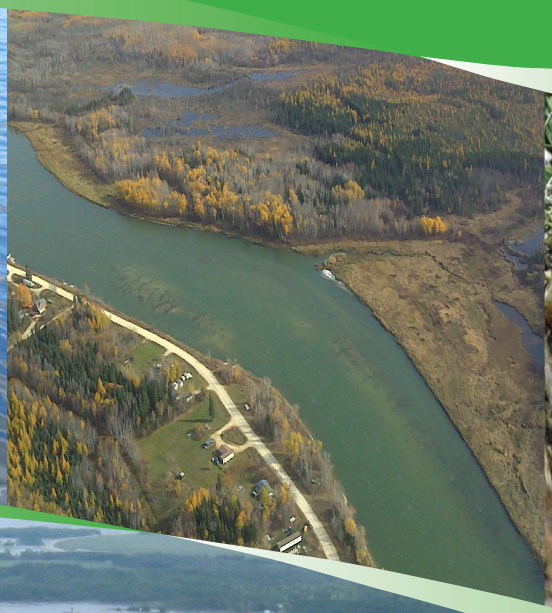
LAKE MANITOBA AND LAKE ST. MARTIN OUTLET CHANNELS PROJECT EIS

Manitoba



VOLUME 2:
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6.0 - Physical Environment

March 2020

Manitoba

LAKE MANITOBA AND LAKE ST. MARTIN OUTLET CHANNELS PROJECT
Environmental Impact Statement

CHAPTER 6

PHYSICAL ENVIRONMENT EFFECTS ASSESSMENT

March 2020

Manitoba

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6.0 ASSESSMENT OF POTENTIAL EFFECTS ON PHYSICAL ENVIRONMENT

6.1 OVERVIEW OF CHAPTER

This chapter discusses the physical environment setting and the potential effects that the Project will have on the physical environment. Section 7.1 of the Canadian Environmental Assessment Agency Environmental Impact Statement (EIS) Guidelines for the Project (CEAA 2018) and Section 3.1 of the Environmental Assessment Scoping Document (Manitoba Infrastructure 2018) submitted to Manitoba Sustainable Development indicate that existing conditions should be documented for atmospheric environment, geology and geochemistry, topography and soil, groundwater and surface water. Section 7.2 of the EIS Guidelines indicates that predicted changes to the physical environment should be determined for atmospheric environment, groundwater, surface water and fluvial geomorphology. To characterize these changes in a structured way, the following physical environment valued components (VCs) and associated sub-components have been established:

- Atmospheric Environment
  - air quality and climate (including greenhouse gases)
  - acoustic environment
  - ambient light
- Geology and Soils
  - geology
  - soils and terrain
- Groundwater and Surface Water
  - groundwater
  - surface water

Information is provided on the scope of assessment, existing conditions, Project interactions, assessment of residual environmental effects, cumulative effects, effects on federal lands, and follow-up and monitoring requirements. However, while these physical environment components are assessed as VCs, the significance of residual effects is not being determined in this chapter. The changes predicted by the physical environment VCs are used in the assessment of other VCs that are based on biological receptors (e.g., vegetation, wildlife, land and resource use, human health and Indigenous peoples) through analyses of pathways of effect, and the resultant significance is then determined for those VCs.

6.2 ATMOSPHERIC ENVIRONMENT

6.2.1 Scope of the Assessment

This assessment of effects on atmospheric environment is in accordance with the requirements described in both federal and provincial guidance documents for the Project. Concordance tables, demonstrating where EIS Guidelines are addressed, are provided at the beginning of this EIS.

The Canadian Environmental Assessment Agency (the Agency) EIS Guidelines for the Project (CEAA 2018, Section 7.1.1) indicate that the EIS will present information on the atmospheric environment, including historical records of relevant meteorological information (e.g., precipitation, temperatures and wind speed/direction), ambient air quality, noise and night-time light levels, emissions sources, and greenhouse gas emission targets. The Environmental Assessment Scoping Document for the Project (Manitoba Infrastructure 2018) submitted to Manitoba Sustainable Development indicates that the EIS will describe attributes such as prevailing climate and meteorological conditions (temperature and precipitation) and local air quality, including parameters related to climate change, and existing greenhouse gas and other emissions sources and production.

Atmospheric environment is a VC for the Project and consists of air quality and climate (including greenhouse gases), the acoustic environment, and ambient light. Chapter 4 (Section 4.4.1) describes VCs as features that may be affected by the Project as related to the role of the VC in the ecosystem and the value people place on it. Atmospheric environment is a VC because there is potential for reduction in air quality, increased noise and ambient light issues due to Project activities, and potential for the Project to be sensitive to change in climate parameters.

6.2.1.1 Regulatory and Policy Setting

Air Quality

Criteria air contaminants (CACs) are common air pollutants that can potentially cause harm to health and the environment, and cause property damage. These pollutants are particulate matter (PM), carbon monoxide (CO), sulphur oxides (SO_x), nitrogen oxides (NO_x) and volatile organic compounds (VOCs). These contaminants are called “criteria” because the Manitoba Government has set ambient air quality criteria for their concentrations based upon these pollutants’ potential effects on health and welfare.

Relevant ambient air quality criteria include the Manitoba Conservation and Water Stewardship (MCWS) Manitoba Ambient Air Quality Criteria (MAAQC) (MCWS 2005) and the Canada Ambient Air Quality Standards (CAAQS). Table 6.2-1 identifies the maximum tolerable, acceptable and desirable level MAAQCs and CAAQSs for relevant substances and associated averaging periods.

The CAAQS are health-based standards for concentrations in outdoor air. Currently, CAAQS have been developed and are in place for $PM_{2.5}$ and ozone. The CAAQS are developed for managing regional air quality based on concentrations measured at local monitoring stations. These standards are not intended for evaluating near-field impacts at a Project boundary. CAAQS have also been developed for SO_2 and NO_2 to be implemented in 2020 and 2025.

Table 6.2-1 Provincial (Manitoba) and National Ambient Air Quality Criteria

Substance	Averaging Period	Provincial			National	
		Maximum Tolerable Level MAAQC[a] (µg/m³)	Maximum Acceptable Level MAAQC[a] (µg/m³)	Maximum Desirable Level MAAQC[a] (µg/m³)	2020 CAAQS (µg/m³)	2025 CAAQS (µg/m³)
CAC gases						
NO_2	1-hour	1000	400	–	113 [b]	79 [b]
	24-hour	–	200	–	–	–
	Annual	–	100	60	32 [b]	23 [b]
SO_2	1-hour	–	900	450	183 [c]	170[c]
	24-hour	800	300	150	–	–
	Annual	–	60	30	13 [c]	10 [c]
CO	1-hour	–	35,000	15,000	–	–
	8-hour	20,000	15,000	6,000	–	–
O_3	8-hour	–	128	–	122 [d]	118 [d]
Particulates						
$PM_{2.5}$	24-hour	–	30	–	27 [e]	–
	Annual	–	–	–	8.8 [e]	–
PM_{10}	24-hour	–	50	–	–	–
TSP	24-hour	–	120	–	–	–
	Annual	–	70	–	–	–

NOTES:

a Manitoba Conservation and Water Stewardship Manitoba Ambient Air Quality Criteria (MCWS 2005)

b The Canadian Ambient Air Quality Standard for NO2 (GOC 2017a). For 1-hour NO_2, the CAAQS refer to the three-year average of the annual 98th percentile of the NO_2 daily-maximum 1-hour average concentrations. For annual NO_2, the CAAQS refer to the average over a single calendar year of all the 1-hour average NO_2 concentrations.

c The CAAQS for SO_2 (GOC 2017b). For 1-hour SO_2, the CAAQS refer to the three-year average of the annual 99th percentile of the SO_2 daily-maximum 1-hour average concentrations. For annual SO_2, the CAAQS refer to the average over a single calendar year of all the 1-hour average SO_2 concentrations.

d The CAAQS for O_3 (CCME 2019).The 8-hour O_3 refers to the 3-year average of the annual 4th highest daily maximum 8-hour average concentrations.

e The CAAQS for $PM_{2.5}$ (CCME 2012). For 24-hour $PM_{2.5}$, the CAAQS refers to the 98th percentile 24-hour average from each year, averaged over three years. For annual $PM_{2.5}$, the CAAQS refers to the three-year average of the annual average concentrations.

– No applicable objective or standard in this jurisdiction.

µg/m³ = micrograms per cubic metre

Greenhouse Gases

Carbon dioxide and other GHGs produce a "greenhouse effect", affect the flow of energy coming into and leaving the earth's climate system, and they cause the global climate to warm. The management of GHG emissions takes place on provincial, national, and international scales. However, the existing acts and accords are primarily related to operational emissions above a threshold or are related to emission reductions on a provincial and federal scale, as follows (also, Section 6.2.4.3 summarizes the estimated Project GHG emissions that are anticipated to be less than the various thresholds stipulated):

- Made-in-Manitoba Output-based Pricing System (The *Industrial Greenhouse Gas Emissions Control and Reporting Act*) only applies to industrial facilities with emissions greater than 50,000 tonnes of CO_2e (t CO_2e)/year (MCGP 2017) and the Project does not meet this criteria, having much less operations GHG emissions.
- The June 2019 Report from the Expert Advisory Council to the Minister of Sustainable Development, established under Section 7 of the *Climate and Green Plan Implementation Act*, has recommended that Manitoba set a GHG reduction goal of no less than 1 Mt of CO_2e cumulative emissions reductions for the province's first five-year carbon savings account period of 2018-2022 (MEAC 2019).
- The national GHG Emission Reporting Program under the authority of the *Canadian Environmental Protection Act* (ECCC 2019) applies to operations emissions of greater than 10,000 t CO_2e/year.
- Under the 2009 Copenhagen Accord, Canada committed to a 17% reduction in national GHG emissions below the 2005 level by 2020 (UNFCCC 2009).
- Under the 2015 Paris Agreement, Canada committed to a 30% reduction in national GHG emissions below the 2005 level by 2030 (UNFCCC 2015).

Acoustic Environment

Regulatory framework and guidance for the acoustic environment is provided by the Manitoba Guidelines for Sound Pollution published by Manitoba Environmental Management Division (MEMD 2000) and Health Canada Guidance for Evaluating Human Health Impacts in Environmental Assessment: Noise (Health Canada 2017). For construction noise with durations of less than one year at receptors (i.e., short-term), the Health Canada document references the methods based in the U.S. EPA publication Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety (U.S. EPA 1974). The methodology provides mitigation noise levels (MNLs) and adjustments based on the type of community to determine if adverse effects from short-term construction noise are likely.

For construction noise with durations greater than one year at receptors (i.e., long-term), as applies to this Project, Health Canada advises that health impact endpoints be evaluated on the change in percentage of the population (at a specific receptor location) who become highly annoyed (%HA). The %HA measure is based on ISO1996-1:2003, standard ISO (2003, Annex D). The change in %HA is defined from the existing conditions. Health Canada Guidance describes methods for measuring or estimating the existing

noise levels in different types of communities with different population densities. According to Health Canada Guidance, a conservative (i.e., more protective of environment) approach is to assume an Ldn (day-night 24 hour average A-weighted sound level with a 10 decibel penalty added to night-time level) of 35 dBA for rural areas. This approach was chosen and existing noise levels of 35 dBA Ldn are assumed for the LMOC, LSMOC, and PR 239 realignment because no measurement data are available. Table 6.2-2 summarizes the determination of MNLs

Table 6.2-2 Calculating Suggested Mitigation Noise Level for Construction Noise (Based on US EPA 1974)

Suggested Basic MNL 47 dBA Ldn[1]		
Suggested MNL		
Community Description	**Applied Correction Factors**	**Suggested MNL**
Quiet suburban or rural	+0 dB	47 dBA Ldn
Normal suburban	+5 dB	52 dBA Ldn
Urban residential	+10 dB	57 dBA Ldn
Noisy urban	+15 dB	62 dBA Ldn
Very noisy urban	+20 dB	67 dBA Ldn
Additional Corrections (If applicable, add any or all of the following corrections):		
Construction duration less than two months	+10 dB	N/A
Winter (or windows always closed)	+5 dB	
Negligible tonal or impulsive noise[2]	+5 dB	
SOURCE: U.S. EPA 1974		

Notes:

1 Due to backup alarms, slamming tailgates, for example, construction noise normally contains both tonal and impulsive components. For the suggested basic MNL, the reasonable worst-case is used and all construction noise is assumed to be due to tonal or impulsive noise

2 When the contribution from tonal or impulsive noise may be negligible, +5 dB may be added to the suggested basic MNL. Health Canada prefers that a rationale be provided if this adjustment is applied.

None of the corrections of Table 6.2-2 are applicable to Project receptors and the basic MNL of 47 dBA Ldn is used to define the noise threshold. For construction activities occurring 12 hours per day (during the daytime hours), the level of 47 dBA Ldn is equivalent to 50 dBA Leq. The lower noise threshold is, therefore, set at 50 dBA Leq.

For long-term construction noise exposure, Health Canada Guidance suggests that in general, an increase in %HA of less than 6.5% may be acceptable. An increase in %HA of 6.5% is a cautionary limit. Above that limit, Health Canada suggests implementation of noise mitigation measures. An increase in %HA of 6.5% corresponds to Project noise level of 54 dBA Ldn. This level is equivalent to 57 dBA Leq for construction activities occurring 12 hours a day. The upper noise threshold based on 6.5% increase in %HA is therefore set at 57 dBA Leq.

Manitoba Environmental Management Division (MEMD) has published the Guidelines for Sound Pollution (MEMD 2000), which define sound level limits of noise emissions to the outdoor environment. The guideline is a receptor-oriented regulation, which specifies the sound level objectives at designated residential, commercial and industrial receptor areas. MEMD (2000) defines a point of reception as "any point on the premises of a person where sound originating from other than those premises is received." The guideline provides two separate sound level limits, the maximum acceptable and the maximum desired limits, which are dependent on the receptor category. The guideline also has provisions for tonal and impulsive characteristics of noise. The Project noise emissions associated with construction activities are compared to the objectives from the Guideline for Sound Pollution. Those objectives for residential areas are provided in Table 6.2-3 .

Table 6.2-3 Manitoba Environmental Management Division Guideline for Sound Pollution - Sound Level Objectives in Residential Areas

Schedule A				
Residential Area:		**Continuous or Intermittent Sounds**		
		Ldn[1]	**Leq(1) (day)[2] 7:00am to 10:00pm**	**Leq(1) (night) 10:00pm to 7:00am**
a) Maximum desirable[3]		55	55	45
b) Maximum acceptable[4]	i) Summer or year round operations	60	60	50
	ii) predominant discrete tone(s) or appreciable impulsive/ impact character	55	55	45
	iii) winter operations only or temporary operations	65	65	55
SOURCE: MEMD 2000				

Notes:

1 Ldn is the day-night average sound level; the 24-hour A-weight equivalent sound level, with a 10 decibel penalty added to night-time (10:00 p.m. to 7:00 a.m.) levels;

2 Leq(1) is the one-hour continuous equivalent A-weighted sound level;

3 Maximum Desirable Level is a noise level at which fewer than 1% of households would be expected to complain, although 17% of the people may respond as highly annoyed when questioned in a social survey;

4 Maximum Acceptable Level is a noise level at which fewer than 2% of households would be expected to complain, although up to 23% of the people may respond as highly annoyed when questioned.

Ambient Lighting

Three attributes are used to describe light:

- Light trespass refers to the transmission of light from fixtures within a facility to the environment and receptors outside the facility. The unit of measure for light incidence either in or outside the facility is a lux. A lux is equal to one lumen/m^2. Light trespass reaches problematic levels, for example, when lights located outside of an industrial facility shine in through the windows of nearby residential homes at levels that could disrupt sleep or distract from normal levels.
- Glare refers to intense, harsh, or contrasting lighting conditions that reduce humans, birds and other organisms' ability to see. The most common example of glare is oncoming high-beam headlights that provide ample light but result in poor visibility, potentially reaching hazardous conditions. The unit of measure is luminance, which is equal to lumens per steradian: this is the unit candela (cd).
- Sky glow refers to the illumination of the clouds by light sources on the surface of the earth such as street lighting, and haze in the atmosphere that replaces the natural nighttime sky with a translucent to opaque lighted dome. The sky appears washed out, or brownish-purple and may be devoid of visible stars in the extreme. Sky glow is the cumulative effect of all the lights at the surface either emitting upward or being reflected upward by the surface plus the emission from photochemical activity in the atmosphere. The unit of measure for the brightness of the sky, including sky glow, is magnitudes per square arcsecond (mag/$arcsec^2$).

Most guidelines and regulations for lighting have been directed toward providing suitable lighting to promote safe and efficient activities. For example, street lighting, indoor lighting, and lighting around industrial plants are all subject to various guidelines to facilitate a safe work environment. Currently, there are no regulations in Manitoba to regulate obtrusive light during construction or operation of industrial facilities.

However, guidelines have been developed to avoid obtrusive lighting and are often used for the design of new projects. These include guidelines from the International Dark Sky Association (IDA) and from the Commission Internationale de L'Éclairage (CIE), also known as the International Commission on Illumination. These organizations have developed recommendations to limit light pollution and associated effects on humans and wildlife. Many lighting design elements adhere to these guidelines through design standards developed by the Illuminating Engineering Society (IES), who have adopted IDA and CIE guidelines and recommendations for use in developing new outdoor lighting guidance and standards.

CIE has established guidelines for light trespass and glare for various levels of urbanization. The values represented in the guidelines are based on environmental zones and time of day. Four environmental zones have been established by the CIE for outdoor lighting (CIE 2003), listed in Table 6.2-4. The maximum values recommended by CIE for light trespass (illuminance) on properties by environmental zone and time of day are presented in Table 6.2-5. The maximum values recommended by CIE for glare (intensity of luminaires) in designated directions by environmental zone and time of day are presented in Table 6.2-6.

Reference levels of sky glow are presented in Table 6.2-7. Larger numbers are associated with darker conditions, while smaller numbers are associated with brighter nighttime conditions with more contributions from exterior lighting.

Table 6.2-4 Ambient Light Environmental Zones

Zone	Surrounding	Lighting Environment
E1 (natural)	Natural	Intrinsically dark
E2 (rural)	Rural	Low distinct brightness
E3 (suburban)	Suburban	Medium distinct brightness
E4 (urban)	Urban	High distinct brightness
SOURCE: CIE 2003		

Table 6.2-5 Recommended Maximum Values of Light Trespass (Illumination) per Environmental Zones

Time of Day	Environmental Zones			
	E1 (natural)	E2 (rural)	E3 (suburban)	E4 (urban)
Pre-curfew (19:00–23:00)	2 lux	5 lux	10 lux	25 lux
Post-curfew (23:00–6:00)	0 lux	1 lux	2 lux	5 lux
SOURCE: CIE 2003				

Table 6.2-6 Recommended Maximum Values for Glare (Intensity of Luminaires) in Designated Directions

Time of Day	Environmental Zones			
	E1 (natural)	E2 (rural)	E3 (suburban)	E4 (urban)
Pre-curfew (19:00–23:00)	2,500 cd	7,500 cd	10,000 cd	25,000 cd
Post-curfew (23:00–6:00)	0 [1] cd	500 cd	1,000 cd	2,500 cd

NOTE:
[1] If for public lighting value may be up to 500 cd
SOURCE: CIE 2003

Table 6.2-7 Reference Levels of Sky Glow

Sky Glow (mag/arcsec^2)	Corresponding Appearance of the Sky
21.7 (Rural)	The sky is covered with stars that appear large and close. In the absence of haze, the Milky Way can be seen to the horizon. The clouds appear as black silhouettes against the sky.
21.6	Glow in the direction of one or more cities is seen on the horizon. Clouds are bright near the city glow.

Table 6.2-7 Reference Levels of Sky Glow

Sky Glow (mag/arcsec^2)	Corresponding Appearance of the Sky
21.1	The Milky Way is brilliant overhead but cannot be seen near the horizon. Clouds have a greyish glow at the zenith and appear bright in the direction of one or more prominent city glows.
20.4	The contrast to the Milky Way is reduced and detail is lost. Clouds are bright against the zenith sky. Stars no longer appear large and near.
19.5	Milky Way is marginally visible and only near the zenith. The sky is bright and discoloured near the horizon in the direction of cities. The sky looks dull grey.
(18.5 Urban)	Stars are weak and washed out and reduced to a few hundred. The sky is bright and discoloured everywhere.
SOURCE: Berry 1976	

6.2.1.2 Engagement and Key Concerns

Influence of Consultation on the Identification of Issues and the Assessment Process

Manitoba Infrastructure has undertaken consultation prior to and throughout preparation of the EIS and will continue to consult with Indigenous groups, public, government agencies, and stakeholders throughout the life of the Project. A discussion of the consultation process is provided in Section 5 Indigenous and Public Engagement.

The current outputs of the engagement process were reviewed to determine information related to the atmospheric environment. Public concerns regarding air quality were related to construction dust and air pollution. Dust is addressed by the application of mitigation measures (Section 6.2.4.2).

Consultation feedback from Indigenous groups has been an important consideration in identifying issues of concern, framing the scope of the EIS and effects assessment, and in identification of specific mitigation measures, where provided. Consultation feedback specifically related to air quality was provided by Fisher River Cree Nation, who expressed concern that the Project would lead to an altered cultural experience due to dust effects and the presence of permanent structures. Dust is addressed by the application of mitigation measures (Section 6.2.4.2).

Consideration of Indigenous Information and Traditional Knowledge

While the engagement process is ongoing, Manitoba Infrastructure has yet to receive specific additional information on air quality, GHG emissions, the acoustic environment, or ambient light through receipt of the Project related Traditional knowledge (TK) studies. However, Manitoba Infrastructure understands the importance of air quality to Indigenous groups through information shared during the community and stakeholder consultation process and will consider additional TK provided by Indigenous groups throughout the EIS process. Effects of the Project on air quality, GHG emissions, the acoustic environment, or ambient light are assessed in this chapter.

6.2.1.3 Potential Effects, Pathways and Measurable Parameters

Table 6.2-8 presents potential effects, pathways and measurable parameters for air quality, GHG, acoustics, and ambient light components.

Table 6.2-8 Potential Effects, Effects Pathways and Measurable Parameters for Air Quality, Greenhouse Gases, Acoustics, and Ambient Light

Potential Environmental Effect	Effect Pathway	Measurable Parameter(s) and Units of Measurement
Air Quality Changes in ambient air quality, expressed collectively or singly, by changes in the following: • ambient concentration of criteria air contaminants (CACs) including nitrogen dioxide ($NO_{2,}$), sulphur dioxide (SO_2), carbon monoxide (CO), fine particulate matter of 2.5 microns (µm) in diameter or less ($PM_{2.5}$), particulate matter of 10 microns (µm) in diameter or less (PM_{10}), total suspended particulate (TSP) • ambient concentration of volatile organic compounds (VOCs)	The release of air contaminants to the atmosphere due to the Project activities may adversely affect the quality of the ambient air	Change in ambient air quality outside the PDA boundary evaluated through comparison of the Project and regional NO_X, SO_2, CO, $PM_{2.5}$, TSP, and VOC emissions in t/y.
Greenhouse Gases Change in GHG emissions, including: • carbon dioxide (CO_2) • methane (CH_4) • nitrous oxide (N_2O)	GHG emissions from the Project could contribute to accelerating climate change.	CO_2, CH_4 and N_2O are the primary GHGs that would be released from the Project in kt/y.
Acoustic Environment Change in acoustic environment	The Project construction may result in temporary and localized increases in sound levels	L_d – Daytime sound, dBA L_n – Nighttime sound level, dBA L_{dn} –Day-night average sound level, dBA %HA – percent highly annoyed
Ambient Light Change in ambient light	The Project lighting can have adverse effects through changes in nighttime lighting, such as: Light Trespass – Light output beyond the project perimeter on vertical or horizontal surfaces of receptors Glare – Contrast between the Project lighting and background lighting Sky Glow – Upward directed lighting reflected back to the ground	Change in light trespass in units of lux. Changes in glare in units of candela (cd). Changes in sky glow in units of magnitude/arcsec^2.

6.2.1.4 Boundaries

Spatial Boundaries

The Project development area (PDA), local assessment area (LAA) and regional assessment area (RAA) for the assessment of effects on the atmospheric environment are shown in Appendix 6B, Figure 6.2B-1 and Figure 6.2B-2 and described below. Federal lands within these boundaries consist of reserve lands associated with the Indigenous communities.

Project Development Area

The PDA is an area of 2,099 ha and is the area in which the main Project components and activities are located. The MAAQC (MCWS 2005) are only applied to areas where there is public access (i.e., on the boundary of and outside the PDA). Similarly, the CAAQS for NO_2, SO_2 and $PM_{2.5}$ (GOC 2017a; GOC 2017b; CCME 2012) are only applied to areas where there is public access.

Local Assessment Area

The LAA for the assessment of effects on air quality and lighting includes the PDA plus a 5 km buffer on each side along the outlet channels. The 5 km buffer is based on the minimum spatial boundary requirement (MC 2006), which is the area where the potential for changes in air quality due to the Project is greatest. The LAA for the LMOC encompasses four communities (i.e., Grahamdale, Steep Rock Junction, Faulkner and Birch Bay), a portion of PTH 6, and provincial roads (i.e., PR 237 and PR 239). The LAA around LSMOC does not contain any communities or major roads.

The LAA for the assessment of effects on acoustic environment extends 1 km beyond the PDA and the proposed PR 239 realignment route. Project-related noise effects may be present within the LAA; outside the LAA, noise effects are expected to be negligible due to natural atmospheric attenuation and ground absorption. Project residual noise effects are not expected to extend beyond the LAA.

While GHG emissions are generated in PDA and LAA, their effects associated with GHG emissions are on a global scale and are not quantifiable at these spatial scales.

Regional Assessment Area

The RAA for the assessment of effects on air quality and lighting includes the PDA, a 15 km buffer on each side along the PDA to capture all the major communities near the Project, and part of Lake St. Martin to connect the RAA for LMOC and LSMOC. The RAA includes First Nation communities (Little Saskatchewan First Nation, Lake St. Martin First Nation, Dauphin River First Nation, Dauphin River NAC, and Pinaymootang First Nation), other communities (Fairford Reserve, Steep Rock, Davis Point, St. Martin Junction, Anama Bay, Spearhill, Moosehorn, Hibre, Fairford, St. Martin, Gypsumville) and provincial roads (PR 328, MB 513). Appendix 6B, Figure 6.2B-1 shows the spatial boundaries for air quality and lighting.

No local or regional spatial boundaries are used for the GHG assessment because the environmental effects associated with GHG emissions are on a global scale; GHGs mix well in the atmosphere and disperse from their local emission sources (IPCC 2013). However, as a reference point, this assessment quantifies and evaluates GHG emissions during construction and compares it to the total provincial and federal GHG inventories.

The RAA for the assessment of effects on acoustic environment was set as an area extending 3 km from the PDA to account for other existing and future physical activities acting cumulatively with the Project. Physical activities located beyond the 3 km buffer are not expected to interact with Project residual acoustic effects. Appendix 6B, Figure 6.2B-2 shows the spatial boundaries for the acoustic environment.

Temporal Boundary

The temporal boundary for the assessment of effects on air quality and ambient lighting covers the duration of the construction and operation and maintenance phases of the Project. The temporal boundary for the assessment of effects on the acoustic environment is limited to the duration of construction phase of the Project. Noise emissions during operations are not considered continuous because the operation of water control structures (WCS) will be limited to potential flooding periods and regular maintenance.

The active construction spread is expected to be a staged sequence of 5 km long linear noise sources gradually progressing along the PDA of LSMOC and PR 239 alignment, and 5 km long linear noise sources starting from both ends of LMOC and progressing along the PDA until meeting in the center. Construction is tentatively expected to occur over a period of approximately 2.5 to 3 years with approximately 1-2 years for post-construction, such as site clean-up, survey, and environmental works. It is currently estimated that construction would occur from fall 2020 to spring/summer 2023, with operation and maintenance starting in fall 2023. The overall schedule is contingent largely on receipt of the final regulatory approvals in 2020. The operation and maintenance phase of the Project is expected to be indefinite because there are no plans to decommission the Project.

6.2.1.5 Residual Effects Characterization

Table 6.2-9 presents definitions for the characterization of residual environmental effects on atmospheric environment. The criteria describe the potential residual effects that remain after mitigation measures have been implemented.

Ambient air quality, acoustic, and ambient light changes vary considerably with time and location. For consistency with other sections of the environmental assessment, the predicted changes are also examined in context with the characterization criteria that are provided in Table 6.2-9. The characterization criteria are discussed in the context of the Project emissions. The definition and application of the characterization criteria have elements of subjectivity.

The characterization parameters in Table 6.2-9 refer specifically to air quality, acoustic, and light changes and not to the potential responses of receptors exposed to these changes. Other VCs address the receptor responses to the predicted air quality changes (e.g., human health in Section 9.5).

Table 6.2-9 Characterization of Residual Effects on Atmospheric Environment

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Direction	The long-term trend of the residual effect	Positive – a residual effect that changes measurable parameters in a direction beneficial relative to the existing conditions Adverse – a residual effect that changes measurable parameters in a direction detrimental relative to existing conditions Neutral – no net change in measurable parameters relative to the existing conditions.
Magnitude	The amount of change in measurable parameters or the VC relative to existing conditions	**For Air Quality:** Negligible – Estimated Project emissions are less than 10% of estimated regional emissions. Low – Estimated Project emissions are between 10% and 25% of estimated regional emissions Moderate – Estimated Project emissions are between 25% and 100% of estimated regional emissions. High – Estimated Project emissions are more than 100% of estimated regional emissions. **For Greenhouse Gases:** Negligible – no measurable change in GHG emissions Low - although a change is measurable, based on Agency guidance (CEAA 2003) and professional judgment, relatively small changes are expected in provincial and national GHG emissions Moderate – based on Agency guidance (CEAA 2003) and professional judgment, notable changes are expected in provincial and national GHG emissions High – based on Agency guidance (CEAA 2003) and professional judgment, material changes are expected in provincial and national GHG emissions
		For Ambient Lighting: Negligible – no measurable change Low - effect is detectable but is limited through design mitigation Moderate – facility lighting is effectively controlled, but navigation, security and other required lighting have a measurable effect High – the design is without regard to lighting design criteria

Table 6.2-9 Characterization of Residual Effects on Atmospheric Environment

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Geographic Extent	The geographic area in which a residual effect occurs	**For Air Quality, Acoustic Environment, and Ambient Light:** PDA – residual effects are restricted to the PDA LAA – residual effects extend into the LAA RAA – residual effects extend into the RAA
		For Greenhouse Gases: Global – residual effects extend into the global extent
Frequency	Identifies how often the residual effect occurs and how often during the Project or in a specific phase	Infrequent - The potential effect occurs once or seldom during the life of the Project Sporadic/Intermittent - The potential effect occurs only occasionally and without any predictable pattern during the life of the Project Regular/Continuous - The potential effect occurs at regular and frequent intervals during the Project phase in which they occur or over the life of the Project
Duration	The period of time required for the measurable parameter to return to its existing condition, or the residual effect can no longer be measured or otherwise perceived	Short-term – residual effect restricted to less than the duration of the construction phase Medium-term – residual effect extends through the construction phase partially into the operations and maintenance phase Long-term – residual effect extends throughout the operations and maintenance phase of the Project
Reversibility	Pertains to whether a measurable parameter or the VC can return to existing conditions after the Project activity ceases	Reversible (short-term) – the residual effect is likely to be reversed after the construction phase Reversible (long-term) – the residual effect is likely to be reversed after construction but during the operations and maintenance phase of the Project Irreversible – the residual effect is unlikely to be reversed
Ecological Context	Existing conditions and trends in the area where residual effects occur	Undisturbed – Atmosphere relatively unaffected, or not affected, by human activity (anthropogenic sources) Disturbed – Atmosphere has been previously disturbed by human activity (anthropogenic sources)
Timing	Periods of time where residual effects from the Project activities could affect the VC	Seasonality – residual effect is greater in one season than another (e.g., spring/summer vs. fall/winter) Time of day – residual effect is greater during daytime or nighttime Regulatory – provincial or federal restricted activity periods or timing windows (e.g., migration, breeding, spawning) related to the VC Not applicable - the residual effect of the Project activities will have the same effect on the VC, regardless of timing

6.2.1.6 Significance Definition

Significance is not determined for atmospheric environment. The significance of effects caused by Project-related changes to atmospheric environment are discussed as part of the assessment of effects on human health, wildlife and Indigenous peoples.

6.2.2 Existing Conditions for Atmospheric Environment

6.2.2.1 Atmospheric Methods

Air Quality and Climate

Air quality and climate are characterized in terms of three subcomponents, namely climate and meteorology, ambient air quality, and greenhouse gases, as follows.

Climate and Meteorology

Climate is described in terms of average and extreme weather conditions that occur over a 30-year period; these values being referred to as climate normals. Long-term meteorological data are available from the Dauphin climate station, which is the nearest and most representative Environment and Climate Change Canada (ECCC) monitoring station with climate normals data for Manitoba Interlake Region. The Dauphin station is located at latitude 51°06' N and longitude 100°03' W at an elevation of 304.5 m. This station is approximately 105 km west of Watchorn Bay on Lake Manitoba.

Ambient Air Quality

Ambient air quality data are collected continuously by the Manitoba Government in cooperation with the National Air Pollution Surveillance Program (NAPS) framework operated by ECCC in populated regions of Canada. Manitoba has five continuous air quality monitoring stations to measure a range of air substances and meteorological parameters. The locations of these five continuous air-monitoring stations are shown in Appendix 6B, Figure 6.2B-3. Table 6.2-10 and Table 6.2-11 summarize the air quality monitoring station information and the air quality parameters that are monitored at these stations, respectively.

Table 6.2-10 Monitoring Stations Used in the Assessment

NAPS ID	Monitoring Station	UTM Zone 14		Elevation	Type
		Easting	Northing	(m)	
70118	Winnipeg (299 Scotia St.)	635409.86	5532784.55	227	Urban
70119	Winnipeg (65 Ellen St.)	633109.70	5528935.95	229	Urban
70203	Brandon (1430 Victoria Avenue East)	433803.95	5521156.69	385	Urban
70301	City of Flin Flon (143 Main Street)	314900.30	6072830.98	339	Rural
70501	City of Thompson (Westwood School)	570711.73	6178517.69	205	Rural
SOURCE: MSD 2019					

Table 6.2-11 Parameters Measured at Continuous Air Monitoring Stations

Monitoring Station	Data Period	Parameters Monitored												
		SO_2	NO	NO_2	NO_X	PM_{10}	$PM_{2.5}$	O_3	CO	NH_3	Temperature	Pressure	Wind Speed	Wind Direction
Winnipeg (299 Scotia St.)	2016-2018		x	x	x		x	x	x				x	x
Winnipeg (65 Ellen St.)	2016-2018	x	x	x	x	x	x	x	x				x	x
Brandon (1430 Victoria Avenue East)	2016-2018		x	x	x	x	x	x		x			x	x
City of Flin Flon (143 Main Street)	2016-2018	x				x	x	x					x	x
City of Thompson (Westwood School)	2016-2018	x				x	x	x			x	x		
SOURCE: MSD 2019														

The City of Flin Flon (Flin Flon) and the City of Thompson (Thompson) continuous air quality monitoring stations are located in smaller communities, whereas the Brandon and Winnipeg monitoring stations are located in urban areas. The Project is in a predominantly rural area with few nearby industrial or non-industrial emission sources. There are no current or historic ambient air quality monitoring data available in the immediate vicinity of the Project. The closest two locations in a similar remote or small community setting with ambient air quality monitoring data are located in Flin Flon and Thompson. However, ambient air quality in both the communities of Flin Flon and Thompson are influenced by emissions from nearby metallurgical mines and processing facilities. In the case of Flin Flon, the Hudbay Minerals smelter was shutdown in 2010, significantly reducing pollutant emissions. In the case of Thompson, Vale operates the Thompson and Birchtree mines along with the Thompson mill, smelter (which closed in June 2018) and refinery operations. Industrial emissions from the Vale operations in Thompson over the 2016 to 2018 period were much larger than those associated with the Hudbay facilities near Flin Flon. As a result, ambient air quality measured in Flin Flon is considered the most representative publicly available monitoring data for the RAA.

For substances that are not measured at either of these two rural stations, data from the Brandon air quality monitoring station are used because this community has a smaller population when compared to Winnipeg. If a particular substance is not measured at the Brandon station, then data from the Winnipeg monitoring stations are used for the assessment, if required. Pollutant concentrations measured at monitoring stations in these urban areas likely overestimate the ambient concentration in the PDA and RAA. The analyzed data measured at these stations are from January 2016 to December 2018 (the most recent three-year period of data available).

Greenhouse Gases

Existing GHG emissions are characterized by summarizing provincial and national inventory totals. The 2017 data (most recently available) for the province and Canada are used (ECCC 2019a).

Acoustic Environment

No sound level measurements were performed within the Project's LAA. The existing acoustic environment in the LAA was estimated based on the recommendations by Health Canada Guidance (Health Canada 2017) for areas where measurement data are not available. The acoustic environment within the LAA was assumed to correspond to a that of a quiet rural area. A conservative (i.e., more protective) approach was chosen whereby the existing sound level is assumed to be 35 dBA Ldn in what Health Canada Guidance considers a reasonable worst-case. There are no heavily developed urban/suburban areas encompassed within the LAA and, therefore, the assumed sound level of 35 dBA Ldn is appropriate. There are no communities or residential receptors located within LAA for the LSMOC. Some residential receptors were identified within the LAAs of the LMOC and PR 239 realignment route. Appendix 6B, Figure 6.2B-4 shows the buildings identified within LAA of LMOC and PR 239 realignment route.

Lighting

The three types of light pollution, light trespass, glare and sky glow, form the framework for discussing the existing environment in the PDA.

In the absence of site-specific data to characterize the existing levels of light trespass, glare and sky glow within and surrounding the PDA, the existing ambient light environment was characterized using:

- satellite observations of artificial light
- assumptions based on the Project location, nearby communities, nearby sources of light and professional experience

6.2.2.2 Overview of Atmospheric Environment

Climate and Meteorology

Climate in the Project Area

Historic trends and climate change are discussed in Chapter 15 (Effects of the Environment on the Project, Section 15.3). Table 6.2-12 provides an overview of selected climate parameters based on measurements at the Dauphin station for the 30-year period 1981 to 2010. The results indicate:

- temperature

  The coldest months of the year are in the December to February period, and the warmest months of the year are in the June to August period.
- precipitation

  The greatest precipitation occurs in the June to September period.
- winds

  Average winds are in the 13.0 km/h to 16.6 km/h (3.6 m/s to 4.6 m/s) range. The most frequent wind direction is from the west. The highest wind speeds are associated with west winds.
- relative humidity

  The relative humidity tends to be higher in the morning; this is likely due to the closer proximity to Lake Manitoba. In the afternoon, the relative humidity is lower due to warmer temperatures.
- visibility

  Visibilities less than 1 km occur less than 1% of the time. Visibilities between 1 km and 9 km occur less than 7% of the year, with the majority of the year yielding visibility ranges greater than 9 km.

Table 6.2-12 Dauphin Station Climate Parameters (1981 to 2010)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Temperature													
Extreme Maximum (°C)	9.6	13.9	24.2	35.2	39.2	37.3	36	39	37.8	31.1	22.2	12.3	-
Daily Maximum (°C)	-10.0	-7.1	-0.5	10.1	17.6	22.1	25.2	24.6	18.1	10.1	-0.6	-8.0	8.5
Daily Average (°C)	-15.4	-12.6	-6.1	3.6	10.5	15.7	18.7	17.7	11.7	4.4	-5.3	-13.1	2.5
Daily Minimum (°C)	-20.7	-18.0	-11.6	-2.9	3.4	9.2	12.1	10.6	5.2	-1.4	-10.0	-18.1	-3.5
Extreme Minimum (°C)	-43.3	-44.4	-39.0	-27.8	-12.2	-3.9	0.6	-0.6	-9.7	-20.9	-34.5	-39.4	-
Precipitation													
Extreme Daily Rainfall (mm)	6.4	3.8	52.1	40.4	61.5	100.3	90.9	74.9	83.3	51.3	18.6	6.4	-
Average Rainfall (mm)	0.4	0.3	5.5	17.1	52.9	81.7	73.1	61.3	57.2	29.4	4.5	0.6	383.7
Extreme Daily Snowfall (cm)	18.3	21.6	25.4	26.1	18.4	5.6	0	0	10.5	24.4	26.2	23.4	-
Average Snowfall (cm)	16.6	14.3	20.2	12.9	3.3	0.3	0	0	1	6	17.9	21.3	113.7
Average Precipitation (mm)	13.7	10.7	24	29.6	54.9	82	73.1	61.3	58.2	35.2	20.8	18.6	481.9
Winds													
Average Wind Speed (km/h)	15.8	15.4	14.7	15.8	16.6	14.9	13.0	13.6	15.4	15.9	15.6	15.8	15.2
Most Frequent Direction	W	W	W	W	W	W	W	W	W	W	W	W	W
Relative Humidity													
Average Relative Humidity - 0600LST (%)	73.2	75.7	80	78.8	78.4	82.4	86.9	87.9	84.3	80.9	80.7	75.5	80.4
Average Relative Humidity - 1500LST (%)	68.7	67.9	65.2	50.2	48.4	54.1	56.4	52.8	53	56.9	67.6	70.3	59.3
Hours with visibility													
Less than 1 km	3.2	4.8	13.2	6.3	2.6	1.3	0.9	4.3	2.4	5.3	8.8	7.9	60.9
Between 1 km to 9 km	80.4	61.7	70	32	35	22.7	17.3	25.7	23	36.5	63.1	92.7	560.1
More than 9 km	660.4	612.1	660.8	681.7	706.5	696	725.9	714	694.6	702.2	648.2	643.4	8145.7
Source: ECCC 1981-2010 Climate normal http://climate.weather.gc.ca/climate_normals/index_e.html													

Local Meteorology

There is no available meteorological data measured in the LAA or RAA. To describe the local meteorology, a five-year (2012-2016) Weather Research and Forecasting (WRF) prognostic meteorological data set was developed for the Project area. Prognostic data was developed because elements of meteorology, such as wind speed and direction, can be influenced by features such as local terrain. A three-dimensional CALMET data set was developed based on the WRF data. Wind fields representative of site conditions at 10 m above ground level were extracted from the CALMET data at eight locations (listed in Table 6.2-13 and shown in Appendix 6B, Figure 6.2B-5) selected to be representative of the proposed Project LAA.

Table 6.2-13 Coordinates of Extracted WRF Model Data Locations

Project Component		UTM NAD 83 (Zone 14)		Location Name
		m East	m North	
LMOC	Inlet	529841	5681518	LMOC_INLET
	Outlet	534090	5703781	LMOC_OUTLET
	Water Control Structure	532294	5701501	LMOC_WCS
	Municipal Bridge PTH6	532037	5699259	LMOC_PTH6
LSMOC	Inlet	557122	5738284	LSMOC_INLET
	Outlet	572725	5751400	LSMOC_OUTLET
	Power Distribution Line (Start)	548483	5749379	LSMOC_HDLS
	Power Distribution Line (End)	557122	5738284	LSMOC_HDLE

The dispersion of atmospheric contaminants is affected both by winds (mechanical mixing) and by thermal effects (buoyancy enhanced mixing). Horizontal winds interact with terrain and other obstructions (e.g., buildings, trees) to generate turbulence, which disperses contaminants. Vertical air movement (e.g., rising thermals, downslope breezes) also generate turbulence and disperses contaminants.

Figure 6.2-1 shows the WRF predicted annual wind roses at four locations along the LMOC for the five-year (2012-2016) period. The features of the annual wind roses illustrate that winds at the LMOC PDA are mainly from southeasterly, southerly, westerly and northwesterly directions. Winds from the southwest are infrequent. It shows a pronounced northwesterly wind in this area. It also shows that the strong winds greater than 8 m/s) most frequently originate from the northwest, north and south. Calm winds (less than 0.5 m/s) are rare (approximately 1.1% at all four sites).

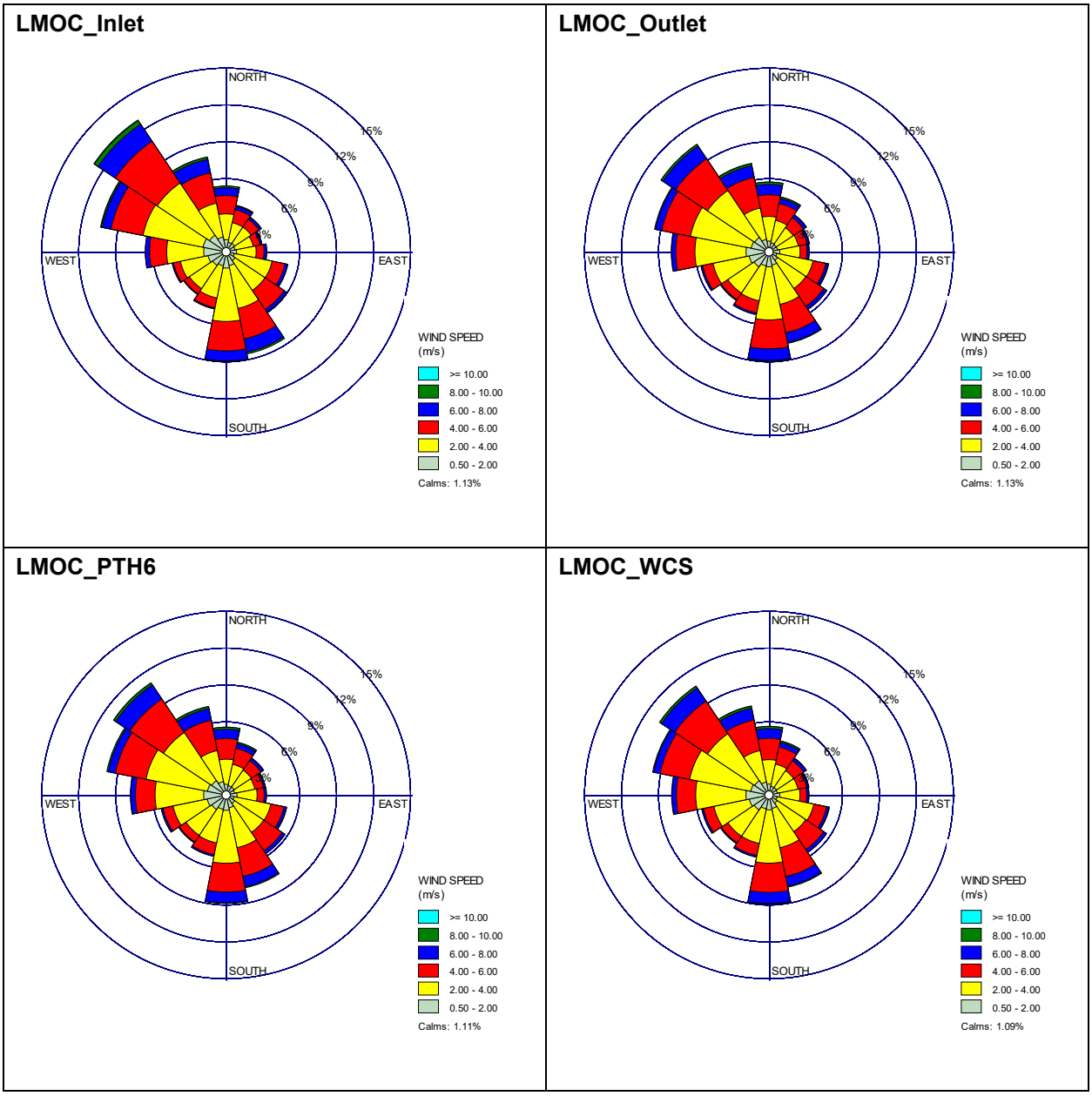

Figure 6.2-1 WRF Predicted Wind Roses at Four Sites along the LMOC (2012-2016)

Figure 6.2-2 shows the WRF predicted annual wind roses at four locations along the LSMOC for the five-year (2012-2016) period. The features of the annual wind roses illustrate that winds at the LSMOC are mainly from southeasterly, southerly, westerly and northwesterly directions. Winds from the southwest are infrequent. It does not show the same pronounced northwesterly trend as the wind roses shown for the LMOC PDA. It also shows that the strong winds (greater than 8 m/s) most frequently originate from the northwest, north and south. Calm winds (less than 0.5 m/s) are rare (approximately 1.1% at all four sites).

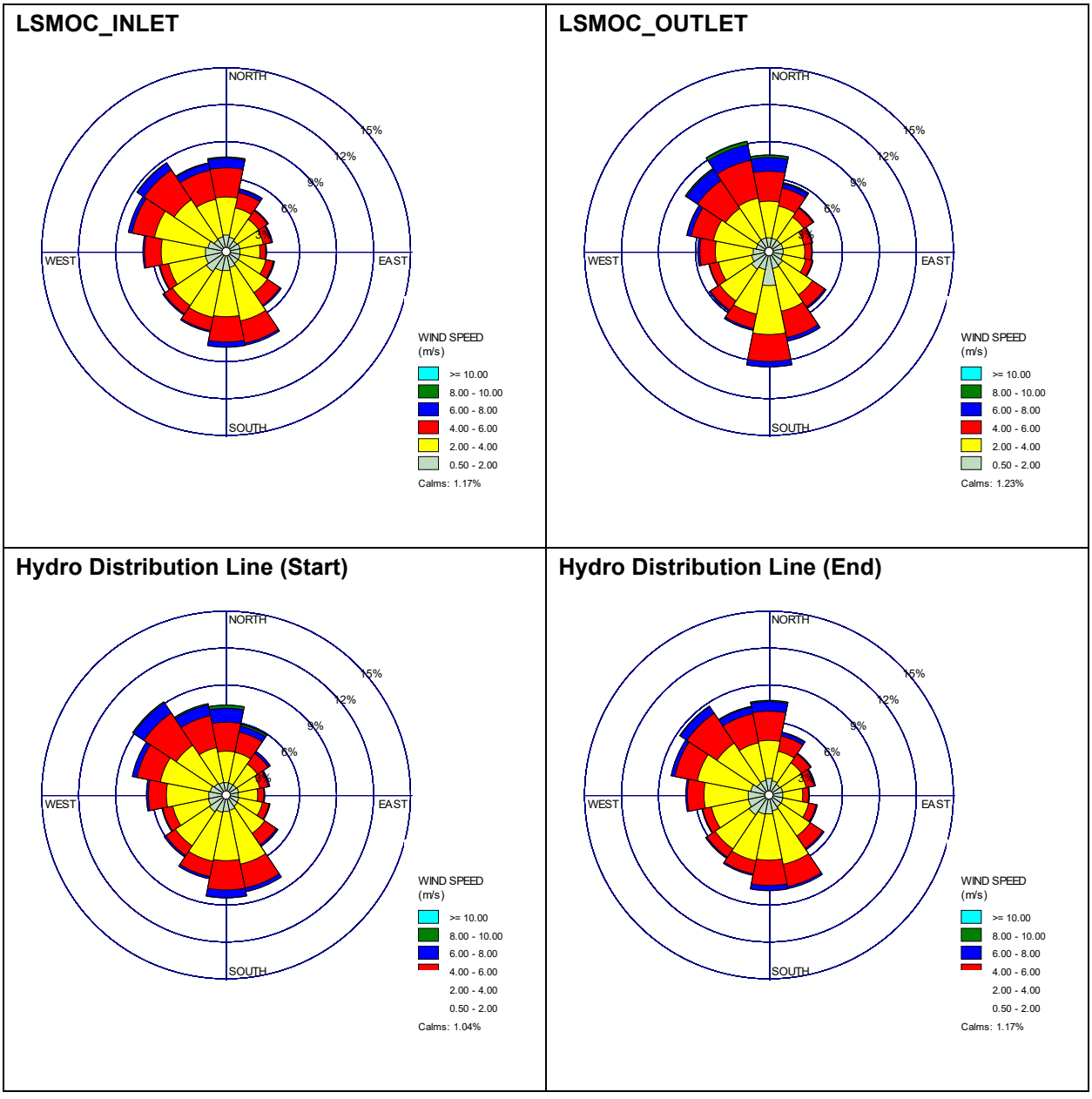

Figure 6.2-2 WRF Predicted Wind Roses at Four Sites along the LSMOC (2012-2016)

Figure 6.2-3 shows the WRF predicted monthly average temperatures at the four locations for the both LMOC and LSMOC PDAs. The Dauphin station 1981-2010 climate normal monthly average temperature data are also included for comparison. The results show that WRF predicted temperatures at all four selected locations have reasonable seasonal patterns and also agree with the long-term climate data measured at the nearest and most representative ECCC climate station at Dauphin, MB.

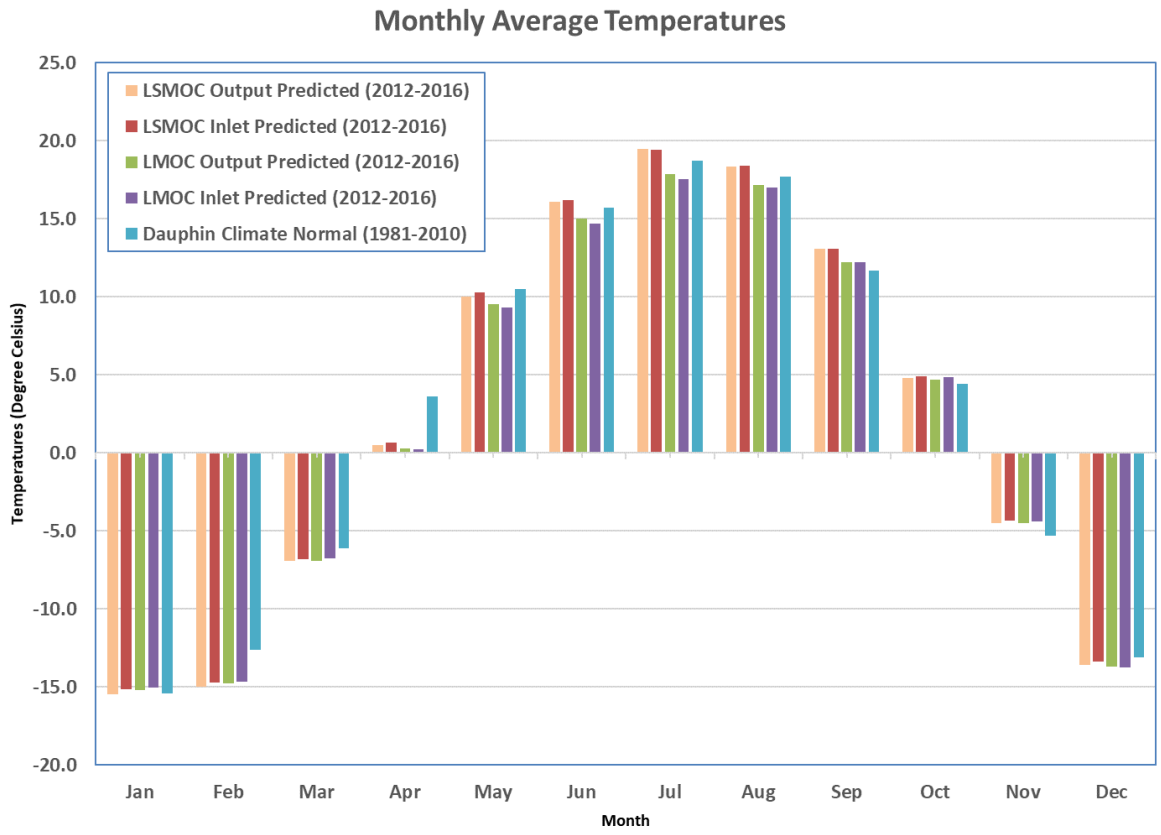

Figure 6.2-3 WRF-predicted Monthly Average Temperatures at Four Sites along the LMOC and LSMOC (2012-2016)

Ambient Air Quality

Key Components Assessed

Common Air Quality Contaminants of Concern

Air quality contaminants of concern assessed includes criteria air contaminants (CACs) – common air pollutants with known human health and environmental effects – including nitrogen oxides (NO_x), sulphur dioxide (SO_2), ozone (O_3), carbon monoxide (CO) and particulate matter (PM). Available long-term ambient air quality data for CACs: NO_X, SO_2, PM_{10}, $PM_{2.5}$, O_3 , and CO are from the stations, as identified in Appendix 6B, Figure 6.2B-3.

The following sections provide a short description of the CACs measured.

Nitrogen Oxides (NO_x)

NO_X are produced in most combustion processes and are almost entirely made up of NO and NO_2. Together, they are often referred to as NO_X. NO_2 is an orange to reddish gas that is corrosive and irritating. Most NO_2 in the atmosphere is formed by the oxidation of NO, which is emitted directly by combustion processes, particularly those at high temperature and pressure, such as diesel engines used in construction equipment. NO is a colorless gas. The levels of NO and NO_2, and the ratio of the two gases, together with the presence of hydrocarbons and sunlight, are the most important factors in the formation of ground-level ozone. Further oxidation of these gases and combination with water in the atmosphere forms what is known as acid rain.

Nitrogen oxides are emitted from a variety of combustion sources including vehicles, industrial heaters and boilers, and residential gas-fired furnaces and hot water boilers. Generally, for combustion, 5% to 10% of the initial total emissions of NO_X are NO_2, with the remaining 90% to 95% being NO. The conversion of the majority of NO occurs after emission to the atmosphere. The rate of conversion depends on the oxidizing potential of the atmosphere at the time of release. For example, if the ambient concentration of O_3 is high at the time of release, the conversion might be expected to be higher than if the ambient concentration of O_3 is low.

Sulphur Dioxide (SO_2)

Sulphur dioxide (SO_2) is a colorless gas with a distinctive pungent sulphur odour. It is produced in combustion processes by the oxidation of sulphur in the fuel. Sulphur dioxide is emitted mainly from industrial sources utilizing coal, coke or oil-fired heaters and boilers, as well as diesel and gasoline-fired construction equipment. The presence of SO_2 can, at high enough concentrations, cause damage to vegetation and health effects to animals through the respiratory system. The SO_2 can also be further oxidized and combines with water to form the sulphuric acid component of acid rain.

Fine and Respirable Particulate Matter

Total suspended particulate matter (TSP) is a measure of the particles in the atmosphere that are too small (an aerodynamic diameter of less than 44 µm) to settle out quickly and remain suspended for long periods of time. TSP is produced by a variety of emission sources including wind erosion of agricultural fields and other open areas, abrasion of vehicles tires on paved and unpaved roads, agricultural activities, and combustion processes (e.g., industrial boilers and heaters, power generation, vehicle emissions).

Although TSP is a good measure of the loading of particulate matter in the air, it does not necessarily reflect the health risks of particulate matter. For humans, particulate matter smaller than 10 microns (PM_{10}) is typically trapped in the upper airways, and do not enter the lungs (US EPA 2014). Smaller diameter particles less than 2.5 microns ($PM_{2.5}$) can make their way deep into the lungs, and may become lodged there (US EPA, 2014). Over the past few years, greater concern with regard to these fine particles has led to research resulting in new sampling methods and criteria.

Ozone (O_3)

Ground level ozone is not emitted directly to the atmosphere. Enhanced ground level ozone can result from chemical reactions involving volatile organic compounds (VOCs), NO_X, and many other compounds in the atmosphere in the presence of sunlight. The chemical transformation in the atmosphere follows a complex process in which NO_2 is transformed into NO plus O_3 in the presence of oxygen. In the vicinity of combustion sources, which emit a significant portion of their NO_X emissions as NO, an opposite chemical reaction (which occurs faster than the ozone formation reaction during periods of enhanced ozone) can occur in which ozone is used up in the chemical transformation of NO to NO_2. Due to this atmospheric reaction, decreased ground level ozone concentrations are often seen within the vicinity of power generation facilities during regional ozone episodes.

Carbon Monoxide (CO)

Carbon monoxide (CO) is a colorless, odourless gas that is produced by the incomplete combustion of fuel sources. Carbon monoxide is emitted from a variety of combustion sources including vehicles, industrial heaters and boilers, and residential gas-fired furnaces and hot water boilers.

Review of Historical Ambient Air Quality Data

The following sections provide a review of available ambient monitoring data for the monitoring sites identified in Table 6.2-10 . Monitoring data for nitrogen dioxide (NO_2), sulphur dioxide (SO_2), particulate matter less than 2.5 microns ($PM_{2.5}$), ozone (O_3), and carbon monoxide (CO) from the period 2012 to 2016 were reviewed.

Continuous Air Monitoring Data Review

Nitrogen Dioxide (NO_2)

Nitrogen dioxide (NO_2) concentrations are routinely measured continuously at three of the five continuous air quality monitoring stations (i.e., Brandon, Winnipeg Scotia Street and Winnipeg Ellen Street). For this assessment, as the continuous air monitoring data for ambient NO_2 concentrations from Flin Flon and Thompson stations were not available, the Brandon station data for the period of 2016 to 2018 is used to characterize existing NO_2 concentrations.

A summary of the 1-hour frequency statistics, 24-hour frequency statistics and the annual average over the 3-year period is shown in Appendix 6A (Table 6.2A-1 to Table 6.2A-3). The 1-hour and 24-hour average concentrations at the Brandon Station are shown in Appendix 6B (Figure 6.2B-6 and Figure 6.2B-7). The maximum acceptable 1-hour, 24-hour and annual MAAQC (acceptable level) for NO_2 are 400, 200 and 100 µg/m^3, respectively while the maximum desirable annual NO_2 MAAQC is 60 µg/m^3. The following observations are based on a review of the 3-year data set:

- The maximum 1-hour, 24-hour and annual NO_2 concentrations at Brandon station are 76.2 µg/m^3, 33.9 µg/m^3, and 7.72 µg/m^3, respectively.
- There is a seasonal variation, with the highest values occurring during the winter and the lowest values during the summer. This reflects the enhanced dispersion during the summer and/or lower NO_X emissions during the summer. This seasonal behaviour is typically associated with near surface releases (e.g., traffic).
- There is a diurnal variation with the highest values occurring during the early morning and in the late evening and the lowest values during the afternoon.

Sulphur Dioxide (SO_2)

Sulphur dioxide is measured at three of the five continuous air quality monitoring stations (i.e., Flin Flon, Thompson and Winnipeg Ellen Street stations). The continuous air monitoring data for ambient SO_2 concentrations from Flin Flon and Thompson stations were reviewed for the period of 2016 to 2018. However, the measured ambient SO_2 data at the Thompson station is not representative of the PDA due to high SO_2 emissions from smelter operations in the area; therefore, the existing SO_2 concentrations for the Project are conservatively based on the Flin Flon station data.

A summary of the 1-hour frequency statistics, 24-hour frequency statistics and the annual average over the 3-year period is shown in Appendix 6A (Table 6.2A-4 to Table 6.2A-6). 1-hour and 24-hour average concentrations at the Flin Flon Station are illustrated in Appendix 6B (Figure 6.2B-8 and Figure 6.2B-9). The maximum acceptable 1-hour, 24-hour and annual MAAQC for SO_2 are 900 µg/m^3, 300 µg/m^3, and 60 µg/m^3, respectively. The maximum desirable 1-hour, 24-hour and annual MAAQC for SO_2 are

450 µg/m^3, 150 µg/m^3, and 30 µg/m^3, respectively. The following observations are based on a review of the 3-year data set:

- The maximum 1-hour, 24-hour and annual SO_2 concentrations at the Flin Flon station are 25.9 µg/m^3, 6.32 µg/m^3 and 2.33 µg/m^3, respectively and they are all below the respective maximum acceptable and desirable MAAQC SO_2 levels.
- The highest 1-hour SO_2 concentrations tend to occur during April (Flin Flon) and there is no apparent seasonal trend.
- There is a diurnal variation with the highest 1-hour SO_2 concentrations occurring during the afternoon and the lowest 1-hour SO_2 concentrations during the nighttime and early morning. This is likely because high concentrations from stacks are associated with convective conditions, which are more intense and frequent during the afternoons.

Particulate Matter Less Than 2.5 Microns

Particulate matter that is less than 2.5 microns in diameter ($PM_{2.5}$) is continuously measured at all the five stations listed in Table 6.2-10. The continuous air monitoring data for ambient $PM_{2.5}$ concentrations from Flin Flon and Thompson stations were reviewed for the period of 2016 to 2018.

In 2012, all Canadian provinces and territories except Quebec agreed to implement a national Air Quality Management System (AQMS) in which CAAQS defined color-coded air management levels for $PM_{2.5}$ and O_3 (CCME 2019). The color-coded air management levels were developed to identify and improve the management of ambient air quality. Each of the AQMS management levels and their corresponding actions associated with $PM_{2.5}$ are summarized below:

- Green indicates actions for keeping clean areas clean (i.e., when the 24-hour average is less than 10 µg/m^3 or the annual average is less than 4 µg/m^3).
- Yellow indicates actions for preventing air quality deterioration (i.e., when the 24-hour average concentration is greater than 10 µg/m^3 or the annual average is greater than 4 µg/m^3).
- Orange indicates actions for preventing CAAQS exceedances (i.e., when the 24-hour average concentration is greater than 19 µg/m^3 or the annual average is greater than 6.4 µg/m^3).
- Red indicates actions for achieving CAAQS (i.e., when the 24-hour average is greater than 27 µg/m^3 or the annual average concentration is greater than 8.8 µg/m^3).

The 24-hour $PM_{2.5}$ MAAQC, 24-hour $PM_{2.5}$ CAAQS and annual $PM_{2.5}$ CAAQS are 30 µg/m^3, 27 µg/m^3 and 8.8 µg/m^3, respectively. A summary of the 1-hour frequency statistics, 24-hour frequency statistics, the annual 98th percentile of the 24-hour average and the annual average, over the 3-year data set is shown in Appendix 6A (Table 6.2A-7 to Table 6.2A-10). The 1-hour and 24-hour average concentrations at the Flin Flon and Thompson Stations are shown in Appendix 6B (Figure 6.2B-10 to Figure 6.2B-13).

The following observations are based on a review of the 3-year data set:

- The maximum 24-hour average $PM_{2.5}$ concentrations range from 30.5 µg/m^3 to 272 µg/m^3. Ambient $PM_{2.5}$ values were greater than the 24-hour $PM_{2.5}$ MAAQC of 30 µg/m^3 at both stations for all three years.
- The three-year average of the annual 98th percentile of the daily 24-hour average $PM_{2.5}$ concentrations at Flin Flon is 27.9 µg/m^3.
- The three-year average of the annual 98th percentile of the 24-hour average $PM_{2.5}$ concentrations at Thompson is 19.1 µg/m^3, which is less than the CAAQS of 27 µg/m^3. Hence, Thompson falls under the orange management level for the 24-hour $PM_{2.5}$ concentration.
- The Manitoba 2015 Provincial Summary Report (MSD, 2016) states that the $PM_{2.5}$ management action level for Flin Flon and Thompson are at the yellow $PM_{2.5}$ management level, which is the second lowest of the four levels.
- The annual three-year average $PM_{2.5}$ concentrations at Flin Flon and Thompson are 4.99 µg/m^3 and 5.36 µg/m^3, respectively which are less than the annual CAAQS of 8.8 µg/m^3. Therefore, both Flin Flon and Thompson fall under the yellow $PM_{2.5}$ management level for annual $PM_{2.5}$ concentrations.
- The Manitoba 2015 Provincial Summary Report (MSD, 2016) states that the $PM_{2.5}$ management action level for Flin Flon and Thompson are at the yellow and green $PM_{2.5}$ management level, respectively.
- The highest 1-hour $PM_{2.5}$ concentrations tend to occur mainly during summer months with the exception at Thompson during March 2017. The high values during summer months are largely due to wildfires and long-range transport during the summer.

Ozone (O_3) Concentrations

Ambient O_3 concentration is continuously measured at all the five stations listed in Table 6.2-10. The continuous air monitoring data for ambient O_3 concentrations from the Flin Flon and Thompson stations were reviewed for the period of 2016 to 2018.

The AQMS color-coded air management levels and their corresponding actions associated to O_3 are summarized below (CCME 2019):

- Green indicates actions for keeping clean areas clean (i.e., when 4th highest daily maximum 8-hour concentration is less than 98 µg/m^3)
- Yellow indicates actions for preventing air quality deterioration (i.e., when 4th highest daily maximum 8-hour concentration is greater than 98 µg/m^3)
- Orange indicates actions for preventing CAAQS exceedances (i.e., 4th highest daily maximum 8-hour concentration is greater than 110 µg/m^3)
- Red indicates actions for achieving CAAQS (i.e., when 4th highest daily maximum 8-hour concentration is greater than 120 µg/m^3)

A summary of the 1-hour frequency statistics, CAAQS 4th highest daily maximum 8-hour (CCME 2019), 24-hour frequency statistics and the annual average over the 3-year period is shown in Appendix 6A (Table 6.2A-11 to Table 6.2A-14) for the two stations. The 1-hour and 8-hour average concentrations at the Flin Flon and Thompson Stations are illustrated in Appendix 6B (Figure 6.2B-14 to Figure 6.2B-17). The 4th highest daily maximum 8-hour CAAQS is 122 µg/m^3. The following observations are based on a review of the 3-year data set:

- The three-year average of the 4th highest daily maximum 8-hour O_3 concentrations at Flin Flon and Thompson are 97.0 µg/m^3 and 102 µg/m^3 which are less than the 8-hour CAAQS of 122 µg/m^3.
- The Manitoba 2015 Provincial Summary Report (MSD, 2016) states that the ozone management action level for Flin Flon is at the green management level, the lowest of the four levels.

Carbon Monoxide (CO) Concentrations

Ambient CO concentrations are measured at two of the five continuous air quality monitoring stations (i.e., Winnipeg Scotia Street and Winnipeg Ellen Street). The Winnipeg Ellen Street station data for the period of 2016 to 2018 were selected over the Winnipeg Scotia Street station data based on the data recovery rate (less than 50%).

A summary of the 1-hour frequency statistics and 8-hour frequency statistics over the 3-year period is provided in Appendix 6A (Table 6.2A-15 to Table 6.2A-16). The 1-hour and 8-hour average concentrations at the Winnipeg Ellen Street Station are also shown in Appendix 6B (Figure 6.2B-18 and Figure 6.2B-19). The maximum acceptable 1-hour and 8-hour MAAQC for CO are 35,000 and 15,000 µg/m^3, respectively. The maximum desirable 1-hour and 8-hour MAAQC for CO are 15,000 and 6,000 µg/m^3, respectively. The following observations are based on a review of the 3-year data set:

- The maximum 1-hour CO concentrations range from 2,631 to 3,790 µg/m^3. Ambient CO values were less than the 1-hour acceptable and desirable MAAQC.
- The maximum 8-hour average CO concentrations range from 683 to 2,188 µg/m^3. Ambient CO values were less than the 8-hour acceptable and desirable MAAQC.

Greenhouse Gases

According to CEAA guidance (CEAA 2003), the Project GHG emissions should be compared to local, provincial, and federal GHG inventories. There are no local GHG emission inventories for the LAA because of scarce industrial activity; therefore, the Project GHG emissions cannot be compared to local emissions.

The provincial and national GHG emissions (ECCC 2019b) are presented in Table 6.2-14. The emissions presented are for the latest year for which data has been published (2017). Manitoba GHG emissions accounted for 3.0% of the national GHG emissions and Manitoba is the sixth largest provincial emitter of GHGs in Canada.

Table 6.2-14 2017 Provincial and National GHG Emissions

Jurisdiction	GHG Emissions (kt)				
	CO_2	CH_4	N_2O	Other GHGs [a] (CO_2e)	Total (CO_2e)
Manitoba	13,300	160	13	501	21,700
Canada	571,000	3,700	130	14,150	716,000
Manitoba contribution to national	2.3%	4.3%	10.0%	3.5%	3.0%
NOTE: [a] Other GHGs include sulphur hexafluoride, hydrofluorocarbons, perfluorocarbons, and nitrogen trifluoride.					
SOURCE: ECCC NIR (ECCC 2019b)					

Acoustic Environment

A review of the LAA was carried out as a part of the desktop studies to estimate the existing sound levels as well as identify potential receptor locations within it. No urban/suburban areas exist within the LAA. All areas within the Project LAA are considered quiet rural locations and the existing sound levels are conservatively assumed to be 35 dBA Ldn, as recommended in Health Canada Guidance.

There are no communities or residential receptors located within LAA for the LSMOC. Some residential receptors were identified within the LAA of the LMOC and PR 239 realignment route. Appendix 6B, Figure 6.2B-4 shows the buildings identified within LAA of LMOC and PR 239 realignment route. At present, the location of disposal haul roads and aggregate quarries is not known. Any residential receptors found within these Project elements is assessed using the assumed existing sound level of 35 dBA Ldn.

Lighting

The LMOC and LSMOC PDAs are located approximately 180 km to 220 km north of the City of Winnipeg. There are three small communities (Grahamdale, Steep Rock Junction and Birch Bay), numerous residential receptors, and PTH 6 located within 5 km of the LMOC PDA and there are no communities, residential receptors or major roadways located within 5 km (i.e., within the LAA) of the LSMOC PDA. Communities of the size of Grahamdale, Steep Rock Junction and Birch Bay typically have localized light pollution, such that only in the immediate vicinity of a street-light is the night sky masked by light, and backyards, parks and other areas afford ready views of the major constellations. The views of very dark skies, including features such as the Milky Way, are typically available within a few kilometres of small communities, as topography permits.

Lacking site-specific measurements of existing ambient light levels, satellite observations of the global distribution of artificial light were reviewed. Figure 6.2-4 shows the distribution of artificial light surrounding the LSMOC and LMOC PDAs (Interactive world Light pollution map based on NOAA/EOG overlay 2015, NOAA 2015).

As can be seen in Figure 6.2-4, there are essentially no existing sources of artificial light contributing to the existing ambient light environment within the LSMOC portion of the LAA. The sky glow levels within these areas are 22.0 mag/arc sec^2 and they drop slightly to 21.9 mag/arc sec^2 in the northern part of the LAA close to Dauphin River First Nation. As presented in Table 6.2-7, sky glow levels in this range are representative of rural areas, where, on clear nights with no haze, the sky would be covered with stars that appear large and close and the Milky Way could be visible (Berry 1976).

As shown in Figure 6.2-4, although there are a few communities located within 5 km of the LMOC PDA, existing sky glow levels are also representative of rural areas (21.9 mag/arc sec^2) because the communities are small with minimal sources of night time lighting. However, levels of sky glow within the LAA start to decrease closer to the larger communities of Steep Rock (approximately 15 km to 20 km west of the LMOC PDA) and the Pinayootang First Nation (approximately 15 km north of LMOC PDA). Near these communities, sky glow levels range from 21.4 – 21.5 mag/arc sec^2. Generally, measurable light from these communities would extend to a distance of 5 km to 6 km from the towns; areas beyond would have sky glow measurements closer to 22.0 mag/arc sec^2.

No site-specific data was collected and, therefore, there are no measured data for light trespass or glare within or surrounding the LMOC and LSMOC PDAs. The levels of light trespass and glare within the LMOC PDA would likely be between 5 and 2 lux and 500 to 7,500 cd, characteristic of a rural area with low distinct brightness. Such levels may be a little lower in areas farthest away from the existing communities. Based on the general area and the information presented above, it is likely that levels of light trespass and glare would likely be below 2 lux and 2,500 cd within the LSMOC PDA and LAA portion of the LSMOC , characteristic of a natural, intrinsically dark environment (refer to Table 6.2-4, Table 6.2-5, Table 6.2-6).

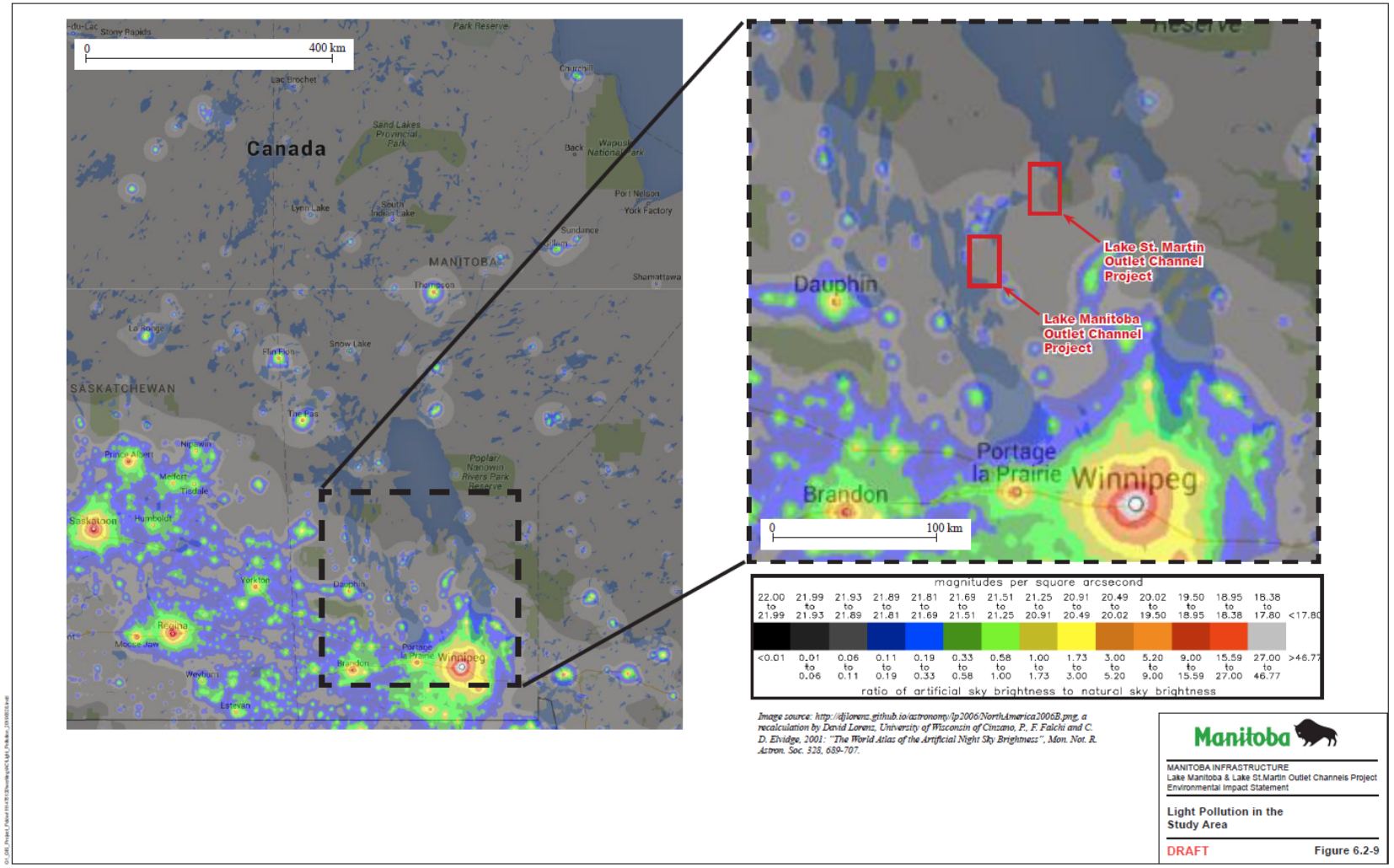

Figure 6.2-4 Distribution of Artificial Light Surrounding the LMOC and LSMOC PDAs

6.2.3 Project Interactions with Atmospheric Environment

Table 6.2-15 identifies for each potential effect, the Project components and physical activities that might interact with Atmospheric Environment during the construction and operations and maintenance phases and result in the identified environmental effect. These interactions are identified by check marks and are discussed in detail in Section 6.2.4 in the context of effects pathways, standard and Project-specific mitigation and residual effects. A justification for no effect is provided following the table.

Table 6.2-15 Project-Environment Interactions with Atmospheric Environment During Construction and Operations and Maintenance

Project Components and Physical Activities	Environmental Effects			
	Change in Air Quality	Greenhouse Gases	Change in Acoustic Environment	Change in Ambient Light
Construction				
Site preparation of Project components[1] (development of the PDA prior to construction activities [e.g., removal of existing infrastructure, vegetation clearing and initial earthworks, development of temporary construction camp and staging areas])	✓	✓	✓	✓
Project-related transportation within the LAA (movement of trucks, equipment, bulk materials, supplies, and personnel within the LAA)	✓	✓	✓	✓
Construction of Project components[1] (physical construction of utilities, infrastructure, and other facilities)	✓	✓	✓	✓
Quarry development (blasting and aggregate extraction used for the construction of Project components[1])	✓	✓	✓	✓
Water development and control (dewatering and realignment of existing water works)	✓	✓	✓	–
Operations and Maintenance				
Operation and maintenance of the outlet channels (normal operational conditions when the outlet channels and associated infrastructure [e.g., water control structure gates are open, conveying water or are closed)	–	–	–	✓
Operation and maintenance of other Project components[1] (normal operations conditions associated with PR 239 and municipal road realignments, distribution line and bridges and culverts)	✓	✓	✓	✓

Table 6.2-15 Project-Environment Interactions with Atmospheric Environment During Construction and Operations and Maintenance

Project Components and Physical Activities	Environmental Effects			
	Change in Air Quality	Greenhouse Gases	Change in Acoustic Environment	Change in Ambient Light
Project-related transportation within the LAA (movement of trucks, equipment, bulk materials, supplies, and personnel within the LAA)	✓	✓	✓	✓

NOTES:
✓ indicates a potential interaction.
– indicates no potential interactions are expected.
[1] Components include: outlet channels, water control structures, distribution line, bridges and culverts, PR 239 and municipal road realignments, temporary construction camps and staging areas, and quarries.

Atmospheric emissions during the construction phase result from construction vehicle exhaust and from fugitive dust associated with the construction activities. The magnitude of these emissions is directly related to the construction activity intensity. Project-related transportation within the LAA and construction of Project components involve the movement of the most material, and hence these two activities are associated with the largest emissions during the construction phase. Smaller emissions are associated with other activities such as site preparation and quarry development.

During the operations and maintenance phase, associated activities would be limited to periodic inspections and routine maintenance. The operational interactions of the activities with the Project include permanent lighting at the control structure and maintenance related transportation for air quality, greenhouse gases, acoustic environment and lighting.

The release of GHGs and other substances would be limited to small quantities of fuel combusted for these periodic maintenance activities. The operations phase is not assessed for the ambient air quality, noise and light components because there are no continuous emissions and lighting requirements are minimal.

After the construction phase is completed, banks of the channels and the floodplain berm will be covered with a layer of topsoil and revegetated. These areas would undergo a short-term land-use change because they can fix carbon when re-vegetated. Considering the small area that would be affected by this activity, the magnitude of the change in carbon sequestration is expected to be low. For these reasons, GHGs are not assessed for the operations phase.

6.2.4 Assessment of Residual Environmental Effects on Atmospheric Environment

6.2.4.1 Analytical Assessment Techniques

Ambient Air Quality

The Project construction emissions are estimated and contrasted with assumed exisiting concentrations in the RAA, relative to appropriate criteria.

The construction activities include combustion exhaust and fugitive dust sources. The Project SO_2, NO_X, CO, TSP, PM_{10}, $PM_{2.5}$, and VOC emissions are estimated for the five-year LMOC and LSMOC construction period. The maximum number of pieces of construction equipment operating in half-a-year intervals for the construction period was used to scale diesel exhaust and off-road equipment dust emissions from publicly available construction emission estimates for a similar project, the Springbank Project (Stantec 2018). The number of pieces of construction equipment represents the relative upper limits of the pieces of equipment that would be operating/working on any one day based on a preliminary sequencing plan. Haul road dust emissions were scaled from the same data source based on the volume of earth excavated during the construction period.

In addition, emission rates are required for existing sources of air emissions in the RAA to evaluate the relative contribution of the Project. Emissions in the RAA are primarily from residential heating, vehicles, agriculture, and wildfires. Therefore, regional emissions were established using Canada's Air Pollutant Emission Inventory (APEI). The APEI is a national emission inventory that is based on the data submitted to the National Pollutant Release Inventory (NPRI) and other sources. The NPRI data is supplemented with additional information provided by provincial governments and emission data developed by ECCC for sources not reported to the NPRI, or for sectors which contain facilities that are below the NPRI reporting threshold (ECCC 2019c). Among other sectors, the APEI includes emissions from transportation and mobile equipment, agriculture, and road dust. Because APEI data are reported on a provincial basis, emissions for the RAA were scaled. The following assumptions are applied to estimate the emissions in various sectors to the RAA:

- Commercial/residential/industrial heating emissions are based on the population of the RAA.
- Transportation and mobile equipment emissions are based on the population of the RAA.
- Agriculture emissions are based on the number of farms in the RAA.
- Paved and unpaved road dust emissions are based on the length (km) of paved and unpaved road in the RAA.
- Construction dust and combustion emissions are based on the population of the RAA.
- Rail emissions are based on the length (km) of rail track used in 2017.

There is one industrial facility in the RAA with emissions that exceed the NPRI reporting thresholds. The Graymont Western Canada Inc. Faulkner Plant is located outside the LAA and inside the RAA for the LMOC. Emissions from this facility are based on data reported to the NPRI for 2017.

Greenhouse Gases

The Canadian Environmental Assessment Agency (CEAA) guidance document (CEAA 2003) outlines how to incorporate GHG considerations in environmental assessments (EAs). This assessment aligns with the guidance document by comparing the Project GHG emissions to provincial and national GHG inventories. As stated in the Agency (CEAA 2003) document, GHG assessments cannot address the significance of a single project's potential effect on climate change because the incremental effect of one project on climate change cannot be accurately quantified or measured. Although it is understood that there is a relationship between GHG emissions from anthropogenic sources over the past 100+ years and a changing climate as an effect thereof, direct effects on climate change cannot be addressed in this GHG assessment.

GHG emissions associated with construction activities are estimated and compared to provincial and national totals. The methods used to estimate GHG emissions from the Project are guided by the principles of the GHG Protocol (WRI 2013). The GHG Protocol is an internationally accepted accounting standard and provides guidance on preparing a GHG emissions inventory. Relevance, completeness, consistency, transparency, and accuracy are the five principles that should build the base of any GHG accounting and, therefore, guide this assessment.

The Project GHG emissions are estimated for the five-year LMOC and LSMOC construction and post construction period (see Chapter 3, Section 3.5.2). The maximum number of pieces of construction equipment operating in one-year intervals for the construction period was used to estimate diesel exhaust emissions from publicly available construction emission estimates for the Springbank Project (Stantec 2018).

Acoustic Environment

The method used to assess potential noise effects during the Project construction is Health Canada Guidance (Health Canada 2017) and MEMD Guidelines for Sound Pollution (MEMD 2000). At this time, the construction schedule and construction equipment usage have not yet been finalized. As a result, the Project noise emissions are defined based on past experience with construction noise emissions and the overall tonnage of the material being removed. The method can be summarized as follows:

1. identify noise thresholds applicable to the Project
2. determine the Project noise emissions
3. identify receptors that may be affected by the Project noise emissions
4. calculate the Project noise contribution at the identified receptors and define the extent of likely noise affected area or buffer area beyond which the magnitude of noise effects is low to negligible.

5. compare predicted noise levels to the established thresholds at receptors.
6. identify the potential noise effects associated with the predicted changes in noise levels
7. if required, recommend receptor-specific noise mitigation measures

The effects assessment focuses on humans; effects on wildlife are addressed in the Chapter 8, Section 8.3 (Wildlife and Wildlife Habitat).

A summary of Project noise thresholds in shown in Table 6.2-16. The applicable noise thresholds are determined using Health Canada Guidance (Health Canada 2017) and MEMD Guidelines for Sound Pollution (MEMD 2000). Health Canada suggests that short-term noise exposure (less than one year in duration) be assessed based on the US EPA (1974) methodology. This method provides mitigation noise levels (MNLs) and associated adjustments for community types. The basic MNL is defined as the threshold recommended by Health Canada to avoid widespread complaints. The basic MNL is 47 dBA L_{dn} and is applicable to quiet suburban or rural communities. No adjustments to the basic MNL (Table 6.2-2) were seen as applicable to the Project, since no urban or suburban receptor locations were identified within the Project LAA. Additionally, tonal and impulsive characteristics of the Project noise are expected. The construction activities are assumed to last 12 hours a day and occur during daytime only. For the daytime schedule, the continuous equivalent sound level (Leq) that corresponds to the basic MNL is 50 dBA. Leq of 50 dBA represents a noise threshold for short-term (less than 1 year) construction activities that take place during daytime hours on 12 hour per day basis, that is equivalent to MNL of 47 dBA Ldn.

Table 6.2-16 Summary of Project Noise Thresholds

Criterion	Equivalent Noise Threshold for the Project dBA, Leq
Health Canada Basic MNL of 47 dBA Ldn	50
Health Canada Increase in %HA of 6.5%	57
MEMD Maximum Acceptable Sound Level Objective for Daytime	55
SOURCE: MEMD 2000	

While the construction schedule has not been finalized yet, it is likely that some receptors may be exposed to noise effects lasting longer than one year in any given area. Therefore, in accordance with Health Canada recommendations, the criterion for change in %HA measure was also assessed. For the existing noise level of 35 dBA Ldn, the area of maximum rated Project noise level (i.e., noise level associated with an increase in %HA by more than 6.5%) is estimated at 59 dBA Ldn. The rated noise level includes the 5-dB adjustment for the potential tonal and impulsive characteristics of construction noise. The corresponding Leq for 12-hour-per-day daytime construction is 57 dBA. The Leq of 57 dBA represents the long-term (more than one year in duration) Project construction noise threshold equivalent to an increase in %HA by 6.5%.

MEMD Guidelines for Sound Pollution advise the maximum acceptable environmental sound level objective for daytime hours as 55 dBA Leq for noise containing discrete tones or appreciable impulsive character. Therefore, Leq of 55 dBA represents the Project threshold corresponding to MEMD daytime environmental sound level objective.

Leq of 50 dBA is used to define the extent of noise affected area (buffer) beyond which the magnitude of noise effects is low to negligible. For Leq between 50 dBA and 57 dBA the noise effects are expected to be of moderate magnitude and may in some cases require steps to control noise emissions. Leq above 57 dBA at residential receptors are expected to result in high magnitude of noise effects and will likely require site/receptor specific noise mitigation.

Acoustic models based on Cadna/A software were used to calculate the extent of the noise buffer around the Project construction activities. Sound level predictions using Cadna/A were carried out in accordance with ISO standard 9613 Acoustics – Attenuation of Sound during propagation outdoors Parts1 (ISO 1993) and Part 2 (ISO 1996) for outdoor noise propagation. Calculations under this standard meet the requirements of provincial regulators and are also recognized by Health Canada. Parameters used in the noise model are summarized in Table 6.2-17.

Table 6.2-17 Noise Modelling Parameters

Model Parameter	Model Setting
Temperature	10^0C
Relative humidity	70%
Propagation standard	ISO 9613-2, ISO 9613-2
Ground conditions and attenuation factor	Ground absorption (G) 0.7
Receptor height	1.5 m above grade
Topography	Flat
Foliage attenuation	None (conservative)

Generally, excluding topography in the noise models does not affect the accuracy of the prediction over gently rolling terrain. For the LAA around LMOC, substantial terrain elevation changes do not occur, however, for LAA around LSMOC the terrain is generally rolling. For both channels, a conservative assumption is made that the terrain is flat and there is no substantial foliage to reduce sound propagation.

The LAA around LMOC is generally set in rural areas with low lying open fields. The LAA around LSMOC is generally set in rural areas with rolling terrain. The ground absorption constant used in the model varies between 0 for hard, reflective ground (e.g., water, pavement) and 1 for porous ground (e.g., grass and other vegetation). Under summertime conditions, the land in the LAA is covered in vegetation. Therefore, the ground factor G = 0.7 was selected which, based on professional experience, is representative of the ground condition within the LAA.

The ISO 9613 sound propagation algorithms have a published accuracy of +/-3 dB over source-to-receiver distances of between 100 m and 1,000 m. To accommodate this level of uncertainty, the following assumptions are made: downwind conditions exist 100% of the time and all normally operated equipment is operating at 100% power during their use. These conditions do not occur at all times and, therefore, the model predictions are conservative.

Preliminary construction equipment lists were established based on experience with similar construction projects (Stantec 2018). Noise source levels were established using manufacturer published data, past measurements of similar equipment, and commonly accepted engineering methods (DEFRA 2006) in estimating machinery noise emissions.

The existing human receptor locations within the LAA have been considered in the assessment. A map of building structures was developed for the assessment to understand the relative distances from construction noise sources to potential receptors. Appendix 6B, Figure 6.2B-4 shows the location of building structures identified within the LAA for the LMOC. There are no building structures identified within the LAA for the LSMOC. All building structures identified within the LAA were considered as potential permanent dwellings. Health Canada also recommends that locations that may have a heightened sensitivity to noise exposure (e.g., Indigenous peoples, schools, childcare centers, hospitals) be included in the assessment.

In addition to assessment of noise levels at specific identified receptors, this assessment also establishes the noise buffers around the PDAs (i.e., precautionary potential noise influence areas). Any additional receptors found within the noise buffers of LSMOC, LMOC and PR 239 realignment route or within the noise buffers of proposed quarries and haul routes, once their location is known, will be assessed once such information is available.

The assessment presents noise effects at the identified receptors located within the LAA. However, it is acknowledged that the construction scope and schedule are preliminary. Predicted noise levels at individual receptor locations and respective mitigation measures can be refined once detailed construction equipment lists and schedules are available.

Ambient Light

The analysis of a change in ambient light focuses on the potential effects that the Project infrastructure and activities could have on light trespass, glare, and sky glow. Lighting can become obtrusive if the light criteria in Table 6.2-5 and Table 6.2-6 are not met.

The effects of the Project lighting on nearby locations are assessed by comparing predicted light levels to the specified light criteria. However, the method is qualitative because the design of the Project is not at a stage to allow quantification of the Project light levels at the time. While the predictions are qualitative, they are based on the professional judgment of the study team and incorporate design mitigation to manage potential light effects to acceptable levels, as published in the CIE guidelines.

The final design of the Project will incorporate the lighting design recommendations at the WCSs as presented in this EIS. These recommendations will represent a conservative approach to the reduction of Project-related light pollution.

6.2.4.2 Change in Ambient Air Quality

Project Pathways

During construction, there are two types of air emissions: exhaust emissions from construction equipment and fugitive dust emissions from surface disturbance activities.

Exhaust emissions from construction equipment include, but are not limited to, bulldozers, scrapers, graders, and haul trucks. These vehicles consume diesel fuel and the products of combustion are vented the atmosphere. The exhaust emissions primarily are nitrogen (N_2), carbon dioxide (CO_2), and water vapour (H_2O); with trace amounts of substances such as oxides of nitrogen (NO_X), sulphur dioxide (SO_2), carbon monoxide (CO), particulate matter (PM), volatile organic compounds (VOCs). These gases and particles are common by-products of fossil fuel combustion.

Fugitive dust emissions from surface disturbance activities result in particle emissions of various size ranges (e.g., $PM_{2.5}$, PM_{10} and TSP) that can also be deposited to off-site ground surfaces (i.e., dustfall). $PM_{2.5}$ refers to respirable particulate matter that has an aerodynamic diameter less than 2.5 µm and total suspended particulate (TSP) includes larger particles, nominally up to 30 µm in diameter. The larger dust particles are removed near the disturbance area by gravitational settling and is the main contributor to dustfall. TSP, PM_{10} and $PM_{2.5}$ emissions are carried off-site by the wind; the smaller PM_{10} and $PM_{2.5}$ fraction tends to be transported further downwind than the TSP.

Project Mitigation Measures

Manitoba Infrastructure's Environmental Management Program and associated Project Environmental Requirements (PERs) are described in Chapter 3, Section 3.7. The following mitigation options would be implemented for the management of combustion emissions (i.e., construction vehicles) during the construction phase:

- Project off-road construction equipment will comply with emission standards in the Canadian Off-Road Compression-Ignition Engine Emission Regulations (GOC 2019a).
- Engines and exhaust systems will be properly maintained. Equipment will not be operated, including construction equipment, that shows excessive emissions of exhaust gases until corrective repairs or adjustments are made.
- The concentration of sulphur in diesel fuel will not exceed 15 mg/kg to comply with Sulphur in Diesel Fuel Regulations (GOC 2019b).
- Construction vehicle idling times will be reduced to the extent possible in order to reduce emissions, as a best management practice.

- Cold starts will be limited to the extent possible to reduce emissions, as a best management practice.
- Use of a work camp will reduce emissions associated with transportation of staff to and from site during construction.

The following mitigation measures are planned for the management of fugitive dust emissions during all Project phases, according to the PERs:

- All work will be conducted in a manner that minimizes the raising of dust from construction or maintenance operations.
- Only water or approved dust suppressants will be used for dust control. The use of waste petroleum or petroleum by-products as dust suppressants is not allowed.
- All vehicles used to haul materials to or from the work site will have the load covered with a tarpaulin cover during transport as required to minimize dust and prevent material from falling out (i.e., vehicles hauling cohesive items such as forms or steel will not tarp loads, but those transporting soils or aggregate will).
- All material stockpiles or spoil piles prone to wind erosion will be maintained as to minimize release of particulate matter or dust. This may include, but is not limited to, covering or stabilization of material stockpiled at the work site as required.

Considerations for the application of dust suppressant include:

- The application of dust suppressants will be limited to the roadway, driveway or designated area.
- Carefully monitor the application rate of all dust suppressants to ensure adequate coverage without pooling or runoff of products.
- The amount of dust suppressant applied should not exceed the minimum amount required to effectively suppress dust.
- The material must not migrate or run off the traveled portion of the roadway or designated area.
- Dust suppressants must conform to the manufacturer's specifications and must not contain concentrations of contaminants that would not normally be found in the suppressant.
- Ensure that dust suppressants do not enter and contaminate waterbodies, including surface and groundwater. Do not allow the product to leave the roadway.
- Do not apply products to areas of roads that are subject to flooding.
- Do not apply products if precipitation is occurring or forecast to occur before the product sets or cures.
- Avoid over-application or application beyond the road shoulder.

Emissions were estimated based on publicly available information (Stantec 2018). The following are explicitly quantified in the document used as the basis for the Project construction emission inventory:

- The concentration of sulphur in diesel fuel will not exceed 15 mg/kg.
- 75% control efficiency applied to particulate emissions from haul roads corresponding to watering twice daily (U.S. EPA, 2006).
- Stabilized surfaces of temporary soil and overburden stockpiles during extended periods between usage, resulting in no fugitive dust emissions during these periods.

Additional mitigation measures can be implemented on an as-required basis. As part of the Dust Control Plan included in the EMP (Chapter 3, Section 3.7), construction staff will visually monitor effectiveness of dust control throughout construction (i.e., visible dust), review weather forecasts for unfavourable weather conditions such as hot, dry and high wind conditions, as well as respond to any potential stakeholder complaints by reviewing effectiveness of current dust control activities, adjusting water application frequency and/or using chemical dust suppressants on a case-by-case basis.

Project Residual Effects

As noted in Chapter 3, the Project construction, operation and maintenance activities will include the use of a number of various types of vehicles, materials and equipment in the PDAs to complete the clearing, excavations, drainage realignments, road works, and installation of bridges, culverts and water control structures required for the construction and operation of the outlet channels. These activities will create dust and combustion emissions.

Effects on air quality during the Project operation and maintenance activities are expected to be lower in magnitude, duration and extent than during the construction phase due to the completion of excavation work, reduced use of vehicles and equipment, limited areal extent, and infrequent nature of the operation and maintenance activities. Effects during the operation and maintenance phases are expected to be minor and limited mainly to the PDAs, with some use of the Project area roadways. Therefore, only emissions associated with the Project construction activities are quantified for the Project residual effects. Table 6.2-18 and Table 6.2-19 summarize the estimated Project emissions due to construction activities at the LMOC and LSMOC, respectively.

- As a detailed inventory of Project construction equipment was not available, the construction emissions for LMOC are estimated from the Springbank Project (Stantec 2018) annual construction emissions based on the number of pieces of construction equipment and the volume of earth excavation for LMOC as per Chapter 3, Section 3.5.2.9. To consider the construction conditions specific to the LMOC, the assumed average haul truck speed is assumed to be 10 km/h.
- The construction emissions for LSMOC are scaled from those of the LMOC based on the volume of earth excavation for LSMOC provided in Chapter 3, Section 3.5.2.2. To consider the land type specific to LSMOC, the transportable fraction has been adjusted to 0.05 to reflect “forest” land type.

Table 6.2-18 Summary of LMOC Construction Emissions

Year	LMOC Maximum Number of Equipment	Source Type	CAC Annual Emissions (tonnes/half year)						
			NO_X	SO_2	TSP	PM_{10}	$PM_{2.5}$	CO	VOC
Year 0 - 0.5	75	Off-Road Diesel Exhaust Emissions	106	0.262	6.04	6.04	5.86	101	8.68
		Off-Road Equipment Dust Emissions	—	—	29.0	6.26	2.47	—	—
		Haul Roads Dust Emissions	—	—	469	134	13.4	—	—
		Truck Loading/Unloading Dust Emissions	—	—	1.63	0.769	0.116	—	—
		Wind Erosion Dust Emissions	—	—	0.0005	0.0004	0.0001	—	—
Year 0.5 - 1	100	Off-Road Diesel Exhaust Emissions	142	0.349	8.06	8.06	7.81	135	11.6
		Off-Road Equipment Dust Emissions	—	—	38.7	8.34	3.29	—	—
		Haul Roads Dust Emissions	—	—	625	179	17.9	—	—
		Truck Loading/Unloading Dust Emissions	—	—	2.17	1.03	0.155	—	—
		Wind Erosion Dust Emissions	—	—	0.001	0.001	0.0001	—	—
Year 1 - 1.5	175	Off-Road Diesel Exhaust Emissions	248	0.610	14.10	14.10	13.67	236	20.25
		Off-Road Equipment Dust Emissions	—	—	67.7	14.60	5.76	—	—
		Haul Roads Dust Emissions	—	—	1093	312	31.2	—	—
		Truck Loading/Unloading Dust Emissions	—	—	3.79	1.79	0.272	—	—
		Wind Erosion Dust Emissions	—	—	0.001	0.001	0.0001	—	—
Year 1.5 - 2	175	Off-Road Diesel Exhaust Emissions	248	0.610	14.1	14.1	13.7	236	20.2
		Off-Road Equipment Dust Emissions	—	—	67.7	14.6	5.76	—	—
		Haul Roads Dust Emissions	—	—	1093	312	31.2	—	—
		Truck Loading/Unloading Dust Emissions	—	—	3.79	1.79	0.272	—	—
		Wind Erosion Dust Emissions	—	—	0.001	0.001	0.0001	—	—

Table 6.2-18 Summary of LMOC Construction Emissions

Year	LMOC Maximum Number of Equipment	Source Type	CAC Annual Emissions (tonnes/half year)						
			NO_X	SO_2	TSP	PM_{10}	$PM_{2.5}$	CO	VOC
Year 2 - 2.5	200	Off-Road Diesel Exhaust Emissions	283	0.697	16.1	16.1	15.6	269	23.1
		Off-Road Equipment Dust Emissions	—	—	77.4	16.7	6.58	—	—
		Haul Roads Dust Emissions	—	—	1250	357	35.7	—	—
		Truck Loading/Unloading Dust Emissions	—	—	4.33	2.05	0.310	—	—
		Wind Erosion Dust Emissions	—	—	0.001	0.001	0.0002	—	—
Year 2.5 - 3	175	Off-Road Diesel Exhaust Emissions	248	0.610	14.1	14.1	13.7	236	20.2
		Off-Road Equipment Dust Emissions	—	—	67.7	14.6	5.76	—	—
		Haul Roads Dust Emissions	—	—	1093	312	31.2	—	—
		Truck Loading/Unloading Dust Emissions	—	—	3.79	1.79	0.272	—	—
		Wind Erosion Dust Emissions	—	—	0.001	0.001	0.0001	—	—
Year 3 - 3.5	175	Off-Road Diesel Exhaust Emissions	248	0.610	14.1	14.1	13.7	236	20.2
		Off-Road Equipment Dust Emissions	—	—	67.7	14.6	5.76	—	—
		Haul Roads Dust Emissions	—	—	1093	312	31.2	—	—
		Truck Loading/Unloading Dust Emissions	—	—	3.79	1.79	0.272	—	—
		Wind Erosion Dust Emissions	—	—	0.001	0.001	0.0001	—	—
Year 3.5 - 5	50	Off-Road Diesel Exhaust Emissions	70.8	0.174	4.03	4.03	3.91	67.3	5.78
		Off-Road Equipment Dust Emissions	—	—	19.3	4.17	1.65	—	—
		Haul Roads Dust Emissions	—	—	312	89.3	8.93	—	—
		Truck Loading/Unloading Dust Emissions	—	—	1.08	0.513	0.078	—	—
		Wind Erosion Dust Emissions	—	—	0.0003	0.0003	0.00004	—	—
Total Off-Road Diesel Exhaust Emissions (tonnes/5-year)			867	2.14	49.3	49.3	47.9	824	70.9

Table 6.2-18 Summary of LMOC Construction Emissions

Year	LMOC Maximum Number of Equipment	Source Type	CAC Annual Emissions (tonnes/half year)						
			NO_X	SO_2	TSP	PM_{10}	$PM_{2.5}$	CO	VOC
Total Off-Road Equipment Dust Emissions (tonnes/5-year)			—	—	237	51.1	20.2	—	—
Total Haul Road Dust Emissions (tonnes/5-year)			—	—	3827	1093	109	—	—
Total Truck Loading/Unloading Dust Emissions (tonnes/5-year)			—	—	24.4	11.5	1.75	—	—
Total Wind Erosion Dust Emissions (tonnes/5-year)			—	—	0.007	0.006	0.001	—	—
Total Construction Emissions for 5 years for LMOC (tonnes/5-year)			867	2.14	4137	1205	179	824	70.9

NOTE:
Text highlighted in grey represent the maximum annual emission from the 5-year construction period

Table 6.2-19 Summary of LSMOC Construction Emissions

Year	Source Type	CAC Annual Emissions (tonnes/half year)						
		NO_X	SO_2	TSP	PM_{10}	$PM_{2.5}$	CO	VOC
Year 0 - 0.5	Off-Road Diesel Exhaust Emissions	77.2	0.190	4.39	4.39	4.26	73.4	6.31
	Off-Road Equipment Dust Emissions	—	—	1.41	0.303	0.120	—	—
	Haul Roads Dust Emissions	—	—	22.7	6.49	0.649	—	—
	Truck Loading/Unloading Dust Emissions	—	—	0.079	0.037	0.006	—	—
	Wind Erosion Dust Emissions	—	—	0.00002	0.00002	0.000003	—	—
Year 0.5 - 1	Off-Road Diesel Exhaust Emissions	103	0.254	5.86	5.86	5.68	97.9	8.41
	Off-Road Equipment Dust Emissions	—	—	1.88	0.405	0.160	—	—
	Haul Roads Dust Emissions	—	—	30.3	8.66	0.866	—	—
	Truck Loading/Unloading Dust Emissions	—	—	0.105	0.050	0.008	—	—
	Wind Erosion Dust Emissions	—	—	0.00003	0.00003	0.000004	—	—
Year 1 - 1.5	Off-Road Diesel Exhaust Emissions	180	0.444	10.253	10.253	9.95	171	14.7
	Off-Road Equipment Dust Emissions	—	—	3.3	0.708	0.279	—	—
	Haul Roads Dust Emissions	—	—	53.0	15.1	1.51	—	—
	Truck Loading/Unloading Dust Emissions	—	—	0.184	0.087	0.013	—	—
	Wind Erosion Dust Emissions	—	—	0.00006	0.00004	0.00001	—	—
Year 1.5 - 2	Off-Road Diesel Exhaust Emissions	180	0.444	10.3	10.3	9.95	171	14.7
	Off-Road Equipment Dust Emissions	—	—	3.28	0.708	0.279	—	—
	Haul Roads Dust Emissions	—	—	53.0	15.1	1.51	—	—
	Truck Loading/Unloading Dust Emissions	—	—	0.184	0.087	0.013	—	—
	Wind Erosion Dust Emissions	—	—	0.00006	0.00004	0.00001	—	—

Table 6.2-19 Summary of LSMOC Construction Emissions

Year	Source Type	CAC Annual Emissions (tonnes/half year)						
		NO_X	SO_2	TSP	PM_{10}	$PM_{2.5}$	CO	VOC
Year 2 - 2.5	Off-Road Diesel Exhaust Emissions	206	0.507	11.7	11.7	11.4	196	16.8
	Off-Road Equipment Dust Emissions	—	—	3.75	0.809	0.319	—	—
	Haul Roads Dust Emissions	—	—	60.6	17.3	1.73	—	—
	Truck Loading/Unloading Dust Emissions	—	—	0.210	0.099	0.015	—	—
	Wind Erosion Dust Emissions	—	—	0.00006	0.00005	0.00001	—	—
Year 2.5 - 3	Off-Road Diesel Exhaust Emissions	180	0.444	10.3	10.3	9.95	171	14.7
	Off-Road Equipment Dust Emissions	—	—	3.28	0.708	0.279	—	—
	Haul Roads Dust Emissions	—	—	53.0	15.1	1.51	—	—
	Truck Loading/Unloading Dust Emissions	—	—	0.184	0.087	0.013	—	—
	Wind Erosion Dust Emissions	—	—	0.00006	0.00004	0.00001	—	—
Year 3 - 3.5	Off-Road Diesel Exhaust Emissions	180	0.444	10.3	10.3	9.95	171	14.7
	Off-Road Equipment Dust Emissions	—	—	3.28	0.708	0.279	—	—
	Haul Roads Dust Emissions	—	—	53.0	15.1	1.51	—	—
	Truck Loading/Unloading Dust Emissions	—	—	0.184	0.087	0.013	—	—
	Wind Erosion Dust Emissions	—	—	0.00006	0.00004	0.00001	—	—
Year 3.5 - 5	Off-Road Diesel Exhaust Emissions	51.5	0.127	2.93	2.93	2.84	48.9	4.21
	Off-Road Equipment Dust Emissions	—	—	0.938	0.202	0.080	—	—
	Haul Roads Dust Emissions	—	—	15.1	4.3	0.433	—	—
	Truck Loading/Unloading Dust Emissions	—	—	0.053	0.025	0.004	—	—
	Wind Erosion Dust Emissions	—	—	0.00002	0.00001	0.000002	—	—
Total Off-Road Diesel Exhaust Emissions (tonnes/5-year)		631	1.55	35.9	35.9	34.8	600	51.5
Total Off-Road Equipment Dust Emissions (tonnes/5-year)		—	—	11.5	2.48	0.977	—	—

Table 6.2-19 Summary of LSMOC Construction Emissions

Year	Source Type	CAC Annual Emissions (tonnes/half year)						
		NO_X	SO_2	TSP	PM_{10}	$PM_{2.5}$	CO	VOC
Total Haul Road Dust Emissions (tonnes/5-year)		—	—	186	53	5.30	—	—
Total Truck Loading/Unloading Dust Emissions (tonnes/5-year)		—	—	1.18	0.559	0.085	—	—
Total Wind Erosion Dust Emissions (tonnes/5-year)		—	—	0.0004	0.0003	0.00004	—	—
Total Construction Emissions for 5 years for LSMOC (tonnes/5-year)		631	1.55	234	91.9	41.2	600	51.5
NOTE: Text highlighted in grey represent the maximum annual emission from the 5-year construction period								

Table 6.2-20 Summary of Annual LMOC and Construction Emissions

Location	Year	CAC Annual Emissions (tonnes/year)						
		NO_X	**SO_2**	**TSP**	**PM_{10}**	**$PM_{2.5}$**	**CO**	**VOC**
LMOC	1	124	0.305	591	172	25.6	118	10.1
LSMOC	1	90.1	0.222	33.5	13.1	5.88	85.6	7.36
LMOC + LSMOC	*1*	*214*	*0.527*	*625*	*185*	*31.5*	*203*	*17.5*
LMOC	2	248	0.610	1,183	345	51.2	236	20.2
LSMOC	2	180	0.444	66.9	26.3	11.8	171	14.7
LMOC + LSMOC	*2*	*428*	*1.05*	*1,250*	*371*	*63.0*	*407*	*35.0*
LMOC	3	265	0.654	1,267	369	54.9	252	21.7
LSMOC	3	193	0.476	71.7	28.2	12.6	184	15.8
LMOC + LSMOC	*3*	*458*	*1.13*	*1,339*	*397*	*67.5*	*436*	*37.5*
LMOC	4	159	0.392	760	221	32.9	151	13.0
LSMOC	4	116	0.285	43.0	16.9	7.56	110	9.47
LMOC + LSMOC	*4*	*275*	*0.678*	*803*	*238*	*40.4*	*262*	*22.5*
LMOC	5	70.8	0.174	336	97.8	14.5	67.3	5.78
LSMOC	5	51.5	0.127	19.0	7.48	3.36	48.9	4.21
LMOC + LSMOC	*5*	*122*	*0.301*	*356*	*105*	*17.9*	*116*	*10.0*
LMOC	Total	867	2.14	4,137	1,205	179	824	70.9
LSMOC	Total	631	1.55	234	91.9	41.2	600	51.5
LMOC + LSMOC	Total	1,498	3.69	4,371	1,297	220	1,424	122

NOTE:
Text highlighted in grey represent the maximum annual emission from the 5-year construction period

As noted in Section 7.1.1.3 and Section 7.1.1.4, there are existing transportation, agricultural, residential, industrial, and recreational activities in the RAA that contribute to background air quality and would occur with or without the Project. Regional emissions developed following the approach described in Section 6.2.4.1 for the RAA are presented in Table 6.2-21. Regional emissions are characteristic of a sparsely populated area with minor industrial development.

The maximum annual emissions from LMOC and LSMOC construction occur during year 3. To put the Project construction emissions into context, maximum annual emissions are compared to existing emissions in the RAA in Table 6.2-22. The contribution of the maximum annual Project emissions to total emissions in the RAA is also presented. The Project represents between 3.9% ($PM_{2.5}$) and 51% (NO_X) of total emissions in the RAA. The substantial increase of NO_X emissions in the RAA due to the Project is mainly associated with fuel use by construction equipment during the Project construction phase. However, due to the short-term nature of construction emissions, the increased NO_X emissions are not expected to have an adverse impact on long-term ambient air quality.

On a short-term basis, the existing NO_2 concentrations summarized in Section 6.2.2.2 indicate that the maximum measured 90th percentile 1-hour, 24-hour and annual average concentrations in the RAA are 15.0 µg/m^3, 13.2 µg/m^3 and 7.72 µg/m^3, respectively, about 4%, 7% and 8% of the MAAQCs, respectively. It is unlikely that the increase of the NO_X emissions in the RAA due to the Project contribution will cause a substantial change to ambient air quality. Similarly, it is unlikely that the increase in the other CAC emissions, specifically SO_2, TSP, PM_{10}, $PM_{2.5}$ and CO in the RAA due to the Project contribution will cause the ambient air quality to exceed the respective MAAQCs.

An air quality assessment for the Springbank Project was carried out by quantifying the Project emissions and applying a dispersion model (Stantec 2018), and the applicable findings are summarized below:

- The primary emission sources of the Project are from construction equipment vehicle exhausts, and fugitive dust emissions result from surface disturbance activities.
- The primary effect on air quality is related to dust concentrations (TSP, PM_{10}, $PM_{2.5}$). This reinforces the fact that dust control should be the primary focus of Project air quality mitigation, and that adaptive management through the EMP is a key component to monitoring effectiveness of mitigation to minimize dust emissions and effects.
- CAC ambient air quality concentrations due to the Project emissions are the greatest near the PDA and decrease substantially with increasing distance from the PDA. The Springbank Project assessment found that maximum predicted concentrations of fine particulate matter ($PM_{2.5}$) and total suspended particulates (TSP) decreased to approximately 50% of the relevant regulatory objective at distances of 0 to 4 km ($PM_{2.5}$), 2.5 to 7 km (PM_{10}), and 0 to 6 km (TSP) from that project perimeter.
- CAC concentrations at the nearest occupied receptors will be lower than those that occur next to the PDA and exceedances of ambient air quality criteria, attributable to the Project, are unlikely at these receptors.

- There are no communities, residential receptors or major roadways located within 5 km of the LSMOC PDA. The Dauphin River First Nation is approximately 5 km away from the LSMOC PDA and the Lake St. Martin First Nation, Little Saskatchewan First Nation, and Pinaymootang First Nation are approximately 24 km, 18 km, and 13 km from the LMOC PDA, respectively. There are three small communities (Grahamdale, Steep Rock Junction and Birch Bay), numerous residential receptors, and Provincial Trunk Highway 6 located within 5 km of the LMOC PDA. In addition, the communities of Grahamdale, Hillbre, Faulkner, Moosehorn, and Gypsumville are located approximately 4 km, 4 km, 7.5 km, 9 km, and 30 km from the LMOC PDA, respectively. It is unlikely that air quality in these communities and First Nations will be substantially affected by Project construction due to the intervening distances.

Table 6.2-23 compares maximum annual Project construction emissions to total Manitoba emissions. The Project represents less than 0.01% of provincial CAC emissions.

Table 6.2-21 Summary of Regional Emissions within the RAA

Source Category	Regional Emissions (tonnes/year)						
	NO_x	**SO_2**	**TSP**	**PM_{10}**	**$PM_{2.5}$**	**CO**	**VOC**
Industrial Facility within RAA							
Graymont Western Canada Inc. - Faulkner Plant	313	0.00	160	103	66.0	32.0	0.00
Other Regional Sources within RAA							
Commercial / Residential / Institutional	24.0	1.20	33.7	32.2	31.8	193	57.5
Transportation and Mobile Equipment	104	0.154	6.09	6.07	5.74	446	42.0
Agriculture	0.343	0.014	9,172	3,047	911	0.056	152
Paved Road Dust	0.00	0.00	7,226	1,390	335	0.00	0.00
Un-Paved Road Dust	0.00	0.00	4,767	1,570	231	0.00	0.00
Construction Operations Dust	0.00	0.00	1,183	355	71.0	0.00	0.00
Rail Transportation	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Construction Fuel Combustion	0.958	0.202	0.074	0.068	0.063	0.166	0.012
Total Emissions within RAA	**442**	**1.57**	**22,549**	**6,504**	**1,651**	**671**	**251**
SOURCE: APEI (ECCC 2019c)							

Table 6.2-22 Contribution of the Project Emissions to the RAA

Substance	Emissions (tonnes/year)			Project Contribution (%)
	Regional Emissions	Project [a]	Cumulative Emissions (Regional + Project)	
NO_X	442	458	901	50.9%
SO_2	1.57	1.13	2.70	41.8%
TSP	22,549	1,339	23,887	5.6%
PM_{10}	6,504	397	6,901	5.8%
$PM_{2.5}$	1,651	67.5	1,718	3.9%
CO	671	436	1,107	39.4%
VOC	251	37.5	289	13.0%

NOTE:
[a] Maximum annual construction emission for the 5-year construction period is presented as the Project emission

Table 6.2-23 Contribution of the Project Emissions to the 2017 Provincial (Manitoba) Emissions

Substance	Emission Summary (tonnes/year)		Project Contribution (%)
	Project [a]	Manitoba [b]	
NO_X	458	1,782,856	0.03%
SO_2	1.13	953,789	0.000%
TSP	1,339	23,531,561	0.01%
PM_{10}	397	7,499,724	0.01%
$PM_{2.5}$	67.5	1,673,988	0.004%
CO	436	5,661,980	0.01%
VOC	37.5	1,811,220	0.002%

NOTES:
[a] Maximum annual construction emission for the 5-year construction period is presented as the Project emission
[b] Manitoba emissions are for 2017 based on APEI (ECCC 2019c).

6.2.4.3 Greenhouse Gases

Project Pathways

Construction vehicle exhaust is a source of GHG emissions. These GHG emissions are primarily carbon dioxide (CO_2), with smaller amounts of methane (CH_4) and nitrous oxide (N_2O). As per the GHG Protocol (WRI 2013), the estimated GHG emissions include all direct emissions from the Project.

Project Mitigation Measures

Manitoba Infrastructure's Environmental Management Program and associated PER are described in Chapter 3, Section 3.7. The mitigation measures associated with ambient air quality to reduce combustion emissions in Section 6.2.4.2 are also applicable to the mitigation of GHG emissions because combustion sources account for virtually all the GHG emissions associated with the construction phase.

Project Residual Effects

Emissions of GHGs from construction equipment are presented in Table 6.2-24. Approximately 417,397 t CO_2e are estimated to be released over the construction period and the peak annual Project emission during the construction period is 127,774.7 t CO_2e (year 3). About 78% of the construction GHG emissions are estimated to be to be released between construction years 2 to 4. LMOC and LSMOC construction emissions contribute 58% and 42% of overall project construction emissions, respectively.

Table 6.2-25 compares the maximum annual Project construction emissions to total Canada and Manitoba emissions. Project GHG emissions are less than 0.02% and 0.6% of 2017 national and provincial annual GHG emissions, respectively. Therefore, the Project GHG emissions have negligible contribution to the national and provincial GHG emissions. 2017 Canada and Manitoba GHG emissions data are the most recent data available.

Table 6.2-24 Estimated GHG Emissions from Construction

Construction Location	Construction Year	Construction Emissions (tonnes)			
		CO_2	CH_4	N_2O	CO_2e
LMOC	1	33,649.65	0.92	2.85	34,521.59
LSMOC	1	24,472.47	0.67	2.07	25,106.61
LMOC + LSMOC	1	58,122.11	1.58	4.92	59,628.20
LMOC	2	67,299.29	1.83	5.70	69,043.17
LSMOC	2	48,944.94	1.33	4.14	50,213.22
LMOC + LSMOC	2	116,244.23	3.17	9.84	119,256.39
LMOC	3	72,106.38	1.96	6.11	73,974.83
LSMOC	3	52,441.01	1.43	4.44	53,799.88
LMOC + LSMOC	3	124,547.39	3.39	10.55	127,774.70
LMOC	4	43,263.83	1.18	3.66	44,384.90
LSMOC	4	31,464.60	0.86	2.66	32,279.93
LMOC + LSMOC	4	74,728.43	2.03	6.33	76,664.82
LMOC	5	19,228.37	0.52	1.63	19,726.62
LSMOC	5	13,984.27	0.38	1.18	14,346.63
LMOC + LSMOC	5	33,212.64	0.90	2.81	34,073.25
LMOC	Total	235,547.52	6.41	19.94	241,651.11

Table 6.2-24 Estimated GHG Emissions from Construction

Construction Location	Construction Year	Construction Emissions (tonnes)			
		CO_2	CH_4	N_2O	CO_2e
LSMOC	Total	171,307.29	4.66	14.50	175,746.26
LMOC + LSMOC	Total	406,854.80	11.08	34.45	417,397.37
NOTES: Aggregated totals may not equal disaggregated values in this table due to rounding Text highlighted in grey indicate the peak annual emissions from 5 year of construction period					

Table 6.2-25 Comparison of Construction GHG Emissions to Provincial and National Totals

Year	Canada CO_2e (t/y)	Project Contribution (Canada) [a] (%)	Manitoba CO_2e (t/y)	Project Contribution (Manitoba) [a] (%)
2017	716,000,000	0.02%	21,700,000	0.6%
NOTE: [a] Compared to peak annual construction emissions out of 5-year construction period i.e. Year 3				

6.2.4.4 Change in Acoustic Environment

Project Pathways

Noise propagation from the Project construction activities is considered to potentially affect nearby receptors within the acoustic LAA. The Project noise emission levels during the Project construction phase are predicted for the identified receptors within the LAA (Appendix 6B, Figure 6.2B-4) and compared to the established thresholds (Table 6.2-2 and Table 6.2-3). Table 6.2-26 summarizes the results and establishes expected noise effects at the 89 receptors that are preliminarily identified within the LAA (under the initial assessment condition at full equipment utilization). Noise effects at 61 of the 89 receptors are expected to be of low magnitude, with predicted levels below 50 dBA Leq. At seven of the receptors, the magnitude of noise effects is predicted to be high with the Project noise levels in excess of 57 dBA Leq. The remainder of the receptors are expected to experience moderate noise impacts. The receptors are preliminarily identified within the LMOC and PR 239 realignment LAA and considered as habitable dwellings. The receptors with high expected noise impact should be confirmed and reassessed once the construction schedule and the equipment usage are known.

Table 6.2-26 Noise Modelling Results and Noise Effects at the Receptors

Building Structure ID	Approximate Distance to PDA (m)	Predicted Noise Level, Leq (dBA)[1]	Meets Lower Noise Threshold of 50 dBA Leq[2] (Yes/No)	Meets Upper Noise Threshold of 57 dBA, Leq [3] (Yes/No)	Expected Noise Impact[4]
R44	316	51.2	NO	YES	MODERATE
R45	752	46.1	YES	YES	LOW
R73	25	56.4	NO	YES	MODERATE
R79	898	51.0	NO	YES	MODERATE
R90	185	48.6	YES	YES	LOW
R91	212	48.0	YES	YES	LOW
R92	283	46.3	YES	YES	LOW
R93	280	46.3	YES	YES	LOW
R94	300	45.3	YES	YES	LOW
R95	760	44.5	YES	YES	LOW
R105	740	38.2	YES	YES	LOW
R119	68	53.2	NO	YES	MODERATE
R120	56	54.0	NO	YES	MODERATE
R130	488	47.4	YES	YES	LOW
R130a	800	50.2	NO	YES	MODERATE
R131	396	48.2	YES	YES	LOW
R133	18	57.1	NO	NO	HIGH
R134	28	55.9	NO	YES	MODERATE
R141	749	45.1	YES	YES	LOW
R143	656	46.1	YES	YES	LOW
R144	719	45.4	YES	YES	LOW
R147	406	49.3	YES	YES	LOW
R148	473	48.3	YES	YES	LOW
R149	451	49.5	YES	YES	LOW
R150	484	49.9	YES	YES	LOW
R151	1108	45.2	YES	YES	LOW
R152	551	48.4	YES	YES	LOW
R153	490	49.6	YES	YES	LOW
R154	1183	44.8	YES	YES	LOW
R155	74	61.3	NO	NO	HIGH
R156	20	56.9	NO	YES	MODERATE
R157	90	59.6	NO	NO	HIGH

Table 6.2-26 Noise Modelling Results and Noise Effects at the Receptors

Building Structure ID	Approximate Distance to PDA (m)	Predicted Noise Level, Leq (dBA)[1]	Meets Lower Noise Threshold of 50 dBA Leq[2] (Yes/No)	Meets Upper Noise Threshold of 57 dBA, Leq [3] (Yes/No)	Expected Noise Impact[4]
R158	1338	47.2	YES	YES	LOW
R159	303	49.1	YES	YES	LOW
R160	727	48.0	YES	YES	LOW
R161	639	48.8	YES	YES	LOW
R166	726	46.0	YES	YES	LOW
R167	1146	48.9	YES	YES	LOW
R168	517	48.5	YES	YES	LOW
R171	1138	48.9	YES	YES	LOW
R172	947	50.3	NO	YES	MODERATE
R187	698	51.2	NO	YES	MODERATE
R188	768	50.7	NO	YES	MODERATE
R189	321	60.7	NO	NO	HIGH
R190	321	61.7	NO	NO	HIGH
R193	1095	44.6	YES	YES	LOW
R232	146	49.4	YES	YES	LOW
R233	695	40.5	YES	YES	LOW
R234	58	52.4	NO	YES	MODERATE
R244	1012	45.6	YES	YES	LOW
R245	925	46.0	YES	YES	LOW
R246	234	54.7	NO	YES	MODERATE
R248	353	51.0	NO	YES	MODERATE
R249	912	43.4	YES	YES	LOW
R250	852	44.1	YES	YES	LOW
R259	599	37.0	YES	YES	LOW
R260	580	37.4	YES	YES	LOW
R261	526	38.0	YES	YES	LOW
R262	638	36.8	YES	YES	LOW
R263	270	42.0	YES	YES	LOW
R264	521	38.2	YES	YES	LOW
R265	535	37.9	YES	YES	LOW
R266	931	35.4	YES	YES	LOW
R267	543	38.3	YES	YES	LOW

Table 6.2-26 Noise Modelling Results and Noise Effects at the Receptors

Building Structure ID	Approximate Distance to PDA (m)	Predicted Noise Level, Leq (dBA)[1]	Meets Lower Noise Threshold of 50 dBA Leq[2] (Yes/No)	Meets Upper Noise Threshold of 57 dBA, Leq [3] (Yes/No)	Expected Noise Impact[4]
R268	635	37.0	YES	YES	LOW
R269	655	37.1	YES	YES	LOW
R270	668	37.1	YES	YES	LOW
R271	780	36.8	YES	YES	LOW
R272	616	37.6	YES	YES	LOW
R273	728	37.0	YES	YES	LOW
R274	629	37.1	YES	YES	LOW
R275	883	35.6	YES	YES	LOW
R276	551	38.0	YES	YES	LOW
R277	700	37.1	YES	YES	LOW
R284	325	54.9	NO	YES	MODERATE
R285	525	57.4	NO	NO	HIGH
R287	703	46.2	YES	YES	LOW
R289	679	46.4	YES	YES	LOW
R290	289	52.1	NO	YES	MODERATE
R291	17	58.6	NO	NO	HIGH
R292	541	48.1	YES	YES	LOW
R293	715	46.3	YES	YES	LOW
R295	1079	49.6	YES	YES	LOW
R303	411	53.5	NO	YES	MODERATE
R305	563	56.8	NO	YES	MODERATE
R306	392	51.7	NO	YES	MODERATE
R307	404	49.8	YES	YES	LOW
R308	378	50.5	NO	YES	MODERATE
R309	263	52.4	NO	YES	MODERATE

NOTES:

1 Calculated results are based on preliminary construction schedule and conservative assumptions used for calculation of noise emissions from construction equipment

2 The lower noise threshold is based on MNL of 47 dBA.

3 The upper noise threshold is based 6.5% increase in %HA from the existing level of 35 dBA Ldn.

4 Based on classification shown in Table 6.2-9

Additionally, the geographic areas of noise buffers were established for various Project components. These were defined by the distances at which the Project noise levels would be estimated to fall below 50 dBA Leq. The distances of established noise buffers are summarized in Table 6.2-27. Any additional receptors (not included in the analysis) found within the noise buffers may be subjected to noise effects that are moderate to high in magnitude. Such receptors can be assessed individually once the construction schedule and equipment use information are known to determine whether additional noise mitigation measures are required.

Table 6.2-27 Predicted Distances of Noise Influence Areas (Noise Buffers)

Project components	Predicted Distance of Noise Buffer (m)	Notes
LMOC	525	The distance is from the LMOC center line to where the noise levels are expected to attenuate below 50 dBA Leq. Based on noise emission intensity of 85 dB/m
LSMOC	570	The distance is from the LSMOC center line to where the noise levels are expected to attenuate below 50 dBA Leq. Based on noise emission intensity of 85 dBA/m.
Township Line Road Bridge	900	The distance is from the center of bridge footprint to where the noise levels are expected to attenuate below 50 dBA Leq. Based on approximate construction area of 400 m x 500 m and noise emission intensity of 72 dBA/m^2.
Revised PR 239 bridge	950	The distance is from the center of bridge footprint to where the noise levels are expected attenuate below 50 dBA Leq. Based on approximate construction area of 400 m x 500 m and noise emission intensity of 72 dBA/m^2.
PTH 6 bridge	1000	The distance is from the center of bridge footprint to where the noise levels are expected attenuate below 50 dBA Leq. Based on approximate construction area of 420 m x 530 m and noise emission intensity of 71 dBA/m^2.
LMOC WCS (Iverson Rd)	900	The distance is from the center of WCS footprint to where the noise levels are expected attenuate below 50 dBA Leq. Based on approximate construction area of 400 m x 500 m and noise emission intensity of 72 dBA/m^2
LSMOC WCS	810	The distance is from the center of WCS footprint to where the noise levels are expected attenuate below 50 dBA Leq. Based on approximate construction area of 400 m x 500 m and noise emission intensity of 72 dBA/m^2
PR 239 realignment route	300	The distance is from the PR 239 realignment route center line to where the noise levels are expected attenuate below 50 dBA Leq. Based on noise emission intensity of 63 dBA/m^2.
Quarries	550	Based on a theoretical quarry size of 200 m x 200 m and noise emission intensity of 75 dBA/m^2.
Haul Roads	300	Assuming the same noise intensity as that for PR 239.

The predicted results are based on the preliminary information for the Project and do not include the application of receptor-specific mitigation measures. Further development of mitigation and refinement of the predicted results may be completed once a detailed construction execution plan is available.

Noise emissions during the operation phase are not considered continuous because the operation of WCS will be limited to potential flooding periods and regular maintenance. Therefore, noise emissions from the operation phase are not assessed quantitatively.

Project Mitigation Measures

Manitoba Infrastructure's Environmental Management Program and associated PERs are described in Chapter 3, Section 3.7. The need for mitigation depends on the type of activity and the proximity of receptors to the Project activities. Mitigation measures were not incorporated in the acoustic models for the assessment of effects since the construction equipment list and schedule are preliminary.

Overall noise emissions are expected to be reduced during the construction of the outlet channels as excavation proceeds and occurs below the existing ground level. In addition, the spoil sites located along the channel are expected to act as noise barriers.

At present, potential acoustic mitigation measures are applying best practices in construction noise management and reducing or restricting equipment activities in specific areas or during specific time periods. The following best management practices would be implemented to help mitigate noise effects at receptors with moderate to high potential noise impacts:

- Residents near construction noise-generating activities where noise impacts are expected to be moderate or high (see Table 6.2-26) will be notified as required. Temporary noise abatement barriers may be used to reduce noise levels. If noise abatement barriers are ineffective, a temporary reduction in the intensity of construction activities or a change in timing of activities may be considered.
- Machinery and factory supplied noise-abatement equipment (e.g., mufflers) will be maintained in good working order.
- Machinery idling should be minimized.
- A noise complaint response procedure will be implemented to address noise complaints should they arise.

Project Residual Effects

During the construction phase of the Project, the potential noise effects of the Project activities are expected to occur within the PDA and extend to the LAA. Increased noise emissions may also occur along the provincial and municipal roads used for access and transport of materials, equipment and crews in the Project area during construction activities. Duration of noise emissions from construction activities will be limited to the construction phase.

The temporal boundary of the Project construction activities will exceed one year. The active construction spread was assumed to represent a 5 km long linear noise source gradually progressing along the LSMOC and PR 239 realignment PDA, and 5 km long linear noise sources starting at both ends of LMOC and progressing along PDA until meeting at the water control structure. Following the construction phase, the sound levels within LAA are expected to decrease to pre-construction levels.

Effects on acoustic environment during the Project operation and maintenance activities are expected to be lower in magnitude, duration and extent than during the construction phase due to the reduced use of vehicles and equipment and infrequent nature of activities. Effects during the operation and maintenance phase are expected to be negligible and limited mainly to the PDAs, with some use of Project area roadways.

6.2.4.5 Change in Ambient Light

Project Pathways

The construction of the Project includes the mobilization of equipment and materials to the Project site, and the preparation of Project components, including the construction camps and staging areas, Project related transportation, as well as the construction of the Project components (i.e. the outlet channels, inlet and outlet works, water control structures, road realignment, and bridges). The majority of the site preparation and construction activities will likely occur during daytime hours; however, there is the potential for such activities to occur during the night time depending on the construction schedule and the time of year (i.e., during the fall and winter when days are shorter). During this time, it is likely that portable lighting units would be used to meet visibility and worker safety needs. There would also be light associated with the use of vehicles to support the Project related transportation.

The operation and maintenance phase of the Project refers to the open and closed conditions of the WCS gates. During the operation and maintenance phase of the Project there will be minimum interactions with the light environment as there will be minimum sources of permanent lighting. As the design of the Project has not yet been completed, the locations, type or number of permanent lighting structures are unknown at this time. If required, however, permanent lighting structures will use directed lighting (when and where required) and would likely be installed around the control structures only.

Project Mitigation Measures

Manitoba Infrastructure's Environmental Management Program and associated PERs are described in Chapter 3, Section 3.7. Mobile lighting may be required to provide a secure and safe working environment during the Project construction and there may be a need to install permanent lighting around the control structures during the Project operation. To limit potential effects from the use of the mobile lighting and/or permanent lighting structures on light trespass, glare, and sky glow, the following mitigation measures would be employed:

- Full cut-off luminaire will be used wherever possible to reduce glare, light trespass, and sky glow from the Project lighting.

- As much as is possible, lighting will be located such that unavoidable light spill off the working area is not directed toward receptors outside of the PDAs.
- Lighting will be located so that the lights are not directed toward oncoming traffic on nearby roads on or off-site because of the objectionable nuisance and safety hazard this may present.
- Lights will be designed to avoid excessive use of the mobile flood lighting units and reduce potential effects by turning off lighting when they are not required.
- There will be adherence to lighting design guidelines, such as the CIE, IDA, IES, and the lighting requirements for workspaces as enforced by Labour Canada.
- The Project will comply with applicable federal and provincial health and safety guidelines related to adequate task.

Project Residual Effects

Construction

The majority of the Project construction will occur during daytime hours and, therefore, Project-related lighting during nighttime will be limited. The use of mobile artificial lighting may occur for short periods of time during the fall and winter seasons when the working day extends into the dark or during times when nighttime construction is required to meet schedule demands. During these times, the use of mobile lighting will be required so that there is a secure and safe work environment for construction workers. The exact number of mobile lighting units that would be required and their locations are currently unknown because the design of the Project is not complete. It is likely that such equipment would be used throughout the PDA, surrounding the proposed locations of the diversion channels, channel inlets and outlets, drop structures, water control structures, bridges, road works, construction camps, and staging areas.

Levels of light trespass and glare from mobile lighting units would typically be less than CIE guidelines during the post-curfew period for a rural environmental zone (i.e. environmental zone 2, E2) (refer to Table 6.2-5 and Table 6.2-6) within a kilometer from the source of the light (Stantec 2018).

There are no communities, residential receptors or major roadways located within 5 km of the LSMOC PDA. The Dauphin River First Nation is approximately 5 km away from the LSMOC PDA and the Lake St. Martin First Nation, Little Saskatchewan First Nation, and Pinaymootang First Nation are approximately 24 km, 18 km, and 13 km from the LMOC PDA, respectively. There are three small communities (Grahamdale, Steep Rock Junction and Birch Bay), numerous residential receptors, and Provincial Trunk Highway 6 located within 5 km of the LMOC PDA. In addition, the communities of Grahamdale, Hillbre, Faulkner, Moosehorn, and Gypsumville are located approximately 4 km, 4 km, 7.5 km, 9 km, and 30 km from the LMOC PDA, respectively. In consideration of the potential levels of light trespass and glare from the operation of mobile lighting units and the proposed mitigation, it is unlikely that sky glow levels would increase to such a level that would be representative of an urban environment.

In consideration that the majority of the Project construction will occur during daytime hours, and that if night time construction were to occur and mobile lighting units required, it would be limited and the use of the lighting units would be mitigated through implementing the proposed mitigation measures which will be included in the lighting design for the Project.

Operation and Maintenance

During the Project operation and maintenance, nighttime safety lighting will be limited to water control structures. The final lighting design has not yet been completed. Light trespass and glare from the permanent structures will be reduced where possible using full cut-off luminaires to focus light on the work area. With this approach, light trespass and glare are anticipated to maintain an E2 lighting zone (i.e., a rural environmental lighting zone) within the LAA (refer to Table 6.2-5 and Table 6.2-6). Full cut-off lighting is also expected to reduce sky glow contributions to light reflected off nearby surfaces, which will be minimal.

6.2.4.6 Summary of Project Residual Effects

Table 6.2-28 summarizes the residual environmental effects on atmospheric environment during construction and operations and maintenance.

The direction for change in air quality, ambient light, greenhouse gases and acoustic environment during construction is rated adverse because the Project results in a predicted increase in CAC and greenhouse gas emissions, light trespass and glare, as well as elevated daytime noise levels compared to existing conditions. The magnitude for change in air quality during construction is rated negligible to moderate because the Project results in emissions that represent between 5% and 51% of existing emissions in the RAA for different substances. The magnitude for change in ambient light during construction is rated low because the Project results in light trespass and glare that is detectable but is limited through design mitigation. The magnitude for change in greenhouse gases during construction is rated negligible because the Project results in a relatively small change in GHG emissions compared to provincial and national totals. The magnitude for change in noise levels during construction is rated moderate because at only six of the identified receptor locations the noise levels are expected to be in excess of 57 dBA Leq (a threshold equivalent to an increase in %HA by 6.5% from the existing sound level of 35 dBA, Ldn).

The geographic extent for change in air quality, and ambient light during construction is limited to the LAA because the areas where the Project results in estimated criteria air contaminant emissions, light trespass and glare greater than existing conditions is limited to the LAA. The geographic extent for change in noise levels is limited to the LAA because the noise levels at greater distances will be negligible due to natural atmospheric attenuation as well as shielding due to the Project dikes and excavation.

The duration for change in air quality, ambient light, greenhouse gases and noise levels during construction is short-term because the estimated increase in criteria air contaminant emissions, light trespass and glare, greenhouse gas emissions and noise levels due to the Project is restricted to the duration of the construction phase (approximately five years).

Table 6.2-28 Summary of Project Residual Effects on Atmospheric Environment

Residual Effect	Residual Effects Characterization								
	Project Phase	Direction	Duration	Magnitude	Timing	Geographic Extent	Frequency	Reversibility	Ecological Context
Change in Air Quality	C	A	ST	N/M	NS	LAA	RC	R	D
Greenhouse Gases	C	A	ST	N	NS	-	RC	I	D
Change in Acoustic Environment	C	A	ST	M	HS	LAA	SI	R	D
Change in Ambient Light	C	A	ST	L	NS	LAA	SI	R	D

KEY
See Table 6.2-9 for detailed definitions

Project Phase
C: Construction
O: Operation

Direction:
P: Positive
A: Adverse
N: Neutral

Duration:
ST: Short-term
MT: Medium-term
LT: Long-term

Magnitude:
N: Negligible
L: Low
M: Moderate
H: High

Timing
NS: No sensitivity
MS: Moderate sensitivity
HS: High sensitivity

Geographic Extent:
PDA: Project development area
LAA: local assessment area
RAA: regional assessment area

N/A: Not applicable

Frequency:
IF: Infrequent
SI: Sporadic/Intermittent
RC: Regular/Continuous

Reversibility:
R: Reversible
I: Irreversible

Ecological Context:
U: Undisturbed
D: Disturbed

The frequency for change in CAC concentrations and greenhouse gases during construction is rated continuous because GHG emissions will occur continuously during the construction phase. The frequency for change in ambient light during construction is rated regular event because the predicted increase in light trespass and glare occurs regularly at nighttime. The frequency for change in noise levels during construction is rated irregular because the noise emission sources (e.g., internal combustion engines, back-up alarms, drilling and pile driving equipment) will be operated intermittently and at partial loads during the construction phase.

The reversibility for change in air quality, ambient light and noise levels during construction is rated reversible because the estimated criteria air contaminant emissions, light trespass and glare, and noise levels due to the Project would return to existing conditions after the end of the construction phase. Greenhouse gases are rated irreversible because they will remain in the atmosphere after the Project construction is complete.

The LAA, where the changes in air quality, ambient light, and noise emissions are assessed, is rated as disturbed for the LMOC because there are existing emission sources within the LAA prior to the Project construction and as undisturbed surrounding LSMOC because there are fewer existing emission sources. The LAA is rated as undisturbed for light because the light conditions are typical of a rural area.

6.2.5 Potential Atmospheric Environment Effects on Federal Lands

There are no federal lands located within the LAA. The Project is not expected to affect the atmospheric environment on Dauphin River, Lake St. Martin, Little Saskatchewan First Nation, or Pinyamootang First Nation Reserves, which are located in the RAA. Follow-up and monitoring for the atmospheric environment are provided in Section 6.2.7; no additional follow-up and monitoring programs beyond those identified are required specifically for federal lands.

6.2.6 Prediction Confidence

6.2.6.1 Ambient Air Quality and Greenhouse Gases

The Project vehicle exhaust emissions due to construction activities are estimated from the Springbank Project Assessment (Stantec 2018) using the preliminary construction equipment estimate in Chapter 3. The vehicle exhaust emissions were estimated based on local traffic data and accepted industry emission factors. The level of confidence associated with the estimation of CAC emissions (e.g., NO_X, SO_2, CO) and GHG emissions from these sources is greater than that for the estimation of TSP, $PM_{2.5}$, and VOC emission rates, as discussed further below. However, the number of pieces of equipment operating during the Project construction phase represent the relative upper limits of the pieces of equipment that would be operating/working on any one day based on a very preliminary sequencing plan. The estimated vehicle exhaust emissions for the Project construction is conservative and subject to change if construction sequencing or equipment composition changes.

The Project fugitive TSP (and associated $PM_{2.5}$) emissions due to construction activities are estimated from the Springbank Project (Stantec 2018) using the estimated total volume of earth excavation in Chapter 3. Fugitive TSP (and associated $PM_{2.5}$) emission rates depend on the properties of the surface material, the occurrence and history of surface disturbances, and meteorological conditions. While the Springbank Project used emission algorithms developed by the US EPA, there is uncertainty associated with estimating these emissions. In response to the difficulty in estimating fugitive road dust emissions, the New York State Department of Environmental Conservation rates fugitive dust estimates using the US EPA approach as “indeterminate” (NYSDOEC 2013). They find that the approach has many shortcomings and the estimates do not correlate with ambient monitoring. Nonetheless, fugitive dust emissions using US EPA approach were estimated for the Springbank Project and used in the assessment to obtain a first order understanding of potential magnitude in the LAA due to construction. For this Project, there is more uncertainty related to fugitive emissions estimation as the provided volume of earth excavation is subject to change pending detailed design.

Regional CAC emissions are estimated from provincial data published by Canada's Air Pollutant Emission Inventory (APEI). As stated by Government of Canada (ECCC 2019c), "The Air Pollutant Emission Inventory is compiled from many different data sources. Emissions data reported by individual facilities to Environment and Climate Change Canada's National Pollutant Release Inventory are supplemented with well documented, science-based estimation tools to quantify total emissions. Together these data sources provide a comprehensive overview of pollutant emissions across Canada."

Although the level of confidence of the APEI is relatively high, the regional emissions were scaled from the provincial aggregate data in the RAA based on different spatial and statistical data surrogates as listed in Section 6.2.4.1 (i.e., population, number of farms, lengths of paved and unpaved roads, etc.). Due to the simplified approach for scaling the provincial emissions to the LAA the level of confidence for the estimated regional emissions is lower than the APEI data.

The prediction confidence for GHG emissions is rated as high because the construction emissions are estimated from the Springbank Project (Stantec 2018) using the estimated number of pieces of construction equipment, published GHG emission factors and manufacturer specifications. The confidence in the effectiveness of the GHG mitigation measures is also high because most the measures are known to effectively reduce the source of GHG emissions (e.g., lower fuel consumption is directly proportional to lower GHG emissions).

6.2.6.2 Acoustic Environment

The assessment of the Project effects was conducted based on industry standards for modelling the propagation of noise. Input data used in the model are based on experience with similar construction projects, information provided from vendors or conservative estimates considering equipment horsepower ratings or capacity and commonly accepted engineering methods, as well as past measurements of similar equipment. Based on the conservative assumptions applied to the acoustic modelling, source sound power data and propagation algorithms used in predictions of residual effects, and the effectiveness of the proposed mitigation measures, the prediction confidence is high.

6.2.6.3 Lighting

The assessment of the Project effects is based on industry design standards for lighting and internationally adopted guidelines for illuminance. Input data used in the assessment are based on experience with similar construction projects, satellite imagery, and available design standards for lighting. Based on the design mitigation for Project and construction lighting, the prediction confidence is high.

6.2.7 Follow-Up and Monitoring

Follow-up and monitoring are not proposed for air quality; however, in terms of acoustic environment, monitoring may be required in the event of residential complaints related to construction noise. As such, any acoustic monitoring program will be designed on an as-needed basis if and when response to complaints is required.

6.2.8 Conclusions for Atmospheric Environment

6.2.8.1 Change in Ambient Air Quality

Changes in air quality are expected to be consistent with those of a typical channel construction project. The findings are summarized below:

- The primary emission sources of the Project are from construction equipment vehicle exhausts, and fugitive dust emissions result from surface disturbance activities.
- The primary effect on air quality is related to dust concentrations (TSP, PM10, PM2.5). This reinforces the fact that dust control should be the primary focus of Project air quality mitigation, and that adaptive management through the EMP is a key component to monitoring effectiveness of mitigation to minimize dust emissions and effects.
- The CAC ambient air quality concentrations due to the Project emissions are the greatest near the PDA and decrease substantially with increasing distance from the PDA.
- The CAC concentrations at the nearest occupied receptors will be lower than those that occur in or near the PDA and exceedances of ambient air quality criteria, attributable to the Project, are unlikely at these receptors.

6.2.8.2 Greenhouse Gases

Approximately 417,397 t CO2e are estimated to be released over the construction period and the peak annual Project emission during the construction period is 127,774.7 t CO2e (year 3). About 78% of the construction GHG emissions are estimated to be to be released between construction years 2 to 4. LMOC and LSMOC construction emissions contribute 58% and 42% of overall project construction emissions, respectively.

Project GHG emissions are less than 0.02% and 0.6% of 2017 national and provincial annual GHG emissions, respectively. Therefore, the Project GHG emissions have negligible contribution to the national and provincial GHG emissions.

6.2.8.3 Change in Acoustic Environment

During the construction phase of the Project, the potential noise effects of the Project activities are expected to occur within the PDA and extend to the LAA. Increased noise emissions may also occur along the provincial and municipal roads used for access and transport of materials, equipment and

crews in the Project area during construction activities. Duration of noise emissions from construction activities will be limited to the construction phase. Following the construction phase, the sound levels within LAA are expected to decrease to pre-construction levels.

6.2.8.4 Change in Ambient Light

The majority of the Project construction will occur during daytime hours and, therefore, Project-related lighting during nighttime will be limited. The use of mobile artificial lighting may occur for short periods of time during the fall and winter seasons when the working day extends into the dark or during times when nighttime construction is required to meet schedule demands. During these times, the use of mobile lighting will be required to so that there is a secure and safe work environment for construction workers and the public. During the Project operation and maintenance, some nighttime safety lighting may be required for water control structures. The final lighting design has not yet been completed. Light trespass and glare from the permanent structures will be reduced where possible using full cut-off luminaires to focus light on the work area.

6.3 GEOLOGY AND SOILS

6.3.1 Scope of the Assessment

This assessment of effects on geology and soils is in accordance with the requirements described in both federal and provincial guidance documents for the Project. Concordance tables, demonstrating where EIS Guidelines are addressed, are provided at the beginning of this EIS.

The Canadian Environmental Assessment Agency (the Agency) Environmental Impact Statement (EIS) Guidelines for the Project (CEAA 2018) indicate that the EIS will present information on geology and geochemistry (Section 7.1.2) and topography and soil (Section 7.1.3). The geology and geochemistry discussion is to include the bedrock and host rock geology of the deposit, geomorphology, topography and geotechnical characteristics, geochemical characterizations, geological hazards and history of seismic activity, isostatic rebound, stability and slope erosion, existing concentrations of contaminants of concern, and sites that may be of palaeontological and palaeobotanical interest. The topography and soils discussion is to include a description of landforms and soils, soil type distribution and properties, potential for soil instability and wind and water erosion potential of soils, and suitability of topsoil and overburden for use in the rehabilitation of disturbed areas.

The Environmental Assessment Scoping Document for the Project (Manitoba Infrastructure 2018) submitted to Manitoba Sustainable Development indicates that the EIS will describe geology and geochemistry (Section 3.1.2) including surficial materials, geological deposits or resources that may be used for or otherwise potentially affected by the proposed Project. It also indicates that the EIS will include discussion on topography and soils (Section 3.1.2), including soils and landform features within the Project region.

Chapter 4 (Section 4.4.1) describes VCs as features that may be affected by the Project as related to the role of the VC in the ecosystem and the value people place on it. Geology and soils is a VC because geology determines groundwater resources (Chapter 6.4), which supply potable water to most residents in the area, including Indigenous communities, supports wetlands (Chapter 8.1), which are numerous along the outlet channels PDA. Soils provides the foundation for natural vegetation (Chapter 8.1), and the associated creation of wildlife habitat (Chapter 8.2). Additionally, agricultural land use (Chapter 9.1) is dependent on soils and terrain.

6.3.1.1 Regulatory and Policy Setting

A list of the various federal and provincial regulatory requirements that were considered in the assessment of geology can be found in the Introduction (Chapter 1, Section 1.5). There are limited additional federal or provincial acts or regulations that are pertinent to the assessment of the geology and soils VC. Manitoba has legislation such as:

- The *Mines and Minerals Act*, which identifies and outlines requirements for sustainable development of mineral product exploration and production, including quarrying, in Manitoba. This Act includes requirements for protecting the environment against adverse effects from operations, filing a closure plan prior to commencement of work and rehabilitation of sites, namely leaving the site in a state that is compatible with appropriate and adjoining land use.
- The *Dangerous Goods Handling and Transportation Act*, which outlines reporting requirements in the case of an accidental spill. This is relevant to soils due to the potential for spills, particularly during construction of the Project.
- The Contaminated Sites Remediation Act and associated Contaminated Sites Remediation Regulation which provide for the protection of soils from contamination. The *Act* is pertinent to soils, including site investigation requirements and remediation of contaminated sites.
- The *Forest Act* which provides for the management and conservation of Crown forest land, including preservation, renewal and improvement. While there are no specifics regarding soils, it is of general relevance.

