glaciofluvial plains and terraces (22%), glaciofluvial (22%), and morainal and glaciolacustrine veneers and blankets over bedrock (26%). Colluvial deposits overlying bedrock are found in 14% of the LAA, and bedrock outcrops tend to occur on the steepest slopes where river incision has exposed rock faces. There are also areas of organic and lacustrine terrain units.



Elbow River at McLean Creek Dam (MC1)

Terrain Units

Legend

- MC1 Option Area
- Soils and Terrain Local Assessment Area
- MC1 Dam
- 2013 Flood Event (1424.1m)
- Highway 66 Re-alignment
- Highway
- Watercourse
- Waterbody

Terrain Units

- Not Classified
- Bedrock
- Fluvial
- Morainal and Glaciolacustine over Bedrock
- Morainal and Glaciolacustrine over Glaciofluvial
- Colluvium over Bedrock
- Glaciofluvial
- Glaciolacustine
- Organics
- Water

Notes

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2. This map is not intended to be a "stand-alone" document, but a visual aid of the information contained within the referenced Report. It is intended to be used in conjunction with the scope of services and limitations described therein.

Sources

- Basedata: Government of Alberta, 2017
- Preferred Road Option and Disturbed Areas: Opus International Consultants Limited, 2017
- Dam Details: Hatch Ltd., 2017
- Terrain Units: AMEC, 2014
- Aerial Imagery: SPOT 1.5 m, 2016

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Table 6.2-5 Landform Areas within the Local Assessment Area

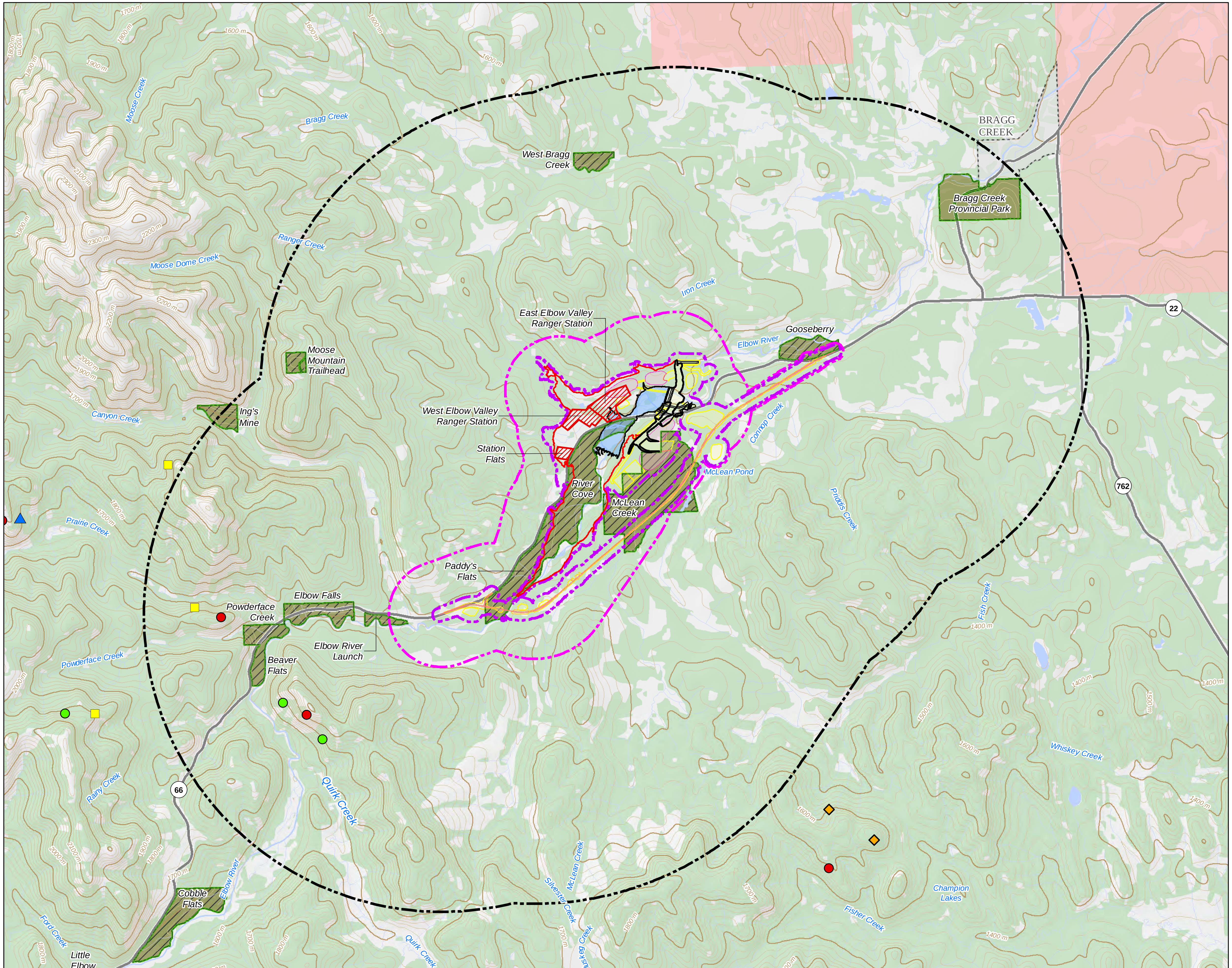
Terrain Label	Landform	ha	%
Organic Plains (Peatland)		**63.25**	**2.43**
uOp	fibric, mesic, humic organic plain	39.79	1.53
uOvb|zcMLGp	fibric, mesic, humic organic veneer/blanket over silty, clayey morainal + glaciolacustrine plain	23.46	0.9
Fluvial Plains		**294.639**	**11.30**
gsFAp	gravelly, sandy, fluvial (active) plain	195.97	7.52
zsFAp	silty, sandy, fluvial (active) plain	42.32	1.62
zsFAv|gsLAp	silty, sandy fluvial (active) veneer over gravelly, sandy, fluvial (active) plain	56.35	2.16
Glaciolacustrine and Lacustrine		32.95	1.26
zcMLGp	silty, clayey morainal + glaciolacustrine plain	22.46	0.86
szcLAp	sandy, silty, clayey, lacustrine (active) - plain (beaver ponds)	10.49	0.4
Morainal and Glaciolacustrine Veneers and Blankets over Glaciofluvial Plains and Terraces		**747.42**	**22.35**
gszcMv|sgFGt	gravelly, sandy, silty, clayey morainal blanket over sandy, gravelly, glaciofluvial terrace	164.74	6.32
zcMLGb|sgFGp	silty, clayey morainal + glaciolacustrine blanket over sandy, gravelly, glaciofluvial plain	449.3	17.23
szcMb|gsFGp	sandy, silty, clayey morainal blanket over gravelly, sandy glaciofluvial plain	133.38	5.12
Glaciofluvial Plains and Terraces		**582.68**	**22.35**
zsFv|sgFGt	silty, sandy fluvial veneer over sandy, gravelly, glaciofluvial terrace	73.35	2.81
sFGv|sgFGt	sandy, glaciofluvial veneer over gravelly, sandy glaciofluvial terrace	337.33	12.94
Colluvium over Bedrock		**371.68**	**14.26**
rCb|Rk	rubbly colluvial blanket over moderately steep bedrock	285.44	10.95
rCvb|Rk	rubbly colluvial veneer/blanket over moderately steep bedrock	86.24	3.31
Morainal and Glaciolacustrine Veneers and Blankets over Bedrock		685.07	26.28
gszcMb|Rm	gravelly, sandy, silty, clayey morainal blanket over rolling bedrock	584.46	22.42
gszcMvb|Rk	gravelly, sandy, silty, clayey morainal veneer/blanket over moderately steep bedrock	37.77	1.45
szcMb|Rm	sandy, silty, clayey morainal blanket over rolling bedrock	7.3	0.28
szcMv|Rm	sandy, silty, clayey morainal blanket over rolling bedrock	1.1	0.04
gszcMv|Rs	gravelly, sandy, silty clayey morainal veneer over steep bedrock	3.89	0.15
zcMLGb|Rm	silty, clayey morainal + glaciolacustrine blanket over moderately steep bedrock	46.94	1.8
zcMLGb|Rk	silty, clayey morainal + glaciolacustrine blanket over steep bedrock	3.6	0.14
Bedrock		**0.51**	**0.02**
Rs	steep bedrock	0.51	0.02
WAT	Open Water	0.7	0.03
	Totals	**2,606.89**	**100.00**

Source: AMEC 2015

6.2.2.2 Geohazards

A terrain stability assessment and an inventory of existing landslide geohazards was carried out for a study area including the area within the probable maximum flood (1,428 m above sea level) by BGC (2017). The scope of work in the report provides a preliminary assessment of geohazards, as it did not include field verification of previous terrain assessments, assessment of wave erosion impacts, or delineation of setback lines defining the estimated extent of shoreline erosion or landslide impact above a given reservoir shoreline elevation.

A desktop-level landslide inventory was prepared for the Elbow River Watershed upstream of the MC1 dam to characterize the number and distribution of landslide geohazards with the potential to disrupt the flow of the Elbow River or its tributaries (BGC 2017). The inventory identified rock avalanche/rock slides, deep seated gravitational slope deformation, and rock fall and rotational slide areas. No existing landslide geohazards were identified within the LAA. Within the RAA, there are several identified existing landslide geohazards. Of note is a large landslide south of the Beaver Flats campground, located approximately 12 km upstream of the MC1 dam (see **Figure 6.2-3**).



Elbow River at McLean Creek Dam (MC1)

Landslide Inventory in the Regional Assessment Area Upstream of the MC1 Dam

Legend

- MC1 Option Area
- Soils and Terrain Local Assessment Area
- Soils and Terrain Regional Assessment Area
- MC1 Dam
- 2013 Flood Event (1424.1m)
- Highway 66 Re-alignment
- Borrow Area
- Laydown Area/Disturbed Area
- Permanent Pond
- Existing Park Infrastructure to be Removed
- Major Contour (m)
- Minor Contour (m)
- Highway
- Reserve
- Provincial Recreational Area
- Provincial Park
- Watercourse
- Waterbody

Landslide Type

- DSGSD
- Rock Avalanche
- Rock Fall
- Rock Slide
- Rotational Slide

Notes

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2. This map is not intended to be a "stand-alone" document, but a visual aid of the information contained within the referenced Report. It is intended to be used in conjunction with the scope of services and limitations described therein.

Sources

- Basedata: Government of Alberta, 2017
- Preferred Road Option and Disturbed Areas: Opus International Consultants Limited, 2017
- Dam Details: Hatch Ltd., 2017
- Landslide Types: BGC Engineering Inc., 2017
- Inset Basemap: ESRI Topographic Basemap

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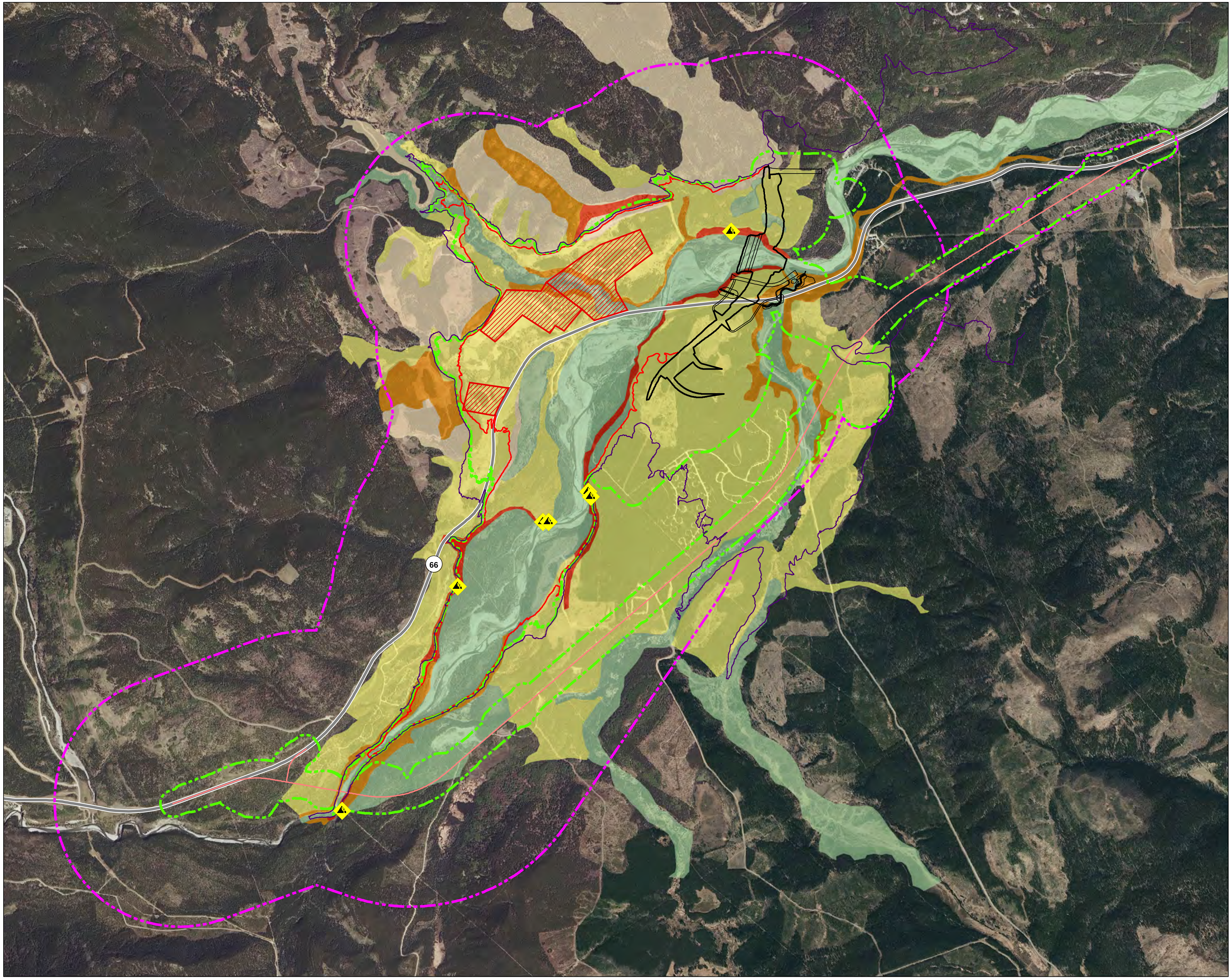
Slope stability ratings were determined based on terrain mapping, focussing on delineating those terrain features with slope stability concerns. Standard slope stability classes were adapted by BGC to consider hazards from flooding. Areas with a Class IV or V rating are considered to be relatively more sensitive to the effects of the reservoir impoundment than lower rated areas. The terrain stability class ratings developed by BGC are outlined in **Table 6.2-6** and the ratings are presented by terrain polygon in **Figure 6.2-4**.

Table 6.2-6 Terrain Stability Class

Class	Description
I	No significant stability problems exist.
II	There is a very low likelihood of landslides following reservoir filling or rapid drawdown. Minor slumping would be expected along reservoir shorelines, especially for 1 or 2 years following construction.
III	There is a low likelihood of landslide initiation following reservoir filling or rapid drawdown. Minor to moderate slumping would be expected along reservoir shorelines, especially for 1 or 2 years following construction.
IV	Expected to contain areas with a moderate likelihood of landslide initiation following reservoir filling or rapid drawdown. Wet season construction would increase the potential for construction-related landslides.
V	Expected to contain areas with a high likelihood of landslide initiation following reservoir filling or rapid drawdown. Wet season construction would increase the potential for construction related landslides.

Source: BGC 2017



Elbow River at McLean Creek Dam (MC1)

Terrain Stability

Legend

- MC1 Option Area
- Soils and Terrain Local Assessment Area
- MC1 Dam
- Highway 66 Re-alignment (Centreline)
- 2013 Flood Event (1424.1m)
- Highway
- Existing Park Infrastructure to be Removed
- Potential Landslide Location
- 1430 m asl Elevation Contour

Terrain Stability Class

- I
- II
- III
- IV
- V

Notes

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Sources

- Basedata: Government of Alberta, 2017
- Preferred Road Option and Disturbed Areas: Opus International Consultants Limited, 2017
- Dam Details: Hatch Ltd., 2017
- Terrain Stability and Landslide: Opus, 2017
- Aerial Imagery: SPOT 1.5 m, 2016

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6.2.2.3 Soils

Soil Classification and Distribution

Soil classification follows the Canadian system of soil classification (Soil Classification Working Group 1998), which has five taxonomic levels: order, great group, subgroup, family and series. A summary of the soil orders in the Canadian System is presented in **Table 6.2-7** (University of Saskatchewan, Dept of Soil Science undated). Mapping units present named soil series, which are defined by their classification, distinguishing soil horizons, and general location.

Table 6.2-7 Brief Description of the Soil Orders in the Canadian System of Soil Classification

Order	Diagnostic Horizon	Comments
Chernozemic	Ah, Ap, Ahe	A grassland soil whose diagnostic horizon is formed by high levels of organic matter additions from the roots of grasses.
Solonetzic	Bn or Bnt	A grassland soil with high sodium levels in the B horizon; usually associated with a clay-rich B horizon and often with saline C horizon material.
Podzolic	Bf or Bh	A forest soil normally associated with coniferous vegetation on igneous-rock derived parent materials. High acidity in the A horizon results in formation of a bleached Ae horizon and deposition of iron and aluminum in the B horizon.
Luvisolic	Bt	A forest soil found in areas with parent materials derived from sedimentary rocks. Dominant process is eluviation of clay from the Ae horizon and its deposition in the Bt horizon.
Brunisolic	Bm	A forest soil whose properties are not strongly enough developed to meet the criteria for the Luvisolic or Podzolic Orders.
Gleysolic	Bg, Cg	Found throughout Canada wherever temporary or permanent water saturation cause formation of gleyed features in the profile.
Regosolic	No B horizon	Found throughout Canada wherever pedogenic conditions prevent the formation of B horizons (unstable slopes, sand dunes, floodplains etc.).
Vertisolic	Bss, or Css and Bv	Associated with high clay glacio-lacustrine landscapes; characterized by shrinking and swelling of clays.
Cryosolic	By, Cy, Cz	A soil of arctic and tundra regions; characterized by presence of permafrost.
Organic	O horizon	Organic soils are associated with the accumulation of organic materials (peat) in water-saturated conditions. They are most commonly associated with Boreal Forest soils.

Source: Soils of Canada. (http://www.soilsofcanada.ca/)

In the foothills and outlying Montane areas of southern and southwestern Alberta, Orthic Black Chernozems are typical under grasslands with Orthic Dark Gray Chernozems becoming dominant in the wooded areas (Natural Regions Committee 2006). On moister northern slopes and higher elevations, Gray Luvisols become more dominant. Bedrock exposures (non-soils) also occur (Natural Regions Committee 2006).

In the valleys, Eutric Brunisols are the dominant soil on fluvial and glaciofluvial deposits (Natural Regions Committee 2006). Regosols are typical of both active fluvial terraces adjacent to the rivers, and side slopes where erosion or slope movement has recently occurred (Natural Regions Committee 2006). Valley side soils may also include Luvisols and Dystric Brunisols where slopes are stable enough to allow soil development to occur (Natural Regions Committee 2006). Gleysols and Organic soils are typically associated with fens (Natural Regions Committee 2006).

The dominant soil orders found in the RAA are Luvisols, Brunisols, and Chernozems (Agriculture and Agri-Food Canada 1995). Within the LAA, the dominant soil orders are Brunisols, Luvisols, and Regosols (described below), with fewer areas of Gleysols and Organic soils. The soil polygons within the LAA were mapped by AMEC in 2015, and reproduced for this EIA report (see **Figure 6.2-2)**. Areas that were not mapped by AMEC are not included in the descriptions.

Luvisols

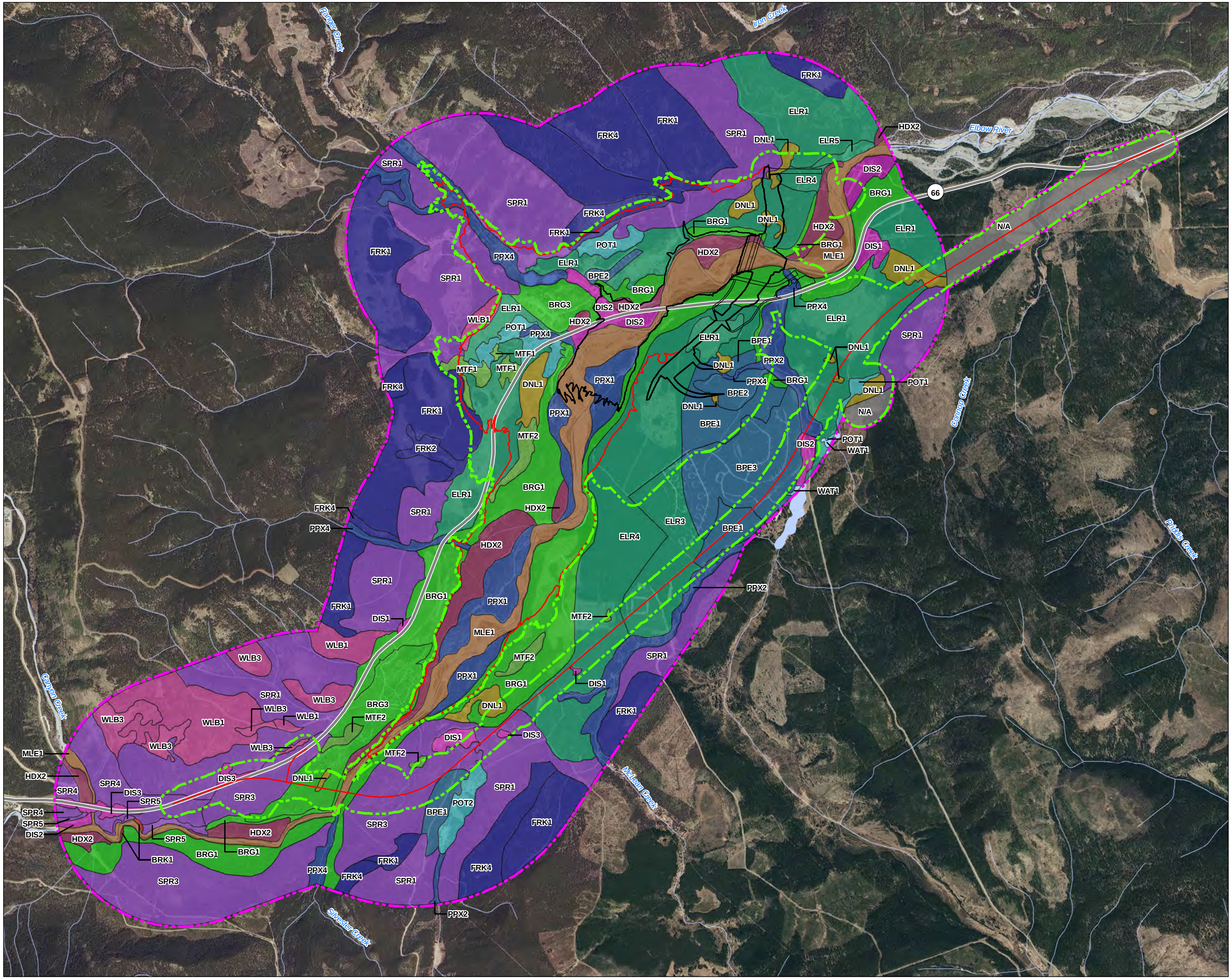
The Luvisols, usually Gray Luvisols in the LAA, are well-drained soils primarily composed of mineral particles, with an intermediate available water storage capacity (4 cm to 5 cm) (Agriculture and Agri-Food Canada 2013). The parent materials are till and glaciolacustrine deposits. Luvisols are dominant in the area between steeper slopes (colluvium-dominated) and the floodplains and glaciofluvial terraces (AMEC 2015).

Brunisols

Brunisols are well-drained mineral soils primarily composed of mineral particles, with an intermediate available water storage capacity (4 cm to 5 cm) (Agriculture and Agri-Food Canada 2013). The Eutric and Dystric Brunisols in the assessment area are variably-textured with minimal soil profile development (AMEC 2015). The parent materials for these soils are generally stratified glaciofluvial deposits (Agriculture and Agri-Food Canada 2013).

Regosols

Regosols are formed on very rapidly drained coarse textured soils with a high percentage of coarse fragments on colluvial deposits, and in active floodplains disturbed by periodic flooding (AMEC 2015).



Elbow River at McLean Creek Dam (MC1)

Soil Units

Legend

- MC1 Option Area
- Soils and Terrain Local Assessment Area
- MC1 Dam
- Highway 66 Re-alignment (Centreline)
- 2013 Flood Event (1424.1m)
- Highway
- Watercourse
- Waterbody

Soil Unit

- BPE1; BPE2; BPE3
- BRG1; BRG3
- BRK1
- DIS1; DIS2; DIS3
- DNL1
- ELR1; ELR3; ELR4; ELR5
- FRK1; FRK2; FRK4
- HDX2
- MLE1
- MTF1; MTF2
- N/A (not classified)
- POT1; POT2
- PPX1; PPX2; PPX4
- SPR1; SPR3; SPR4; SPR5
- WAT1
- WLB1; WLB3

Notes

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Sources

- Basedata: Government of Alberta, 2017
- Preferred Road Option and Disturbed Areas: Opus International Consultants Limited, 2017
- Dam Details: Hatch Ltd., 2017
- Soil Units: AMEC, 2014
- Aerial Imagery: SPOT 1.5 m, 2016

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Soil Series in the MC1 Option area

Based on information presented AMEC 2015 (as shown on **Figure 6.2-5),** the following soil series are located within the MC1 Option area.

- MLE – McLean Creek soils are Orthic Regosols formed on very gravelly, very coarse fluvial parent material. Within the MC1 Option area, these soils are mapped at the bottom of the Elbow River valley.
- BRG – Bragg Creek soils are Dystric Brunisols formed on gravelly – moderately fine to moderately coarse glaciofluvial deposits on level terraces that are often steeply incised by the Elbow River and its tributaries.
- ELR – Elbow (ELB) and Robinson (RNS) soils are Gray Luvisols, mapped together as Elbow Robinson (ELR). ELB has glaciolacustrine parent material while RNS has morainal till; this lacustrotill is often mixed together. This Luvisolic soil is formed on fine to moderately fine deposits on level topography to gentle slopes, well to imperfectly drained.
- PPX – Pipestone soils are Cumulic Regosols or Gleyed Cumulic Regosols.
- HDX – Hillsdale soils are Orthic Regosols on moderately coarse fluvial over gravelly to moderately coarse glaciofluvial.
- DNL – Darnel soils are Organic soils composed primarily of organic materials at various stages of decomposition; classified as DNL when peat thickness is greater than 160 cm.
- POT – Pothole Creek soils are Humic and Luvic Gleysols that generally form on fine to moderately fine glaciolacustrine soils.
- MTF – Mitford soils are Organic soils composed primarily of organic materials at various stages of decomposition; classified as MTF when peat thickness is less than 160 cm; overlie glaciolacustrine, glaciofluvial, or morainal till materials.
- WLB – Willoughby soils are Dystric Brunisols formed on gravelly, medium-textured glaciofluvial deposits on gentle to moderately steep slopes; sometimes occur as a veneer of blanket over glaciofluvial deposits due to soil creep.
- SPR – Spruce Ridge soils are Gray Luvisols formed on gravelly, moderately fine-textured morainal till deposits on gentle to moderately steep slopes; sometimes occur as veneer of blanket over glaciofluvial deposits due to soil creep.
- FRK – Frank soils are Eutric Brunisols formed on very gravelly, medium-textured colluvium; occur on moderately steep to very steep slopes or at the base of moderately steep to very steep slopes, and are generally well to rapidly drained.
- BPE – Beaupre soils are Dystric Brunisols formed on fine to moderately coarse morainal till, and are general well to moderately well drained.
- BRK – Bedrock
- DIS – Disturbed

Reclamation Information

Soil reclamation assessments have been developed for soil correlation areas in Alberta. The soil correlation area (SCA) is a concept developed in Alberta to provide a framework for differentiating and naming soil series across the province (CAESA SIP 1998). An SCA is a geographic entity having an appropriately limited range of climatic parameters that restrict the use of a soil series name (Brierley et al. 2006). It is used to identify areas of similar soil climate and landscape ecology, thereby facilitating standardization and correlation of soil mapping procedures, development of soil maps, and interpretations regarding soil uses. Soils information for the MC1 Option area was correlated to existing soil series names in SCA 16 based on parent material type, soil subgroup, and topographic features as outlined in the Alberta Soil Names File, Generation 3 (Alberta Soil Information Centre 2016).

Soil reclamation issues in SCA 16 include the following:

- Frequent Chinook winds cause droughtiness (less capability to supply water to a crop or other cover).
- Potential soil erosion by wind is high on disturbed sites.
- Potential soil erosion by water is high because slopes are often steep and long.
- Short growing season occurs due to late spring and early fall frost.
- Frost action in soil at exposed sites can increase the risk of erosion (Pedocan 1993b).

Erosion-sensitive Soils

Soil erosion risk ratings for wind and water were assigned and mapped by soil series, with reference to the topographical expression (water erosion) and soil texture (wind erosion) of the mapped soils (AMEC 2015). Erosion sensitive soils are presented in **Table 6.2-8**, **Figure 6.2-6**, and **Figure 6.2-7**. Areas that were not mapped by AMEC (2015) are not included in the descriptions.

Table 6.2-8 Soil Series and Wind and Water Erosion Risk

Soil Series Code	Soil Series Name	Wind Erosion	Water Erosion Risk		
			< 5% Slope	5-9% Slope	> 9% Slope
BPE	Beaupre	Moderate	Low	Moderate	High
BPEgl	Beaupre-GL	Moderate	Low	Moderate	High
DNL	Darnell	N/A	N/A	N/A	N/A
ELB	Elbow	Low	Low	Moderate	High
FRK	Frank	Moderate	Moderate	High	High
FRKgl	Frank-GL	Moderate	Moderate	High	High
FRKzz	Frank-ZZ	Moderate	Moderate	High	High
HDX	Hillsdale	Moderate	Moderate	High	High

Soil Series Code	Soil Series Name	Wind Erosion	Water Erosion Risk		
			< 5% Slope	5-9% Slope	> 9% Slope
MLE	McLean Creek	High	Moderate	High	High
MTF	Mitford	N/A	N/A	N/A	N/A
POT	Pothole Creek	Low	Low	Moderate	High
PPX	Pipestone	Low	Low	Moderate	High
PPXgl	Pipestone-GL	Low	Low	Moderate	High
PPXgr	Pipestone-GR	Low	Low	Moderate	High
SPR	Spruce Ridge	Moderate	Moderate	Moderate	High
SPRxg	Spruce Ridge-XG	Moderate	Moderate	Moderate	High
SPRxl	Spruce Ridge-XL	Moderate	Moderate	Moderate	High
RNS	Robinson	Low	Low	Moderate	High
WLB	Willoughby	Moderate	Moderate	Moderate	High
WLBzz2	Willoughby-ZZ	Moderate	Moderate	Moderate	High

Source: AMEC 2015

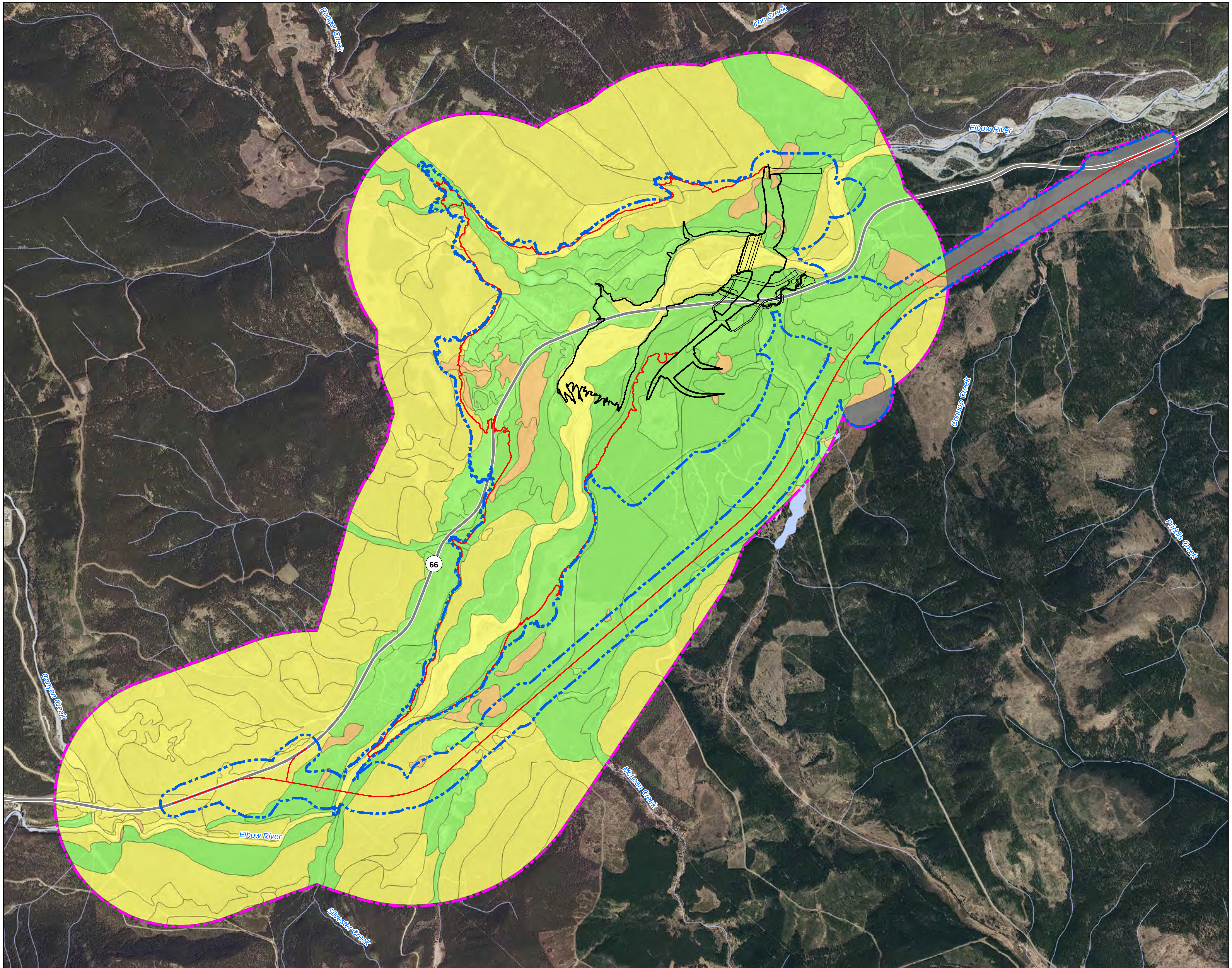
Generally, mineral soils having a loamy to clay soil texture (BPE, FRK, HDX, and SPR) have a moderate risk of wind erosion. The MLE soil series, on active fluvial deposits that are often unvegetated, has a coarse textured (sand) surface layer, and is ranked as having a high wind erosion risk.

Organic soils (DNL and MTF) are generally rated as having negligible wind and water erosion risk due to their level topography and moist condition, unless the soil face (at an excavation) is exposed or dried. Gleysolic soil units (POT) are rated as having a low risk to erosion due to their organic surface layer, level topography, and clayey subsoil.

In all cases, slope gradient affects the potential for water erosion in the LAA. Most of the mineral soils are found on level to undulating terrain with moderate to gentle slopes (< 9%) in the Elbow River Valley. Areas with steep slopes (> 9%) and high water erosion potential occur further from the river or in the south portion of the LAA where the river and its tributaries are more incised and the valley walls are steeper. Steep slopes have a relatively small spatial extent.

Elbow River at McLean Creek Dam (MC1)

Soil Water Erosion Risk



Legend

- MC1 Option Area
- Soils and Terrain Local Assessment Area
- MC1 Dam
- Highway 66 Re-alignment
- 2013 Flood Event (1424.1m)
- Highway
- Watercourse
- Waterbody

Water Erosion Risk

- Moderate
- Low
- NA
- Not Classified

Notes

1. All locations and features should be considered approximate and are to be used for discussion purposes only.
2. This map is not intended to be a "stand-alone" document, but a visual aid of the information contained within the referenced Report. It is intended to be used in conjunction with the scope of services and limitations described therein.

Sources

- Basedata: Government of Alberta, 2017
- Preferred Road Option and Disturbed Areas: Opus International Consultants Limited, 2017
- Dam Details: Hatch Ltd., 2017
- Soil Water Erosion Risk: AMEC, 2014
- Aerial Imagery: SPOT 1.5 m, 2016

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2025-001.01	Production Date: Sep 15, 2017	Figure 6.2-6

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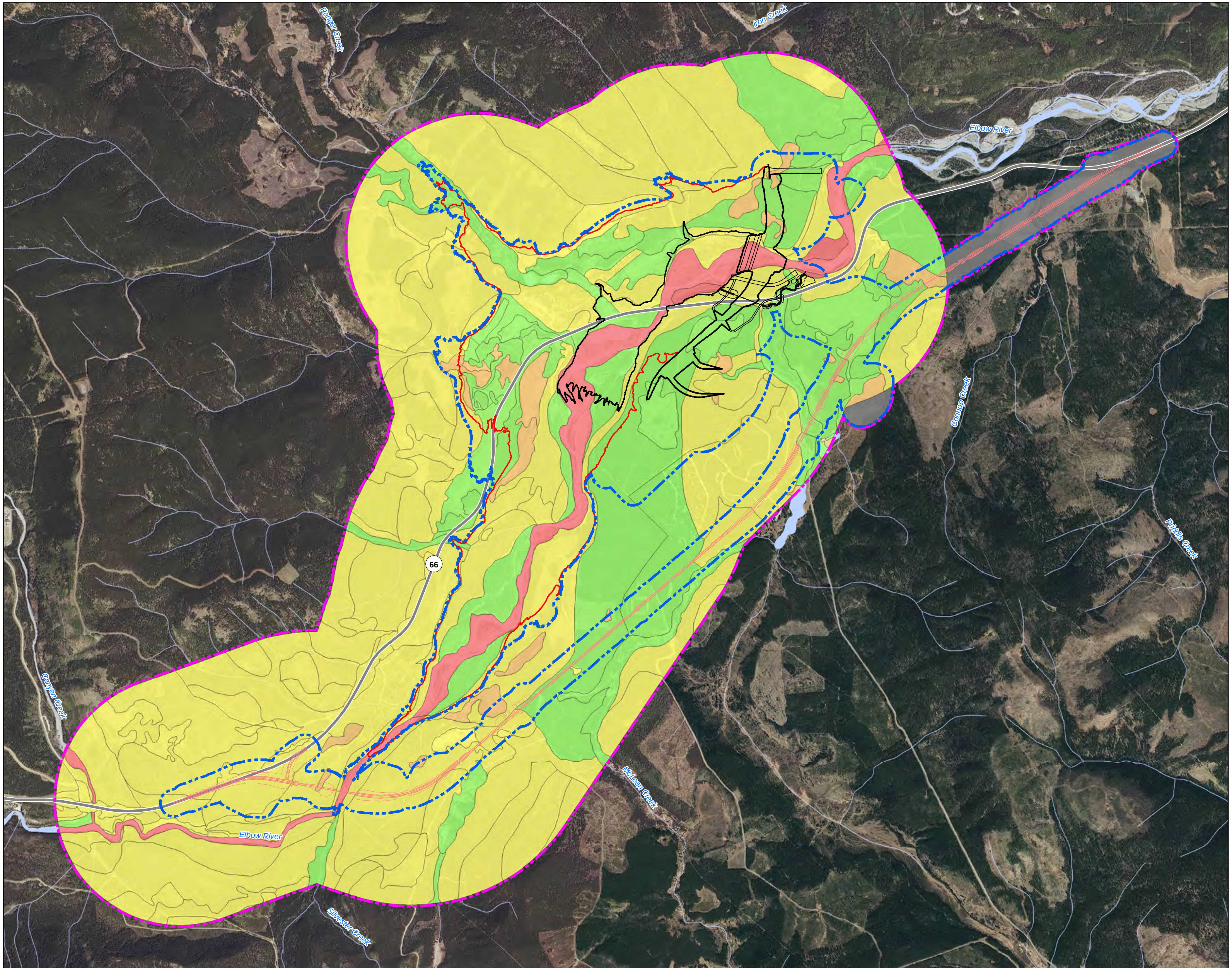

Elbow River at McLean Creek Dam (MC1)

Soil Wind Erosion Risk

Legend

- MC1 Option Area
- Soils and Terrain Local Assessment Area
- MC1 Dam
- 2013 Flood Event (1424.1m)
- Highway 66 Re-alignment
- Highway
- Watercourse
- Waterbody

Wind Erosion Risk

- High
- Moderate
- Low
- NA
- Not Classified

Notes

1. All locations and features should be considered approximate and are to be used for discussion purposes only.
2. This map is not intended to be a "stand-alone" document, but a visual aid of the information contained within the referenced Report. It is intended to be used in conjunction with the scope of services and limitations described therein.

