LAKE MANITOBA LAKE ST. MARTIN

OUTLET CHANNELS PROJECT

MANITOBA INFRASTRUCTURE

Groundwater Management Plan

November 9, 2020

Manitoba

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DISCLAIMER

This document was developed to support the Lake Manitoba and Lake St. Martin Outlet Channel Environmental Management and Monitoring Program. This document has been prepared by Manitoba Infrastructure as a way to share information and have discussion with Indigenous Communities and Groups and the public. This document has been prepared using existing environmental and preliminary engineering information, professional judgement as well as information from previous and ongoing public and Indigenous engagement and consultation. The contents of this document are based on conditions and information existing at the time the document was prepared and do not take into account any subsequent changes. The information, data, recommendations, and conclusions in this report are subject to change as the information has been presented as draft and will not be considered complete until further engagement and consultation is complete. The plans may be further revised based on information and direction received from provincial and federal environmental regulators. This draft report be read as a whole, and sections or parts should not be read out of context.

PREFACE

The Lake Manitoba and Lake St. Martin Permanent Outlet Channels Project (the "Project") is proposed as a permanent flood control mitigation for Lake Manitoba and Lake St. Martin to alleviate flooding in the Lake St. Martin region of Manitoba. It will involve the construction and operation of two new diversion channels: The Lake Manitoba Outlet Channel (LMOC) will connect Lake Manitoba to Lake St. Martin and the Lake St. Martin Outlet Channel (LSMOC) will connect Lake St. Martin to Lake Winnipeg. Associated with these outlet channels are the development of bridges, control structures with power connections, a new realignment of PR 239, and other ancillary infrastructure.

Manitoba Infrastructure (MI) is the proponent for the proposed Project. After receipt of the required regulatory approvals, MI will develop, manage and operate the Project. This Groundwater Management Plan is one component of the overall Environmental Management Program (EMP) framework which describes the environmental management processes that will be followed during the construction and operation phases of the Project. The goal of the EMP is to ensure that the environmental protection measures committed to in the Environmental Impact Statement (EIS) and the conditions of The Environment Act Licence and Federal Decision Statement Conditions are undertaken in a timely and effective manner. This includes the verification that environmental commitments are executed, monitored and evaluated for effectiveness, and that information is reported back in a timely manner to the Project management team for adjustment if required.

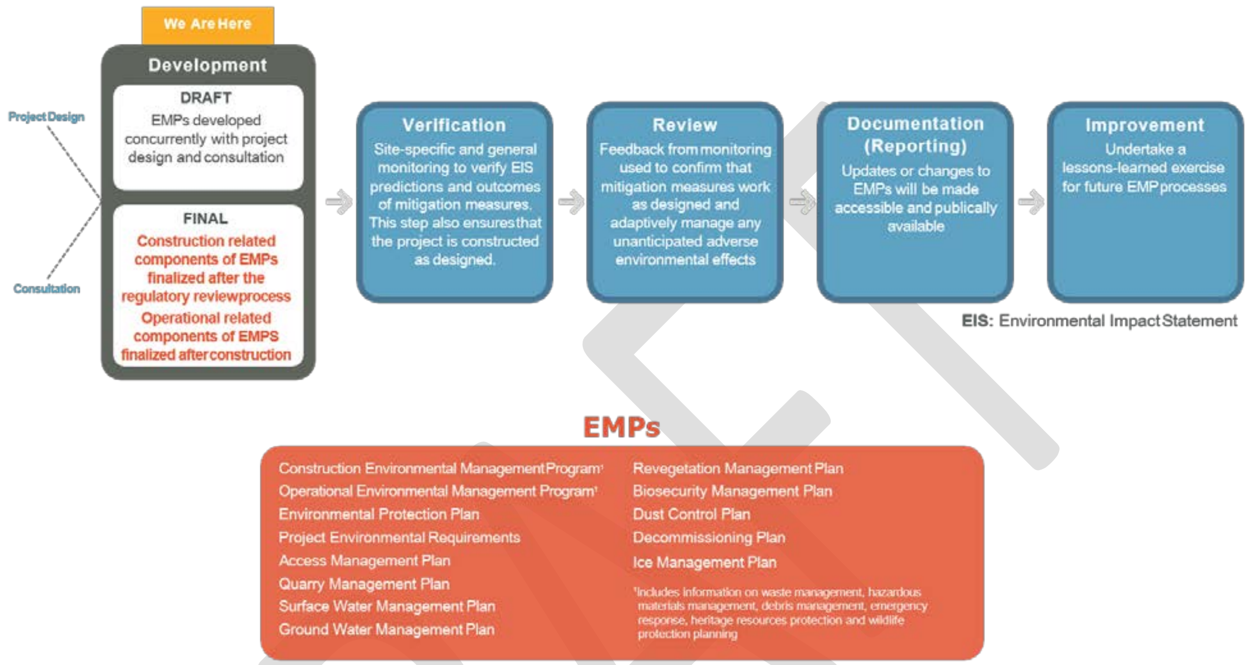
Manitoba Infrastructure remains committed to ongoing engagement and consultation with Indigenous groups and other stakeholders that are potentially impacted by the Project. Detailed EMP review discussions have been incorporated into community-specific consultation work plans and additional engagement opportunities will be provided prior to EMP finalization. Engagement opportunities include virtual open house events and EMP-specific questionnaires. EMP-specific questionnaires will be provided to Indigenous groups and stakeholders to obtain feedback and views on the draft plans, in addition to exploring opportunities for Indigenous participation in follow-up monitoring. Feedback and recommendations will be used to inform the completion of the plans.