At the federal level, Canadian Council of Ministers of the Environment (CCME) provides thresholds for maintaining soil quality contained within the Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health (CCME 2007).

The Biomass Management Guidebook (MB Conservation and Water Stewardship 2015) provides guidance on maintaining soil fertility and site productivity. The Soil Management Guide (Manitoba Agriculture, Food and Rural Development 2008) deals with aspects of protecting soil resources and using soils in a sustainable manner and addresses drainage management, erosion, compaction, salinity, soil moisture management, nutrient management and other soil conservation practices.

6.3.1.2 Engagement and Key Concerns

Public Engagement Program

Manitoba Infrastructure conducted four rounds of public engagement as part of the engagement program. Detailed information on the engagement program is provided in Chapter 5 (Indigenous and Public Engagement Program). Issues and concerns were raised in relation to other VCs, such as agriculture and vegetation, for which soil can be a pathway to effects. This included concerns about alterations to drainage patterns, including flooding land and drying up surface water bodies, and affecting vegetation and agricultural production. One landowner also noted potential drainage improvements to agricultural land as a result of the Project. The effects of the Project on soil capability as a result of changes in drainage are assessed in section 6.3.4.2, while the effects on soil capability and agricultural land use are assessed in Section 8.2 (vegetation) and Section 9.2 (land and resource use [agriculture]), respectively.

A landowner indicated concern about a manure stockpile located within the LMOC right of way. Manure stockpiles and feedlot areas within areas of construction are a concern related to potential for nutrient runoff. While the effects of the Project on agricultural land use are addressed in Section 9.2, the handling of soils, including potentially nutrient-impacted soils in areas disturbed by the Project is addressed in the soil assessment. The issue of potential manure stockpiles is also addressed as part of soil handling recommendations in section 6.3.4.3.

Indigenous Engagement Program

Manitoba Infrastructure has undertaken engagement prior to and throughout preparation of the EIS, and will continue to consult with Indigenous groups, government agencies, and stakeholders throughout the life of the Project. A discussion of the engagement process is provided in Chapter 5: Indigenous and Public Engagement.

Engagement feedback from Indigenous groups has been an important consideration in identifying issues of concern, framing the scope of the effects assessment, and in identification of specific mitigation measures, where provided.

Geology

There were no specific concerns raised that relate to geology.

Soils

Engagement feedback where it relates to soil was provided by multiple Indigenous groups. Concerns expressed were related to erosion and runoff from farmland. Concerns were raised by numerous Indigenous communities related to the potential to increase sediment and debris in surface water; however, these are not applicable to the soils assessment. The concerns are discussed in Changes in Regional and/or Local Fluvial Geomorphology and Shoreline Geomorphology (Section 6.4.7.3.)

Environmental contamination resulting from Project construction activities was raised as a concern by Interlake Reserves Trible Council. Known impacted sites are addressed in this assessment in Section 6.3.4.3. Potential contamination from spills from Project construction activities is addressed under Accidents and Malfunctions (Chapter 14).

Traditional Knowledge (TK) information related to erosion has been collected through engagement and was provided by Indigenous groups through a Project specific TK study[1]. Erosion may potentially occur during Project activities that result in soil disturbance, resulting in loss of soil from disturbed areas and soil loading into waterways. Soil erosion is addressed in Section 6.3.4.3.

Regulatory Engagement Program

Manitoba Infrastructure engaged various provincial departments through Project meetings, information sessions, and specific group discussions (e.g., Water) in 2018. Specific questionnaires were developed and facilitated between Manitoba Infrastructure and focus groups (lands, socio-economics, policy, terrestrial, and water. Comments related to soil were limited to concerns about site rehabilitation following construction and erosion and sedimentation issues (e.g., increased sedimentation in Sturgeon Bay).

6.3.1.3 Potential Effects, Pathways and Measurable Parameters

The focus of this assessment is on Project effects that have the potential to result in an environmental effect on geology and soils. Potential environmental effects, the effect pathways and measurable parameters are used to assess potential effects on geology and soils as outlined in Table 6.3-1. Environmental effects on geology can alter terrain conditions that can result in changes to water quality, soils, vegetation communities, wildlife habitat and agriculture; environmental effects on soils could result in changes to soil quantity and quality, which can in turn affect soil capability for vegetation communities and agriculture.

Table 6.3-1 Potential Effects, Effect Pathways and Measurable Parameters for Geology and Soils

Potential Effect	Effect Pathway	Measurable Parameter(s) and Units of Measurement
Change in terrain conditions	Construction and Project components can affect terrain conditions by changing slope morphology and drainage paths. This could affect soil stability, unique landform features, and soil moisture conditions, resulting in erosion and sedimentation in waterways.	• terrain stability class ratings [ha] (BC Ministry of Forests and BC Ministry of Environment 1999) • areas of drainage alteration [ha] • sensitive soil and terrain locations, features and areas [occurrences], including steep slopes

[1] Proposed Lake Manitoba and Lake St. Martin Outlet Channels Project: Interlake Reserves Tribal Council October Phase 1 Traditional Land Use and Traditional Knowledge Report 2018; Fisher River Cree Nation—Consultation Report, including Appendix D and E, 2018.

Table 6.3-1 Potential Effects, Effect Pathways and Measurable Parameters for Geology and Soils

Potential Effect	Effect Pathway	Measurable Parameter(s) and Units of Measurement
Change in soil quantity and quality	Construction and reclamation activities that alter the soil landscape can change soil capability for agriculture and reclamation suitability as a result of soil handling, admixing, compaction and rutting, and wind and water erosion. These activities could also result in a change in soil thickness or loss of soil volume. Contaminated or impacted soils disturbed by Project activities could result in exposure of contaminants and release to surface water from runoff.	• agricultural land capabiity classes [ha] (CLI 1969) • reclamation suitability classes [ha] (AAFRD 1987) • wind erosion risk rating classes [ha] (Coote and Pettapiece 1989) • water erosion risk rating classes [ha] (Wall et al. 2002) • compaction and rutting risk rating [ha] classes (Archibald et al. 1997, Cannon and Landsburg 1990) • sensitive soil and terrain locations, features and areas [occurrences], including known and suspected impacted or contaminated sites/areas, sandy materials, saline soils, shallow soils and exposed bedrock, soils highly prone to erosion

6.3.1.4 Boundaries

The project development area (PDA), local assessment area (LAA) and regional assessment area (RAA) for the assessment of effects on geology are shown in Appendix 6B, Figure 6.3B-1 and soils in Figure 6.3B-2. These boundaries are described below. Federal lands within these boundaries consist of reserve lands associated with the Indigenous communities. Spatial assessment boundaries for geology and soils have been defined based on areas that include permanent disturbance as well as temporary disturbance during construction.

Spatial Boundaries

Project Development Area

The PDA is an area of 2,099 ha or 21.0 km^2 and is the area in which the Project components and activities and are located and where alteration of terrain features and soil disturbance are expected:

- the outlet channels (LMOC and LSMOC)
- the water control infrastructures, drop structures, and bridges
- inlets and outlets at both channels
- realignment of PR 239 and municipal roads

There are two primary PDA components, the LMOC and the LSMOC. The LMOC, which is approximately 24.1 km in length and occupies approximately 1,022 ha, is predominantly soils under agricultural land use. The LSMOC, which is approximately 23.8 km in length and occupies approximately 993 ha, consists primarily of wetland soils. This contrasting land use is an important distinction and soil conservation varies between these two land uses.

There are no Federal lands within the PDA.

Local Assessment Area

Geology that contains and transports the groundwater drives groundwater movement and quality. The groundwater LAA (see Section 6.4.1.4) is, therefore, consistent with the LAA for geology. Indirect effects of the Project on geology will be located at quarries and borrow pits within the LAA where Project construction material will be extracted. However, specific locations of rock quarries and borrow materials to be used for the Project are not yet identified; because potential sites are located within relatively short distance from the PDA while others could be at great distances, this remains a variable. Because locations of quarries and borrow pits are not definitive yet, the LAA limits are based on effects from the Project on groundwater which could potentially have effects on geology (e.g., geology chemistry).

The LAA for soils encompasses the PDA and a 1 km buffer around the PDA and around Lake St. Martin. This represents the area where direct and indirect project-specific environmental effects to intact and undisturbed soils are expected. This assessment area is also consistent with that used in the vegetation and wildlife assessments. The LAA consists of an area of 63,852 ha or 63.9 km^2.

For the purposes of the assessment of soils, three different components of the LAA are discussed. The LMOC portion of the LAA consists of the buffered area around LMOC and the PR 239 realignment. The LSMOC portion of the LAA consists of the buffered area around LSMOC. The buffered area around Lake St. Martin is referred to as the LSM shoreline portion of the LAA. Differentiating these three components of the LAA is important due to the varying land uses and soil capabilities between them, similar to that discussed for the PDA components. The LMOC portion of the LAA is mostly under agricultural land use and is an area predominantly covered in soil and rated for agricultural capability. The LMOC portion of the LAA is predominantly under natural vegetation and wetlands and is an area that is not rated for agricultural capability. The LAA contains a substantive amount of water (predominantly due to Lake St. Martin) which is not of relevance to the soils assessment. Therefore, existing conditions for soils have been characterized and quantified based on soil areas within the LAA (excluding the large area of water) and assessed accordingly. This is of relevance to the discussion of soils around the LSM shoreline portion of the LAA. The LSM shoreline portion of the LAA has contrasting areas of land use and soil capability within it, with agricultural land uses predominant along the southern and western shorelines, while the eastern and northern shorelines are occupied by natural vegetation.

Federal lands within the LAA include reserve lands associated with the Indigenous communities of Lake St. Martin First Nation, Little Saskatchewan First Nation and Pinaymootang First Nation. These are located along the eastern shoreline of Lake St. Martin within the LSM portion of the LAA.

Regional Assessment Area

Groundwater movement and quality are dependent upon the geology that contains and transports the groundwater. Aquifer recharge is dependent on watershed characteristics, geology and topography; conditions must be met to allow for aquifer recharge. Watersheds define water volume available for potential aquifer natural recharge, while geology and topography define recharge rates and potentiometric head. In lower topographic areas, the balance between potentiometric head and ground counter-pressure could be offset by a change in geology (e.g., excavation) or in potentiometric head (e.g., greater aquifer recharge). Therefore, because geology and groundwater are interdependent the RAA for geology is the same as the groundwater RAA (See Section 6.4.1.4) Indirect effects on geology will be located at quarries and borrow pits within the RAA; construction material from within the RAA could be extracted if quality and/or quantity within the more proximal sites within the LAA do not suffice.

The RAA for soils encompasses both the PDA and LAA and a 12 km buffer around the PDA and Lake St. Martin. The RAA is used to assess Project contributions to cumulative effects, including the effects of past, present and reasonably foreseeable future activities, on soil and terrain. The 12 km buffer was selected as it includes the contributing drainage basins in which changes in hydrology may occur and is large enough to characterize regional soil and terrain representation and distribution. The RAA is also with the same as that used in the vegetation and wildlife assessments. The RAA consists of an area of 339,264 ha or 339.3 km^2.

Federal lands within the geology and soils RAA consist of the reserve lands associated with the Indigenous communities of Lake St. Martin First Nation, Little Saskatchewan First Nation, Pinaymootang First Nation and Dauphin River First Nation.

Temporal Boundary

The temporal boundary for the assessment of effects on geology, soils and terrains covers the duration of the construction and operation phases of the Project. Construction is tentatively expected to occur over a period of approximately 2.5 years to 3 years with approximately one year to two years for post-construction activity, such as site clean-up, survey, and environmental offset works. Construction and post-construction is expected to start in the fall 2020 and be completed in the spring/summer 2023, with operation and maintenance starting in the fall 2023. The overall schedule is contingent largely on receipt of the final regulatory approvals in 2020.

During construction, soil and terrain will be affected primarily by physical disturbance (e.g., excavation and soil handling). The operation phase of the Project is expected to be indefinite as there are no plans to terminate operations and decommission the Project.

6.3.1.5 Residual Effects Characterization

Table 6.3-2 presents definitions for the characterization of residual environmental effects on geology and soils. The criteria describe the potential residual effects that remain after mitigation measures have been implemented.

Table 6.3-2 Characterization of Residual Effects on Geology and Soils

Characterization	Range of Criteria	Level of Effect and Definition
Direction of Change (type of effect)	Neutral	No measurable change on geology and soils.
	Negative	Net loss (adverse or undesirable change) on geology and soils.
	Positive	Net benefit (or desirable change) on geology and soils.
Duration (period of time the effect occurs)	Short-Term	The potential effect results from short-term events or activities such as the time required to complete a discrete component during construction, maintenance, or post-construction activities (i.e., a timeframe of several months up to two years).
	Medium-Term	The potential effect is likely to persist until the completion of construction and post construction activities (i.e., > 2 years to 5 years).
	Long-Term	The potential effect is likely to persist beyond the completion of construction and rehabilitation activities into the operations and maintenance phase of the Project (i.e., a timeframe of greater than 5 years).
Magnitude (degree or intensity of the change)	Negligible or Low	Negligible – no measurable change in geology and soils Low – Geology and terrain: a measurable change in geological conditions but no change in terrain stability; alterations to drainage do not affect soil capability; no change in unique landforms (i.e., no physical disturbance to unique landform) Soil quantity and/or quality: a measurable change but no change in agricultural capability class or change that limits the ability to reclaim and rehabilitate areas disturbed by the Project.
	Moderate	Geology and terrain: a change in terrain stability but direct and indirect effects are not expected beyond the PDA; a change in drainage conditions that alter agricultural capability class within the PDA; a change in but not loss of unique landforms within the PDA (i.e. physical disturbance to unique landform) Soil quantity and/or quality: a change in agricultural capability class within the PDA[1]; a change in quantity or quality of soil that limits the ability to reclaim and rehabilitate areas disturbed by the Project.
	High	Geology and terrain: a change in terrain stability that results in effects that extend beyond the PDA; a change in drainage conditions that alter agricultural capability class beyond the PDA; a loss of a unique landform due to the Project Soil quantity and/or quality: a change in agricultural capability class that extends beyond the PDA[1]; a change in quantity or quality of soil that precludes successful reclamation and rehabilitation of areas disturbed by the Project.

Table 6.3-2 Characterization of Residual Effects on Geology and Soils

Characterization	Range of Criteria	Level of Effect and Definition
Timing	No Sensitivity	Timing does not affect the interaction between the Project and geology and soils. Residual effects do not change with seasonal timing of construction (e.g., winter vs. summer conditions) or during periods of varying soil conditions within season (e.g., wetter or drier soils).
	Moderate Sensitivity	Geology: Timing does not affect geology. Soils: Timing of Project activities will affect the residual effects to soil, but the influence of timing is not expected to change effects in a substantive manner. Residual effects may change with seasonal timing of construction or during periods of varying soil conditions within season.
	High Sensitivity	Geology: Timing does not affect geology. Soils: Timing of Project activities have a substantial impact on residual effects to soils. Effects are highly sensitive to seasonal conditions (e.g., organic soil compaction in summer) or within season soil conditions.
Extent (Spatial Boundary)	Project Development Area	The physical space or directly affected area on which Project components or activities are located and/or immediately the adjacent area, including designated ROWs, and permanent and temporary facilities (e.g., borrow pits and quarries)
	LAA	Area within which potential Project effects are measurable and extending beyond the PDA to, but not beyond, the LAA.
	RAA	The regional extent of potential direct, indirect and cumulative effects that may extend beyond the LAA.
Frequency (how often the effect occurs)	Infrequent	The potential effect occurs once or seldom during the life of the Project (e.g., initial clearing and grubbing).
	Sporadic/Intermittent	The potential effect occurs only occasionally and without any predictable pattern during the life of the Project (e.g., soil disturbance during construction).
	Regular/Continuous	The potential effect occurs at regular and frequent intervals during the Project phase in which they occur or over the life of the Project (e.g., alterations to surface water flow as a result of the presence of the channels).
Reversibility (the degree of permanence)	Reversible (short-term)	Potential effect is readily reversible over a relatively short period (<five years).
	Reversible (long-term)	Potential effect is potentially reversible but over a long period (>five years).
	Irreversible	Project-specific potential effects are permanent and irreversible.
Ecological Context (resilience of a VC to adapt to changes as a result of the project)	Undisturbed	Area is relatively undisturbed or not adversely affected by human activity.
	Disturbed	Area has been substantially previously disturbed by human development or human development is still present.

NOTE:

1. A reduction or loss in agricultural capability may be offset by compensation or other means. This is addressed in Section 9.2: Land and Resource Use.

6.3.1.6 Significance Definition

Significance is not determined for geology and soils. The changes to geology and soils are used to determine changes and effects on the terrestrial environment (Chapter 8), human environment (Chapter 9), and Indigenous peoples' VCs (Chapter 10)."

6.3.2 Existing Conditions for Geology and Soils

6.3.2.1 Geology Methods

The first step in assessing the geological setting for the RAA involved the compilation of geological data available from publicly accessible sources. They provide description of the physical characteristics of rocks (lithologies including geochemistry) and structural features (e.g., fracture zones). Report and mapping products and online data available from Manitoba Sustainable Development (MSD), the Geological Survey of Canada (GSC) and other published papers were reviewed and relevant geological information for the RAA was extracted.

Additional information from previous geotechnical studies conducted for the Project and MSD database were also included in the historical information review:

- Existing conditions are described based on review of existing geotechnical studies performed by the engineering team responsible for conceptual engineering studies (KGS Group 2016b, 2017 and 2018), including literature review, geotechnical borehole logs, standard penetration tests (SPT), rock quality designation (RQD), sieve analysis and sedimentation analysis
- The GWDrill database was used to gather existing water well locations and sequential lithostratigraphy, when available

The quality of data varied depending on the section of the PDA, i.e., LMOC or LSMOC or the location in the LAA or RAA. For example, substantially more data were available to characterize geology conditions along the LMOC compared to LSMOC.

Existing documents were reviewed for different components of geology, as described below:

- Stratigraphy
  - Geoscientific compilation maps were reviewed to identify the regional geological features and general stratigraphy. Project-specific geotechnical data were reviewed to cross-check local data with regional features and identify local geological features that are meaningful in the Project perspective (e.g., permeable water-bearing horizon disturbance, local accrued concentration of mineral of concern).
  - Bedrock and Quaternary (unconsolidated) geological maps were reviewed for the purpose of the assessment of geological conditions.

- Geochemistry
  - Acid (ARD/ML) is generally associated with oxidation of sulphides exposed to the atmosphere. Available documents were reviewed for sulphide and acid consuming content to try to identify areas of interest.
- Paleontology and paleobotany
  - Discussions took place with provincial paleontologists and paleobotanists to obtain guidance in terms of locations of paleontological features, like fossiliferous beds of chronological significance (i.e., marker beds), or existence of fossils with extraordinary state of conservation.
- Mining and mineral exploration
  - Mineral resources and industrial mining maps were reviewed for identification of products and locations. A review of the Province of Manitoba registry of existing claims and mining permits was conducted.
- Geological hazard
  - There are many geological hazards, but only those relevant to the RAA were reviewed.
  - GSC earthquake database was reviewed to identify recorded seismic events within Manitoba.
- Subsidence
  - GSC memoirs and Quaternary specific studies by research and academic institutes were reviewed.
- Slope stability
  - topographical maps were reviewed for steep terrain conditions.

Above-listed data were cross-checked with Project-specific geotechnical studies.

6.3.2.2 Geology Overview

The geology presented will be of both the bedrock geology and surficial material.

Stratigraphy

Regional and Local Bedrock Geology

The Project is located at the north-east border of the Western Canada Sedimentary Basin, which is a massive wedge of sedimentary rock composed of limestone, dolomite, sandstone and shale. Appendix 6B, Figure 6.3B-3 is a geologic map of the assessment area.

The regional and local bedrock geology is composed of layers of Devonian, Silurian and Ordovician (Appendix 6C.1: Geological Age) carbonates and sandstone formed during the Paleozoic era that overlay or onlap with Precambrian granites or gneisses (KGS Group 2017a; Leybourne et al. 2007). The age and type of rock units varies from east to west, with the older Ordovician rock units found between the east

shore of Lake St. Martin and Lake Winnipeg, followed by Silurian-aged bedrock, and the younger Devonian bedrock formations located along the east shore of Lake Manitoba (KGS Group 2017a).

Appendix 6B, Figure 6.3B-3 also shows the location and geological effects of a meteor that impacted Paleozoic and Precambrian rocks in the Gypsumville area 230 million years ago (Leybourne et al. 2007, McCabe 1971, Schmieder 2014). The Lake St. Martin impact structure was described by McCabe (1971) as a crypto-explosion crater consisting of a crater or hole about 22 km in diameter and more than 350 m deep, with a central core approximately 3 to 5 km in diameter, consisting of highly shock-metamorphosed Precambrian gneiss that was uplifted by at least 213 m, and is exposed in the centre of the crater (McRitchie 2000). At the crater rim, lower Paleozoic and Precambrian rocks have been uplifted and are exposed in an outcrop near The Narrows of Lake St. Martin; beyond the crater rim is a structurally uplifted belt extending for about 22 km (McCabe 1971).

The carbonate bedrock in the area has also undergone paleokarst processes, whereby some areas of carbonate deposits were dissolved in earlier geologic times by surface water that was undersaturated in terms of carbonate (KGS Group 2017a). Over long time periods, areas within carbonate bedrock composed of limestone and dolomite can become dissolved, forming what is referred to as karst topography, which produces a variety of features such as epikarst, vertical shafts, sinkholes, springs, complex subsurface drainage systems and caves (Province of British Columbia 2001; Bilecki 2003).

KGS Group (2017a) noted that paleo-karst processes have enhanced the permeability of the uppermost 8 to 10 m of the carbonate bedrock in the region. These karstic processes no longer occur in most of the RAA, as the repeated advance and retreat of the continental ice sheets during the periods of glaciation and de-glaciation in Manitoba deposited tills and other overburden materials over the carbonate bedrock, blocking the entry of surface water and ending further dissolution of the underlying carbonate bedrock. KGS Group (2016) noted that the Silurian Interlake Group, denoted as “S” on Appendix 6B, Figure 6.3B-3 is highly permeable in the uplift zone surrounding the meteor impact structure due to the paleo-karst features and impact-related fracturing. Although the regional carbonate lithology profiles are consistent with karst development, caves have been mapped only near Gypsumville. Those caves are not flooded with groundwater according to McRitchie (2000) except for occasional spring seasons depending on snowmelt and precipitation.

The PDA will be located in the limestones, dolomites and shales from the Elm Point, Ashern, East Arm (Cedar Lake), Stonewall, and Red River Formations (Appendix 6B, Figure 6.3B-3). Other Project components will be located within similar lithologies, namely PR 239 will be located in the dolomites of the East Arm Formation, while the Manitoba Hydro Distribution Line will be located in the dolomites of the Stonewall and East Arm Formations, and the Interlake Group. Quarries are not part of the Project but may be developed and permitted separately to support the Project. Quarries will be located within limestones of the Winnipegosis Formation and dolomites of the Elm Point, Ashern, East Arm and Stony Mountain Formations. Table 6.3-3 provides a summary of the bedrock geology associated with each of the Project components.

Table 6.3-3 Summary of Bedrock Geology in Project Component Locations

Project Component	Bedrock Geology Symbols	Bedrock Geology in Area
LMOC, inlet and outlet, water control structure, bridges and culverts	Dep, Da, Sea	Elm Point, Ashern, East Arm Formations
LSMOC, inlet and outlet, water control structure, drop structures, bridges and culverts	Sea, Os, Orrfg	East Arm, Stonewall, Red River Formations
PR 239 realignment	Sea	East Arm Formation

Along the LMOC channel, the bedrock is expected to remain untouched by the Project, although further investigation on bedrock elevation are occurring as part of engineering studies. Along the LSMOC channel, the bedrock might be exposed at the most downstream drop structure location (KGS – P. Leclercq, personal communication 2019).

Regional and Local Surficial Geology

The carbonate bedrock in the region had effectively reached its present-day condition by the beginning of the Pleistocene Epoch (approximately 2 million years ago). A succession of glaciations occurred, associated with the deposition of till and stratified drift, separated by nonglacial stratified alluvial, lacustrine, interglacial deposits, during the Pleistocene. The deposition of the youngest tills (i.e., Inwood and Komarno tills), and associated stratified drift, created the fluted till blanket morphology typical of the region today, marking the last glacial advance in the area. Final deglaciation of the region was accompanied by inundation by Glacial Lake Agassiz. The Komarno till is interpreted to have been at least partially deposited within, or along the margins of Lake Agassiz. Wave erosion of pre-existing glacial deposits occurred, with deposition of a discontinuous blanket of lake bottom clay, silt, and sand, though within the Interlake these deposits are poorly preserved. The upper till sheet was disturbed and ploughed by icebergs within Lake Agassiz, producing the turbate deposits that are noted on the till sheet in the region. The last drainage of Lake Agassiz is represented by discontinuous relict beach ridge/shoreline deposits, which today form limited granular borrow sources in the region.

Isostatic rebound is the uplift of the earth's crust in response to glacial retreat on the landscape. In Manitoba, isostatic rebound shows a general trend of rates that diminish inland from Hudson Bay in all directions, in keeping with the pattern of glacial retreat from south to north in the province (Thorleifson 2015). Isostatic rebound affects shoreline elevations, water levels and flows in low lying relief conditions. The Lake Winnipeg basin has been rising more rapidly at the north end of the basin than the south end of the basin. Estimates suggest uplift rates of approximately 1 m/century at Lake Winnipeg (the north end lifting faster than the south end of the Lake), indicating that the mean water level in the south basin has been rising approximately 20 cm/century over the last three hundred years (Manitoba Conservation 2001).

The regional and local surficial geology in the area was described by Smith et al. (1998) as very calcareous, stony (cobble or gravel), water-worked till that is deep to shallow (20 m to 30 m) over carbonate bedrock. The carbonate bedrock in the area is overlain by layers of till, intertills, post-glacial sediments and peat or organic deposits of varying thicknesses, with most areas having less than 10 m of overburden materials over bedrock (KGS Group 2017a). Localized areas near Watchorn Bay and the Fairford River were found to have overburden layers of greater than 20 m in thickness, with other areas having thin sediment layers over bedrock, such as near the communities of Fairford and Grahamdale, and the shores of Lake Manitoba (KGS Group 2017a). There are several bedrock outcrop areas along the east shores of Lake Manitoba and in the Steep Rock area; at localized sites east of Birch Creek; along the west and southwest shores of Lake St. Martin; west of Dauphin River; and south of the Dauphin River outlet (KGS Group 2017a). Appendix 6B, Figure 6.3B-4 provides an overview of the regional and local surficial geology. A number of areas with bedrock close to the surface (i.e., less than 2.5 m) are present near the communities of Fairford, Steep Rock, Grahamdale and Moosehorn, with several quarries and gravel pits located in these areas.

The PDA will be located in areas mainly within till, as well as some areas of organic deposits, glaciolacustrine sediments, rock, and near-surface bedrock (Appendix 6B, Figure 6.3B-4). Other Project components will be located within similar lithologies, namely PR 239 will be located in areas within organic deposits and till, while the Manitoba Hydro Distribution Line will be located in areas within sediments of glaciolacustrine origin and till. Borrow Pits will be aiming at sands from beaches of glaciolacustrine origins.

Table 6.3-4 provides a summary of the surficial geology associated with each of the Project components. Additional surficial geology summaries for the LMOC and LSMOC are found below, based on a review of Project geotechnical investigations.

Table 6.3-4 Summary of Surficial Geology in Project Component Locations

Project Component	Surficial Geology in PDA
LMOC, inlet and outlet, water control structure, bridges and culverts	• Offshore Glaciolacustrine Sediments • Till – Calcareous Silt Diamicton
LSMOC, inlet and outlet, water control structure, drop structures, bridges and culverts	• Offshore Glaciolacustrine Sediments • Till – Calcareous Silt Diamicton
PR 239 realignment	• Organic Deposits • Till – Calcareous Silt Diamicton

Surficial Geology – LMOC

The geotechnical investigations for the LMOC found that the stratigraphy generally consisted of a layer of topsoil overlying till and bedrock (KGS Group 2017a). A thin layer of topsoil was encountered at the surface of each borehole and extended to approximate depths of 0.3 m to 1.2 m; this is described with more detail in Section 6.3.2.4. Lenses of sand or silty sand (Appendix 6C.2 – Unconsolidated Sediments Classification) with a thickness of up to 4 m were encountered in boreholes inland from Lake Manitoba.

The till extended to limestone bedrock at an approximate depth of 21 m in the borehole located about 2.6 km inland from Lake Manitoba and extended to the end of the borehole at an approximate depth of 22 m; all other boreholes investigated along the LMOC alignment were terminated prior to reaching bedrock (KGS Group 2017a). Because of the proximity of the PR 239 and municipal road realignment to the LMOC, the available data mentioned above are likely to apply. Appendix 6.B, Figure 6.3B-5 illustrates the stratigraphic distribution of those formations along the LMOC section of the PDA.

Surficial Geology – LSMOC

Based on the results of peat probes and hand auger investigations, the stratigraphy in the region of the proposed LSMOC typically consists of a surficial peat layer ranging between 1 m to 3 m thick overlying till (KGS Group 2017b). Thicknesses of the till overburden and depth to bedrock will be defined during the current detailed design phase of the Project but were assumed to be located below the proposed channel invert along the proposed LSMOC alignment based on the limited investigations previously conducted in the area (KGS Group 2017b). The stratigraphy in the LAA of the proposed LSMOC was described as having typically 1 m to 2 m of saturated peat; 0.5 m to 2.5 m of gray silty clay in some places; 0.3 m to 1.0 m of typical buff colored carbonate silty till; and 0.9 m to 2.0 m of hard basal till (KGS Group 2017b). No specific data are available for the Lake St. Martin access road and the Manitoba Hydro distribution line, but because of their proximity the above information are likely to apply.

Geochemistry

Acid rock drainage and metal leaching (ARD/ML) is generally associated with oxidation of sulphides exposed to the atmosphere. Sulphide oxidation produces sulfuric acid and results in ARD if the acid is not neutralized by carbonates and other acid consuming minerals (e.g., pyroxenes) present in the rock. Metals leached from sulphides partially precipitate during neutralization, but some portion will migrate to the environment.

A desktop assessment for ARD/ML risks was carried out based on the geological descriptions and maps developed by KGS (2017). Dolomite and dolomitic limestone comprise the lower Paleozoic bedrock underlying the RAA (Appendix 6B, Figure 6.3B-3). The proposed Project components are located in carbonate rich sedimentary rock. Sulphides occurrences are rare, localized and described as follows, based on Norris et al. (1982) and KGS (2017):

- 0.3 m to 0.6 m thick greenish shale consisting of clay-like material and iron sulphide located between Ashern and Elm Point Formations
- drusy iron sulphide in light to medium brown calcareous dolomite containing the Winnipegosis Formation near contact with the Elm Point Formation
- iron sulphide as disseminated specks and fine nodules are common in some beds of the Ashern Formation

A few exploration programs show low potential for metals deposits (e.g., lead-zinc Mississippi valley type) in the rocks exposed by the Project components (Norris et al. 1982).

Palaeontology and Palaeobotany

Generally speaking, Paleozoic rocks are beneath the PDA. All the major phyla of the animal kingdom, such as Porifera, Coelenterata, Mollusca, Annelida, Arthropoda, Echinodermata and Chordata, are represented in the Paleozoic rocks in Manitoba (Corkery 1996). Fossils of concern, if any, would be located strictly within the PDA and/or potential quarries; the following summary focuses only on formations that show fossil content within the PDA.

It is observed that the more dolomitized the carbonate rocks, the more altered and less recognizable is the fossil content. Megafossils are sporadic throughout the Elm Point Formation but are generally not abundant except for local concentrations in some beds. It is a fauna of low diversity. The very few colonial corals and bulbous stromatoporoids present seem to be confined to the upper part of the formation where widely separated colonies up to 0.6 m in diameter have been seen. The Elm Point Formation features brachiopods locally abundant in the lower beds of the Elm Point Formation but also sporadic in higher beds of the formation, but those are distributed widely in central and northwestern Canada and in Michigan. Relatively abundant brachiopods can be observed at the Spear Hill quarry and the Steep Rock quarry where the base of the Elm Point Formation is exposed. The Steep Rock quarry features index brachiopods, which are useful for dating and correlating strata, and some good Devonian fish specimen.

The Ashern Formation consist of dusky red to greyish orange, very finely granular to aphanitic, variably argillaceous dolomite; the formation appears to be unfossiliferous (Norris and McCabe 1982).

Along the LMOC section, the East Arm Formation contains variable fossiliferous content in the form of stromatolitic and stromatoporoidal beds. As the overlying Cedar Lake Formation is deposited in a quieter hydrodynamic environment, crinoids are observed (Lapenskie et al. 2018), but there in uncertainty in whether this Formation is present along the proposed channel, although the Cedar Lake Formation could be difficult to distinguish from the older East Arm Formation. However, the bedrock will not be exposed according to current engineering construction plans.

Along the LSMOC section, the Stonewall Formation is sparsely fossiliferous (Bezys 2002), biostromal (Lapenskie 2018) in places, but the upper part of the Formation would be devoid of fossils. The current status of the bedrock topographical profile suggests that the lithology could be exposed near the outlet.

The Selkirk Member of the Red River Formation is well known for its burrow-mottled biomicritic dolomitic limestones (i.e., "Tyndall Stone") and are fairly typical of the more basinal facies of this unit. The Lake St. Martin area shows development of distinctly primary lithofacies variations, such as where bedded micritic and calcarenitic limestones occur, with no evidence of burrow-mottling or dolomitization (Bezys 2002).

The Lower Red River formation is grey-buff lime mudstone (Appendix 6C.4 – Carbonate Rock Classification) to lime wackestone and is interbedded with dolomudstone to dolowackestone. It shows mottled and burrowed features and is fossiliferous (Lapenskie 2018).

The Gunton Member of the Stoney Mountain Formation is a dolomudstone that rarely exhibits fossils (Lapenskie 2018). A partial list of fossils from the Stony Mountain Formation (Ordovician) includes several kinds of coral, snails, brachiopods, crinoids, sponges, trilobites, nautiloid cephalopods, and even some of the earliest armoured fishes (Corkery 1996). This member of the Stoney Mountain Formation is present only in the southwest corner of the Sturgeon Bay Provincial Park, which intercepts the RAA, but is not within the PDA.

Based on discussions with Dr. Robert Elias (personal communication 2019), whose research expertise covers paleontology and geology of the Ordovician-Silurian strata in Manitoba, there is nothing of paleobotanical interest within the RAA.

Mining and Mineral Exploration

Mining and mineral exploration activities in the RAA identified the large deposits of limestone, dolomite and gypsum, which led to the development of several rock quarries, rock processing plants and gravel pit operations in the area.

Geological Hazards

Seismic activity

Seismic activity in Manitoba is very low, with no earthquakes with a magnitude greater than 2.5 (Richter scale – Appendix 6C.3) reported between the years 1600 to 2008 (Cassidy et al. 2010). The area of fewest earthquakes in Canada is located within the tectonic features of the stable craton, which includes the plains of Saskatchewan and Manitoba (Cassidy et al. 2010).

The Earthquakes Canada database was searched to identify the recent and historical occurrences of earthquakes in Manitoba (Natural Resources Canada 2018b). Table 6.3-5 provides a summary of the earthquake data for Manitoba from 1985 to 2018.

Table 6.3-5 Summary of Earthquakes in Manitoba from 1985 to 2018

Date	Location	Magnitude
May 3, 2012	230 km SW from Churchill	1.7
January 27, 2012	145 km N from Pinawa	1.9
May 17, 2011	145 km N from Pinawa	2.1
April 27, 2011	70 km E from Pinawa	1.5
January 10, 2011	145 km N from Pinawa	2.0
January 4, 2011	70 km E from Pinawa	1.5
February 17, 2010	145 km N from Pinawa	1.9
February 20, 2005	60 km SE from Pinawa	1.3
October 10, 2004	55 km SE from Pinawa	1.1
May 30, 1993	301 km SE of Flin Flon	2.5

A total of 10 earthquake incidents of magnitude 2.5 or less were recorded within Manitoba from 1985 to 2018. These earthquakes occurred in the Precambrian Shield area of Manitoba, about 200 km to 700 km northeast of the Project. No effects from seismic activity are foreseen within the RAA, except for localized vibrations created by machinery during construction. Additional information can be found in Chapter 15, Section 15.6.

Subsidence

Natural subsidence can occur as sinkholes in areas of karst, such as the sinkholes identified in areas of higher elevation between Lake St. Martin and the Forestry Road (Forster 2017). As previously mentioned, the processes causing the dissolution of carbonate rock and formation of karstic features such as sinkholes and caves in the region no longer occur (KGS Group 2017a). Karst is located in the Gyspsumville area. However, the East Arm Formation (LMOC section) is characterized by vuggy porosity.

Human-induced activities such as underground mining, construction activities and groundwater withdrawals can create underground voids that result in ground collapses and land subsidence (Colorado Geological Survey 2018). However, as previously mentioned, mining in the area is limited to the excavation of limestone, dolomite and gypsum, and there are no underground mines, or other underground developments or construction activities in the area. Subsidence caused by human activity is unlikely to occur.

Slope stability

Geological hazards such as landslides, avalanches and slope failures have not occurred in the area due to the low relief of the topography, low seismic activity and the regional and local geology of till over bedrock. No slopes or topographical features are present along the PDA, except for the engineered slopes that will result from construction of the channels; no slope erosion and potential for ground and rock instability are likely to occur.

6.3.2.3 Soils and Terrain Methods

The existing conditions for soils and terrain comes from a synthesis of data from a variety of literature sources and provincial and federal databases. Analysis and interpretation of existing, available data were required to support the assessment. A summary of methods used in developing existing conditions for soil and terrain are provided in this section.

Terrain Conditions

Terrain information was compiled using existing information on the ecological stratification of Manitoba's landscapes (Smith et al. 1998) and existing soil resource information (CanSIS 2019). This included a review of surficial materials (parent materials and mode of deposition), slope classes and internal drainage. Additionally, surface elevation LiDAR data collected for the LMOC and LSMOC portions of the PDA was reviewed to confirm slopes and surface landform characteristics for these components.

Terrain map units were developed to provide a visual representation of the range in terrain conditions and aid in interpretation and evaluation. Terrain map units were identified as follows:

Dominant Surface Material / Dominant Subsurface Material – Slope Class (Drainage)

For example, a common terrain map unit in the PDA for the LSMOC is as follows:

ORG / LACU – 1-3 (VP)

Where:

ORG = dominant surface material is organic

LACU = dominant subsurface material is lacustrine

1-3 = slope classes are class 1 to class 3

(VP) = drainage is very poor

Changes to terrain conditions can, in turn, result in changes in geomorphological and hydrological processes. For example, mass movement processes, either slow (e.g., soil creep) or fast (e.g., slope failures and landslides), can be influenced or initiated resulting in terrain stability issues. The potential for terrain to experience mass movement is determined by a series of factors including the nature and texture of the surficial material, slope angle, active geomorphological processes and local soil drainage conditions. Human activity such as the construction of linear infrastructure such as roads, transmission lines and channels, can trigger a mass movement where potential exists. Changes to surface and subsurface drainage paths will alter hydrological processes and can result changes to seepage, inundation and flooding, as well as drought conditions.

The identification of unstable or potentially unstable terrain within the LAA is based on a review of existing literature relevant to slope stability, existing soil and terrain mapping data as well as a review of available imagery and LiDAR elevation data. Changes to hydrological processes and conditions as a result of the Project was informed by the groundwater and surface water assessment (Section 6.3). Unique landform features are addressed under Sensitive Sites, below.

Sensitive Sites

Soil and terrain data were reviewed for potentially sensitive sites. These are locations, features or areas, that are identified to be environmentally or socially important or sensitive to disturbance and require special consideration for protection and mitigation during construction and operation. This evaluation was limited to the PDA and LAA as these are the areas subject to direct and indirect effects from Project activities. Sensitive sites considered for identification and evaluation included:

- Unique landform features can be of social importance (e.g., aesthetic and spiritual importance) and ecological importance (rare and endangered ecosystems and wildlife habitat).

- Steep slopes/areas prone to gravity movement or slopes on bedding planes can be prone to gravity erosion and are prone to terrain stability issues.
- Soils highly prone to wind and water erosion are at higher risk of soil losses when disturbed
- Sandy soils can support unique vegetation communities and once exposed can be sensitive to wind erosion and difficult to revegetate.
- Saline soils can support unique vegetation communities, contain mineral licks, and can be sensitive to admixing and limit revegetation success.
- Shallow soils and exposed bedrock can be sensitive to disturbance and revegetation.
- Known and potential impacted sites are areas of impacted soils are a concern, particularly where soils are being exposed or excavated. Known or suspected soil impacts or contamination, include sites from the following sources:
  - Contaminated, Impacted and Other Sites Database (Manitoba Sustainable Development 2018)
  - Federal Contaminated Sites Inventory (Treasury Board of Canada Secretariat 2019)
  - solid waste (MLI [Manitoba Land Initiative] 2019a) and wastewater management facilities (MLI 2019b)
  - airports
  - potential manure-impacted sites are areas where manure stockpiling or feedlots or concentrated feeding areas were identified visually using orthoimagery review

Soil Resource Information

Existing soil resource information was obtained from the RM-based Manitoba Agricultural Interpretation Databases (MLI 2019c) and the Canadian Soil Information Service (CanSIS 2019, CanSIS 2020). These provide digital repositories for provincial and national soil survey data and reports for Manitoba. The combined SRI provides an overview of soil resources within the RAA, predominantly at a scale of 1:126,720. The origin of much this soil information is based on information contained in the following soil survey reports:

- Soils of the Grahamdale Area (Mills and Smith 1971) covers the RM of Grahamdale portion of the RAA, at a scale of 1:126,720.
- Soils of the Red Rose–Washow Bay Area (Smith et al. 1975) covers the northern portion of the RAA (north of the RM of Grahamdale), at a scale of 1:126,720.
- Soils of the West Interlake Area (Podolsky 1981) covers a minimal portion of the RAA, consisting of Moosehorn Bay (south of Watchorn Bay), at a scale of 1:20,000.

The Soil Landscapes of Canada v3.2 Soil Name File (CanSIS 2019) was used to complete the soil database used for the Project, including provision of soil taxonomic information (i.e., sub-group classification), mode of material deposition, parent material texture, drainage and topography (slope

class). Additional information on topography, texture and drainage classes is found in Appendix 6A (Tables 6.3A-1, 6.3A-2 and 6.3A-3).

The Soil Layer Table (SLT), version 2 (CanSIS 2020) was used to compile additional information on soil characteristics associated with soils found within the Project assessment and development areas. These characteristics include pH, organic matter and soil layer thickness for discrete soil layers (or horizons) of interest. These data represent the modal (or typical) soil properties for a soil series (the basic unit for identifying and classifying soils within a soil map unit).

Topsoil depth and subsoil thickness were evaluated using existing soil resource information and supplemental data collected by the Project engineering service providers during geotechnical field investigations. Typical soil layer and horizon data presented in existing soil resource information (CanSIS 2020) was used as a basis for providing topsoil depths for each soil series found within the LAA and PDA of the LMOC and LSMOC Project components. Topsoil is identified for mineral soils as soils with total organic carbon ranging from 1.5 to 17%, while soils with total organic carbon greater than 17% are classified as peat or organic soil (Soil Classification Working Group, 1998). Topsoil is not as clearly defined for organic soils by existing criteria; however, it is generally accepted that topsoil in organic soils includes organic soil horizons and underlying organic matter enriched mineral horizons, if present. This existing soil information was evaluated in relation to available geotechnical field investigation information from boreholes and stratigraphic cross-sections (KGS Group 2017a; KGS Group 2019, pers. comm.) to support topsoil depth interpretations and estimates of subsoil thickness over bedrock.

Agricultural Capability

An agricultural capability class rating for each soil map unit exists in SoilAID (MLI 2019) polygons. These ratings were developed according to Canada Land Inventory (CLI) soil capability for agriculture rating system developed for Manitoba (Fraser et al. 2001). The CLI is a seven-class system based on the degree of limitation of land for agricultural crop production, with Class 1 having no significant limitations in use for crops and Class 7 having no capability for crop production or permanent pasture. Additional information on this rating system is found in Appendix 6A (Tables 6.3A-4 and 6.3A-5).

Compaction Risk

A generalized rating system for compaction risk was developed using professional judgment and review of two compaction systems that had been designed for forestry applications; specifically, the Soil Compaction and Puddling Hazard Key (British Columbia Ministry of Forests 1999) and the table of Compaction and Rutting Hazard for Soils in Ontario (Archibald et al. 1997). The generalized rating system developed for compaction risk takes into consideration soil texture and drainage regime within a given polygon. Susceptibility to soil compaction is dependent on soil physical properties, the moisture content during the disturbance and the nature of the applied force (Cannon and Landsburg 1990). Generally, in mineral soils, compaction risk increases with higher clay content, higher soil moisture content and lower organic matter content (Cannon and Landsburg 1990). Mineral soils are rated as having a low, moderate

or high risk to compaction. All organic soils are considered to have a high risk to compaction. Additional information on this rating system is found in Appendix 6A, Table 6.3A-6.

Wind and Water Erosion Risk

Wind erosion risk classes were determined using the methods of Coote and Pettapiece (1989). The rating system is based on a land surface that is bare and unprotected (no vegetation or litter cover) with a non-crusted surface. The classification of potential wind erosion risk consists of five classes from negligible to severe based on the potential for soil movement by wind. Additional information on this rating system is found in Appendix 6A (Table 6.3A-7).

Water erosion risk classes were determined using the Revised Universal Soil Loss Equation for Application in Canada (RUSLEFAC) method (Wall et al. 2002). RUSLEFAC ratings were developed to predict average soil loss by water erosion, taking into account rainfall, soil and landscape characteristics and management practices. Soils are rated in five risk categories ranging from very low to severe based on potential annual soil losses to water erosion. Additional information on this rating system is found in Appendix 6A (Table 6.3A-8).

Reclamation Suitability

Reclamation suitability ratings were determined for the topsoil (first excavation lift) and upper subsoil (second excavation lift) for each soil map unit in the PDA and LAA following the approached presented in Soil Quality Criteria Relative to Disturbance and Reclamation (AAFRD 1987). These ratings were based on existing physical and chemical data available for soil map units and representative soil series profiles (CanSIS 2019). Criteria for evaluating suitability in the plains region was used for the southern portion of the assessment area, corresponding to the LMOC portion of the LAA and the southern and western shorelines of the Lake St. Martin (LSM) shoreline portion of the LAA. Criteria for evaluating the suitability of materials in the northern forest region were used for the northern portions of the assessment area, corresponding to the LSMOC portion of the LAA and the eastern and northern shorelines of the LSM shoreline portion of the LAA. A substantial portion of the assessment area, particularly in the LSMOC portion of the LAA and the western shoreline of the LSM shoreline portion of the LAA, has organic soil materials overlying mineral soils. These organic soils have been rated for reclamation suitability, but for reclamation purposes, organic materials should be used as a soil conditioner to provide increased organic matter to mineral soils to be used for reclamation (AAFRD 1987). Tables outlining the physical and chemical properties that rate the soils based on the criteria are found in Appendix 6A (Table 6.3A-9; 6.3A-10, 6.3A-11, 6.3A-12 and 6.3A-13).

6.3.2.4 Soils and Terrain Overview

Soils and Terrain in the RAA

The majority of the RAA and entire LAA are located within the Ashern, Gypsumville and Sturgeon Bay ecodistricts. A very minor portion of the northwest portion of the RAA is found in the Waterhen ecodistrict; however, it has a negligible bearing on the assessment and, therefore, is not characterized.

The Ashern Ecodistrict, which encompasses a portion of the RAA and LAA from Lake Manitoba to the south and west side of Lake St. Martin, is characterized as having drumlinoid or ridge and swale topography oriented in a northwest to southeast direction, with slope gradients generally less than 5% and slope lengths between 50 m to 200 m. The area encompassed by the ecodistrict slopes very gently towards Lake Winnipeg and west towards Lake Manitoba, with local relief (difference in elevation) of approximately 0.5 m to 3.0 m between ridges and swales (Smith et al. 1998).

The Gypsumville Ecodistrict is located along the north and west sides of Lake St. Martin in the RAA and LAA. This ecodistrict is characterized as having elevations ranging from 410 m asl to 218 m asl near Lake Winnipeg. Topography consists of low relief, northwest to southeast oriented drumlinoid or ridge and swale landform features, and slopes that range from 1% to 3%. Inclusions of bedrock at or near the surface can be found within this ecodistrict (Smith et al. 1998).

The Sturgeon Bay Ecodistrict encompasses the northern portion of the RAA and LAA, from the north end of Lake St. Martin to Sturgeon Bay at Lake Winnipeg. This area has a mean elevation of approximately 259 m asl with the eastern half of the ecostrict characterized as having northwest to southeast oriented drumlinoid or ridge and swale topography (Smith et al. 1998). The ridges range from 400 to 800 m wide with approximately 800 m swales separating the ridges. This ecodistrict slopes gently towards Lake Winnipeg in a northeastward direction and local relief (from ridge to swale) ranges from 0.5 to 3.0 m. Slopes are typically gentle with slope percentages ranging from 0% to less than 5%. Level peatlands are a dominant feature in the west half of the ecodistrict (Smith et al. 1998). The presence of the low ridge and swale landform type and level to gently undulating topography limits drainage, with soils being predominantly imperfectly to very poorly drained.

The soil materials occurring in the southern portion of the RAA, from Lake Manitoba to the south end of Lake St. Martin (including the west and east side) consist of extremely calcareous, very stony water-worked loamy textured glacial till. A portion of this area was modified by wave action and scouring by icebergs during the retreat of glacial lake Agassiz (Smith et al. 1998). The ridges are composed of relatively coarse textured, cobbly and gravelly deposits, while depressions contain the finer deposits (Smith et al. 1998). Discontinuous veneers of level to very gentling undulating glaciolacustrine clay sediments also occur on the west side of Lake St. Martin (Smith et al. 1998). The changing topography in this portion of the RAA has resulted in imperfectly, very poorly and well drained soils.

Organic soils are predominant in the northern portion of the RAA, extending from Lake St. Martin to Lake Winnipeg. The organic soils are found in lower lying and depressional areas and are very poorly to poorly drained. The organic materials are not deep, and generally mineral soil (glaciolacustrine or till) contact

occurs within the top 1 m of the soil surface. The organic material is sphagnum peat, forest peat or fen peat and ranges from being nutrient poor to nutrient rich.

Minor inclusions of carbonate bedrock occur in the RAA and are composed of unconsolidated bedrock on nearly level to gently sloping topography. Vegetation on the carbonate bedrock is stunted and sparse as a result of little to no soil profile development.

With respect to permafrost, the RAA is located south of the localized permafrost zone (Lockery 1984). A review of permafrost information through Natural Resources Canada (1995), identifies that the RAA is approximately 150 km south of any isolated of permafrost and approximately 630 km south of continuous permafrost.

Soils and Terrain in the LAA and PDA

Terrain and Surficial Materials

Within the LMOC portion of the LAA and PDA, the nature of the land surface is predominantly characterized by drumlinoid or ridge and swale landforms. However, a natural, topographic low runs between Watchorn Bay on Lake Manitoba and the southern tip of Lake St. Martin. Within the LSMOC portion of the LAA and PDA, the land surface is predominantly level and of low relief associated with the organic deposits.

Within the Project LAA, 29.4% is classified as level topography with slopes from 0 to 0.5% (Table 6.3-6; CanSIS 2019). Nearly level slopes with slopes ranging from greater than 0.5% to 2% comprise 9.4% of the LAA, while 6.1% is considered very gently sloping with slopes ranging from greater than 2% to 5%. Approximately 55% of the LAA is not rated – this area is associated with permanent water, intermittent lakes and unclassified land. When only soil and terrain areas rated within the LAA are considered, 65.4%, 21.0% and 13.7% of the LAA are level, nearly level and very gently sloping, respectively. The dominant slope length in the LAA, are slopes from 0 to 75 m, followed by slope lengths greater than 300 m. Slope lengths ranging from 75 to 300 m make up a minor portion of the LAA.

Within the soil and terrain portion of the Project PDA, 71.3% is classified as level topography, 16.5% as nearly level and 12.2% as very gently sloping (Table 6.3-6).

The soil materials occurring in the LMOC portion of the LAA, from Lake Manitoba to the south end of Lake St. Martin (including the west and east side) consist primarily of extremely calcareous, very stony water-worked loamy textured glacial till (CanSIS 2019). A portion of this area was modified by wave action and scouring by icebergs during the retreat of glacial lake Agassiz (Smith et al. 1998). The ridges are generally composed of more coarse-textured, cobbly and gravelly deposits, while depressions contain finer deposits (Smith et al. 1998). Discontinuous veneers of glaciolacustrine clay sediments also occur on the west side of Lake St. Martin (CanSIS 2019; Smith et al. 1998).

Table 6.3-6 Slope Classes in the Project LAA and PDA

Slope Class	Slope Gradient Range (%)	Description	Summary of Areas					
			LAA			PDA		
			ha	% area	% of soil area	ha	% area	% of soil area
1	0-0.5	Level	18,745	29.4	65.4	1,365	65.0	71.3
2	>0.5-2	Nearly level	6,009	9.4	21.0	316	15.1	16.5
3	>2-5	Very gently sloping	3,915	6.1	13.7	234	11.1	12.2
4	>5-10	Gently sloping	--	--	--	--	--	--
5	>10-15	Moderately sloping	--	--	--	--	--	--
6	>15-30	Strongly sloping	--	--	--	--	--	--
7	>30-45	Very strongly sloping	--	--	--	--	--	--
8	>45-70	Extremely sloping	--	--	--	--	--	--
9	>70-100	Steeply sloping	--	--	--	--	--	--
10	>100	Very steeply sloping	--	--	--	--	--	--
Not rated[1]			35,183	55.1	--	184	8.8	--
Totals – Assessment Area			63,852	100.0	--	2,099	100.0	--
Totals – Area Rated as Soils			28,670	44.9	100.0	1,915	91.2	100.0

NOTES:
Source: CanSIS 2019; MLI 2019
Areas and proportions may not add up to totals due to rounding
1. Not rated areas include those classified as water and unclassified land

The organic deposits found in the Project LAA are mainly in the LSMOC portion of the LAA extending from the north end of Lake St. Martin to Lake Winnipeg, however they are common along the eastern shoreline of the LSM shoreline portion of the LAA. Organic materials are sphagnum, fen and forest peats of mesic to fibric textures (CanSIS 2019). The northern end of the LSMOC portion of the LAA is predominantly coarse sand, gravelly and cobbly surficial deposits.

While bedrock is not indicated as a parent material as it is considered non-soil, inclusions of carbonate or limestone bedrock occur in the LAA. Some bedrock is exposed while some is overlain by a veneer (<1 m) of organic material or till. The bedrock is located within the LSM shoreline portion of the LAA, mostly along the western shoreline. No bedrock is mapped in the PDA.

Surficial material within the LAA and PDA are predominantly till (45.0% of the soil area within the LAA, 49.7% of soil area in PDA) and organic materials greater than 1 m in depth (1.5%, 1.3%) or overlying till (11.5%, 11.4%) or recent lacustrine sediments (16.5%, 20.9%) (Table 6.3-7). Fluvial and glaciofluvial deposits occupy 4.6% of the soils area within the LAA and 11.4% of the soils area within the PDA, including those thin deposits overlying till. Bedrock is a minor portion of the assessment areas, with exposed bedrock occupying 0.4% of soil area within the LAA, while some occurrences of bedrock are overlain by a veneer (less than 1 m) of organic material (0.1%) or till (1.8%).

Surficial materials within the LAA and PDA are predominantly medium textured (49.9% of the soil area within the LAA, 49.8% of soil area in PDA) (Table 6.3-8). Organic materials, including those overlying medium to fine materials within 1.2 m of the surface, occupy 29.3% of the soil area within the LAA and 33.6% of soil area in PDA. Coarse textured materials, including gravelly and cobbly (skeletal) deposits, occupy 8.5% of the soils area within the LAA and 14.6% of the soils area within the PDA, including those thin deposits overlying medium textured materials.

Table 6.3-7 Parent Material Mode of Deposition in the LAA and PDA

Mode of Deposition	Mode of Deposition Abbreviation	Summary of Areas					
		LAA			PDA		
		ha	% area	% of soil area	ha	% area	% of soil area
Organic	FNPT, SPPT or FOPT	433	0.7	1.5	24	1.1	1.3
Organic overlying Recent Lacustrine	FNPT, SPPT or FOPT over LACU	4,677	7.3	16.5	401	19.1	20.9
Organic overlying till	FNPT, SPPT or FOPT over TILL	3,243	5.1	11.5	218	10.4	11.4
Organic overlying Limestone Bedrock	FNPT, SPPT or FOPT over RKLS	40	0.1	0.1	--	0.0	0.0
Fluvial	FLUV	38	0.1	0.1	--	0.0	0.0
Glaciofluvial	GLFL	309	0.5	1.1	53	2.5	2.8
Glaciofluvial over till	GLFL over TILL	954	1.5	3.4	165	7.9	8.6
Recent Lacustrine	LACU	959	1.5	3.4	20	0.9	1.0
Recent Lacustrine over till	LACU over till	1,880	2.9	6.7	27	1.3	1.4
Glaciolacustrine	GLLC	--	0.0	0.0	--	0.0	0.0
Glaciolacustrine over till	GLLC over till	306	0.5	1.1	53	2.5	2.8
Lacustro-Till	LATL	1,172	1.8	4.1	--	0.0	0.0
Till	TILL	12,714	19.9	45.0	950	45.3	49.7
Till over Limestone Bedrock	TILL over RKLS	1,161	1.8	4.1	--	0.0	0.0
Undifferentiated Mineral Materials	UNDM	376	0.6	1.3	2	0.1	0.1
Limestone Bedrock	RKLS	262	0.4	0.9	--	0.0	0.0
Not rated[1]		35,327	55.3	--	186	8.9	--
Totals – Assessment Area		63,852	100.0	--	2,099	100.0	--
Totals – Area Rated as Soils		28,263	44.3	100.0	1,913	91.1	100.0

NOTES:
Source: CanSIS 2019; MLI 2019
Areas and proportions may not add up to totals due to rounding
1. Not rated areas include those classified as water and unclassified land

Table 6.3-8 Parent Material Texture in the LAA and PDA

Parent Material Description	Summary of Areas					
	LAA			PDA		
	ha	% area	% of soil area	ha	% area	% of soil area
Coarse (FS, LCS, LS ,LFS, GLS, CBLS)	808	1.3	2.9	7	0.3	0.4
Coarse skeletal (VGS, VGLS)	309	0.5	1.1	53	2.5	2.8
Coarse skeletal (VGS, VGLS) overlying Medium (VFSL, L, SIL, SI, GL, GSIL)	1,260	2.0	4.5	218	10.4	11.4
Medium (VFSL, L, SIL, SI, GL, GSIL)	14,118	22.1	49.9	952	45.4	49.8
Moderately fine (SCL, FSCL, VFSCL, CL, SICL, GSCL, GL, CBCL)	27	0.0	0.1	--	0.0	0.0
Moderately fine (SCL, FSCL, VFSCL, CL, SICL, GSCL, GL, CBCL) overlying medium (VFSL, L, SIL, SI, GL, GSIL)	886	1.4	3.1	19	0.9	1.0
Fine (SC, SIC, C, GSIC)	1,237	1.9	4.4	6	0.3	0.3
Fine (SC,SIC,C,GSIC) overlying medium (VFSL, L, SIL, SI, GL, GSIL)	1,045	1.6	3.7	3	0.1	0.1
Very fine (HC (more than 60% clay)	296	0.5	1.0	13	0.6	0.7
Organic (Fibric to Mesic) Materials	101	0.2	0.4	17	0.8	0.9
Organic (Fibric to Mesic) materials overlying Fine (SC, SIC, C, GSIC) to moderately Fine (SCL, FSCL, VFSCL, CL, SICL, GSCL, GL, CBCL) to medium (VFSL, L, SIL, SI, GL, GSIL)	7,919	12.4	28.0	618	29.5	32.3
Organic (Fibric to Mesic) materials overlying undifferentiated materials	262	0.4	0.9	7	0.3	0.4
Not rated[1]	35,583	55.7	--	186	8.9	-
Totals – assessment area	63,852	100.0	--	2,099	100.0	-
Totals – area rated as soils	28,269	44.3	100.0	1,913	91.1	100.0

NOTES:
Source: CanSIS 2019; MLI 2019
Areas and proportions may not add up to totals due to rounding
1. Not rated areas include those classified as water and unclassified land

Terrain map units are displayed for the LMOC PDA in Appendix 6B, Figure 6.3B-6 and for the LSMOC PDA in Appendix 6B, Figure 6.3B-7. A review of the terrain within the LAA and PDA has confirmed that the natural landscape would all be considered stable and expected to have a negligible likelihood of landslide initiation, according to the guidelines provided by BC Ministry of Forests and BC Ministry of Environment (1999). This is due to the low slope gradients within the assessment areas, slope classes 1 to 3 with corresponding slope gradients less than 5% and confirmed using Project LiDAR elevation data, and occurrence of underlying till materials throughout the PDA.

Soil and Drainage – Overview of the LAA and PDA

The four dominant soil orders found within the soils area portion of the LAA and PDA (Table 6.3-9) are Chernozems, Organics, Gleysols and Brunisols. A minor portion of the LAA and PDA is composed of Regosols. A summary of these soils is provided below.

Chernozems comprise 9,519 ha (33.6% of the soil area) within the LAA and 700 ha (36.6% of the soil area) within the PDA. These soils are often associated with natural grasslands and much of these soils are now under cultivation. They are found primarily in the LMOC portion of the LAA and western LSM shoreline portion of the LAA; however, they are also found along the eastern shoreline of the LSM shoreline portion of the LAA and at the north end of the LSMOC portion of the LAA in proximity to Sturgeon Bay. The Chernozemic soils are dominantly gleyed (gleyed dark gray, gleyed rego dark gray, and gleyed rego black) soils and are represented by the Inwood, Faulkner, Goose Island, Lundar and McCreary soil series. The stoniness of these soils ranges from moderately to very stony and they are moderately to very calcareous. Drainage ranges from slow to well depending on the composition of the surface textures and underlying deposits.

Organics comprise 7,349 ha (25.9%) of the LAA and 605 ha (31.6%) of the PDA. These soils are wetland soils and are generally found in association with fen or bog wetlands. This is the predominant order found within the LSMOC portion of the LAA and these soils are also common along the eastern shoreline of the LSM shoreline portion of the LAA. Some organic soils are also found in low-lying areas on the east side of the LMOC centreline. The Organic soils are dominantly Mesisols (typic, terric and lithic) of the Baynham, Crane, Grindstone, Janora, Okno and Stead soils series). Inclusions of Terric Mesic Fibrosols of the Kilkenny and Molson soil series can also be found. These soils occupy depressional to low areas, as a result, drainage is very poor to poor. High water tables are also evident in some of the organic soils as well as high carbonates and stoniness. Sphagnum peat, forest peat and fen peat are the dominant organic materials found in these soils and range from being nutrient poor to nutrient rich.

Gleysols comprise 5,317 ha (18.7%) of the LAA and 248 ha (12.9%) of the PDA. These are wet, mineral soils. Gleysols are found throughout the LMOC portion of the LAA and LSM shoreline portion of the LAA. The Gleysols found in the LAA and PDA are either Rego Humic or Rego Gleysols of the Marsh, Fyala, Meleb, Magnet and Partridge soil series. Gleysolic soils are calcareous, with high water tables that result in poor to very poor drainage. They are commonly in association with ridge and swale topography, where they are found in the swale locations, or depressional portions of the landscape.

Brunisols comprise 5,243 ha (18.5%) of the LAA and 351 ha (18.4%) of the PDA. These mineral soils are often associated with forested lands. While most are found within the LSM shoreline portion of the LAA, there are also some within the LMOC portion of the LAA and few occurrences in the LSMOC portion of the LAA. Some of these soils in the LMOC portion of the LAA have been cleared for agriculture. The Brunisolic soils in the LAA and PDA are Eutric Brunisols of the Chitek, Fairford and Hilbre soils series. Drainage in these soils ranges from imperfect to well depending on the presence of a high water table. These soil series are extremely calcareous and have excessive stoniness.

Regosols make up 3.0% of the soil areas within the LAA (and 0% of the PDA) and Luvisols only 0.3% of the LAA (and 0.1% of the PDA). These soils are poorly developed and often in an area of steep slopes or flooding where erosional processes have slowed soil development. Regosols within the LAA are predominantly associated with sand beaches around Lake St. Martin and along the shoreline of Watchorn Bay at the south end of the LMOC portion of the LAA. At the scale of existing soil resource inventory, no areas within the PDA (LMOC PDA or the LSMOC PDA) are classified as developed.

Table 6.3-9 Soil Series in the LAA and PDA

Soil Series	Series Code	Classification	Summary of Areas					
			LAA			PDA		
			ha	% area	% of soil area	ha	% area	% of soil area
Cayer (incl. Benito phase)	CAY	Terric Mesisol	2,484	3.9	8.8	67	3.2	3.5
Chitek	CHK	Gleyed Eluviated Eutric Brunisol	336	0.5	1.2	80	3.8	4.2
Crane	CRN	Terric Mesisol	1,666	2.6	5.9	172	8.2	9.0
Fairford	FFD	Eluviated Eutric Brunisol	2,722	4.3	9.6	170	8.1	8.9
Faulkner	FKR	Gleyed Dark Gray Chernozem	939	1.5	3.3	--	0.0	0.0
Goose Island	GOI	Gleyed Rego Dark Gray Chernozem	954	1.5	3.4	165	7.9	8.6
Hilbre	HIB	Eluviated Eutric Brunisol	381	0.6	1.3	--	0.0	0.0
Inwood	IWO	Gleyed Dark Gray Chernozem	5,908	9.3	20.9	415	19.8	21.7
Kilkenny	KEY	Terric Mesic Fibrisol	825	1.3	2.9	11	0.5	0.6
Louis Island	LUN	Gleyed Dark Gray Chernozem	306	0.5	1.1	53	2.5	2.8
Lundar	LUR	Gleyed Rego Humic Gleysol	706	1.1	2.5	--	0.0	0.0
Magnet, peaty phase	MGT	Rego Humic Gleysol	459	0.7	1.6	19	0.9	1.0
Marsh	$MH	Rego Gleysol	376	0.6	1.3	2	0.1	0.1
McCreary (incl. saline phase)	MCR & MCRs	Gleyed Rego Black Chernozem	427	0.6	1.5	--	0.0	0.0
Meleb	MEB	Rego Humic Gleysol	3,702	5.8	13.1	286	13.6	14.9

Table 6.3-9 Soil Series in the LAA and PDA

Soil Series	Series Code	Classification	Summary of Areas					
			LAA			PDA		
			ha	% area	% of soil area	ha	% area	% of soil area
Molson	MLS	Terric Mesic Fibrisol	1,098	1.7	3.9	153	7.3	8.0
Okno, drained phase	OKO	Terric Mesisol	438	0.7	1.6	84	4.0	4.4
Partridge Creek	PGE	Rego Humic Gleysol	867	1.4	3.1	1	0.1	0.1
Sand Beaches	$SB	Gleyed Regosol	808	1.3	2.9	7	0.3	0.4
Sisib	SSB	Terric Fibric Mesisol	384	0.6	1.4	53	2.5	2.8
Woodworth	WOG	Gleyed Orthic Luvisol	308	0.5	1.1	53	2.5	2.8
Miscellaneous soils[1]	Numerous	Numerous	2,175	3.4	7.7	123	5.8	6.4
Non-soil								
Carbonate Bedrock	$CR		255	0.4	0.9	--	0.0	0.0
Unclassified Island	$UI		35	0.0	-	--	0.0	-
Water	$ZZ & $ZI		35,292	54	-	186	7	-
Totals – Assessment Area			63,852	100	-	2,099	100	-
Totals – Area Rated as Soils			28,269	44	101	1,913	91	100

NOTES:

Source: CanSIS 2019; MLI 2019

Areas and proportions may not add up to totals due to rounding

1. Miscellaneous soils include 24 soils series that occupy less than 1% of the soils area of the LAA. These soils occupy a total of 3.4% of the LAA and 6.4% of the PDA. These soils include the following soil series:

   Baynham[BYH], Davis Point[DVP], Devils Lake[DVK], Elmore[EME], Ferland[FLD], Fisher[FIH], Freshford[FHF], Fyala[FYL], Grindstone[GDT], Halcrow[HCW], Holditch[HCH], Homebrook[HOK], Howell[HWL], Janora[JOR], Julius[JUS], Katimik[KMK], Kinwow[KNW], Lamb Lake[LBK], Lee Lake[LEK], Orok[OOK], Narcisse[NCS], Peguis[PGU], Rochelle[RLL], Stead[STD]

SURFACE soil textures are predominantly medium within the soil areas of the LAA (49.9%) and PDA (60.9%) (Table 6.3-10) and are common in the LMOC portion of the LAA and PDA. Organic (fibric to mesic) textures occupy a significant area of the LAA (29.3%) and PDA (41.1%) and are located primarily in the LSMOC portion of the LAA and predominate the LSMOC PDA. Coarse (sand) to coarse skeletal (gravelly sand) textures occupy 8.5% of the soils LAA and 17.7% of the PDA.

Table 6.3-10 Surface Soil Texture in the LAA and PDA

Soil Type	Description	Summary of Areas					
		LAA			PDA		
		ha	% area	% of soil area	ha	% area	% of soil area
Mineral Soil	Coarse (FS, LCS, LS, LFS, GLS, CBLS)	808	1.3	2.9	7	0.3	0.4
	Coarse Skeletal (VGS, VGLS)	1,570	2.5	5.6	271	12.9	17.3
	Medium (VFSL, L, SIL, SI, GL, GSIL)	14,118	22.1	49.9	952	45.4	60.9
	Moderately Fine (SCL, FSCL, VFSCL, CL, SICL, GSCL, GL, CBCL)	913	1.4	3.2	19	0.9	1.2
	Fine (SC, SIC, C, GSIC)	2,282	3.6	8.1	8	0.4	0.5
	Very Fine (HC (more than 60% clay))	296	0.5	1.0	13	0.6	0.8
Organic Soil	Fibric	3,227	5.1	11.4	294	14.0	18.8
	Mesic	5,056	7.9	17.9	348	16.6	22.3
Totals – Assessment Area		63,852	100.0	--	2,099	100.0	--
Totals – Area Rated as Soils		28,269	44.3	100.0	1,564	74.5	100.0

NOTES:
Source: CanSIS 2019; MLI 2019
Areas and proportions may not add up to totals due to rounding
1. Not rated areas include those areas covered by non-soil (i.e., water, bedrock, unclassified land)

Within the soils portion of the LAA and PDA, soils are co-dominantly very poorly and imperfectly drained (Table 6.3-11). A minor portion of the assessment areas are classified as well drained and a very small portion are rapidly or poorly drained. Very poorly drained soils are predominant in the LSMOC portion of the LAA and PDA and are in association with organic soils under natural vegetation and wetlands. At the north end of these assessment areas, in proximity to Sturgeon Bay on Lake Winnipeg, soils are predominantly imperfectly drained. Within the LMOC portion of the LAA, there is a mix of well drained, imperfectly drained and very poorly drained soils. The well and imperfectly drained soils predominate on the west side of the LMOC centerline and are found in association with Chernozemic and Brunisolic soils, many of which are under agricultural land use. Most of the very poorly drained soils in the LMOC portion of the LAA are found on the east side of the LMOC centerline, in lower lying areas associated with wetlands.

Table 6.3-11 Drainage Class in the LAA and PDA

Drainage Class	Description	Summary of Areas					
		LAA			PDA		
		ha	% area	% of soil area	ha	% area	% of soil area
Rapid	R	309	0.5	1.1	53	2.5	2.8
Well	W	3,355	5.3	11.9	171	8.2	8.9
Imperfect	I	11,031	17.3	39.0	809	38.5	42.3
Poor	P	411	0.6	1.5	14	0.7	0.8
Very Poor	VP	13,163	20.6	46.6	865	41.2	45.2
Not Rated	NR	35,583	55.7	-	186	8.9	--
Totals – Assessment Area		63,852	100.0	-	2,099	100.0	--
Totals – Area Rated as Soils		28,269	44.3	100.0	1,913	91.1	100.0

NOTES:
Source: CanSIS 2019; MLI 2019
Areas and proportions may not add up to totals due to rounding
1. Not rated areas include those areas covered by non-soil (i.e., water, bedrock, unclassified land)

Soil Series and Soil Characteristics – LMOC LAA and PDA

Within the LMOC LAA and PDA, soil types are predominantly mineral and include the Fairford, Hilbre, Inwood, Lundar, McCreary, Narcisse, Magnet and Meleb series, as well as Marsh Complex and Sand Beaches soils. One organic soil type, the Crane soil series, is present within the LMOC LAA and PDA. A summary of soil series identified within the LMOC LAA and PDA, and soil characteristics associated with those soil series, is presented in Appendix 6A (Table 6.3A-14).

Ranges of pH values are provided for surface and subsurface horizons (soil layers) for the dominant soil series within the LMOC LAA and PDA in Appendix 6A (Table 6.3A-14). For mineral soils, surface soil horizon pH values range from 6.3 to 8.0 and subsurface values range from 7.6 to 8.1. For the one organic soil identified within the LMOC LAA and PDA, surface and subsurface horizon pH values are indicated as 6.7 and 7.5, respectively. Considering mineral and organic soils, surface horizon pH values range from 6.3 to 8.0 and subsurface values range from 7.5 to 8.1.

Ranges of organic matter values are provided for surface soil horizons for the dominant soil series within the LMOC LAA and PDA in Appendix 6A (Table 6.3A-14). For mineral soils, surface horizon organic matter content ranges from 2.8 to 20.6% (or 1.6 to 12.0% organic carbon). For the one organic soil identified within the LMOC LAA and PDA, surface organic matter content is estimated as 68.8% (or 40.0% organic carbon). Considering mineral and organic soils, surface horizon organic matter content ranges from 2.8 to 68.8% (or 1.6 to 40.0% organic carbon).

Soil Series and Soil Characteristics – LSMOC LAA and PDA

Within the LSMOC LAA and PDA, soil types include a similar proportion of mineral and organic soil types. Mineral soils include the Chitek, Goose Island, Inwood, Fyala, Meleb, Partridge Creek, Kinwow and Woodworth series. Organic soils include the Cayer, Crane, Kilkenny, Molson, Okno and Stead series. A summary of soil series identified within the LMOC LAA and PDA, and soil characteristics associated with those soil series, is presented in Appendix 6A (Table 6.3A-15).

Ranges of pH values are provided for surface and subsurface horizons for the dominant soil series within the LSMOC LAA and PDA in Appendix 6A (Table 6.3A-15). For mineral soils, surface horizon pH values range from 5.7 to 7.5 and subsurface values range from 7.3 to 7.9. For organic soils, surface horizon pH values range from 3.6 to 6.7 and subsurface values range from 6.7 to 7.7. Considering mineral and organic soils, surface horizon pH values range from 3.6 to 7.5 and subsurface values range from 6.7 to 7.9.

Ranges of organic matter values are provided for surface soil horizons for the dominant soil series within the LSMOC LAA and PDA in Appendix 6A (Table 6.3A-15). For mineral soils, surface horizon organic matter content ranges from 3.3 to 12.9% (1.9 to 7.5% organic carbon). For organic soils, surface horizon organic matter content ranges from 67.1 to 100.0% (39.0 to 60.0% organic carbon). Considering mineral and organic soils, surface horizon organic matter content ranges from 3.3 to 100.0% (1.9 to 60.0% organic carbon).

Topsoil Depth and Subsoil Thickness

In the LMOC LAA and PDA, surficial soils are underlain by two till substrates. The first till layer, known as Komarno till, is characterized as more loosely consolidated than the underlying Inwood till, which is over-consolidated and well-cemented (KGS Group 2017a). The thickness of till over the underlying bedrock within the PDA ranges from 10 to 20 m. Topsoil depths are provided for the dominant soil series within the LMOC LAA and PDA in Appendix 6A (Table 6.3A-14), based on existing soil resource information (CanSIS 2020). For mineral soils, topsoil depths range from 6 to 50 cm, with an average of approximately 20 cm across identified soil series. The one organic soil within the LMOC LAA and PDA is characterized as having organic horizons (i.e., those layers with organic carbon content >17%) to a depth of 125 cm overlying a subsurface C horizon (i.e., non-topsoil mineral soil layer). Therefore, the depth of topsoil is considered to be 125 cm based on the characteristics of the one organic soil series encountered within the LMOC LAA and PDA. The minor portion of PDA, which is organic soil, would be expected to have till contact below the organic topsoil. Considering mineral and organic soils, topsoil depths range from 6 to 125 cm, with an average of approximately 29 cm across identified soil series. These topsoil depths are consistent with the findings of preliminary geotechnical investigations for this channel route (KGS Group 2017a).

In the LSMOC LAA and PDA, surficial soils are underlain by till substrate. The thickness of till over the underlying bedrock ranges from very thin (about less than 1 m) to over 20 m, but generally ranges from approximately 5 to 12 m (KGS Group 2019). A very dense and cemented till underlies a more loosely consolidated upper till layer which is a few metres in thickness. A thin layer of lacustrine or water-worked till is generally found overlying the upper till. Topsoil depths are provided for the dominant soil series within the LSMOC LAA and PDA in Appendix 6A (Table 6.3A-15), based on existing soil resource information (CanSIS 2020). For mineral soils, topsoil depths range from 8 to 30 cm, with an average across identified soil series of approximately 17 cm. Within the LSMOC LAA and PDA, the organic soils are characterized as having organic horizons (i.e., those layers with organic carbon content >17%) overlying mineral materials, and, in some cases, organic matter enriched mineral A horizons. Where organic materials are overlying mineral C horizons (non-topsoil mineral soil layer), only the overlying organic materials are considered in the topsoil depth. For organic soils, topsoil depths are considered to range from 95 to greater than 180 cm, with an average across identified soil series of approximately 133 cm. Considering mineral and organic soils, topsoil depths range from 8 to greater than 180 cm, with an average across identified soil series of approximately 67 cm.

Wind and Water Erosion Risk

Wind erosion risk ratings for the LAA and PDA are presented in Table 6.3-12 and Appendix 6B, Figure 6.3B-9. Within soil areas of the LAA and PDA, soils are rated predominantly as a negligible risk for wind erosion losses. A minor portion of the assessment areas are rated as low (3.6% of the soils LAA, 6.2% of the soils PDA), moderate (0.8% of the soils LAA, 0.2% of the soils PDA) and high (0.2% of the soils LAA, 0.3% of the soils PDA). These areas are almost all located in the LSMOC portion of the LAA and PDA. There are no soils rated as severe for wind erosion in the PDA.

Water erosion risk ratings for the LAA and PDA are presented in Table 6.3-13 and Appendix 6B, Figure 6.3B-10. Within soil areas of the LAA and PDA, soils are rated predominantly as a very low risk for water erosion losses (82.7% of the soils LAA, 86.3% of the soils PDA). A significant portion of the assessment areas are rated as moderate (16.9% of the soils LAA, 13.7% of the soils PDA). These moderate risk areas are located in the LMOC portion of the LAA and LSM shoreline portion of the LAA. There are no soils rated as high in PDA.

Table 6.3-12 Wind Erosion Risk in the LAA and PDA

Wind Erosion Class	Summary of Areas					
	LAA			PDA		
	ha	% area	% of soil area	ha	% area	% of soil area
Severe	24	0.0	0.1	--	--	--
High	46	0.1	0.2	5	0.2	0.3
Moderate	224	0.4	0.8	4	0.2	0.2
Low	1,027	1.6	3.6	119	5.7	6.2
Negligible	27,047	42.4	95.3	1,785	85.0	93.3
Not Rated[1]	35,484	55.6	--	186	8.9	--
Totals – Assessment Area	63,852	100.0	--	2,099	100.0	--
Totals – Area Rated as Soils	28,368	44.4	99.9	1,913	91.1	100.0

NOTES:
Source: ratings developed by Stantec based on Coote and Pettapiece 1989
Areas and proportions may not add up to totals due to rounding
Ratings are based on a weighted rating based on each soil polygon component
1. Not rated areas include those areas covered by non-soil (i.e., water, bedrock, unclassified land)

Table 6.3-13 Water Erosion Risk in the LAA and PDA

Water Erosion Class	Summary of Areas					
	LAA			PDA		
	ha	% area	% of soil area	ha	% area	% of soil area
High	13	0.0	0.0	--	--	--
Moderate	4,787	7.5	16.9	261	12.5	13.7
Low	112	0.2	0.4	--	--	--
Very Low	23,456	36.7	82.7	1,651	78.7	86.3
Not Rated[1]	35,484	55.6	--	186	8.9	--
Totals – Assessment Area	***63,852***	***100.0***	***--***	***2,099***	***100.0***	***--***
Totals – Area Rated as Soils	***28,368***	***44.4***	***100.0***	***1,913***	***91.1***	***100.0***

NOTES:
Source: ratings developed by Stantec using the Revised Universal Soil Loss Equation for Application in Canada (RUSLEFAC) method presented in Wall et al. 2002
Areas and proportions may not add up to totals due to rounding
Ratings are based on a weighted rating based on each soil polygon component
1. Not rated areas include those areas covered by non-soil (i.e., water, bedrock, unclassified land)

Compaction Risk

Compaction risk ratings for the LAA and PDA are presented in Table 6.3-14 and Appendix 6B, Figure 6.3B-11. Within soil areas of the LAA and PDA, soils are rated predominantly as a high risk for compaction (51.3% of the soils LAA, 44.6% of the soils PDA). Substantial components of the assessment areas are rated as moderate (27.6% of the soils LAA, 29.4% of the soils PDA) and low (21.1% of the soils LAA, 26.0% of the soils PDA). The areas within the LSMOC portion of the LAA and PDA are predominantly rated high for compaction risk due to the prevalence of organic soils. The north end of the LSMOC portion of the LAA and PDA, in proximity to Sturgeon Bay, is predominantly rated as moderate for compaction risk. The LMOC portion of the LAA and PDA are rated from low to moderate on the west side of the channel centerline, while they are rated as predominantly high on the east side of the channel centreline.

Table 6.3-14 Compaction Risk in the LAA and PDA

Compaction Risk	Summary of Areas					
	LAA			PDA		
	ha	% area	% of soil area	ha	% area	% of soil area
High	14,545	22.8	51.3	852	40.6	44.6
Moderate	7,833	12.3	27.6	562	26.8	29.4
Low	5,990	9.4	21.1	498	23.7	26.0
Not Rated[1]	35,484	55.6	--	186	8.9	--
Totals – Assessment Area	63,852	100.0	--	2,099	100.0	--
Totals – Area Rated as Soils	28,368	44.4	100.0	1,913	91.1	100.0

NOTES:

Source: ratings developed by Stantec using professional judgment and review of two compaction rating systems: the Soil Compaction and Puddling Hazard Key (British Columbia Ministry of Forests 1999) and the table of Compaction and Rutting Hazard for Soils in Ontario (Archibald et al. 1997)

Areas and proportions may not add up to totals due to rounding

Ratings are based on a weighted rating based on each soil polygon component

1. Not rated areas include those include those classified as water and unclassified land

Agricultural Capability

Agricultural capability ratings for the LAA and PDA are presented in Table 6.3-15 and Appendix 6B, Figure 6.3B-12. As presented in Figure 6.3B-12, agricultural capability ratings are provided for the LMOC portion of the LAA and most of the western shoreline of the LSM portion of the LAA. Agricultural capability ratings are not provided for the eastern or northern shorelines of the Lake St. Martin portion of the LAA or along the LMOC portion of the LAA. These areas are predominantly organic soils with low potential for agriculture and are not currently developed for agricultural land use. Within soil areas of the LAA and PDA, soils are rated predominantly as Class 4 to 5 (60.7% of the soils LAA, 57.0% of the soils PDA). Class 4 to 5 soils are generally considered marginal for cropping agriculture and have severe to very

severe limitations (CLI 1969). A minor portion of the LAA (2.7% of the soils area) and none of the PDA are rated as Class 1 to 3, which is generally considered prime agricultural land, with no limitations to moderately severe limitations. A substantial portion of the assessment areas are rated as Class 6 (22.6% of the soils LAA, 29.1% of the soils PDA) and are considered limited to producing perennial forage crops. A minor portion of the assessment areas are rated as Class 7 and are considered to have no capability for arable agriculture or permanent pasture. Organic soils are rated as Class O3W and O5WD and occupy 8.6 and 13.1% of the soils LAA and PDA, respectively, and have severe limitations for agriculture. Agricultural capability ratings are similar between the LMOC portion of the LAA and the LSM shoreline portion of the LAA. These are discussed further in Section 9.2.

Limitations to agricultural capability across the portion of the LAA with agricultural capability ratings are:

- structure and permeability (D); 60.9% of the soils LAA, 70.1% of the soils PDA
- stoniness (P); 59.7% of the soils LAA, 57.1% of the soils PDA
- excess water (W); 35.0% of the soils LAA, 42.4% of the soils PDA
- moisture limitations (M); 2.4% of the soils LAA, 0.6% of the soils PDA
- slope (T); 1.0% of the soils LAA, 0.0% of the soils PDA
- consolidated bedrock (R); 0.7% of the soils LAA, 0.0% of the soils PDA

Soils are not rated for agricultural capability in the LSMOC portion of the LAA or the northern shoreline and much of the eastern shoreline of the LSM shoreline portion of the LAA. For the LMOC portion of the LAA and PDA, west of the centerline, soils are predominantly rated as Class 4. East of the centerline, much of the soil area is rated as Class 6 and 7 due to excess water, while the drier areas are rated predominantly as Class 4.

Table 6.3-15 Agricultural Capability in the LAA and PDA

Agricultural Capability Class	Agricultural Capability Class and Subclass	Summary of Areas					
		LAA			PDA		
		ha	% area	% of soil area	ha	% area	% of soil area
Class 1		--	--	--	--	--	--
Class 2		392	0.6	2.7	--	--	--
	2W	163	0.3	1.1	--	--	--
	2WP	86	0.1	0.6	--	--	--
	2TD	142	0.2	1.0	--	--	--
Class 3		--	--	--	--	--	--
Class 4		8,028	12.6	54.8	584	27.8	57.0
	4DP	7,820	12.2	53.3	584	27.8	57.0
	4N	207	0.3	1.4	--	--	--

Table 6.3-15 Agricultural Capability in the LAA and PDA

Agricultural Capability Class	Agricultural Capability Class and Subclass	Summary of Areas					
		LAA			PDA		
		ha	% area	% of soil area	ha	% area	% of soil area
Class 5		870	1.4	5.9	--	--	--
	5P	818	1.3	5.6	--	--	--
	5RP	25	0.0	0.2	--	--	--
	5W	26	0.0	0.2	--	--	--
Class 6		3,309	5.2	22.6	298	14.2	29.1
	6W	3,309	5.2	22.6	298	14.2	29.1
Class 7		805	1.3	5.5	8	0.4	0.8
	7M	348	0.5	2.4	6	0.3	0.6
	7R	163	0.3	1.1	--	--	--
	7W	293	0.5	2.0	2	0.1	0.2
Organic Soils		1,258	2.0	8.6	134	6.4	13.1
	O3W	299	0.5	2.0	--	--	--
	O5WD	959	1.5	6.5	134	6.4	13.1
Not Rated[1]		49,192	77.0	--	1,075	51.2	--
Totals – Assessment Area		63,852	100.0	--	2,099	100.0	--
Totals – Area Rated as Soils		14,661	23.0	100.0	1,023	48.8	100.0

NOTES:
Source: CanSIS 2019; MLI 2019
Areas and proportions may not add up to totals due to rounding
1. Not rated includes soil polygons that don't have an agricultural capability rating in the existing provincial (MLI 2019) and federal (CanSIS 2019) soil databases and areas covered by water. Soil areas not rated are organic and mineral soils located north of areas of existing agricultural land uses

Reclamation Suitability

Reclamation suitability ratings for the LAA and PDA are presented in Table 6.3-16. Topsoil within soil areas of the LAA and PDA are rated predominantly as a poor for reclamation suitability (70.2% of the soils LAA, 55.0% of the soils PDA). A significant portion of the assessment areas are rated as fair (17.0% of the soils LAA, 26.4% of the soils PDA) and good (12.8% of the soils LAA, 18.6% of the soils PDA). Reclamation suitability for topsoil is displayed in Appendix 6B, Figure 6.3B-13.

Subsoil within soil areas of the LAA and PDA are rated predominantly as poor for reclamation suitability (74.5% of the soils LAA, 68.3% of the soils PDA; Appendix 6B, Figure 6.3B-14). A substantial portion of the assessment areas are rated as fair (12.2% of the soils LAA, 16.6% of the soils PDA) and good (12.5% of the soils LAA, 15.0% of the soils PDA).

The reclamation suitability for soils in the LMOC portion of the LAA and PDA areas is generally limited by high calcium carbonate content and high stoniness in the till materials, while in the soils in the LSMOC portion of the LAA and PDA suitability is generally limited by pH, texture and calcium carbonate content.

Table 6.3-16 Reclamation Suitability in the LAA and PDA

Reclamation Suitability Class	Summary of Areas					
	LAA			PDA		
	ha	% area	% of soil area	ha	% area	% of soil area
Topsoil Suitability						
Good	4,088	6.4	14.4	355	16.9	18.6
Fair	5,063	7.9	17.8	507	24.2	26.5
Poor	19,218	30.1	67.7	1,050	50.0	54.9
Unsuitable	-	-	-	-	-	-
Not rated - Bedrock	157	0.2	-	-	-	-
Not applicable[1]	35,327	55.3	-	186	8.9	-
Totals – Assessment Area	63,852	100.0	-	2,099	100.0	-
Totals – Area Rated as Soils	28,368	44.4	100.0	1,913	91.1	100.0
Subsoil Suitability						
Good	3,418	5.4	12.8	287.3	13.7	15.0
Fair	3,962	6.2	14.0	320	15.2	16.7
Poor	19,107	29.9	67.4	1,306	62.2	68.3
Unsuitable	207	0.3	0.7	-	-	-
Not suitable - bedrock	1,831	2.9	-	-	-	-
Not applicable[1]	35,327	55.3	-	186	8.9	-
Totals – Assessment Area	63,852	100.0	-	2,099	100.0	-
Totals – Area Rated as Soils	26,694	41.8	94.1	1,913	91.1	100.0

NOTES:

Source: ratings were developed by Stantec following the approached presented in Soil Quality Criteria Relative to Disturbance and Reclamation (AAFRD 1987).

Areas and proportions may not add up to totals due to rounding

Ratings are based on dominant soil characteristics within each soil polygon

1. Not applicable areas include those classified as water and unclassified land

Sensitive Sites

A total of 116 sensitive sites were identified within the LAA, of which 12 are found within the PDA (Table 6.3-17). As discussed in Section 6.3.2.3, these are locations, features or areas, that are identified to be environmentally or socially important or sensitive to disturbance and require special consideration for protection and mitigation during Project construction and operation. No terrain-related sensitive sites were identified, including unique terrain features or steep slopes. Three areas of soils highly prone to wind erosion were identified in the LAA while only one is found in the PDA, in the central portion of the LSMOC PDA (Appendix 6B, Figure 6.3B-15). Numerous sandy soil areas were identified in the LAA (59) and PDA (7). Of the sites within the PDA, five are within the LMOC PDA and two are within the LSMOC PDA (Appendix 6B, Figure 6.3B-15). These soils can support unique vegetation communities and, once exposed, can be sensitive to wind erosion and difficult to revegetate (see Section 8.2). One saline soil area was identified in the LAA, along the western shoreline of Lake St. Martin within the LSMOC portion of the LAA; however, this is outside of the PDA. A total of 17 areas of exposed or shallow (within 1 m of the surface) bedrock were identified in the LAA, mostly along the eastern shoreline of Lake St. Martin in the LSM shoreline LAA; however, none of these areas appear to extend into the PDA.

Table 6.3-17 Sensitive Soil and Terrain Sites in the LAA and PDA

Sensitive Site Category	Sensitive Site Type	LAA	PDA
Unique terrain features		0	0
Steep slopes		0	0
Soils highly prone to erosion		3	1
	wind erosion (high to severe)	3	1
	water erosion (high)	0	0
Sandy soils		59	7
	coarse material (sands)	56	5
	coarse-skeletal materials (sands and gravels)	3	2
Saline soils		1	0
Shallow soils and exposed bedrock		17	0
	shallow bedrock (within 1 m of surface)	12	0
	exposed and shallow bedrock (within 1 m of surface)	5	0
Known and potential impacted sites		37	4
	active impacted sites	3	0
	suspected impacted sites	11	0
	closed impacted sites	6	0
	solid waste facilities	0	0
	wastewater management facilities	1	0
	manure-impacted (potential)	16	4
Totals – Assessment Area		116	12

A total of 37 known and potential impacted soils or sources of soil contamination occur within the LAA. The locations of these sites are presented in Appendix 6B, Figure 6.3B-15. These include:

- active (3), suspected (11) and closed (6) provincially and federally identified impacted or contaminated sites, all located along the western shoreline of Lake St. Martin within the LSM shoreline portion of the LAA, within the Little Saskatchewan First Nation and Lake St. Martin First Nation communities
- a single wastewater management site located along the western shoreline of Lake St. Martin within the LSM shoreline portion of the LAA, within the Little Saskatchewan First Nation
- sixteen areas of potential manure-impacted sites, all located within the LMOC portion of the LAA

Only potential manure-impacted sites were identified as known and potential impacted sites within the PDA, with four being identified within the LMOC PDA.

6.3.3 Project Interactions with Geology and Soils

Table 6.3-18 identifies for each potential effect, the Project components and physical activities that might interact with geology and soils during construction and operation and result in the identified environmental effect. These interactions are identified by check marks and are discussed in detail in Section 6.3.4 in the context of effects pathways, standard and project-specific mitigation and residual effects. A justification for no effect is provided following the table.

Table 6.3-18 Project-Environment Interactions with Geology and Soils During Construction and Operations

Project Components and Physical Activities	Environmental Effects	
	Change in Terrain Conditions	Change in Soil Quantity and Quality
Construction		
Site preparation of Project components[1] (development of the PDA prior to construction activities [e.g., removal of existing infrastructure, vegetation clearing and initial earthworks, development of temporary construction camp and staging areas])	✓	✓
Project-related transportation within the LAA (movement of trucks, equipment, bulk materials, supplies, and personnel within the LAA)	–	–
Construction of Project components[1] (physical construction of utilities, infrastructure, and other facilities)	✓	✓
Quarry development (blasting and aggregate extraction used for the construction of Project components[1])	ü	✓

Table 6.3-18 Project-Environment Interactions with Geology and Soils During Construction and Operations

Project Components and Physical Activities	Environmental Effects	
	Change in Terrain Conditions	**Change in Soil Quantity and Quality**
Water development and control (dewatering and realignment of existing water works)	✓	✓
Reclamation	✓	✓
Operations		
Operation and maintenance of the outlet channels (normal operational conditions when the outlet channels and associated infrastructure [e.g., water control structure gates are open, conveying water or are closed)	✓	–
Operation and maintenance of other Project components[1] (normal operations conditions associated with PR 239 and municipal road realignments, distribution line and bridges and culverts)	–	–
Project-related transportation within the LAA (movement of trucks, equipment, bulk materials, supplies, and personnel within the LAA)	–	–
Operation, maintenance, and reclamation of quarries	✓	✓

NOTES:
✓ indicates a potential interaction.
– indicates no potential interactions are expected.
[1] Components include: outlet channels, water control structures, distribution line, bridges and culverts, PR 239 and municipal road realignments, temporary construction camps and staging areas, and quarries.

Project-related transportation on existing highways and roadways within the LAA is not expected to create a pathway for effects to geology and soils. Manitoba Infrastructure standard construction specifications for dust control will be followed to reduce dust from Project-related transportation on gravel roads. This will reduce dust generated from Project-related traffic and potential deposition of dust in roadside ditches and natural and agricultural land uses adjacent to gravel roads used to service the Project during construction. Project-related transportation during operation will be minimal in relation to existing conditions.

Operation and maintenance of Project components, not including the channels, are not expected to interact with, or have a measurable effect on geology and soils.

The Project will not have interactions with geology. Preparation of the PDA and construction-associated transportation are above ground, thus above surficial and bedrock geology. Construction of the Project components other than LMOC and LSMOC (e.g., PR 239 and municipal roads realignment, Manitoba Hydro distribution line) involve excavation of surficial and bedrock geology, but ultimate interactions involve groundwater rather than geology; these interactions are identified and described in Section 6.4: Groundwater and Surface Water. Construction and operation of PR 239 and municipal roads realignment

as well as Manitoba Hydro distribution line have no interaction with geology as those activities occur above ground. The interactions summarized in Table 6.3-18 do not include areas outside of the PDA that may be affected by other Project components, such as rock quarries and borrow sites; quarries and borrow pits are related to the Project, although those are considered distinct projects to be permitted separately. Interactions with water development and controls, namely dewatering operations (during construction and operation), are identified and addressed in Chapter 6.4: Groundwater and Surface Water. Construction-related reclamation has no interaction with geology as it occurs above ground surface. Operations have no interactions with geology because related activities occur above ground surface.

6.3.4 Assessment of Residual Environmental Effects on Geology and Soils

6.3.4.1 Analytical Assessment Techniques

Project effects on terrain conditions included assessing changes to physical aspects of terrain, including unique landform features, as well as to geomorphological processes, including hydrological processes related to inundation and flooding. Terrain stability was evaluated following the guidelines provided by BC Ministry of Forests and BC Ministry of Environment (1999) to asses potential Project effects on terrain stability, namely associated with Project construction activities within the PDA.

Areas of drainage alteration within the LAA are estimated based on information provided by the groundwater and surface water assessment (Section 6.4) and these areas are assessed against LAA area (proportional analysis) and based on interactions and effects to terrain conditions and, in turn, land productivity, capability and use.

Ortho-imagery interpretation combined with a review of desktop data on topography and surface materials was used to identify potential unique landform features within the LAA to provide the basis to determine if these features may be disturbed by the Project (i.e., in proximity to or intersected by the PDA). Project-specific, high-resolution imagery was collected for LMOC and LSMOC portions of the PDA by Manitoba Infrastructure (2018). Google Earth Pro (2019) imagery was used for interpretation of areas within the LAA not covered by the Project-specific imagery.

Project effects on soil quantity and quality during construction in the LAA is assessed by means of changes to agricultural land capability, wind and water erosion risk and reclamation suitability. Agricultural capability (CLI 1969) provides a rating which provides an indication of the inherent capability of the soil-landscape to support agricultural crop production. The hierarchical classification constitutes a single measure based on multiple soil and landscape factors. If one or more factors are substantially affected by Project construction activities, the agricultural capability class will be affected. Agricultural capability class, therefore, provides a qualitative measure to assess Project effects to soils in landscapes under agricultural land use.

Reclamation suitability (AAFRD 1987) characterizes soil quality based on attributes of soil including pH, salinity, sodicity, texture, consistence, coarse fragment content and calcium carbonate equivalent (CCE). It provides an indication of the ability for the soil to support post-construction reclamation efforts.

Comparisons of areal extent by agricultural capability and reclamation classes are used to quantify residual effects from Project activities.

Wind erosion risk (Coote and Pettapiece 1989), water erosion risk (Wall et al. 2002) and compaction risk ratings (Cannon and Landsburg 1990; Archibald et al. 1997) are also calculated to inform the assessment, including identifying appropriate mitigation measures and evaluating potential changes to soil quantity (i.e., soil thickness parameters) and quality (i.e., estimating changes to agricultural capability and reclamation suitability ratings).

6.3.4.2 Change in Terrain Conditions

Changes to terrain conditions due to the Project could potentially occur within the PDA in areas where surficial materials are disturbed by Project activities. The assessment of changes to terrain pertains to the pre-disturbance landscape (i.e., those areas that remain in their natural state following Project construction). The assessment does not consider engineered Project components such as channels, dikes and berms, rather, issues such as soil stability for these engineered components are addressed by the engineering service providers.

Project Pathways

Project pathways of effects to terrain conditions are limited. Due to the subtle topography and nature of the materials within the LAA, the potential for terrain stability issues in natural landscape features is low and is not a pathway that needs to be considered further in the assessment. However, the stability of constructed Project infrastructure features, such as channel banks, berms, dikes and soil stockpiles, is an issue that needs to be considered and is being addressed by the engineering service providers for the Project design.

Based on a review and interpretation of Project orthoimagery, LiDAR and existing soil resource information, there were no unique landforms determined to be present within the LAA. The absence of unique landform features precludes the potential for effects to those features.

The primary pathway for Project effects to terrain conditions is through alterations to natural drainage paths and shallow groundwater flow. Hydrologic processes of seepage and inundation are important within the LAA, and the presence of the LMOC and LSMOC will alter these processes locally, in the vicinity of these components. Regional surface and shallow groundwater flows occur in a general west to east direction within the LMOC portion of the LAA and a general east to west direction within the LSMOC portion of the LAA. The presence of the outlet channels will affect the movement of surface and shallow groundwater flow. Unmitigated, this will result in wetting-up on the upgradient side of the channels and drying-down on the downgradient side of the channels. This would be expected to result in inundation and flooding on the upgradient sides of the channels—the west side of LSMOC and east side of LMOC—and adversely affecting soil capability and productivity for current land uses, including natural vegetation and agricultural crop production, haylands and pasture. Conversely, this could result in increased droughtiness in soils on the downgradient side of the channels and affect soil capability and productivity for natural vegetation and agriculture.

The presence of the EOC has been confirmed to affect local drainage conditions. Post-construction analysis of vegetation has indicated drainage has been altered up to 1,600 m upgradient to the east of this structure (see Section 8.2). Effects to drainage downgradient of the channel have been found to extend to a distance of up to 600 m. No mitigations to reduce the effects to natural surface drainage paths and shallow subsurface water flow were incorporated as part of this emergency channel design, so these effects will be less for the LSMOC that will have drainage channels incorporated into the design.

Mitigation

MI's Environmental Management Program and associated PERs are described in Chapter 3, Section 3.7. Mitigation measures provided in various CEMPs that will developed for the Project, including the PERs (Manitoba Infrastructure 2019) are generally not applicable to effects to terrain conditions.

Standard and Project-specific construction mitigation that lessen residual effects on terrain stability include the following:

- Engineering design of Project infrastructure including berms, dikes, ditches and channels will be completed to reduce the potential for soil stability issues.
- Channel banks, berms, dikes and ditches will be seeded and revegetated with an appropriate native seed or erosion control mix to improve stability of these features, unless these features are being stabilized by rip-rap.
- Drainage channels and realignments on upgradient sides of LMOC and LSMOC will channel water downslope and into the channels to minimize the risk of inundation and flooding as a result of channel presence
- Surface drainage patterns for other Project components will be re-established where possible.

Project Residual Effects

As effects to terrain stability and unique landform features have been determined to not be a concern, Project residual effects to terrain conditions are expected to be limited to drainage alterations as a result of the presence of LMOC and LSMOC. There are no residual effects to terrain conditions during the construction phase of the Project.

Residual effects are expected following the implementation of general and Project-specific mitigation during Project operation related to the presence of LMOC and LSMOC as a result of alterations to surface drainage pathways and shallow subsurface drainage flow.

LMOC

Following the implementation of mitigation, composed primarily of surface drainage structures on the upgradient side of the channel, it is anticipated that residual effects to upgradient (i.e., west side of the LMOC) surface drainage and shallow subsurface flow will be limited in extent to the channel ROW or PDA (see Section 6.4 Groundwater and Surface Water). Effects to subsurface drainage in the till materials with

discontinuous sand lenses are expected to be localized. Further, surface drainage will be improved near the drainage structure.

However, residual effects downgradient (i.e., east side) of the LMOC are expected to extend beyond the channel ROW or LMOC PDA. It is challenging to model or otherwise predict changes to near-surface hydrology in these mineral and organic soil complexes; therefore, it is unknown to what distance these effects will extend perpendicular to the channel (see Section 6.4 Groundwater and Surface Water). Further, the EOC does not provide a useful example of potential changes to the water balance in the vicinity of the LMOC owing to the different terrain, soil and hydrologic conditions between these areas. The change in water balance east of the LMOC PDA may result in changes to water levels in wetlands (see Section 6.4 Groundwater and Surface Water). Should this drying-down occur it could, in turn, adversely affect soil productivity for natural vegetation but have positive effects to agricultural capability.

Project planning will include the development of a Groundwater Management Plan (GWMP) and a Surface Water Management Plan (SWMP), which will provide for management of drainage during construction and operation. Additionally, monitoring during Project construction and operation will allow for these effects to be better understood. Additional mitigation may be applied as this understanding develops.

LSMOC

A drainage structure on the upgradient side (i.e., east side) of the LSMOC will provide Project-specific mitigation for increased soil wetness, and ultimately inundation and flooding on this side of the channel structure. However, a high proportion of poorly and very poorly drained soils developed on organic soils (i.e., deep organics and organic materials overlying lacustrine and till materials) suggest that, even with mitigation, residual effects to drainage upgradient of the channel will occur beyond the channel ROW or PDA. As mentioned above for the LMOC, it is challenging to model or otherwise predict changes to near-surface hydrology in these organic soil complexes (see Section 6.4 groundwater and surface water). Additionally, there is the potential of artesian groundwater contributing in this area, which complicates understanding of the conditions. The LSMOC traverses a similar terrain complex as the EOC. Therefore, the EOC provides a useful example of what may occur along the LSMOC. However, the upgradient effects should be minimized and limited compared to the effects assessed on the EOC, due to the presence of the drainage structure incorporated as design mitigation. It is reasonable to assume that the downgradient effects at the LSMOC will be similar to the unmitigated conditions assessed at the EOC.

Natural surface and shallow subsurface drainage flow may be affected along the entire approximately 24 km length of LSMOC, with effects to drainage not expected to occur beyond 500 m upgradient or downgradient of the channel (see Section 6.4 Groundwater and Surface Water). This would be expected to affect drainage over an area of up to approximately 1,200 ha on either side of the channel (or 2,400 ha in total). Therefore, on the east side of the channel, there is a potential for increased soil wetness and inundation and flooding of an area of up to 1,200 ha, while on the west side of the channel up to 1,200 ha in area would be expected to experience a drying- down, resulting in reduced surface and near-surface moisture conditions.

The very poorly, poorly, and imperfectly drained soils in the area of residual effects from the LSMOC are expected to experience increased soil wetness upgradient of the channel resulting in inundation and flooding as a result of alterations to drainage. Conversely, downgradient of the channel effects from decreased soil wetness are expected. Wetting-up and drying down will both adversely affect soil capability and productivity for natural vegetation and wetlands in this area (see Section 8.2: Vegetation). These effects are not expected to alter drainage in the entire 2,400 ha area; rather, effects will occur within portions of the area as dictated by local flow conditions, similar to what has been noted on the EOC.

6.3.4.3 Change in Soil Quantity and Quality

Specific locations of rock quarries and borrow materials, and temporary camps and staging areas to be used for the Project are not yet identified, but the following text describes potential changes in a general sense.

The predominant land uses in the LMOC portion of the LAA and potential locations of Lake Manitoba rock quarries and borrow material areas, and temporary construction camps and staging areas, is agricultural. In the LSMOC portion of the LAA and potential locations of Lake St. Martin rock quarries and borrow material areas, and temporary construction camps and staging areas, natural vegetation predominates. For the LSM shoreline portion of the LAA, land use is mixed, with natural vegetation predominating on the eastern and northern shorelines, and agricultural land use occurring on the western and southern shorelines[2]. As such, different primary parameters are used to assess changes to soil quantity and quality for the LMOC portion of the LAA and associated Lake Manitoba Project components (predominantly agriculture) and LSMOC portion of the LAA and associated Lake St. Martin Project components (predominantly natural vegetation). For the LMOC portion of the LAA and associated components, where agriculture predominates, effects to soils are assessed using agricultural capability class ratings. For the LSMOC portion of the LAA and associated components, changes are assessed using reclamation suitability.

Conversion of areas of soils supporting agricultural and natural vegetation land uses to industrial land use is an expected outcome of constructing the Project components, including the LMOC, LSMOC, PR 239 and municipal road alignments, Lake Manitoba drainage realignment and Lake St. Martin drainage realignment. This conversion will affect these areas through Project operation.

As previously mentioned, specific locations of rock quarries and borrow materials, and temporary camps and staging areas to be used for the Project are not yet identified. However, pathways to effects can be identified based on a general understanding of the Project activities associated with these components and an assumption that they will be located in areas characterized in existing conditions. Further, it is assumed that the areas on which these components are developed can be reclaimed for pre-Project land

[2] The assessment of geology and soils does not consider built-up areas such as the developed areas within the Indigenous communities on reserve lands.

uses, as feasible, or returned to a state that is compatible with adjoining land uses, when they are no longer required to support Project construction or operation.

Project Pathways

Construction and presence of Project components and infrastructure will affect soils, and, in turn, the agricultural capability and reclamation suitability of these soils. There are multiple pathways for Project effects through the construction and operations phases of the Project.

During the construction phase, site preparation and construction of Project components will require clearing, topsoil stripping, soil excavation, and soil handling and stockpiling. These components include LMOC, PR 239 and municipal road realignments, and LSMOC, as well as rock quarry and borrow material sites and temporary construction camps and staging areas. These activities will affect existing capability of the land through changes in organic and mineral topsoil and upper subsoil thickness. Loss of soil quantity (thickness/depth/volume) and/or loss of soil quality can result from various mechanisms, including improper soil stripping, excavation and handling, admixing, compaction of topsoil and upper subsoil, and wind and/or water erosion of disturbed, exposed and stockpiled soils. Changes to soil properties including texture, organic matter content and structure can affect wind erosion risk. Similarly, water erosion risk may be affected by changes to topsoil texture, organic matter content, slope, structure and related infiltration characteristics. The loss of vegetative cover, particularly in areas of permanent, natural vegetation, will result in soils being more susceptible to erosion losses from wind and water.

During post-construction reclamation activities and reclamation of quarries and borrow sites, soil replacement activities are important in re-establishing the surficial soils for re-vegetation in natural landscapes, soil stockpiles, berms and dikes, or return to agricultural land uses, where applicable. Proper soil replacement will maintain topsoil and upper subsoil quantity (thickness/depth) and quality (e.g., organic matter content), to the extent feasible.

For permanent Project components, soil areas will be lost for agricultural or natural vegetation land uses throughout operations. The Project is a permanent installation with an indefinite operation life cycle; decommissioning of physical infrastructure is not planned. However, if the Project is decommissioned in the future, these areas could hypothetically be reclaimed for pre-Project land uses using salvaged and stockpiled soils.

Loss of pre-Project land uses will occur at rock quarry and borrow material sites, as well as at temporary construction camps and staging areas. These losses will be temporary, and areas will be reclaimed and returned to pre-Project land uses following the construction phase, or during the operation phase, when they are no longer required to support the Project.

The LMOC PDA is located within an area of livestock production. This includes cattle feedlots and the presence of manure stockpiles. Soils under cattle feedlots and under manure stockpiles are considered potentially manure-impacted sites due to the likelihood of high soil nutrient concentrations, such as nitrogen and phosphorus. Potentially manure-impacted sites have been identified as sensitive sites (Appendix 6B, Figure 6.3B-13; Section 6.3.2.4). Disturbance such as excavation and stockpiling of these

potential manure-impacted soils may result in increased potential for nutrient runoff and entry into surface waters, which could in turn affect water quality. The translocation of manure stockpiles is addressed under land and resource use (see Section 9.2).

No known or potential federally or provincially identified impacted or contaminated sites occur within the PDA. There may be other unknown sites of existing, potential and former impacts to soil or sources of contamination within the LAA and PDA. The encountering of previously identified or unknown impacted or contaminated sites during Project construction will be addressed through the CEMPs.

The Project will lower water levels in Lake St. Martin during flood conditions. The reduction of lake levels in Lake Manitoba during flood conditions, in a manner that reduces inundation of lands surrounding Lake St. Martin, due to the operation of the LMOC and LSMOC is a desired positive outcome and objective of the Project.

Under the current operating conditions without the outlet channels, Lake St. Martin is above the top of its desired operating range 24.4% of the time; with the operation of the outlet channels, the amount of time that Lake St. Martin is above the top of its desired operating range changes to 5.2% (see Section 6.4: Groundwater and Surface Water; Manitoba Infrastructure 2019b).

Review of the modelled results showed that operation of the new outlet channels will decrease the peak water levels substantially in high flood years, and reduce peak levels in all years, which will increase the amount of time the lake is within its desired operating range. For the 2011 flood event, the calculated decrease in the peak water level on Lake St. Martin was 0.76 m (2.5 ft). This is a decrease of 27.5 km^2 (2,750 ha) in the amount of area that would have been inundated by flood waters (see Section 6.4 Groundwater and Surface Water; Manitoba Infrastructure 2019b).

For a minor flood year (Lake Manitoba elevation between 812.5 ft and 813.5 ft, or 247.65 m and 247.95 m), the average decrease in water level is 0.52 m (1.7 ft). This is a decrease of 21.4 km^2 (2,140 ha) in the amount of area that would have been inundated by flood waters (see Section 6.4 Groundwater and Surface Water; Manitoba Infrastructure 2019b).

During non-flood conditions (Lake Manitoba less than 812.5 ft, or 247.65 m), the average decrease in water levels is 0.06 m (0.21 ft). The area affected by this change was not reported (see Section 6.4: Groundwater and Surface Water; Manitoba Infrastructure 2019b) but is expected to be less than a few square kilometres.

These reductions in lake levels will affect soils within the LSM shoreline portion of the LAA. A reduction in flood levels will have a positive effect associated with the return of soil capability and productivity for natural vegetation and agricultural land uses adversely affected during pre-Project conditions, particularly during flooding conditions.

Shoreline erosion is a process that will continue following construction of the Project. However, a reduction in lake levels and reduction in the frequency and level of flood events due to the Project will occur. This is expected to have a neutral effect on shoreline erosion.

Mitigation

MI's Environmental Management Program and associated PERs are described in Section 3.7. General mitigation measures will be provided in various CEMPs that will developed for the Project by Manitoba Infrastructure and Project contractors. The PER (Manitoba Infrastructure 2019) is being developed to achieve regulatory compliance, meet requirements of Project approvals, permits, licences and authorizations and integrate environmentally responsible construction practices into planning. The PER include mitigation measures to address potential effects to soil and these are summarized as follows:

- Designated areas and access
  - Topsoil in designated areas[3] will be stripped and stockpiled for later reuse in site restoration. Granular material or other surface preparation, as approved by the Engineer, will be placed to ensure all weather accessibility.
  - Locations within Designated Areas where equipment, hazardous material and/or wastes will be stored or maintained will be underlain with at least 30 cm of impermeable soil[4] or approved equal and lined with an impermeable groundsheet to contain spills and minimize cleanup costs. Hazardous materials must also comply with the additional requirements outlined in Machinery, Fuel Storage, Materials Handling and Storage, Spill Response and Remediation (see below).
  - Immediately following construction, all salvaged and stockpiled organics and soils which were set aside during site development will be spread back over the area from which they originated and will be seeded. If local soils are not available, other organic-based covers may be used to allow seed germination.
- Clearing, grubbing and brush disposal
  - All grubbed organic and topsoil layers with leaf litter and root mass will be stockpiled in appropriate locations and retained for reclamation efforts.
  - Slash will be piled in a manner that allows for clean, efficient burning of all material. Avoid mixing soil into the slash.
- Erosion and sediment control:
  - Erosion and sediment control measures include maintenance of vegetation cover, where possible, long-term, temporary or emergency stabilization of soil, other erosion and sediment controls (e.g., erosion control blankets), setback of soil stockpiles from waterbodies, revegetation of disturbed areas, and runoff diversion to prevent undesirable soil movement or soil releases and discharges to a waterbody.
  - Stripped topsoil will be stored and used in the reclamation of the site.

[3] Designated Areas include, but are not necessarily limited to, laydown and staging areas, waste storage areas, fuel storage and refueling area, work camps and others as required by the Project Engineer
[4] Till or overburden should be used

  - Spills, leads or releases will be reported within 24 hours and contaminated soil will be appropriately disposed of at a licensed facility or stored in a designated storage area to prevent secondary contamination.
- Site decommissioning (temporary works):
  - Designated areas leveled to natural or pre-existing grade and slope as part of decommissioning. Stockpiled topsoil and other organic matter that had been removed from the site will be spread to promote natural re-establishment of vegetation.
  - Revegetation and vegetation maintenance.
  - Immediately following construction and decommissioning, salvaged and stockpiled organics and soils set aside during site development spread back over the area from which they originated and will be seeded. If local soils are not available, other organic-based covers may be used to allow seed germination.

Additional plans to the CEMPs will be developed by Manitoba Infrastructure or required to be prepared by Project contractors and followed to ensure environmental protection and regulatory compliance during Project construction. The CEMP will include soil-related plans such as the Environmental Protection Plan (EPP), Access Management Plan, Quarry Management Plan, Sediment Management Plan, Revegetation Plan, Dust Control Plan, Waste Management Plan, Hazardous Materials Management Plan, Emergency Response Plan, and Construction Decommissioning Plan.

Mitigation for permanent loss of soils supporting agricultural land or natural vegetation and wetlands is addressed in the land and resource use assessment (Section 9.2) and vegetation assessment (Section 8.2), respectively.

The following specific mitigation measures provide additional measures to reduce the potential for residual effects to soil quality and quantity:

- Strip and stockpile topsoil for future use in the reclamation of disturbed areas (i.e., LMOC, LSMOC, PR 239 and municipal road realignments, rock quarry and borrow areas, temporary construction camps and staging areas):
  - Mineral and organic topsoil horizons (i.e., O, LFH, A horizons) will be stripped and salvaged separately from subsoils to prevent admixing and stockpiled separately for later use in reclamation of disturbed areas, including temporary and permanent Project components. Only necessary volumes of topsoil will be stripped and stockpiled.
  - Topsoil replacement plans will be developed for the reclamation of temporarily disturbed areas and permanent berms, dikes and ditches (i.e., those not being protected by rock rip-rap). These plans will be addressed under planned CEMPs. Topsoil replacement in disturbed areas will promote revegetation.

- During subsoil excavation, better quality upper subsoil will be segregated from poorer quality subsoil (i.e., cemented till) using separate lifts where subsoil is required for recontouring sites to be reclaimed. These lifts will be stockpiled separately for potential, future reclamation activities (i.e., LMOC and/or LSMOC decommissioning and in-filling), as required. Only necessary volumes of upper subsoil will be excavated and stockpiled.
- The area of disturbance within the PDA will be kept to the smallest possible size to complete Project construction.
- If compaction of soils occurs beyond the PDA in areas under agricultural land use, additional mitigation or rehabilitation measures will be identified.
- Erosion and sediment control for general construction areas will be addressed through the CEMP and associated planning documents (PERs, Environmental Protection Plan, Revegetation Plan or an Erosion and Sediment Control Plan).
- Soil stockpiles will be stabilized by contouring (Project design side slopes) and re-vegetation. If necessary, soil tackifiers, erosion blankets or other means will be used to control erosion prior to revegetation.

The following specific mitigation measures are intended to reduce the potential for nutrient runoff from soils impacted by high nutrient concentrations from livestock feedlot operations and manure stockpiles:

- Where locations of manure stockpiles and cattle feedlots within the PDA are confirmed, these areas of potential manure-impacted soils will be delineated.
- Manure stockpiles should be relocated from the PDA prior to construction.
- Soils within areas delineated as potential manure-impacted sites will be sampled and analyzed for nutrient concentrations and other pertinent parameters.
- A plan for treatment and/or disposal of impacted soils will be developed. This may include excavation and spreading of identified impacted soils onto agricultural lands outside of the LMOC PDA, as appropriate.

Additional details on the planned mitigation for Project effects on soil will be developed as part of the CEMPs following filing of the EIS and prior to construction.

Project Residual Effects

Following the implementation of general and Project-specific mitigation, there are residual effects on soil quality and quantity.

Agricultural Capability in LMOC portion of the Soils LAA

Changes in agricultural capability at post-construction relative to existing conditions is presented in Table 6.3-19. These changes are attributable to the presence of Project infrastructure within the LMOC PDA. In the PDAs for the LMOC and PR 239 realignment, land with agricultural capability will be permanently lost. While agricultural capability of the land could be restored through post-Project

reclamation, there are no plans to decommission the Project. While changes to agricultural capability represent only 1.6% of the LAA, they represent 7.0% of the area rated for agricultural capability. This consists of a loss of 1,023 ha of land with agricultural capability, comprising 584 ha of Class 4 land, 298 ha of Class 6 land and 134 ha of Organic soils, which may have some limited capability for agriculture.

The results summarized in Table 6.3-19 do not include land areas outside the LMOC PDA that may be affected by other Project components, including rock quarries and borrow sites, and temporary construction camps and staging areas. These components are temporary disturbances and if these components are in areas rated for agricultural capability, that equivalent land capability will be restored with the implementation of general and Project-specific mitigation measures.

As Project activities with the potential to degrade agricultural capability by reducing soil quality or quantity by erosion losses, compaction, or soil excavation and handling, for example, are not expected to extend beyond the LMOC and PR 239 and municipal road alignments PDAs, there are no additional Project residual effects on agricultural capability than those presented in Table 6.3-19.

Effects to soil quantity and quality which in turn potentially degrade agricultural capability are of relevance to agricultural production and agricultural landowners. As such, the effects of change in areas of agricultural capability classes on agricultural land use is assessed in Section 9.2.

Table 6.3-19 Change in Agricultural Capability Classes in the LAA

Agricultural Capability Class	Agricultural Capability Class and Subclass	LAA - Existing Conditions	LAA – Post-Construction[2]	LAA - Change in Areas		
		ha	ha	ha	% of LAA	% of Area of LAA Rated for Agricultural Capability
Class 1		0	0	0	0.0	0.0
Class 2		392	392	0	0.0	0.0
	2W	163	163	0.0	0.0	0
	2WP	86	86	0.0	0.0	0
	2TD	142	142	0.0	0.0	0
Class 3		0	0	0	0.0	0.0
Class 4		8,028	7,444	-584	-0.9	-4.0
	4DP	7,820	7,236	-0.9	-4.0	-4
	4N	207	207	0.0	0.0	0
Class 5		870	870	0	0.0	0.0
	5P	818	818	0.0	0.0	0
	5RP	25	25	0.0	0.0	0
	5W	26	26	0.0	0.0	0

Table 6.3-19 Change in Agricultural Capability Classes in the LAA

Agricultural Capability Class	Agricultural Capability Class and Subclass	LAA - Existing Conditions	LAA – Post-Construction[2]	LAA - Change in Areas		
		ha	ha	ha	% of LAA	% of Area of LAA Rated for Agricultural Capability
Class 6		3,309	3,011	-298	-0.5	-2.0
	6W	3,309	3,011	-0.5	-2.0	-2
Class 7		805	797	-8	0.0	-0.1
	7M	348	342	0.0	0.0	0
	7R	163	163	0.0	0.0	0
	7W	293	291	0.0	0.0	0
Organic Soils		1,258	1,124	-134	-0.2	-0.9
	O3W	299	299	0.0	0.0	0
	O5WD	959	825	-0.2	-0.9	-1
Not rated[1]		49,192	50,215	1,023	1.6	7.0
Totals - assessment area		63,852	63,852	0	0.0	0.0
Totals - area rated for agricultural capability		14,661	13,637	-1,023	-1.6	-7.0

NOTES:

Areas and proportions may not add up to totals due to rounding

1. Not rated includes soils in areas not covered by the rural municipality databases and is not provided as an agricultural capability rating in existing soil databases. This area roughly corresponds to the area of the LAA and PDA that does not have agricultural land uses

2. Areas of the LAA rated for agricultural capability in existing conditions that in the PDA are classified as not rated for post-construction consideration

Reclamation Suitability in LSMOC portion of the LAA

Changes in reclamation suitability at post-construction relative to existing conditions is presented in Table 6.3-20. These changes are attributable to the presence of Project infrastructure in the LSMOC PDA. This component will be permanent and there are no plans for decommissioning. However, the reclamation suitability of soils in this area will not be lost. Through general and Project-specific mitigation, organic and mineral topsoil materials and good quality upper subsoil materials will be excavated and stored in separate soil stockpiles adjacent to the channel, as necessary to support revegetation on soil stockpiles. These soil materials could be used for future reclamation activities should the structure be decommissioned at some point in the future.

A total of 1,911 ha is estimated to be affected by soil disturbance in the LSMOC portion of the LAA including the PR 239 realignment. This includes 355 ha, 505 ha, and 1,050 ha of topsoil rated as good,

fair and poor for reclamation suitability, respectively. For subsoils, it is 287 ha, 317 ha and 1,306 ha rated as good, fair and poor for reclamation suitability, respectively. The total area of 1,911 ha is 3.0% of the LAA or 7.0% of the area of the LAA rated as soils (i.e., water and unclassified land removed).

For construction reclamation purposes, it is important that adequate amounts of sufficient quality soils are salvaged and stored to facilitate reclamation and revegetation needs. Amounts of soil required will be identified as part of detailed Project design, including the Revegetation Plan.

The change areas in Table 6.3-20 do not include land areas outside of the PDA that may be affected by other Project components, including rock quarries and borrow sites, and temporary construction camps and staging areas. These components are temporary disturbances and soils will be reclaimed to equivalent land capability for natural vegetation, through the implementation of general and Project-specific mitigation measures. As Project activities with the potential to degrade reclamation suitability by reducing soil quality or quantity by erosion losses, compaction, or soil excavation and handling, for example, are not expected to extend beyond the LSMOC PDA, there are no additional Project residual effects on reclamation suitability than described above and presented in Table 6.3-20.

Table 6.3-20 Change in Reclamation Suitability Classes

Reclamation Suitability Class	Summary of Area				
	LAA - Existing Conditions	LAA - Post-construction	LAA - Change in Areas		
	ha	ha	ha	% of LAA	% of area of LAA rated as soils
Topsoil Suitability					
Good	3,503	3,147	-355	-0.6	-1.3
Fair	4,648	4,143	-505	-0.8	-1.8
Poor	19,218	18,168	-1,050	-1.6	-3.8
Unsuitable	0	0	0	0.0	0.0
Not rated - marsh	376	374	-2	0.0	0.0
Not rated - bedrock	157	157	0	0.0	0.0
Not applicable[1]	35,951	37,864	1,913	3.0	7.0
Totals - assessment area	63,852	63,852	0	0.0	0.0
Totals - area rated as soils	27,368	25,458	-1,911	-3.0	-7.0
Subsoil Suitability					
Good	3,418	3,131	-287	-0.4	-1.0
Fair	3,346	3,029	-317	-0.5	-1.2
Poor	20,396	19,091	-1,306	-2.0	-4.8
Unsuitable	207	207	0	0.0	0.0

Table 6.3-20 Change in Reclamation Suitability Classes

Reclamation Suitability Class	Summary of Area				
	LAA - Existing Conditions	LAA - Post-construction	LAA - Change in Areas		
	ha	ha	ha	% of LAA	% of area of LAA rated as soils
Not rated - marsh	376	374	-2	0.0	0.0
Not rated - bedrock	157	157	0	0.0	0.0
Not applicable[1]	35,951	37,864	1,913	3.0	7.0
Totals - assessment area	63,852	63,852	0	0.0	0.0
Totals - area rated as soils	27,368	25,458	-1,911	-3.0	-7.0

NOTES:
Areas and proportions may not add up to totals due to rounding
Ratings are based on dominant soil characteristics within each soil polygon
1. Not applicable areas include those classified as water and unclassified land
2. Areas of the LAA rated for agricultural capability in existing conditions that in the PDA are classified as not rated for post-construction consideration

Potential Project residual effects to soil quantity and quality during construction can result from activities involving soil stripping and excavation, handling, stockpiling and replacement, in the cases where soils are being reclaimed for vegetation rehabilitation. These residual effects may occur at permanent Project components, including the outlet channels and PR 239 and municipal realignments, as well as at temporary components including rock quarries and borrow sites, as well as temporary construction camps and staging areas. These effects to soil quantity and quality may occur through such mechanisms as over-stripping, improper soil handling, admixing, wind and water erosion losses and compaction. In their natural condition, soils in the PDA have low to negligible risk to wind erosion and predominantly very low risk to water erosion. However, once exposed and stockpiled, the risk for erosion losses will increase appreciably. Approximately half of the soils in the PDA and LAA (predominantly the organic soils) are at high risk of degradation through compaction. However, construction traffic is not expected outside of the PDA and high compaction risk for organic soils being stockpiled is not a concern as these soils will generally be mixed with mineral soils for reclamation purposes. General and Project-specific mitigation should limit soil quantity and quality losses; therefore, these losses are not expected to be substantive.

There are no residual effects on soil quantity and quality during operation. This conclusion assumes surface soils associated with Project features such as channels, berms, dikes, soil stockpiles, and reclaimed areas, such as rock quarries, borrow sites, temporary construction camps and marshalling yards, have been adequately stabilized and protected from soil erosion by wind and/or water.

A reduction in flooded area around Lake St. Martin due to the Project is estimated to be 2,750 ha during major flood events (i.e., the 2011 flood level when the lake reached 245.48 m) and 2,140 ha during minor flood events (i.e., when the lake levels are at 244.43 m without the Project). This will affect reserve lands, including those associated with the Indigenous communities of Lake St. Martin First Nation, Little Saskatchewan First Nation and Pinaymootang First Nation. The reduction in lake levels will allow for the return of soil capability and productivity for flooded soils over the long term and is a positive residual effect. Shoreline erosion is a process that will continue following construction of the Project. However, a reduction in lake levels and reduction in the frequency and level of flood events due to the Project will occur. This is expected to have a neutral effect on shoreline erosion.

Potential Manure-Impacted Soils

With the implementation of mitigation, there will not be residual effects from nutrient runoff as a result of construction activities and operation of the Project in areas of soils potentially impacted by high nutrient concentrations from cattle feedlot operations and the presence of manure stockpiles. Through the implementation of mitigation, these potentially impacted soils will be identified, delineated, excavated and properly disposed of prior to the commencement of construction activities.

6.3.4.4 Summary of Project Residual Effects

Table 6.3-21 summarizes the residual environmental effects on geology and soil during construction and operations.

Change in terrain conditions

Residual effects to terrain conditions will be limited to alterations to drainage through the operation phase in relation to the presence of the LMOC and the LSMOC. These residual effects are considered adverse in direction, will persist over the long-term (i.e., through Project operation) and are irreversible. In other words, soil capability and productivity are not expected to return to existing conditions (Table 6.3-21). The effects are not sensitive to timing and are expected to occur continuously throughout the operation phase. The effects will occur over an estimated area of up to 2,400 ha within the LSMOC portion of the LAA, representing approximately 4% of the total LAA area and up to between approximately 40 and 50% of the LSMOC portion of the LAA. An undetermined but limited area within the LMOC portion of the LAA is expected to be affected. As the effects resulting from alterations in drainage will extend into the LAA, they are considered to be of high magnitude. The effects will occur in both disturbed, agricultural landscapes, and undisturbed areas of natural vegetation and wetlands. The residual effects to vegetation and wetlands and agriculture are assessed in Section 8.2 (vegetation) and Section 9.2 (land and resource use), respectively.

Change in soil quantity and quality

Residual effects to soil quantity and quality will include the following:

- adverse effects due to the loss of 1,023 ha of soils with agricultural capability within the LMOC portion of the LAA (7.0% of the area rated for agricultural capability within the LAA). As these effects will be confined to the LMOC PDA they are considered to be of moderate magnitude
- adverse effects due to soil disturbance of 1,911 ha of soils with reclamation suitability within the LSMOC portion of the LAA (7.0% of the soils area within the LAA). These effects will be confined to the LSMOC PDA. As the effects to soil quality and quantity will not limit the ability to reclaim and rehabilitate areas disturbed by the Project, they are considered of moderate magnitude
- positive effects due to return of soil capability and productivity for agricultural and natural vegetation over the long-term in the LSM shoreline portion of the LAA due to reduced flooding levels on Lake St. Martin. This will affect between approximately 2,140 and 2,750 ha, which represents between 3.5 and 4.5% of the LAA or 13 to 16% of the LSM Shoreline LAA.

These residual effects are considered adverse to positive in direction and will persist over the short-term to the long-term (i.e., through Project operation; Table 6.3-21). The effects are generally considered irreversible for the permanent Project components; in other words, soil capability and productivity are not expected to return to existing conditions. The effects are not sensitive to timing and are expected to occur infrequently during the construction phase (i.e., soil excavation and handling) to sporadically/intermittently throughout the operation phase (i.e., changes to flooding levels). The effects will occur in both disturbed, agricultural landscapes, and undisturbed areas of natural vegetation and wetlands.

The residual effects to vegetation and wetlands and agriculture as a result of Project effects to soils are assessed in Section 8.2 (vegetation) and Section 9.2 (land and resource use), respectively.

Table 6.3-21 Summary of Project Residual Effects on Geology and Soil

Residual Effect	Residual Effects Characterization								
	Project Phase	Direction	Duration	Magnitude	Timing	Geographic Extent	Frequency	Reversibility	Ecological Context
Change in terrain conditions	O	A	LT	H	NS	LAA	RC	I	U and D
Change in soil quantity and quality	C and O	A and P	LT	M	NS	PDA and LAA	SI	I	U and D

KEY
See Table 6.3-2 for detailed definitions

Project Phase
C: Construction
O: Operation

Direction:
P: Positive
A: Adverse
N: Neutral

Duration:
ST: Short-term
MT: Medium-term
LT: Long-term

Magnitude:
N: Negligible
L: Low
M: Moderate
H: High

Timing
NS: No sensitivity
MS: Moderate sensitivity
HS: High sensitivity

Geographic Extent:
PDA: Project development area
LAA: local assessment area
RAA: regional assessment area

N/A: Not applicable

Frequency:
IF: Infrequent
SI: Sporadic/Intermittent
RC: Regular/Continuous

Reversibility:
R: Reversible
I: Irreversible

Ecological Context:
U: Undisturbed
D: Disturbed

6.3.5 Potential Geology and Soils Effects to Federal Lands

Federal Lands within the geology and soils RAA consist of the reserve lands associated with the Indigenous communities of Lake St. Martin First Nation, Little Saskatchewan First Nation, Pinaymootang First Nation and Dauphin River First Nation. Locations of these lands are presented in Appendix 6B, Figure 6.3B-1 and Figure 6.3B-2.

There are no potential effects to geology on Federal Lands.

Potential soils effects to Federal lands are limited to the LSM shoreline portion of the LAA and include the reserve lands associated with the Indigenous communities of Lake St. Martin First Nation, Little Saskatchewan First Nation and Pinaymootang First Nation. A reduction in lake levels and the frequency and levels of floods will allow for the return of soil capability and productivity over the long term and is a positive residual effect. The Project is expected to have a neutral effect on shoreline erosion on Lake St. Martin.

6.3.6 Prediction Confidence

Based on available data and scientific information, the confidence level of prediction of potential effects on geology along the LMOC portion of the Project is high. Less PDA-specific data was available to assess the potential effects on geology along the LSMOC. Despite that status, the confidence level of prediction of potential effects on geology is considered high. Current data and interpretation allow qualitative identification of potential effects on geology with high confidence.

Prediction confidence on soils is limited as the assessment was based largely on existing and available, desktop soil resource information of limited scale. However, some soil and terrain field information collected by engineering service providers was used to improve the confidence in, and reliability of, existing information sources. Additionally, soil analytical information from geotechnical investigations is expected from the engineering service providers post-EIS filing but prior to Project construction and this information can be used to confirm and update pertinent information in the assessment. Additional in-field and/or finer scale soil information would improve the reliability of information and confidence in interpretation for the soil and terrain assessment. For example, field investigations would allow for more confidence in identification of sensitive sites and refinement of their boundaries. However, additional field investigations or finer scale soil information would not be expected to materially impact the findings or key conclusions of assessment.

Detailed soil information collected by engineering service providers as part of ongoing geotechnical investigations will be used to support Project planning, design and mitigation. This detailed soil information will be used to further assess soil suitability and support detailed planning and design for reclamation and revegetation. Additionally, it will be used support detailed design and mitigation for Project infrastructure features such as channels, berms, dikes and soil stockpiles.

6.3.7 Follow-Up and Monitoring

Most follow-up and monitoring recommendations for geology are stated in Section 6.4 because the end effects are more closely related to groundwater rather than geology.

Because there are no residual effects to geology, no follow-up is required.

The residual effects to soil and terrain that require follow up include the following:

- Effects on soil capability in areas of temporary project components whose locations are yet to be confirmed, including rock quarries, borrow material sites, temporary construction camps and staging areas.
- Effects of drainage alterations on soils in the vicinity of LMOC and LSMOC that may result in soil moisture changes (wetter or drier) needs conformation. This follow-up should be conducted jointly with vegetation in sensitive areas (e.g. wetlands or listed ecosystems) and land and resource use (agriculture) for agricultural capability in areas of agricultural land use.

- The location of feedlot areas and manure stockpiles with potential manure-impacted soils need to identified and delineated. Manure piles should be relocated to appropriate areas outside of the LMOC PDA in cooperation with landowners (this follow-up should be completed in conjunction with land and resource use [Section 9.2]). Soils in feedlot areas and under manure stockpiles should be sampled and analyzed for nutrient concentrations and other relevant parameters. A plan for the proper treatment and/or disposal, as required, should be developed for these soils.

Monitoring for soils to confirm the effectiveness of mitigations applied include:

- monitoring soil salvage during construction including soil excavation, handling and stockpiling to confirm appropriate soil salvage and maintenance of soil quantity
- periodic monitoring through construction of soil stockpiles to confirm adequate stabilization and erosion control

6.3.8 Conclusions for Geology and Soils

6.3.8.1 Geology

The Project is considered not to have interactions with geology. Preparation of the PDA and construction-associated transportation are above ground and thus above surficial and bedrock geology. Construction of the Project components other than the LMOC and LSMOC (e.g., PR 239 and municipal roads realignment, Manitoba Hydro distribution line) involve excavation of surficial and bedrock geology, but ultimate interactions involve groundwater rather than geology; these interactions are identified and described in Section 6.4: Groundwater and Surface Water

6.3.8.2 Change in Terrain Conditions

Residual effects to terrain conditions will be limited to alterations to drainage through the operation and maintenance phase in relation to the presence of the LMOC and the LSMOC. These residual effects are considered adverse in direction, will persist over the long-term operation and maintenance) and are irreversible. In other words, soil capability and productivity are not expected to return to existing conditions. The residual effects to vegetation and wetlands and agriculture are assessed in Section 8.2: Vegetation and Section 9.2: Land and Resource Use), respectively.

6.3.8.3 Change in Soil Quantity and Quality

In the PDAs for the LMOC and PR 239, land with agricultural capability will be permanently lost. While agricultural capability of the land could be restored through post-Project reclamation, there are no plans to decommission the Project. While changes to agricultural capability represent only 1.6% of the LAA, they are 7.0% of the area rated for agricultural capability. This consists of a loss of 1,023 ha of land with agricultural capability, comprising 584 ha of Class 4 land, 298 ha of Class 6 land and 134 ha of Organic soils, which may have some limited capability for agriculture.

Through general and Project-specific mitigation, organic and mineral topsoil materials and good quality upper subsoil materials will be excavated and stored in separate soil stockpiles adjacent to the channel, as necessary to support revegetation on soil stockpiles. These soil materials could be used for future reclamation activities should the structure be decommissioned at some point in the future.

With the implementation of mitigation, there will not be residual effects from nutrient runoff as a result of construction activities and operation of the Project in areas of soils potentially impacted by high nutrient concentrations from cattle feedlot operations and the presence of manure stockpiles. Through the implementation of mitigation, these potentially impacted soils will be identified, delineated, excavated and properly disposed of prior to the commencement of construction activities.

6.4 GROUNDWATER AND SURFACE WATER

6.4.1 Scope of the Assessment

This groundwater and surface water is assessed in accordance with the requirements described in both federal and provincial guidance documents for the Project. Concordance tables, demonstrating where EIS Guidelines are addressed, are provided at the beginning of this EIS.

The Canadian Environmental Assessment Agency EIS Guidelines for the Project (CEAA 2018; Section 7.1.4) indicate that the EIS is to present information on groundwater and surface water. Information on local and regional hydrogeology is to include hydrogeological context, including the delineation of key stratigraphic and hydrogeologic boundaries, physical properties of the hydrogeological units, groundwater flow patterns, rates, use and quality. Information on hydrology and water quality of the local watershed is to include delineation of drainage basins, regional and local hydrology, historic conditions including flood patterns, seasonal water quality data, sediment quality and quantity, local and regional potable water sources and ice processes. The Environmental Assessment Scoping Document for the Project (Manitoba Infrastructure 2018; Section 3.1.4) submitted to Manitoba Sustainable Development indicated that the EIS will describe groundwater quantity and quality, watersheds, regional surface water flow and quality.

Chapter 4 (Section 4.4.1) describes VCs as features that may be be affected by the Project as related to the role of the VC in the ecosystem and the value people place on it. Groundwater is a subcomponent of the Groundwater and Surface Water VC. Groundwater is an integral part of the hydrologic system and serves as a water resource that supports both the ecologic function within a watershed, and a variety of human land uses including residential, agricultural, commercial and industrial uses. Groundwater can be used as a source of raw water for domestic supply, and many rural landowners who are not serviced by municipal supplies rely on groundwater to meet their water demands. Groundwater also interacts with surface water resources in the vicinity of rivers, lakes, or wetlands, and can serve as baseflow contributions to surface water balances throughout the hydrologic year. Groundwater is included in a VC for the Project because there is potential for changes to local and regional groundwater flows, levels and quality.

Surface water in the area is important to people and the environment for sustaining fisheries and other wildlife, and for recreational and resource use activities. Surface water is a subcomponent of the Groundwater and Surface Water VC. The Project is in important surface water areas of Manitoba. The Interlake Region lies between Lake Manitoba to the west and Lake Winnipeg to the east, with the Fairford River, Lake St. Martin and Dauphin River positioned between these two large drainage basins. Surface water is included as a VC for the Project because there is the potential for changes to drainage conditions, channel regimes, water levels, sediment transport and yield, and open-water areas because of the Project. There is also the potential for the Project to affect water quality in Lake Manitoba, Lake St. Martin and Lake Winnipeg.

6.4.1.1 Regulatory and Policy Setting

Federal Guidance

This Project is a designated project under the *Canadian Environmental Assessment Act, 2012.* This is because it meets the threshold stated in section 6 of the Regulations Designating Physical Activities "The construction, operation, decommissioning, and abandonment of a new structure for the diversion of 10,000,000 m^3/year or more a year from a natural body into another natural water body." If operated continually, the LMOC and LSMOC could divert approximately 6.7 billion and 10.3 billion m^3 of water, respectively, when operating during floods in approximately 1 in 5 years.

Although drinking water quality is generally an area of provincial jurisdiction, the federal government has some responsibilities for drinking water quality, including on federal lands and in First Nations communities located south of 60° N latitude. Guidelines, standards and objectives provide utility managers and system owners with drinking water quality targets to strive to achieve within their systems. In some jurisdictions, meeting these targets is mandatory. Since it is prudent to protect raw water supplies to ensure they are maintained as good sources of drinking water, the following guidelines, part of the Guidance document, may be used as benchmarks to develop protection measures or corrective actions in watersheds and around wells and to measure the success of management practices.

The Canadian Council of Ministers of the Environment (CCME 1999) and Health Canada (2017) Canadian Drinking Water Quality Guidelines set out the basic parameters that every water system should strive to achieve in order to provide the cleanest, safest and most reliable drinking water possible. They are used by every jurisdiction in Canada as the basis for establishing their own requirements for drinking water quality, thereby ensuring national consistency.

Guidance on Drinking Water Vulnerability and Source Protection (Health Canada 2017) includes the need for sanitary survey, vulnerabilities assessment, and chemical analysis to be conducted at all water distribution systems. They should continue to be conducted regularly, and when there are substantial changes to the treatment system, land use, or other conditions which may adversely affect water quality. Additional potential and new sources of contamination within water wells' zone of contribution (ZOC) would initiate a Source Protection update.

The *Canada Water Act* provides for the management of water resources including conservation and utilization of water resources and provides guidelines for Canadian drinking water quality. It also provides for the protection of water resources, including water quality. The *Navigation Protection Act* provides protection of the right to navigation on navigable and scheduled waterways. Identifies prohibitions for the construction, placement, alteration, repair, reconstruction, removal or decommissioning or works in, on, over, under, through or across scheduled navigable water.

Provincial Guidance

The Project requires an Environment Act Licence under Manitoba's *Environment Act*. It is classified as a Class 3 development under the Classes of Development Regulation because it is a flood control project protecting areas greater than 100 km^2.

The *Water Rights Act* regulates the use or diversion of water in Manitoba and is administered by Manitoba Sustainable Development (MSD). Section 9.1(1) of The *Water Rights Act* requires the Minister to consider scientific or other information relating to the groundwater and water body levels and the instream flows that are necessary to ensure that aquatic ecosystems are protected and maintained. Sections 9.1(2), 9.2, and 14(1) allow the Minister to refuse to issue a water use license, to suspend an existing water use license, or cancel an existing water use license, respectively if, in the opinion of the Minister, the action authorized by the license would negatively affect an aquatic ecosystem. Section 14.1 allows the Minister to undertake scientific investigations into groundwater, waterbody levels, or instream flows anywhere in Manitoba to determine whether aquatic ecosystems are being negatively affected by insufficient levels or flows.

The *Water Resources Conservation Act* prohibits the diversion, extraction, taking, storage, or transport of water for removal from a water basin or sub-water basin in Manitoba that could, individually or collectively, have significant adverse effects on the ecological integrity of Manitoba's water resources or their associated ecosystems.

The *Water Protection Act* provides for the protection and stewardship of Manitoba's water resources and aquatic ecosystems. It does so by establishing the Manitoba Water Quality Standards, Objectives, and Guidelines (MWQSOG) which lists water quality standards (Tier I), objectives (Tier II), and guidelines (Tier III) for drinking water, agricultural use, and protection of aquatic resources. Additionally, the MWQSOG list fish tissue residue guidelines for wildlife and/or human consumers for arsenic, fluoride, lead, mercury, methylmercury, and four organic compounds.

The Groundwater and Water Well Act provides for the protection and stewardship of Manitoba's aquifers and groundwater. Under this Act, construction, maintenance and sealing of wells and test holes must meet standards that protect environmental quality of aquifers and groundwater as well as human health and safety. It does so by establishing the Well Standards Regulation for construction and decommissioning. It also provides for the collection and sharing of well, aquifer and groundwater information by establishing the Groundwater and Water Well (General Matters) Regulation.

The *Water Resources Administration Act* outlines a framework for the use and administration of water control works, including requirements and processes for approval of operating guidelines. The *Water Rights Act* identifies rights and use of water in Manitoba and prohibitions against diversion of water or operation of water works and sets requirements for permitting and protections of aquatic ecosystems. The *Sustainable Watersheds Act* amends four other Acts (Conservation Districts Act, Manitoba Habitat Heritage Act, Water Protection Act and Water Rights Act) to deal with improving water management in Manitoba.

Appendix 6J describes the management of flows and lake levels in Lake Manitoba and Lake St. Martin with the operation of the Fairford Water Control Structure, LMOC and LSMOC.

6.4.1.2 Engagement and Key Concerns

Groundwater

The public and Indigenous engagement process is discussed in Chapter 5. Engagement has been ongoing and will continue with agencies, public stakeholders and Indigenous groups through the life of the Project. The outputs of the process were reviewed to determine whether the information applied to groundwater.

Public input included questions about the local drainage, concerns about impacts to aquifers and water quality, relief wells along the ditch, depressurization and compensation for any impacts, risks of water wells drying up, and a specific concern that Steep Rock is a recharge aquifer (*charged aquifer*) while water is flowing under artesian pressure. Input from Indigenous communities included concerns that excavation of wetlands, quarries, borrow pits, and ditches may impact groundwater and aquifers and residential wells, and concerns about pesticides from agricultural lands entering Lake St. Martin (by speeding up water moving from one lake to the other). There were also concerns expressed about the potential for the channels to affect groundwater including potential impacts to drinking water, how effects to groundwater would be dealt with, an interest in who would be doing the testing, and the role of the community in this process.

Engagement feedback from Indigenous groups has been an important consideration in identifying issues of concern, framing the scope of the EIS and effects assessment, and in identification of specific mitigation measures, where provided. Engagement feedback was provided by multiple Indigenous groups and the general concerns expressed were related to potential for the Project to contaminate groundwater and aquifers.

Fisher River Cree Nation, Lake St. Martin First Nation, Pinaymootang First Nation and Interlake Reserves Tribal Council raised concerns that components of the Project including, excavation during the construction and operation and maintenance phases, could impact groundwater, aquifers and residential drinking wells.

These issues of concern are incorporated in the assessment of residual effects in sections on Changes in Local Groundwater Flows, Levels and Quality (Section 6.4.4.2) and Changes in Local Groundwater/ Surface Water Interactions (6.4.4.3). Each section considers the pathway in which the effect could occur and the activities that would mitigate the potential effect.

Traditional knowledge (TK), including information about existing conditions, potential effects, and mitigation measures related to groundwater has been collected through engagement and was provided by Indigenous groups through a Project specific TK study[5]. A summary of recommended Project-related effects/issues of concern related to groundwater for inclusion in the EIS shared by Indigenous groups, and an explanation of how information has been considered in this section, is provided in Table 6.4-1.

Table 6.4-1 Issues of Concern Identified in Traditional Knowledge

Indigenous Group	Project-related Effect/Issue of Concern	EIS Consideration
Fisher River Cree Nation	• There are concerns that excavation of the wetlands for the channel, quarries, borrow pits and ditches may impact groundwater and aquifers in the area and ultimately affect the quality of water in residential wells	Changes in Local Groundwater/Surface Water Interactions (6.4.4.3).
Dauphin River First Nation	• Potential changes in ground water quality	Changes in Local Groundwater/Surface Water Interactions (6.4.4.3).

Surface Water

Manitoba Infrastructure has undertaken engagement prior to and throughout preparation of the EIS and will continue to engage with Indigenous groups, government agencies, and stakeholders throughout the Project operations. A discussion of the engagement process is provided in Section 5: Indigenous and Public Engagement.

Public questions and concerns referenced regional water levels and flows and how they would be managed. Other concerns included the potential changes to upstream water control structures, such as the Portage Diversion, during operations. There were concerns existing operation of the current water control structures and changes in the future could affect water levels and water quality. There were also concerns about local watersheds and wetlands adjacent to the channels and how they would be affected for both Buffalo Creek and Birch Creek. The public was concerned about whether the Project could potentially change water quality. Specific issues involved how the inlets and outlet of the channels in Lake Manitoba, Lake St. Martin and Lake Manitoba may change sediment transport. The effect of lake ice also needs to be considered for operation during winter.

[5] Proposed Lake Manitoba and Lake St. Martin Outlet Channels Project: Interlake Reserves Tribal Council October Phase 1 Traditional Land Use and Traditional Knowledge Report 2018; Fisher River Cree Nation—Consultation Report, including Appendix D and E, 2018

Consultation feedback from Indigenous groups, has been an important consideration in identifying issues of concern, framing the scope of the EIS and effects assessment, and in identification of specific mitigation measures, where provided. Concerns related to surface water are summarized under the following topics and are described further below:

- increased sedimentation, debris, silt and erosion
- water quality effects and runoff from farmland
- increased water levels during peak flow events
- potential for flooding
- contamination of water bodies
- changes in flow rates
- pathways for contamination from Lake Manitoba to Lake Winnipeg
- possibility of water flowing back down the channel during high water

Engagement feedback where it relates to surface water is discussed in greater detail below, and is cross referenced throughout this section, as appropriate.

Increased Sedimentation, Debris, Silt and Erosion

Dauphin River First Nation, Fisher River Cree Nation, Lake St. Martin First Nation, Ebb and Flow First Nation, Norway House Cree Nation, Seymourville Northern Affairs Community, Interlake Reserves Tribal Council, and Kinonjeoshtegon First Nation expressed concerns that the Project's additional flow and larger channels would lead to an increase in sediment, debris, silt and erosion in surface water. Dauphin River First Nation expressed specific concern about the possibility of an increase in sediment and debris in Dauphin River and Lake St. Martin First Nation voiced similar concerns related to Bear Creek.

These issues of concern are incorporated in the assessment of residual effects in Section 6.4.7.3 and Section 6.4.7.5. Each section considers the pathway in which the effect could occur and the activities that would mitigate the potential effect.

Water Quality Effects

Concerns related to the effects of the Project on water quality were expressed by multiple Indigenous groups, including Dauphin River First Nation, Norway House Cree Nation, Pinaymootang First Nation, Peguis First Nation and Little Saskatchewan First Nation. Peguis First Nation and Lake St. Martin First Nation were concerned about the possibility of mercury content coming through the channels. Comments from Dauphin River First Nation and Interlake Reserves Tribal Council were related to the potential contaminants entering water during construction, including spills from construction practices and machinery.