Sources

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- Soil Wind Erosion Risk: AMEC, 2014
- Aerial Imagery: SPOT 1.5 m, 2016

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2025-001.01	Production Date: Sep 15, 2017	Figure 6.2-7

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6.2.3 APPLICATION CASE

The Application Case describes the effects of the MC1 Option added to Baseline Case (i.e., assesses the MC1-related effects). The following sections present the potential MC1-related interactions, effects, and mitigation measures, along with an assessment of residual effects.

6.2.3.1 Potential Option Interactions

Potential MC1-related interactions with Terrain and Soils and potential effects from each interaction are presented in **Table 6.2-9**.

Table 6.2-9 Identification of Potential Option Interactions with Terrain and Soils

Phase	Activity	Terrain and Soil	
		Interaction	Potential Effect
Construction	Clearing	X	Increased erosion risk
	Road construction	X	Increased erosion risk
			Change in soil quantity
	Decommissioning and removal of existing parks infrastructure and ranger station	X	Change in soil quantity
			Change in soil quality
			Increased erosion risk
	Dam (cofferdam and earth fill) construction	X	Change in soil quantity
			Change in soil quality
			Increased erosion risk
			Change in topography
	Spillway construction	X	Change in soil quantity
			Change in soil quality
			Increased erosion risk
	Rock groin and diversion tunnels construction	X	Change in soil quantity
			Increased erosion risk
	Laydown areas construction and use	X	Change in soil quality
	Stockpile development and use	X	Change in soil quality
			Increased erosion risk
	Borrow and spoil areas development and use	X	Change in soil quantity
			Change in soil quality
			Increased erosion risk
			Change in topography
	Realignment of McLean Creek and other small waterbodies	X	Change in soil quantity

Phase	Activity	Terrain and Soil	
		Interaction	Potential Effect
	Realignment of Highway 66	X	Change in soil quality
			Change in soil quantity
	Storage of water in permanent pond	X	Change in soil quantity
			Increased erosion risk
	Reclamation	X	Change in soil quality
			Increased erosion risk
Operation and Maintenance	Routine and flood operation and maintenance	X	Increased erosion risk
			Decrease in slope stability
			Effects due to inundation and sediment deposition

Note: X – potential interaction

6.2.3.2 Potential MC1-related Effects

This section considers potential adverse MC1-related effects on the Terrain and Soil VC arising from potential interactions with Option activities, as identified in **Table 6.2-9**, and in relation to the measurable parameters listed in **Table 6.2-2**. Mitigation measures for each potential effect are described in **Section 6.2.3.3**.

Anticipated adverse effects to terrain and soils are based on the spatial extent of the Option construction and operation footprints (**Figure 6.2-1**). The MC1 footprint has been buffered by 100 m around the embankment, borrow and spoil areas, spillways and outlet works, and areas of road construction and the highway realignment location, thus producing a conservative estimate of the overall disturbance. The buffer area is inclusive of temporary disturbances including soil stockpiles, haul roads add work zones.

Change in Soil Quantity

A change in soil quantity, measured by the spatial extent of disturbed areas, would occur during construction or realignment of infrastructure; i.e., roads, Highway 66, earth fill dam, spillways, diversion tunnels, borrow and spoil development and use, and water storage in the permanent pond. The decommissioning of parks infrastructure is also included. Changes to soil quantity would occur with direct disturbance of the ground, either removal of soil (e.g., borrow areas), or covering of the ground (e.g., roads, permanent pond). The estimated areas of disturbance are calculated in **Table 6.2-10**.

Table 6.2-10 Elbow River at McLean Creek Dam Option Soil Disturbance Areas

Soil Group	Dominant Soil Series	Disturbance Type (ha)	
		Permanent	Temporary
Brunisol	BPE	14.7	18.9
	BRG	15.5	20.8
	WLB	-	0.6
Luvisol	ELR	31.6	84.2
	SPR	13.4	16.6
Regosol	HDX	11.5	1.7
	MLE	42.2	0.7
	PPX	12.5	0.9
Organic	DNL	3.7	7.3
Gleysol	POT	-	8.3
Unknown	Unknown (unmapped)	7.5	1.7
N/A	N/A - Disturbed	8.4	3.1
Total		**161**	**165**

The temporary or permanent disturbance or removal of soil associated with the MC1 footprint would only occur during the Construction phase, and is considered an adverse MC1-related effect. Approximately 165 ha of soil (51% of the MC1 Option area) would be temporarily disturbed (e.g., borrow areas) during Construction. The depth of soil disturbance is dependent upon the Option component. For example, up to 19.7 m of clay-rich till on the bench west of McLean Creek (BGC 2016), considered for borrow areas for construction of the earth fill dam, may be excavated. An estimated 161 ha covered by permanent infrastructure (e.g., permanent pond, earth fill dam) represents a permanent reduction in soil quantity; 8.4 ha of this area is already disturbed, which indicates that the quantity of soil that would be permanently disturbed is approximately 153 ha, or 47% of the MC1 Option area and approximately 6% of the total area of the LAA.

Change in Soil Quality

Changes in soil quality may occur where in situ soils are likely to be disturbed by Option activities, but would remain or be reclaimed following construction activities (e.g., use of laydown areas). Soil quality may also change indirectly through proximity to construction or excavation areas (e.g., activities that generate dust). Soils that would be salvaged and stockpiled for reclamation are included, as the properties of stockpiled soils can change depending on handling and stockpile methods, and would therefore affect the soil quality of the area in which they are laid during reclamation. Other potential effects on the Terrain and Soils VC due to inundation in a flood event are discussed as a separate effect (see **Effects Due to Inundation and Sediment Deposition**).

The areas that would be reclaimed, and therefore may experience a change in soil quality following construction, are calculated in **Table 6.2-11**. The areal extent that would be reclaimed is the representative measurable parameter for potential disturbance effects due to admixing (mixing of soil horizons), rutting, compaction, increased surface stoniness, and loss of structure, and is estimated to be to 165 ha.

Table 6.2-11 Elbow River at McLean Creek Dam Option Soil Reclamation Areas

Option Component	Reclamation Area (ha)
Laydown Areas	18.0
Temporary Haul Roads	11.1
Miscellaneous (e.g., spoil areas, stockpiles)	45.4
Borrow Areas	52.9
Elbow Valley Ranger Station	37.5
Total	165

The change in soil quality would occur during the Construction phase and the Operation and Maintenance phase, and is considered an adverse MC1-related effect.

Increased Erosion Risk

Soil disturbance may also increase the potential for erosion, particularly if soils remain exposed for longer periods of time following vegetation removal, and are subject to high winds or rainfall or snow melt events. Erosion can result in the loss of soils (sediment) that mobilize into the receiving environment. The potential for increased erosion risk would occur from clearing and earth-moving activities and shoreline wave action. MC1 interactions that may contribute to this include all site clearing activities in the MC1 footprint during the Construction phase, including site clearing, road construction, dam construction, spillway construction, diversion tunnels construction, borrow and spoil area development and use, and the permanent pond construction (until filled), approximately 326 ha. The increased erosion risk may occur during both the Construction and Operation and Maintenance phases.

The risk to wind and water erosion in the LAA is interpreted to increase with increasing slope steepness (water) and exposure of soil faces (wind and water), as identified in the ratings for erosion-sensitive soils (**Table 6.2-8**) and shown in **Figure 6.2-6** and **Figure 6.2-7**. The majority of the soils in the vicinity of the MC1 dam are at either low or moderate risk of water erosion (i.e., less than 5% slope, or 5% to 9% slope, respectively), and low, moderate, or high risk of wind erosion. Approximately 56 ha (17%) of the MC1 footprint has a high water erosion risk rating, and approximately 43 ha (13%) has a high wind erosion risk rating.

Potential erosion effects during the MC1 Option's Operation and Maintenance phase would be associated with maintenance activities, such as culvert maintenance and fluctuations in water levels, both in the permanent pond and during flood events. During routine operation, the rate of inflow would balance outflow in the permanent pond, thus maintaining a stable water volume and a stable surface elevation with little variation. Under these conditions, erosion of the shoreline would likely be minor. The potential for erosion from wave action on the shoreline-water interface of the permanent pond is considered in terms of increased turbidity in **Section 6.5 Water Quality**. Effects due to flood events are considered separately below for effects to soil from inundation.

Change in Topography

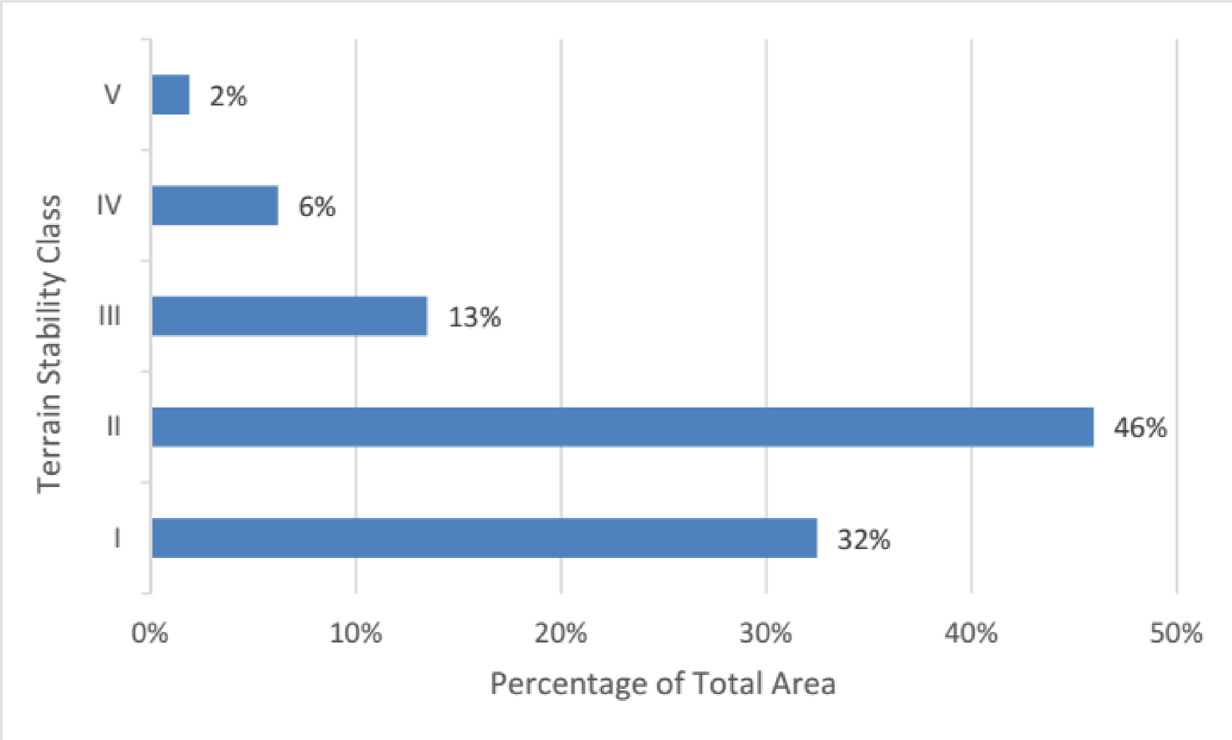
A change in topography during the Construction Phase would occur in areas of substantial earth-moving activities (i.e., four borrow areas and the MC1 dam). A change in topography is a pathway effect that may result in additional changes to the local environment (e.g., a change in the vegetation species that are able to grow following reclamation, or a change in visual quality, compared to the Baseline Case).

The greatest extent of change in topography is anticipated to occur in borrow areas and the MC1 dam. The volume of material would be excavated from borrow areas may be up to 4,250,000 m^3 (Borrow Areas #3). The total length of the main dam would be approximately 2,400 m and would be a height of 50 m, which represents a considerable increase in elevation. The areal extent of the borrow areas and MC1 dam footprint is approximately 54 ha, or 2% of the LAA.

Decrease in Slope Stability

Potentially unstable slopes located within or at the edge of the reservoir may be destabilized by changes in groundwater gradients caused by impoundment of water in the reservoir. Types of instability may include shoreline erosion (above the permanent pond water level) and regression, and landslides. The potential for a decrease in slope stability within the reservoir and upstream of the MC1 Option was reviewed by BGC (2017) and is summarized in this section.

About 8% of the reservoir was mapped as having a moderate or high likelihood of landslide initiation following reservoir filling or rapid drawdown (terrain stability classes IV or V) (**Figure 6.2-8**). The scarp slope on both sides of the Elbow River floodplain is up to 30 m high and was interpreted as being composed of colluvium or glaciofluvial material with a terrain stability Class of IV or V, or exposed bedrock. Several shallow debris slides are visible on the available air photos along these scarp slopes (Polygons 293, 294, 9, 291) (**Figure 6.2-4**). The scarps are located either within the permanent pond, or within the flood level equivalent to the 2013 flood event. There is potential for an increase in the spatial and temporal frequency of debris slides, or the development of deeper seated slumping along this slope due to increased erosion and slope saturation in those areas not in the permanent pond.



Source: BGC 2017

Figure 6.2-8 Distribution of Terrain Stability Classes within the Permanent Pond and Reservoir

On the northwest side of the Elbow River, moderately steep colluvium and rock slopes are present at the back of the terraces, and extend to below the 1,430 m contour. These were mapped as terrain stability class IV (**Figure 6.2-4**) and could be destabilized if water levels reach the toe of the slopes with sufficient depth to increase toe erosion.

Existing geohazards upstream of the MC1 dam may disrupt the flow of the Elbow River or its tributaries and affect the Option. No existing geohazards in the geohazard inventory have been identified in the reservoir (excluding those previously noted landslides on steep slopes in the slope stability analysis). The Beaver Flats Landslide Complex is regarded to be most likely to interrupt flows given the proximity to downstream infrastructure, two prehistoric rock avalanches and the large storage afforded by the upstream channel geometry. The effects of a landslide at this location on the Option are considered further in **Section 10 Effects of the Environment on the MC1 Option**.

Effects Due to Inundation and Sediment Deposition

Potential MC1-related effects on terrain and soils due to a flood event during the Operation and Maintenance phase would include erosion and changes in soil quality (i.e., texture, structure, moisture content), which may lead to slope instabilities within the reservoir; as well as sedimentation from flood waters.

Within the reservoir zone there is a potential for suspended sediment and debris in the flood waters to be deposited and a potential for erosion; however, more detailed information would be required to predict specific sedimentation or erosion rates. Assuming the reservoir water level rises gradually, vegetation is not cleared from the zone, and the outflow following the flood event when returning to the permanent pond level is controlled, erosion is not considered likely. Deposition of finer sediments (clay and silt) and other upstream debris is considered likely, however. The effect may be positive or adverse depending on the characteristics of the original soil, rate of deposition, type of material, and depth of deposition (USDA 1996), and the consequent effects to vegetation would be plant-specific (see **Section 7.1 Vegetation and Wetlands**). It is likely that sedimentation rates would vary across the flooded area of the reservoir. The highest deposition rates are anticipated in areas subject to longer periods of inundation at the lower elevations, and areas in the vicinity of the input to the flooded area where velocity decreases and larger sediments can no longer be held in suspension. Regosolic soils on the fluvial deposits of the Elbow River are not considered likely to be affected by the Option. Potential changes to fluvial geomorphology are considered in **Section 6.4 Fluvial Geomorphology**.

Inundation may cause oxygen depletion, or reducing conditions, which may in turn affect the chemistry of the soil-water system and soil aggregation (structure). Information on the effects of inundation focuses on effects to agricultural soils in floodplains, and other riparian areas, rather than short-term flooding in non-fluvial deposits such as in this Option. For example, assessment of potential effects to agricultural soil includes consideration of potential adverse effects to crop productivity and the recovery time following a one-time flood event, which would depend on the depth and texture of the deposited soil; lesser deposition (10 centimetres (cm) to 20 cm) of finer materials includes a recovery period of five years (USDA 1996). Changes in soil structure, assuming that flood waters remain long enough to have an effect, may not be reversible because natural drainage would carry away any released chemicals. The long-term reversibility in soil aggregation caused by short-term reducing conditions is not clear (SSSA 2009)

6.2.3.3 Mitigation Measures

Mitigation measures comprise any practical means taken to manage potential adverse effects, and may include applicable standards, guidelines, and best management practices (BMPs) supported by specific guidance documents. In accordance with Alberta Transportation standard practice, BMPs and standard mitigation measures, including those outlined below to address potential effects to Terrain and Soils, would be included in the Environmental Construction Operations (ECO) Plan that would be developed by the contractor and reviewed by Alberta Transportation prior to the start of construction.

Mitigation measures to address the potential adverse effects discussed in **Section 6.2.3.2**, are described below and summarized in **Table 6.2-12**. The final column in the table identifies whether or not there is the potential for a residual effect. Potential residual effects are carried forward for further assessment (**Section 6.2.3.4**).

In addition to the measures listed below, measures incorporated into Option design to maintain vegetation in the reservoir area, and mitigation measures proposed for other VCs, such as for Water Quality, Surface Hydrology, and Vegetation, would also minimize the potential effects to the Terrain and Soils VC. The current Option layout reduces effects to slope stability by locating construction activities (borrow pits, laydown areas) in areas of low slope stability.

Soil Salvage Measures

Soil salvage measures would be developed and implemented prior to the start of the Construction phase. Appropriate soil salvage measures would include the appropriate excavation, handling, and stockpiling of soils that would be used for reclamation. Soil salvage measures would include the following (adapted from AER 2014):

- Topsoil salvage depths and range of variability (minimum and maximum)
- Detailed volume estimates of salvageable topsoil
- Stockpile locations
- Soil conditions that may require special consideration or handling techniques (if any), as well as a proposed mitigation approach.

This mitigation measure, in conjunction with the revegetation and reclamation measures, would likely be effective in minimizing the extent of soil loss and change in soil quality. With proper handling and storage of topsoil, the viability of the soil can be maintained and the change in soil loss at the end of the Construction phase would be minimized.

Revegetation and Reclamation Measures

Progressive revegetation of areas of temporary disturbance, including laydown areas, borrow areas and embankment areas that are available for revegetation, would be conducted. Revegetation of disturbed areas would support the re-establishment of native vegetation and reduce the overall change in soil quantity and quality. The revegetation and reclamation would include site-specific information (i.e., for each of the constructed landforms), soil conditions, performance standards for revegetated areas, and direction on monitoring and maintenance. The revegetation and reclamation measures would be developed using the BMPs outlined in the *Native Plant Revegetation Guidelines for Alberta* (NPWG 2001), where feasible.

This mitigation measure would likely be effective in minimizing the extent of soil loss and changes in soil quality through the establishment of stable, self-sustaining ecosystems. This measure would become effective during the Operation and Maintenance phase, as vegetation matures and stabilizes the terrain and soil.

Erosion and Sediment Control Plan

An Erosion and Sediment Control Plan would be developed and implemented for the Construction phase and the Operation and Maintenance phase until revegetated areas are stable and erosion and sediment controls are no longer needed. The Erosion and Sediment Control Plan would outline measures to minimize water and wind erosion of exposed areas to prevent loss of soil, sediment mobilization into the water, and dust deposition onto vegetation. The Erosion Prevention and Sediment Control plan would be developed using BMPs identified in the *Field Guide for Erosion and Sediment Control* (Government of Alberta 2011). During the Operation and Maintenance phase, erosion and sediment controls would be installed that may include bank stabilization procedures to prevent entry of sediment into the Elbow River within the boundaries of the reservoir, or along the shoreline of the permanent pond.

This mitigation measure would likely be effective in minimizing the increased erosion risk and extent of soil loss, as BMPs for erosion prevention and sediment controls are routinely used to reduce erosion risks and are known to be effective. Additional erosion prevention and sediment control measures are discussed in **Section 6.5 Water Quality**.

Monitoring and Maintenance Measures for Flood Events

The effects on terrain and soils from periodic inundation of the reservoir during flood events would likely vary due to a number of factors including frequency, severity, and depth of the flood event, as well as terrain and soil characteristics of the reservoir (e.g., depth of soil).

Post-flood monitoring and maintenance measures would be implemented. The objectives of the measures would be to identify the short-term and long-term effects of inundation in the reservoir, including on terrain stability and vegetation (and indirectly on soil quality) with the goal of identifying the potential effects early and developing appropriate mitigation measures to minimize the potential effects. Components would include the following mitigation measures:

- Document the immediate effects of flood events on the reservoir (e.g., record locations and magnitude of sediment and debris deposition areas, erosion areas, slope failures).
- Conduct maintenance activities as required after each flood event to stabilize terrain and soils and manage flood debris.
- Document the longer-term (i.e., multi-year) effects of inundation in the reservoir. Monitoring is recommended to include vegetation health and areas of slope instability.
- Develop an adaptive management plan as required to mitigate the effects of inundation and sediment deposition on the soils within the reservoir.

Table 6.2-12 Summary of Potential Effects and Mitigation Measures for Terrain and Soils

Summary of Potential Effect and Classification	Option Components	Contributing Option Activities	Proposed Mitigation Measure	Detectable / Measurable Residual Effect
Construction Phase				
Change in soil quantity	Construction or realignment of infrastructure (i.e., road, utilities, parks infrastructure, dam and embankment, spillway and outlet), borrow and spoil development and use, and permanent pond	Disturbance to soil or loss of area of soil in footprint	Soil salvage measures Reclamation and revegetation measures	Yes
Change in soil quality	Reclaimed areas	Soil stockpiling Reclamation of areas not needed for operation	Soil salvage measures Reclamation and revegetation measures	No
Increased erosion risk	Construction or realignment of infrastructure (i.e., road, utilities, parks infrastructure, dam and embankment, spillway and outlet), borrow and spoil development and use, and permanent pond	Site clearance activities leading to exposure of soil during construction activities	Erosion and Sediment Control Plan	No
Change in topography	Development and use of borrow areas; construction of MC1 dam	Excavation of borrow areas Construction of MC1 dam	Reclamation and revegetation measures	Yes
Operation and Maintenance Phase				
Increased erosion risk	Permanent pond	Effects of the permanent pond on shoreline erosion	Erosion and Sediment Control Plan	No
Decrease in slope stability	Reservoir	Reservoir filling or rapid drawdown Option layout	Monitoring and maintenance measures for flood events	Yes
Effects due to inundation and sediment deposition	Reservoir	Use of reservoir in flood events, leading to inundation and sediment deposition	Monitoring and maintenance measures for flood events	Yes

6.2.3.4 Residual Effects

Residual effects are MC1-related effects that would likely occur to VCs after the application of mitigation measures. This section describes how the residual effects of the Option are characterized and summarized for Terrain and Soils for those detectable/measurable effects identified in **Table 6.2-12**. The determination of a substantive or non-substantive residual effect includes a characterization including magnitude, regional extent, and duration. The magnitude definition considers two cases for the degree of alteration of the soil: complete loss of the soil productivity (loss of quantity of soil such as for permanent infrastructure), or adverse change in soil productivity (soil area remains but productivity decreases dues to change in soil characteristics).

Potential MC1-related residual effects are delineated as:

- Non-substantive residual effect – mitigation measures have not fully eliminated adverse effects, but have reduced the magnitude, extent, or duration to such a degree as to avoid a substantive effect on the VC. This characterization is based on the definitions and rating of effects characteristics outlined in **Table 6.2-13**.
- Substantive residual effect – adverse effects are likely to be high in magnitude, regional in extent, and long term in duration after implementation of mitigation.

Residual Effects Characteristics

Residual effects for the Soils and Terrain VC are characterized based on the criteria defined in **Table 6.2-13**.

Table 6.2-13 Residual Effects Characteristics for Terrain and Soils

Residual Effect Characteristic	Rating	Definition
Direction	Positive	Net benefit to Terrain and Soils.
	Adverse	Net loss to Terrain and Soils.
Extent	Local	Confined to the area directly disturbed by MC1 construction footprint and permanent pond. Excludes reservoir area.
	Limited	Confined to area in reservoir.
	Sub-regional	Effects to areas outside of MC1 Option area.
	Regional	Extends beyond the LAA.
Magnitude	Negligible	Loss of soil productivity in less than 1% of the LAA, or change in soil or terrain characteristics for less than 5% of LAA. A discernible change to the resource that is quantifiable at the scale of mapping relative to the Baseline Case, but is considered likely to have no detectable effect on the parameter or resource.
	Minor	Loss of soil productivity in less than 5% of the LAA, or change in soil or terrain characteristics for less than 10% of LAA. A potentially detectable change related to the Baseline Case.

Residual Effect Characteristic	Rating	Definition
	Moderate	Loss of soil productivity in less than 10% of the LAA, or change in soil or terrain characteristics for less than 15% of LAA. A detectable change relative to the Baseline Case, or that affects a relatively large proportion of a single resource
	Major	Loss of soil productivity in greater than 10% of the LAA, or change in soil or terrain characteristics in greater than 15% of LAA. A detectable change relative to the Baseline Case or that affects a relatively large proportion of a single parameter or resource, and is considered to pose a substantial risk to the associated parameter or resource.
Duration	Short term	Effect would occur for a portion of the Construction phase or for a flood event.
	Medium term	Effect would occur for the duration of the Construction phase.
	Long term	Effect would occur for the duration of the Operation and Maintenance phase (lifetime of the structure).
Reversibility	Reversible	Effect could be reversed once the activity causing the residual effect ceases.
	Partially reversible	Effect could be partially reversed once the activity causing the residual effect ceases.
	Not reversible	Effect would be permanent.
Frequency	Isolated	Effect would occur at a specific time.
	Rare	Effect would be intermittent and sporadic over the life of the MC1 Option.
	Frequent	Effect would occur recurrently over the life of the MC1 Option.
	Continuous	Effect would occur continuously over the life of the MC1 Option.
Confidence	High	Rating predictions are based on a good understanding of cause-effect relationships and/or using data specific to the MC1 Option area.
	Moderate	Rating predictions are based on a good understanding of cause-effect relationships relying on data from elsewhere, or incomplete understanding of cause-effect relationships from data specific to the MC1 Option.
	Low	Rating predictions are based on an incomplete understanding of cause-effect relationships and incomplete data.

Change in Soil Quantity

Residual effects of the MC1 Option on soil quantity would be adverse, of moderate magnitude, and restricted to the MC1 footprint (**Table 6.2-14**). The residual MC1-related effect would occur once as part of construction activities but would persist continuously into the long-term for those areas with permanent infrastructure. Residual effects would not be reversible in the areas of permanent infrastructure; however, they would be reversible in areas reclaimed following construction. Soil replacement (reclamation) would occur on some areas disturbed for construction but the MC1 Option would result in a net loss of soil. The residual effect is likely to occur, as soil loss is unavoidable with MC1 construction. The mitigation measures presented in **Section 6.2.3.3** reflect standard BMPs, and would likely be effective. Because the residual effects would be restricted to the MC1 footprint, they would likely be non-substantive. This assessment has a high level of confidence.

Table 6.2-14 Summary of Effect Characteristics Ratings for Soil Quantity

Residual Effects Characteristic	Rating	Rationale for Rating
Direction	Adverse	Permanent loss of soil from the footprint of the MC1 dam, permanent pond, and highway relocation.
Extent	Local	Permanent loss of soil would only occur in the areas of permanent MC1 infrastructure.
Magnitude	Moderate	Permanent loss in area of 6% of the LAA from the Baseline Case.
Duration	Long-term	Effect would occur over the lifetime of the MC1 Option.
Reversibility	Not reversible	Effect would be permanent for loss associated with permanent infrastructure.
Frequency	Continuous	Effect would occur once and persists continuously over the life of the MC1 Option.
Confidence	High	Rating predictions are based on a good understanding of cause-effect relationships and using data specific to the MC1 Option area.

Change in Topography

Residual effects of the Option on topography would be adverse, of negligible magnitude, and restricted to a portion of the MC1 footprint (**Table 6.2-15**). The residual MC1-related effect would occur once as part of construction activities but would persist continuously into the long-term. Residual effects would not be reversible. The residual effect would be likely to occur, as change in topography is unavoidable with MC1 construction. The mitigation measures presented in **Section 6.2.3.3** reflect standard BMPs, and would likely be effective. Because the residual effects would be restricted to a portion of the MC1 footprint, they would likely be non-substantive. This assessment has a high level of confidence.

Table 6.2-15 Summary of Effect Characteristics Ratings for Change in Topography

Residual Effects Characteristic	Rating	Rationale for Rating
Direction	Adverse	Permanent change in topography.
Extent	Local	Permanent change in topography would only occur in MC1 footprint and is less than 5% of the LAA.
Magnitude	Negligible	Change in terrain characteristics of less than 5% of LAA.
Duration	Long-term	Effect would occur over the lifetime of the MC1 Option.
Reversibility	Not reversible	Effect would be permanent for changes associated with the borrow pits and the dam.
Frequency	Continuous	Effect would occur once and persists continuously over the life of the MC1 Option.
Confidence	High	Rating predictions are based on a good understanding of cause-effect relationships and using data specific to the MC1 Option area.

Decrease in Slope Stability

Residual effects of the MC1 Option on slope stability would be adverse, of moderate magnitude, and likely restricted to portions of the MC1 footprint with low slope stability (**Table 6.2-16**). The residual MC1-related effect would be likely to occur during flood events or close thereafter during the Operation and Maintenance phase. Residual effects would be partially-reversible following a flood event, as slope failure risks would likely decrease as soil water saturation levels decrease. The monitoring plan would identify and manage (where practicable) potential changes in slope stability following a flood event. The residual effect would be likely to occur, as the purpose of the Option is to impound water during a flood event. Because the residual effects would be restricted to isolated areas of the reservoir (slope stability class IV and V areas are less than 8% of the reservoir, and less than 1 % of the LAA), they would likely be non-substantive. This assessment has a moderate level of confidence, as the slope stability assessment is a preliminary desktop review for instability, therefore monitoring following flood events is proposed.

Table 6.2-16 Summary of Effect Characteristics Ratings for Slope Stability

Residual Effects Characteristic	Rating	Rationale for Rating
Direction	Adverse	Decrease in slope stability in areas of reservoir with a Class IV or V terrain stability rating
Extent	Local	Decrease in slope stability within the reservoir for approximately 8% of the area (Class IV or V).
Magnitude	Minor	A potentially detectable change related to the Baseline Case.
Duration	Long-term	Effect would occur over the lifetime of the MC1 Option.
Reversibility	Partially reversible	Effect would be partially reversible once the activity causing the residual effect ceases.
Frequency	Rare	Effect would occur during a flood event.
Confidence	Moderate	Rating predictions are based on a good understanding of cause-effect relationships and using data specific to the MC1 Option area, however detailed field work and geotechnical analyses have not been undertaken.

Effects Due to Inundation and Sediment Deposition

The extent of the residual effect would be dependent on the magnitude of the flood. A flood similar in magnitude to the 2013 flood would affect 379 ha or 14% of the LAA and would be moderate in magnitude. The residual MC1-related effect to soil characteristics from inundation would occur frequently over the life of the MC1 Option, and the duration may persist for several years for portions of the reservoir area, depending on the length of inundation and the level of sedimentation. Residual effects are considered partially reversible, as soil changes (increase or decrease in productivity) may persist once the flood event is over. The potential residual effect is considered non-substantive because although characteristics may change, the soils would likely to continue to be productive (**Table 6.2-17**).

This assessment is based on a limited understanding of the cause-effect relationship and a lack of site-specific data; therefore, the assessment has a low level of confidence. Development and implementation of a monitoring and maintenance plan and adaptive management throughout the Operation and Maintenance phase would support a better understanding of the residual effect, and would help mitigate the effects of inundation and sedimentation on terrain and soils (**Section 6.2.3.3**).

Table 6.2-17 Summary of Effect Characteristics Ratings for Effects Due to Inundation and Sediment Deposition

Residual Effects Characteristic	Rating	Rationale for Rating
Direction	Adverse	Net loss to soil (quality or quantity)
Extent	Limited	Effects would be confined to the reservoir
Magnitude	Moderate	Extent of effect is dependent upon the magnitude of the flood event. A flood similar to the 2013 flood would affect 379 ha within the reservoir.
Duration	Short-term to long-term	Effect would occur during a flood event and may persist for several years in localized areas.
Reversibility	Partially reversible	Effect may be reversed after the flood event, depending on the length of inundation and sedimentation levels
Frequency	Rare	Effect would occur recurrently over the life of the Option with flood events.
Confidence	Low	Rating predictions are based on a limited understanding of cause-effect relationships and relying on data from elsewhere

6.2.3.5 Summary of Terrain and Soils Assessment

Based on the determination of no substantive residual effects**,** there is no potential for substantive residual effects on the Terrain and Soils VC. The residual effects of the Option on soil quantity, topography and slope stability would be restricted to portions of the MC1 footprint. While the residual effects to soil from inundation during a flood event may be major in magnitude for the worst case, given the spatial extent of the reservoir, the effects would be likely to vary across the reservoir and may not be adverse for the entire area, the effects would likely reverse over time, and the soils would likely to continue to be productive. Therefore, this residual effect is not considered substantive.

6.2.4 FOLLOW-UP MONITORING FOR TERRAIN AND SOILS

Additional geotechnical investigations are required as part of the design phase to further characterize land capability classifications, soil types and geohazards. The results of these investigations would feed into detailed design, and would refine the mitigation measures that have been proposed.

Post-flood monitoring and maintenance measures, as described in **Section 6.2.3.3** would be implemented as a part of follow-up monitoring.

6.2.5 REFERENCES

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6.3 HYDROGEOLOGY

This section describes potential effects to Hydrogeology from the proposed Elbow River at McLean Creek Dam (MC1) Option (MC1, Option, or MC1 Option). For the purposes of this assessment, Hydrogeology is defined as the interrelationship between geological materials and water. The Valued Components (VCs) that may be affected from MC1-related disturbances include Groundwater Quantity and Groundwater Quality.

The assessments presented in this section are supported by or linked to the assessments presented in the following sections:

- Section 6.2 Terrain and Soils
- Section 6.4 Fluvial Geomorphology
- Section 7.1 Vegetation and Wetlands
- Section 7.3 Aquatic Environment
- Section 8.1 Land Use and Management

6.3.1 SCOPE OF ASSESSMENT

This section reviews the scope of assessment for Hydrogeology, and includes relevant regulatory framework, data sources, VCs, measurable parameters, and assessment boundaries. The assessment of MC1-related effects on Hydrogeology relies on information compiled through the review of publicly available literature as well as results of past studies completed for the MC1 Option.

6.3.1.1 Regulatory Framework

An overview of the regulatory framework and requirements that are relevant to the assessment of potential MC1-related effects to Hydrogeology is summarized in **Table 6.3-1**.

Table 6.3-1 Summary of Applicable Regulatory and Policy Framework for Hydrogeology

Name	Jurisdiction	Description
Health Canada Drinking Water Guidelines	Federal	Use of groundwater for drinking purposes is common in the MC1 Option area, and consideration of potential water quality effects is important. The Health Canada Guidelines for Canadian Drinking Water Quality provide relevant drinking water quality standards.
Canadian Environmental Quality Guidelines for the Protection of Aquatic Life – Canadian Council of Ministers of the Environment (CCME 2001)	Federal	Groundwater quality at contaminated sites on federal lands is compared to these guidelines. Although this standard pertains to surface water quality, groundwater contributes to creeks as baseflow that can affect aquatic habitat; therefore, exceedance of this guideline in groundwater can trigger follow-up investigation to assess effects on aquatic life.
Water Act	Provincial	The MC1 Option would alter groundwater levels, and would therefore require approval for impounding water, and a licence for any diversion or use of groundwater
Groundwater Remediation Guidelines (*Alberta Environmental Protection and Enhancement Act)*	Provincial	Provides groundwater quality clean-up guidelines under Alberta's contaminated sites framework. Contamination of groundwater resulting from construction (e.g., fuel spill) would require clean-up to these levels.

6.3.1.2 Data Sources

Data sources included MC1-specific data (e.g. the drilling investigation carried out along the proposed dam alignment), the Alberta Water Wells database (AEP 2017), conceptual design reports and associated environmental studies for MC1 (AMEC 2015); and other scientific literature available online. The following hydrogeological data sources were relied on for this assessment:

- Hydrogeology of the Kananaskis Lake Area, Alberta (Borneuf 1980)
- Environmental Overview of the Conceptual Elbow River Dam at McLean Creek (AMEC 2015)
- Terrain Analysis for Borrow Sites (BGC 2016)
- Surficial Geology and Erosion Potential: Rocky Mountains and the Foothills of Alberta (Bayrock and Reimchen Surficial Geology Ltd. 1977)
- Groundwater-Surface Water Interaction and Water Quality in the Lower Elbow River (Manwell 2015)
- Water Quality of the Elbow River (Beers and Sosiak 1993)
- Groundwater resources in the City of Calgary vicinity (Meyboom 1961)
- Elbow River Basin Water Management Plan (Elbow River Watershed Partnership 2008)
- Alberta Water Wells Database (AEP 2017)

6.3.1.3 Valued Components

Groundwater may interact directly with MC1-related activities (e.g., earthworks and restricting surface water flow), and may adversely affect other biophysical components (e.g., slope stability and water quality) (**Table 6.3-2).**

Table 6.3-2 Valued Components for Hydrogeology

Valued Components	Interactions
Groundwater Quantity	Groundwater Quantity (flow) maintains ecosystem integrity, particularly during dry periods when it contributes base flow that sustains wetlands and creeks. Land inundation can result in groundwater level rise in proximity of inundated areas. Groundwater Quantity may be affected through both permanent and periodic inundation of land and the interruption of groundwater flow resulting from a dam on the Elbow River. Changes in groundwater quantity may affect terrain stability (see **Section 6.2 Terrain and Soils**). The assessment of Groundwater Quantity contributes to the assessment of the following VCs: Terrain and Soils, Vegetation, Wetland, and Fish and Fish Habitat.
Groundwater Quality	Groundwater Quality refers to a change in baseline (existing) groundwater quality. Groundwater Quality may be affected through permanent and periodic inundation of the reservoir; and from interruption of groundwater baseflow to the Elbow River downstream of the dam. The assessment of Groundwater Quality contributes to the assessment of the following VCs: Vegetation, Wetlands, and Fish and Fish Habitat.

6.3.1.4 Measurable Parameters

Measurable parameters are quantitative or qualitative measures used to describe existing conditions and trends, and to evaluate potential MC1-related effects on the VCs. The measurable parameters selected for Groundwater Quantity and Groundwater Quality are shown in **Table 6.3-3***.*

Table 6.3-3 Measurable Parameters for Hydrogeology

Selected VC	Potential MC1-related Effects	Measurable Parameter
Groundwater Quantity	Land saturation close to the permanent pond and temporarily beneath the full flood footprint, may lead to terrain instability (e.g. landslide) where the strength of fine-grained or poorly-drained materials may decrease due to saturation	Depth of groundwater
	Groundwater flow reduction (baseflow) downstream of the dam affecting aquatic/riparian ecosystem	Depth of groundwater
	Loss of water supply wells within MC1 Option area	Damage to wells rendering them inoperable
Groundwater Quality	Surface water contaminants (e.g. bacteriological and nutrients) may enter aquifers and affect suitability for use (e.g., for drinking) either by rapid infiltration in flooded area footprint, via cleared / borrow areas or through non-decommissioned wells.	Total coliforms; E-coli. Ammonia, Nitrate, Phosphate
	Reduced flow in alluvial aquifer downstream of dam may locally affect aquatic organisms	Electrical conductivity or total dissolved salts

6.3.1.5 Assessment Boundaries

Spatial Boundaries

Spatial boundaries for the assessment of Hydrogeology are described in **Table 6.3-4** and shown in **Figure 6.3-1**.