Interlake Reserves Tribal Council and Lake St. Martin First Nation commented around the potential for chemicals (pesticides, herbicides) used on farmland to drain into the channel. Keewahtinook Fishers of Lake Winnipeg provided the following specific comment, “The channels will allow for polluted waters from Lake Manitoba to get into Lake Winnipeg. We will get the pollution from the farmer’s, pig operations and sewage. This will ruin our water quality and the commercial fisheries. Our nets are covered in slime from the poor water quality in Lake Winnipeg. The channels will make this worse.”

Fisher River Cree Nation, Hollow Water First Nation, Lake Manitoba First Nation, Norway House Cree Nation, Seymourville Northern Affairs Community, Kinonjeoshtegon First Nation, Peguis First Nation, Black River First Nation, Keewahtinook Fishers of Lake Winnipeg and Interlake Reserves Tribal Council expressed concerns in relation to the deterioration of Lake Winnipeg as a result of increased sedimentation, turbidity, health of the lake (algae blooms), and invasive species. Lake St. Martin First Nation and Interlake Reserves Tribal Council also noted that the channel will change the water quality of Lake St. Martin and/or Lake Manitoba as result of being connected to Lake Winnipeg.

These issues of concern are incorporated in the assessment of residual effects in Section 6.4.7.7 and in Section 14.4. Each section considers the pathway in which the effect could occur and the activities that would mitigate the potential effect.

Water Levels, Flooding During Peak Flow Events, Ice Formation

Hollow Water First Nation, Kinonjeoshtegon First Nation, Black River First Nation, Keewahtinook Fishers of Lake Winnipeg, Berens River First Nation, Interlake Reserves Tribal Council, Peguis First Nation, Lake St. Martin First Nation, Norway House Cree Nation, Seymourville Community Council NAC, and Fisher River Cree Nation expressed concern about the water levels in Lake Winnipeg and Lake St. Martin.

Interlake Reserves Tribal Council and Manitoba Métis Federation raised concerns about the channels affecting surface water regimes and the potential for flood waters moving towards communities instead of following natural drainage patterns. Manitoba Métis Federation noted that flooding risk may increase for communities adjacent to Dauphin River as natural flows are diverted. Interlake Reserves Tribal Council and Lake St. Martin First Nation were concerned about what changes in the speed of flow would do to water in Lake St. Martin and whether changing currents or fluctuating water levels could result in in inconsistency or delays in ice formation. Interlake Tribal Council commented that Lake St. Martin is already struggling with inconsistent ice formation due to existing currents and the Project has the potential to exacerbate this issue.

Dauphin River First Nation identified that restricted flow and floods could affect the south basin of Lake St. Martin. Lake Manitoba First Nation, Lake St. Martin First Nation, Seymourville Community Council NAC, Interlake Reserves Tribal Council and Peguis First Nation expressed concern about the potential for water to flow backwards through the channels. Little Saskatchewan First Nation identified a natural bottleneck at the Narrows Reserve 48 and expressed concern that water will not be able to move through this natural feature quick enough to allow the LSMOC to stop flooding in Lake St. Martin. Peguis First Nation expressed concern that construction of the Project may block water to Mantagao Lake.

These issues of concern are incorporated in the assessment of residual effects in Section 6.4.7.2 and Section 6.4.7.6. Each section considers the pathway in which the effect could occur and the activities that would mitigate the potential effect.

Traditional knowledge (TK), including information about existing conditions, potential effects, and mitigation measures, has been provided by Indigenous groups through Project specific studies[6].

A summary of recommended Project-related effects/issues of concern related to surface water for inclusion in the EIS shared by Indigenous groups during TK studies, and an explanation of how information has been considered in this section, are provided in Table 6.4-2.

Table 6.4-2 Issues of Concern Identified in Traditional Knowledge

Indigenous Group	Project-Related Effect/Issue of Concern	EIS Consideration
Manitoba Metis Federation	• effects of a water volume from operation of the channel on receiving water body water quality parameters, including Total Suspended Solids (TSS) • nutrient effects downstream due to the change in hydrology; specifically, the changing nutrient levels and sedimentation with respect to the receiving waters in Sturgeon Bay	Changes in Regional and/or Local Surface Water Quality (6.4.7.7)
Dauphin River First Nation	• potential changes in water quality • concerns about the potential for the Lake St. Martin Outlet Channel to change the drainage pattern of surface water • availability of water quality existing conditions to understand the contaminants in the water	Changes in Regional and/or Local Surface Water Quality (6.4.7.7), Changes in Regional Flow and Water Levels (6.4.7.2.), Changes in Local Drainage Areas and Local Drainage Patterns (6.4.7.4)
Interlake Tribal Council	• potential for the outlet of the Lake Manitoba channel to result in changing currents in Lake St. Martin	Changes in Regional Flow and Water Levels (6.4.7.2.), Changes in Local Drainage Areas and Local Drainage Patterns (6.4.7.4)

[6] Lake St. Martin Emergency Outlet Channel: Technical Review of the Environmental Act Proposal Report - Prepared for Manitoba Metis Federation; Proposed Lake Manitoba and Lake St. Martin Outlet Channels Project: Interlake Reserves Tribal Council October Phase 1 Traditional Land Use and Traditional Knowledge Report 2018; Dauphin River Community Report On the Use of Reach 1, 2017; Fisher River Cree Nation—Additional Information for FRCN's L. St. Martin Consultation Reports; Fisher River Cree Nation—Consultation Report, including Appendix D and E, 2018.

Table 6.4-2 Issues of Concern Identified in Traditional Knowledge

Indigenous Group	Project-Related Effect/Issue of Concern	EIS Consideration
Multiple Indigenous Groups[7]	• discharge through Big Buffalo marsh and down Buffalo Creek will affect water quality in Dauphin River channel will cut off creeks and affect the natural process within Buffalo Lake bog • potential silting of the mouth of Dauphin River • concerns with respect to effects of frazil ice formation at Dauphin River • Dauphin River is at receiving end of all the water which affects fishers, water quality, increases shoreline erosion • the narrows on Lake St. Martin will be a restriction for flows and will result in flooding on Lake St. Martin with these channels • Buffalo Creek as the outlet for the emergency channel will increase debris in Dauphin River and Lake Winnipeg • permanent channels will increase levels of Lake Winnipeg and bring water from Lake Manitoba into Lake Winnipeg	Changes in Regional Flow and Water Levels (6.4.7.2.), Changes in Regional and/or Local Fluvial Geomorphology or Shoreline Geomorphology (6.4.7.3), Changes in Local Drainage Areas and Local Drainage Patterns (6.4.7.4), Changes in Regional and/or Local Sediment and Debris Transport (6.4.7.5) , Changes in Regional and/or Local Ice Processes (6.4.7.6), Changes in Regional and/or Local Surface Water Quality (6.4.7.7)

Indigenous groups also recommended mitigation measures that, when implemented, may limit or reduce potential Project effects on surface water. Mitigation measures identified by Indigenous groups that have been incorporated into the assessment are provided below.

The Manitoba Metis Federation had the following recommendations for mitigation measures:

- “MI should incorporate measures to reduce TSS into the receiving waters through modifications of the emergency channel and operation to reduce further declines in water quality.
- Measures are put in place to reduce the amount of erosion and scour of the channel to reduce sedimentation impacts on the downstream environment, including improving the substrate material, providing a better solution to the limestone and clay plug, and other operational procedures of the emergency channel that reduce erosion and sedimentation.
- It is recommended that Manitoba Infrastructure vegetate the banks, which could provide additional protection from erosion and sedimentation along the banks, as well as creating better habitat for aquatic, terrestrial and avian species.

[7] Multiple Indigenous groups including the following, Fisher River First Nation, Ebb and Flow First Nation, Lake Manitoba First Nation, O-Chi-Chak-Ko-Sipi First Nation, Manitoba Metis Federation, Little Saskatchewan First Nation, Peguis First Nation, Berens River First Nation, Berens River NAC, Bloodvein First Nation, Dauphin River First Nation, Fisher Bay NAC, Hollow Water First Nation, Interlake Regional Tribal Council, Pinaymootang First Nation, Pine Dock NAC, Princess Harbour NAC, Sagkeeng First Nation, Seymourville NAC

- A more gradual release of water from the upstream system to limit the impact on downstream environments, with lower velocities and flow volumes is recommended. The option of storage and/or delayed release could be incorporated into the spillway design to lessen the impact of the flood surge.
- The emergency channels should incorporate some natural channel design and some meanders to increase flow length, which could reduce flow velocities by the time it reaches the end and thus reducing the impact of the receiving waters downstream. Other options could include structures at the outlet to dissipate hydraulic energy or divert water away from erodible areas (i.e., groynes), or the creation of lower velocity off channel areas as refugia during higher flows.
- The emergency channel material including the base and the plug are a source of sediment, debris and increased loadings for the downstream environment. MI should consider mitigation measures and develop a contingency plan to reduce the amount of sedimentation that enters the receiving waters from these anthropogenic sources."

Other mitigation measures have been recommended by Indigenous groups and are subject to ongoing discussions with Manitoba Infrastructure.

The Manitoba Métis Federation (MMF) also had the following comments in regard to surface water:

- "The water quality from Lake St. Martin differs from the water quality of the downstream river system and may have altered the water chemistry in the creeks to more lake-like properties, negatively impacting the aquatic species that inhabit the creeks. Declines in water quality were seen in Buffalo Creek, Dauphin River and Sturgeon Bay due to the operation of the emergency channel, including increased water hardness, decreased dissolved oxygen, increased total dissolved solids (TDS), increased total suspended sediments (TSS), increase in nutrients (phosphorus, nitrogen and ammonia), increases in metals and increases in chloride. Many of these parameters had results which exceeded water quality guidelines and occurred for long durations (weeks to months) during the operation of the EOC. Buffalo Creek had the greatest decline in water quality during the operation, with substantial increases in conductivity, TDS (exceeded 500 mg/L drinking water objective) and hardness, and TSS ranged from 10 to 180 mg/L, well above the existing concentrations of 2-6 mg/L". Furthermore, MMF commented that "the influx of a significant volume of water for months at a time into these receiving water bodies (Buffalo Creek, Dauphin River and Sturgeon Bay) is causing declines in many of the routine water quality parameters that are important to protection of aquatic life. TSS is the most problematic of these parameters, which can deplete oxygen in the river and further affect aquatic life by clogging gills and increases turbidity in the water.
- "Compact fines comprise the substrate within Reach 1, so the channel walls of the inlet, which were designed to extend 3.0 m above the regulated water levels within Reach 1, were armoured with till boulders and a geotextile underlay. The Proponent states that increased sedimentation and erosion will likely occur at the outlet of Reach 1 because of channel substrates and increased velocity. It's unclear and not documented what this may do to the aquatic habitat in the long-term and the downstream end of the channel"

- "Reach 3 originates at Buffalo Creek and is approximately 6 km in length and terminates in a lowland area 3.5 km inland of Sturgeon Bay. Substrate within the channel is mostly clayey till but an area of bedrock occurs just upstream of the channel outlet. The channel base is 21 m wide in areas where the substrate is comprised of fines, but it expands to a width of 28 m within the bedrock section. As with Reach 1, it is unclear what impact the increased sedimentation and continuous discharge will have on receiving aquatic habitat"

The assessment of changes in regional and local surface water quality is provided in Section 6.4.7.7 and the assessment of changes in regional and local sediment and debris transport is provided in Section 6.4.7.5. The assessment of potential changes to aquatic habitat and potential effects to fish and other aquatic organisms are provided in Chapter 7: Aquatic Environment.

6.4.1.3 Potential Effects, Pathways and Measurable Parameters

Groundwater

The value of groundwater resources can be broadly evaluated through two characteristics: groundwater quantity and groundwater quality. Groundwater quantity refers to the availability of groundwater at a given rate for production and use, and it varies widely depending upon the local geologic setting, hydrogeological conditions and past/current groundwater use. Groundwater quality refers to the chemical composition of groundwater and its suitability for various uses and also varies widely depending upon the local geologic setting, hydrogeological conditions, and past/current land use practices that may contribute anthropogenic effects.

In evaluating effects on groundwater resources, both quantity and quality need to be considered together. For example, abundant groundwater (i.e., high quantity) may not be of meaningful value if its quality precludes its use. Similarly, high quality groundwater may not be of meaningful value if it is not available in sufficient quantity for a given use. However, there can be users for any quantity and any quality, depending on their needs.

Effect pathways describe the mechanisms through which the Project can cause a potential effect on groundwater resources through physical infrastructure or associated activities. Effects pathways can change throughout the phases of the Project, depending upon the activities and physical infrastructure present within a given timeframe. As such, effect pathways discussed in this section are those that are relevant during the construction and operations and maintenance phases of the Project.

Measurable parameters are a means through which change in groundwater quantity or quality can be characterized. The measurable parameter for a change in groundwater quantity is the potentiometric head (measured as an elevation above sea level) in a given hydrostratigraphic unit (defined in Section 6.3.2.2). Potentiometric head controls the movement of groundwater in the subsurface, creates artesian pressures in certain geological conditions, and is directly related to the availability of groundwater for use. Potentiometric head can be readily measured in water wells and can be interpreted to understand potential spatial or temporal variation in groundwater quantity.

Changes in groundwater quality can be assessed through examination of a wide range of water quality parameter concentrations. Parameter concentrations can readily be determined from laboratory analysis of groundwater samples collected from water wells, and the analysis results can be used to understand spatial and temporal variation in groundwater quality.

Potential environmental effects, the effect pathway and measurable parameters used to assess potential effects on groundwater are provided in Table 6.4-3.

Table 6.4-3 Potential Effects, Effect Pathways and Measurable Parameters for Groundwater

Potential Effect	Effect Pathway	Measurable Parameter(s) and Units of Measurement
Changes in regional groundwater flows, levels and quality and surface water interactions	Interactions between the Project and groundwater quantity can include: • groundwater diversion for construction dewatering • groundwater seepage into open excavations • groundwater seepage into the diversion channel • groundwater recharge from a channel when in operation or in wet conditions where there is no passive depressurization • alteration of groundwater flow to discharge areas, i.e., wetlands and lakes • groundwater level drawdown and/or artesian pressure decrease can affect availability Interactions between the Project and groundwater quality can include: • changes to groundwater quantity or flow patterns that can in turn affect groundwater quality • groundwater contamination related to construction activities • groundwater recharge from a channel when in operation or in wet conditions, conveying surface contamination • water wells in flooded area can be contaminated by infiltration at well head	Potentiometric head (measured in metres above sea level) Various water quality parameters (variable units of measure, including aqueous concentrations, pH units, conductivity, and others)

Table 6.4-3 Potential Effects, Effect Pathways and Measurable Parameters for Groundwater

Potential Effect	Effect Pathway	Measurable Parameter(s) and Units of Measurement
Changes in local groundwater flows, levels and quality	Interactions between the Project and groundwater quantity can include: • groundwater diversion for construction dewatering • groundwater diversion for passive depressurization where there are risks of aquitard/aquiclude breakage • groundwater seepage into open excavations • groundwater seepage into the diversion channel when dry • groundwater recharge from a channel when in operation or in wet conditions where there is no passive depressurization • alteration of groundwater flow to discharge areas, i.e., wetlands and lakes • groundwater level drawdown and/or artesian pressure decrease can affect availability in water wells Interactions between the Project and groundwater quality can include: • changes to groundwater quantity or flow patterns that can in turn affect groundwater quality • groundwater contamination related to construction activities • groundwater recharge from a channel when in operation or in wet conditions, conveying surface contamination	Potentiometric head (measured in metres above sea level) Various water quality parameters (variable units of measure, including aqueous concentrations, pH units, conductivity, and others)
Changes in local groundwater and surface water interactions	Alteration of groundwater flow to discharge areas, including: • wetlands • lakes • springs	Flow rate at springs (L/s)

Surface Water

The focus of this assessment is on effects that have the potential to change surface water hydrology or surface water quality in a way that could cause harm to ecological and human receptors (these are discussed in the receptor VCs). Potential environmental effects, the effect pathway and measurable parameters used to assess potential effects on surface water are provided in Table 6.4-4.

Table 6.4-4 Potential Effects, Effect Pathways and Measurable Parameters for Surface Water

Potential Effect	Effect Pathway	Measurable Parameter(s) and Units of Measurement
Changes in regional flow and water levels	Operation of the LMOC and LSMOC during periods of high flows, which will alter the rate of movement of water from Lake Manitoba to Lake St. Martin to Sturgeon Bay	• Flow levels (cubic feet per second, cfs and m^3/s) • Lake levels (m asl, feet) • Flow duration curves • Flood routing analyses
Changes in regional fluvial geomorphology and shoreline morphology	Changes in flow levels, flow duration and lake water levels that may affect river channel or lake shoreline morphology, riverbank or shoreline stability, substrate composition, sediment release and/or transport Changes in bathymetry at channel inlet and outlet areas	• Flow levels (cubic feet per second, cfs and m^3/s) • Lake levels (m asl, feet) • Qualitative assessment of rate and direction of changes or erosion and sedimentation
Changes in local drainage areas and local drainage patterns	Alteration of existing local drainage areas and patterns along the outlet channel alignments due to construction and operation of the LMOC and LSMOC	• Flow levels (cubic feet per second, cfs and m^3/s) • Lake levels (m asl, feet) • Drainage area (square metres, hectares) • Measurement of changes in area using GIS mapping analysis (square metres, hectares)
Changes in regional and/or local sediment and debris transport	Alteration of existing regional and local sediment transport due to changes in flows related to construction and operation of the LMOC and LSMOC	• Measurement of TSS and turbidity (NTUs, mg/L) • Measurement of changes in substrate sizes (mm, cm) • Measurement of changes in sediment volumes (cubic metres) and locations • Data and results from sediment transport studies conducted for the LMSEOC and Project

Table 6.4-4 Potential Effects, Effect Pathways and Measurable Parameters for Surface Water

Potential Effect	Effect Pathway	Measurable Parameter(s) and Units of Measurement
Changes in regional and/or local ice processes	Alteration of existing regional and local sediment transport due to changes in flows related to construction and operation of the LMOC and LSMOC	• Measurement of ice thickness (cm, m) • Measurement of ice formation and ice breakup periods (days, weeks) • Data and results from ice process studies conducted for the LMSEOC and Project
Changes in regional and/or local surface water quality	Changes in flows, drainage areas or drainage patterns may alter surface water quality in regional or local watercourses	• Surface water quality parameters such as temperature, TSS/ turbidity, conductivity, pH and nutrients in appropriate units, such as mg/L

6.4.1.4 Boundaries

Spatial Boundaries

The Project development area (PDA), local assessment area (LAA) and regional assessment area (RAA) for the assessment of effects on groundwater and surface water are shown in Appendix 6B, Figure 6.4B-1 and Figure 6.4B-2, respectively. Federal lands within these boundaries consist of reserve lands associated with Indigenous communities.

Project Development Area

The PDA for groundwater and surface water is the immediate area of Project physical works and activities. The PDA is limited to the area of physical disturbance associated with the construction and operation of the Project. The PDA is approximately 2,099 ha and includes:

- the outlet channels (LMOC and LSMOC)
- the water control infrastructures, drop structures, and bridges
- inlet and outlet at both channels
- realignment of PR 239

Local Assessment Area

The LAA for the assessment of effects on groundwater corresponds to the Lake St. Martin watershed and includes the PDA and upper aquifers in overburden that will have limited effects away from the Project (3 km), and deeper confined carbonate aquifer that can have theoretical pressure changes. It also includes buffer zones surrounding the PDA to address potential localized hydrogeological effects, such as

water level, artesian pressure and water quality changes near to the construction areas, localized seepage into the diversion channel, and artesian pressure decrease in areas where passive depressurization will be implemented. Specifically, the groundwater LAA includes the PDA and the following:

- a 500 m buffer around Fairford River, Lake St. Martin and Dauphin River
- the Lake Manitoba shoreline
- a 20 km buffer around the LMOC
- a 5 km buffer around the LSMOC

The surface water LAA for the assessment of effects includes the PDA and the following:

- the Lake St. Martin watershed
- the Lake Manitoba shoreline from the Fairford River inlet in Portage Bay south and east to Watchorn Bay
- a portion of the Lake Winnipeg watershed in Sturgeon Bay

The Lake Manitoba shoreline was included to capture potential effects related to groundwater and surface water interactions at shorelines. The areas in Watchorn Bay and Sturgeon Bay are included to capture potential effects related to construction and operation activities at the channel inlet and outlet areas, and potential changes in sediment and/or debris transport due to construction and operation activities.

Regional Assessment Area

The RAA for the assessment of effects on groundwater includes the area that provides water (recharge areas) to the regional confined carbonate aquifer. It also includes buffer zones surrounding the LAA to cover recharge and discharge areas. The RAA includes

- a 2 km buffer of Fairford River, Lake Pineimuta, Lake St Martin and Dauphin River
- the Lake Manitoba shoreline
- a 20 km buffer around the LMOC
- a 5 km buffer around the LSMOC
- a manually delineated area based on topography and knowledge of regional geology, extending up to 60 km east of the LMOC and containing the main upland recharge area that supplies the regional confined carbonate aquifer

The RAA for the assessment of effects on surface water was selected to capture potential direct and/or indirect effects of changes in surface water flows or surface water quality related to the construction and operation of the Project. In addition to the PDA and LAA, it includes:

- the north and south basins of Lake Manitoba

- the north basin of Lake Winnipeg from the Lake Winnipeg Narrows to Limestone Bay
- the Nelson River inlet (outlet of Lake Winnipeg to Playgreen Lake)

Temporal Boundary

The temporal boundary for the assessment of effects on groundwater and surface water covers the duration of the construction and operation and maintenance phases of the Project. Construction is tentatively expected to occur over a period of approximately 2.5 to 3 years with approximately 1-2 years for post construction-related works, such as site clean-up, survey, and environmental offset works. It is currently estimated that construction would occur from fall 2020 to spring/summer 2023, with operation and maintenance starting in fall 2023. The overall schedule is contingent largely on receipt of the final regulatory approvals in 2020. Once construction is complete, the Project would be ready for operational usage on an as-required basis. The operation and maintenance phase of the Project is expected to be indefinite because the Project does not have a fixed end-of-life.

6.4.1.5 Residual Effects Characterization

Groundwater

Table 6.4-5 presents definitions for the characterization of residual environmental effects on groundwater. The criteria describe the potential residual effects that remain after mitigation measures have been implemented.

Table 6.4-5 Characterization of Residual Effects on Groundwater

Characterization	Range of Criteria	Level of Effect and Definition
Direction of Change The long-term trend of the residual effect	Neutral	No net change in measurable parameters for groundwater resources relative to existing conditions.
	Adverse	A residual effect that changes measurable parameters in a direction detrimental to groundwater resources relative to existing conditions.
	Positive	A residual effect that changes measurable parameters in a direction beneficial to groundwater resources relative to existing conditions.
Duration (period of time the effect occurs)	Short-Term	Residual effect restricted to 36 months (construction phase) or less
	Medium-Term	Residual effect extends through the construction phase (3 years) but not exceeding 2 years into operation phase
	Long-Term	Residual effect extends beyond the medium term and for the duration of the Project

Table 6.4-5 Characterization of Residual Effects on Groundwater

Characterization	Range of Criteria	Level of Effect and Definition
Magnitude (degree or intensity of the change)	Negligible or Low	Negligible – no measurable change in potentiometric head or groundwater quality parameters Low – a measurable change in potentiometric head or groundwater quality parameters, but within the range of expected natural variability
	Moderate	Measurable change groundwater quantity as measured by the potentiometric head beyond the range of expected natural variability, but does not materially alter groundwater flow patterns or lead to an exceedance of an applicable water quality guideline
	High	Measurable change in potentiometric head beyond the range of expected natural variability that materially alters groundwater flow patterns or a measurable change in groundwater quality parameters beyond the range of expected natural variability that directly leads to and exceedance of an applicable water quality guideline for those parameters which did not exceed the guideline under existing conditions
Timing[8]	No Sensitivity	Effect does not occur during critical life stage (e.g., outside fish spawning or elk calving periods) or timing does not affect the VC.
	Moderate Sensitivity	Effect may occur during a lower sensitive period of a critical life stage; for many species this is the start (e.g., several days prior to nesting for birds) or end (e.g., periods when birds have fledged but remain in proximity to their nest) of the critical period.
	High Sensitivity	Effect occurs during a critical life stage (e.g., fish spawning or bird nesting periods).
Extent (Spatial Boundary)	PDA	The physical space or directly affected area on which Project components or activities are located and/or immediately the adjacent area, including designated ROWs, and permanent and temporary facilities (e.g., borrow pits and quarries)
	LAA	Area within which potential Project effects are measurable and extending beyond the PDA to, but not beyond, the LAA.
	RAA	The regional extent of potential direct, indirect and cumulative effects that may extend beyond the LAA.

[8] In terms of Timing, the critical life stages include attributes such as nesting, breeding, spawning and calving which will vary by VC and will vary annually depending on seasonal conditions. For example, it is clear that winter is outside of bird nesting and breeding period and that spring is fully within this critical time period, whereas early spring and late fall is a transitional period that depending on the seasonal conditions may or may not affect the life stage.

Table 6.4-5 Characterization of Residual Effects on Groundwater

Characterization	Range of Criteria	Level of Effect and Definition
Frequency (how often the effect occurs)	Infrequent	The potential effect occurs once or seldom during the life of the Project
	Sporadic/Intermittent	The potential effect occurs only occasionally and without any predictable pattern during the life of the Project
	Regular/Continuous	The potential effect occurs at regular and frequent intervals during the Project phase in which they occur or over the life of the Project
Reversibility (the degree of permanence)	Reversible (short-term)	Potential effect is readily reversible over a relatively short period (< than five years).
	Reversible (long-term)	Potential effect is potentially reversible but over a long period (> than five years).
	Irreversible	Project-specific potential effects are permanent and irreversible.
Ecological Context	Undisturbed	Ecological: Area is relatively undisturbed or not adversely affected by human activity.
	Disturbed	Ecological: Area has been substantially previously disturbed by human development or human development is still present.

Surface Water

Table 6.4-6 presents definitions for the characterization of residual environmental effects on surface water. The criteria describe the potential residual effects that remain after mitigation measures have been implemented.

Table 6.4-6 Characterization of Residual Effects on Surface Water

Characterization	Range of Criteria	Level of Effect and Definition
Direction of Change (type of effect)	Neutral	No measurable change on the VC.
	Adverse	Net loss (adverse or undesirable change) on the VC.
	Positive	Net benefit (or desirable change) on the VC.
Duration (period of time the effect occurs)	Short-Term	Residual effect restricted to 36 months (construction phase) or less
	Medium-Term	Residual effect extends through the construction phase (3 years) but not exceeding 2 years into operation phase
	Long-Term	Residual effect extends beyond the medium term and for the life of the project

Table 6.4-6 Characterization of Residual Effects on Surface Water

Characterization	Range of Criteria	Level of Effect and Definition
Magnitude (degree or intensity of the change)	Negligible or Low	For flow-related changes: Negligible – little to no variation predicted in measurable parameters, with variations that are less than 10% relative change from existing condition values. Low – small variation predicted in measurable parameters, with variations that are between 10% and 15% relative change from existing conditions. For water quality related changes: Negligible – no measurable change compared to existing conditions Low – a measurable change but within 10% to 20% of existing conditions and not causing water quality guideline exceedances
	Moderate	For flow-related changes: Moderate – modest variation predicted in measurable parameters, with variations that are between 15% and 30% relative change from existing conditions. For water quality related changes: Moderate – measurable change but within 20% to 50% of existing conditions and not causing water quality guideline exceedances
	High	For flow-related changes: High – large variation predicted in measurable parameters, with variations that are greater than 30% relative change from existing conditions For water quality related changes: High – measurable change of higher than 50% change compared to existing conditions and/or causing water quality guideline exceedances
Timing[9]	No Sensitivity	Effect does not occur during critical life stage (e.g., outside fish spawning periods) or timing does not affect the VC.
	Moderate Sensitivity	Effect may occur during a lower sensitive period of a critical life stage; for many species this is the start (e.g., several days prior to nesting for birds) or end (e.g., periods when birds have fledged but remain in proximity to their nest) of the critical period.
	High Sensitivity	Effect occurs during a critical life stage (e.g., fish spawning or bird nesting periods).

[9] In terms of Timing, the critical life stages include attributes such as nesting, breeding, spawning and calving which will vary by VC and will vary annually depending on seasonal conditions. For example, it is clear that winter is outside of bird nesting and breeding period and that spring is fully within this critical time period, whereas early spring and late fall is a transitional period that depending on the seasonal conditions may or may not affect the life stage.

Table 6.4-6 Characterization of Residual Effects on Surface Water

Characterization	Range of Criteria	Level of Effect and Definition
Extent (Spatial Boundary)	PDA	The physical space or directly affected area on which Project components or activities are located and/or immediately the adjacent area, including designated ROWs, and permanent and temporary facilities (e.g., borrow pits and quarries)
	LAA	Area within which potential Project effects are measurable and extending beyond the PDA, but not beyond, the LAA.
	RAA	The regional extent of potential direct, indirect and cumulative effects that may extend beyond the LAA.
Frequency (how often the effect occurs)	Infrequent	The potential effect occurs once or seldom during the life of the Project (e.g., initial clearing and grubbing).
	Sporadic/Intermittent	The potential effect occurs only occasionally and without any predictable pattern during the life of the Project.
	Regular/Continuous	The potential effect occurs at regular and frequent intervals during the Project phase in which they occur or over the life of the Project (e.g., noise associated with vehicle traffic along the realigned portions of PR 239).
Reversibility (the degree of permanence)	Reversible (short-term)	Potential effect is readily reversible over a relatively short period (< than five years).
	Reversible (long-term)	Potential effect is potentially reversible but over a long period (> than five years).
	Irreversible	Project-specific potential effects are permanent and irreversible.
Ecological Context	Undisturbed	Ecological: Area is relatively undisturbed or not adversely affected by human activity.
	Disturbed	Ecological: Area has been substantially previously disturbed by human development or human development is still present.

6.4.1.6 Significance Definition

Significance is not determined for groundwater and surface water. The changes to groundwater and surface water are used to determine changes and effects on the aquatic environment (Chapter 7), terrestrial environment (Chapter 8), human environment (Chapter 9), and Indigenous peoples' VCs (Chapter 10).

6.4.2 Existing Conditions for Groundwater

6.4.2.1 Groundwater Methods

The first step in developing the hydrogeological framework for the RAA involved the compilation of hydrogeological data available from publicly accessible sources. Report and mapping products and online data available from Manitoba Sustainable Development (MSD), the Geological Survey of Canada (GSC) and other published papers were reviewed and relevant hydrogeological information for the RAA was extracted.

Additional information from previous geotechnical studies conducted for the Project and MSD database was also included in the historical information review:

- Existing conditions are described based on review of existing geotechnical studies performed by the engineering team responsible for conceptual engineering groundwater studies (KGS Group 2016b, 2017a, 2017b and 2018), including groundwater monitoring and sampling, and aquifer tests.
- Historical regional groundwater levels were obtained through the active MSD groundwater monitoring network.
- The GWDrill database was used to gather existing water wells location and completion details, when available.

Quality of data consistency varied depending on the section of the PDA, i.e., LMOC or LSMOC: substantially more data were available to characterize groundwater conditions along LMOC compared to LSMOC.

6.4.2.2 Groundwater Overview

Groundwater flow and quality are closely dependent on geology (Section 6.3.1). There are three main hydrogeological components, which correspond to the following lithologic formations with some characteristics:

- surficial aquifer is relatively thin, discontinuous, composed of soils, peat and isolated thin sand layers; related to wetlands
- aquitard–aquiclude is undifferentiated till; this is the principal geological component in which the Project will be embedded. Intertill lenses composed of till occur with greater proportions of coarse sediments (water bearing) and major lakes intercept this horizon.
- bedrock aquifer is confined carbonate aquifer; regional extent and connected with major lakes

Regional Groundwater Flow

Overview

The carbonate (bedrock) aquifer is overlain with an aquiclude of till within the PDA. The fluted morphology of the till surface is particularly apparent with the distribution of low-lying organic deposits within till troughs. Those wetlands are believed to be fed with water from precipitation trapped within those low-lying depressions and by slow-leaking groundwater under continuous artesian pressures from an upward hydraulic gradient, where unconsolidated lithologies are relatively thin and pervious (details on existing geology are found in Section 6.3.2.2).

Domestic and livestock wells are generally located in the carbonate aquifer in the LAA. Groundwater use is discussed further in land and resource use (See Chapter 9.2). Livestock wells are often flowing or artesian wells.

The regional carbonate bedrock aquifer is confined and underlies the RAA (see Section 6.3.2). The carbonate aquifer recharge occurs in the uplands area (see Appendix 6B, Figure 6.4B-3) under unconfined conditions where bedrock elevations are relatively high, above 280 m asl, and sediment cover is thin to non-existent.

The groundwater flow radiates out from the uplands in all directions towards the major lakes (St. Martin, Manitoba and Winnipeg). In general, the uppermost 10 m of the carbonate bedrock aquifer exhibits some karsticity: this is the most productive horizon of the aquifer. The aquifer very likely discharges into bogs, streams, and lakes; namely, Lake Manitoba, Lake St. Martin and Lake Winnipeg. Discharge to lakes could be widely distributed, but most likely near where bedrock outcrops. Discharge is under a flowing artesian aquifer condition in places.

The aquifer pressure head varies seasonally as shown at two long term monitoring wells from the Province of Manitoba Water Resource Branch (WRB 122050 and WRB-116766). The upland well (WRB 122050) piezometric head varies between 272 and 277 m asl (see Appendix 6B, Figure 6.4B-3), rising after spring snow melt and dropping over the winter, indicating that recharge is occurring in the uplands at elevation above 277 m asl.

LMOC

The carbonate aquifer in the area of the LMOC is overlain by 5 m to 18 m of till. The LMOC is located in the Birch Creek valley with the ground surface being at 246 m asl to 250 m asl. The piezometric head in this area, ranging from 249 m asl to 255 m asl, is higher than ground surface, or up to 5 m above ground level; because the bedrock aquifer is confined, it is entirely saturated. Seasonal variation in the area, as measured by the long-term monitoring well (WRB 116766) shows that the piezometric head varies between 252 m asl and 256 m asl (Appendix 6B, Figure 6.4B-4). Typical seasonal piezometric head varies 2.5 m to 3 m per year in the aquifer in the area of the LMOC. The variation is consistent with the upland well (WRB 122050) indicating the source of water for both is from the upland area. The elevation of Lake Manitoba and Lake St. Martin is lower than the groundwater in the area (see Appendix 6B, Figure

6.4B-4) indicating groundwater flow in the carbonate aquifer would be from the LMOC area towards the lakes.

The GWDrill database was used to evaluate a bulk transmissivity for the bedrock aquifer; values between 12 m^2/d and 185 m^2/d (KGS 2017a) are considered good estimates. A value calculated from aquifer test (conducted along the LMOC) data was within that range, with 50 m^2/d. Transmissivity is generally low but could be highly variable, depending on fracture presence. Measured bedrock hydraulic conductivity is in the range of $1.7x10^{-5}$ m/s and $5.2x10^{-5}$ m/s, while surficial geology hydraulic conductivity is much more variable, with values from $2.9x10^{-10}$ m/s to $1.9x10^{-5}$ m/s (KGS, 2017a). Storativity calculated with aquifer test data was indicative of a confined aquifer, with a value of $5.6x10^{-6}$ (KGS 2017a). Because bedrock geology is fairly uniform within the LAA, those values are considered representative throughout.

LSMOC

The carbonate aquifer, in the area of the LSMOC, is overlain by 2 m to 22 m of till. The LSMOC will run northeast from Lake St. Martin towards Lake Winnipeg through a wetland area, with the ground surface dropping from approximately 246 m asl to 218 m asl. According to KGS Group (2017) the piezometric head in this area is, at some places, higher than ground surface, and is under artesian pressure everywhere but where the bedrock surface is at its highest elevation (231 m asl). Seasonal piezometric variation in the area is not measured yet, but according to similarities with LMOC hydrogeological context, it could be of the same range (typical seasonal piezometric head variation in the aquifer in the area of the LMOC is 2.5 m to 3 m per year). Bedrock topography is such that groundwater seepage to surface is likely where surficial till is very thin; typical artesian groundwater spring sites occur where ground surface slope is relatively steep, near Lake Winnipeg, generally along the 240 m asl contour line (Appendix 6B, Figure 6.4B-3). Near the northeast part of the LSMOC, groundwater discharges through springs and to Lake Winnipeg as well.

Local Surficial Groundwater Flow

The till layer is overlain by a discontinuous horizon composed of localized, discontinuous areas of glaciolacustrine silts and clays, or relict shoreline sands, gravels, and silty littoral sands scattered in the region and overlying the till surface. Groundwater flows is limited within the coarser sediments due to the discontinuous nature of these layers. The surficial aquifer is not suitable for drinking water purposes because it is too shallow, but the overall quantity is enough to provide water to wetlands in the LSMOC area.

At slightly greater depths, within the till horizon, sparse intertill lenses (coarser sediments) exist along the LMOC section. Depending on continuity and interconnectivity to the overall groundwater flow system, intertill zones may slowly discharge groundwater to the surface for extended periods of time, if the water saturated coarse sediment unit intersects the surface.

Surface Water-Groundwater Interactions and Water Temperature

Groundwater temperature remains relatively constant in the bedrock aquifer at around 6 C (the average annual air temperature in the region) (KGS 2018). Surface water temperature will vary with the weather during the year, varying from close to zero in the winter up to 20-22 C during the summer (KGS 2018). The surface water will recharge into the groundwater in the upland areas away from the Project during spring and summer and is typically warmer than the groundwater. However, the rate of recharge and movement of groundwater is slow, so the temperature of the recharging surface water will moderate to the ground temperature (i.e., 6 C) by the time in enters the deeper bedrock aquifer.

As discussed above, the aquifer likely discharges into bogs, streams, and lakes (i.e., Lake Manitoba, Lake St. Martin, and Lake Winnipeg). Discharge to lakes could be widely distributed but is most likely to occur proximate to bedrock outcrops. The lakes in the vicinity of the Project are large and have large flows through them (e.g., the average flow through Lake Manitoba and Lake St. Martin is approximately 60 m^3/s); while the rate of groundwater discharge into each lake is expected to be much smaller. There will be localized temperature changes in the vicinity of lake-bottom groundwater discharges; however, it is not anticipated to substantially alter the overall temperature of the lake. The groundwater will quickly mix with the lake water and changes in water temperature, compared to current existing conditions, are expected to be nearly indiscernible and within the range of natural temperature variations in the lake.

Groundwater Quality

Groundwater quality information comes from sampling programs conducted on seven observation wells distributed along the LMOC PDA, including five programs completed between fall of 2016 and spring of 2018 (KGS Group 2016b, 2017, 2018). Monitoring protocols and data collection methodology for groundwater sampling is described by KGS Group for each program (2016b, 2017, 2018). Table 6.4-7 provides a summary of findings. Results are compared to Health Canada Canadian Drinking Water Quality Guidelines (HC-CDWQG; Health Canada 2017) and CCME Freshwater Aquatic Life Guidelines (CCME-FAL; CCME 1999).

Table 6.4-7 Historical Groundwater Quality Data from October 2016 to May 2018 –of the LMOC PDA (KGS 2018)

Parameter	HC-CDWQG	CCME-FAL	Results	
			Min	Max
pH (pH units)	6.5 - 8.5 (AO)	6.5 - 9.0	7.53	8.46
Hardness as $CaCO_3$		-	125	420
Chloride (5)	≤250 (AO)	120/640	5.28	17.8
Fluoride	1.5 (MAC)	0.12	0.47	0.82
Sulphate	500 (AO)	-	21.6	165
Nitrate (as N)	10 (MAC)	3/124	<0.0050	0.211
Nitrite (as N)	1.0 (MAC)	0.06	<0.0010	0.019

Table 6.4-7 Historical Groundwater Quality Data from October 2016 to May 2018 –of the LMOC PDA (KGS 2018)

Parameter	HC-CDWQG	CCME-FAL	Results	
			Min	Max
Total Phosphorus	-		0.0129	0.081
Total Dissolved Solids	500 (AO)	-	295	532
E. coli (MPN/100 mL)	None Detect per 100 mL (MAC)	-	<1	<1
Total Coliform (MPN/100 mL)	None Detect per 100 mL (MAC)	-	2	24
Aluminum, Dissolved	0.1- 0.2 (OG)	0.005/0.1	<0.0010	0.0189
Antimony, Dissolved	0.006 (MAC)	-	<0.00010	0.00074
Arsenic, Dissolved	0.010 (MAC)	0.00500	<0.00010	0.00103
Barium, Dissolved	1.0 (MAC)	-	0.0136	0.0275
Boron, Dissolved	5.0 (MAC)	29/1.5	0.168	0.732
Cadmium, Dissolved	0.005 (MAC)	0.00009/0.001	<0.0000050	0.0000123
Chromium, Dissolved	0.05 (MAC)	0.0089 (III)/0.001 (VI)	<0.00010	0.00069
Copper, Dissolved	1.0 (AO)		<0.00020	0.00146
Iron, Dissolved	0.3 (AO)	0.3	<0.010	0.154
Lead, Dissolved	0.010 (MAC)		<0.000050	0.000108
Manganese, Dissolved	0.05 (AO)	-	0.00413	0.103
Molybdenum, Dissolved	-	0.0730	0.00017	0.0392
Nickel, Dissolved	-		<0.00050	0.00454
Selenium, Dissolved	0.05 (MAC)	0.001	<0.000050	0.00017
Silver, Dissolved	-	0.00025	<0.000010	<0.00010
Sodium, Dissolved	200 (AO)	-	30.3	74.1
Thallium, Dissolved	-	0.0008	<0.000010	0.000024
Uranium, Dissolved	0.02 (MAC)	0.033/0.015	0.000593	0.0049
Zinc, Dissolved	5 (AO)	0.03	<0.0010	0.0054

NOTES:
This table shows parameters with established guidelines.

Results are in mg/L unless otherwise specified in the parameter column.
HC-CDWQG-Drinking Water - Health Canada Canadian Drinking Water Quality guidelines. (Health Canada 2017).

MAC: maximum acceptable concentration; AO: aesthetic objective; OG: operational guidance.
CCME-FAL - Canadian Council of Ministers of the Environment. Canadian Environmental Quality Guidelines for the protection of Freshwater Aquatic Life (CCME 1999).
Exceedance of HC-CDWQG are double underlined and exceedances of CCME-FAL are shaded.

Groundwater type is magnesium-calcium-bicarbonate or calcium-magnesium-bicarbonate to magnesium-bicarbonate (KGS Group 2017), which is typical of carbonate aquifer waters.

Comparison of groundwater quality with the HC-CDWQG suggests that groundwater that would be pumped up during dewatering along the LMOC is generally of good quality. All components are below their corresponding guideline except total dissolved solids (TDS), total coliforms and manganese. Below are comments about those latter parameters and others with lower concentrations than guidelines but still high values:

- Hardness

  Till groundwater seems to be four times less hard than groundwater from the carbonate aquifer. Hardness is not subject to a maximum acceptable concentration (MAC), but there is no health effect due to hardness. Public acceptance varies. Values between 80 mg/L and 100 mg/L $CaCO_3$ are indicative of balanced water with regard to incrustation or corrosion; other parameters (i.e., pH, temperature, alkalinity, TDS) must be considered along with hardness to define the incrustation–corrosion status. Carbonate aquifer groundwater is naturally of incrustation-type. Surface waters are generally not as hard as groundwaters.

- Total dissolved solids

  TDS is not subject to a MAC but is considered for aesthetic reasons. Carbonate aquifer groundwater of the area is generally characterized with a TDS content of approximately 500 mg/L. Water with high TDS concentrations can have a light salty taste. Higher TDS concentrations generally contribute to corrosion.

- Total coliforms

  Measured values vary between 2 MPN/100 mL and 24 MPN/100 mL while the MAC is non-detect. Positive results are very likely when the sampling well is not disinfected prior to sampling. Groundwater is free of total coliforms and the results need to be validated.

- Manganese

  The manganese concentration is high in till groundwater compared to the carbonate aquifer groundwater. The highest concentration measured (0.103 mg/L) is twice as high as the corresponding aesthetic guideline (0.05 mg/L), but manganese does not have a health guideline. Its presence in water can stain laundry and plumbing fixtures with a grey to black colour and can give a metallic taste.

6.4.3 Project Interactions with Groundwater

Table 6.4-8 identifies for each potential effect, the Project components and physical activities that might interact with groundwater during construction and operations and result in the identified environmental effect. These interactions are identified by check marks and are discussed in detail in Section 6.4.4 in the context of effects pathways, standard and project-specific mitigation and residual effects. A justification for no effect is provided after the table.

Table 6.4-8 Project-Environment Interactions with Groundwater During Construction and Operations

Project Components and Physical Activities	Environmental Effects		
	Changes in Regional Groundwater flows, Levels and Quality & Surface Water Interactions	Changes in Local Groundwater Flows Levels and Quality	Changes in Local Groundwater – Surface Water Interactions
Construction			
Site preparation of Project Components[1] (development of the PDA prior to construction activities [e.g., removal of existing infrastructure, vegetation clearing and initial earthworks, development of temporary construction camp and staging areas])	-	-	-
Project-related transportation within the LAA (movement of trucks, equipment, bulk materials, supplies, and personnel within the LAA)	-	-	-
Construction of Project components[1] (physical construction of utilities, infrastructure, and other facilities)	-	✓	✓
Quarry development (blasting and aggregate extraction used for the construction of Project components[1])	-	✓	✓
Water development and control (dewatering and realignment of existing water works)	-	✓	✓
Reclamation	-	-	-
Operations and Maintenance			
Operation and maintenance of the outlet channels (normal operational conditions when the outlet channels and associated infrastructure [e.g., water control structure gates are open, conveying water or are closed)	-	✓	✓
Operation and maintenance of other Project components[1]	-	-	-

Table 6.4-8 Project-Environment Interactions with Groundwater During Construction and Operations

Project Components and Physical Activities	Environmental Effects		
	Changes in Regional Groundwater flows, Levels and Quality & Surface Water Interactions	**Changes in Local Groundwater Flows Levels and Quality**	**Changes in Local Groundwater – Surface Water Interactions**
(normal operations conditions associated with PR 239 and municipal road realignments, distribution line and bridges and culverts)			
Project-related transportation within the LAA (movement of trucks, equipment, bulk materials, supplies, and personnel within the LAA)	-	-	-
Operation, maintenance, and reclamation of quarries	-	-	-

NOTES:
✓ indicates a potential interaction.
– indicates no potential interactions are expected.
[1] Components include: outlet channels, water control structures, distribution line, bridges and culverts, PR 239 and municipal road realignments, temporary construction camps and staging areas, and quarries.

There is no potential for interaction between the Project (construction and operations) and regional groundwater flows, levels, quality or surface water/groundwater interactions. Regional groundwater flow from the carbonate aquifer is not affected by direct Project construction or construction dewatering. The intersection of the Project with groundwater will cause local groundwater level and flow effects but will not change the regional groundwater flows from the uplands to the major regional lakes (Lake Winnipeg, Lake Manitoba or Lake St. Martin). Lake St. Martin would be a potential discharge area for groundwater discharge from the uplands (see Appendix 6B, Figure 6.4B-3) and this will not be affected by construction of either channel because effects on the flow in the carbonate aquifer will be limited to less than 5 km, likely less than 3 km from the channels.

During Project construction, site preparation activities are not expected to interact with groundwater resources because these activities occur at or above the ground surface and above the water table except where it is at surface (e.g. springs).

Project-related transportation within the LAA (movement of trucks, equipment, bulk materials, supplies, and personnel within the LAA) activities are not expected to interact with groundwater resources because these activities occur at the ground surface and above the water table.

Laydown areas are not expected to interact with groundwater quantity such that effects on groundwater quantity result, because lay down activities occur at the ground surface and above the water table. Laydown areas could potentially interact with groundwater resources such that groundwater quality is affected (e.g., incidental spills).

Reclamation activities related to restoration of constructed areas (e.g., roads, dam and berm) are not expected to interact with groundwater resources because these activities occur at or above the ground surface and above the water table.

6.4.4 Assessment of Residual Environmental Effects on Groundwater

6.4.4.1 Analytical Assessment Techniques for Groundwater

The following information sources are used in this assessment:

- conceptual engineering studies (KGS 2016b, 2017a, 2017b) on groundwater:
  - compilation of borehole data
  - pump tests to determine hydraulic conductivity and potential connections between SW and GW
  - analytical groundwater modelling to determine potential extent of dewatering impacts
  - sensitivity analysis
  - review of wells in the area
  - assessment of Groundwater Under the Direct Influence of Surface Water (GUDI) potential
- provincial well data from GWdrill and groundwater level records
- topographic and geological data

6.4.4.2 Changes in Local Groundwater Flows, Levels and Quality

Project Pathways

LMOC

Construction Phase

The LMOC will be excavated in the till overlaying the carbonate aquifer that is under high artesian pressure. The piezometric head can be up to 5 m above ground level. As till is under pressure, there is a risk that the water pressure will break through the till – termed “blowout”. Geotechnical engineers will work with the hydrogeologists on the engineering design to determine the reduction in pressure head required in the carbonate aquifer to construct the channel while reducing the risk of a blowout of the till.

Groundwater dewatering wells will be installed in the confined aquifer in the area of construction and water will be pumped out to lower the pressure in the aquifer, below the channel, during construction. In the conceptual design, KGS Group (2017a) developed an estimate of the drawdown using analytical models. Sensitivity analysis was performed by varying transmissivity and storativity coefficients. At the channel, the drawdown would be about 14 m, reducing to a drawdown of 1.5 m to 3.3 m at the 3 km distance from the segments of the channel being depressurized. It will further decrease to an estimated 0.9 m to 2.7 m at 5 km distance. Typical seasonal piezometric head variation in the aquifer in the area of

the LMOC is 2.5 m to 3 m per year. In most cases (at a distance greater than 3 km) and in all cases (at a distance greater than 5 km), the decrease in pressure (piezometric head) from the Project dewatering will be within the typical season variation of pressure and would have no impact on domestic well operation.

A schematic (not to scale) of the process of depressurization of the aquifer during construction of the channel, and issues involved, is shown in Figure 6.4-1. This is a typical cross-sectional and a geotechnical/hydrogeological investigation occurring during the preliminary engineering study may find different values for cover of till. The original piezometric head is above ground and pumping of water from the confined carbonate aquifer is required to reduce the head to a level determined by the geotechnical analysis for each section. This reduction in head in the aquifer will also occur away from the Project in the carbonate aquifer used by domestic wells. Domestic wells that are installed into the carbonate aquifer pump the water out of the aquifer to provide potable water inside the house for domestic use. Water pressure within dwellings on private wells is usually provided by a pressure tank; pressure provided by those tanks is usually semi-independent from the well pump: the well pump provides water and some pressure while the pressure tank controls constant water pressure. Consequently, a small reduction in hydraulic head could affect well pump efficiency, but it will not be noticeable by water end-users because water pressure is regulated by the pressure tank rather than the well pump. Some wells may have the piezometric head impacted to a large enough degree to require mitigation.

In some cases, landowners have installed wells to supply livestock using only the natural artesian pressure. The well will discharge above the ground and flow to a livestock watering dugout. These wells will be more susceptible to the effects of construction dewatering: when the pressure head drops below ground, the well will not flow. Some of the wells in the area may flow only seasonally as the pressure head in the aquifer varies seasonally by 2.5 m to 3 m.

The 5 km potential effects buffer is shown on Appendix 6B, Figure 6.4B-5 align with the number of potential wells affected as determined from the provincial data base (GWdrill). There are 154 wells that are within the potential affected area within the buffer of 3 km of the PDA and 273 wells within the buffer of 5 km from the PDA. It is likely that many of the wells may not be active at this time. As part of the engineering design a Groundwater Management Plan will be developed. This plan will refine the area affected (very likely reduced) and provide a current enumeration of wells potentially affected by the dewatering at each stage of construction. More discussion on the type of groundwater use and effects on groundwater use are provided in Chapter 9, Section 9.2: Land and Resource Use). The effects of water removed and discharged to the surface is discussed in Section 6.4.7. There may be a small local effect on groundwater pressure under Lake Manitoba and Lake St. Martin (in Birch Bay or Watchorn Bay) during construction dewatering for the area within 3 km to 5 km of the inlet or outlet. This will have a small effect on groundwater flows to the lake at those locations, although the groundwater pumped will be discharged to the surface and will ultimately discharge to Birch Bay in Lake St. Martin or Watchorn Bay in Lake Manitoba.

Specific locations of quarry operation have not been identified; however, if quarry operations require dewatering, the zone of influence due to dewatering will extend a distance from the given quarry depending on several local geological factors. Water availability can be affected at water wells located within a zone of influence due to dewatering. The effects on groundwater users are mitigable, as discussed below.

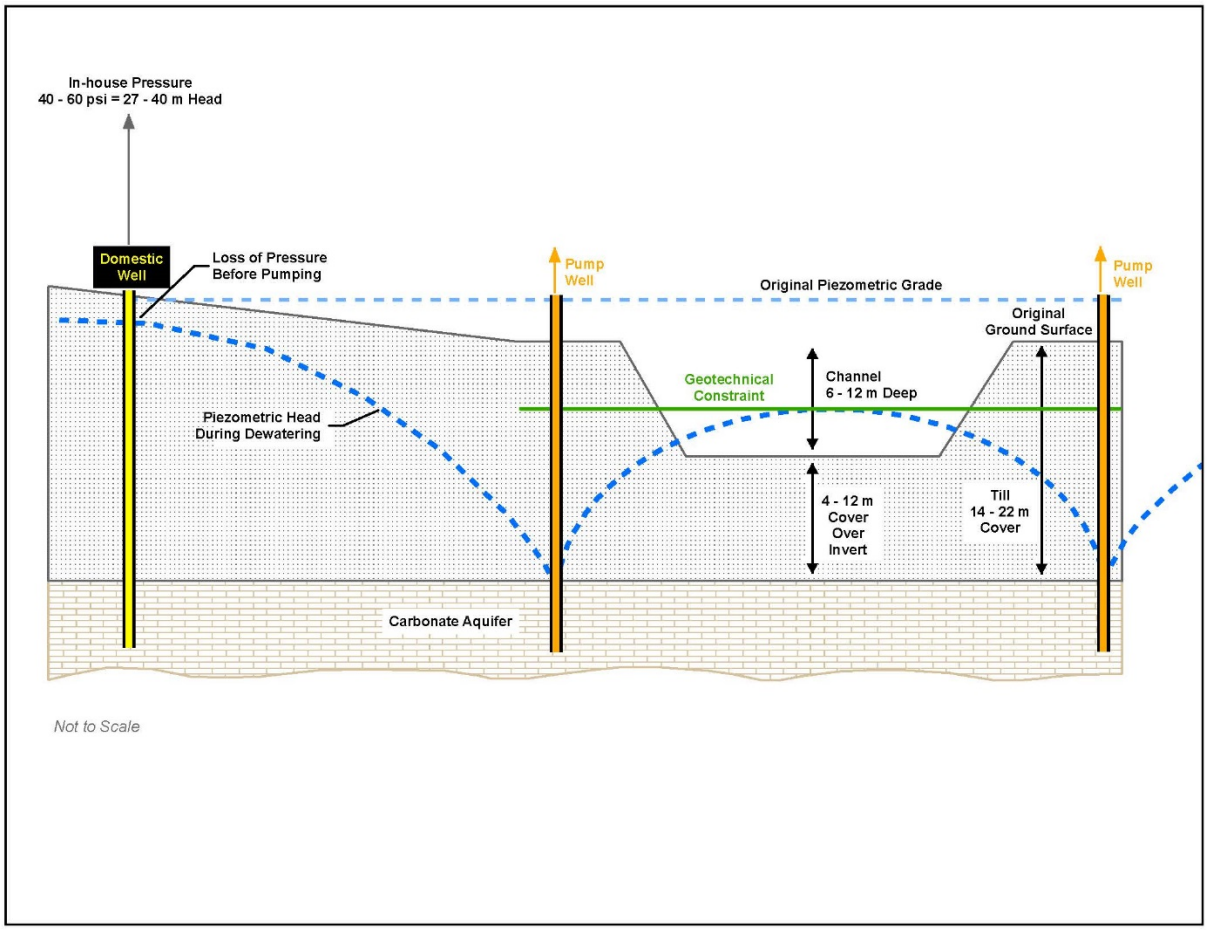

Figure 6.4-1 Schematic of Typical Cross-Section Showing Possible Dewatering Effects During Construction on Wells

Operation Phase

After construction, water from Lake Manitoba and Lake St. Martin will be permanently allowed to fill the channel. This water adds a counterweight on the till to prevent blowouts. It is possible that passive depressurization is required by developing pressure relief wells along the channel to remove water and pressure where till and remaining water is not enough to maintain safe ground pressure. The pressure reduction in the confined aquifer would continue after construction but be small and local (less than the construction effects and within the ROW, or 200 m). The most likely area for this type of passive long-term depressurization is in the north section, downstream of the control structure because the water level in the channel is lower in that section (downstream of the control structure, water levels will be at Lake St. Martin elevation while upstream of the control structure, channel water levels will be at Lake Manitoba elevation).

Water from depressurization will be discharged to the channel or to an outside drain constructed parallel to the channel if required or may be discharged to the Birch Creek or Watchorn Creek systems. For impacts on surface water, see Section 6.4.7.

LSMOC

The construction of the LSMOC will intersect with the carbonate aquifer in the region close to Lake Winnipeg (Appendix 6B, Figure 6.4B-6). This is discussed below in “Changes in Local Groundwater/Surface Water interactions.” The discussion on effects of wetlands adjacent due to both changes in surface water and groundwater from the LSMOC are discussed in Section 6.4.4.3.

General Effects on Surficial Aquifers

The surficial overburden is generally composed of till and organic soils. The distance that changes in water level are transferred through the groundwater are limited. Changes in groundwater around the channel excavations will be small (less than 1m), and the effects will transfer only 10 to 200 m at most. Around Lake St. Martin, the Fairford River and Dauphin River, water levels will decrease during high dewatering conditions due to the Project. There will be a decrease in groundwater discharge in the saturated soils along the shoreline due to the pressure reduction. The effects will not be noticeable within a short distance of the shoreline. In the region of the LMOC, the channel construction and operation will improve drainage in the PDA (i.e., within the ROW) lowering the saturation level in the surficial overburden and soils.

Groundwater Mitigation

LMOC

Further aquifer investigation and modelling will be carried out to determine the effect of construction dewatering on specific private wells in the potentially affected area. A Groundwater Management Plan (GWMP) will be developed to refine the analyses of effects of dewatering, and then communicated to the local well users that may be affected. Developing the mitigation plans will involve working with affected

well users. Additional observation wells will be installed prior to construction dewatering to monitor the effects in the area during dewatering of each section during construction. Mitigation plans will be modified if/as required during the dewatering as specific information is received from observation wells and local well users. Mitigation could include:

- Domestic wells
  - lower existing pump if feasible or necessary
  - supply new pumps if needed
  - drill new wells if needed
  - provide water tanks to affected well users
- Artesian livestock water wells
  - bring water from construction dewatering pumps to dugouts, supplied by pressure relief artesian wells

LSMOC

Groundwater and Surface Water Management plans are being developed as part of the engineering design (Section 3.7). The drainage along LSMOC will be maintained to reduce the potential effects of water backing up in the wetlands upstream (south and east) of the LSMOC.

Project Residual Effects

The residual effects of the changes in local groundwater flows, levels and quality due to the construction of the Project after mitigation, can be characterized as follows:

- direction is negative because of effects on the piezometric head
- duration of the effect is short-term because it occurs during the construction of the Project.
- magnitude is moderate because piezometric head change is the greater than natural variability
- geographic extent of the effects is LAA
- timing is not sensitive for this change because groundwater in the carbonate aquifer is not directly interacting with biological VCs
- frequency of the effect is infrequent because it occurs during Project construction
- effects are reversible because dewatering will discontinue after construction
- ecological and socio-economic context is characterized as the groundwater resource being relatively undisturbed; although domestic and agricultural use occurs in the area, it is relatively small when compared to the groundwater resources availability

Although the change in groundwater piezometric head effect is measurable and within the LAA, the effect on the groundwater resource use will be mitigated by the measures described in the mitigation sub-section of 6.4.4.2.

The residual effects of the changes in local groundwater flows, levels and quality due to the operation of the Project can be characterized as:

- direction is negative because of effects on the piezometric head
- duration of the effect is long-term because it occurs during the life of the Project.
- magnitude is low because the piezometric head change is likely to be less than natural variability
- geographic extent of the effects is confined to the PDA
- timing is not an issue for this change because groundwater in the carbonate aquifer is not directly interacting with biological VCs
- frequency of the effect is continuous because it occurs during life of the Project
- effects are irreversible because passive depressurization will continue after construction
- ecological and socio-economic context is characterized by the groundwater resource being relatively undisturbed, although domestic and agricultural use occurs in the area, it is relatively small when compared to the groundwater resources availability

6.4.4.3 Changes in Local Groundwater/Surface Water interactions

Project Pathways

LMOC

Concern of GUDI (Drinking Water Quality)

During discussions with landowners, concerns were often expressed that surface water may be transferred to groundwater creating a risk that pathogens may contaminate the domestic water supply; this is groundwater under the direct influence (GUDI) of surface water. Currently, the groundwater in the confined carbonate near the LMOC comes from the upland region of the Interlake Region (see Section 6.4.2.2 Existing Conditions). The location of the proposed channel (Route D, as discussed in Chapter 2, Section 2.3.2) was selected to reduce the risk of GUDI; this concern was regularly raised by First Nation Communities during the engagement sessions. This area is under high artesian pressure (the carbonate aquifer is under pressure at higher head than ground surface, lake levels and water level in wetlands), meaning that the water will flow from the aquifer to the surface if there is a pathway. Currently, there is a thick till aquiclude (i.e., does not transmit water) protecting the underlying carbonate aquifer. If the till is breached during construction, then the surface water will not flow into the aquifer. The most likely location the till may be breached, and the bedrock exposed (often referred to as daylighting), is in the vicinity of the water control structure (see Figure 6.4.B-6). This physical location of the Project, although creating a challenge for construction, does not create the same GUDI concerns as other options (i.e.,

Route C in Chapter 2) did. Route D was selected over Route C (located further west and closer to Fairford River) to reduce concern of GUDI (KGS Group 2016b, 2017a) as part of the alternate route selection for LMOC. The GUDI at the proposed LMOC is very low due to high artesian pressure maintaining flow in the direction from groundwater to surface water.

GUDI is generally an issue in flooded areas because flooding surface water has the potential to flow overland into wells. The wells then become contaminated and need extensive purging and disinfecting to become safe for drinking. The Project will reduce the frequency of flooding along Fairford River, Lake St. Martin and Dauphin River and it will, therefore, protect wells located in the current flood zones. The Project should reduce the risk of GUDI in the region by reducing flooding.

Impacts on Wetlands adjacent to LMOC

Wetlands and small wetland lakes and ponds located along the east side of the LMOC alignment (i.e., Goodison Lake, Water Lake, Clear Lake, Reed Lake) will potentially be affected during construction. Due to the thick confining layer of till, it is unlikely that there is a connection between the confined carbonate aquifer and the wetlands (KGS Group 2017a). Because of the long-term artesian pressure from the carbonate aquifer, it is likely that, over time, water does seep upwards towards the wetlands. If this happened to be an undetected artesian discharge into the wetlands, water would flow upwards into the wetlands and then it may be affected during construction dewatering (Figure 6.4-2). Although water will likely not drain back through the till towards the limestone a source of water may be lost for this wetland when the construction dewatering occurs in the region. Water that is being discharged from the dewatering wells can easily be directed to the wetland to mitigate this potential although unlikely effect. Water quality monitoring would be required before a discharge occurs to ensure no harm is done to the vegetation or aquatic life (see Section 6.4.7.7). Another pathway that could affect the wetlands during construction would be a lateral shallow connection between the channel and the wetlands. It is not likely that a continuous sand lens would occur between the wetland and the channel. The current understanding of the till is that there are sand lenses; however, they are infrequently found in boreholes and are likely not continuous for any considerable length.

During construction, there will be the need to discharge groundwater from active aquifer depressurization activities. For the LMOC, groundwater will be discharged to the channel or to an outside drain constructed parallel to the channel if, required, or it may be discharged to the Birch Creek or Watchorn Creek systems. The discharge locations will be determined as part of detailed design and will be related to construction sequencing (i.e., how construction will advance across the landscape from the inlet or outlet areas). Regardless of the discharge locations, the groundwater released to the outside drain or creeks will ultimately discharge into Birch Bay in Lake St. Martin or Watchorn Bay in Lake Manitoba. During engineering design, drainage capacity will be assessed to develop the details of the groundwater dewatering discharge plan. The capacity of potential drains will be assessed, and discharge locations will be selected to ensure capacity is available in the downstream ditches and creeks. During construction, the capacity of the drainage system will be monitored to ensure the system is not surcharged beyond its capacity. Water quality effects are discussed below in Section 6.4.7.7 Changes in Regional and/or Local Surface Water Quality.

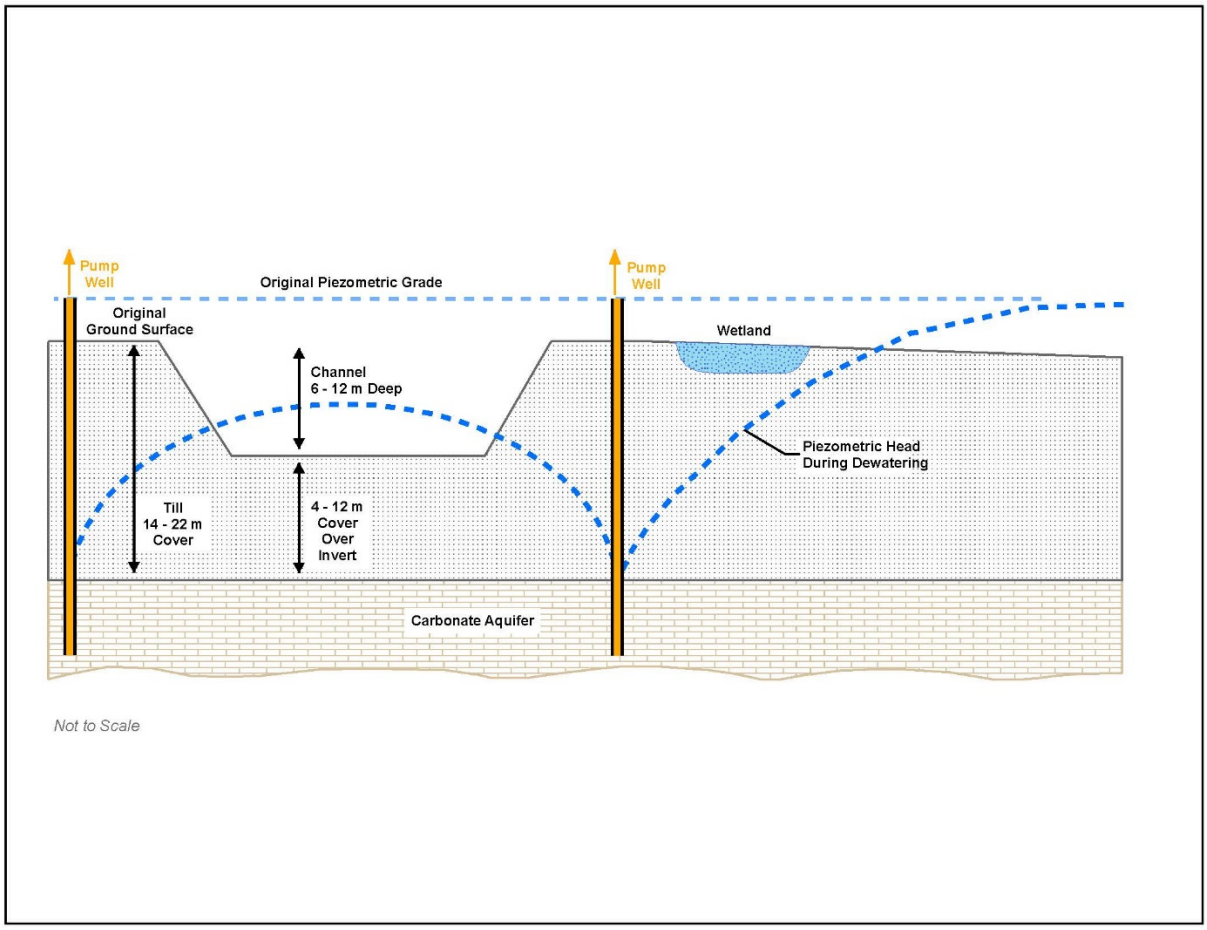

Figure 6.4-2 Schematic of Typical Cross-Section Showing Potential Effects on Wetlands

Effects on surficial geology (soils and till) will occur due to improved drainage around the LMOC. Effects are expected to remain within the ROW of the channels. Effects of the Project on surficial geology and soils are discussed in Section 6.3.4.

LSMOC

The LSMOC route will pass through wetland areas, similar to wetlands encountered by the EOC, Reach 1 route. Impacts on wetland hydrology are difficult to determine with typical groundwater or surface water analytical tools or models. It is very challenging to determine the watershed boundaries or flow paths for surface water in a wetland, and peat in the wetlands does not have typical groundwater properties that allow effects to be assessed with groundwater models. A map showing generalized flows paths in the area of the LSMOC is shown in Figure 6.4B-10. The wetland water levels can be disturbed by channel construction, and this disturbance will affect wetland vegetation.

A vegetation analysis of the EOC effects (See Section 8.2 Vegetation) determined that wetland vegetation in some areas was affected by the construction and operation of the EOC, Reach 1 up to 1,600 m perpendicular to the channel. This effect was most likely caused by a change in water levels in the wetland, which occurred due to the construction of the EOC. The changes in water level caused by the LSMOC on the wetlands in proximity to the channel are expected to be similar in distance from the channel as effects from the EOC (i.e., 1,600 m). However, it should be noted that the effects due to the LSMOC would be of a lesser magnitude than the effects of the EOC because the LSMOC will be constructed and operated with considerations for drainage and wetland connectivity.

The effects on wetlands adjacent to the LSMOC will differ from the effects from the EOC due to the complexity of hydrology within the wetland areas. The LSMOC will include improved drainage to reduce the effects of backwater impacting the wetland to the south and east of the channel. Effects should be minimized and limited compared to the effects of the EOC.

Natural surface and shallow subsurface drainage flow may be affected along the approximately 24 km length of the LSMOC. Based on examination of the effects of the EOC, effects on drainage are not expected to occur beyond 500 m from the channel. Unmitigated, this effect would be expected to affect drainage over an area of up to approximately 1,200 ha on either side of the channel. Therefore, on the east side of the channel, increased potential for inundation and flooding of an area of up to 1,200 ha is anticipated, while on the west side of the channel a similar area would be expected to dry down and experience reduced surface and near-surface moisture conditions.

Drainage channels are incorporated as part of Project design. Therefore, inundation and flooding due to the presence of the channel is not expected to occur on the southeast side of the channel; however, drier soil conditions are still expected on the north and west side.

Impact on Artesian Discharges

Bedrock surface is shallow at the proposed location of the most upstream drop structure, to a point that the carbonate aquifer might be exposed to surface (referred to as daylighting; Appendix 6B, Figure 6.4B-6). Hydraulic head at this location is at a higher elevation than the channel invert.

Consequently, artesian pressure will be relieved at this location, locally depressurizing the carbonate aquifer. The depressurization zone of influence will expand over a limited distance, centred on the artificially created groundwater discharge. Based on hydrogeological conditions, springs are likely present in that general area. Provided that depressurization is expanding to the point of reaching a spring originating from the carbonate aquifer, the flow of this spring could decrease; the closer the spring, the greater the flow could decrease.

Mitigation

Project Environmental Management Program

Manitoba Infrastructure is developing a comprehensive Environmental Management Program (EMP) that encompasses several mitigation methods to reduce or prevent potential effects to groundwater and surface water during Project construction and operation (Section 3.7). The EMP is organized into a Construction Environmental Management Program (CEMP) and an Operations Environmental Management Program (OEMP) that will be finalized prior to Project construction and operation. A detailed description of the CEMP and OEMP are provided in Section 3.7. The EMP includes several management plans and mitigation measures designed to address specific components of the Project activities and provide protection of groundwater and surface water resources.

The Environmental Protection Plans (EPPs), Project Environmental Requirements (PERs), waste management plan, construction decommissioning plan, hazardous materials management plan and emergency response plan will include mitigation measures that will protect groundwater and surface water resources, and mitigation measures specific to the protection of groundwater and surface water resources will be outlined in the groundwater management plan (GWMP),surface water management plan (SWMP), the debris management plan (DMP) and the sediment management plan (SMP).

LMOC

Selection of Route D over other options reduces the risk of groundwater being affected by surface water due to high artesian pressure maintaining flow in upward direction where hydraulic head is at higher elevation than channel water levels. If groundwater under artesian pressure stops leaking to wetland bottoms, dewatering water can be conveyed to wetlands. If seepage through sand lenses occurs, clay cut-off walls (or other means of reducing groundwater flows) can be built through the sand lenses during construction to stop leakage, if leakage substantially changes water balance of the wetlands.

Groundwater and surface water management plans are being developed as part of the engineering design (see Chapter 3, Section 3.7). The locations of discharge and the monitoring will be developed in consultation with Rural Municipality of Grahamdale and local residents.

LSMOC

As indicated, groundwater and surface water management plans are being developed as part of the engineering design (see Chapter 3, Section 3.7). The drainage along LSMOC will be maintained to reduce the potential effects of water backing up in the wetlands upstream (south and east) of the LSMOC.

If the risk is sufficient, grout injection of the pervious top horizon of carbonate aquifer in areas of potential exposure prior to excavation will cut off possible artificial groundwater discharge. This would serve to maintain local artesian pressure if necessary, based on the detailed design process.

Project Residual Effects

The residual effects of the potential changes in local groundwater/surface water interactions due to the construction of the Project can be characterized as follows:

- direction is adverse because the changes affect existing groundwater and surface flows and/or flow patterns
- magnitude is low for the LMOC area and moderate for the LSMOC area
- geographic extent of the effects is LAA
- the timing of the effect has a high sensitivity because the effect occurs during a critical life stage (e.g., fish spawning or bird nesting periods)
- frequency of the effect is continuous given the permanent nature of the Project
- the duration of the effect is long-term given the permanent nature of the Project
- the effects are irreversible, given the permanent nature of the Project
- the ecological and socio-economic context is disturbed for LMOC because the PDA has been previously disturbed by human development
- the ecological and socio-economic context is disturbed for LSMOC because the PDA has been previously disturbed by human activities and previous floods when water was diverted from Lake St. Martin through the EOC and into the Buffalo Creek system

6.4.5 Existing Conditions for Surface Water

6.4.5.1 Surface Water Methods

The existing conditions for surface water in the RAA was determined through the compilation and review of existing technical data and reports, field investigations, and hydrologic modelling, as follows:

- historical flow data and lake level data for RAA rivers and lakes from the federal hydrometric database
- National Hydro Network (NHN) spatial data for the RAA
- Project-related reports and information, e.g., Lake Manitoba and Lake St. Martin Regulation Review Committee Report 2013; Lake Manitoba Regulation Review Advisory Committee 2003.
- Project-related engineering and monitoring reports (KGS Group Ltd. 2014, 2016a, 2016b, 2017a, 2017b, 2018)
- Project-related aquatic studies and monitoring reports for the EOC (NSC and KGS 2016)
- RAA surface water quality data collected by MSD at various times and sites from 1973 to 2017

- RAA surface water quality data collected under Manitoba Hydro's Coordinated Aquatic Monitoring Program (CAMP) from 2008 to 2016
- other published and unpublished literature relevant to the RAA and Project activities

A list of the technical reports and data sources used to determine the existing conditions for surface water is provided in Section 6.5.3.

The field investigations included the following:

- studies conducted in Fairford River, Lake St. Martin, Dauphin River and Sturgeon Bay from August 2011 to September 2015 as part of the Lake St. Martin Emergency Relief Channel Monitoring program (N/S Consultants Inc. (NSC) and KGS Group 2016)
- fisheries investigations conducted in Lake Manitoba, Watchorn Bay, Watchorn Creek, Lake St. Martin, Birch Bay and Birch Creek in the fall of 2015 and spring of 2016 (AAE 2016)
- bathymetric surveys conducted in the Fairford River, Watchorn Bay, Lake St. Martin, Dauphin River and Sturgeon Bay from 2011 to 2018 (Manitoba Infrastructure 2019, N/S Consultants Inc. (NSC) and KGS Group 2016)
- sediment transport studies conducted in the Fairford River, Watchorn Bay, Lake St. Martin, Dauphin River and Sturgeon Bay from 2011 to 2018 by Manitoba Infrastructure, KGS Group and NSC
- surface water quality monitoring completed in the area of the proposed LMOC route from 2016 to 2018 (KGS Group 2018)

The hydrologic modelling included the following:

- modelling of flow scenarios by Manitoba Infrastructure with and without operation of the Project (Manitoba Infrastructure 2019b)
- modelling of flood routing, sediment transport, and ice processes (KGS Group Ltd. 2014, 2016a, 2016b, 2017a, 2017b, 2018)
- modelling of channel flows for design and operation of the LMOC and LSMOC (see Chapter 3.0 Project Description)

6.4.5.2 Surface Water Overview

The assessment of potential effects on surface water due to the Project was completed by examining the existing conditions for surface water hydrology and surface water quality in the regional and local waterways and comparing these existing conditions without the Project to the conditions that will occur in regional and local surface water areas with the Project. Information on existing conditions is provided below and additional details are provided in Appendices 6D to 6K.

Surface Water Quality

Appendix 6D provides a general description of the existing conditions for surface water hydrology and surface water quality for the watercourses and waterbodies that may be affected in the RAA, including information on hydraulic and sediment transport studies and ice processes. Table 6.4-9 provides an overview of existing conditions for surface water quality in the RAA waterways. Surface water quality data provided by MSD to Manitoba Infrastructure have been incorporated in the summary.

Table 6.4-9 Summary of Surface Water Quality Parameters for Regional and Local Waterways

Parameter	Fairford River	Watchorn Bay	Watchorn Creek	Birch Bay	Birch Creek	Lake St. Martin	Buffalo Creek	Dauphin River	Sturgeon Bay
Water temperature (°C)	0 to 23.5	0.5 to 26.1	4.5 to 21.5	5.5 to 21.8	5.4 to 20.5	0 to 26	0 to 25	0 to 26	0 to 23.5
Laboratory pH	7.59 to 8.67	8.35 to 8.62	7.56 to 8.22	8.24 to 8.61	8.06 to 8.49	8.03 to 8.68	8.12 to 8.19	7.48 to 9.15	7.8 to 8.60
Laboratory conductivity (µmho/cm)	898 to 2000	604 to 886	561 to 841	813 to 917	667 to 857	857 to 1310	217 to 237	767 to 3630	410 to 1100
Dissolved oxygen (mg/L)	4.4 to 15.1	5.2 to 12.7	1.60 to 8.31	5.4 to 10.6	3.11 to 10.04	6.1 to 14.4	6.4 to 12.2	1.1 to 17.1	7.2 to 16.7
TSS (mg/L)	< 2.0 to 44	1 to 51	< 2.0 to 4	3.6 to 10.4	< 2.0 to 6.4	< 2.0 to 47	< 2.0 to 6.0	< 2.0 to 69	< 2.0 to 28
TDS (mg/L)	508 to 1480	373 to 532	358 to 511	488 to 532	436 to 549	488 to 772	164 to 177	240 to 1470	230 to 756
Hardness ($CaCO_3$) (mg/L)	203 to 348	229 to 322	316 to 476	196 to 270	419 to 526	224 to 350	155 to 166	178 to 358	149 to 324
Total nitrogen (mg/L)	0.64 to 2.96	0.87 to 2.6	1.22 to 2.12	0.82 to 2.18	1.36 to 2.55	0.40 to 2.33	0.76 to 1.15	0.34 to 2.51	0.35 to 1.38
Total phosphorus (mg/L)	0.002 to 0.045	0.008 to 0.089	0.032 to 0.082	0.014 to 0.027	0.016 to 0.073	0.010 to 0.054	< 0.010 to 0.026	0.002 to 0.070	0.012 to 0.108
Chlorophyll α (µg/L)	<0.50 to 19.5	Not Analyzed	Not Analyzed	Not Analyzed	Not Analyzed	<0.50 to 9.16	0.37 to 0.52	0.47 to 9.0	0.13 to 14.7
E. coli (CFU/100 mL)	1 to 461	<1 to 114	20 to <100	1 to 613	11 to 249	Not Detected	Not Analyzed	1 to 100	Not Detected
Petroleum hydrocarbons	Not Analyzed	Not Analyzed	Not Analyzed	Not Analyzed	Not Analyzed	Not Detected	Not Detected	Not Detected	Not Analyzed

The water quality in Fairford River, Lake St. Martin, Dauphin River, and Sturgeon Bay was described as moderately nutrient rich, low to moderately turbid, slightly alkaline, very hard, and well-oxygenated (NSC and KGS Group 2016). The review of existing conditions for surface water quality included an examination of existing sources of potential contaminants to surface water (Appendix 6D). A number of parameters exceeded the Manitoba Water Quality Standards, Objectives, and Guidelines (MWQSOGs) for the protection of freshwater aquatic life (FAL) (MCWS 2011), the Canadian Council of Ministers of the Environment (CCME) guidelines for the protection of freshwater aquatic life (CCME 1999), or the MWQSOGs/Health Canada aesthetic objective for drinking water (Health Canada 2017). The most notable is fluoride that exceeded the CCME guideline in groundwater (See section 6.4.2.2) and which also exceeds the same guideline in most of the surface samples taken in the RAA. There are existing contributions of nutrients, wastewater effluents, fertilizers, pesticides, animal waste and other contaminants associated with human residential, industrial (e.g., Graymont plant) and recreational activities, that enter the area waterways through runoff or as direct discharges. In land areas that were previously inundated during high flow events, overland flooding may have released or transported compounds that can affect water quality in the area. For example, a 1989 study concluded that private wells throughout the Pinaymootang First Nation community were contaminated and not suitable for drinking as they had been impacted during water table rises that likely occurred when the land was flooded, saturating the soil and with it, septic tanks and water wells (LM and LSMRRC 2013). Table 6D.5-1 in Section 6D.5 of Appendix 6D provides a qualitative summary of existing sources of potential contaminants to surface water in the LAA.

Sediment Quality

Sediment quality data (limited to organic carbon content and particle size for aquatic habitat characterization) was previously collected in the vicinity of the Project as part of the aquatic monitoring work conducted for the operation of the nearby Emergency Outlet Channel project. The NSC 2013 report (pages 62 to 66), described the methods and results of the sediment quality sampling conducted in Sturgeon Bay in the fall of 2011. Table 4-2 on pages 65 and 66 of the report provides a summary of the Total Carbon by percentage (%) and Particle Size (%) for each sample. Total organic carbon (TOC) ranged from 0.2-3.91% in the Sturgeon Bay nearshore sites, and the relative proportion of organic carbon increased with distance offshore (NSC 2013). Within the Intensive Zone (within 2 km of the Dauphin River mouth), TOC ranged from 0.2-0.75 % (NSC 2013).

Hydrology

Lake Manitoba has a length of 225 km from north to south and 915 km of shoreline (LMRRC 2003). The lake is naturally divided into north and south basins at the Lake Manitoba Narrows, located approximately halfway along its length. The large south basin has a surface area of about 261 km^2 and an average depth of about 4.1 m. The smaller north basin has a surface area of about 79 km^2 and an average depth of about 1.5 m (LMRRC 2003). Water depths overall are about 5 m on average, with a maximum depth of about 7 m (LMRRC 2003). Lake Manitoba, as measured at the Fairford River inlet, has a drainage area of approximately 79,800 $km^{2,}$ and a surface area of approximately 4,500 km^2 (KGS Group 2016a).

Lake St. Martin has a surface area of approximately 345 km^2 with about 260 km of shoreline (LMRRC 2003). Lake St. Martin receives flows from Lake Manitoba through Fairford River. The existing range of water levels (see Table 6.4-10) is based on modelled data and assumes that the Fairford River Water Control Structure has been operating under the current operating guidelines for the entire period of record (1915-2017). This analysis provides the expected existing condition without the Project, assuming the historic period of record is representative of the possible range of inflows into Lake Manitoba for the near future (30 years). By assuming the existing infrastructure to the long term record of inflows the range in water levels for high, median and low-level conditions can be developed as shown on Table 6.4-10.

Table 6.4-10 Range of Water Levels on Lake Manitoba and Lake St. Martin

Scenario (percentage time that indicated levels are exceeded)	Lake Manitoba (m asl)	Lake St. Martin (m asl)
Low Level (95% of levels exceeded)	246.85	242.65
Median Level (50% of levels exceeded)	247.36	243.26
High Level (5% of levels exceeded)	247.74	244.40

The 16 km long Fairford River is the only outlet for Lake Manitoba and is located at the northeast corner of the lake. Flows on the Fairford River are regulated by the Fairford River Water Control Structure (FRWCS), which has been in operation since 1961, and allows higher and lower outflows from Lake Manitoba than under natural conditions (LMRRC 2003). Dauphin River has a gross total drainage area of about 82,300 km^2 and a length of about 50 km from its inlet on Lake St. Martin to its outlet into Sturgeon Bay on Lake Winnipeg. The range of flows on the Fairford and Dauphin Rivers for low, median and high flow conditions is shown in Table 6.4-11. The Lake St. Martin Emergency Outlet Channel (EOC) was built during the flood of 2011 and operated again in 2014. Without the Project, it could be expected to operate again in the future about 3% of the time up to a maximum of 170 m^3/s. It discharges through the Reach 1 channel and the bog to Big Buffalo Lake and through Buffalo Creek and then into Dauphin River.

Table 6.4-11 Range of Flows on the Fairford and Dauphin Rivers

Flow Exceedance Scenario	Fairford River Flow (m^3/s)	Dauphin River Flow (m^3/s))
Low Flow (95% of flows exceeded)	10.4	5.22
Median Flow (50% of flows exceeded)	55.0	58.1
High Flow (5% of flows exceeded)	271.0	240.2

Further information on existing condition regional water levels and flows for the lakes (Lake Manitoba and Lake St. Martin) and rivers (Fairford River and Dauphin River) that may be affected by the Project are provided in Appendix 6E. Simulated data are also provided in Appendix 6E assuming consistent regulation over the entire period of record with existing permanent infrastructure (without the Project) and with the Project. This data includes elevation-duration curves for each lake without the Project and with the Project, as well as flow-duration curves for each river without the Project and with the Project. The monthly average and median (50%) flows and water levels are provided for each regional lake and river. To illustrate seasonal conditions during high flow conditions, monthly flows that are exceeded only 5% of the time are also provided in Appendix 6E. Low flow conditions are illustrated by monthly flows that are exceeded 95% of the time. Appendix 6F provides the bathymetric maps developed from surveys and investigations conducted in the RAA waterways. Winter ice forms on the Fairford River upstream and downstream of the Fairford River Water Control Structure (FRWCS) (KGS Group 2014) and along Dauphin River. Ice conditions in Dauphin River can restrict outflows from Lake St. Martin, which can cause increased water levels on the lake (KGS Group 2014). Higher flows on Dauphin River during freeze up can cause overland flooding at Dauphin River First Nation due to the formation of hanging ice dams caused by frazil ice. As such, the FRWCS has historically been operated to limit inflows into Lake St. Martin during winter, and control water levels on the lake.

The outflow from Lake St. Martin is controlled by Dauphin River, which is the only natural outlet from Lake St. Martin. A solid ice cover typically forms on Lake St. Martin in November and remains until the following spring break-up in April or May (NSC and KGS Group 2016). Ice thickness on Lake St. Martin in January 2012 was measured as 0.46 m (NSC and KGS Group 2016).

The LMOC will cross the Birch Creek and Watchorn Creek systems (Appendix 6B, Figure 6.4B-7) and the LSMOC will cross the upper reaches of the Buffalo Creek system (Appendix 6B, Figure 6.4B-8). Birch Creek flows from the wetlands, ponds and small lakes located adjacent to the proposed LMOC route north to Birch Bay in Lake St. Martin and has a drainage area of approximately 286 km² (Figure 6.4B-7). Watchorn Creek originates near Reed Lake and flows south to Watchorn Bay in Lake Manitoba and has a drainage area of approximately 93 km² (Appendix 6B, Figure 6.4B-7). A preliminary hydrologic assessment of the drainage area of Birch Creek was conducted based on a regional flood analysis (KGS Group 2016b). It was estimated that flows expected at the outlet of Birch Creek during the 1:10 year and 1:100 year flood events range between approximately 40 m^3/s and 75 m^3/s (1,400 cfs and 2,600 cfs). The median annual flow (1:2 year flood event) was estimated at approximately 15 m^3/s (540 cfs). On an annual basis, the largest flows in Birch Creek typically occur in the spring after the snowmelt period. Peak water levels in the wetlands and small lakes that outlet into Birch Creek also typically occur in the spring. However, large storm water events may result in peak flows and water levels occurring in the summer or in the fall (KGS Group 2016b).

The Buffalo Creek watershed consists of Big Buffalo Lake, Little Buffalo Lake, Buffalo Creek and several small unnamed lakes, ponds and creeks (Appendix 6B, Figure 6.4B-8). Big Buffalo Lake flows east into Little Buffalo Lake and Buffalo Creek, which then winds its way northeast for approximately 16 km across the landscape to its confluence with Dauphin River. Big Buffalo Lake lies within an area of mainly herb and shrub wetlands, with some areas of floating bog and pockets of sparse coniferous forest present

around the lake. The hydrology of the Buffalo Creek system is very complex. Surface water runoff in a wetland does not flow uniformly; therefore, flows cannot be estimated using typical approaches using information from nearby measured creeks as a proxy for local flows. In addition, Big Buffalo Lake may be supplied by groundwater upwelling from the carbonate aquifer, thereby supplying Buffalo Creek with additional water, which is difficult to measure and quantify.

Manitoba Hydro regulates Lake Winnipeg outflow for power production when the wind-eliminated water levels are between elevation 216.71 m asl (711 feet) and 217.93 m asl (715 feet) (Manitoba Hydro 2019). When the lake level rises above elevation 715 feet, Manitoba Hydro is required to initiate maximum discharge from Lake Winnipeg. During periods when the level falls below elevation 711 feet, control of Lake Winnipeg outflow is under the direction of the Province of Manitoba Minister of Sustainable Development.

The estimated changes in areas of inundation in Lake Manitoba and Lake St. Martin without the Project (and with the Project) are shown in the figures provided in Appendix 6G. The calculation of drainage areas without the Project (and with the Project) in the local waterways that will be affected by the Project are provided in Appendix 6H. Existing conditions for Lake Winnipeg are summarized in Appendix 6I in the technical memorandum provided by Manitoba Hydro that examines the effects of the Project on downstream water levels (Manitoba Hydro 2019).

The memo ‘Development of the Operating Rules for the Lake Manitoba and Lake St. Martin Outlet Channels’ prepared by Manitoba Infrastructure (2019a) is provided in Appendix 6J, and the technical memo ‘Lake Manitoba and Lake St. Martin Outlet Channels Impacts on Lake Manitoba and Lake St. Martin’ prepared by Manitoba Infrastructure (2019b) is provided in Appendix 6K.

6.4.6 Project Interactions with Surface Water Environment

Overview

Table 6.4-12 identifies, for each potential effect, the Project components and physical activities that might interact with surface water during construction and operations and result in the identified environmental effect. These interactions are identified by check marks and are discussed in detail in Section 6.4.7 in the context of effects pathways, standard and project-specific mitigation and residual effects. A justification for no effect is provided following the table.

Table 6.4-12 Project-Environment Interactions with Surface Water During Construction and Operations

Project Components and Physical Activities	Environmental Effects					
	Changes in Regional Flow and Water Levels	Changes in Regional Fluvial Geomorphology and Shoreline Geomorphology	Changes in Local Drainage Areas and Local Drainage Patterns	Changes in Regional and/or Local Sediment and Debris Transport	Changes in Regional and/or Local Ice Processes	Changes in Regional and/or Local Surface Water Quality
Construction						
Site preparation of project components[1] (development of the PDA prior to construction activities [e.g., removal of existing infrastructure, vegetation clearing and initial earthworks, development of temporary construction camp and staging areas])	-	-	✓	✓	-	✓
Project-related transportation within the LAA (movement of trucks, equipment, bulk materials, supplies, and personnel within the LAA)	-	-	-	-	-	✓
Construction of Project components[1] (physical construction of utilities, infrastructure, and other facilities)	-	✓	✓	✓	-	✓
Quarry development (blasting and aggregate extraction used for the construction of Project components[1])	-	-	-	-	-	-
Water development and control (dewatering and realignment of existing water works)	-	-	✓	✓	-	✓
Reclamation	-	-	-	-	-	✓

Table 6.4-12 Project-Environment Interactions with Surface Water During Construction and Operations

Project Components and Physical Activities	Environmental Effects					
	Changes in Regional Flow and Water Levels	Changes in Regional Fluvial Geomorphology and Shoreline Geomorphology	Changes in Local Drainage Areas and Local Drainage Patterns	Changes in Regional and/or Local Sediment and Debris Transport	Changes in Regional and/or Local Ice Processes	Changes in Regional and/or Local Surface Water Quality
Operations						
Operation and maintenance of the outlet channels (normal operational conditions when the outlet channels and associated infrastructure [e.g., water control structure gates are either open or are closed)	✓	✓	✓	✓	✓	✓
Operation and maintenance of other Project components[1] (normal operations conditions associated with PR 239 and municipal road realignments, distribution line and bridges and culverts)	-	-	-	-	-	✓
Project-related transportation within the LAA (movement of trucks, equipment, bulk materials, supplies, and personnel within the LAA)	-	-	-	-	-	✓
Operation, maintenance, and reclamation of quarries	-	-	-	-	-	-

NOTES:

✓ indicates a potential interaction.

– indicates no potential interactions are expected.

[1] Components include: outlet channels, water control structures, distribution line, bridges and culverts, PR 239 and municipal road realignments, temporary construction camps and staging areas, distribution lines, and quarries.

Construction

Appendix 6B, Figure 6.4B-7 shows the selected alignment for the LMOC and illustrates where Project infrastructure and construction activities will be located in the LMOC PDA. Appendix 6B, Figure 6.4B-8 shows the selected alignment for the LSMOC and illustrates where Project infrastructure and construction activities will be located in the LSMOC PDA.

There is no interaction with regional surface water flows or water levels during the construction phase of the Project because the interactions with regional flows and lake levels occur only when the Project is in operation. Regional flows and lake levels will not be changed during construction activities.

Changes in regional fluvial geomorphology and shoreline geomorphology will occur during the construction phase of the Project in Lake Manitoba, Lake St. Martin and Sturgeon Bay due to the construction of the inlet and outlet areas for the LMOC and LSMOC.

A watercourse crossing may be required over Dauphin River for the construction of the Manitoba Hydro distribution line, but this activity is not expected to alter fluvial or shoreline geomorphology. There are no other Project activities that interact with regional fluvial geomorphology and shoreline geomorphology during the Project construction phase.

Changes in local drainage areas and local drainage patterns, as well as changes in local sediment transport, will occur during the construction phase of the Project due to the installation of the outlet channels infrastructure and realignment of PR 239. Changes in regional sediment transport do not occur during construction, but may occur during operation of the outlet channels, in relation to changes in regional flows and lake levels. There are no other Project construction activities identified that interact with local drainage areas and local drainage patterns, or regional and/or local sediment transport.

Changes in regional and/or local ice processes do not occur during construction, but may occur during operation of the outlet channels, in relation to changes in regional flows and lake levels.

The changes in regional and/or local surface water quality that could occur during the construction phase are related to potential accidents, spills or malfunctions. These effects are examined in Section 14.4.

There were no interactions identified between surface water and Project construction components such as site preparation, Project related transportation, and quarry development because these activities or sites will not cross or come within proximity of surface water areas (Table 6.4-12).

Operations

The operation of the Project will alter regional flows and lake levels, which could also affect regional fluvial geomorphology and shoreline geomorphology, as well as regional and/or local sediment transport or ice processes. The changes to local drainage areas and local drainage patterns that will occur in the construction phase will continue into the operations phase of the Project. The alteration in regional flows and lake levels may affect regional and/or local water quality, but the majority of potential interactions with

surface water during the operations phase are related to potential accidents, spills or malfunctions. These effects are examined in Section 14.4.

There are no interactions identified among surface water and Project operation and maintenance of other Project components (e.g., realignment of PR 239), Project-related transportation, or the operation, maintenance and reclamation of quarries, as these activities or sites do not cross or come within proximity of surface water areas.

6.4.7 Assessment of Residual Environmental Effects on Surface Water

6.4.7.1 Analytical Assessment Techniques for Surface Water

Overview

The assessment of residual effects on surface water uses information generated for the Project area from 2011 to 2019 from a number of studies conducted by Manitoba Infrastructure, KGS Group, North/South Consultants, Hatch, Stantec, Manitoba Sustainable Development and the Province of Manitoba, as well as relevant historical reports for the region. The methods used in the collection and analysis of the Project information are provided in Section 6.4.5.1. A list of the technical reports and data sources used in the surface water assessment is provided in Section 6.5.3.

As noted in Chapter 3, preliminary and detailed design of the Project components has been ongoing during development of the EIS. Additional studies to further refine the assessment of the residual effects of the Project on surface water are planned as part of detailed design. These studies will include the collection of data to supplement existing hydrologic and hydraulic modelling and enable further examination and quantification of the residual effects on surface water. The information generated by these additional studies planned for the detailed design phase will be provided as it becomes available.

A description of the model sources and assumptions used to assess changes in regional flows and lake levels due to the operation of the Project is provided in the following.

Regional Flows and Water Levels

The ‘Development of the Operating Rules for the Lake Manitoba and Lake St. Martin Outlet Channels’ prepared by Manitoba Infrastructure (2019a) is provided in Appendix 6J, and the ‘Lake Manitoba and Lake St. Martin Outlet Channels Impacts on Lake Manitoba and Lake St. Martin’ prepared by Manitoba Infrastructure (2019b) is provided in Appendix 6K.

Manitoba Infrastructure’s Hydrologic Operations group uses water balance models to evaluate the impact of water control structure operations on the Lake Manitoba to Lake Winnipeg drainage system. Water balance models use inflow, precipitation, evaporation data, and stage storage curves to calculate changes in lake level, and rating curves to determine lake outflow (see Appendix 6J and Appendix 6K for details on calibration and model error).

The Lake Manitoba Water Balance model was run to produce lake levels and outflows for over 100 years using inflow and precipitation data from 1915 to 2017. The model was run under three scenarios:

1. current operation assuming the EOC would not be used
2. current operation assuming the EOC would be used
3. future operation (with the Project and no operation of EOC for flood control).

As the EOC is not licensed, the current operation described in the Manitoba Infrastructure memo (Appendix 6K) assumes that the Fairford River Water Control Structure is operated under the current operating guidelines for the entire period of record (1915-2017) and omits the operation of the EOC entirely.

Because the EOC is in the existing environment, was used in the past under emergency conditions, and may be used before construction is complete (if an emergency occurs), then, for the purpose of the assessment, the use of EOC is included the EIS existing conditions (without the Project). This analysis shows that the EOC would only be used 3.3% of the time and has very little effect on most scenarios. The results of both scenarios are shown in the tables in Appendix 6E.

The future operation scenario assumes that Lake Manitoba and Lake St. Martin have been regulated with the proposed Project outlet channels according to the proposed operating guidelines (Appendix 6J) for the entire period of record and omits any operation of the EOC. This is consistent with the Project scenario used in this assessment because there is no need to use the EOC for flood control after completion of the Project.

The assessment of the Project residual effects for Changes in Regional Flow and Water Levels (Section 6.4.7.2) would not change even if the EOC was not considered in the existing conditions (without the Project).

The Lake Winnipeg Water Balance Model

Manitoba Infrastructure provided Manitoba Hydro with a time series data set of changes to Lake Winnipeg inflows as a result of the Project and developed a simulation of Lake Winnipeg water levels and Nelson River flows. The simulations were performed using a water balance model to simulate Lake Winnipeg water levels and outflows and a Nelson River routing model to simulate water levels and river flows downstream of Lake Winnipeg (Appendix 6I; Manitoba Hydro 2019). These models were originally developed to provide information to the Manitoba Clean Environment Commission (CEC), as part of its review of the Lake Winnipeg Regulation (WR) Project.

Other Studies

The modelling sources and assumptions for other studies conducted for the Project can be found in the reports and data referenced within each of the assessment sections below.

6.4.7.2 Changes in Regional Flow and Water Levels

Project Pathways

Overview

Changes in regional flow and water levels will occur as a result of the operation of the LMOC and LSMOC, which is a desired positive outcome and objective of the Project. A complete description of the LMOC and LSMOC current design, function, capacity and operation is provided in Chapter 3. In summary, the LMOC and LSMOC will provide an additional mechanism for managing the outflows from Lake Manitoba and Lake St. Martin. Water flowing from Lake Manitoba that previously was routed to Lake St. Martin by the primary pathway of the Fairford River will be routed through the Fairford River and the LMOC to Lake St. Martin. Water from Lake St. Martin that previously was routed to Sturgeon Bay through the primary pathway of Dauphin River will be routed through Dauphin River and the LSMOC to Sturgeon Bay. The additional hydraulic conveyance provided by the LMOC and LSMOC will increase the amount of time that Lake Manitoba and Lake St. Martin can be maintained within the desired lake levels, reduce peak flood levels, and decrease inundation of low-lying areas around the lakes. The changes in how flows and water levels will be managed with operation of the LMOC and LSMOC were analyzed and modelled by Manitoba Infrastructure's Hydrologic Operations Section. These changes are described in Appendix 6J.

The operation of the LMOC and LSMOC will increase the outflows from Lake Manitoba and Lake St. Martin during flood conditions. The gates will operate about 20% of the time for both the LMOC and the LSMOC. A flow duration curve for the LMOC is in Appendix 6E, Figure 6E-1 c) and for the LSMOC in Appendix 6E, Figure 6E-2c). This increased outflow capacity will allow the lake levels to be maintained at lower levels, thus decreasing flood risks around the lakes. Less flow will also pass though Fairford River and Dauphin River during flood conditions. This decreased flow will reduce flooding along these rivers and in Lake Pineimuta. No discernable effect is expected on Lake Winnipeg or further downstream. The LMOC and LSMOC will be operated such that, during low flow conditions, lake levels and river flows will be maintained or only marginally decreased. The potential effects of these changes on regional flow and water levels are further described in the sections below.

Lake Manitoba

The reduction of lake levels in Lake Manitoba due to the operation of the LMOC and LSMOC is a desired positive outcome and objective of the Project. The operation of the LMOC and LSMOC will allow more water to be conveyed from Lake Manitoba to Sturgeon Bay more quickly than without the outlet channels, and aid in the regulation of Lake Manitoba within the desired range of 247.0 to 247.7 m (810.5 to 812.5 ft). Figure 6.4-3 provides the Lake Manitoba elevation-duration curve with and without the Project that was developed using information from Manitoba Infrastructure (Appendix 6K; Manitoba Infrastructure 2019b).

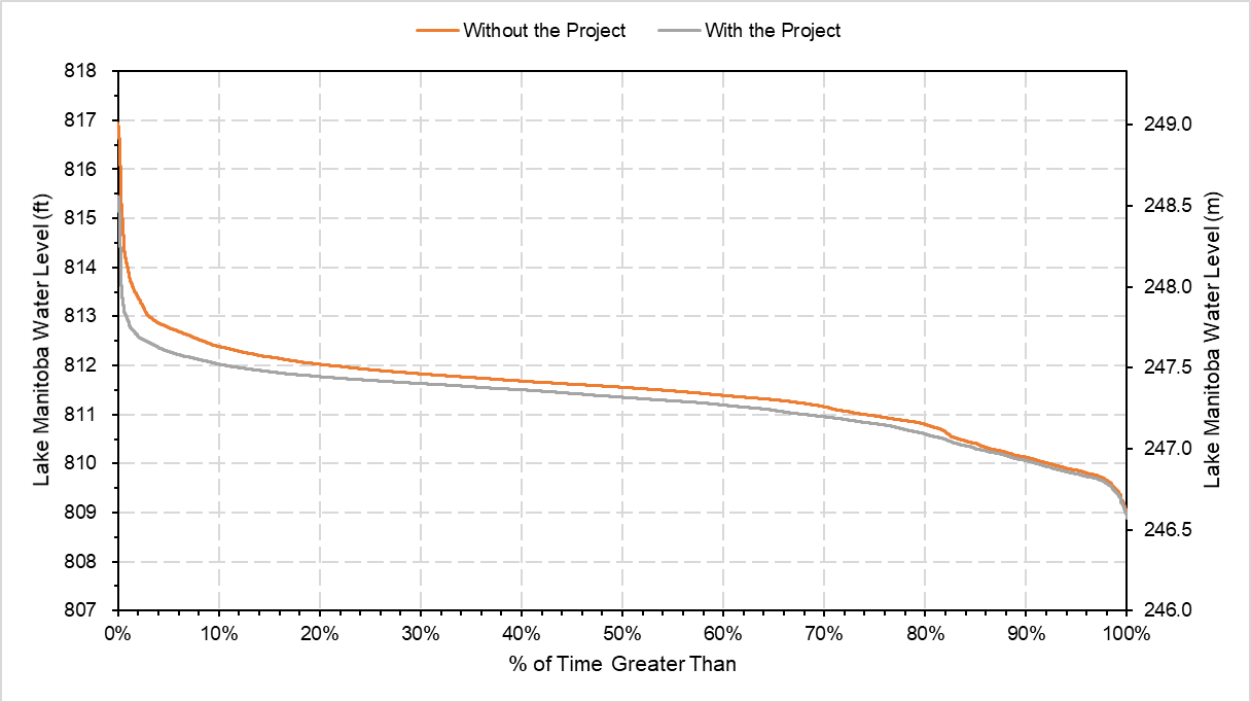

Figure 6.4-3 Lake Manitoba Duration Curve Showing Lake Levels with and without the Project

The change in the percentage of time that the lake can be managed at the desired levels with the operation of the outlet channels is summarized in Table 6.4-13 (Appendix 6K; Manitoba Infrastructure 2019b).

Table 6.4-13 Summary of Percent Changes in Lake Manitoba Levels

Lake Manitoba Level	% Higher Than		
	Without the Project	With the Project	Change
815 ft (248.86 m)	0.6%	0.3%	0.3%
812.5 ft (247.65 m)	8.4%	2.8%	5.6%
810.5 ft (247.05 m)	83.3%	81.8%	1.5%
810 ft (246.89 m)	92.3%	91.1%	1.2%

Under the current operating conditions without the outlet channels, Lake Manitoba is above the top of its desired operating range 8.4% of the time; with the operation of the outlet channels, the amount of time that Lake Manitoba is above the top of its desired operating range changes to 2.8%, which is a decrease of 5.6% (Appendix 6K; Manitoba Infrastructure 2019b).

Review of the modelled results showed that operation of the new outlet channels will decrease the peak water levels substantially in high flood years and reduce peak levels in almost all years, which will increase the amount of time the lake is within its desired operating range. Based on the water balance model developed by Manitoba Infrastructure, the LMOC would have operated in 34% of the years that were simulated (35 years out of 103 years). The amounts by which the lake levels will decrease were also analyzed. Table 6.4-14 summarizes the average decrease in the Lake Manitoba water levels for a non-flood, minor flood and high flood conditions (Appendix 6K; Manitoba Infrastructure 2019b).

Table 6.4-14 Summary of Average Decrease in Lake Manitoba Peak Water Levels with the Project

Average Decrease in Lake Manitoba Peak Water Level	
Non-flood (Lake Manitoba < 812.5 ft or 247.65 m)	-0.08 ft or -0.024 m
Minor flood (Lake Manitoba elevation between 812.5 ft and 813.5 ft, or 247.65 m and 247.95 m)	-0.28 ft or -0.085 m
High flood (Lake Manitoba > 813.5 ft or 247.95 m)	-1.27 ft or -0.387m

For the 2011 flood, the calculated decrease in the peak water level on Lake Manitoba is 0.46 m (1.5 ft). Figure 6G-1 in Appendix 6G shows the difference between the area of inundation that occurred around Lake Manitoba during the 2011 flood when the lake level reached 249.0 m (816.94 ft), and the predicted area of inundation around Lake Manitoba that would have occurred during the 2011 flood with the LMOC and LSMOC in operation. It is estimated that the operation of the outlet channels would have decreased the lake level to about 248.56 m (815.46 ft), which is a decrease of 754.1 km^2 in the amount of area that would have been inundated by flood waters (Appendix K, Manitoba Infrastructure 2019b). Appendix 6E provides a tabulated summary of the estimated monthly change in outflows and lake levels that would occur in Lake Manitoba at low, median and high flow levels with and without the Project, and a series of graphs that illustrate how the changes in flow levels are distributed over the year.

Fairford River System

As noted in Chapter 2 and Section 6.4.5.2 flows in the Fairford River system have been managed since 1961 through use of the Fairford River Water Control Structure (FRWCS) and the current operating guidelines for the FRWCS will remain the same during the operation of the LMOC and LSMOC (Appendix J; Manitoba Infrastructure 2019a). Total inflows from Lake Manitoba will be split between the LMOC and the Fairford River system, which will reduce peak flow amounts in the Fairford River system. The change in flow in the Fairford River system was estimated by comparing the regional flows and lake levels without the Project to the regional flows and lake levels with the Project, at low, median and high levels of flow. The data used to calculate the changes are provided in Appendix 6E. Table 6.4-15 provides a summary of the estimated percent change in Fairford River flows with operation of the Project.

Table 6.4-15 Percent Changes in Fairford River Flows with and without the Project

Flows	Fairford River Flow without the Project (m^3/s)	Fairford River Flow with the Project (m^3/s)	Change in Fairford River Flow (m^3/s and %)
Low Flow (95% of flows exceeded)	10.4	10.3	-0.1 (-1.2%)
Median Flow (50% of flows exceeded)	55.0	43.0	-12.0 (-21.8%)
High Flow (5% of flows exceeded)	271.0	184.7	-86.3 (-31.9%)

NOTE:
The percent changes shown represent an overall reduction in flow, see Figure 6.4-12 and Figure 6.4-13 for an estimation of monthly changes in Fairford River flows

Reductions in peak flows will occur mainly during periods of high flows, as well as during periods of median flows, with some minor reductions in flow at low flow levels (Table 6.4-12). The flows in the Fairford River system are estimated to be reduced by up to 1.2% during low flow periods, by up to 21.8% during median flow periods, and by up to 31.9% during high flow periods. These percent changes are the estimated total changes in flows at the applicable percent flow exceedance. Changes occur at lower flows due to a carryover effect from a reduction in Lake Manitoba levels due to higher outflows from the Project. To maintain the lake level during low flows once it is lowered, the Fairford River flows are reduced.

The median hydrograph for the Fairford River will be lower with the Project than without the Project but will retain typical seasonal variation (Figure 6.4-4).

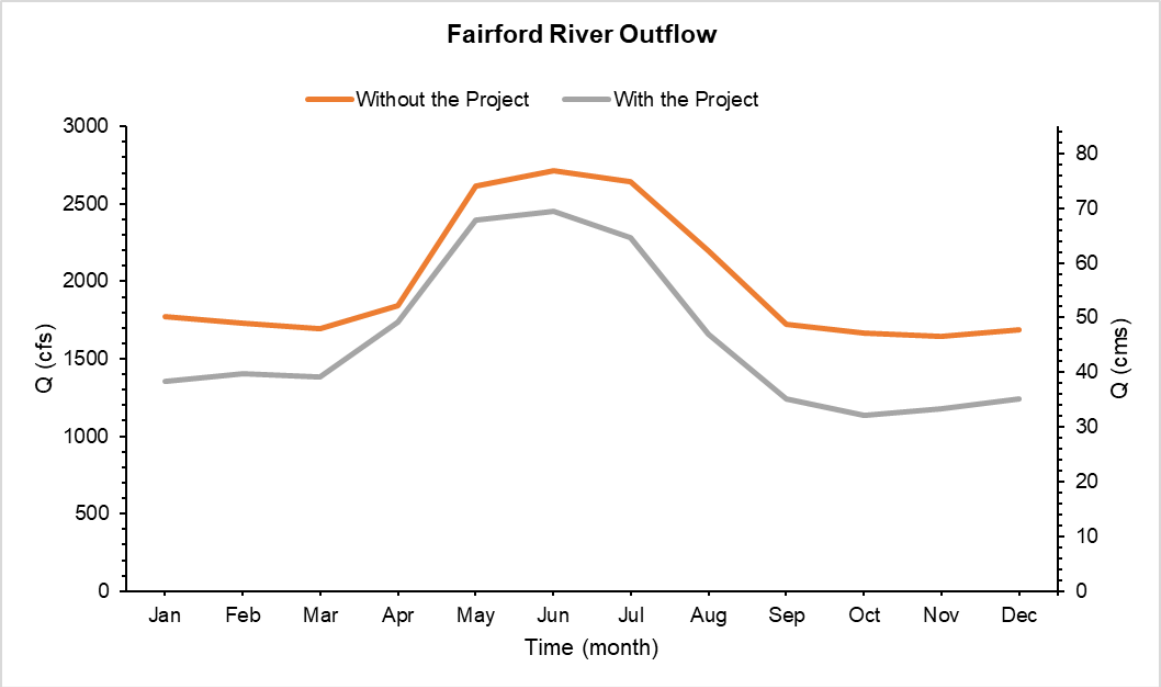

Figure 6.4-4 Fairford River Median Flows (50%) with and without the Project

(Note: cms = m^3/s)

During high flow events, flows on the Fairford River without the Project are four times the median flows and will remain at those high flow levels for most of the season (Figure 6.4-5). With the Project, higher spring and summer flows will still occur; however, in winter, flows will be reduced to more typical flow rates. The Project will still allow high flows that are required in river systems for flushing and natural fluvial geomorphologic processes to occur.

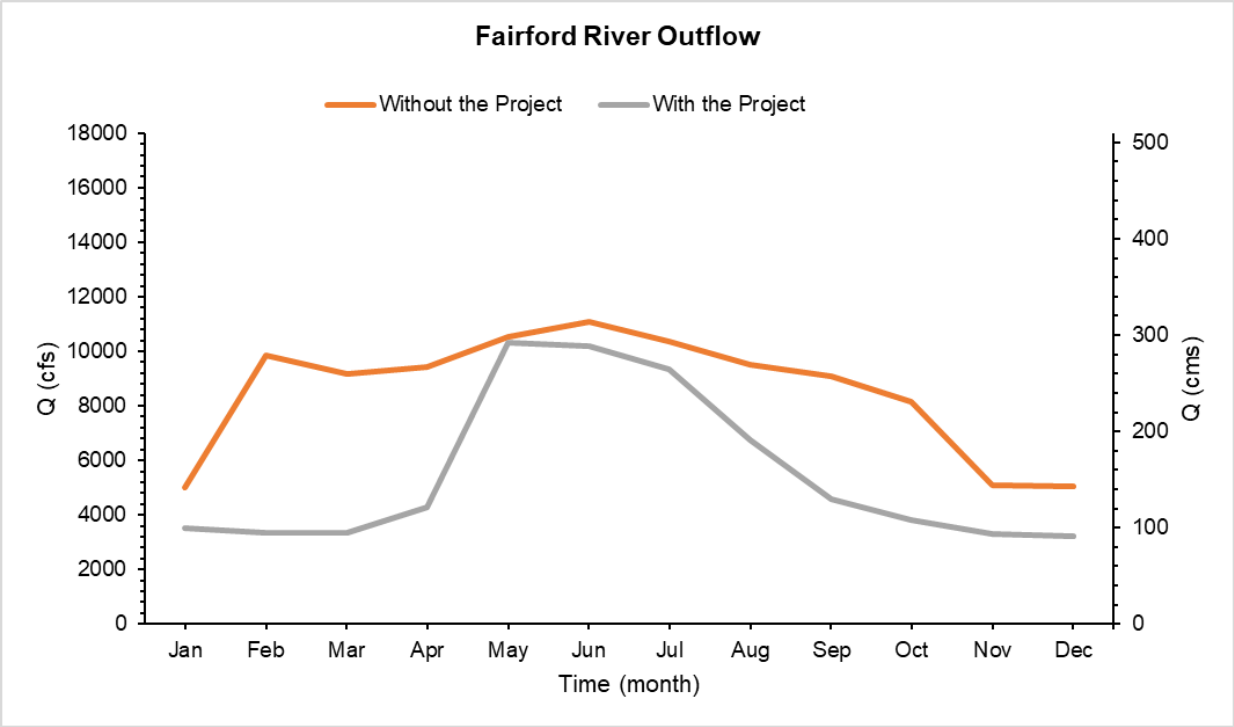

Figure 6.4-5 Fairford River High Flows (5% of flows greater than) with and without the Project

(Note: cms=m^3/s)

Appendix 6E provides a tabulated summary of the estimated monthly change in outflows that would occur in the Fairford River system at low, median and high flow levels, with and without the Project, and a series of graphs that illustrate how the changes in flow levels are distributed over the year. The reduction of peak flows on the Fairford River will reduce the rate and frequency of peak flows entering Lake Pineimuta, which would result in lower lake levels and decrease the area of inundation during peak flow periods.

Lake St. Martin

The operation of the LMOC and LSMOC will allow more water to be conveyed from Lake Manitoba to Sturgeon Bay more quickly than without the outlet channels, and aid in the regulation of Lake St. Martin within the desired range of 242.9 to 243.8 m (797 to 800 ft). The reduction of lake levels in Lake St. Martin due to the operation of the LMOC and LSMOC is a desired positive outcome and objective of the Project. Figure 6.4-6 provides the Lake St. Martin elevation-duration curve with and without the Project that was developed using information from Manitoba Infrastructure (Appendix 6K; Manitoba Infrastructure 2019b).

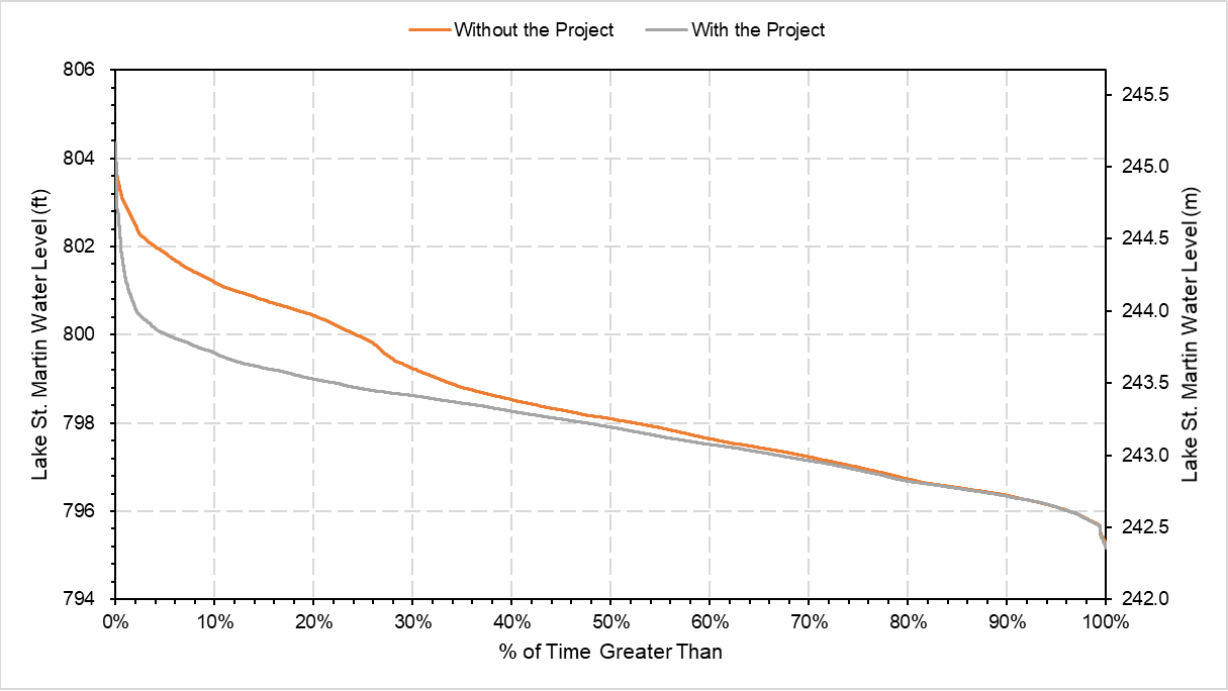

Figure 6.4-6 Lake St. Martin Duration Curve Showing Lake Levels with and without the Project

The increase in the percentage of time that the lake can be managed at the desired levels with the operation of the outlet channels is summarized in Table 6.4-16 (Appendix 6K; Manitoba Infrastructure 2019b).

Table 6.4-16 Summary of Percent Changes in Lake St. Martin Levels

Lake St. Martin Level (ft)	% Higher Than		
	Without the Project	With the Project	Change
803 ft (244.75 m)	2.5%	0.1%	2.4%
800 ft (243.84 m)	24.4%	5.2%	19.2%
797 ft (242.93 m)	74.9%	73.6%	1.3%
796 ft (242.62 m)	96.2%	96.2%	0.0%

Under the current operating conditions without the outlet channels, Lake St. Martin is above the top of its desired operating range 24.4% of the time; with the operation of the outlet channels, the amount of time that Lake St. Martin is above the top of its desired operating range changes to 5.2%, which is a decrease of 19.2% (Appendix 6K; Manitoba Infrastructure 2019b).

Review of the modelled results showed that operation of the new outlet channels will decrease the peak water levels substantially in high flood years, and reduce peak levels in all years, which will increase the amount of time the lake is within its desired operating range. Based on the hydrologic model developed

by Manitoba Infrastructure, the LSMOC would have been operated in 34% of the years simulated (35 years out of 103 years). The amounts by which the lake levels will decrease were also analyzed. Table 6.4-17 summarizes the average decrease in the Lake St. Martin water levels for a non-flood, low flood and high flood conditions (Manitoba Infrastructure 2019b).

Table 6.4-17 Summary of Average Decrease in Lake St. Martin Peak Water Levels with the Project

Average Decrease in Lake St. Martin Peak Water Levels for Various Floods Defined by Lake Manitoba Lake Levels	
Non-flood condition (i.e., Lake Manitoba < 812.5 ft or 247.65 m)	-0.21 ft (-0.06 m)
Minor flood condition (i.e., Lake Manitoba elevation is between 812.5 ft and 813.5 ft, or 247.65 m and 247.95 m)	-1.50 ft (-0.46 m)
High flood condition (i.e. Lake Manitoba > 813.5 ft or 247.95 m)	-2.43 ft (-0.74 m)

Appendix 6E provides a tabulated summary of the estimated monthly change in lake levels and outflows that would occur in Lake St. Martin at low, median and high flow levels with and without the Project, and a series of graphs that illustrate how the changes in flow levels are distributed over the year.

For the 2011 flood event, the calculated decrease in the peak water level on Lake St. Martin is 0.76 m (2.5 ft). Figure 6G-2 in Appendix 6G shows the difference between the area of inundation that occurred around Lake St. Martin during the 2011 flood when the lake level reached 245.48 m (805.38 ft) and the predicted area of inundation around Lake St. Martin that would have occurred during the 2011 flood with the LMOC and LSMOC in operation. It is estimated that the operation of the outlet channels would have decreased the lake level to approximately 244.72 m (802.87 ft), which represents a decrease of 27.5 km^2 the amount of area that would have been inundated by flood waters (Appendix K, Manitoba Infrastructure 2019b).

For a minor flood year, the average decrease in water level is 0.52 m (1.7 ft). Figure 6G-3 in Appendix 6G shows the difference between the area of inundation around Lake St. Martin for a low flood event under the current operating regime, which would result in a lake level of 244.43 m (801.93 ft); and the predicted area of inundation around Lake St. Martin for a low flood event with the LMOC and LSMOC in operation. It is estimated that the operation of the outlet channels would have decreased the lake level to about 243.91 m (800.22 ft), which represents a decrease of 21.4 km^2 in the amount of area that would have been inundated by flood waters around Lake St. Martin (Appendix K, Manitoba Infrastructure 2019b).

Dauphin River System

Flows in Dauphin River are currently managed through operation of the FRWCS, and the current operating guidelines for the FRWCS will remain the same during the operation of the LMOC and LSMOC (Appendix 6J; Manitoba Infrastructure 2019a). Total inflows from Lake St. Martin split between the LSMOC and the Dauphin River system, which will reduce peak flow amounts in the Dauphin River

system. The change in flow in the Dauphin River system was estimated by comparing the regional flows and lake levels without the Project to the regional flows and lake levels with the Project, at low, median and high levels of flow frequency (Appendix 6E). Table 6.4-18 provides a summary of the estimated percent change in Dauphin River flows with operation of the Project.

Table 6.4-18 Changes in Dauphin River Flows

Flows	Dauphin River Flow without the Project (m^3/s)	Dauphin River Flow with the Project (m^3/s)	Change in Dauphin River Flow (m^3/s)
Low Flow (95% of flows exceeded)	5.22	5.17	-0.05 (-0.96%)
Median Flows (50% of flows exceeded)	58.1	48.8	-9.3 (-16.0%)
High Flow (5% of flows exceeded)	240.2	139.2	-101.0 (-42.0%)
NOTE: The percent changes shown represent an overall reduction in flow, see Figure 6.4-7 and Figure 6.4-8 for an estimate of monthly changes in Dauphin River flows			

The median hydrograph for Dauphin River will be slightly lower with the Project than without the Project; however, it will still retain typical seasonal variation (Figure 6.4-7). Reductions in peak flows will occur mainly during periods of high flows, as well as during periods of median flows, with some minor reductions in flow at low flow levels (Table 6.4-18). The flows in the Dauphin River system are estimated to be reduced by less than 1.0% at low flows, by up to 16.0% at median flows, and by up to 42.0% at high flows. These percent changes are the estimated change in flows at the applicable percent flow exceedance.

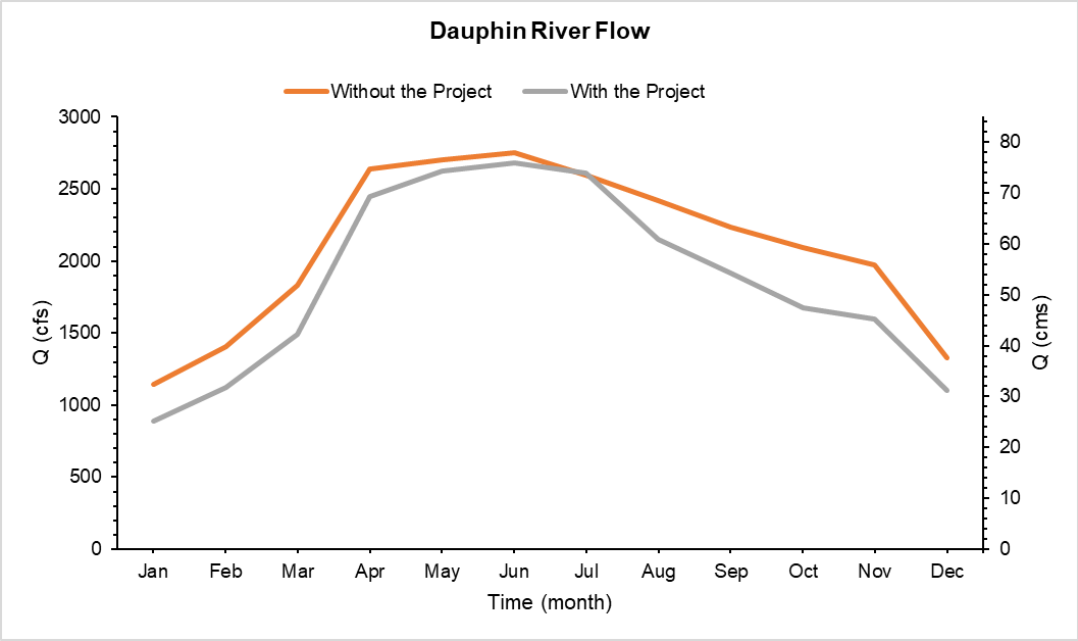

Figure 6.4-7 Dauphin River Median Flows (50%) with and without the Project

During floods, flows on Dauphin River without the Project are four to five times the median flows (Figure 6.4-8). With the Project, the flows will be reduced to two times median flows and retain the same seasonal flow patterns. The Project will still allow high flows for flushing and natural fluvial geomorphologic processes to occur, while protecting the communities along Dauphin River from floods.

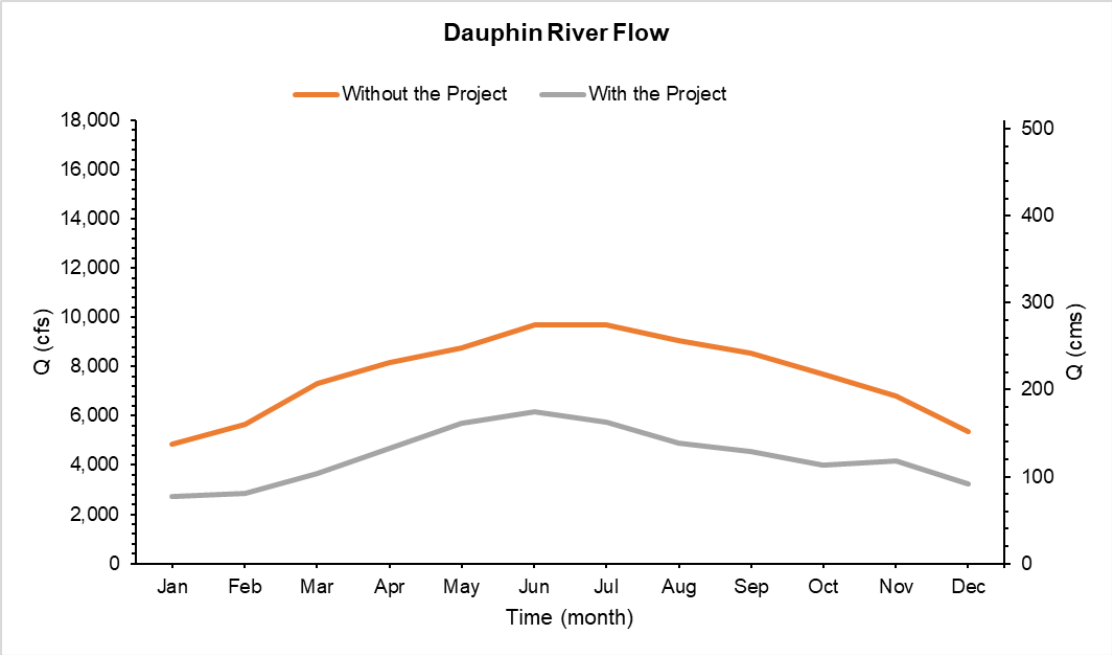

Figure 6.4-8 Dauphin River High Flows (5% of flows greater than) With and Without the Project

Appendix 6.E provides a tabulated summary of the estimated monthly change in outflows that would occur in the Dauphin River system at low, median and high flow levels with and without the Project, and a series of graphs that illustrate how the changes in flow levels are distributed over the year.

EOC

It is not expected that EOC, Reach 1 will be operated for flood control after the construction of the LSMOC.

Sturgeon Bay and Lake Winnipeg North Basin

The operation of the LMOC and LSMOC does not alter the volume of flows that will enter Sturgeon Bay; the volume of water in the system is dependent on the amount of flow entering Lake Manitoba. The operation of the LMOC and LSMOC alters the timing and location of outflows to Sturgeon Bay but does not change the volume of water that needs to be passed through the system.

Without the Project, all outflows to Sturgeon Bay are conveyed by Dauphin River through one outlet area into the bay. With the operation of the LMOC and LSMOC, outflows to Sturgeon Bay will be conveyed through the Dauphin River outlet and through the LSMOC, which creates an additional outlet area in the bay near Willow Point (Appendix 6B, Figure 6.4B-8). The total volume of outflows from Lake Manitoba to Sturgeon Bay remains the same with or without the Project, but with the operation of the outlet channels, the timing of when peak flows reach Sturgeon Bay will be altered.

Manitoba Hydro completed an analysis of the differences in water levels on Lake Winnipeg and waterways downstream of Lake Winnipeg in relation to the changes in flows due to the Project. This analysis concluded that any potential changes in water levels are not expected to be discernible in the context of existing water level variations. Details of the analysis are provided in Appendix 6I (Manitoba Hydro 2019). As such, there is no pathway of effects to surface water hydrology in the north basin of Lake Winnipeg and Nelson River.

Mitigation

The Project is designed as a mitigation project to modify regional flows and water levels in order to reduce flooding on Lake Manitoba, Lake St. Martin and the Fairford and Dauphin Rivers. No additional mitigation to effects on regional flows and water levels is required.

Project Residual Effects

The residual effects of the changes in regional flow and water levels due to the operation of the Project can be characterized by the following:

- direction is positive; positive effects include reduction in peak flood levels, reduced flood inundation areas, and an increase in the amount of time that the lakes are within the desired operating range
- magnitude is low to moderate; there is a low magnitude change for low to average flows, and a moderate magnitude change for high flows
- geographic extent of the effects is the LAA
- frequency of the effect is regular/continuous; as long as the Project continues operating, the effects of regional flows and water levels will continue as floods occur
- the duration of the effect is long-term; as long as the Project continues operating, the effects of regional flows and water levels will continue
- the effects are reversible; if the Project was not operated, regional water levels and flows would revert to conditions without the Project
- the ecological and socio-economic context is disturbed for LMOC because the PDA has been previously disturbed by human development
- the ecological and socio-economic context is disturbed for LSMOC because the PDA has been previously disturbed by human activities and previous flood events that diverted water from Lake St. Martin to the Buffalo Creek system
- the timing of the effect has a high sensitivity because the effect occurs during a critical life stage (e.g., fish spawning or bird nesting periods)

6.4.7.3 Changes in Regional and/or Local Fluvial Geomorphology and Shoreline Geomorphology

Project Pathways

Overview

Changes in regional fluvial geomorphology may occur in the Fairford River system or Dauphin River system as a result of the operation of the LMOC and LSMOC. As noted in the section on flows above, the operation of the LMOC and LSMOC results in changes in the flow regimes of these river systems. Changes in flow amounts can affect erosional and depositional patterns in rivers and alter the processes of aggradation and degradation in the channel, which can result in changes to river bedload, channel bed elevations and/or channel morphology.

The PDAs of the outlet channels also represent a change in regional fluvial geomorphology because the channels create additional flow pathways for water in the region. However, the channels will be constructed, operated and maintained as hydraulic channels for the purpose of managing flows and lake levels, not as natural rivers. The channel design will provide for downstream fish passage, but the channels are hardened to prevent erosion, and they are not designed to mimic a natural riverine system with ecological functions. Therefore, the PDAs of the LMOC and LSMOC are not included in further discussion of effects on regional fluvial geomorphology.

Changes in local shoreline geomorphology will occur in Watchorn Bay in Lake Manitoba, Lake St. Martin and Sturgeon Bay due to construction of the Lake Manitoba and Lake St. Martin inlet and outlet areas, and operation of the LMOC and LSMOC. The construction of the inlet and outlets for the outlet channels will require excavation of the lake bottom in these areas, and operation of the outlet channels will require that these areas be maintained at the constructed elevations to provide conveyance of flows as designed for each channel. These local shoreline changes could alter existing wind, wave and ice action, sediment transport, or beach forming processes in these areas. The potential changes to regional and/or local sediment transport are discussed in the Section 6.4.7.6 on Changes in Regional and/or Local Sediment and Debris Transport below this section.

A reduction in lake levels in Lake Manitoba and Lake St. Martin due to the operation of the outlet channels will reduce the amount of shoreline area inundated during high flows, which may alter the amount of exposed shoreline in the area. This change could alter existing wind, wave and ice action in some localized shoreline areas, but is not expected to change shoreline geomorphology.

Discharge into Lake St. Martin near Birch Bay from the LMOC and discharge into Sturgeon Bay near Willow Point from the LSMOC may alter the lake bed in these outlet areas during periods when outflows are high enough to cause scouring and movement of lake bed sediments or other substrates (e.g., sand, gravel, rock).

The potential changes in regional or local fluvial geomorphology and shoreline geomorphology due to the construction and operation of the Project are further described in the sections below.

Lake Manitoba

A description of the current design for the LMOC inlet and outlet areas is provided in Chapter 3. In summary, the hydraulic profile of the LMOC will require the lake bottom to be excavated at the channel inlet and outlet areas to match proposed channel invert elevations. The LMOC will have an invert elevation of approximately 242 m asl at Lake Manitoba and approximately 239 m asl at Lake St. Martin. Excavations will be tapered over 500 m or less from the shoreline to meet existing lakebed elevations. Cofferdams may be required to construct the inlet and outlet in the dry, although alternative measures may be implemented dependent on detailed design and *Fisheries Act* approvals processes. The selected inlet and outlet design will be intended to protect the channel and the channel capacity by reducing the potential for erosion and sediment transport. The use of rock-filled jetties or other engineered structures may be included as part of the channel design to reduce changes in shoreline geomorphology and shoreline erosion. Additional studies are planned as part of ongoing detailed design and include the collection of additional shoreline data to aid in detailed design and reduce changes to shoreline geomorphology where possible. Engineering studies will be used to optimize the inlet design to reduce environmental effects.

Fairford River

The operation of the LMOC and LSMOC will reduce peak flows in the Fairford River during periods of high flows and flood events. This reduction in flow is expected to reduce the occurrence of bed or bank erosion along the river and decrease the size and amount of sediment or other substrates transported in the river. The sediment load to the Fairford River from Lake Manitoba is also expected to decrease because a portion of the peak flows from Lake Manitoba will be diverted to the LMOC. The reduction in flows may cause some localized changes in channel aggradation and degradation processes but is not expected to create a change in the fluvial geomorphology of the Fairford River. Regular spring/summer high flows will still occur; however, they will be reduced in magnitude, which will reduce overbank flooding. The Project will still allow high flows that are required in river systems for flushing and natural fluvial geomorphologic processes to occur.

Lake St. Martin

A complete description of the current design for the LSMOC inlet and outlet areas is provided in Chapter 3. In summary, the hydraulic profile of the channel will require the lake bottom to be excavated at the channel inlet and outlets to match proposed channel invert elevations. The selected inlet and outlet design will be intended to protect the channel and the channel capacity by reducing the potential for erosion and sediment transport. The inlet will include excavation into Lake St. Martin starting approximately 800 m from shore to allow a smooth transition from the lakebed to the start of the channel. The width of excavation will flare gradually from a width of approximately 400 m in the lake to 100 m at the channel entrance near the shoreline. Rock-filled jetties will likely be required for a short distance from the shoreline and will extend into the lake parallel to the channel excavation to protect the channel entrance from erosion. Efforts will be made to minimize the overall excavation at the inlet during the

detailed design process. A preliminary drawing of the conceptual inlet design is provided in Appendix 3B, Figure 3B-12.

Based on the current design concept, the outlet will include excavation from the shoreline to a distance approximately 400 m into Lake Winnipeg. The excavated area will flare gradually from a width of approximately 80 m near the shoreline to a width of approximately 180 m in the lake. Rock-filled jetties will likely be required and will extend into the lake parallel to most of the excavation area to prevent excessive sediment deposition in the outlet and protect the channel outlet from erosion. Efforts will be made to minimize the overall excavation at the inlet during the detailed design process. A preliminary drawing of the conceptual outlet is provided in Appendix 3B, Figure 3B-13.

Additional studies are planned as part of ongoing detailed design and include the collection of additional shoreline data to aid in detailed design and reduce changes to shoreline geomorphology where possible. Engineering studies will optimize LMOC outlet design to minimize environmental effects.

Dauphin River

The operation of the LMOC and LSMOC will reduce peak flows in Dauphin River during periods of high flows and flood events. This reduction in flow is expected to reduce the occurrence of bed or bank erosion along the river and decrease the size and amount of sediment or other substrates transported in the river. Based on the relationship between flow levels and velocities, it is expected that velocities may also decrease in areas where flows are reduced. The sediment load to Dauphin River is also expected to decrease because as a portion of the peak flows from Lake Manitoba will be diverted to the LMOC and a portion of the Lake St. Martin flows will be diverted to the LSMOC. The reduction in flows may cause some localized changes in channel aggradation and degradation processes but is not expected to create a change in the fluvial geomorphology of Dauphin River. Regular spring/summer high flows will still occur; however, they will be reduced in magnitude, which will reduce overbank flooding. The Project will still allow high flows that are required in river systems for flushing and natural fluvial geomorphologic processes to occur.

Sturgeon Bay

Changes to shoreline geomorphology in Sturgeon Bay will occur due to the construction of the LSMOC outlet area and operation of the LSMOC, as described above for Lake St. Martin. Engineering studies will optimize LSMOC outlet design to minimize environmental effects.

North Basin of Lake Winnipeg

Changes in shoreline geomorphology in Lake Winnipeg are limited to the Lake St. Martin channel outlet in Sturgeon Bay. There were no pathways of effects identified for changes in shoreline geomorphology in the north basin of Lake Winnipeg.

Mitigation

Engineering studies will be conducted to further understand fluvial geomorphology and optimize the design of the inlets and outlets on the channels to minimize environmental impacts. Goals for these studies are list below.

LMOC Inlet

1. The Inlet and associated works will be designed such that change to the morphology of the natural and modified shorelines is minimized and/or prevented.
2. Excavation of the Inlet will be completed in a manner where suspension and transport of lakebed sediments is minimized and/or prevented.
3. Sediment transport out of Lake Manitoba through the Inlet and into the channel will be minimized or prevented.

LMOC Outlet

1. The outlet and associated works will be designed such that change to the geomorphology of the natural and modified shorelines is minimized and/or prevented.
2. Excavation of the outlet will be completed in a manner where suspension and transport of lakebed sediments is minimized and/or prevented.
3. Sediment transport out of the channel through the outlet and into Lake St. Martin will be minimized or prevented.

LSMOC, Inlet and Outlet

This design will build on the work done to date to finalize the location and configuration of the inlet and outlet to set the configuration for subsequent design work. This work will include but not be limited to examination and resolution of issues to facilitate detailed design to proceed, including lakebed excavation, shoreline geomorphology, sediment transport and deposition modelling, and navigation.

Project Environmental Management Program

In addition to the above engineering design objectives, Manitoba Infrastructure is developing a comprehensive Environmental Management Program (EMP) that encompasses several mitigation methods and measures to reduce or prevent potential effects to surface water during Project construction and operation and maintenance (Section 3.7). The EMP is organized into a Construction Environmental Management Program (CEMP) and an Operations Environmental Management Program (OEMP) that will be finalized prior to Project construction and operation. A description of the CEMP and OEMP are provided in Section 3.7. The EMP includes several management plans and mitigation measures designed

to address specific components of the Project activities and provide protection of surface water resources.

The environmental protection plans (EPPs), project environmental requirements (PERs), waste management plan, construction decommissioning plan, hazardous materials management plan and emergency response plan will include mitigation measures that will protect surface water resources, and mitigation measures specific to the protection of surface water resources will be outlined in the Surface Water Management Plan (SWMP) and the Sediment Management Plan (SMP). If necessary, a stand-alone Debris Management Plan may be developed to address any material entering, within or exiting the LMOC and LSMOC, including floating or submerged (e.g., driftwood, plants), suspended sediment or bed load moved by flowing water.

Project Residual Effects

The residual effects of the changes in fluvial geomorphology and shoreline geomorphology due to the operation of the Project can be characterized by the following:

- direction is neutral because the changes in flows and lake levels that will occur are within the range of high and low flows that have previously occurred in the Project area
- magnitude is negligible to low
- geographic extent of the effects is LAA because there are no changes beyond Sturgeon Bay
- frequency of the effect is continuous, given the permanent nature of the changes the Project will have on fluvial morphology
- the duration of the effect is long-term, given the permanent nature of the changes from Project on fluvial morphology
- the effects are irreversible, given the permanent nature of the changes from Project on fluvial morphology
- the ecological and socio-economic context is disturbed for LMOC because the PDA has been previously disturbed by human development
- the ecological and socio-economic context is disturbed for LSMOC because the PDA has been previously disturbed by human activities and previous flood events that diverted water from Lake St. Martin to the Buffalo Creek system
- the timing of the effect has a high sensitivity as the effect occurs during a critical life stage (e.g., fish spawning or bird nesting periods)

6.4.7.4 Changes in Local Drainage Areas and Local Drainage Patterns

Project Pathways

LMOC

Changes to local drainage areas and local drainage patterns will occur due to the construction and operation of the LMOC. The PDA required for the LMOC will alter drainage patterns in the Birch Creek and Watchorn Creek drainage basins as it cuts across some of the drainage areas for these basins (Appendix 6B, Figure 6.4B-9). This alteration of drainage patterns will occur only along the west side of the LMOC. Drainage along the east side of the LMOC from Clark's Lake, Birch Creek and Watchorn Creek will not be altered. The wetlands and small wetland lakes and ponds located along the east side of the LMOC alignment (Goodison Lake, Water Lake, Clear Lake, Reed Lake) are outside the PDA and will not be directly altered by the Project construction or operation activities; however, alterations in drainage area and drainage patterns will affect flows in the Birch Creek and Watchorn Creek drainage basins, which may also affect surface water levels in these wetlands and small wetland lakes and ponds.

A complete description of the LMOC current design, function, capacity and operation is provided in Chapter 3. In summary, the LMOC will run northwards from Watchorn Bay on Lake Manitoba to Birch Bay on Lake St. Martin with an invert elevation of approximately 242 m asl (794 ft) at Lake Manitoba and approximately 239 m asl (784 ft) at Lake St. Martin. Appendix 3B provides maps and figures illustrating the location and design elements of the LMOC. The channel depth from existing ground will vary between 6 m and 12 m and, since the invert of the channel will be lower than water levels in the lakes, there will be standing water in the channel on both sides of the water control structure when the channel is not in operation. The current conceptual design is based on a channel design capacity of 212 m^3/s (7,500 cfs) when operated at a Lake Manitoba water level of 248.1 m (814 ft). The gates will operate about 20% of the time for the LMOC. A flow duration curve for the LMOC is in Appendix 6E, Figure 6E-1c). During operation for flood control (WCS gates open), average velocities in the LMOC are expected to range between approximately 0.9 m/s and 1.3 m/s, with locally higher velocities occurring in the vicinity of the bridges and the water control structure when the channel is operated at higher lake levels, e.g., at a Lake Manitoba level of 248.1 m (814 ft) and a Lake St. Martin level of 244.1 m (801 ft).

The expected depth and width of the LMOC is described in Appendix 3B, Figure 3B-4 and Figure 3B-5. The deepest point of the channel (the invert) is shown on the profile in Appendix 3B, Figure 3B-4. When the WCS gates are closed, the water depth will vary from 5 m to 8 m upstream of the control structure, to 4 m to 5 m downstream of the control structure. The preliminary channel design is approximately 24.1 km in length, with a base width varying between 8 m and 13 m, and side slopes between 5H:1V and 6H:1V depending on bank slope stability requirements. Therefore, the wetted width of the channel when the WCS gates are closed will vary between 30 m and 60 m. When the WCS gates are open, the channel depth will be more consistent at approximately 6 m (decreasing from 8m deep just upstream of the control structure) with a wetted width of 30 m to 45 m.

The route selection process for the LMOC included consideration of potential effects to the wetlands and small wetland lakes and ponds located along the east side of the selected route, and the final alignment for the LMOC was selected to reduce hydrological changes to these areas. However, the selected alignment will unavoidably cross existing areas of the Birch Creek and Watchorn Creek drainage basins, and some of the drainage along the west side will need to be diverted to accommodate the LMOC and manage flows and drainage in the PDA. Field surveys and desktop analyses were conducted to identify the existing drainage areas and drainage patterns in the LMOC area and compare the existing drainage conditions without the Project to the drainage conditions that will exist with the Project. Appendix 6H provides the data prepared to estimate the changes to drainage areas within each drainage basin. Appendix 6B, Figure 6.4B-9 shows the existing drainage patterns in the Birch Creek and Watchorn Creek drainage basins and how the location of the LMOC will intercept some of the existing drainage areas.

Table 6.4-19 provides a summary of the expected changes in drainage area in the Birch Creek and Watchorn Creek drainage basins due to the construction and operation of the LMOC.

Table 6.4-19 Summary of Expected Changes in Drainage Area in the Birch Creek and Watchorn Creek Drainage Basins

Drainage Basin	Waterbodies within Drainage Basin	Existing Drainage Area (km^2)	Change in Drainage Area (km^2)	% Change in Drainage Area
Birch Creek Drainage Basin	Clark's Lake, Goodison Lake, Clear Lake, Water Lake, Reed Lake	286.2	-78.5	-27.4
Watchorn Creek Drainage Basin	None	92.7	-3.7	-4.0

The construction and operation of the LMOC will result in a decrease of 27.4% of the total drainage area of the Birch Creek drainage basin and a decrease of 4.0% of the total drainage area in the Watchorn Creek drainage basin. These changes to drainage area are expected to result in a low to moderate magnitude reduction in flows in the Birch Creek system and a negligible change in flows in the Watchorn Creek system.

Local land drainage in the area of the LMOC generally travels from the west to the east towards the wetlands and small lakes (Appendix 6B, Figure 6.4B-9). As such, an outside drain will be constructed along the length of the west side of the LMOC to capture the drainage from the Birch Creek and Watchorn Creek systems on the west side of the LMOC and re-direct the flow into the LMOC. A typical cross section of the proposed LMOC outside drain is provided in Appendix 3B, Figure 3B-8. Outside drains are not required along the east side of the LMOC because surface runoff slopes away from the channel on the east side.

Detailed design of the LMOC and development of a SWMP are ongoing during preparation of the EIS, and final plans for drainage management in the LMOC area will be determined for the final design and final SWMP. In the current preliminary design, portions of the flow captured on the west side of the LMOC will be redirected to areas along the alignment that may experience reduced flows due to the construction

and operation of the LMOC. Flows will be re-directed through small diameter culverts and small water control structures. As noted in Section 6.4.4.3, surface water flows may also be augmented with groundwater that will be redirected to the LMOC during the active and passive aquifer depressurization activities required for construction and operation of the Project. The potential effects on surface water due to changes in groundwater and surface water interactions is provided in the Changes in Regional and/or Local Groundwater and Surface Water Interactions (Section 6.4.4.3).

Surveys and analyses were conducted from 2015 to 2017 to determine if the small lakes, ponds and wetland areas along the LMOC are hydraulically connected to groundwater sources (KGS Group 2017a). These studies showed that the small lakes, ponds and wetlands along the LMOC are dependent on surface water sources to maintain flows and water levels, and they do not appear to be hydraulically connected to groundwater sources in the area (KGS Group 2017a).

LSMOC

Changes to local drainage areas and local drainage patterns will occur due to the construction and operation of the LSMOC. The PDA required for the LSMOC intercepts surface water drainage from the upper reaches of the Buffalo Creek system, as well as some areas of ephemeral streams and wetlands (Appendix 6B, Figure 6.4B-8). A complete description of the LSMOC current design, function, capacity and operation is provided in Chapter 3. In summary, the LSMOC will run northeast from Lake St. Martin towards Sturgeon Bay through a wetland area, eventually connecting to an existing partially completed, but unused, addition to the Emergency Outlet Channel (known as Reach 3) located east of the approximate midpoint of Buffalo Creek. Approximately 1 km of the Reach 3 Emergency Outlet Channel (at the upstream end near Buffalo Creek) will not be included as part of the LSMOC. The LSMOC will discharge to Sturgeon Bay south of Willow Point (Appendix 3B, Figure 3B-3).

The length of the channel will be approximately 23.8 km with a base width of about 44 m. The channel will have an invert elevation of approximately 239.5 m asl (785.8 ft) at Lake St. Martin and 213 m asl (698.8 ft) at Sturgeon Bay (Appendix 3B, Figure 3B-11). The current design is based on a uniform trapezoid shaped channel with a flat base and 4H:1V side slopes. The channel will have a capacity of 326 m^3/s (11,500 cfs) at a Lake St. Martin water elevation of 244.15 m asl (801 ft) and a Lake Winnipeg water elevation of 217.6 m asl (713.9 ft). The gates will be open about 20% of the time for the LSMOC. A flow duration curve for the LSMOC is in Appendix 6E, Figure 6E-2c). The range in depths and flows in the LSMOC channel (on a monthly basis) when the WCS gates are open are presented in Appendix 3A, Table 3A-1. These values are based on the period of record, Manitoba Infrastructure's operating guidelines (Appendix 3D) and the current status of the design. The results are for the channel only and exclude the inlet, water control structure, drop structures, and the outlet. The values presented during winter months assume open-water conditions in the channel with reduced flow rates at the inlet. If considering potential ice effects in the channel, a larger range of potential water levels and velocities are likely to occur than those presented in the table. Changes in regional and local ice processes are discussed in Section 6.4.7.6.