The Local Assessment Area (LAA) encompasses the maximum geographical area where the MC1 Option is expected to interact, and potentially have a direct or indirect effect on Hydrogeology. It includes the MC1 Option area plus the downstream Area of Influence (AOI) incorporating Elbow Creek and the associated alluvial aquifer from the dam to the outlet of the permanent gated outlet conduit structure.

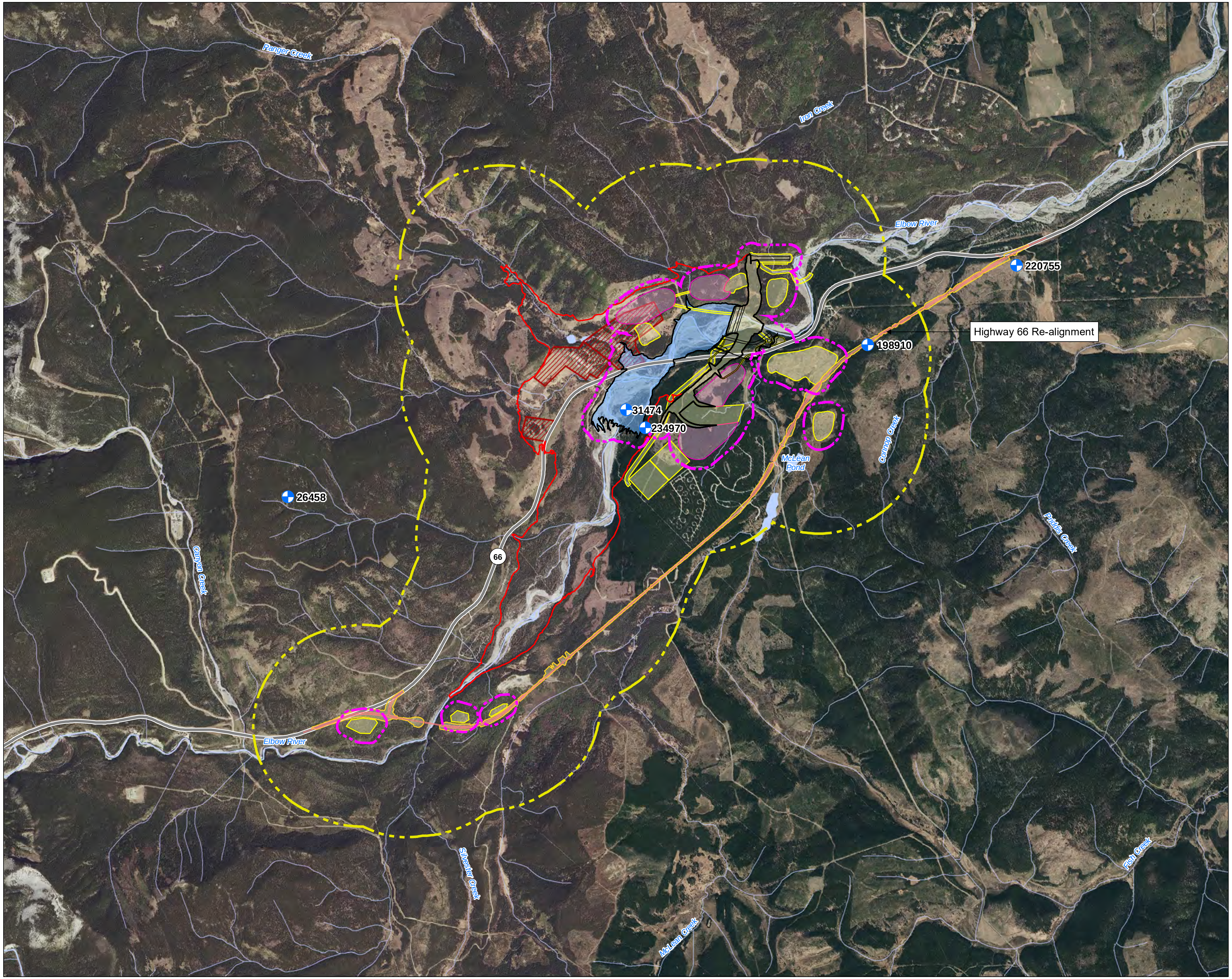
The Regional Assessment Area (RAA), which encompasses the LAA, is established to provide a regional context for the assessment of MC1-related effects. The RAA also encompasses the area where the residual effects of the MC1 Option are likely to interact with the residual effects of other past, present, or future projects or activities to result in a cumulative effect or effects.

Table 6.3-4 Spatial Boundary Definitions for Hydrogeology

Spatial Boundary	Description of Assessment Area
MC1 Option area	Encompasses the MC1 footprint and a 100-m buffer around the embankment and excavation areas, spillways and outlet works, road and borrow areas.
Local Assessment Area	Encompasses the MC1 Option area plus the downstream AOI incorporating Elbow Creek and the associated alluvial aquifer from the dam to the outlet of the permanent gated outlet conduit structure
Regional Assessment Area	Encompasses the area within 1 km off the LAA and the pond level during a 1-in100-year flood event.

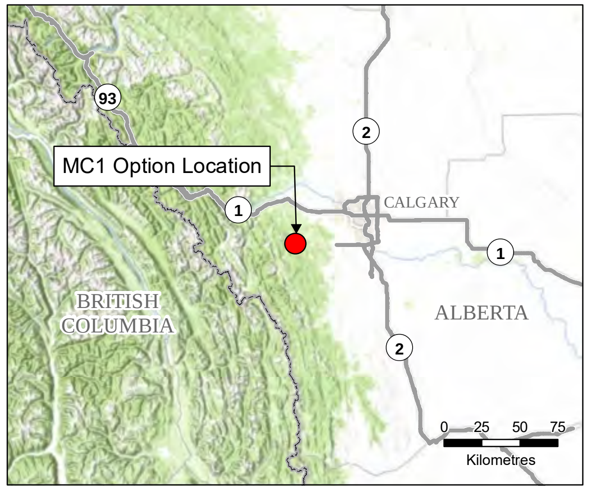
The extent of the LAA is considered equivalent to the MC1 Option area because, given the transient (e.g., short-term, reversible) nature of flood retention events, it is unlikely that groundwater effects would extend beyond the MC1 Option area. The permanent pond elevation resulting from the dam on Elbow River (1,395 metres (m)) is approximately 10 m above the existing river elevation at the dam. Most of the permanent pond's shoreline would be on less-permeable bedrock; therefore, limited interaction with overlying and more permeable surficial deposits is expected. During routine operation, the rate of inflow would balance outflow in the permanent pond, thus maintaining a stable water volume and a stable surface elevation with little variation

The highway realignment would not likely interact with groundwater, and therefore the Hydrogeology LAA does not extend to include the highway realignment. Potential MC1 related effects on groundwater are described and assessed in **Section 6.3.3.**



Elbow River at McLean Creek Dam (MC1)

Hydrogeology Local Assessment Area and Regional Assessment Area



Legend

- MC1 Option Area and Hydrogeology Local Assessment Area
- Hydrogeology Regional Assessment
- MC1 Dam
- 2013 Flood Event (1424.1m)
- Highway 66 Re-alignment
- Borrow Area
- Laydown Area/Disturbed
- Permanent Pond
- Highway
- Watercourse
- Waterbody
- Existing Park Infrastructure to be
- Groundwater Diversion License

Notes

1. All locations and features should be considered approximate and are to be used for discussion purposes only.
2. This map is not intended to be a "stand-alone" document, but a visual aid of the information contained within the referenced Report. It is intended to be used in conjunction with the scope of services and limitations described therein.

Sources

- Basedata: Government of Alberta, 2017
- Preferred Road Option and Disturbed Areas: Opus International Consultants Limited, 2017
- Dam Details: Hatch Ltd., 2017
- Aerial Imagery: SPOT 1.5 m, 2016
- Inset Basemap: ESRI Topographic Basemap

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Temporal Boundaries

The temporal boundaries of the MC1 Option consist of the Construction phase as well as the Operation and Maintenance phase of the MC1 Option, which are described in **Section 3.0 Option Description**.

During Construction, changes to ambient groundwater conditions within the MC1 Option area are expected (e.g. changes to local flow paths in the alluvial aquifer). A new equilibrium would be established under normal operating conditions (e.g., from the permanent pond elevation). Flood water retention is a transient effect as the raised water level in the dam would interact with groundwater throughout the retention and release period.

Administrative Boundaries

There are no administrative boundaries (e.g., political, economic, or social issues, as well as fiscal or other resourcing issues constraining the assessment of potential effects of the Option) within the Hydrogeology RAA.

Technical Boundaries

Data compiled to support the Hydrogeology assessment consisted of a review of existing information. The various data sources considered come with inherent technical limitations, which form the basis of the technical boundaries for this assessment (e.g., location of water wells and availability of recent monitoring data). The identification of geological units as aquifers provides a level of detail necessary to support the assessment of MC1-related effects on Hydrogeology.

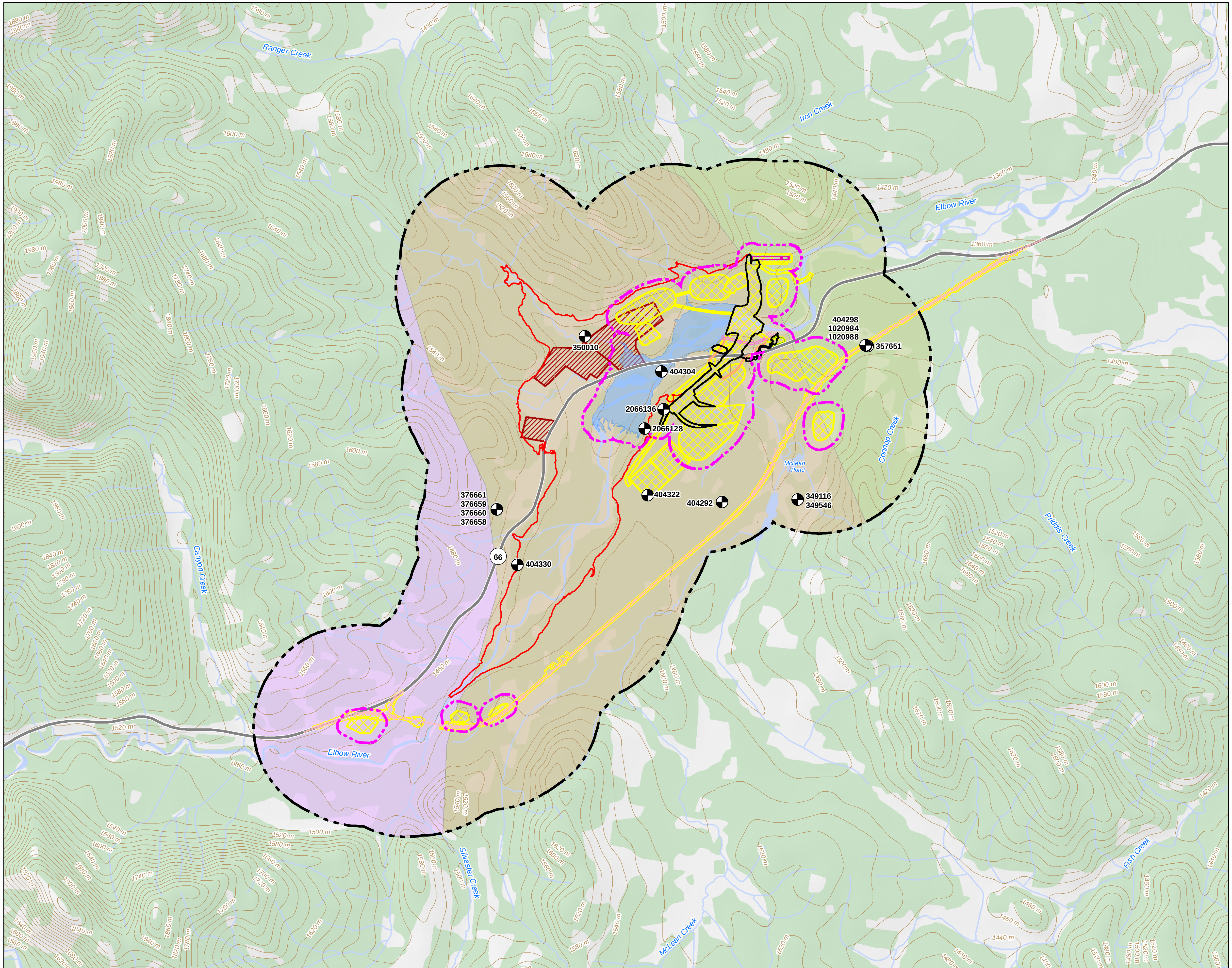
The limitations identified for this assessment are common to effects assessments that rely on these types of data, and do not impede the ability to assess potential MC1-related effects. They can be offset using a conservative approach to the identification of potential MC1-related effects, which involves the establishment of a 100-m buffer around proposed infrastructure; this buffer would provide an over-estimation of potential effects resulting from the MC1 Option.

6.3.2 Baseline Case

The baseline case summarizes existing hydrogeological information for the area without the proposed Option. The Option team has assumed that the existing groundwater conditions are consistent with those reported in the data sources and literature reviewed (**Section 6.3.1.2**). Current field data (groundwater sampling or water level measurement) has not been collected for this assessment; if this Option proceeds through future regulatory approvals, a full groundwater baseline data collection and characterization program would be required to confirm baseline conditions remain consistent with information summarized from existing literature.

6.3.2.1 Geological Setting

The MC1 Option area is located within the Rocky Mountain foothills, approximately 19 kilometres (km) west of the McConnell Thrust fault, which separates the foothills from the front ranges of the Rocky Mountains (Borneuf 1980). Bedrock throughout the RAA is composed of sedimentary rock. Toward the extreme west of the RAA, there are older (Paleozoic) limestone rocks with karst features formed by dissolution of the limestone. The geological formations in the western portion of the RAA (Upper Paleozoic and Lower Mesozoic / Lower Cretaceous, shown in **Figure 6.3-2**) comprise limestone, and non-marine sandstone, and shale with coal, respectively. The Alberta Group (Wapiabi and Blackstone Formations), which occupies the central and largest area within the RAA, comprises marine shale and sandstone. The Brazeau Formation is located downstream of the proposed MC1 dam embankment, and comprises marine and non-marine shale and sandstone. The formations exhibit a high degree of deformation and the geological boundaries between them are defined by steep thrust faults. Geological structures (e.g., faults) are aligned in a north-south direction in the RAA, which is orthogonal to the regional deformation. Geological cross-sections are provided in **Figure 6.3-3** and **Figure 6.3-4**.



Elbow River at McLean Creek Dam (MC1)

Bedrock Geology in the Hydrogeology Regional Assessment Area

Legend

- MC1 Option Area and Hydrogeology Local Assessment Area
- Hydrogeology Regional Assessment
- Dam Footprint
- Access Road
- 2013 Flood Event (1424.1m)
- Diversion/Low Level Outlet Tunnels
- Preferred Road Option
- Re-alignment of McLean Creek
- Rockfill Berm
- Service Spillway
- Disturbed Area
- Permanent Pond
- Existing Park Infrastructure to be Removed
- Contour (m)
- Highway
- Waterbody
- Watercourse
- Bedrock Groundwater Well

Bedrock Geology

- Alberta Group
- Brazeau Formation
- Lower Mesozoic-Lower Cretaceous

Notes

1. All locations and features should be considered approximate and are to be used for discussion purposes only.
2. This map is not intended to be a "stand-alone" document, but a visual aid of the information contained within the referenced Report. It is intended to be used in conjunction with the scope of services and limitations described therein.

Sources

- Basedata: Government of Alberta, 2017
- Preferred Road Option and Disturbed Areas: Opus International Consultants Limited, 2017
- Dam Details: Hatch Ltd., 2017
- Bedrock Geology: Alberta Energy Regulator/Alberta Geological Survey, 2017

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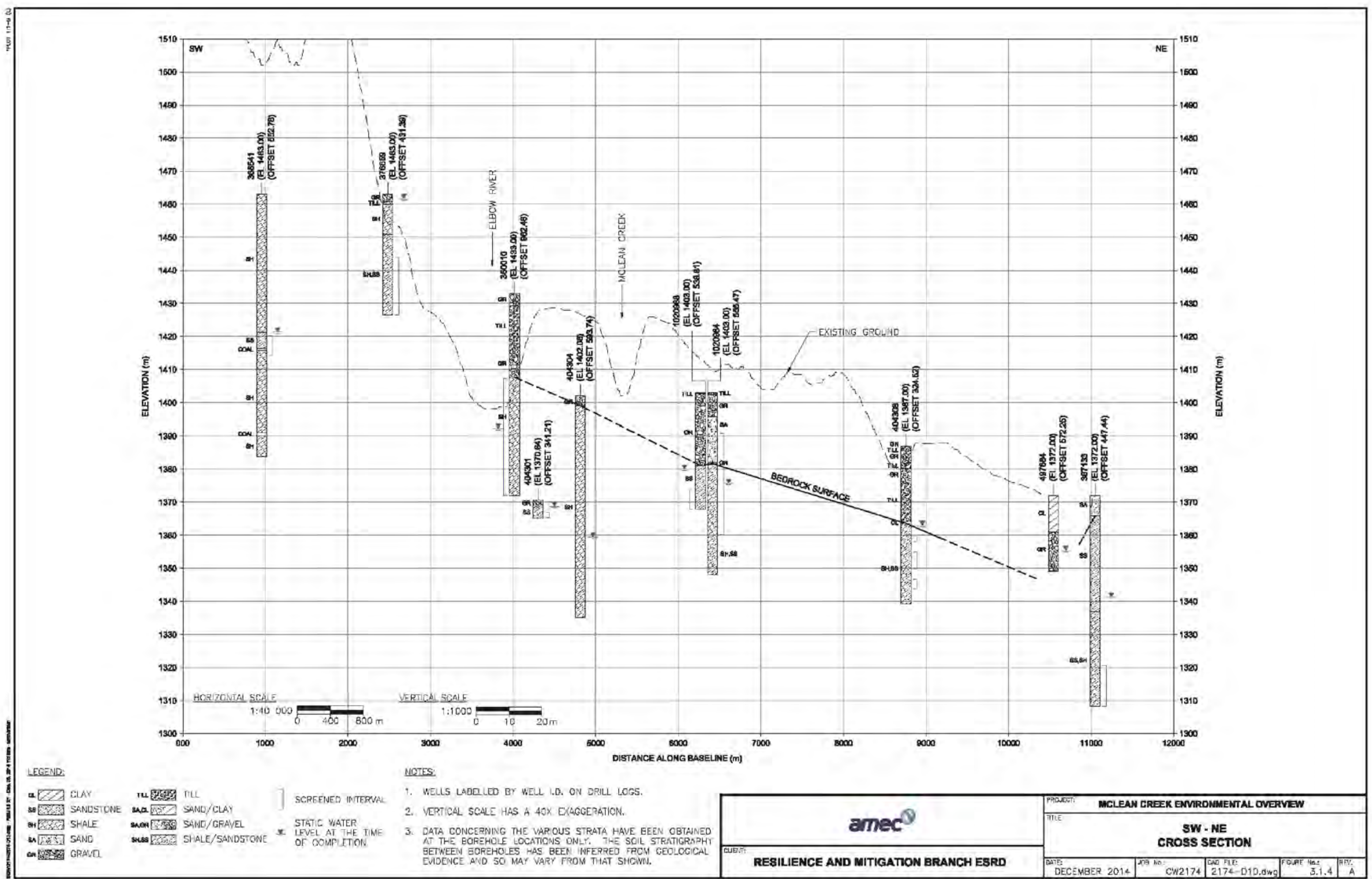
Elbow River at McLean Creek Dam (MC1)

Southwest – Northeast Cross-Section (AMEC 2015)



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Refer to AMEC figure 3.1-4

Notes

1. This map is not intended to be a "stand-alone" document, but a visual aid of the information contained within the referenced Report. It is intended to be used in conjunction with the scope of services and limitations described therein.

Sources

- Cross-section completed by AMEC Environment and Infrastrucure. Environmental Overview of the Conceptual Elbow River Dam at McLean Creek, 2015.

Scale: Refer to AMEC figure 3.1-4

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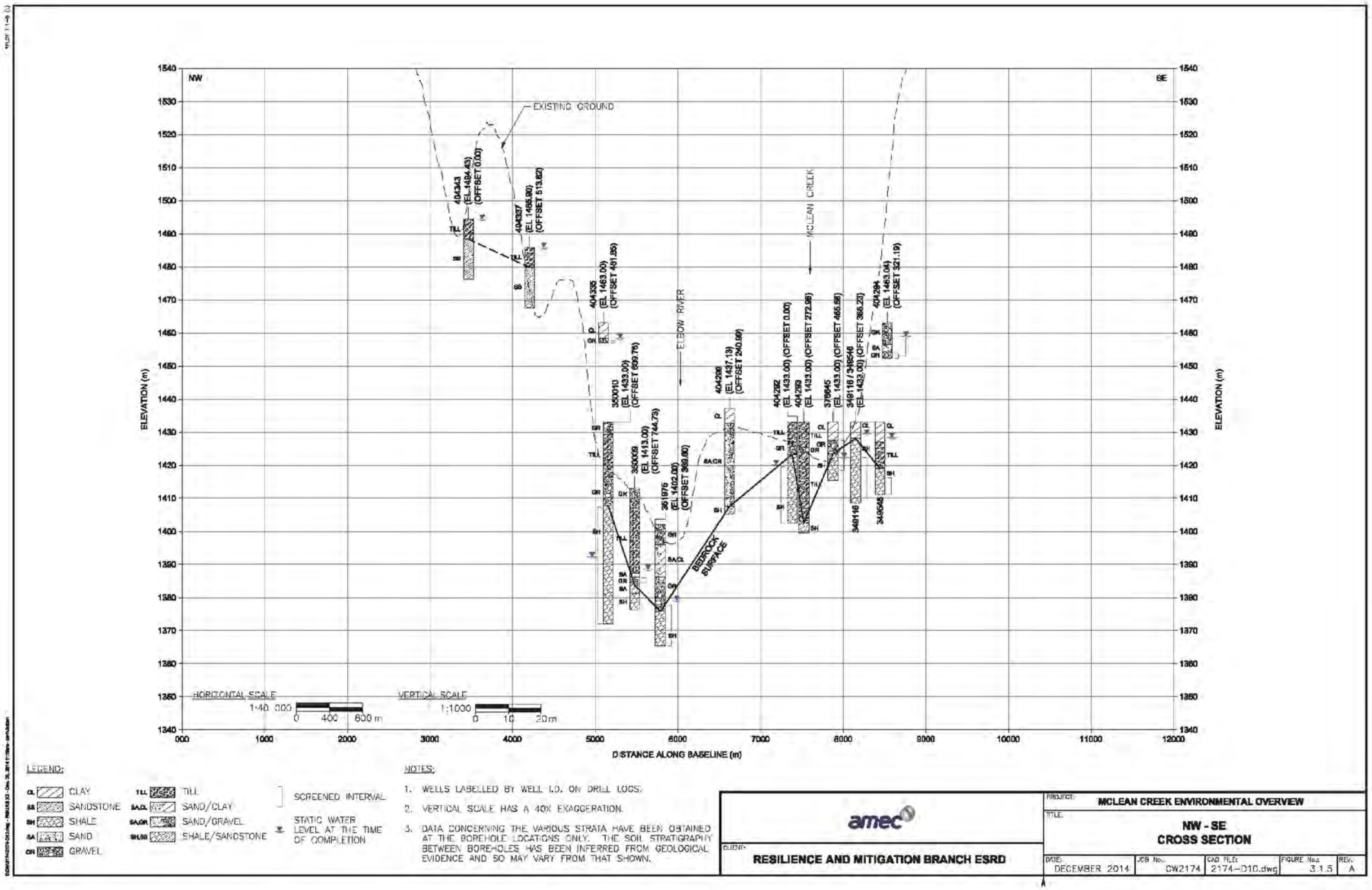
Elbow River at McLean Creek Dam (MC1)

Northwest – Southeast Cross-Section (AMEC 2015)



Legend

Refer to AMEC figure 3.1-5

Notes

1. This map is not intended to be a "stand-alone" document, but a visual aid of the information contained within the referenced Report. It is intended to be used in conjunction with the scope of services and limitations described therein.

Sources

- Cross-section completed by AMEC Environment and Infrastrucure. Environmental Overview of the Conceptual Elbow River Dam at McLean Creek, 2015.

Scale: Refer to AMEC figure 3.1-5

Page Size: 11" x 17"

2025-001.01	Production Date: Sep 15, 2017	Figure 6.3-4

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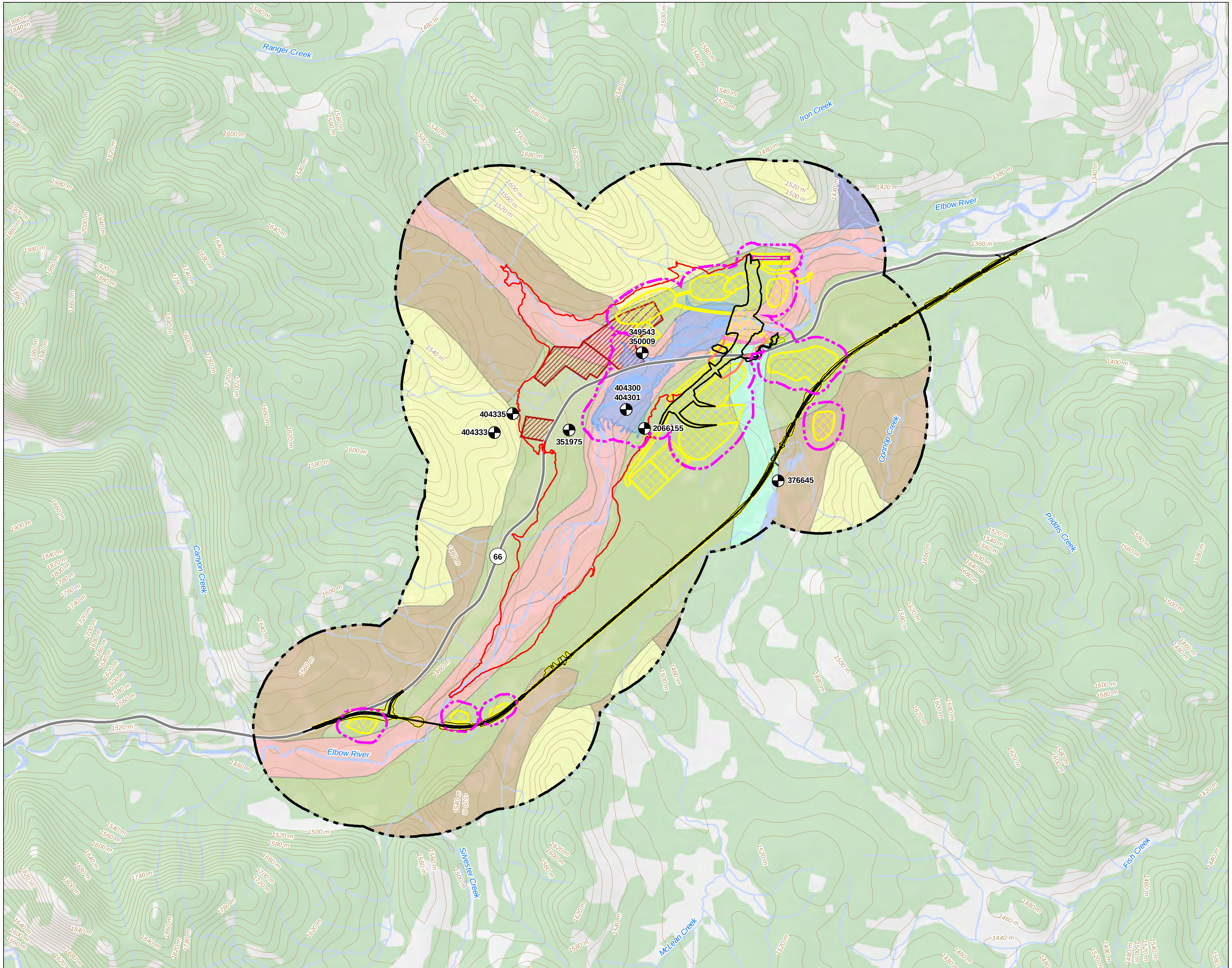
The Elbow River occupies an incised valley comprising a sand and gravel floodplain bordered by river terraces. The glaciated landscape has been dissected by the Elbow River and its tributaries to expose bedrock in the canyon wall near the MC1 dam embankment. The unconsolidated deposits are predominantly composed of till, glacial outwash, and alluvial deposits (**Figure 6.3-5**). The following surficial materials (lithology) have been identified from a recent terrain mapping exercise to help identify borrow material for construction of the dam (BGC 2016):

- Organic material - sediment largely composed of partially decomposed vegetative matter. Wet organic areas are present on some terraces, particularly those underlain by glacio-lacustrine material or till and flood plains of smaller streams.
- Colluvium – typically a thin veneer of silt to gravel-sized material that is weathered and eroded from bedrock and transported downhill by gravity.
- Fluvial – sand and gravel deposited by current rivers in active channel, floodplains, fans. or low terraces.
- Glaciofluvial – typically composed of sand and gravel deposited during the post-glaciation, and located along the terraces above and on both sides of Elbow River and Ranger Creek.
- Glacio-lacustrine – typically composed of interbedded sand, silt, and clay that was deposited in lakes that formed near the onset and end of the last glacial period. Occurs on the south side of the Elbow River and downstream of the proposed dam location.
- Till – basal till is deposited below an ice sheet, is often highly consolidated, and comprises a poorly sorted material. Ablation till is deposited on the surface of an ice sheet as it diminishes. Clay-rich till is present in thick deposits on a bench on the south side of the Elbow River and as a thin veneer throughout the area.

The valley slopes within the RAA are typically covered by thin till deposits with bedrock outcrop at higher elevations. In some locations, a thin veneer of colluvium is present above the till and bedrock. Glacio-lacustrine deposits of less than 10 m thickness occur in the far northeastern portions of the RAA, and there are small, localized deposits of rock-slide material and talus rock debris throughout the RAA along steep slopes (Bayrock and Reimchen 1977). The average thickness of the surficial deposits is approximately 30 m.

Elbow River at McLean Creek Dam (MC1)

Surficial Geology in the Hydrogeology Regional Assessment Area



Legend

- MC1 Option Area and Hydrogeology Local Assessment Area
- Hydrogeology Regional Assessment Area
- Dam Footprint
- Access Road
- 2013 Flood Event (1424.1m)
- Diversion/Low Level Outlet Tunnels
- Preferred Road Option
- Re-alignment of McLean Creek
- Rockfill Berm
- Service Spillway
- Disturbed Area
- Permanent Pond
- Contour (m)
- Highway
- Waterbody
- Watercourse
- Overburden Groundwater Well

Surficial Geology

- Outwash Plains
- Moderately Leached Till, Cordilleran Provenance
- Kames, kame terraces and kame morraines
- Glaciolacustrine deposits
- Fine Stream Alluvium
- Deeply Leached Till, Cordilleran Provenance
- Colluvium
- Coarse Stream Alluvium

Notes

1. All locations and features should be considered approximate and are to be used for discussion purposes only.
2. This map is not intended to be a "stand-alone" document, but a visual aid of the information contained within the referenced Report. It is intended to be used in conjunction with the scope of services and limitations described therein.

Sources

- Basedata: Government of Alberta, 2017
- Preferred Road Option and Disturbed Areas: Opus International Consultants Limited, 2017
- Dam Details: Hatch Ltd., 2017
- Surficial Geology: Alberta Energy Regulator/Alberta Geological Survey, 2017

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6.3.2.2 Major Aquifers

The main surficial aquifer in the RAA is made up of the fluvial and glaciofluvial sand and gravel (alluvial) deposits adjacent to the Elbow River (AMEC 2015). Borehole records show that, apart from the Elbow River aquifer, the surficial geological deposits are largely unsaturated and therefore do not comprise substantial aquifers in the RAA. The Elbow River aquifer was formed by river deposition and comprises high-permeability fluvial deposits (Manwell 2005). The fine- to coarse-grained fluvial deposits (gravel, sand, and minor silt beds) are beneath and immediately adjacent to Elbow River and its tributaries (Bayrock and Reimchen 1977). The aquifer is hydraulically connected to the Elbow River such that groundwater flows to the river during periods of low flow, and river water recharges the aquifer during times of high river or flood flow. Groundwater reportedly accounts for approximately 40% of the total flow to the Elbow River basin between August and April (Beers and Sosiak 1993). Despite the limited thickness of the floodplain alluvium, they have high transmissivity (hydraulic conductivity multiplied by the aquifer's saturated thickness) compared to bedrock aquifers. For example, Borneuf (1980) reported 700 square metres per day (m^2/day) to 2,000 m^2/day for surficial sand and gravel compared to 1 m^2/day to 44 m^2/day for sandstone bedrock aquifers from pumping test analysis.

The underlying bedrock aquifer is typically used for domestic supply, but yields are low compared to wells screened in the Elbow River aquifer. Replenishment of bedrock aquifers is via diffuse recharge from snowmelt and precipitation, whereas recharge of the alluvium adjacent to the Elbow River can be directly from stream flow (particularly during snowmelt) but also from underlying bedrock.

Water level monitoring in two bedrock wells at Camp Horizon (1020984 and 1020988 – see **Figure 6.3-2**) from 2009 to 2014 shows that the seasonal water level can change up to 20 m but the average annual variation is approximately 10 m (**Figure 6.3-6**). These wells are located close to the Elbow River and are overlain by approximately 20 m of unsaturated sand and gravel. The water level increases rapidly in the spring, presumably from snowmelt, but then recedes from summer through the fall and winter. The water level changes include the effect of pumping, which lower the ambient groundwater level and increase natural seasonal variation.

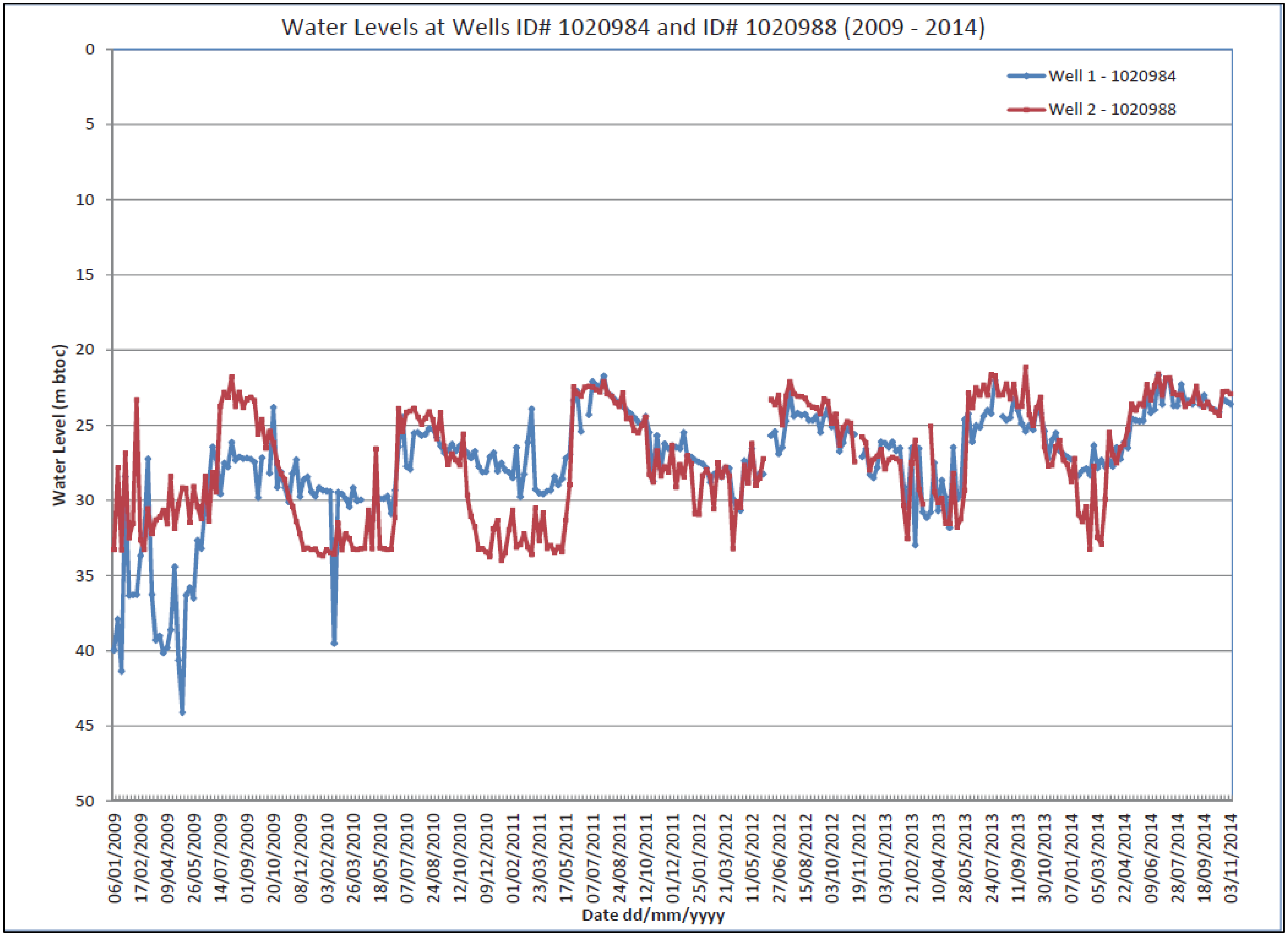

Figure 6.3-6 Groundwater Level Fluctuation in Camp Horizon Wells from 2009-2014

6.3.2.3 Groundwater Flow

Groundwater flow is understood in the context of vertical and lateral vectors. The lateral flow direction is influenced by the groundwater gradient, which typically follows topography. Lateral groundwater flow direction data are not available, but the flow is assumed to be toward the Elbow River within the LAA (Borneuf 1980). Groundwater levels have been measured at different times since the 1970s, but these cannot be used for interpreting groundwater flow directions as they change seasonally and are affected by pumping.

Vertical flow is influenced by recharge and the conductivity of geological units. Borneuf (1980) reported that non-pumping water levels in bedrock are deep (typically between 20 m and 30 m below ground surface), while there is typically no water level in the overburden, which suggests rapid downward movement of precipitation (**Figure 6.3-7**). In addition, several boreholes drilled to approximately 20 m in depth near the slope break in Ranger Creek valley (a tributary to the Elbow River) were flowing (artesian), thus indicating vertical upward gradient and groundwater flow at the base of the mountains north of the Elbow River.