When the WCS gates are closed (70% to 87% of the time depending on the month), there will be approximately 1 m to 2.5 m depth of water in the channel, as a minimum, with average velocities typically less than 0.1 m/s depending on base flow. The deepest areas will be located immediately upstream of the drop structures. There will be a baseflow in the channel when the WCS gates are closed, concentrated in the channel center based on slope design. Expected flow sources include, but are not limited to, the following:

- There is a known area of groundwater discharge that will occur in locations where the channel invert is in bedrock. Section 6.4.4.3 provides a discussion on surface water and groundwater interactions due to the construction and operation of the Project, and information on groundwater is provided in Section 6.4.1.
- Surface water runoff within the local drainage basin intercepted by the channel will be discharged into the outlet channel at multiple locations. Surface water runoff and groundwater seepage will be collected from an outside drain that will be constructed parallel to the outlet channel.
- A limited discharge from Lake St. Martin may be conveyed through the LSMOC water control structure to maintain adequate water flow and water quality in the channel when the WCS gates are essentially closed, and to sustain water quality within parameters required for fish and other aquatic life.

The construction and operation of the LSMOC does not physically alter the drainage areas, but the location of the LSMOC intercepts drainage from the south and east of the channel to the Buffalo Creek system.

The Buffalo Creek system is very complex. Surface water runoff in a wetland does not flow uniformly; therefore, effects cannot be predicted using typical approaches of measurement of drainage area and flow analysis, as was done with the Birch Creek and Watchorn Creek drainage areas to examine the effects of the LMOC. In addition, Big Buffalo Lake may be supplied by groundwater upwelling from the carbonate aquifer, thereby supplying Buffalo Creek with additional water, which is difficult to measure and quantify.

It will be difficult to quantify effects to flows in the Buffalo Creek system before construction is complete, although the construction and operation of the LSMOC will likely cause a reduction in flows. It is not expected that the EOC will be operated for flood control after the construction of the LSMOC. Repurposing of the EOC to allow additional flows to the Buffalo Lakes and Buffalo Creek from Lake St. Martin would potentially replace any flows lost from interception of wetland flows to the creek. The amount of flows would need to be adjusted based on concurrent studies of flows, wetland hydrology and fish habitat to optimize the mitigation.

Mitigation

Manitoba Infrastructure is developing a comprehensive Environmental Management Program (EMP) that encompasses a number of mitigation methods and measures to reduce or prevent potential effects to surface water during Project construction and operation (Section 3.7). The EMP is organized into a Construction Environmental Management Program (CEMP) and an Operations Environmental Management Program (OEMP) that will be finalized prior to Project construction and operation. A detailed description of the CEMP and OEMP are provide in Section 3.7. The EMP includes several management plans and mitigation measures designed to address specific components of the Project activities and provide protection of surface water resources.

The environmental protection plans (EPPs), Project environmental requirements (PERs), waste management plan, construction decommissioning plan, hazardous materials management plan and emergency response plan will include mitigation measures that will protect surface water resources, and mitigation measures specific to the protection of surface water resources will be outlined in the Surface Water Management Plan (SWMP), the Debris Management Program (DMP), and the Sediment Management Program (SMP).

Consideration may also be given to using EOC Reach 1 to convey additional flow to the Buffalo Lake and Buffalo Creek from Lake St. Martin for potentially replacing flows lost from interception of wetland flows to Buffalo creek by LMOC.

Project Residual Effects

The residual effects of the changes in local drainage areas and local drainage patterns due to the operation of the Project can be characterized by the following:

- direction is adverse because the changes affect existing flows and/or flow patterns
- magnitude is low to moderate; low for the Watchorn Creek system and moderate for the Birch Creek and Buffalo Creek systems
- geographic extent of the effects is LAA because changes in PDA affect drainage beyond the PDA
- frequency of the effect is continuous, given the permanent nature of the Project
- the duration of the effect is long-term, given the permanent nature of the Project
- the effects are irreversible, given the permanent nature of the Project
- the ecological and socio-economic context is disturbed for LMOC because the PDA has been previously disturbed by human development
- the ecological and socio-economic context is disturbed for LSMOC because the PDA has been previously disturbed by human activities and previous flood events that diverted water from Lake St. Martin to the Buffalo Creek system
- the timing of the effect has a high sensitivity as the effect occurs during a critical life stage (e.g., fish spawning or bird nesting periods)

6.4.7.5 Changes in Regional and/or Local Sediment and Debris Transport

Project Pathways

Overview

Changes in regional and/or local sediment and debris transport may occur due to the construction and operation of the Project. Clearing, excavation and other Project construction activities in the PDA could result in the release and transport of sediment and/or debris to waterways within or adjacent to the PDA. Operation of the LMOC and LSMOC will reduce flows and lake levels in Lake Manitoba, the Fairford River, Lake St. Martin and Dauphin River, which is expected to alter sediment and debris transport at a local scale. The changes that will occur within each system are not expected to be of a magnitude that would result in a change in regional erosional or sedimentation processes. As such, the pathways of effects due to the construction and operation of the Project are limited to local changes, and the potential effects of these local changes are discussed below.

Construction

Construction activities for the Project will take place on land and in water in the PDA. Land-based activities such as clearing, excavation and vehicle and equipment movements can result in the release and transport of sediment from work sites to area waterways. In-water excavation and slope contouring required to construct the LMOC and LSMOC inlet and outlet areas may cause a temporary increase in suspended sediments in these areas during these activities.

Operation

The reduction in lake levels and flows that will occur due to the operation of the Project is expected to reduce the amount of sediment and debris (floating or submerged) transport in the Fairford River, Lake St. Martin, Dauphin River and Sturgeon Bay as there will be less erosion at high flows or high lake levels occurring in these systems. The amount of erosion, transport and deposition in an area is dependent on the type and size of materials present (clay, silt, sand, gravel, rock) and the erosive force of the water flow or water level to entrain and transport particles of different sizes.

The sediment transport studies conducted for the EOC from 2011 to 2015 showed that sediment is transported from the upper Dauphin River into Sturgeon Bay. The velocities in Dauphin River moved suspended materials several hundred metres into Sturgeon Bay, with limited local deposition of sediments along the Dauphin River shoreline or in back eddies (KGS Group 2016a). The suspended solids were examined for grain size distribution and were found to consist mainly of clays and silts. The studies found that smaller particles of sediment up to about sand size could be transported in suspension to Sturgeon Bay, while larger cobble sized substrates could be transported by bed load, and gravel sized substrates could be eroded in the river (KGS Group 2016a).

Sediment deposition in Sturgeon Bay was found to vary among open-water and ice-covered periods (KGS Group 2016a). Sediment deposition under ice cover was more evenly distributed and at lower levels than during the open-water season (KGS Group 2016a). Under open-water, wind and currents caused re-suspension of sediment particles, such that the deposition was still distributed across the sampling area but was at higher levels (KGS Group 2016a). There was no relationship found between sedimentation rates and trap distances from the mouth of Dauphin River (KGS Group 2016a). The studies noted that these results were in agreement with information provided in the "State of Lake Winnipeg 1999 to 2007" report, which reported higher sedimentation rates in the fall than spring and summer, and that wind was a more significant factor in suspended sediment dynamics than inputs from rivers that discharge into the lake (Environment Canada and Manitoba Water Stewardship 2011).

The operation of the EOC did not divert any high flows from the lower Dauphin River, as flows from the Buffalo Creek system enter Dauphin River several kilometres upstream of the outlet into Sturgeon Bay. As such, the sediment transport studies included a period of very high flows in the Project area and provided information on the relationship between sediment transport and changes in flows and lake levels.

The operation of the EOC re-routed high flows that would have entered the upper Dauphin River to Reach 1 of the EOC, resulting in the passage of very high flows through the Buffalo Lakes and Buffalo Creek system. The passage of these flow volumes was unprecedented for this system and resulted in the erosion and transport of sediment and various large and small organic or woody debris (soil, peat, grasses, shrubs, trees) from these areas to Dauphin River and Sturgeon Bay. This effect will no longer occur because flows will be routed through the LMOC and LSMOC, and no high flows will be passed through the Buffalo Lakes and Buffalo Creek system as part of the operation of the LMOC and LSMOC.

The operation of the EOC did not reduce flow volumes or lake levels in the Fairford River, Lake St. Martin or Dauphin River, whereas the operation of the LMOC and LSMOC will reduce high flows and high lake levels. This reduction in flow and lake levels is expected to reduce erosion potential, resulting in a decrease in the release and transport of sediment and debris in these systems. The outlet channels will be designed to be non-erodible for normal operating conditions (KGS Group 2016b,2017) and are not expected to contribute additional sediment or debris to Lake St. Martin, Dauphin River or Sturgeon Bay. Based on the shoreline investigations and sediment transport studies conducted to date, it is expected that sediment movement at the inlet areas for the LMOC and LSMOC will be minimal and is unlikely to occur to an extent that will affect the channel inlet areas. As noted above in the discussion of effects on shoreline geomorphology, the selected inlet and outlet design will be intended to protect the channel and the channel capacity by reducing the potential for erosion and sediment transport. The use of rock-filled jetties are included as part of the channel design to reduce changes in shoreline geomorphology and shoreline erosion.

The diversion of high flows through the LMOC and LSMOC when the WCS gates are open will change how sediment is transported to, and deposited in, Lake St. Martin or Sturgeon Bay because the channels will be designed to not erode and contribute additional sediment or debris to the system. However, they will create additional outflow areas in Lake St. Martin at Birch Bay and in Sturgeon Bay near Willow Point

(Appendix 6B, Figure 6.4B-7, Figure 6.4B-8). Without the Project, all high flows pass through Fairford River to Lake St. Martin and Dauphin River to Sturgeon Bay and enter Lake St. Martin and Sturgeon Bay at one location. With the Project, high flows are split between the rivers and the constructed channels, which reduces the amount of outflow to the existing river outlet areas within Lake St. Martin and Sturgeon Bay. This decrease in outflow is expected to reduce erosion and transport of sediment to these local areas because less flow will entrain and transport less sediment or debris, but the changes are expected to be localized in nature, minor and not measurable.

The channel outflows to Lake St. Martin at Birch Bay and to Sturgeon Bay near Willow Point are expected to have a lower amount of sediment or debris than the Fairford or Dauphin river systems because water from Lake Manitoba and Lake St. Martin will pass through the approximately 24 km long constructed channels, which will be designed to be non-erodible and not contribute additional sediment or debris.

Sediment deposition in Lake St. Martin and Sturgeon Bay may be reduced with a reduced sediment load, but it is expected that the changes in sediment deposition due to operation of the Project may not be discernible from existing conditions, particularly in Sturgeon Bay, where the effects of wind on sedimentation rates and suspended sediment dynamics may exceed the effects of sediment inputs from river outflows.

Dividing the flows will also reduce the erosion potential of each outflow to cause scouring or erosion of the lakebed in Lake St. Martin or Sturgeon Bay. As noted above in the effects on shoreline geomorphology, rock-filled jetties are included as part of the design of the inlet and outlet areas to reduce changes in shoreline geomorphology and help prevent erosion.

There may be a temporary increase in suspended sediments at inlet and outlet areas when the WCS gates are open and after gates-closed periods. The LMOC and LSMOC gates are expected to be open approximately 20% of the time. During gates-closed periods, sediment that enters the channels from Lake Manitoba or Lake St. Martin may be from prior operation; or from providing baseflows; or from aquatic or other vegetation that enters or is established in the channels. Sediment and vegetation may be flushed out when the WCS gates are opened, which could temporarily increase sediment and debris transport.

The overall changes in sediment erosion, transport and deposition due to the Project are expected to be localized in nature, minor and not measurable. The overall amount of sediment and debris in the Lake Manitoba–Lake St. Martin–Lake Winnipeg system is not expected to be altered, but it is expected to be distributed differently.

Mitigation

Project Environmental Management Program

MI is developing a comprehensive Environmental Management Program (EMP) that encompasses several mitigation methods and measures to reduce or prevent potential effects to surface water during Project construction and operation (Section 3.7). The EMP is organized into a construction environmental management program (CEMP) and an operations environmental management program (OEMP) that will be finalized prior to Project construction and operation. A detailed description of the CEMP and OEMP are provided in Section 3.7. The EMP includes several management plans and mitigation measures designed to address specific components of the Project activities and provide protection of surface water resources.

The environmental protection plans (EPPs), project environmental requirements (PERs), waste management plan, construction decommissioning plan, hazardous materials management plan and emergency response plan will include mitigation measures that will protect surface water resources, and mitigation measures specific to the protection of surface water resources will be outlined in the surface water management plan (SWMP), the debris management program (DMP) and the sediment management program (SMP).

Sediment Management Program

The EMP for the Project includes a Sediment Management Program that includes Best Management Practices (BMPs), mitigation measures and monitoring plans to address potential effects of the Project due to changes in sediment erosion or transport.

Debris Management Program

The EMP for the Project includes a Debris Management Program that includes Best Management Practices (BMPs), mitigation measures and monitoring plans to address potential effects of the Project due to changes in the presence or transport of debris.

Project Residual Effects

The residual effects of the changes in regional and/or local sediment transport due to the operation of the Project can be characterized by the following:

- direction is neutral because there is no net measurable change; the overall amount of sediment and debris in the system is not expected to be altered, but it is expected to be distributed differently
- magnitude is negligible to low
- geographic extent of the effects is LAA
- frequency of the effect is regular/continuous; as long as the Project continues operating, the effects of regional flows and water levels will continue

- the duration of the effect is long-term given; as long as the Project continues operating, the effects of regional flows and water levels will continue
- the effects are irreversible, given the permanent nature of physical changes from the Project
- the ecological and socio-economic context is disturbed for LMOC because the PDA has been previously disturbed by human development
- the ecological and socio-economic context is disturbed for LSMOC because the PDA has been previously disturbed by human activities and previous flood events that diverted water from Lake St. Martin to the Buffalo Creek system
- the timing of the effect has a high sensitivity as the effect occurs during a critical life stage (e.g., fish spawning or bird nesting periods)

6.4.7.6 Changes in Regional and Local Ice Processes

Project Pathways

The changes to regional flows and lake levels due to operation of the Project, and the changes in local drainage areas and local drainage patterns due to construction and operation of the Project, may affect ice processes in these waterways because freeze and thaw cycles in lakes and rivers are related to flow and lake levels. The ice processes in the area waterways were examined during operation and non-operation of the EOC (KGS Group 2014), and consideration of ice issues in the constructed channels and channel infrastructure is included in the conceptual and preliminary design of the outlet channels. Based on the observations and results of previous studies in the Project area, it is expected that the reduced flows and lake levels will reduce the risk of ice jamming and flooding in the Fairford and Dauphin rivers. The addition of the inlet and outlet areas in Watchorn Bay, Birch Bay, Lake St. Martin and Sturgeon Bay will likely alter ice forming processes in these areas because there will be changes in flows and, in some areas, changes in local shoreline geomorphology. If the WCS gates are opened during early winter periods, the changes in flows could slow the formation of ice at the inlet and outlet areas, and it would require longer periods of time to achieve a solid ice cover in these areas. This localized effect on ice formation could affect transportation across these areas in winter periods.

Without the Project, the prevention of formation of frazil ice and hanging dams in Dauphin River is managed through manipulation of flows in the Fairford River, which are outlined in the operating guidelines that were developed by the Province of Manitoba for the FRWCS. These principles for ice management were also included in the development of the operating rules for Lake Manitoba and Lake St. Martin outlet channels (Appendix 6J). With the Project, flows will also be managed through use of the LMOC and LSMOC, which will allow greater flexibility in the system, and aid in meeting ice management objectives for the area. Most of the changes to flows and lake levels due to operation of the Project will occur during peak flow periods in the open-water season after ice-out, and operation of the FRWCS, LMOC and LSMOC will be managed in accordance with the applicable operating guidelines. As such, the magnitude of the potential change to ice processes in regional waterways is predicted to be low to negligible.

The changes in flows in the Watchorn Creek system are negligible, and any changes in ice processes in this system are expected to be negligible. The changes to flows in the Birch Creek system could affect the timing and amount of freeze up in this system, although it is expected that the shallow wetland lakes and some, if not all channel sections of the Birch Creek system, would freeze to the bottom in most Manitoba winters, with or without the Project. As such, the magnitude of the potential change to ice processes in the Birch Creek system is predicted to be low to negligible.

The surface water areas that will be affected by the LSMOC are small intermittent stream sections in the headwaters of the Buffalo Lake and Buffalo Creek system. It is expected that these areas would freeze to the bottom in most Manitoba winters, with or without the Project. As such, the magnitude of the potential change to ice processes in the surface water areas that will be affected by the LSMOC is predicted to be negligible.

Mitigation

Surface Water Management Plan

The mitigation measures for ice management will refer to the facility operations manuals and the SWMP.

Operation of the Outlet Channels

The LMOC and LSMOC will be operated in accordance with the Operating Rules developed for the Project, which includes considerations for ice management.

Navigational Signage

Signs indicating potential areas of thin ice will be used at LMOC and LSMOC inlet and outlet areas in accordance with Transport Canada requirements.

Project Environmental Management Program

Manitoba Infrastructure is developing a comprehensive Environmental Management Program (EMP) that encompasses several mitigation methods and measures to reduce or prevent potential effects to surface water during Project construction and operation, including ice processes (Section 3.7). The EMP is organized into a construction environmental management program (CEMP) and an operations management program (OEMP) that will be finalized prior to Project construction and operation. A detailed description of the CEMP and OEMP are provide in Section 3.7. The EMP includes several management plans and mitigation measures designed to address specific components of the Project activities and provide protection of surface water resources.

The environmental protection plans (EPPs), project environmental requirements (PERs), waste management plan, construction decommissioning plan, hazardous materials management plan and emergency response plan will include mitigation measures that will protect surface water resources, and mitigation measures specific to the protection of surface water resources will be outlined in the surface

water management plan (SWMP), the debris management program (DMP) and the sediment management program (SMP).

Project Residual Effects

The residual effects of the changes in regional and/or local ice processes due to the Project can be characterized by the following:

- direction is neutral after mitigation. The adverse effects are minor and localized in nature and will be mitigated by navigational signage; the potential positive effects are not easy to measure
- magnitude is negligible to low
- geographic extent of the effects is LAA
- frequency of the effect is intermittent, given the seasonal nature of ice formation
- the duration of the effect is long-term, as long as the Project continues operating
- the effects are irreversible, given the permanent nature of the Project
- the ecological and socio-economic context is disturbed for LMOC because the PDA has been previously disturbed by human development
- the ecological and socio-economic context is disturbed for LSMOC because the PDA has been previously disturbed by human activities and previous flood events that diverted water from Lake St. Martin to the Buffalo Creek system
- the timing of the effect has a high sensitivity as the effect occurs during a critical life stage (e.g., fish spawning or bird nesting periods)

6.4.7.7 Changes in Regional and/or Local Surface Water Quality

Project Pathways

Construction Phase

There are no pathways of effects for regional changes to surface water quality identified for the construction phase of the Project. Local changes to sediment transport and suspended sediments due to clearing and excavation activities on land and in water that can affect local surface water quality are discussed above in the Section 6.4.7.5 on Changes in Regional and/or Local Sediment and Debris Transport. During the construction phase of the Project, there will be the need to discharge groundwater from active aquifer depressurization activities. For the LMOC, groundwater will be discharged to the channel or to an outside drain constructed parallel to the channel if required or may be discharged to the Birch Creek or Watchorn Creek systems. The discharge locations will be determined as part of detailed design, and will be related to construction sequencing (i.e., how construction will advance across the landscape from the inlet or outlet areas). Regardless of the discharge locations, the groundwater released to the outside drain or creeks will ultimately discharge to Birch Bay in Lake St. Martin. The areas along the LMOC where aquifer depressurization will be required include areas where local residents currently

draw groundwater for drinking water supplies (Section 6.4.2), and the groundwater system currently naturally discharges to Lake Manitoba and Lake St. Martin. The water quality of the groundwater resources in the area is discussed in Section 6.4.2. Based on the existing use of groundwater in the area and existing groundwater quality, it is expected that the groundwater that will be released to surface water areas will be within MSD and CCME recommended guidelines for the protection of aquatic life (CCME 1999) and within the CCME guidelines for the protection of agricultural water uses (CCME 1999). The exception is for fluoride, although the groundwater exceeds CCME aquatic life guidelines, the surface water also exceeds the same guideline for all surface water in the RAA. As such, the magnitude of potential adverse changes to surface water quality during construction of the LMOC is predicted to be low to negligible.

For the LSMOC, groundwater will be discharged to the outside drain constructed parallel to the channel. The discharge locations will be determined as part of detailed design and will be related to construction sequencing (i.e., how construction will advance across the landscape from the inlet or outlet areas). Regardless of the discharge locations, the groundwater released to the outside drain will ultimately discharge to Sturgeon Bay in Lake Winnipeg. The groundwater system currently naturally discharges to Lake Winnipeg (Section 6.4.2). The water quality of the groundwater resources in the area is discussed in Section 6.4.2. Based on existing groundwater quality, it is expected that the groundwater that will be released to surface water areas will be within MSD and CCME recommended guidelines for the protection of aquatic life (CCME 1999) and within the CCME guidelines for the protection of agricultural water uses (CCME 1999). The exception is for fluoride, although the groundwater exceeds CCME aquatic life guidelines, the surface water also exceeds the same guideline for all surface water in the RAA. As such, the magnitude of potential adverse changes to surface water quality during construction of the LSMOC is predicted to be low to negligible.

Operation and Maintenance Phase

The changes in regional flows due to the operation of the Project will alter the timing of how water is passed through the existing system and divert high flows from the Fairford and Dauphin rivers to the LMOC and LSMOC. The addition of the outlet channels alters the route for the passage of high flows from Lake Manitoba to Sturgeon Bay but does not change the overall composition or volume of water entering or leaving the system. That is, all flows from the Lake Manitoba basin will enter Sturgeon Bay, with or without the Project. Some of the water that currently flows through the Fairford and Dauphin Rivers will be diverted through the LMOC and the LSMOC when the Project is operated. The Project does not retain water and the diversion of water is not expected to substantially change the water temperature in the lakes and rivers in the region.

Surface water quality in Lake Manitoba varies spatially and is not well studied or understood (LMWSB 2016). During the 2011 flood, total phosphorus concentrations were elevated at Delta Marsh, but not at the station located at the Narrows in Lake Manitoba, and average total nitrogen concentrations in the lake were not affected (LM and LSMRRC 2013).TSS in Lake Manitoba in 2011 was similar to the long-term average and within the range of historical concentrations (LM and LSMRRC 2013). Surface water quality

monitoring in Lake Manitoba has shown increases in phosphorus and chlorophyll and decreases in conductivity, but water levels do not appear to be a major driver of water quality (LM and LSMRRC 2013).

The regional and local surface water quality studies conducted for the EOC from 2011 to 2015 initially included sampling sites in the Waterhen River and at the Lake Manitoba Narrows. Sampling at these two sites was discontinued after the first year of study as the site in the Fairford River captured the condition of the water quality entering Lake St. Martin and the Dauphin River system (NSC and KGS Group 2016b).

The 2011 to 2015 EOC studies in the Fairford River, Lake St. Martin, Dauphin River and Sturgeon Bay found that the majority of the surface water quality parameters monitored showed some natural variability and fluctuated seasonally and among years (Appendix 6D; NSC and KGS Group 2016). There was no linkage between operation of the EOC and surface water quality in the sampled waterways, with some exceptions. Temporary increases in total suspended solids (TSS) occurred in Lake St. Martin during dredging of the EOC inlet in 2011, and in some areas of Dauphin River and Sturgeon Bay during operation of the EOC in the high flow events that occurred in 2011 and 2014. Dissolved oxygen levels were occasionally below recommended guidelines in Dauphin River, but it was noted that dissolved oxygen levels were also periodically below guideline levels in the historic records for the river, and the changes to dissolved oxygen levels were not attributed to the operation of the EOC (NSC and KGS Group 2016). During the 2011/2012 operation and closure of the EOC, temporary increases in phosphorus concentrations were observed in Dauphin River and temporary increases in phosphorus and nitrogen concentrations were observed in Sturgeon Bay. Except for mercury and methylmercury, there were no changes to concentrations of most metals or major ions that were attributed to the operation and closure of the EOC. During operation of the EOC in 2011 and 2014, methylmercury was detected more often and at higher concentrations near Dauphin River and Willow Point than in the rest of Sturgeon Bay, but concentrations were consistently well below the MSD and CCME FAL guidelines (NSC and KGS Group 2016).

As noted in Section 6.4.7.5 in the discussion of Changes in Regional and/or Local Sediment and Debris Transport, the operation of the EOC re-routed high flows that would have entered the upper Dauphin River to Reach 1 of the EOC, resulting in the passage of very high flows through the Buffalo Lakes and Buffalo Creek system. The passage of these flow volumes was unprecedented for this system and resulted in the erosion and transport of sediment and various large and small organic or woody debris (soil, peat, grasses, shrubs, trees) from these areas to Dauphin River and Sturgeon Bay. This release of peat, soils and other organic materials to the system may be related to the changes in TSS, phosphorus, nitrogen and methylmercury observed in the EOC studies. The transport of peat and other organic materials from the Buffalo Lakes or Buffalo Creek system is not expected to occur during operation of the LMOC and LSMOC because flows will be routed through the LMOC and LSMOC, and no high flows will be passed through the Buffalo Lakes and Buffalo Creek system as part of the operation of the LMOC and LSMOC. The LMOC and LSMOC will be designed to be non-erodible for normal operating conditions (KGS Group 2016b; 2017) and are not expected to contribute additional sediment or debris to Lake St. Martin, Dauphin River or Sturgeon Bay.

There is the potential for low dissolved oxygen conditions to occur in the LMOC when the WCS gates remain closed for an extended period. When the WCS gates are closed, the water depth will vary from 5 m to 8 m upstream of the control structure, to 4 m to 5 m downstream of the control structure. With the LMOC receiving agricultural runoff, there will be the potential for oxygen depletion in the water column due to bacterial decomposition of organic material depositing on the bottom of the channel. There will be no baseflow, so the channel reaeration will be dependent upon wind mixing. This risk of low dissolved oxygen is greatest in winter when there is ice on the surface and no chance for oxygen to be mixed into the water by wind and waves. It is also a potential problem in summer when water temperatures increase thereby reducing the oxygen saturation level. Due to the depth of the channel (4 -8 m) wind induced mixing to the lower depths will be very limited even in summer, creating low dissolved oxygen at depth. The geographic area of this impact will be very limited and remain within the LMOC. The low dissolved oxygen will not extend beyond the channel into Lake St. Martin or Lake Manitoba, so effects do not extend into the LAA beyond the PDA.

Based on historical and existing surface water quality data for the LAA, and information on the potential effects of high flows on surface water quality obtained from the EOC studies, it is not expected that the operation of the LMOC and LSMOC will alter the surface water quality in the LAA beyond the range of variability already observed in these waterways. The operation of the LMOC and LSMOC diverts high flows from the Fairford and Dauphin rivers and avoids passing high flows through the Buffalo Lake or Buffalo Creek system. As such, the changes in surface water quality that occurred in relation to very high flows during the operation of the EOC are not expected to occur with the operation of the Project.

Mitigation

Application of CCME/MSD Guidelines

The SWMP will outline the methods and approach to document surface water quality in the Project area during construction, operation and maintenance activities, including comparison of collected samples to recommended guidelines.

Project Environmental Management Program

Manitoba Infrastructure is developing a comprehensive Environmental Management Program (EMP) that encompasses several mitigation methods and measures to reduce or prevent potential effects to surface water during Project construction and operation, including ice processes. The EMP is organized into a construction environmental management program (CEMP) and an operations environmental management program (OEMP) that will be finalized prior to Project construction and operation. A detailed description of the CEMP and OEMP are provided in Section 3.7. The EMP includes several management plans and mitigation measures designed to address specific components of the Project activities and provide protection of surface water resources.

The environmental protection plans (EPPs), project environmental requirements (PERs), waste management plan, construction decommissioning plan, hazardous materials management plan and emergency response plan will include mitigation measures that will protect surface water resources, and mitigation measures specific to the protection of surface water resources will be outlined in the surface water management plan (SWMP), the debris management program (DMP) and the sediment management program (SMP).

Project Residual Effects

The residual effects of the changes in regional and/or local surface water quality due to the construction and operation of the Project can be characterized by the following:

- direction is neutral because there are no adverse changes to overall surface water quality in the regional or local area waterways
- magnitude is negligible to low
- geographic extent of the effects is LAA
- frequency of the effect is intermittent due to the seasonal and annual variability of surface water quality in the regional and local area waterways
- the duration of the effect is long-term, as long as the Project continues operating
- the effects are irreversible, given the permanent nature of the Project
- the ecological and socio-economic context is disturbed for LMOC because the PDA has been previously disturbed by human development
- the ecological and socio-economic context is disturbed for LSMOC because the PDA has been previously disturbed by human activities and previous flood events that diverted water from Lake St. Martin to the Buffalo Creek system
- the timing of the effect has a high sensitivity as the effect occurs during a critical life stage (e.g., fish spawning or bird nesting periods)

6.4.8 Summary of Project Residual Effects

6.4.8.1 Groundwater

Table 6.4-20 summarizes the residual environmental effects on groundwater during construction and operations and maintenance.

The regional flows from the uplands to the major lakes in the area will not be affected by the Project. The local groundwater piezometric head and flows will be affected during construction dewatering. This may affect pressure in domestic or livestock wells within 3 km to 5 km of the LMOC. The effect is mitigable by a Groundwater Management Plan that will further study effects, consult with local landowners and develop specific mitigation plans for each well user's circumstance.

Table 6.4-20 Summary of Project Residual Effects on Groundwater

Residual Effect	Residual Effects Characterization								
	Project Phase	Direction	Duration	Magnitude	Timing	Geographic Extent	Frequency	Reversibility	Ecological Context
Change in Local Groundwater Flows, Levels and Quality	C	A	ST	M	NS	LAA	IF	RS	U
Change in Local Groundwater Flows, Levels and Quality	O	A	LT	NL	NS	PDA	RC	I	U
Changes in Local Groundwater/Surface Water interactions	C	A	ST	NL	HS	LAA	IF	RS	U
Changes in Local Groundwater/Surface Water interactions	O	A	LT	NL	HS	PDA	RC	I	U

KEY

See Table 6.4-5 for detailed definitions

Project Phase
C: Construction
O: Operation

Direction:
P: Positive
A: Adverse
N: Neutral

Duration:
ST: Short-term
MT: Medium-term
LT: Long-term

Magnitude:
NL: Negligible or Low
M: Moderate
H: High

Timing
NS: No sensitivity
MS: Moderate sensitivity
HS: High sensitivity

Geographic Extent:
PDA: Project development area
LAA: local assessment area
RAA: regional assessment area

N/A: Not applicable

Frequency:
IF: Infrequent
SI: Sporadic/Intermittent
RC: Regular/Continuous

Reversibility:
RS: Reversible (short-term)
RL: Reversible (long-term)
I: Irreversible

Ecological/Socio-Economic Context:
U: Undisturbed
D: Disturbed

The surficial overburden is generally till and organic soils and the distance that changes in water level are transferred through the groundwater are limited. Changes in surficial groundwater elevation around the channel excavations will be small (less than 1 m), and the effects will transfer only 10 m to 200 m at most. Around Lake St. Martin, the Fairford River and Dauphin River, water levels will decrease during high dewatering conditions due to the Project.

The location of the proposed LMOC (Route D) was selected to reduce the risk of GUDI as this concern was regularly raised by First Nation Communities during the engagement sessions. This area is under high artesian pressure (the carbonate aquifer is under pressure at higher head than ground surface, lakes levels and water levels in wetlands), meaning that the water will flow from the aquifer to the surface if

there is a pathway. Currently, there is a thick till aquiclude (i.e., does not transmit water) protecting the underlying carbonate aquifer. If the till is breached during construction, then the surface water will not flow into the aquifer. The physical location of the Project, although creating a challenge for construction, does not create the same GUDI concerns as Route C did.

It is unlikely that wetlands adjacent to the LMOC will be affected during construction dewatering; however, if this occurs it can be easily mitigated by adding the pumped water to the wetlands. Natural surface and shallow subsurface drainage flow may be affected along the approximately 24 km length of the LSMOC. Based on examination of the effects of the EOC, effects to drainage are not expected to occur beyond 500 m from the channel. Unmitigated, this effect would be expected to affect drainage over an area of up to approximately 1,250 ha on either side of the channel.

6.4.8.2 Surface Water

The potential effects of the operation of the proposed LMOC and LSMOC on regional flows and lake levels include a reduction in peak flood levels, reduced flood inundation areas, and an increase in the amount of time that Lake Manitoba and Lake St. Martin are within the desired regulated range. These effects are a desired positive outcome and objective of the Project. Local drainage areas and drainage patterns will be unavoidably altered in the areas where the LMOC and LSMOC will be located, but considerations for drainage in detailed design and application of mitigation measures will limit the magnitude and extent of these changes.

Minor, localized changes may occur in fluvial or shoreline geomorphology, and sediment and debris transport, but the changes in flows and lake levels that will occur in the regional and local waterways are within the range of high and low flows that have previously occurred in the Project area, and the magnitude of these potential effects are considered to be negligible to low.

The potential changes in groundwater and surface water interactions due to the Project are determined to be of low magnitude in the LMOC area based on the understanding of surface water and groundwater flows in this area and the design mitigation that will be incorporated (e.g., maintenance of drainage and flows to the Birch Creek and Watchorn Creek systems) to reduce potential effects. The potential changes in groundwater and surface water interactions due to the Project are determined to be of moderate magnitude in the LSMOC area based on examination of past effects of the EOC on wetland vegetation in the area, and the need for further understanding of the wetland hydrology in the area and interactions with the LSMOC.

The potential changes to ice processes in the regional and local waterways are neutral in direction and of negligible to low magnitude after mitigation, as the potential for adverse effects is minor and localized in nature and can be mitigated by navigational signage.

There are no adverse changes found to overall surface water quality in the regional or local area waterways because the composition and volume of water being transported from Lake Manitoba to Sturgeon Bay is not altered by the Project construction or operation. That is, all flows from the Lake Manitoba basin will enter Sturgeon Bay, with or without the Project. Temporary increases in suspended

sediments may occur in local waterways due to construction activities, or at the channel inlet and outlet areas during periods of initial outlet channel operation.

The potential effects on surface water resources in the regional or local waterways are determined to be limited to the LAA. There were no pathways of effects or residual effects to the RAA.

Table 6.4-21 summarizes the residual environmental effects on surface water during construction and operations.

Table 6.4-21 Summary of Project Residual Effects on Surface Water

Residual Effect	Residual Effects Characterization								
	Project Phase	Direction	Duration	Magnitude	Timing	Geographic Extent	Frequency	Reversibility	Ecological Context
Changes in regional flow and water levels	O	P	LT	L-M	HS	LAA	RC	R	DR
Changes in regional fluvial geomorphology and shoreline geomorphology	O	N	LT	NL	HS	LAA	RC	I	D
Changes to local drainage areas and local drainage patterns	C, O	A	LT	L-M	HS	LAA	RC	I	D
Changes in regional and/or local sediment and debris transport	C, O	N	ST in C, LT in O	NL	HS	LAA	RC	I	D
Changes in regional and/or local ice processes	O	N	LT	NL	HS	LAA	SI	I	D
Changes in regional and/or local surface water quality	C, O	N	ST in C, LT in O	NL	HS	LAA	SI	I	D

KEY

See Table 6.4-6 for detailed definitions

Project Phase
C: Construction
O: Operation

Direction:
P: Positive
A: Adverse
N: Neutral

Duration:
ST: Short-term
MT: Medium-term
LT: Long-term

Magnitude:
NL: Negligible or Low
M: Moderate
H: High

Timing
NS: No sensitivity
MS: Moderate sensitivity
HS: High sensitivity

Geographic Extent:
PDA: Project development area
LAA: local assessment area
RAA: regional assessment area

N/A: Not applicable

Frequency:
IF: Infrequent
SI: Sporadic/Intermittent
RC: Regular/Continuous

Reversibility:
RS: Reversible (short-term)
RL: Reversible (long-term)
I: Irreversible

Ecological Context:
U: Undisturbed
D: Disturbed

6.4.9 Potential Effects to Federal Lands

There are no potential groundwater effects on federal lands in the region. The changes to surface water resources due to the construction and operation of the Project are expected to help alleviate flooding and inundation of low-lying areas, which is a desired and positive outcome of the Project. This positive outcome is expected to benefit federal lands in the same manner as other non-federal lands in the area. Follow-up and monitoring for surface water resources are provided in Section 6.4.12 There are no additional follow-up and monitoring programs beyond those identified that are required specifically for federal lands.

6.4.10 Prediction Confidence

There is no determination of significance on the groundwater and surface water VC; however, the prediction confidence is discussed below for each change in general terms.

6.4.10.1 Groundwater

There is always uncertainty in the extent of effects of groundwater due to high natural variability of physical properties of aquifers. Sensitivity analysis was used when modelling the expected extent of changes in piezometric head to ensure the effects were not understated. The actual extent of measurable effects will likely be less than presented. There is a high degree of confidence that the effects on domestic and livestock wells and wetlands (if there are any effects) can be mitigated by the proposed Groundwater Management Plan.

6.4.10.2 Surface Water

The effect of the Project on regional flows and levels was modelled with a high degree of confidence because as there are over 100 years of inflow data to ensure a large range of flows were assessed. LiDAR was used to estimate watersheds and watershed changes due to the project which also provides a high degree of confidence.

The Buffalo Creek system is very complex. Surface water runoff in a wetland does not flow uniformly; therefore, effects cannot be predicted using typical approaches of measurement of drainage area and flow analysis, as was done with the Birch Creek and Watchorn Creek drainage areas to examine the effects of the LMOC. In addition, Big Buffalo Lake may be supplied by groundwater upwelling from the carbonate aquifer, thereby supplying Buffalo Creek with additional water, which is difficult to measure and quantify. It will be difficult to quantify effects to flows in the Buffalo Creek system before construction is complete, although the construction and operation of the LSMOC will likely cause a reduction in flows.

The prediction on changes in fluvial geomorphology and shoreline geomorphology, sediment transport, debris and water quality are dependent upon understanding of changes in flows. Confidence in the change in flows and levels is high and, therefore, the confidence in direction of the effects on fluvial geomorphology and shoreline geomorphology, sediment transport, debris and water quality is high. The

remaining residual effects characterizations, such as magnitude, duration and frequency are discussed qualitatively with moderate prediction confidence.

6.4.11 Follow-Up and Monitoring

6.4.11.1 Groundwater

Follow-up and monitoring for groundwater will include:

- A Groundwater Management Plan (GWMP) will be developed incorporating;
  - the analyses of effects of dewatering, and then communication to the local well users that may be affected. Developing the mitigation plans will involve working with affected well users.
  - additional observation wells will be installed prior to construction dewatering to monitor the effects in the area during dewatering of each channel during construction.
  - mitigation plans will be modified if/as required during the dewatering as specific information is received from observation wells and local well users.

More details on the follow-up and monitoring programs for Groundwater are presented in Chapter 12.

6.4.11.2 Surface Water

Follow-up and monitoring for surface water resources will include the following:

- The operation of the LMOC and LSMOC are dependent upon the existing level monitoring network on Lake Manitoba and Lake St. Martin, as well as the existing flow monitoring on the Fairford and Dauphin River.
- A Surface Water Management Plan will be developed as part of the engineering design. For the LMOC, the locations of discharge and the monitoring will be developed in consultation with the Rural Municipality of Grahamdale and local residents. Drainage improvements will be developed and required to mitigate effects. For the LSMOC, the drainage along LSMOC will be maintained to reduce the potential effects of water backing up in the wetlands upstream (south and east) of the LSMOC.
- the LMOC and LSMOC (along with the Fairford Water Control Structure) will be operated in accordance with the operating guidelines developed for the Project, which includes considerations for maintaining flow levels, and ice management.
- Navigational signage will indicate potential areas of thin ice at LMOC and LSMOC inlet and outlet areas, in accordance with Transport Canada requirements.
- The SWMP will outline the methods and approach to document surface water quality in the Project area during construction, operation and maintenance activities, including comparison of collected samples to recommended guidelines.
- As part of the SWMP, Manitoba Infrastructure is developing an Aquatic Effects Monitoring Plan (AEMP) that will include a water quality monitoring and follow up component. The AEMP being

developed for the Project area waterways will include the continued collection of surface water samples from regional and local waterways and analyses of a suite of parameters that will provide information on surface water quality in the Project area during Project construction, operation and maintenance activities.

More information on the follow-up and monitoring programs for surface water are presented in Chapter 12.

6.4.12 Conclusions for Groundwater and Surface Water

6.4.12.1 Changes in Local Groundwater Flows, Levels and Quality

The regional flows from the uplands to the major lakes in the area will not be affected by the Project. The local groundwater piezometric head and flows will be affected during construction dewatering. This dewatering may affect pressure in domestic or livestock wells within 3 km to 5 km of the LMOC. The effect is mitigable by a Groundwater Management Plan that will further study effects, consult with local landowners and develop specific mitigation plans for each well user.

The surficial overburden is generally composed of till and organic soils. The distance that changes in water level are transferred through the groundwater are limited. Changes in shallow groundwater around the channel excavations will be small (less than 1m), and the effects will transfer only 10 m to 200 m, at most. Around Lake St. Martin, the Fairford River and Dauphin River, water levels will decrease during high dewatering conditions due to the Project.

6.4.12.2 Changes in Local Groundwater/Surface Water interactions

The location of the proposed LMOC (Route D) was selected to reduce the risk of GUDI as this concern was regularly raised by First Nation Communities during the engagement sessions. This area is under high artesian pressure (the carbonate aquifer is under pressure at higher head than ground surface, lakes levels and water level in wetlands), meaning that the water will flow from the aquifer to the surface if there is a pathway. Currently, there is a thick till aquiclude (i.e., does not transmit water) protecting the underlying carbonate aquifer. If the till is breached during construction, then the surface water will not flow into the aquifer. This physical location of the Project, although creating a challenge for construction, does not create the same GUDI concerns as other route alternatives would have done.

It is unlikely that wetlands adjacent to the LMOC will be affected during construction dewatering; however, if this occurs, the effect can be mitigated by directing the depressurization groundwater to the wetlands.

Natural surface and shallow subsurface drainage flow may be affected along the approximately 24 km length of the LSMOC. Based on examination of the effects of the EOC, effects to drainage are not expected to occur beyond 500 m of the channel. Unmitigated, this effect would be expected to affect drainage over an area of up to approximately 1,250 ha on either side of the channel.

6.4.12.3 Changes in Regional Flows and Water Levels

The operation of the LMOC and LSMOC will increase the outflows from Lake Manitoba and Lake St. Martin during flood conditions. This increased outflow capacity will allow the lake levels to be maintained at lower levels, thus decreasing flood risks around the lakes. Less flow will also pass through the Fairford River and Dauphin River during flood conditions. This decreased flow will reduce flooding along these rivers and in Lake Pineimuta. No discernable effect is expected on Lake Winnipeg or further downstream. The LMOC and LSMOC will be operated such that, during low flow conditions, lake levels and river flows will be maintained and not decreased.

6.4.12.4 Changes in Regional and/or Local Fluvial Geomorphology and Shoreline Geomorphology

Minor, localized changes may occur in fluvial or shoreline geomorphology, and sediment and debris transport, but the changes in flows and lake levels that will occur in the regional and local waterways are within the range of high and low flows that have previously occurred in the Project area, and the magnitude of these potential effects were considered to be negligible to low.

6.4.12.5 Changes in Local Drainage Areas and Local Drainage Patterns

Local drainage areas and drainage patterns will be unavoidably altered in the areas where the LMOC and LSMOC will be located, but considerations for drainage in detailed design and application of mitigation measures will limit the magnitude and extent of these changes.

6.4.12.6 Changes in Regional and/or Local Sediment and Debris Transport

Temporary increases in suspended sediments may occur in local waterways due to construction activities, or at the channel inlet and outlet areas during initial periods when WCS gates are open.

6.4.12.7 Changes in Regional and/or Local Ice Processes

Most of the changes to flows and lake levels due to operation of the Project will occur during peak flow periods in the open-water season after ice-out, and operation of the FRWCS, LMOC and LSMOC will be managed in accordance with the applicable operating guidelines. As such, the magnitude of the potential change to ice processes in regional waterways is predicted to be low to negligible. In the Birch Creek, Watchorn Creek and Buffalo Creek systems, it is expected that these areas would freeze to the bottom in most Manitoba winters, with or without the Project. Therefore, the magnitude of the potential change to ice processes in the surface water areas that will be affected by the LMOC and LSMOC is predicted to be negligible.

6.4.12.8 Changes in Regional and/or Local Surface Water Quality

There are no adverse changes found to overall surface water quality in the regional or local area waterways because the composition and volume of water being transported from Lake Manitoba to

Sturgeon Bay is not altered by the Project construction or operation. That is, all flows from the Lake Manitoba basin will enter Sturgeon Bay, with or without the Project.

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6A.1 ATMOSPHERIC ENVIRONMENT – AIR QUALITY TABLES

6A.1.1 Introduction

This appendix provides all the existing ambient air quality tables which were discussed in Review of Historical Ambient Air Quality Data in Section 6.2.2.2.

Table 6.2A-1 1-Hour NO_2 Concentrations (µg/m^3)

Monitoring Station	1-hour Statistical Descriptor (2016)							
	Maximum	**99.9th %ile**	**99th %ile**	**90th %ile**	**75th %ile**	**60th %ile**	**50th %ile**	**Mean**
Brandon	76.2	52.2	33.4	15.0	9.78	7.15	6.02	7.72
Monitoring Station	**1-hour Statistical Descriptor (2017)**							
	Maximum	**99.9th %ile**	**99th %ile**	**90th %ile**	**75th %ile**	**60th %ile**	**50th %ile**	**Mean**
Brandon	49.5	43.2	18.1	3.20	0.000	0.000	0.000	1.05
Monitoring Station	**1-hour Statistical Descriptor (2018)**							
	Maximum	**99.9th %ile**	**99th %ile**	**90th %ile**	**75th %ile**	**60th %ile**	**50th %ile**	**Mean**
Brandon	32.5	26.2	17.8	5.08	1.50	0.000		1.53
Monitoring Station	**1-hour Statistical Descriptor (2016-2018)**							
	Maximum	**99.9th %ile**	**99th %ile**	**90th %ile**	**75th %ile**	**60th %ile**	**50th %ile**	**Mean**
Brandon	76.2	52.2	33.4	15.0	9.78	7.15	6.02	7.72

NOTES:

- Values are provided to three significant figures
- 1-hour NO_2 MAAQC is 400 µg/m^3
- Hourly raw ambient data are downloaded from Manitoba Air Quality Website (Manitoba Conservation, 2019)
- Hourly raw ambient data less than zero were assumed to be Zero
- Brandon data recovery rate: 2016 (94.1%), 2017 (67.2%) and 2018 (99.6%)

SOURCE: MSD 2019

Table 6.2A-2 24-Hour NO_2 Concentrations (µg/m^3)

Monitoring Station	24-hour Statistical Descriptor (2016)							
	Maximum	**99.9th %ile**	**99th %ile**	**90th %ile**	**75th %ile**	**60th %ile**	**50th %ile**	**Mean**
Brandon	33.9	31.8	21.8	13.2	9.50	7.76	6.88	7.74
Monitoring Station	**24-hour Statistical Descriptor (2017)**							
	Maximum	**99.9th %ile**	**99th %ile**	**90th %ile**	**75th %ile**	**60th %ile**	**50th %ile**	**Mean**
Brandon	18.0	17.9	13.5	2.65	1.26	0.448	0.133	1.06
Monitoring Station	**24-hour Statistical Descriptor (2018)**							
	Maximum	**99.9th %ile**	**99th %ile**	**90th %ile**	**75th %ile**	**60th %ile**	**50th %ile**	**Mean**
Brandon	16.2	15.2	11.1	4.21	2.13	1.07	0.596	1.52
Monitoring Station	**24-hour Statistical Descriptor (2016-2018)**							
	Maximum	**99.9th %ile**	**99th %ile**	**90th %ile**	**75th %ile**	**60th %ile**	**50th %ile**	**Mean**
Brandon	33.9	31.8	21.8	13.2	9.50	7.76	6.88	7.74

NOTES:

- Values are provided to three significant figures
- 24-hour average NO_2 MAAQC is 200 µg/m^3
- Hourly raw ambient data are downloaded from Manitoba Air Quality Website (Manitoba Conservation, 2019)
- Hourly raw ambient data less than zero were assumed to be zero
- Brandon data recovery rate: 2016 (94.1%), 2017 (67.2%) and 2018 (99.6%)

SOURCE: MSD 2019

Table 6.2A-3 Annual NO_2 Concentrations (µg/m^3)

Monitoring Station	Annual NO_2 Concentration (µg/m^3)						
	2016	**2017**	**2018**	**Max**	**Min**	**Mean**	**Max/Min**
Brandon	**7.72**	**1.05**	**1.53**	**7.72**	**1.05**	**3.43**	**7.35**

NOTES:

- Values are provided to three significant figures
- Maximum acceptable and desirable annual Average NO_2 MAAQC are 100 µg/m^3 and 60 µg/m^3, respectively.
- Hourly raw ambient data are downloaded from Manitoba Air Quality Website (Manitoba Conservation, 2019)
- Hourly raw ambient data less than zero were assumed to be zero
- Brandon data recovery rate: 2016 (94.1%), 2017 (67.2%) and 2018 (99.6%)

SOURCE: MSD 2019

Table 6.2A-4 1-Hour SO_2 Concentrations (µg/m³)

Monitoring Station	1-hour Statistical Descriptor (2016)							
	Maximum	**99.9th %ile**	**99th %ile**	**90th %ile**	**75th %ile**	**60th %ile**	**50th %ile**	**Mean**
Flin Flon	23.6	14.9	4.98	2.62	1.05	0.3	0.000	0.734
Monitoring Station	**1-hour Statistical Descriptor (2017)**							
	Maximum	**99.9th %ile**	**99th %ile**	**90th %ile**	**75th %ile**	**60th %ile**	**50th %ile**	**Mean**
Flin Flon	25.9	11.4	6.02	3.93	3.67	3.41	0.524	1.81
Monitoring Station	**1-hour Statistical Descriptor (2018)**							
	Maximum	**99.9th %ile**	**99th %ile**	**90th %ile**	**75th %ile**	**60th %ile**	**50th %ile**	**Mean**
Flin Flon	21.7	10.2	5.24	4.45	3.93	1.83	1.57	2.33
Monitoring Station	**1-hour Statistical Descriptor (2016-2018)**							
	Maximum	**99.9th %ile**	**99th %ile**	**90th %ile**	**75th %ile**	**60th %ile**	**50th %ile**	**Mean**
Flin Flon	25.9	14.9	6.02	4.45	3.93	3.41	1.57	2.33

NOTES:

- Values are provided to three significant figures
- Maximum acceptable and desirable 1-hour SO_2 MAAQC are 900 µg/m³ and 450 µg/m³, respectively.
- Hourly raw ambient data are downloaded from Manitoba Air Quality Website (Manitoba Conservation, 2019)
- Hourly raw ambient data less than zero were assumed to be zero
- Flin Flon data recovery rate: 2016 (68.1%), 2017 (70.2%) and 2018 (90.4%)

SOURCE: MSD 2019

Table 6.2A-5 24-Hour SO_2 Concentrations (µg/m^3)

Monitoring Station	24-hour Statistical Descriptor (2016)							
	Maximum	**99.9th %ile**	**99th %ile**	**90th %ile**	**75th %ile**	**60th %ile**	**50th %ile**	**Mean**
Flin Flon	5.64	5.60	4.98	2.43	0.87	0.29	0.14	0.73
Monitoring Station	**24-hour Statistical Descriptor (2017)**							
	Maximum	**99.9th %ile**	**99th %ile**	**90th %ile**	**75th %ile**	**60th %ile**	**50th %ile**	**Mean**
Flin Flon	5.51	5.50	5.09	4.02	3.58	3.43	0.345	1.80
Monitoring Station	**24-hour Statistical Descriptor (2018)**							
	Maximum	**99.9th %ile**	**99th %ile**	**90th %ile**	**75th %ile**	**60th %ile**	**50th %ile**	**Mean**
Flin Flon	6.32	6.04	5.04	4.37	3.98	1.78	1.57	2.32
Thompson	132	130	87.2	36.8	28.4	18.6	17.4	21.4
Monitoring Station	**24-hour Statistical Descriptor (2016-2018)**							
	Maximum	**99.9th %ile**	**99th %ile**	**90th %ile**	**75th %ile**	**60th %ile**	**50th %ile**	**Mean**
Flin Flon	6.32	6.04	5.09	4.37	3.98	3.43	1.57	2.32

NOTES:

- Values are provided to three significant figures
- Maximum acceptable and desirable 24-hour average SO_2 MAAQC are 300 µg/m^3 and 150 µg/m^3, respectively.
- Raw ambient data are downloaded from Manitoba Air Quality Website (Manitoba Conservation, 2019)
- Raw ambient data less than zero were assumed to be Zero
- Flin Flon data recovery rate: 2016 (68.1%), 2017 (70.2%) and 2018 (90.4%)

SOURCE: MSD 2019

Table 6.2A-6 Annual SO_2 Concentrations (µg/m^3)

Monitoring Station	Maximum Annual SO_2 Concentration (µg/m^3)						
	2016	**2017**	**2018**	**Max**	**Min**	**Mean**	**Max/Min**
Flin Flon	0.734	1.81	2.33	2.33	0.734	1.62	3.17

NOTES:

- Values are provided to three significant figures
- Maximum acceptable and desirable annual average SO_2 MAAQC are 60 µg/m^3 and 30 µg/m^3, respectively.
- Raw ambient data are downloaded from Manitoba Air Quality Website (Manitoba Conservation, 2019)
- Raw ambient data less than zero were assumed to be Zero
- Flin Flon data recovery rate: 2016 (68.1%), 2017 (70.2%) and 2018 (90.4%)

SOURCE: MSD 2019

Table 6.2A-7 1-Hour $PM_{2.5}$ Concentrations (µg/m^3)

Monitoring Station	1-hour Statistical Descriptor (2016)							
	Maximum	**99.9th %ile**	**99th %ile**	**90th %ile**	**75th %ile**	**60th %ile**	**50th %ile**	**Mean**
Flin Flon	246	136	26.6	7.70	5.20	4.00	3.40	4.83
Thompson	162	77.6	32.7	7.60	4.30	3.00	2.40	3.96
Monitoring Station	**1-hour Statistical Descriptor (2017)**							
	Maximum	**99.9th %ile**	**99th %ile**	**90th %ile**	**75th %ile**	**60th %ile**	**50th %ile**	**Mean**
Flin Flon	725	492	85.7	9.00	5.00	3.60	2.90	6.70
Thompson	313	131	35.3	10.3	4.90	3.10	2.50	4.99
Monitoring Station	**1-hour Statistical Descriptor (2018)**							
	Maximum	**99.9th %ile**	**99th %ile**	**90th %ile**	**75th %ile**	**60th %ile**	**50th %ile**	**Mean**
Flin Flon	204	101	46.7	8.70	3.40	0.30	0.00	3.43
Thompson	171	123	48.5	13.5	6.20	3.40	2.70	6.12
Monitoring Station	**1-hour Statistical Descriptor (2016-2018)**							
	Maximum	**99.9th %ile**	**99th %ile**	**90th %ile**	**75th %ile**	**60th %ile**	**50th %ile**	**Mean**
Flin Flon	725	492	85.7	9.00	5.20	4.00	3.40	6.70
Thompson	313	131	48.5	13.5	6.20	3.40	2.70	6.12

NOTES:

- Values are provided to three significant figures
- There is no 1-hour $PM_{2.5}$ MAAQC/CAAQS.
- Hourly raw ambient data are downloaded from Manitoba Air Quality Website (Manitoba Conservation, 2019)
- Hourly raw ambient data less than zero were assumed to be zero
- Flin Flon data recovery rate: 2016 (54.6%), 2017 (80.6%) and 2018 (99.2%)
- Thompson data recovery rate: 2016 (88.6%), 2017 (98.9%) and 2018 (97.7%)
- Hourly ambient data associated with wildfire are not removed for this assessment

SOURCE: MSD 2019

Table 6.2A-8 24-Hour $PM_{2.5}$ Concentrations (µg/m^3)

Monitoring Station	24-hour Statistical Descriptor (2016)							
	Maximum	**99.9th %ile**	**99th %ile**	**90th %ile**	**75th %ile**	**60th %ile**	**50th %ile**	**Mean**
Flin Flon	**77.9**	67.2	19.3	6.62	5.08	4.45	3.99	4.83
Thompson	**30.5**	26.9	18.0	7.31	4.96	3.61	3.12	3.96
Monitoring Station	**24-hour Statistical Descriptor (2017)**							
	Maximum	**99.9th %ile**	**99th %ile**	**90th %ile**	**75th %ile**	**60th %ile**	**50th %ile**	**Mean**
Flin Flon	**272**	220	84.1	8.30	4.85	3.67	3.28	6.66
Thompson	**74.1**	65.7	24.5	8.89	5.09	3.76	3.38	4.86
Monitoring Station	**24-hour Statistical Descriptor (2018)**							
	Maximum	**99.9th %ile**	**99th %ile**	**90th %ile**	**75th %ile**	**60th %ile**	**50th %ile**	**Mean**
Flin Flon	**54.7**	54.1	31.2	7.62	4.76	2.72	1.77	3.45
Thompson	**121**	120	30.1	13.5	6.24	3.80	3.08	6.02
Monitoring Station	**24-hour Statistical Descriptor (2016-2018)**							
	Maximum	**99.9th %ile**	**99th %ile**	**90th %ile**	**75th %ile**	**60th %ile**	**50th %ile**	**Mean**
Flin Flon	**272**	220	84.1	8.30	5.08	4.45	3.99	6.66
Thompson	**121**	120	20.1	13.5	6.24	3.80	3.38	6.02

NOTES:

- Values are provided to three significant figures
- 24-hour average $PM_{2.5}$ MAAQC is 30 µg/m^3
- Concentrations that are greater than a criterion or target are shown in **underlined bold** text
- Hourly raw ambient data are downloaded from Manitoba Air Quality Website (Manitoba Conservation, 2019)
- Hourly raw ambient data less than zero were assumed to be zero
- Flin Flon data recovery rate: 2016 (54.6%), 2017 (80.6%) and 2018 (99.2%)
- Thompson data recovery rate: 2016 (88.6%), 2017 (98.9%) and 2018 (97.7%)
- Hourly ambient data associated with wildfire are not removed for this assessment

SOURCE: MSD 2019

Table 6.2A-9 Annual 98th percentile of 24-hour Average $PM_{2.5}$ Concentrations ($\mu g/m^3$)

Monitoring Station	Annual 98th percentile of 24-hour average ($\mu g/m^3$)			
	2016	2017	2018	3-year Average
Flin Flon	15.4	52.0	16.4	**27.9**
Thompson	15.2	20.4	21.8	19.1

NOTES:

- Values are provided to three significant figures
- Annual 98th percentile of 24-hour average $PM_{2.5}$ CAAQS is 27 $\mu g/m^3$
- Concentrations that are greater than a criterion or target are shown in **underlined bold** text
- Hourly raw ambient data are downloaded from Manitoba Air Quality Website (Manitoba Conservation, 2019)
- Hourly raw ambient data less than zero were assumed to be zero
- Flin Flon data recovery rate: 2016 (54.6%), 2017 (80.6%) and 2018 (99.2%)
- Thompson data recovery rate: 2016 (88.6%), 2017 (98.9%) and 2018 (97.7%)
- Hourly ambient data associated with wildfire are not removed for this assessment

SOURCE: MSD 2019

Table 6.2A-10 Annual $PM_{2.5}$ Concentrations ($\mu g/m^3$)

Monitoring Station	Maximum Annual $PM_{2.5}$ Concentration ($\mu g/m^3$)						
	2016	2017	2018	Max	Min	Mean	Max/Min
Flin Flon	4.83	6.70	3.43	6.70	3.43	4.99	1.95
Thompson	3.96	5.99	6.12	6.12	3.96	5.36	1.55

NOTES:

- Values are provided to three significant figures
- Annual average $PM_{2.5}$ CAAQS is 8.8 $\mu g/m^3$
- Concentrations that are greater than a criterion or target are shown in **underlined bold** text
- Hourly raw ambient data are downloaded from Manitoba Air Quality Website (Manitoba Conservation, 2019)
- Hourly raw ambient data less than zero were assumed to be zero
- Flin Flon data recovery rate: 2016 (54.6%), 2017 (80.6%) and 2018 (99.4%)
- Thompson data recovery rate: 2016 (88.6%), 2017 (98.9%) and 2018 (97.7%)
- Hourly ambient data associated with wildfire are not removed for this assessment

SOURCE: MSD 2019

Table 6.2A-11 1-Hour O_3 Concentrations (µg/m^3)

Monitoring Station	1-hour Statistical Descriptor (2016)							
	Maximum	**99.9th %ile**	**99th %ile**	**90th %ile**	**75th %ile**	**60th %ile**	**50th %ile**	**Mean**
Flin Flon	93.0	90.3	81.8	67.9	54.2	45.3	42.0	43.5
Thompson	113	107	91.8	78.9	68.5	61.0	56.1	54.2
Monitoring Station	**1-hour Statistical Descriptor (2017)**							
	Maximum	**99.9th %ile**	**99th %ile**	**90th %ile**	**75th %ile**	**60th %ile**	**50th %ile**	**Mean**
Flin Flon	116	110	93.6	72.2	62.8	56.1	52.2	51.4
Thompson	116	104	89.1	76.1	69.3	63.4	59.7	57.1
Monitoring Station	**1-hour Statistical Descriptor (2018)**							
	Maximum	**99.9th %ile**	**99th %ile**	**90th %ile**	**75th %ile**	**60th %ile**	**50th %ile**	**Mean**
Flin Flon	116	107	96.6	75.6	66.1	58.7	54.0	53.3
Thompson	123	116	102	81.6	70.8	63.6	58.3	56.5
Monitoring Station	**1-hour Statistical Descriptor (2016-2018)**							
	Maximum	**99.9th %ile**	**99th %ile**	**90th %ile**	**75th %ile**	**60th %ile**	**50th %ile**	**Mean**
Flin Flon	116	110	96.6	75.6	66.1	58.7	54.0	53.3
Thompson	123	116	102.2	81.6	70.8	63.6	59.7	57.1

NOTES:

- Values are provided to three significant figures
- There is no 1-hour O_3 MAAQC/CAAQS.
- Hourly raw ambient data are downloaded from Manitoba Air Quality Website (Manitoba Conservation, 2019)
- Hourly raw ambient data less than zero were assumed to be zero
- Flin Flon data recovery rate: 2016 (81.9%), 2017 (78.1%) and 2018 (99.8%)
- Thompson data recovery rate: 2016 (77.5%), 2017 (88.1%) and 2018 (97.3%)

SOURCE: MSD 2019

Table 6.2A-12 4th Highest Daily Maximum 8-hour O_3 Concentrations (µg/m^3)

Monitoring Station	4th Highest Daily Maximum 8-hour O_3 (µg/m^3)			
	2016	2017	2018	3-year Average
Flin Flon	86.8	103	101	97.0
Thompson	97.7	94.8	113	102

NOTES:

- Values are provided to three significant figures
- 4th Highest Daily Maximum 8-hour O3 CAAQS is 122 µg/m^3
- Hourly raw ambient data are downloaded from Manitoba Air Quality Website (Manitoba Conservation, 2019)
- Hourly raw ambient data less than zero were assumed to be zero
- Flin Flon data recovery rate: 2016 (81.9%), 2017 (78.1%) and 2018 (99.8%)
- Thompson data recovery rate: 2016 (77.5%), 2017 (88.1%) and 2018 (97.3%)

SOURCE: MSD 2019

Table 6.2A-13 24-Hour O_3 Concentrations (µg/m^3)

Monitoring Station	24-hour Statistical Descriptor (2016)							
	Maximum	**99.9th %ile**	**99th %ile**	**90th %ile**	**75th %ile**	**60th %ile**	**50th %ile**	**Mean**
Flin Flon	78.7	78.5	76.2	66.7	53.3	44.2	41.0	43.6
Thompson	91.2	89.9	84.8	76.0	66.0	59.8	54.4	54.1
Monitoring Station	**24-hour Statistical Descriptor (2017)**							
	Maximum	**99.9th %ile**	**99th %ile**	**90th %ile**	**75th %ile**	**60th %ile**	**50th %ile**	**Mean**
Flin Flon	97.1	95.2	87.0	69.1	61.3	55.7	51.6	51.6
Thompson	90.6	89.3	84.8	72.8	66.7	62.4	58.1	57.2
Monitoring Station	**24-hour Statistical Descriptor (2018)**							
	Maximum	**99.9th %ile**	**99th %ile**	**90th %ile**	**75th %ile**	**60th %ile**	**50th %ile**	**Mean**
Flin Flon	100	98.1	89.9	72.7	64.8	57.8	53.6	53.3
Thompson	107	106	100.1	78.1	69.1	62.6	56.0	56.5
Monitoring Station	**24-hour Statistical Descriptor (2016-2018)**							
	Maximum	**99.9th %ile**	**99th %ile**	**90th %ile**	**75th %ile**	**60th %ile**	**50th %ile**	**Mean**
Flin Flon	100	98	89.9	72.7	64.8	57.8	53.6	53.3
Thompson	107	106	100.1	78.1	69.1	62.6	58.1	57.2

NOTES:

- Values are provided to three significant figures
- There is no 24-hour average O_3 MAAQC/CAAQS.
- Hourly raw ambient data are downloaded from Manitoba Air Quality Website (Manitoba Conservation, 2019)
- Hourly raw ambient data less than zero were assumed to be zero
- Flin Flon data recovery rate: 2016 (81.9%), 2017 (78.1%) and 2018 (99.8%)
- Thompson data recovery rate: 2016 (77.5%), 2017 (88.1%) and 2018 (97.3%)

SOURCE: MSD 2019

Table 6.2A-14 Annual O_3 Concentrations (µg/m^3)

Monitoring Station	Maximum 1-hour O_3 Concentration (µg/m^3)						
	2016	2017	2018	Max	Min	Mean	Max/Min
Flin Flon	43.5	51.4	53.3	53.3	43.5	49.4	1.23
Thompson	54.2	57.1	56.5	57.1	54.2	56.0	1.05

NOTES:

- Values are provided to three significant figures
- There is no annual average O_3 MAAQC/CAAQS.
- Hourly raw ambient data are downloaded from Manitoba Air Quality Website (Manitoba Conservation, 2019)
- Hourly raw ambient data less than zero were assumed to be zero
- Flin Flon data recovery rate: 2016 (81.9%), 2017 (78.1%) and 2018 (99.8%)
- Thompson data recovery rate: 2016 (77.5%), 2017 (88.1%) and 2018 (97.3%)

SOURCE: MSD 2019

Table 6.2A-15 1-Hour CO Concentrations (µg/m^3)

Monitoring Station	1-hour Statistical Descriptor (2016)							
	Maximum	**99.9th %ile**	**99th %ile**	**90th %ile**	**75th %ile**	**60th %ile**	**50th %ile**	**Mean**
Winnipeg Ellen Street	3,790	1,863	1,185	696	465	308	249	324
Monitoring Station	**1-hour Statistical Descriptor (2017)**							
	Maximum	**99.9th %ile**	**99th %ile**	**90th %ile**	**75th %ile**	**60th %ile**	**50th %ile**	**Mean**
Winnipeg Ellen Street	2,631	1,785	592	133	24	0.00	0.00	43.1
Monitoring Station	**1-hour Statistical Descriptor (2018)**							
	Maximum	**99.9th %ile**	**99th %ile**	**90th %ile**	**75th %ile**	**60th %ile**	**50th %ile**	**Mean**
Winnipeg Ellen Street	2,753	888	265	34	0.00	0.00	0.00	14.6
Monitoring Station	**1-hour Statistical Descriptor (2016-2018)**							
	Maximum	**99.9th %ile**	**99th %ile**	**90th %ile**	**75th %ile**	**60th %ile**	**50th %ile**	**Mean**
Winnipeg Ellen Street	3,790	1,863	1,185	696	465	308	249	324

NOTES:

- Values are provided to three significant figures
- 1-hour CO MAAQC is 35,000 µg/m^3.
- Hourly raw ambient data are downloaded from Manitoba Air Quality Website (Manitoba Conservation, 2019)
- Hourly raw ambient data less than zero were assumed to be zero
- Winnipeg Ellen Street data recovery rate: 2016 (98.8%), 2017 (61.7%) and 2018 (99.4%)

SOURCE: MSD 2019

Table 6.2A-16 8-Hour CO Concentrations (µg/m^3)

Monitoring Station	8-hour Statistical Descriptor (2016)							
	Maximum	**99.9th %ile**	**99th %ile**	**90th %ile**	**75th %ile**	**60th %ile**	**50th %ile**	**Mean**
Winnipeg Ellen Street	2,188	1,277	1,041	662	447	313	264	324
Monitoring Station	**8-hour Statistical Descriptor (2017)**							
	Maximum	**99.9th %ile**	**99th %ile**	**90th %ile**	**75th %ile**	**60th %ile**	**50th %ile**	**Mean**
Winnipeg Ellen Street	903	768	459	134	33.7	18.5	10.9	43.4
Monitoring Station	**8-hour Statistical Descriptor (2018)**							
	Maximum	**99.9th %ile**	**99th %ile**	**90th %ile**	**75th %ile**	**60th %ile**	**50th %ile**	**Mean**
Winnipeg Ellen Street	683	344	132	40	16.6	6.41	2.29	14.7
Monitoring Station	**8-hour Statistical Descriptor (2016-2018)**							
	Maximum	**99.9th %ile**	**99th %ile**	**90th %ile**	**75th %ile**	**60th %ile**	**50th %ile**	**Mean**
Winnipeg Ellen Street	2,188	1277	1,041	662	447	313	264	324

NOTES:

- Values are provided to three significant figures
- 8-hour CO MAAQC is 15,000 µg/m^3.
- Hourly raw ambient data are downloaded from Manitoba Air Quality Website (Manitoba Conservation, 2019)
- Hourly raw ambient data less than zero were assumed to be zero
- Winnipeg Ellen Street data recovery rate: 2016 (98.8%), 2017 (61.7%) and 2018 (99.4%)

SOURCE: MSD 2019

6A.2 SOIL AND TERRAIN TECHNICAL INFORMATION TABLES

This appendix section contains information on classifications and ratings used in the soil and terrain assessment.

6A.2.1 Topography

Slope gradient classes, slope gradient ranges and class descriptions are provided in Table 6.3A-1.

Table 6.3A-1 Slope Gradient Classes and Descriptions

Class	Slope	Description
1	0-0.5%	Level
2	0.5-2%	Nearly level
3	2-5%	Very gently sloping
4	5-9%	Gently sloping
5	9-15%	Moderately sloping
6	15-30%	Strongly sloping
7	30-45%	Very strongly sloping
8	45-70%	Extremely sloping

6A.2.2 Drainage

Drainage classes and definitions are provided in Table 6.3A-2.

Table 6.3A-2 Drainage Classes and Definitions

Drainage Class	Definition
Very Rapid (VR)	Water is removed from the soil very rapidly in relation to supply. Soils have very low available water storage capacity (<2.5 cm) within the control section.
Rapid (R)	Water is removed from the soil rapidly in relation to supply. Soils have low available water storage capacity (2.5-4 cm) within the control section.
Well (W)	Water is removed from the soil readily but not rapidly. Soils have intermediate available water storage capacity (4-5 cm) within the control section.
Moderately Well (MW)	Water is removed from the soil somewhat slowly in relation to supply. Soils have intermediate to high available water storage capacity (5-6 cm) within the control section.
Imperfect (I)	Water is removed from the soil sufficiently slowly in relation to supply. Soils have a wide range in available water storage capacity.
Poor (P)	Water is removed so slowly in relation to supply that the soil remains wet for a comparatively large part of the time the soi is not frozen. Soils have a wide range in available water storage capacity and excess water is evident in the soil.

Table 6.3A-2 Drainage Classes and Definitions

Drainage Class	Definition
Very Poor (VP)	Water is removed so slowly that the water table remains at or on the surface for the greater part of the time the soil is not frozen. Soils have a wide range in available water storage capacity and excess water is present in the soil.
NOTES: Modified from CanSIS 2019 (http://sis.agr.gc.ca/cansis/)	

6A.2.3 Texture

Texture groups, classes and class codes are provided in Table 6.3A-3.

Table 6.3A-3 Soil Texture Groups and Classes

Texture Group	Texture Class	Texture Class Code
Very Coarse	Very Coarse Sand	VCS
	Coarse Sand	CS
	Sand	S
	Gravelly Sand	GS
Coarse	Fine Sand	FS
	Loamy Coarse Sand	LCS
	Loamy Sand	LS
	Loamy Fine Sand	LFS
	Gravelly Loamy Sand	GLS
Moderately Coarse	Very Fine Sand	VFS
	Loamy Very Fine Sand	LVFS
	Coarse Sandy Loam	CSL
	Sandy Loam	SL
	Fine Sandy Loam	FSL
	Gravelly Sandy Loam	GSL
	Gravelly Fine Sandy Loam	GFSL
Medium	Very Fine Sandy Loam	VFSL
	Loam	L
	Silt Loam	SiL
	Silt	Si
	Gravelly Loam	GL
	Gravelly Silt Loam	GSiL

Table 6.3A-3 Soil Texture Groups and Classes

Texture Group	Texture Class	Texture Class Code
Moderately Fine	Sandy Clay Loam	SCL
	Fine Sandy Clay Loam	FSCL
	Very Fine Sandy Clay Loam	VFSCL
	Clay Loam	CL
	Silty Clay Loam	SiCL
	Gravelly Sandy Clay Loam	GSCL
Fine	Sandy Clay	SC
	Silty Clay	SiC
	Clay	C
	Gravelly Silty Clay	GSiC
Very Fine	Heavy Clay	HC (>60% clay)
Coarse Skeletal	Very Gravelly Sand	VGS
	Very Gravelly Loamy Sand	VGLS
Medium Skeletal	Very Gravelly Sandy Loam	VGSL
Fine Skeletal	Very Gravelly Loam	VGL
	Very Gravelly Clay	VGC

6A.2.4 Agricultural Capability Class Ratings

An agricultural capability class rating for each soil map unit exists in SoilAID (MLI 2014) polygons. These ratings were determined according to the modified Canada Land Inventory (CLI) soil capability for agriculture rating system developed for Manitoba (Fraser et al. 2001). The CLI is a seven class system based on the degree of limitation of land for production of a specified crop.

The system rates climate, soil and landscape factors independently as each factor can control the suitability of land for dryland agricultural crop production. The CLI is intended as an interpretive classification for the productive capacity of soils for common field crops. The combination of a class and a subclass denotes the agricultural capability: the class rating provides the degree of limitation while the subclass provides the kind of limitation. The seven classes that reflect variations in agricultural capability are described in Table 6.3A-4. Subclasses are assigned within the classes to denote the type of limitation for agricultural use. For the limitations associated with the agricultural capability subclasses, see Table 6.3A-5.

Table 6.3A-4 Agricultural Capability Class Descriptions

Agricultural Capability Class	Class Description
1	Soils in this class have no significant limitations in use for crops
2	Soils in this class have moderate limitations that restrict the range of crops or require moderate conservation practices
3	Soils in this class have moderately severe limitations that restrict the range of crops or require special conservation practices
4	Soils in this class have severe limitations that restrict the range of crops or require special conservation practices or both
5	Soils in this class have very severe limitations that restrict their capability to producing perennial forage crops, and improvement practices are feasible
6	Soils in this class are capable only of producing perennial forage crops, and improvement practices are not feasible
7	Soils in this class have no capability for arable culture or permanent pasture
O	Organic soils are rated based on potential agricultural capability recognizing that most organic soils have little or no value for agriculture in their native state and their potential is only achieved through reclamation or development implemented with varying degrees of difficulty
SOURCES: CLI 1969; Podolsky 1981; Leeson et al. 1969.	

Table 6.3A-5 Agricultural Capability Subclass Limitation Descriptions

Agricultural Capability Class	Type of Limitation
C – Climate	Significant adverse climate for crop production
D – Undesirable Soil Structure and or Low Permeability	Soils difficult to till, or which absorb water very slowly or in which the depth of rooting zone is restricted by conditions other than a high water table or consolidated bedrock.
E – Erosion	Soils where damage from erosion is a limitation to agricultural use.
F – Low Fertility	Soils having low fertility that either is correctable with careful management in the use of soil fertilizers and soil amendments or is difficult to correct in a feasible way.
I – Inundation	Soils subjected to inundation causing crop damage or restricting agricultural use.
M – Moisture Limitation	Soils where crops are adversely affected by droughtiness owing to inherent soil characteristics.
N – Salinity	Soils with enough soluble salts to adversely affect crop growth or restrict the range of crops that may be grown.

Table 6.3A-5 Agricultural Capability Subclass Limitation Descriptions

Agricultural Capability Class	Type of Limitation
P – Stoniness	Soils sufficiently stony to significantly hinder tillage, planting and harvesting operations.
R – Consolidated Bedrock	Soils where the presence of bedrock near the surface restricts their agricultural use.
S – Adverse Soil Characteristics	Used in place of subclasses D, F, M and N either individually or collectively.
T – Topography	Soils where topography is a limitation.
W – Excess Water	Soils where excess water other than that brought about by inundation is a limitation to their use for agriculture.
X – Cumulative Minor Adverse Characteristics	Soils with a moderate limitation caused by the cumulative effect of two or more adverse characteristics which are singly not serious enough to affect the rating.
SOURCE: Canada Land Inventory 1969	

6A.2.5 Soil Compaction Risk

A generalized rating system for compaction risk was developed using professional judgment and review of two compaction systems that had been designed for forestry applications; specifically the Soil Compaction and Puddling Hazard Key (British Columbia Ministry of Forests 1999) and the table of Compaction and Rutting Hazard for Soils in Ontario (Archibald et al. 1997). The generalized rating system developed for compaction risk (see Table 6.3A-6) takes into consideration soil texture and drainage regime within a given polygon.

Susceptibility to soil compaction is dependent on soil physical properties, the moisture content during the disturbance and the nature of the applied force (Cannon and Landsburg 1990). Generally, in mineral soils, compactibility increases with higher clay content, higher soil moisture content and lower organic matter content (Cannon and Landsburg 1990).

Table 6.3A-6 Compaction Risk Matrix

Drainage	Textural Class					
	Very Coarse (S, LS, LFS)	Moderately Coarse (SL, FSL)	Medium (VFSL, L, SiL)	Moderately Fine (SCL, CL, SiCL, Si)	Fine/Very Fine (SC, SiC, C, HC)	Organic
Rapid	Low	Low	-	-	-	-
Well	Low	Low	Low	Moderate	Moderate	
Imperfect	Low	Low	Moderate	High	High	
Poor	Moderate	Moderate	High	High	High	
Very Poor	-					High

NOTES:

S=sand	LS = loamy sand	LFS = loamy fine sand	SL = sandy loamy
FSL = fine sandy loam	VFSL = very fine sandy loam	L = loam	SiL = silt loam
SCL = sandy clay loam	CL = clay loam	SiCL = silty clay loam	Si = silt
SC = sandy clay	SiC = silty clay	C = clay	HC = heavy clay

6A.2.6 Water Erosion Risk

Water erosion risk classes are determined using the Revised Universal Soil Loss Equation for Application in Canada (RUSLEFAC, Wall et al. 2002) using soil data provided in the publically-available SoilAID (MLI 2019) database and other derived data. The RUSLEFAC was developed to predict average soil loss by water erosion, taking into account rainfall, soil and landscape characteristics and management practices. The following factors are considered in the method:

$$A = R * K * LS * C * P$$

Where:

A = Potential, long-term average annual soil loss (tonnes ha^{-1} yr^{-1})

R = Rainfall and Runoff Factor - a measure of the total annual erosive rainfall for a specific location, and the distribution of erosive rainfall throughout the year (MJ mm ha^{-1} h^{-1})

K = Erodibility Factor - a quantitative measure of the soil's inherent susceptibility to erosion and the soil's influence on runoff amount and rate (t h MJ^{-1} mm^{-1})

LS = Topographic Factor - accounts for the slope angle and length on erosion (dimensionless)

C = Crop/Vegetation and Management Factor - used to determine the effectiveness of soil and crop management systems in terms of preventing or reducing erosion (dimensionless)

P = Support Practice Factor - accounts for the erosion control effectiveness of support practices, and supports the C factor (dimensionless)

The RUSLEFAC system has five classes of water erosion risk. Water erosion classes and categories and associated potential soil losses are presented in Table 6.3A-7.

Table 6.3A-7 Water Erosion Risk Classes

Water Erosion Class	Category	Potential Loss (t/ha/y)
1	Very Low	<6
2	Low	6–11
3	Moderate	11–22
4	High	22–33
5	Severe	> 33

6A.2.7 Wind Erosion Risk

Wind erosion risk classes were determined using the methods of Coote and Pettapiece (1989). The following algorithm is used to calculate the risk of wind erosion:

$$E = KC(V_*^2 - \gamma W^2)^{1.5}$$

Where:

E = maximum instantaneous soil movement by wind (dimensionless)

K = surface roughness and aggregation factor (dimensionless)

C = factor representing soil resistance to movement by wind (dimensionless)

V_* = drag velocity of wind at the soil surface (cm s^{-1})

Table 6.3A-8 Wind Erosion Risk Classes

Wind Erosion Class	Category	(maximum instantaneous soil movement by wind, dimensionless)
N	Negligible	<100
L	Low	100-249.9
M	Moderate	250-399.9
H	High	400-699.9
S	Severe	>700

6A.2.8 Reclamation Suitability

Reclamation suitability ratings were determined for the first (topsoil) and second lifts (upper subsoil) only of each undisturbed mineral soil map unit using Soil Quality Criteria Relative to Disturbance and Reclamation (AAFRD 1987). Classes and limitations are presented in Table 6.3A-9.

Criteria for reclamation suitability for topsoil and subsoil for the plains region (used for the LMOC LAA and southern and western portions of LSM LAA) and northern forest region (used for the LSMOC LAA and eastern and northern portions of LSM LAA) are found in Figures 6.3A-1 to 6.3A-4.

Table 6.3A-9 Reclamation Suitability Classification

Reclamation Suitability Class	Limitations
Good	None to slight soil limitations that affect use for plant growth
Fair	Moderate soil limitations that affect use but can be overcome by proper planning and good management
Poor	Severe soil limitations that make use questionable careful planning and very good management are required
Unsuitable	Chemical or physical soil properties are so severe that reclamation is not possible or economically feasible
SOURCE: AAFRD 1987	

Table 6.3A-10 Criteria for Evaluating Suitability of Topsoil in the Plains Region (AAFRD 1987)

Rating/Property	Good (G)	Fair (F)	Poor (P)	Unsuitable (U)
Reaction (pH)	6.5 to 7.5	5.5 to 6.4 & 7.6 to 8.4	4.5 to 5.4 & 8.5 to 9.0	<4.5 and >9.0
Salinity (EC) (dS/m)	<2	2 to 4	4 to 8	>8
Sodicity (SAR)	<4	4 to 8	8 to 12	>12[1]
Saturation (%)	30 to 60	20 to 30, 60 to 80	15 to 20, 80 to 120	<15 and >120
Stoniness Class	S0, S1	S2	S3, S4	S5
Texture	FSL, VFSL, L, SL, Sil	CL, SCL, SiCL	LS, SiC, C[2], S, HC[3]	
Moist Consistency	very friable, friable	loose	firm, very firm	extremely firm
Organic Carbon (%)	>2	1 to 2	<1	
$CaC0_3$ Equivalent (%)	<2	2 to 20	20 to 70	>70

[1] Materials characterized by an SAR of 12 to 20 may be rated as poor if texture is sandy loam or coarser and saturation % is less than 100.

[2] C – May be upgraded to fair or good in some arid areas.

[3] HC – May be upgraded to fair or good in some arid areas.

Table 6.3A-11 Criteria for Evaluating Suitability of Subsoil in the Plains Region (AAFRD 1987)

Rating/Property	Good (G)	Fair (F)	Poor (P)	Unsuitable (U)
Reaction (pH)	6.5 to 7.5	5.5 to 6.4 & 7.6 to 8.5	4.6 to 5.4 & 8.6 to 9.0	<4.5 and >9.0
Salinity (EC) (dS/m)	<3	3 to 5	5 to 10	>10
Sodicity (SAR)	<4	4 to 8	8 to 12	>12[1]
Saturation (%)	30 to 60	20 to 30, 60 to 80	15 to 20, 80 to 120	<15 and >120
Stone Content (% Vol)	<3	3 to 25	25 to 50	>50
Texture	FSL, VFSL, L, SiL, SL	CL, SCL, SiCL	S, LS, SiC, C, HC	Bedrock
Moist Consistency	very friable, friable	loose, firm	very firm	extremely firm
Gypsum $CaC0_3$ Equivalent (%)	The suitability criteria for sodicity (SAR) may be altered by the presence of high levels of either lime ($CaC0_3$) or gypsum ($CaS0_4$) in excess of other soluble salts.			

[1] Materials characterized by an SAR of 12 to 20 may be rated as poor if texture is sandy loam or coarser and saturation % is less than 100.

Table 6.3A-12 Criteria for Evaluating Suitability of Topsoil in the Northern Forest Region (AAFRD 1987)

Rating/Property	Good (G)	Fair (F)	Poor (P)	Unsuitable (U)
Reaction (pH)[1]	5.0 to 6.5	4.0 to 5.0 6.5 to 7.5	3.5 to 4.0 7.5 to 9.0	<3.5 and >9.0
Salinity (EC)[2] (dS/m)	<2	2 to 4	4 to 8	>8
Sodicity (SAR)[2]	<4	4 to 8	8 to 12	>12[3]
Saturation (%)[2]	30 to 60	20 to 30, 60 to 80	15 to 20, 80 to 120	<15 and >120
Stoniness/ Rockiness[4] (% area)	<30/<20	30-50/ 20-40	50-80/ 40-70	>80/>70
Texture	FSL, VFSL, L, SiL, SL	CL, SCL, SiCL	LS, SiC, C, HC, S	
Moist Consistency	very friable, friable	loose, firm	very firm	extremely firm
$CaC0_3$ Equivalent (%)	<2	2 to 20	20 to 70	>70

[1] pH values presented are most appropriate for trees, primarily conifers. Where reclamation objective is for other end land uses, such as erosion control, and where other plant species may be more important, refer to Table 6.

[2] Limits may vary depending on plant species to be used.

[3] Materials characterized by an SAR of 12 to 20 may be rated as poor if texture is sandy loam or coarser and saturation % is less than 100.

[4] <25 cm diameter stones/rocks intercepting surface.

Table 6.3A-13 Criteria for Evaluating Suitability of Subsoil in the Northern Forest Region (AAFRD 1987)

Rating/Property	Good (G)	Fair (F)	Poor (P)	Unsuitable (U)
Reaction (pH)[1]	5.0 to 7.0[2]	4.0 to 5.0 7.0 to 8.0[2]	3.5 to 4.5 8.0 to 9.0	3.5 and >9.0
Salinity (EC)[3] (dS/m)	<3	3 to 5	5 to 8	>8
Sodicity (SAR)	<4	4 to 8	8 to 12	>12[4]
Saturation (%)[2]	30 to 60	20 to 30, 60 to 80	15 to 20, 80 to 100	<15 and >100
Coarse Fragments (% Vol)	<30[5] <15[6]	30 to 50[5] 15 to 30[6]	50 to 70[5] 30 to 50[6]	>70[5] >50[6]
Texture	FSL, VFSL, L, SiL, SL	CL, SiC, SiCL	S, LS, S, C, HC	bedrock
Moist Consistency	very friable, friable, firm	loose, very firm	extremely firm	Hard rock
$CaC0_3$ Equivalent (%)	<5	5 to 20	20 to 70	>70

[1] pH values presented are most appropriate for trees, primarily conifers. Where reclamation objective is for other end land uses, such as erosion control, and where other plant species may be more important, refer to Table 6.

[2] Higher values takes into consideration that in the lower lift the pH values of the soils are generally higher. Normally the pH rating should not be different from those shown in Tables 9 and 11.

[3] Limit may vary depending on plant species to be used.

[4] Materials characterized by an SAR of 12 to 20 may be rated as poor if texture is sandy loam or coarser and saturation % is less than 100.

[5] Matrix texture (modal) finer than sandy loam.

[6] Matrix texture (modal) sandy loam and coarser.

6A.2.9 Soil Series and Soil Characteristics in LMOC and LSMOC LAA and PDA

Summaries of soil series and associated soil characteristics are provided for the LMOC LAA and PDA in Table 6.3A-14 and for the LSMOC LAA and PDA in Table 6.3A-15.

Table 6.3A-14 Soil Series and Soil Characteristics for LMOC LAA and PDA

Soil Type	Soil Series	Soil Name	Soil Order	Soil Drainage	Parent Material[1]		pH[2]		Organic Matter - Surface[3]		Topsoil depth[4]	Study Areas			
												Proportion of LAA		Proportion of PDA	
					Parent Material 1	Parent Material 2	Surface	Sub-surface	Organic carbon	Organic matter					
									%	%	cm	ha	% area	ha	% area
Mineral	FFD	Fairford	Brunisol	Well	Till		6.9	7.9	2.5	4.3	14	2039.7	23.5	250.4	22.6
	HIB	Hilbre	Brunisol	Well	Till	Bedrock	6.3	7.7	5.3	9.1	6	3.5	<0.0	0.0	<0.0
	IWO	Inwood	Chernozem	Imperfect	Till		7.4	7.9	5.5	9.5	9	3369.6	38.9	429.0	38.8
	LUR	Lundar	Chernozem	Imperfect	Till		7.5	7.8	4.0	6.9	15	17.8	0.2	0.0	<0.0
	MCR	McCreary	Chernozem	Imperfect	Lacustrine	Till	7.9	8.1	3.4	5.8	18	3.2	<0.0	0.0	<0.0
	NCS	Narcisse	Chernozem	Well	Till	Bedrock	7.0	7.7	4.8	8.3	15	9.3	0.1	0.0	<0.0
	MGTp	Magnet, peaty phase	Gleysol	Very poor	Lacustrine	Till	8.0	8.1	1.6	2.8	50	228.3	2.6	18.9	1.7
	$MH	Marsh Complex	Gleysol	Very poor	Undifferentiated		7.6	7.8	12.0	20.6	20	293.4	3.4	2.1	0.2
	MEBp	Meleb, peaty phase	Gleysol	Very poor	Till		7.5	7.9	4.9	8.4	30	1093.0	12.6	197.0	17.8
	$SB	Sand Beaches	Regosol	Imperfect	Lacustrine		7.3	7.6	3.5	6.0	20	90.9	1.0	6.7	0.6
Organic	CRN	Crane	Organic	Very poor	Fen Peat	Till	6.7	7.5	40.0	68.8	125	775.9	9.0	120.4	10.9
Non-soil	$ZZ	Open Water	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	738.8	8.5	81.7	7.4
Totals – Assessment Area												8663.6	100.0	1106.1	100.0
Totals – Area Rated as Soil												7924.8	91.5	1024.4	92.6

SOURCE: CanSIS (Canadian Soil Information Service), 2020. The National Soil DataBase (NSDB) – Soil Layer Table (SLT), version 2. Available at: http://sis.agr.gc.ca/cansis/nsdb/soil/v2/download.html. Accessed: February 2020.
NOTES:

Soil characteristics are provided for dominant soil series within each soil map unit presented in CanSIS (Canadian Soil Information Service), 2019. The National Soil DataBase (NSDB). Available at: http://sis.agr.gc.ca/cansis/nsdb/index.html. Accessed: May 2019.

1. Parent Material identifies the type of material on which soils were developed – Parent Material 1 is the uppermost parent material; Parent Material 2 occurs below the uppermost parent material, if applicable.

2. pH based on a calcium chloride (CaCl) extraction – Surface pH is the pH of the upper-most mineral soil horizon (layer) in mineral soils or upper-most organic soil horizon in organic soils; Subsurface pH is the pH of the lower-most soil horizon.

3. Organic carbon of the upper-most mineral horizon in mineral soils or upper-most organic horizon in organic soils; Organic matter is estimated as Organic carbon x 1.72 (USDA-NRCS, Soil Quality Indicators. Available at: https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_019177.pdf. Accessed: February 2020). A maximum organic matter content of 100% is presented.

4. Topsoil depth is estimated as follows – for mineral soils, the thickness of surficial, organic matter enriched soil layers (e.g., A soil horizons with between 1.5 and 17% organic carbon content)plus the thickness of overlying surficial peaty or litter layers (e.g., LFH, LH or Om soil horizons); for organic soils, the thickness of organic layers (i.e., soil horizons with > 17% organic carbon content) plus the thickness of underlying, organic matter enriched mineral layers (e.g., A horizons between 1.5 and 17% organic carbon content), if present.

Table 6.3A-15 Soil Series and Soil Characteristics for LSMOC LAA and PDA

Soil Type	Soil Series	Soil Name	Soil Order	Soil Drainage	Parent Material[1]		pH[2]		Organic Matter - Surface[3]		Topsoil depth[4]	Study Areas			
					Parent Material 1	Parent Material 2	Surface	Sub-surface	Organic carbon	Organic matter		Proportion of LAA		Proportion of PDA	
									%	%	cm	ha	% area	ha	% area
Mineral	CHK	Chitek	Brunisol	Imperfect	Till		7.3	7.9	2.9	5.0	8	436.2	6.9	101.1	10.2
	GOI	Goose Island	Chernozem	Imperfect	Glaciofluvial	Till	6.9	7.7	3	5.2	29	1566.6	24.8	271.3	27.3
	IWO	Inwood	Chernozem	Imperfect	Till		7.4	7.9	5.5	9.5	9	43.2	0.7	0.0	<0.0
	FYL	Fyala	Gleysol	Poor	Lacustrine		7	7.7	7.5	12.9	20	216.6	3.4	18.5	1.9
	MEBp	Meleb, peaty phase	Gleysol	Very poor	Till		7.5	7.9	4.9	8.4	30	152.1	2.4	9.2	0.9
	PGE	Partridge Creek	Gleysol	Poor	Lacustrine	Till	7.3	7.9	3.2	5.5	20	86.0	1.4	1.8	0.2
	KNW	Kinwow	Luvisol	Well	Lacustrine	Till	5.7	7.3	1.9	3.3	8	87.6	1.4	2.0	0.2
	WOG	Woodworth	Luvisol	Rapid	Glaciofluvial		6.3	7.7	2	3.4	15	5.3	0.1	0.0	<0.0
Organic	CAY	Cayer	Organic	Very poor	Fen Peat	Lacustrine	6.6	7.4	39	67.1	95	774.7	12.2	123.2	12.4
	CRN	Crane	Organic	Very poor	Fen Peat	Till	6.7	7.5	40	68.8	125	437.1	6.9	52.3	5.3
	KEY	Kilkenny	Organic	Very poor	Sphagnum Peat	Forest Peat	3.6	7.5	55.4	95.3	130	46.3	0.7	15.4	1.5
	MLS	Molson	Organic	Very poor	Sphagnum Peat /Forest Peat	Till	4.7	7.1	40	68.8	130	1197.9	18.9	181.7	18.3
	OKO	Okno, drained phase	Organic	Imperfect	Forest Peat	Lacustrine	5.4	7.7	47.5	81.7	135	419.1	6.6	87.8	8.8
	STD	Stead	Organic	Very poor	Fen Peat		6.3	6.4	60	100.0	>180	77.3	1.2	23.9	2.4
Non-soil	$ZI	Intermittent Lake	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	116.5	1.8	35.1	3.5
	$ZZ	Water	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	662.5	10.5	69.2	7.0
Totals – Assessment Area												6325.0	100.0	992.6	100.0
Totals – Area Rated as Soil												5546.0	87.7	888.3	89.5

SOURCE:CanSIS (Canadian Soil Information Service), 2020. The National Soil DataBase (NSDB) – Soil Layer Table (SLT), version 2. Available at: http://sis.agr.gc.ca/cansis/nsdb/soil/v2/download.html. Accessed: February 2020.
NOTES:

Soil characteristics are provided for dominant soil series within each soil map unit presented in CanSIS (Canadian Soil Information Service), 2019. The National Soil DataBase (NSDB). Available at: http://sis.agr.gc.ca/cansis/nsdb/index.html. Accessed: May 2019.

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3. Organic carbon of the upper-most mineral horizon in mineral soils or upper-most organic horizon in organic soils; Organic matter is estimated as Organic carbon x 1.72 (USDA-NRCS, Soil Quality Indicators. Available at: https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_019177.pdf. Accessed: February 2020). A maximum organic matter content of 100% is presented.
4. Topsoil depth is estimated as follows – for mineral soils, the thickness of surficial, organic matter enriched soil layers (e.g., A soil horizons with between 1.5 and 17% organic carbon content)plus the thickness of overlying surficial peaty or litter layers (e.g., LFH, LH or Om soil horizons); for organic soils, the thickness of organic layers (i.e., soil horizons with > 17% organic carbon content) plus the thickness of underlying, organic matter enriched mineral layers (e.g., A horizons between 1.5 and 17% organic carbon content), if present.

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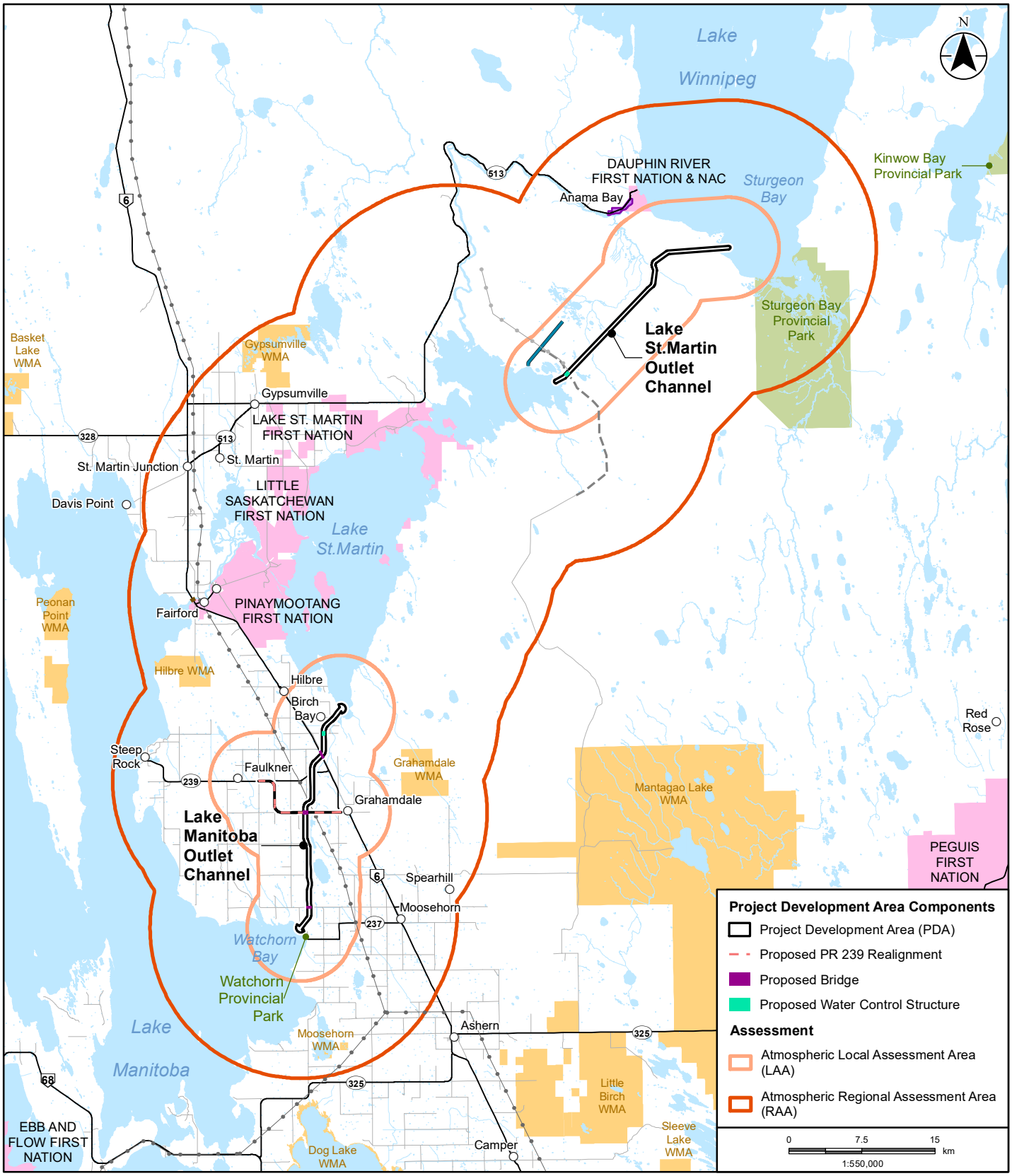
6B.1 ATMOSPHERIC ENVIRONMENT FIGURES



Legend

- Fairford Water Control Structure
- Lake St.Martin Emergency Outlet Channel (Reach 1)
- Lake St.Martin Access Road
- Existing Transmission Line
- Existing Distribution Line
- Planned Distribution Line
- Provincial Highway (PTH/PR)
- Municipal Road
- Northern Affairs Community (NAC)
- First Nation
- Wildlife Management
- Provincial Park

Notes

1. Coordinate System: NAD 1983 UTM Zone 14N
2. Data Sources: Governments of Manitoba and Canada, Manitoba Infrastructure
3. Last Update: 8/9/2019 2:14:34 PM

Manitoba

MANITOBA INFRASTRUCTURE
Lake Manitoba & Lake St.Martin Outlet Channels Project
Environmental Impact Statement

Air Quality and Lighting Spatial Boundaries

Figure 6.2B-1

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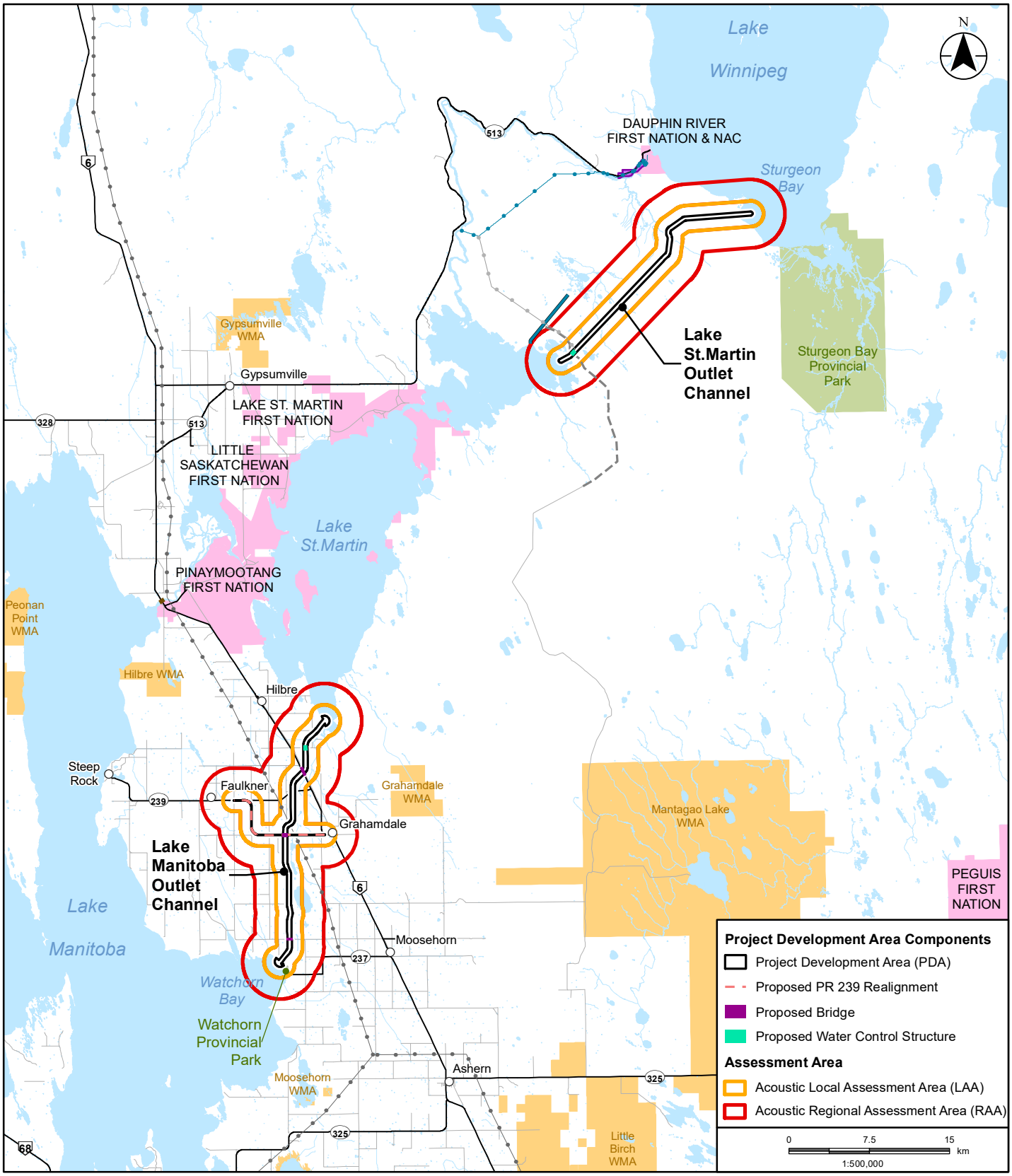

Legend

- Fairford Water Control Structure
- Lake St.Martin Emergency Outlet Channel (Reach 1)
- Lake St.Martin Access Road
- Existing Transmission Line
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- Provincial Highway (PTH/PR)
- Municipal Road
- Northern Affairs Community (NAC)
- First Nation
- Wildlife Management Area
- Provincial Park

Notes

1. Coordinate System: NAD 1983 UTM Zone 14N
2. Data Sources: Governments of Manitoba and Canada, Manitoba Infrastructure
3. Last Update: 8/9/2019 2:14:56 PM

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Environmental Impact Statement

Acoustic Environment Spatial Boundaries

Figure 6.2B-2

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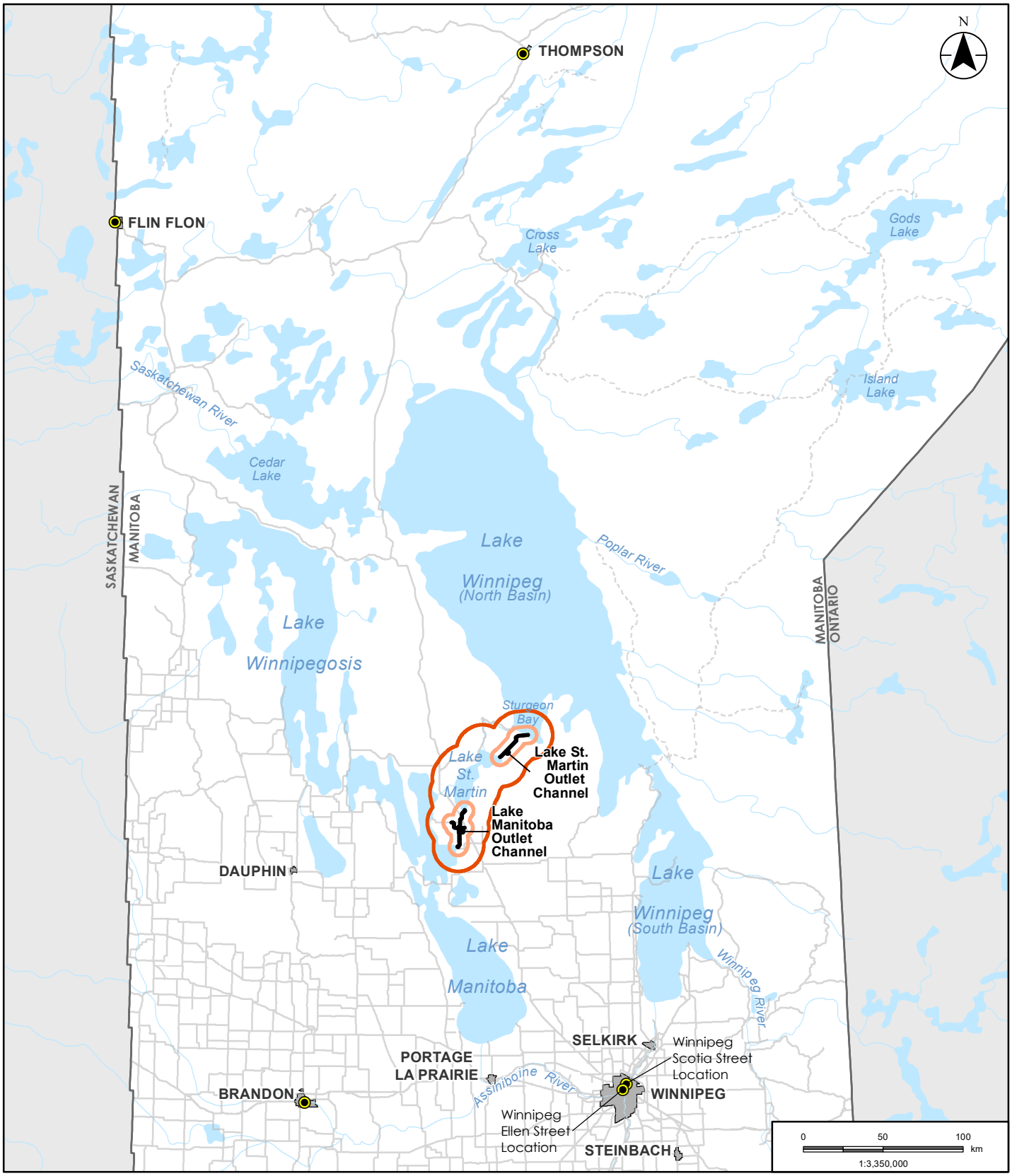

Legend

- Project Development Area (PDA)
- Ambient Air Monitoring Stations

Assessment Area

- Air Quality Local Assessment Area (LAA)
- Air Quality Regional Assessment Area (RAA)
- City
- Major Highway
- Winter Road

Notes

1. Coordinate System: NAD 1983 UTM Zone 14N
2. Data Sources: Governments of Manitoba and Canada, Manitoba Infrastructure
3. Last Update: 8/9/2019 2:13:10 PM

Manitoba

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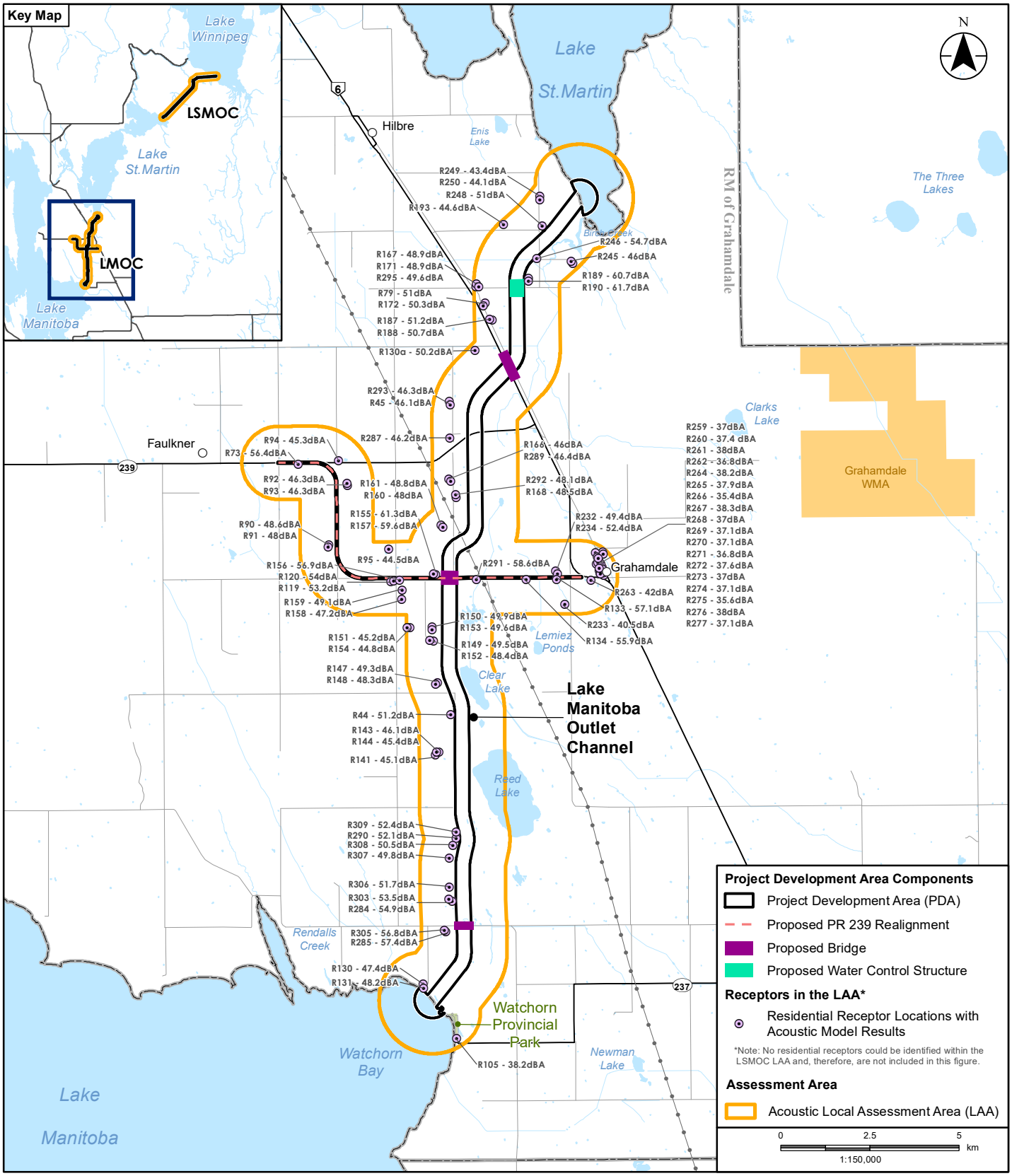
Lake Manitoba & Lake St.Martin Outlet Channels Project
Environmental Impact Statement

Location of Ambient Air Quality Monitoring Stations within Manitoba

Figure 6.2B-3

G:_GIS_Project_Folder\1114751200\figures\Ch6_Physical_Environment\Final\Fig 6.2B-3 PE Air Quality Monitoring Stations.mxd



Legend

- Existing Transmission Line
- Provincial Highway (PTH/PR)
- Municipal Road
- Rural Municipality
- Wildlife Management
- Provincial Park

Notes

1. Coordinate System: NAD 1983 UTM Zone 14N
2. Data Sources: Governments of Manitoba and Canada, Manitoba Infrastructure, Stantec
3. Last Update: 8/9/2019 2:11:22 PM

Manitoba

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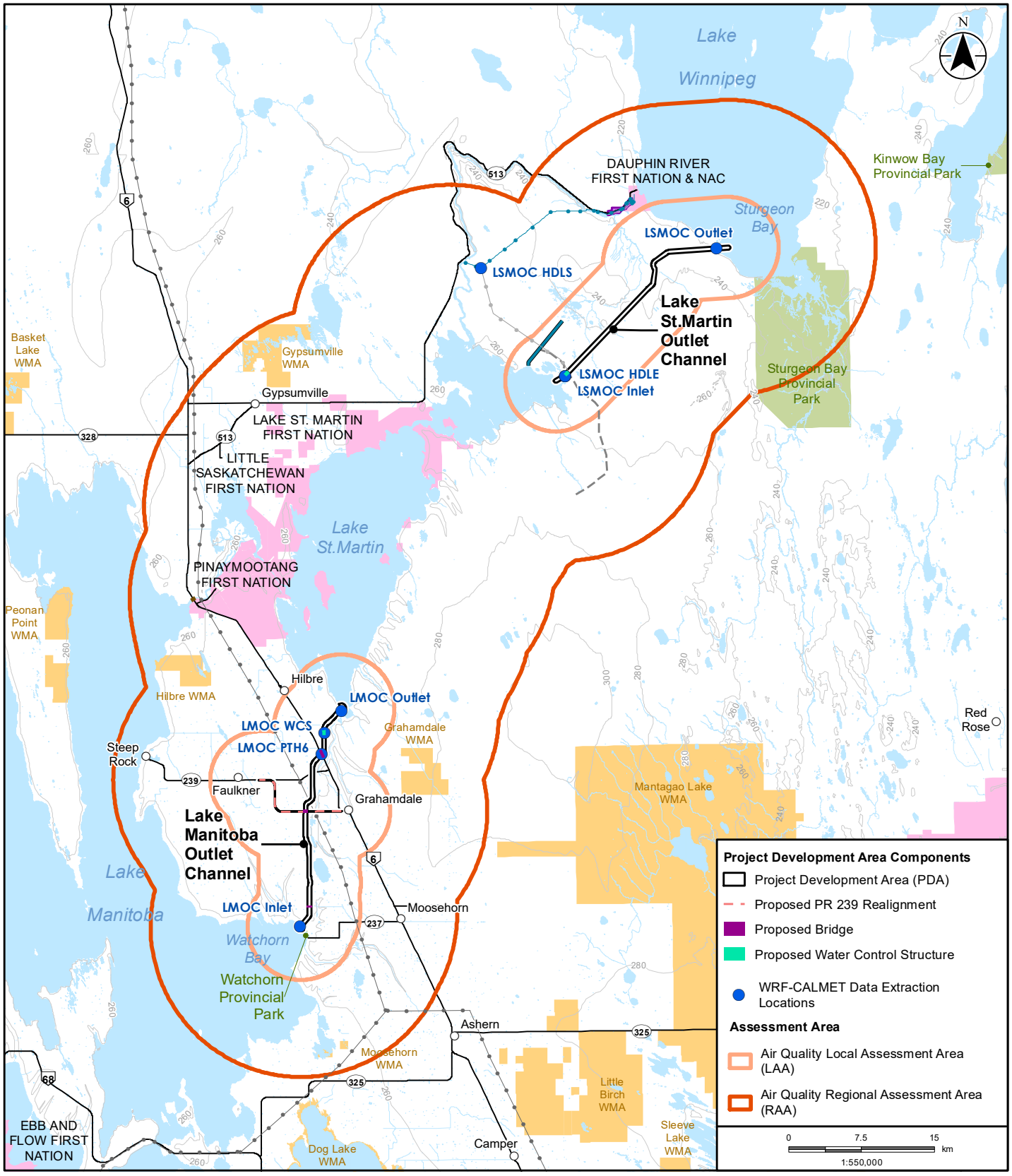
Lake Manitoba & Lake St.Martin Outlet Channels Project
Environmental Impact Statement

Residential Receptor Locations within LAA of LMOC and PR239

Figure 6.2B-4

G:_GIS_Project_Folder\111475120\figures\Ch6_Physical_Environment\Final\Fig 6.2B-5 PE Acoustic Residential Receptors in LAA.mxd



Legend

- Fairford Water Control Structure
- Lake St.Martin Emergency Outlet Channel (Reach 1)
- Lake St. Martin Access Road
- Existing Transmission Line
- Existing Distribution Line
- Planned Distribution Line
- Provincial Highway (PTH/PR)
- Contours (20m)
- Northern Affairs Community (NAC)
- First Nation
- Wildlife Management Area
- Provincial Park

Notes

1. Coordinate System: NAD 1983 UTM Zone 14N
2. Data Sources: Governments of Manitoba and Canada, Manitoba Infrastructure
3. Last Update: 8/13/2019 12:08:05 PM

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Lake Manitoba & Lake St.Martin Outlet Channels Project
Environmental Impact Statement

Locations of WRF-CALMET Data Extractions

Figure 6.2B-5

G:\ GIS Project Folder\11473120\figures\Ch6 Physical Environment\Por Review\Air\Figure 6.2B-4 WRF-Calmet Data Extraction Locations.mxd

Figures 6.2B-6 through 6.2B-19provide all the existing ambient air quality figures which were discussed in Review of Historical Ambient Air Quality Data in Section 6.2.2.2.

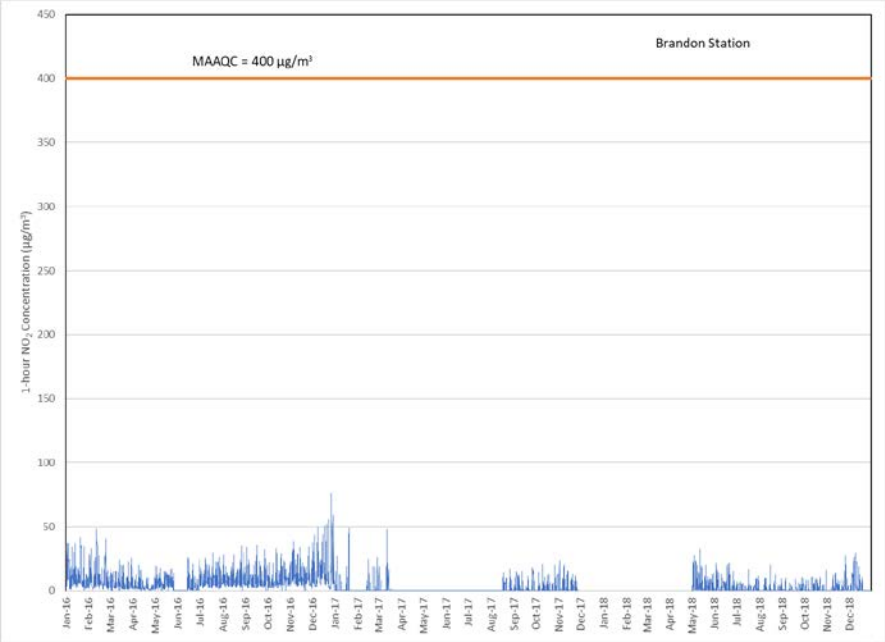


Figure 6.2B-6 1-Hour NO_2 Concentrations at the Brandon Station

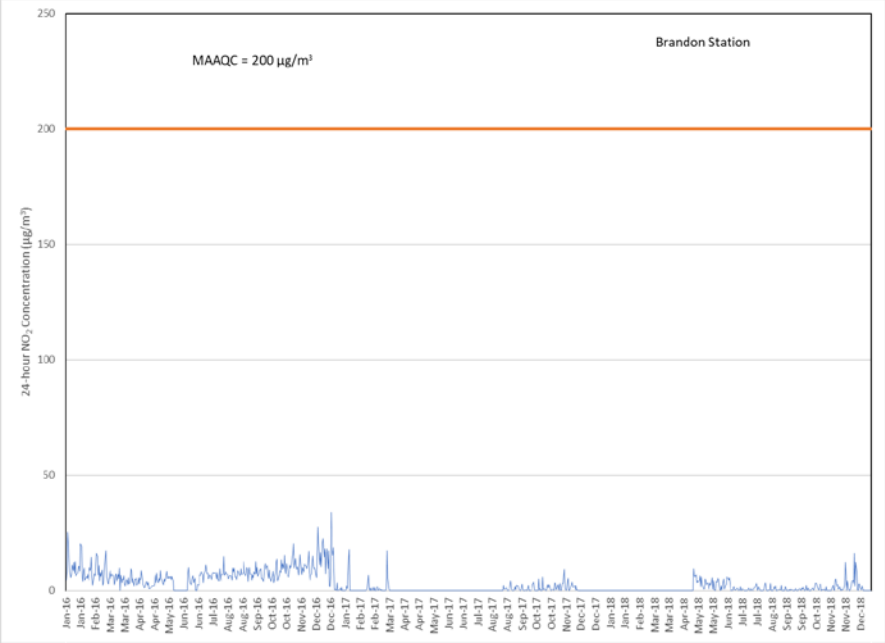


Figure 6.2B-7 24-Hour NO_2 Concentrations at the Brandon Station

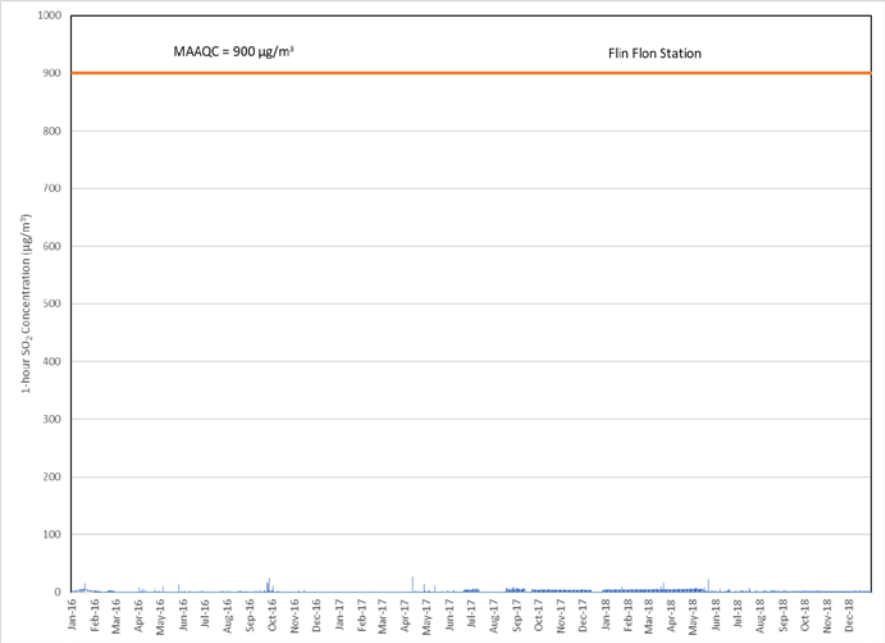


Figure 6.2B-8 1-Hour SO_2 Concentrations at the Flin Flon Station

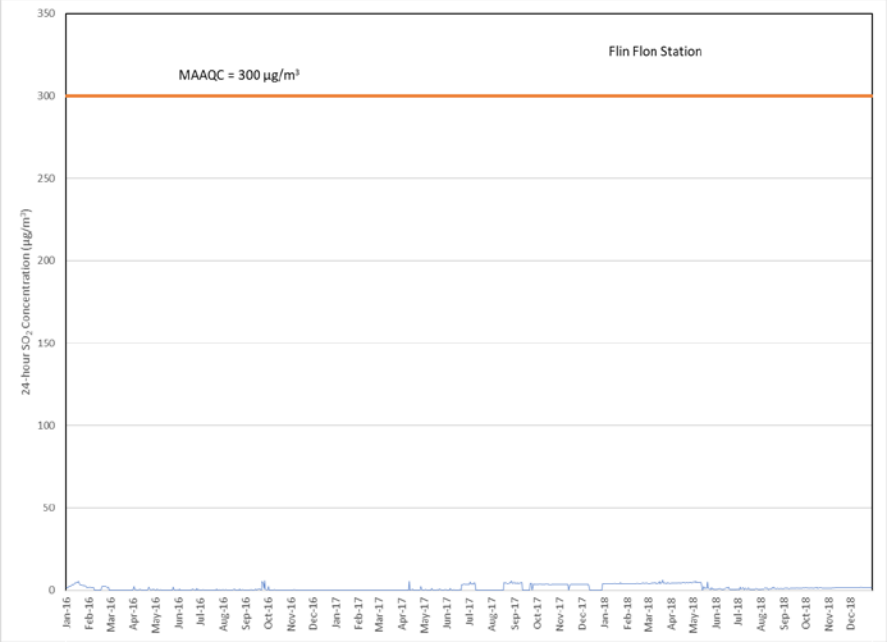


Figure 6.2B-9 24-Hour SO_2 Concentrations at the Flin Flon Station

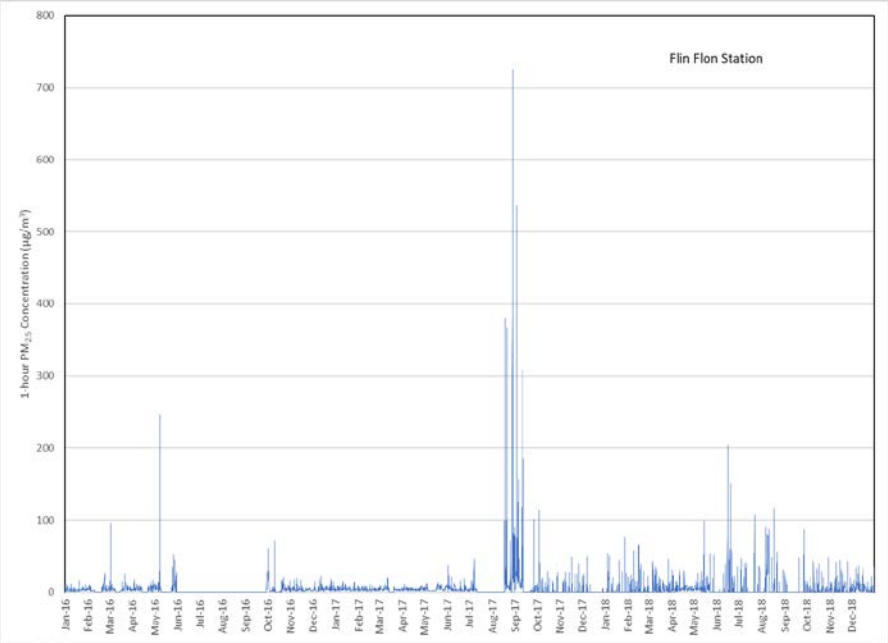


Figure 6.2B-10 1-Hour $PM_{2.5}$ Concentrations at the Flin Flon Station

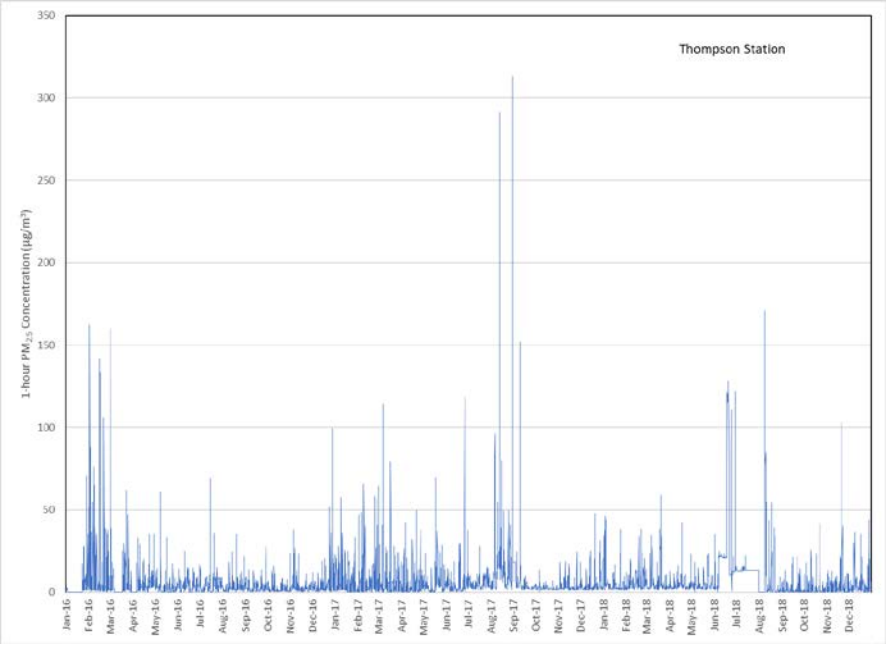


Figure 6.2B-11 1-Hour $PM_{2.5}$ Concentrations at the Thompson Station

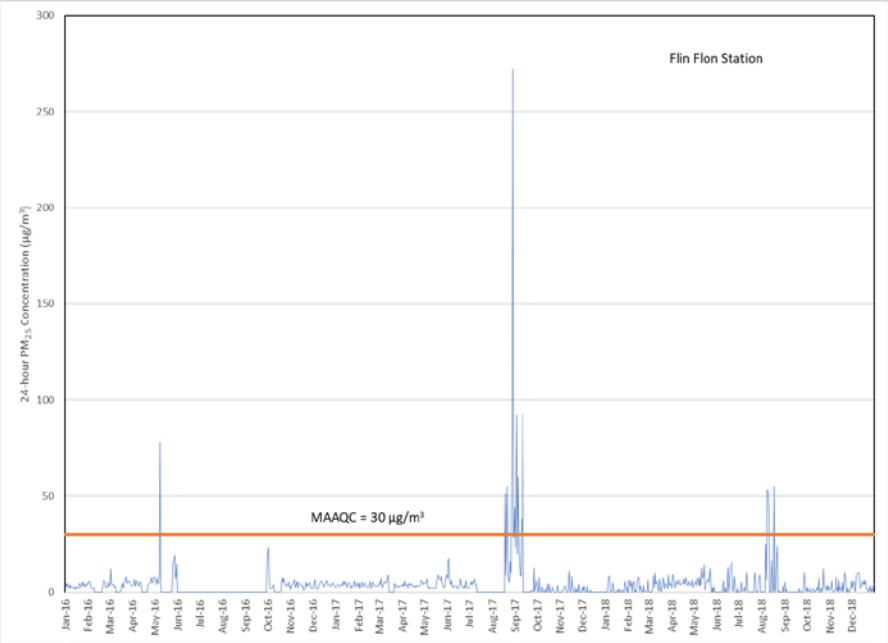


Figure 6.2B-12 24-Hour $PM_{2.5}$ Concentrations at the Flin Flon Station

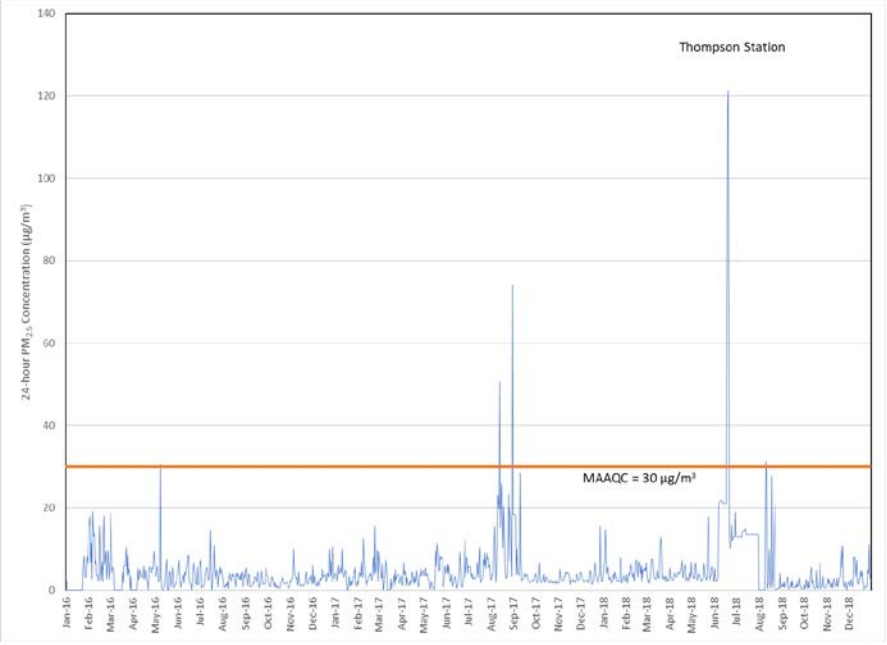


Figure 6.2B-13 24-Hour $PM_{2.5}$ Concentrations at the Thompson Station

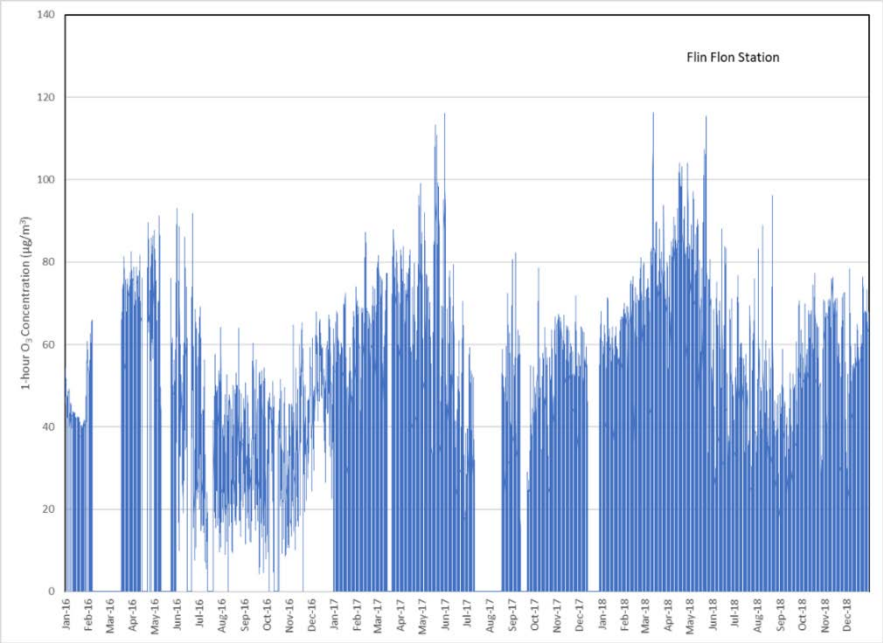


Figure 6.2B-14 1-Hour O_3 Concentrations at the Flin Flon Station

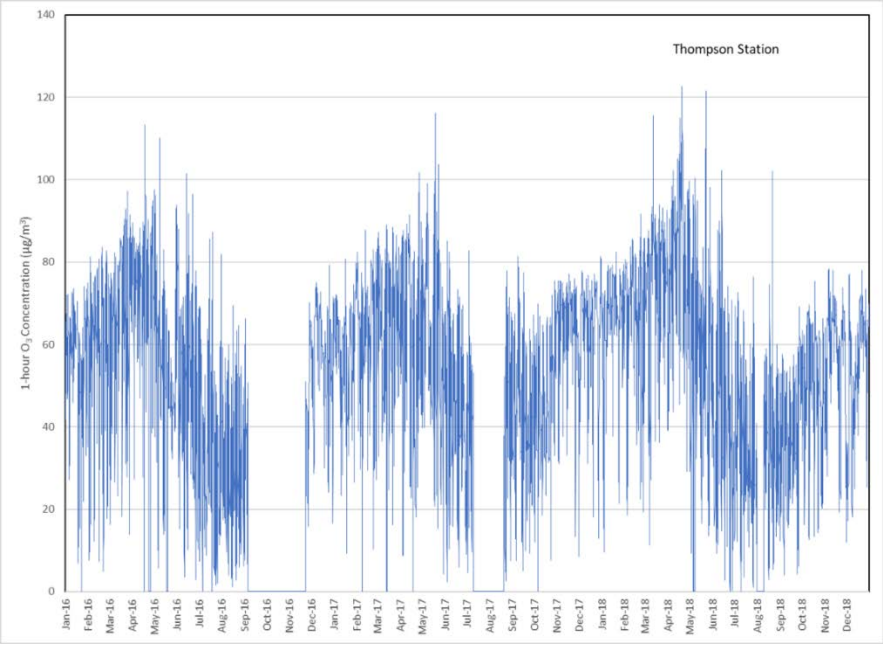


Figure 6.2B-15 1-Hour O_3 Concentrations at the Thompson Station

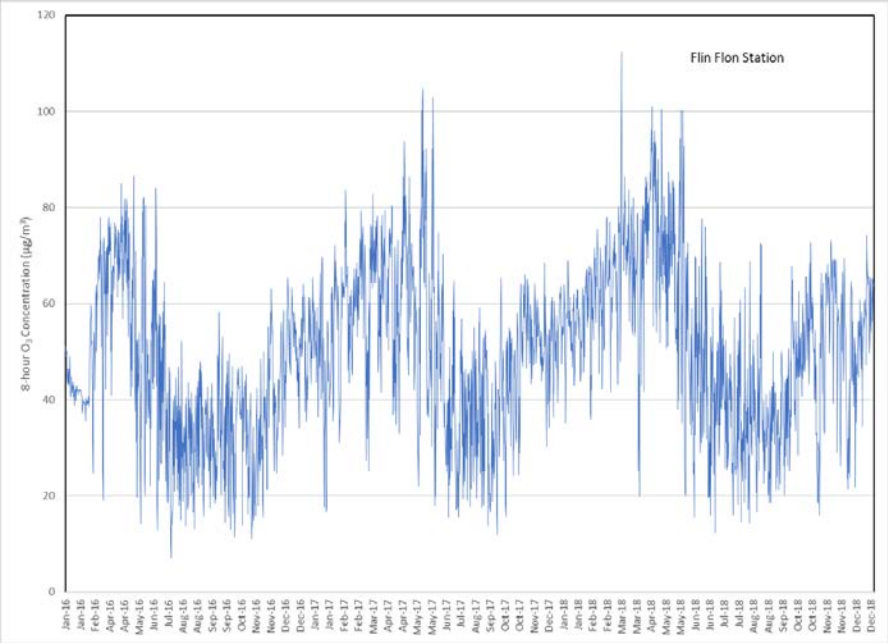


Figure 6.2B-16 8-Hour O_3 Concentrations at the Flin Flon Station

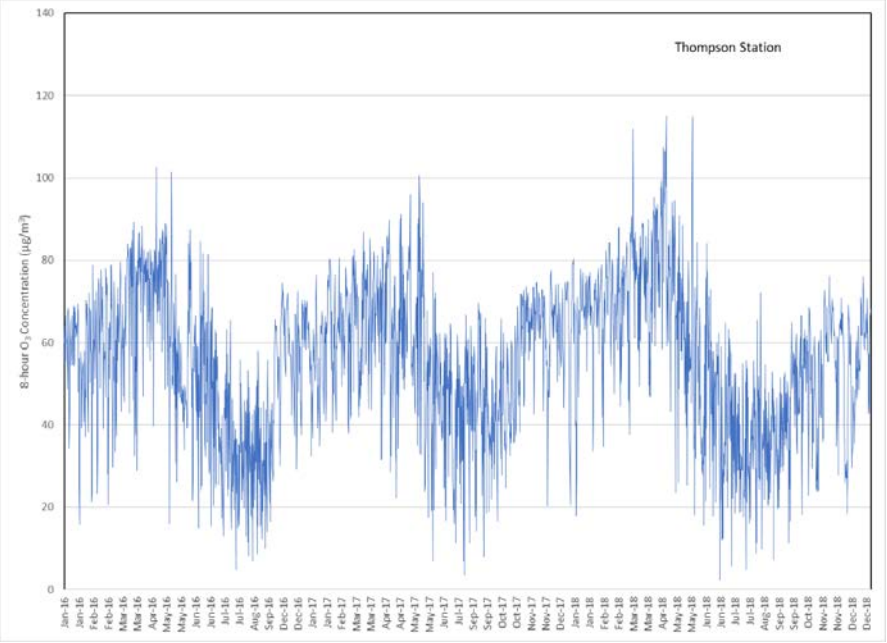


Figure 6.2B-17 8-Hour O_3 Concentrations at the Thompson Station

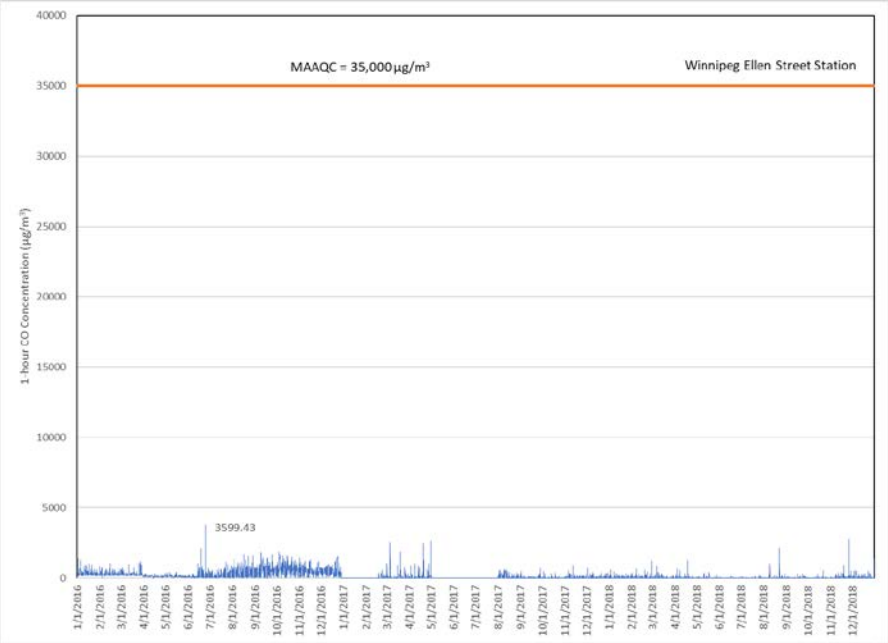


Figure 6.2B-18 **Maximum 1-Hour CO Concentrations at the Winnipeg Ellen Street Station**

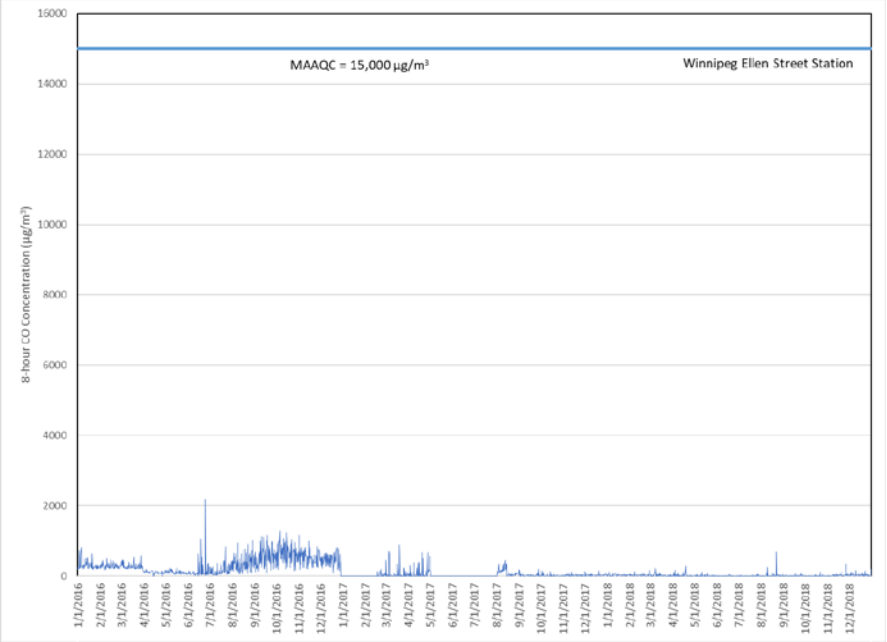
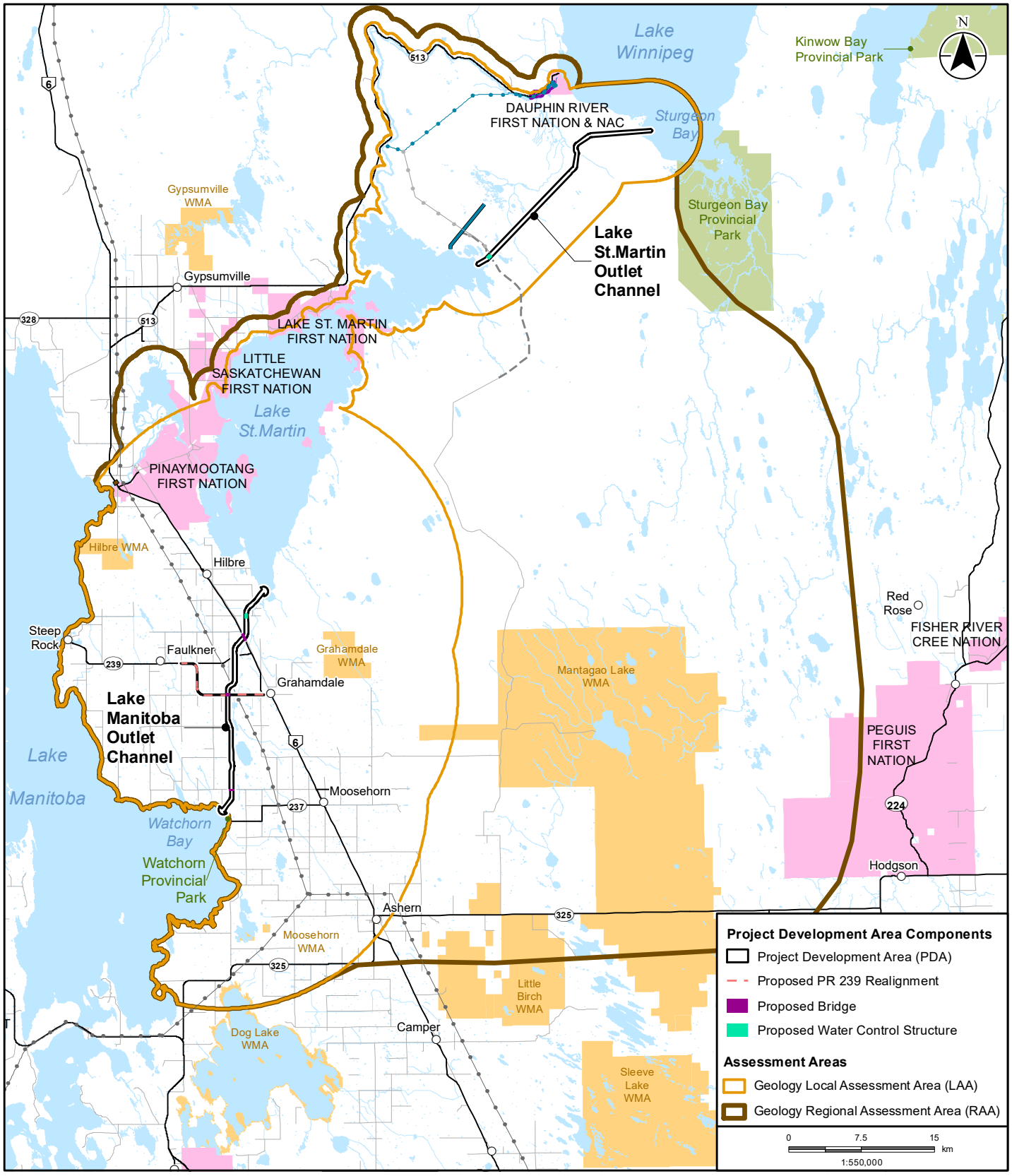


Figure 6.2B-19 **Maximum 8-Hour CO Concentrations at the Winnipeg Ellen Street Station**

6B.2 GEOLOGY AND SOILS FIGURES



Legend

- Fairford Water Control Structure
- Lake St.Martin Emergency Outlet Channel (Reach 1)
- Lake St.Martin Access Road
- Existing Transmission Line
- Existing Distribution Line
- Planned Distribution Line
- Provincial Highway (PTH/PR)
- Municipal Road
- Northern Affairs Community (NAC)
- First Nation
- Wildlife Management Area
- Provincial Park

Notes

1. Coordinate System: NAD 1983 UTM Zone 14N
2. Data Sources: Governments of Manitoba and Canada, Manitoba Infrastructure
3. Last Update: 8/9/2019 2:26:34 PM

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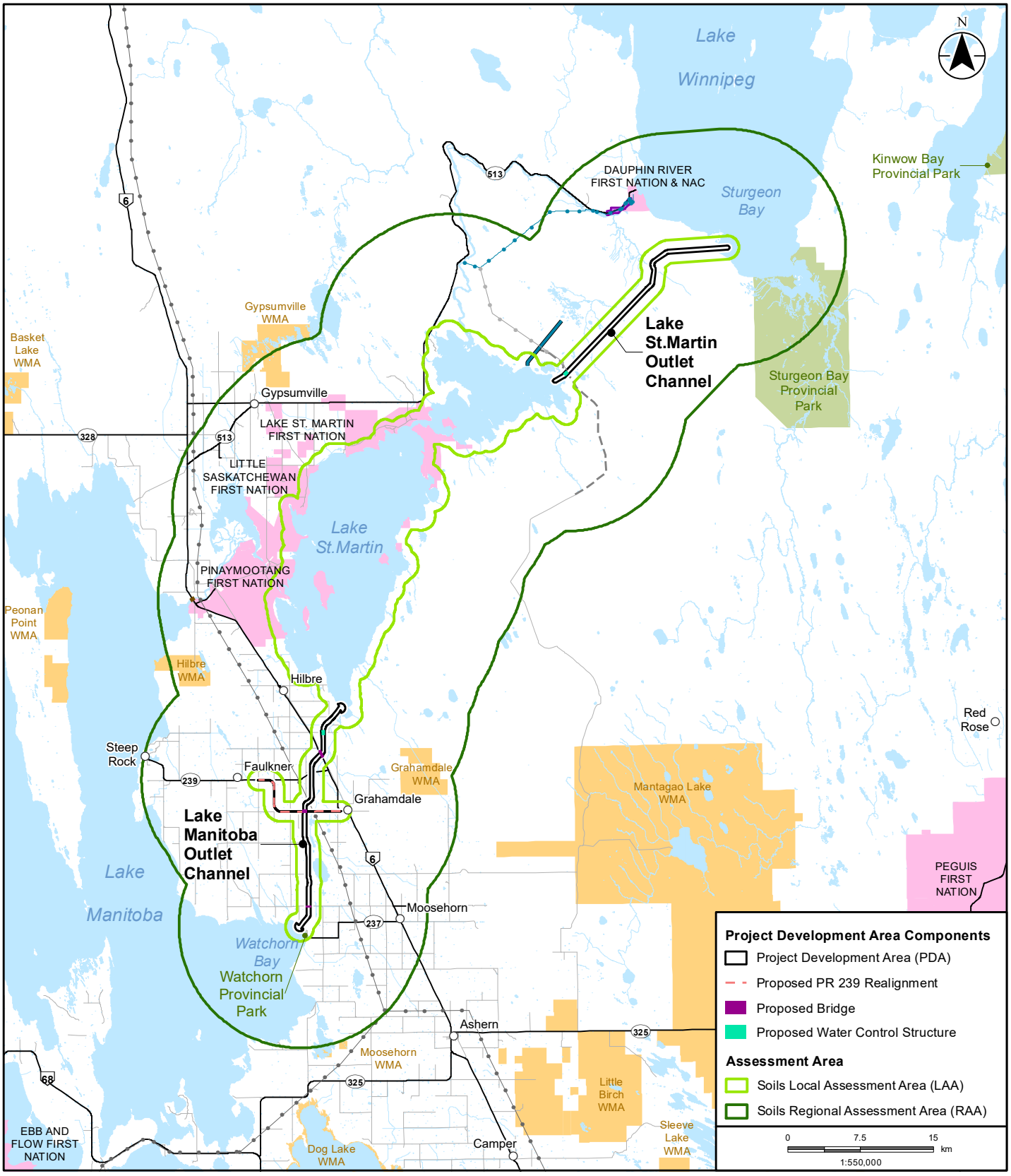
Lake Manitoba & Lake St.Martin Outlet Channels Project
Environmental Impact Statement

Geology Spatial Boundaries

Figure 6.3B-1

G:\ GIS Project Folder\11473120\Figures\Ch6 Physical Environment\Final\Fig 6.3B-1 PE Geology Spatial Boundaries.mxd



Legend

- Fairford Water Control Structure
- Lake St.Martin Emergency Outlet Channel (Reach 1)
- Lake St.Martin Access Road
- Existing Transmission Line
- Existing Distribution Line
- Planned Distribution Line
- Provincial Highway (PTH/PR)
- Municipal Road
- Northern Affairs Community (NAC)
- First Nation
- Wildlife Management Area
- Provincial Park

Notes

1. Coordinate System: NAD 1983 UTM Zone 14N
2. Data Sources: Governments of Manitoba and Canada, Manitoba Infrastructure
3. Last Update: 8/9/2019 2:59:30 PM

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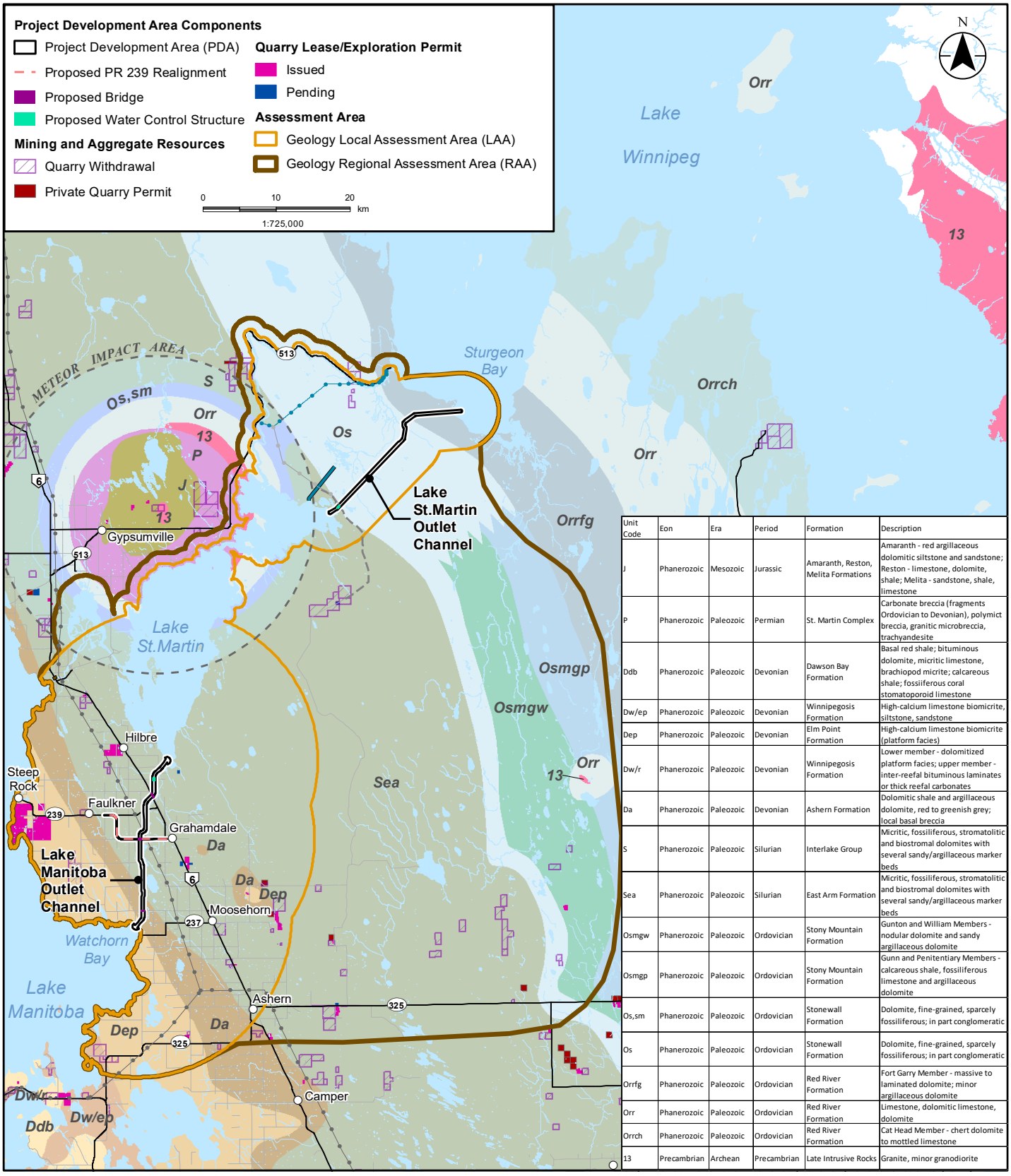
Lake Manitoba & Lake St.Martin Outlet Channels Project
Environmental Impact Statement

Soils Spatial Boundaries

Figure 6.3B-2

G:\ GIS Project Folder\11473120\figures\Ch6 Physical Environment\Final\Fig 6.3B-2 PE Soils Spatial Boundaries.mxd



Unit Code	Eon	Era	Period	Formation	Description
J	Phanerozoic	Mesozoic	Jurassic	Amaranth, Reston, Melita Formations	Amaranth - red argillaceous dolomitic siltstone and sandstone; Reston - limestone, dolomite, shale; Melita - sandstone, shale, limestone
P	Phanerozoic	Paleozoic	Permian	St. Martin Complex	Carbonate breccia (fragments Ordovician to Devonian), polymict breccia, granitic microbreccia, trachyandesite
Ddb	Phanerozoic	Paleozoic	Devonian	Dawson Bay Formation	Basal red shale; bituminous dolomite, micritic limestone, brachiopod micrite; calcareous shale; fossiferous coral stomatoporoid limestone
Dw/ep	Phanerozoic	Paleozoic	Devonian	Winnipegosis Formation	High-calcium limestone biomicrite, siltstone, sandstone
Dep	Phanerozoic	Paleozoic	Devonian	Elm Point Formation	High-calcium limestone biomicrite (platform facies)
Dw/r	Phanerozoic	Paleozoic	Devonian	Winnipegosis Formation	Lower member - dolomitized platform facies; upper member - inter-reefal bituminous laminates or thick reefal carbonates
Da	Phanerozoic	Paleozoic	Devonian	Ashern Formation	Dolomitic shale and argillaceous dolomite, red to greenish grey; local basal breccia
S	Phanerozoic	Paleozoic	Silurian	Interlake Group	Micritic, fossiliferous, stromatolitic and biostromal dolomites with several sandy/argillaceous marker beds
Sea	Phanerozoic	Paleozoic	Silurian	East Arm Formation	Micritic, fossiliferous, stromatolitic and biostromal dolomites with several sandy/argillaceous marker beds
Osmgw	Phanerozoic	Paleozoic	Ordovician	Stony Mountain Formation	Gunton and William Members - nodular dolomite and sandy argillaceous dolomite
Osmgp	Phanerozoic	Paleozoic	Ordovician	Stony Mountain Formation	Gunn and Penitentiary Members - calcareous shale, fossiliferous limestone and argillaceous dolomite
Os,sm	Phanerozoic	Paleozoic	Ordovician	Stonewall Formation	Dolomite, fine-grained, sparcely fossiliferous; in part conglomeratic
Os	Phanerozoic	Paleozoic	Ordovician	Stonewall Formation	Dolomite, fine-grained, sparcely fossiliferous; in part conglomeratic
Orrfg	Phanerozoic	Paleozoic	Ordovician	Red River Formation	Fort Garry Member - massive to laminated dolomite; minor argillaceous dolomite
Orr	Phanerozoic	Paleozoic	Ordovician	Red River Formation	Limestone, dolomitic limestone, dolomite
Orrch	Phanerozoic	Paleozoic	Ordovician	Red River Formation	Cat Head Member - chert dolomite to mottled limestone
13	Precambrian	Archean	Precambrian	Late Intrusive Rocks	Granite, minor granodiorite

Legend

- Fairford Water Control Structure
- Lake St.Martin Emergency Outlet Channel (Reach 1)
- Lake St.Martin Access Road
- Existing Transmission Line
- Existing Distribution Line
- Planned Distribution Line
- Provincial Highway (PTH/PR)
- Municipal Road

Notes

1. Coordinate System: NAD 1983 UTM Zone 14N
2. Data Sources: Governments of Manitoba and Canada, Manitoba Infrastructure
3. Last Update: 8/9/2019 2:32:35 PM

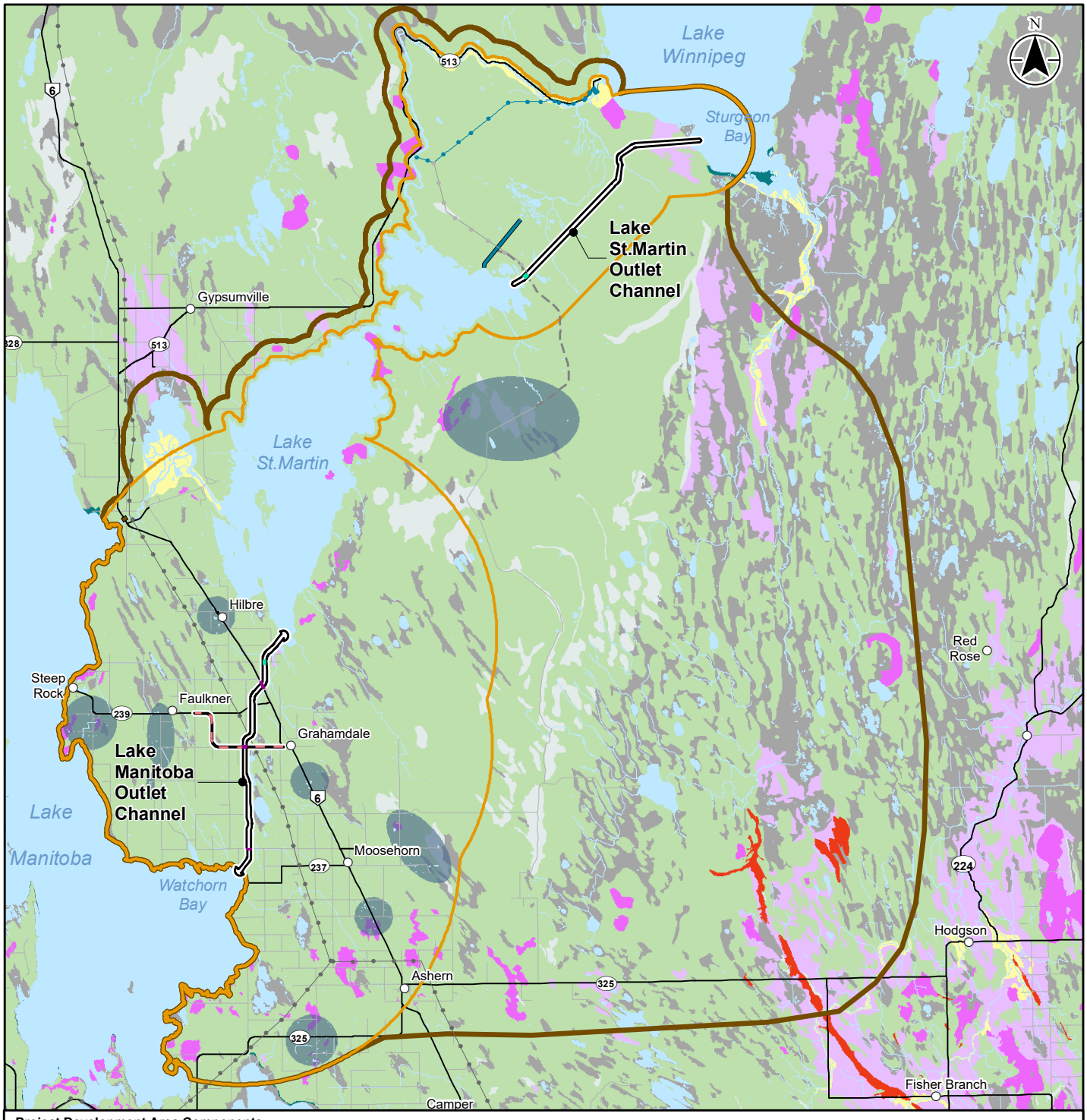
Manitoba

MANITOBA INFRASTRUCTURE
Lake Manitoba & Lake St.Martin Outlet Channels Project
Environmental Impact Statement

Regional and Local Bedrock Geology

Figure 6.3B-3

G:\ GIS_Project_Folder\11147520\Figures\Ch6_Physical_Environment\Final\Fig 6.3B-3 PE Bedrock Geology.mxd



Project Development Area Components

- Project Development Area (PDA)
- Proposed PR 239 Realignment
- Proposed Bridge
- Proposed Water Control Structure
- Potential Aggregate Sites

Surficial Geology

- Alluvial Sediments
- Proximal Glaciofluvial Sediments
- Distal Glaciofluvial Sediments
- Offshore Glaciolacustrine Sediments
- Shoreline Sediments
- Marginal Glaciolacustrine Sediments
- Organic Deposits
- Till - Calcareous Silt Diamicton
- Rock - Paleozoic Terraine

Assessment Areas

- Geology Local Assessment Area (LAA)
- Geology Regional Assessment Area (RAA)

0 7.5 15 km

1:550,000

Legend

- Fairford Water Control Structure
- Lake St.Martin Emergency Outlet Channel (Reach 1)
- Lake St.Martin Access Road
- Existing Transmission Line
- Existing Distribution Line
- Planned Distribution Line
- Provincial Highway (PTH/PR)
- Municipal Road

Notes

1. Coordinate System: NAD 1983 UTM Zone 14N
2. Data Sources: Governments of Manitoba and Canada, Manitoba Infrastructure
3. Last Update: 8/9/2019 2:33:49 PM

Manitoba

MANITOBA INFRASTRUCTURE
Lake Manitoba & Lake St.Martin Outlet Channels Project
Environmental Impact Statement

Regional and Local Surficial Geology

Figure 6.3B-4

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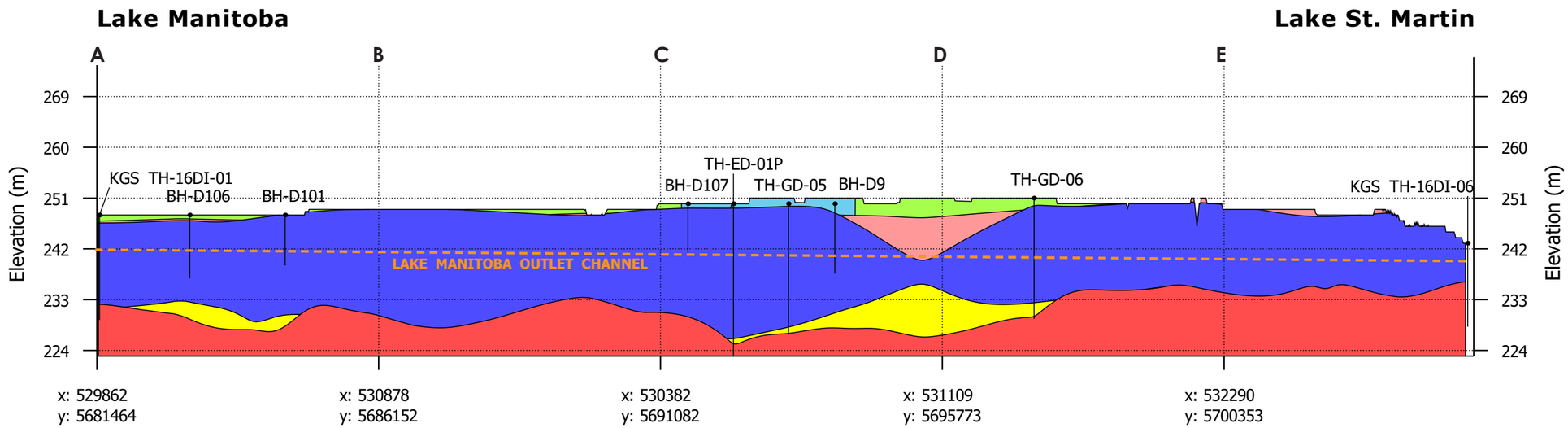

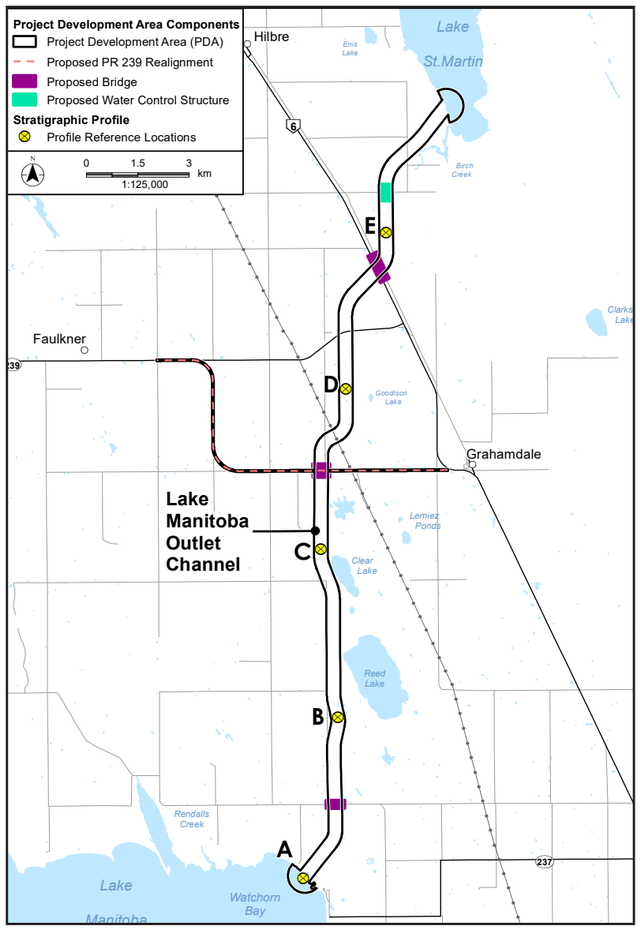

- Peat
- Clay
- Upper Sand and Gravel
- Till
- Lower Sand and Gravel
- Bedrock (Carbonate Aquifer)

Location

Lake Manitoba: 529862, 5681464

Lake St. Martin : 534093, 5704112

Scale: 1:82,000

Vertical exaggeration: 100x

0m 5000m

Manitoba

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Lake Manitoba & Lake St.Martin Outlet Channels Project
Environmental Impact Statement

Stratigraphic Profile along LMOC Section of the Project

Figure 6.3B-5

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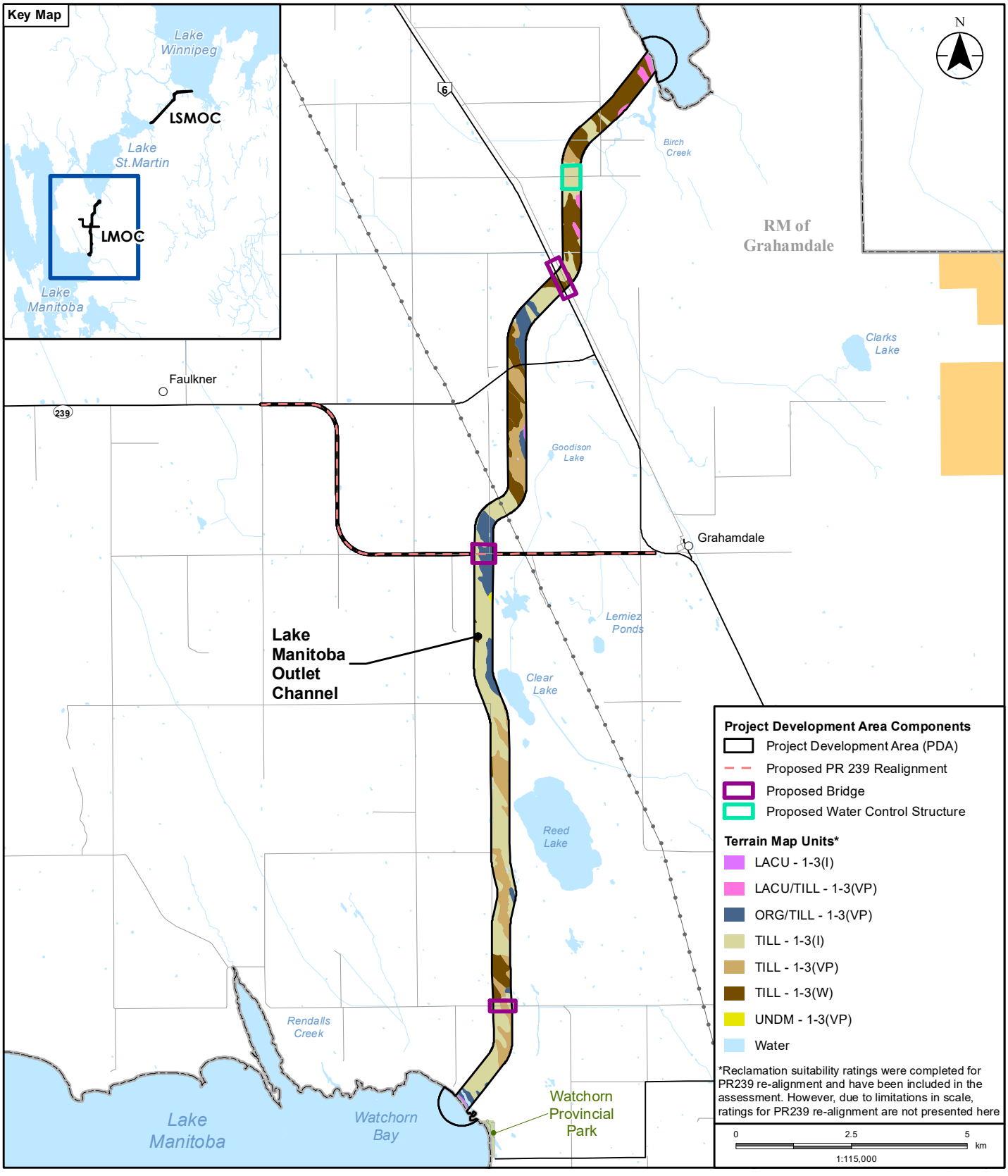

Legend

- Existing Transmission Line
- Provincial Highway (PTH/PR)
- Municipal Road
- Rural Municipality

Notes

1. Coordinate System: WGS 1984 UTM Zone 14N
2. Data Sources: Governments of Manitoba and Canada, Manitoba Infrastructure, CanSIS 2019, MLI 2019
3. Last Update: 8/9/2019 3:00:56 PM

Manitoba

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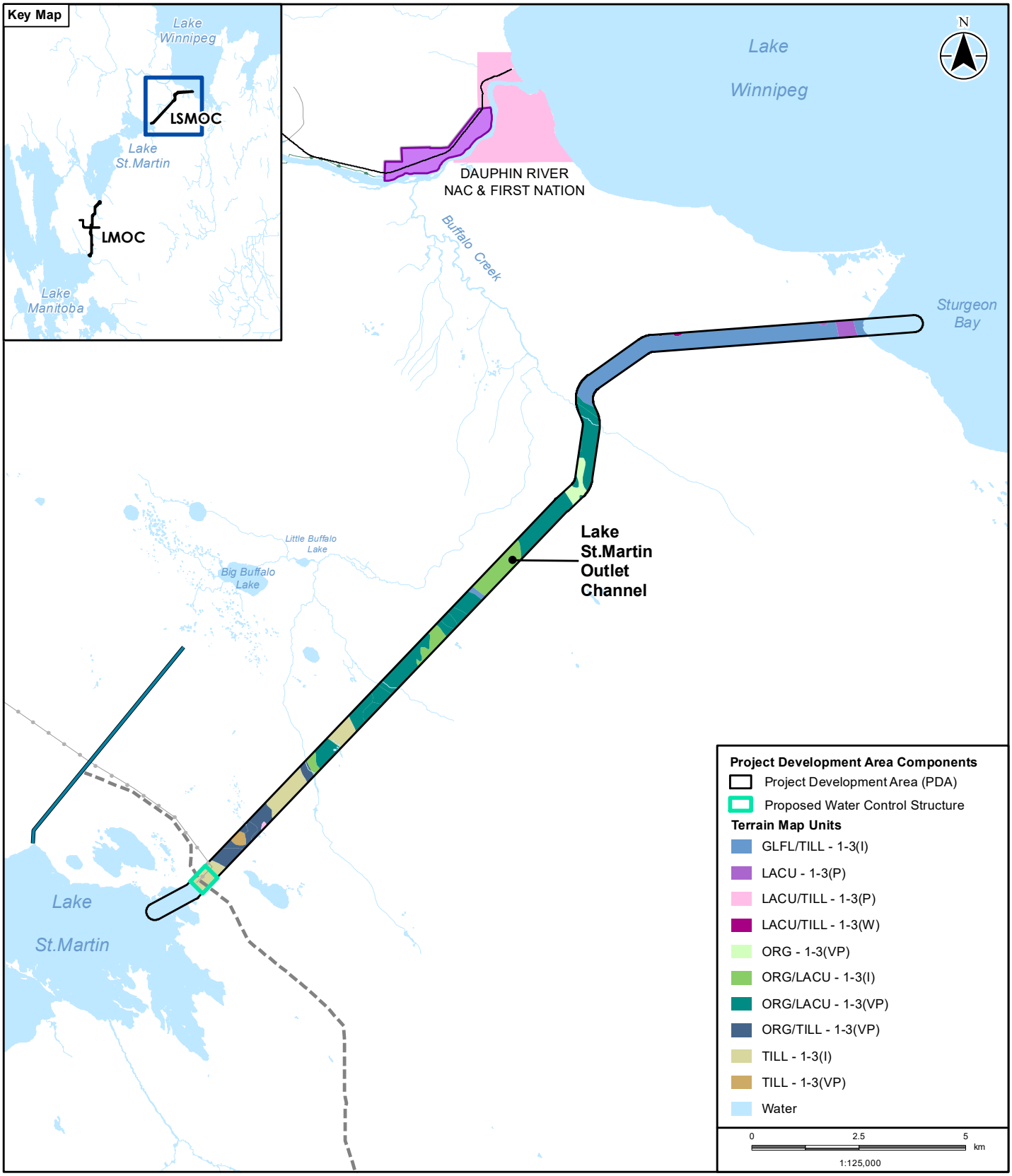
Lake Manitoba & Lake St.Martin Outlet Channels Project
Environmental Impact Statement

Terrain Map Units - Lake Manitoba Outlet Channel PDA

Figure 6.3B-6

G:\ GIS_Project_Folder\111473120\Figures\Ch6 Physical Environment\Final\Fig 6.3B-6 PE Terrain Units - LMOC.mxd



Legend

- Lake St.Martin Emergency Outlet Channel (Reach 1)
- Lake St.Martin Access Road
- Existing Distribution Line
- Planned Distribution Line
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- Municipal Road
- Northern Affairs Community (NAC)
- First Nation

Manitoba

MANITOBA INFRASTRUCTURE
Lake Manitoba & Lake St.Martin Outlet Channels Project
Environmental Impact Statement

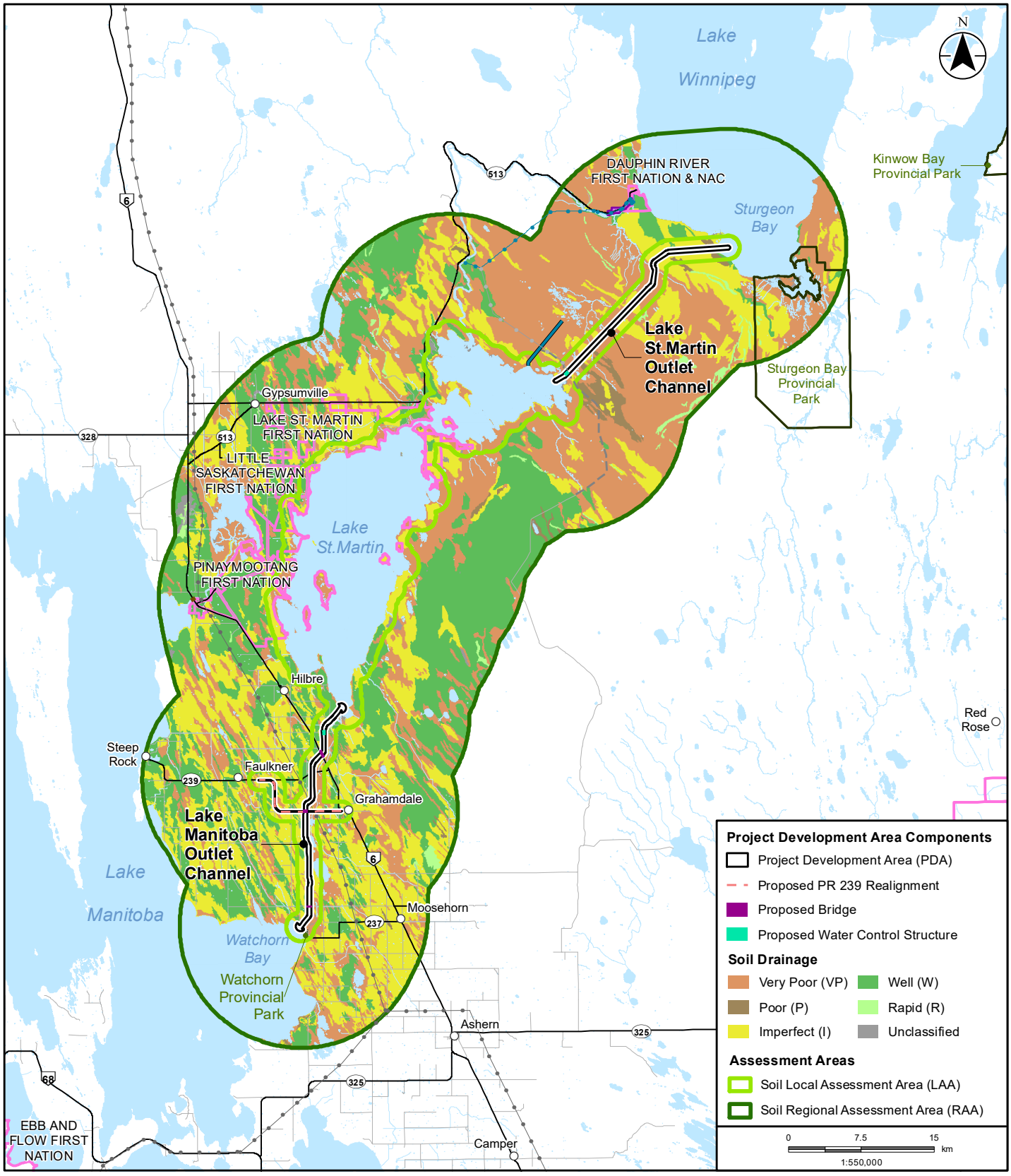
Terrain Map Units - Lake St.Martin Outlet Channel PDA

Figure 6.3B-7

Notes

1. Coordinate System: WGS 1984 UTM Zone 14N
2. Data Sources: Governments of Manitoba and Canada, Manitoba Infrastructure, CanSIS 2019, MLI 2019
3. Last Update: 8/9/2019 3:01:19 PM

G:\ GIS_Project_Folder\11473120\figures\Ch6_Physical_Environment\Final\Fig 6.3B-7 PE Terrain Units - LSMOC.mxd



Legend

- Fairford Water Control Structure
- Lake St.Martin Emergency Outlet Channel (Reach 1)
- Lake St.Martin Access Road
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Notes

1. Coordinate System: NAD 1983 UTM Zone 14N
2. Data Sources: Governments of Manitoba and Canada, Manitoba Infrastructure, CanSIS 2019, MLI 2019
3. Last Update: 8/9/2019 3:01:56 PM

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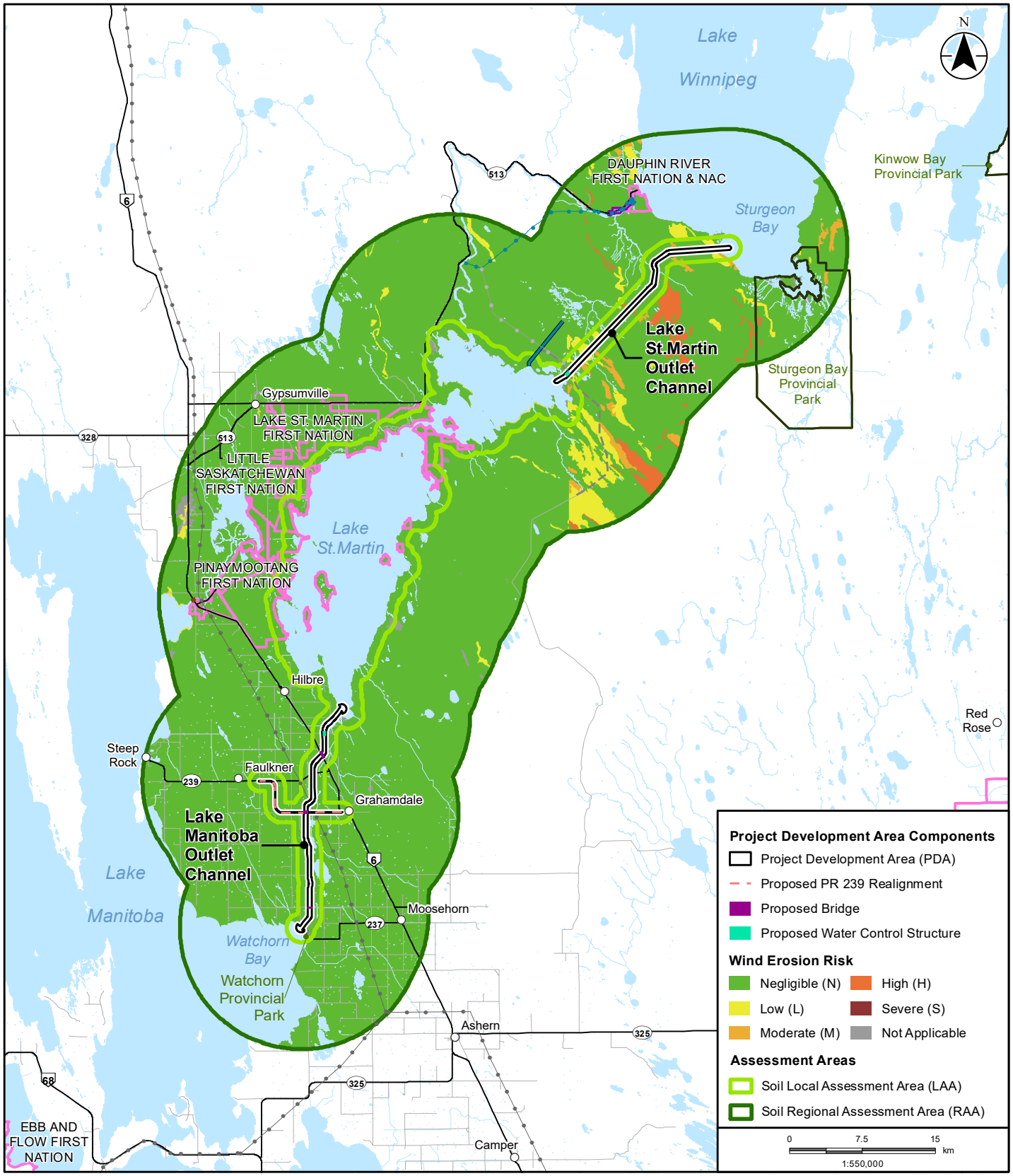
Lake Manitoba & Lake St.Martin Outlet Channels Project
Environmental Impact Statement

Soil Drainage Class

Figure 6.3B-8

G:\ GIS_Project_Folder\11475120\Figures\Ch6_Physical_Environment\Final\Fig 6.3B-8 PE Soil Drainage Class.mxd



Legend

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Notes

1. Coordinate System: NAD 1983 UTM Zone 14N
2. Data Sources: Governments of Manitoba and Canada, Manitoba Infrastructure, CanSIS 2019, MLI 2019
3. Last Update: 8/9/2019 3:02:24 PM

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Lake Manitoba & Lake St.Martin Outlet Channels Project
Environmental Impact Statement

Wind Erosion Risk

Figure 6.3B-9

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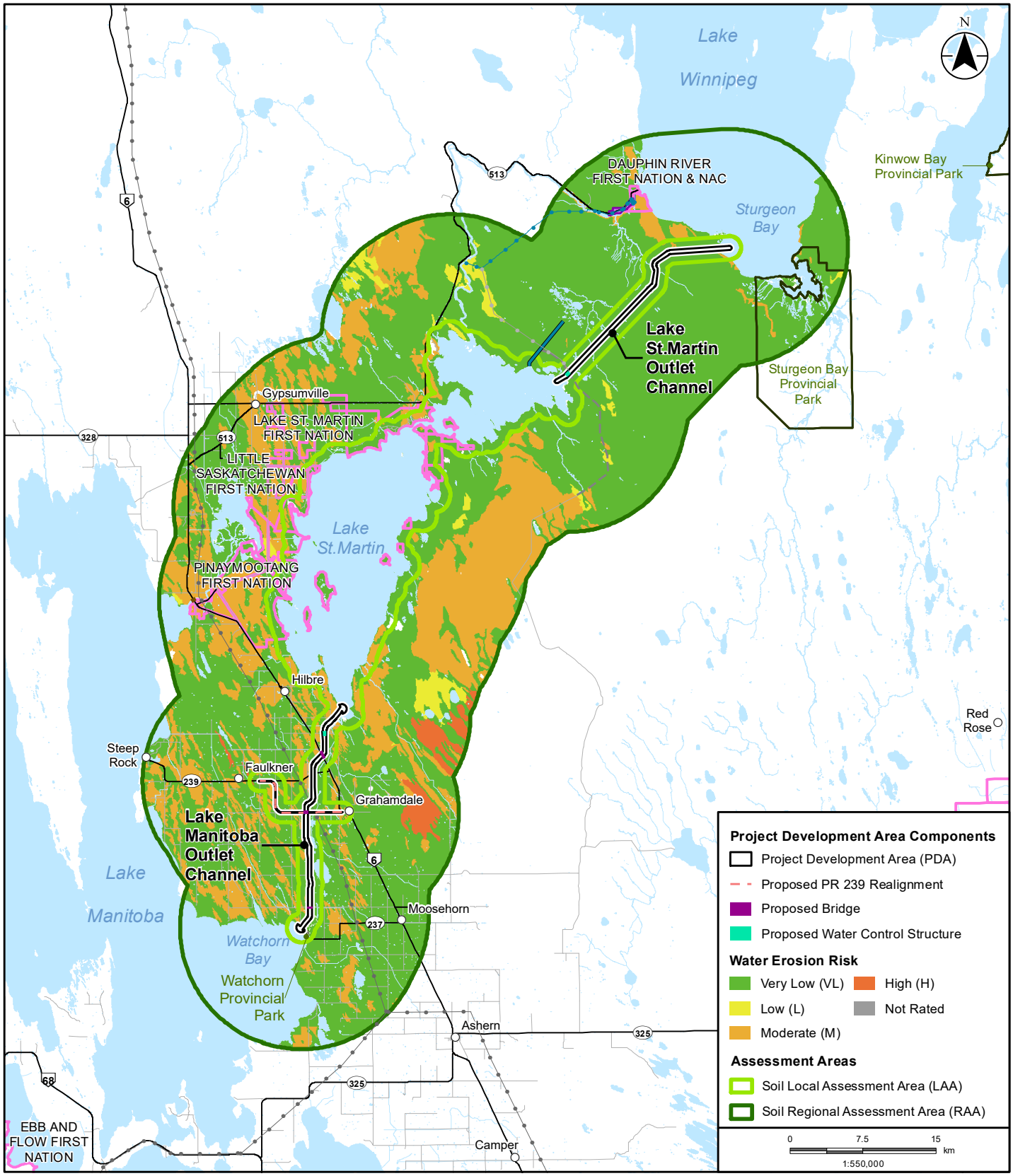

Legend

- Fairford Water Control Structure
- Lake St.Martin Emergency Outlet Channel (Reach 1)
- Lake St.Martin Access Road
- Existing Transmission Line
- Existing Distribution Line
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- Provincial Highway (PTH/PR)
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Notes

1. Coordinate System: NAD 1983 UTM Zone 14N
2. Data Sources: Governments of Manitoba and Canada, Manitoba Infrastructure. CanSIS 2019, MLI 2019
3. Last Update: 8/9/2019 3:03:24 PM

Manitoba

MANITOBA INFRASTRUCTURE
Lake Manitoba & Lake St.Martin Outlet Channels Project
Environmental Impact Statement

Water Erosion Risk

Figure 6.3B-10

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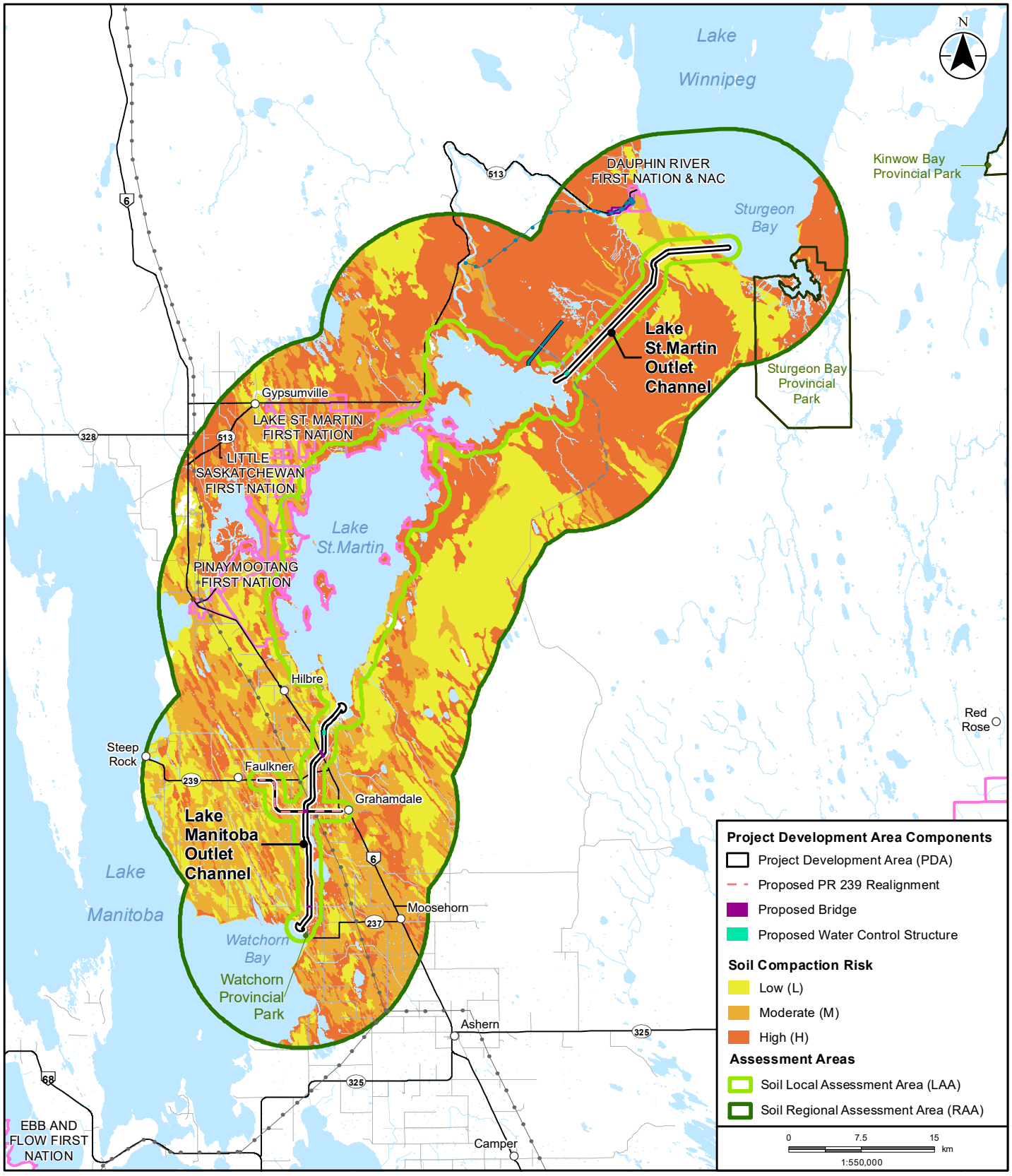


Legend

- Fairford Water Control Structure
- Lake St.Martin Emergency Outlet Channel (Reach 1)
- Lake St.Martin Access Road
- Existing Transmission Line
- Existing Distribution Line
- Planned Distribution Line
- Provincial Highway (PTH/PR)
- Municipal Road
- Northern Affairs Community (NAC)
- First Nation
- Provincial Park

Notes

1. Coordinate System: NAD 1983 UTM Zone 14N
2. Data Sources: Governments of Manitoba and Canada, Manitoba Infrastructure, CanSIS 2019, MLI 2019
3. Last Update: 8/9/2019 3:03:57 PM

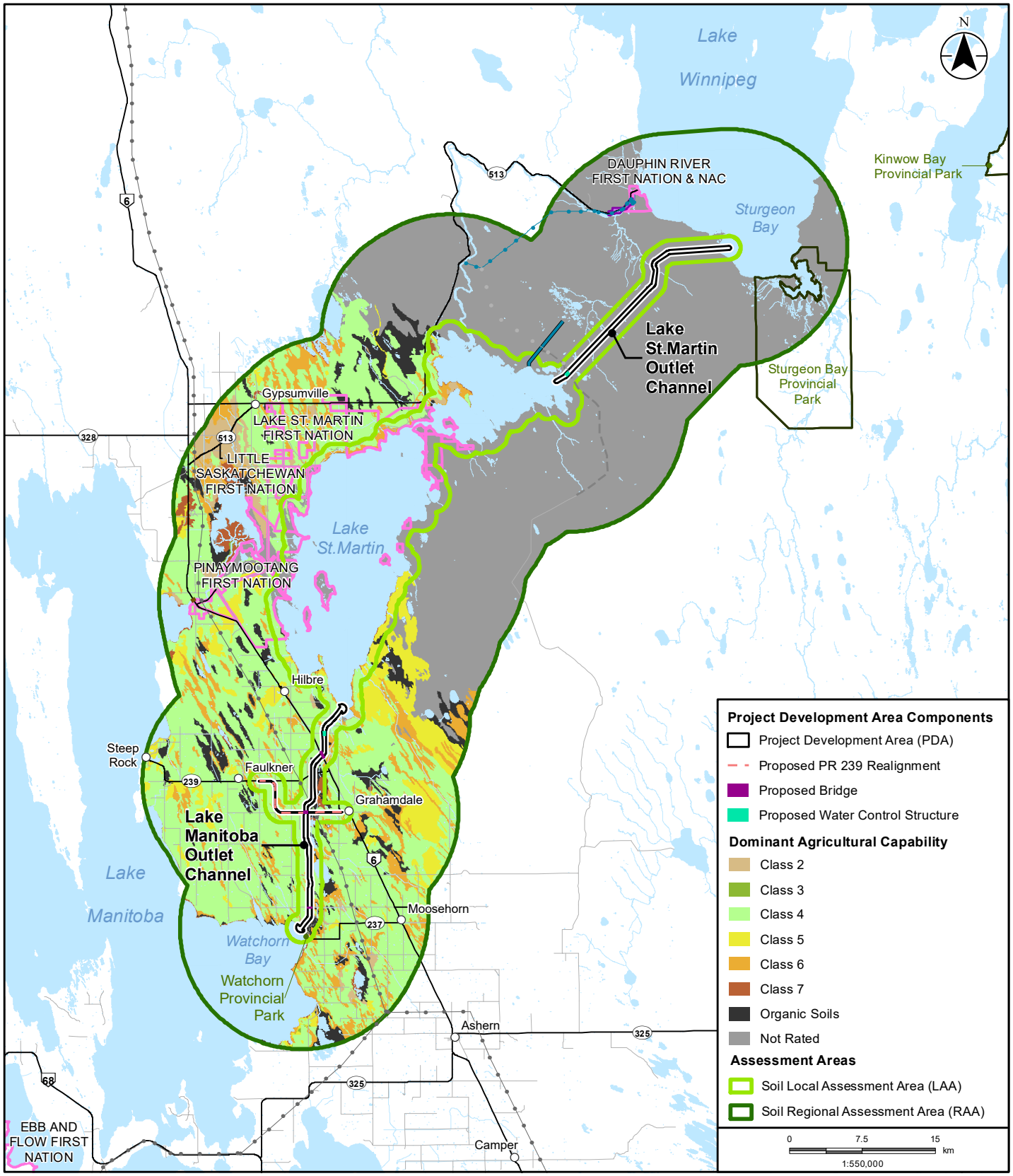
Manitoba

MANITOBA INFRASTRUCTURE
Lake Manitoba & Lake St.Martin Outlet Channels Project
Environmental Impact Statement

Soil Compaction Risk

Figure 6.3B-11

G:_GIS_Project_Folder\11473120\Figures\Ch6_Physical_Environment\Final\Fig 6.3B-11 PE Soil Compaction Risk.mxd



Legend

- Fairford Water Control Structure
- Lake St.Martin Emergency Outlet Channel (Reach 1)
- Lake St.Martin Access Road
- Existing Transmission Line
- Existing Distribution Line
- Planned Distribution Line
- Provincial Highway (PTH/PR)
- Municipal Road
- Northern Affairs Community (NAC)
- First Nation
- Provincial Park

Notes

1. Coordinate System: NAD 1983 UTM Zone 14N
2. Data Sources: Governments of Manitoba and Canada, Manitoba Infrastructure, CanSIS 2019, MLI 2019
3. Last Update: 8/9/2019 3:04:40 PM

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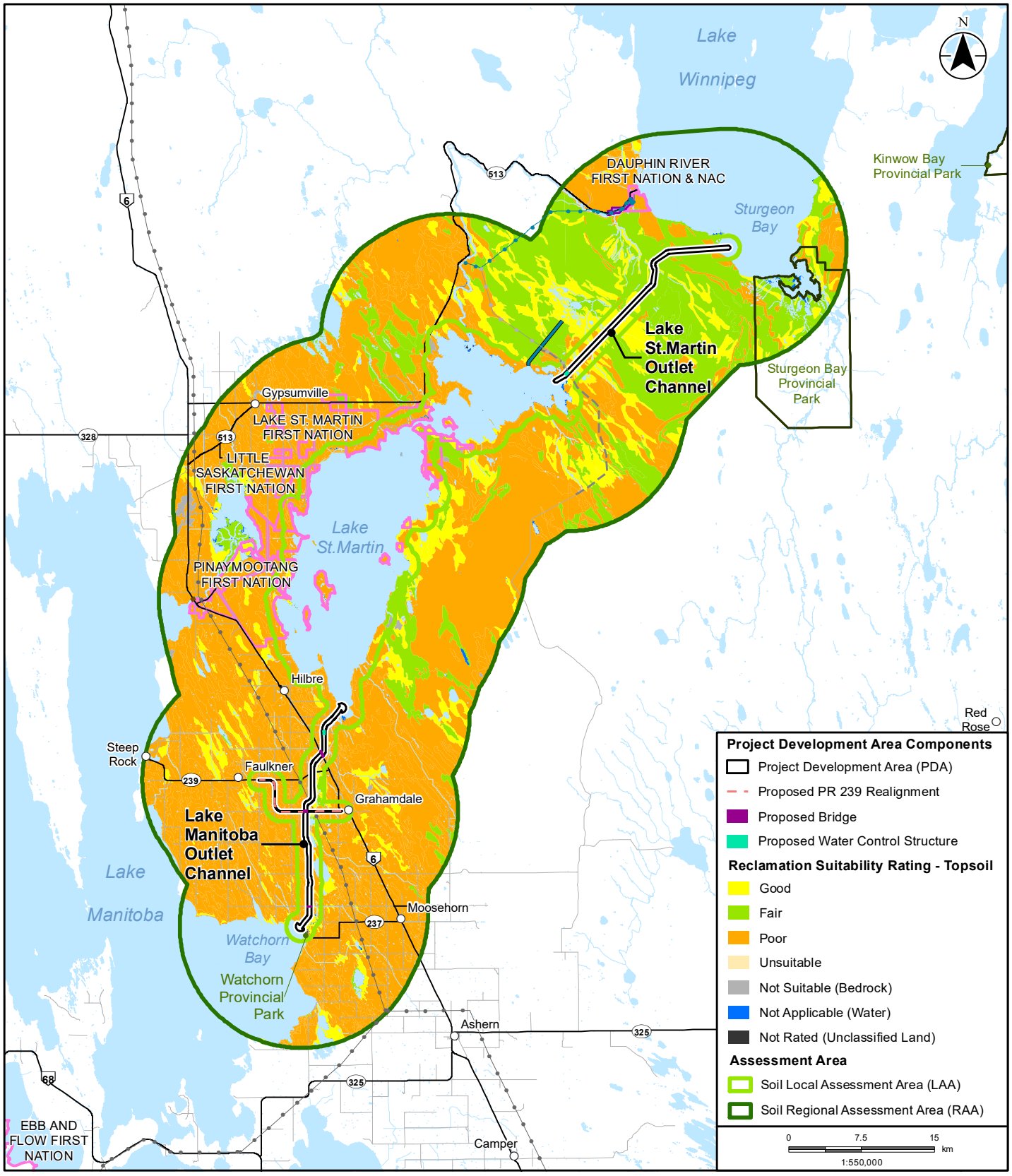
Environmental Impact Statement

Dominant Agricultural Capability

Figure 6.3B-12

G:\ GIS_Project_Folder\11475120\Figures\Ch6_Physical_Environment\Final\Fig 6.3B-12 PE Dominant Ag Capability.mxd



Legend

- Fairford Water Control Structure
- Lake St.Martin Emergency Outlet Channel (Reach 1)
- Lake St.Martin Access Road
- Existing Transmission Line
- Existing Distribution Line
- Planned Distribution Line
- Provincial Highway (PTH/PR)
- Municipal Road
- Northern Affairs Community (NAC)
- First Nation
- Provincial Park

Notes

1. Coordinate System: NAD 1983 UTM Zone 14N
2. Data Sources: Governments of Manitoba and Canada, Manitoba Infrastructure, CanSIS 2019, MLI 2019
3. Last Update: 8/9/2019 3:05:22 PM

Manitoba

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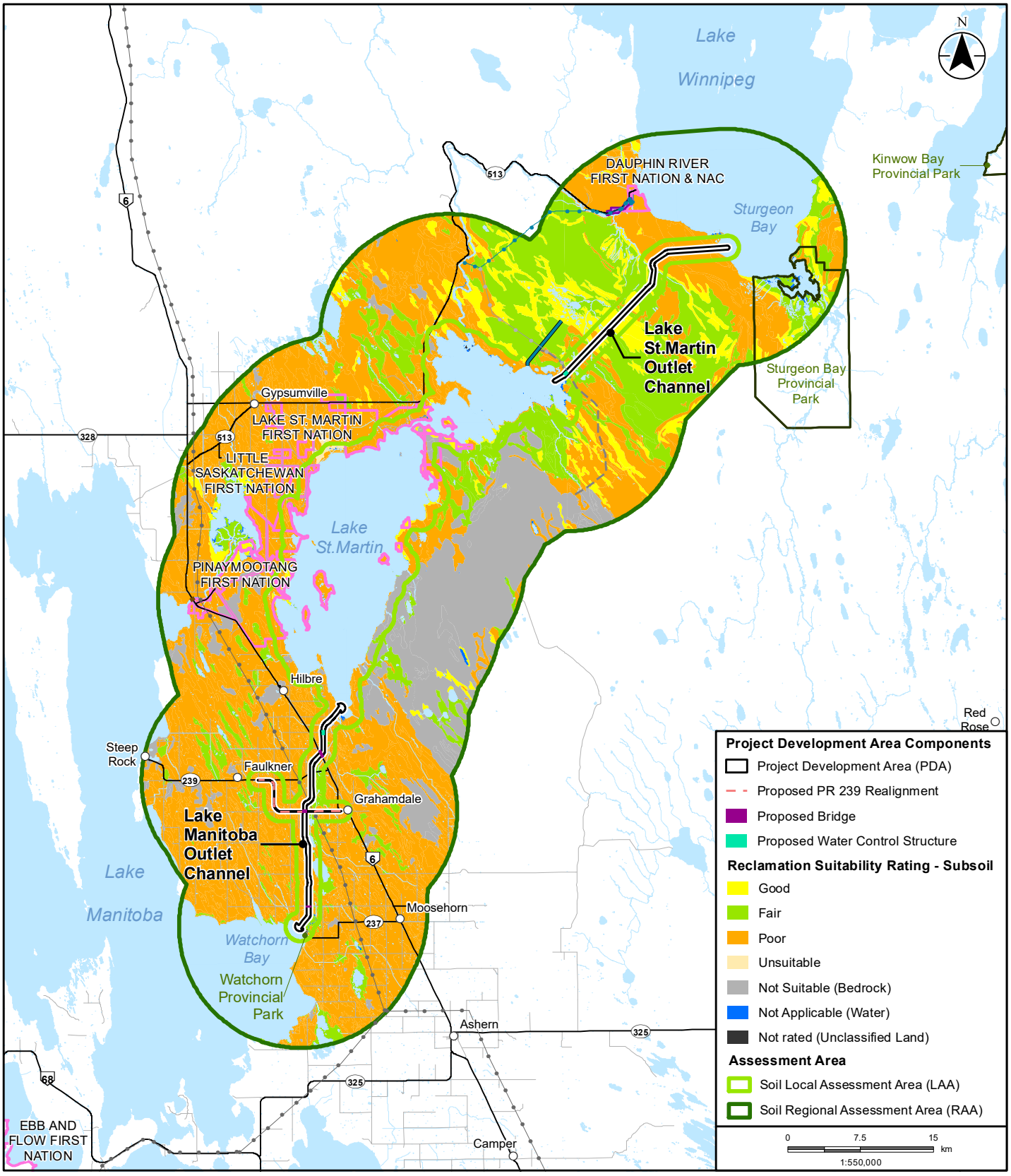
Lake Manitoba & Lake St.Martin Outlet Channels Project
Environmental Impact Statement

Reclamation Suitability Rating - Topsoil

Figure 6.3B-13

G:\ GIS_Project_Folder\114731201\figures\Ch6_Physical_Environment\Final\Fig 6.3B-13 PE Reclamation Suitability - Topsoil.mxd



Legend

- Fairford Water Control Structure
- Lake St.Martin Emergency Outlet Channel (Reach 1)
- Lake St.Martin Access Road
- Existing Transmission Line
- Existing Distribution Line
- Planned Distribution Line
- Provincial Highway (PTH/PR)
- Municipal Road
- Northern Affairs Community (NAC)
- First Nation
- Provincial Park

Notes

1. Coordinate System: NAD 1983 UTM Zone 14N
2. Data Sources: Governments of Manitoba and Canada, Manitoba Infrastructure, CanSIS 2019, MLI 2019
3. Last Update: 8/9/2019 3:06:45 PM

Manitoba

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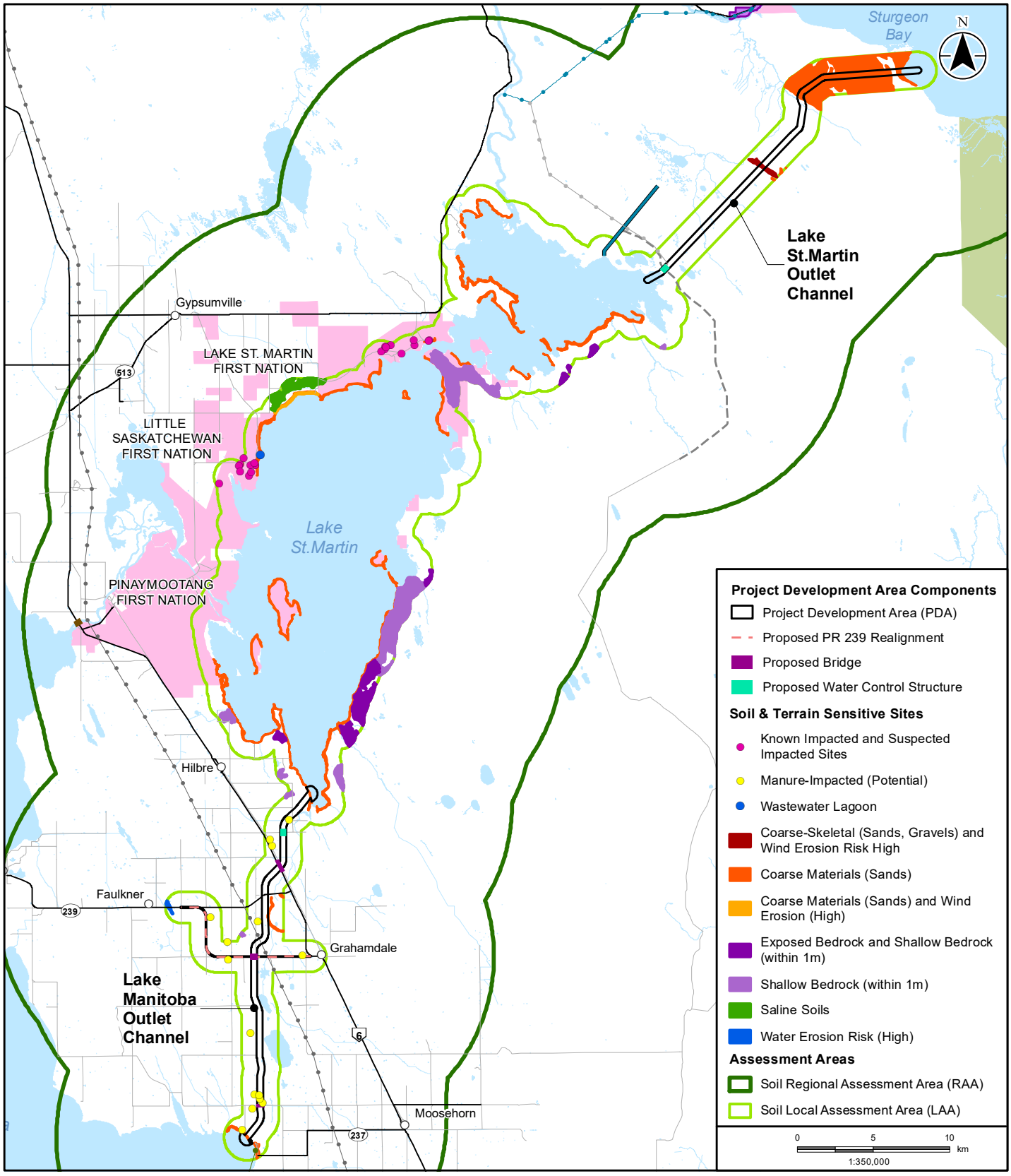
Lake Manitoba & Lake St.Martin Outlet Channels Project
Environmental Impact Statement

Reclamation Suitability Rating - Subsoil

Figure 6.3B-14

G:\ GIS_Project_Folder\11475120\figures\Ch6 Physical_Environment\Final\Fig 6.3B-14 PE Reclamation Suitability - Subsoil.mxd



Legend

- Fairford Water Control Structure
- Lake St.Martin Emergency Outlet Channel (Reach 1)
- Lake St.Martin Access Road
- Existing Transmission Line
- Existing Distribution Line
- Planned Distribution Line
- Provincial Highway (PTH/PR)
- Municipal Road
- Northern Affairs Community (NAC)
- First Nation
- Provincial Park

Notes

1. Coordinate System: NAD 1983 UTM Zone 14N
2. Data Sources: Governments of Manitoba and Canada, Manitoba Infrastructure, CanSIS 2019, MLI 2019
3. Last Update: 8/9/2019 3:07:49 PM

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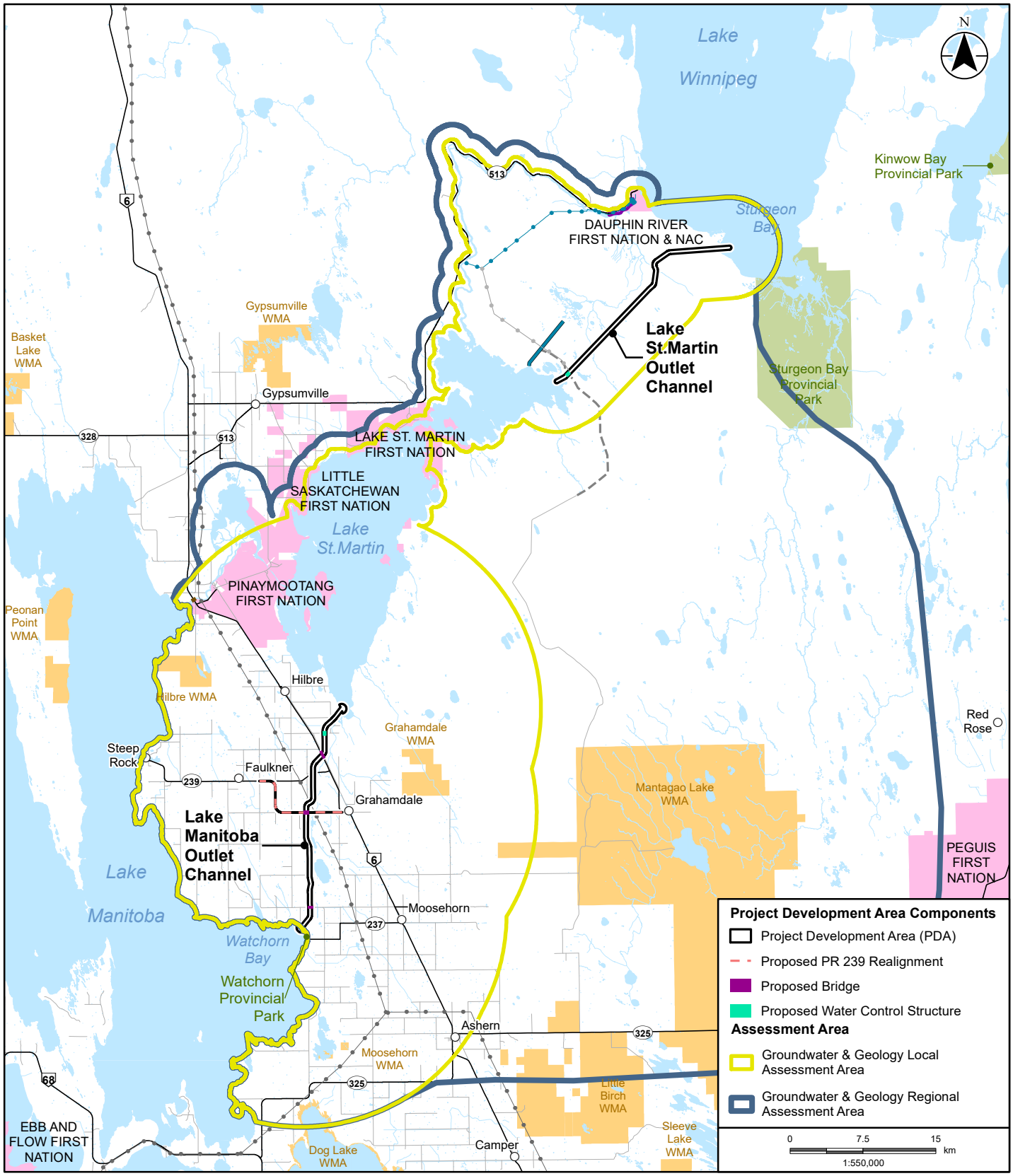
Lake Manitoba & Lake St.Martin Outlet Channels Project
Environmental Impact Statement

Soil and Terrain Sensitive Sites

Figure 6.3B-15

G:\ GIS Project Folder\11473120\figures\Ch6 Physical Environment\Final\Fig 6.3B-15 PE Soil Sensitive Soil and Terrain.mxd

6B.3 GROUNDWATER AND SURFACE WATER FIGURES



Legend

- Fairford Water Control Structure
- Lake St.Martin Emergency Outlet Channel (Reach 1)
- Lake St.Martin Access Road
- Existing Transmission Line
- Existing Distribution Line
- Planned Distribution Line
- Provincial Highway (PTH/PR)
- Municipal Road
- Northern Affairs Community (NAC)
- First Nation
- Wildlife Management
- Provincial Park

Notes

1. Coordinate System: NAD 1983 UTM Zone 14N
2. Data Sources: Governments of Manitoba and Canada, Manitoba Infrastructure, RM of Grahamdale
3. Last Update: 8/6/2019 5:04:35 PM

Manitoba

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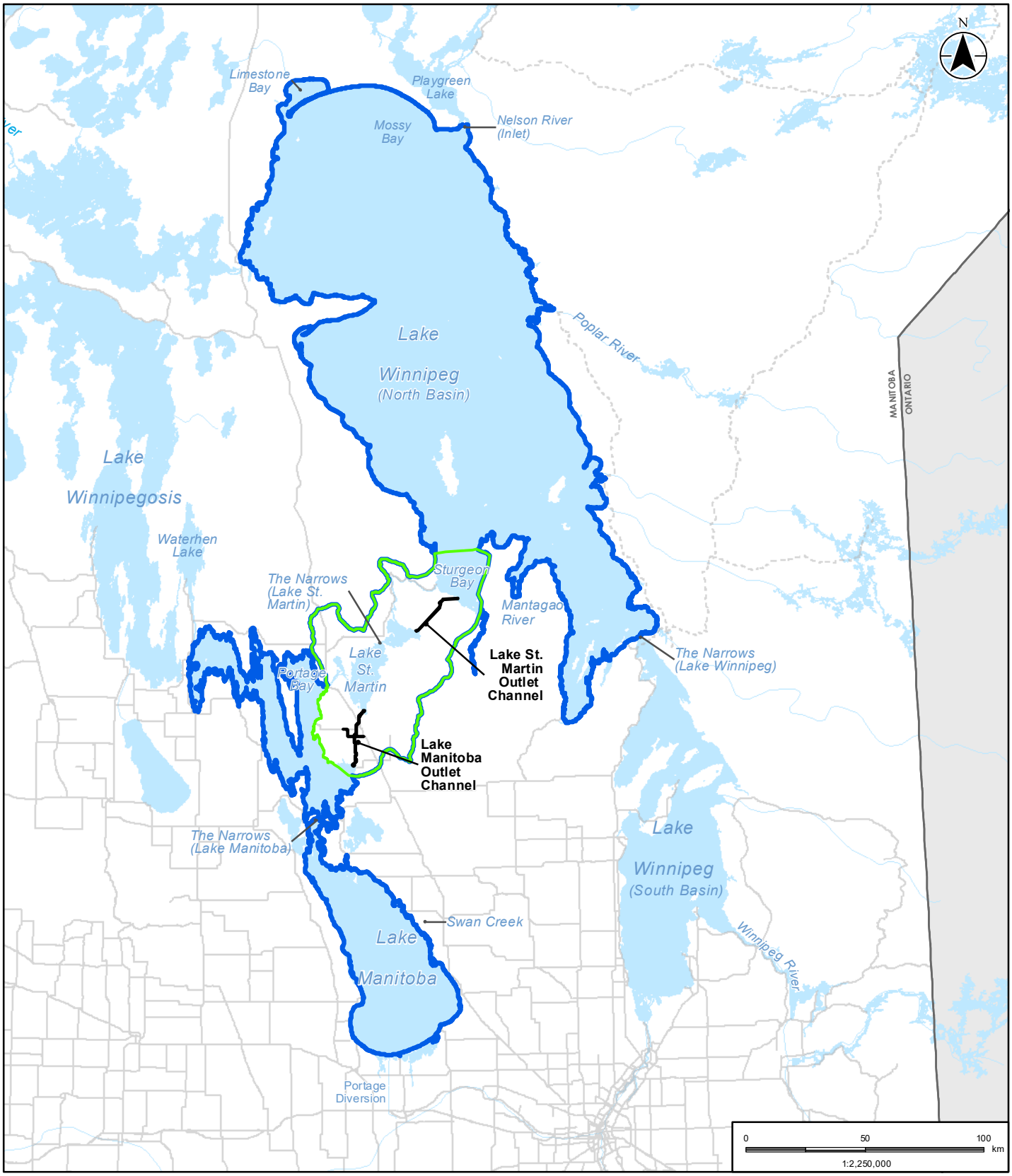
Lake Manitoba & Lake St.Martin Outlet Channels Project
Environmental Impact Statement

Groundwater Spatial Boundaries

Figure 6.4B-1

G:\ GIS Project Folder\11475120\figures\Ch6 Physical Environment\Pcr Review\Groundwater\Fig 6.4B-1 PE Groundwater Spatial Boundaries FINAL.mxd



Legend

- PDA
- LAA - Fish & Fish Habitat, Surface Water
- RAA - Fish & Fish Habitat, Surface Water
- Waterbody
- Major Highway
- Winter Road

Notes

1. Coordinate System: NAD 1983 UTM Zone 14N
2. Data Sources: Governments of Manitoba and Canada, Manitoba Infrastructure, RM of Grahamdale
3. Last Update: 8/6/2019 5:16:58 PM

Manitoba

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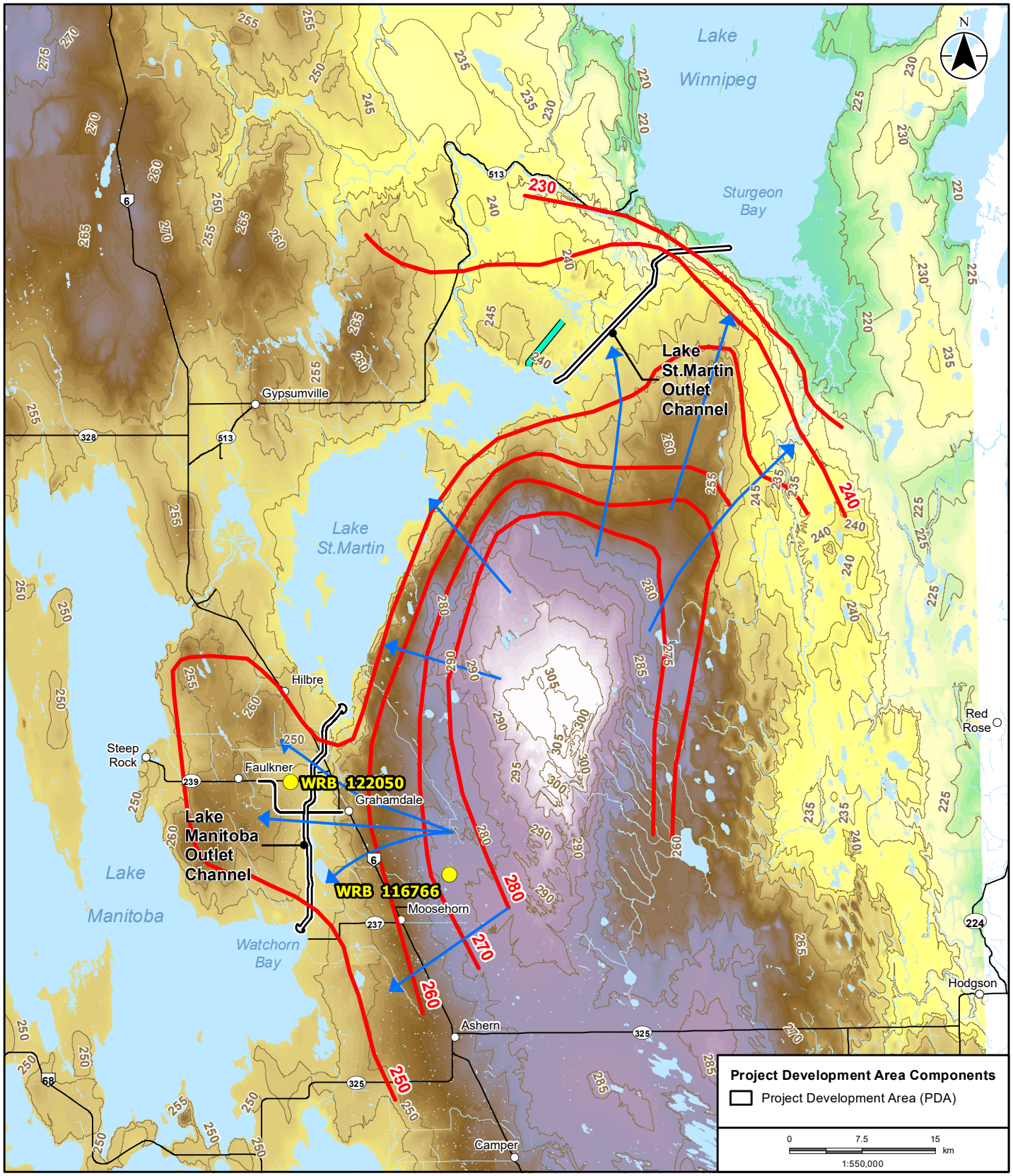
Lake Manitoba & Lake St.Martin Outlet Channels Project
Environmental Impact Statement

Surface Water Spatial Boundaries

Figure 6.4B-2

G:\ GIS_Project_Folder\114751201\gures\Ch6_Physical_Environment\Final\Fig 6.4B-2 SurfaceWater Boundaries.mxd



Legend

- Lake St.Martin Emergency Outlet Channel (Reach 1)
- Groundwater Flow Direction
- Groundwater Piezometric Head
- Surface Elevation Contour (masl)
- Ground Surface Elevation (masl)
  - High : 310
  - Low : 216
- Provincial Highway (PTH/PR)

Notes

1. Coordinate System: NAD 1983 UTM Zone 14N
2. Data Sources: Governments of Manitoba and Canada, Manitoba Infrastructure
3. Last Update: 8/7/2019 9:02:39 AM

Manitoba

MANITOBA INFRASTRUCTURE
Lake Manitoba & Lake St.Martin Outlet Channels Project
Environmental Impact Statement

Regional Groundwater Flow

Figure 6.4B-3

G:\ GIS Project Folder\11473\200\figures\Ch6 Physical Environment\Final\Fig 6.4B-3 PE Regional Groundwater Flow.mxd

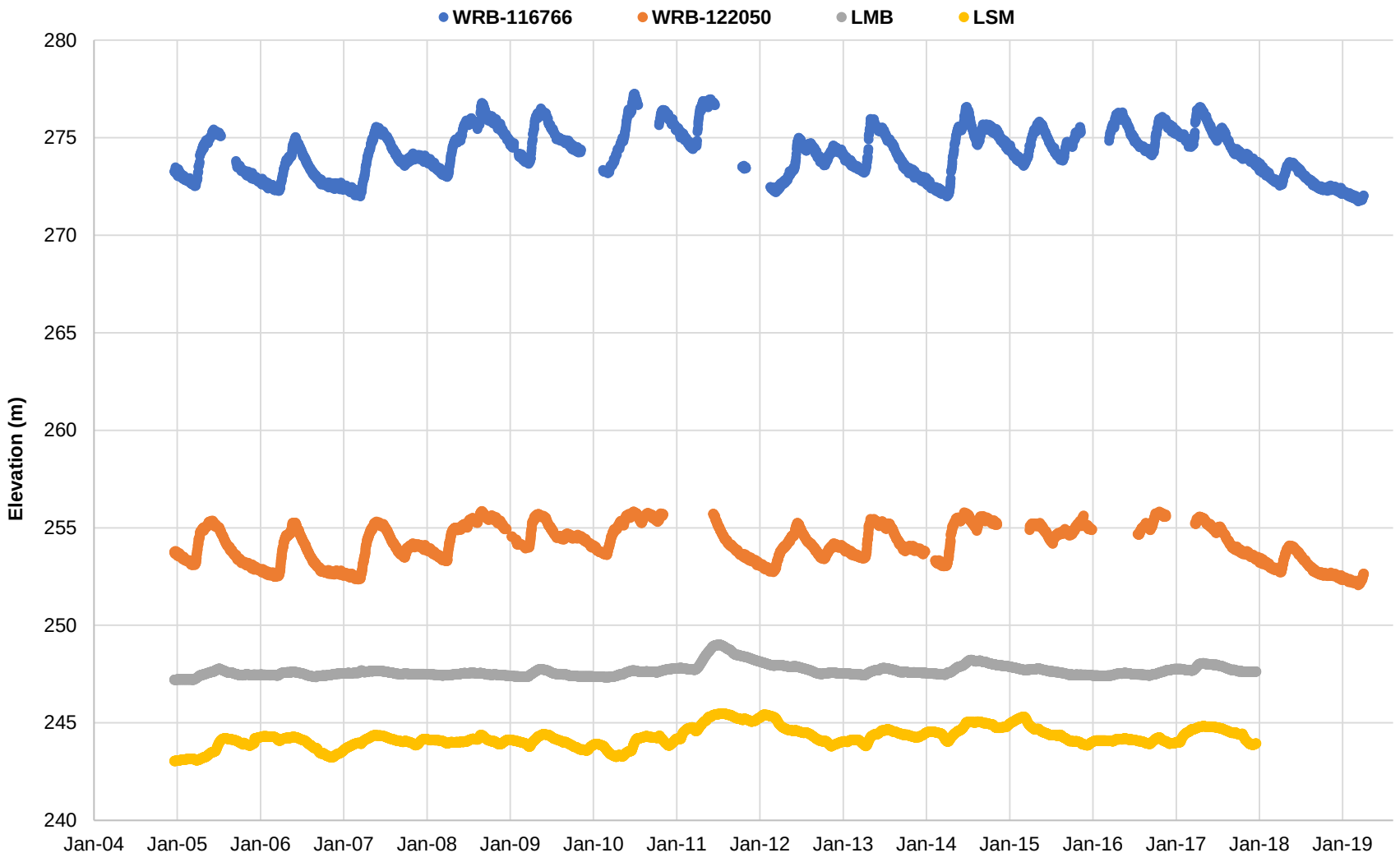
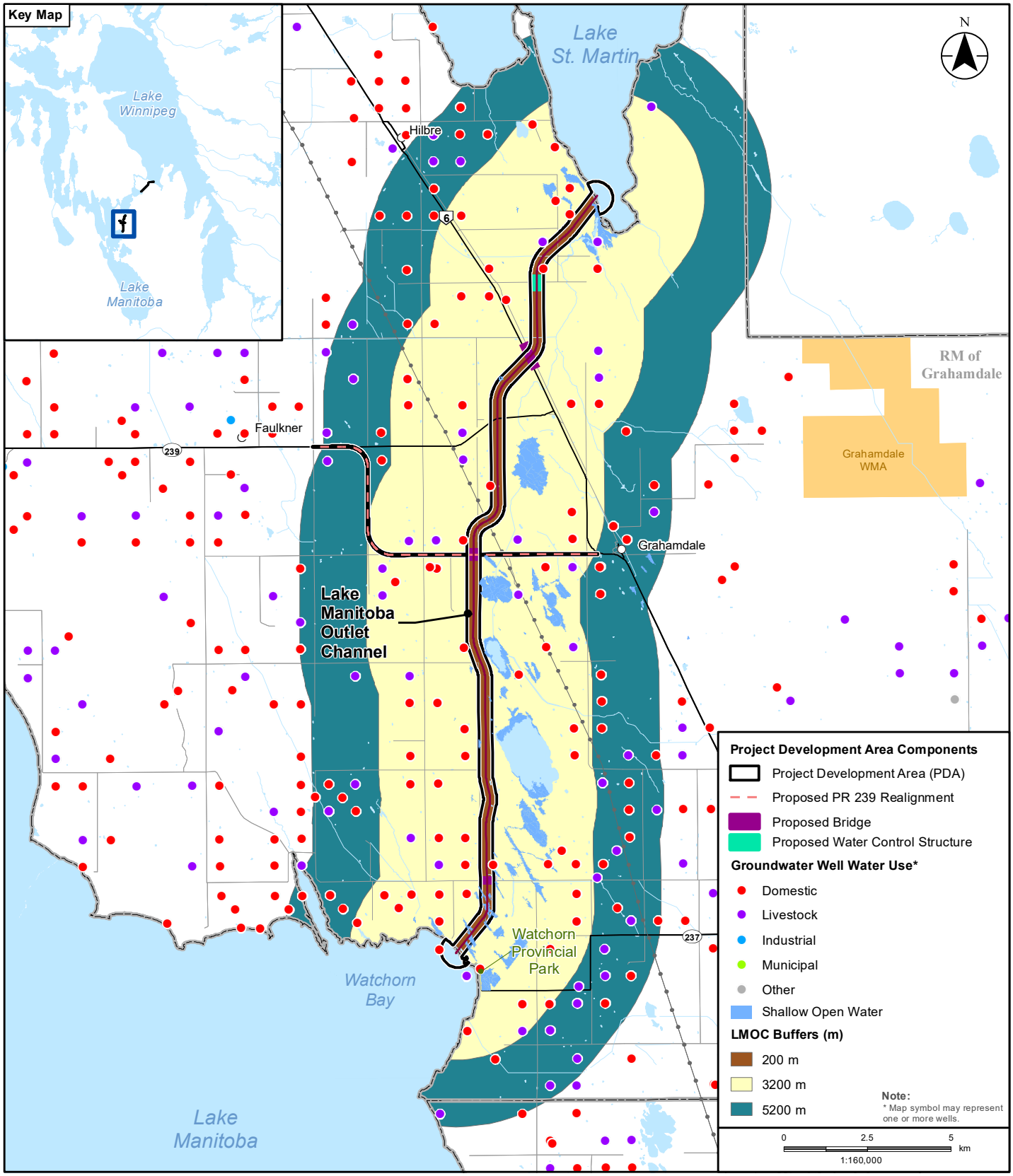


Figure 6.4B-4
Piezometric Water Elevations in the Carbonate Aquifer and Water Elevations in Lake Manitoba (LMB) and Lake St. Martin (LSM) (2005-2019)



Legend

- Existing Transmission Line
- Provincial Highway (PTH/PR)
- Municipal Road
- Wildlife Management
- Provincial Park
- Rural Municipality

Notes

1. Coordinate System: WGS 1984 UTM Zone 14N
2. Data Sources: Governments of Manitoba and Canada, Manitoba Infrastructure
3. Last Update: 8/7/2019 9:14:24 AM

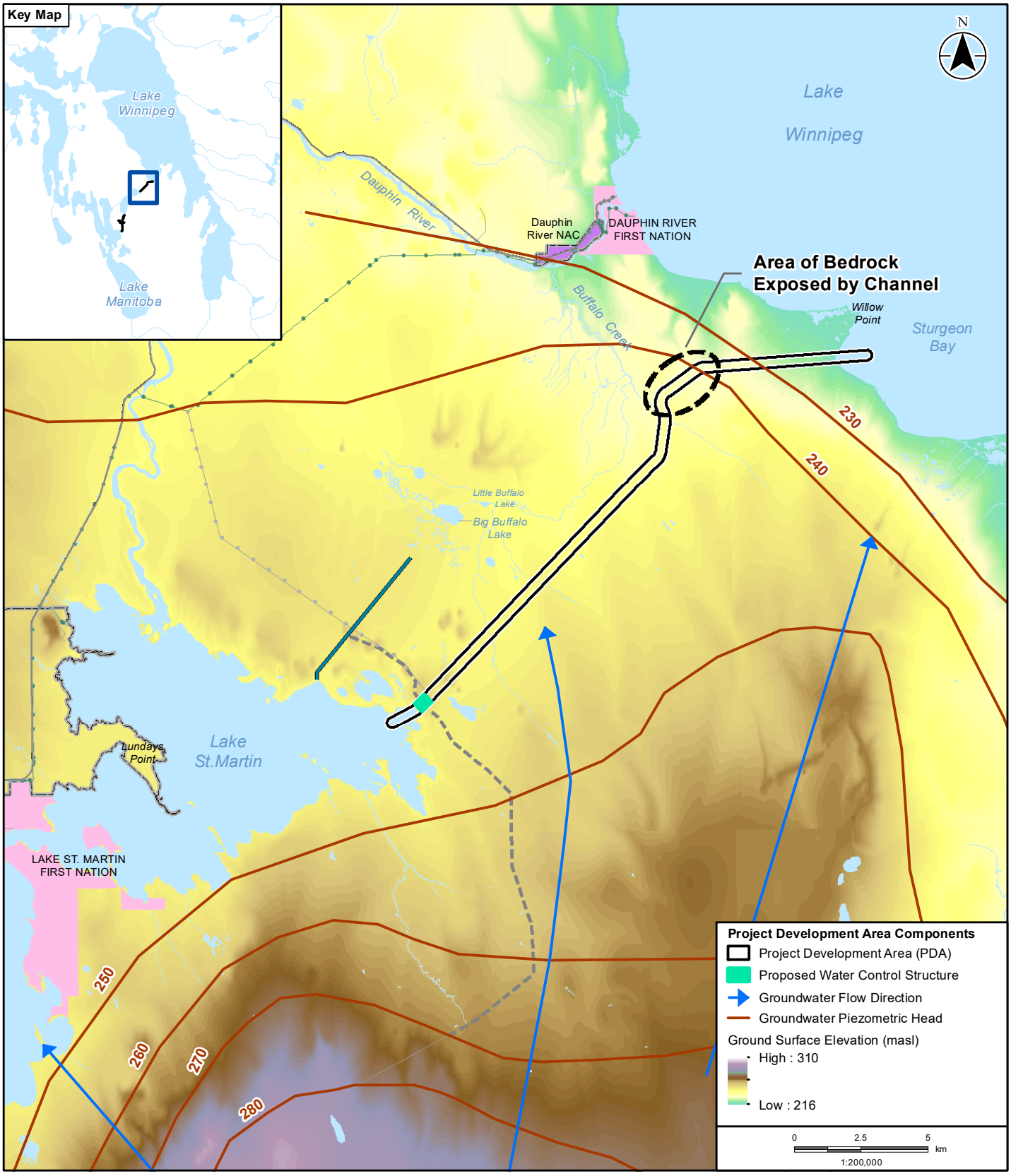
Manitoba

MANITOBA INFRASTRUCTURE
Lake Manitoba & Lake St.Martin Outlet Channels Project
Environmental Impact Statement

Location of Water Wells within the Buffer Zone

Figure 6.4B-5

G:\ GIS Project Folder\11473120\figures\Ch6 Physical Environment\Final\Fig 6.4B-5 PE Location of Water Wells within the Buffer Zone.mxd



Legend

- Lake St.Martin Emergency Outlet Channel (Reach 1)
- Lake St.Martin Access Road
- Existing Distribution Line
- Planned Distribution Line
- Provincial Highway (PTH/PR)
- Municipal Road
- First Nation
- Northern Affairs Community (NAC)
- Rural Municipality

Notes

1. Coordinate System: WGS 1984 UTM Zone 14N
2. Data Sources: Governments of Manitoba and Canada, Manitoba Infrastructure
3. Last Update: 8/6/2019 5:30:07 PM

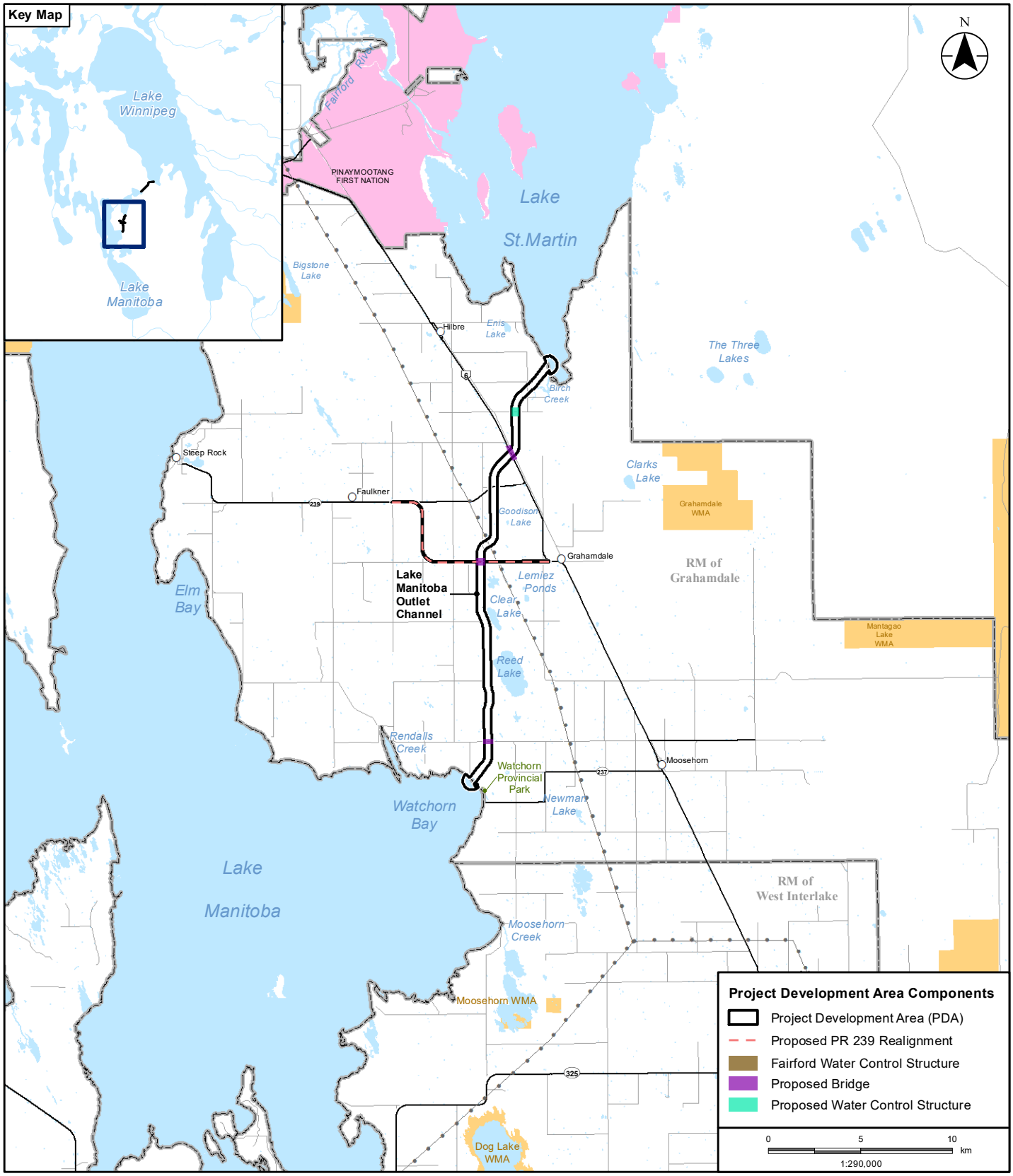
Manitoba

MANITOBA INFRASTRUCTURE
Lake Manitoba & Lake St.Martin Outlet Channels Project
Environmental Impact Statement

Location of Possible Carbonate Aquifer Daylighting

Figure 6.4B-6

G:\ GIS Project Folder\11473120\figures\Ch6 Physical Environment\Final\Fig 6.4B-6 PE Location of Possible Carbonate Aquifer Daylighting RNAL.mxd



Legend

- Existing Transmission Line
- Provincial Highway (PTH/PR)
- Municipal Road
- First Nation
- Wildlife Management Area
- Provincial Park
- Rural Municipality

Notes

1. Coordinate System: WGS 1984 UTM Zone 14N
2. Data Sources: Governments of Manitoba and Canada, Manitoba Infrastructure
3. Last Update: 8/7/2019 8:52:00 AM

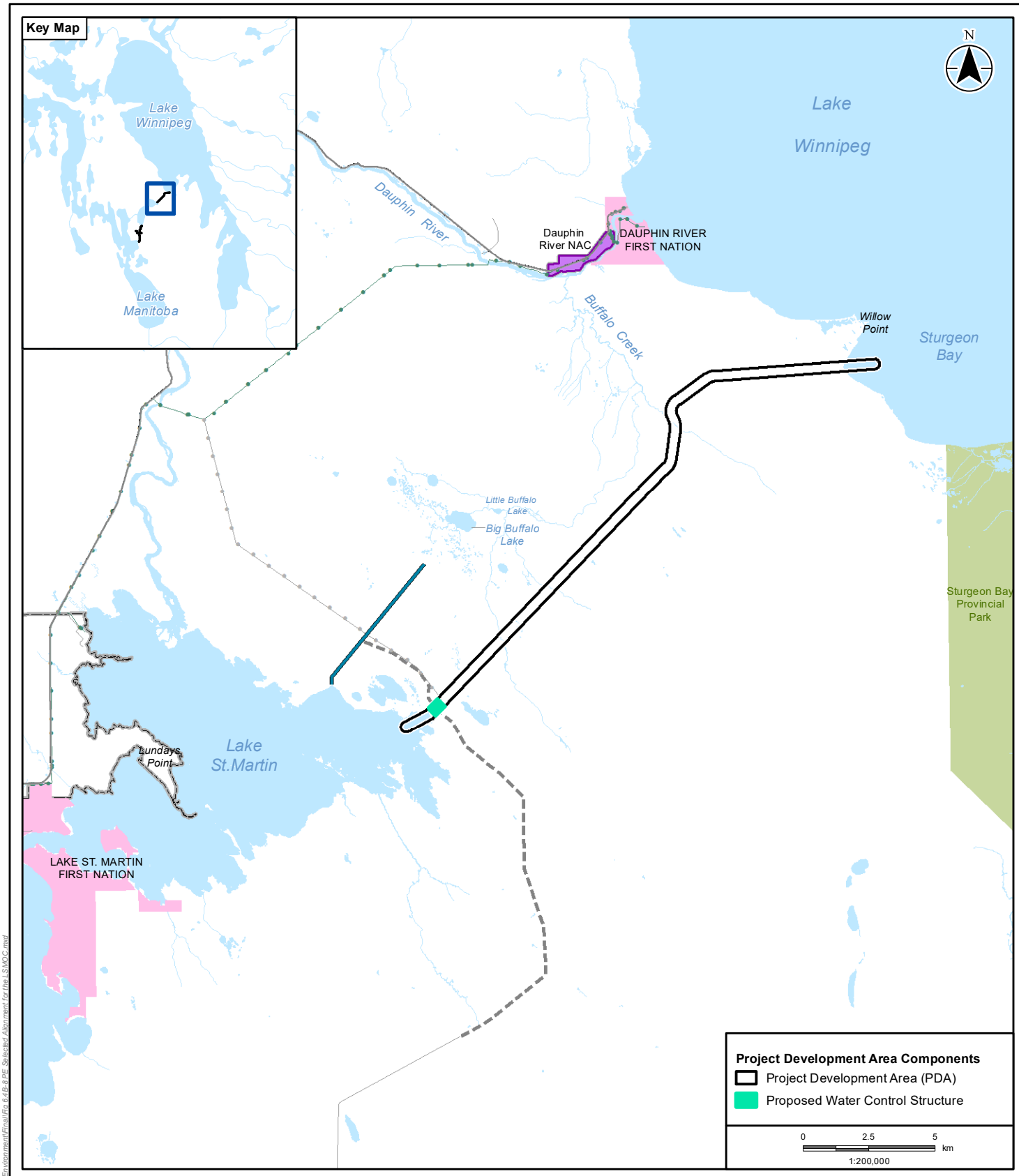
Manitoba

MANITOBA INFRASTRUCTURE
Lake Manitoba & Lake St.Martin Outlet Channels Project
Environmental Impact Statement

Selected Alignment for the LMOC

Figure 6.4B-7

\\Ca0045-ctbgf01\gis_GIS Project Folder\1147512\0\figures\Ch6 Physical Environment\Final\Fig 6.4B-7 PE Selected Alignment for the LMOC.mxd



Legend

- Lake St.Martin Emergency Outlet Channel (Reach 1)
- Lake St.Martin Access Road
- Existing Distribution Line
- Planned Distribution Line
- Provincial Highway (PTH/PR)
- Municipal Road
- Rural Municipality
- Northern Affairs Community (NAC)
- First Nation
- Provincial Park

Notes

1. Coordinate System: WGS 1984 UTM Zone 14N
2. Data Sources: Governments of Manitoba and Canada, Manitoba Infrastructure
3. Last Update: 8/6/2019 6:20:16 PM

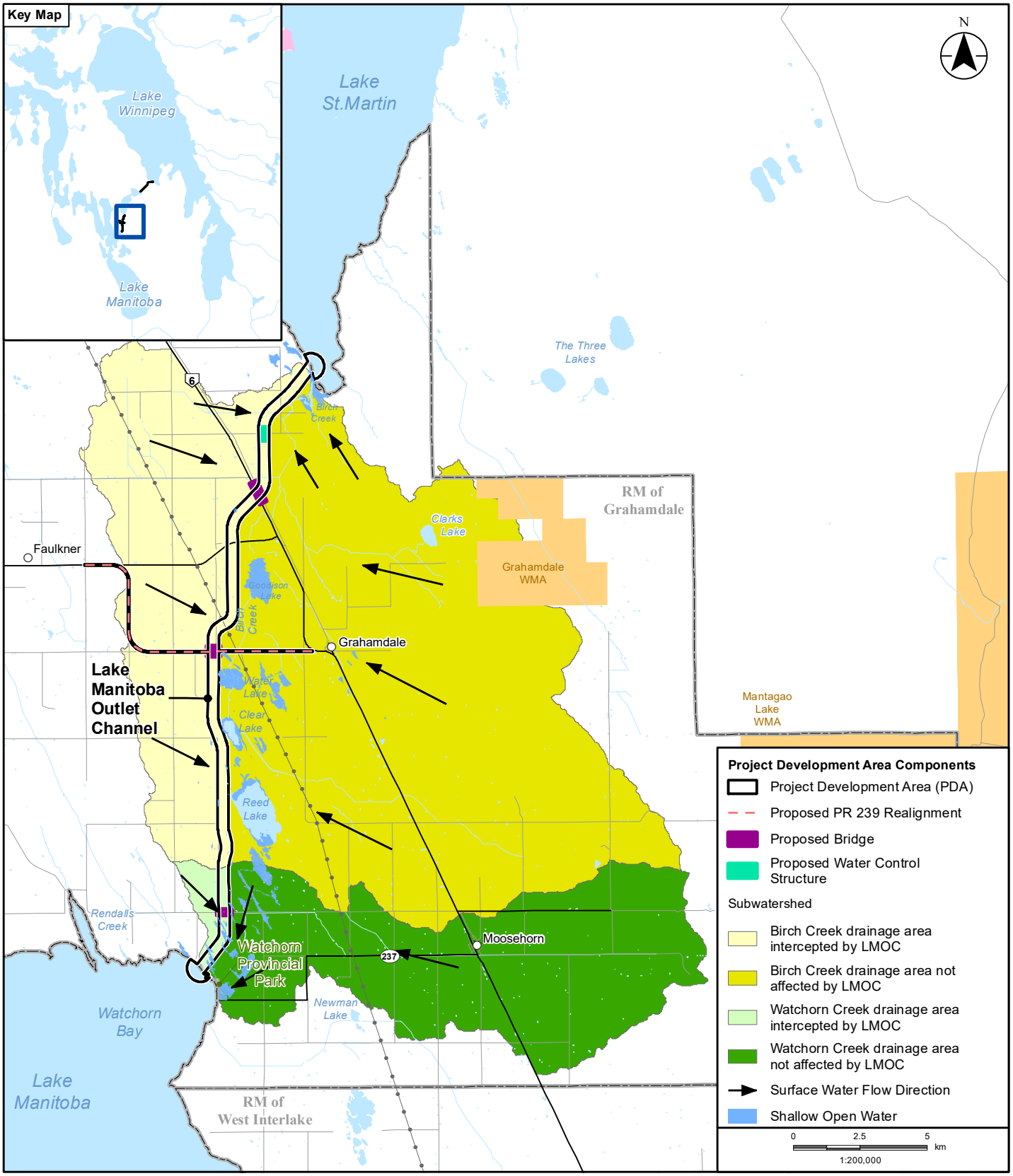
Manitoba

MANITOBA INFRASTRUCTURE
Lake Manitoba & Lake St.Martin Outlet Channels Project
Environmental Impact Statement

Selected Alignment for the LSMOC

Figure 6.4B-8

G:\ GIS Project Folder\11473120\figures\Ch6 Physical Environment\Final\Fig 6.4B-8 PE Selected Alignment for the LSMOC.mxd



Legend

- Existing Transmission Line
- Provincial Highway (PTH/PR)
- Municipal Road
- First Nation
- Wildlife Management Area
- Provincial Park
- Rural Municipality
- Watercourse
- Waterbody

Notes

1. Coordinate System: WGS 1984 UTM Zone 14N
2. Data Sources: Governments of Manitoba and Canada,Manitoba Infrastructure
3. Last Update: 8/6/2019 6:28:54 PM

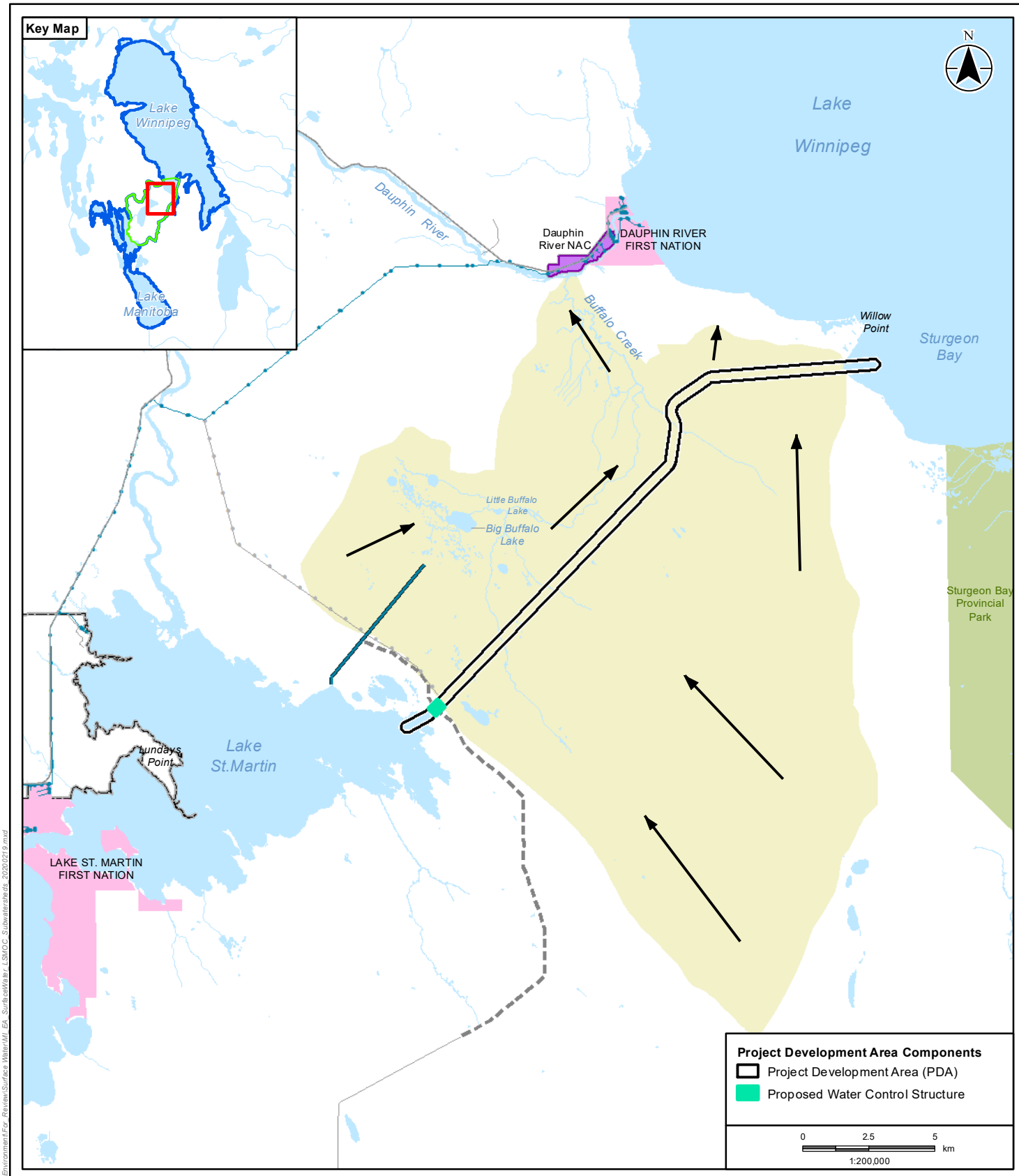
Manitoba

MANITOBA INFRASTRUCTURE
Lake Manitoba & Lake St.Martin Outlet Channels Project
Environmental Impact Statement

Lake Manitoba Outlet Channel and Existing Drainage Patterns

Figure 6.4B-9

G:\ GIS Project Folder\11473120\figures\Ch6 Physical Environment\Final\Fig 6.4B-9 PE Lake Manitoba Outlet Channel and Existing Drainage Patterns.mxd



Legend

- Lake St.Martin Emergency Outlet Channel (Reach 1)
- Lake St.Martin Access Road
- Existing Distribution Line
- Planned Distribution Line
- Provincial Highway (PTH/PR)
- Municipal Road
- Rural Municipality
- Northern Affairs Community (NAC)
- First Nation
- Provincial Park
- Surface Water Flow Direction
- Estimated Drainage Area

Notes

1. Coordinate System: WGS 1984 UTM Zone 14N
2. Data Sources: Governments of Manitoba and Canada, Manitoba Infrastructure, RM of Grahamdale
3. Last Update: 2/19/2020 9:14:43 AM

Manitoba

MANITOBA INFRASTRUCTURE
Lake Manitoba & Lake St.Martin Outlet Channels Project
Environmental Impact Statement

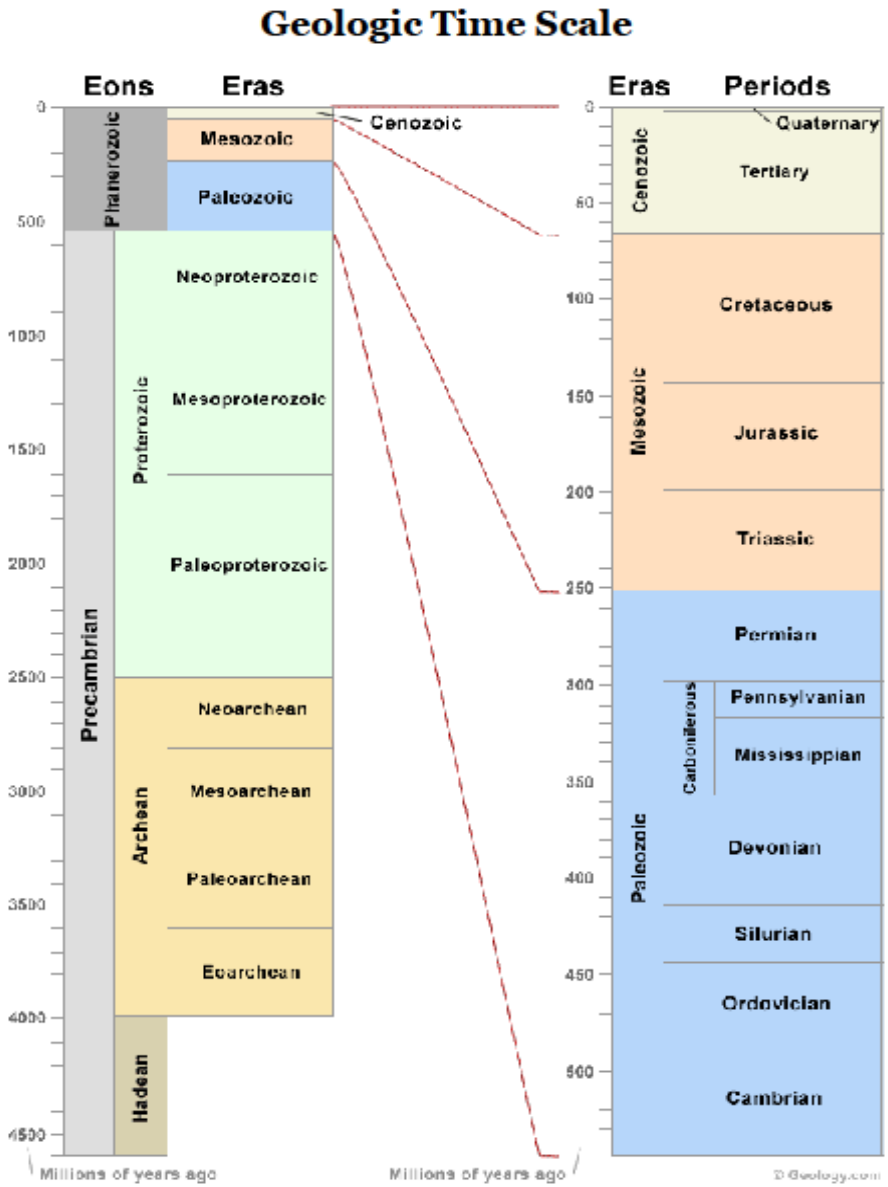
Location of the LSMOC and Existing Drainage Patterns

Figure 6.4B-10

G:\ GIS Project Folder\1147512\0\figures\Ch6 Physical Environment\For Review\Surface Water\MM_EA_SurfaceWater_LSMOC_Subwatersheds_20200219.mxd

Appendix 6C GEOLOGY DOCUMENTS

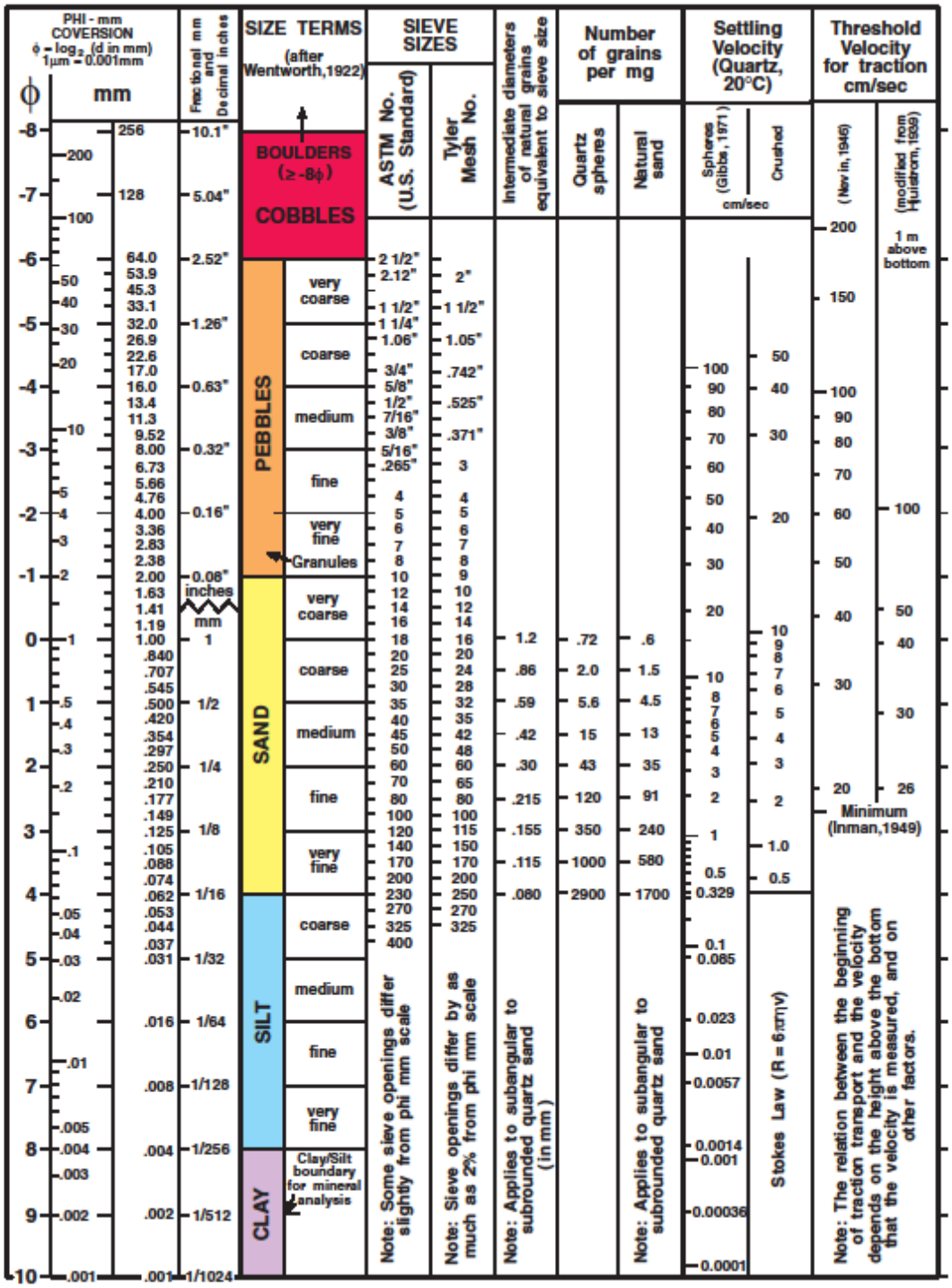
6C.1 GEOLOGICAL AGE SCALE



Geological Time Scale copyright 2010 - geology.com

http://www.geology.com/ http://geology.com/time.htm

6C.2 UNCONSOLIDATED SEDIMENTS CLASSIFICATION



6C.3 EARTHQUAKE SCALE

:

Earthquake Magnitude Scales

The severity of an earthquake is generally proportional to the amount of seismic energy it releases. Seismologists use a Magnitude scale to express this energy release. Here are the typical effects of earthquakes in various magnitude ranges.

Magnitude	Effects
Less than 3.5	Recorded on local seismographs, but generally not felt.
3.5 - 5.4	Often felt, but rarely cause damage.
Under 6.0	At most slight damage to well-designed buildings. Can cause major damage to poorly constructed buildings over small regions.
6.1 - 6.9	Can cause damage to poorly constructed buildings and other structures in areas up to about 100 kilometers across where people live.
7.0 - 7.9	"Major" earthquake. Can cause serious damage over larger areas.
8.0 - 8.9	"Great" earthquake. Can cause serious damage and loss of life in areas several hundred kilometers across.
9	Rare great earthquake. Can cause major damage over a large region over 1000 km across.

6C.4 CARBONATE ROCKS CLASSIFICATION

<table>
<tr><td colspan="9">Modified Dunham Classification (Dunham, 1962;[1] Embry and Klovan, 1971[2])</td></tr>
<tr><td colspan="5">Allochthonous Limestones - No evidence that the original components were bound together at the time of deposition</td><td colspan="4" rowspan="2">Autochthonous Limestones - Original components were organically-bound during deposition</td></tr>
<tr><td colspan="3">Less that 10% of the components are > 2 mm</td><td colspan="2" rowspan="2">Greater that 10% of the components are > 2 mm</td></tr>
<tr><td colspan="2">Contains lime mud</td><td>No lime mud</td><td rowspan="3">Bound by organisms that act as baffles</td><td rowspan="3">Bound by organisms that encrust and bind - the rock is supported by the matrix</td><td rowspan="3">Bound by organisms that build a rigid framework - the rock is supported by the fossil framework</td></tr>
<tr><td colspan="2">Mud-supported</td><td rowspan="2">Grain-supported</td><td rowspan="2">Matrix-supported</td><td rowspan="2">Grain-supported by the >2 mm size fraction</td></tr>
<tr><td>Less than 10% grains - 2 mm)</td><td>Greater than 10% grains - 2 mm)</td></tr>
<tr><td>Mudstone</td><td>Wackestone</td><td>Packstone Grainstone</td><td>Floatstone</td><td>Rudstone</td><td>Bafflestone</td><td>Bindstone</td><td>Framestone</td></tr>
</table>

Appendix 6D EXISTING CONDITIONS FOR SURFACE WATER

6D.1 REGIONAL AND LOCAL HYDROLOGY

The proposed Project components will be located mainly within the Lake St. Martin watershed, which is connected to the Lake Manitoba watershed to the south and west, and to the Lake Winnipeg watershed to the north and east (Figure 6.4B-2). The Lake St. Martin watershed receives flows from the Lake Manitoba watershed via the Fairford River, which is the only outlet for the Lake Manitoba watershed. Water from Lake Manitoba flows through the Fairford River and Lake Pineimuta to Lake St. Martin, then enters the Dauphin River and flows to Sturgeon Bay in Lake Winnipeg. Prior to the construction and operation of the Lake St. Martin Emergency Outlet Channel (EOC), the Dauphin River was the only outlet from Lake St. Martin to Lake Winnipeg. Figure 6.4B-2 (Appendix 6B), Figure 6.4B-7 and Figure 6.4B-8 (Appendix 6B) above provide maps and locations of the regional and local waterways discussed below.

6D.1.1 Lake Manitoba

Lake Manitoba is the 33rd largest lake in the world with a length of 225 kilometres (km) from north to south and 915 km of shoreline (LMRRC 2003). The lake is naturally divided into north and south basins at the Lake Manitoba Narrows, located approximately halfway along its length (Figure 6.4B-2). Water depths are about five metres on average, with a maximum depth of about seven metres (LMRRC 2003). The south basin is broad and shallow, and measures approximately 40 km across at its widest point, with a shoreline composed mainly of sand and clay, and generally soft and silty substrates (LMRRC 2003). The shoreline of the northern basin is more irregular, with prominent limestone bedrock outcrops, and the lake bottom has more rock and gravel than the south basin (LMRRC 2003). Lake Manitoba as measured at the Fairford River inlet has a drainage area of approximately 79,800 km^2, and a surface area of approximately 4,500 km^2 (KGS Group 2016a).

With the exception of the Whitemud River, the major streams in the Lake Manitoba watershed flow either directly or indirectly into Lake Winnipegosis, which outlets to the Waterhen River. The Waterhen River enters Lake Manitoba from the northwest area of the basin, and the Whitemud River enters Lake Manitoba from the southwest area of the basin. The majority of inflow to Lake Manitoba is from Lake Winnipegosis through the Waterhen River, with smaller amounts contributed via the Whitemud River, artificial drains, intermittent streams, groundwater, and from overland runoff (LMRRC 2003). The Lake Manitoba basin also receives flows from the Assiniboine River watershed via the Portage Diversion when the diversion is in operation.

Fisheries investigations conducted in the fall of 2015 and spring of 2016 in Lake Manitoba south of the Fairford River inlet included sonar analysis and ground-truthing of the lake substrates (AAE Tech Services Inc. [AAE] 2016). The sonar analysis identified that substrates within approximately 200 m of the shoreline at depths less than 1 m were composed primarily of gravel with some sand and cobbles, with boulder gardens also common in this nearshore habitat (AAE 2016). At about 200 m to 400 m from the shoreline at depths of about 1.0 m - 1.5 m, the substrate consisted primarily of a mix of 50% gravel and

50% sand, and beyond a distance of about 400 m at depths > 1.5 m, the substrate consisted primarily of sand (>80%) with some gravel (AAE 2016). The shoreline in this area extended about 30 m from the edge of the waterline, and was composed of a compacted substrate of gravel, cobble and sand, with cobble and boulder fields that were visible within the shallow nearshore habitat, and became more prevalent (> 50%) at the shoreline (AAE 2016).

Monthly mean water levels in Lake Manitoba as measured at the Environment Canada station at Steep Rock (Station 05LK002) for the period of record from 1923 to 2017 ranged from a minimum of 246.94 masl in December 1942 to a maximum of 249.02 masl in July 2011, with an overall monthly mean water level of 247.51 masl (Government of Canada 2018).

6D.1.2 Fairford River

The Fairford River is the only outlet for Lake Manitoba and is located at the northeast corner of the lake (Figure 6.4B-2). The Fairford River is about 16 km long and has a total drainage area of 79,800 km^2 (NSC 2012). Flows on the Fairford River are regulated via the Fairford River Water Control Structure (FRWCS), which has been in operation since 1961, and allows higher and lower outflows from Lake Manitoba than under natural conditions (LMRRC 2003). The FRWCS is part of the PTH 6 highway bridge and consists of 11 bays; discharge is regulated by removing or replacing stop logs in one or more of the bays (Derksen 1988). Additional information on the FRWCS is provided in Section 2.

Bathymetric data for the Project area waterways are provided in Appendix 6.F Bathymetry for the Fairford River in the vicinity of the PTH06 bridge collected in the fall of 2017 showed river bed elevations that ranged from 241.0 masl downstream of the bridge to 246.5 masl upstream of the bridge.

Monthly mean discharge for the Fairford River as measured at the Environment Canada station near Fairford (Station 05LM001) for the period of record from 1912 to 2017 ranged from a minimum of 1.22 m^3/s in November 1964 to a maximum of 610 m^3/s in July 2011, with an overall monthly mean discharge of 102 m^3/s (Government of Canada 2018).

6D.1.3 Lake Pineimuta

Lake Pineimuta is a shallow, 39 km^2 wetland complex located between Lake Manitoba and Lake St. Martin. The LMRRC (2003) noted that the area is comprised of deltaic deposits formed through centuries of deposition from floodwaters passing through the area, especially in the southern portion of the lake. There are no control structures on Lake Pineimuta, and the operation of the FRWCS has resulted in an increased variability in water levels that are even greater on Lake Pineimuta than on Lake St. Martin (LMRRC 2003). Modeling conducted by UMA Engineering for Indian and Northern Affairs Canada (INAC) showed that the maximum annual range of Pineimuta Lake levels has increased by approximately three-fold, and the maximum Pineimuta Lake level was over two feet higher than under natural conditions (LMRRC 2003). Bathymetry collected in the fall of 2017 for Lake Pineimuta are provided in Appendix 6.F).

6D.1.4 Lake St. Martin

Lake St. Martin has a total surface area of approximately 345 km^2 with about 260 km of shoreline (LMRRC 2003). The lake consists of two basins: a large south basin with a surface area of about 261 km^2 and an average depth of about 4.1 m; and a smaller north basin with a surface area of about 79 km^2 and an average depth of about 1.5 m (LMRRC 2003). Lake St. Martin receives flows from Lake Manitoba via the Fairford River. From Lake St. Martin, water flows northeast into the Dauphin River, which outlets to Sturgeon Bay in Lake Winnipeg (LMRRC 2003). The lake also receives water from local surface run off and from a number of small springs in the north east basin (Stone 1965 In NSC 2012).

There is a change in elevation from Lake St. Martin to Sturgeon Bay in Lake Winnipeg of about 27 m, whereas the change in elevation between Lake Manitoba and Lake St. Martin is about 4 m (LMRRC 2003). NSC (2012) described Lake St. Martin as having substrates primarily composed of soft mud, with an extensive area of gravel, sand, and compacted mud along the Lake St. Martin western shore near the mouth of the Fairford River, and areas of bare bedrock in the northeast basin and at the narrows. It was noted that extensive gravel bars and boulders are abundant in Lake St. Martin (NSC 2012).

Fisheries investigations conducted in the fall of 2015 and spring of 2016 in Lake St. Martin at the Harrison Creek outlet to Lake St. Martin included sonar analysis and ground-truthing of the lake substrates (AAE 2016). Sonar analysis showed that substrates along the shoreline to depths of about 1.5 m were predominantly sand (> 80%) with some gravel, while at depths greater than 1.5 m, the substrates were a combination of sand (> 80%) and gravel, with a bottom cover of evenly mixed sand and gravel (AAE 2016). In the southern half of the study area, a bar of coarse gravel (70%) and cobble (30%) was found at depths between about 2.5 m and 3.0 m. Gravel and cobble shoreline was common to the north of the study area, with occasional boulders observed in the nearshore habitat at depths < 1.2 m (AAE 2016).

Bathymetric data for Lake St. Martin collected in the fall of 2017 showed lake bed elevations that ranged from 238.3 masl to 244.3 masl (Appendix 6F). Bathymetric data were also collected in the area of the proposed LSMOC inlet in fall 2016, which showed lake bed elevations that ranged from 242.89 masl to 244.51 masl (Appendix 6F).

Monthly mean water levels in Lake St. Martin as measured at the Environment Canada station near Hilbre (Station 05LM005) for the period of record from 1966 to 2017 ranged from a minimum of 242.60 masl in November 2003 to a maximum of 245.51 masl in July 2011, with an overall monthly mean water level of 243.5 masl (Government of Canada 2018). Lake levels above 243.8 masl start to flood haylands along the edge of the lake (LM and LSMRRC 2013).

6D.1.5 Dauphin River

The Dauphin River has a gross total drainage area of about 82,300 km^2 and a length of about 50 km from its inlet on Lake St. Martin to its outlet into Sturgeon Bay on Lake Winnipeg; results from bathymetric surveys in the Dauphin River indicated a river length of 52 km (KGS Group 2013). From its inlet at Lake St. Martin, the Dauphin River winds its way northwards for about 25 km, where it reaches the area known as the Big Bend; from the Big Bend, the river turns eastward and flows over the Big Rapids to Sturgeon

Bay. Buffalo Creek enters the Dauphin River downstream of the Big Rapids about 4 km from the outlet of the Dauphin River to Sturgeon Bay. The river gradient is relatively flat in the first 25 km, whereas the lower 30 km of the river is steeply inclined, with a gradient of about 25 m over the relatively short length of the lower river (NSC and KGS Group 2015a). Flow velocities can range between 0.5 to 1.5 m/s over the first 40 km and increase to about 2 m/s over the lower 10 km (NSC and KGS Group 2016a).

During 2011 bathymetry and substrate surveys, water depths ranged from 0 m to 6 m, with an average water depth of 1.2 m and average water velocity of 0.5 m/s (NSC 2013a). The shallowest sections were generally found in the area of the confluence with Buffalo Creek, and along sections of the river's south shoreline; depths were typically higher along the north shore and increased towards the mouth of the river (NSC 2013a). During 2012 bathymetry surveys, water depths in the lower 4 km of the Dauphin River ranged from 0.7 m at Km 46 to 3.0 m at the mouth of the river (KGS Group 2013).

Substrates were classified as bedrock/limestone, cobble/boulder, compacted gravel, gravel/cobble, gravel/sand and sand (NSC 2013a). Cobble/boulder and gravel/sand were cited as the most abundant substrate type, with each of these substrate types composing almost 28% of the mapped area of the river; gravel/cobble and bedrock were the next most common substrate types (NSC 2013a).

Bedrock/limestone shelves were observed near the Buffalo Creek confluence, with patches of sand and cobble/boulder substrates upstream of the mouth of the creek, and mainly gravel/cobble substrate downstream of the confluence, until about 1 km upstream of Sturgeon Bay, after which the substrates downstream to Sturgeon Bay consisted largely of gravel/sand (NSC 2013a). KGS Group (2013) reported that the substrates downstream of Km 51+250m in the lower reaches of the Dauphin River were composed mostly of gravels and sands, whereas substrates upstream of Km 51+250m were more compact and contained more cobbles and boulders. The bathymetry collected for the Dauphin River are provided in Appendix 6F.

Monthly mean discharge for the Dauphin River as measured at the Environment Canada station near Dauphin River (Station 05LM006) for the period of record from 1977 to 2016 ranged from a minimum of 0.659 m^3/s in February 1982 to a maximum of 579 m^3/s in July 2011, with an overall monthly mean discharge of 105 m^3/s (Government of Canada 2018).

6D.1.6 Sturgeon Bay

Sturgeon Bay is a large U-shaped bay located in the southwestern portion of the north basin of Lake Winnipeg with a surface area of about 575 km^2. Sturgeon Bay has an approximate width of 17.7 km and length of 25.7 km and is marked by a cluster of islands at its mouth (Government of Manitoba 2017). The Dauphin River flows into the west side of Sturgeon Bay, and the Mantagao River and a number of small unnamed streams flow into the south-eastern corner and eastern side of the bay. The southern part of the bay is adjacent to the Sturgeon Bay Provincial Park. Water depths of 2.7 m to 8 m under ice thicknesses of 0.65 m to 0.90 m were recorded in Sturgeon Bay in February 2012 during the deployment of sediment traps throughout the bay (NSC 2013b). Data obtained by NSC (2012) from the Canadian Hydrographic Service indicated a maximum depth of about 10.4 m at the northern end of the bay.

NSC conducted substrate sampling in Sturgeon Bay in fall 2011 from the outlet of the Dauphin River to a distance of about 6 km offshore at several transects along the shoreline, from south of the Dauphin River outlet to the east side of Willow Point, and from the southern shoreline of Sturgeon Bay across Mantagao Bay to the eastern shoreline of Sturgeon Bay (NSC 2013a). NSC (2013a) reported the presence of substrates of cobble/boulder, compacted gravel, gravel/cobble, gravel/sand, sand and clay; nearshore sites were typically sand and gravel, with the exception of nearshore sites near Hay Point and north of Poplar Point, where substrates of boulder and boulder/cobble were dominant; offshore sites were composed of clay.

Detailed bathymetry at the outlet of the Dauphin River showed substrates of gravel/sand in the area of the river outlet as well as about 1.5 km to 2 km offshore, with an area of sand extending from the shoreline north of the river outlet to about 0.25 km offshore, and areas of compacted gravel, gravel/cobble, and cobble/boulder among the gravel/sand areas; substrates of gravel, cobble and some boulders were found at several locations in nearshore areas of Sturgeon Bay, including to the west and east of Willow Point (NSC 2013a). NSC (2012) noted that review of satellite imagery and aerial photographs for Sturgeon Bay showed that shorelines to the north and south of the Dauphin River were largely sand and cobble beaches with gently sloping nearshore areas.

Bathymetric data were collected in the fall of 2017 in Sturgeon Bay in the area of the proposed LSMOC outlet near Willow Point. Lake bed elevations ranged from 210.7 masl to 216.8 masl based on the data collected in fall 2017 (Appendix 6F).

There is no water level monitoring station for Lake Winnipeg in Sturgeon Bay. Monthly mean water levels in Lake Winnipeg as measured at the Environment Canada station in the north basin of Lake Winnipeg at at Matheson Island (Station 05SD002) for the period of record from 1957 to 2017 ranged from a minimum of 216.64 masl in November 1961 to a maximum of 218.88 masl in July 1974, with an overall monthly mean water level of 217.66 masl (Government of Canada 2018). The monthly mean water level at this station in July 2011 was 218.49 masl (Government of Canada 2018).

6D.1.7 Watchorn Bay

The inlet for the LMOC is proposed to be constructed in Watchorn Bay, the bay of Lake Manitoba located north of the Lake Manitoba Narrows and south of the Fairford River inlet (Figure 6.4B-8). Bathymetric data were collected as part of fisheries and aquatic habitat assessments conducted in Watchorn Bay in the area of the proposed LMOC inlet in the fall of 2015 and spring of 2016 (Appendix 6F). The lake bottom was described as having a relatively uniform gradient with an average slope of 0.0059 and a maximum depth of 2.7 m at about 750 m from shore (AAE 2016). The shoreline was composed of compacted gravel, cobble and sand substrates, with boulders visible within the sandy nearshore areas (AAE 2016).

A gravel and cobble berm with a height of about 1.5 m and a width of 15 m was located parallel to the shoreline about 5m to 10 m back from the water's edge. This berm was constructed to provide flood protection for adjacent agricultural lands (AAE 2016).

As noted above, monthly mean water levels in Lake Manitoba as measured at the Environment Canada station at Steep Rock (Station 05LK002) for the period of record from 1923 to 2017 ranged from a minimum of 246.94 masl in December 1942 to a maximum of 249.02 masl in July 2011, with an overall monthly mean water level of 247.51 masl (Government of Canada 2018).

6D.1.8 Watchorn Creek

Watchorn Creek originates near Reed Lake and flows south to Watchorn Bay in Lake Manitoba. Cross-sectional profiles were completed in Watchorn Creek upstream and downstream of existing water control structures (culverts and a bypass drain) as part of fisheries and aquatic habitat assessments conducted in spring 2016 (AAE 2016). At the time of the surveys, creek width ranged from 8.0 m to 11.3 m, with a thalweg depth of 0.49 m to 0.97 m, and water velocity ranged from 0.00 m/s (no measurable flow) to 0.14 m/s. Depth profiles for the creek depicted a W-shaped channel, with a steeper left bank and shallow, sloping right bank (AAE 2016).

Substrate composition at the site located downstream of the culvert and bypass drain was a uniform clay (70% > 90%) with some silt (< 10%), while the substrate composition at the site located at the upstream extent of the bypass drain was primarily silt (30% > 70%), with some sand and gravel substrates, and a sand-gravel-cobble mixture along the left bank (AAE 2016).

6D.1.9 Birch Bay

The outlet for the LMOC is proposed to be constructed in Birch Bay, the bay located in the south end of Lake St. Martin (Figure 6.4B-7). Birch Creek drains into Birch Bay south of the proposed LMOC outlet site, through a large, vegetated wetland and floodplain area (AAE 2016). Bathymetric data were collected as part of fisheries and aquatic habitat assessments conducted in Watchorn Bay in the area of the proposed LMOC inlet in the fall of 2015 and spring of 2016. The lake bottom was described as having a relatively uniform gradient within the bay with an average slope of 0.0035 (AAE 2016). Areas adjacent to the proposed LMOC outlet site were steeper, with an average slope of 0.012 from the water's edge to depths of 3 m (AAE 2016). Substrate along the shoreline to depths of about 2.5 m was a uniform mix of mostly gravel with some sand, becoming a mostly sand substrate at depths greater than 2.5 m, with small areas of gravel substrate observed at depths greater than 3.0 m. Gravel and cobble were common along the shoreline, with occasional boulders observed in the nearshore habitat at depths less than 1.0 m (AAE 2016). Bathymetric data collected in the fall of 2017 in Birch Bay showed lake bed elevations that ranged from 238.7 masl to 243.0 masl (Appendix 6F).

As noted above, monthly mean water levels in Lake St. Martin as measured at the Environment Canada station near Hilbre (Station 05LM005) for the period of record from 1966 to 2017 ranged from a minimum of 242.60 masl in November 2003 to a maximum of 245.51 masl in July 2011, with an overall monthly mean water level of 243.5 masl (Government of Canada 2018).

6D.1.10 Birch Creek

Birch Creek flows from the wetlands, ponds and small lakes located adjacent to the proposed LMOC route north to Birch Bay in Lake St. Martin. Five cross-sectional profiles were completed in different areas of Birch Creek as part of fisheries and aquatic habitat assessments conducted in spring 2016 (AAE 2016). At the time of the surveys, creek width ranged from 8.6 - 10.4 m, water depth ranged from 0.68 to 1.10 m, and water velocity ranged between 0.54 and 0.80 m/s (AAE 2016). Depth profiles depicted a consistent, U-shaped channel, and a prominent reef was also observed extending from the south across the mouth of Birch Creek, rising to a height of less than 1.0 m (AAE, 2016). Substrate composition was highly variable within and among the sites, with varying amounts of clay, silt, sand, gravel, and cobble materials found within and along the channels (AAE 2016). Based on surface water quality sampling data, the depths in the small wetland lakes that are part of the Birch creek system (Goodison Lake, Water Lake, Clear Lake, Reed Lake) ranged from 0 to 1 m (KGS Group 2018).

6D.1.11 Buffalo Creek Watershed

The Buffalo Creek watershed consists of Big Buffalo Lake, Little Buffalo Lake, Buffalo Creek and a number of small unnamed lakes, ponds and creeks (NSC 2013a) (Figure 6.4B-8 in Appendix 6B). Big Buffalo Lake has a surface area of 0.55 km^2 and is located about 7 km northeast of LSM (NSC 2012), with depths ranging from 1.1 m to 2.1 m, and a mean depth of 1.7 m (NSC 2013a). Big Buffalo Lake flows east into Little Buffalo Lake and Buffalo Creek, which then winds its way northeast for about 16 km across the landscape to its confluence with the Dauphin River. The first approximately 4 km of Buffalo Creek downstream of Big Buffalo Lake flows through a treeless wetland over flat topography (NSC 2013a). Further past the wetland areas, the creek develops a meandering pattern and gradient increases along this portion of the creek, as well as beaver dams, are common (NSC 2013a). Prior to the construction and operation of Reach 1, the Buffalo Creek watershed did not receive water from the LM or LSM watersheds (NSC 2013a).

Big Buffalo Lake lies within an area of mainly herb and shrub wetlands, with some areas of floating bog and pockets of sparse coniferous forest present around the lake (NSC 2012). Lake substrates were cited as a being composed of a deep layer of loosely compacted organic sediments; aquatic vegetation (mainly *Potamogeton* spp.) was present throughout most of the lake, with less dense areas in the centre of the lake vs. the shallower areas (NSC 2012). Inflow to the lake is provided as runoff from the surrounding wetland areas, with outflow to Little Buffalo and Buffalo Creek.

Downstream of this wetland area, soils are better-drained and the creek channel has a meandering pattern with a series of run/riffle/pool habitat over substrates of cobble, gravel and sand. This area of the creek contained gradient changes and beaver dams were common. Where flow was perennial, the substrate was made up of sand, gravel and occasional boulders; where flow was intermittent or ephemeral, a film of loosely compacted organic sediment deposited over the harder granular materials was observed in some areas.

In areas upstream of the beaver dams, there was a greater deposition of organic materials and large dense beds of lily pads (*Nymphaea* spp.) in the lower reaches of the creek; water depths in this area were > 1 m with riparian vegetation of willows and spruce trees. The stream banks become higher and wider in the downstream areas, and the lower-most 1.5 km of the creek had a well-defined channel with substrates of mostly compacted granular materials. At the time of the survey in August 2011, water depth in the lower-most reach of the creek was greater than 1.0 m deep due to back water effects caused by high flows in the Dauphin River (NSC 2012).

6D.2 HYDRAULIC AND SEDIMENT TRANSPORT STUDIES

The studies conducted in the area from 2011 to 2015 included hydraulic and sediment transport studies to analyze flow patterns and trends in sediment transport, and identify areas with potential for sediment erosion and deposition (NSC and KGS Group 2016a). The focus of these studies was to examine the effect of the operation and closure of the EOC between 2011 and 2015; as such, the studies provide information for a range of flows and water levels throughout this period. The studies included the collection and collation of data on water levels and flows, bathymetry, ice conditions, turbidity and Total Suspended Solids (TSS), and sedimentation rates. The analysis was facilitated with the development of an empirical model and a 2-Dimensional (2D) hydraulic and sediment transport model of the Lower Dauphin River.

The studies showed that sediment is transported from the upper Dauphin River into Sturgeon Bay; the velocities in the Dauphin River move suspended materials several hundred meters into Sturgeon Bay, with limited local deposition of sediments along the Dauphin River shoreline or in back eddies (NSC and KGS Group 2016a). The suspended solids were examined for grain size distribution and were found to consist mainly of clays and silts. The studies found that smaller particles of sediment up to about sand size could be transported in suspension to Sturgeon Bay, while larger cobble sized substrates could be transported by bed load, and gravel sized substrates could be eroded in the river (NSC and KGS Group 2016a).

Sediment deposition in Sturgeon Bay was found to vary among open water and ice-covered periods (NSC and KGS Group 2016a). Sediment deposition under ice cover was more evenly distributed and at lower levels than during the open water season (NSC and KGS Group 2016a). Under open water, wind and currents caused re-suspension of sediment particles, such that the deposition was still distributed across the sampling area but was at higher levels (NSC and KGS Group 2016a). There was no relationship found between sedimentation rates and trap distances from the mouth of the Dauphin River (NSC and KGS Group 2016a). The study noted that these results were in agreement with information provided in the “State of Lake Winnipeg 1999 to 2007” report, which reported higher sedimentation rates in the fall than spring and summer, and that wind was a more significant factor in suspended sediment dynamics than inputs from rivers that discharge into the lake (Environment Canada and Manitoba Water Stewardship 2011).

Detailed information on the hydraulic and sediment transport studies is provided in the 'Lake St. Martin Emergency Outlet Channel Assessment of Effects and Development of Offsetting Physical Environment Supporting Volume (PESV)' (NSC and KGS Group 2016a).

6D.3 ICE PROCESSES

Studies conducted from 2011 to 2015 in the area included an examination of the processes affecting the formation, movement and breakup of ice cover in the Fairford River, Lake St. Martin, the Dauphin River and Sturgeon Bay. The focus of the ice studies conducted in 2011 and 2012 was to determine the potential extents of the effects from ice on flooding to local communities (e.g., Dauphin River First Nation), and the impacts on lake levels and outflows (KGS Group 2014). These studies included the development of river ice models that analyzed different scenarios based on freeze-up dates and rate of decline of the river flows in the system (KGS Group 2014). In December of 2012 and December of 2013, ice reconnaissance surveys were conducted to assess the ice conditions in the Dauphin River; confirm the location and type of ice cover that restricts flows on the Dauphin River at the outlet of Lake St. Martin; and to determine winter discharges in the Dauphin River (NSC and KGS Group 2016a). The surveys were conducted by helicopter and documented with photos (NSC and KGS Group 2016a).

Winter ice forms on the Fairford River upstream and downstream of the Fairford River Water Control Structure (FRWCS) (KGS Group 2014). Ice conditions in the river can restrict outflows on Lake St. Martin, which can cause increased water levels on the lake (KGS Group 2014). As such, the FRWCS has historically been operated to limit inflows into Lake St. Martin during winter, and control water levels on the lake.

The outflow from Lake St. Martin is controlled by the Dauphin River, which is the only natural outlet from Lake St. Martin. A solid ice cover typically forms on Lake St. Martin in November and remains until the following spring break-up in April or May (NSC and KGS Group 2016a). Ice thickness on Lake St. Martin in January 2012 was measured as 0.46 m (NSC and KGS Group 2016a).

The gradient and flow velocities in the Dauphin River vary over its length. This variation in slope and velocities results in a wide range of ice conditions (KGS Group 2014). Ice cover will form in the upper reaches of the river in areas of lower velocities and gradient, prior to ice cover advancing from downstream (NSC and KGS Group 2016a). In the lower reaches of the river where velocities and slope are higher, the river surface typically freezes in early November and frazil ice begins to generate and coalesce into slush ice pans that travel downstream to Sturgeon Bay in Lake Winnipeg (NSC and KGS Group 2016a). There is also ice cover in Sturgeon Bay near the Dauphin River outlet typically by early November, and the slush ice travelling downstream from the Dauphin River can accumulate at the river mouth and back up the water levels, potentially forming a hanging ice dam (NSC and KGS Group 2016a).

In 2010, MI reported that the river developed a full ice cover that extended from Lake Winnipeg to Lake St. Martin by mid-December, with only short reaches of open water remaining at that time (KGS Group 2014). During the winter of 2012, ice thicknesses in Sturgeon Bay ranged from 0.45 m to 0.61 m in

January, from 0.66 m to 0.90 m in February, and from 0.44 m to 0.77 m in March (NSC and KGS Group 2016a).

In spring, a sudden increase in flow due to melting and open water conditions at the outlet of Lake St. Martin could cause elevated water levels and ice jams in the lower Dauphin River. This complex pattern of ice formation, movement and breakup in the area occurs annually, and can affect the discharge capacity from Lake St. Martin (NSC and KGS Group 2016a).

Detailed information on the ice processes studies is provided in the 'Emergency Reduction of Lake Manitoba and Lake St. Martin Water Levels Analysis and Monitoring of Discharges and Ice Processes' (KGS Group 2014) and the 'Lake St. Martin Emergency Outlet Channel Assessment of Effects and Development of Offsetting Physical Environment Supporting Volume (PESV)' (NSC and KGS Group 2016a).

6D.4 REGIONAL AND LOCAL SURFACE WATER QUALITY

Regional and local surface water quality was characterized through the review of several sources of information for the area. These sources included:

- information provided in the Lake Manitoba and Lake St. Martin Regulation Review Committee Report (LM and LSMRRC 2013);
- monitoring results from MSD collected at various times and sites from 1973 to 2017 in Lake Manitoba, the Fairford River, Lake St. Martin, the Dauphin River and Watchorn Bay;
- studies conducted in the Fairford River, Lake St. Martin, Dauphin River and Sturgeon Bay from August 2011 to September 2015 as part of the Lake St. Martin Emergency Relief Channel Monitoring program (NSC and KGS Group 2016b);
- fisheries investigations conducted in Lake Manitoba, Watchorn Creek, Lake St. Martin, and Birch Creek in the fall of 2015 and spring of 2016 (AAE 2016); and
- surface water quality monitoring completed in the area of the proposed LMOC route from 2016 to 2018 (KGS Group 2018).

6D.4.1 Lake Manitoba

Surface water quality in Lake Manitoba is monitored by the Water Quality Management Section of MSD. Long term water quality is monitored on major streams, rivers and lakes in Manitoba, including several lake and river sampling stations in the Lake Manitoba watershed (MSD 2017). There are three long-term lake monitoring stations: two stations are located on Lake Manitoba, at Delta Marsh and at the Narrows, and a third station is located on the Fairford River at PTH 6 (LM and LSMRRC 2013). River monitoring is conducted at three long-term stations located on three of the major rivers of the Lake Manitoba watershed: the Waterhen River at PR 328, the Whitemud River at Highway 16, and the Assiniboine River.

In addition to water quality sampling and monitoring, MSD investigated the potential relationship between water levels in Lake Manitoba and water quality, using average concentrations of total phosphorus (TP) and total nitrogen (TN) as the basis for the examination of water quality. Lake Manitoba average TP levels from 1992 to 2011 as measured at the Delta Marsh station ranged from about 0.045 milligrams per litre (mg/l) to about 0.13 mg/l, with the highest concentration observed in the 2011 sampling (LM and LSMRRC 2013). Lake Manitoba average TN levels from 1992 to 2011 as measured at the Delta Marsh station ranged from about 0.09 mg/l to about 1.8 mg/l, with the highest concentration observed in the 1999 sampling (LM and LSMRRC 2013).

Water from the Assiniboine River watershed routed through the Portage Diversion has been identified as the largest source of phosphorus loading to Lake Manitoba when the Portage Diversion is flowing; in 2011, more than 60 percent of the TP load to Lake Manitoba was transported by the Portage Diversion (LM and LSMRRC 2013). TP was elevated at Delta Marsh in 2011, as well as in other wet years, but an increase in average TP was not found in the water quality sampling done at the station located at the Narrows in Lake Manitoba (LM and LSMRRC 2013).

The Waterhen River was identified as the largest source of TN loading to Lake Manitoba; in 2011, nearly 60 percent of the TN load to Lake Manitoba was transported by the Waterhen River (LM and LSMRRC 2013). It was also noted that the percentage of the TN load is greater in years when the Portage Diversion does not flow, and, unlike the average TP concentrations, average TN concentrations were not affected by the 2011 flood, with no significant increases observed (LM and LSMRRC 2013).

Other indicators of water quality being sampled by MSD include chlorophyll α, total suspended solids (TSS), conductivity, dissolved oxygen (DO), metals and pesticides. The average chlorophyll α concentration in Lake Manitoba was slightly higher in 2011 than the long-term average, but within the range of historical concentrations. When it flows, the Portage Diversion is the largest source of TSS to Lake Manitoba, and water from the Portage Diversion contributed more than 85% of the lake's load in 2011; however, TSS in Lake Manitoba in 2011 was similar to the long-term average and within the range of historical concentrations (LM and LSMRRC 2013). Dissolved oxygen concentrations in Lake Manitoba are typically sufficient for aquatic life but have occasionally been below the guideline for supporting aquatic life, including measurements in May 2011 and in August 2011. Conductivity has been declining in Lake Manitoba in recent years, it appeared to be affected by the 2011 flood and can be linked to the inflow from the Portage Diversion (LM and LSMRRC 2013). The saline groundwater discharged to the west side of Lake Manitoba contributes to the dissolved solids, sodium and chloride concentrations found in LMB, the Fairford River and Lake St. Martin (KGS Group 2017a).

As such, water quality monitoring over time has shown increases in phosphorus and chlorophyll and decreases in conductivity in Lake Manitoba, but water levels do not appear to be a major driver of water quality (LM and LSMRRC 2013). Water quality in the south basin of Lake Manitoba does appear to have been significantly affected by the operation of the Portage Diversion (LM and LSMRRC 2013). Analysis of a 17 year historical water quality dataset from a station in the south basin indicated that Lake Manitoba has become more dilute and nutrient rich over time; geospatial mapping and principal components

analysis revealed that the south basin of the lake was more turbid, nutrient rich, and more dilute in comparison to the north basin (Lake Manitoba Water Stewardship Board [LMWSB] 2016).