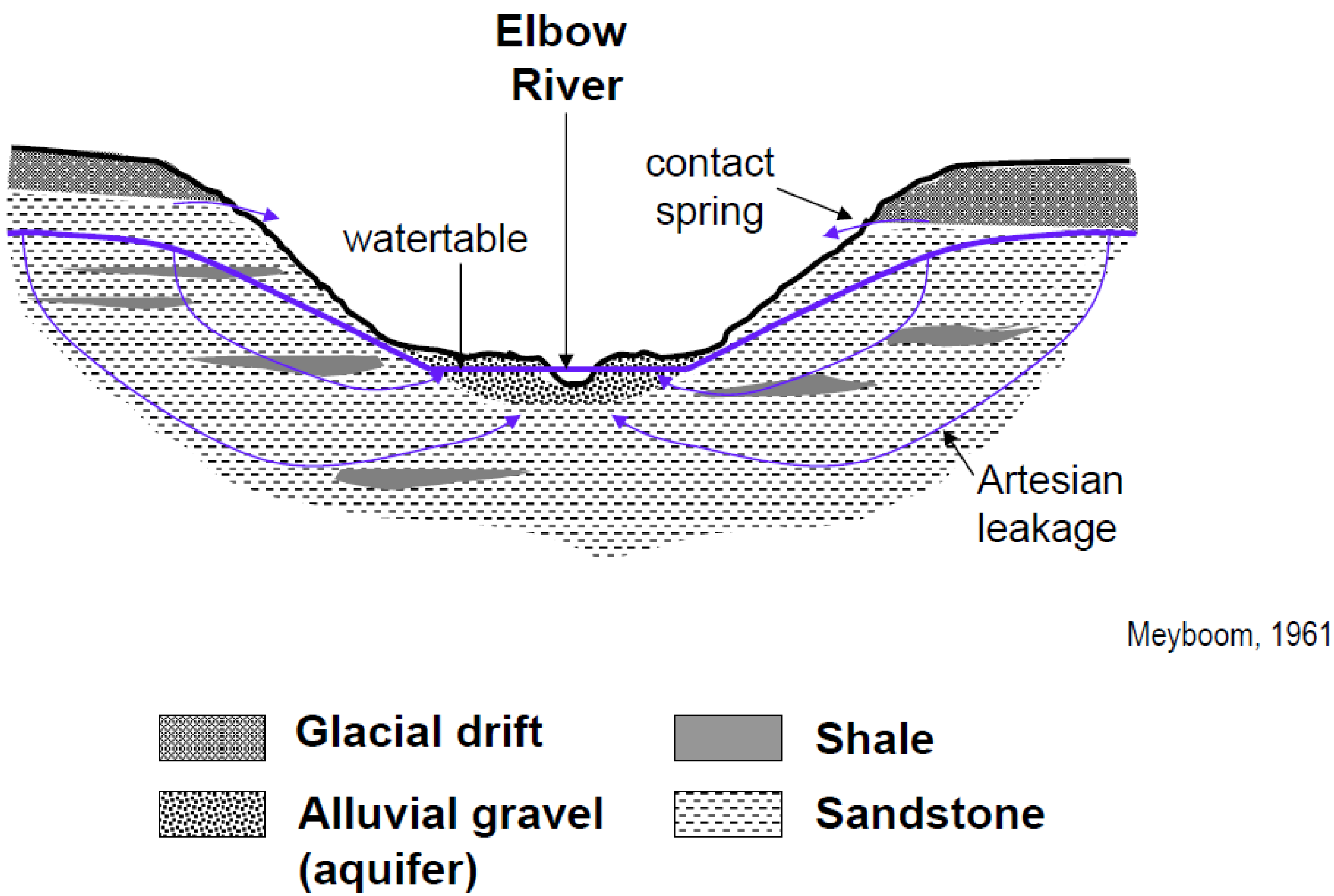

Figure 6.3-7 Groundwater Flow in Proximity of the Elbow River

6.3.2.4 Groundwater Quality

There is limited groundwater quality information from recent years compared to the 1970s and 1980s, when most of the wells were installed in the area. The following is a brief description of groundwater quality in the RAA, based on this information as well as more recent groundwater analyses (e.g. for the Camp Horizon wells - 1020984 and 1020988). Given the generally low level of groundwater use, the groundwater depth and land use in the RAA, the Option study team does not consider that groundwater quality has changed measurably relative to that reported in the literature.

Groundwater quality is generally excellent with concentrations of total dissolved solids typically in the 200 milligrams per litre (mg/L) to 300 mg/L range. Calcium is the predominant cation (30 mg/L to 100 mg/L) with lesser magnesium. Sodium is significant (up to 80 mg/L) in wells that intersect black marine shales. Bicarbonate is the predominant anion (175 mg/L to 472 mg/L) with sulfate typically present in concentrations ranging from 10 mg/L to 30 mg/L. Chloride concentrations are low, typically less than 10 mg/L. These concentrations do not affect taste; however, the groundwater is typically hard and can result in mineral precipitates in appliances and pipes. The groundwater is also sub-alkaline (pH 7.4 to 8.5), whereas surface water pH is more alkaline (i.e., pH 8 to 8.4). Nutrient concentrations (potassium, nitrogen, and phosphorus) are generally low and bacteriological parameters are generally below detection limits; however, septic systems on the alluvial aquifer in the Hamlet of Bragg Creek (downstream of the proposed Option) have reportedly contaminated the groundwater with over 50% of resident's water wells reporting total coliform bacteria (an indicator of pathogens), making the water potentially unsafe to drink (Elbow River Watershed Partnership 2008). Since the alluvial aquifer is vulnerable to contamination, various land uses (and waste disposal) can contaminate groundwater that eventually flows into the Elbow River, and may deteriorate river water quality.

6.3.2.5 Groundwater Use

The RAA is sparsely populated and most wells are owned by Alberta Environment and Parks (formerly Alberta Parks, Recreation and Tourism; and Alberta Forestry), and a small number of private recreational facilities. Records are available for twenty-seven wells within the RAA (**Table 6.3-5**). Water well drilling reports are provided in AMEC's 2015 report. Four artesian wells (also referred to as flowing shot holes) were reported in the Alberta Water Well database, but have not been included in **Table 6.3-5** because they were not developed as wells. Most of the wells are classified for domestic use. The locations of water wells in the RAA are indicated in **Table 6.3-5.**

Table 6.3-5 Water Supply Wells in the Regional Assessment Area

Well ID	Completion Date	Depth (m)	Use	Owner	Aquifer	Lithology	Static Water Level (mtoc)	Test Rate (L/min)	Test Rate (L/s)	Hydraulic Conductivity (m/s)	Transmissivity (m^2/d)
349116	1995-10-13	24.38	Domestic	Elbow Valley Campgrounds #2824	Bedrock	Shale	3.51	18.18	0.30	1.3E-05	14
349546	1983-07-25	21.95	Municipal	Alta Parks & Rec	Bedrock	Shale	4.57	68.19	1.14	NM	NM
350010	1997-08-21	60.96	Unknown	Kananaskis Country	Bedrock	Shale	41.15	0.45	0.01	NM	NM
357651	1991-02-27	54.86	Domestic	Camp Horizon	Bedrock	Sandstone	21.64	54.55	0.91	NM	NM
376643	1982-03-12	27.43	Domestic	Alta Env #Well 1	Bedrock	Sandstone & Shale	14.42	13.64	0.23	NM	NM
376658	1979-09-13	30.48	Domestic	Alta Env #Well 3	Bedrock	Sandstone	3.08	22.73	0.38	2.2E-05	44
376659	1979-09-14	36.58	Domestic	Alta Parks & Rec #Well 4	Bedrock	Sandstone	1.65	18.18	0.30	2.3E-05	32
376660	1979-09-12	35.05	Domestic	Alta Parks & Rec #Well 2	Bedrock	Sandstone & Shale	0.00	68.19	1.14	NM	NM
376661	1979-09-11	24.38	Domestic	Alta Parks & Rec #Well 1	Bedrock	Sandstone	1.13	27.28	0.45	1.6E-05	17
404292	1985-03-14	30.48	Domestic	Alta Parks & Rec	Bedrock	Black Sand	12.80	3.41	0.06	NM	NM
404298	1987-09-15	54.86	Domestic	Kinsmen Camp Horizon	Bedrock	Sandstone	26.82	54.55	0.91	NM	NM
404304	1972-08-08	67.06	Unknown	Alta Forest Svc	Bedrock	Shale	42.98	4.55	0.08	4.0E-08	0.2
404322	1972-08-11	31.09	Domestic	Alta Lands & Forests	Bedrock	Sandstone & Shale	28.04	18.18	0.30	NM	NM
404330	1972-08-14	16.76	Domestic	Alta Forest Svc #Well2	Bedrock	Sandstone & shale	13.41	25	0.42	1.1E-05	7
1020984	2005-06-03	54.86	Municipal	Camp Horizon	Bedrock	Sandstone	27.16	27.28	0.45	2.4E-05	21
1020988	2003-05-08	35.05	Municipal	Camp Horizon	Bedrock	Sandstone	22.86	13.64	0.23	2.9E-05	22
2066128	2015-09-28	60.96	Commercial	AB Environment & Parks	Bedrock	Shale		9.09	0.15	NM	NM
2066136	2015-09-25	48.77	Commercial	AB Environment & Parks	Bedrock	Shale		1.14	0.02	NM	NM

Notes: NM = not measured; mtoc - metres below top of casing

Eighteen wells source water from bedrock at depths ranging from 17 m to 67 m. The average yields are approximately 0.5 litres per second (L/s), which is adequate for domestic supply. Nine wells drilled into surficial aquifers range from depths of approximately 5 m to 37 m. Wells installed in surficial aquifers are typically shallow because the water table is near surface and deep drilling is not required to provide adequate supply. For example, Well ID 404301 located in the Elbow River floodplain approximately 500 m upstream of the MC1 dam embankment is only 5.5 m deep but yields 8 L/s because it is completed in permeable sand and gravel alluvium. Borneuf (1980) reported yields in the range of 0.38 L/s to 38 L/s for surficial sands and gravels adjacent to the Elbow River and McLean Creek. Groundwater withdrawn from alluvial aquifer is surface water and is licensed as such by Alberta Environment and Parks under the Alberta *Water Act*, RSA 2000, c. W-3. There are five groundwater licences in the area (**Table 6.3-6**), but only three groundwater licences are within the RAA (**Figure 6.3-1**). The licences are not referenced to a Well ID but can be cross-referenced in the figures and tables in this section.

Table 6.3-6 Groundwater Licences in the Regional Assessment Area

Approval ID	Priority	Licensee	Point of Diversion	Volume (m^3)	Diversion Rate (m^3/d)	Purpose
26458	1989-11-08-003	Bow Forest Area	16-25-022-06-5	4,536	32.73	Municipal
220755	2005-05-26-001	Alberta Infrastructure, Calgary	SE-33-022-05-5	4,920	13.5	Other Purpose Specified by the Director
31474	1980-06-06-002 1980-06-06-003	Alberta Tourism, Parks and Recreation	05-30-022-05-5	1,230	163.66	Recreation
198910	2003-07-09-001	Easter Seals Camp Horizon	NE-29-022-05-5	4,000	20.5	Recreation
234970	1989-11-08-003	Alberta Tourism, Parks and Recreation	SW-30-022-05-5	3,690	54.64	Recreation

6.3.2.6 Summary of Baseline Case

The Hydrogeology Baseline was compiled from the data sources listed in **Section 6.3.1.2**. The MC1 Option is located within the Montane Sub-region of the Rocky Mountain Natural Region of Alberta, which is characterized by mountains and foothills separated by deep glacial valleys. Low-yielding bedrock aquifers are more commonly used than surficial aquifers associated with the Elbow River and tributaries in the RAA. Groundwater use is considered low and probably seasonal because of summer occupancy in many of the facilities in the area (i.e. tourism and camps). There is no evidence of anthropogenic effects on Groundwater Quantity or quality within the RAA. Locally, pumping may cause drawdown in aquifers around extraction wells; however, these effects are unlikely to propagate far in the aquifer. Well records indicate that some wells were deepened, possibly because of limited available drawdown; however, overall usage is considered low compared to the groundwater resource. The limited time-series data show that groundwater levels recover annually after the spring freshet. While there is limited recent analytical groundwater information, it is unlikely that Groundwater Quality is being affected from current land uses. Locally, poor well completions and inadequate maintenance of septic systems can contaminate groundwater (e.g. as reported in the hamlet of Bragg Creek by the Elbow River Watershed Partnership 2008).

6.3.3 APPLICATION CASE

The Application Case describes the potential effects of the MC1 Option added to Baseline Case (i.e., assesses potential MC1-related effects). The following sections present the potential MC1 Option interactions, effects, and mitigation measures, along with an assessment of residual effects.

6.3.3.1 Potential MC1 Option Interactions

The purpose of this section is to focus the assessment on those interactions of greatest potential consequence to groundwater. To support this, the potential for interactions between Option activities and Groundwater Quantity and Groundwater Quality were reviewed and identified in an Option interaction table as presented in **Table 6.3-7**. The table identifies potential Option interactions with Hydrogeology, and potential effects from each interaction.

Table 6.3-7 Identification of Potential Option Interactions with Hydrogeology

Phase	Activity	Groundwater Quantity		Groundwater Quality	
		Interaction	Potential Effect	Interaction	Potential Effect
Construction	Clearing	X	Increases infiltration and groundwater recharge	X	Increased nutrient (nitrogen, potassium, phosphorus, and organics) loading; methyl-mercury
	Road construction	-	-	-	-
	Decommissioning and removal of existing provincial parks infrastructure and ranger station	-	-	-	-
	Dam and embankment construction	X	Cuts off groundwater flow in Elbow River alluvial aquifer and underling aquifers	-	-
	Spillway construction	-	-	-	-
	Rock groin and diversion tunnels construction	-	-	-	-
	Laydown areas construction and use	-	-	-	-
	Stockpile development and use	-	-	-	-
	Borrow and spoil areas development and use	X	Excavation for borrow dewater aquifer close to these areas	X	Excavation for borrow may increase vulnerability of aquifer to surface contamination
	Realignment of McLean Creek and other small waterbodies	-	-	-	-
	Realignment of Highway 66	-	-	-	-
	Storage of water in permanent pond	X	Recharges groundwater in proximity of pond	-	-
	Reclamation	-	-	-	-
Operations and Maintenance	Routine and Flood Operations and Maintenance	X	Flood conditions would increase groundwater recharge in aquifers beneath flood footprint	X	Aquifers within the 100-year flood footprint could be contaminated if existing wells are not sealed

Note: X – potential interaction; '-' – no interaction

During the Construction phase, clearing of the site would locally increase infiltration and groundwater recharge. Groundwater Quality may also be affected if there is inadequate management of stripped materials. The foundations of the dam and embankment are designed to be impervious, and construction of these components would involve removal of granular and other loose material and replacement with engineered materials. The bedrock beneath the dam and embankment would be grouted to seal fractures and joints that can transmit water. During the Construction phase, these measures would effectively cut off groundwater flow in the Elbow River alluvial aquifer as well as in underlying bedrock aquifers that have been grouted.

During flood events in the Operation and Maintenance phase, flood waters would potentially recharge aquifers in the flood footprint until the water levels recede. Groundwater Quality would accordingly be influenced by flood water quality. During normal operation and maintenance, the dam embankment would continue to cut off groundwater flow in the alluvial aquifer immediately downstream of the dam. This cut-off flow may reduce groundwater level in the alluvial aquifer for some distance downstream of the dam and affect Groundwater Quality since groundwater inputs from bedrock aquifers to the alluvial aquifer likely predominate in this area. Bedrock aquifers tend to have harder water (higher calcium, magnesium, and bicarbonate) than shallow, surface-influenced groundwater. Water wells within the probable maximum flood (PMF) footprint are likely to be damaged under flood conditions, and surface water (potentially pathogen-containing) may enter and contaminate aquifers; such wells would therefore need to be decommissioned.

6.3.3.2 Potential MC1-related Effects

This section considers potential adverse MC1-related effects on Groundwater Quantity and Quality arising from potential Option interactions, as identified in **Table 6.3-8**, and in relation to the measurable parameters listed in **Table 6.3-3**. Mitigation measures for each potential effect are described in **Section 6.3.3.3.**

Groundwater Quantity

Local Dewatering in Borrow areas - diversion of groundwater may be required to allow safe excavation of granular material. The diversion can dewater the surrounding aquifer affecting Groundwater Quantity.

Groundwater Flow Reduction Downstream of the Dam - removal of the sand and gravel aquifer materials in the bed of the Elbow Creek and replacement with impervious fill material (and grout curtain) would cut-off groundwater flow through the aquifers and reduce Groundwater Quantity downstream of the embankment.

Loss of Groundwater Supply Wells - all supply wells within the flood footprint are vulnerable to damage from floodwaters in the reservoir. These wells would need to be decommissioned to prevent possible aquifer contamination from floodwater.

Land Saturation Leading to Increased Groundwater Elevation – land saturation in proximity to the permanent pond would result in a permanent increase in Groundwater Quantity, and may result in a temporary increase in Groundwater Quantity beneath the full flood footprint.

Groundwater Quality

***Clearing of vegetation and topsoil during Construction Activities* –** vegetation and topsoil removal may affect Groundwater Quality without appropriate handling practices. Decaying vegetation leaches nutrients to groundwater, and there is risk of methylmercury mobility (see **Section 5.5 Water Quality**). This effect is less likely in the dam and embankment areas as they are temporarily exposed compared to borrow pits that may remain operational for longer periods

Deterioration from Improperly Decommissioned or Not Decommissioned Wells - there is risk of contamination entering aquifers in supply wells that have not been identified (in the Alberta Water Well Database) and that may not have been properly decommissioned. There are approximately 10 wells indicated in the reservoir boundary (Government of Alberta 2017).

6.3.3.3 Mitigation Measures

Mitigation measures comprise any practical means that can be taken to manage potential adverse effects, and may include adherence to applicable standards and guidelines as well as application of best management practices (BMPs) supported by specific guidance documents. In accordance with Alberta Transportation standard practice, BMPs and standard mitigation measures, including those outlined below to address potential effects to Hydrogeology, would be included in the Environmental Construction Operations (ECO) Plan that would be developed by the contractor and reviewed by Alberta Transportation prior to the start of construction.

Mitigation measures to address potential adverse effects discussed in **Section 6.3.3.2** are described below and summarized in **Table 6.3-8.** The final column in the table identifies whether there is the potential for a residual effect.

Soil Salvage and Reclamation and Revegetation Measures

Cleared overburden material would be stockpiled and saved for reclamation. Progressive reclamation of areas (e.g., borrow areas) would occur as soon as feasible after clearing activities are complete. These mitigation measures are considered to be effective, and would prevent measurable residual effects to groundwater. More information on these measures is included in **Section 6.2 Terrain and Soils**.

Maintain Flows Downstream of the Dam

Intercepting water, including groundwater, is inherent in dam building. Under normal conditions, the dam would divert surface flow through tunnels that discharge immediately downstream of the dam embankment. The tunnel discharge would mitigate most of the effect of the dam embankment and cut-off wall (grout curtain); however, it cannot completely mitigate the effect because the tunnel discharge is a point flow and not distributed over the extent of the aquifer (i.e., only in the river channel). This mitigation (albeit normal operating practice) is expected to be somewhat effective in replenishing the alluvial aquifer. The effect of the dam embankment on the flow in the alluvial aquifer is anticipated to diminish with distance from the dam embankment, but has not been quantified in this assessment. No other mitigation, to address groundwater flow reduction downstream of the dam is considered feasible or effective.

Decommission Groundwater Wells

Supply wells within the reservoir would require decommissioning under the supervision of a Qualified Professional following Alberta Regulation 205/1998 (section 66) to prevent the risk of groundwater contamination during the Operation and Maintenance phase. Decommissioning would involve removal of all down-holed equipment and casing and closure with a cementitious grout. No residual effects are anticipated following the application.

Table 6.3-8 Summary of Potential Effects and Mitigation Measures for Groundwater

Summary of Potential Effect and Classification	Option Components	Contributing Option Activities	Proposed Mitigation Measure	Detectable / Measurable Residual Effect
Construction Phase				
Clearing vegetation, topsoil, and overburden leading to increased nutrient loading and fuel spill risk. Effect on Groundwater Quality	All disturbance areas, particularly those underlain by granular material (e.g. borrow areas)	Vegetation and topsoil clearing; excavation of aquifer materials; fuel spills	Soil salvage measures Reclamation revegetation measures	No
Borrow area development leading to localized aquifer dewatering. Effect on Groundwater Quantity	Borrow areas	Groundwater diversion (trenching, pumping)	None	No
Dam construction leading to reduced downgradient groundwater flow. Effect on Groundwater Quantity	Dam embankment	Replacement of alluvial aquifer material with low-permeability dam construction materials and bedrock grouting	Maintain flows downstream of the dam	Yes
Operations and Maintenance Phase				
Loss of groundwater supply wells. Effect on Groundwater Quantity	Pre-existing water supply wells	Flood water retention	Provide alternative water source for decommissioned supply wells	No
Aquifer quality deterioration from contamination through unsealed water wells. Effect on Groundwater Quality.	Permanent pond and PMF Footprint	Normal Operations	Decommission groundwater wells	No
Land saturation leading to increased groundwater elevation and terrain instability. Effect on Groundwater Quantity	Permanent pond and PMF Footprint	Operation of the pond at full supply level or higher levels during flood conditions	None	Yes

6.3.3.4 Residual Effects

Residual effects are MC1-related effects on VCs that are considered likely to occur even with the application of mitigation measures. This section describes how the residual effects of the MC1 Option are characterized and summarized for Hydrogeology. The determination of a substantive or non-substantive residual effect is supported by a characterization of such effects which includes consideration of the direction, extent, magnitude, duration, reversibility, and frequency of the effect, and confidence in prediction of the effect.

Two residual effects for hydrogeology are considered:

- Reduced Groundwater Quantity downgradient of the dam embankment
- Increased Groundwater Quantity in proximity of the permanent pond and the flood footprint.

Reduced Groundwater Quantity downgradient of the dam embankment is considered a non-substantive residual effect since mitigation measures would not fully eliminate the effect, but would reduce the magnitude, extent, and duration to such a degree as to avoid substantive effect on the VC (**Table 6.3-9**). Increased Groundwater Quantity in proximity of the permanent pond is considered a positive residual effect as a higher water table may support riparian vegetation surrounding the permanent pond and enhance recreational value. Potential residual effects on terrain stability are discussed here but in **Section 6.2 Terrain and Soils.** The characteristics and ratings of the residual effects are described below.

Residual Effects Characteristics

Residual effects are characterized based on the criteria defined in **Table 6.3-9**. The effect characteristics are assessed in the context of the Hydrogeology discipline.

Table 6.3-9 Residual Effects Characterization Criteria for Hydrogeology

Residual Effect Characteristic	Rating	Definition
Direction	Positive	Net benefit to Hydrogeology.
	Adverse	Net loss to Hydrogeology.
Extent	Local	Confined to the area directly disturbed by Option facilities.
	Sub-regional	Limited to one natural region and within the LAA.
	Regional	Within the RAA.
Magnitude	Negligible	No detectable change in Groundwater Quantity from baseline conditions.
	Minor	Detectable Groundwater Quantity change but remains protective of aquatic life / drinking water standards or causes small resource change (<15%).
	Moderate	Causes a moderate Groundwater Quantity change (15% - 35%).
	Major	Causes a major Groundwater Quantity loss that cannot be readily replaced.
Duration	Short-term	Effect would occur during Construction or from seasonal changes (e.g. freshet).

Residual Effect Characteristic	Rating	Definition
	Long-term	Permanent effect.
Reversibility	Reversible	Effect could be reversed once the activity causing the residual effect ceases.
	Not reversible	Effect would be permanent.
Frequency	Isolated	Effect would occur during periods of drought or abnormal climatic conditions.
	Rare	Effect would occur several times a year during normal climatic conditions.
	Frequent	Effect would occur regularly throughout the year.
Confidence	High	Rating predictions are based on a good understanding of cause-effect relationships and/or using data specific to the MC1 Option area.
	Moderate	Rating predictions are based on a good understanding of cause-effect relationships relying on data from elsewhere, or incomplete understanding of cause-effect relationships from data specific to the Option.
	Low	Rating predictions are based on an incomplete understanding of cause-effect relationships and incomplete data.

Reduced Groundwater Quantity Downstream of Dam Embankment

Removal of the alluvial material and grouting of surficial and bedrock beneath the dam footprint would cut off groundwater flow downstream of the dam embankment. This would be mitigated by release of surface water from the permanent pond via the low-level outlet tunnels; however, the release would be a point source and is unlikely to recharge groundwater across the width of the alluvial aquifer immediately downstream of the dam embankment. The surface water discharge is therefore unlikely to completely mitigate the effect of the dam embankment on Groundwater Quantity. The extent of the effect would likely be limited to the AOI (included in the LAA) immediately downstream of the dam because the point-source flow from the diversion tunnel would likely spread out within the alluvial aquifer relatively quickly after discharge from the tunnel outlet. Other surface and groundwater inputs would likely re-establish normal flow patterns and surface water / groundwater interaction several kilometres from the dam. Therefore, the residual effects are considered non-substantive and **Table 6.3-10** identifies the rating and rationale assigned to each residual effect characteristic.

Table 6.3-10 Summary of Effect Characteristics Ratings for Reduced Groundwater Quantity Downstream of Dam Embankment

Residual Effect Characteristic	Rating	Rationale for Rating
Direction	Adverse	Removal of alluvial material and grouting of foundation would cut-off groundwater flow.
Extent	Sub-regional	Not likely to extend beyond the alluvial channel outside of the RAA.
Magnitude	Moderate	Moderate loss of the resource immediately downstream of the embankment.
Duration	Long-term	Would be the case with the dam in place.
Reversibility	Not reversible	Would not be reversed since the dam is considered in perpetuity.
Frequency	Frequent	Ongoing effect from dam and management.
Confidence	High	Prediction based on well-understood cause-effect relationship.

Increased Groundwater Quantity from Permanent Pond

The permanent pond would raise surface water elevation by up to 15 m from the current Elbow River elevation near the outlet tunnels from approximately 1,380 m to 1,395 m, the Full Supply Level. The higher-water elevation would cause flow into aquifers beneath and adjacent to the permanent pond, which would result in greater aquifer saturated thickness and transmissivity (**Table 6.3-11)**.

Table 6.3-11 Summary of Effect Characteristics Ratings for Increased Groundwater Quantity from Permanent Pond

Residual Effect Characteristic	Rating	Rationale for Rating
Direction	Positive	Increase aquifer transmissivity
Extent	Sub-regional	Unlikely to have measurable effect beyond the LAA
Magnitude	Minor	Considered to increase saturated aquifer thickness by less than 10 m
Duration	Long-term	In effect when dam is operated per current design
Reversibility	Reversible	Could be changed if the permanent pond is operated at lower level
Frequency	Frequent	Occurs throughout the year
Confidence	High	Prediction based on cause-effect relationship

6.3.3.5 Summary of Hydrogeology Assessment

The MC1 Option would likely result in two potential residual effects to Groundwater Quantity**:** an adverse residual effect to due to reduced groundwater quantity downstream of the dam embankment, and a positive residual effect due to increased groundwater quantity from the permanent pond**.** The residual adverse effect is likely to be not substantive because constant release of surface water to the Elbow River downgradient of the MC1 dam is predicted. The positive residual effect is also likely to be non-substantive because of the minor nature of the effect.

6.3.4 FOLLOW-UP MONITORING FOR HYDROGEOLOGY

Groundwater quantity effects would be anticipated immediately downstream of the dam embankment. However, there are no water wells in the alluvial aquifer within the LAA. The closest supply well in the alluvial aquifer is approximately 3.5 km downstream of the dam embankment (Well ID 404306 - Depth 13.41 m; Owner Alberta Forestry, Well2; lithology gravel; static water level 5.85 m) and is not expected to be affected. Therefore, no monitoring is proposed.

6.3.4.1 Groundwater Well Decommissioning

The following wells (**Figure 6.3-2** and **Figure 6.3-5)** would need to be decommissioned during the Construction phase and signed off by a Qualified Professional (**Table 6.3-12**):

Table 6.3-12 Groundwater Wells that Require Decommissioning during the Construction Phase

Well ID	Depth (m)	Owner
350010	60.96	Kananaskis Country
404304	67.06	Alta Forest Svc
404330	16.76	Alta Forest Svc #Well2
2066128	60.96	AB Environment & Parks
2066136	48.77	AB Environment & Parks
349543	13.72	Alta Parks & Rec
350009	36.58	Kananaskis Country#3259
351975	36.58	Station Flats
404300	5.49	Alta Parks & Rec
404301	5.49	Whissel Ent
404335	6.10	Chevron Standard #Rig Well
2066155	10.67	AB Environment & Parks

The flood footprint area should also be inspected for water wells and other boreholes (e.g., oil and gas exploration wells) not identified in the Alberta Water Well Database.

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6.4 Fluvial Geomorphology

This section describes effects to Fluvial Geomorphology from the proposed Elbow River at McLean Creek Dam (MC1) Option (MC1, Option, or MC1 Option). For the purposes of this assessment, Fluvial Geomorphology is defined as sediment transport and river channel shape.

The assessments presented in this section are linked to the assessments presented in the following sections:

- Section 6.2 Terrain and Soils
- Section 6.3 Hydrogeology
- Section 6.5 Water Quality
- Section 7.1 Vegetation and Wetlands
- Section 7.2 Wildlife and Wildlife Habitat
- Section 7.3 Aquatic Environment

6.4.1 Scope of Assessment

This section reviews the scope of the assessment for Fluvial Geomorphology Valued Component (VC), and includes the regulatory framework, data sources, VCs, measurable parameters, and assessment boundaries relevant for Fluvial Geomorphology.

6.4.1.1 Regulatory Framework

Changes to Fluvial Geomorphology must be considered as part of other legislative requirements (e.g., the federal *Fisheries Act*, RSC 1985, c. F-14). Other legislative requirements are included in the effects assessments of the VCs identified for the MC1 Option (e.g., Aquatic Environment).

6.4.1.2 Data Sources

Data sources for the assessment of Fluvial Geomorphology include MC1-specific data and government databases, as well as scientific literature such as journal publications and white papers. The Option study team reviewed the following data sources:

- South Saskatchewan Regional Plan: 2014 – 2024 (Government of Alberta 2014)
- Elbow River Basin Water Management Plan (Elbow River Watershed Partnership 2009)
- McLean Creek (MC1) Dam: Updated Conceptual Design Report – Final Vol 1 of 2 (Opus 2017a)
- McLean Creek (MC1) Dam: Updated Conceptual Design Report – Final Vol 1 of 2 (Opus 2017b)
- Elbow River – Fluvial Geomorphology Assessment (BGC 2017)

6.4.1.3 Valued Components

Fluvial Geomorphology may interact directly with MC1-related activities (e.g., dam and embankment construction, outlet structure construction). Changes to river flow and sediment transport may affect other VCs, including Fish and Fish Habitat (**Table 6.4-1)**.

Table 6.4-1 Valued Components for Fluvial Geomorphology

Valued Components	Interaction
Fluvial Geomorphology	Construction of the dam and impoundment of water would cause sediment to settle out in the reservoir and lead to increased erosion downstream of the dam until the sediment balance is restored (i.e., sediment supply matches transport capacity). Changes to sediment transport may affect other VCs, including fish.

6.4.1.4 Measurable Parameters

Measurable parameters are quantitative or qualitative measures used to describe existing conditions and trends and evaluate potential MC1-related effects to identified VCs. The measurable parameters selected for the Fluvial Geomorphology VC are shown in **Table 6.4-2**. Potential adverse MC1-related effects to geomorphology arising from potential interactions are discussed in more detail in **Section 6.4.3**.

Table 6.4-2 Measurable Parameters for Fluvial Geomorphology

Selected Valued Component	Potential MC1-related Effect	Measurable Parameter
Fluvial Geomorphology	Accumulation of sediment in the reservoir	Volume of sediment (m^3)
	Change in the Elbow River channel	Channel form

6.4.1.5 Assessment Boundaries

This section presents the assessment boundaries for the Fluvial Geomorphology VC, including spatial, temporal, administrative, and technical.

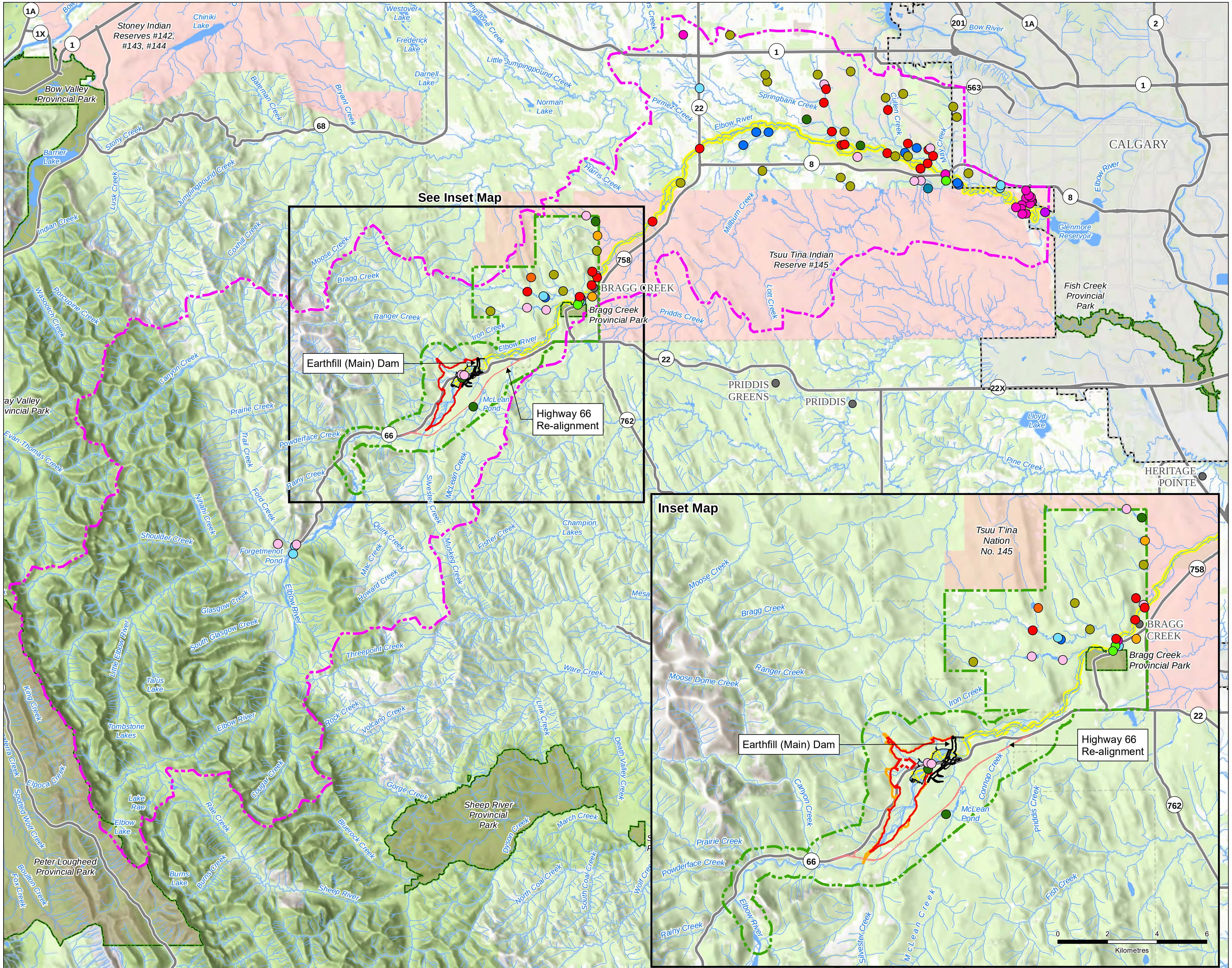
Spatial Boundaries

Spatial boundaries for the assessment of geomorphology are described in **Table 6.4-3** and shown on **Figure 6.4-1**.

The Local Assessment Area (LAA) encompasses the maximum geographical area where the Option is expected to interact with and potentially have a direct or indirect effect on Surface Water. The point where the Elbow River enters the Glenmore Reservoir (approximately 52 km downstream of the Option) was selected as the downstream extent of the LAA for Fluvial Geomorphology VC because, as is currently the case, the existing reservoir would cause sediment to settle out. The Regional Assessment Area (RAA), which encompasses the LAA, is established to provide a regional context for the assessment of MC1-related effects. The RAA also encompasses the area where the residual effects of the Option are likely to interact with the residual effects of other past, present, or future projects or activities to result in a cumulative effect or effects.

Table 6.4-3 Spatial Boundary Definitions for Fluvial Geomorphology

Spatial Boundary	Description of Assessment Area
MC1 Option area	Area directly affected by the proposed works, related relocations and new constructions, a buffer area and the reservoir.
Local Assessment Area	The Elbow River from the MC1 Reservoir downstream to where the Elbow River enters the Glenmore Reservoir
Regional Assessment Area	The Elbow River watershed to where the Elbow River enters the Glenmore Reservoir



Elbow River at McLean Creek Dam (MC1)

Fluvial Geomorphology
Local Assessment Area
and Regional Assessment Area

Legend

- Surface Water Local Assessment Area
- Surface Water Regional Assessment Area
- Land Use and Management and Infrastructure Regional Assessment Area
- 2013 Flood Event (1,424.5 m)
- MC1 Dam
- Highway 66 Re-alignment
- Permanent Pond
- Hamlet
- Highway
- First Nations Reserve
- Provincial Park
- Urban Area
- Watercourse
- Waterbody

Surface Water Diversion Locations

Purpose

- Agricultural
- Commercial
- Construction & Transportation
- Dewatering
- Government Hold Back
- Habitat Enhancement
- Industrial
- Irrigation
- Management of Fish
- Municipal
- Recreation
- Water Management

Notes

1. This map is not intended to be a "stand-alone" document, but a visual aid of the information contained within the referenced Report. It is intended to be used in conjunction with the scope of services and limitations described therein.

Sources

- Basedata: Government of Alberta
- Diversion Locations: Alberta Environment, 2017
- Dam and flood details: Opus International Consultants Limited, 2017
- Borrow Areas: Hatch Ltd., 2017
- Background Image: ESRI World Topographic Map
- Inset Maps: ESRI World Topographic Map

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Temporal Boundaries

The temporal boundaries of the MC1 Option consist of the Construction phase as well as the Operation and Maintenance phases of the Option, which are described in **Section 3.0 MC1 Option Description**.

Peak flows in the Elbow River commonly occur from mid-May through to mid-July, which coincides with the timing of the highest precipitation, as well as the spring snowmelt (Opus 2017b). Sediment transport and channel-forming events occur during periods of elevated streamflow; these events are the focus of the assessment.

Administrative Boundaries

No administrative boundaries (e.g., political, economic, or social issues, as well as fiscal or other resourcing issues that constrain the assessment of potential effects of the Option) were identified for the assessment of potential MC1-related effects on Surface Water.

Technical Boundaries

Technical boundaries for the assessment of effects on Fluvial Geomorphology are discussed in Opus 2017a and Opus 2017b.

6.4.2 Baseline Case

The Baseline Case for the Surface Water assessment is presented for the RAA and LAA using data compiled from the sources listed in **Section 6.4.1.2**. Specifically, this section is a summary of information presented in Opus 2017a and 2017b.

The headwaters of the Elbow River begin outside of Peter Lougheed Provincial Park, approximately 70 kilometres (km) southwest of Calgary. The Elbow River flows 90 km northeast before entering the Glenmore Reservoir (**Figure 6.4-1**). The Elbow River is unregulated upstream of the Glenmore Reservoir, and receives flow from four main tributaries: Little Elbow River, McLean Creek, Bragg Creek, and Lott Creek. The Little Elbow River is the largest tributary, and drains the northwestern portion of the watershed.

The total watershed area upstream of Glenmore Reservoir (and the city of Calgary) is 1,217 square kilometres (km^2). The MC1 Option area is located immediately upstream of the McLean Creek confluence, approximately 40 km west of Calgary, and has a watershed area of 702 km^2 (BGC 2017).

The Elbow River is a low-order braided system in the vicinity of the MC1 dam site. This channel pattern is characterized by frequent unvegetated mid-channel bars that divide the channel into multiple flow paths (channels). Braiding generally occurs in relatively steep environments with high sediment supply, and is commonly observed in unconfined sections of mountain streams, particularly downstream of glaciated terrain. The Elbow River exhibits a braided pattern in unconfined reaches, and a single-thread (single channel) pattern where the river is confined by less erodible channel banks (e.g., bedrock) (BGC 2017).

Early work by Henderson (1963) and others showed that braided rivers can be differentiated from single-thread rivers based on their gradient, discharge, and grain size. The Elbow River exceeds the threshold for braiding described in Henderson (1963). Later work by Desloges and Church (1989) identified a transitional channel pattern called wandering. Wandering gravel-bed channels contain alternating single-thread and multi-thread reaches. According to Eaton et al. (2010), the Elbow River lies near the wandering-braiding threshold. The unconfined reaches are therefore best described as exhibiting low-order braiding, with a pattern that is transitional between braided and wandering. Confined reaches display a moderate sinuosity channel pattern (BGC 2017).

Glaciation has created an unconventional pattern of watershed sediment routing in many rivers throughout Canada. Sediment is supplied primarily by thick valley fills of glacial sediment, and the unit sediment yield increases with distance downstream throughout much of the country (Ashmore 1993; Church and Slaymaker 1989; Church et al. 1998). Stream incision into glacial deposits is an ongoing process and is likely to continue for 100,000 years or more (Ashmore 1993).

There are some notable landforms in the Elbow River watershed that influence sediment availability and transport, including a large landslide south of the Beaver Flats campground. Because the landslide deposit is visible on both sides of Elbow River, it is assumed that the event dammed Elbow River and eventually led to an outbreak flood. The landslide dam height is estimated to have been 25 metres (m) to 30 m, and may have occurred within the last 1,000 years. The landslide feature is of importance for two reasons. First, the landslide deposit is experiencing ongoing erosion, which provides an active sediment source relatively close to the Option reservoir. Second, southeast of the failure slope a large portion of the rock slope in presumably a similar geologic setting has not yet failed. If the slope were to fail, it could create another landslide dam, like the dam created by the original failure. The impoundment would likely fill with water and eventually breach the landslide dam. Such a failure could substantially exceed the peak flow estimates for hydrological floods. The landslide dam outbreak flood would also induce dramatic channel changes downstream of the landslide dam.

6.4.3 APPLICATION CASE

The Application Case describes the effects of the MC1 Option added to Baseline Case (i.e., includes an assessment of MC1-related effects). The following sections present the potential MC1-related interactions, effects, and mitigation measures, along with an assessment of residual effects.

6.4.3.1 *Potential Option Interactions*

Potential MC1-related interactions with Fluvial Geomorphology, and potential effects from each interaction are presented in **Table 6.4-4**. Sediment retention and the associated changes to downstream channel morphology would be expected to commence once the cofferdam is constructed.

Table 6.4-4 Identification of Potential Option Interactions with Fluvial Geomorphology

Phase	Activity	Fluvial Geomorphology	
		Interaction	Potential Effect
Construction	Clearing	-	-
	Road construction	X	Change in channel morphology
	Decommissioning and removal of existing provincial parks infrastructure and ranger station	-	-
	Dam (cofferdam and earth fill) construction	X	Sediment retention in the reservoir Change in channel morphology
	Spillway construction	-	-
	Rock groin and diversion tunnels construction	-	-
	Laydown areas construction and use	-	-
	Stockpile development and use	-	-
	Borrow and spoil areas development and use	-	-
	Realignment of McLean Creek and other small waterbodies	X	Change in channel morphology (McLean Creek)
	Realignment of Highway 66	X	Change in channel morphology
	Storage of water in permanent pond	X	Sediment retention in the reservoir Change in channel morphology
	Reclamation	-	-
Operation and Maintenance	Routine and Flood Operation and Maintenance	X	Sediment retention in the reservoir Change in channel morphology

Note: X – potential interaction; ‘- ‘– no interaction

6.4.3.2 *Potential MC1-related Effects*

This section considers potential adverse MC1-related effects on VCs arising from potential interactions, as identified in **Table 6.4-4**, and in relation to the measurable parameters listed in **Table 6.4-2**. Mitigation measures for each potential effect are described in **Section 6.4.3.3**.

Sediment Retention in the Permanent Pond

Following impoundment of the Elbow River, sediment would accumulate at the upstream end of the permanent pond due to the associated decrease in water velocity. Sediment accumulation is highly variable year to year and is associated with high flows. Air photo analysis of the Glenmore Reservoir, located on the Elbow River approximately 52 km downstream from the MC1 Dam, shows that the delta has prograded (grown) at a rate of 6.3 m per year (m/year) to 8.4 m/year since 1976, and previous sediment sampling shows that the delta accumulation is primarily related to the suspended sediment yield (BGC 2017). A similar pattern is expected at the MC1 dam site, with the delta at the upstream end of the permanent pond prograding (growing) as suspended sediment settles out and bedload transport stops due to the reduced velocities associated with the permanent pond.

BGC (2017) estimated the expected sediment retention in the permanent pond based on channel characteristics of the Elbow River upstream of the MC1 Option area. This analysis considered both the sources of sediment upstream of the MC1 site, which dictate the volume of sediment stored in the upstream channel, and the rate at which sediment is transported from the upper reaches to the MC1 dam site. Additional information regarding the analysis, along with case studies, is presented in BGC's Fluvial Geomorphology Assessment (2017).

BGC (2017) assessed upstream sedimentation through an analysis of both sediment sources and suspended and bedload yields. Sediment is supplied to the Elbow River by hillslope failures, tributaries, and bank and island erosion, and routed downstream by the flow. Several tributaries also deliver substantial volumes of sediment to the Elbow River upstream of the MC1 dam site, including the Little Elbow River, Powderface Creek, Prairie Creek, and Canyon Creek. At the MC1 dam site, BGC (2017) estimated a suspended sediment yield of 11,200 tonnes per year (9,300 m^3) using a sediment rating curve developed with Elbow River suspended sediment data from 1969 to 1975, applied over a 35-year period prior to 2013. However, the yield is highly variable over time, and the estimated suspended sediment yield during the 2013 flood was 958,000 tonnes, with more than 715,000 tonnes delivered in a single day.

BGC (2017) also modelled bedload transport in a reach located upstream of the proposed MC1 permanent pond, and developed a bedload rating curve to estimate annual bedload yield. Using a transport equation developed by Wilcock (2001), BGC estimates that an average of 19,400 tonnes to 77,000 tonnes (9,240 m^3/year to 36,700 m^3/year) of bedload may be delivered to the channel upstream of the permanent pond annually. As with the suspended sediment yield, bedload yield is highly variable from year to year; BGC estimates that 350,700 tonnes to 700,600 tonnes of sediment were transported through the reach from late May 2013 to early July 2013.

Changes to Channel Morphology

Construction of the MC1 dam would result in both a decrease in downstream peak flows and a decrease in the sediment supply. There are several common changes to channel morphology from the damming of braided rivers, including:

- Degradation (i.e., channel incision)
- Channel narrowing
- Coarsening of bed material
- Pattern simplification (e.g., loss of off-channel habitat, loss of multiple channels)
- Aggradation (i.e., increase in bed elevation due to deposition of sediment) and possible widening at tributary junctions.

The effects to channel morphology downstream of the dam are typically spatially and temporally complex. For example, a river may experience degradation, narrowing, and coarsening near the dam as a result of the imbalance between sediment supply and transport capacity, while experiencing aggradation of fine material and channel widening at a tributary junction, where supply locally exceeds the transport capacity (BGC 2017).

Generally speaking, geomorphic effects as a result of dam construction have been shown to extend for several hundreds of km downstream of the structure (e.g., due to construction of the Flaming Gorge Dam on the Green River (Andrews 1986)). The impacts of the dam may therefore occur throughout the 52-km segment between the MC1 Dam and the Glenmore Reservoir. The direction and magnitude of downstream adjustment would primarily depend on two factors: the sediment supply provided by downstream tributaries and other point sources of sediment, and the change in the frequency of flows capable of mobilizing bed material. No major sediment-bearing tributaries enter the Elbow River in the 52-km segment between the proposed MC1 Dam and the Glenmore Reservoir. As a result, it is anticipated that this entire segment may be subject to a sediment imbalance, and could experience changes to the channel morphology due to the reduction in sediment supply. Bank erosion may provide localized point sources of sediment in the downstream segment, though the amount of bank erosion would depend on the regulated flow regime (BGC 2017). Because Glenmore Reservoir is already acting as a sediment sink, MC1-related effects to Fluvial Geomorphology are not likely downstream of this reservoir.

In order to assess the potential for geomorphic adjustment between the MC1 dam site and the Glenmore Reservoir, BGC (2017) developed a simple classification system. The system considers reach sensitivity in terms of both the likelihood of geomorphic change and the proximity of the river to infrastructure. Using this analysis, approximately 1% of the 52-km-long segment is rated as very high sensitivity, 31% is rated high sensitivity, 32% is rated moderate sensitivity, and 36% is rated low sensitivity. Downstream degradation on the Elbow River may undermine riprap along the communities of Bragg Creek and Redwood

Meadows, and may cause instability to the pile foundations or abutment in downstream bridges. Furthermore, glaciolacustrine deposits border much of the channel length between MC1 and the Glenmore Reservoir. Localized erosion and undermining of these weak, fine-grained cohesive sediments may lead to deep-seated slope failures along the channel margins (BGC 2017).

Construction of a new bridge and realignment of McLean Creek and other small waterbodies may also affect channel morphology; however, any effects would be small compared to those associated with the MC1 Dam.

6.4.3.3 Mitigation Measures

Mitigation measures comprise practical means taken to manage potential adverse effects, and may include applicable standards, guidelines, and BMPs supported by specific guidance documents. In accordance with Alberta Transportation standard practice, BMPs and standard mitigation measures would be included in the Environmental Construction Operations (ECO) Plan that would be developed by the contractor and reviewed by Alberta Transportation prior to the start of construction.

Mitigation measures to address potential adverse effects, discussed in **Section 6.4.3.2,** are described below and are summarized in **Table 6.4-5**. The final column in the table identifies whether there is the potential for a residual effect.

Maintain Flow Competence

The magnitude of effects to channel morphology is affected by the amount of time in a given year that flows exceed the threshold for sediment entrainment (the flow competence). Although a reduction in peak flows is the purpose of the MC1 Option, allowing moderate floods to pass the MC1 Dam would reduce potential effects to downstream river morphology.

Sediment Augmentation

Sediment augmentation is a management technique that involves excavating sediment from the prograding delta upstream of a dam and reintroducing it downstream of the dam. This approach can be used to both reduce upstream permanent pond infilling and limit the sediment imbalance downstream. Sediment augmentation is increasingly being used in Japan and China to manage sediment deficits downstream of dams (BGC 2017).

Table 6.4-5 Summary of Potential Effects and Mitigation Measures for Fluvial Geomorphology

Summary of Potential Effect and Classification	Option Components	Contributing Option Activities	Proposed Mitigation Measure	Detectable / Measurable Residual Effect
Construction Phase				
Sediment retention in the reservoir	Dam, permanent pond	Construction of dam and embankment Storage of water in permanent pond	No mitigation proposed – The Construction phase is relatively short-term, and large accumulations of sediment would not be expected.	Yes
Change in channel morphology	Dam, permanent pond	Construction of dam and embankment Storage of water in permanent pond	No mitigation proposed – The Construction phase is relatively short term, and the flow regime would not be changed over the Construction phase.	Yes
Operation and Maintenance Phase				
Sediment retention in the reservoir	Dam, reservoir	Routine and Flood Operation and Maintenance	Sediment Augmentation	Yes
Change in channel morphology	Dam, reservoir	Routine and Flood Operation and Maintenance	Sediment Augmentation Maintain flow competence	Yes

6.4.3.4 Residual Effects

Residual effects are MC1-related effects that are anticipated to occur to VCs after the application of mitigation measures. This section describes how the residual effects of the MC1 Option are characterized and summarized for Fluvial Geomorphology. The determination of a substantive or non-substantive residual effect includes a characterization including magnitude, regional extent, and duration.

Potential MC1-related residual effects are delineated as:

- Non-substantive residual effect – mitigation measures have not fully eliminated the effects, but have reduced the magnitude, extent, or duration to such a degree as to avoid substantive effect on the VC.
- Substantive residual effect – adverse effects are predicted to be high in magnitude, regional in extent, and/or long-term in duration even after implementation of mitigation.

Residual Effects Characteristics

Residual effects are characterized based on the criteria defined in **Table 6.4-6**. The effect characteristics are assessed in the context of the Fluvial Geomorphology discipline.

Table 6.4-6 Residual Effects Characteristics for Fluvial Geomorphology

Residual Effect Characteristic	Rating	Definition
Direction	Positive	Net benefit to Fluvial Geomorphology
	Adverse	Net loss to Fluvial Geomorphology
Extent	Local	Confined to the MC1 Option area
	Sub-regional	Limited to the LAA
	Regional	Within the RAA
Magnitude	Negligible	No detectable change from background
	Minor	Little retention of upstream sediment supply in the permanent pond
	Moderate	Partial retention of upstream sediment supply in the permanent pond
	Major	Majority of upstream sediment supply is retained in the permanent pond
Duration	Short-term	The effect would persist for the duration of the Construction phase.
	Long-term	The effect would persist for the duration of the Operation and Maintenance phase.
Reversibility	Reversible	Effect could be reversed once the activity causing the residual effect ceases.
	Not reversible	Effect would be permanent.
Frequency	Rare	Effect would occur with the 1-in-20-year return period.
	Frequent	Effect would occur with the 1-in-5-year return period.
	Continuous	Effect would occur continuously over the life of the Option.

Residual Effect Characteristic	Rating	Definition
Confidence	High	Rating predictions are based on a good understanding of cause-effect relationships and/or using data specific to the MC1 Option area.
	Moderate	Rating predictions are based on a good understanding of cause-effect relationships relying on data from elsewhere, or incomplete understanding of cause-effect relationships from data specific to MC1.
	Low	Rating predictions are based on an incomplete understanding of cause-effect relationships and incomplete data.

Sediment Retention in the Reservoir

Sediment is expected to accumulate at the upstream end of the reservoir at an average rate of 19,400 tonnes to 77,000 tonnes annually. This accumulation would be mitigated though sediment augmentation, such that the upstream sediment supply is only partially retained at the MC1 dam site. Residual effects of MC1 on sediment retention are adverse, of moderate magnitude, and would occur over a local extent (**Table 6.4-7**). The residual effect would occur for the life of the Option. Residual effects are reversible if the MC1 dam is removed. Because the residual effects would be confined to the MC1 Option area and would be of moderate magnitude, they are not likely to be substantive. This assessment has a high level of confidence.

Table 6.4-7 Summary of Effect Characteristics Ratings for Sediment Retention

Residual Effect Characteristic	Rating	Rationale for Rating
Direction	Adverse	The permanent pond would be expected to partially retain bedload (i.e., retain all sediment that is not transported downstream of the MC1 Dam).
Extent	Local	Effects would be confined to the MC1 Option area.
Magnitude	Moderate	Partial retention of sediment in the permanent pond.
Duration	Long-term	Effects would occur for the duration of the Operation phase.
Reversibility	Reversible	Effect could be reversed once the MC1 dam is removed.
Frequency	Continuous	The effect would be ongoing throughout the life of the MC1 Option.
Confidence	High	Rating predictions are based on a good understanding of cause-effect relationships and using data specific to the MC1 Option area.

Changes to Channel Morphology

Retention of sediment upstream of the dam may cause a sediment deficit downstream, which may result in channel degradation, channel narrowing, coarsening of bed material, pattern simplification, and aggradation at tributary junctions. MC1-related effects would be mitigated though sediment augmentation, such that the upstream sediment supply is only partially retained at the MC1 dam site as well as through maintaining flow competence. Residual effects of the MC1 on channel morphology are adverse, of moderate magnitude, and would occur over a sub-regional extent (**Table 6.4-8**). The residual effect would occur for the life of the Option. Residual effects are considered not reversible because localized erosion could cause slope failures within the LAA. Because the residual effects would occur over the LAA, would be of moderate magnitude, and are not considered reversible, they are likely to be substantive. This assessment has a high level of confidence.

Table 6.4-8 Summary of Effect Characteristics Ratings for Channel Morphology

Residual Effect Characteristic	Rating	Rationale for Rating
Direction	Adverse	Retention of sediment in the permanent pond would cause sediment imbalance downstream.
Extent	Sub-regional	Effect would be limited to the LAA.
Magnitude	Moderate	Sediment supply would be partially cut off.
Duration	Long-term	Effects would occur for the duration of the Operation phase.
Reversibility	Not reversible	Localized erosion could cause slope failures within the LAA.
Frequency	Continuous	The effect would be ongoing throughout the life of the MC1 Option.
Confidence	High	Rating predictions are based on a good understanding of cause-effect relationships and using data specific to the MC1 Option area.

6.4.3.5 Summary of Fluvial Geomorphology Assessment

There is potential for a substantive residual effect to the Fluvial Geomorphology VC. Sediment is expected to accumulate at the upstream end of the permanent pond; this sediment retention would cause a sediment deficit downstream, which may result in changes to channel morphology downstream of MC1, including channel degradation, channel narrowing, coarsening of bed material, pattern simplification, and aggradation at tributary junctions. MC1-related effects to Fluvial Geomorphology would be reduced though sediment augmentation, such that the upstream sediment supply would be only partially retained at the MC1 dam site.

All substantive residual effects are carried forward for consideration in the cumulative effects assessment (**Section 9.0 Planned Development Case**).

6.4.4 Follow-up Monitoring for Fluvial Geomorphology

The majority of the mitigation measures developed to offset potential MC1-related effects to Fluvial Geomorphology would rely largely on engineered solutions. Additional investigations are required as part of the design phase in order to further characterize effects Fluvial Geomorphology. The results of these investigations would feed into detailed design and would refine the mitigation measures proposed.

BGC (2017) recommends a three-part monitoring program to monitor morphologic adjustments associated with the MC1 dam. This monitoring program would inform monitoring of other VCs (e.g., fish) and help understand MC1-related effects to those VCs and whether additional mitigation measures are required. This monitoring program would include:

- A baseline air photo assessment to assess the lateral migration rate and channel pattern throughout the period of air photo record for several tens of km downstream of the dam site; this would enable managers to separate dam impacts from pre-existing trends in channel processes and morphology.
- Repeat aerial surveys for a distance of 10 km downstream of the MC1 dam site during low flow to assess changes in bed topography and texture, including visually inspecting images for obvious changes. Imagery should also be processed using the methods outlined in Tamminga et al. (2015a, b) to map grain size throughout the reach and to produce high-resolution digital elevation models.
- Complete detailed air photo assessments throughout the reach mapped in the baseline air photo assessment at 10-year intervals. The imagery and mapping can be used to monitor long-term, reach-scale changes in channel pattern and lateral mobility downstream of the dam. Air photos could be used to monitor delta progradation as well as changes in the upstream channel reaches resulting from bedload accumulation.

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6.5 WATER QUALITY

This section describes potential effects to Water Quality from the proposed Elbow River at McLean Creek Dam (MC1) Option (MC1, Option, or MC1 Option). Water Quality is defined here as the dissolved and particulate chemical and microbiological attributes of water (temperature, pH, nutrients, algae, bacteria, metals, carbon, pesticides).

The assessment in this section are supported by or linked to the assessments in the following sections:

- Section 6.2 Terrain and Soils
- Section 6.4 Fluvial Geomorphology
- Section 7.1 Vegetation and Wetlands
- Section 7.3 Aquatic Environment
- Section 8.1 Land Use and Management

6.5.1 SCOPE OF ASSESSMENT

This section reviews the scope of the assessment for Water Quality, and includes the relevant regulatory framework, data sources, Valued Components (VCs), measurable parameters and assessment boundaries relevant for Water Quality. The assessment of MC1-related effects on Water Quality relies on information compiled through the review of publicly available literature as well as past and new studies for the MC1 Option.

6.5.1.1 Regulatory Framework

An overview of the regulatory framework and requirements that are relevant to the assessment of potential MC1-related effects to Water Quality is summarized in **Table 6.5-1**.

Table 6.5-1 Summary of Applicable Regulatory and Policy Framework for Water Quality

Name	Jurisdiction	Description
Fisheries Act R.S.C. 1985, c. F-14	Federal	The Fisheries Act contains clauses for fisheries protection and pollution prevention (Sections 34 and 35) and its scope includes “all internal waters of Canada” (Section 2(1)). This scope means the Fisheries Act is in effect in the MC1 Option area and must be considered in the Application Case. The assessment of surface water quality is a pathway of effects to the assessment of fish and fish habitat.
Canada Water Act, R.S.C. 1985, c. C-11	Federal	The Canada Water Act protects freshwater in Canada from hazardous material inputs. Section 9 prohibits the deposition of waste material in or upstream of a water quality management area designated in Sections 11 and 13.
Canadian Environmental Quality Guidelines from the Canadian Council of Ministers of the Environment (CCME)	Federal	The Canadian Council of Ministers of the Environment (CCME) establishes Canadian Environmental Quality Guidelines to provide science-based goals for the quality of aquatic and terrestrial ecosystems. This document outlines the water quality guidelines for the protection of aquatic life in Canada.

Name	Jurisdiction	Description
Water Act, R.S.A. 2000, C. W-3	Provincial	Section 8 of the Water Act relates to the Aquatic Environment Protection Strategy, which establishes guidelines and strategies for protection of the aquatic environment and biological diversity within species and ecosystems while Section 16 and 17 defines terms for the application of the Environmental Assessment Process.

6.5.1.2 Data Sources

Data sources including MC1-specific data, data collected for the Springbank Off-stream Reservoir (SR1) Project, government databases, as well as grey literature are listed below. Scientific literature such as journal publications and white papers that are cited throughout the Water Quality section can be found in the Reference section.

- Alberta Water Quality Guideline for the Protection of Freshwater Aquatic Life – Copper (AEP 1996)
- Alberta Water Quality Guidelines for the Protection of Freshwater Aquatic Life – Mercury and Methylmercury (AEP 1998)
- Canadian System of Soil Classification, 3rd Edition. (Agricultural and Agri-Food Canada 2013)
- Chemical Expense Index for the Agricultural Area of Alberta (Agricultural Land Resource Atlas of Alberta 2016a)
- Fertilizer Expense Index for the Agricultural Area of Alberta (Agricultural Land Resource Atlas of Alberta 2016b)
- Surface Water Quality Risk for the Agricultural Area of Alberta (Agricultural Land Resource Atlas of Alberta 2016c)
- Water Quality of the Elbow River (Beers and Sosiak 1993)
- Approved Water Quality Guidelines (British Columbia (BC) Environment 2014)
- British Columbia Approved Water Quality Guidelines (Criteria) (British Columbia Ministry of Water, Land and Air Protection 1998)
- Appendix XV - Protocols for deriving water quality guidelines for the protection of agricultural water uses (October 1993) (CCME 1993)
- Canadian Water Quality Guidelines for the Protection of Aquatic Life. Guidance on the site- specific application of water quality guidelines in Canada: Procedures for deriving numerical water quality objectives (CCME, 1998, 2001, 2003)
- Phosphorus: Canadian guidance framework for the management of freshwater systems (CCME 2004)
- Canadian Environmental Quality Guidelines Summary Table (CCREM 1987; CCME 2014)
- Elbow River Basin Water Management Plan: A Decision Support Tool for the Protection of Water Quality in the Elbow River Basin (Elbow River Watershed Partnership 2009)

- Presence and levels of priority pesticides in selected Canadian aquatic ecosystems (Environment Canada 2011)
- Environmental Quality Guidelines for Alberta Surface Waters (ESRD 2014)
- Beneficial Management Practices: Environmental Manual for Crop Producers in Alberta – Pest Management and Pesticides (Government of Alberta, Agriculture and Forestry 2004)
- South Saskatchewan Regional Plan (Government of Alberta 2014)
- Elbow River at Bragg Creek (05BJ004) River Data April 1, 2016 to November 1, 2016 (Government of Alberta 2017)
- Guidelines for Canadian Drinking Water Quality—Summary Table (Health Canada 2014)
- National Recommended Water Quality Criteria – Correction (US EPA 1999)
- Aquatic life criterion – selenium (US EPA 2016)
- The Water Survey of Canada website (Environment and Climate Change Canada 2014)

No baseline data or studies were available for the following attributes:

- Chlorinated ethanes, ethylbenzene, pentachlorophenol, polycyclic aromatic hydrocarbons (PAHs) and toluene
- Chloramines, chlorate, dichlorophenol, trihalomethanes
- Nitrite and soluble reactive phosphorus (SRP)
- Dissolved organic carbon (DOC)
- Phytoplankton density, biomass and species composition
- Periphyton density, biomass and species composition
- Microcystin concentration

Chlorinated ethanes, ethylbenzene, pentachlorophenol, PAHs and toluene are derived from fuels and other fluids used in heavy machinery. Chloramines, chlorate, dichlorophenol and trihalomethanes are common by-products from water disinfection methods used for drinking water and produced when DOC combines with disinfection chemicals. These chemicals are monitored downstream of a water filtration plant and would be in the Elbow River only if treated water was diverted back to the river. There are no known sources of these fuel-based and disinfection-based chemicals in the Elbow River, which would explain why there are currently no data on record. Despite the lack of data for the above chemicals, mitigation measures can still be identified for the MC1 Option based on best management practices (BMPs).

6.5.1.3 Valued Components

Water Quality may be influenced by construction and operation of the MC1 Option and may influence other ecological assemblages and processes when disturbed **(Table 6.5-2).**

Table 6.5-2 Valued Components for Water Quality

Valued Component	Interaction
Surface Water Quality for Aquatic Organisms	Water quality can affect all aquatic life, which can change the underlying food web, effect fish health and survival by influencing fish metabolism, and change the habitat used by fish in the MC1 Option area. MC1 construction and operation may interact with water quality, with resultant potential effects to aquatic organisms. Potential changes to water quality may be caused by modified terrain stability due to permanent and ephemeral inundation within a flood zone of the reservoir, and from construction activities above the permanent pond flood zone and roads. An assessment of Surface Water Quality for Aquatic Organisms interacts with other VCs including Fluvial Geomorphology, Vegetation and Wetlands, Wildlife, Fish and Fish Habitat, and Land Use and Management.
Drinking Water Quality	Drinking water licences for the Elbow River exist downstream of the MC1 site up to the Glenmore Reservoir (**Figure 6.5-1**). During construction, MC1-related activities may affect Water Quality downstream of the MC1 Option area and consequently affect drinking water quality. Immediately following permanent pond filling, water quality may change from that presently found in the river and not meet standards for drinking water supply.

6.5.1.4 Measurable Parameters

Measurable parameters are quantitative or qualitative measures used to describe existing conditions and trends, and to evaluate potential MC1-related effects on the VCs. The measurable parameters selected to support the Surface Water Quality for Aquatic Organisms and Drinking Water Quality VCs are listed in **Table 6.5-3**. Potential adverse MC1-related effects to the VCs arising from potential interactions are discussed in more detail in **Section 6.5.3**.

Measurable parameters are variables sensitive to MC1-related activities. The measurable parameters for Surface Water Quality for Aquatic Organisms were identified from a list of CCME water quality guidelines about which effects to aquatic life are known to occur. A similar approach was used to identify measurable parameters for Drinking Water Quality where water quality standards, identified by Health Canada, have been identified to assess potential changes in water quality in the context of existing drinking water licences in the MC1 Option area. Measurable parameters for each VC and potential MC1-related effects are outlined in **Table 6.5-3**.

Table 6.5-3 Measurable Parameters for Water Quality

Valued Component	Potential MC1-related Effect	Measurable Parameter
Surface Water Quality for Aquatic Organisms Drinking Water Quality	Exceedance of turbidity guidelines	Turbidity[1] Total suspended solid (TSS) concentration[2] Conductivity Particle size distribution in water

Valued Component	Potential MC1-related Effect	Measurable Parameter
Surface Water Quality for Aquatic Organisms Drinking Water Quality	Exceedance of chemical contaminant guidelines	Chemical Contaminants ▫ Barium ▫ Boron ▫ Chloramines[3] ▫ Chlorate[3] ▫ Chloride[4] ▫ Chlorinated ethanes[4] ▫ Chromium ▫ Dichlorophenol[3] ▫ Ethylbenzene ▫ Ethylene glycol[4] ▫ Methylmercury (MeHg) and total mercury concentration ▫ Methyl tertiary-butyl ether (MTBE) ▫ Molybdenum ▫ Polycyclic aromatic hydrocarbons (PAHs) ▫ Pentachlorophenol and other phenols ▫ Toluene ▫ Trihalomethanes†
Surface Water Quality for Aquatic Organisms Drinking Water Quality	Release of nutrients leading to excessive algal growth	Nutrients ▫ All forms of nitrogen (N) and phosphorus (P) Biological Attributes ▫ Phytoplankton biomass and species composition ▫ Periphyton biomass and species composition* Hydrological Attributes ▫ Secchi[5] depth in the permanent pond
Surface Water Quality for Aquatic Organisms Drinking Water Quality	Exceedance of temperature guidelines	Temperature (ºC)
Surface Water Quality for Aquatic Organisms Drinking Water Quality	Exceedance of methylmercury guidelines	Methylmercury (MeHg) and total mercury concentration Diagnostic Attributes ▫ Water temperature ▫ Dissolved oxygen (DO) concentration Hydrological Attributes ▫ Water residence time in the permanent pond
Drinking Water Quality	Introduction of organic matter combining with disinfectants in distribution system downstream of the Option	Carbon ▫ Total and dissolved organic carbon (TOC and DOC)
Drinking Water Quality	Exceedance of pathogen guidelines	Pathogens ▫ Microcystin concentrations ▫ Fecal and total coliforms

Note: [1] Turbidity is a measure of water clarity and based on the amount of light scattered by particles in the water column. Higher turbidity equates to more light being scattered by particles and more cloudy water.

[2] Total suspended solids is a measure of particles > 2 μm suspended in the water column. High values of TSS equate to more suspended particles in the water.

[3] Parameter only relevant to Drinking Water Quality

[4] Parameter only relevant to Surface Water Quality for Aquatic Organisms

[5] Secchi depth is a measure of water transparency using a Secchi disk. Deeper Secchi depths are indicative of less particles in the water column and clearer water.

6.5.1.5 Assessment Boundaries

Spatial Boundaries

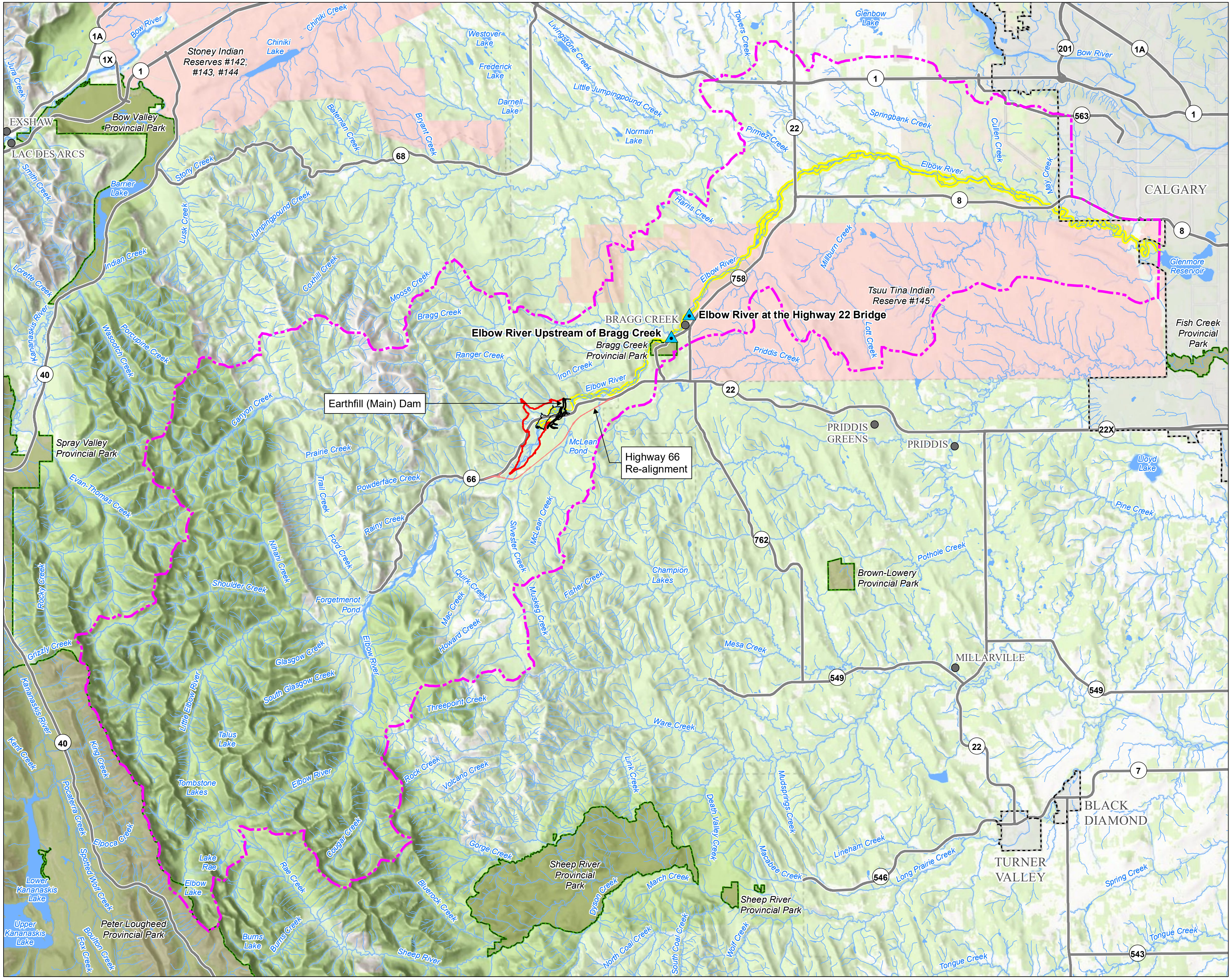
Spatial boundaries for the assessment of Water Quality are described in **Table 6.5-4** and presented in **Figure 6.5-1** and **Figure 6.5-2**. The Local Assessment Area (LAA) encompasses the maximum geographical area within which the MC1 Option would be likely to interact, and potentially have a direct or indirect effect on Water Quality. The Regional Assessment Area (RAA), which encompasses the LAA, is established to provide a regional context for the assessment of MC1-related effects. The RAA encompasses the area within which the residual effects of the MC1 Option would be likely to interact with the residual effects of past, present or future projects or activities to result in a cumulative effect or effects.

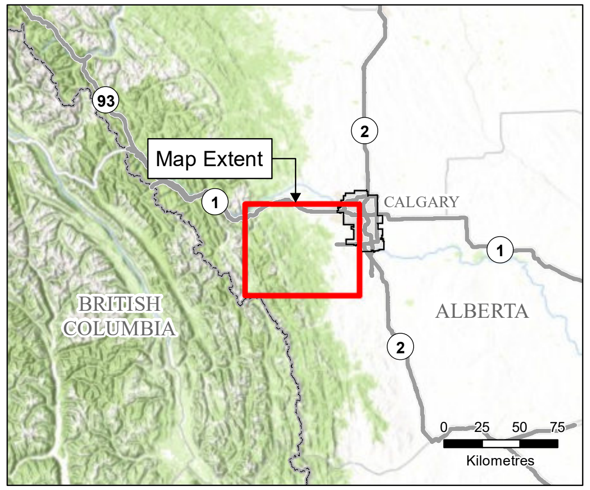
Table 6.5-4 Spatial Boundary Definitions for Water Quality

Spatial Boundary	Description of Assessment Area
MC1 Option area	Encompasses the MC1 footprint and a 100 m buffer around the embankment and excavation areas, spillways and outlet works, road and borrow areas.
Local Assessment Area	The LAA includes the Elbow River from the upstream extent of the reservoir formed by the MC1 dam down to the upstream extent of the Glenmore Reservoir. See **Figure 6.5-1**
Regional Assessment Area	The RAA is the Elbow River Watershed from headwaters to the upstream extent of the Glenmore Reservoir.

Elbow River at McLean Creek Dam (MC1)

Water Quality Local Assessment Area and Regional Assessment Area





Legend

- Water Quality Local Assessment Area
- Water Quality Regional Assessment Area
- Water Quality Sampling Location
- 2013 Flood Event (1424m)
- MC1 Dam
- Highway 66 Re-alignment
- Permanent Pond
- Hamlet
- Highway
- Reserve
- Provincial Park
- Urban Area
- Watercourse
- Waterbody

Notes

1. This map is not intended to be a "stand-alone" document, but a visual aid of the information contained within the referenced Report. It is intended to be used in conjunction with the scope of services and limitations described therein.

Sources

- Basedata: Government of Alberta
- Dam and flood details: Opus International Consultants Limited, 2017
- Borrow Areas: Hatch Ltd., 2017
- Background Image: ESRI World Topographic Map
- Inset Maps: ESRI World Topographic Map

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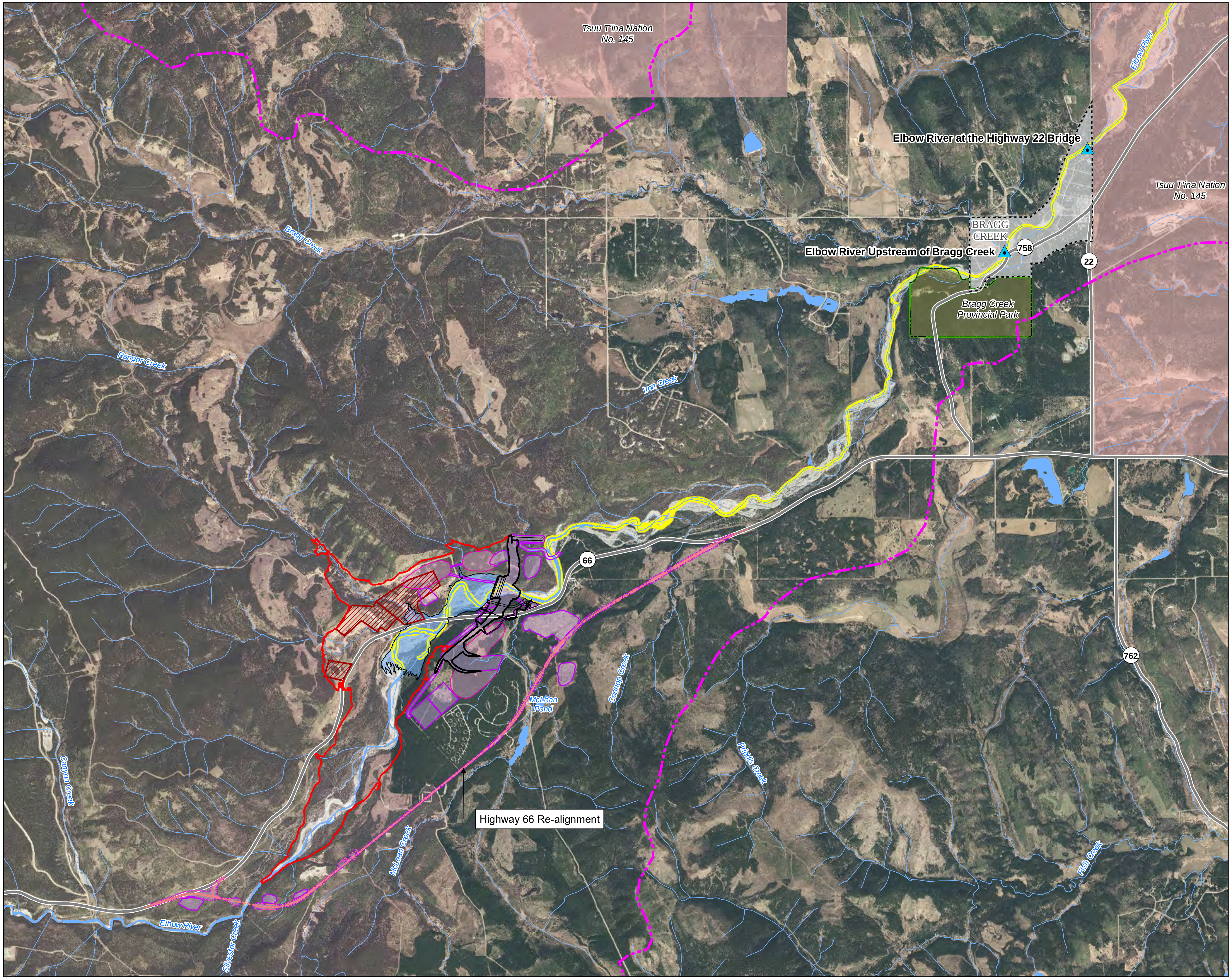
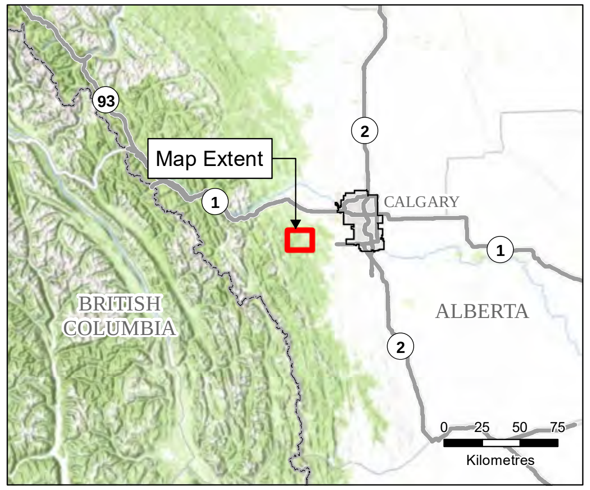
Alberta Transportation



Elbow River at McLean Creek Dam (MC1)

Water Quality Local Assessment Area and Regional Assessment Area and Option Layout



Legend

- Water Quality Local Assessment Area
- Water Quality Regional Assessment Area
- Water Quality Sampling Location
- 2013 Flood Event (1,424.5 m)
- MC1 Dam
- Highway 66 Re-alignment
- Borrow Area
- Laydown Area/Disturbed Area
- Permanent Pond
- Existing Park Infrastructure to be Removed
- Highway
- Reserve
- Provincial Park
- Urban Area
- Watercourse
- Waterbody

Notes

1. This map is not intended to be a "stand-alone" document, but a visual aid of the information contained within the referenced Report. It is intended to be used in conjunction with the scope of services and limitations described therein.