High levels of nutrients such as nitrogen and phosphorus can lead to the development of algal blooms in lakes, where the water may appear like thick pea soup and have an unpleasant odour. MSD monitors algal blooms at about 60 beaches across Manitoba for the presence of cyanobacteria, which can produce a toxin called microcystin. Microcystin is produced by some species of cyanobacteria and can be harmful to the liver or nervous system if large amounts of water containing this toxin are swallowed (MCWS 2011). MSD also conducts sampling for the *Escherichia coli* (*E.coli*) bacterium at about 60 beaches across Manitoba, including four beaches in Lake Manitoba: Lynch's Point; Delta; St. Ambroise and Twin Lakes. From 2006 to 2010, *E. coli* levels were below the recreational guideline of 200 CFU/100ml at Delta and St. Ambroise Beaches, but exceeded the guideline at either Lynch's Lake Point Beach or Twin Lakes Beach on four occasions (LM and LSMRRC 2013). In 2018, the guideline was exceeded once at Delta Beach and exceeded three times at Twin Beaches; *E. coli* was measured as 7077 CFU/100ml on June 11, 2018 at Twin Lakes Beach (MSD 2018).

The Lake Manitoba Water Stewardship Board (LMWSB 2016) noted that, while there is some monitoring of water quality and other ecosystem parameters in Lake Manitoba and its watershed, surface water quality in Lake Manitoba is poorly understood in comparison to other large lakes, and more study is required to understand the spatial and temporal variation in water quality and the ecological system functions of Lake Manitoba.

Regional and local surface water quality monitoring was conducted in the Lake Manitoba and Lake St. Martin watersheds from August 2011 to September 2015 as part of the Lake St. Martin Emergency Relief Channel Monitoring program (NSC and KGS Group 2016b). Monitoring activities in 2011 and 2012 included data from the Lake Manitoba Narrows and Waterhen River long-term monitoring stations. However, the sites at the Lake Manitoba Narrows and Waterhen River were removed from the monitoring program after 2012 as the site in the Fairford River was considered to adequately capture the water quality conditions of Lake Manitoba water entering the Lake St. Martin watershed and Dauphin River system (NSC and KGS Group 2016b).

6D.4.2 Fairford River

Surface water quality data for the Fairford River were obtained from samples collected and analyzed by MSD from 1978 to 2017, and the studies conducted from August 2011 to September 2015 as part of the Lake St. Martin Emergency Relief Channel Monitoring program by NSC and KGS Group (2016a). Samples from 2011 to 2015 were collected and analyzed for routine parameters such as pH and conductivity, as well as for several nutrients, major ions, metals, and potential contaminants such as *E. coli* or pesticides. Detailed information on the sampling methods, parameters of interest, analysis and results are provided in the 'Lake St. Martin Emergency Relief Channel Monitoring and Development of Habitat Compensation 2011-2015. Volume 3 – Water Quality' (NSC and KGS Group 2016b).

Table 6D.4-1 provides an overview of the collected data for selected parameters. Surface water quality data provided by MSD have been incorporated in Table 6D.4-1.

Table 6D.4-1 Overview of Surface Water Quality for the Fairford River

Parameter	Values
Temperature (°C)	0 to 23.5
Laboratory pH	7.59 to 8.67
Laboratory Conductivity (µmhos/cm)	898 to 2000
Dissolved Oxygen (mg/l)	4.4 to 15.1
TSS (mg/l)	< 2.0 to 44
TDS (mg/l)	508 to 1480
Hardness (CaCO3) (mg/l)	203 to 348
Total Nitrogen (mg/l)	0.64 to 2.96
Total Phosphorus (mg/l)	0.002 to 0.045
Chlorophyll α (µg/l)	<0.50 to 19.5
E. coli (CFU/100 ml)	1 to 461
Petroleum Hydrocarbons	Not Analyzed

The water quality of the Fairford River was described as moderately nutrient rich, low to moderately turbid, slightly alkaline, very hard, and well-oxygenated (NSC and KGS Group 2016b). The TN:TP molar ratios indicated that the river was phosphorus limited, and TOC:TN molar ratios showed that organic matter was a mix of within river (autochthonous) and outside of the river (allochthonous) sources (NSC and KGS Group 2016b). TSS concentrations fluctuated over time, with increases in TSS observed during periods of high wind and spring melt conditions. Chlorophyll α concentrations indicated a moderate level of primary productivity, with concentrations increasing over the open water seasons (NSC and KGS Group 2016b).

A number of parameters exceeded the Manitoba Water Quality Standards, Objectives, and Guidelines (MWQSOGs) for the protection of aquatic life (PAL) (MCWS 2011), the Canadian Council of Ministers of the Environment (CCME) guidelines for the protection of freshwater aquatic life (CCME 1999), or the MWQSOGs/Health Canada aesthetic objective for drinking water (Health Canada 2017). Chloride concentrations exceeded the CCME long-term exposure guideline for PAL in all 78 samples, fluoride levels exceeded the guideline in 14 out of 15 samples, and aluminum and selenium concentrations exceeded the MWQSOGs/CCME guideline for PAL in eight (8) out of 71 samples (NSC and KGS Group 2016). Silver concentrations exceeded the MWQSOGs/CCME PAL in two (2) out of 78 samples. A number of metals were consistently within the applicable MWQSOGs and CCME PAL guidelines at all sites and times, including arsenic, boron, cadmium, dissolved chromium, copper, lead, mercury, methyl mercury, molybdenum, nickel, thallium, uranium, and zinc (NSC and KGS Group 2016b).

DO levels were below the MWQSOGs long-term objective/CCME lowest acceptable concentration for cold-water early-life of 9.5 mg/l when water temperatures were ≤ 5°C in five (5) out of 29 samples, and

was below the MWQSOGs long-term objective/CCME lowest acceptable concentration for cool-water mature-life/warm-water other-life stages of 5.5 mg/l when water temperatures were ≤ 5°C in one (1) out of 29 samples (NSC and KGS Group 2016b).

True Colour and laboratory pH levels occasionally exceeded the MWQSOGs/Health Canada aesthetic objective for drinking water in the Fairford River, while TDS concentrations consistently exceeded this objective (NSC and KGS Group, 2016). Chloride concentrations exceeded the MWQSOGs/Health Canada aesthetic objective for drinking water in 28 out of 78 samples, and sodium levels exceeded this guideline in 10 out of 78 samples. Parameters with maximum acceptable concentrations that were within the guideline amounts included antimony; arsenic; barium; boron; lead; mercury; selenium; and, uranium (NSC and KGS Group 2016b).

A total of 58 types of pesticides were analyzed at selected sites in the Fairford River, Dauphin River and Sturgeon Bay (NSC and KGS Group 2016b). Glyphosate was detected at all sites sampled on July 16 and July 17, 2011, and October 28 and October 29, 2011; all other pesticides for which sufficient sample was collected to conduct the analysis were below analytical detection limits on these dates (NSC and KGS Group 2016b). Pesticides were consistently below the analytical detection limits in samples collected from the Fairford and Dauphin rivers on November 6, 2011 after Reach 1 was in operation, and glyphosate concentrations did not exceed the MWQSOGs or CCME guideline for PAL, or the MWQSOGs for drinking water, in any samples collected in fall 2011 (NSC 2013a). In the data provided by MSD, pesticide analysis of eight (8) samples from the Fairford River collected from January 2010 to July 2012 detected glyphosate in six (6) out of eight samples, thifensulfuron methyl in two (2) out of eight samples and tribenuron methyl in one (1) out of eight samples.

E. coli was measured as 72 CFU/100ml in the Fairford River in July 2012 (W. Bernhardt, pers.comm., 2018). *E. coli* was measured in 20 samples from the Fairford River by MSD from March 02, 2015 to October 02, 2017. The *E.coli* amounts exceeded the Health Canada Guidelines for Canadian Recreational Water Quality (Health Canada 2012) of ≤ 200 *E. coli* /100 mL on two occasions (July 13, 2016 and August 28, 2017), and exceeded the single sample maximum concentration of ≤ 400 *E. coli* /100 mL on one occasion (August 28, 2017). Petroleum hydrocarbon concentrations were not monitored in the Fairford River.

6D.4.3 Lake St. Martin

Surface water quality data for Lake St. Martin was obtained from two studies conducted in Lake St. Martin in the 1960's, samples collected and analyzed by MSD in 2011, and the studies conducted from August 2011 to September 2015 as part of the Lake St. Martin Emergency Relief Channel Monitoring program by NSC and KGS Group. Samples from 2011 to 2015 were collected and analyzed for routine parameters such as pH and conductivity, as well as for a number of nutrients, major ions, metals, and potential contaminants such as *E. coli* or petroleum hydrocarbons. Detailed information on the sampling methods, parameters of interest, analysis and results are provided in the 'Lake St. Martin Emergency Relief Channel Monitoring and Development of Habitat Compensation 2011-2015. Volume 3 – Water Quality' (NSC and KGS Group 2016b).

Table 6D.4-2 provides an overview of the collected data for selected parameters. Surface water quality data provided by MSD have been incorporated in Table 6D.4-2.

Table 6D.4-2 Overview of Surface Water Quality for Lake St. Martin

Parameter	Values
Temperature (°C)	0 to 26
Laboratory pH	8.03 to 8.68
Laboratory Conductivity (µmhos/cm)	857 to 1310
Dissolved Oxygen (mg/l)	6.1 to 14.4
TSS (mg/l)	< 2.0 to 47
TDS (mg/l)	488 to 772
Hardness (CaCO3) (mg/l)	224 to 350
Total Nitrogen (mg/l)	0.40 to 2.33
Total Phosphorus (mg/l)	0.010 to 0.054
Chlorophyll α (µg/l)	<0.50 to 9.16
E. coli (CFU/100 ml)	Not Detected
Petroleum Hydrocarbons	Not Detected

Historical data for Lake St. Martin included two studies conducted by the Province of Manitoba: a winter survey in 1965 and a water quality study in 1968 (NSC 2012). The studies were conducted during low water periods in the 1960s, and reported that Lake St. Martin had a high level of TSS and a pH level that generally ranged from 7.8 to 8.4, with DO levels that dropped to about 50% saturation between freeze-up and late February (Stone 1965 In NSC 2012). DO values dropped below 3 ppm in shallow bays and in the deepest areas of the lake, and in the northeast basin, DO dropped to 0 ppm by the middle of February (Stone 1965 In NSC 2012). The low DO values occurred with discharges of 1.42 to 1.98 cms from the Fairford River dam; during higher discharge rates of 88.9 cms in the winter of 1967/68, DO levels were significantly higher and did not inhibit fish activity (Crowe 1969 In NSC 2012). Lake St. Martin was regularly mixed by winds during the open water season, and thermal stratification was not evident (Stone 1965 In NSC 2012). Freeze-up typically occurred in early November and the lake remained ice-covered until early April (Stone 1965 In NSC 2012a). NSC and KGS Group (2016) also noted that Lake St. Martin was typically isothermal during sampling periods.

The water quality of Lake St. Martin was described as moderately nutrient rich, low to moderately turbid, slightly alkaline, very hard, and well-oxygenated (NSC and KGS Group 2016b). The TN:TP molar ratios indicated that the lake was phosphorus limited, and TOC:TN molar ratios showed that organic matter was a mix of autochthonous and allochthonous sources (NSC and KGS Group 2016b). TSS concentrations fluctuated over time, with increases in TSS observed during periods of high wind and spring melt conditions. Chlorophyll α concentrations indicated a moderate level of primary productivity, with concentrations increasing over the open water seasons (NSC and KGS Group 2016b).

Concentrations of chloride, fluoride and silver were the only parameters found to exceed guideline levels in Lake St. Martin. Chloride concentrations exceeded the CCME long-term exposure guideline for PAL in all 16 samples, fluoride levels exceeded this guideline in 13 out of 16 samples, and silver exceeded guidelines levels in one (1) of 16 samples. A number of metals were consistently within the applicable MWQSOGs and CCME PAL guidelines at all sites and times, including arsenic, boron, cadmium, dissolved chromium, copper, lead, mercury, methyl mercury, molybdenum, nickel, thallium, uranium, and zinc (NSC and KGS Group 2016b).

DO levels were below the MWQSOGs PAL for cold water mature life and CCME PAL for other life stages of cold water biota of 6.5 mg/l when water temperatures were >5°C in two (2) out of 35 samples, and was below the MWQSOGs long-term objective/CCME lowest acceptable concentration for cold-water early-life of 9.5 mg/l when water temperatures were ≤ 5°C in two (2) out of 15 samples (NSC and KGS Group 2016b).

There were no parameters that exceeded the MWQSOGs/Health Canada aesthetic objective for drinking water in Lake St. Martin (NSC and KGS Group, 2016). Samples collected in 2011 were analyzed for *E. coli* and petroleum hydrocarbons, but these substances were not detected.

6D.4.4 Dauphin River

Surface water quality data for the Dauphin River were obtained from samples collected and analyzed by MSD from 1978 to 2017, and the studies conducted from August 2011 to September 2015 as part of the Lake St. Martin Emergency Relief Channel Monitoring program by NSC and KGS Group. Samples from 2011 to 2015 were collected and analyzed for routine parameters such as pH and conductivity, as well as for a number of nutrients, major ions, metals, and potential contaminants such as *E. coli*, pesticides or petroleum hydrocarbons. Detailed information on the sampling methods, parameters of interest, analysis and results are provided in the 'Lake St. Martin Emergency Relief Channel Monitoring and Development of Habitat Compensation 2011-2015. Volume 3 – Water Quality' (NSC and KGS Group, 2016).

Table 6D-3 provides an overview of the collected data for selected parameters. Surface water quality data provided by MSD have been incorporated in Table 6D.4-3.

Table 6D.4-3 Overview of Surface Water Quality for the Dauphin River

Parameter	Values
Temperature (°C)	0 to 26
Laboratory pH	7.48 to 9.15
Laboratory Conductivity (µmhos/cm)	767 to 3630
Dissolved Oxygen (mg/l)	1.1 to 17.1
TSS (mg/l)	< 2.0 to 69
TDS (mg/l)	240 to 1470
Hardness (CaCO3) (mg/l)	178 to 358
Total Nitrogen (mg/l)	0.34 to 2.51

Table 6D.4-3 Overview of Surface Water Quality for the Dauphin River

Parameter	Values
Total Phosphorus (mg/l)	0.002 to 0.070
Chlorophyll α (µg/l)	0.47 to 9.0
E. coli (CFU/100 ml)	1 to 100
Petroleum Hydrocarbons	Not Detected

The water quality of the Dauphin River was described as moderately nutrient rich, low to moderately turbid, slightly alkaline, very hard, and well-oxygenated (NSC and KGS Group 2016b). The TN:TP molar ratios indicated that the river was phosphorus limited, and TOC:TN molar ratios showed that organic matter was a mix of autochthonous and allochthonous sources (NSC and KGS Group, 2016). TSS concentrations fluctuated over time, with increases in TSS observed during periods of high wind and spring melt conditions; TSS concentrations also increased during some periods when the EOC was in operation (NSC and KGS Group 2015a). Chlorophyll α concentrations indicated a moderate level of primary productivity (NSC and KGS Group 2016b).

A number of parameters exceeded the Manitoba Water Quality Standards, Objectives, and Guidelines (MWQSOGs) for the protection of aquatic life (PAL) (MCWS 2011), the Canadian Council of Ministers of the Environment (CCME) guidelines for the protection of freshwater aquatic life (CCME 1999), or the MWQSOGs/Health Canada aesthetic objective for drinking water (Health Canada 2017). Chloride concentrations exceeded the CCME long-term exposure guideline for PAL in all 104 samples and fluoride levels exceeded the guideline in 56 out of 64 samples.

Aluminum concentrations exceeded the MWQSOGs/CCME guideline for PAL in four (4) out of 104 samples, while selenium concentrations exceeded this guideline in six (6) out of 104 samples and silver concentrations exceeded this guideline in one (1) out of 104 samples (NSC and KGS Group, 2016). A number of metals were consistently within the applicable MWQSOGs and CCME PAL guidelines at all sites and times, including arsenic, boron, cadmium, dissolved chromium, copper, lead, mercury, methyl mercury, molybdenum, nickel, thallium, uranium, and zinc (NSC and KGS Group 2016b).

Ammonia levels exceeded the CCME PAL guidelines in three (3) out of 228 samples (NSC and KGS Group 2016b). TP concentrations between the confluence of the Dauphin River and Sturgeon Bay were found to increase at the onset of operation of the EOC, and exceeded the MWQSOGs narrative guidelines on four occasions: during the onset of operation of the EOC in 2011 and 2014, in the spring of 2013, and in March of 2015 (NSC and KGS Group 2016b). TSS concentrations also increased in the Dauphin River at the onset of operation and during operation of the EOC; at the onset of operation in both 2011 and 2014, TSS concentrations exceeded the MWQSOGs /CCME short-term PAL as far downstream as Sturgeon Bay, and TSS levels were above the MWQSOGs 30 day/CCME long-term PAL from 04-25 November 2011, 05-16 July 2014, and 27 March 2015 (NSC and KGS Group 2016b).

DO levels were below the MWQSOGs PAL for cool water early life, and the CCME PAL for early life stages of warm water biota of 6.0 mg/l when water temperatures were >5°C in two (2) out of 120

samples, and below the MWQSOGs PAL for cold water mature life and CCME PAL for other life stages of cold water biota of 6.5 mg/l when water temperatures were >5° in six (6) out of 120 samples (NSC and KGS Group 2016b).

There were also samples with DO levels below the MWQSOGs PAL for cold water early life, and CCME PAL for early life stages of cold water biota of 9.5 mg/l when water temperatures were ≤ 5°C in 10 out of 63 samples, and MWQSOGs PAL for cool water mature life and CCME PAL for other life stages of warm water biota of 5.5 mg/L when water temperatures were ≤ 5°C in one (1) out of 63 samples (NSC and KGS Group 2016b).

True Colour and laboratory pH levels occasionally exceeded the MWQSOGs/Health Canada aesthetic objective for drinking water in the Dauphin River, while TDS and turbidity consistently exceeded this objective (NSC and KGS Group, 2016). Chloride concentrations exceeded the MWQSOGs/Health Canada aesthetic objective for drinking water in 21 out of 101 samples, and sodium levels exceeded this guideline in seven (7) out of 101 samples. Parameters with maximum acceptable concentrations that were within the guideline amounts included antimony; arsenic; barium; boron; lead; mercury; selenium; and, uranium (NSC and KGS Group 2016b).

As noted above, a total of 58 types of pesticides were analyzed at selected sites in the Fairford River, Dauphin River and Sturgeon Bay (NSC 2013b). Glyphosate was detected at all sites sampled on July 16 and July 17, 2011, and October 28 and October 29, 2011; in one sample from the Dauphin River on July 17, 2012, 2-4-D was detected at the detection limit amount of 0.50 µg/L (NSC 2013b); all other pesticides for which sufficient sample was collected to conduct the analysis were below analytical detection limits on these dates (NSC 2013a,b). Pesticides were consistently below the analytical detection limits in samples collected from the Fairford and Dauphin rivers on November 6, 2011 after Reach 1 was in operation, and glyphosate concentrations did not exceed the MWQSOGs or CCME guideline for PAL, or the MWQSOGs for drinking water, in any samples collected in fall 2011 (NSC 2013a). In the data provided by MSD, pesticide analysis of six (6) samples from the Dauphin River collected from October 2009 to April 2012 detected glyphosate in five (5) out of six samples, MCPA in one (1) out of six samples and thifensulfuron methyl in in one (1) out of six samples.

E. coli was detected in 27 out of 71 samples collected by MSD from the Dauphin River from June 14, 2004 to February 04, 2016, and in two samples collected by NSC in July 2012 (W.Bernhardt, pers.comm., 2018). The *E.coli* amounts ranged from 1 to 40 CFU/100ml, with one incident where *E. coli* amounts were 100 CFU/100ml. Petroleum hydrocarbons were not detected in the Dauphin River. Mercury and methylmercury concentrations increased in the Dauphin River downstream of Buffalo Creek at the onset of the operation of the EOC in 2014/2015 but remained well below the MWQSOGs/CCME PAL guidelines (26 and 4 ng/L, respectively) during the 2014/2015 operation of the EOC (NSC and KGS Group 2016b).

6D.4.5 Sturgeon Bay

Surface water quality data for Sturgeon Bay were obtained the studies conducted from August 2011 to September 2015 as part of the Lake St. Martin Emergency Relief Channel Monitoring program by NSC

and KGS Group. Samples from 2011 to 2015 were collected and analyzed for routine parameters such as pH and conductivity, as well as for a number of nutrients, major ions, metals, and potential contaminants such as pesticides. Detailed information on the sampling methods, parameters of interest, analysis and results are provided in the 'Lake St. Martin Emergency Relief Channel Monitoring and Development of Habitat Compensation 2011-2015. Volume 3 – Water Quality' (NSC and KGS Group 2016b).

Table 6D.4-4 provides an overview of the collected data for selected parameters. Surface water quality data provided by MSD have been incorporated in Table 6D.4-4.

Table 6D.4-4 Overview of Surface Water Quality for Sturgeon Bay

Parameter	Values
Temperature (°C)	0 to 23.5
Laboratory pH	7.8 to 8.60
Laboratory Conductivity (µmhos/cm)	410 to 1100
Dissolved Oxygen (mg/l)	7.2 to 16.7
TSS (mg/l)	< 2.0 to 28
TDS (mg/l)	230 to 756
Hardness (CaCO3) (mg/l)	149 to 324
Total Nitrogen (mg/l)	0.35 to 1.38
Total Phosphorus (mg/l)	0.012 to 0.108
Chlorophyll α (µg/l)	0.13 to 14.7
E. coli (CFU/100 ml)	Not Detected
Petroleum Hydrocarbons	Not Analyzed

The water quality of Sturgeon Bay was described as moderately nutrient rich, low to moderately turbid, slightly alkaline, hard to very hard, and well-oxygenated (NSC and KGS Group 2016b). NSC and KGS Group (2015b) noted that Sturgeon Bay experiences higher turbidity levels than other deeper areas of Lake Winnipeg due to wind and wave driven sediment re-suspension. Satellite imagery of Sturgeon Bay under different wind, seasons and Dauphin River flow conditions showed how wind affects sediment re-suspension within the bay, and how sedimentation during periods of open water was much greater than when Sturgeon Bay was ice covered (NSC and KGS Group 2015b).

The TN:TP molar ratios indicated that Sturgeon Bay was phosphorus limited, and TOC:TN molar ratios showed that organic matter was a mix of autochthonous and allochthonous sources (NSC and KGS Group 2016b). TSS concentrations varied throughout the bay, with increases in TSS observed near the Dauphin River outlet during spring melt conditions and operation of the EOC (NSC and KGS Group 2016b). In data collected prior to 2011, TSS concentrations and turbidity were higher near Poplar Point (east of Willow Point at sampling station LKW1) than in the rest of the bay (NSC and KGS Group 2015a). Chlorophyll$_{\alpha}$ concentrations indicated a moderate level of primary productivity (NSC and KGS Group 2016b). Sturgeon Bay was typically isothermal, with some thermal stratification observed at two sites near

the middle of Sturgeon Bay in June 2013 and near the mouth of the Dauphin River in May 2014 (NSC and KGS Group 2016b).

A number of parameters exceeded the Manitoba Water Quality Standards, Objectives, and Guidelines (MWQSOGs) for the protection of aquatic life (PAL) (MCWS 2011), the Canadian Council of Ministers of the Environment (CCME) guidelines for the protection of freshwater aquatic life (CCME 1999), or the MWQSOGs/Health Canada aesthetic objective for drinking water (Health Canada, 2017). Chloride concentrations exceeded the CCME long-term exposure guideline for PAL in 49 out of 123 samples and fluoride levels exceeded the guideline in 61 out of 123 samples.

Aluminum concentrations exceeded the MWQSOGs/CCME guideline for PAL in 104 out of 123 samples, while chromium levels exceeded this guideline in nine (9) out of 123 samples, iron concentrations exceeded this guideline in 28 out of 123 samples, selenium concentrations exceeded this guideline in three (3) out of 123 samples and silver concentrations exceeded this guideline in five (5) out of 123 samples (NSC and KGS Group 2016b). A number of metals were consistently within the applicable MWQSOGs and CCME PAL guidelines at all sites and times, including arsenic, boron, cadmium, dissolved chromium, copper, lead, mercury, methyl mercury, molybdenum, nickel, thallium, uranium, and zinc (NSC and KGS Group 2016b).

TP concentrations exceeded the MWQSOGs narrative guideline for lakes and river mouths at most sites sampled in Sturgeon Bay, with concentrations lower in sites sampled near the Dauphin River and higher at sites sampled farther from the Dauphin River (NSC and KGS Group 2016b).

DO levels were below the MWQSOGs PAL for cold water early life, and CCME PAL for early life stages of cold water biota of 9.5 mg/l when water temperatures were ≤ 5°C in one (1) out of 28 samples (NSC and KGS Group 2016b).

Turbidity consistently exceeded the MWQSOGs/Health Canada aesthetic objective for drinking water in Sturgeon Bay, while TDS and iron levels frequently exceeded this objective, and True Colour and laboratory pH levels occasionally exceeded this objective (NSC and KGS Group 2016b). Iron concentrations exceeded the MWQSOGs/Health Canada aesthetic objective for drinking water in 28 out of 123 samples, with no exceedances of chloride or sodium concentrations for this objective found in samples collected and analyzed from Sturgeon Bay (NSC and KGS Group 2016b). Parameters with maximum acceptable concentrations that were within the guideline amounts included antimony; arsenic; barium; boron; lead; mercury; selenium; and, uranium (NSC and KGS Group 2016b).

A total of 58 types of pesticides were analyzed at selected sites in the Fairford River, Dauphin River and Sturgeon Bay (NSC and KGS Group 2016b). Glyphosate was detected at all sites sampled on July 16 and July 17, 2011, and October 28 and October 29, 2011; all other pesticides for which sufficient sample was collected to conduct the analysis were below analytical detection limits on these dates (NSC and KGS Group 2016b). One sample collected in July 2012 by NSC did not detect any *E. coli* (W. Bernhardt, pers. comm. 2018). Petroleum hydrocarbon concentrations were not monitored in Sturgeon Bay.

6D.4.6 Watchorn Bay

Surface water quality data for Watchorn Bay were obtained from samples collected and analyzed by MSD from 2005 to 2007, fisheries investigations conducted in Watchorn Bay in the fall of 2015 and spring of 2016 (AAE 2016) and surface water quality monitoring completed in the area of the proposed LMOC route from 2016 to 2018 (KGS Group 2018). Detailed information on the monitoring sampling methods, parameters of interest, analysis and results are provided in the 'Investigations and Preliminary Engineering for Lake Manitoba Outlet Channels Options C and D Deliverable D3, Annual Monitoring Report to July 01, 2018' (KGS Group 2018).

Table 6D-5 provides an overview of the collected data for selected parameters. Surface water quality data provided by MSD have been incorporated in Table 6D.4-5.

Table 6D.4-5 Overview of Surface Water Quality for Watchorn Bay

Parameter	Values
Temperature (°C)	0.47 to 26.1
Laboratory pH	8.35 to 8.62
Laboratory Conductivity (µS/cm)	604 to 886
Dissolved Oxygen (mg/l)	5.2 to 12.7
TSS (mg/l)	1 to 51
TDS (mg/l)	373 to 532
Hardness (CaCO3) (mg/l)	229 to 322
Total Nitrogen (mg/l)	0.87 to 2.6
Total Phosphorus (mg/l)	0.008 to 0.089
Chlorophyll α (µg/l)	Not Analyzed
E. coli (MPN/100 ml)	<1 to 114
Petroleum Hydrocarbons	Not Analyzed

The water quality of Watchorn Bay could be generally described as moderately nutrient rich, low to moderately turbid, slightly alkaline, hard to very hard, and well-oxygenated. Some parameters exceeded the Manitoba Water Quality Standards, Objectives, and Guidelines (MWQSOGs) for the protection of aquatic life (PAL) (MCWS 2011), or the Canadian Council of Ministers of the Environment (CCME) guidelines for the protection of freshwater aquatic life (CCME 1999). Chloride concentrations exceeded the CCME long-term exposure guideline for PAL in four (4) out of five (5) samples, and fluoride concentrations exceeded the CCME guideline for PAL in five out of five samples collected during the monitoring activities (KGS Group 2018). TP concentrations exceeded the MWQSOGs narrative guideline for lakes and streams entering lakes in four out of five samples (KGS Group 2018) and in one (1) out of eight (8) samples collected by MSD.

Aluminum concentrations exceeded the MWQSOGs and CCME guidelines for PAL in one sample collected in November 2016 (KGS Group 2018). All other metals detected in Watchorn Bay were at

concentrations within the applicable MWQSOGs and CCME PAL guidelines at all sites (KGS Group 2018).

DO levels were below the MWQSOGs PAL for cool water early life, and the CCME PAL for early life stages of warm water biota of 6.0 mg/l when water temperatures were >5°C in one (1) out of five samples, and below the MWQSOGs PAL for cold water mature life and CCME PAL for other life stages of cold water biota of 6.5 mg/l when water temperatures were >5° in one out of five samples (KGS Group 2018).

E. coli amounts ranged from <1 CFU/100ml to 114 CFU/100ml in the five samples collected in Watchorn Bay (KGS Group 2018). Chlorophyll α and petroleum hydrocarbon concentrations were not monitored in Watchorn Bay.

6D.4.7 Watchorn Creek

Surface water quality data for Watchorn Creek were obtained from fisheries investigations conducted in Watchorn Creek in the fall of 2015 and spring of 2016 (AAE 2016) and surface water quality monitoring completed in the area of the proposed LMOC route from 2016 to 2018 (KGS Group 2018). Detailed information on the monitoring sampling methods, parameters of interest, analysis and results are provided in the 'Investigations and Preliminary Engineering for Lake Manitoba Outlet Channels Options C and D Deliverable D3, Annual Monitoring Report to July 01, 2018' (KGS Group 2018).

Table 6D.4-6 provides an overview of the collected data for selected parameters.

Table 6D.4-6 Overview of Surface Water Quality for Watchorn Creek

Parameter	Values
Temperature (°C)	4.5 to 21.5
Laboratory pH	7.56 to 8.22
Laboratory Conductivity (µmhos/cm)	561 to 841
Dissolved Oxygen (mg/l)	1.60 to 8.31
TSS (NTU)	< 2.0 to 4
TDS (mg/l)	358 to 511
Hardness (CaCO3) (mg/l)	316 to 476
Total Nitrogen (mg/l)	1.22 to 2.12
Total Phosphorus (mg/l)	0.032 to 0.082
Chlorophyll α (µg/l)	Not Analyzed
E. coli (CFU/100 ml)	20 to <100
Petroleum Hydrocarbons	Not Analyzed

The water quality of Watchorn Creek could be generally described as moderately nutrient rich, low to moderately turbid, slightly alkaline, very hard, and with periods of poor oxygenation. Some parameters

exceeded the Manitoba Water Quality Standards, Objectives, and Guidelines (MWQSOGs) for the protection of aquatic life (PAL) (MCWS 2011), or the Canadian Council of Ministers of the Environment (CCME) guidelines for the protection of freshwater aquatic life (CCME 1999). Chloride concentrations were well below the CCME long-term exposure guideline for PAL but fluoride concentrations exceeded the CCME guideline for PAL in five out of five samples collected during the monitoring activities (KGS Group 2018). TP concentrations exceeded the MWQSOGs narrative guideline for lakes and streams entering lakes in all five samples (KGS Group, 2018). The Watchorn Creek samples increased in conductivity, bicarbonate, hardness, and chloride over the 2016 to 2018 sampling period (KGS Group 2018).

Dissolved phosphorus concentrations exceeded the MWQSOGs and CCME guidelines for PAL in two (2) of the five samples collected from Watchorn Creek (KGS Group 2018). All other metals detected in Watchorn Creek were at concentrations within the applicable MWQSOGs and CCME PAL guidelines at all sites (KGS Group 2018).

DO levels were below the MWQSOGs PAL for cool water early life, and the CCME PAL for early life stages of warm water biota of 6.0 mg/l when water temperatures were >5°C in three (3) out of five samples, and below the MWQSOGs PAL for cold water mature life and CCME PAL for other life stages of cold water biota of 6.5 mg/l when water temperatures were >5° in three (3) out of five samples (KGS Group 2018).

E. coli amounts ranged from 20 CFU/100ml to <100 CFU/100ml in the five samples collected in Watchorn Creek (KGS Group 2018). Chlorophyll α and petroleum hydrocarbon concentrations were not monitored in Watchorn Creek.

6D.4.8 Birch Bay

Surface water quality data for Birch Bay were obtained from fisheries investigations conducted in Birch Bay in the fall of 2015 and spring of 2016 (AAE 2016) and surface water quality monitoring completed in the area of the proposed LMOC route from 2016 to 2018 (KGS Group 2018). Detailed information on the monitoring sampling methods, parameters of interest, analysis and results are provided in the 'Investigations and Preliminary Engineering for Lake Manitoba Outlet Channels Options C and D Deliverable D3, Annual Monitoring Report to July 01, 2018' (KGS Group 2018).

Table 6D.4-7 provides an overview of the collected data for selected parameters.

Table 6D.4-7 Overview of Surface Water Quality for Birch Bay

Parameter	Values
Temperature (°C)	5.5 to 21.8
Laboratory pH	8.24 to 8.61
Laboratory Conductivity (µS/cm)	813 to 917
Dissolved Oxygen (mg/l)	5.4 to 10.6

Table 6D.4-7 Overview of Surface Water Quality for Birch Bay

Parameter	Values
TSS (NTU)	3.6 to 10.4
TDS (mg/l)	488 to 532
Hardness (CaCO3) (mg/l)	196 to 270
Total Nitrogen (mg/l)	0.82 to 2.18
Total Phosphorus (mg/l)	0.014 to 0.027
Chlorophyll α (µg/l)	Not Analyzed
E. coli (MPN/100 ml)	1 to 613
Petroleum Hydrocarbons	Not Analyzed

The water quality of Birch Bay could be generally described as moderately nutrient rich, low to moderately turbid, slightly alkaline, hard to very hard, and well-oxygenated. Some parameters exceeded the Manitoba Water Quality Standards, Objectives, and Guidelines (MWQSOGs) for the protection of aquatic life (PAL) (MCWS 2011), or the Canadian Council of Ministers of the Environment (CCME) guidelines for the protection of freshwater aquatic life (CCME 1999). Chloride concentrations exceeded the CCME long-term exposure guideline for PAL and fluoride concentrations exceeded the CCME guideline for PAL exceeded in all five (5) samples collected during the monitoring activities (KGS Group 2018). TP concentrations exceeded the MWQSOGs narrative guideline for lakes and streams entering lakes in one (1) out of five (5) samples, with the other four sample concentrations close to the guideline limit (concentrations of 0.02 to 0.024 mg/l) (KGS Group 2018).

A number of metals were detected in all five (5) sample collected from Birch Bay with concentrations within the applicable MWQSOGs and CCME PAL guidelines at all sites (KGS Group 2018).

DO levels were below the MWQSOGs PAL for cool water early life, and the CCME PAL for early life stages of warm water biota of 6.0 mg/l when water temperatures were >5°C in one (1) out of five (5) samples, and below the MWQSOGs PAL for cold water mature life and CCME PAL for other life stages of cold water biota of 6.5 mg/l when water temperatures were >5° in one (1) out of five (5) samples (KGS Group 2018).

E. coli amounts ranged from 1 CFU/100ml to 613 CFU/100ml in the five samples collected in Birch Bay, with the 613 CFU/100ml concentration found in the sample collected on May 30, 2018 (KGS Group 2018). Chlorophyll α and petroleum hydrocarbon concentrations were not monitored in Birch Bay.

6D.4.9 Birch Creek

Surface water quality data for Birch Creek were obtained from fisheries investigations conducted in Birch Creek in the fall of 2015 and spring of 2016 (AAE 2016) and surface water quality monitoring completed in the area of the proposed LMOC route from 2016 to 2018 (KGS Group 2018). Detailed information on the monitoring sampling methods, parameters of interest, analysis and results are provided in the

'Investigations and Preliminary Engineering for Lake Manitoba Outlet Channels Options C and D Deliverable D3, Annual Monitoring Report to July 01, 2018' (KGS Group 2018).

Table 6D.4-8 provides an overview of the collected data for selected parameters.

Table 6D.4-8 Overview of Surface Water Quality for Birch Creek

Parameter	Values
Temperature (°C)	5.4 to 20.5
Laboratory pH	8.06 to 8.49
Laboratory Conductivity (µmhos/cm)	667 to 857
Dissolved Oxygen (mg/l)	3.11 to 10.04
TSS (mg/l)	< 2.0 to 6.4
TDS (mg/l)	436 to 549
Hardness (CaCO3) (mg/l)	419 to 526
Total Nitrogen (mg/l)	1.36 to 2.55
Total Phosphorus (mg/l)	0.016 to 0.073
Chlorophyll α (µg/l)	Not Analyzed
E. coli (MPN/100 ml)	11 to 249
Petroleum Hydrocarbons	Not Analyzed

The water quality of Birch Creek could be generally described as moderately nutrient rich, low to moderately turbid, slightly alkaline, hard to very hard, and mostly well-oxygenated. Some parameters exceeded the Manitoba Water Quality Standards, Objectives, and Guidelines (MWQSOGs) for the protection of aquatic life (PAL) (MCWS 2011), or the Canadian Council of Ministers of the Environment (CCME) guidelines for the protection of freshwater aquatic life (CCME 1999). Chloride concentrations were well below the CCME long-term exposure guideline for PAL but fluoride concentrations exceeded the CCME guideline for PAL in 10 out of 10 samples collected during the monitoring activities (KGS Group 2018). TP concentrations exceeded the MWQSOGs narrative guideline for lakes and streams entering lakes in eight (8) out of 10 samples (KGS Group 2018).

Iron and dissolved phosphorus concentrations exceeded the MWQSOGs and CCME guidelines for PAL in one (1) out of 10 samples collected; the exceedances occurred in the May 30, 2018 sample (KGS Group 2018). All other metals detected in Birch Creek were at concentrations within the applicable MWQSOGs and CCME PAL guidelines at all sites (KGS Group 2018).

DO levels were below the MWQSOGs PAL for cool water early life, and the CCME PAL for early life stages of warm water biota of 6.0 mg/l when water temperatures were >5°C in four (4) out of ten samples, and below the MWQSOGs PAL for cold water mature life and CCME PAL for other life stages of cold water biota of 6.5 mg/l when water temperatures were >5° in four (4) out of ten samples (KGS Group 2018).

E. coli amounts ranged from 11 CFU/100ml to 249 CFU/100ml in the 10 samples collected in Birch Creek (KGS Group 2018). Chlorophyll α and petroleum hydrocarbon concentrations were not monitored in Birch Creek.

6D.4.10 Buffalo Creek Watershed

Surface water quality data for the Buffalo Creek Watershed were obtained from the studies conducted from August 2011 to September 2015 as part of the Lake St. Martin Emergency Relief Channel Monitoring program by NSC and KGS Group. Samples from 2011 to 2015 were collected and analyzed for routine parameters such as pH and conductivity, as well as for a number of nutrients, major ions, metals, and potential contaminants such as E. coli or pesticides. Detailed information on the sampling methods, parameters of interest, analysis and results are provided in the 'Lake St. Martin Emergency Relief Channel Monitoring and Development of Habitat Compensation 2011-2015. Volume 3 – Water Quality' (NSC and KGS Group 2016b).

A brief sampling program was conducted in Big Buffalo Lake in August of 2011 to support the planning of field studies and monitoring in the Project area (NSC 2012; 2013). *In situ* water temperatures collected on August 17, 2011 ranged from 18.8 to 19.8°C with pH values from 7.28 to 7.53 and turbidity values from 3.5 to 6.2 NTUs. Secchi disk depths ranged from 1.2 to 2.2 m. The lake was considered to be not thermally stratified, relatively well-oxygenated and near-neutral based on *in situ* measurements collected from four sites in Big Buffalo Lake (NSC 2012).

In situ measurements of surface water quality collected at the mouth of Buffalo Creek immediately upstream of its confluence with the Dauphin River showed that water at the creek mouth was slightly more turbid, acidic, less oxygenated, and warmer than measured at Big Buffalo Lake (NSC 2013). It was noted that the parameter values measured at this site in August 2011 varied slightly from comparable samples collected along Buffalo Creek and in the Dauphin River during fall 2011 (NSC 2013).

NSC and KGS Group (2016) described the water quality of Buffalo Creek as generally well-oxygenated, nutrient moderate, clear, slightly alkaline, highly coloured and hard. Table 6D.4-9 provides an overview of the collected data for selected parameters.

Table 6D.4-9 Overview of Surface Water Quality for Buffalo Creek

Parameter	Values
Temperature (°C)	0 to 25
Laboratory pH	8.12 to 8.19
Laboratory Conductivity (µmhos/cm)	217 to 237
Dissolved Oxygen (mg/l)	6.4 to 12.2
TSS (mg/l)	< 2.0 to 6.0
TDS (mg/l)	164 to 177
Hardness (CaCO3) (mg/l)	155 to 166
Total Nitrogen (mg/l)	0.76 to 1.15

Table 6D.4-9 Overview of Surface Water Quality for Buffalo Creek

Parameter	Values
Total Phosphorus (mg/l)	< 0.010 to 0.026
Chlorophyll α (µg/l)	0.37 to 0.52
E. coli (CFU/100 ml)	Not Analyzed
Petroleum Hydrocarbons	Not Detected

TSS concentrations were similar throughout the creek and ranged from < 2.0 to 6.0 mg/L. Laboratory data for pH were limited, but values ranged from 8.12 to 8.19. True colour ranged from 51.5 to 53.2 CU and it was noted that true colour exceeded the MWQSOGs/Health Canada aesthetic objectives for drinking water (i.e., ≤ 15 CU) throughout the creek. Conductivity ranged from 217 to 237 µmhos/cm, TDS ranged from 164 to 177 mg/L and Hardness ranged from 155 to 166 mg/L. DO concentrations ranged from 6.4 to 12.2 mg/L. One of five DO measurements from the upstream end of the creek was below the MWQSOGs PAL for cold water mature life/CCME lowest acceptable concentration for other life stages of cold water biota (i.e., <6.5 mg/L). All other routine parameters were within MWQSOGs and CCME guidelines for PAL, including ammonia, TP, nitrate, nitrite, and pH (NSC and KGS Group 2016b).

TN ranged from 0.76 to 1.15 mg/L and was mostly composed of organic forms. TP concentrations in the creek ranged from < 0.010 to 0.026 mg/L and were predominately composed of dissolved forms. Carbon concentrations were composed of similar amounts of organic and inorganic forms and, organic carbon was primarily dissolved. Chlorophyll α concentrations ranged from 0.37 to 0.52 µg/L, which indicated that primary productivity in the creek was low and turbidity exceeded the MWQSOGs/Health Canada aesthetic objectives for drinking water (i.e., 1.0 NTU) throughout the creek. All other routine parameters were within drinking water guidelines, including pH, nitrate/nitrite, nitrate, nitrite, and TDS (NSC and KGS Group 2016b).

Antimony, total boron, cadmium, chromium, lead, molybdenum, nickel, selenium, silver, thallium, uranium and zinc were not detected in Buffalo Creek whereas total aluminum, arsenic, barium, calcium, chloride, fluoride, magnesium, manganese, mercury, total methyl mercury, potassium, sodium, and sulphate were consistently detected (NSC and KGS Group 2016b). Dissolved boron, copper, iron, and dissolved methyl mercury were detected in some samples and aluminum exceeded the MWQSOGs and CCME PAL (i.e., 0.1 mg/L) at the downstream end of Buffalo Creek. All other metals and major ions were within MWQSOGs and CCME guidelines for PAL and drinking water and petroleum hydrocarbons were not detected in Buffalo Creek (NSC and KGS Group 2016b).

The water quality of Buffalo Creek differed from Lake St. Martin, the Dauphin River or Sturgeon Bay; Buffalo Creek had lower turbidity/TSS, lower conductivity and TDS, lower chlorophyll α, higher concentrations of organic carbon, greater colour, and a higher amount of phosphorus in dissolved form than the other waterbodies in the study area (NSC 2013).

NSC (2016) reported that water temperature in Buffalo Creek was typically 5°C to 10°C at the onset of monitoring in mid-April, increased to about 20°C to 25°C by July/August, and began decreasing in late

August/early September to a low of 0°C to 5°C by the end of monitoring each year, i.e., by mid-November. Water temperature trends in Big Buffalo Lake were similar, with the exception of a slower rate of warming in the lake during spring (NSC 2016).

6D.5 EXISTING AND POTENTIAL SOURCES OF SURFACE WATER CONTAMINANTS

The review of existing surface water conditions within the area included the identification of existing and potential sources of surface water contaminants. Table 6D.5-1 provides a summary of the existing and potential sources of contaminants identified, including information on federally or provincially listed contaminated sites.

Table 6D.5-1 Sources of Existing and Potential Surface Water Contaminants in the Area

Contaminant Source	Site Location or Area of Use	Existing or Potential Contaminants
Air Transportation	Airports in area	De-icing chemicals and fire fighting foam surfactants; fuel and equipment spills/leaks
Agricultural Practices	Agricultural fields	Fertilizers, herbicides, pesticides; fuel and equipment spills/leaks
Federal Contaminated Sites	Several locations around Lake St. Martin within Indigenous communities in the area	Petroleum hydrocarbons; metal, metalloid, and organometallic compounds
Quarries and Rock-Processing	Graymont plant and quarries in area (Gypsumville, Hilbre)	Fuel and equipment spills; release of sediment, metals
Recreational Activities	Roads, trails, waterways	Transfer of invasive plant and animal species; fuel and equipment spills/leaks; lead from ammunition/fishing gear
Road, Bridge and Culvert Maintenance	Highways and roads in area	Fuel and equipment spills/leaks; road de-icing chemicals, road salt
Underground Fuel Storage Tanks	St. Martin Garage	Petroleum hydrocarbons, other fuels/oils
Vegetation Management	ROWs of roadways, transmission lines, distribution lines, Wildlife Management Areas	Herbicides, pesticides; fuel and equipment spills/leaks
Waste Disposal	Waste disposal grounds, waste transfer stations, households, businesses, farms	Household/commercial/industrial cleaning, building and healthcare products and waste; fuel and equipment spills/leaks
Wastewater Discharge	Wastewater lagoon effluent discharge locations and receiving waters	Household/commercial/industrial cleaning and healthcare products and waste; *E. coli* and other coliforms

In addition to the wastewater lagoons, there are also a number of residences and farms located throughout the area that use septic tanks and septic fields for wastewater treatment and disposal. There was only one location found with underground fuel storage tanks, at the St. Martin Garage. There are also a number of gasoline and diesel fuel stations operating in the area.

There were no provincially listed contaminated sites found in the area. There were a number of suspected, active or closed federally listed contaminated sites identified in the area.

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PERSONAL COMMUNICATIONS

Bernhardt, W. 2018. Senior Aquatic Biologist/Principal. North/South Consultants Inc.

Appendix 6E REGIONAL FLOW AND LAKE LEVEL DATA

Table 6E-1

Average Monthly Flows For Fairford & Dauphin Rivers and Lake Outflows

Time	Fairford River Outflow (cfs)			LMB Outflow (cfs)			Dauphin River Flow (cfs)			LSM Outflow (cfs)		
	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project
Jan	2,368	2,368	1,625	2,368	2,368	2,014	1,767	1,704	1,079	1,787	1,787	1,509
Feb	2,591	2,591	1,667	2,591	2,591	1,985	2,084	2,008	1,259	2,095	2,095	1,585
Mar	2,436	2,436	1,648	2,436	2,436	1,958	2,552	2,461	1,677	2,541	2,541	1,982
Apr	2,716	2,716	1,998	2,716	2,716	2,416	3,412	3,318	2,576	3,380	3,380	2,921
May	3,654	3,654	3,112	3,654	3,654	4,425	3,602	3,489	2,803	3,638	3,638	4,413
Jun	4,177	4,177	3,520	4,177	4,177	5,250	3,892	3,749	2,864	3,910	3,910	5,184
Jul	4,182	4,182	3,244	4,182	4,182	5,012	4,085	3,889	2,825	4,114	4,114	5,071
Aug	3,630	3,630	2,377	3,630	3,630	3,764	3,803	3,595	2,459	3,793	3,793	3,997
Sep	3,057	3,057	1,778	3,057	3,057	2,918	3,399	3,219	2,157	3,382	3,382	3,167
Oct	2,754	2,754	1,620	2,754	2,754	2,591	3,005	2,857	1,911	2,978	2,978	2,725
Nov	2,400	2,400	1,554	2,400	2,400	2,502	2,682	2,581	1,860	2,661	2,661	2,547
Dec	2,384	2,384	1,585	2,384	2,384	2,051	1,989	1,914	1,311	1,990	1,990	1,722
Annual												

Conversion 1ft= 0.3048 m 1cfs = 0.028317 cms

Time	Fairford River Outflow (cms)			LMB Outflow (cms)			Dauphin River Flow (cms)			LSM Outflow (cms)		
	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project
Jan	67.0	67.0	46.0	67.0	67.0	57.0	50.0	48.2	30.5	50.6	50.6	42.7
Feb	73.4	73.4	47.2	73.4	73.4	56.2	59.0	56.9	35.7	59.3	59.3	44.9
Mar	69.0	69.0	46.7	69.0	69.0	55.5	72.3	69.7	47.5	72.0	72.0	56.1
Apr	76.9	76.9	56.6	76.9	76.9	68.4	96.6	94.0	72.9	95.7	95.7	82.7
May	103.5	103.5	88.1	103.5	103.5	125.3	102.0	98.8	79.4	103.0	103.0	125.0
Jun	118.3	118.3	99.7	118.3	118.3	148.7	110.2	106.2	81.1	110.7	110.7	146.8
Jul	118.4	118.4	91.9	118.4	118.4	141.9	115.7	110.1	80.0	116.5	116.5	143.6
Aug	102.8	102.8	67.3	102.8	102.8	106.6	107.7	101.8	69.6	107.4	107.4	113.2
Sep	86.6	86.6	50.3	86.6	86.6	82.6	96.2	91.2	61.1	95.8	95.8	89.7
Oct	78.0	78.0	45.9	78.0	78.0	73.4	85.1	80.9	54.1	84.3	84.3	77.2
Nov	68.0	68.0	44.0	68.0	68.0	70.9	75.9	73.1	52.7	75.4	75.4	72.1
Dec	67.5	67.5	44.9	67.5	67.5	58.1	56.3	54.2	37.1	56.4	56.4	48.8
Annual												

Table 6E-2

Average Monthly Lake Water Levels and OC channel Flows

Time	LMB Water Level (ft)			LSM Water Level (ft)			LMB Outlet Channel Flow (cfs)			LSM Outlet Channel Flow (cfs)		
	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project
Jan	811.3	811.3	811.1	798.5	798.5	798.0	-	-	389	-	83	430
Feb	811.3	811.3	811.1	798.8	798.8	798.3	-	-	317	-	87	326
Mar	811.3	811.3	811.1	798.9	798.9	798.3	-	-	310	-	80	305
Apr	811.4	811.4	811.3	798.5	798.5	798.1	-	-	418	-	61	345
May	811.7	811.7	811.5	798.6	798.6	798.2	-	-	1,313	-	149	1,610
Jun	811.8	811.8	811.6	798.7	798.7	798.2	-	-	1,729	-	161	2,320
Jul	811.8	811.8	811.5	798.8	798.8	798.2	-	-	1,768	-	225	2,246
Aug	811.6	811.6	811.3	798.6	798.6	797.9	-	-	1,387	-	198	1,538
Sep	811.4	811.4	811.1	798.4	798.3	797.7	-	-	1,139	-	163	1,010
Oct	811.3	811.3	811.0	798.1	798.1	797.5	-	-	971	-	120	814
Nov	811.3	811.3	811.0	798.0	797.9	797.4	-	-	949	-	80	687
Dec	811.3	811.3	811.1	798.0	798.0	797.5	-	-	466	-	77	410
Annual												

Conversion

Time	LMB Water Level (m)			LSM Water Level (m)			LMB Outlet Channel Flow (cms)			LSM Outlet Channel Flow (cms)		
	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project
Jan	247.30	247.30	247.23	243.39	243.38	243.23	-	-	11.01	-	2.36	12.18
Feb	247.29	247.29	247.23	243.49	243.48	243.31	-	-	8.99	-	2.47	9.24
Mar	247.28	247.28	247.23	243.51	243.50	243.33	-	-	8.78	-	2.26	8.64
Apr	247.32	247.32	247.27	243.39	243.38	243.25	-	-	11.83	-	1.74	9.76
May	247.40	247.40	247.35	243.42	243.41	243.30	-	-	37.19	-	4.23	45.58
Jun	247.43	247.43	247.37	243.46	243.44	243.30	-	-	48.97	-	4.55	65.70
Jul	247.42	247.42	247.35	243.48	243.46	243.29	-	-	50.06	-	6.37	63.59
Aug	247.36	247.36	247.28	243.43	243.40	243.20	-	-	39.27	-	5.61	43.54
Sep	247.31	247.31	247.22	243.35	243.33	243.13	-	-	32.27	-	4.62	28.59
Oct	247.28	247.28	247.20	243.27	243.26	243.07	-	-	27.48	-	3.41	23.04
Nov	247.28	247.28	247.20	243.22	243.21	243.06	-	-	26.87	-	2.28	19.45
Dec	247.29	247.29	247.21	243.23	243.22	243.08	-	-	13.21	-	2.17	11.62
Annual												

Table 6E-3

Median (50%tile) Monthly Flows For Fairford & Dauphin Rivers and Lake Outflows

Time	Fairford River Outflow (cfs)			LMB Outflow = Fairford + LMOC (cfs)			Dauphin River Flow (cfs)			LSM Outflow = Dauphin plus LSM EC or LSM OC (cfs)			
	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	No LSMEOC	Without the Project (with LSM EOC)	With the Project	
Jan	1,775	1,775	1,355	1,775	1,775	1,591	1,146	1,146	890	1,146	1,146	950	
Feb	1,727	1,727	1,403	1,727	1,727	1,628	1,410	1,410	1,120	1,410	1,410	1,249	
Mar	1,691	1,691	1,382	1,691	1,691	1,568	1,829	1,829	1,491	1,829	1,829	1,576	
Apr	1,847	1,847	1,735	1,847	1,847	1,816	2,637	2,637	2,446	2,637	2,637	2,483	
May	2,613	2,613	2,399	2,613	2,613	2,559	2,703	2,703	2,624	2,703	2,703	2,624	
Jun	2,714	2,714	2,450	2,714	2,714	2,850	2,750	2,750	2,681	2,750	2,750	2,724	
Jul	2,643	2,643	2,281	2,643	2,643	2,632	2,594	2,594	2,607	2,594	2,594	2,614	
Aug	2,196	2,196	1,661	2,196	2,196	2,042	2,418	2,418	2,148	2,418	2,418	2,205	
Sep	1,720	1,720	1,243	1,720	1,720	1,667	2,235	2,235	1,916	2,235	2,235	1,916	
Oct	1,663	1,663	1,136	1,663	1,663	1,513	2,090	2,090	1,677	2,090	2,090	1,677	
Nov	1,646	1,646	1,174	1,646	1,646	1,521	1,970	1,970	1,599	1,970	1,970	1,599	
Dec	1,689	1,689	1,245	1,689	1,689	1,574	1,327	1,327	1,103	1,327	1,327	1,134	
Annual													

Conversion 1ft = 0.3048 m 1cfs = 0.028317 cms

Time	Fairford River Outflow (cms)			LMB Outflow (cms)			Dauphin River Flow (cms)			LSM Outflow (cms)			
	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	No LSMEOC	Without the Project (with LSM EOC)	With the Project	
Jan	50.3	50.3	38.4	50.3	50.3	45.1	32.4	32.4	25.2	32.4	32.4	26.9	
Feb	48.9	48.9	39.7	48.9	48.9	46.1	39.9	39.9	31.7	39.9	39.9	35.4	
Mar	47.9	47.9	39.1	47.9	47.9	44.4	51.8	51.8	42.2	51.8	51.8	44.6	
Apr	52.3	52.3	49.1	52.3	52.3	51.4	74.7	74.7	69.3	74.7	74.7	70.3	
May	74.0	74.0	67.9	74.0	74.0	72.5	76.5	76.5	74.3	76.5	76.5	74.3	
Jun	76.9	76.9	69.4	76.9	76.9	80.7	77.9	77.9	75.9	77.9	77.9	77.1	
Jul	74.8	74.8	64.6	74.8	74.8	74.5	73.5	73.5	73.8	73.5	73.5	74.0	
Aug	62.2	62.2	47.0	62.2	62.2	57.8	68.5	68.5	60.8	68.5	68.5	62.4	
Sep	48.7	48.7	35.2	48.7	48.7	47.2	63.3	63.3	54.3	63.3	63.3	54.3	
Oct	47.1	47.1	32.2	47.1	47.1	42.8	59.2	59.2	47.5	59.2	59.2	47.5	
Nov	46.6	46.6	33.2	46.6	46.6	43.1	55.8	55.8	45.3	55.8	55.8	45.3	
Dec	47.8	47.8	35.2	47.8	47.8	44.6	37.6	37.6	31.2	37.6	37.6	32.1	
Annual													

Table 6E-4

Median (50%tile) Monthly Lake Water Levels and OC channel Flows

Time	LMB Water Level (ft)			LSM Water Level (ft)			LMB Outlet Channel Flow (cfs)			LSM Outlet Channel Flow (cfs)		
	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project
Jan	811.52	811.52	811.30	798.27	798.27	797.99	-	-	-	-	-	-
Feb	811.50	811.50	811.30	798.57	798.57	798.24	-	-	-	-	-	-
Mar	811.48	811.48	811.31	798.58	798.58	798.33	-	-	-	-	-	-
Apr	811.54	811.54	811.44	798.18	798.18	798.04	-	-	-	-	-	-
May	811.77	811.77	811.65	798.23	798.23	798.17	-	-	-	-	-	-
Jun	811.81	811.81	811.66	798.27	798.27	798.22	-	-	-	-	-	-
Jul	811.77	811.77	811.56	798.15	798.15	798.16	-	-	-	-	-	-
Aug	811.62	811.62	811.40	798.01	798.01	797.79	-	-	-	-	-	-
Sep	811.49	811.49	811.24	797.86	797.86	797.60	-	-	-	-	-	-
Oct	811.47	811.47	811.19	797.74	797.74	797.40	-	-	-	-	-	-
Nov	811.46	811.46	811.20	797.64	797.64	797.33	-	-	-	-	-	-
Dec	811.48	811.48	811.25	797.72	797.72	797.49	-	-	-	-	-	-
Annual												

Conversion

Time	LMB Water Level (m)			LSM Water Level (m)			LMB Outlet Channel Flow (cms)			LSM Outlet Channel Flow (cms)		
	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	No LSMEOC	Without the Project (with LSM EOC)	With the Project
Jan	247.35	247.35	247.28	243.31	243.31	243.23	-	-	-	-	-	-
Feb	247.34	247.34	247.28	243.40	243.40	243.30	-	-	-	-	-	-
Mar	247.34	247.34	247.29	243.41	243.41	243.33	-	-	-	-	-	-
Apr	247.36	247.36	247.33	243.29	243.29	243.24	-	-	-	-	-	-
May	247.43	247.43	247.39	243.30	243.30	243.28	-	-	-	-	-	-
Jun	247.44	247.44	247.39	243.31	243.31	243.30	-	-	-	-	-	-
Jul	247.43	247.43	247.36	243.28	243.28	243.28	-	-	-	-	-	-
Aug	247.38	247.38	247.31	243.23	243.23	243.17	-	-	-	-	-	-
Sep	247.34	247.34	247.27	243.19	243.19	243.11	-	-	-	-	-	-
Oct	247.34	247.34	247.25	243.15	243.15	243.05	-	-	-	-	-	-
Nov	247.33	247.33	247.26	243.12	243.12	243.03	-	-	-	-	-	-
Dec	247.34	247.34	247.27	243.15	243.15	243.08	-	-	-	-	-	-
Annual												

Table 6E-5

High (5% greater than) Monthly Flows For Fairford & Dauphin Rivers and Lake Outflows

Time	Fairford River Outflow (cfs)			LMB Outflow = Fairford + LMOC (cfs)			Dauphin River Flow (cfs)			LSM Outflow = Dauphin plus LSM EC or LSM OC (cfs)			
	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	No LSMEOC	Without the Project (with LSM EOC)	With the Project	
Jan	5,014	5,014	3,498	5,014	5,014	6,639	4,846	4,834	2,707	4,846	4,846	6,044	
Feb	9,846	9,846	3,348	9,846	9,846	6,447	6,053	5,672	2,844	6,053	6,053	5,215	
Mar	9,154	9,154	3,329	9,154	9,154	5,347	7,644	7,304	3,639	7,641	7,641	5,424	
Apr	9,406	9,406	4,288	9,406	9,406	7,408	10,620	8,166	4,686	10,495	10,495	7,239	
May	10,545	10,545	10,319	10,545	10,545	16,807	9,994	8,744	5,681	9,994	9,994	15,545	
Jun	11,085	11,085	10,194	11,085	11,085	16,654	10,229	9,681	6,164	10,142	10,142	16,538	
Jul	10,373	10,373	9,337	10,373	10,373	15,643	10,137	9,682	5,730	10,067	10,067	15,645	
Aug	9,511	9,511	6,735	9,511	9,511	12,677	9,674	9,071	4,902	9,622	9,622	12,763	
Sep	9,068	9,068	4,576	9,068	9,068	10,045	9,166	8,526	4,549	9,166	9,166	10,042	
Oct	8,163	8,163	3,799	8,163	8,163	7,626	8,820	7,690	4,010	8,117	8,117	8,197	
Nov	5,111	5,111	3,296	5,111	5,111	8,150	6,933	6,794	4,166	6,794	6,794	8,324	
Dec	5,037	5,037	3,232	5,037	5,037	6,535	5,369	5,345	3,245	5,345	5,345	6,194	
Annual													

Conversion 1 ft = 0.3048 m 1 cfs= 0.0283168 cms

Time	Fairford River Outflow (cms)			LMB Outflow = Fairford + LMOC (cms)			Dauphin River Flow (cms)			LSM Outflow = Dauphin plus LSM EC or LSM OC (cms)			
	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	No LSMEOC	Without the Project (with LSM EOC)	With the Project	
Jan	142	142	99	142	142	188	137	137	77	137	137	171	
Feb	279	279	95	279	279	183	171	161	81	171	171	148	
Mar	259	259	94	259	259	151	216	207	103	216	216	154	
Apr	266	266	121	266	266	210	301	231	133	297	297	205	
May	299	299	292	299	299	476	283	248	161	283	283	440	
Jun	314	314	289	314	314	472	290	274	175	287	287	468	
Jul	294	294	264	294	294	443	287	274	162	285	285	443	
Aug	269	269	191	269	269	359	274	257	139	272	272	361	
Sep	257	257	130	257	257	284	260	241	129	260	260	284	
Oct	231	231	108	231	231	216	250	218	114	230	230	232	
Nov	145	145	93	145	145	231	196	192	118	192	192	236	
Dec	143	143	92	143	143	185	152	151	92	151	151	175	
Annual													

Table 6E-6

High (5% Greater Than) Monthly Lake Water Levels and OC channel Flows

Time	LMB Water Level (ft)			LSM Water Level (ft)			LMB Outlet Channel Flow (cfs)			LSM Outlet Channel Flow (cfs)		
	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	No LSMEOC	Without the Project (with LSM EOC)	With the Project
Jan	812.9	812.9	811.9	801.0	801.0	799.9	-	-	3,362	-	-	3,535
Feb	812.8	812.8	811.9	802.1	802.0	800.0	-	-	3,168	-	-	2,317
Mar	812.6	812.6	811.9	802.7	802.3	800.1	-	-	3,091	-	-	2,632
Apr	812.7	812.7	812.2	802.5	801.5	799.7	-	-	3,685	-	-	2,884
May	813.0	813.0	812.7	802.3	801.8	800.3	-	-	6,491	-	-	9,684
Jun	813.2	813.2	812.6	802.3	802.1	800.6	-	-	6,465	-	-	10,373
Jul	813.0	813.0	812.5	802.3	802.1	800.4	-	-	6,312	-	2,181	9,915
Aug	812.7	812.7	812.2	802.1	801.9	799.9	-	-	5,973	-	2,103	8,009
Sep	812.6	812.6	811.9	801.9	801.7	799.6	-	-	5,733	-	-	5,576
Oct	812.4	812.4	812.0	801.8	801.3	799.2	-	-	5,582	-	-	4,353
Nov	812.4	812.4	811.9	801.0	800.9	799.3	-	-	5,712	-	-	4,229
Dec	812.5	812.5	811.8	800.6	800.6	799.3	-	-	3,517	-	-	2,981
Annual												

Conversion

Time	LMB Water Level (m)			LSM Water Level (m)			LMB Outlet Channel Flow (cms)			LSM Outlet Channel Flow (cms)		
	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	No LSMEOC	Without the Project (with LSM EOC)	With the Project
Jan	247.76	247.76	247.47	244.15	244.15	243.81	-	-	95.2	-	-	100.1
Feb	247.74	247.74	247.47	244.48	244.46	243.85	-	-	89.7	-	-	65.6
Mar	247.68	247.68	247.46	244.67	244.54	243.86	-	-	87.5	-	-	74.5
Apr	247.70	247.70	247.55	244.60	244.31	243.75	-	-	104.3	-	-	81.7
May	247.81	247.81	247.70	244.53	244.38	243.94	-	-	183.8	-	-	274.2
Jun	247.86	247.86	247.69	244.55	244.49	244.02	-	-	183.1	-	-	293.7
Jul	247.79	247.79	247.64	244.54	244.49	243.95	-	-	178.7	-	61.8	280.8
Aug	247.71	247.71	247.55	244.49	244.42	243.80	-	-	169.1	-	59.5	226.8
Sep	247.67	247.67	247.48	244.43	244.35	243.72	-	-	162.3	-	-	157.9
Oct	247.61	247.61	247.49	244.39	244.25	243.60	-	-	158.1	-	-	123.3
Nov	247.62	247.62	247.46	244.15	244.13	243.64	-	-	161.7	-	-	119.8
Dec	247.66	247.66	247.45	244.01	244.01	243.63	-	-	99.6	-	-	84.4
Annual												

Table 6E-7

Low (95% greater than) Monthly Flows For Fairford & Dauphin Rivers and Lake Outflows

Time	Fairford River Outflow (cfs)			LMB Outflow (cfs)			Dauphin River Flow (cfs)			LSM Outflow (cfs)			
	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	No LSMEOC	Without the Project (with LSM EOC)	With the Project	
Jan	365	365	363	365	365	363	23	23	23	23	23	23	
Feb	369	369	370	369	369	370	44	44	45	44	44	45	
Mar	377	377	381	377	377	381	65	65	65	65	65	65	
Apr	442	442	452	442	442	453	751	751	761	751	751	761	
May	474	474	488	474	474	488	791	791	798	791	791	798	
Jun	514	514	530	514	514	531	587	587	592	587	587	592	
Jul	479	479	494	479	479	494	537	537	547	537	537	547	
Aug	374	374	377	374	374	377	385	385	391	385	385	391	
Sep	316	316	314	316	316	314	337	337	340	337	337	340	
Oct	268	268	262	268	268	262	295	295	296	295	295	296	
Nov	260	260	254	262	262	254	279	279	277	279	279	277	
Dec	335	335	331	335	335	331	102	102	102	102	102	102	
Annual													

Conversion 1ft 0.3048 m 1cfs 0.028317 cms

Time	Fairford River Outflow (cms)			LMB Outflow (cms)			Dauphin River Flow (cms)			LSM Outflow (cms)			
	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	No LSMEOC	Without the Project (with LSM EOC)	With the Project	
Jan	10.3	10.3	10.3	10.3	10.3	10.3	0.7	0.7	0.7	0.7	0.7	0.7	
Feb	10.4	10.4	10.5	10.5	10.5	10.5	1.3	1.3	1.3	1.3	1.3	1.3	
Mar	10.7	10.7	10.8	10.7	10.7	10.8	1.8	1.8	1.8	1.8	1.8	1.8	
Apr	12.5	12.5	12.8	12.5	12.5	12.8	21.3	21.3	21.5	21.3	21.3	21.5	
May	13.4	13.4	13.8	13.4	13.4	13.8	22.4	22.4	22.6	22.4	22.4	22.6	
Jun	14.6	14.6	15.0	14.6	14.6	15.0	16.6	16.6	16.8	16.6	16.6	16.8	
Jul	13.6	13.6	14.0	13.6	13.6	14.0	15.2	15.2	15.5	15.2	15.2	15.5	
Aug	10.6	10.6	10.7	10.6	10.6	10.7	10.9	10.9	11.1	10.9	10.9	11.1	
Sep	8.9	8.9	8.9	8.9	8.9	8.9	9.6	9.6	9.6	9.6	9.6	9.6	
Oct	7.6	7.6	7.4	7.6	7.6	7.4	8.4	8.4	8.4	8.4	8.4	8.4	
Nov	7.4	7.4	7.2	7.4	7.4	7.2	7.9	7.9	7.8	7.9	7.9	7.8	
Dec	9.5	9.5	9.4	9.5	9.5	9.4	2.9	2.9	2.9	2.9	2.9	2.9	
Annual													

Table 6E-8

Low (95% Greater Than) Monthly Lake Water Levels and OC channel Flows

Time	LMB Water Level (ft)			LSM Water Level (ft)			LMB Outlet Channel Flow (cfs)			LSM Outlet Channel Flow (cfs)		
	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	No LSMEOC	Without the Project (with LSM EOC)	With the Project
Jan	809.9	809.9	809.8	796.2	796.2	796.2	-	-	-	-	-	-
Feb	809.9	809.9	809.8	796.4	796.4	796.4	-	-	-	-	-	-
Mar	809.9	809.9	809.8	796.5	796.5	796.5	-	-	-	-	-	-
Apr	810.0	810.0	810.0	796.5	796.5	796.5	-	-	-	-	-	-
May	810.1	810.1	810.0	796.5	796.5	796.5	-	-	-	-	-	-
Jun	810.2	810.2	810.1	796.3	796.3	796.3	-	-	-	-	-	-
Jul	810.1	810.1	810.0	796.2	796.2	796.2	-	-	-	-	-	-
Aug	809.9	809.9	809.8	796.0	796.0	796.0	-	-	-	-	-	-
Sep	809.8	809.8	809.7	796.0	796.0	796.0	-	-	-	-	-	-
Oct	809.7	809.7	809.6	795.8	795.8	795.8	-	-	-	-	-	-
Nov	809.6	809.6	809.6	795.8	795.8	795.8	-	-	-	-	-	-
Dec	809.8	809.8	809.7	795.9	795.9	795.9	-	-	-	-	-	-
Annual												

Conversion

Time	LMB Water Level (m)			LSM Water Level (m)			LMB Outlet Channel Flow (cms)			LSM Outlet Channel Flow (cms)		
	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	Without the Project (No LSM EOC)	Without the Project (with LSM EOC)	With the Project	No LSMEOC	Without the Project (with LSM EOC)	With the Project
Jan	246.85	246.85	246.82	242.69	242.69	242.69	-	-	-	-	-	-
Feb	246.85	246.85	246.83	242.76	242.76	242.76	-	-	-	-	-	-
Mar	246.85	246.85	246.83	242.79	242.79	242.79	-	-	-	-	-	-
Apr	246.89	246.89	246.87	242.76	242.76	242.77	-	-	-	-	-	-
May	246.91	246.91	246.90	242.78	242.78	242.78	-	-	-	-	-	-
Jun	246.94	246.94	246.92	242.71	242.71	242.71	-	-	-	-	-	-
Jul	246.92	246.92	246.90	242.69	242.69	242.69	-	-	-	-	-	-
Aug	246.85	246.85	246.83	242.63	242.63	242.64	-	-	-	-	-	-
Sep	246.81	246.81	246.79	242.61	242.61	242.61	-	-	-	-	-	-
Oct	246.78	246.78	246.76	242.57	242.57	242.57	-	-	-	-	-	-
Nov	246.78	246.78	246.76	242.56	242.56	242.56	-	-	-	-	-	-
Dec	246.83	246.83	246.80	242.59	242.59	242.59	-	-	-	-	-	-
Annual												

Figure 6E-1

Duration Curves for Lake Manitoba Elevations, Fairford River and LMOC Flows

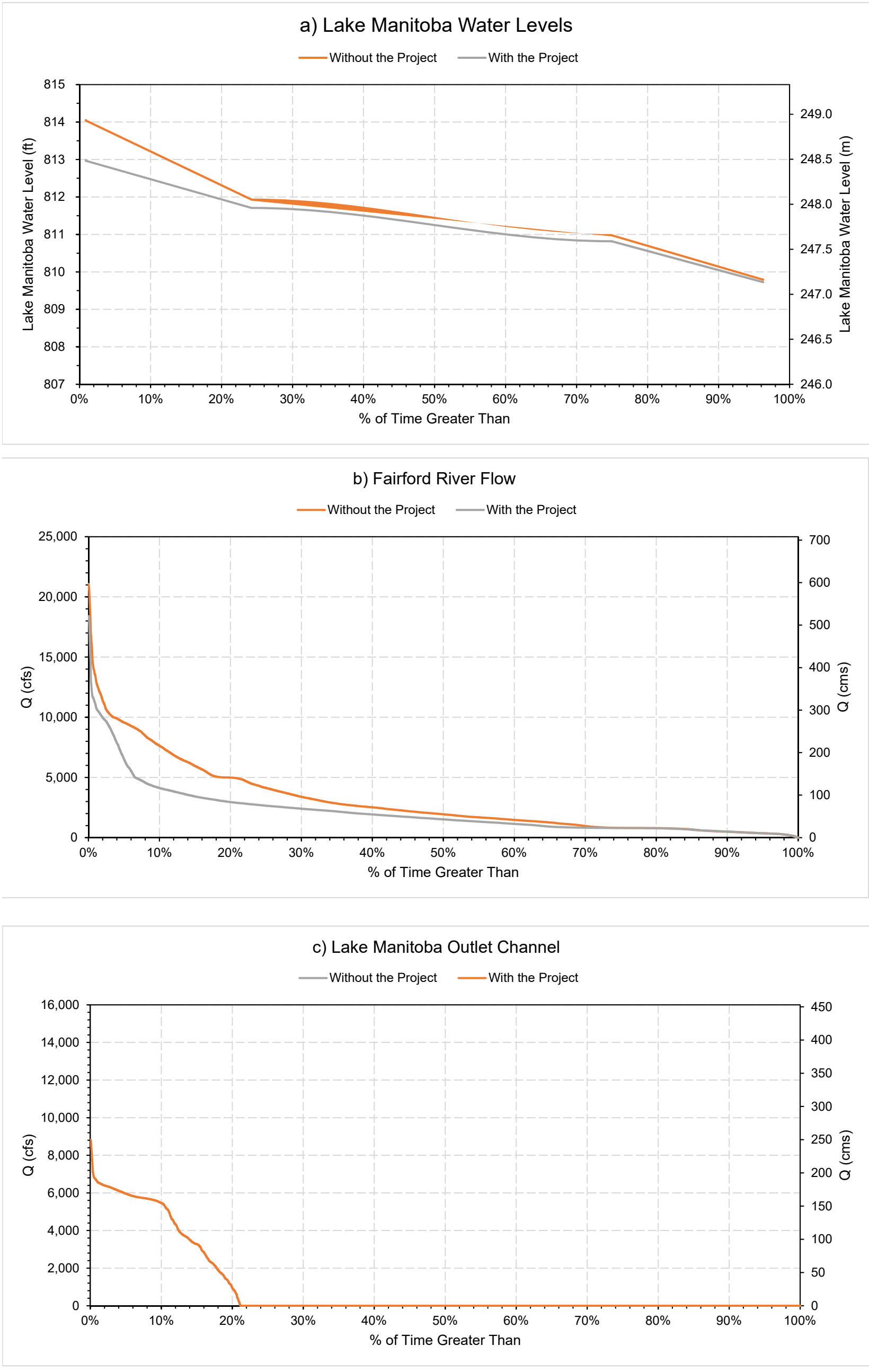
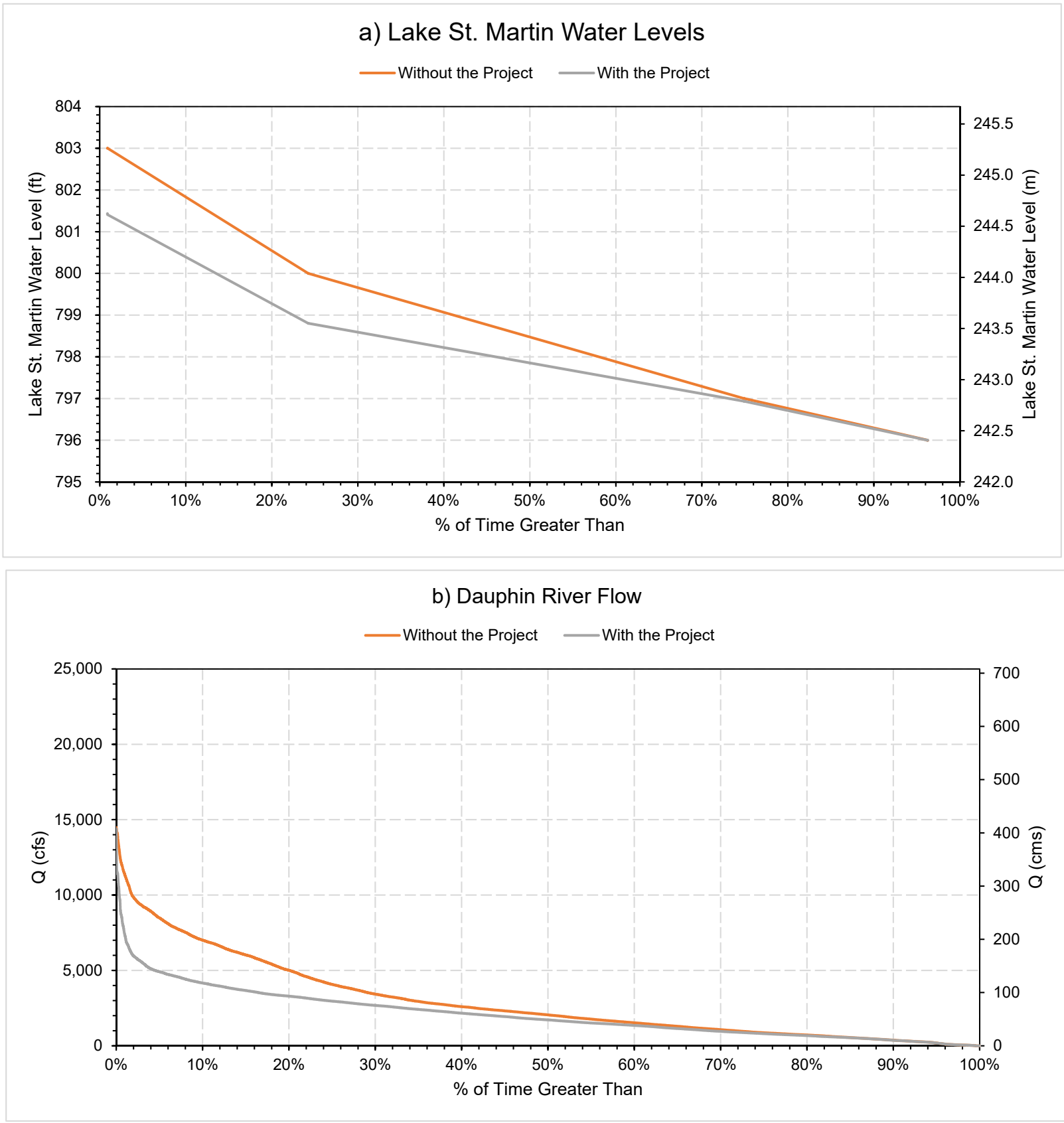


Figure 6E-2

Duration Curves for Lake St. Martin Elevations, Dauphin River and LSMEC/LSMOC Flows



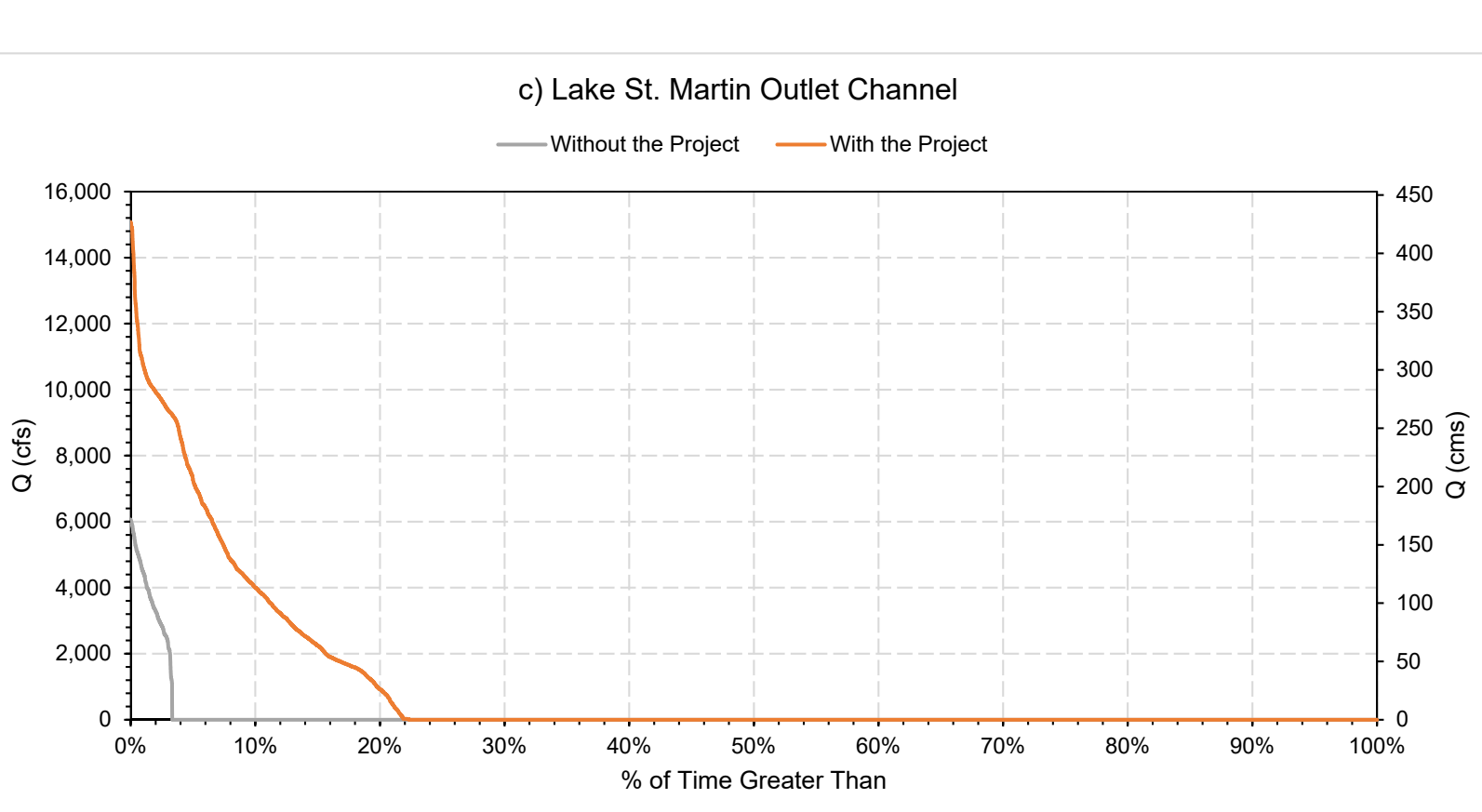
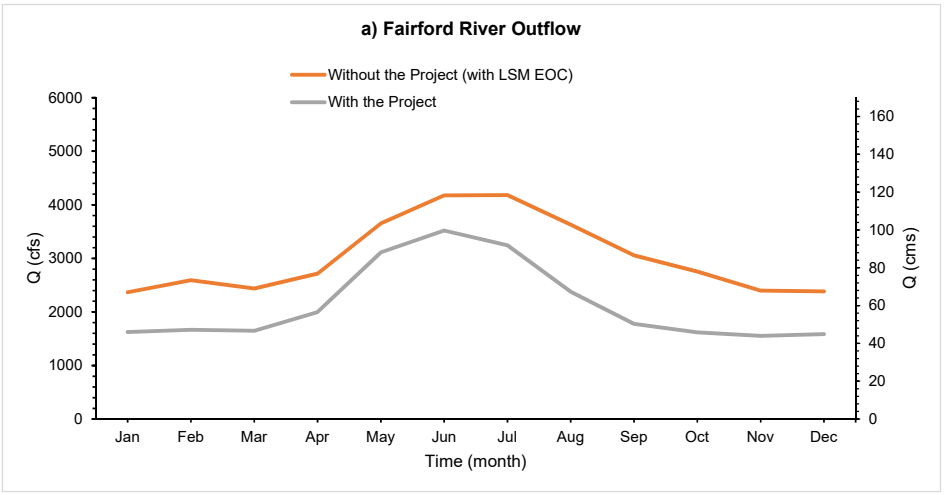
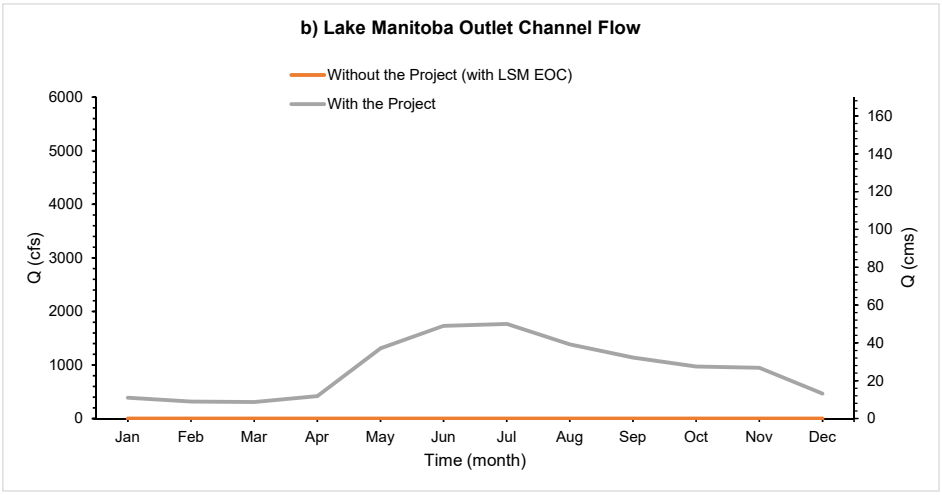


Figure 6E-3
Lake Manitoba Levels and Fairford and LMOC Flows for Average Monthly Conditions





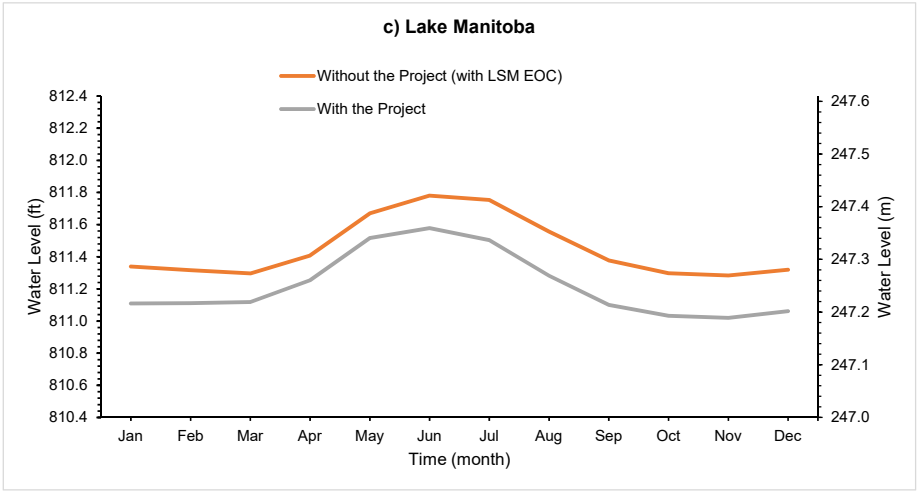
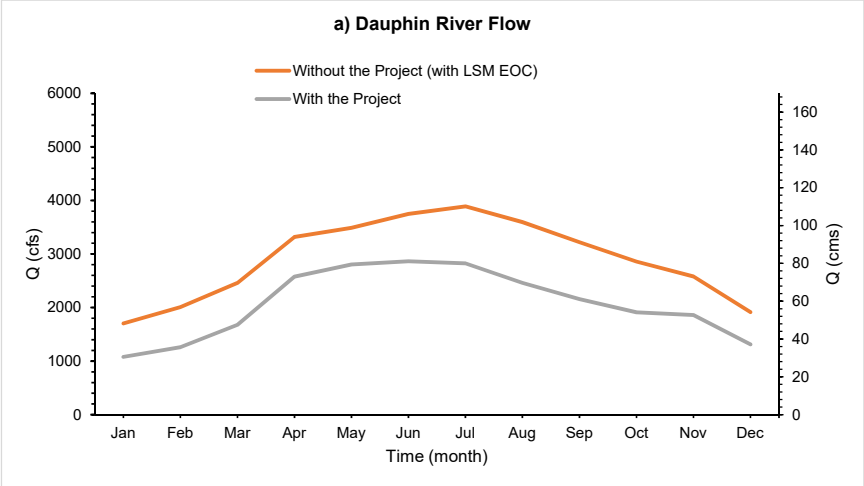
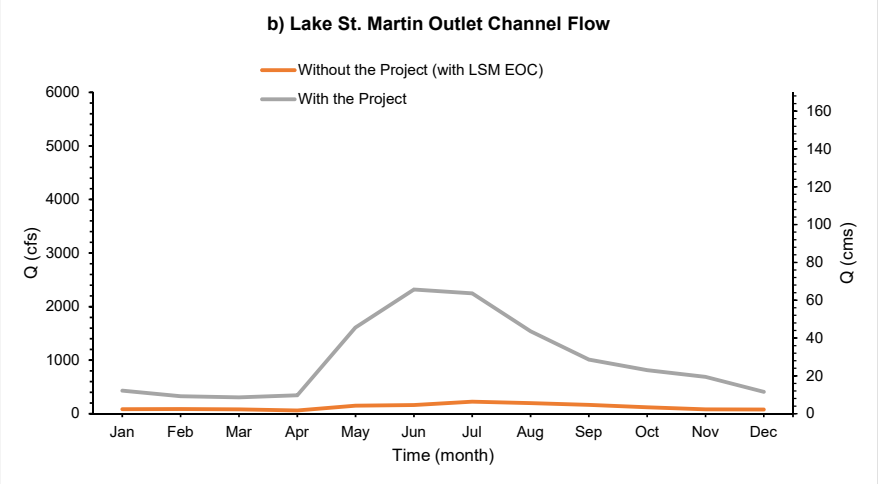


Figure 6E-4

Lake St. Martin Levels and Dauphin and LSMOC/(EC) Flows for Average Monthly Conditions





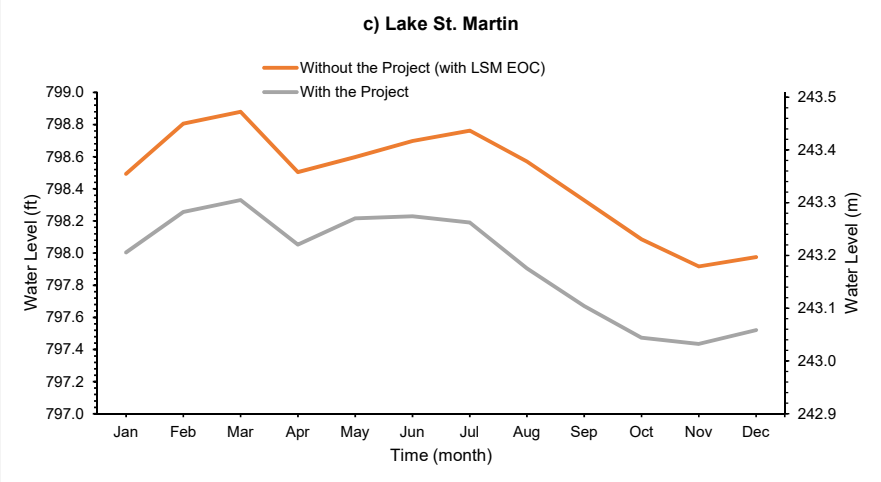
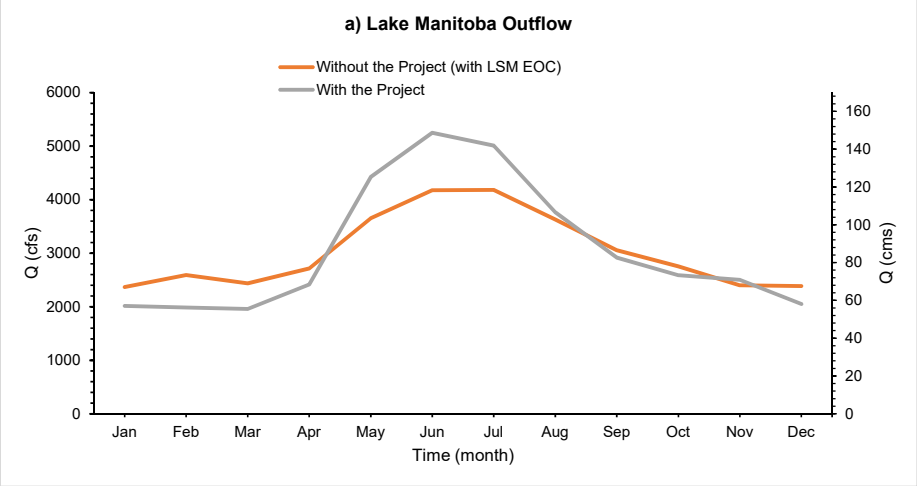


Figure 6E-5
Total Outflows for Lake Manitoba and Lake St. Martin for Average Monthly Conditions



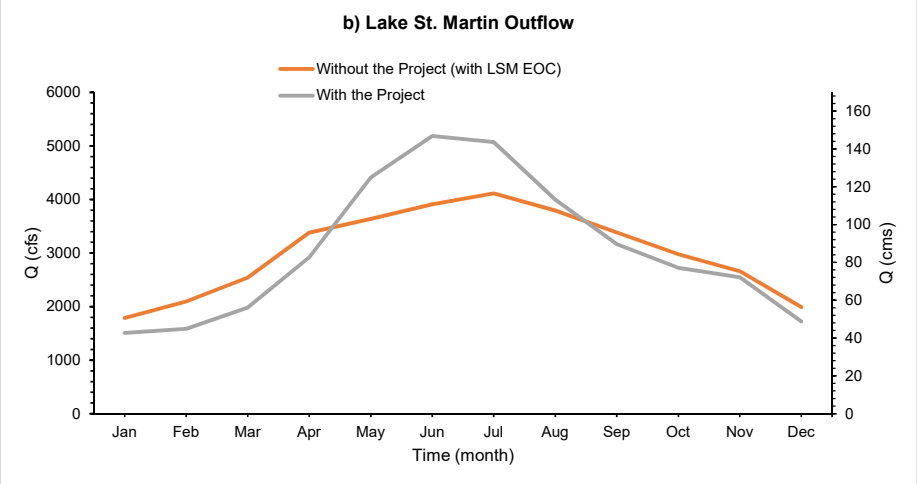
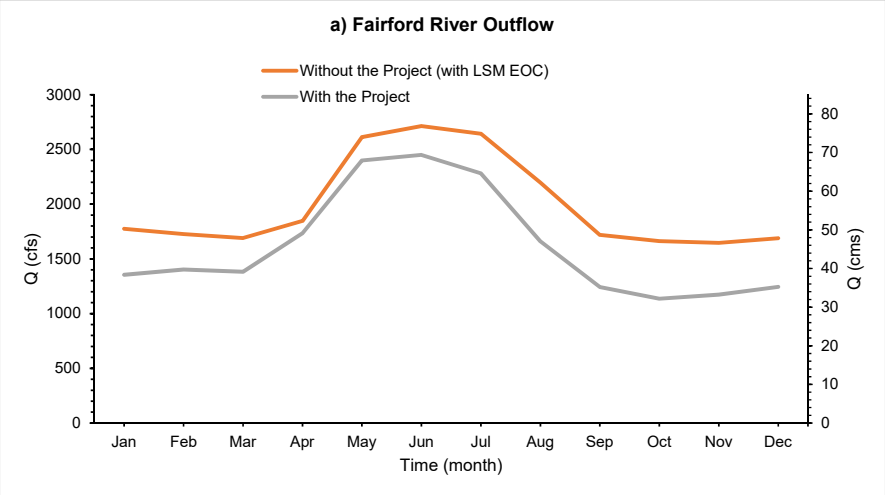
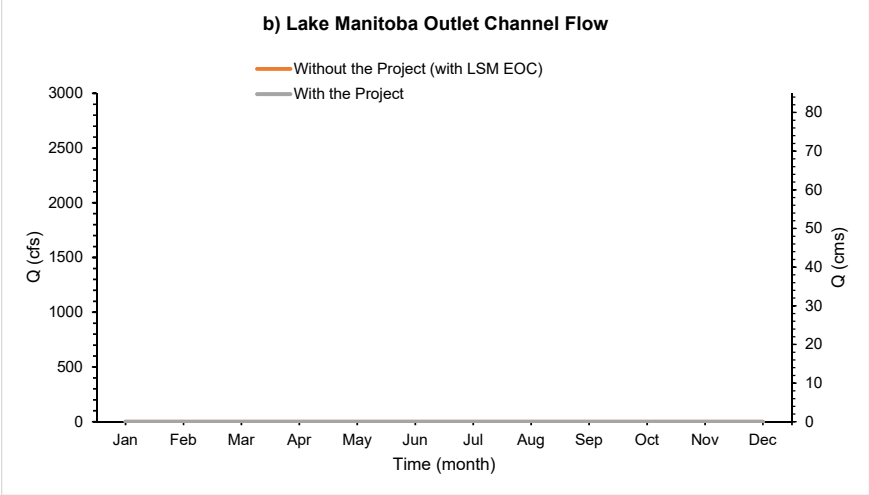


Figure 6E-6
Lake Manitoba Levels and Fairford and LMOC Flows for Median (50%tile) Monthly Conditions





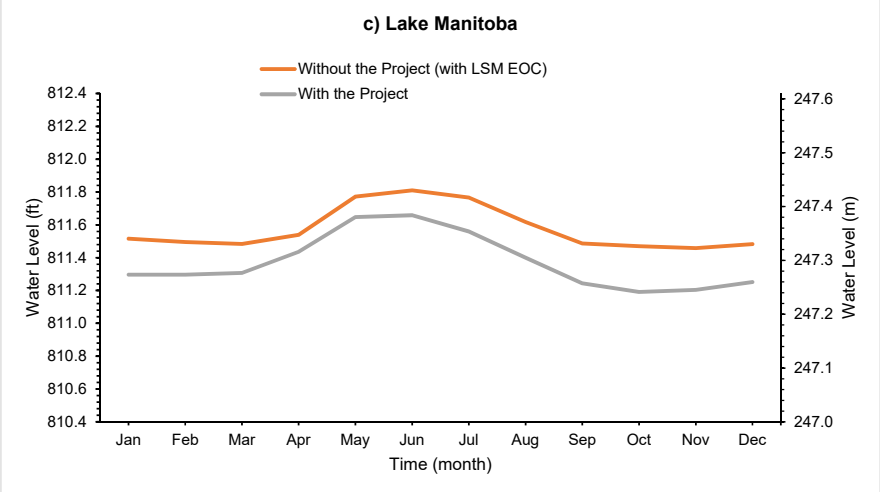
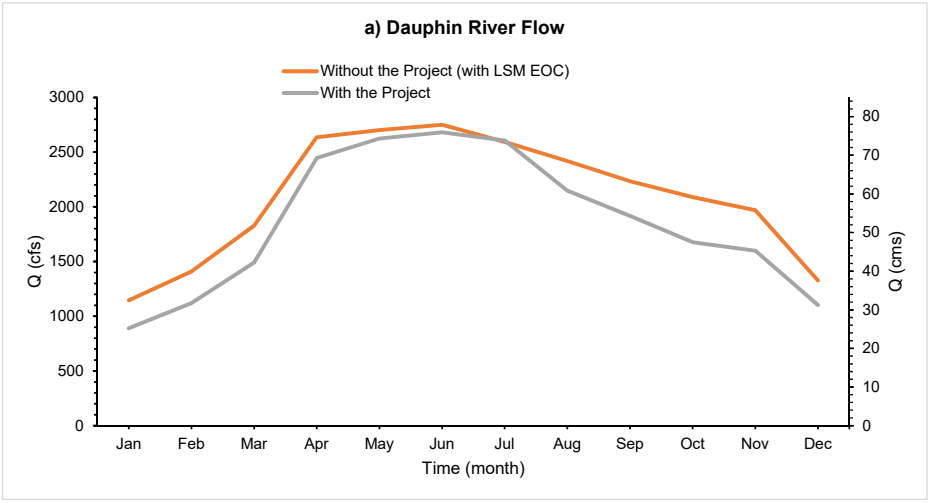
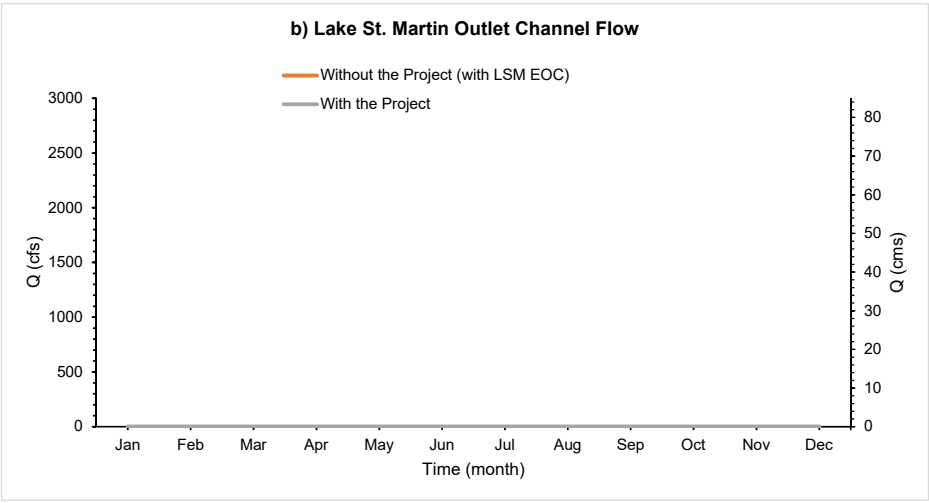


Figure 6E-7

Lake St. Martin Levels and Dauphin and LSMOC/(EC) Flows for Median (50%tile) Monthly Conditions





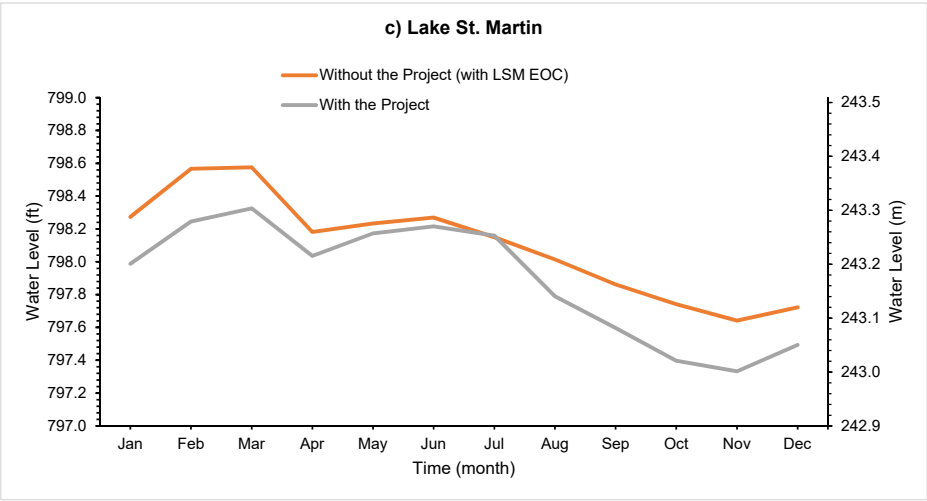
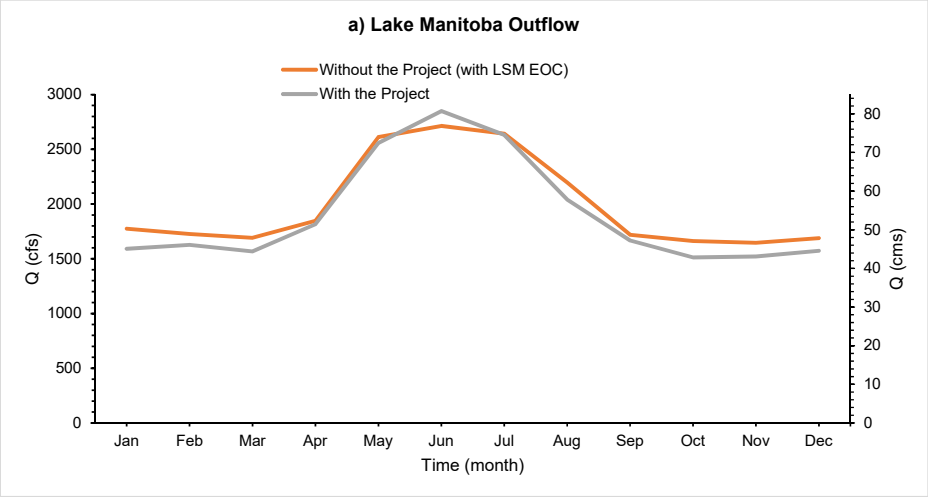


Figure 6E-8
Total Outflows for Lake Manitoba and Lake St. Martin for Median (50%tile) Monthly Conditions



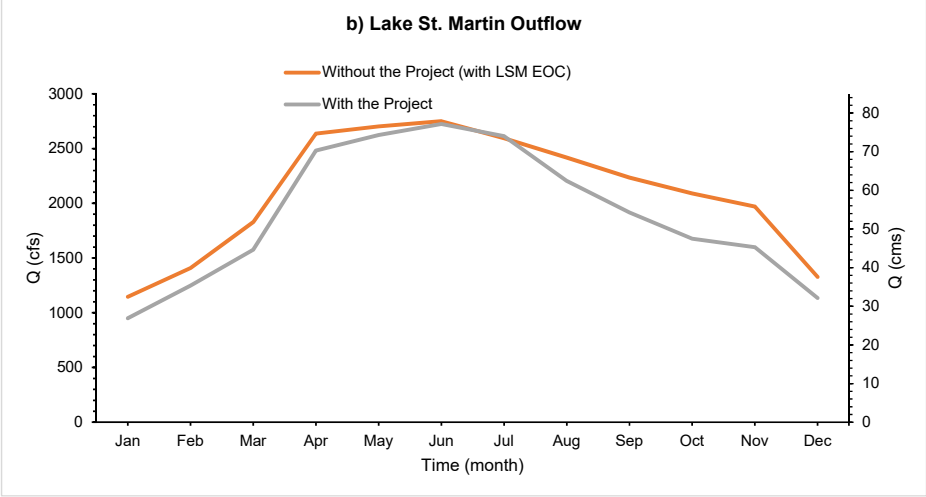
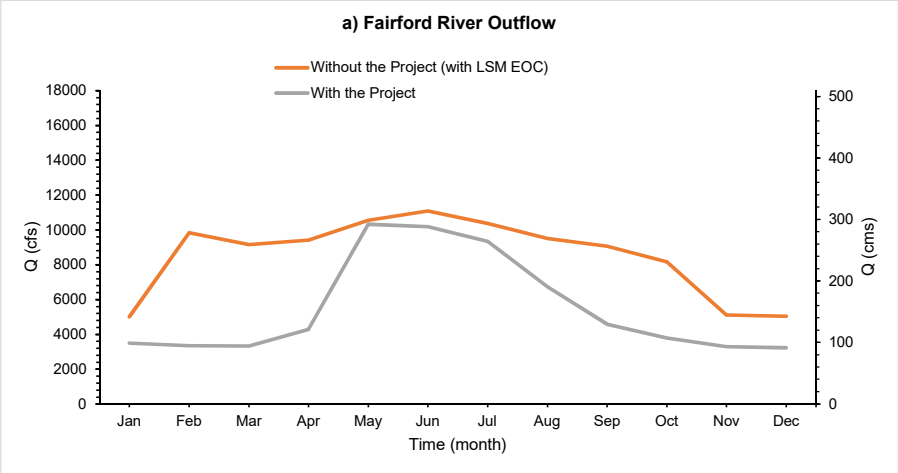
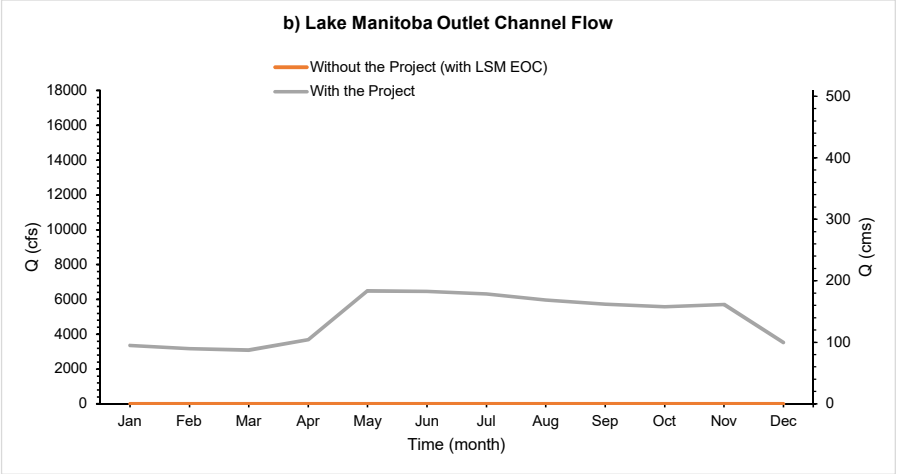


Figure 6E-9
Lake Manitoba Levels and Fairford and LMOC Flows for High (5% Greater Than) Monthly Conditions





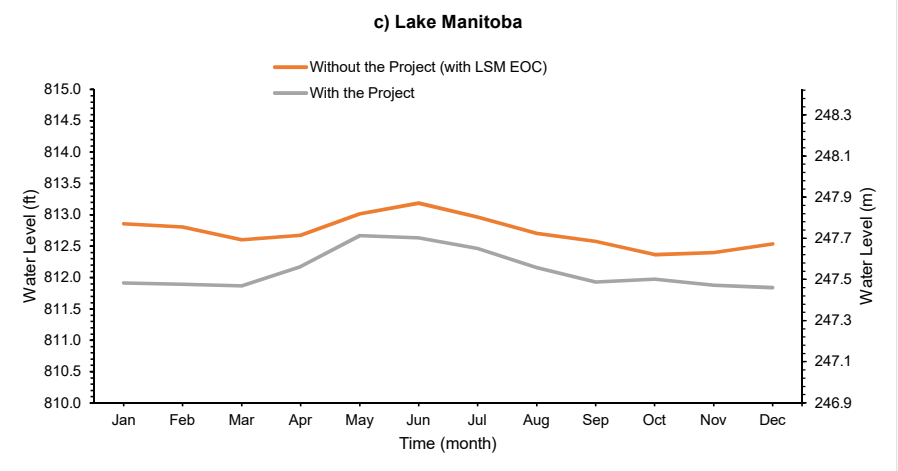
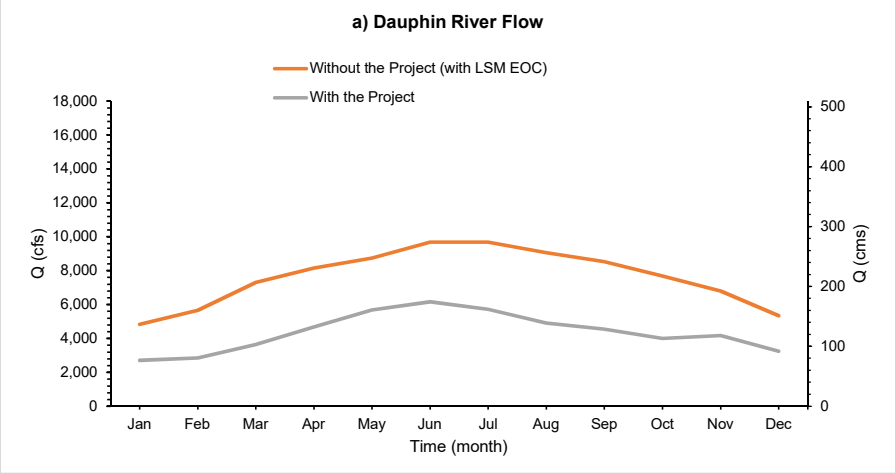
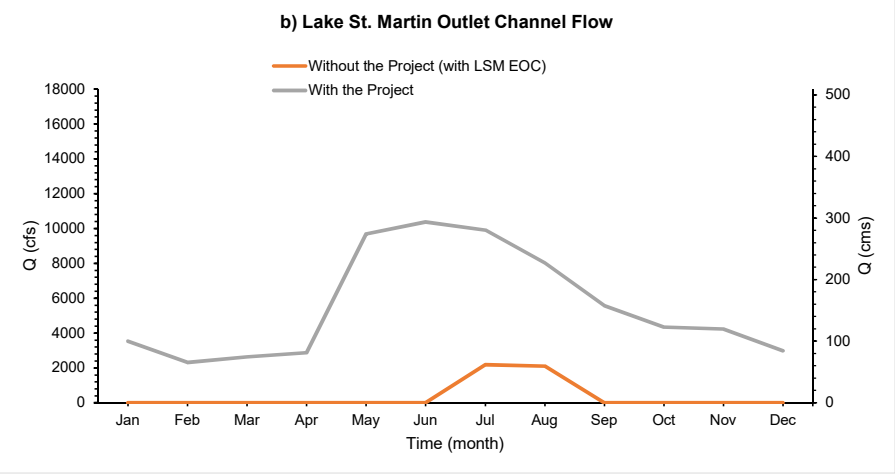


Figure 6E-10

Lake St. Martin Levels and Dauphin and LSMOC/(EC) Flows for High (5% Greater than) Monthly Conditions





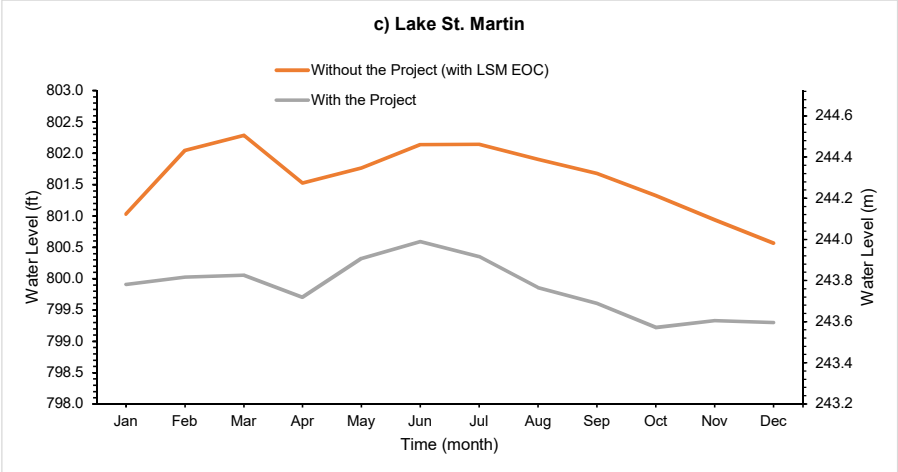


Figure 6E-11

Total Outflows for Lake Manitoba and Lake St. Martin for High (5% Greater than) Monthly Conditions

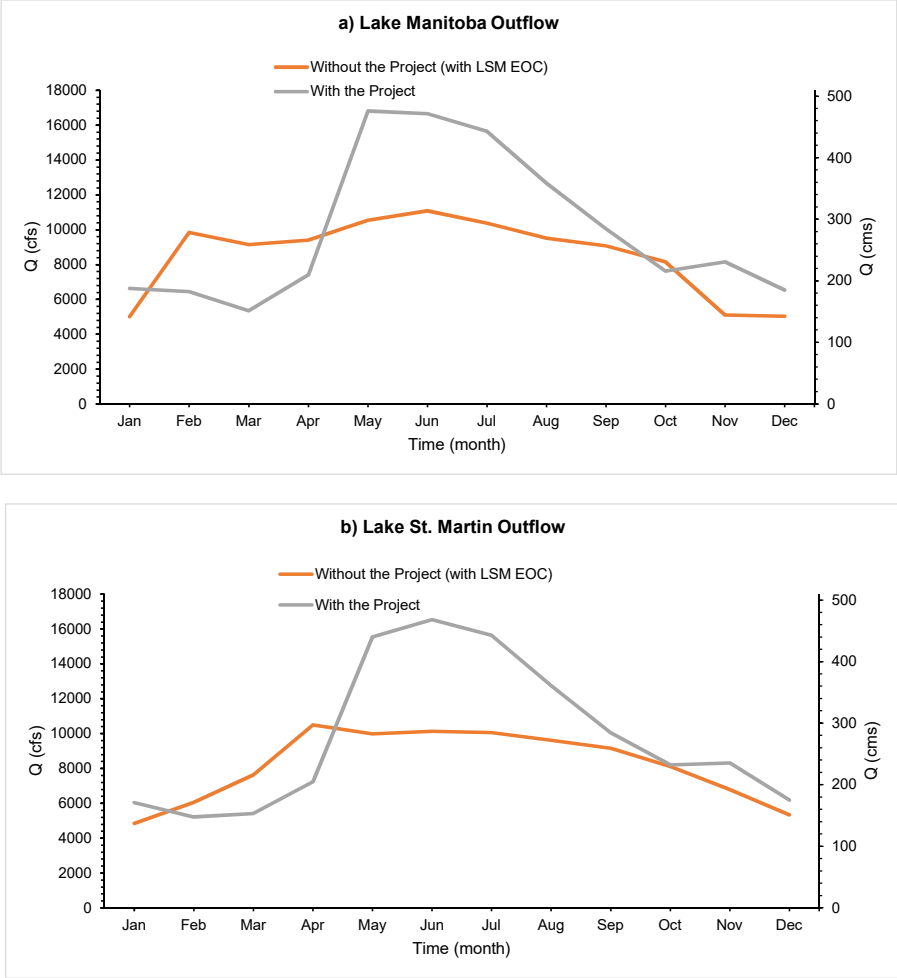
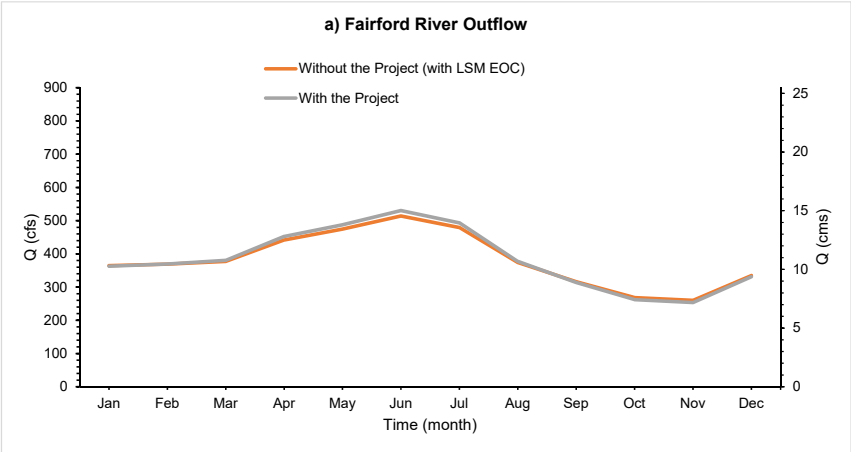
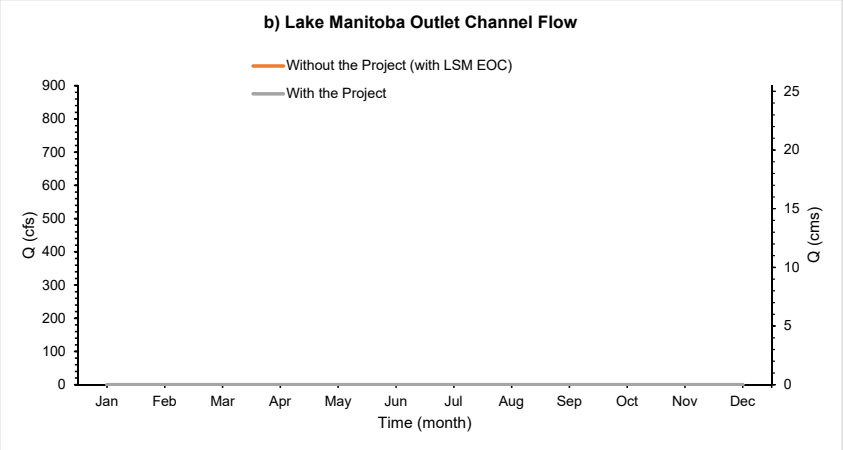


Figure 6E-12

Lake Manitoba Levels and Fairford and LMOC Flows for MLow (95% Greater Than) Monthly Conditions





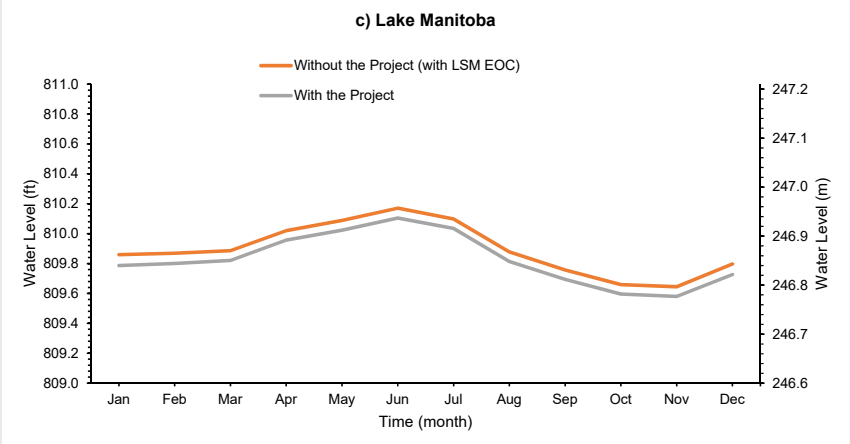
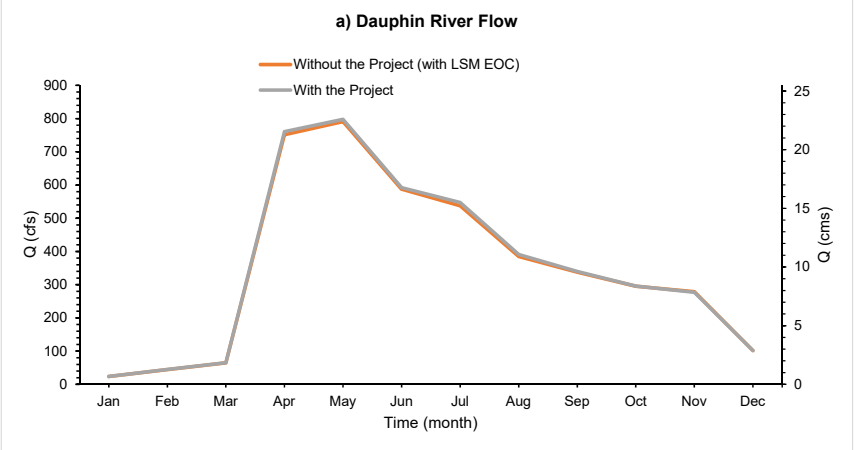
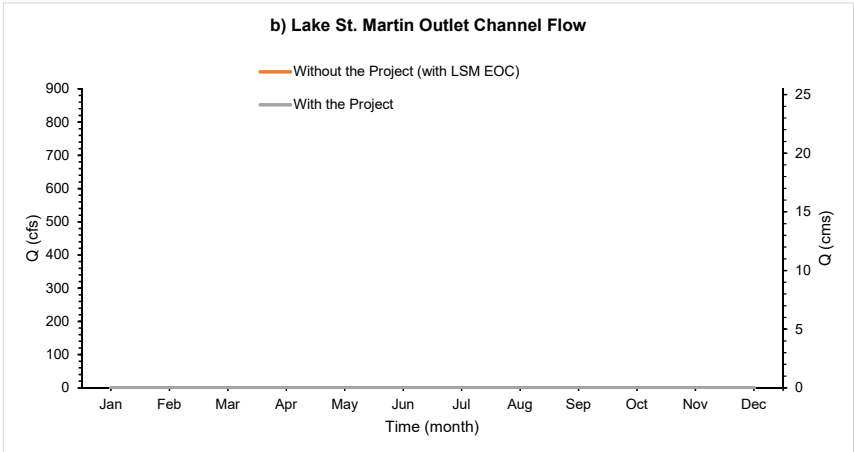


Figure 6E-13

Lake St. Martin Levels and Dauphin and LSMOC/(EC) Flows for Low (95% Greater than) Monthly Conditions





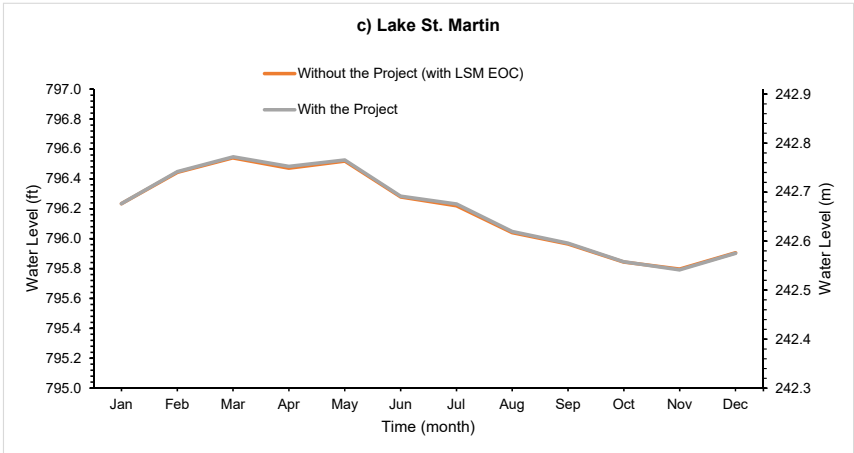
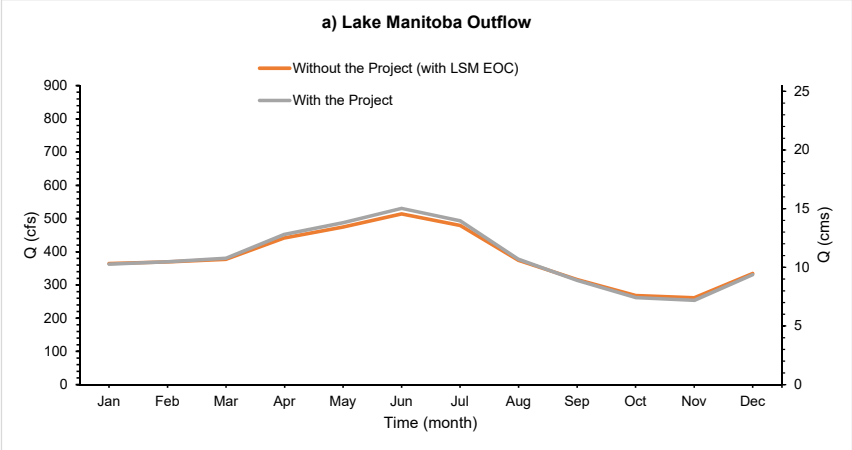
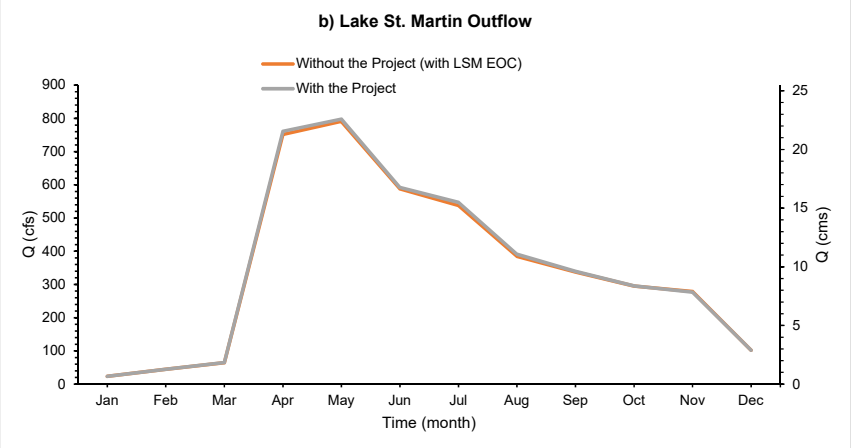


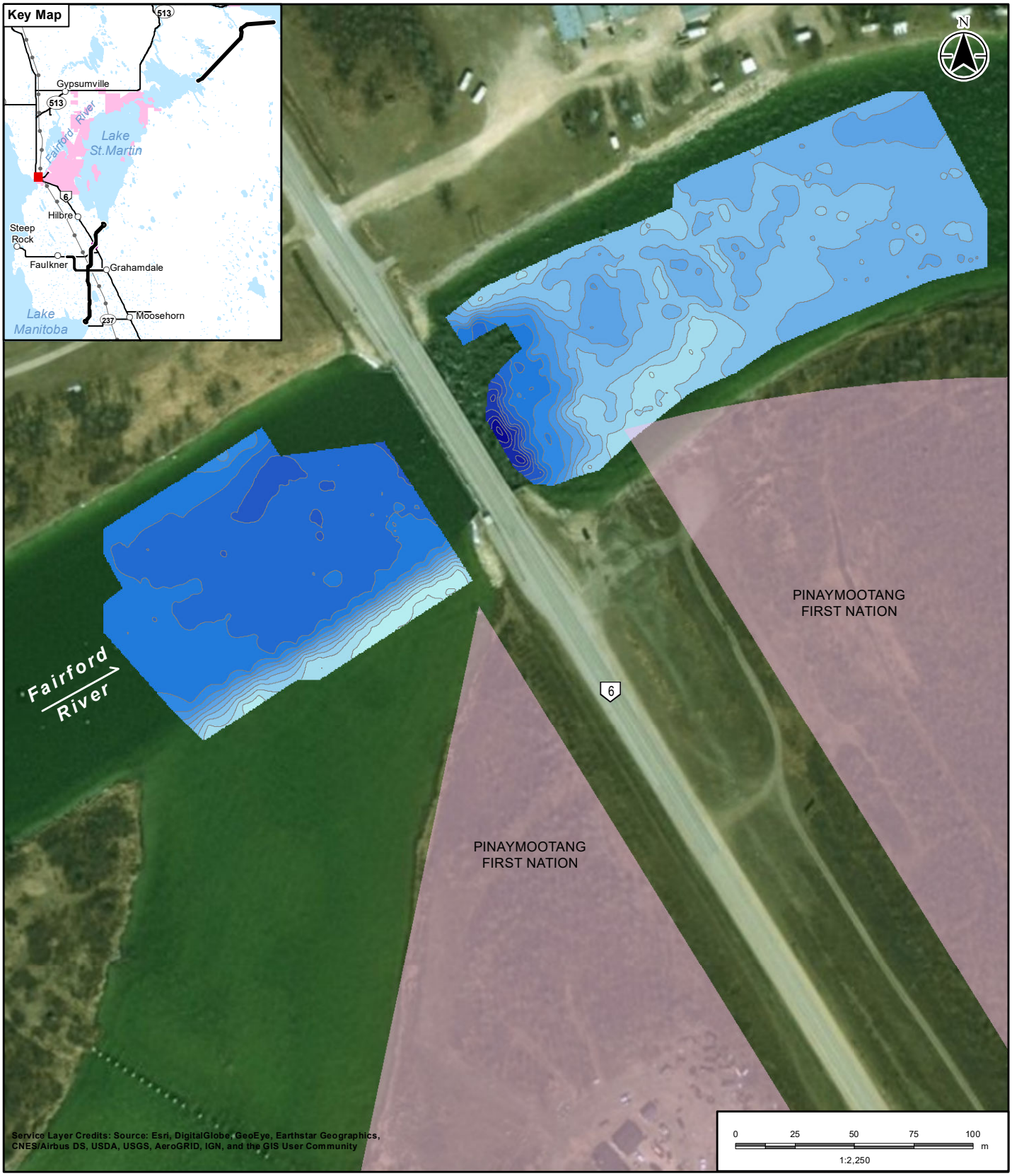
Figure 6E-14

Total Outflows for Lake Manitoba and Lake St. Martin for Low (95% Greater than) Monthly Conditions





Appendix 6F BATHYMETRY



Legend

- Project Development Area (PDA)
- First Nation
- Depth Contours (0.25m)

Depth (m)

- 1.0 - 1.25
- 1.25 - 1.5
- 1.5 - 1.75
- 1.75 - 2.0
- 2.0 - 2.25
- 2.25 - 2.5
- 2.5 - 2.75
- 2.75 - 3.0
- 3.0 - 3.25
- 3.25 - 3.5
- 3.5 - 3.75
- 3.75 - 4.0
- 4.0 - 4.25
- 4.25 - 4.5
- 4.5 - 4.75
- 4.75 - 5.0

Notes

1. Coordinate System: NAD 1983 UTM Zone 14N
2. Data Sources: Governments of Manitoba and Canada, Manitoba Infrastructure
3. Last Update: 8/13/2019 2:16:28 PM

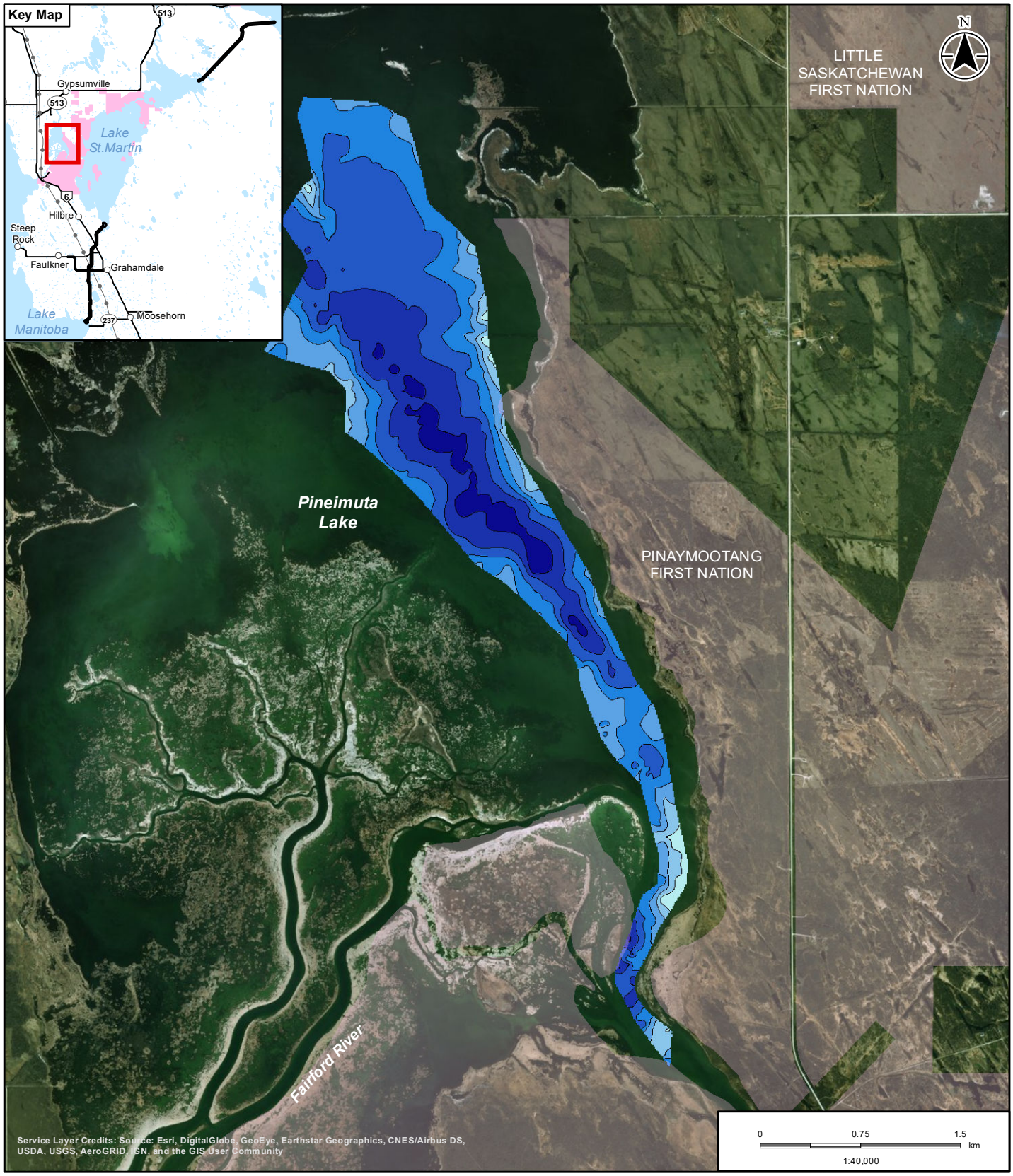
Manitoba

MANITOBA INFRASTRUCTURE
Lake Manitoba & Lake St.Martin Outlet Channels Project
Environmental Impact Statement

Fairford River Bathymetry, Fall 2017

Figure 6F-1

G:\ GIS_Project_Folder\114731201\gures\Ch6_Physical_Environment\Final\Fig 6F-1 PE SW Fairford River Bathymetry.mxd



Legend

Depth Contours (0.25m)

First Nation

Depth (m)

- 1.0 - 1.25
- 1.25 - 1.5
- 1.5 - 1.75
- 1.75 - 2.0
- 2.0 - 2.25
- 2.25 - 2.5
- 2.5 - 2.75

Notes

1. Coordinate System: NAD 1983 UTM Zone 14N
2. Data Sources: Governments of Manitoba and Canada, Manitoba Infrastructure
3. Last Update: 8/13/2019 2:13:03 PM

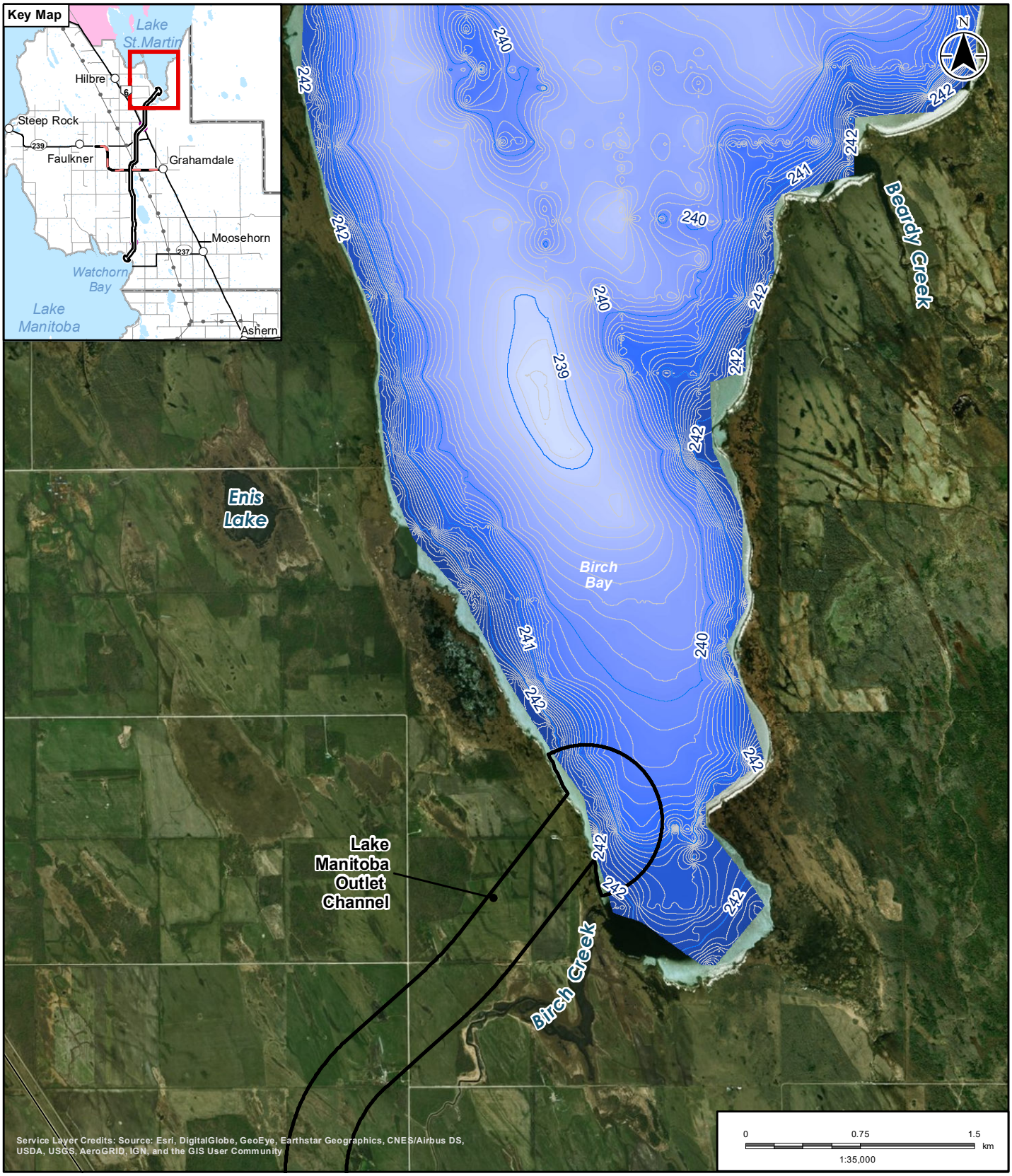
Manitoba

MANITOBA INFRASTRUCTURE
Lake Manitoba & Lake St.Martin Outlet Channels Project
Environmental Impact Statement

Lake Pineimuta Bathymetry

Figure 6F-2

G:_GIS_Project_Folder\114731201\figures\Ch6_Physical_Environment\Final\Fig 6F-2 PE SW Pineimuta Bathymetry.mxd



Legend

- Project Development Area (PDA)
- 1 m Bed Elevation Contour Interval (CGVD 28)
- 10 cm Bed Elevation Contour Interval (CGVD 28)

Bed Elevation- meters (CGVD 28)

- High : 243.0
- Low : 238.7

Notes

1. Coordinate System: NAD 1983 UTM Zone 14N
2. Data Sources: Governments of Manitoba and Canada, Manitoba Infrastructure
3. Last Update: 8/13/2019 2:15:05 PM

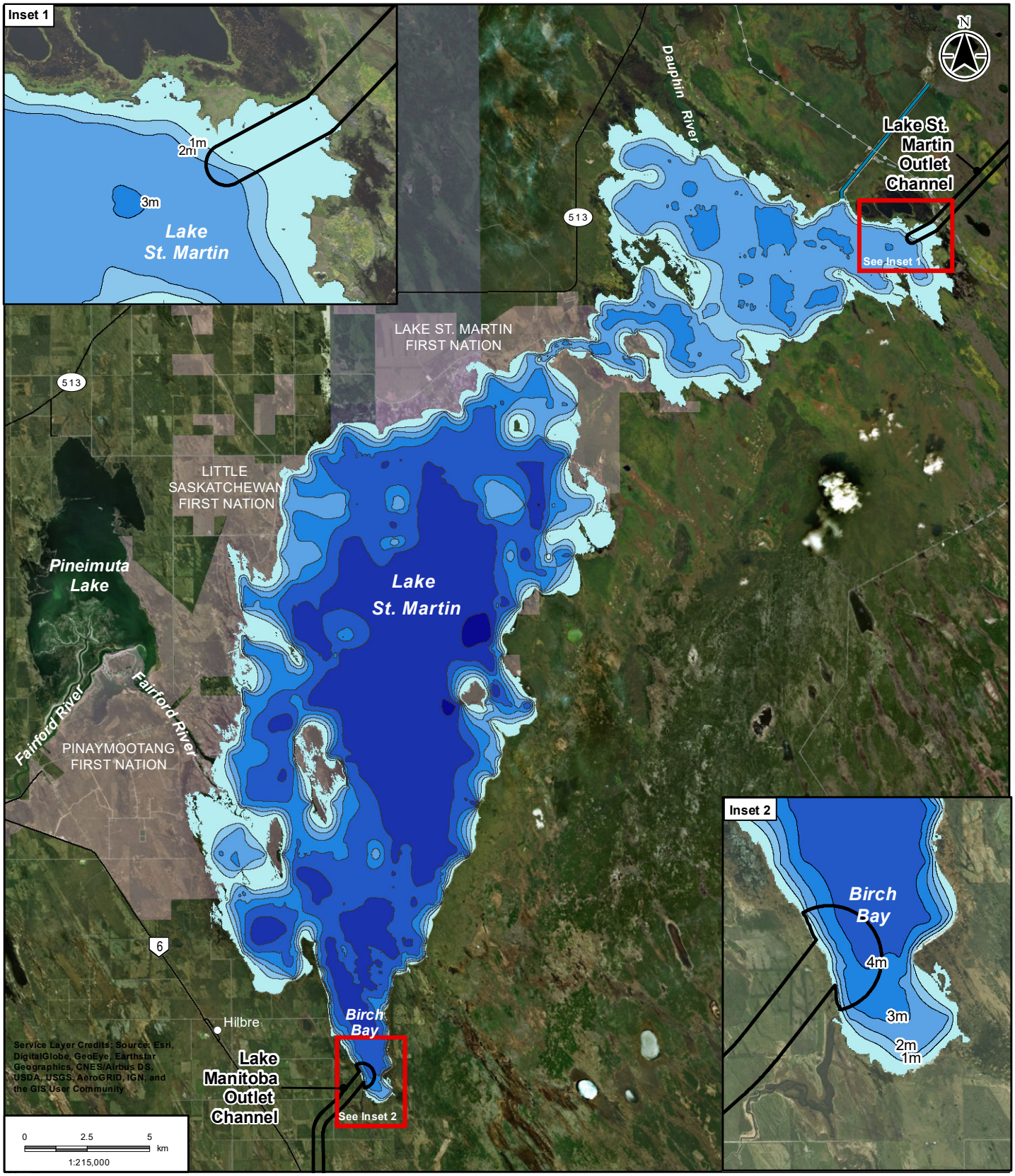
Manitoba

MANITOBA INFRASTRUCTURE
Lake Manitoba & Lake St.Martin Outlet Channels Project
Environmental Impact Statement

Lake St.Martin South End Bathymetry

Figure 6F-3

G:\ GIS_Project_Folder\111473120\figures\Ch6_Physical_Environment\Final\Fig 6F-3 PE SW Lk St Martin South End Bathymetry.mxd



Legend

- Project Development Area (PDA)
- Lake St.Martin Emergency Outlet Channel (Reach 1)
- Lake St.Martin Access Road
- Planned Distribution Line
- Depth Contours (1m)

Depth (m)

- 0 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 6.0
- 6.0 - 6.6

- Provincial Highway (PTH/PR)
- Municipal Road
- First Nation

Notes

1. Coordinate System: NAD 1983 UTM Zone 14N
2. Data Sources: Governments of Manitoba and Canada, Manitoba Infrastructure
3. Last Update: 8/13/2019 2:04:26 PM

Manitoba

MANITOBA INFRASTRUCTURE
Lake Manitoba & Lake St.Martin Outlet Channels Project
Environmental Impact Statement

Lake St. Martin Bathymetry, Fall 2017

Figure 6F-4

G:\ GIS_Project_Folder\114751200\figures\Ch6_Physical_Environment\Final\Fig 6F-4 PE SW LK St Martin Bathymetry.mxd

Legend

- Existing Distribution Line
- Depth Contours (5m)

Depth (m)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- 5.0 - 5.6

- Provincial Highway (PTH/PR)
- Northern Affairs Community (NAC)
- First Nation

Notes

1. Coordinate System: NAD 1983 UTM Zone 14N
2. Data Sources: Governments of Manitoba and Canada, Manitoba Infrastructure
3. Last Update: 8/13/2019 2:01:23 PM

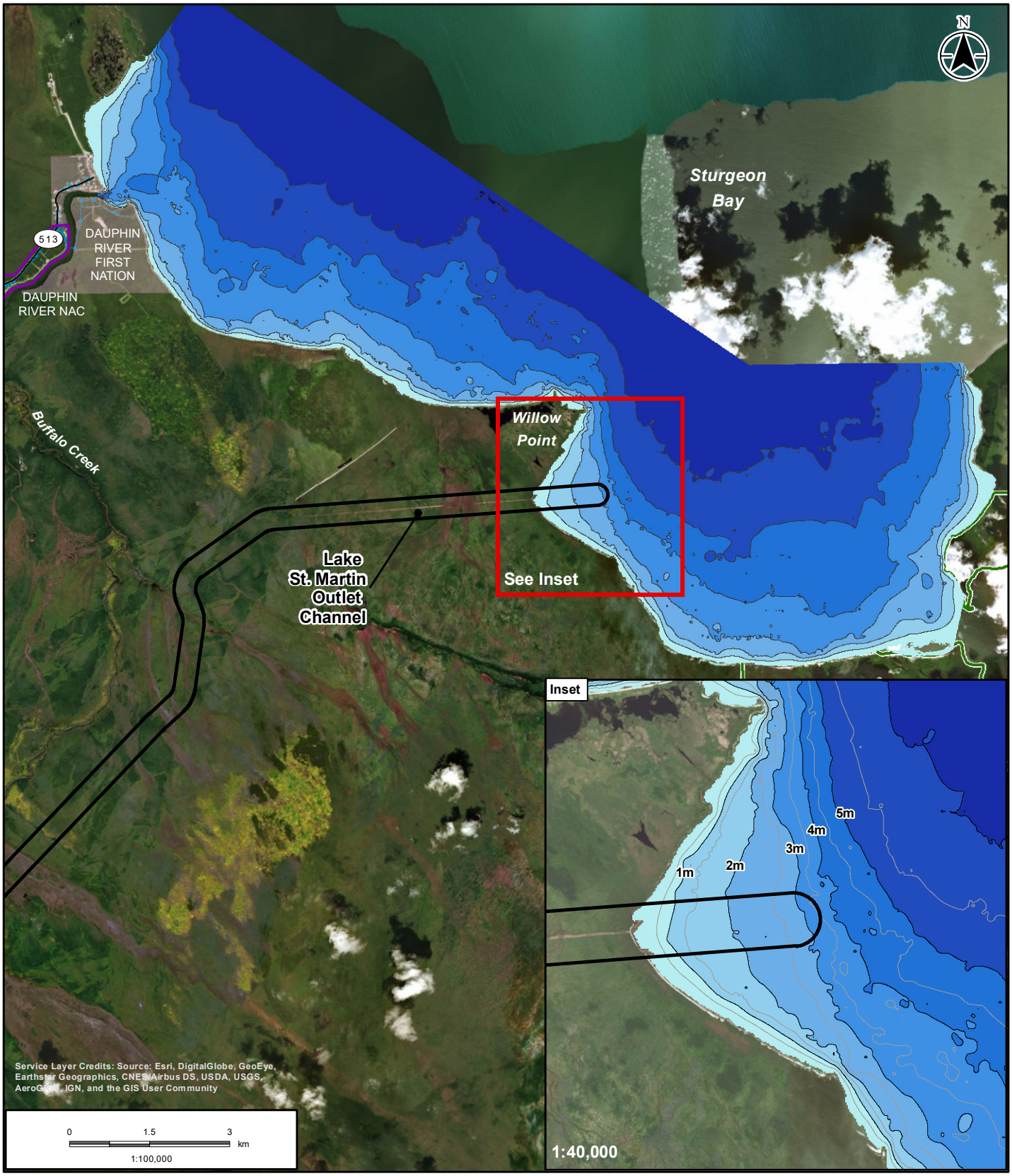
Manitoba

MANITOBA INFRASTRUCTURE
Lake Manitoba & Lake St.Martin Outlet Channels Project
Environmental Impact Statement

Dauphin River Bathymetry

Figure 6F-5

G:_GIS_Project_Folder\114751200\figures\Ch6_Physical_Environment\Final\Fig 6F-5 PE SW Dauphin River Bathymetry.mxd



Legend

- Project Development Area
- Existing Distribution Line

Depth (m)

- 0.0 - 1.0
- 1.0 - 2 .0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 6.0
- 6.0 - 7.0
- 7.0 - 7.1

- Provincial Highway (PTH/PR)
- Northern Affairs Community (NAC)
- First Nation
- Provincial Park

Notes

1. Coordinate System: NAD 1983 UTM Zone 14N
2. Data Sources: Governments of Manitoba and Canada, Manitoba Infrastructure
3. Last Update: 8/13/2019 2:05:56 PM

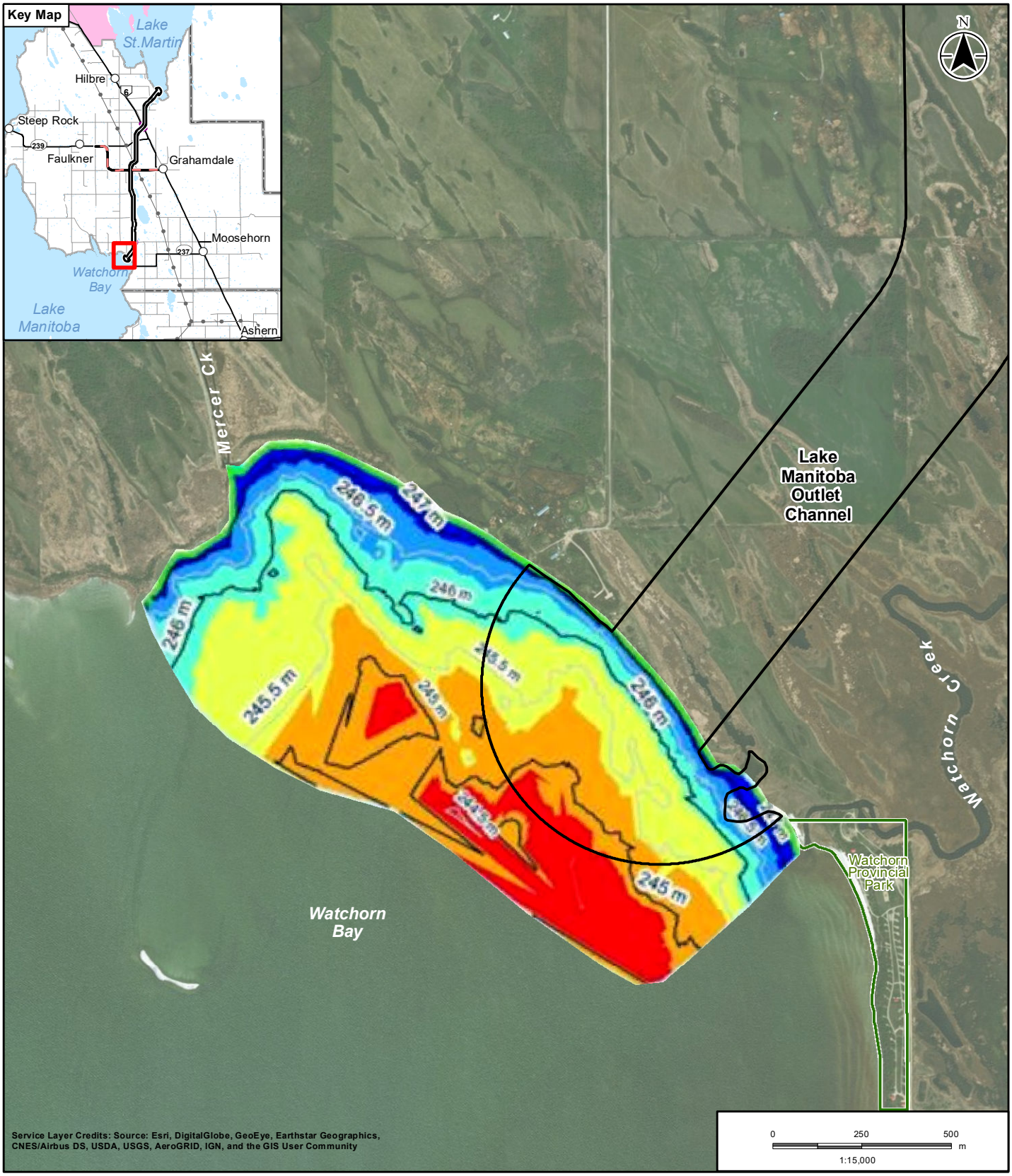
Manitoba

MANITOBA INFRASTRUCTURE
Lake Manitoba & Lake St.Martin Outlet Channels Project
Environmental Impact Statement

Sturgeon Bay & Willow Point LSMOC Outlet Bathymetry

Figure 6F-6

G:_GIS_Project_Folder\114751200\figures\Ch6_Physical_Environment\Final\fig 6F-6 pE Sturgeon Bay Bathymetry.mxd



Legend

- Project Development Area (PDA)

Depth (m)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 2.97

Notes

1. Coordinate System: NAD 1983 UTM Zone 14N
2. Data Sources: Governments of Manitoba and Canada, Manitoba Infrastructure, AAE Tech Services 2016
3. Last Update: 8/13/2019 2:20:55 PM

Manitoba

MANITOBA INFRASTRUCTURE
Lake Manitoba & Lake St.Martin Outlet Channels Project
Environmental Impact Statement

Watchorn Bay (LMBOC Inlet) Bathymetry, Fall 2016

Figure 6F-7

G:\ GIS_Project_Folder\114731201\figures\Ch6 Physical Environment\Final\Fig 6F-7 PE Watchorn Bay Bathymetry.mxd

Appendix 6G FLOOD EXTENT MAPS

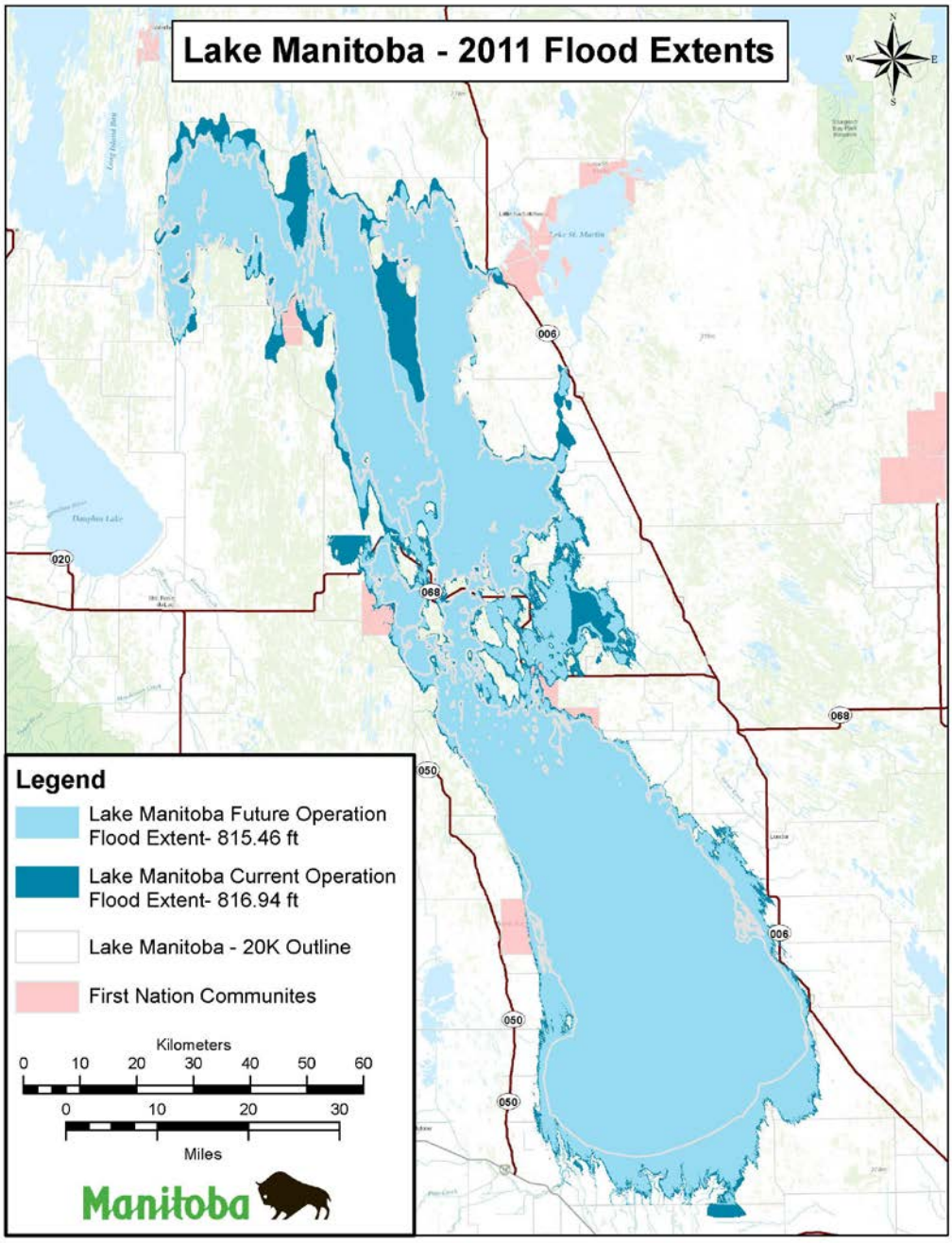


Figure 6G-1 Shoreline Inundation of Lake Manitoba at the 2011 Flood Level

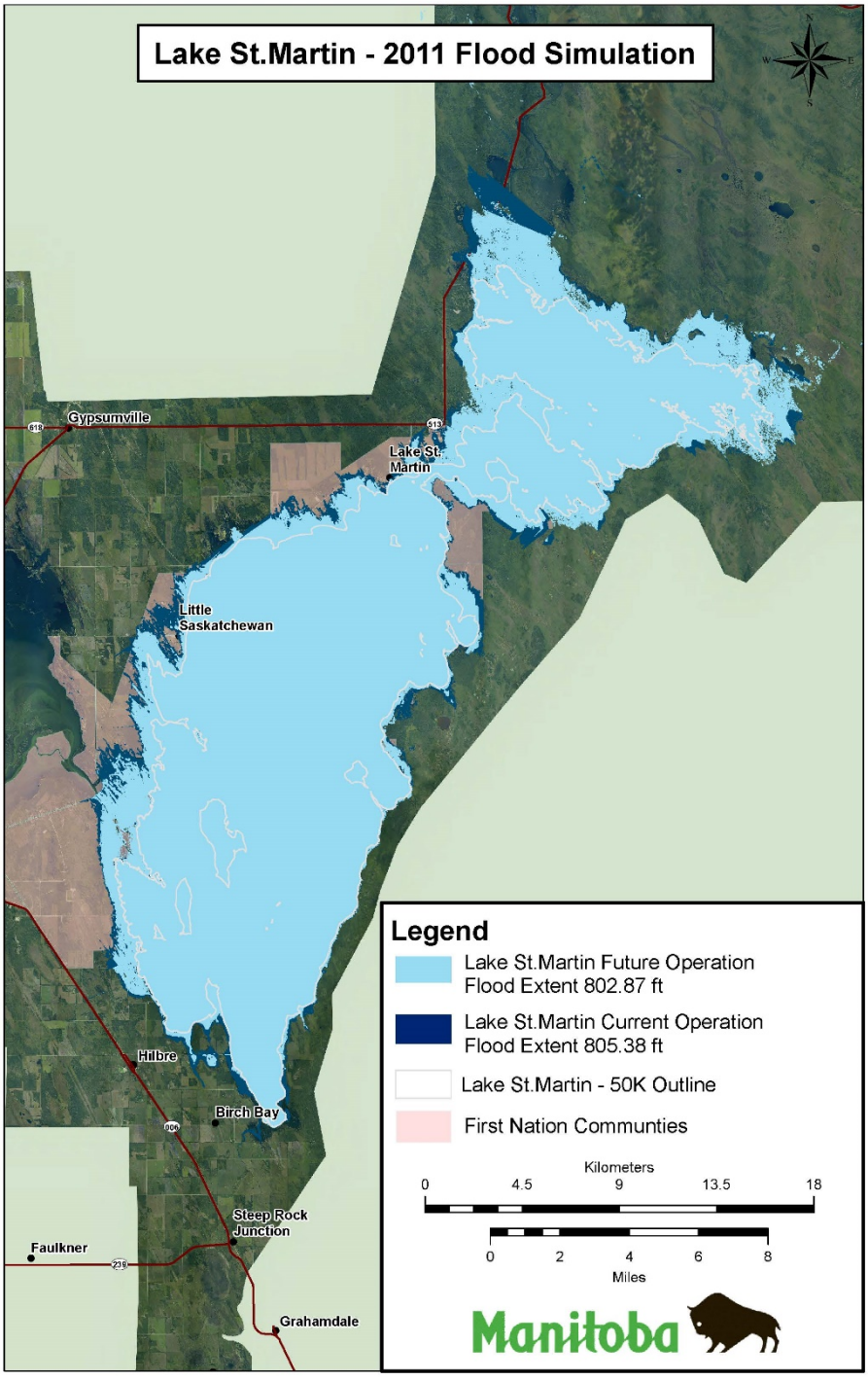


Figure 6G-2 Shoreline Inundation of Lake St. Martin at the 2011 Flood Level

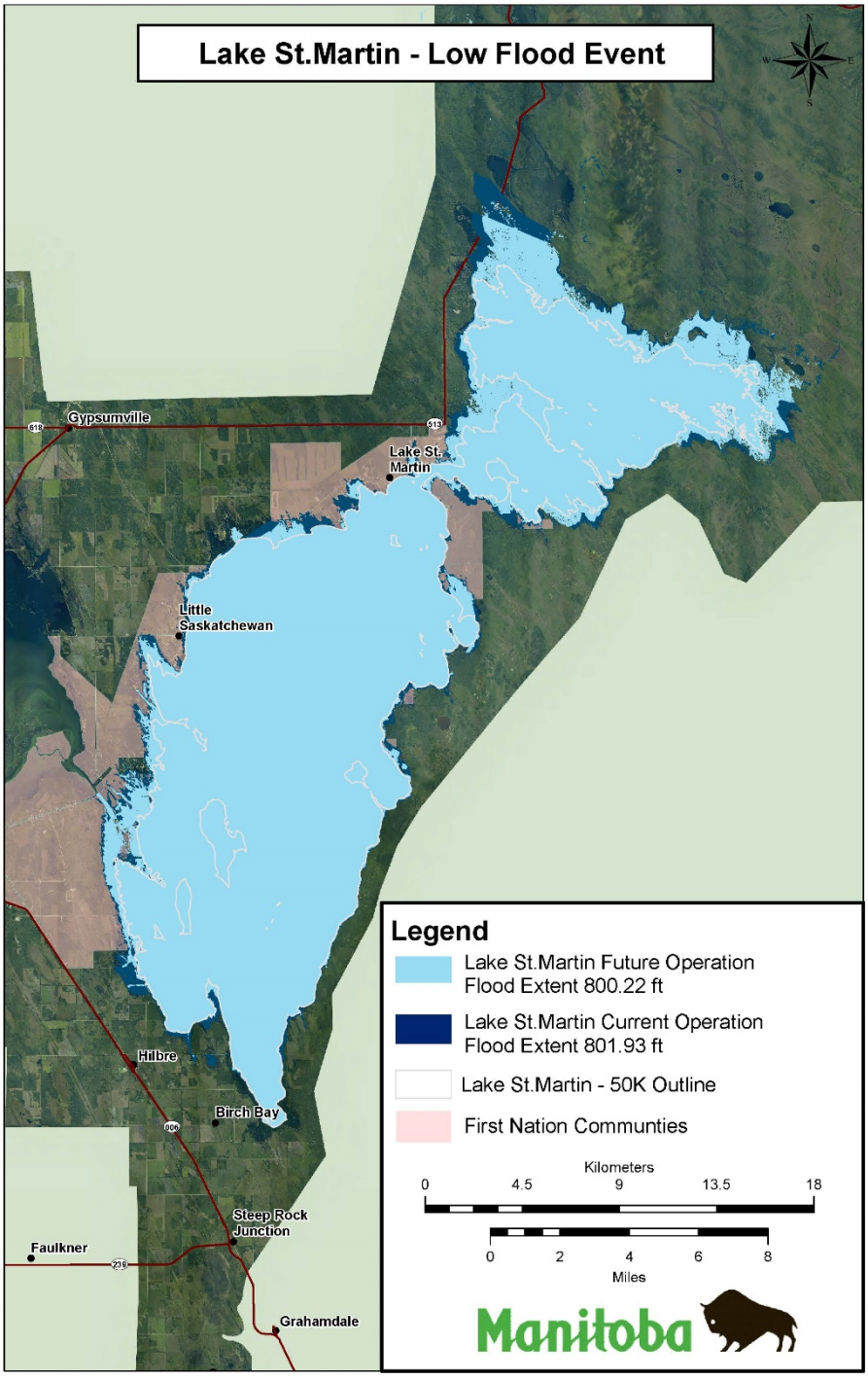


Figure 6G-3 Shoreline Inundation of Lake St. Martin during a Low Flood Event

Appendix 6H BIRCH CREEK AND WATCHORN CREEK DRAINAGE AREA DATA

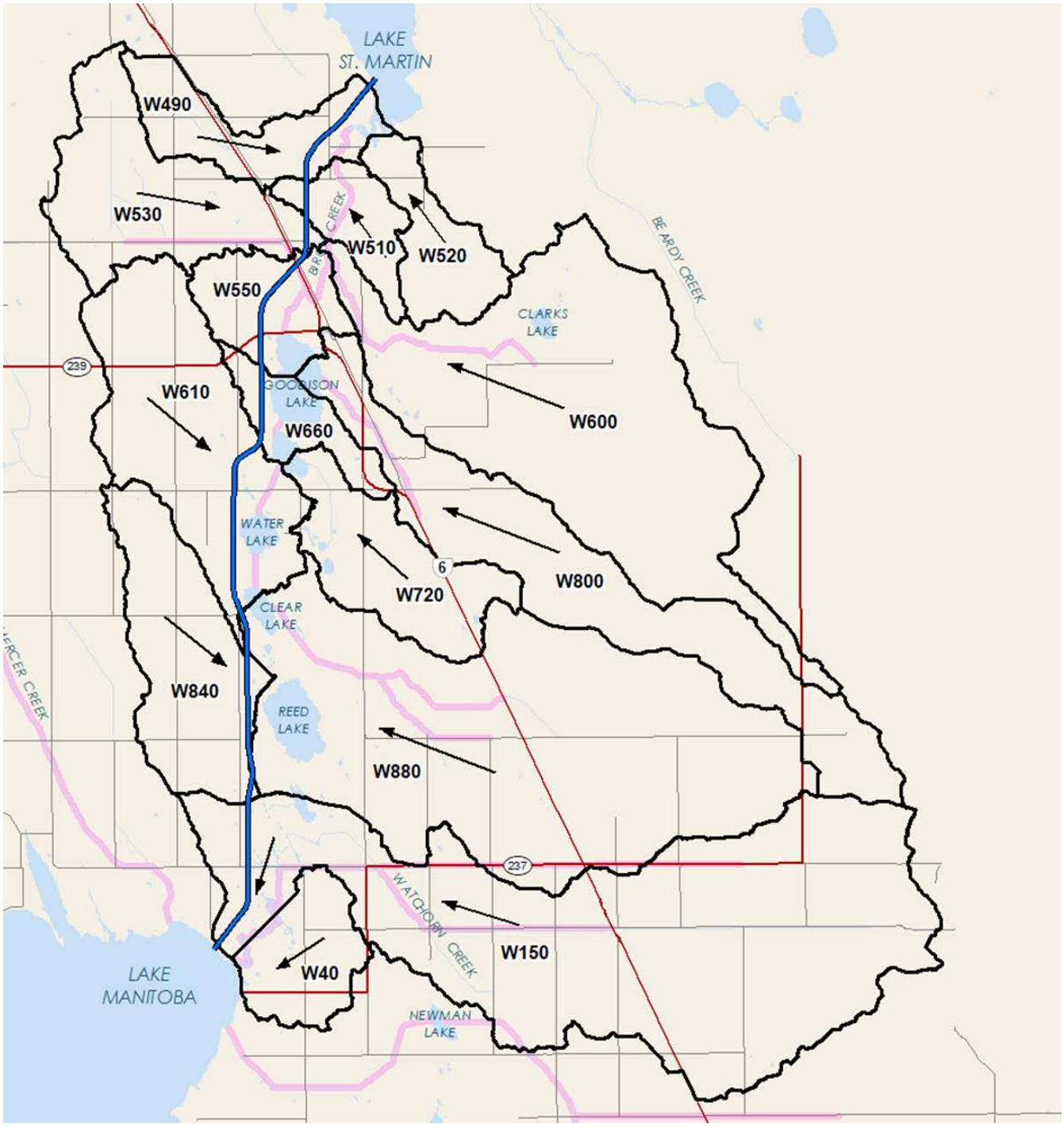

LAKE
ST. MARTIN
W490
W530
W510
W520
W550
BIRCH CREEK
BEARDY CREEK
CLARKS
LAKE
239
W610
GOODISON
LAKE
W660
W600
WATER
LAKE
6
W720
W800
CLEAR
LAKE
MERCER CREEK
W840
REED
LAKE
W880
237
WATCHORN CREEK
W150
LAKE
MANITOBA
W40
NEWMAN
LAKE

Table 6H-1 Summary of Sub-watershed Areas Affected by the Proposed Lake Manitoba Outlet Channel (LMOC)

Sub-Watershed Name	Area Without the Project (Baseline) (km^2)	Area With the Project (km^2)	Area Affected by the Project (km^2)	Percent Area Affected by the Project	Tributary to
W40	9.6	9.6	0.0	0%	Lake Manitoba
W150	83.1	79.4	3.7	4%	Watchorn Creek to Lake Manitoba
W490	11.5	2.2	9.3	81%	Birch Creek to Lake St. Martin
W510	6.7	6.1	0.6	8%	Birch Creek to Lake St. Martin
W520	9.0	9.0	0.0	0%	Lake St. Martin
W530	20.7	0.2	20.5	99%	Birch Creek to Lake St. Martin
W550	9.8	5.1	4.7	48%	Birch Creek to Lake St. Martin
W600	57.7	57.7	0.0	0%	Birch Creek to Lake St. Martin
W610	29.1	6.1	23.0	79%	Birch Creek to Lake St. Martin
W660	6.4	5.1	1.3	20%	Birch Creek to Lake St. Martin
W720	15.2	15.2	0.0	0%	Birch Creek to Lake St. Martin
W800	32.9	32.9	0.0	0%	Birch Creek to Lake St. Martin
W840	20.0	0.8	19.2	96%	Birch Creek to Lake St. Martin
W880	76.3	76.3	0.0	0%	Birch Creek to Lake St. Martin
Summary by Watershed					
Birch Creek Watershed	286.2	207.7	78.5	27.4%	Lake St. Martin
Watchorn Creek Watershed	92.7	89.0	3.7	4.0%	Lake Manitoba

Appendix 6I IMPACTS OF LAKE MANITOBA AND LAKE ST. MARTIN OUTLET CHANNELS PROJECT ON DOWNSTREAM WATER LEVELS (MANITOBA HYDRO 2019)

Manitoba Hydro

2019 05 27

Peter Johnston, P.Eng
Senior Hydrologic Operations Engineer
Hydrologic Forecasting and Water Management
Manitoba Infrastructure
2nd Floor - 280 Broadway
Winnipeg MANTIOBA R3C 0R8

Dear Mr. Johnston:

IMPACTS OF LAKE MANITOBA AND LAKE ST. MARTIN OUTLET CHANNELS PROJECT ON DOWNSTREAM WATER LEVELS

Enclosed are results of updated simulated water level impacts on Lake Winnipeg and downstream locations resulting from the proposed Lake Manitoba and Lake St. Martin Outlet Channels Project (LMB/LSM Project). This information is being provided in response to your May 17th, 2019 request for updated information to be used in your environmental review submission.