Sources

- Basedata: Government of Alberta
- Dam and flood details: Opus International Consultants Limited, 2017
- Borrow Areas: Hatch Ltd., 2017
- Aerial Image: SPOT 1.5 m, 2016
- Inset Maps: ESRI World Topographic Map

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Temporal Boundaries

The temporal boundaries of the MC1 Option consist of the Construction, and the Operation and Maintenance phases, which are described in **Section 3.0 MC1 Option Description**.

During the Operation and Maintenance phase, the peak summer inflow rate is estimated to be 13.4 cubic metres per second (m^3/s) resulting in a water residence time of 3.5 days in the permanent pond, while the peak winter flow is estimated to be 3 m^3/s, resulting in a water residence time in the permanent pond of 19.3 days. The water residence time, while relatively short, would affect the chemistry and biology in the permanent pond.

Administrative Boundaries

No administrative boundaries (e.g., political, economic, or social issues, as well as fiscal or other resourcing issues constraining the assessment of potential effects of the Option) were identified for the assessment of potential MC1-related effects on Water Quality.

Technical Boundaries

Standard modelling procedures for key response variables such as biomass or abundance of aquatic organisms and pathogens could not be completed and limit the Baseline Case for phytoplankton, periphyton and microcystin to an assessment of available nutrients in the Elbow River. Dissolved nitrogen and phosphorus can offer insight into the biological production potential of a system but quantitative comparisons between pre- and post-MC1 Water Quality with respect to biological attributes and microcystin cannot not be made in large part because of the fundamental shift in the biological community that occurs when changing a river to a reservoir. The absence of these data do not preclude a screening level effects assessment, including identification of mitigation measures and residual effects to Water Quality.

Total organic carbon (TOC) was used in place of DOC and total dissolved phosphorus (TDP) was used in place of SRP to evaluate baseline carbon and phosphorus conditions in the Elbow River. TOC and TDP overestimate DOC and SRP, respectively, but it are sufficient for assessing carbon and phosphorus content in the river.

6.5.2 BASELINE CASE

The Baseline Case summarizes existing water quality for the area without the MC1 Option using data compiled from the sources listed in **Section 6.5.1.4**. The existing conditions of the Elbow River Water Quality VCs are described using the physical, chemical and biological attributes listed below.

Water Quality Guidelines for Surface Water Quality for Aquatic Organisms and Drinking Water Quality

Water quality guidelines for the protection of aquatic life are outlined in **Table 6.5-5** and are adapted from the *Alberta Water Quality Guideline for the Protection of Freshwater Aquatic Life* (AEP 1996, 1998), reports from the Canadian Council of Ministers of the Environment (CCREM, CCME 1987, 1993, 1998, 2001, 2003, 2004, 2014), *Approved Water Quality Guidelines for British Columbia* (BC MMWLAP 1998, Oliver and Fidler 2001, BC Environment 2014), *Environmental Quality Guidelines for Alberta Surface Waters* (ESRD 2014), *National Recommended Water Quality Criteria (*US EPA 1999, 2016).

Water is drawn from the Elbow River for multiple purposes including drinking water, irrigation of agricultural land and golf courses, stock watering, fish and wildlife management, habitat enhancement and recreation (Elbow River Watershed Partnership 2009). Alberta Environment and Parks (AEP) issues water licences for surface water diversions under the *Water Act*. Surface water diversions for drinking water and other purposes are located downstream from MC1, to the Glenmore Reservoir. While water is diverted from the Elbow River for several reasons, drinking water quality standards are the most stringent. Therefore, the needs of other users can be met by protecting drinking water quality in the Elbow River (discussed in more detail in **Section 8.3 Public Health and Safety**). Guidelines for drinking water quality are sourced from Health Canada (2014) and are outlined in **Table 6.5-5.**

The Water Quality attributes in the following tables are grouped by attribute. The attribute groups are used to organize the measurable parameters in **Table 6.5-3** and the tables for existing water quality conditions in **Section 6.5.2.2.**

Table 6.5-5 Canadian Guidelines for Chemical, Biological and Physical parameters for the Protection of Aquatic Life and Drinking Water Quality

Attribute Group*	Water Quality Attribute for Assessment	Guideline for the Protection of Aquatic Life	Reference	Guideline for Drinking Water Quality	Classification	Reference
Chemical Contaminants	Barium	No guidelines	CCME 2014	1,000 µg/L	MAC	Health Canada 2014
	Boron	1,500 µg/L	CCME 2014	5,000 µg/L	MAC	Health Canada 2014
	Chloride	640 mg/L	CCME 2014	3,000 µg/L	MAC	Health Canada 2014
	2,4-Dichlorophenol	-	-	900 µg/L ≤ 0.3 µg/L	MAC AO	Health Canada 2014
	Chlorinated Ethanes	Dichloroethane: Long-term: 90 µg/L	CCME 2014	-	-	-
	Chromium	Hexavalent: Long term: 1 µg/L Trivalent: Long term: 8.9 µg/L	CCME1997	50 µg/L	MAC	Health Canada 2014
	Ethylbenzene	Long-term: 90 µg/L	CCME 2014	140 µg/L 1.6 µg/L	MAC AO	Health Canada 2014
	Ethylene glycol	-	-	No guideline		Health Canada 2014
	Mercury (methylated)	Short-term (1 hour): 0.002 µg/L Long-term (4 days): 0.001 µg/L	AEP 1998	1 µg/L	MAC	Health Canada 2014
	Mercury (total)	Short-term (1 hour): 0.005 µg/L Long-term (4 days): 0.0013 µg/L	CCME 2014	1 µg/L	MAC	Health Canada 2014
	MTBE	Long-term: 10,000 µg/L	CCME 2003a	≤ 15 µg/L	AO	Health Canada 2014
	Molybdenum	73 µg/L	CCME 2014	No guideline		Health Canada 2014
	Pentachlorophenol	Long-term: 0.5 µg/L	CCRME 1987	60 µg/L ≤ 30 µg/L	MAC AO	Health Canada 2014

Attribute Group*	Water Quality Attribute for Assessment	Guideline for the Protection of Aquatic Life	Reference	Guideline for Drinking Water Quality	Classification	Reference
	PAHs	Acenaphthene: 5.8 µg/L Acridine: 4.4 µg/L Anthracene: 0.012 µg/L Benz(a)anthracene: 0.018 µg/L Benzo(a)pyrene: 0.015 µg/L Fluoranthene: 0.04 µg/L Fluorene: 3 µg/L Naphthalene: 1.1 µg/L Phenanthrene: 0.4 µg/L Pyrene: 0.025 µg/L Quinoline: 3.4 µg/L No or insufficient data for: 2-Methylnaphthalene, Acenaphthylene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene and Indeno(1,2,3-c,d)pyrene	CCME 2014	Benzo(a)pyrene: 0.04 µg/L No or insufficient data for: Acenaphthene, Acridine, Anthracene, Benz(a)anthracene, 2-Methylnaphthalene, Acenaphthylene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene Fluoranthene, Fluorene, Indeno(1,2,3-c,d)pyrene, Naphthalene, Phenanthrene, Pyrene, and Quinoline	AO	Health Canada 2014
Nutrients	Toluene	No Data	CCME 2014	60 µg/L 24 µg/L	MAC AO	Health Canada 2014
	Trihalomethanes	-	-	100 µg/L	MAC	Health Canada 2014
	Nitrite (NO_2-N)	Varies with chloride concentration. Short term: From 0.06 to 0.6 mg/L at chloride values from <2 mg/L to >10 mg/L, respectively Long term: From 0.02 to 0.20 mg/L at chloride values from <2 mg/L to >10 mg/L, respectively	BC Environment 2014	1 mg/L	MAC	Health Canada 2014

Attribute Group*	Water Quality Attribute for Assessment	Guideline for the Protection of Aquatic Life	Reference	Guideline for Drinking Water Quality	Classification	Reference
	Soluble Reactive Phosphorus (SRP)	No provincial or federal guidelines. The Government of Alberta is developing science-based values for phosphorus concentrations for major rivers. Concentrations should be maintained to prevent detrimental changes to algal and aquatic plant communities, aquatic biodiversity, oxygen levels, and recreational quality.	ESRD 2014	No guidelines		Health Canada 2014
	Total Dissolved Phosphorus (TDP)	No guidelines. See SRP.	ESRD 2014	No guidelines		Health Canada 2014
	Total Phosphorus (TP)	Trigger ranges that would signify a change in the trophic classification: <4 µg/L: ultra-oligotrophic 4 to 10 µg/L oligotrophic 10 to 20 µg/L mesotrophic 20 to35 µg/L meso-eutrophic 35 to100 µg/L eutrophic > 100 µg/L hyper-eutrophic	CCME 2004	No guidelines		Health Canada 2014
	N:P	No guidelines	ESRD 2014	No guidelines		Health Canada 2014

Attribute Group*	Water Quality Attribute for Assessment	Guideline for the Protection of Aquatic Life	Reference	Guideline for Drinking Water Quality	Classification	Reference
Biological Attributes	Phytoplankton biomass measured as chlorophyll *a* concentration	No Federal guidelines. BC guideline for aquatic life in streams is 100 mg/L	BC Ministry of Water, Land and Air Protection 1998	No Federal guideline BC guideline for lakes is 2 µg/L to 2.5 µg/L		Health Canada 2014
	Phytoplankton species composition measured as % by dominant taxa	No guidelines	ESRD 2014	No guideline		Health Canada 2014
	Periphyton biomass measured as chlorophyll a concentration	No guidelines	ESRD 2014	-	-	-
	Periphyton species composition measured as % by dominant taxa	No guidelines	ESRD 2014	-	-	-
Carbon	Total Organic Carbon (TOC)	No guidelines	ESRD 2014	No guideline		Health Canada 2014
	Dissolved Organic Carbon (DOC)	No guidelines	ESRD 2014	No guideline		Health Canada 2014

Attribute Group*	Water Quality Attribute for Assessment	Guideline for the Protection of Aquatic Life	Reference	Guideline for Drinking Water Quality	Classification	Reference
Diagnostic Attributes	Water temperature	The rate of temperature change in natural water bodies not to exceed 1°C per hour. For streams with unknown fish distribution, the: maximum weekly mean temperature is 18 ºC, maximum daily temperature is 19 ºC maximum incubation temperature should not exceed 12ºC (in the spring and fall).	Oliver & L. E. Fidler 2001	≤ 15°C	AO	Health Canada 2014
	pH	6.5 – 9.0, and should not change more than 0.5 from background levels.	USEPA 1999	6.5 – 8.5	AO	Health Canada 2014
	Dissolved Oxygen (DO)	Minimum values: Short term (instantaneous value): 5 mg/L Long term (7 day mean): 6.5 mg/L To protect mayfly emergence from mid-May to the end of June: 8.3 mg/L For areas and times to protect larval fish development: 9.5 mg/L	AEP 1998	No guideline		Health Canada 2014
	Total Alkalinity (as calcium carbonate, $CaCO_3$)	Minimum value of 20 mg/L unless natural values are less.	US EPA 1986	No guideline. Alkalinity is a diagnostic analyte to examine acid neutralizing capacity.		Health Canada 2014
	Conductivity	None listed. Using in place of Total dissolved solids	ESRD 2014	No guideline		Health Canada 2014

Attribute Group*	Water Quality Attribute for Assessment	Guideline for the Protection of Aquatic Life	Reference	Guideline for Drinking Water Quality	Classification	Reference
	TSS	**For clear water:** Short term (24-hour period): Suspended sediment concentrations should not exceed background levels by more than 25 mg/L (hourly sampling preferred). Long term (24 hours to 30 days): The average suspended sediment concentration should not exceed background by more than 5 mg/L (daily sampling preferred). **For high flow or turbid waters:** When background levels are 25 – 250 mg/L suspended sediment, concentrations should not exceed background levels by more than 10 mg/L. When background > 250 mg/L, suspended sediments should not increase by more than 10 % of the measured background level at any one time.	CCME 1999, BC Environment 2014	Refer to turbidity		Health Canada 2014
	Turbidity	**For clear water:** Short term (24-hour period): Maximum increase of 8 NTU from background level. Long term (> 24-hour period): Maximum average increase of 2 NTU from background level **For high flow or turbid waters:** When background levels are 8 – 80 NTU: Maximum increase of 8 NTU from background level. When background levels are > 80 NTU: Should not increase more than 10% of background level.	CCME 1999, BC Environment 2014	0.3 NTU using chemically assisted filtration 1 NTU using sand or diatomaceous earth filtration 0.1 NTU using membrane filtration		Health Canada 2014

Attribute Group*	Water Quality Attribute for Assessment	Guideline for the Protection of Aquatic Life	Reference	Guideline for Drinking Water Quality	Classification	Reference
	Size distribution of particles in the water column	No guideline	ESRD 2015	No guideline		Health Canada 2014
Pathogens	Fecal coliforms	-	-	None detectable per 100 mL	MAC	Health Canada 2014
	Total coliforms	-	-	None detectable per 100 mL	MAC	Health Canada 2014
	Microcystin concentration	-	-	0.0015 $mg{\cdot}L^{-1}$	MAC	Health Canada 2014
Hydrological Attributes	Secchi depth	-	-	No guideline		Health Canada 2014
	Water residence time	No guideline	ESRD 2014	No guideline		Health Canada 2014

Note: * The attributes listed have been categorized into "Attribute Groups" in this table to facilitate comparison between the federal guidelines for the protection of aquatic life and existing conditions presented in Tables 5.5-10 to 5.5-16 in Section 5.5.2.3; Maximum acceptable concentration (MAC), aesthetic objective (AO) or operation guideline (OG).

* The attributes listed in Table 6.5-3 have been categorized into "Attribute Groups" in this table to facilitate comparison between the federal guidelines for the protection of aquatic life and existing conditions presented in **Section 6.5.2.2**.

Water quality guidelines for the protection of aquatic life for total ammonia are included in **Table 6.5-6**. Guidelines for total ammonia are dependent on pH and temperature. In the case of a mean pH that falls between the values in the table, the guideline is calculated by using established relationships in the table. For example, for pH of 8.25 and temperature of 5°C, the mean ammonia concentration is calculated from the values for pH 8.0 and 8.5 at 5°C. The guideline for pH 8.25 at 5°C is therefore 1.02 mg/L, and increases as temperature and pH decrease.

Table 6.5-6 Water Quality Guidelines for Total Ammonia for the Protection of Aquatic Life in Freshwater (mg $NH_3 \cdot L^{-1}$)

		pH							
		6.0	**6.5**	**7.0**	**7.5**	**8.0**	**8.5**	**9.0**	**9.5**
Temperature (°C)	**0**	231	73.0	23.1	7.32	2.33	0.749	0.25	0.042
	5	153	48.3	15.3	4.84	1.54	0.502	0.172	0.034
	10	102	32.4	10.3	3.26	1.04	0.343	0.121	0.029
	15	69.7	22.0	6.98	2.22	0.715	0.239	0.089	0.026
	20	48.0	15.2	4.82	1.54	0.499	0.171	0.067	0.024
	25	33.5	10.6	3.37	1.08	0.354	0.125	0.053	0.022
	30	23.7	7.50	2.39	0.767	0.256	0.094	0.043	0.021

Note: Adapted from the CCME water quality guidelines (CCME 2014).

6.5.2.1 Site Description Near the MC1 Option and other Elbow River Sampling Locations

Three sampling locations with existing data for the Elbow River are used to describe the chemical, physical and biological water quality conditions. These sites are the closest known water quality data to the MC1 Option area, and include Elbow River upstream of Bragg Creek, Elbow River at the Highway 22 Bridge, and Elbow River at the Weaselhead Foot Bridge (**Table 6.5-7;** Figure 6.5-1 and **Figure 6.5-2)**. The Elbow River upstream of Bragg Creek and at the Highway 22 Bridge are approximately 9 kilometres (km) and 11 km, respectively, downstream of the MC1 Option area, while the sampling location on the Elbow River at Weaselhead Foot Bridge is approximately 48 km downstream of the MC1 area.

Table 6.5-7 UTM Coordinates for the Elbow River Sampling Locations

Label	Sampling Location	Zone	Easting	Northing	Proximity to MC1
Site 1	Elbow River upstream of Bragg Creek	11	670229	5646648	9 km downstream
Site 2	Elbow River at the Highway 22 Bridge	11	671308	5648056	11 km downstream
Site 3	Elbow River at the Weaselhead Foot Bridge	11	698898	5653150	48 km downstream

The MC1 area, Elbow River upstream of Bragg Creek (Site 1) and Elbow River at the Highway 22 Bridge (Site 2) are in the Montane Sub-region of the Rocky Mountain Natural Region of Alberta. This area is characterized by mountains and foothills separated by deep glacial valleys (Natural Regions Committee 2006). The soil groups in this area are broadly categorized as Brunisols and Gray Luvisols, which are well to imperfectly drained soils that are commonly found under forests in all temperatures and from subhumid to humid conditions (Agricultural and Agri-Food Canada 2013). Gravely sand to gravel material, up to 3 metres (m) thick, forms the substratum of the Elbow River near the MC1 area with well sorted and rounded fluvial and glaciofluvial gravels adjacent to the river (Opus 2017a). Total annual precipitation near these sampling locations is 500 millimetres (mm) to 550 mm with 300 mm to 325 mm falling as rain between May and August and the rest as snow.

Approximately 42 % of the flow in the Elbow River is groundwater-sourced, which maintains relatively high flows throughout the winter when precipitation is low (Meyboom 1961). Vegetation is generally a mix of grasslands and deciduous-coniferous forests on southern and western aspects, and predominantly coniferous forests on northern aspects and at higher elevations. There are areas of disturbed (anthropogenic) influence where the tree canopy has been removed for timber harvesting, infrastructure, or other manmade disturbance. Wetlands in the eastern portion of the MC1 area are thought to be acidic and have low nutrient concentrations (See **Section 7.1 Wetlands and Vegetation**).

Agricultural intensity around the Elbow River near MC1, upstream of Bragg Creek and at the Highway 22 Bridge, measured as expenses on agricultural chemicals by farmers, is rated as low (0 to 0.2[1]) (**Table 6.5-8**). This measure is calculated as the ratio between the cost of herbicides, pesticides and fungicides and the total area of application (Agricultural Land Resource Atlas of Alberta 2016a). Fertilizer and lime use in the area, measured as the cost of fertilizer and lime applied divided by the area of application, is also low (0 to 0.2[1]) (Agricultural Land Resource Atlas of Alberta 2016b). These indices combined with livestock and crop production were used to generate a surface water quality risk index, which for this area is also low (0.11 to 0.19[1]) (Agricultural Land Resource Atlas of Alberta 2016c).

Table 6.5-8 Land Use and Surface Water Quality Risk Summary Derived from the Agricultural Land Resource Atlas of Alberta

Label	Sampling Location	Agricultural Intensity[a]	Fertilizer and Lime Use[a]	Surface Water Quality Risk[b]
Site 1	Elbow River upstream of Bragg Creek	0 to 0.2	0 to 0.2	0.11 to 0.19
Site 2	Elbow River at the Highway 22 Bridge	0 to 0.2	0 to 0.2	0.11 to 0.19
Site 3	Elbow River at the Weaselhead Foot Bridge	0.4 to 0.6	0.4 to 0.6	0.76 to 1

Note: These ratios are on a scale of 0 to 1 where 0 represents no expenses incurred[a] or low land use[b] in a given area and 1 represents high expenses incurred or heavy land use[b]. (Agricultural Land Resource Atlas of Alberta 2016a-c)

[1] On a scale from 0 to 1, where 0 is low and 1 is high.

The Elbow River at the Weaselhead Foot Bridge (Site 3) is located within Calgary city limits immediately upstream of the Glenmore Reservoir, which supplies drinking water to Calgary. This area receives less precipitation (450 to 500 mm) than at the upstream sites (Sites 1 and 2) and is in an area characterized by Black Chernozemic soil, which are typical of cold, subhumid climates and associated with grasses, forbs and occasionally tree cover (Agricultural and Agri-Food Canada 2013). This area is in a region with moderate agricultural intensity (chemical expense ratio 0.4 to 0.6) and fertilizer use (0.4 to 0.6) but with a high surface water quality risk (0.76 to 1). Given the higher ratios for agricultural intensity, fertilizer and lime use and surface water quality risk, it is likely that the existing water quality for the Elbow River immediately upstream of the Glenmore Reservoir (i.e., Site 3) is more effected by existing anthropogenic activities compared to closer to the MC1 area (i.e., Sites 1 and 2).

This assessment relies on available data collected upstream of Bragg Creek and at the Highway 22 Bridge, given their proximity to the MC1 area and because these sites are within the same physical, chemical and biological zones identified by the Agricultural Land Resource Atlas of Alberta (2016a-c).

6.5.2.2 Existing Water Quality Parameters for the Elbow River

Existing physical, chemical and biological conditions for the Elbow River upstream of Bragg Creek (Site 1) and at the Highway 22 Bridge (Site 2) between 1991 to 2015 are summarized in **Table 6.5-9**. These tables summarize means and standard deviations (SD) across all months and years sampled. Standard deviation is a measure of dispersion around the mean. More disperse data equates to a larger standard deviation while a standard deviation equal to 0 indicates that all samples used to calculate the mean had the same value. When the standard deviation is higher than the mean (e.g. TSS and Turbidity in **Table 6.5-9**), data used to calculate the mean included outliers (a few data points that are extremely high compared to majority of data points in the sample). Outliers can skew the overall mean when sample sizes are small but have less of an effect on larger sample sizes. The 95% confidence interval (95% CI) presented for each mean in **Table 6.5-9** gives the range in which 95% of the data occurs. As with SD, a smaller 95% CI indicates less variation in the data.

Samples were typically collected once per month, at irregular intervals, between March and October, with a few collected in January. The sampling methods and purpose for these samples are unknown, as is the project(s) they were collected for, but they do provide some information on the baseline conditions in the Elbow River. Sample size for each calculated mean is indicated by “n” and “Year Range” defines the years when samples were collected. A summary of the data presented is provided below in **Section 6.5.2.3**. Yellow cells indicate the mean existing water quality parameter is 90 to 95% of the guideline listed in **Table 6.5-9**, orange cells indicate the mean parameter is 95 to 105% of the guideline listed and red cells indicate mean parameter values are greater than 105% of the guideline. Unshaded cells indicate mean parameter values are less than 90% of the guidelines listed in **Table 6.5-5**.

Table 6.5-9 Existing Water Quality Parameters for Elbow River

Parameter	Form	Units	Elbow River upstream of Bragg Creek (Site 1)					Elbow River at Highway 22 Bridge (Site 2)				
			Mean	SD	95% CI	n	Year Range	Mean	SD	95% CI	n	Year Range
Chemical Contaminants												
Barium	Total	µg/L	57.19	19.3	51.13 - 63.25	39	2006-2015	58.15	11.82	54.44 - 61.86	39	2006-2015
	Extractable	µg/L	50.48	6.76	47.72 - 53.24	23	2004-2006	57.34	5.56	56.09 - 58.59	76	1999-2006
	Dissolved*	µg/L	6.71	20.45	1.62 - 11.8	62	2004-2015	0.81	13.06	0 - 3.2	115	1999-2015
Boron	Total**	µg/L	7.78	1.48	7.32 - 8.24	39	2006-2015	7.70	1.37	7.27 - 8.13	39	2006-2015
	Extractable	µg/L	7.90	2.72	6.79 - 9.01	23	2004-2006	16.43	5.67	15.16 - 17.7	76	1999-2006
	Dissolved	µg/L	-	-	-	-	-	-	-	-	-	-
Chloramines	Total	µg/L	-	-	-	-	-	-	-	-	-	-
Chlorate	Total	µg/L	-	-	-	-	-	-	-	-	-	-
Chlorinated ethanes	Total	µg/L	-	-	-	-	-	-	-	-	-	-
Chromium	Total**	µg/L	0.92	1.12	0.57 - 1.27	39	2006-2015	0.96	1.14	0.6 - 1.32	39	2006-2015
	Extractable	µg/L	0.74	0.29	0.62 - 0.86	23	2004-2006	2.08	1.52	1.74 - 2.42	76	1999-2006
	Dissolved*	µg/L	0.18	1.16	0 - 0.47	62	2004-2015	-	-	-	-	-
Dichlorophenol	Total	µg/L	-	-	-	-	-	-	-	-	-	-
Ethylbenzene	Total	µg/L	-	-	-	-	-	-	-	-	-	-
Ethylene glycol	Total	µg/L	0.76	0.32	0.66 - 0.86	39	2006-2015	0.75	0.31	0.65 - 0.85	39	2006-2015

Parameter	Form	Units	Elbow River upstream of Bragg Creek (Site 1)					Elbow River at Highway 22 Bridge (Site 2)				
			Mean	SD	95% CI	n	Year Range	Mean	SD	95% CI	n	Year Range
Mercury	Methylated	µg/L	0.89 Exceeds guideline for protection for aquatic life Below the guideline for drinking water quality	0.29	0.8 - 0.98	39	2006-2015	7.26 Exceeds guideline for protection for aquatic life Exceeds the guideline for drinking water quality	39.89	0 - 19.78	39	2006-2015
	Total	µg/L	1.0 Exceeds guideline for protection for aquatic life At the guideline for drinking water quality	0.0	1 - 1	23	2004-2006	1.0 Exceeds guideline for protection for aquatic life At the guideline for drinking water quality	0.0	1 - 1	76	1999-2006
MTBE	Total	µg/L	3.51	3.99	0.71 - 0.89	39	2006-2015	3.2	3.47	2.11 - 4.29	39	2006-2015
Molybdenum	Total**	µg/L	0.8	0.29	0.57 - 0.65	39	2006-2015	0.84	0.32	0.74 - 0.94	39	2006-2015
	Extractable	µg/L	0.61	0.10	0.11 - 0.27	23	2004-2006	0.89	0.20	0.85 - 0.93	76	1999-2006
	Dissolved*	µg/L	0.19	0.31	0.71 - 0.89	62	2004-2015	-	-	-	-	-
Pentachlorophenol	Total	µg/L	-	-	-	-	-	-	-	-	-	-
PAHs	All forms listed in (**Table 6.5-5**)	µg/L	-	-	-	-	-	-	-	-	-	-
Toluene	Total	µg/L	-	-	-	-	-	-	-	-	-	-
Trihalomethanes	Total	µg/L	-	-	-	-	-	-	-	-	-	-

Parameter	Form	Units	Elbow River upstream of Bragg Creek (Site 1)					Elbow River at Highway 22 Bridge (Site 2)				
			Mean	SD	95% CI	n	Year Range	Mean	SD	95% CI	n	Year Range
Nutrients												
NH_4-N	N/A	mg/L	0.04	0.07	0.03 - 0.05	136	2000-2013	0.03	0.05	0.02 - 0.04	310	1999-2013
NO_3-N	N/A	mg/L	0.10	0.03	0.1 - 0.1	179	1999-2015	0.09	0.03	0.09 - 0.09	353	1999-2015
NO_2-N	N/A	mg/L	-	-		-	-	-	-	-	-	-
SRP	N/A	mg/L	-	-		-	-	-	-	-	-	-
TDP	N/A	mg/L	Below detection limit	-		167	2000-2015	< 0.01	-		334	1999-2015
TP	N/A	mg/L	0.01	0.08	0 - 0.02	179	1999-2015	0.01	0.03	0.01 - 0.01	351	1999-2015
Molar N:P	N/A	mg/L	146	-		167	2000-2015	124	-		334	1999-2015
Biological Attributes												
Periphytic Chl-a	N/A	mg/L	-	-	-	-	-	-	-	-	-	-
Mean Periphytic Abundance by Taxonomical Group	N/A	%	-	-	-	-	-	-	-	-	-	-
Phytoplankton Chl-a	N/A	mg/L	-	-	-	-	-	-	-	-	-	-
Mean Phytoplankton Abundance by Taxonomical Group	N/A	%	-	-	-	-	-	-	-	-	-	-
Carbon												
TOC	N/A	mg/L	1.47	1.58	1.23 - 1.71	172	2000-2015	1.26	1.35	1.12 - 1.4	339	1999-2015
DOC	N/A	mg/L	-	-	-	-	-	-	-	-	-	-
Diagnostic Attributes												
Water Temperature	N/A	°C	5.61	4.02	5.04 - 6.18	191	1998-2015	5.05	4.51	4.59 - 5.51	363	1998-2015
pH	N/A	N/A	8.28	0.10	8.26 - 8.3	161	2001-2015	8.27	0.10	8.26 - 8.28	341	1999-2015

Parameter	Form	Units	Elbow River upstream of Bragg Creek (Site 1)					Elbow River at Highway 22 Bridge (Site 2)				
			Mean	SD	95% CI	n	Year Range	Mean	SD	95% CI	n	Year Range
Dissolved Oxygen	N/A	mg/L	11.46	1.60	11.22 - 11.7	169	2001-2015	11.35	1.72	11.17 - 11.53	340	1999-2015
Total Hardness	N/A	mg $CaCO_3$/L	198.98	21.89	195.38 - 202.58	142	2004-2015	203.91	21.03	200.97 - 206.85	196	1999-2015
Total Alkalinity	N/A	mg $CaCO_3$/L	139.04	31.43	133.87 - 144.21	142	2004-2015	140.03	8.49	138.84 - 141.22	196	1999-2015
Conductivity	N/A	µS/cm at 25 °C	350.73	59.00	341.81 - 359.65	168	2001-2015	368.53	45.50	363.71 - 373.35	343	1999-2015
TSS	N/A	mg/L	28.51	251.89	0 - 67.42	161	2001-2015	12.49	51.83	6.97 - 18.01	339	1999-2015
Turbidity	N/A	NTU	37.01	252.65	0 - 75.22	168	2000-2015	13.06	63.67	6.4 - 19.72	351	1999-2015
Pathogens												
Fecal Coliforms (E. coli)	N/A	MPN/ 100mL*	14.36	49.21	103.92 - 218.22	199	1998-2015	10.8	20.46	8.72 - 12.88	370	2000-2003, 2005, 2010
Total Coliforms	N/A	MPN/ 100mL*	161.07	411.35	5.04 - 6.18	199	1998-2015	215.05	488.85	165.24 - 264.86	370	1998-2015
Microcystin	N/A	mg/L	-	-	-	-	-	-	-	-	-	-

Notes: Yellow cells indicate the mean existing water quality parameter is 90 to 95% of the guideline listed in (**Table 6.5-5**).
Orange cells indicate the mean parameter is 95 to 105% of the guideline listed in (**Table 6.5-5**).
Red cells indicate mean parameter values are greater than 105% of the guideline listed in in (**Table 6.5-5**).
Unshaded cells indicate mean parameter values are less than 90% of the guidelines listed in (**Table 6.5-5**).
'-' = No Data available for parameter
Mean ± SD = mean across all years and months samples were collected and the corresponding standard deviation
95% CI = the range in which 95% of the data occurs.
n = sample size
Year Range = years when samples were collected
**In these marked instances, the mean total analyte concentration is less than the extractable analyte concentration, which can't chemically happen. In these cases, the standard deviations strongly overlap, which indicates that the means are not statistically different. This outcome suggests the total analyte concentration is comprised entirely of the extractable fraction.
NH_4-N is ammonium by ICP, NO_3-N is nitrate by ICP, NO_2-N is nitrite by ICP, SRP is soluble reactive phosphorus, TDP is total dissolved phosphorus, TP is total phosphorus and Molar N:P is the ratio between dissolved inorganic nitrogen and phosphorus. See equation (1) below for the full description.
*MPN/100 mL is mean probable number per 100 mL of water

6.5.2.3 Summary of Baseline Conditions

The Elbow River near Bragg Creek shows chemical attributes of a highly productive system that would be likely to support a diverse food web for fish and other aquatic organisms. The river is turbid, particularly during the spring and summer snowmelt periods, which infers rapid weathering of parent materials upstream of sampling sites. The occurrence of pathogens indicates upstream contamination from uncontained seepage of untreated wastewater and agricultural sources. Total and methylated mercury levels are also high and could increase due to MC1-related activities if vegetation is not adequately removed prior to inundation. Nitrogen:phosphorus (N:P) ratios indicate potential phosphorus deficiency of algal growth in the Elbow River at the sampling sites, which means that any addition of phosphorus could greatly increase algal growth rates and biomass. However, without information on existing periphyton and phytoplankton assemblages in the Elbow River no conclusions can be drawn on the existing risk of increased algal production (i.e., blue green algae, or cyanobacteria), as a result of the MC1 Option. Increased algal growth can be linked to the production of a toxin called microcystin that is harmful when ingested by mammals. Detailed descriptions below provide more information about each attribute group presented in **Table 6.5-3**, and existing conditions presented in **Table 6.5-9** in **Section 6.5.2.2.**

Chemical Contaminants

Boron, barium, chlorinated ethanes, chromium, ethylbenzene, molybdenum, MTBE, pentachlorophenols, PAHs and toluene are derived from fuels and other fluids used in heavy machinery. No known sources of these chemicals currently exist for the Elbow River in the MC1 area but may be found in the contaminated soils around the Elbow Valley Ranger Station (EVRS) and other provincial park infrastructure. The 2017 Phase II Environmental Site Assessment (ESA) identified elevated chemical contaminants, including barium, from background conditions around the east and west ends of the septic field by the EVRS that were at or above guidelines (**Appendix 3-B 2017 Phase II Environmental Site Assessment Elbow River at McLean Creek Dam Option**). Concentrations of boron, barium and molybdenum were, however, well below the guidelines for the protection of aquatic life and drinking water quality (**Table 6.5-9**). There is no baseline data for chlorinated ethanes, ethylbenzene, MTBE, pentachlorophenols, PAHs and toluene for the Elbow River in the MC1 area.

Two chemical species of chromium, hexavalent and trivalent, are monitored for the protection of aquatic life and drinking water quality. It is uncertain which chromium species was recorded for Sites 1 and 2 but both forms can be toxic (CCME 1998). The mean total concentration of chromium in the Elbow River between 2006 and 2015 was just below the guideline for the protection of aquatic life for hexavalent chromium and below the guideline for trivalent chromium for both drinking water quality and the protection of aquatic life. Further investigation would be required to determine which chemical form of chromium is present in the Elbow River to accurately assess the risk.

Chloramines, chlorate, dichlorophenol and trihalomethanes are common by-products from water disinfection methods used for drinking water when DOC combines with disinfection chemicals. These chemicals are monitored when a water source is being treated for drinking water. There are surface water diversion licences downstream of the MC1 dam site up to the Glenmore Reservoir (**Figure 8.1-6**). There is however, no existing data for these chemicals in the Elbow River near the MC1 area.

Methylated mercury (an organic form of mercury) originates from the decomposition of vegetation or from the transformation of inorganic mercury in sediment by micro-organisms under anoxic (no oxygen) conditions (Health Canada 2009). Methylmercury will readily associate with suspended and organic matter and has a high affinity for lipids (fat tissue), which can lead to the bioaccumulation of methylmercury in aquatic species as it transfers through the food web. While it can be excreted slowly through various pathways in the body, absorption of methylmercury from food and water is almost complete in the human body (Health Canada 2009). Between 2006 and 2015, mean methylated mercury concentration in the Elbow River upstream of Bragg Creek and at the Highway 22 Bridge was between 0.89 ± 0.29 µg/L and 7.26 ± 39.89 µg/L, while mean total mercury between 2004 and 2006 was 1.0 ± 0 µg/L. These values are higher than the current Canadian guidelines for the protection of aquatic life and drinking water quality and higher than those found in a study on the Elbow River by Beers and Sosiak (1993), which reported mercury concentrations lower than the method detection limit (0.05 µg/L) at eight out of nine sites tested. In the study by Beers and Sosiak (1993), the peak mercury concentration on the Elbow River between 1988 and 1989 was 0.1 µg/L at the Highway 22 Bridge. The methods used to quantify methylmercury between 2006 and 2015 are unknown, so it is unclear whether the increase in mercury in the Elbow River is because of a difference in methodology (e.g., increased detection) or because it is in fact increasing over time.

Nutrients

Mean ammonium (NH_4-N) concentration in the Elbow River between 1999 and 2013 was below the guidelines for the protection of aquatic life (0.04 ± 0.07 mg/L and 0.03 ± 0.05 mg/L upstream of Bragg Creek and at the Highway 22 Bridge, respectively) as was dissolved nitrate (NO_3-N). Data for dissolved nitrite could not be located for the Elbow River upstream of Bragg Creek and at the Highway 22 Bridge but water quality can be assessed without it because it is a transient form of inorganic N. For the Elbow River near Bragg Creek, ammonium and nitrate concentrations were well below the guidelines for the protection of aquatic life and drinking water quality, which is consistent with the low surface water quality risk index assessed by the Government of Alberta (Agricultural Land Resource Atlas of Alberta 2016c).

There are no provincial or federal guidelines for phosphorus outside of avoiding increases in total phosphorus that can influence algal growth and biomass in the Elbow River and affect its trophic classification (**Table 6.5-5**). Total dissolved phosphorus and TP concentrations were near or below the method detection limit of 0.01 mg/L from 1999 to 2015. The low TDP and TP concentrations coincide with the low chemical expense ratio, low fertilizer and lime expense ratio and a low surface water quality risk index described in **Section 6.5.2.1**. The low concentration of phosphorus results in high molar N:P ratios. There are no federal guidelines for molar N:P for the protection of aquatic life or drinking water quality because it is merely an indication of nutrient availability for biological production. It is a standard metric that describes which essential nutrients may be limiting algal growth in aquatic environments and is calculated as,

$$\text{Molar N:P} = \frac{\text{DIN}/14}{\text{TDP}/31} \quad (1)$$

where DIN is the sum of ammonium, nitrate and nitrite, 14 is the molecular weight of nitrogen and 31 is the molecular weight of phosphorus. Total dissolved phosphorus was used in place of soluble reactive phosphorus (SRP) because there is no SRP data for the Elbow River upstream of Bragg Creek and at the Highway 22 Bridge.