As a matter of record: Manitoba Infrastructure has provided us with updated data for the LMB/LSM Project on May 17th, 2019. Manitoba Hydro has not analyzed that data to determine its accuracy or whether it reasonably quantifies the modified inflows that can be expected into Lake Winnipeg with the Project. Manitoba Hydro expresses no opinion on the need for or merits of the LMB/LSM Project and has performed no studies or analysis on the impacts of the proposed LMB/LSM on the environment generally. We have performed a limited analysis confined strictly to the use of our model described herein.

Summary of Results

Note the results using updated time series of changes to Lake Winnipeg inflows as a result of the LMB/LSM Channels Project (provided by Manitoba Infrastructure on May 17th) are virtually unchanged from the original analysis summarized in my May 2nd, 2019 letter. The summary data is unchanged but are included here again for completeness.

Table 1 summarizes estimated changes to flood peak levels for historic floods on Lake Winnipeg and the Nelson River as a result of the proposed LMB/LSM Project. Also included in the table for context are historic actual peak elevations and average water levels for the time of year that the peak occurred.

Table 1. Summary of estimated changes to flood peak levels.

Location	Historic Peak Elevation (date of peak)	Average Water Level at this Time of Year	Simulated Peak Level with Existing System	Simulated Peak Level with LMB/LSM Project	Change in Peak Level due to LMB/SLM Project
	(m)	(m)	(m)	(m)	(m)
Lake Winnipeg	218.51 (July-2011)	217.76	218.51	218.58	0.07
Cross Lake[1]	209.16 (Aug-2011)	207.92	209.16	209.22	0.06
Split Lake	169.23 (Aug-2005)	167.24	169.18	169.19	0.01
	169.39 (May-2017)	167.10	169.39	169.39	0.00

Notes: 1. Post Cross Lake weir (1991)

Attachment 1 and the file "LMB-LSM-STUDY-Simulation_Results_RevisedOPS.xlsx" includes detailed results from the simulations.

Methodology

The simulations were performed using a water balance model to simulate Lake Winnipeg water levels and outflows and a Nelson River routing model to simulate water levels and river flows downstream of Lake Winnipeg. These models were originally developed to provide information to the Manitoba Clean Environment Commission (CEC), as part of its review of the Lake Winnipeg Regulation (WR) Project[1]. Appendix 10 of Manitoba Hydro's submission[2] to the CEC describes the underlying modelling methodology. In order to respond to this request, additional input and assumptions were used and are summarized below.

Key assumptions are as follows:

1. Historical flow record 1976 to 2018 for inflows to Lake Winnipeg, flows from the Churchill River Diversion and Nelson River Local Inflows. The starting year of 1976 was chosen because this was the year operation of Lake Winnipeg Regulation commenced (Manitoba Hydro records).
2. The time series of changes to Lake Winnipeg inflows as a result of the LMB/LSM Channels Project (provided by Manitoba Infrastructure on May 17th, 2019) was added

to Manitoba Hydro's record of historic Lake Winnipeg Total Inflow Available for Outflow to represent the Lake Winnipeg Total Inflow Available for Outflow case with the LMB/LSM Channels Project (i.e. the "with project case").

3. No change to Manitoba Hydro's operation of Lake Winnipeg Regulation when Lake Winnipeg water levels are within the power production range established in the LWR Interim WPA licence.
4. No change to Manitoba Hydro's operation of the Churchill River Diversion.

The results are based on simulations of Lake Winnipeg Regulation operations. As with any modelling exercise, simulations will not perfectly reflect historic or future conditions. However, the focus of this analysis is the difference in water levels attributable to the LSM/LMB Channels Project that can be expected under flood conditions. By differencing the results of the simulations, the impact of the change in inflows to Lake Winnipeg and therefore operational changes can be reasonably estimated by differencing simulation results.

Discussion on Results

- When Lake Winnipeg Levels are above 715 feet and Manitoba Hydro is operating at maximum discharge, outflow from the lake is restricted by the outflow capacity of the lake outlet and Lake Winnipeg Regulation outlet channels. Under these conditions, the level of Lake Winnipeg is the primary factor that influences outflows from the lake. To the extent that the LMB/LSM Channels Project increase inflows to Lake Winnipeg during flood and Lake Winnipeg levels are as a result higher, then the outflow from Lake Winnipeg will also be higher resulting in incremental increases to downstream peak water levels.
- The assumption that MH's operations will not change when Lake Winnipeg levels are within the power production range or CRD operations will not change is a simplifying assumption. Manitoba Hydro may alter its operation to anticipate and mitigate the effect of higher intensity Lake Winnipeg inflows due to the LMB/LSM Channels Project. The effect of this simplifying assumption is to slightly overstate the impacts on peak flood levels on Lake Winnipeg and downstream locations.
- Under some flood conditions, the duration of maximum Lake Winnipeg outflow operations are extended in the case with the LMB/LSM Channels Project, resulting in longer periods of higher water levels along the Nelson River.
- Aside from the flood peaks, water levels on Lake Winnipeg and downstream may differ slightly at other times of the year. However, the dominant factor influencing operation of LWR is the overall amount of water inflow to the system, which varies widely from year to year. The differences in water levels on Lake Winnipeg and water bodies downstream of Lake Winnipeg associated with the LSM/LMB Channels Project are not expected to be discernible in the context of existing water level variations.

Background

Manitoba Hydro regulates Lake Winnipeg outflow for power production purposes when the wind-eliminated water levels are between elevation 711 feet and 715 feet. When the lake level rises above elevation 715 feet Manitoba Hydro is required to affect maximum discharge from Lake Winnipeg. During periods when the level falls below elevation 711 feet, control of Lake Winnipeg outflow is under the direction of the Province of Manitoba Minister of Sustainable Development.

Manitoba Hydro operates the Churchill River Diversion (CRD) in accordance with the terms of the Interim CRD Water Power Act Licence and Approvals of the CRD Augmented Flow Program.

I trust this information will be of assistance to the environmental review process for the LMB/LSM Channels Project. Please contact me should you have questions.

Yours truly,

/kdg/LMB-LSM_Channels_Project_Gawne_Johnston_20190527.docx

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[1] Clean Environment Commission, Lake Winnipeg Regulation Report, 2015.
[2] Manitoba Hydro, Lake Winnipeg Regulation – A Document in Support of Manitoba Hydro's Request for a Final Licence under the Manitoba Water Power Act, 2014.

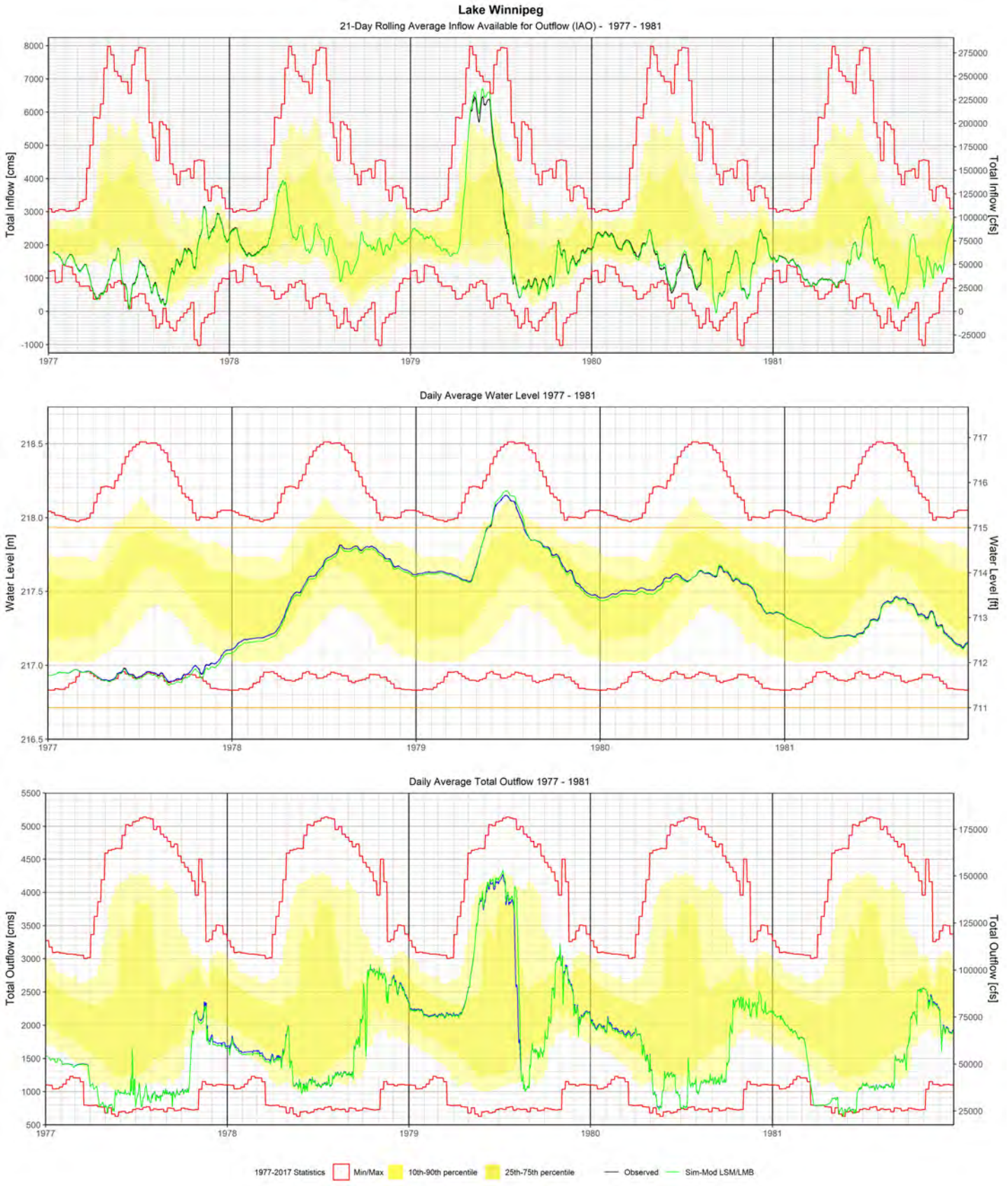


Figure 1: Lake Winnipeg 1977-1981

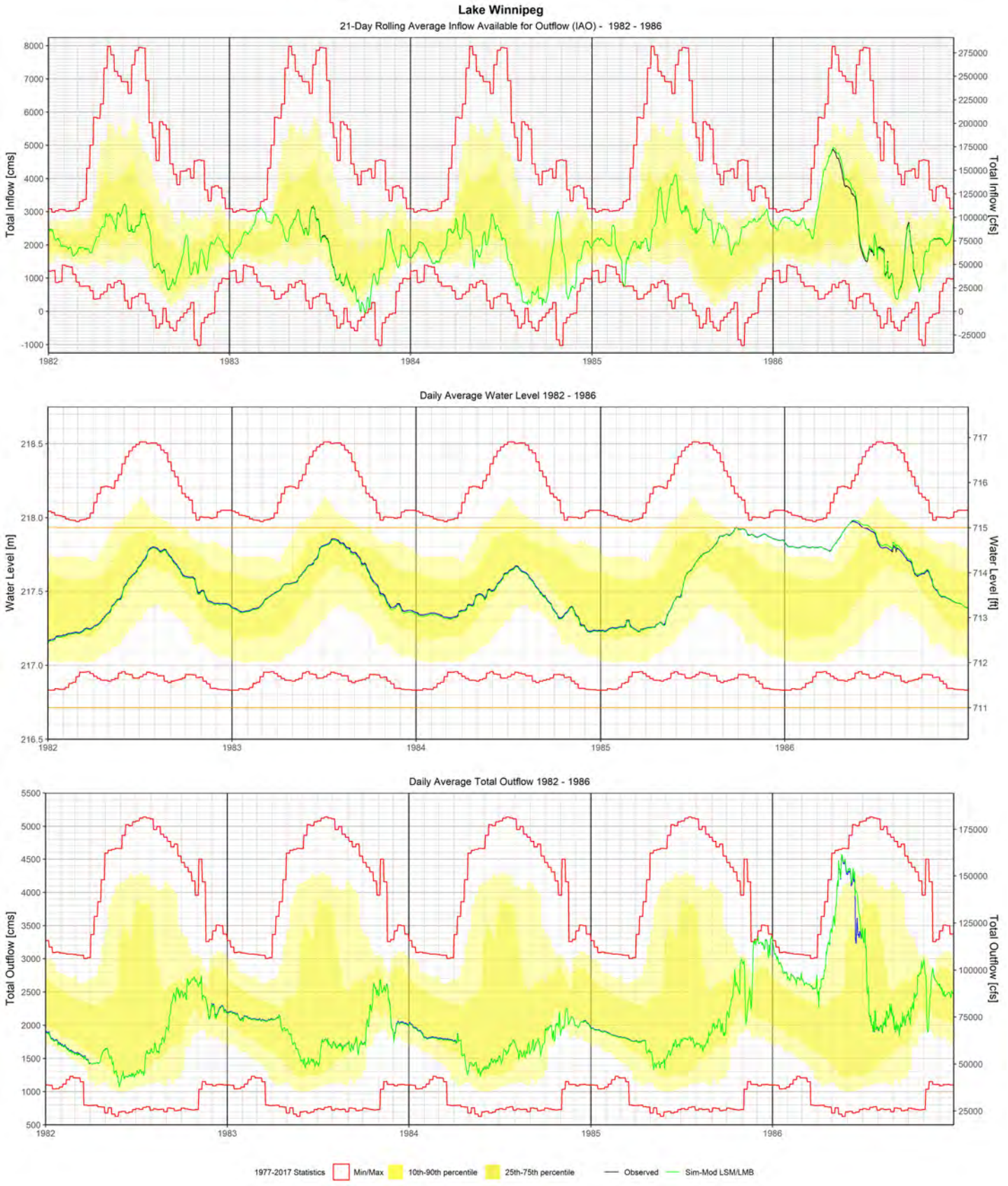


Figure 2: Lake Winnipeg 1982-1986

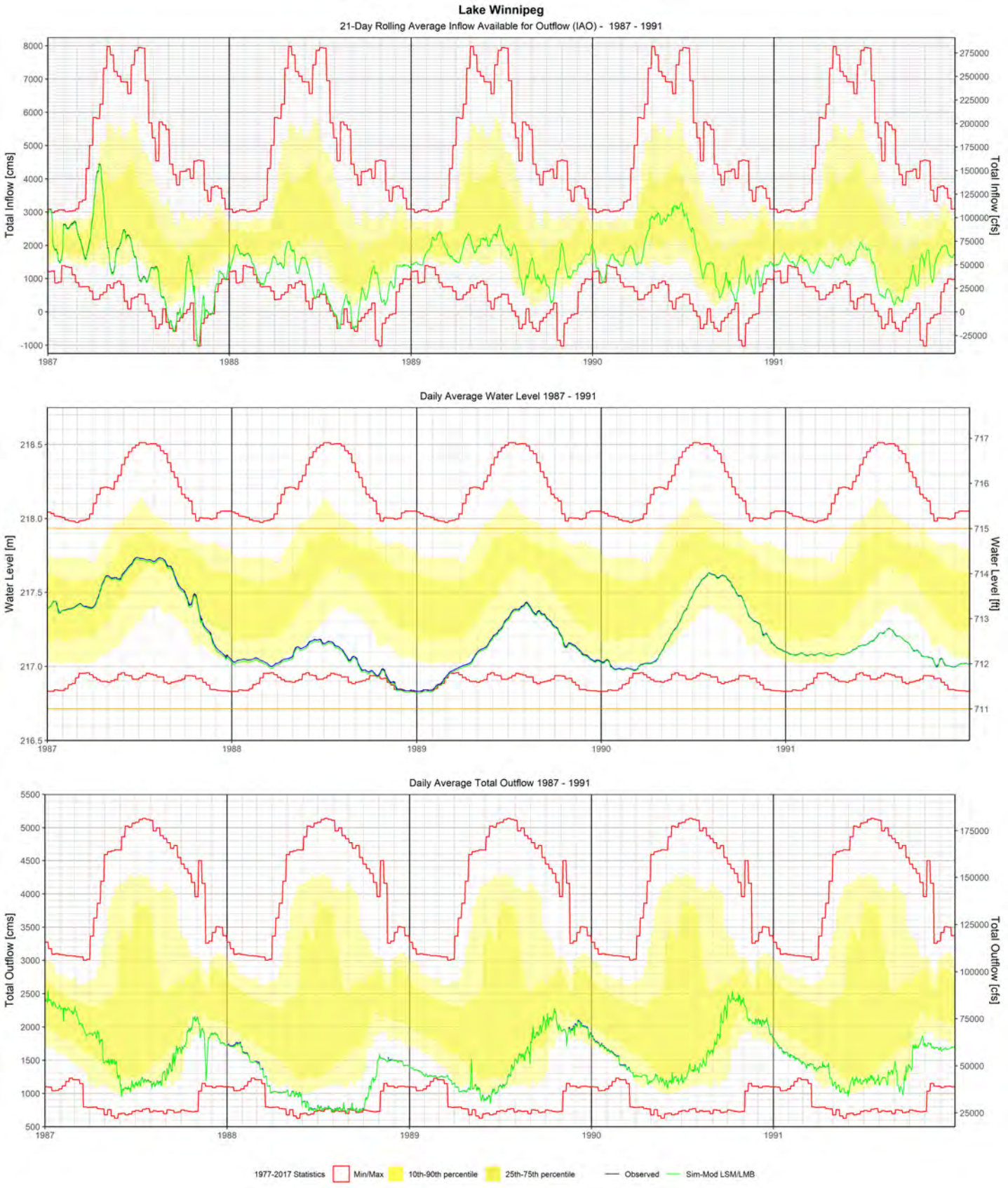


Figure 3: Lake Winnipeg 1987-1991

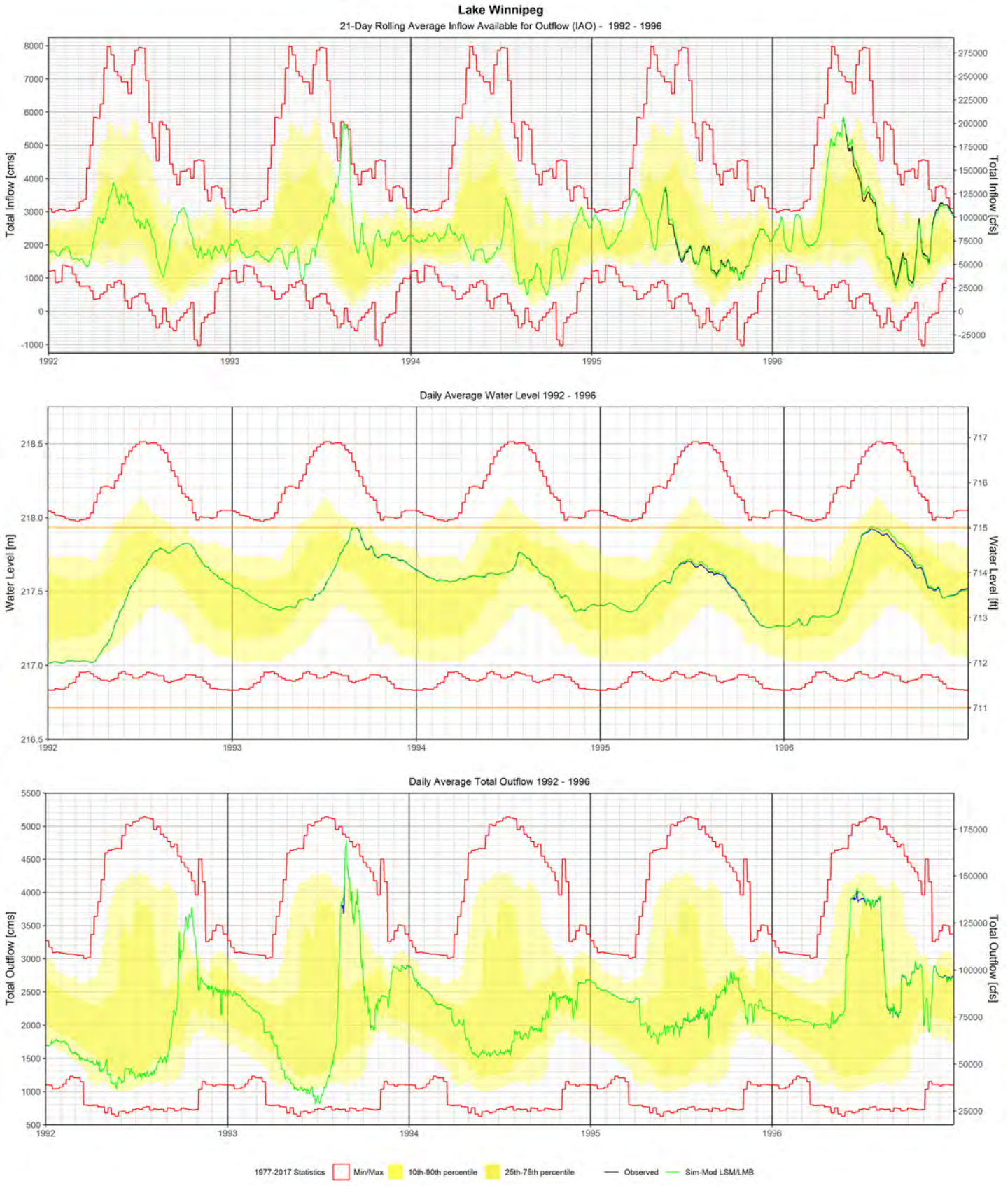


Figure 4: Lake Winnipeg 1992-1996

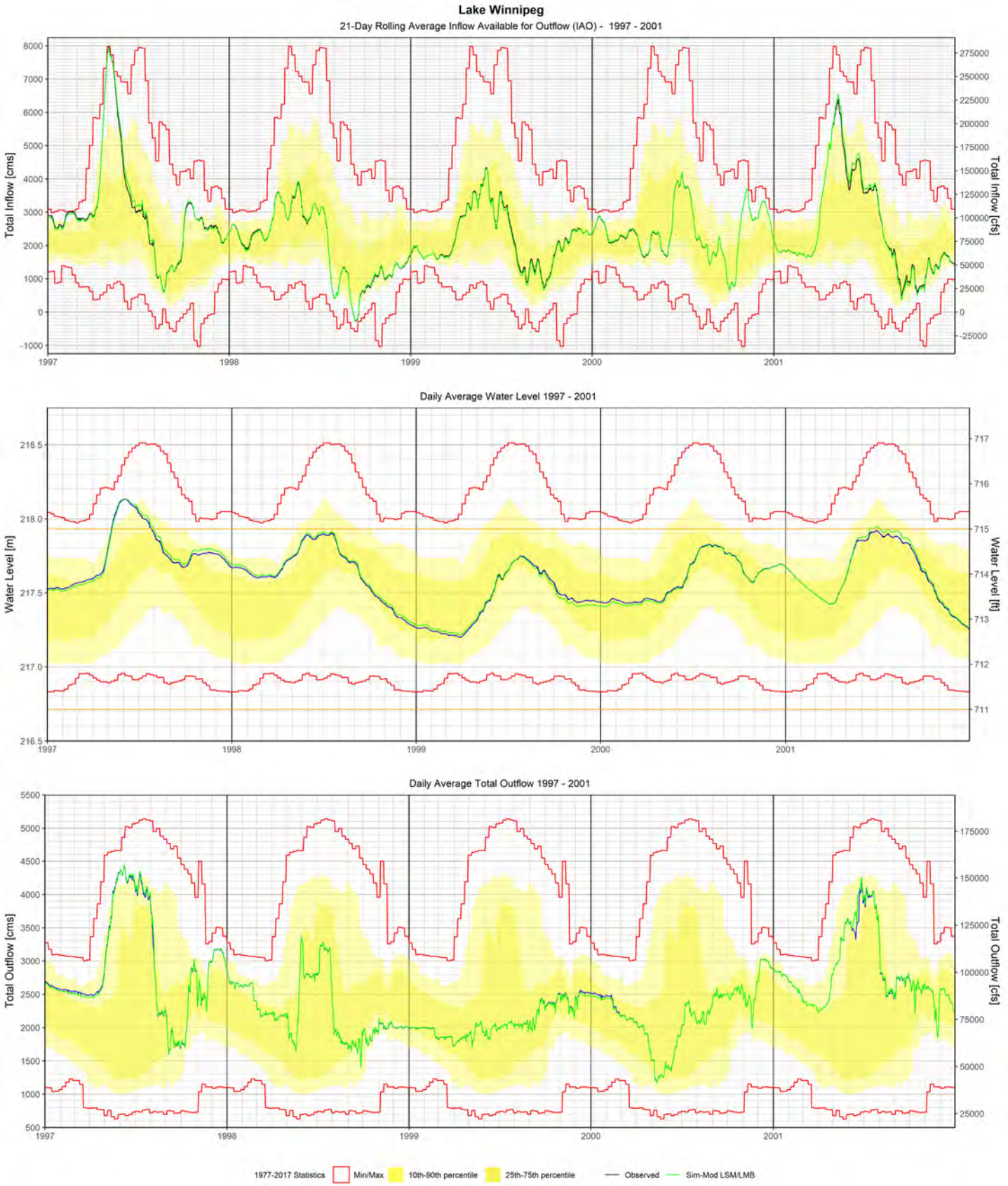


Figure 5: Lake Winnipeg 1997-2001

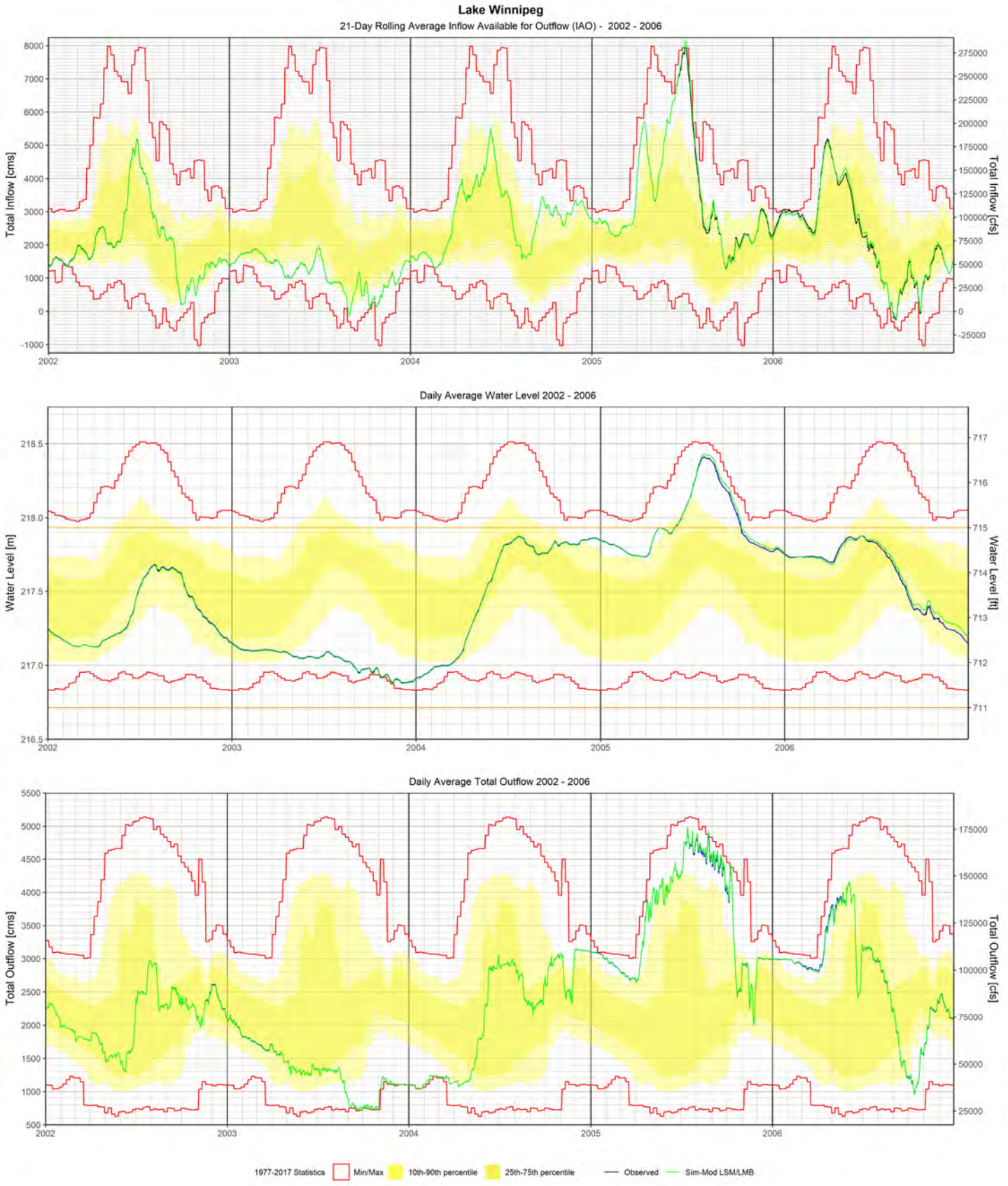


Figure 6: Lake Winnipeg 2002-2006

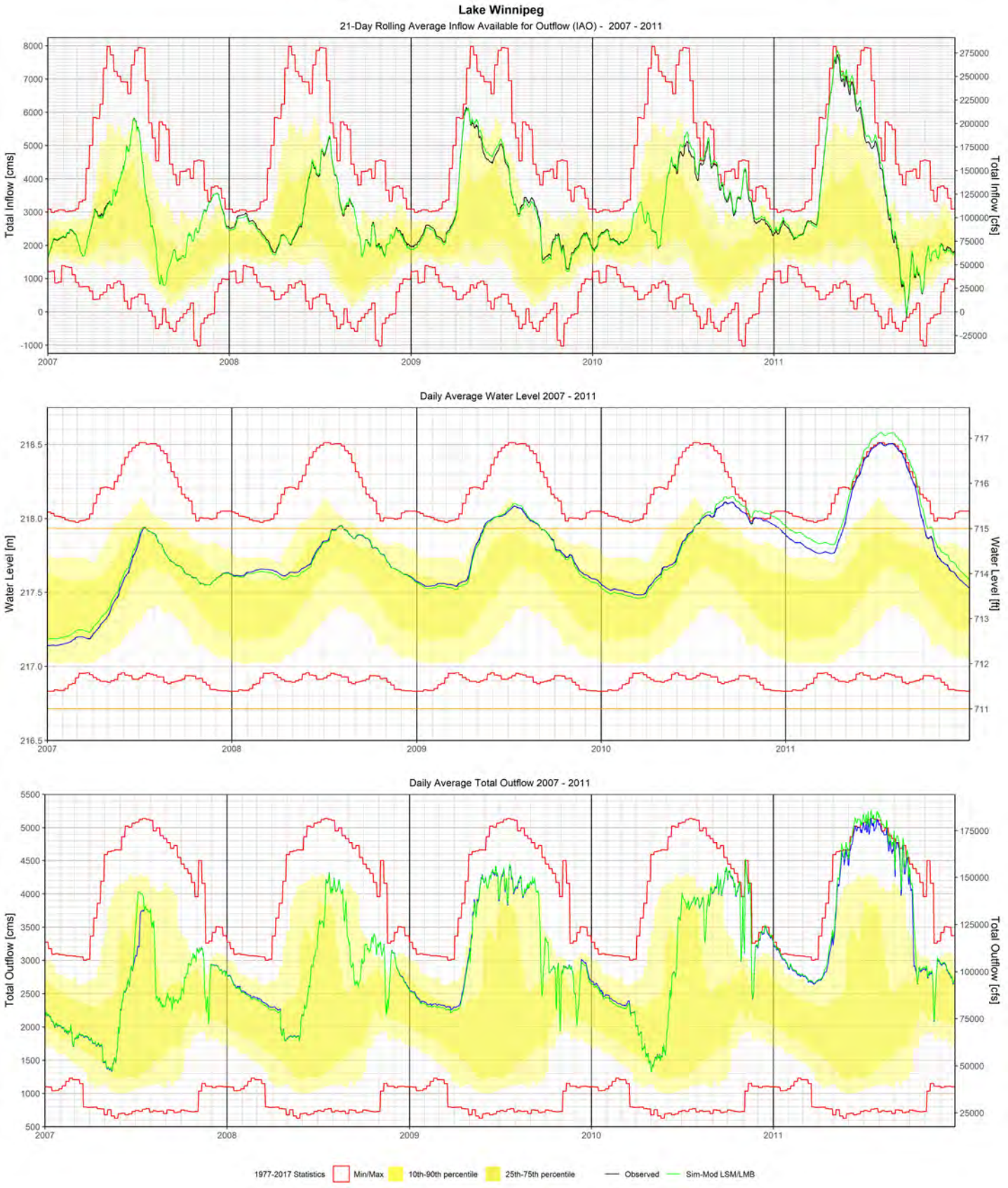


Figure 7: Lake Winnipeg 2007-2011

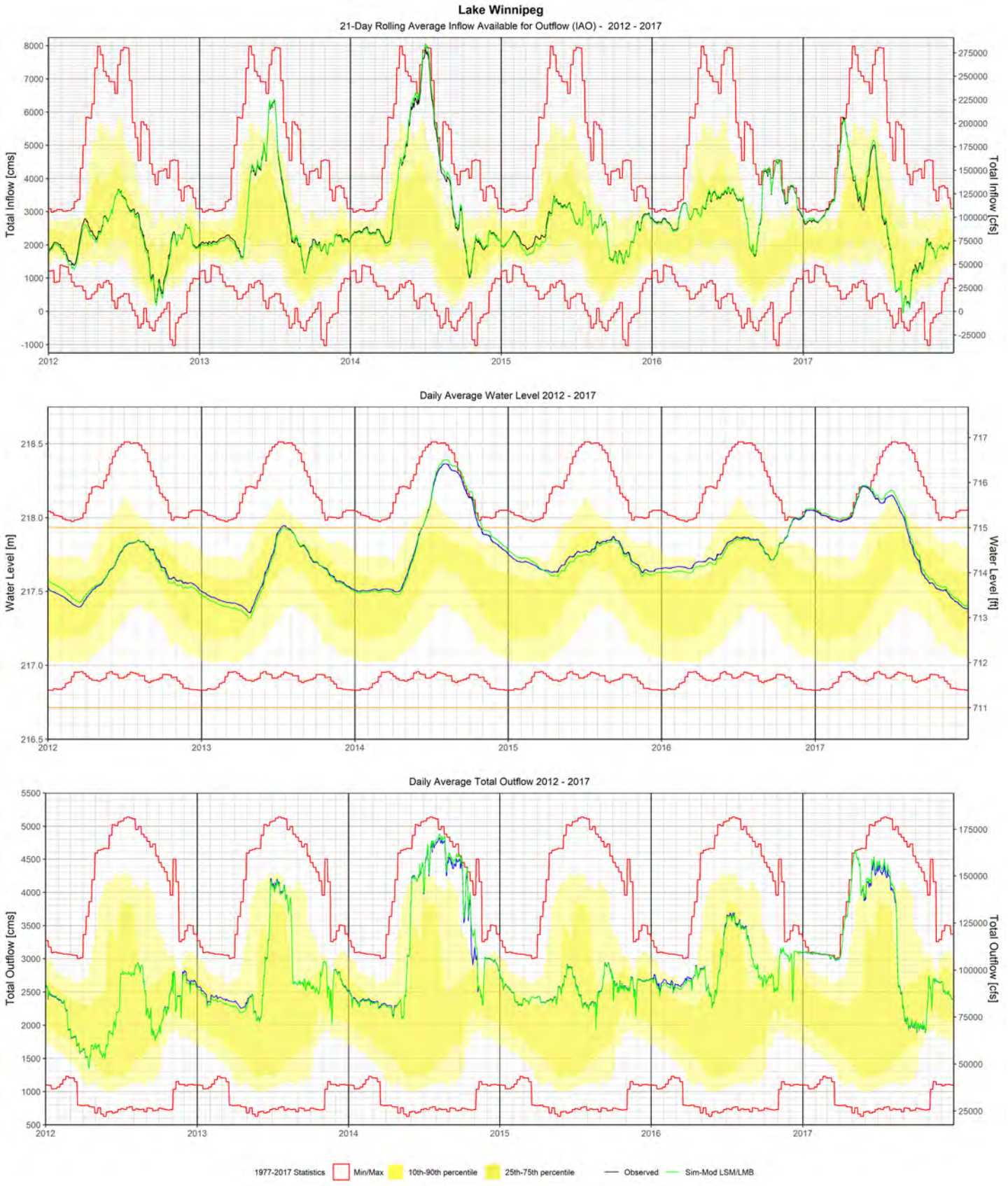


Figure 8: Lake Winnipeg 2012-2017

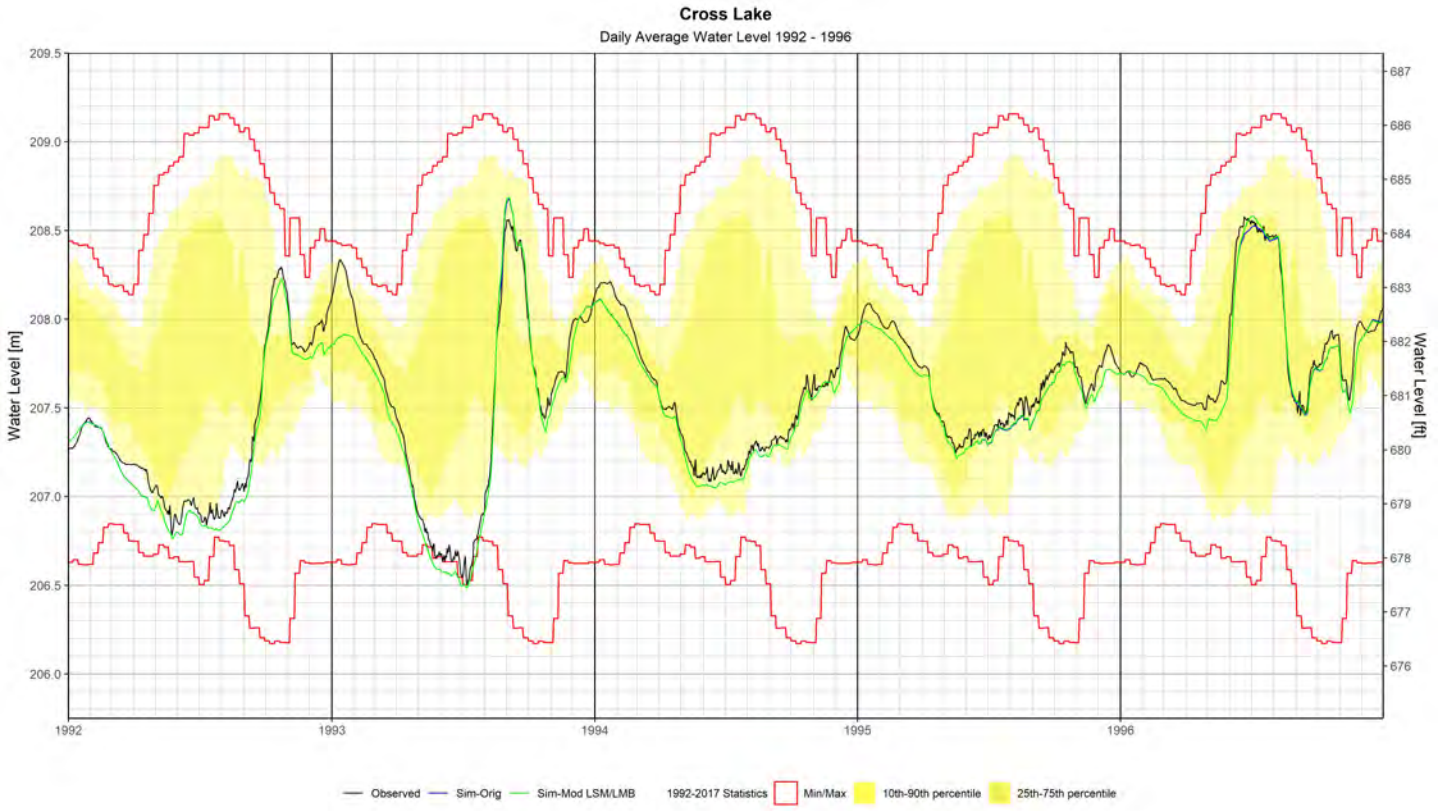


Figure 9: Cross Lake 1992-1996

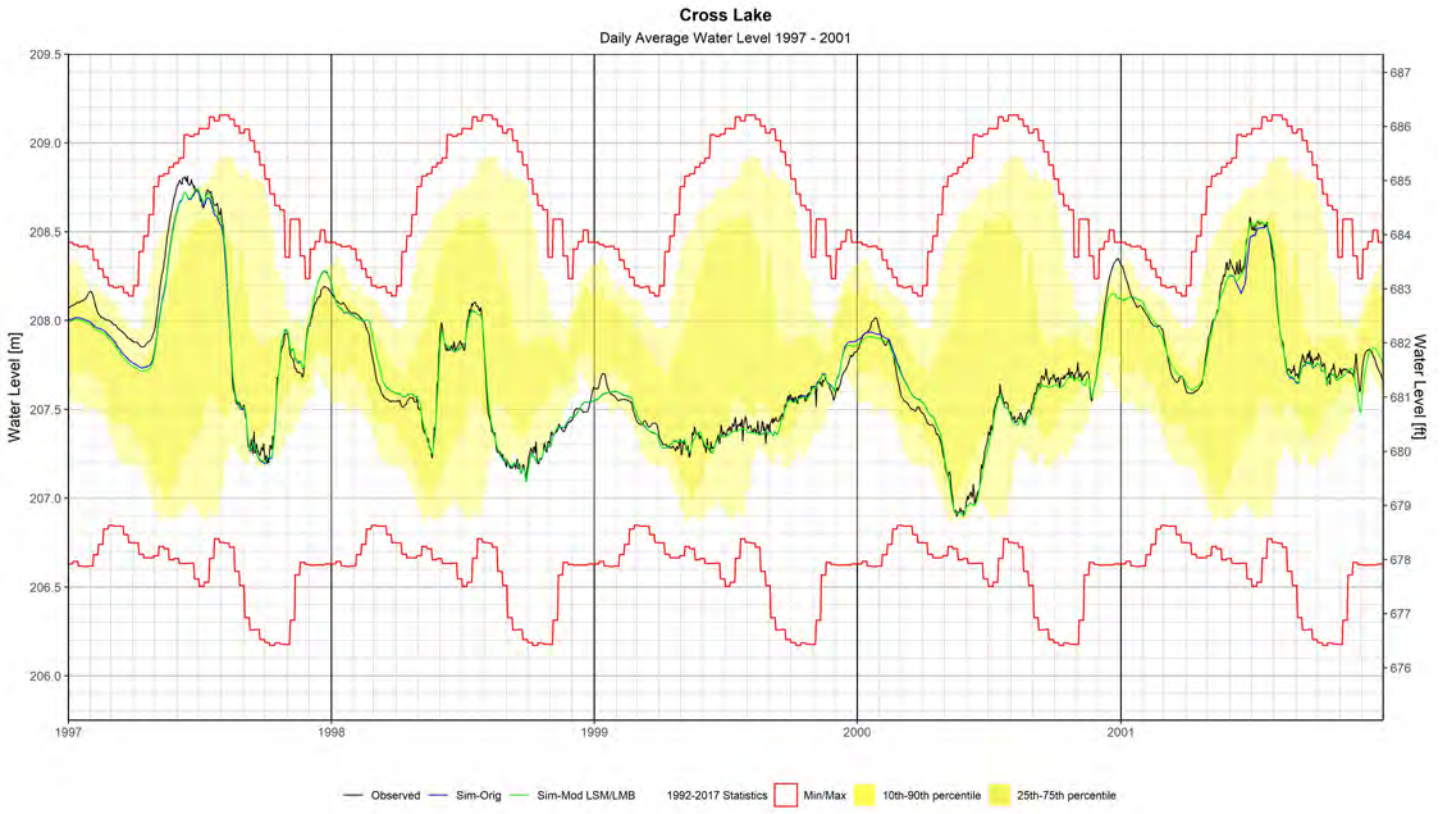


Figure 10: Cross Lake 1997-2001

Figure 11: Cross Lake 2002-2006

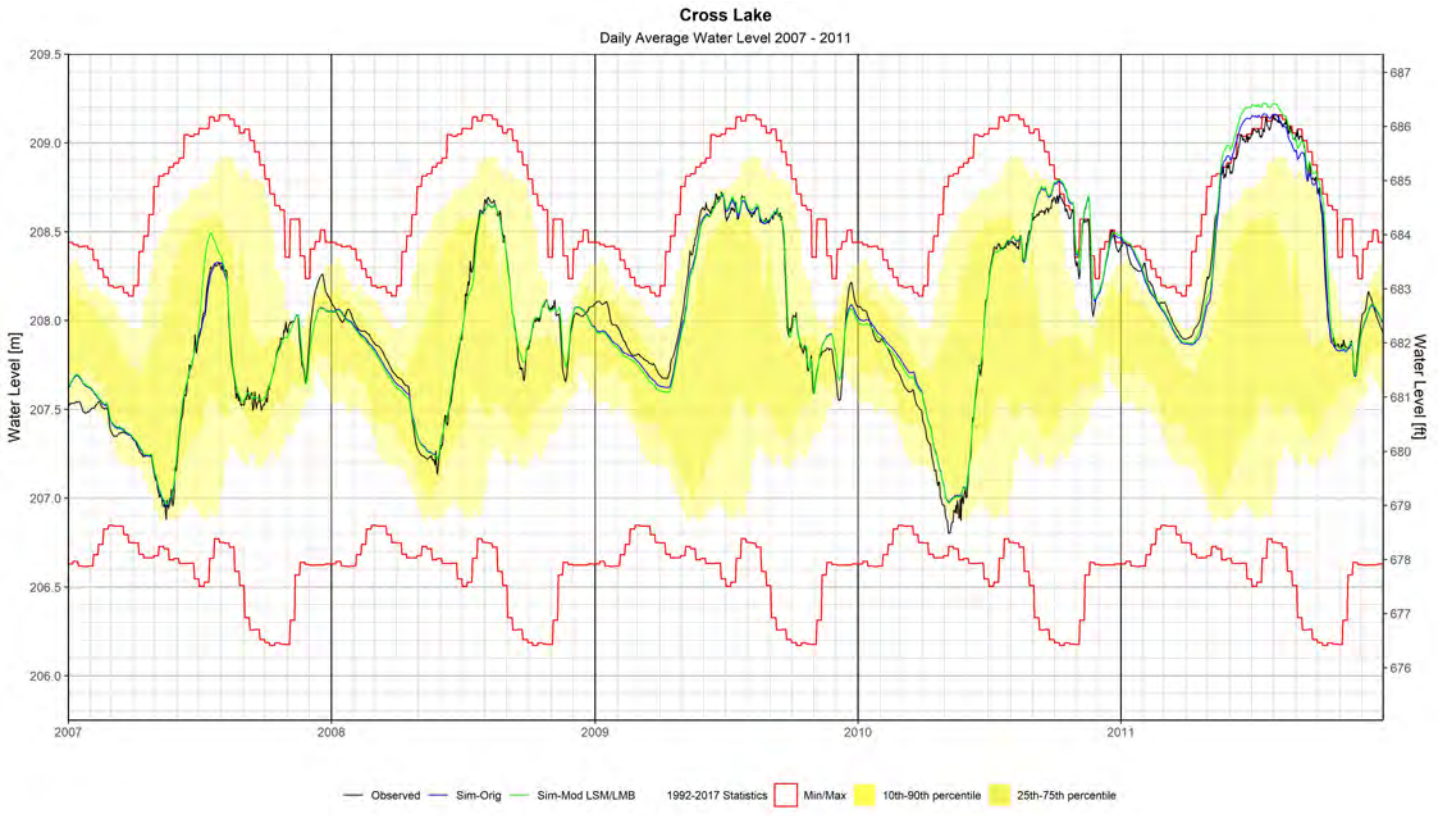


Figure 12: Cross Lake 2007-2011

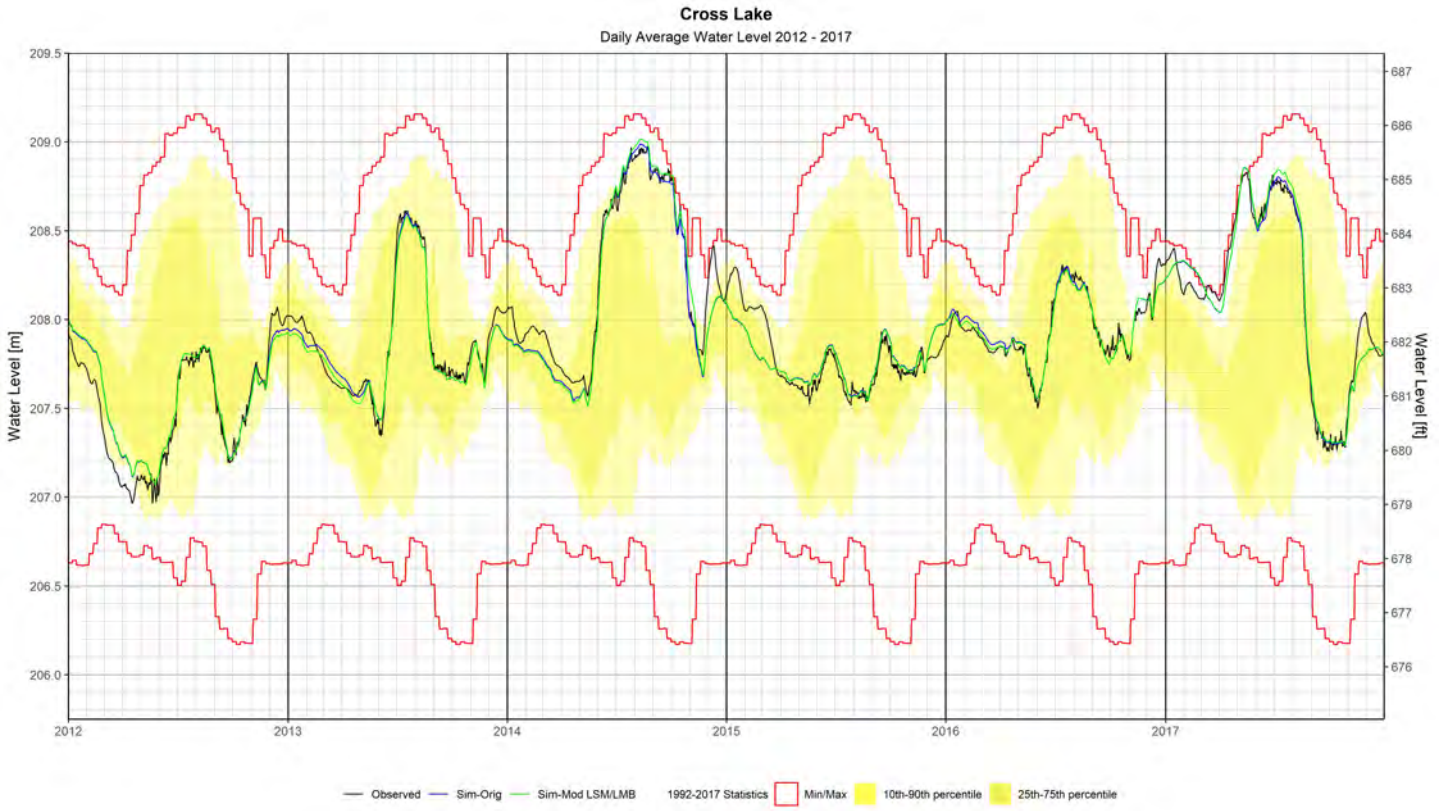


Figure 13: Cross Lake 2012-2017

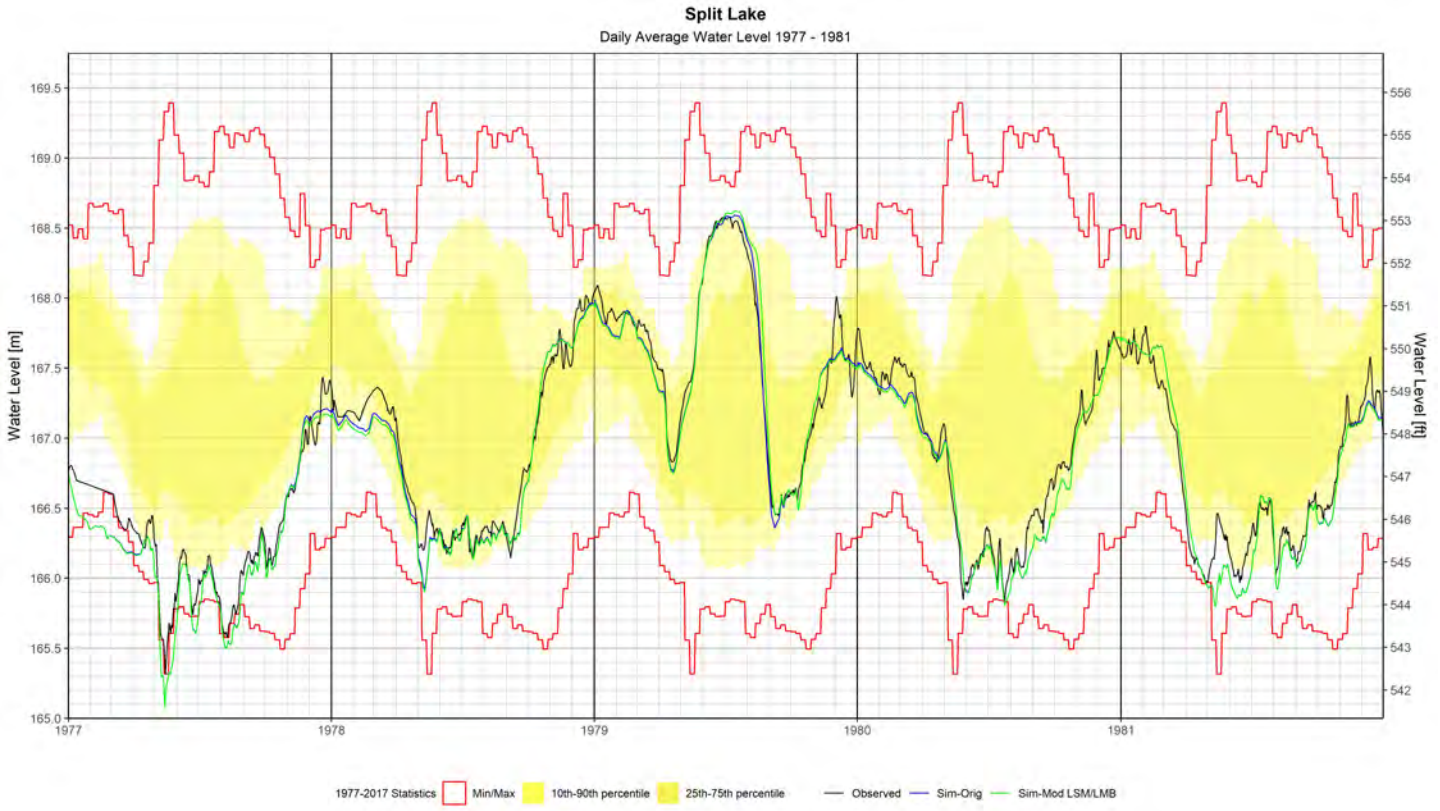


Figure 14: Split Lake 1977-1981

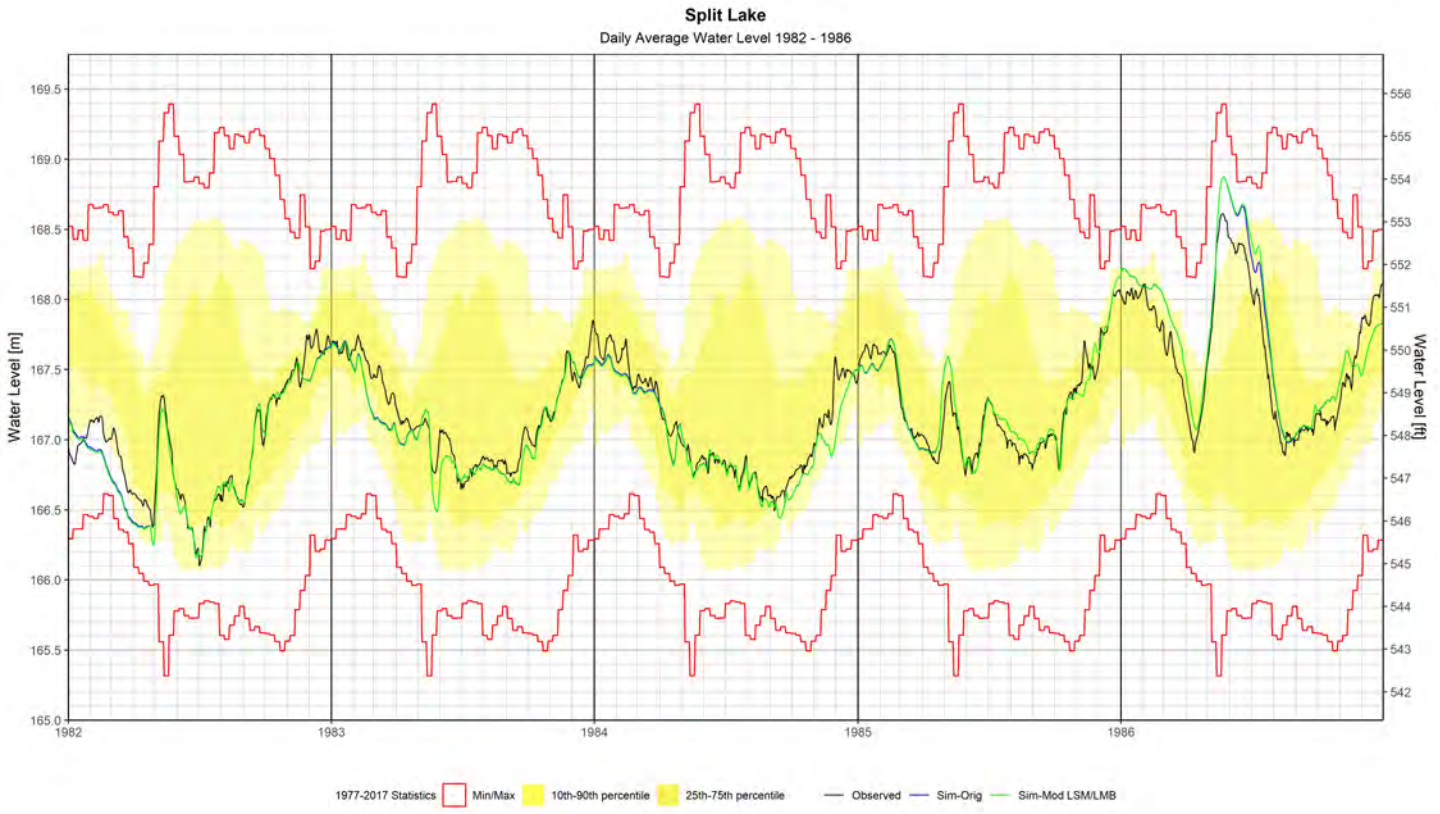


Figure 15: Split Lake 1982-1986

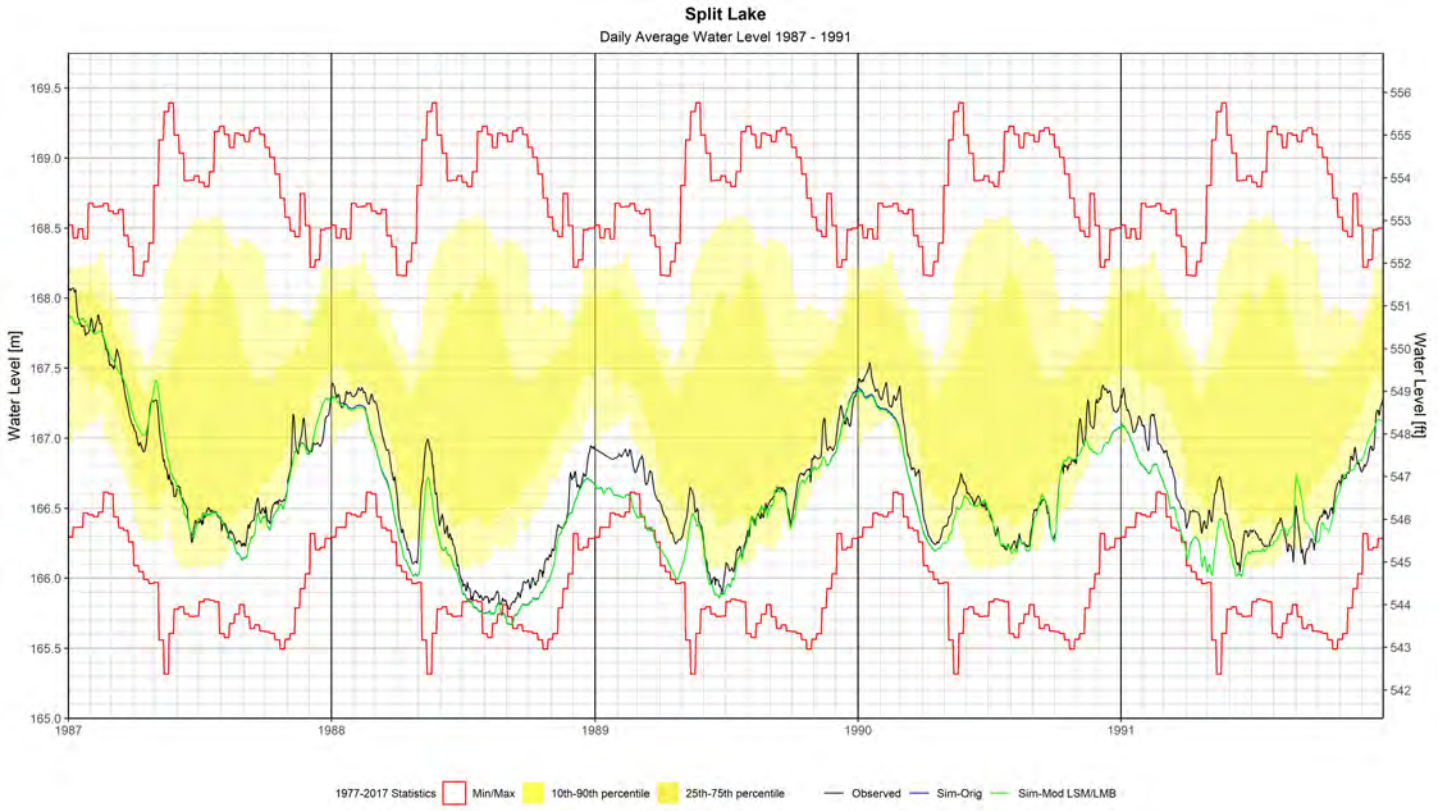


Figure 16: Split Lake 1987-1991

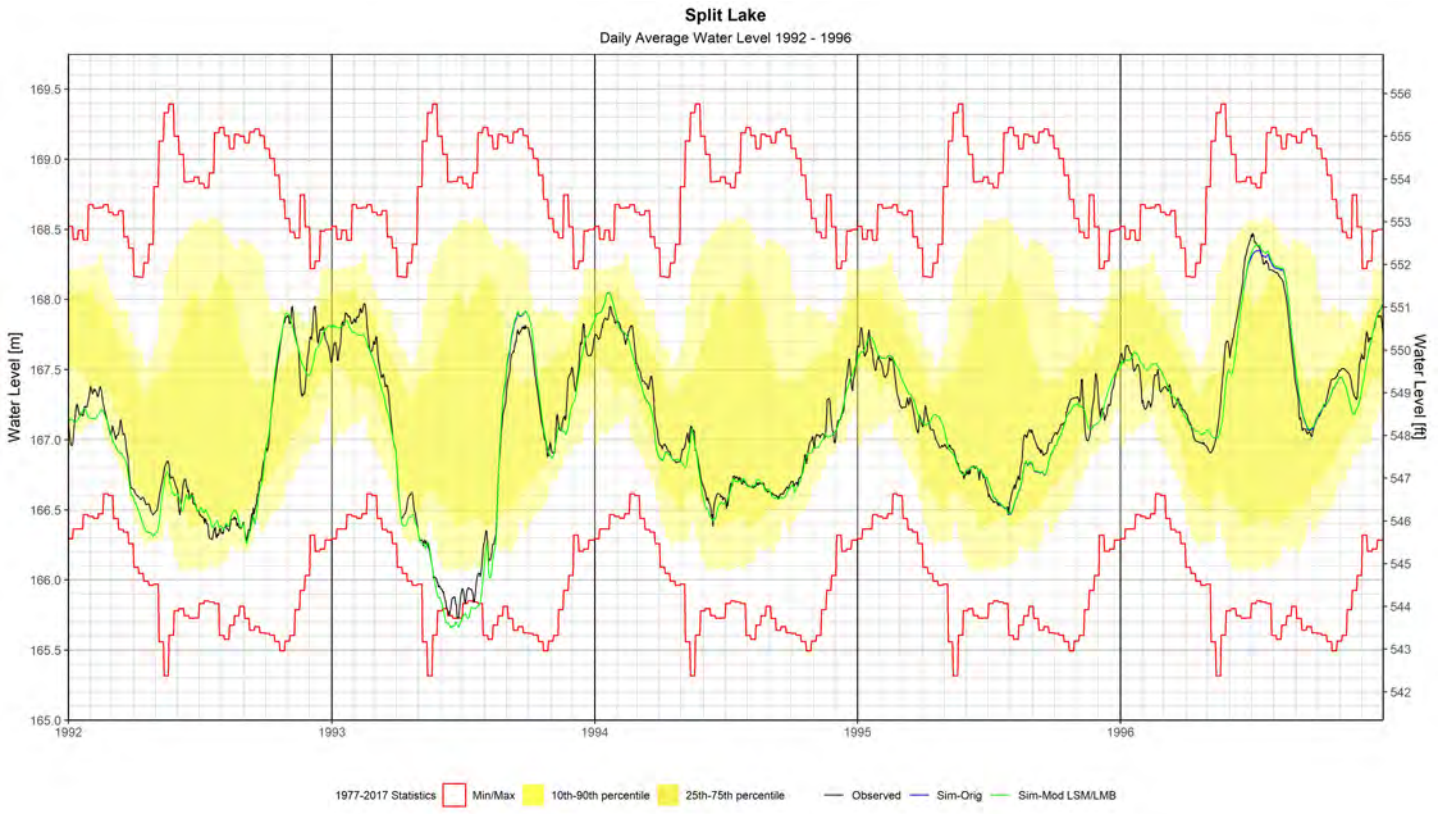


Figure 17: Split Lake 1992-1996

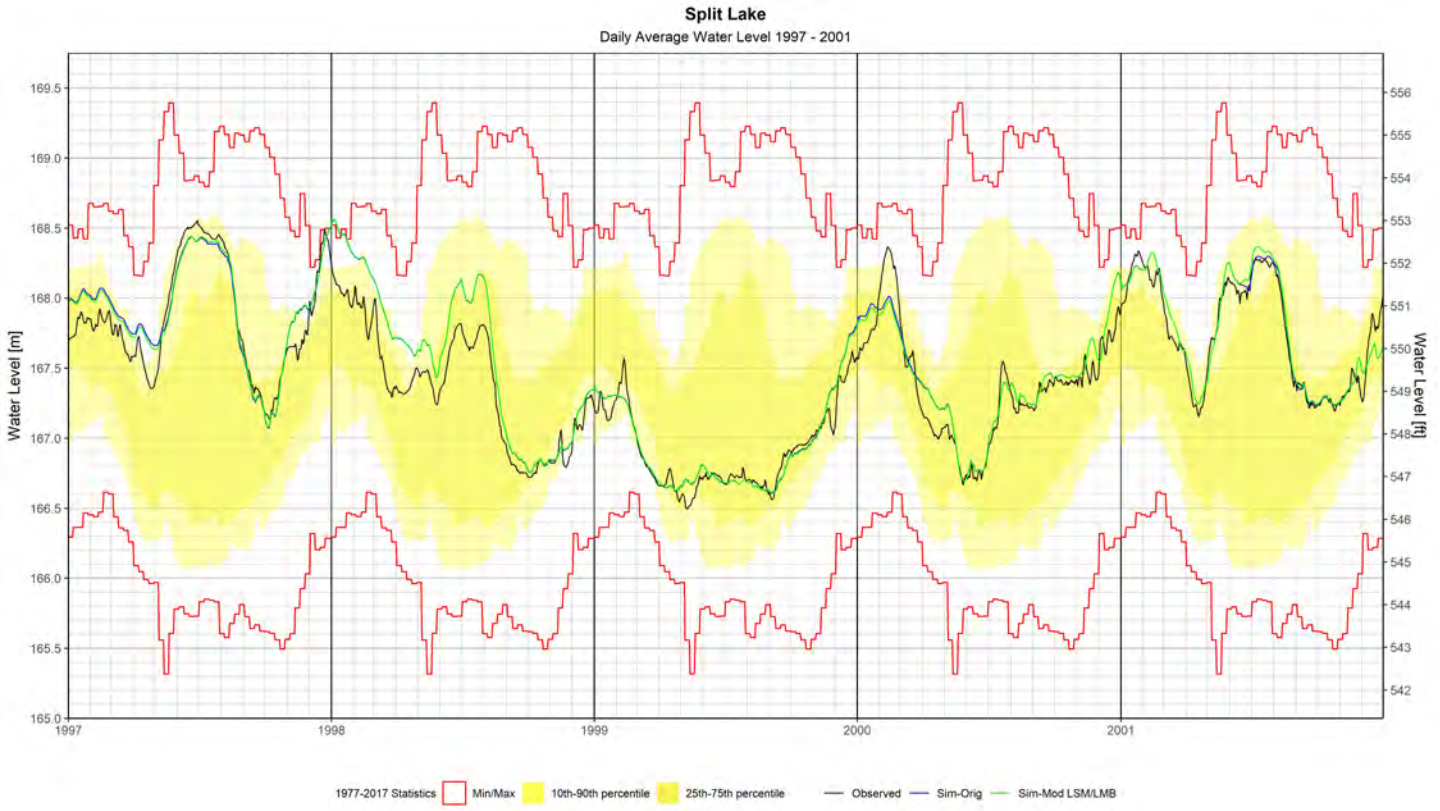


Figure 18: Split Lake 1997-2001

Figure 19: Split Lake 2002-2006

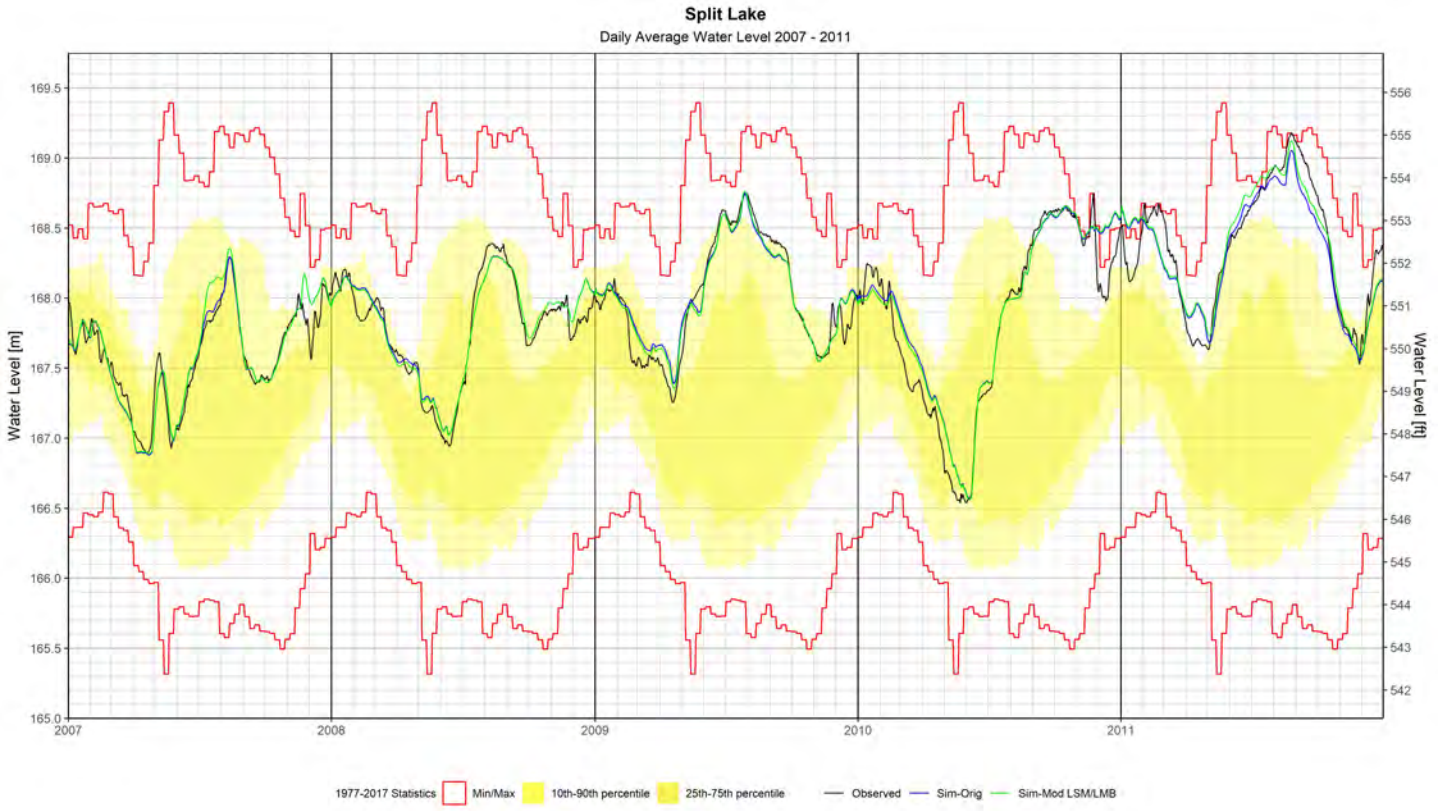


Figure 20: Split Lake 2007-2011

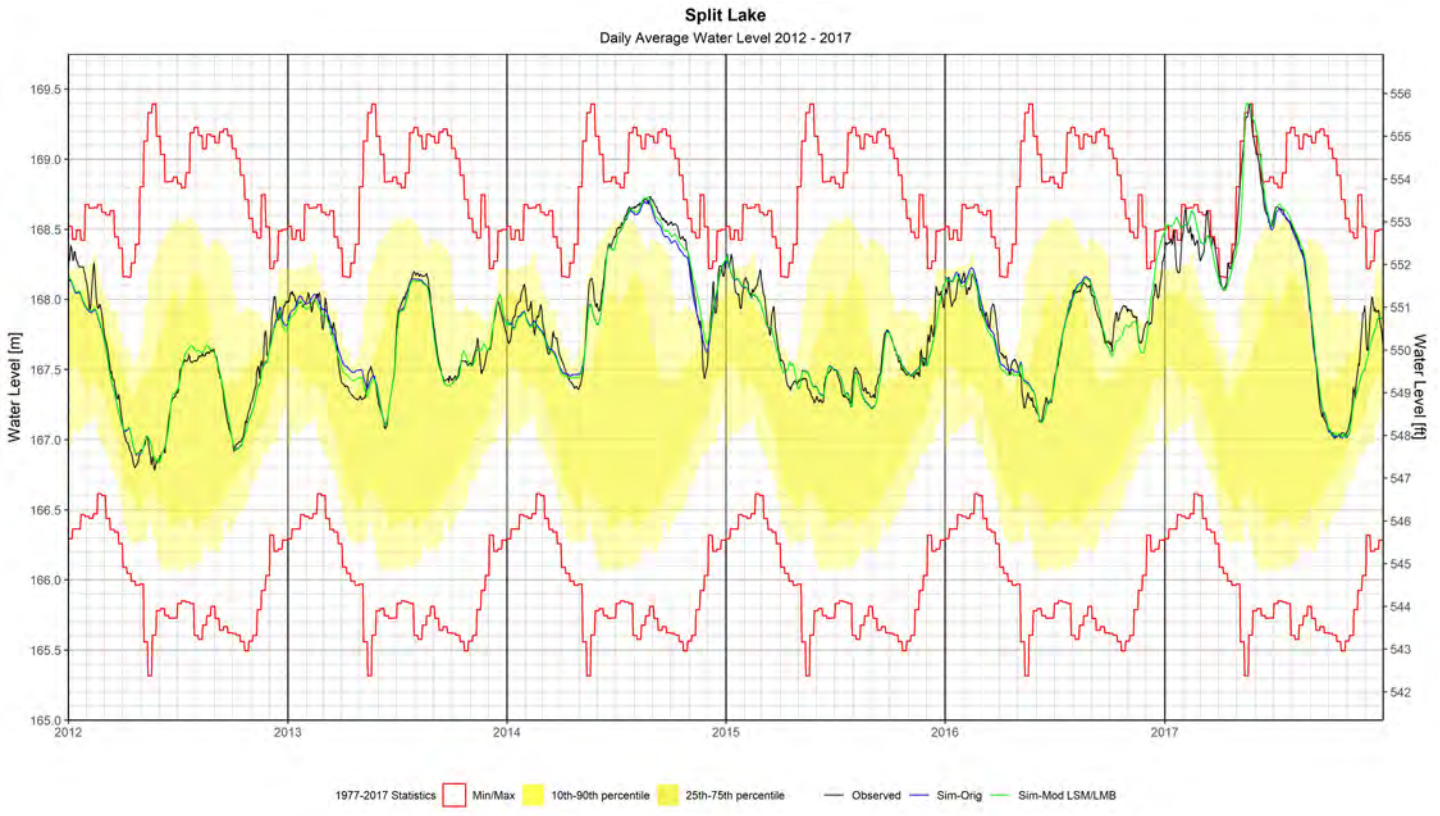


Figure 21: Split Lake 2012-2017

Appendix 6J Development Of Operating Rules For Lake Manitoba And Lake St. Martin Outlet Channels With Recommended Revisions (Manitoba Infrastructure 2019a)

Manitoba

Memorandum

DATE: February 4th, 2019

TO: Eugene Kozera
Director
Hydrologic Forecasting & Water Management
Manitoba Infrastructure

FROM: Chris Propp, P.Eng.
Hydrologic Services Engineer
Hydrologic Operations
Manitoba Infrastructure

SUBJECT: Development of Operating Rules for Lake Manitoba and Lake St. Martin Outlet Channels with Recommended Revisions

This memorandum summarizes the recommendations made by the Lake Manitoba and Lake St. Martin Outlet Channels Operating Guidelines Technical Committee. The Committee was formed to develop the operating guidelines for the proposed Lake Manitoba and Lake St. Martin Outlet Channels in 2016. The Committee was composed of Chris Propp (MI), Eugene Kozera (MI), Ron Richardson (MI), Rick Bowering (MI), Eric Blais (AECOM), and Rick Carson (KGS). The proposed operating guidelines developed by the Committee for the Lake Manitoba and Lake St. Martin Outlet Channels are summarized in Appendix A.

At the onset of the project the Committee decided that the principles of Lake Manitoba and Lake St. Martin regulation laid out by the 2003 Lake Manitoba Regulation Review Advisory Committee and the 2013 Lake Manitoba, Lake St. Martin Regulation Review Committee would be used as the starting point for the development of the operating rules for the proposed Outlet Channels. The Committee agreed that the lake regulation ranges recommended by the 2003 and 2013 committees should not be changed and agreed with the recommendation to minimize outflow adjustments once the lakes are within their respective regulation ranges.

Included in this memo are recommended revisions to the operating guidelines based on further review of the hydrologic modelling and recent discussions with the Engineering Service Providers responsible for the preliminary design of the Outlet Channels. These revisions are highlighted in bold and are noted as revisions. The revisions to the operating guidelines have minimal impact to the hydrologic regime when compared to the impact of the guidelines developed in 2016.

Guidelines and Regulation Ranges Recommended by 2003 and 2013 Committees

The regulation ranges of 810.5 ft – 812.5 ft for Lake Manitoba and 797 ft – 800 ft for Lake St. Martin proposed by the 2003 review committee were accepted for the proposed operating guidelines. The Lake Manitoba regulation range was based on input from cottagers, residents, ranchers, and wildlife interests around Lake Manitoba. The residents and cottagers at Twin Lakes Beach and Delta Beach and the ranchers around the lake identified 811.5 ft as the desirable water level. Residents and cottagers north of Twin Lake and Delta Beach prefer a target range of 812.2 ft. Wildlife interests stated that the narrow range of regulation from 1961-2003 had degraded the marshland around the lake. They stated that a 3 feet fluctuation in lake level would likely restore the health of the marshes over time.

The regulation range and operating guidelines recommended by the 2003 committee for Lake

Manitoba were also intended to reduce negative impacts on Lake St. Martin. Attempts to maintain Lake Manitoba within a narrow range from 1961-2003 increased the frequency and severity of flood and drought periods on Lake St. Martin. First Nations communities around Lake St. Martin stated that the desirable range on Lake St. Martin is 797 ft – 800 ft and that the minimum flows in the Fairford and Dauphin Rivers should be 1100 cfs.

In response to the majority of the interested parties, the 2003 Committee recommended operating guidelines that would have Lake Manitoba water levels managed so that the levels at the high end of the range would be similar to those reached during the period of regulation and low water levels similar to those reached under natural conditions before regulation. The recommended guidelines would also reduce the wide fluctuations in flow and water level that had been transferred to downstream water bodies, which had created severe problems for First Nations, downstream wildlife, fisheries, and tourist operators.

The Lake Manitoba and Lake St. Martin regulation guidelines for the Fairford River Water Control Structure that were recommended by the 2003 Committee and later amended by the 2013 Committee are as follows:

a) The desired regulation range on Lake Manitoba is 812.5 ft to 810.5 ft. The desired regulation range on Lake St. Martin is 797.0 ft to 800.0 ft.

b) During recovery from flood conditions on Lake Manitoba, the Fairford River Water Control Structure is kept wide open until Lake Manitoba recedes to the middle of the desired regulation range after which it should be cut back to achieve normal (natural) outflow (50-60% capacity)

c) During recovery from drought, the Fairford River Water Control Structure is kept at 800 cfs until Lake Manitoba levels increase to middle of the desired regulation range after which point the structure will be operated to achieve normal outflow (50-60% capacity)

d) Under normal operating conditions, once outflow reaches normal, there are no further stop-log adjustments, as long as Lake Manitoba remains within the desired regulation range.

e) Any variances in the lake levels outside of the desired regulation range shall be shared between Lake Manitoba and Lake St. Martin insofar as this may be reasonably possible.

f) The minimum flow on the Fairford River should be 800 cfs with a desirable minimum flow of 1,000 cfs as often as possible.

These guidelines are the currently accepted operating guidelines for the Fairford River Water Control Structure.

Water Level Simulation

A Lake Manitoba/Lake St. Martin Water Balance Model developed in MS Excel by Mr. Rick Bowering was used to evaluate the impacts of the proposed operating guidelines for the outlet channels. Historical daily inflows to Lake Manitoba were estimated for a 103 year period (1915-2017) based on recorded flow and water level data, a stage-storage curve for Lake Manitoba, and precipitation and evaporation data from Environment Canada. The inflows were then routed through the model using the Continuity Equation to simulate levels and outflows on Lake Manitoba and Lake St. Martin for the period of 1915-2017 under different operating regimes.

The stage-discharge rating curves for the Outlet Channels in the model were taken from the KGS Assiniboine River & Lake Manitoba Basins Flood Mitigation Study finalized in 2016 (will be referred to as the ARLM study). It was also assumed that the fish ladder would be removed from the Fairford River Water Control Structure to increase outflow capacity.

The daily inflows form the Portage Diversion had to be simulated under the assumption of a consistent operating regime for the entire analysis period (1915-2017). It was assumed that the Portage Diversion would be operated according to the rules proposed in the Provincial Flood Control Infrastructure Review of Operating Guidelines Report - August 2015 (Appendix B) and that the capacity of the Assiniboine River dikes would be 18,000 cfs. The simulated flows were developed by applying the operating rules to historical daily Assiniboine River flows using algorithms to consider maximum allowable flow on the Assiniboine River, James Avenue water levels, volume of water to be diverted to Lake Manitoba, and Lake Manitoba forecasted peak water level. Manual adjustments were made in some years to capture how the province would actually operate in certain situations rather than rigidly applying the operating guidelines. Examples of this would be timing of operation for ice break-up and not operating if a target threshold is only going to be exceeded by a small amount.

Hydrographs showing simulated water levels and flows are attached in Appendix C.

Proposed Operating Guidelines

As stated previously, the guidelines developed by the 2003 and 2013 Committees for Lake Manitoba and Lake St. Martin regulation were used as the starting point for the development of the operating guidelines for the proposed Outlet Channels. Numerous iterations of operating regimes for the Outlet Channels were simulated to develop an optimal operating regime that would maximize flood protection while staying true to the principles laid out by the 2003 and 2013 review committees; namely, the desired regulation range, minimization of operations when within the desired regulation range, and maintaining a desired minimum flow on the Fairford River.

Consideration was also given to the impact of outlet channel operation during the winter on the stability of ice. Ice stability is an important factor for safe working conditions for the commercial fishery and for avoiding damage and scouring along the outlet channels.

The proposed operating guidelines are summarized in Appendix A. The following is a discussion of the rationale behind the proposed guidelines.

Fairford River Water Control Structure

The Technical Committee agreed that the current operating guidelines for the Fairford River Water Control Structure should not be changed. These operating guidelines were recommended by the 2003 Lake Manitoba Regulation Review Advisory Committee and the 2013 Lake Manitoba, Lake St. Martin Regulation Review Committee and are the result of extensive analyses and consultations.

Lake Manitoba Outlet Channel

1. *The Lake Manitoba Outlet Channel will be opened to maximum capacity when Lake Manitoba is above the top of the regulation range (812.5 ft),*

This operating guideline conforms with the principle of minimizing operations within the desired regulation range (810.5 ft – 812.5 ft)

2. ***The Lake Manitoba Outlet Channel may be opened pro-actively (when the water level is below 812.5 ft) if the water level on Lake Manitoba is forecasted to be above 813 ft in the same season (REV 1).***

REV 1 (2019-01-24) – This allows for pro-active operation for larger floods but also maintains the spirit of the operating guidelines recommended by the 2003 and 2013 Committees (i.e., water levels are generally maintained between 810.5 to 812.5 ft with the expectation that water levels will occasionally reach 810.0 ft or lower on the low side, and 813.0 ft or higher on the high side). Modelling of the 103 years with data indicated that Operating Guideline #2 has minimal impact on reducing the peak water level when compared to no pro-active operation (i.e., outlet only open when water level is above 812.5 ft). However, it will likely be widely supported over a reactive approach based on perceived effectiveness.

3. *The outflow from the Lake Manitoba Outlet Channel will be reduced when the water level on Lake Manitoba recedes to the middle of the regulation range (811.5 ft), so that the combined flow through the Fairford River Water Control Structure and in the Lake Manitoba Outlet Channel, insofar as practicable, matches the inflow into Lake Manitoba.*

This operating guideline is consistent with the Fairford River Water Control Structure operating guidelines with respect to the lake level of 811.5 ft. However, it differs in its requirement that the total lake outflow has to match total Inflows when at the middle of the regulation range. The initial version of this guideline specified that the Lake Manitoba Outlet Channel would be shut off when the Lake Manitoba water level receded below 811.5 ft; however, this created an undesirable effect in certain years where peak water levels from the Lake Manitoba Outlet Channel simulation were higher than the simulated peak water levels without the new Outlet Channel. This is because in some simulation years the operation of the Lake Manitoba Outlet Channel decreased the water level to the middle of the regulation range whereas lake regulation without the Lake Manitoba outlet channel would not have. Consequently, the Fairford River Water Control Structure is reduced to 60% capacity in the simulation with the Lake Manitoba Outlet Channel while the Fairford River Water Control Structure is left at 100% in the simulation without the Lake Manitoba Outlet Channel resulting in higher lake levels the following year in the simulation with the Lake Manitoba Outlet Channel.

Figure 1 shows peak level increases comparing the simulated peaks under the assumption that the Lake Manitoba Outlet is closed when the lake level reaches 811.5 ft, to the simulated peaks under the current operating regime. As shown in the figure, the effect of shutting off the Lake Manitoba Outlet Channel at 811.5 ft results in an increase in peak water level of 0.1 ft or more 19 times. Sixteen of the nineteen instances of peak increase result in levels above the regulation range (812.5 ft). Figure 2 highlights the effects of using the Lake Manitoba Outlet to match inflows into Lake Manitoba once Lake Manitoba reaches 811.5 ft. As can been seen, this adjustment to the operating regime reduces the number of times that peak water levels under the proposed operating regime is higher than 0.1 ft above the peak for the current operating regime from 19 to 4. In three of the four instances, the Lake Manitoba peak level is above 812.5 ft; however, the highest peak in these four instances is only 812.67 ft.

Figure 1

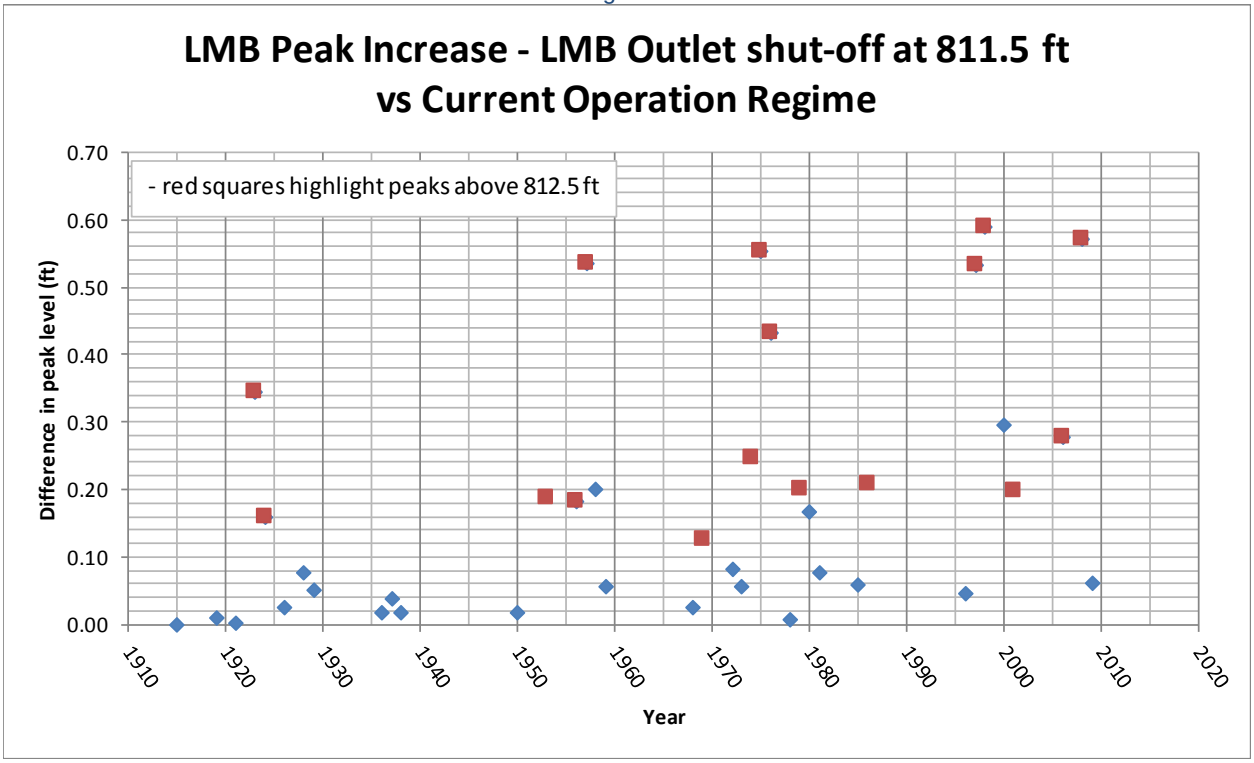
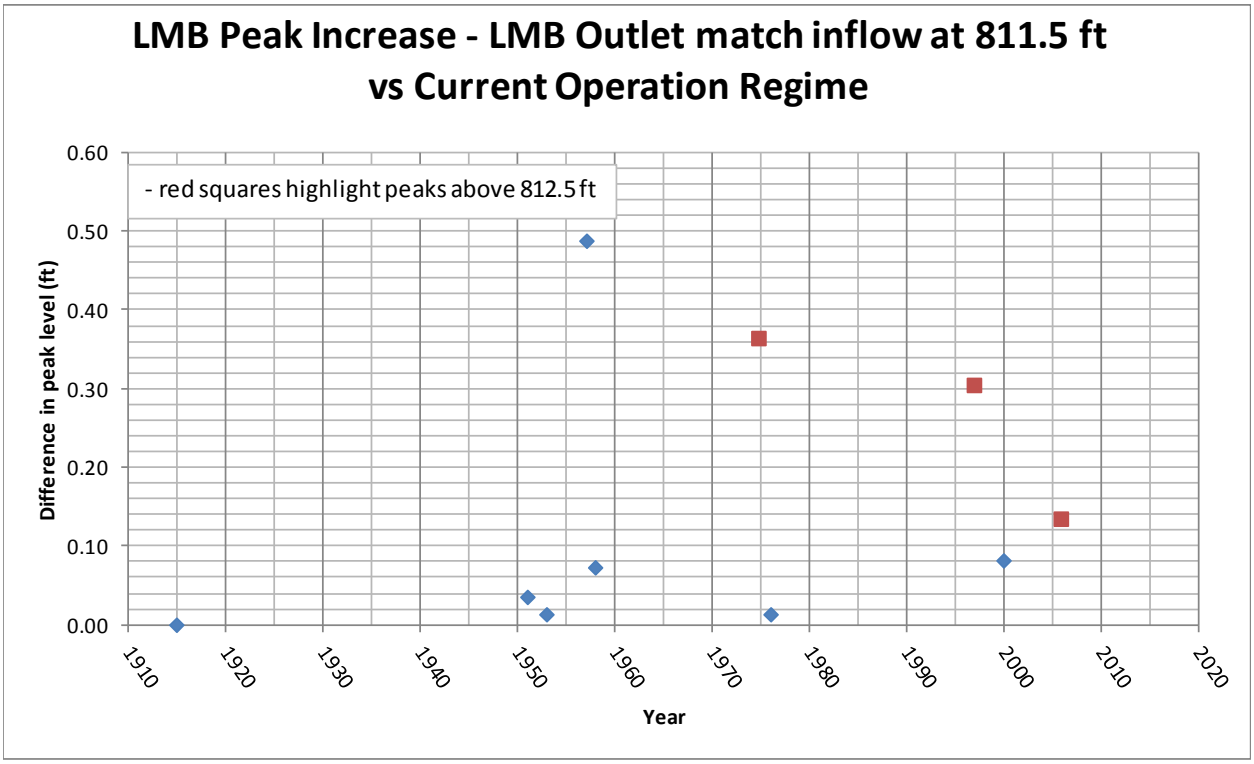


Figure 2



It should be noted that the implementation of proposed guideline #3 increases the number of operating days for the Lake Manitoba Outlet Channel by almost two-fold over the simulation

period when compared to simply shutting off the Lake Manitoba Outlet at the middle of the regulation range.

4. *The Lake Manitoba Outlet Channel will be closed once the Lake Manitoba water level recedes below 811.5 ft and the flow through the Fairford River Water Control Structure is greater than the total inflow into Lake Manitoba.* ***During Outlet Channel shutdown, consideration will be given to ensuring that the drawdown rate within the Outlet Channel does not compromise channel embankment stability (REV 1).***

The first part of this guideline is the extension of Guideline #3. **REV 1 (2019-02-07) – The second part of the guideline ensures that flow is not reduced too rapidly, in order to maintain embankment stability.**

5. *Initial operation of the outlet control structure will not be initiated during the period in which there is solid ice cover in the channel (typically from Dec 1 – April 30th****). However, operation may be considered if severe flooding is forecasted for the following spring (REV 1).***

This guideline was developed to prevent break-up of solid ice pans in the Lake Manitoba Outlet Channel during winter. The movement of ice pans could potentially result in scouring of the Outlet Channel banks and could cause ice stability issues on Lake St. Martin for the commercial ice fishermen. **REV 1 (2019-02-07) – Includes an exception for when severe flooding is forecasted.**

<u>Lake St. Martin Outlet Channel</u>

1. *The target regulation range for Lake St. Martin is 797-800 ft*

Consistent with the recommendations of the 2003 and 2013 Regulation Review Committees.

2. *The Lake St. Martin Outlet Channel will be operated to full capacity:*

    a. *when the Lake St. Martin water level rises above 800 ft*

    or

    b. *when the Lake Manitoba Outlet is opened for initial operation, Lake St. Martin is above 797 ft, and* ***Lake St. Martin is forecasted to go above 800 ft without operation of the Lake St. Martin Outlet Channel (REV 1).***

    Consideration may be given to opening the Lake St. Martin Outlet Channel to less than full capacity if Lake St. Martin is forecasted to go only slightly above 800 ft (REV1).

Part “a” of this guideline is consistent with the recommended regulation range. Part “b” of this guideline is required to avoid major water level spikes on Lake St. Martin as Lake St. Martin rises rapidly when the Lake Manitoba Outlet Channel is open. **REV 1 (2019-02-07) – Includes wording to ensure that the Outlet Channel is only open when Lake St. Martin is**

forecasted to go above 800 ft. Also provides some leeway for operating to less than full capacity should Lake St. Martin only go slightly above 800 ft.

3. *The outflow from the Lake St. Martin Outlet Channel will be reduced when the lake level decreases below 800 ft, to the greater of the following:*

    a. ***25% (REV 1)*** *of channel capacity,*

    b. *the outflow required to ensure the combined flows in the Dauphin River and the Lake St. Martin Outlet Channel matches the total inflow into Lake St. Martin*

This guideline is in line with Guideline #2 for the Lake Manitoba Outlet Channel and allows for more stability in Lake St. Martin water levels when within regulation range. **REV 1 (2019-02-07) – The original minimum channel capacity setting was set to 50% by the Technical Committee. It is recommended that this be reduced to 25% as the 50% minimum results in drawing down the lake too quickly.**

4. ***The flow in the Lake St. Martin Outlet Channel will be further reduced when the water level on Lake St. Martin recedes below 798 ft, so that the combined flows in the Dauphin River and in the Lake St. Martin Outlet Channel, insofar as practicable, matches the inflow into Lake St. Martin (REV 1)***

REV 1 (2019-01-02) – It is recommended that this guideline be included to eliminate rapid water level rises that were observed to occur upon closure of the Lake St. Martin Outlet Channel in some of the simulation years.

5. *The Lake St. Martin Outlet Channel will be closed fully when Lake St. Martin drops below 798 ft* ***and the outflow from the Dauphin River is equal to or greater than the total inflow into Lake St. Martin from the (REV 1)*** *during the period from when ice cover has cleared out of the channel in the spring to October 31st.* ***During channel shutdown consideration will be given to ensuring that the drawdown rate within the Outlet Channel does not compromise channel embankment stability (REV 1).***

Setting the shut-off trigger below 797 ft was considered; however, it caused the lake to drop below 797 ft (lower than the desired regulation range) in too many years. **REV 1 (2019-02-07) – The additional clause of waiting until outflows to Dauphin River match inflows is recommended to conform with Lake St. Martin Channel guideline #4. The second part of the guideline ensures that flow is not cut back too rapidly for embankment stability.**

6. *If the Lake Manitoba Outlet is in operation in November, the Lake St. Martin Outlet Channel should be operated throughout the winter so that the combined flows in the Dauphin River and in the Lake St. Martin Outlet Channel, insofar as practicable, matches the inflow into Lake St. Martin.*

This guideline is intended to maintain a stable water level on Lake St. Martin over the winter to promote ice stability for the commercial fishery. Shutting down the Lake St. Martin Outlet

Channel over winter results in a rapid increase in water levels on Lake St. Martin when the Lake Manitoba Outlet Channel is still in operation.

7. *Notwithstanding the above guidelines, the Lake St. Martin Outlet Channel will be operated during the spring freshet if the Lake Manitoba Outlet Channel has been in operation over the winter and will continue to be operated into the spring, so that the combined flows in the Dauphin River and the Lake St. Martin Outlet Channel, insofar as practicable, matches the inflow into Lake St. Martin.*

This guideline captures the transition from winter to spring in situations where Lake St. Martin Outlet Channel was not in operation during the winter but the Lake Manitoba Outlet Channel was in operation. Waiting for Lake St. Martin to rise to 800 ft before opening the outlet channel in this situation causes a very rapid spike in Lake St. Martin.

8. *Initial operation of the outlet control structure will not be initiated during the period in which there is solid ice cover in the channel (typically from Dec 1 – April 30th). However, operation* ***may be considered if severe flooding is forecasted for the following spring (REV 1).***

This guideline was developed to prevent break-up of solid ice pans in the Lake St. Martin Outlet Channel during winter. The movement of ice pans could potentially result in scouring of the Outlet Channel banks and could cause ice stability issues on Lake Winnipeg for the commercial ice fishermen. **REV 1 (2019-02-07) – Includes an exception for when severe flooding is forecasted.**

It is assumed that Lake Manitoba and Lake St. Martin Outlet Channel gate settings will be adjusted when required on a weekly or biweekly basis rather than on a daily basis. This means that gate settings made to match inflows and outflows may not perfectly balance inflows and outflows for the whole period between gate operations.

Chris Propp, P.Eng.

Cc: E. Kozera
C. Fourie
C. Baljko
P. Johnston

Appendix A:

Proposed Lake Manitoba and Lake St. Martin Operating Guidelines

Lake Manitoba and Lake St. Martin Outlet Operating Guidelines

Any variances in the lake levels outside of the target regulation ranges specified below shall be shared between Lake Manitoba and Lake St. Martin insofar as this may be reasonably practicable.

It is assumed that Lake Manitoba and Lake St. Martin Outlet Channel gate settings will be adjusted when required on a weekly or biweekly basis rather than on a daily basis. This means that gate settings made to match inflows and outflows may not perfectly balance inflows and outflows for the whole period between gate operations.

Lake Manitoba

Fairford River Water Control Structure

1. The target regulation range on Lake Manitoba is 812.5 ft to 810.5 ft.
2. During recovery from flood conditions on Lake Manitoba, the Fairford River Water Control Structure is kept wide open until Lake Manitoba recedes to the middle of the range after which is should be cut back to a normal setting (50-60% capacity).
3. During recovery from drought, the Fairford River Water Control Structure is kept at 800 cfs until Lake Manitoba levels increase to middle of the range after which point the structure will be operated to achieve normal outflow (50-60% capacity).
4. Under normal operating conditions, once outflow reaches normal, there are no further stop-log adjustments, as long as Lake Manitoba remains within the range.
5. The minimum flow on the Fairford River should be 800 cfs with a desirable flow of 1,000 cfs as often as practicable.

Lake Manitoba Outlet Channel

1. The Lake Manitoba Outlet Channel will be opened to maximum capacity when Lake Manitoba is above the top of the regulation range (812.5 ft*),*
2. **The Lake Manitoba Outlet Channel may be opened pro-actively (when the water level is below 812.5 ft) if the water level on Lake Manitoba is forecasted to be above 813 ft in the same season (REV 1).**
3. The outflow from the Lake Manitoba Outlet Channel will be reduced when the water level on Lake Manitoba recedes to the middle of the regulation range (811.5 ft), so that the combined flow through the Fairford River Water Control Structure and in the Lake Manitoba Outlet Channel, insofar as practicable, matches the inflow into Lake Manitoba.

4. The Lake Manitoba Outlet Channel will be closed once the Lake Manitoba water level recedes below 811.5 ft and the flow through the Fairford River Water Control Structure is greater than the total inflow into Lake Manitoba. **During Outlet Channel shutdown, consideration will be given to ensuring that the drawdown rate within the Outlet Channel does not compromise channel embankment stability (REV 1).**
5. Initial operation of the outlet control structure will not be initiated during the period in which there is solid ice cover in the channel (typically from Dec 1 – April 30th). **However, operation may be considered if severe flooding is forecasted for the following spring (REV 1).**

Lake St. Martin

Lake St. Martin Outlet Channel

1. The target regulation range for Lake St. Martin is 797-800 ft
2. The Lake St. Martin Outlet Channel will be operated to full capacity:
   a. when the Lake St. Martin water level rises above 800 ft

      or

   b. when the Lake Manitoba Outlet is opened for initial operation, Lake St. Martin is above 797 ft, and **Lake St. Martin is forecasted to go above 800 ft without operation of the Lake St. Martin Outlet Channel (REV 1).**

   Consideration may be given to opening the Lake St. Martin Outlet Channel to less than full capacity if Lake St. Martin is forecasted to go only slightly above 800 ft (REV1).

3. The outflow from the Lake St. Martin Outlet Channel will be reduced when the lake level decreases below 800 ft, to the greater of the following:
   a. **25% (REV 1)** of channel capacity,
   b. the outflow required to ensure the combined flows in the Dauphin River and the Lake St. Martin Outlet Channel matches the total inflow into Lake St. Martin
4. **The flow in the Lake St. Martin Outlet Channel will be further reduced when the water level on Lake St. Martin recedes below 798 ft, so that the combined flows in the Dauphin River and in the Lake St. Martin Outlet Channel, insofar as practicable, matches the inflow into Lake St. Martin (REV 1)**

5. The Lake St. Martin Outlet Channel will be closed fully when Lake St. Martin drops below 798 ft **and the outflow from the Dauphin River is equal to or greater than the total inflow into Lake St. Martin from the (REV 1)** during the period from when ice cover has cleared out of the channel in the spring to October 31st. **During channel shutdown consideration will be given to ensuring that the drawdown rate within the Outlet Channel does not compromise channel embankment stability (REV 1).**
6. If the Lake Manitoba Outlet is in operation in November, the Lake St. Martin Outlet Channel should be operated throughout the winter so that the combined flows in the Dauphin River and in the Lake St. Martin Outlet Channel, insofar as practicable, matches the inflow into Lake St. Martin.
7. Notwithstanding the above guidelines, the Lake St. Martin Outlet Channel will be operated during the spring freshet if the Lake Manitoba Outlet Channel has been in operation over the winter and will continue to be operated into the spring, so that the combined flows in the Dauphin River and the Lake St. Martin Outlet Channel, insofar as practicable, matches the inflow into Lake St. Martin.
8. Initial operation of the outlet control structure will not be initiated during the period in which there is solid ice cover in the channel (typically from Dec 1 – April 30th). However, operation **may be considered if severe flooding is forecasted for the following spring (REV 1).**

Appendix B:

Portage Diversion Operation Guidelines Recommended by Provincial Flood Control Infrastructure Review Panel (2015)

Portage Diversion Operation Guidelines Recommended by Provincial Flood Control Infrastructure Review Panel (2015)

Pre-Spring Break-up Operation

1. While there is ice on the Assiniboine River downstream of Portage la Prairie, it is desirable tolimit flows to approximately 5,000 cfs in the river if there is a potential for ice jamming.
2. During the period that there is ice on the reservoir, the water level of the reservoir must not be allowed to exceed 865.0 feet to provide room for releases from breaching of upstream ice jams.
3. If flow forecasts indicate that the Portage Diversion will likely be put into operation, the Diversion should be put into use as soon as practical to flush out snow blockages and in-situ ice.

Spring Run-off Operation

4. During the spring run-off, after the ice has gone from the Assiniboine River downstream of Portage la Prairie:
    a. if the Lake Manitoba level is forecast to peak below 813 feet, maintain a maximum flow in the lower Assiniboine River of 10,000 cfs, reduced as necessary to keep the river level in Winnipeg below 19 feet James Avenue Datum if possible. Even when there is no risk of flooding on Lake Manitoba maintain a target flow of 10,000 cfs in the lower Assiniboine River to minimize the environmental impact of diversion flows on Lake Manitoba.
    b. if the Lake Manitoba level is forecast to peak above 813 feet, and the projected volume of water from the Portage Diversion into Lake Manitoba will be less than 590,000 ac-ft, maintain a flow in the lower Assiniboine River of 12,000 cfs, reduced as necessary to keep the river level in Winnipeg below 20 feet James Avenue Datum.
    c. if the Lake Manitoba level is forecast to peak above 813 feet, and the projected volume of water from the Portage Diversion into Lake Manitoba will be greater than 590,000 ac-ft, increase flows on the Assiniboine River above 12,000 cfs so as to balance impacts between the Lower Assiniboine River and Lake Manitoba, reduced as necessary to keep the river level in Winnipeg below 21 feet James Avenue Datum.

Growing Season Operation

5. On or after May 25th, if Lake Manitoba levels are below 813 feet the lower Assiniboine flow may be limited to 10,000 cfs if the forecast indicates that Lake Manitoba will not go above 813 feet or that the projected volume of water from the Portage Diversion (from May 25th on) will be less than 236,000 ac-ft. Otherwise operate the Portage Diversion so as to balance impacts between the lower Assiniboine River and Lake Manitoba.

6. In years that the spring thaw occurs early (ice clear from the Lower Assiniboine River prior to April 15), flows on the Assiniboine River can be limited to 10,000 cfs at an earlier date than May 25th, conditional on guideline 5.

General

7. The conduit of the spillway structure should be closed while there is water going over thebascule gates.

There may be circumstances in which adhering to the guidelines is determined to be impractical or unbeneficial. In such circumstances the Province shall provide a timely explanation for deviating from the guidelines.

Appendix C:

Simulated Hydrographs for Lake Manitoba and Lake St. Martin

Appendix 6K Lake Manitoba And Lake St. Martin Outlet Channels Impacts On Lake Manitoba And Lake St. Martin (Manitoba Infrastructure 2019b)

DATE: 2019-06-14

TO: Christine Baljko
Environmental Coordinator
Manitoba Infrastructure
280 Broadway

FROM: Chris Propp
Hydrologic Services Engineer
Manitoba Infrastructure
280 Broadway

SUBJECT: Lake Manitoba and Lake St. Martin Outlet Channels Impacts on Lake Manitoba and Lake St. Martin

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This technical memorandum summarizes the hydrologic analysis and modelling conducted by the Hydrologic Operations Section to evaluate the impact of the proposed Lake Manitoba and Lake St. Martin Outlet Channels on Lake Manitoba and Lake St. Martin.

BACKGROUND

Lake Manitoba and Lake St. Martin Regulation

Lake Manitoba is currently regulated by the Fairford River Water Control Structure. The structure, completed in 1961, was built to reduce flooding on Lake Manitoba by allowing additional water to flow down the Fairford River and to maintain lake levels during periods of low inflow by reducing outflow into the Fairford River. In the past 20 years, two Committees (one for each lake) have been formed to develop recommendations for an operating regime that would balance the impacts of the structure to Lake Manitoba and downstream Lake St. Martin.

Construction of new Outlet Channels is proposed for Lake Manitoba and Lake St. Martin to enhance flood protection on both lakes. Operating guidelines for the channels and Fairford River Water Control Structure are included below. Background information on how these guidelines were developed and the rationale for each guideline can be found in an internal memo written by Chris Propp for Eugene Kozera entitled “Development of Operating Rules for Lake Manitoba and Lake St. Martin Outlet Channels with Recommended Revisions” (February 7, 2019).

Fairford River Water Control Structure Operating Guidelines

The current operating guidelines are based on the recommendations of the 2003 Lake Manitoba Regulation Review Advisory Committee and the 2013 Lake Manitoba, Lake St. Martin Regulation Review Committee. The guidelines allow for a more natural fluctuation of lake levels when the lake is within the desire regulation range.

1. The desired operating range on Lake Manitoba is 812.5 fasl to 810.5 fasl. The desired operating range on Lake St. Martin is 797.0 fasl to 800.0 fasl.

2. During recovery from flood conditions on Lake Manitoba, the Fairford Control Structure is kept wide open until Lake Manitoba recedes to the middle of the range after which is should be cut back [*meaning partially closed using stop log adjustment*s] to a normal outflow setting (50-60% capacity).

3. During recovery from drought, the Fairford Control Structure is kept at 800 cfs until Lake Manitoba levels increase to middle of the desired operating range after which point the structure will be operated to achieve normal outflow (50-60% capacity).

4. Under normal operating conditions, once outflow reaches normal (50-60% capacity), there are no further stop-log adjustments, as long as Lake Manitoba remains within the range.

5. Any variances in the lake levels outside of the range shall be shared between Lake Manitoba and Lake St. Martin insofar as this may be reasonably possible.

6. The minimum flow on the Fairford River should be 800 cfs with a desirable flow of 1,000 cfs as often as possible.

Proposed Lake Manitoba Outlet Channel Operating Guidelines

The proposed Lake Manitoba Outlet Channel Operating Guidelines were developed to compliment the operating guidelines for the Fairford River Water Control Structure allowing for natural fluctuation of lake levels when Lake Manitoba and Lake St. Martin are within desired regulation range, i.e. the proposed Lake Manitoba Outlet Channel is not to be operated when Lake Manitoba water levels are, or are forecast to be, within the desirable range.

1. The Lake Manitoba Outlet Channel will be opened to maximum capacity when Lake Manitoba is above the top of the regulation range (812.5 ft),

2. The Lake Manitoba Outlet Channel may be opened pro-actively (when the water level is below 812.5 ft) if the water level on Lake Manitoba is forecasted to be above 813 ft in the same season.

3. The outflow from the Lake Manitoba Outlet Channel will be reduced when the water level on Lake Manitoba recedes to the middle of the regulation range (811.5 ft), so that the combined outflow from the Fairford River Water Control Structure and the Lake Manitoba Outlet Channel, insofar as possible, matches the inflow into Lake Manitoba.

4. The Lake Manitoba Outlet Channel will be closed once the Lake Manitoba water level recedes below 811.5 ft and the outflow from the Fairford River Water Control Structure is greater than the total inflow into Lake Manitoba. During Outlet Channel shutdown, consideration will be given to ensuring that the drawdown rate within the Outlet Channel does not compromise channel embankment stability.

5. Initial operation of the outlet control structure will not be initiated during the period in which there is solid ice cover in the channel (typically from Dec 1 – April 30th). However, operation may be considered if severe flooding is forecasted for the following spring.

Proposed Lake St. Martin Outlet Channel Operating Guidelines

1. The target regulation range for Lake St. Martin is 797-800 ft.

2. The Lake St. Martin Outlet Channel will be operated to full capacity:

    a. when the Lake St. Martin water level rises above 800 ft

or,

b. when the Lake Manitoba Outlet is opened for initial operation, Lake St. Martin is above 797 ft, and Lake St. Martin is forecasted to go above 800 ft without operation of the Lake St. Martin Outlet Channel.

Consideration may be given to opening the Lake St. Martin Outlet Channel to less than full capacity if Lake St. Martin is only forecasted to go slightly above 800 ft.

3. The outflow from the Lake St. Martin Outlet Channel will be reduced when the lake level decreases below 800 ft, to the greater of the following:

   a. 25% of channel capacity,

   b. the outflow required to ensure total outflow from the Dauphin River and the Lake St. Martin Outlet Channel matches the total inflow into Lake St. Martin at the time of the Outlet Channel gate setting adjustment.

4. The outflow from the Lake St. Martin Outlet Channel will be further reduced when the water level on Lake St. Martin recedes below 798 ft, so that the outflow from the Dauphin River and the Lake St. Martin Outlet Channel, insofar as possible, matches the inflow into Lake St. Martin.

5. The Lake St. Martin Outlet Channel will be closed fully when Lake St. Martin drops below 798 ft and the outflow from the Dauphin River is equal to or greater than the total inflow into Lake St. Martin from the period when ice cover has cleared out of the channel in the spring to October 31st (under open water conditions). During channel shutdown consideration will be given to ensuring that the drawdown rate within the Outlet Channel does not compromise channel embankment stability.

6. If the Lake Manitoba Outlet is in operation in November, the Lake St. Martin Outlet Channel should be operated throughout the winter so that the outflow from the Dauphin River and the Lake St. Martin Outlet Channel, insofar as possible, matches the inflow into Lake St. Martin.

7. Notwithstanding the above guidelines, the Lake St. Martin Outlet Channel will be operated during the spring freshet if the Lake Manitoba Outlet Channel has been in operation over the winter will continue to be operated into the spring, so that the outflow from the Dauphin River and the Lake St. Martin Outlet Channel, insofar as possible, matches the inflow into Lake St. Martin.

8. Initial operation of the outlet control structure will not be initiated during the period in which there is solid ice cover in the channel (typically from Dec 1 – April 30th). An exception to this guideline may be considered if severe flooding is forecasted for the following spring.

HYDROLOGIC MODELLING

Manitoba Infrastructure's Hydrologic Operations group uses two water balance models to evaluate the impact of water control structure operations on the Lake Manitoba to Lake Winnipeg drainage system. Water balance models use inflow, precipitation, evaporation data, and stage storage curves to calculate changes in lake level, and rating curves to determine lake outflow, based on the following equations:

$$Q_{in} + Precip - Evap - Q_{out} = \Delta_{storage}$$

$$\Delta_{storage} \xrightarrow{Stage\ Storage\ Curve} \Delta_{lake\ level}$$

$$Lake\ Level \xrightarrow{Discharge\ Rating\ Curve} Q_{out}{}'$$

Where:
Q = Water Flow
$Precip$ = Precipitation (including both rain and snow)
$Evap$ = Evaporation
Δ = Change
Stage Storage Curve = The relationship between lake level and lake volume
Discharge Rating Curve = The relationship between lake level and lake outflow rate

Not all inflow sources into a lake are gauged. However, the total inflow available as outflow (IAO) can be calculated based on the gauged outflows and observed historical stage data collected by Environment and Climate Change Canada (ECCC) for the lake.

Water Balance Models

The Lake Manitoba Water Balance model is used to evaluate the impacts of water control structure on Lake Manitoba and Lake St. Martin. This tool incorporates the operation of the Fairford River Water Control Structure and the proposed Lake Manitoba and Lake St. Martin outlet channels to simulate water levels and outflows on Lake Manitoba and Lake St. Martin under various operational strategies, using the data and relationships described above.

Data

1. IAO data for the model was produced back to 1915. This was done using a combination of recorded data and reconstructed data based on established relationships.

2. Precipitation amounts for the model were based on numerical averages of rain and snow gauge information around the lake.

3. Snow water equivalent was assumed to be 10% of measured snow depths and was applied to the lake surface directly.

4. Historical evaporation data was produced by the Prairie Farm Rehabilitation Association (PFRA).

5. Historical flow and water level data was available from Environment and Climate Change Canada for the following water bodies:

    a. Lake Manitoba 1914 - present
    b. Lake St. Martin 1966 - present

c. Fairford River 1912 – 1920, 1955 - present
d. Dauphin River 1977 – present
e. Portage Diversion 1970 - present
f. Assiniboine River 1913 – present

6. The 1914 data for Lake Manitoba was not used because it was only captured for part of the year.

7. Fairford River outflows for 1921 – 1954 were reconstructed using a the Lake Manitoba/Fairford River stage-discharge relationship based on available data prior to the construction of the Fairford River Water Control Structure.

8. Lake St. Martin levels prior to 1966 and Dauphin River flows prior to 1977 were estimated by routing Fairford River flows through Lake St. Martin, using the established stage-discharge relationship for Dauphin River and the stage-surface area relationship for Lake St. Martin.

9. Portage Diversion flows were estimated prior to 1970 (prior to construction) to develop consistent operating regime scenarios. The flows were estimated by applying the Portage Diversion operating guidelines in years prior to construction based on published Assiniboine River flows, City of Winnipeg river levels, and Lake Manitoba water levels

10. The surface area of Lake Manitoba and Lake St. Martin as a function of water level was based on LiDAR data and historic bathymetric data.

Lake Manitoba / Lake St. Martin Model Calibration

The model was calibrated to a 10-year period from 2006-2015. This period was selected because the operating regime utilized during this period most closely follows the operating guidelines currently utilized for the operation of the Fairford River Water Control structure. The results of the calibration are shown in the figure below.

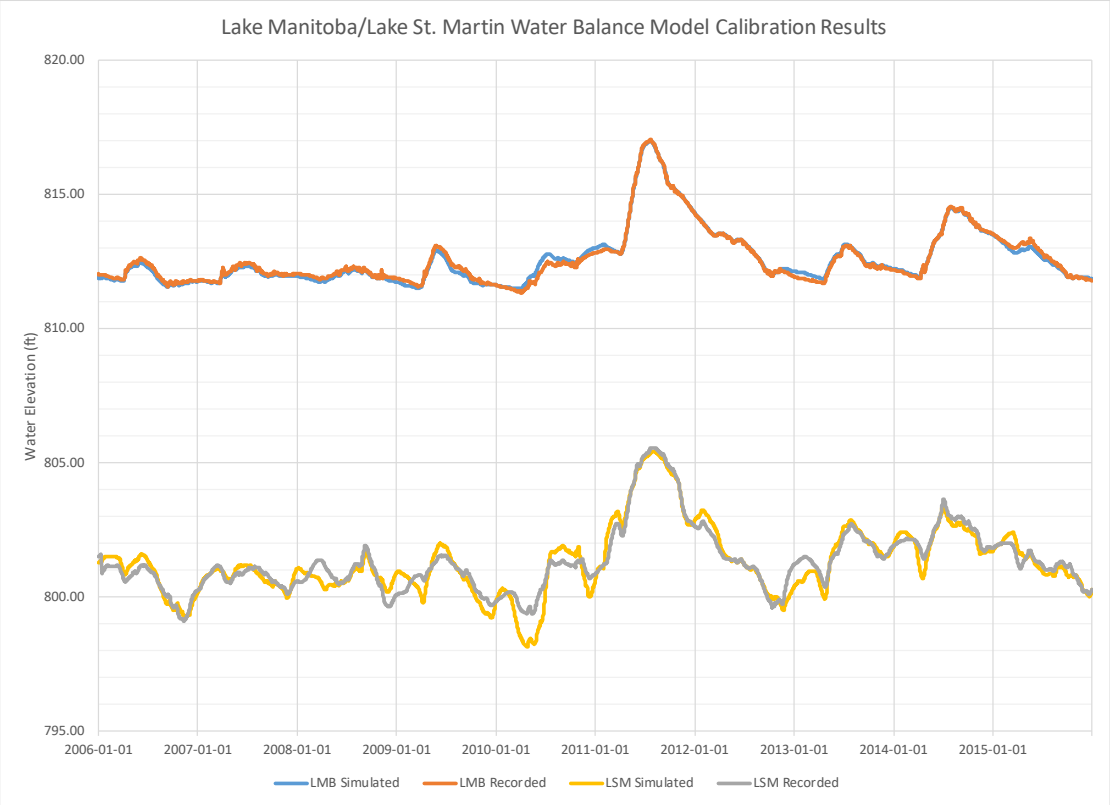


Figure 1: Lake Manitoba/Lake St. Martin Calibration Results

As can be seen in the chart above, the simulated results for Lake Manitoba are in very close agreement with the recorded water levels. The simulated Lake St. Martin water levels deviate more from the recorded values but appear to match the annual peak water levels well. Since Lake St. Martin is a much smaller lake, small differences in flow rates have a more noticeable effect on the lake level. In years where a larger difference between recorded peaks and simulated peaks is observed, the model tends to predict higher peaks and hence more conservative values. This is desirable where flooding is the primary concern.

Potential Sources of Error in Model

1. Adherence to operating guidelines - The model strictly adheres to the operating guidelines of the Fairford River Water Control Structure through use of logic statements whereas in reality operation of the structure may deviate from the guidelines for a period of time due to extenuating circumstances, such as delay in operation to accommodate maintenance or construction activities, or reducing the flow rate through the Fairford River Water Control Structure to manage frazil ice on the Dauphin River.

2. Rating curves – Two sets of rating curves (water level – discharged relationships) are used within the model: open water rating curves and winter rating curves. These relationships are relatively rigid within the model, however in reality there is a degree of natural fluctuation from the rating curves that is not captured by the model. During winter the relationship between water level and discharge changes over time due to ice formation and ice erosion.

3. Stage storage curves – Stage storage curves were developed using the best available topographical and bathymetric data. In some areas, there is a gap between the bathymetry and the topographical data that has to be interpolated. The elevation data also represents a snapshot in time whereas the lake bed and shoreline changes over time.

4. Hydrometric data – Published flow data is not 100% accurate and there is an approximate 5% margin of error on flow measurements.

5. Meteorological data – Evapotranspiration data is calculated using an algorithm rather than directly measured.

Simulation Scenarios

The Lake Manitoba Water Balance model was run to produce lake levels and outflows for over 100 years using inflow and precipitation data for over 100 years from 1915-present. The model was run under two scenarios: “Current Operation” and “Future Operation”. The Current Operation scenario assumes that the Fairford River Water Control Structure is operated under the current operating guidelines for the entire period of record (1915-2017) and omits the operation of the Lake St. Martin Emergency Outlet Channel entirely. The Future Operation scenario assumes that Lake Manitoba and Lake St. Martin have been regulated with the proposed outlet channels according to the proposed operating guidelines for the entire period of record and omits any operation of the Lake St. Martin Emergency Outlet Channel.

Results

Lake level hydrographs have been included in Appendix A to demonstrate the impact of the new outlets’ operation on Lake Manitoba and Lake St. Martin. Specific years of interest have their own plots for clarity; these include the plots for 1954-1955, 2001-2003, and 2010-2012. In 1954-1955, the Lake Manitoba recorded level was above its operating range for an extended period. In 2001, operation of the outlets drops Lake Manitoba below its desired range. The 2011 flood is the flood event of record. The hydrographs show Lake Manitoba and Lake St. Martin levels over time for both simulations and the simulated flow through the Lake St. Martin Outlet Channel. It should be noted that all water levels given are static water levels and do not incorporate wind and wave effects. A typical windstorm event can cause water Lake Manitoba level increases in the range 2.0 ft to 2.5 ft and Lake St. Martin level increases in the range of 1.0 ft to 2.5 ft depending on shoreline location, wind direction, and wind speed.

Operation of the new flood outlets will have an effect on the range of water levels on the lakes. Based on the model results, operation of the new outlets will dramatically decrease the peak water levels in high flood years, and reduce peak levels in almost all years, increasing the amount of time the lake is within its desired operating range. Table 1 below summarizes the model results. See Appendix B for a table of statistics for all years.

Table 1: Average Decrease in Peak Water Levels with Operation of Outlet Channels

Flood Level on Lake Manitoba	LMB Average Decrease	LSM Average Decrease
Non Flood (LMB < 812.5fasl)	-0.08 ft	-0.26 ft
Minor Flood (812.5 fasl < LMB < 813.5 fasl)	-0.28 ft	-1.59 ft
Major Flood (LMB > 813.5 fasl)	-1.27 ft	-2.45 ft

There is also a decrease in minimum water level on the lakes. The decrease primarily effects high water years, where this is a desirable outcome, but it also effects low water years. This is because any additional volume conveyed by the Outlets during a flood event is lost to Lake Winnipeg, and cannot be returned to the system in future low water years. Table 2 summarizes the model results.

Table 2: Average Decrease in Minimum Lake Levels with Outlet Channels

Water Level Regime	Lake Manitoba		Lake St. Martin	
	Level Range	Avg Decrease	Level Range	Avg Decrease
Low Water	< 810.5 fasl	-0.08 ft	< 797 fasl	-0.02 ft
Average	> 810.5 fasl < 812.5 fasl	-0.17 ft	> 797 fasl < 800 fasl	-0.11 ft
High Water	> 812.5 fasl	-0.48 ft	> 800 fasl	-0.85 ft

Duration curves were produced to show the percentage of time that the lakes are below given water levels under the current operating regime and proposed operating regime (see Appendix C). Under the current operating conditions, Lake Manitoba is below the top of its desired operating range 91.6% of the time. With the new outlets it is below the top of its desired operating range 97.2% of the time. There is also a 1.4% increase in the amount of time the lake is below its range. Table 3 summarizes the duration curve results for Lake Manitoba.

Under the current operating conditions, Lake St. Martin is within its desired operating range 50.5% of the time. With the new outlets, it is within its desired operating range 68.4% of the time. This represents a dramatic improvement in flood protection. However, there is an increase in the amount of time the lake is below its range. Under the current regime, Lake St. Martin is below its desired range 25.1% of the time. With the proposed Outlet Channels, this increases by 1.3%. Table 4 summarizes the duration curve results for Lake St. Martin

Table 3: Lake Manitoba Duration Curve Summary

Lake Manitoba Level (fasl)	% of Time Lake is Below Indicated Level		
	Without New Outlets	With New Outlets	Change
815	99.6%	99.9%	0.3%
812.5	91.6%	97.2%	5.6%
810.5	16.7%	18.1%	1.4%
810	7.7%	8.9%	1.2%

Table 4: Lake St. Martin Duration Curve Summary

Lake St. Martin Level (fasl)	% of Time Lake is Below Indicated Level		
	Without New Outlets	With New Outlets	Change
803	97.6%	99.9%	2.3%
800	75.6%	94.8%	19.2%
797	25.1%	26.4%	1.3%
796	3.8%	3.8%	0.0%

The Outlet Channels are operated in 34% of the years simulated (35 years out of 103 years).

DISCUSSION

Impacts to Lake Manitoba

Operation of the new flood outlets will have an effect on the range of water levels on Lake Manitoba. In High Flood years the peak Lake Manitoba is significantly reduced as demonstrated on the 1954-1955 and 2010-2012 detailed hydrographs. In 1955 the peak level is reduced by 1.0 ft, and in 2011 the peak level is reduced by 1.5 ft (see Appendix A). Operation with the new outlets also lowers the minimum water level in Lake Manitoba which, in some years, may drive the level below the lower end of the desired operating range sooner that would otherwise have gone. An example of this is the operation in 2001, which causes the lake level below the lower end of the desired operating range in the fall of 2002. Operation in 2001 affects the timing and magnitude of the lower level, but does not change the fact that the lake would have gone out of range in the following years. Based on the model results, operation of the new outlets will significantly decrease the peak water levels in high flood years, and reduce peak levels in almost all years, increasing the amount of time the lake is within its desired operating range.

There are some years (1956, 1974, and 1996) where operation of the Lake Manitoba creates higher peaks in the subsequent years; these hydrographs have been provided for reference. Operations in these years lower the Lake Manitoba level below 811.5 ft, triggering discharge at the Fairford River Water Control Structure to be reduced to 60% of full capacity. Without the new outlets, the Lake Manitoba level would have stayed above 811.5 ft, and flow at Fairford would have been 100% of full capacity. The reduced capacity in these three years would have allowed Lake Manitoba levels to creep up over the winter, and resulted in higher peaks in the following years. This phenomenon is observed in only 3% of simulation years.

Positive impacts of the proposed Lake Manitoba outlet channel include reduction in peak flood levels, reduced flood inundation areas, and an increase in the amount of time that the lake is within the regulated range.