The growth of algae in streams and lakes is often limited by phosphorus or co-limited by nitrogen and phosphorus (Stockner and Shortreed 1978, Perrin et al. 1987, Bothwell 1988, Suttle and Harrison 1988). Rhee (1978) showed that for a given species of algae there is a sharp transition between phosphorus-limited and nitrogen-limited growth. The particular N:P ratio at which the transition between nitrogen and phosphorus-limitation occurs is species dependent, varying from as low as 7:1 for some diatoms (Rhee and Gotham 1980) to as high as 45:1 for some blue-green algae (Healey 1985). Below a molar N:P of 20, the growth of most algal species will be limited by nitrogen, whereas phosphorus-deficient growth is prevalent at molar N:P ratios greater than 50 (Guildford and Hecky 2000). Because an optimum N:P ratio (above which phosphorus limitation occurs and below which nitrogen limitation occurs) can vary widely among freshwater algae, the range between 20 and 50 may be regarded as a transition range in a community where some species will be phosphorus-limited and others will be nitrogen-limited.

Phosphorus can theoretically generate 500 times its own weight in algae, while nitrogen can only produce 71 times its own weight in algae, meaning that algae are much more reactive to a change in phosphorus supply than to changes in nitrogen supply, when growth is limited by either nutrient. The mean molar N:P ratio for the Elbow River upstream of Bragg creek is 146 and 124 at the Highway 22 Bridge. This ratio shows potential extreme phosphorus limitation for aquatic algae in the Elbow River. At surplus nitrogen, increases in SRP concentrations of less than 1 μg/L (1 part per billion) can increase growth rates and biomass by several fold and the response can show up within two weeks of a sustained change in phosphorus concentration (Bothwell 1985, Perrin et al. 1987).

Biological Attributes

There are currently no federal guidelines for chlorophyll-a concentration or species composition for either group; however, the standard that the Province of BC uses for phytoplankton has been included in **Table 6.5-5** as a guide. Current data for periphyton or phytoplankton biomass or species composition in the Elbow River is unavailable but chlorophyll a from periphyton samples were deemed low (10 mg/m^2) in a report by Beers and Sosiak (1993).

Carbon

Dissolved organic carbon is the result of decomposing organic material such as vegetation. There are no guidelines for carbon content in surface waters. Current data for DOC is unavailable but the mean TOC concentration in the Elbow River near Bragg Creek between 1999 and 2015 ranged between 1.26 ± 1.35 mg/L and 1.47 ± 1.58 mg/L, which is low for TOC concentration. Total organic carbon is a measure of organic matter in surface water and important in assessing water quality.

Diagnostic Attributes

Diagnostic measures of water quality include water temperature, pH, DO, hardness, alkalinity and conductivity. From 1998 to 2015 water temperature in the Elbow River near Bragg Creek was on average 5.05 ± 4.51 °C to 5.61 ± 4.02 °C (**Table 6.5-9**) and ranged from -0.1°C in February/March to 14.6°C in July/August. Despite proportionally higher rain accumulation during the summer months, the Elbow River is a snow-melt dominated system, which explains its low mean water temperature. There are no water quality concerns with the current mean and maximum temperatures recorded for the Elbow River.

The mean DO concentration was high (11.35 mg/L to 11.46 mg/L) at both sampling location and indicates the river was well saturated with DO during the sampling period and there was little DO demand from respiration in bottom sediments. These conditions are ideal for aquatic organisms and greatly reduces the chance of newly-formed methylmercury (discussed above) in the permanent pond.

The mean recorded pH between 1999 and 2001 was 8.27 and 8.28 at Sites 1 and 2, which is within the guideline range of values for protection of aquatic life. This alkaline pH in combination with high alkalinity (139.04 ± 31.43 and 140.03 ± 8.49 mg $CaCO_3$/L), high hardness (198.98 ± 21.89 and 203.91 ± 21.03 mg $CaCO_3$/L) and high conductivity (350.73 ± 59 µS per centimetre (/cm) and 368.53 ± 46 µS/cm) (**Table 6.5-9**) indicates high base cation concentrations typical of productive rivers. The high suspended solids concentrations and turbidity (**Table 6.5-9**) in combination with the high solute concentrations (**Table 6.5-10**) infers rapid weathering rates of parent materials upstream of the sampling sites. The high alkalinity shows high acid neutralizing capacity in the Elbow River.

Table 6.5-10 Mean Concentration of Dissolved Minerals in the Elbow River Across all Years Measured

Parameter	Units	Elbow River upstream of Bragg Creek (Site 1)					Elbow River at Highway 22 Bridge (Site 2)				
		Mean	SD	95% CI	n	Year Range	Mean	SD	95% CI	n	Year Range
Reactive Silica	mg/L	4.44	0.29	4.37 - 4.51	62	2004-2015	4.37	0.37	4.30 - 4.44	116	1999-2015
Calcium	mg/L	53.88	5.79	52.84 - 54.92	118	2004-2013	54.97	5.29	54.19 - 55.75	176	1999-2013
Magnesium	mg/L	15.07	2	14.71 - 15.43	118	2004-2013	15.14	1.82	14.87 - 15.41	176	1999-2013
Potassium	mg/L	0.53	0.22	0.49 - 0.57	118	2004-2013	0.58	0.15	0.56 - 0.60	176	1999-2013
Sodium	mg/L	1.81	0.98	1.63 - 1.99	118	2004-2013	2.04	0.55	1.96 - 2.12	176	1999-2013

Notes: Mean ± SD = mean across all years and months samples were collected and the corresponding standard deviation

95% CI = the range in which 95% of the data occurs.

n = sample size

Year Range = years when samples were collected

Hydrological Attributes

Water clarity is measured by TSS and turbidity. Mean TSS ranged from 12.49 ± 51.83 mg/L to 28.51 ± 251.89 mg/L. These values indicate that TSS is high in the Elbow River but also that there is a high degree of variability throughout the year. The highest values recorded are in June and July, which coincides with peak discharge for the Elbow River at Bragg Creek (Government of Alberta 2017; **Figure 6.5-3**). This suggests that there is a high degree of erosion during spring/summer melt in the upper Elbow River watershed, which is common for snowmelt-dominated systems. Based on the CCME guidelines, this classifies the Elbow River as high flow and/or turbid. Turbidity ranged between 13.06 ± 63.67 NTU and 37.01 ± 252.65 NTU from 1999 to 2015. Peak values occurred between May and July also coinciding with peak flow in the Elbow River (Government of Alberta 2017; **Figure 6.5-3**). These data show that the Elbow River carries a high suspended sediment load.

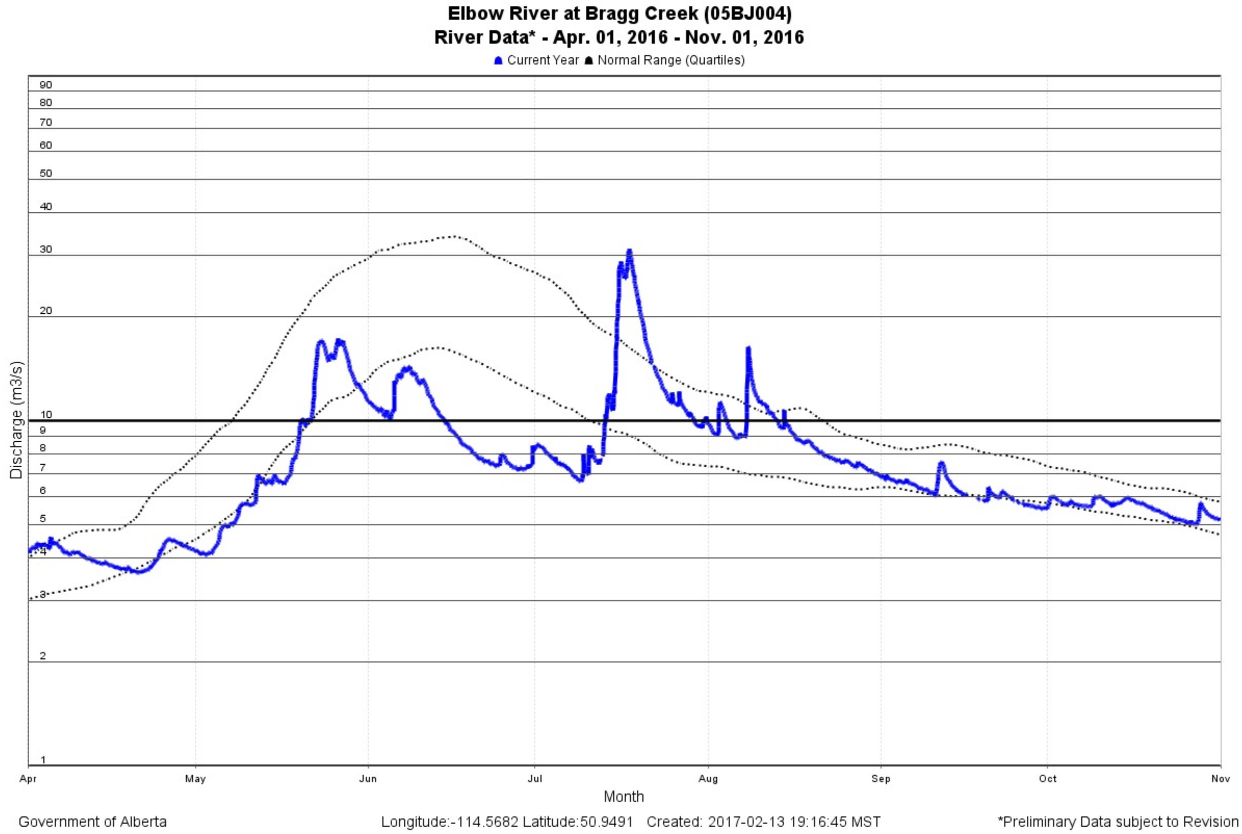

Figure 6.5-3 Elbow River Discharge April 2016 to November 2016, upstream of Bragg Creek (Station 05BJ004)

Pathogens

While there are no guidelines for total and fecal coliforms for the protection of aquatic life, there are strict guidelines imposed by Health Canada (2014) for drinking water quality requiring no detectable coliforms, total or fecal (E. coli), per 100 mL. Between 1998 and 2015 mean total coliforms and mean E. coli concentration exceeded 160 mean probable number (MPN)/mL and 10.8 MPN/mL with the highest recorded values for all water borne pathogens between May and July, when water temperature and flow were at their peak. The 2017 Phase II ESA (**Appendix 3-B**) showed that pathogens in the soil by the EVRS were below the detection limit of 3 MPN/mL. However, a study by Manwell and Ryan (2006) found that septic wastes from Bragg Creek were flushing into the river 5 km to 12 km downstream of Bragg Creek through groundwater intrusions and initial testing of the groundwater around the ranger station also confirm nitrogen products, likely from the septic fields around the station and other park facilities. The studies by Manwell and Ryan (2006) and Cantafio and Ryan (2014) also describe active cattle grazing over the alluvial aquifer, which is a likely source of coliforms between 1998 and 2015. Cattle grazing in areas identified by these studies appear to be downstream of the MC1 area but contaminant sources around the MC1 site should be confirmed as they pose health concerns if disturbed or not decommissioned properly. Microcystin data for the Elbow River is unavailable but this another important pathogen to examine given it is toxic to human health even at very low concentrations (**Table 6.5-6**).

The stream sites in the Elbow River upstream of Bragg Creek and at the Highway 22 Bridge are in a region with low chemical, fertilizer and lime expenses and low surface water quality risk index (Agricultural Land Resource Atlas of Alberta 2016a-c) but some forage crop production and low intensity grazing exists downstream of Bragg Creek (Manwell and Ryan 2006). Therefore, the information for the top six pesticides and herbicides recorded in surface water samples in Alberta (Environment Canada 2011) have been summarized in **Table 6.5-11**. Despite some agricultural activity in the area, pesticides and herbicides in the Elbow River were all below the method detection limits.

Table 6.5-11 Mean Pesticide and Herbicide Concentration Across All Years Measured

Parameter	Units	Elbow River		
		Mean	n	Year Range
2,4 Dichlorophenoxy-acetic acid	µg/L	< 0.005	13	2006-2008
2-methyl-4-chloro-phenoxyacetic acid	µg/L	< 0.010	13	2006-2008
Clopyralid	µg/L	< 0.020	13	2006-2008
Dicamba	µg/L	< 0.005	13	2006-2008
Dichlorprop	µg/L	< 0.005	13	2006-2008
Bromoxynil	µg/L	<0.005	13	2006-2008

Notes: Mean = mean across all years and months samples were collected
n = sample size
Year Range = years when samples were collected

6.5.3 APPLICATION CASE

The Application Case describes the effects of the MC1 Option added to Baseline Case (i.e., assesses the MC1-related effects). The following sections present the potential MC1-related interactions, effects and mitigation measures, along with an assessment of residual effects.

6.5.3.1 Potential Option Interactions

Expected interactions between MC1-related activities and Water Quality are defined as a change from existing conditions. **Table 6.5-12** shows potential interactions through the Construction phase and Operation and Maintenance phase.

Table 6.5-12 Identification of Potential Option Interactions with Water Quality

Phase	Activity	Surface Water Quality for Aquatic Organisms		Drinking Water Quality	
		Interaction	Potential Effect	Interaction	Potential Effect
Construction	Clearing	X	• Exceedance of turbidity guidelines • Algal production associated with a nutrient release	X	• Exceedance of turbidity guidelines • Algal production associated with a nutrient • Release of organic matter into the river, producing precursors for disinfection by-products in a water distribution system
	Road construction	X	• Exceedance of turbidity guidelines	X	• Exceedance of turbidity guidelines
	Decommissioning and removal of existing provincial parks infrastructure and ranger station	X	• Exceedance of turbidity guidelines • Exceedance of chemical contaminants guidelines	X	• Exceedance of turbidity guidelines • Exceedance of chemical contaminants guidelines • Exceedance of pathogen guidelines
	Dam (cofferdam and earth fill) construction	X	• Exceedance of turbidity guidelines • Exceedance of chemical contaminant guidelines	X	• Exceedance of turbidity guidelines • Exceedance of chemical contaminant guidelines
	Spillway construction	X	• Exceedance of turbidity guidelines • Exceedance of chemical contaminant guidelines	X	• Exceedance of turbidity guidelines • Exceedance of chemical contaminant guidelines
	Rock groin and diversion tunnels construction	X	• Exceedance of turbidity guidelines • Exceedance of chemical contaminant guidelines	X	• Exceedance of turbidity guidelines • Exceedance of chemical contaminant guidelines
	Laydown areas construction and use	X	• Exceedance of turbidity guidelines	X	• Exceedance of turbidity guidelines
	Stockpile development and use	X	• Exceedance of turbidity guidelines	X	• Exceedance of turbidity guidelines

Phase	Activity	Surface Water Quality for Aquatic Organisms		Drinking Water Quality	
		Interaction	Potential Effect	Interaction	Potential Effect
	Borrow and spoil areas development and use	X	• Exceedance of turbidity guidelines	X	• Exceedance of turbidity guidelines
Construction	Realignment of McLean Creek and other small waterbodies	X	• Exceedance of turbidity guidelines • Release of nutrients leading to excessive algal growth	X	• Exceedance of turbidity guidelines • Release of organic matter into the river, producing precursors for disinfection by-products in a water distribution system • Release of nutrients leading to excessive algal growth
Construction	Realignment of Highway 66	X	• Exceedance of turbidity guidelines	X	• Exceedance of turbidity guidelines
Construction	Storage of water in permanent pond	X	• Exceedance of turbidity guidelines • Release of nutrients leading to excessive algal growth • Exceedance of temperature guidelines • Exceedance of methylmercury guidelines	X	• Exceedance of water temperature guidelines • Release of nutrients leading to excessive algal growth • Exceedance of methylmercury guidelines • Release of organic matter into the river, producing precursors for disinfection by-products in a water distribution system • Exceedance of pathogen guidelines
Construction	Reclamation	X	• Exceedance of turbidity guidelines • Exceedance of nitrogen guidelines • Release of nutrients leading to excessive algal growth	-	-

Phase	Activity	Surface Water Quality for Aquatic Organisms		Drinking Water Quality	
		Interaction	Potential Effect	Interaction	Potential Effect
Operation and Maintenance	Routine and Flood Operation and Maintenance	X	• Exceedance of turbidity guidelines • Release of nutrients leading to excessive algal growth • Exceedance of temperature guidelines • Exceedance of methylmercury guidelines	X	• Exceedance of turbidity guidelines • Release of nutrients leading to excessive algal growth • Exceedance of methyl-mercury guidelines • Release of organic matter into the river, producing precursors for disinfection by-products in a water distribution system

Note: X – potential interaction; '- '– no interaction

6.5.3.2 Potential MC1-related Effects

This section considers potential adverse MC1-related effects on VCs arising from potential interactions, as identified in and in relation to the measurable parameters listed in **Table 6.5-3.** Mitigation measures for each potential effect are described in **Section 6.5.3.3.**

Surface Water Quality for Aquatic Organisms and Drinking Water Quality

Exceedance of Turbidity Guidelines

Construction Phase

Ground disturbance leading to transport of soil particles into the Elbow River to produce turbidity may occur from the use of heavy equipment, blasting, clearing, and construction activities (**Table 6.5-12**).

An increase in turbidity would be anticipated during the following activities:

- Construction of temporary and permanent access roads (including culvert and temporary bridge installations)
- Realignment of Highway 66, including new clear span bridge over the Elbow River
- Preparation and use of staging, laydown and stockpile areas
- Site preparation and clearing
- Decommissioning and removal of existing provincial parks infrastructure and EVRS
- Construction and maintenance of the cofferdam and rock groin
- Construction of the dam and spillways

- Excavation of borrow pits
- Realignment of McLean Creek and other small waterbodies
- Channelization of the Elbow River
- Blasting and removal of blast rock
- Storage of water in the permanent pond.

Blasting may cause an increase in suspended sediment concentrations in waterways due to blast residues and agitation of rock and soils. The severity of the effect is related to the type of explosive and size of the charge. Turbidity and TSS from disturbance of sediment by an excavator during removal of blast rock would also be expected with the amount of change being related to particle size distribution of disturbed material, the type equipment that is used, duration of continuous machine activity, and proximity to waterways.

The Elbow River is naturally turbid, mainly during high flows associated with snowmelt in the headwaters in spring and summer (see **Section 6.5.2**). This turbidity can be attributed to weathering of parent materials in the headwaters from glacial erosion and snowmelt that is likely to mobilize particles dominated by silt (particle size 0.002 mm to 0.06 mm) clay (<0.002 mm) and to a smaller extent sand (0.06 mm to 0.6mm) and larger particles (Haritashya et al. 2010). Sediment deposition resulting from turbidity events in the Elbow River may affect the Surface Water Quality for Aquatic Organisms VC and the Drinking Water Quality VC by altering the substrate size and availability for benthic organisms, impairing biological production and reducing the Secchi depth in permanent pond habitat, or exceeding federal guidelines for the protection of aquatic life and drinking water quality. Guidelines (see **Table 6.5-5**) indicate that turbidity of 8 NTU above background levels, or values greater than 10% above background when turbidity is greater than 80 NTU, may influence aquatic life.

Drinking water quality at intakes downstream of the Option may also be affected if turbidity guidelines for Drinking Water Quality (**Table 6.5-5**) were exceeded. An individual ground disturbance event may cause small-scale and short-lived introduction of sediment to waterways; however, multiple disturbances during the Construction phase may produce turbidity events affecting surface water quality in the Elbow River for the duration of the Construction phase.

Operation and Maintenance Phase

Wave action in the permanent pond may cause particle resuspension originating along the shoreline sediment – water interface and produce turbidity in the water column (Bailey and Hamilton 1997), sheetwash erosion (Hogg 1982), fluvial erosion (Tullos et al. 2016, Perrin et al. 2000) and bank slumping (Abrahams 2006). These potential effects may be exacerbated and enhanced by fluctuations the water surface level during flood events (Zohary and Ostrovsky 2011).

The magnitude of turbidity production and changes in TSS in the littoral and pelagic water column from these processes would be dependent on the magnitude of water flows, the size distribution of soil and sediment particles along the permanent pond shorelines, steepness of slopes, and the volume of sediment and soil that may be exposed to potential mobilization. Soil Orders within the footprint of the permanent pond include Regosols, Luvisols and Brunisols (see **Section 6.2 Terrain and Soils**). Soil Orders within the footprint of the permanent pond include Regosols, Luvisols and Brunisols. It is reasonable to expect a compliment of silt, sand and perhaps clay-sized materials that are typically susceptible to mobilization would be present following clearing of the permanent pond basin. Slope stability within the footprint of the permanent pond is mainly Class I or II, which corresponds to no or low likelihood of landslides following reservoir filling or rapid drawdown. During and after the time the reservoir is filled, particle resuspension and mobilization from the shorelines would be likely to occur. The process is likely to be episodic in association with the direction, velocity, and duration of wind, rainfall intensity, and river flow resulting in periods of high turbidity and reduced Secchi depth followed by relatively clear water conditions. During turbidity episodes, some particles would settle in deeper areas of the permanent pond and others, having slow settling velocities, would remain suspended and be exported downstream in association with water residence time of the permanent pond.

Similar to the Construction phase, sediment deposition from excess turbidity may affect the Surface Water Quality for Aquatic Organisms VC by altering the substrate size and availability for benthic organisms, impair gill function for aquatic organisms, smother eggs, impair biological production and reduce the Secchi depth in permanent pond habitat. Drinking Water Quality at intakes downstream of the MC1 Option could also be affected if water released from the permanent pond was sufficient to increase downstream turbidity beyond the guidelines for Drinking Water Quality (**Table 6.5-5)**. Normal operation of the permanent pond would likely not affect water quality for aquatic organisms or drinking water quality downstream of the MC1 dam but during flood events, turbidity in the Elbow River could affect water quality as far down as Glenmore Reservoir. The production of turbidity could increase around the shoreline of the permanent pond due to increased wave action and the inundation of infrequently flooded and un-armored sediment. However, MC1-related effect of turbidity increases in the Elbow River during flood events would be small given the small surface area of the permanent pond relative to the much larger surface area affected by a flood in the Elbow River Watershed. Meteorological data, including wind speed and direction around the permanent pond, collected over a year would be required to quantitatively address the effects of MC1-related turbidity downstream of the dam and in Glenmore Reservoir.

Water residence time, calculated as total water volume divided by rate of outflow using hydrological metrics provided by Opus (2017b)**,** show that under normal operating conditions (i.e., no flooding), water is likely to stay in the permanent pond for 3.5 days in summer, when river flows and water release from the pond are relatively high, and approximately 19 days in winter when river flows and water release from the permanent pond are low (**Table 6.5-13**). The rate of inflow would always balance outflow thus maintaining a stable water volume and a stable water surface elevation with little variation. Under these conditions, turbidity associated with sediment mobilization from fluctuations in water surface elevation are likely to be small or absent, depending on amount of armouring at the shoreline sediment – water interface during normal operating conditions in the absence of a flood event. Armouring is a natural process that results in the removal of fine sediments through wave action and changes in water surface elevation, leaving behind larger particles that are less susceptible to mobilization. Turbidity from wind-generated wave action would remain, however it would be dependent on sediment particle size distribution and natural armouring of the shoreline.

Table 6.5-13 Average Values of Hydrological Metrics for the Permanent Pond, by Season

Metric	Summer	Winter
Permanent pond volume (m^3)	4.0 x 106	5.0 x 106
Mean rate of outflow (m^3/s)	13.4	3.0
Mean water residence time (days)	3.5	19.3

Note: volume and flow data are from Opus (2017b).

As armouring progresses (i.e. mobilization of fine sediments), turbidity production from wave action, sheetwash erosion, fluvial erosion, and slumping would be likely to decline. Repeated raising and lowering of the water surface elevation in the reservoir, in association with managing water storage would potentially extend the duration of turbidity production as new sediment sources are exposed to the particle mobilization forces. An offset to sediment depletion would be sediment recruitment from upstream that would mostly influence the source of material that may be mobilized by fluvial activity. The source would be concentrated at the inflow river delta, where the Elbow River would flow into the reservoir, as found elsewhere (e.g. Perrin et al. 2000). See **Section 6.4 Fluvial Geomorphology** for a discussion of sediment retention in the upstream extent of the permanent pond.

In general, the settling rate for clay particles is slower than 1 cm per hour; the settling rate for fine sand is about 1 cm per minute; and silt is in between, at approximately 30 cm per hour (Gee and Bauder 1986). Given that water depth of the permanent pond near the dam would be approximately 16 m (dam height (50 m) less the difference between top of the dam (1,429 m) and maximum water surface elevation of the permanent pond (1,395 m)), it is expected that settlement of silt in the permanent pond would take 53.3 hours, or just over 2 days to settle. The clay-sized particles would take over 65 days to settle. These estimates indicate that in summer, when most of the naturally occurring turbidity would occur, the clay-sized particles would not settle out within the water residence time (3.5 days). However, all of the silt would settle within water residence time; therefore, the permanent pond would trap a portion of inflowing suspended sediment. Water released downstream would remain turbid, but less turbid than upstream of the dam. A more accurate estimate of turbidity would require further detailed information on particle sizes produced in the headwaters of the Elbow River (**see Section 6.5.2.1** and **6.5.2.2**), and size distribution of suspended particles that occur in spring and summer. During winter, natural inflowing turbidity to the permanent pond is likely to be low due to freezing conditions in the headwaters, and would be modified little by the permanent pond. At that time, in-pond processes may be more dominant for turbidity production, as discussed above, but even that source may be small due to low rainfall and low river flows that would induce small or no particle mobilization.

These two turbidity sources (i.e., upstream of the permanent pond and within the permanent pond) are important to distinguish because one is a potential MC1-related effect (i.e., turbidity produced within the permanent pond) and the other is from sources upstream of the permanent pond, and is not a MC1-related effect.

The potential effect of the MC1 Option may involve the in-pond production of turbidity and TSS and a reduction in Secchi depth, which would affect the Surface Water Quality for Aquatic Organisms VC and Drinking Water Quality VC by exceeding water quality guidelines for protection of aquatic life within the permanent pond and exceedance of guidelines for the protection of aquatic life and drinking water quality downstream of the dam (**Table 6.5-5**). This potential effect may be most pronounced at the time of pond formation when the organic layer is initially inundated then decline over time, with temporary increases during flood events or from natural disturbances such as wave action.

Exceedance of Chemical Contaminant Guidelines

Construction Phase

A Phase I and Phase II ESA was conducted to identify and define potentially contaminated soils that may be affected by the MC1 Option (see **Section 3.6, Appendix 3-A Phase I Environmental Site Assessment Elbow River at McLean Creek Dam (MC1) Option** and **Appendix 3-B 2017 Phase II Environmental Site Assessment Elbow River at McLean Creek Dam (MC1) Option**). These studies identified several materials being stored at the EVRS, including diesel, gasoline, aviation fuel, and paint with evidence of potential surface contamination. Chemicals leached into the soil may be released to the Elbow River or a tributary inflow to the Elbow River during the following decommissioning activities:

- Removal of fuel storage tanks and fuelling stations,
- Chemical and soil waste removal

Possible contaminants recognized as potentially toxic are included in the measurable parameters for the MC1 Option (see **Table 6.5-3).** Barium, ethylbenzene, boron, chromium, chlorinated ethanes, molybdenum, MTBE, phenols, PAHs and toluene may be in the soils around where vehicle fuels have been stored (e.g. the EVRS or other provincial park infrastructure). Handling of these materials during the reclamation process may result in potential exceedances of relevant parameters for both Drinking Water Quality and Surface Water Quality for Aquatic Organisms (see **Table 6.5-5)**, through mechanisms such as runoff from any temporary stockpiles. Decommissioning the EVRS and other park infrastructure may also introduce disinfection by-products produced in a water distribution system. These by-products include chlorate, chloramine, dichlorophenol and trihalomethanes and are produced when high levels of DOC in water intakes are combined with chlorinated disinfection chemicals. These disinfection by-products could be introduced into the Elbow River if treated river water is not removed from the site or if contaminated soil in the septic fields is not properly removed.

Operation and Maintenance Phase

Potentially contaminated soils, as identified in the Phase I and Phase II ESA, are within the inundation zone of the permanent pond (see **Figure 4.2-1 MC1 Option area**) but would be removed as a part of the Phase III cleanup, and would therefore not affect Surface Water Quality for Aquatic Organisms and Drinking Water Quality downstream of the MC1 dam.

Release of Nutrients leading to Excessive Algal Growth

Construction Phase

Growth of periphyton (also known as benthic algae) in the Elbow River is likely to be limited mainly by concentration of bio-available phosphorus (see **Section 6.5.2.3**). There are no guidelines for periphyton biomass or bioavailable forms of phosphorus; however, anomalous algal biomass is not desirable when the following conditions occur:

- Excessive algal accrual increases oxygen demand from the decomposition of detrital matter;
- Algal biomass smothers substrata thereby limiting habitat for benthic organisms;
- Algal biomass reduces the aesthetic qualities for people.

Activities during the Construction phase where risk of nutrient release, mainly phosphorus, may occur are as follows:

- Operation of waste storage and disposal
- Flood event causing mobilization of nutrients from on-site septic treatment facilities at the EVRS, existing provincial park infrastructure and handling facilities
- Site reclamation and landscaping with use of fertilizers
- Clearing vegetation leading to release of nutrients from disturbed soils and during filling and operation of the permanent pond
- Blasting that releases nitrogen to watercourses if it coincides with release of phosphorus from another source
- Placement and operation of temporary waste treatment facilities
- Accidental release of wastewater to the reservoir or permanent pond footprint during relocation of decommissioned wastewater infrastructure. This would require discharge occurring over days to weeks.

Anomalous algal growth resulting from nutrient release could affect Surface Water Quality for Aquatic Organisms and Drinking Water Quality downstream of the dam by first decreasing DO in the Elbow River, which creates conditions favourable for methylmercury formation. Nutrient inputs can also favour cyanobacteria, which can produce microcystins that are harmful if ingested.

Operation and Maintenance Phase

Nutrient loading during the Operation and Maintenance Phase could arise from the decomposition of vegetation and organic material following flooding of soil for the permanent pond supplying phytoplankton and periphyton with limiting nutrients essential for growth. Algal growth in the permanent pond would likely be limited mainly by concentration of bio-available phosphorus, which could arise from the dissolution or erosion of sediment around the perimeter of the permanent pond. As with periphyton, there are no guidelines for phytoplankton biomass or for bioavailable forms of phosphorus but anomalous algal biomass is not desirable when the following conditions occur:

- Detrital matter from algae increases oxygen demand in the water column from decomposition at the sediment
- Algal taxa that may be toxic are favoured due to phosphorus loading (e.g., some blue-green algae (cyanobacteria))
- Algae clogs filters used in water intakes
- Algal biomass reduces the aesthetic qualities for people.

In the years immediately following the filling of a reservoir, nutrient loading can increase, leading to “trophic upsurge”, which is an increase in aquatic organism biomass (Ostrofsky and Duthie 1980, Paterson et al. 1997, Grimard and Jones 1982, Hecky and Guildford 1984, Baxter 1977, Stables et al. 1990, Perrin et al. 2006). This increase in biological production is caused by the leaching and mineralization of nutrients that are released to the water column from newly flooded vegetation and soils (Kennedy and Walker 1990). This increase in algal biomass in the permanent pond would decrease the Secchi depth, an indication of light penetration in aquatic environments. After several years, “trophic depression” may occur. This process is thought to be a result of burial of submerged organic substrata due to advanced erosion of shore zones, a lowering of oxygen demand and declining nutrient release as labile vegetation is mineralized, leading to lower abundance of invertebrates (Popp and Hoagland 1995). In some reservoirs, the depression is caused by adsorption of phosphorus and trace electroactive elements (e.g. iron) onto substrates of DOC that can be abundant as leachates from previously flooded vegetation and soils (Jackson and Hecky 1980, Guildford et al. 1987). In reservoirs where flushing rates are high (low water residence time), adsorption of phosphorus to particles can contribute to rapid export of soluble and particulate nutrients, which increases the rate of nutrient depletion (oligotrophication).

Nutrient conditions in other reservoirs in Alberta range from low (oligotrophic) to high (eutrophic), meaning they have wide ranging productivity, driven by supply of bioavailable nutrients. The Chain Lakes Reservoir, southwest of Calgary, that was formed in 1966, is considered mesotrophic or having moderate productivity (Swanson and Zurawell 2006). Over decades there has been no temporal change in trophic state in its north basin and a temporal decline of TP concentration and algal biomass is weakly apparent in its south basin. The Oldman Reservoir in southwestern Alberta, formed in 1991, is oligotrophic (low productivity) and has no trophic upsurge due to loading and sedimentation of phosphorus that is mostly unavailable for uptake by phytoplankton (Mitchell 2001). The Twin Valley Reservoir on the Little Bow River, also in southwestern Alberta, has high levels of algal biomass due to loading of phosphorus that is biologically available, producing algal assemblages with cyanobacteria (Sosiak 2011). Among several criteria, this reservoir is eutrophic (high productivity with poor water quality) with no evidence of temporal change in condition, largely due to external organic material inputs and internal loading of bio-available phosphorus that prevents trophic depression. A general theme from these observations is that loading of phosphorus from sources outside of the reservoirs, rather than internal processes within the reservoirs, largely drive trophic condition in many Alberta reservoirs.

The low water residence times of the reservoir and permanent pond at MC1 and the very low soluble phosphorus concentrations (**Table 6.5-9**) in the Elbow River shows that the amount of trophic upsurge and depression is likely to be low if contaminated soils and vegetation are completely removed from the inundation zone of the permanent pond. However, complete removal of these nutrient sources would be extremely difficult. In spring and summer, an estimated water residence time of 3.5 days would only be a slowing of the Elbow River as it passes through the permanent pond. The Elbow River carries nutrient concentrations typically associated with an oligotrophic (low nutrient) state. However, nutrients that are released from newly flooded soils within the reservoir footprint or introduced during flood events around the perimeter of the permanent pond could support anomalous algal production within the permanent pond. These algal communities could be flushed downstream of the MC1 dam in sufficient concentrations to affect Surface Water Quality for Aquatic Organisms and Drinking Water Quality despite dilution when combined with river flow. In winter, the low river flows and longer water residence times would favour greater retention of nutrients within the permanent pond and potentially lead to an increase in phytoplankton biomass within limits associated with reduced light from ice cover and low water temperature. This increase in phytoplankton biomass could also adversely affect Surface Water Quality for Aquatic Organisms or Drinking Water Quality within and downstream of the permanent pond, respectively.

Exceedance of Temperature Guidelines

Storage of water in a permanent pond could promote thermal stratification during ice-free months, resulting in a warm surface mixed layer called the epilimnion and a cool bottom mixed layer called the hypolimnion separated by a zone of large temperature change (the thermocline) within a middle zone called the metalimnion (Wetzel 2001). As air cools in late summer, this stratification becomes unstable, leading to mixing of the complete water column and cool isothermal conditions in fall through early spring before stratification is again favoured in late spring. During ice cover in winter, water temperature near the ice can be cooler (close to 0°C) than at greater depths (close to 4°C) because water at 4°C is denser than at other temperatures and it sinks. Epilimnetic temperatures in summer may exceed guidelines for the protection of aquatic life (mainly fishes) in summer in some reservoirs, which is why fish may move to deeper water in warmer months of the year.

Temperature stratification is present in reservoirs of Alberta. It is found in the Chain Lakes Reservoir that has surface temperatures close to 10°C in summer and a mean water residence time of 197 days (Swanson and Zurawell 2006). In the Oldman Reservoir where stratification is present in August and September, has a mean water residence time of 100 days, surface temperatures close to 20°C and hypolimnetic (bottom) temperatures near 14°C (Mitchell 2001). Those temperatures may exceed guidelines for protection of some aquatic organisms and they exceed drinking water guidelines. Similarly, stratification is present in summer in one of the Twin Valley Reservoir basins where surface temperatures can exceed 20°C with bottom temperatures near 16°C (Sosiak 2011). Water residence time was not reported. This narrow range is due to shallow depths that limits complete development of a hypolimnion. In other shallow basins of Twin Valley Reservoir, stratification is less pronounced and may be absent with surface temperatures in summer close to 23°C and bottom temperatures of 20°C, both of which exceed guidelines for some fish species and drinking water.

The risk of water temperature exceeding guideline values in the permanent pond is dependent on the interaction between amount of solar heating, water residence time, pond morphometry, and wind-induced mixing (Mazumder and Taylor 1994). Water temperature in the Elbow River near the MC1 area is well below guideline values throughout the year (**Table 6.5-9)**. These low inflow water temperatures, in combination with low water residence time in summer (3.5 days) compared to other reservoirs in Alberta, shows no to low risk of thermal stratification. Wind induced mixing would also destabilize density layers and inhibit rising water surface temperature. Under the present permanent pond design, the lack of a complex basin, where water may be trapped for long durations, also does not favour high surface water temperature in summer. Under these conditions, temperature would not be likely to rise above guideline values for the protection of aquatic life and for drinking water and presents no or low risk to Surface Water Quality for Aquatic Organisms and Drinking Water Quality.

Exceedance of Methylmercury Guidelines

The accumulation of methylmercury in the permanent pond is a potential MC1-related effect during the Construction and Operation and Maintenance phases. Methylmercury in aquatic organisms and water originates from the flooding of vegetation following filling of a reservoir (Kelly et al. 1997). Mercury may also come from weathering of parent materials in the permanent pond where high levels of inorganic mercury may be found. The methylated form of mercury produced by microbial activity is more toxic than elemental mercury (Ullrich et al. 2010). Methylmercury is readily taken up and bio-concentrated in the food web in a reservoir. Toxicity in people occurs when aquatic organisms (Eagles-Smith et al. 2016) or to a lesser extent contaminated water sources (Health Canada 2009) are ingested.

Naturally occurring high concentrations of methylmercury are present in the Elbow River (**Table 6.5-9**) and they exceed guidelines for drinking water quality and for the protection of aquatic life. There is some uncertainty with these findings, however, because they are not consistent with earlier data showing lower concentrations (Beers and Sosiak 1993). Further sampling may be needed to clearly establish mercury concentrations in the Elbow River at the MC1 area. If the more recent data (i.e., higher levels) cited in **Table 6.5-9** are correct, it means an unknown source of mercury is present upstream of the two sampling sites used to establish the Baseline Case (Elbow River upstream of Bragg Creek, Elbow River at Highway 22 Bridge). This source of mercury would add to methylmercury produced within the pond after flooding of vegetation or organic material.

Methylmercury in aquatic organisms and water could be produced in the permanent pond from repeated dewatering and flooding of substrata containing decomposing vegetation containing mercury in the drawdown zone of a newly formed reservoir in low oxygen conditions (Willacker et al. 2016). Mercury may also come from weathering of inorganic material upstream of the MC1 Option and accumulate in the permanent pond. However, weathering of parent materials upstream of the permanent pond would not be related to MC1 activities, and is not considered further.

Low water residence time and high DO in the MC1 permanent pond would be likely to limit rates of reaction in the formation of methylmercury. The rapid water exchange would maintain well-oxygenated conditions throughout the water profile that would not favour the anaerobic (no to low oxygen) methylation process that is mediated by dissimilatory sulfate-reducing and, to a lesser extent, iron-reducing bacteria (Kerin et al. 2006). In winter, when water residence time in the permanent pond increases and DO concentrations may decline under ice, there may be greater opportunity for this methylation process, however low temperature may reduce the rate of production. The estimated winter water residence time of 19 days is also likely to limit development of anaerobic conditions needed for mercury methylation.

A potential MC1-related effect may be mercury methylation, depending on the amount of vegetation that would be flooded and decompose in the permanent pond; however, this is likely to be low because of anticipated well-oxygenated conditions in the permanent pond and low water residence times, which would further promote high DO. The presence of inorganic mercury from upstream sources would be present in the permanent pond at concentrations that could exceed guidelines for drinking water quality and guidelines for protection of aquatic life, however this would not be related to MC1 activities.