For the 2011 flood event, the calculated decrease in the peak water level on Lake Manitoba is 1.5 ft. This represents a decrease in flooded area of 754.1 km^2. An inundation map of the 2011 conditions has been included in Appendix D for reference.

As highlighted previously, regulation of Lake Manitoba with the new outlet channel will increase the amount of time that the lake is below the top of its desired regulation range (812.5 ft) by 5.6%. This represents an improvement in flood protection around the lake.

The regulation of the lake under the future operation scenario also slightly increases the amount of time that the lake is below the lower end of its desired operating range (810.5 ft) by 1.4%. While this is not a large amount, it is still an undesirable effect.

Impacts to Lake St Martin

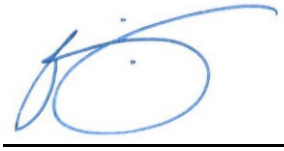
Positive impacts of the proposed Lake St. Martin outlet channel operation include reduction in peak flood levels, reduced flood inundation areas, and a substantial increase in the amount of time that the lake is within the regulated range.

For the 2011 flood event (high flood event), the calculated decrease in the peak water level on Lake St. Martin is 2.5 ft (see Appendix A for hydrograph). This represents a decrease in flooded area of 27.5 km^2. For all years in which Lake St. Martin is in flood stage, the average decrease in water level is 1.7 ft. This represents an average decrease in flooded area of 21.4 km^2. In years where neither Lake Manitoba nor Lake St. Martin are in flood stage, there will be no operation of the new outlets. Inundation maps of both conditions have been included in Appendix D for reference.

As noted above, regulation of Lake St. Martin with the new outlet channel will increase the amount of time that the lake is within the desired regulation range (797 fasl – 800 fasl) by 18%. This represents a large improvement in flood protection around the lake.

The regulation of the lake under the future operation scenario will also slightly increase the amount of time that the lake is below 797 fasl by 1.3%. While this is not a large amount, it is still an undesirable effect.

The only year in which the new operating regime caused Lake St. Martin to drop below the desired regulation range (below 797 fasl), where it would not otherwise have, is 1977. A hydrograph for this year is included in Appendix A. With operation of the Outlet Channels in 1976, the large spring operation would have lowered Lake Manitoba to the bottom of its operating range and Lake St. Martin would have remained in the middle of its range. Carrying over to the following year (1977), the runoff event would not have raised the level of Lake Manitoba significantly, and there would not have been enough flow on the Fairford River to maintain the level on Lake St. Martin, which would have dropped below its desired range later that year. Occasional deviations from the desired operating range are considered acceptable under the operating guidelines in place for the Fairford River Water Control structure.



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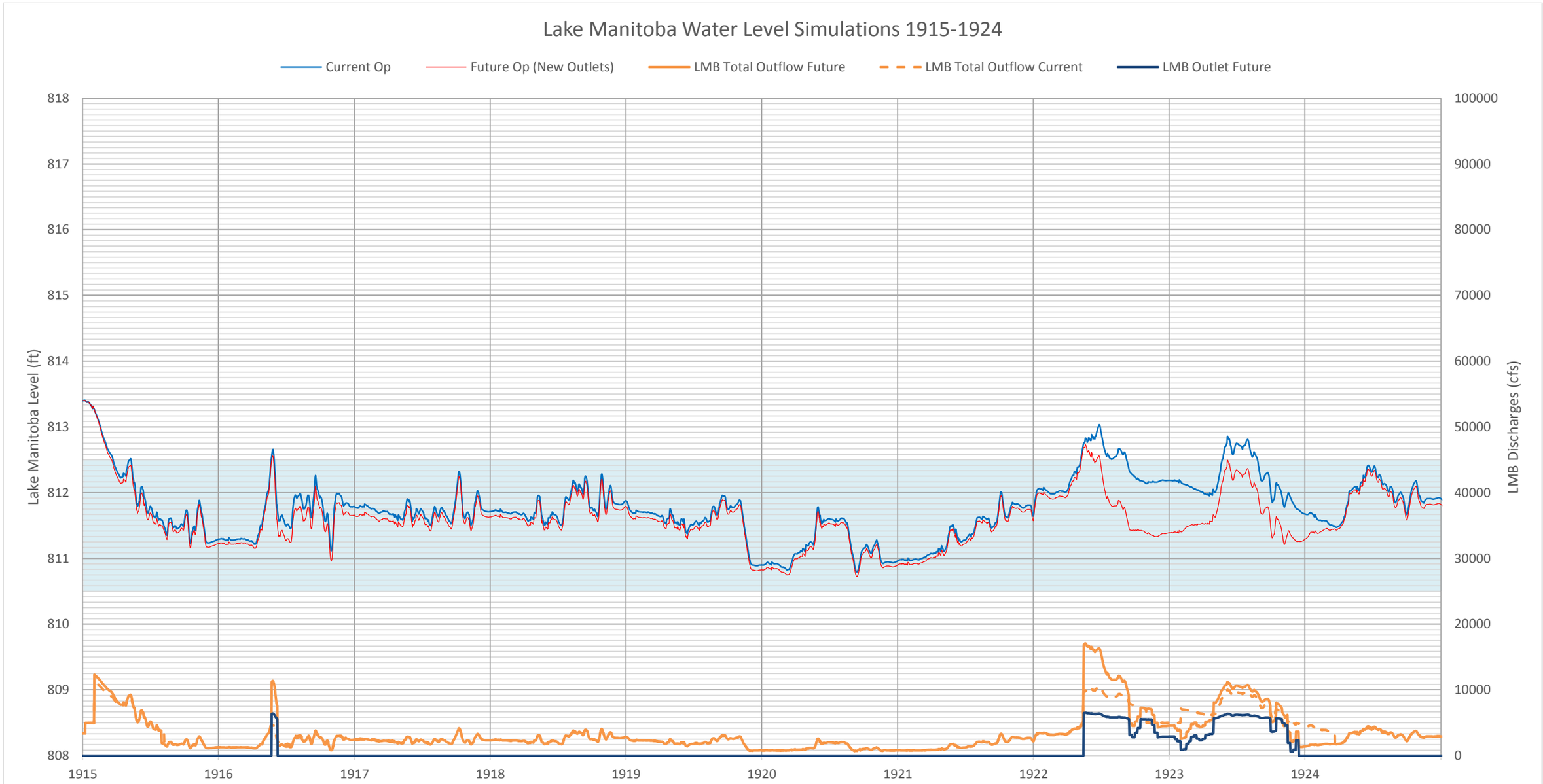
Manitoba
Infrastructure

Appendix A:
Lake Level Hydrographs


Lake Manitoba Water Level Simulations 1915-1924
Current Op
Future Op (New Outlets)
LMB Total Outflow Future
LMB Total Outflow Current
LMB Outlet Future
Lake Manitoba Level (ft)
LMB Discharges (cfs)
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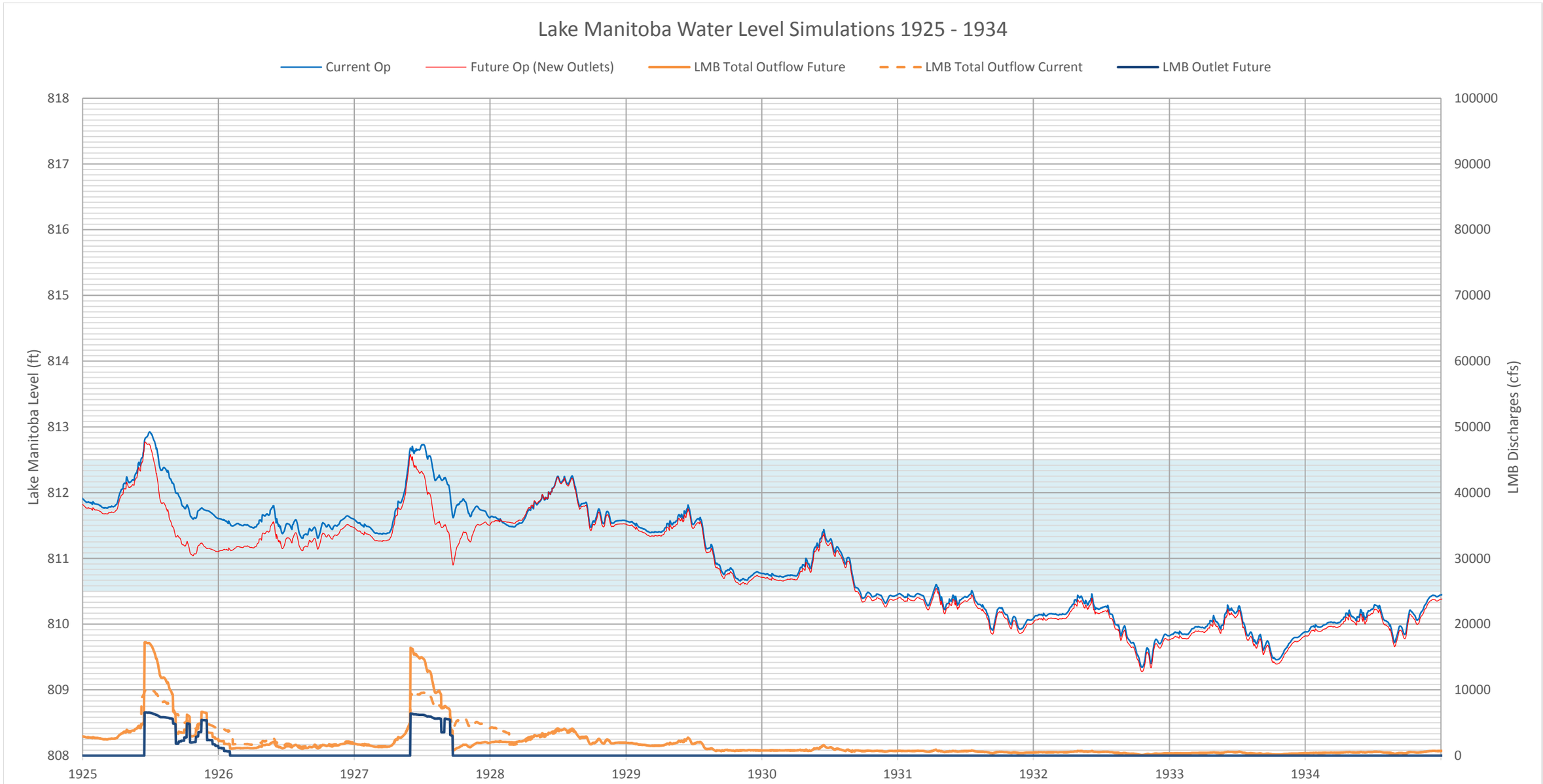
Lake Manitoba Water Level Simulations 1925 - 1934
Current Op
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LMB Total Outflow Current
LMB Outlet Future
Lake Manitoba Level (ft)
LMB Discharges (cfs)
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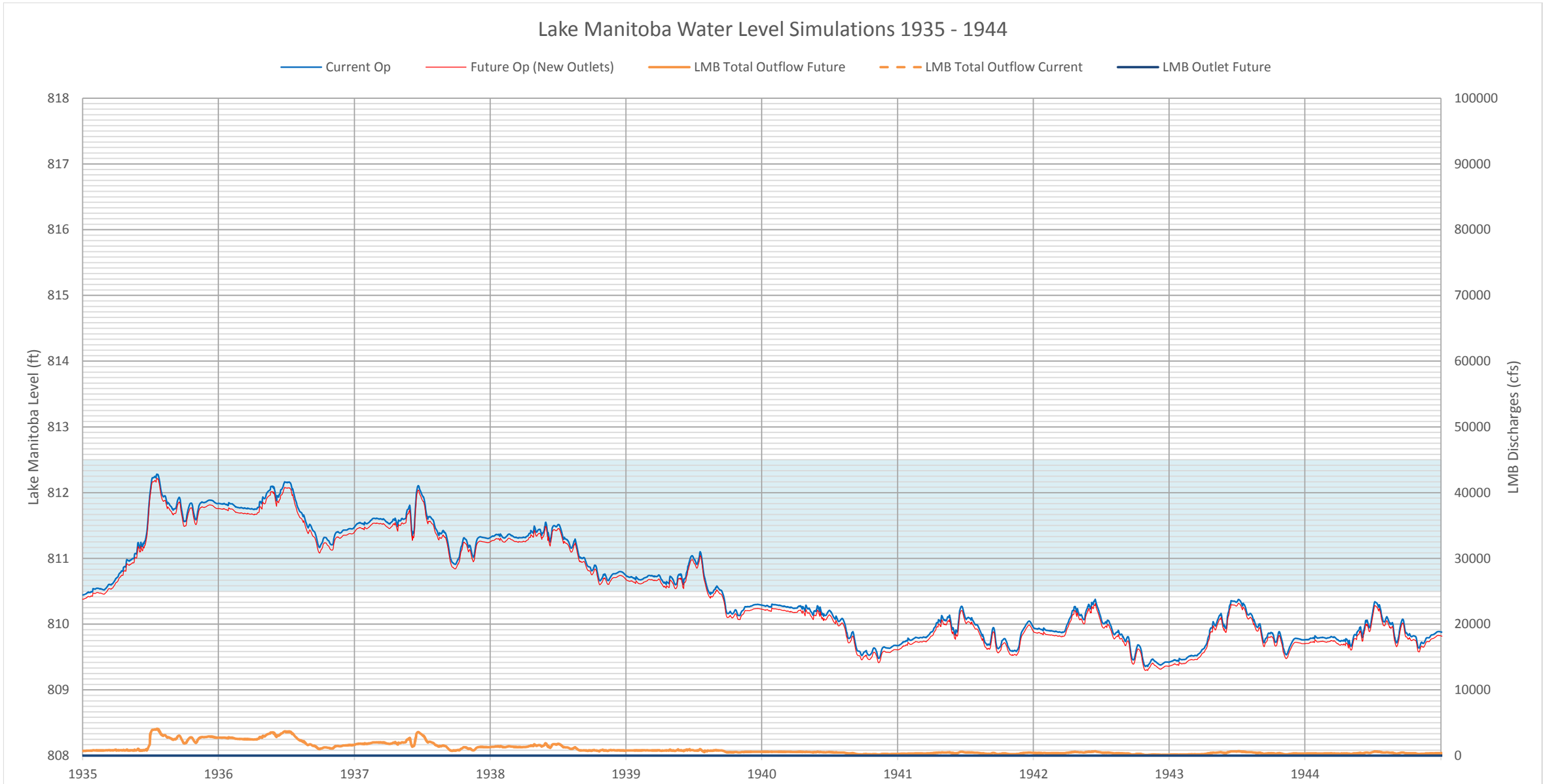
Lake Manitoba Water Level Simulations 1935 - 1944
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Future Op (New Outlets)
LMB Total Outflow Future
LMB Total Outflow Current
LMB Outlet Future
Lake Manitoba Level (ft)
LMB Discharges (cfs)
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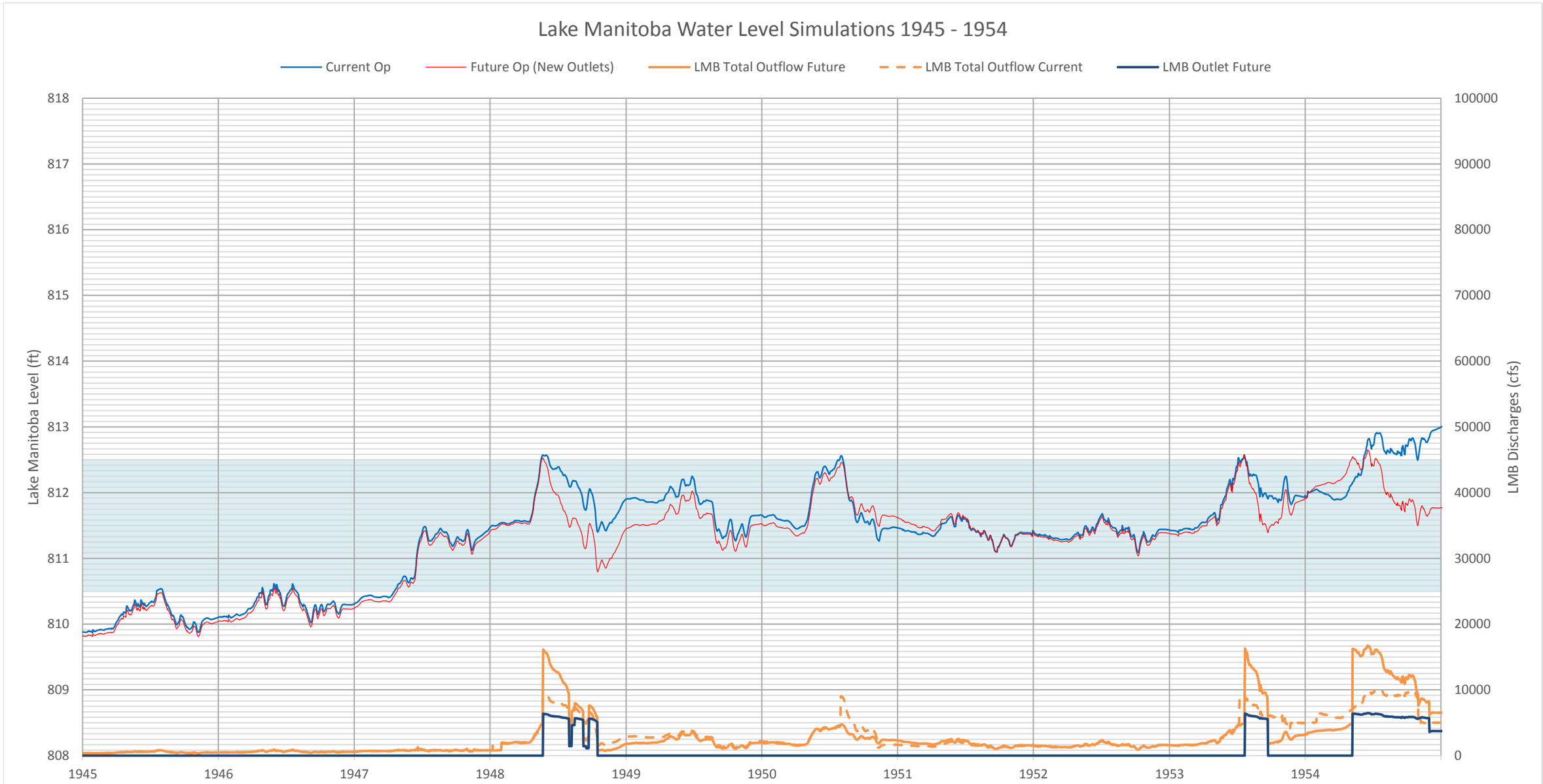
Lake Manitoba Water Level Simulations 1945 - 1954
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Future Op (New Outlets)
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LMB Total Outflow Current
LMB Outlet Future
Lake Manitoba Level (ft)
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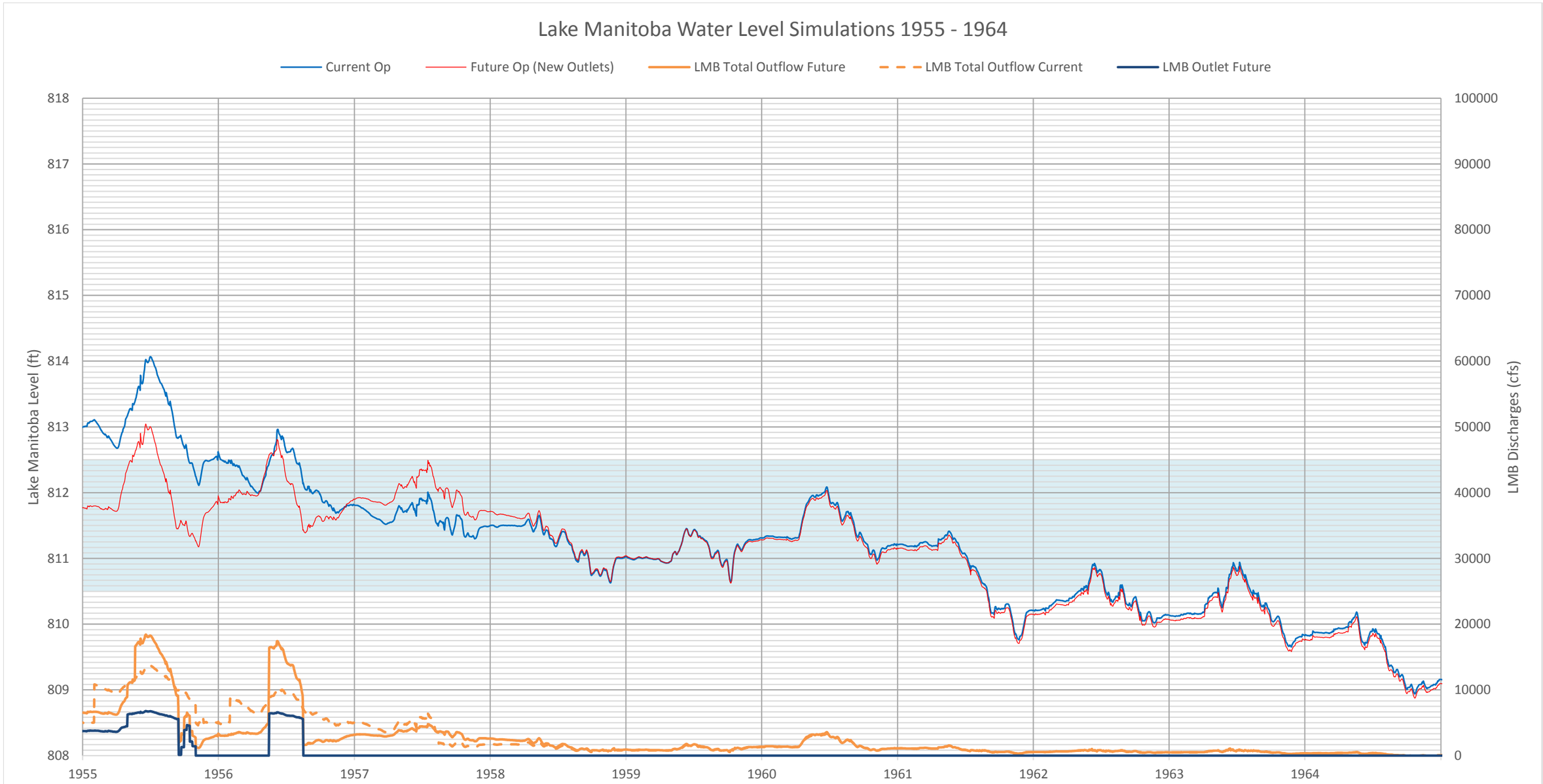
Lake Manitoba Water Level Simulations 1955 - 1964
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Future Op (New Outlets)
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LMB Total Outflow Current
LMB Outlet Future
Lake Manitoba Level (ft)
LMB Discharges (cfs)
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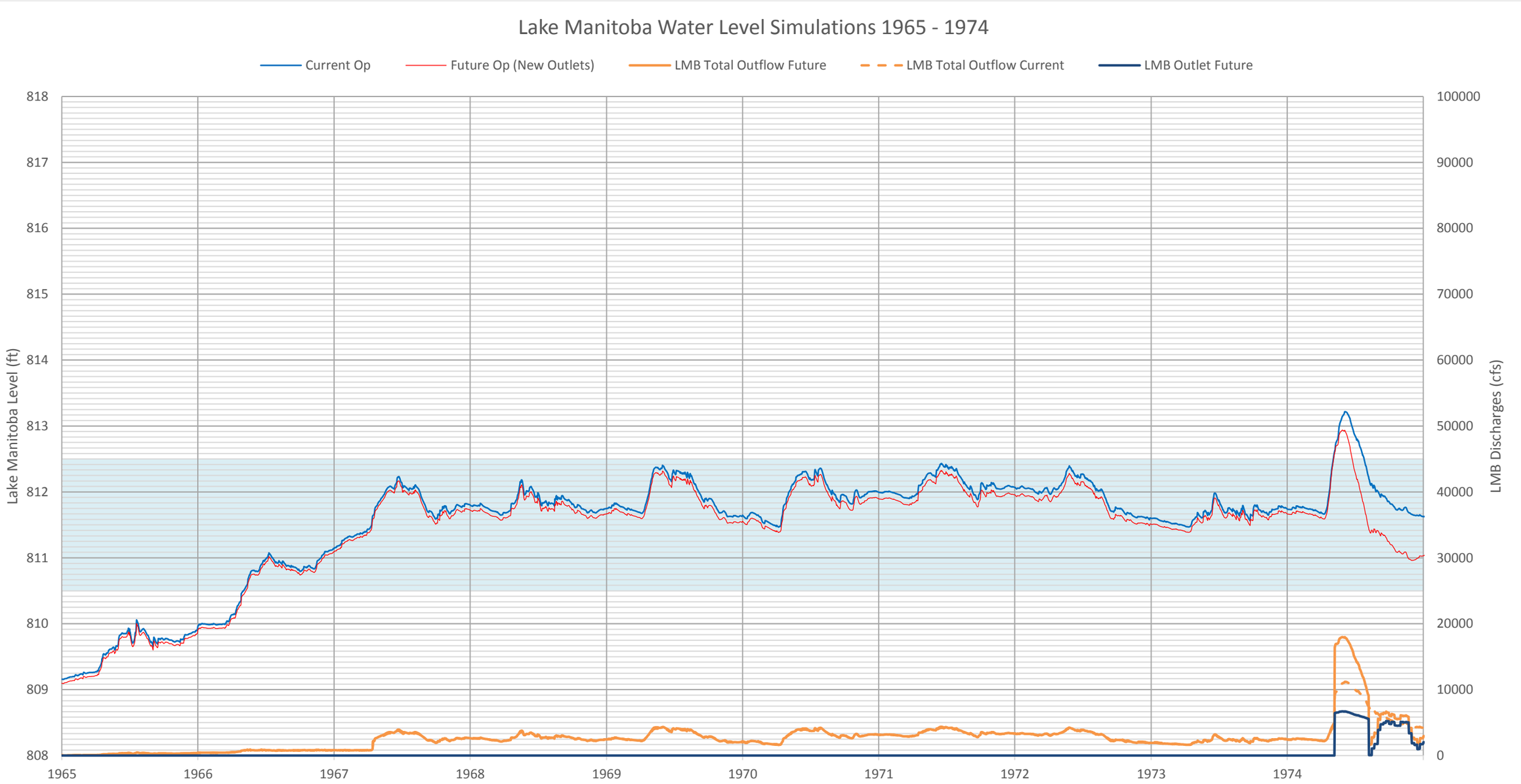
Lake Manitoba Water Level Simulations 1965 - 1974
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LMB Total Outflow Future
LMB Total Outflow Current
LMB Outlet Future
Lake Manitoba Level (ft)
LMB Discharges (cfs)
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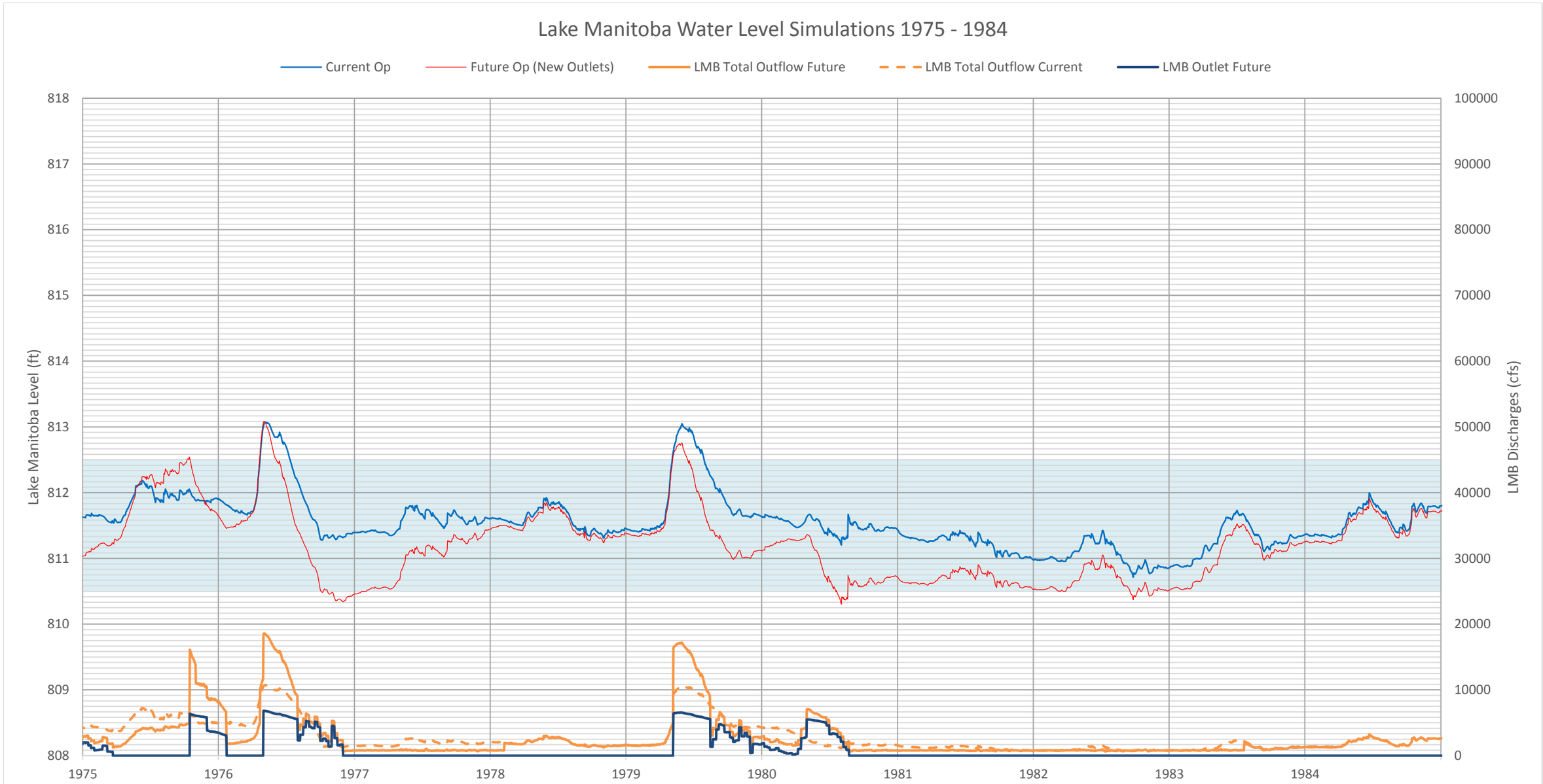
Lake Manitoba Water Level Simulations 1975 - 1984
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Future Op (New Outlets)
LMB Total Outflow Future
LMB Total Outflow Current
LMB Outlet Future
Lake Manitoba Level (ft)
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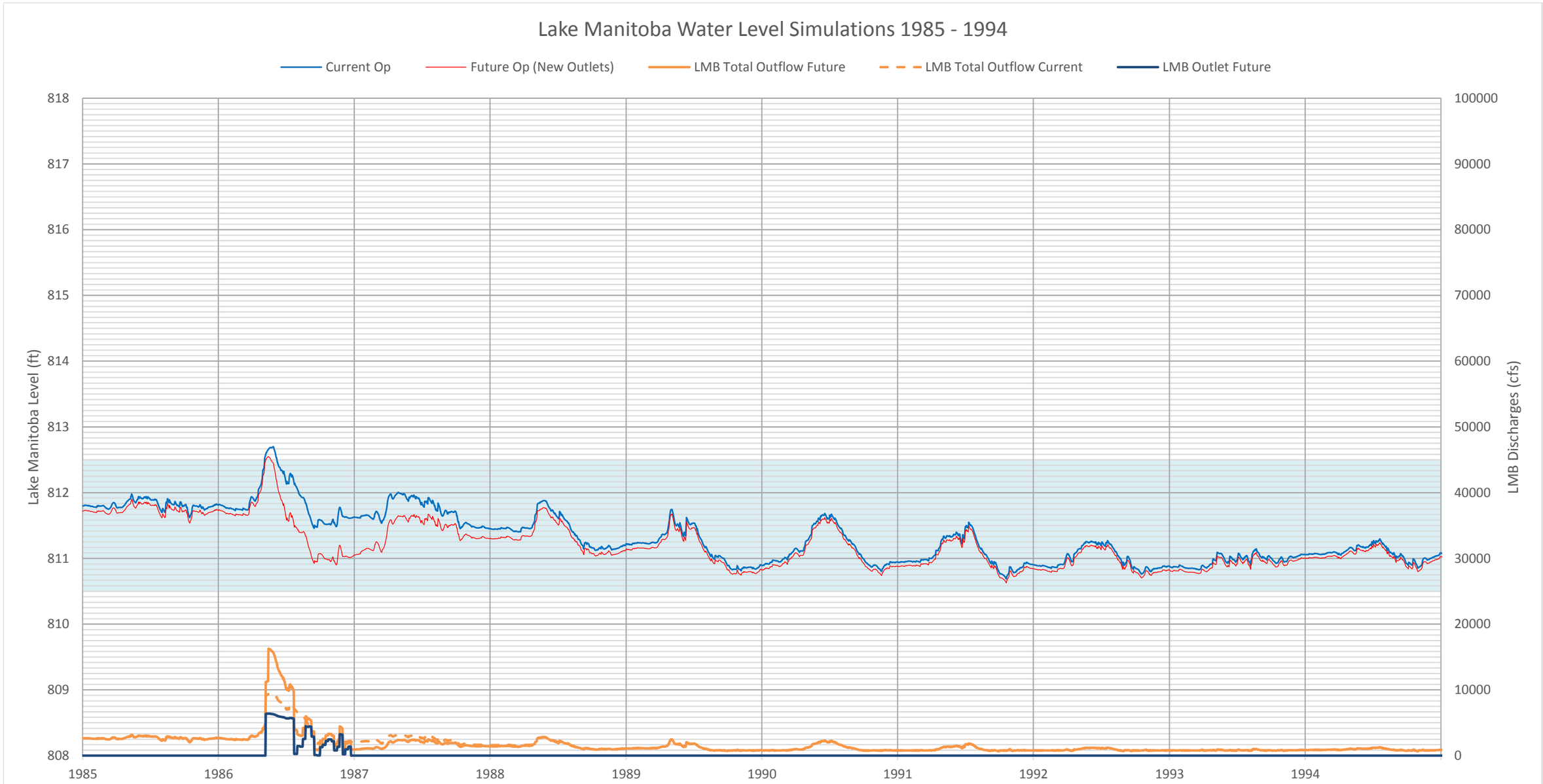
Lake Manitoba Water Level Simulations 1985 - 1994
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Future Op (New Outlets)
LMB Total Outflow Future
LMB Total Outflow Current
LMB Outlet Future
Lake Manitoba Level (ft)
LMB Discharges (cfs)
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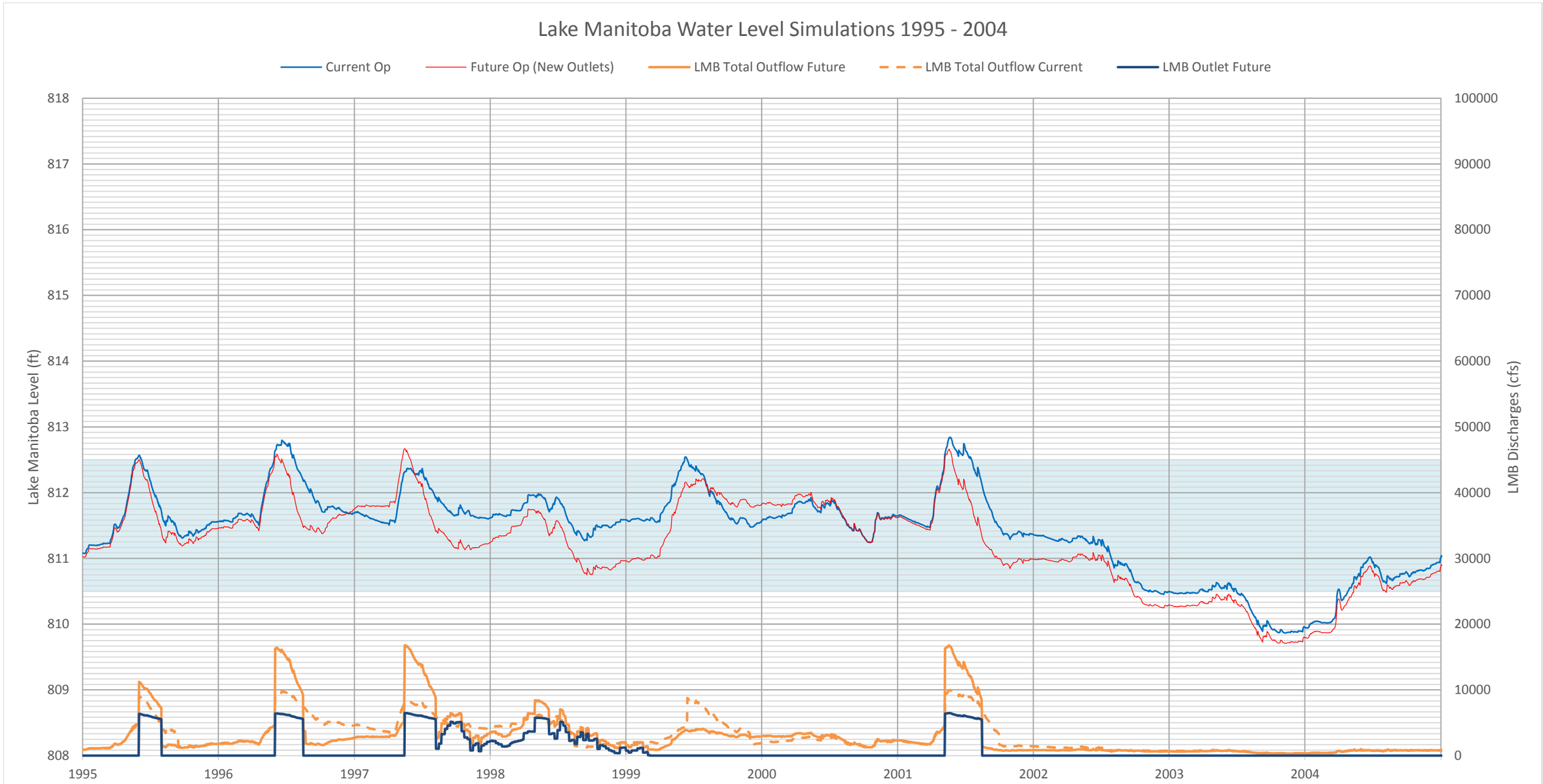
Lake Manitoba Water Level Simulations 1995 - 2004
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Future Op (New Outlets)
LMB Total Outflow Future
LMB Total Outflow Current
LMB Outlet Future
Lake Manitoba Level (ft)
LMB Discharges (cfs)
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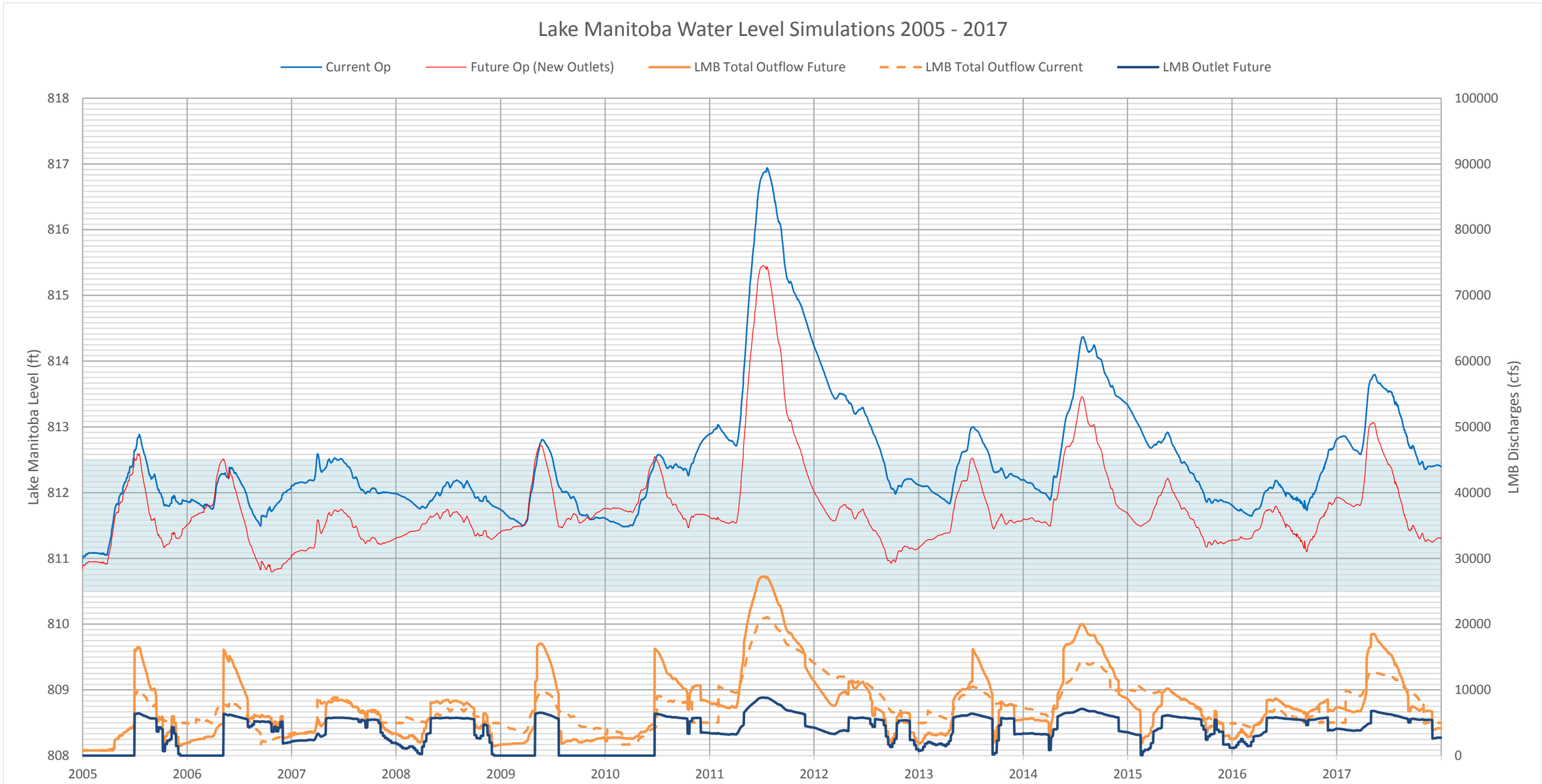
Lake Manitoba Water Level Simulations 2005 - 2017
Current Op
Future Op (New Outlets)
LMB Total Outflow Future
LMB Total Outflow Current
LMB Outlet Future
Lake Manitoba Level (ft)
LMB Discharges (cfs)
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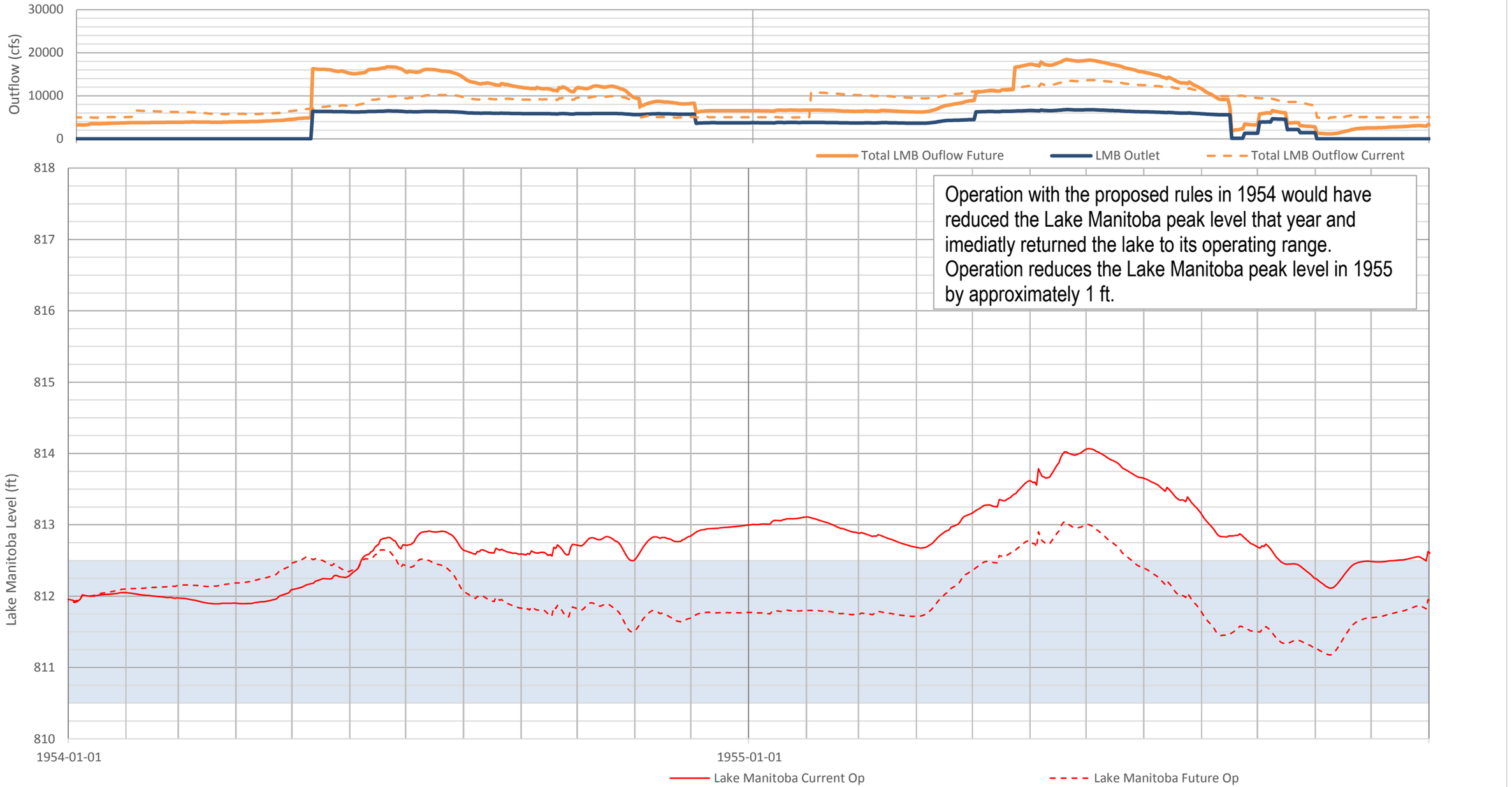
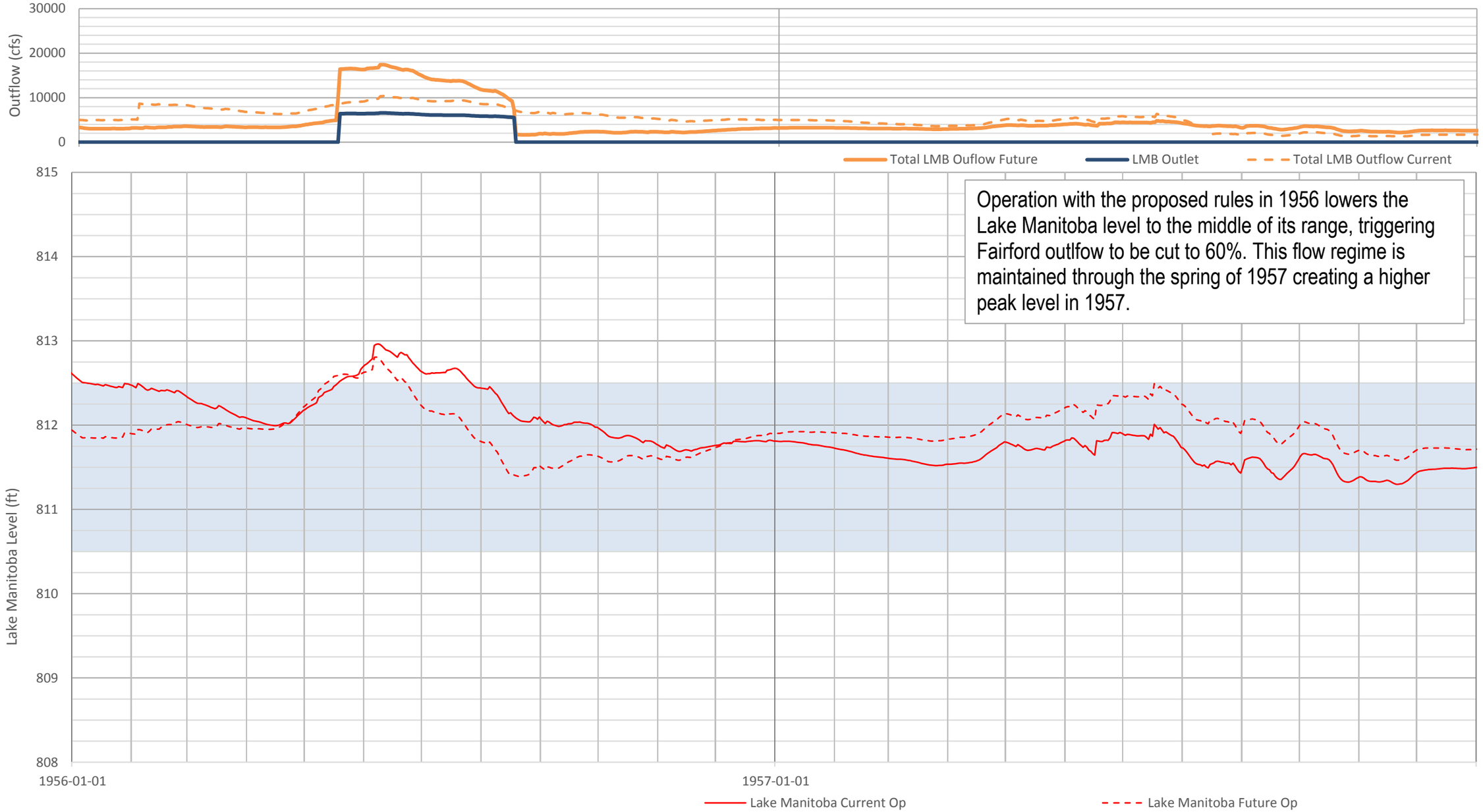
1954 - 1955 Lake Manitoba Water Level Simulations



1956 - 1957Lake Manitoba Water Level Simulations



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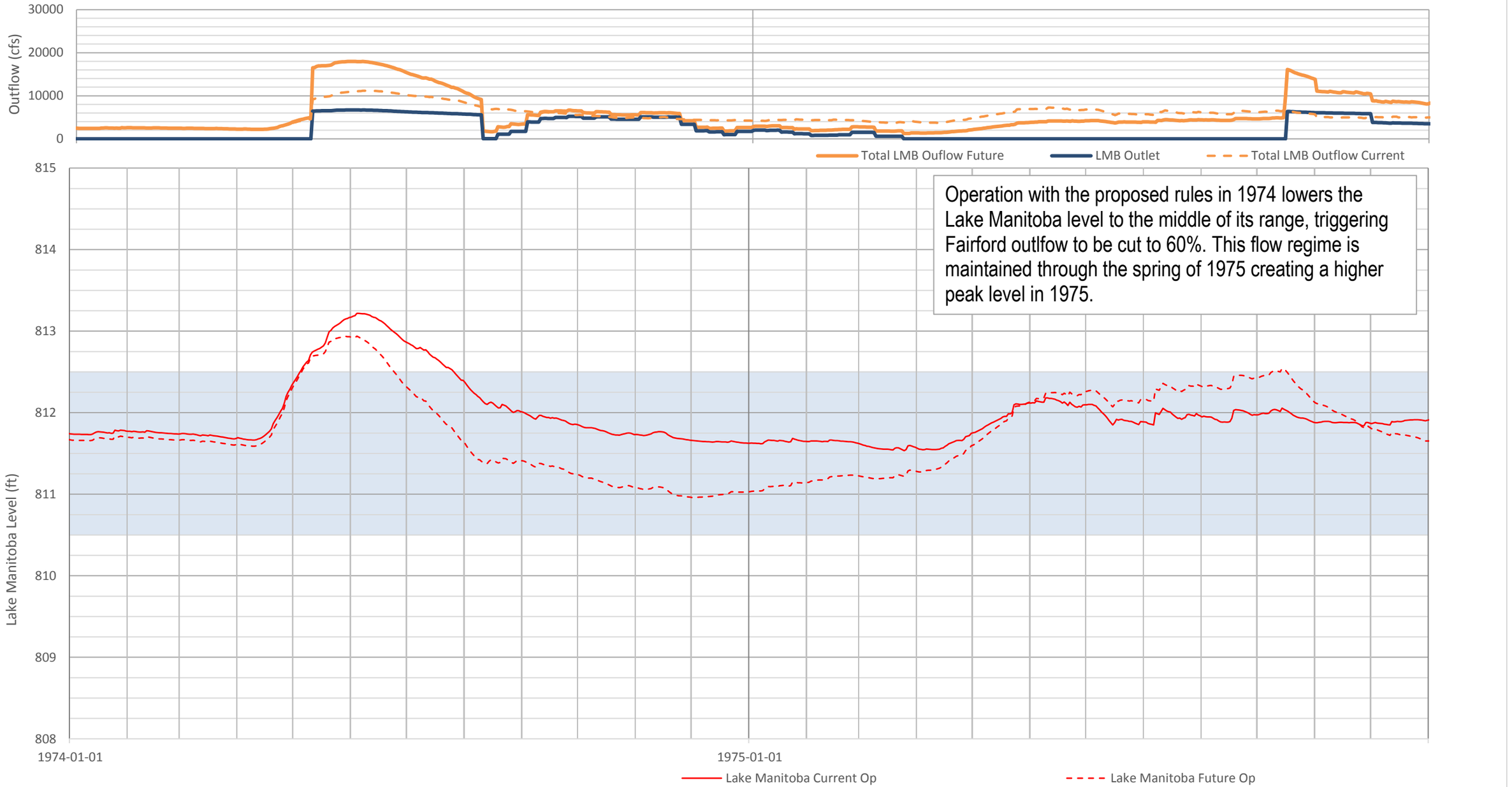
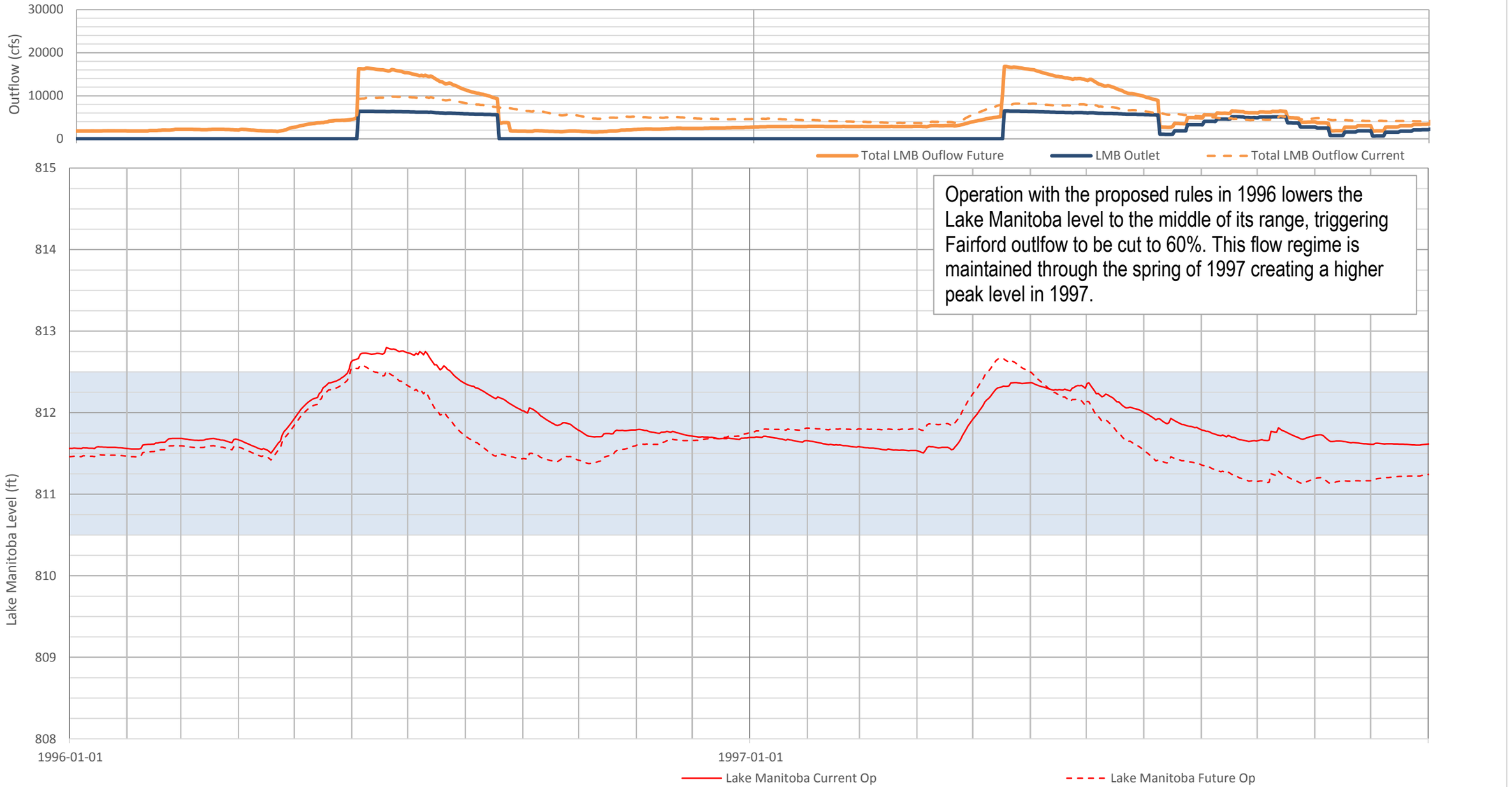
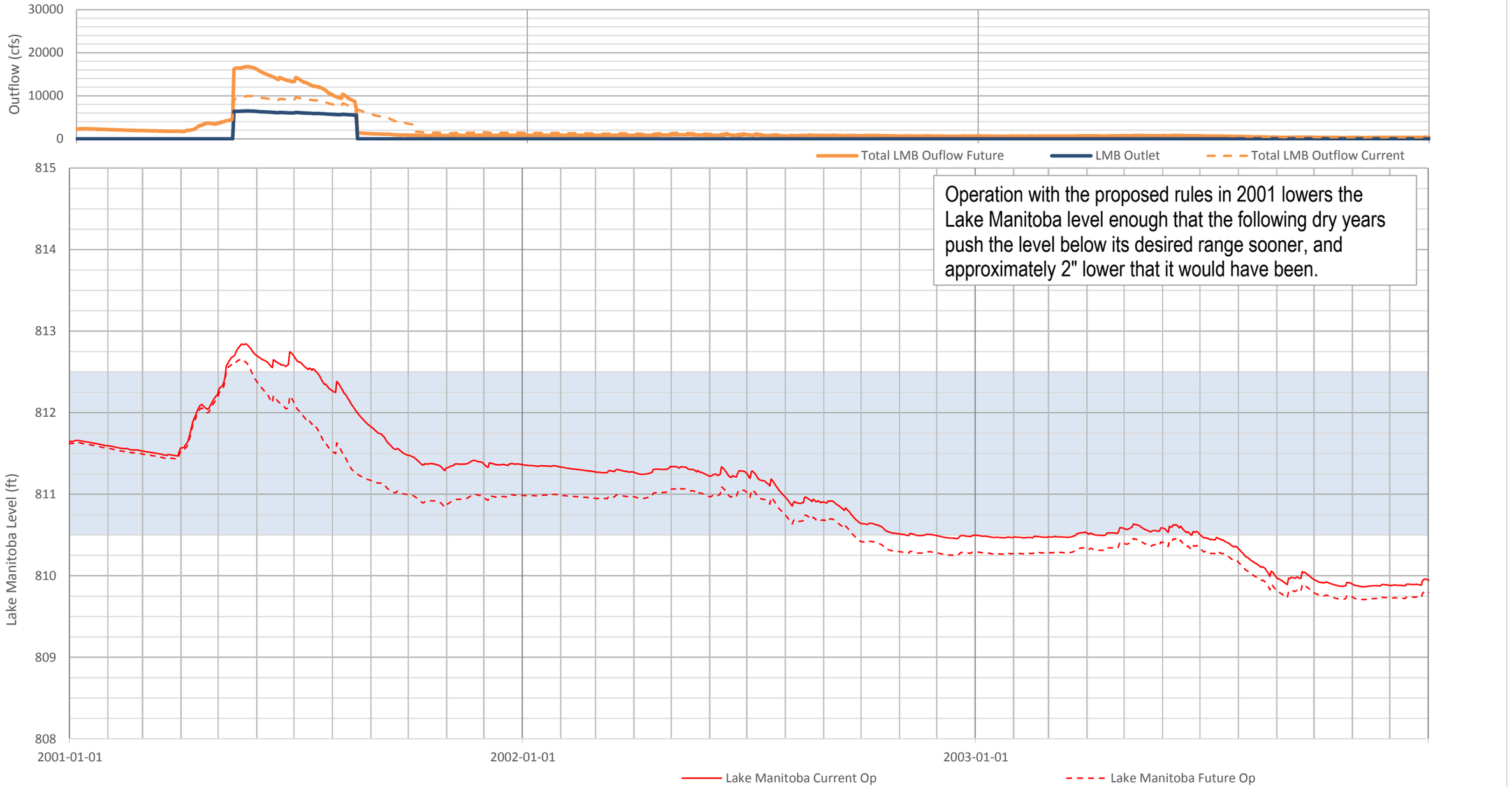


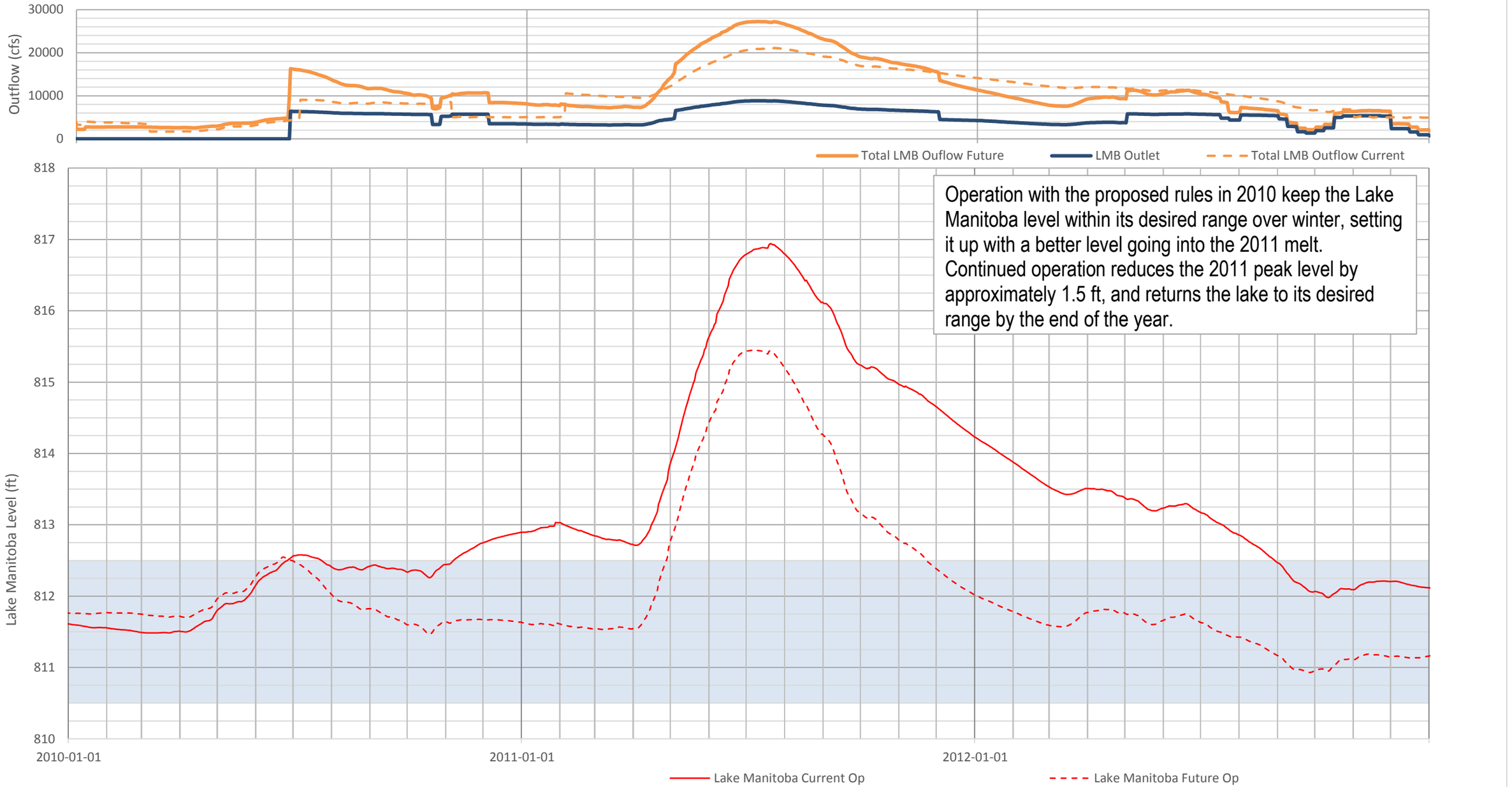
1996 - 1997 Lake Manitoba Water Level Simulations

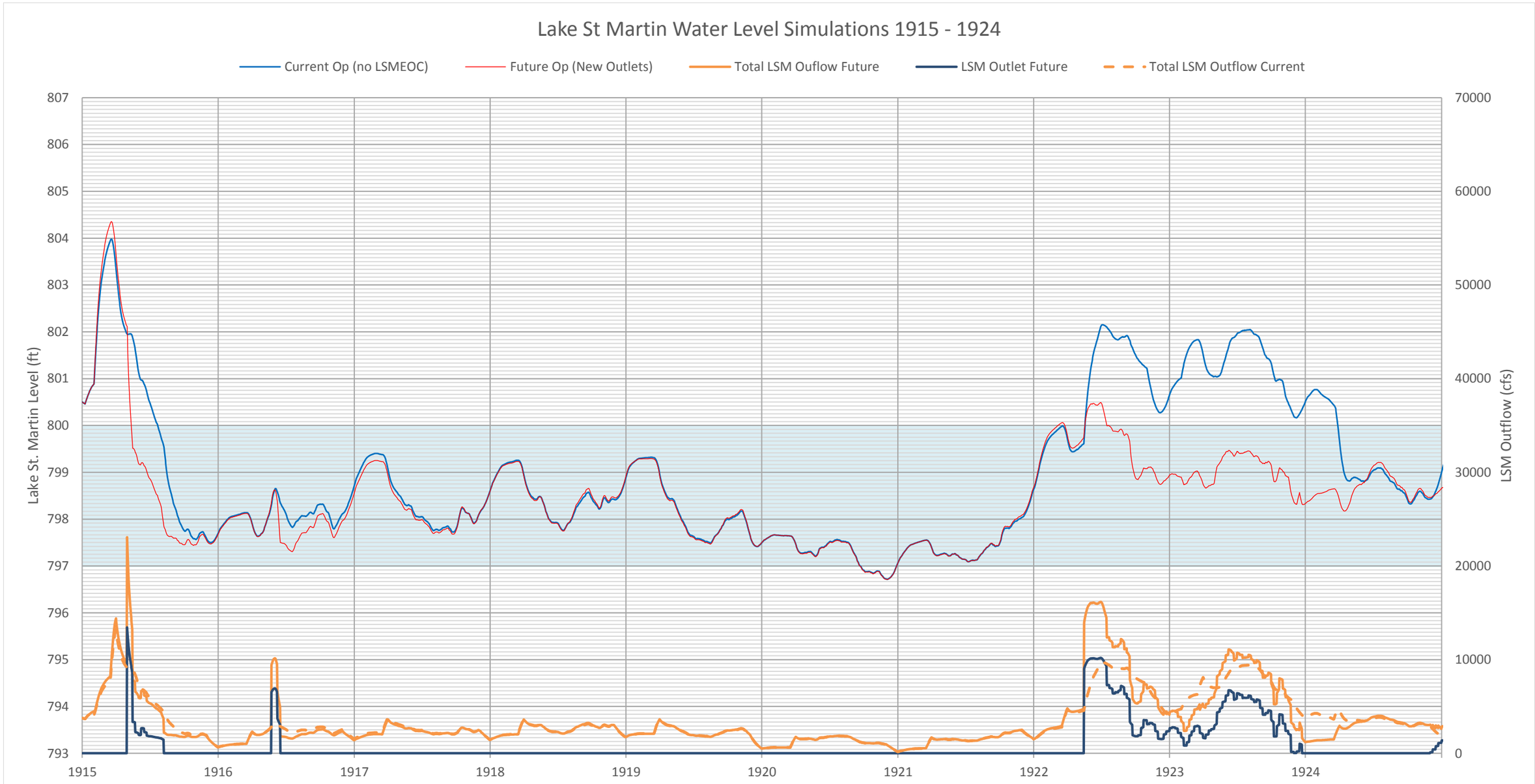


2001 - 2003 Lake Manitoba Water Level Simulations



2010 - 2012 Lake Manitoba Water Level Simulations




Lake St Martin Water Level Simulations 1915 - 1924
Current Op (no LSMEOC)
Future Op (New Outlets)
Total LSM Ouflow Future
LSM Outlet Future
Total LSM Outflow Current
Lake St. Martin Level (ft)
LSM Outflow (cfs)
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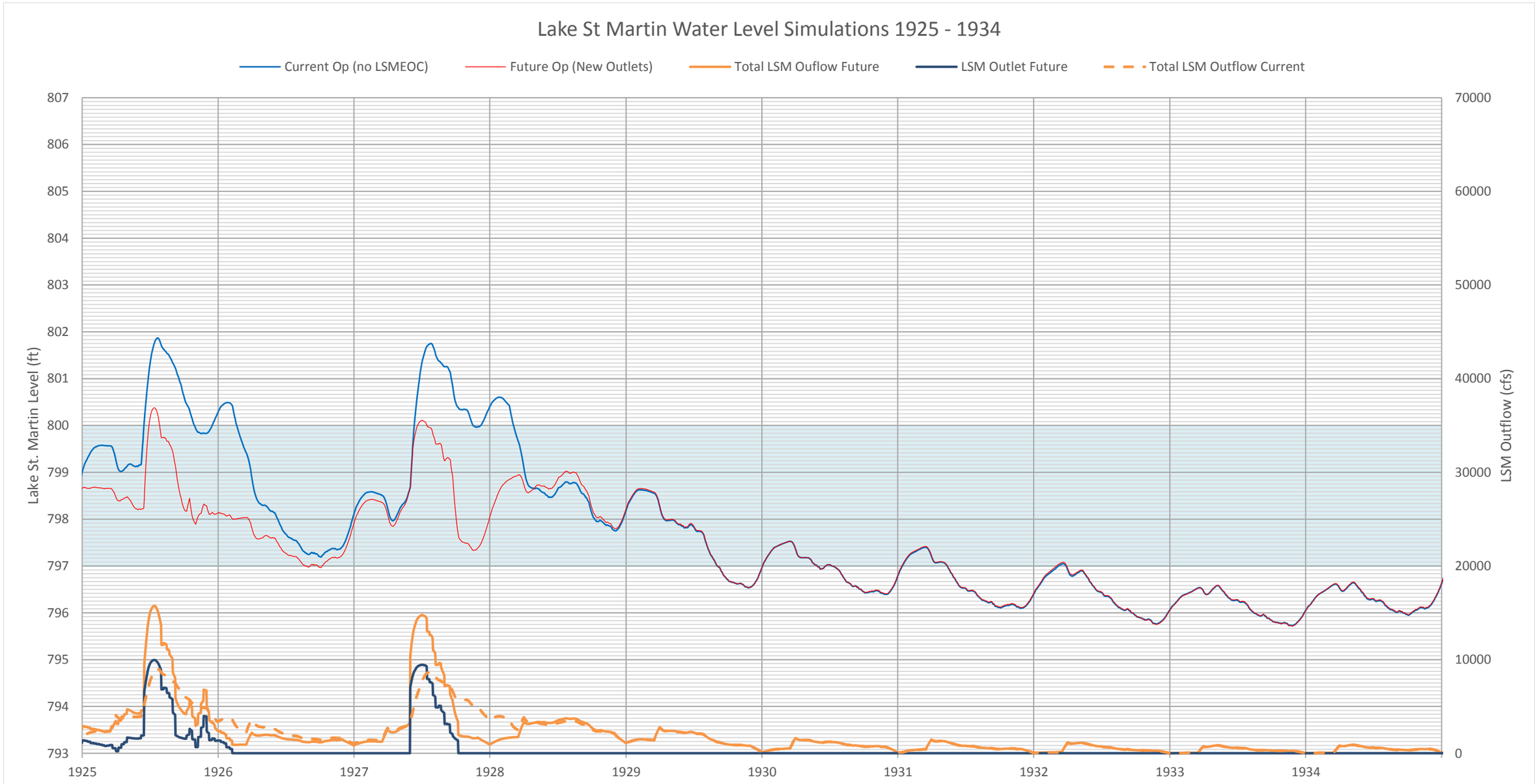
Lake St Martin Water Level Simulations 1925 - 1934
Current Op (no LSMEOC)
Future Op (New Outlets)
Total LSM Ouflow Future
LSM Outlet Future
Total LSM Outflow Current
Lake St. Martin Level (ft)
LSM Outflow (cfs)
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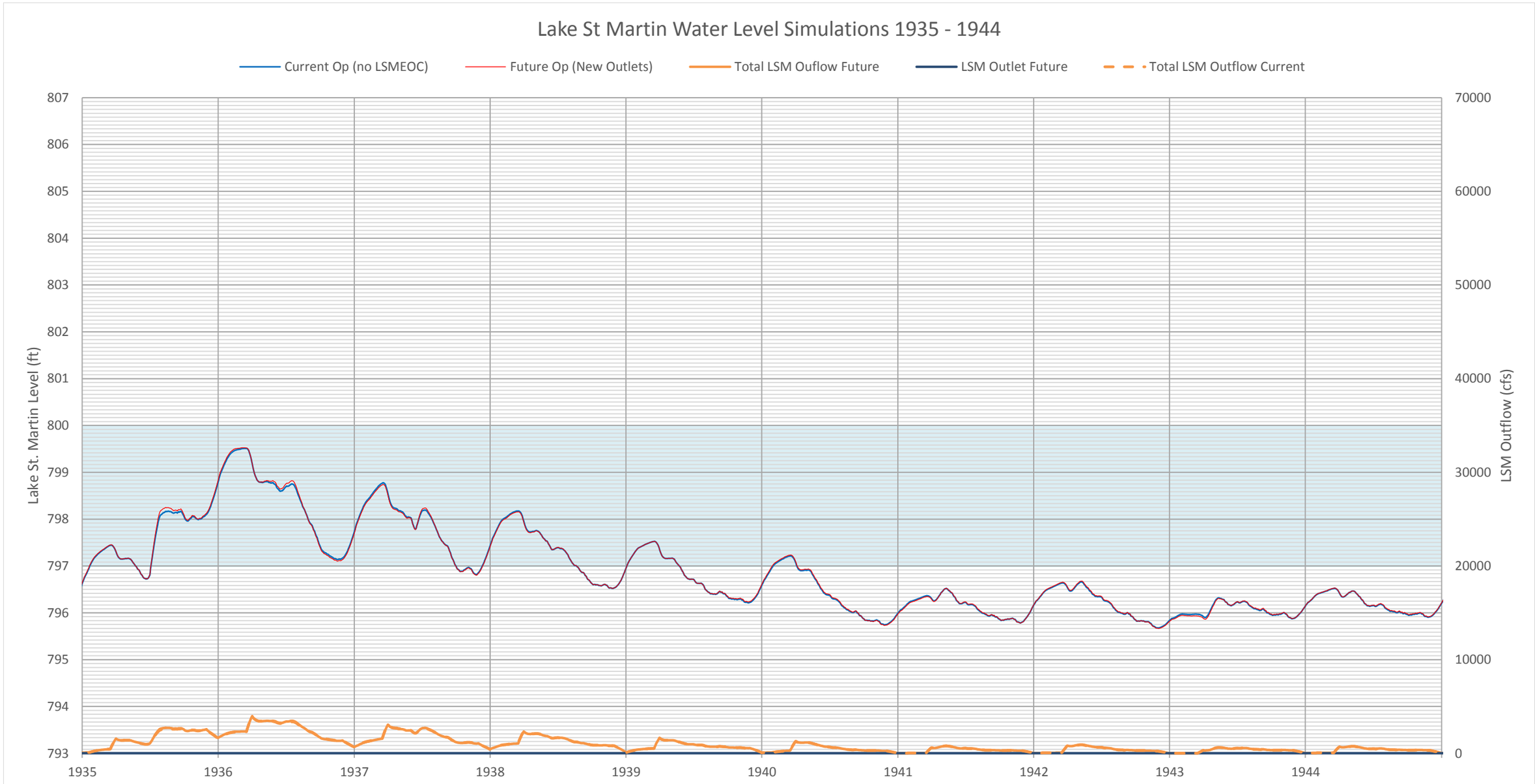
Lake St Martin Water Level Simulations 1935 - 1944
Current Op (no LSMEOC)
Future Op (New Outlets)
Total LSM Ouflow Future
LSM Outlet Future
Total LSM Outflow Current
Lake St. Martin Level (ft)
LSM Outflow (cfs)
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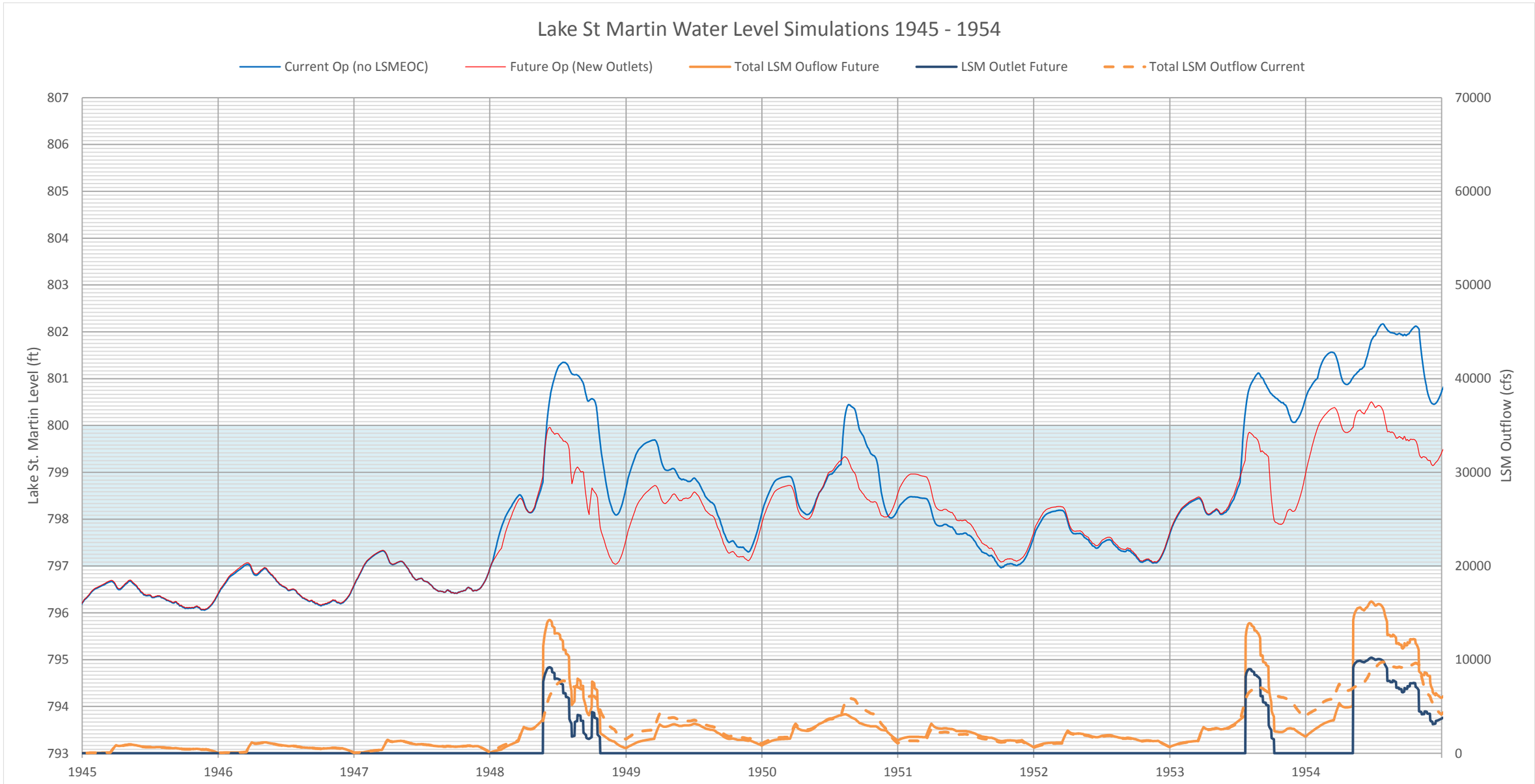
Lake St Martin Water Level Simulations 1945 - 1954
Current Op (no LSMEOC)
Future Op (New Outlets)
Total LSM Ouflow Future
LSM Outlet Future
Total LSM Outflow Current
Lake St. Martin Level (ft)
LSM Outflow (cfs)
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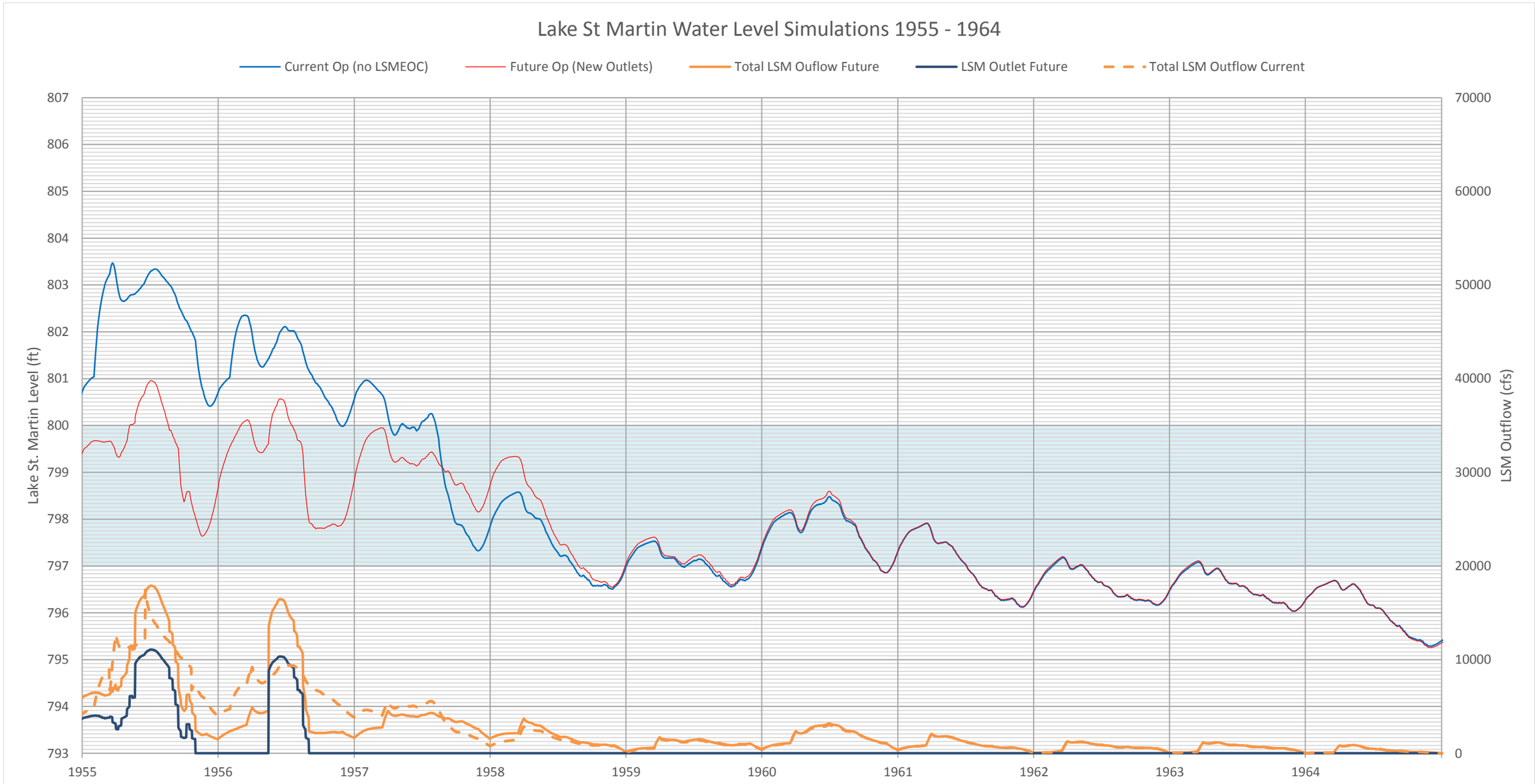
Lake St Martin Water Level Simulations 1955 - 1964
Current Op (no LSMEOC)
Future Op (New Outlets)
Total LSM Ouflow Future
LSM Outlet Future
Total LSM Outflow Current
Lake St. Martin Level (ft)
LSM Outflow (cfs)
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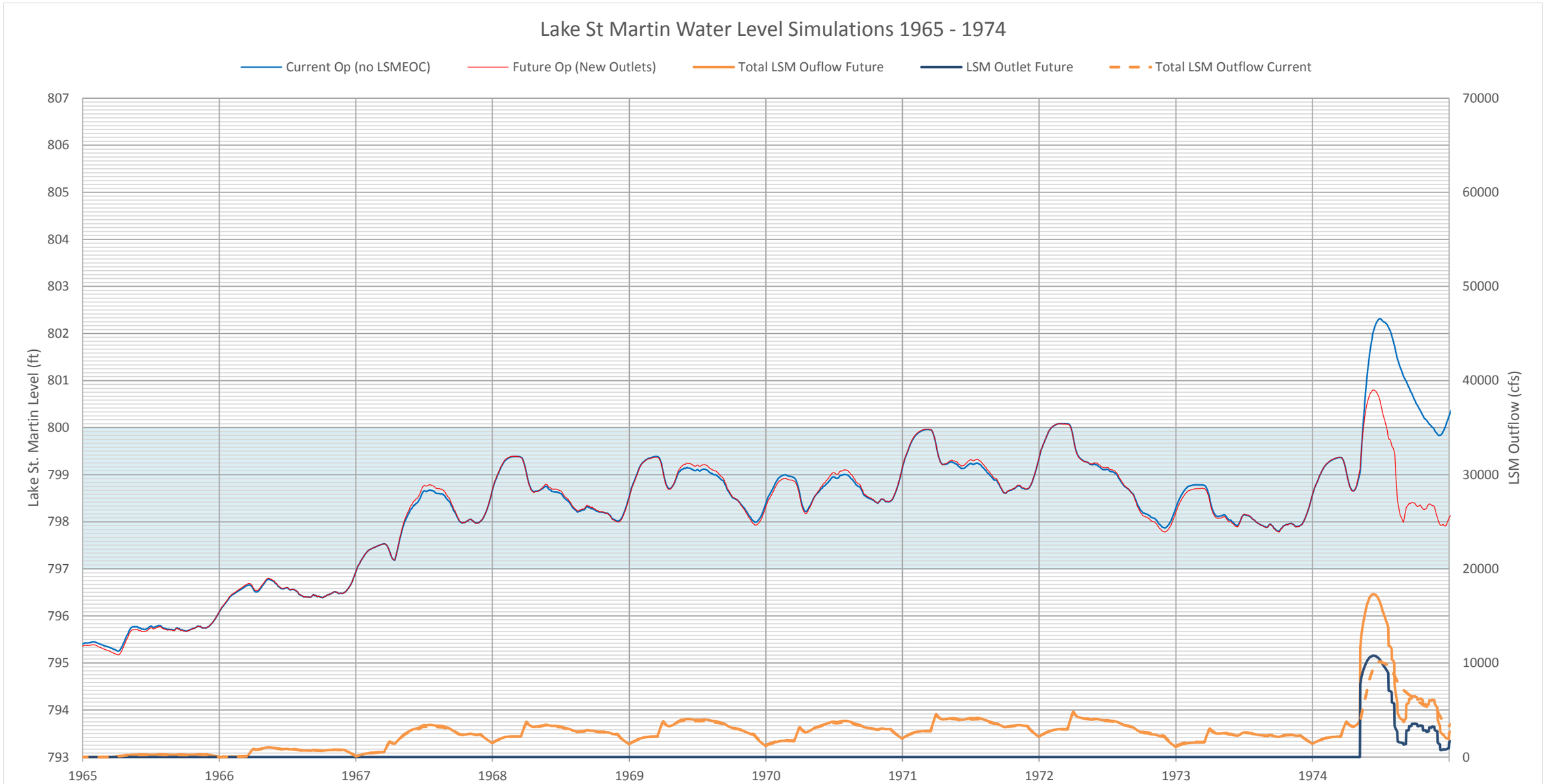
Lake St Martin Water Level Simulations 1965 - 1974
Current Op (no LSMEOC)
Future Op (New Outlets)
Total LSM Ouflow Future
LSM Outlet Future
Total LSM Outflow Current
Lake St. Martin Level (ft)
LSM Outflow (cfs)
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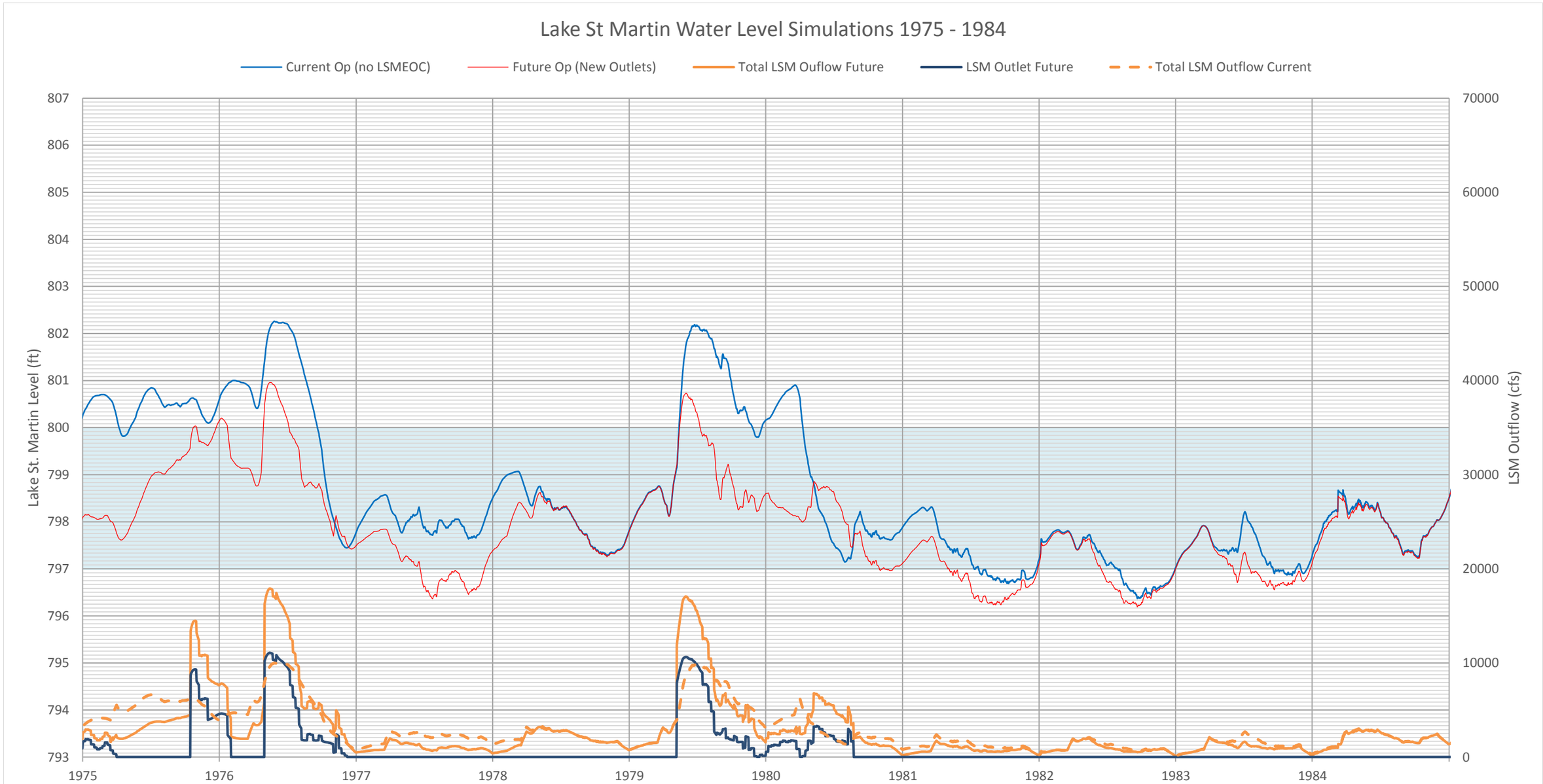
Lake St Martin Water Level Simulations 1975 - 1984
Current Op (no LSMEOC)
Future Op (New Outlets)
Total LSM Ouflow Future
LSM Outlet Future
Total LSM Outflow Current
Lake St. Martin Level (ft)
LSM Outflow (cfs)
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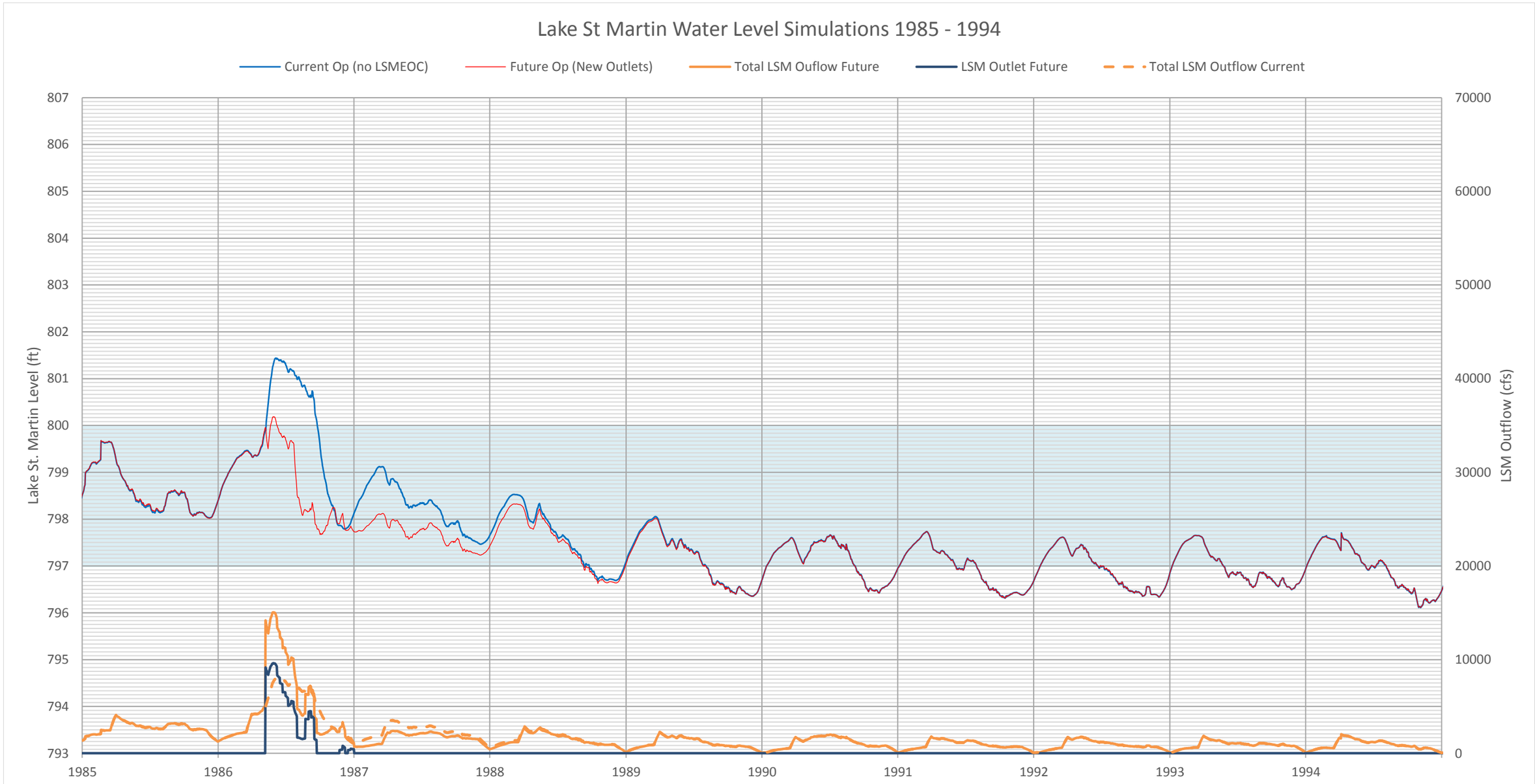
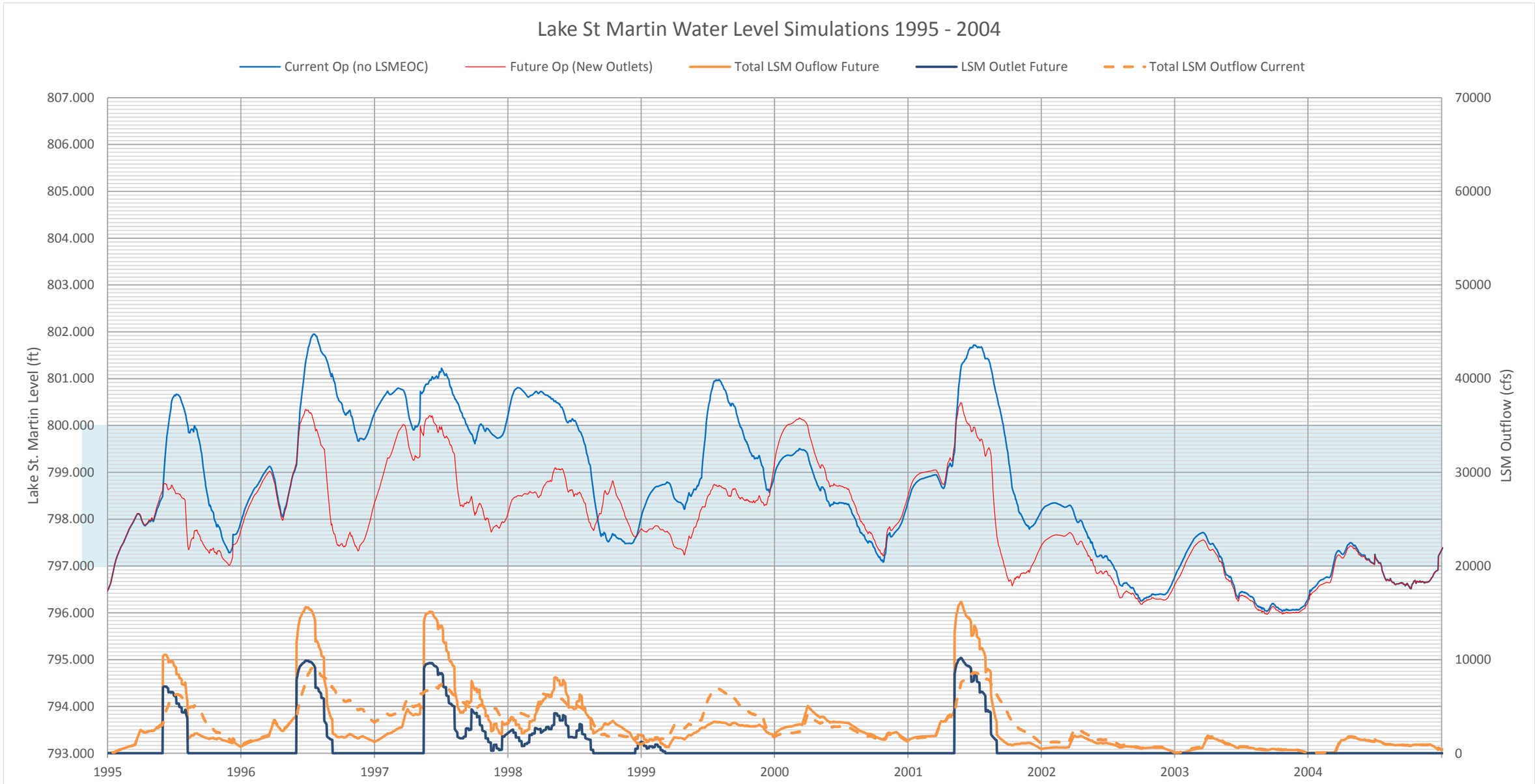
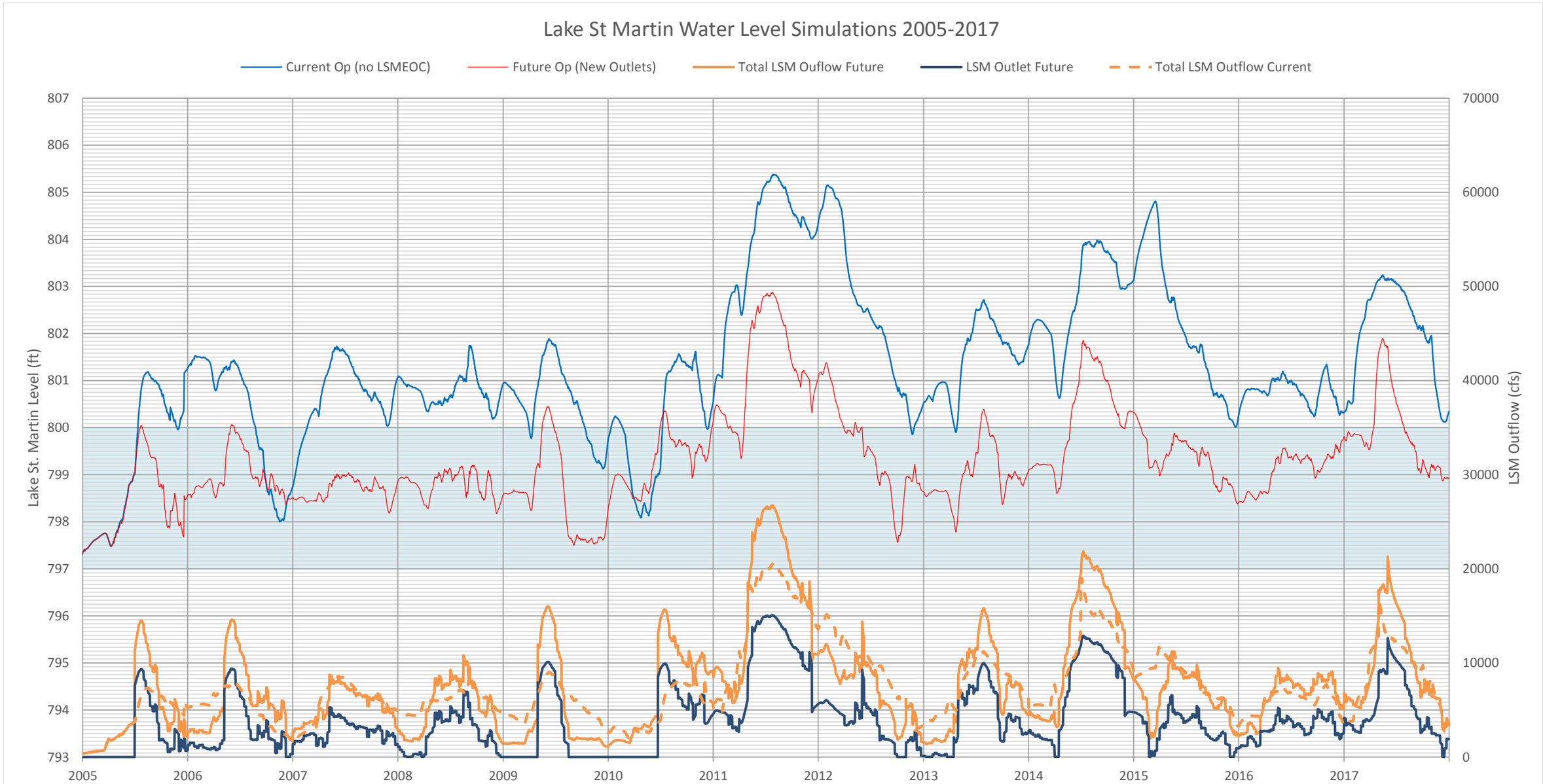
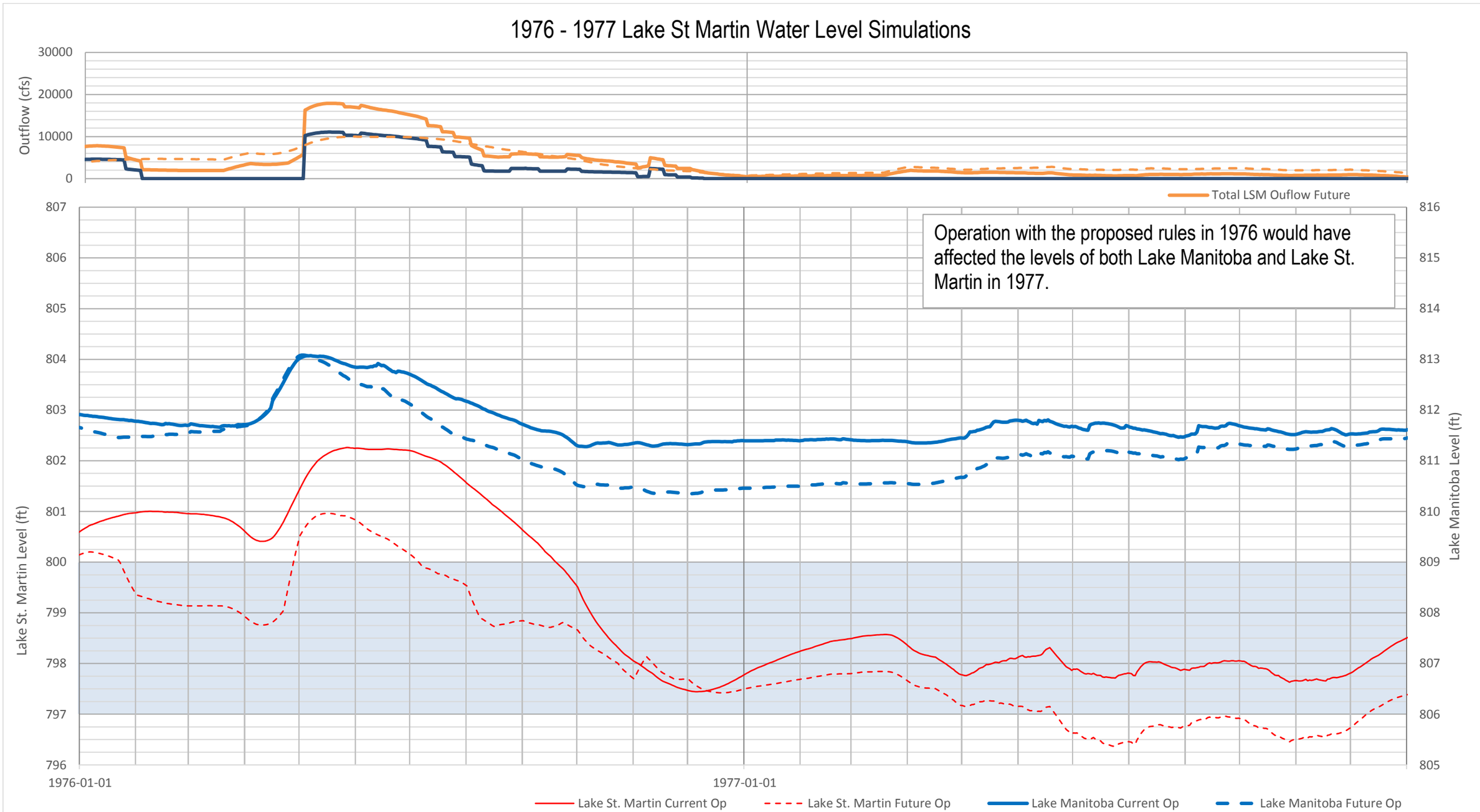
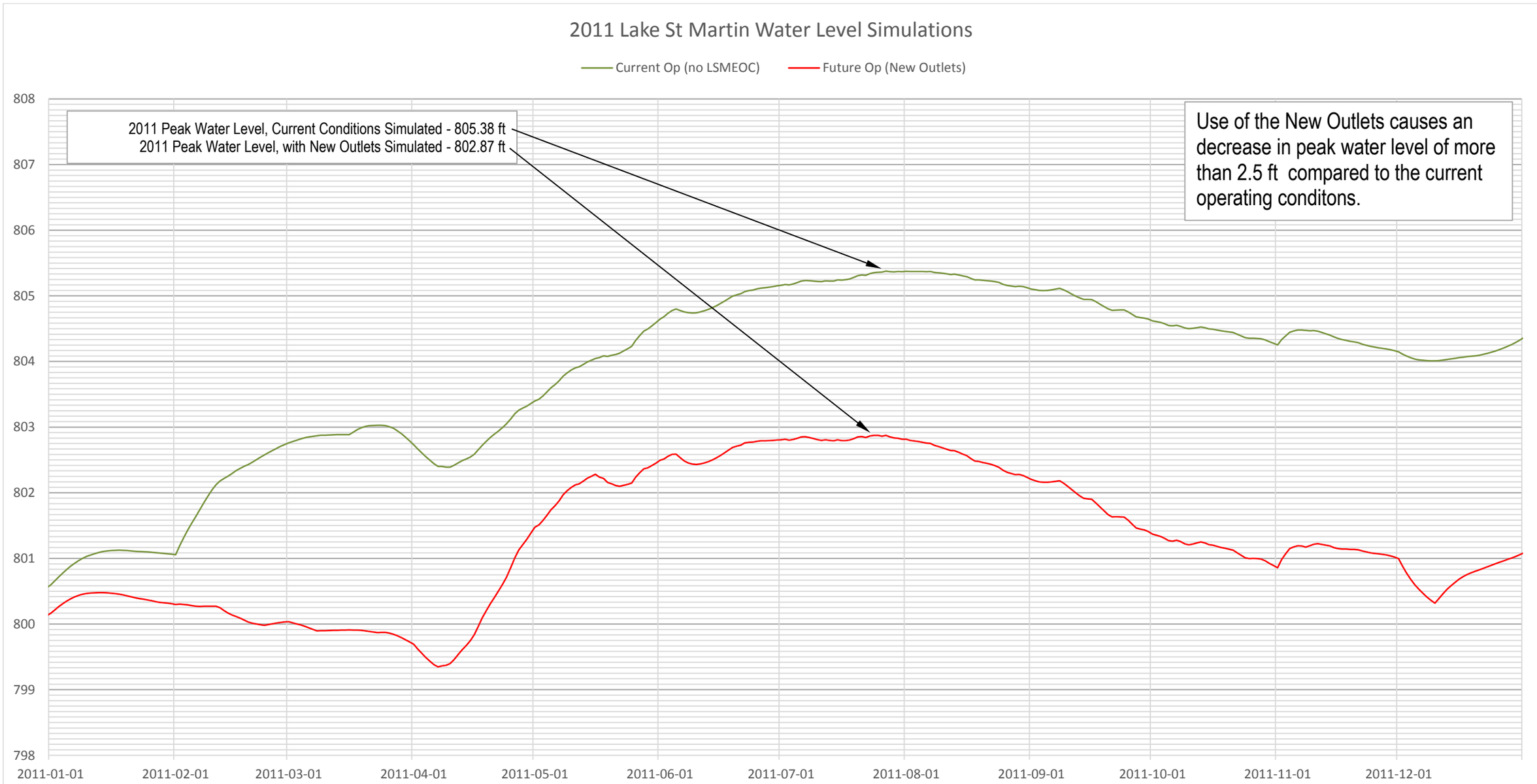
798
797
796
795
794
793
70000
60000
50000
40000
30000
20000
10000
0
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984


Lake St Martin Water Level Simulations 1985 - 1994
Current Op (no LSMEOC)
Future Op (New Outlets)
Total LSM Ouflow Future
LSM Outlet Future
Total LSM Outflow Current
Lake St. Martin Level (ft)
LSM Outflow (cfs)
807
806
805
804
803
802
801
800
799
798
797
796
795
794
793
70000
60000
50000
40000
30000
20000
10000
0
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994


Lake St Martin Water Level Simulations 1995 - 2004
Current Op (no LSMEOC)
Future Op (New Outlets)
Total LSM Ouflow Future
LSM Outlet Future
Total LSM Outflow Current
Lake St. Martin Level (ft)
LSM Outflow (cfs)
807.000
806.000
805.000
804.000
803.000
802.000
801.000
800.000
799.000
798.000
797.000
796.000
795.000
794.000
793.000
70000
60000
50000
40000
30000
20000
10000
0
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004


Lake St Martin Water Level Simulations 2005-2017
Current Op (no LSMEOC)
Future Op (New Outlets)
Total LSM Ouflow Future
LSM Outlet Future
Total LSM Outflow Current
Lake St. Martin Level (ft)
LSM Outflow (cfs)
807
806
805
804
803
802
801
800
799
798
797
796
795
794
793
70000
60000
50000
40000
30000
20000
10000
0
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017


1976 - 1977 Lake St Martin Water Level Simulations
Outflow (cfs)
30000
20000
10000
0
Total LSM Ouflow Future
Operation with the proposed rules in 1976 would have affected the levels of both Lake Manitoba and Lake St. Martin in 1977.
Lake St. Martin Level (ft)
807
806
805
804
803
802
801
800
799
798
797
796
Lake Manitoba Level (ft)
816
815
814
813
812
811
810
809
808
807
806
805
1976-01-01
1977-01-01
Lake St. Martin Current Op
Lake St. Martin Future Op
Lake Manitoba Current Op
Lake Manitoba Future Op


2011 Lake St Martin Water Level Simulations
Current Op (no LSMEOC)
Future Op (New Outlets)
2011 Peak Water Level, Current Conditions Simulated - 805.38 ft
2011 Peak Water Level, with New Outlets Simulated - 802.87 ft
Use of the New Outlets causes an decrease in peak water level of more than 2.5 ft compared to the current operating conditons.
808
807
806
805
804
803
802
801
800
799
798
2011-01-01
2011-02-01
2011-03-01
2011-04-01
2011-05-01
2011-06-01
2011-07-01
2011-08-01
2011-09-01
2011-10-01
2011-11-01
2011-12-01

Manitoba
Infrastructure

Appendix B:
Table of Statistics

Statistics for Lake Manitoba

	Minimum Water Level (ft)			Maximum Water Level (ft)			Water Level Range (ft)			Days Above Operating Range		
Year	Current Operation	Future Operation With LMB Outlet	Change	Current Operation	Future Operation With LMB Outlet	Change	Current Operation	Future Operation With LMB Outlet	Change	Current Operation	Future Operation With LMB Outlet	Change
1915	811.22	811.16	-0.06	813.40	813.40	0.00	2.18	2.25	0.06	98	87	-11
1916	811.11	810.96	-0.15	812.66	812.56	-0.10	1.54	1.60	0.06	11	9	-2
1917	811.50	811.42	-0.08	812.32	812.24	-0.08	0.82	0.83	0.00	0	0	0
1918	811.50	811.43	-0.07	812.28	812.21	-0.08	0.78	0.77	-0.01	0	0	0
1919	810.89	810.81	-0.08	811.96	811.89	-0.07	1.07	1.08	0.01	0	0	0
1920	810.79	810.73	-0.07	811.78	811.71	-0.07	0.99	0.99	0.00	0	0	0
1921	810.96	810.90	-0.06	812.02	811.96	-0.06	1.05	1.06	0.01	0	0	0
1922	811.64	811.33	-0.31	813.03	812.73	-0.30	1.39	1.40	0.01	132	55	-77
1923	811.68	811.21	-0.47	812.86	812.49	-0.36	1.18	1.29	0.10	102	8	-94
1924	811.47	811.29	-0.18	812.42	812.36	-0.06	0.94	1.07	0.12	7	0	-7
1925	811.60	811.04	-0.56	812.92	812.77	-0.15	1.33	1.73	0.41	59	39	-20
1926	811.31	811.11	-0.20	811.80	811.56	-0.24	0.50	0.45	-0.04	0	0	0
1927	811.37	810.90	-0.47	812.73	812.58	-0.15	1.36	1.68	0.32	65	16	-49
1928	811.47	811.42	-0.05	812.26	812.24	-0.02	0.78	0.81	0.03	0	0	0
1929	810.66	810.60	-0.06	811.81	811.76	-0.06	1.16	1.16	0.00	0	0	0
1930	810.32	810.26	-0.06	811.44	811.38	-0.06	1.12	1.13	0.00	0	0	0
1931	809.91	809.85	-0.06	810.61	810.54	-0.06	0.70	0.70	0.00	0	0	0
1932	809.34	809.28	-0.07	810.46	810.39	-0.07	1.12	1.12	0.00	0	0	0
1933	809.46	809.39	-0.07	810.29	810.23	-0.07	0.84	0.83	0.00	0	0	0
1934	809.72	809.65	-0.07	810.44	810.38	-0.07	0.73	0.73	0.00	0	0	0
1935	810.44	810.38	-0.07	812.28	812.22	-0.06	1.84	1.84	0.00	0	0	0
1936	811.17	811.08	-0.08	812.17	812.08	-0.08	1.00	1.00	0.00	0	0	0
1937	810.91	810.84	-0.07	812.11	812.04	-0.07	1.20	1.20	0.00	0	0	0
1938	810.66	810.60	-0.06	811.55	811.49	-0.06	0.89	0.89	0.00	0	0	0
1939	810.13	810.07	-0.06	811.10	811.04	-0.06	0.97	0.97	0.00	0	0	0
1940	809.48	809.41	-0.07	810.31	810.24	-0.06	0.83	0.83	0.00	0	0	0
1941	809.58	809.52	-0.06	810.27	810.21	-0.06	0.69	0.69	0.00	0	0	0
1942	809.36	809.29	-0.06	810.38	810.32	-0.06	1.02	1.02	0.00	0	0	0
1943	809.42	809.36	-0.06	810.38	810.32	-0.06	0.95	0.96	0.00	0	0	0
1944	809.64	809.58	-0.06	810.34	810.28	-0.06	0.70	0.71	0.00	0	0	0
1945	809.87	809.81	-0.06	810.54	810.48	-0.06	0.67	0.67	0.00	0	0	0
1946	810.02	809.96	-0.06	810.62	810.55	-0.06	0.59	0.59	0.00	0	0	0
1947	810.31	810.25	-0.07	811.49	811.42	-0.06	1.18	1.18	0.00	0	0	0
1948	811.40	810.80	-0.61	812.58	812.53	-0.04	1.17	1.74	0.56	28	18	-10
1949	811.27	811.11	-0.16	812.25	812.03	-0.22	0.98	0.92	-0.06	0	0	0
1950	811.27	811.34	0.08	812.56	812.46	-0.10	1.30	1.12	-0.17	27	10	-17
1951	811.10	811.09	0.00	811.66	811.70	0.03	0.57	0.60	0.04	0	0	0
1952	811.09	811.04	-0.05	811.68	811.64	-0.04	0.60	0.60	0.01	0	0	0
1953	811.39	811.34	-0.05	812.57	812.58	0.01	1.18	1.24	0.07	28	24	-4
1954	811.89	811.50	-0.39	813.00	812.65	-0.35	1.11	1.15	0.05	209	74	-135
1955	812.11	811.18	-0.93	814.07	813.05	-1.02	1.96	1.87	-0.09	339	90	-249
1956	811.69	811.39	-0.30	812.97	812.81	-0.16	1.28	1.42	0.14	141	49	-92
1957	811.30	811.58	0.29	812.01	812.49	0.48	0.71	0.91	0.20	0	8	8
1958	810.63	810.65	0.02	811.66	811.73	0.07	1.03	1.08	0.05	0	0	0
1959	810.64	810.62	-0.02	811.45	811.45	0.00	0.81	0.83	0.02	0	0	0
1960	810.97	810.91	-0.06	812.09	812.04	-0.05	1.12	1.13	0.01	0	0	0
1961	809.77	809.71	-0.06	811.41	811.36	-0.06	1.65	1.65	0.00	0	0	0
1962	810.02	809.96	-0.06	810.92	810.86	-0.06	0.90	0.91	0.00	0	0	0
1963	809.65	809.58	-0.07	810.94	810.88	-0.07	1.29	1.29	0.00	0	0	0
1964	808.94	808.87	-0.06	810.18	810.11	-0.07	1.24	1.24	0.00	0	0	0
1965	809.15	809.09	-0.06	810.06	810.00	-0.06	0.90	0.91	0.01	0	0	0
1966	809.97	809.91	-0.06	811.14	811.09	-0.05	1.17	1.18	0.00	0	0	0
1967	811.15	811.09	-0.05	812.23	812.17	-0.06	1.09	1.08	-0.01	0	0	0
1968	811.65	811.57	-0.08	812.18	812.11	-0.08	0.54	0.54	0.00	0	0	0
1969	811.62	811.53	-0.09	812.40	812.32	-0.09	0.78	0.79	0.01	1	0	-1
1970	811.47	811.39	-0.08	812.36	812.27	-0.09	0.89	0.88	-0.01	0	0	0
1971	811.88	811.77	-0.11	812.43	812.33	-0.11	0.55	0.55	0.01	10	0	-10
1972	811.58	811.49	-0.09	812.39	812.28	-0.11	0.82	0.80	-0.02	0	0	0
1973	811.47	811.39	-0.08	811.98	811.91	-0.08	0.51	0.52	0.01	0	0	0
1974	811.63	810.96	-0.67	813.22	812.94	-0.28	1.59	1.98	0.39	89	56	-33
1975	811.54	811.03	-0.50	812.18	812.54	0.36	0.65	1.51	0.86	0	32	32
1976	811.28	810.34	-0.94	813.07	813.08	0.01	1.79	2.74	0.95	88	59	-29
1977	811.35	810.46	-0.89	811.81	811.44	-0.37	0.46	0.98	0.52	0	0	0
1978	811.31	811.24	-0.07	811.92	811.85	-0.07	0.61	0.61	0.00	0	0	0
1979	811.40	810.98	-0.42	813.05	812.75	-0.30	1.64	1.77	0.12	94	51	-43
1980	811.20	810.30	-0.90	811.67	811.36	-0.31	0.47	1.06	0.59	0	0	0
1981	810.98	810.53	-0.45	811.43	810.90	-0.53	0.45	0.38	-0.07	0	0	0

Statistics for Lake Manitoba

	Minimum Water Level (ft)			Maximum Water Level (ft)			Water Level Range (ft)			Days Above Operating Range		
Year	Current Operation	Future Operation With LMB Outlet	Change	Current Operation	Future Operation With LMB Outlet	Change	Current Operation	Future Operation With LMB Outlet	Change	Current Operation	Future Operation With LMB Outlet	Change
1982	810.71	810.37	-0.34	811.43	811.05	-0.37	0.71	0.68	-0.03	0	0	0
1983	810.86	810.51	-0.34	811.73	811.53	-0.21	0.87	1.01	0.14	0	0	0
1984	811.31	811.22	-0.10	812.00	811.91	-0.08	0.68	0.70	0.01	0	0	0
1985	811.62	811.54	-0.08	811.98	811.90	-0.08	0.36	0.36	0.00	0	0	0
1986	811.46	810.90	-0.56	812.70	812.55	-0.15	1.24	1.65	0.41	39	25	-14
1987	811.45	811.05	-0.40	812.01	811.67	-0.33	0.55	0.62	0.07	0	0	0
1988	811.12	811.04	-0.09	811.88	811.77	-0.11	0.76	0.74	-0.02	0	0	0
1989	810.81	810.74	-0.07	811.75	811.67	-0.07	0.93	0.93	0.00	0	0	0
1990	810.80	810.74	-0.06	811.68	811.62	-0.06	0.88	0.88	0.00	0	0	0
1991	810.69	810.63	-0.06	811.55	811.49	-0.06	0.86	0.86	0.00	0	0	0
1992	810.76	810.70	-0.06	811.27	811.21	-0.06	0.51	0.51	0.00	0	0	0
1993	810.83	810.77	-0.06	811.15	811.09	-0.06	0.32	0.32	0.00	0	0	0
1994	810.85	810.80	-0.06	811.30	811.24	-0.05	0.45	0.45	0.00	0	0	0
1995	811.08	811.02	-0.06	812.57	812.50	-0.07	1.49	1.48	-0.01	27	18	-9
1996	811.51	811.38	-0.13	812.80	812.58	-0.22	1.29	1.21	-0.09	65	27	-38
1997	811.51	811.13	-0.37	812.37	812.67	0.30	0.86	1.54	0.67	0	31	31
1998	811.27	810.75	-0.52	811.98	811.75	-0.23	0.71	1.00	0.29	0	0	0
1999	811.48	810.94	-0.53	812.54	812.21	-0.33	1.06	1.27	0.20	27	0	-27
2000	811.24	811.24	0.00	811.93	812.01	0.08	0.69	0.77	0.08	0	0	0
2001	811.29	810.84	-0.44	812.84	812.66	-0.18	1.55	1.82	0.26	78	24	-54
2002	810.45	810.25	-0.21	811.36	811.09	-0.27	0.91	0.84	-0.06	0	0	0
2003	809.87	809.71	-0.16	810.63	810.46	-0.18	0.77	0.75	-0.02	0	0	0
2004	809.94	809.79	-0.15	811.02	810.89	-0.14	1.08	1.10	0.02	0	0	0
2005	811.02	810.89	-0.13	812.89	812.59	-0.30	1.86	1.70	-0.16	55	25	-30
2006	811.49	810.80	-0.70	812.38	812.51	0.13	0.89	1.72	0.83	0	23	23
2007	811.98	811.05	-0.94	812.59	811.75	-0.85	0.61	0.70	0.09	86	0	-86
2008	811.74	811.29	-0.45	812.19	811.75	-0.45	0.45	0.46	0.01	0	0	0
2009	811.50	811.41	-0.09	812.81	812.73	-0.08	1.31	1.32	0.01	63	46	-17
2010	811.48	811.46	-0.02	812.89	812.55	-0.34	1.41	1.08	-0.33	128	31	-97
2011	812.71	811.53	-1.18	816.94	815.46	-1.48	4.23	3.93	-0.30	365	218	-147
2012	811.98	810.93	-1.05	814.23	812.02	-2.21	2.25	1.09	-1.16	249	0	-249
2013	811.83	811.16	-0.67	813.00	812.53	-0.48	1.17	1.36	0.19	121	21	-100
2014	811.89	811.49	-0.40	814.37	813.46	-0.91	2.48	1.97	-0.51	241	147	-94
2015	811.81	811.17	-0.64	813.33	812.22	-1.11	1.52	1.05	-0.47	209	0	-209
2016	811.64	811.10	-0.54	812.80	811.92	-0.88	1.16	0.82	-0.34	43	0	-43
2017	812.35	811.25	-1.11	813.80	813.07	-0.73	1.44	1.82	0.38	341	86	-255

- non-flood year
- minor flood year
-major flood year

Statistics for Lake St. Martin

	Minimum Water Level (ft)			Maximum Water Level (ft)			Water Level Range (ft)			Days Above Operating Range		
Year	Current Operation	With LSM Outlet	Change	Current Operation	With LSM Outlet	Change	Current Operation	With LSM Outlet	Change	Current Operation	With LSM Outlet	Change
1915	797.50	797.44	-0.06	803.98	804.35	0.37	6.48	6.91	0.43	203	132	-71
1916	797.64	797.31	-0.33	798.70	798.63	-0.08	1.07	1.32	0.25	0	0	0
1917	797.72	797.68	-0.04	799.40	799.25	-0.15	1.68	1.57	-0.11	0	0	0
1918	797.76	797.75	-0.02	799.26	799.23	-0.02	1.50	1.49	-0.01	0	0	0
1919	797.41	797.42	0.00	799.32	799.29	-0.03	1.91	1.87	-0.03	0	0	0
1920	796.72	796.71	-0.01	797.66	797.67	0.00	0.95	0.96	0.01	0	0	0
1921	797.07	797.07	0.00	798.62	798.67	0.04	1.55	1.60	0.05	0	0	0
1922	798.64	798.69	0.04	802.15	800.49	-1.66	3.51	1.80	-1.71	227	80	-147
1923	800.16	798.31	-1.85	802.05	799.47	-2.58	1.88	1.16	-0.73	365	0	-365
1924	798.33	798.17	-0.15	800.77	799.21	-1.56	2.44	1.04	-1.40	87	0	-87
1925	799.02	797.89	-1.13	801.87	800.38	-1.49	2.85	2.49	-0.36	151	29	-122
1926	797.19	796.96	-0.23	800.49	798.14	-2.35	3.30	1.18	-2.12	50	0	-50
1927	797.97	797.33	-0.63	801.75	800.11	-1.64	3.79	2.78	-1.01	183	25	-158
1928	797.75	797.79	0.04	800.61	799.02	-1.58	2.86	1.23	-1.63	64	0	-64
1929	796.53	796.53	0.00	798.62	798.65	0.03	2.09	2.12	0.03	0	0	0
1930	796.39	796.41	0.01	797.53	797.53	0.00	1.13	1.12	-0.01	0	0	0
1931	796.10	796.11	0.02	797.40	797.42	0.02	1.30	1.30	0.00	0	0	0
1932	795.76	795.75	-0.01	797.05	797.08	0.03	1.29	1.33	0.04	0	0	0
1933	795.72	795.71	-0.01	796.58	796.59	0.01	0.86	0.88	0.02	0	0	0
1934	795.95	795.96	0.01	796.64	796.66	0.02	0.70	0.70	0.01	0	0	0
1935	796.63	796.65	0.02	798.78	798.81	0.04	2.14	2.16	0.02	0	0	0
1936	797.14	797.10	-0.03	799.51	799.53	0.01	2.38	2.42	0.05	0	0	0
1937	796.81	796.80	-0.01	798.78	798.74	-0.04	1.96	1.94	-0.02	0	0	0
1938	796.52	796.52	0.00	798.18	798.16	-0.02	1.66	1.64	-0.02	0	0	0
1939	796.21	796.23	0.02	797.53	797.52	0.00	1.31	1.29	-0.02	0	0	0
1940	795.74	795.73	-0.01	797.21	797.24	0.02	1.47	1.51	0.03	0	0	0
1941	795.78	795.78	0.00	796.52	796.52	0.00	0.74	0.74	0.01	0	0	0
1942	795.68	795.67	-0.01	796.66	796.68	0.02	0.98	1.01	0.03	0	0	0
1943	795.84	795.82	-0.02	796.32	796.31	-0.01	0.48	0.49	0.01	0	0	0
1944	795.90	795.91	0.01	796.52	796.53	0.01	0.62	0.62	0.00	0	0	0
1945	796.06	796.07	0.01	796.68	796.70	0.02	0.62	0.63	0.01	0	0	0
1946	796.15	796.16	0.02	797.03	797.07	0.03	0.88	0.90	0.02	0	0	0
1947	796.41	796.41	0.00	797.33	797.34	0.01	0.91	0.92	0.01	0	0	0
1948	796.95	796.95	0.00	801.35	799.96	-1.39	4.40	3.01	-1.39	139	0	-139
1949	797.30	797.11	-0.19	799.69	798.72	-0.97	2.39	1.61	-0.79	0	0	0
1950	798.02	797.93	-0.10	800.44	799.33	-1.11	2.42	1.41	-1.01	39	0	-39
1951	796.96	797.08	0.12	798.48	798.96	0.49	1.52	1.88	0.36	0	0	0
1952	797.06	797.08	0.02	798.19	798.27	0.08	1.13	1.19	0.06	0	0	0
1953	797.70	797.73	0.03	801.12	799.85	-1.27	3.42	2.12	-1.30	166	0	-166
1954	800.45	799.00	-1.45	802.17	800.51	-1.66	1.72	1.51	-0.21	365	149	-216
1955	800.41	797.64	-2.78	803.47	800.96	-2.51	3.06	3.32	0.27	365	104	-261
1956	799.98	797.80	-2.19	802.35	800.57	-1.79	2.37	2.77	0.40	356	86	-270
1957	797.33	798.15	0.83	800.97	799.95	-1.02	3.64	1.80	-1.84	149	0	-149
1958	796.51	796.54	0.04	798.58	799.34	0.76	2.07	2.79	0.72	0	0	0
1959	796.55	796.59	0.04	797.53	797.62	0.09	0.98	1.02	0.04	0	0	0
1960	796.86	796.86	0.00	798.48	798.60	0.12	1.62	1.74	0.12	0	0	0
1961	796.12	796.13	0.01	797.91	797.92	0.01	1.79	1.79	0.00	0	0	0
1962	796.16	796.18	0.01	797.18	797.20	0.02	1.02	1.02	0.01	0	0	0
1963	796.04	796.04	0.00	797.08	797.11	0.03	1.05	1.08	0.03	0	0	0
1964	795.29	795.26	-0.03	796.69	796.69	0.00	1.40	1.43	0.03	0	0	0
1965	795.25	795.17	-0.08	796.08	796.08	0.01	0.82	0.91	0.09	0	0	0
1966	796.09	796.10	0.01	796.92	796.92	0.00	0.84	0.83	-0.01	0	0	0
1967	796.95	796.95	0.00	798.67	798.79	0.11	1.73	1.84	0.11	0	0	0
1968	798.01	797.99	-0.02	799.39	799.39	0.00	1.37	1.40	0.03	0	0	0
1969	797.99	797.93	-0.06	799.39	799.37	-0.02	1.40	1.44	0.05	0	0	0
1970	798.22	798.17	-0.04	799.13	799.15	0.02	0.91	0.97	0.06	0	0	0
1971	798.60	798.60	0.00	799.96	799.97	0.01	1.36	1.37	0.01	0	0	0
1972	797.87	797.78	-0.09	800.09	800.08	-0.01	2.22	2.30	0.08	52	52	0
1973	797.80	797.78	-0.01	798.79	798.71	-0.08	0.99	0.93	-0.06	0	0	0
1974	798.59	797.91	-0.68	802.31	800.80	-1.51	3.73	2.89	-0.84	198	62	-136
1975	799.82	797.61	-2.21	800.85	800.14	-0.71	1.03	2.53	1.49	335	17	-318
1976	797.44	797.42	-0.02	802.26	800.96	-1.30	4.82	3.54	-1.28	262	91	-171
1977	797.63	796.36	-1.27	798.57	797.84	-0.73	0.94	1.48	0.54	0	0	0
1978	797.27	797.25	-0.02	799.07	798.62	-0.45	1.80	1.37	-0.43	0	0	0
1979	797.82	797.81	-0.02	802.19	800.73	-1.46	4.36	2.93	-1.44	207	55	-152
1980	797.14	796.96	-0.18	800.91	798.85	-2.05	3.76	1.89	-1.87	99	0	-99
1981	796.69	796.23	-0.46	798.31	797.69	-0.62	1.62	1.46	-0.16	0	0	0
1982	796.37	796.19	-0.18	797.83	797.79	-0.03	1.46	1.60	0.15	0	0	0
1983	796.86	796.55	-0.30	798.22	797.91	-0.30	1.36	1.36	0.00	0	0	0

Statistics for Lake St. Martin

	Minimum Water Level (ft)			Maximum Water Level (ft)			Water Level Range (ft)			Days Above Operating Range		
Year	Current Operation	With LSM Outlet	Change	Current Operation	With LSM Outlet	Change	Current Operation	With LSM Outlet	Change	Current Operation	With LSM Outlet	Change
1984	797.25	797.14	-0.11	798.68	798.56	-0.12	1.43	1.42	-0.01	0	0	0
1985	798.03	798.02	-0.01	799.67	799.68	0.01	1.65	1.66	0.02	0	0	0
1986	797.79	797.67	-0.12	801.44	800.19	-1.25	3.65	2.52	-1.13	137	17	-120
1987	797.47	797.23	-0.23	799.12	798.12	-1.00	1.66	0.89	-0.76	0	0	0
1988	796.69	796.63	-0.06	798.53	798.32	-0.20	1.84	1.70	-0.14	0	0	0
1989	796.36	796.35	0.00	798.06	798.02	-0.03	1.70	1.67	-0.03	0	0	0
1990	796.42	796.42	0.00	797.67	797.66	0.00	1.24	1.24	0.00	0	0	0
1991	796.31	796.31	0.00	797.73	797.73	0.00	1.42	1.42	0.00	0	0	0
1992	796.33	796.33	0.00	797.62	797.62	0.00	1.28	1.28	0.00	0	0	0
1993	796.50	796.50	0.00	797.65	797.65	0.00	1.16	1.16	0.00	0	0	0
1994	796.11	796.11	0.00	797.71	797.70	-0.01	1.60	1.59	-0.01	0	0	0
1995	796.48	796.48	0.00	800.67	798.77	-1.90	4.19	2.28	-1.90	53	0	-53
1996	797.95	797.32	-0.63	801.95	800.34	-1.61	4.00	3.02	-0.98	161	41	-120
1997	799.61	797.72	-1.89	801.22	800.21	-1.01	1.61	2.49	0.88	250	40	-210
1998	797.48	797.62	0.14	800.81	799.10	-1.71	3.33	1.48	-1.85	189	0	-189
1999	798.05	797.24	-0.82	800.98	799.16	-1.81	2.92	1.92	-1.00	93	0	-93
2000	797.08	797.21	0.13	799.51	800.16	0.66	2.42	2.95	0.52	0	56	56
2001	797.79	796.58	-1.21	801.72	800.49	-1.23	3.93	3.91	-0.02	130	37	-93
2002	796.25	796.18	-0.07	798.35	797.71	-0.64	2.10	1.53	-0.57	0	0	0
2003	796.03	795.97	-0.06	797.71	797.56	-0.16	1.68	1.59	-0.10	0	0	0
2004	796.30	796.23	-0.07	797.50	797.43	-0.07	1.20	1.20	0.00	0	0	0
2005	797.35	797.35	0.00	801.26	800.05	-1.21	3.91	2.70	-1.21	165	7	-158
2006	798.00	798.36	0.36	801.52	800.07	-1.46	3.52	1.70	-1.82	236	14	-222
2007	798.76	798.18	-0.57	801.73	799.04	-2.69	2.97	0.86	-2.11	316	0	-316
2008	800.18	798.18	-2.01	801.74	799.20	-2.54	1.56	1.03	-0.53	366	0	-366
2009	799.12	797.50	-1.63	801.89	800.44	-1.44	2.76	2.95	0.19	271	41	-230
2010	798.09	798.30	0.21	801.62	800.36	-1.27	3.53	2.05	-1.48	210	34	-176
2011	800.59	799.35	-1.24	805.38	802.87	-2.50	4.79	3.53	-1.26	365	317	-48
2012	799.86	797.55	-2.30	805.15	801.38	-3.77	5.30	3.83	-1.47	355	101	-254
2013	799.90	797.78	-2.12	802.72	800.39	-2.32	2.82	2.61	-0.20	357	28	-329
2014	800.62	798.60	-2.02	803.98	801.85	-2.13	3.36	3.25	-0.11	365	214	-151
2015	800.01	798.38	-1.63	804.81	800.32	-4.49	4.80	1.94	-2.86	365	25	-340
2016	800.23	798.41	-1.82	801.34	799.79	-1.55	1.11	1.39	0.27	366	0	-366
2017	800.12	798.87	-1.25	803.24	801.90	-1.34	3.12	3.02	-0.10	365	107	-258

- non-flood year
- minor flood year
-major flood year

Manitoba
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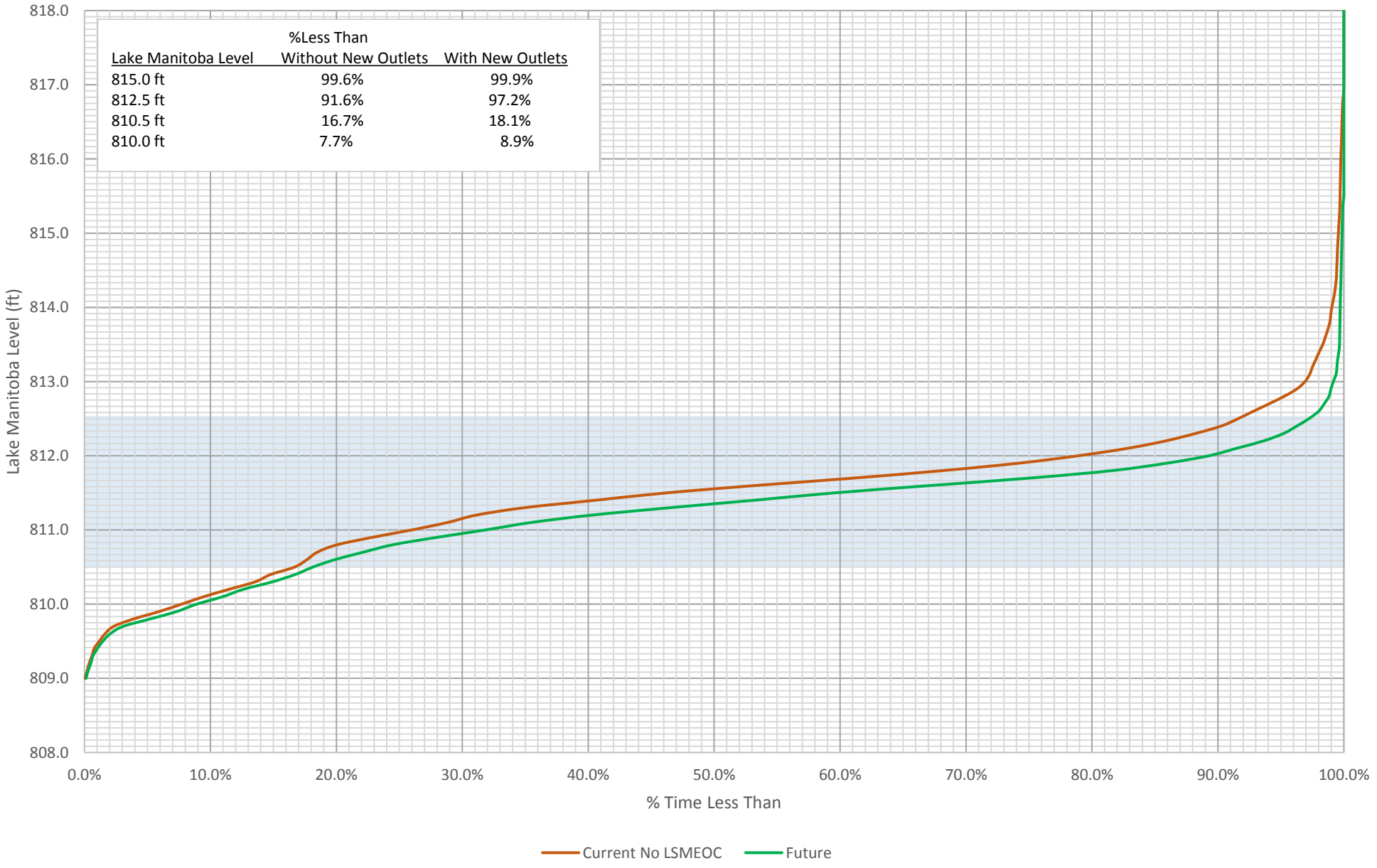
Appendix C:
Duration Curves

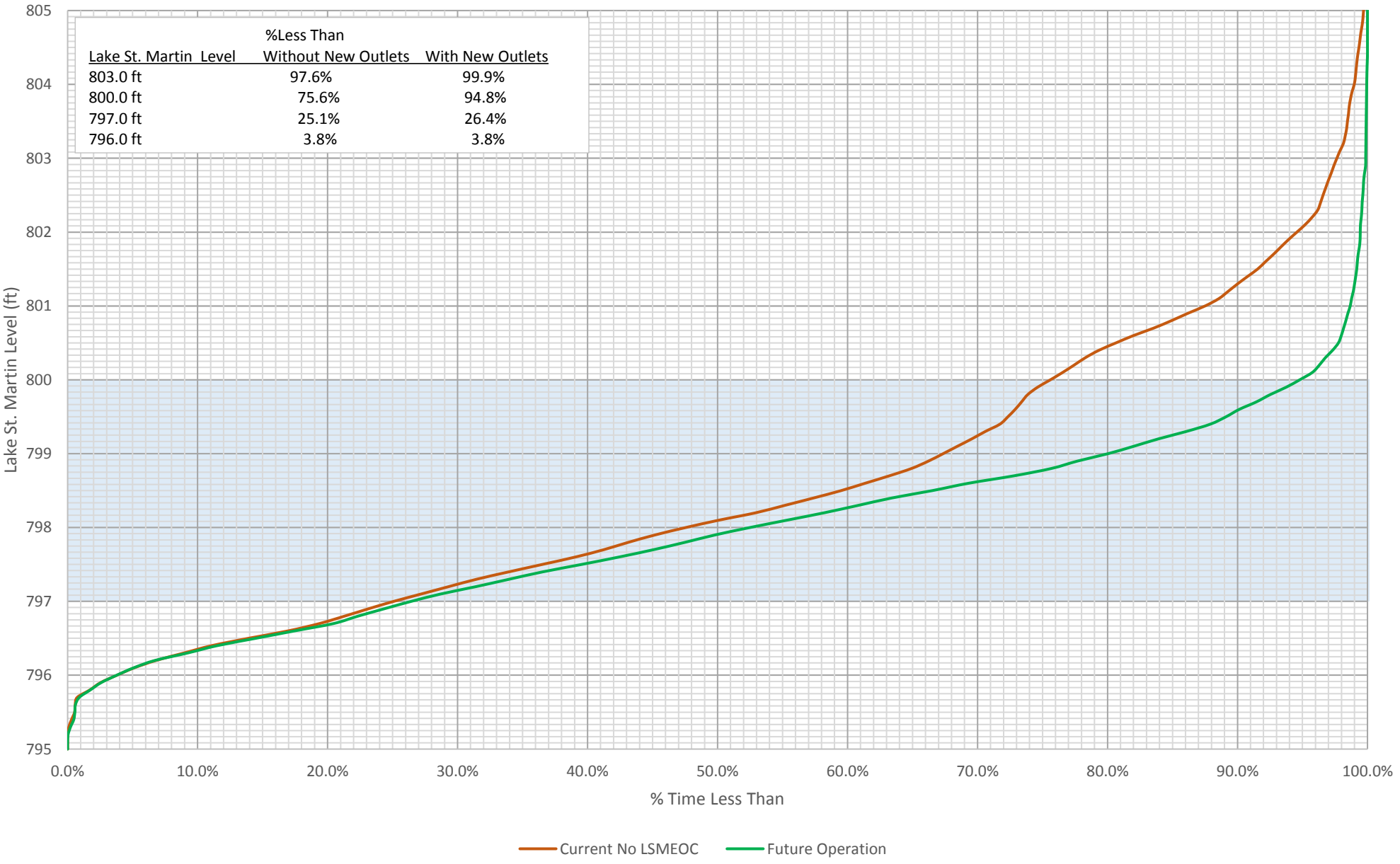
Lake Manitoba Duration Curve

Lake Manitoba Level	%Less Than Without New Outlets	With New Outlets
815.0 ft	99.6%	99.9%
812.5 ft	91.6%	97.2%
810.5 ft	16.7%	18.1%
810.0 ft	7.7%	8.9%



Lake St. Martin Duration Curves

Lake St. Martin Level	%Less Than Without New Outlets	With New Outlets
803.0 ft	97.6%	99.9%
800.0 ft	75.6%	94.8%
797.0 ft	25.1%	26.4%
796.0 ft	3.8%	3.8%



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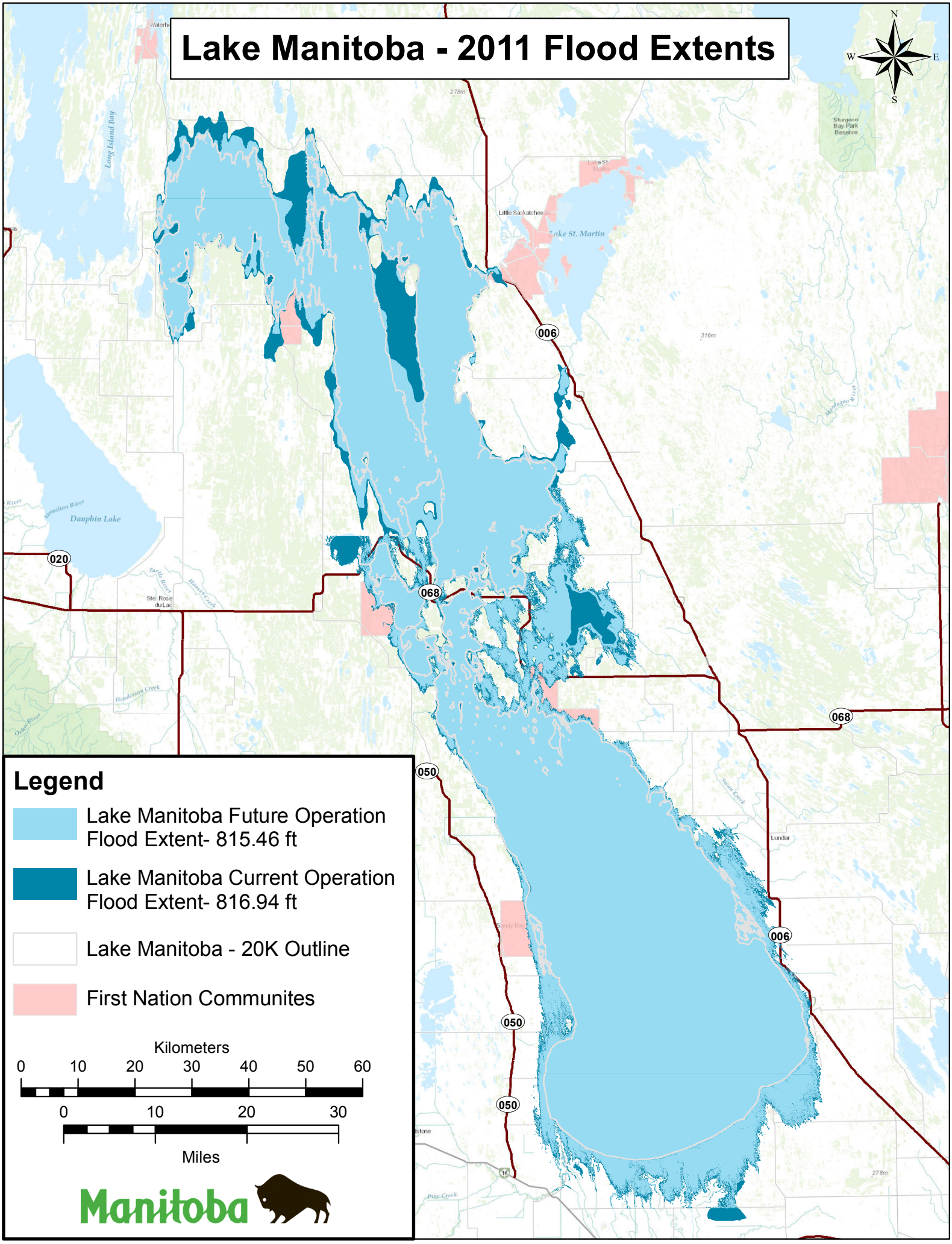
Appendix D:
Flood Inundation Maps


Lake Manitoba - 2011 Flood Extents
N
W
E
S
Legend
Lake Manitoba Future Operation Flood Extent- 815.46 ft
Lake Manitoba Current Operation Flood Extent- 816.94 ft
Lake Manitoba - 20K Outline
First Nation Communites
Kilometers
0 10 20 30 40 50 60
0 10 20 30
Miles
Manitoba
Dauphin Lake
Lake St. Martin
Little Saskatchewan
Ste. Rose du Lac
Lundar
Sturgeon Bay Park Reserve
Long Island Bay
Vermilion River
Turtle River
Hunters Creek
Henderson Creek
Oakes River
Meadows River
Swan Creek
Sandy Bay
Pine Creek
278m
316m
006
020
050
068

Lake St.Martin - 2011 Flood Simulation

N
W E
S

Gypsumville
618
513
Lake St. Martin
Little Saskatchewan
Hilbre
Birch Bay
006
Steep Rock Junction
Faulkner
239
Grahamdale

Legend

- Lake St.Martin Future Operation Flood Extent 802.87 ft
- Lake St.Martin Current Operation Flood Extent 805.38 ft
- Lake St.Martin - 50K Outline
- First Nation Communties

Kilometers
0 4.5 9 13.5 18

0 2 4 6 8
Miles

Manitoba

Lake St.Martin - Low Flood Event

N
W
E
S

Gypsumville
618
513
Lake St.
Martin
Little
Saskatchewan
Hilbre
Birch Bay
006
Steep Rock
Junction
Faulkner
239
Grahamdale

Legend

- Lake St.Martin Future Operation Flood Extent 800.22 ft
- Lake St.Martin Current Operation Flood Extent 801.93 ft
- Lake St.Martin - 50K Outline
- First Nation Communties

Kilometers
0 4.5 9 13.5 18

0 2 4 6 8
Miles

Manitoba