Drinking Water Quality

Introduction of Organic Matter Combining with Disinfectants in Distribution System Downstream of the Option

Construction Phase

Dissolved organic matter (DOM) has the potential to increase in the water column downstream of the MC1 Option during Construction phase-activities including clearing, the realignment of McLean Creek or when soils and vegetation are inundated by the permanent pond. Disinfection by-products can form when DOM in water that is withdrawn from a source like the Elbow River combines with chlorine or ozone disinfectants in a water distribution system (Kraus et al. 2011). Disinfection by-products include chloramines, trihalomethanes, chlorate, dichlorophenol, and can impart unpleasant taste and odour to water and some may be carcinogenic at high concentrations. During construction, DOM may increase if vegetation cleared upstream of the dam is not properly removed from the river and allowed to decompose.

Analysis for DOC is a common surrogate for DOM given that carbon is a large part of organic matter. There are no data for DOC at the sampling sites that were examined for describing the baseline condition; however a mean TOC concentration, which includes organic particulates, was 1.5 mg/L upstream of Bragg Creek (172 observations during 2000-2015) and 1.3 mg/L at the Highway 22 Bridge (339 observations during 1999-2015) (**Table 6.5-9**). These values would be likely to be higher than DOC concentrations because they include the particulate fractions. The TOC concentrations in **Table 6.5-9** are about a third of the concentration required for formation of trihalomethane and haloacetic acid formation potentials (Kraus et al. 2011), and the DOC concentrations would be lower. This suggests that current concentrations of DOC in the Elbow River near the MC1 area may have weak potential for formation of disinfection by-products unless MC1-related activities cause an increase in DOC.

Operation and Maintenance Phase

DOC may originate from the decomposition of temporarily inundated vegetation during flood events as well as phytoplankton production in the permanent pond. Concentrations of DOM in the permanent pond during operation may therefore be higher than current levels in the river due to MC1-related activities. The accumulation of DOM and its uptake into water distribution systems downstream of the MC1 Option, including the Glenmore Reservoir, could lead to the formation of disinfection by products that could affect Drinking Water Quality in the water intakes downstream of the MC1 Option. It would however, be difficult to discern MC1-related DOM from naturally occurring DOM, particularly during flood events.

Exceedance of Pathogen Guidelines

Pathogens may be introduced into the Elbow River in the Construction phase, during the decommissioning of the EVRS and other park infrastructure as contaminated soils from septic fields and waste treatment facilities are removed. Health Canada guidelines require that no detectable coliforms per 100 mL are present. Soil samples for the 2017 Phase II Environmental Site Assessment Elbow River at McLean Creek Dam (MC1) Option (**Appendix 3-B**) revealed total coliforms were below detection of 3 MPN/g. Assuming the septic fields around the EVRS were operating correctly and are decommissioned appropriately during the Phase III cleanup, MC1-related activities would not introduce coliforms into the Elbow River.

The Baseline Case (see **Section 6.5.2.2** and **Section 6.5.2.3**) showed fecal coliforms are already present in the Elbow River beyond acceptable guidelines for Drinking Water Quality. The presence of fecal coliforms indicates infiltration of wastewater containing feces (human or animal) into the Elbow River. These coliforms may contain pathogens that can cause gastrointestinal illness in people who drink the water (Savichtcheva and Okabe 2006) but pre-existing fecal coliforms should not be further effected by MC1-related activities.

6.5.3.3 Mitigation Measures

Mitigation measures comprise any practical means taken to manage potential adverse effects and may include applicable standards, guidelines, and BMPs supported by specific guidance documents. Mitigation measures to address potential adverse effects, discussed in **Section 6.3.3.2,** are described below and summarized in **Table 6.5-14.** The final column in the table identifies whether there is the potential for a residual effect.

In accordance with Alberta Transportation standard practice, BMPs and standard mitigation measures, including those outlined below to address potential effects to Water Quality, would be included in the Environmental Construction Operations (ECO) Plan that would be developed by the contractor and reviewed by Alberta Transportation prior to the start of construction.

Erosion and Sediment Control Plan

In accordance with the ECO Plan (Alberta Transportation 2016), an Erosion and Sediment Control Plan would be developed and implemented using the guidelines and BMPs outlined in the *Erosion Prevention and Sediment Control Manual* (Alberta Transportation 2011) to address the potential for exceedance of turbidity guidelines and the release of organic matter into the permanent pond or reservoir water column, producing precursors for production of disinfection by-products in a water distribution system downstream of the dam during the Construction and Operation and Maintenance phases of the MC1 dam.

During Construction, sediment transport causing turbidity could arise from MC1 Option activities including land clearing, grading, construction, excavation and stockpiling of materials. Finer material can end up as suspended load in the water column while coarser material can end up as bed load on the bottom of the river or permanent pond. Erosion and sediment transport would be mitigated with application of BMPs that are outlined by Alberta Transportation (2011) as well as others such as outlined in Chilibeck *et al.* (1993), MWLAP (2004).

In addition to the BMPs outlined in the Erosion Prevention and Sediment Control Manual (Alberta Transportation 2011) the following mitigation measures related to turbidity produced during the Construction phase from ground disturbance and excavation would also be implemented:

- Excavation and ground disturbance would be completed in-the-dry to limit increases in turbidity and TSS. Particulate in water from dewatering excavations would be managed to confirm that water meets applicable water quality guidelines before it is discharged into the receiving water body.
- Water would not to be discharged directly to the Elbow River. Discharges would be pumped to the river at a dilution rate that would prevent turbidity and other contaminants from exceeding water quality guidelines for protection of aquatic life and drinking water quality. If sediment ponds are used, sediment would be precipitated prior to discharge, and retained sediment would be transported to disposal sites off site or buried on-site.
- Effective erosion and sediment control measures would be installed, including bank stabilization procedures to prevent entry of sediment into any watercourse and maintained until re-vegetation is underway or other slope stabilization is complete to prevent sediment transport.
- Surface drainages would be isolated from upland work areas with silt barriers. If silt barriers prove to be ineffective in preventing sediment transport, drainage water would be directed to one or more detention ponds.
- Turbidity would be monitored at sites upstream and downstream of points of potential entry of sediment from ground disturbance activities to verify compliance with water quality guidelines for the protection of aquatic life. If these measurements show that construction activities are not in compliance, work that affects water quality would be immediately stopped, additional sediment control measures would be implemented, work would restart, and measurements repeated to check compliance. This check on compliance would continue at a regular frequency throughout the period of ground excavation and disturbance.
- Construction activities that introduce risk of sediment transport are to be completed as quickly as possible once they are started.
- Material such as rock, riprap, or other materials placed on the banks or within the active channel or floodplain of the Elbow River would be inert and free of silt, overburden, debris, or other substances deleterious to aquatic life and drinking water quality.
- Organic debris, such as slash from clearing and grubbing, would be prevented from entering watercourses.
- Worker training on BMPs would be implemented.

During the Operation and Maintenance phase, turbidity from particle resuspension would likely originate from erosion and fluvial processes within the permanent pond and reservoir, as well as from upstream sources in the Elbow River. Processes within the permanent pond and reservoir could be controlled to some extent but those upstream of the MC1 Option in the Elbow River could not, which means that mitigation would focus on management of the permanent pond and reservoir itself. Management actions to limit the extent of forces causing resuspension of particulates would be as follows:

- During non-flood operation, stable water surface elevation would be maintained without drawdown. This action would limit particle resuspension processes associated with drawdown (Effler and Matthews 2004) and cause substrata hardening/armouring within a narrow elevation band along the shoreline and at the inflow of the Elbow River, thus limiting the pool of material that may be suspended by erosion processes (Furey et al. 2004). This hardening process may occur over several years
- Soils above the non-flood elevation would be stabilized by planting vegetation that is tolerant to episodic flooding while allowing native plants to colonize and develop through successional phases (e.g. Engel et al. 2014).
- After a flood event, flooded soil and vegetation would be evaluated for damage and loss of habitat with methods developed for repair and mitigation against future flood events. Revegetation would occur in accordance with the vegetation management measures, reclamation and revegetation measures and riparian vegetation management measures listed below.
- Water quality would be monitored in accordance with the aquatic habitat monitoring measures (see **Section 7.3 Aquatic Environment**). Should water quality data indicate non-compliance with the water quality guidelines, further mitigation measures would be implemented until compliance is established

Adherence to the Erosion and Sediment Control Plan would be likely to be highly effective at mitigating potential increases in turbidity due to MC1-related effects.

Blast Management Measures

The detonation of explosives near waterways can introduce sediment and chemicals that could adversely affect Surface Water Quality for Aquatic Organism and Drinking Water Quality. Blast management measures would be developed and implemented to address potential effects from exceedance of turbidity guidelines and exceedance of chemical contaminants guidelines during the Construction phase. Best management practices adapted from *Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters* (Wright & Hopky 1998) for blasting around waterways include:

- The Government of Alberta Environment and Parks and the Fisheries and Oceans Canada Fisheries Protection Program would be consulted to identify alternative measures, if any, to reduce or eliminate the need for blasting.
- The use of ammonium nitrate-fuel oil mixtures would be eliminated to prevent the production of toxic by-products (e.g. ammonia) in the Elbow River.
- Worker training on BMPs would be implemented.

Adherence to the blast management measures would be likely to be highly effective at mitigating the introduction of sediment and chemicals that could adversely affect Water Quality in the Elbow River.

Cementitious Materials Management Measures

Cement would be used during construction of the dam and its components. Cementitious materials management measures would be developed and implemented to address potential effects from exceedance of turbidity guidelines and exceedance of chemical contaminants guidelines during the Construction phase. The following list of BMPs would help to make certain that the proper use and disposal of cementitious materials during construction when working around the Elbow River and permanent pond to prevent increases in turbidity, nitrogen and pH in waterways:

- Concrete would be contained in formed structures.
- The volume and extent of concrete pours would be limited in or about waterbodies.
- Wash down water from exposed surfaces and concrete trucks would be trapped onsite in designated areas to allow sediment to settle out and reach neutral pH before the clarified water percolates into the ground.
- Water quality guidelines for aquatic life would be met in the immediate vicinity of the pour to avoid deleterious effects to aquatic life.
- Water quality would be monitored in accordance with the aquatic habitat monitoring measures (see **Section 7.3 Aquatic Environment**). Should water quality data during concrete pours indicate non-compliance with the water quality guidelines, all concrete pouring activities would be suspended until a plan for maintaining compliance is established.
- Worker training on BMPs would be implemented.

The cementitious materials management measures are likely to be highly effective at mitigating adverse MC1-related effects on the introduction of turbidity and chemical contaminants to the Elbow River.

Chemical Contaminant Measures

Construction-related contaminants could include fuels, lubricants, cementitious materials and nitrogen from blast residues. The Alberta Transportation ECO Plan Framework (Alberta Transportation 2014) outlines the need for measures to control and mitigate harmful effects of chemical contaminants. Chemical contaminant measures would be developed and implemented to address potential effects from exceedance of chemical contaminants guidelines and release of nutrients leading to excessive algal growth during the Construction phase.

Potential introduction of these contaminants to watercourses could be mitigated with application of BMPs listed in the ECO Plan (Alberta Transportation 2016), *Erosion and Sediment Control Plan* (Alberta Transportation 2011), blast management measures, cementitious materials management measures and the wastewater containment measures. Alberta Transportation would also implement the following BMPs to control the introduction of chemicals into the aquatic environment:

- A Code of Practice for operation of aboveground and underground storage tank systems containing petroleum and petroleum products would be implemented through the Petroleum Tank Management Association of Alberta and in accordance with federal guidelines (CCME 2003b).

- All equipment would be refuelled, cleaned, and maintained at designated sites away from watercourses. The risks associated with the potential effects of accidental leaks of lubricants and antifreeze are discussed in **Section 11.0 Accidents and Malfunctions**.
- As warranted, the use of lubricants and anti-freeze would be mitigated, wherever possible, using mineral oil based lubricants (mixture of mineral oil (decomposable) and synthetic oil) and propylene glycol, a food-grade antifreeze.
- Worker training on BMPs would be implemented.

Adherence to the chemical contaminant measures as part of the ECO Plan would be likely to be highly effective at mitigating potentially adverse MC1-related effects.

Wastewater Containment Measures

The release of wastewater from septic fields that contain nitrogen, phosphorus and fecal coliforms into the Elbow River, or during soil inundation could lead to increased algal growth in the river and permanent pond. Wastewater contaminant measures would be developed and implemented to address potential effects from exceedance of pathogen guidelines and release of nutrients leading to excessive algal growth during the Construction phase. The extent of discharge could be prevented with BMPs used for the collection and disposal of wastewater (e.g., soil flushing and effluent capture) from the site facilities at the EVRS and park infrastructure. The following management measures to prevent discharge of nutrients to the Elbow River and the permanent pond are as follows:

- Storage tanks would be used wherever possible, and the disposal of wastewater would be done in compliance with provincial and federal guidelines.
- Wastewater produced during construction activities that is not contained in storage tanks and removed from the MC1 site would be monitored for compliance with water quality guidelines and if not in compliance, work would be stopped and mitigation works would be improved before work can re-start.
- Construction waste management measures would be developed and implemented with BMPs.
- Worker training on BMPs would be implemented.
- BMPs would be applied in the relocation of wastewater facilities.

It is expected that wastewater containment measures would be highly effective at mitigating adverse MC1-related effects due to wastewater production and removal during the Construction Phase.

Contaminated Soil Containment Measures

The release of contaminated soil that contains nitrogen and phosphorus from septic fields and chemical contaminants (e.g., aviation fuel) around the EVRS and park infrastructure into the Elbow River or permanent pond during the Construction phase would be removed from the site during the Phase III cleanup and not pose a risk if all BMPs are adhered to. During the Phase III cleanup, contaminated soil containment measures would be developed and implemented in the Construction phase to address reduce or eliminate potential effects from exceedance of pathogen guidelines, exceedance of chemical contaminants and release of nutrients leading to excessive algal growth and the release of organic matter into the reservoir water column, producing precursors for production of disinfection by-products in a water distribution system downstream of the dam during the Construction and Operation and Maintenance phases.

The extent of wastewater discharge could be prevented by adhering to BMPs of decommissioning site facilities around the EVRS and other areas of the provincial park. Control and prevention of nutrient release could also be included in measures for containment of nutrient-rich soils and fertilizer that may be used in site restoration and landscaping. The following practices to prevent discharge of nutrients into the Elbow River and the permanent pond are as follows:

- Excavation and removal of all contaminated soil would occur prior to inundation during the Phase III cleanup.
- Worker training on BMPs for soil containment and disposal would be implemented.

Contaminated soil containment measures would be likely to be completely successful in mitigating potential adverse MC1-related effects, because once the site has been cleared during the Phase III cleanup it would be remediated during Phase IV back to a natural landscape, which would include forested lands and grasslands.

Vegetation Management Measures

Inundated vegetation in the permanent pond could increase nutrient concentration, encourage methylated mercury formation, increase DOM production as well as decrease DO in the permanent pond and potentially in the Elbow River downstream of the dam. Vegetation management measures would be developed and implemented in the Construction phase to address potential effects from exceedance of methylmercury guidelines, exceedance of chemical contaminants, release of nutrients leading to excessive algal growth and the release of organic matter into the reservoir water column, producing precursors for production of disinfection by-products in a water distribution system downstream of the dam during construction and operation. Mitigation actions would prevent or limit nutrient release, trophic upsurge as well as subsequent depression, reduce the potential for methylmercury formation within the permanent pond affecting aquatic organisms within and downstream of the permanent pond as well as drinking water quality downstream of the dam are as follows:

- Vegetation would be removed from the footprint of the permanent pond. This action would involve not just cutting stems of vegetation but scraping and removing the organic surface layer of soils within the footprint of the permanent pond.
- Vegetation in the reservoir (i.e., above the permanent pond) would be maintained or new flood-tolerant plants planted, wherever possible, to stabilize soils and limit particle transport and production of turbidity during a flood event. Existing vegetation and soils would not be disturbed in the higher elevation strata. This recommendation includes caution to avoid disturbance of those higher elevation land areas by heavy equipment during construction, wherever possible.

Baseline methylated mercury concentrations presently in the Elbow River are above guidelines for protection of aquatic life at both sampling sites. Methylmercury is above the guideline for drinking water quality at Site 2, while it remains just below the guideline at Site 1. Total mercury at both sites are also above the guidelines for the protection of aquatic life but equal to the guideline for drinking water quality. Given total and methylated mercury are just below, at or above the guidelines for the protection of aquatic life and drinking water quality, measures to prevent further increases in mercury concentrations would be required. Removing vegetation would help to reduce the potential for methylmercury formation within the permanent pond affecting aquatic organisms within and downstream of the permanent pond as well as drinking water quality downstream of the dam. Further mitigation against methylmercury formation is discussed in the permanent pond operation measures below.

Dissolved oxygen is also reduced during the decomposition of organic material, which decreases Surface Water Quality for Aquatic Organisms and Drinking Water Quality but also promotes methylmercury formation. Removing vegetation from the inundation zone around the permanent pond would prevent or limit the decrease in DO in the permanent pond as well as its affects downstream of the dam.

Dissolved organic matter that is a precursor to formation of disinfection by-products downstream of disinfection in a water distribution system can come from upstream sources in the Elbow River and from within the reservoir itself. Removing vegetation would also limit the amount of DOM available for reaction with disinfection products in the water distribution system in downstream water intakes along the Elbow River.

Current conditions in the Elbow River make it unlikely for dissolved oxygen and consequently methylmercury to increase in the permanent pond and Elbow River downstream of the MC1 Option, if all vegetation management measures are implemented. However, it is unlikely that all vegetation could be completely removed from the inundation zone around the permanent pond, which could introduce nutrients and dissolved organic matter to the permanent pond and lead to some residual MC1-related effects in the permanent pond and downstream.

Permanent Pond Operation Measures

Permanent pond operation measures would be developed and implemented as part of the ECO Plan to address potential effects from exceedance of methylmercury guidelines, exceedance of temperature guidelines and release of nutrients leading to excessive algal growth during the Construction and Operation and Maintenance phases.

Nutrient concentrations presently in the Elbow River are in a range indicating no anomalous enrichment, which means that any nutrient loading that contributes to algal growth in the permanent pond would be likely to originate in the permanent pond itself, assuming no change in land use patterns that may influence nutrient transport in the Elbow River (see Vegetation Management Measures). To mitigate adverse effects of the permanent pond, water residence time would be kept low to avoid nutrient loading through the decomposition of vegetation and flush any phytoplankton that sequesters the nutrient load before a bloom of unwanted algae can develop. The planned spring and summer time water residence time of 3.5 days would meet this objective. The winter time water residence time of 19 days is less favourable but largely unavoidable due to low river flows at that time of year. Decreasing water residence time in winter by reducing the permanent pond volume is not recommended because that action would introduce seasonal raising and lowering of the water surface elevation, which is not favourable for limiting turbidity production from erosion processes (see Erosion and Sediment Control Plan) and would promote lower DO, creating more favourable conditions for methylmercury production (see Vegetation Management Measures).

Another potential MC1-related effect arising from the permanent pond would be increased water temperature beyond acceptable limits for Surface Water Quality for Aquatic Organisms and Drinking Water Quality. However, mitigation for rising epilimnetic temperature that may exceed guidelines for protection of aquatic life and guidelines for drinking water quality are essentially built in to the existing permanent pond design and operation. Summer time water residence time would be sufficiently low to prevent stable temperature stratification and limit change in temperature from that occurring in the inflow Elbow River. Any change to permanent pond design may change this conclusion.

It is likely that the permanent pond operation measures would be highly effective at mitigating adverse MC1-related effects related to methylmercury formation, water temperature and nutrient release.

Reclamation and Revegetation Measures

Reclamation and revegetation measures would be developed and implemented during the Construction phase to restore altered habitat during the Construction phase of the MC1 Option. This measure would become effective during the Operation and Maintenance phase, as vegetation matures and stabilizes soil.

Additional information on the reclamation and revegetation measures are included in **Section 6.2 Terrain and Soils** and **Section 7.1 Vegetation and Wetlands.**

Adherence to the reclamation and revegetation measures are likely to be effective at mitigating potentially adverse MC1-related effects.

Riparian Vegetation Management Measures

Rehabilitating the aquatic habitat would be required once construction of the dam is complete to prevent harmful effects from the MC1 Option on Water Quality in the permanent pond and downstream of the dam. To minimize or avoid harmful effects from the MC1 Option on Water Quality, the following BMPs would be included (adapted from MWLAP 2004):

- Effects to all species and habitat-types identified in the EIA within the area of the worksite would be considered.
- Restoration measures would be developed and implemented by appropriately qualified professionals.
- Existing or historical biological diversity would be restored, to the extent possible.
- The active floodplain in its existing condition would be maintained to the extent possible.
- The streambed would be protected, to the extent possible.
- Direct and indirect effects would be minimized to aquatic and terrestrial individuals, populations, species, and habitats in the MC1 area.

Additional information on the riparian vegetation management measures is included in **Section 7.3 Aquatic Environment**.

It is likely that the riparian vegetation management measures would be effective at mitigating adverse MC1-related effects to the riparian area around the MC1 area.

Table 6.5-14 Summary of Potential Effects and Mitigation Measures for Water Quality

Summary of Potential Effect and Classification	MC1 Components	Contributing Activities	Proposed Mitigation Measure	Detectable / Measurable Residual Effect
Construction Phase				
Exceedance of turbidity guidelines Effect on Surface Water Quality for Aquatic Organisms and Drinking Water Quality	Ground disturbance during the construction of the main dam, cofferdam, road and road access points, new bridge, material storage, borrow sites and upland work areas	Operation of heavy equipment Flood event during construction Construction and use of access roads Construction of staging areas before construction Site restoration and landscaping Site clearing preparation before construction Cut and fill of drainage ditches and culverts Placement and operation of field offices and other camp buildings Operation of stockpiles of construction materials (aggregate, borrow material) Operation of borrow pits adjacent to river flow Foundation excavation and grouting Realignment of McLean Creek and other small waterbodies Sediment disturbance during culvert construction at McLean Creek Disturbance of river sediment from channelization Sediment and slope erosion on the face of the cofferdam during construction of the rock groin used to divert water into the south tunnels Removal of vegetation and organic soil layer within the permanent pond Placement of piers and riverside disturbance during bridge construction over the Elbow River	Erosion and Sediment Control Plan Blast Management Measures Cementitious Materials Management Measures Reclamation and Revegetation Measures	No

Summary of Potential Effect and Classification	MC1 Components	Contributing Activities	Proposed Mitigation Measure	Detectable / Measurable Residual Effect
Exceedance of chemical contaminant guidelines Effect on Surface Water Quality for Aquatic Organisms and Drinking Water Quality	Equipment use and maintenance during the construction of the main dam, cofferdam, road and road access points, material storage, borrow sites and upland work areas	Operation of heavy equipment during construction Operation of fuel storage in tanks during construction Operation of waste storage and disposal during construction Possible operation of cement batch plant during construction Cement pours Foundation excavation and grouting Paving of roads near watercourses Blasting Decommissioning EVRS, septic fields and other provincial park infrastructure	Erosion and Sediment Control Plan Cementitious Materials Management Measures Chemical Containment Measures Contaminated Soil Containment Measures Blast Management Measures Vegetation Management Measures	No
Release of nutrients leading to excessive algal growth Effect on Surface Water Quality for Aquatic Organisms and Drinking Water Quality	Waste management and ground disturbance during construction of the dam, cofferdam, road and road access points, material storage, borrow sites, upland work areas and provincial park infrastructure.	Flood event during construction Operation of waste storage and disposal during construction Decommissioning of EVRS and park infrastructure Site restoration and landscaping	Chemical Contaminant Measures Wastewater Containment Measures Contaminated Soil Measures Vegetation Management Measures Permanent Pond Operation Measures Reclamation and Revegetation Measures	No
Release of organic matter into the reservoir water column, producing precursors for production of disinfection by-products in a water distribution system downstream of the dam Effect on Surface Water Quality for Aquatic Organisms and Drinking Water Quality	Permanent pond	Initial flooding of land to form the permanent pond	Erosion and Sediment Control Plan Contaminated Soil Containment Measures Vegetation Management Measures Reclamation and Revegetation Measures	No

Summary of Potential Effect and Classification	MC1 Components	Contributing Activities	Proposed Mitigation Measure	Detectable / Measurable Residual Effect
Exceedance of methylmercury guidelines Effect on Surface Water Quality for Aquatic Organisms Drinking Water Quality	Permanent pond	Flooding of land to form the permanent pond. Management of water residence time in the reservoir (balancing pond elevation, inflow, outflow)	Vegetation Management Measures Permanent Pond Operation Measures Reclamation and Revegetation Measures	No
Exceedance of pathogen guidelines Effect on Drinking Water Quality	Decommissioning and removal of existing provincial parks infrastructure and EVRS	Inundating septic fields and other provincial park infrastructure	Wastewater Containment Measures Contaminated Soil Containment Measures	No
Operation and Maintenance Phase				
Release of organic matter into the reservoir water column, producing precursors for production of disinfection by-products in a water distribution system downstream of the dam Effect on Drinking Water Quality	Inundated vegetation and soil during flood event	Infrequent flooding of land around the permanent pond.	Erosion and Sediment Control Plan Permanent Pond Operation Measures Riparian Vegetation Management Measures	No
Exceedance of chemical contaminant guidelines Effect on Surface Water Quality for Aquatic Organisms and Drinking Water Quality	Permanent pond	Inundated soil and vegetation around the permanent pond.	Erosion and Sediment Control Plan Permanent Pond Operation Measures Riparian Vegetation Management Measures	No
Release of nutrients leading to excessive algal growth Effect on Surface Water Quality for Aquatic Organisms and Drinking Water Quality	Permanent pond	Inundated soil and vegetation around the permanent pond. Management of water residence time in the reservoir (balancing pond elevation, inflow, outflow)	Vegetation Management Measures Permanent Pond Operation Measures Riparian Vegetation Management Measures	Yes
Exceedance of temperature guidelines	Permanent pond	Inundated soil and vegetation around the permanent pond.	Permanent Pond Operation Measures	No

Summary of Potential Effect and Classification	MC1 Components	Contributing Activities	Proposed Mitigation Measure	Detectable / Measurable Residual Effect
Effect on Surface Water Quality for Aquatic Organisms and Drinking Water Quality		Management of water residence time in the reservoir (balancing pond elevation, inflow, outflow)		
Exceedance of turbidity guidelines Effect on Surface Water Quality for Aquatic Organisms and Drinking Water Quality	Permanent pond	Flooding of land to form the permanent reservoir	Erosion and Sediment Control Plan Riparian Vegetation Management Measures	No
Exceedance of methylmercury guidelines Effect on Surface Water Quality for Aquatic Organisms and Drinking Water Quality	Permanent pond	Flooding of land to form the permanent pond. Management of water residence time in the reservoir (balancing pond elevation, inflow, outflow)	Permanent Pond Operation Measures Riparian Vegetation Management Measures	No

With the successful implementation of mitigation measures, residual effects to Surface Water Quality for Aquatic Organisms and Drinking Water Quality in the Elbow River are not expected for the production of turbidity, chemical contaminants and algal production in the Elbow River during the Construction phase. Residual effects are not expected with the release of organic matter, chemical contaminants, exceedance of temperature or turbidity guidelines, accumulation of methylmercury or the intake of fecal coliform during the Operation and Maintenance phase.

However, after the successful implementation of mitigation measures, potential residual effects are expected for algal production related to nutrient release from the inundation of any remaining organic material and soil around the permanent pond.

6.5.3.4 Residual Effects

Residual effects are MC1-related effects that are anticipated to occur to VCs after the successful implementation of mitigation measures. This section describes how the residual effects of the MC1 are characterized and summarized for Water Quality. The determination of a substantive or non-substantive residual effect includes a characterization including magnitude, regional extent and duration.

Potential residual effects are delineated as:

- Non-substantive residual effect – mitigation measures have not fully eliminated adverse effects, but have reduced the magnitude, extent, or duration to such a degree as to avoid a substantive effect on the VC. This characterization is based on the definitions and rating of effects characteristics outlined in **Table 6.5-15.**
- Substantive residual effect – adverse effects are likely to be irreversible, high in magnitude, regional in extent, and/or long-term in duration after implementation of mitigation.

Residual Effects Characteristics

Residual effects for the Water Quality VCs are characterized based on the criteria defined in **Table 6.5-15.**

Table 6.5-15 Residual Effects Characteristics for Water Quality

Residual Effect Characteristic	Rating	Definition
Direction	Positive	Net benefit to Surface Water Quality for Aquatic Organisms or Drinking Water Quality
	Adverse	Net loss Surface Water Quality for Aquatic Organisms or Drinking Water Quality
Extent	Local	Confined to the area directly disturbed by MC1 Option
	Subregional	Limited to one natural region and within the LAA
	Regional	Within the RAA
Magnitude	Negligible	No detectable change to Surface Water Quality for Aquatic Organisms or Drinking Water Quality

Residual Effect Characteristic	Rating	Definition
	Minor	Minor change to Surface Water Quality for Aquatic Organisms or Drinking Water Quality that causes no detectable change to the resource or is within acceptable protective standards identified in **Table 6.5-5.**
	Moderate	Moderate change to Surface Water Quality for Aquatic Organisms or Drinking Water Quality that causes a detectable change to the resource but is within acceptable protective standards identified in **Table 6.5-5.**
	Major	Major change to Surface Water Quality for Aquatic Organisms or Drinking Water Quality that causes a detectable change to the resource and exceeds acceptable protective standards identified in **Table 6.5-5.**
Duration	Short-term	Effect would occur during the Construction phase
	Long-term	Effect would continue beyond the Construction phase
Reversibility	Reversible	Effect could be reversed once the activity causing the residual effect ceases
	Not reversible	Effect would be permanent
Frequency	Isolated	Effect would occur at a specific time
	Rare	Effect would be episodic (e.g. flood event)
	Frequent	Effect would occur recurrently over the life of the MC1 Option.
	Continuous	Effect would occur continuously
Confidence	High	Rating predictions are based on a good understanding of cause-effect relationships and/or using data specific to the MC1 area
	Moderate	Rating predictions are based on a good understanding of cause-effect relationships relying on data from elsewhere, or incomplete understanding of cause-effect relationships from data specific to the MC1 Option.
	Low	Rating predictions are based on an incomplete understanding of cause-effect relationships and incomplete data

Release of Nutrients Leading to Excessive Algal Growth During the Operation and Maintenance Phase

An adverse residual effect to the Surface Water Quality for Aquatic Organisms VC and Drinking Water Quality VC is likely to occur due to the release of nutrients leading to excessive algal growth during the Operation and Maintenance phase. The removal of vegetation and topsoil around the permanent pond prior to inundation would reduce the release of nutrients into the permanent pond but it is unlikely that all organic material and soil can be removed during this process. This residual effect would be likely to be more pronounced in winter when the water residence time would be approximately 19 days, which would allow more time for algal biomass to accrue if phosphorus is available to support that growth. This algal response may occur despite low water temperatures and light attenuation under ice. Any winter-time algal response may carry forward into spring when the ice melts in the permanent pond if phosphorus is in sufficient supply to support the algal growth but shorter water residence time in the spring and summer (3.5 days) would help mitigate these effects. The shorter water residence time in the summer would also help flush the organic material, diluting the concentration of nutrients in the soil and groundwater network.

The MC1-related residual effects from anomalous algal biomass in the permanent pond are likely to be non-substantive because they would diminish over time and would require a source of phosphorus to support anomalous growth. Dilution during snow-melt would also facilitate nutrient flushing and reduce long-term downstream effects associated with anomalous algal accrual. Based on the available information, this assessment has a high level of confidence (**Table 6.5-16**).

Table 6.5-16 Summary of Effect Characteristics Ratings of Anomalous Algal Biomass in the Permanent Pond During Operation and Maintenance Phase

Residual Effects Characteristic	Rating	Rationale for Rating
Direction	Adverse	If nutrient concentration in the reservoir increases such that the trophic state changes, despite mitigation measures, there would be adverse effects to Surface Water Quality for Aquatic Organisms and Drinking Water Quality.
Extent	Subregional	Confined to reservoir and the Elbow River downstream of the MC1 dam.
Magnitude	Minor	Minimal effect would be likely due to the short water residence time in the permanent pond and current phosphorus-limited growth in the Elbow River.
Duration	Long-term	Effect would occur for the duration of the Operation and Maintenance phase.
Reversibility	Reversible	The effect could be reversed if the nutrient source is minimized or removed.
Frequency	Continuous	Effect would be continuous but likely diminish over time.
Confidence	High	Based on the available information and implementation of best practices.

6.5.3.5 Summary of Water Quality Assessment

Based on the determination of no substantive residual effects for the residual effect listed in **Section 6.5.3.4,** it is concluded that there is no potential for substantive residual effects on Water Quality**.** This conclusion is based on the Baseline Case for the Elbow River presented in **Section 6.5.2** as well as following best practices and the mitigation measures outlined in **Section 6.5.3.3.**

6.5.4 Follow-Up Monitoring for Water Quality

If the MC1 Option were to proceed through full regulatory approvals and into Construction and Operation and Maintenance, follow-up monitoring would likely be required to confirm that the following objectives are met:

- Verify the accuracy of the MC1-related residual effects predictions
- Assess the efficacy of proposed mitigation measures
- Verify compliance with regulatory guidelines

The measurable parameters for the Surface Water Quality for Aquatic Organisms VC (**Table 6.5-3**) include turbidity during Construction and Operation and Maintenance phases, introduction of contaminants to watercourses during the Construction phase, algal production from nutrient release during Construction and Operation and Maintenance phases, exceedance of temperature guidelines in the permanent pond and reservoir during the Operation and Maintenance phase, accumulation of methylmercury in aquatic organisms in the permanent pond during the Operation and Maintenance phase. The variables of interest for the Drinking Water VC (**Table 6.5-3**) are associated with Construction and Operation and Maintenance phases of the MC1 Option and include release of organic matter as precursors to disinfection by-products in a distribution system, exceedance of temperature guidelines in the permanent pond and reservoir, exceedance of turbidity guidelines, release of nutrients that may produce excessive algae, and intake of Elbow River coliforms into a water distribution system.

Table 6.5-17 and **Table 6.5-18** identify recommended monitoring programs for the Surface Water Quality for Aquatic Organisms VC and the Drinking Water Quality VC, respectively. Based on implementation of these programs, where monitoring data show exceedances of guidelines or standards, the mitigation measures would be adjusted accordingly. If no exceedances occur, the monitoring data would provide technical support that the receiving environment is adequately protected according to accepted standards. Data collected during the monitoring program would also yield important information for decision support regarding current and future reservoir development. Where and when a MC1-related residual effect would be likely to persist (i.e. release of nutrients leading to excessive algal growth) the monitoring data would be used to test hypotheses of the extent of the residual effect and how it may change over time.

These data would also be essential when working with users and regulatory agencies downstream of the MC1 Option. For example, the Glenmore Reservoir is downstream of the MC1 Option area, and is a drinking water source for Calgary. Turbidity and temperature are simple yet valuable metrics collected by small, inexpensive equipment that continuously monitor conditions. It is likely that MC1-related changes to turbidity and temperature would be within the natural variation of the Elbow River and not affect the Glenmore Reservoir. Data collected in the permanent pond would allow this hypothesis to be directly tested and provide useful information on how flood events and the MC1 Option might affect Glenmore Reservoir. Adding telemetry (remote data retrieval) would provide an early warning system for downstream users in cases where high turbidity events occurred.

Table 6.5-17 Recommended Water Quality Monitoring Program for Surface Water Quality for Aquatic Organisms Valued Component

Parameter	Purpose	Location	Timing	Method
Turbidity in the Elbow River during construction	Verify conditions are not exceeding guidelines for the protection of aquatic life	One station upstream and one station downstream of Construction at the point of full mixing	Continuous during Construction phase	Data logging instrumentation
Turbidity in the permanent pond and Elbow River during operation	Verify conditions are not exceeding guidelines for the protection of aquatic life. These data can also provide an early warning system for high turbidity events during floods and valuable information for other similar projects in the province.	One station upstream of the permanent pond and one station at outflow at the dam	Continuous during the Operation and Maintenance phase	Data logging instrumentation
Introduction of contaminants to watercourses during construction and measured as pH, barium, ethylbenzene, boron, chromium, chlorinated ethanes, molybdenum, MTBE, phenols, PAHs, toluene, chloride, ethylene glycol	Verify conditions are not exceeding guidelines for the protection of aquatic life	One station upstream and one station downstream of construction at the point of full mixing	Immediately following a spill event or heavy rainfall causing overland flow and sheetwash erosion Continue hourly throughout the event When the event dissipates drop the frequency to twice a day for 3 days and daily until values are less than guideline values and engineering solutions are installed to prevent contaminant transport	Grab samples using instructions from the laboratory used to analyze the samples
Algal production in the river during construction. Measure nutrient concentrations (NO3, NH4, SRP, TP) as an indicator of potential of algal biomass	Verify conditions are not exceeding guidelines and literature values associated with known nutrient – algal biomass relationships	One station upstream and one station downstream of construction at the point of full mixing	Start immediately following a spill event or heavy rainfall causing overland flow and sheetwash erosion Continue twice daily throughout the event When the event dissipates drop the frequency to once a day until values are less than guideline values and engineering solutions are installed to prevent nutrient transport	Grab samples using instructions from the laboratory used to analyze the samples

Parameter	Purpose	Location	Timing	Method
Algal biomass and nutrient concentrations (NO3, NH4, TN, SRP, TDP, TP) with diagnostic analytes (temperature, dissolved solids concentration, pH, dissolved oxygen, turbidity) in the reservoir during operations.	It is an indicator of trophic state and change to eutrophic state means poor water quality	One station in the permanent pond	Monthly in May to October annually or once every two years and potentially as part of a regional water monitoring program and a cost of operating the dam	Standard limnology methods with possible use of moored instrumentation
Temperature in the permanent pond during operations	Verify conditions are not exceeding guidelines for the protection of aquatic life	One station in the permanent pond	Continuous in the Operation and Maintenance phase as part of a regional water monitoring program	Moored instrumentation
Accumulation of methylmercury in aquatic organisms and water in the permanent pond during operation and downstream of the dam.	Verify conditions are not exceeding guidelines for the protection of aquatic life	Fish sampling site in the permanent pond	Once every two years after permanent pond formation in late summer for 6 years followed by one episode 4 years later (year 10 after reservoir formation) and another 5 years later (year 15 after reservoir formation). This sampling may be made part of a regional water monitoring program	Standard gill netting or angling followed by analysis of methylmercury in tissue as instructed by toxicity lab.

Table 6.5-18 Recommended Water Quality Monitoring Program for Drinking Water Quality Valued Component

Parameter	Purpose	Location	Timing	Method
Dissolve organic matter in the permanent pond during operations	It is a precursor to formation of disinfection by-products	One station in the permanent pond	Monthly in May to October annually	Standard limnology methods
Temperature in the permanent pond during operations	Verify conditions are not exceeding guidelines for drinking water quality and valuable information for other similar projects in the province	One station in the permanent pond	Continuous	Moored instrumentation
Turbidity in the permanent pond during operation	Verify conditions are not exceeding guidelines for drinking water quality and valuable information for other similar projects in the province	One station in the permanent pond	Continuous	Moored instrumentation
Algal biomass and nutrient concentrations (NO3, NH4, TN, SRP, TDP, TP) with diagnostic analytes (temperature, dissolved solids concentration, pH, dissolved oxygen, turbidity) in the permanent pond during operations.	Anomalous algal biomass may contribute to formation of disinfection by-products and some taxa can be toxic	One station in the permanent pond	Monthly in May to October annually	Standard limnology methods and moored instrumentation
Fecal coliforms	Verify conditions are not exceeding guidelines for drinking water quality	One station in the permanent pond and one station downstream of the dam	Monthly in May to October annually	Standard grab samples

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