The EMP provides the overarching framework for the Construction Environmental Management Program (CEMP) and the Operation Environmental Management Program (OEMP), which will be finalized as separate documents prior to Project construction and ideally operation, respectively. Their finalization will consider applicable conditions of The Environment Act Licence and associated approvals, any other pertinent findings through the design and regulatory review processes, and key relevant outcomes of the ongoing Indigenous and public engagement and Consultation processes.

The purpose of the CEMP and OEMP is to guide how environmental issues will be addressed during construction and operation, respectively and how adverse effects of activities will be mitigated. The CEMP is supported by several specific or targeted management plans (e.g. surface water, groundwater, sediment, etc.), as shown in the Figure below, that will guide MI's development of the Project's contract documents and subsequently, the Contractor(s) activities, in constructing the Project in an environmentally responsible manner. The OEMP will likely include the same targeted plans developed to manage issues during construction, but prior to construction completion they would be revised and adapted to suit the specific needs during the operation phase.

Environmental Management Program Process and Associated Environmental Management Plans

Environmental Management Program (EMP) Process



LAKE MANITOBA
LAKE ST. MARTIN
OUTLET CHANNELS PROJECT

GLOSSARY OF TERMS AND ACRONYMS

Acronyms

%	Percent
cfs	Cubic feet per second
CCME	Canadian Council of Ministers of the Environment
CDA	Canadian Dam Association
CEAA	Canadian Environmental Assessment Act
CEMP	Construction Environmental Management Program
DO	Dissolved Oxygen
EA	Environmental Act [Manitoba]
EC	Electronic Conductance
El.	Invert Elevation
EIS	Environmental Impact Statement
EMP	Environmental Management Program
ft	Feet
GWDrill	Provincial Well Record Database
GWMP	Groundwater Management Plan
HC-CDWQ	Health Canada – Canadian Drinking Water Quality
IDF	Inflow Design Flood
Km	Kilometre
LMOC	Lake Manitoba Outlet Channel
LSM	Lake St. Martin
LSMOC	Lake St. Martin Outlet Channel
m	Metres
m^3/s	Cubic metres per second
masl	Metres above sea level
mbgl	Metres below ground level
MI	Manitoba Infrastructure

MWQSOG	Manitoba Water Quality Standards, Objectives and Guidelines Regulation
N	Nitrogen
OEMP	Operation Environmental Management Program
ORP	Oxygen Reducing Potential
Project	The Lake Manitoba and Lake St. Martin Permanent Outlet Channels Project
Q	Quantity (Flow Rate)
SMP	Sediment Management Plan
SP	Standpipe Piezometer
Sta.	Station
SWMP	Surface Water Management Plan
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
VW	Vibrating Wire Piezometer
WCS	Water Control Structure

Glossary of Terms

Alkalinity: A pH value of greater than 7.0 (pH is a way to measure the acidity or alkalinity of a solution).

Aquifer: A body of rock or sediment that is sufficiently porous and permeable to store, transmit, and yield significant or economic quantities of groundwater to wells and springs.

Aquitard: A confining bed and/or formation composed of rock or sediment that retards but does not prevent the flow of water to or from an adjacent aquifer. It does not readily yield water to wells or springs, but stores groundwater.

Artesian aquifer: A body of rock or sediment containing groundwater that is under greater than hydrostatic pressure: that is a confined aquifer. When an artesian aquifer is penetrated by a well, the water level will rise above the top of the aquifer; a flowing artesian well is when the water level will rise above ground surface.

Baseflow: The portion of the streamflow that is sustained between precipitation events, fed to streams by delayed pathways.

Baseline: Initial environmental conditions, prior to construction or anthropogenic actions.

Bedrock: The solid rock that lies beneath the soil and other loose material on the Earth’s surface.

Carbonates: A rock made up primarily of carbonate minerals (minerals containing the CO_3 anionic structure). Examples include: limestone, dolostone, and marble (metamorphosed limestone or dolomite) are the most commonly encountered carbonate rocks.

Carbonate aquifer: See Aquifer; see Carbonates. Refers to an aquifer comprised of a carbonate bedrock.

Cofferdam: An enclosure, usually only partially obstructing a river, from which water is pumped to expose the bottom to permit construction.

Conductivity: A measure of the ability of a solution to conduct electrical flow; units are micro Siemens per centimeter.

Depressurization: Action of decreasing hydrostatic pressure. Active depressurization involves the use of pumps. Passive depressurization does not involve the use of pump, but rather uses a relation between hydrostatic pressure elevation and topographic elevation.

Dewatering: Removal or draining groundwater or surface water from a riverbed, construction site, caisson, or mine shaft, by pumping or evaporation.

Discharge: Rate of outflow; volume of water flowing down a river, from a lake outlet, or man-made structure.

Dissolved oxygen: Oxygen molecules (O_2) dissolved in water.

Dolomite: A sedimentary rock composed mostly of dolomite ($CaMg(CO_3)_2$) which often forms from limestone as the calcium is partly replaced by magnesium, usually as water solutions move through the limestone.

Domestic well: A water well used to supply water for the domestic needs of an individual residence or systems of four or fewer service connections.

Glaciolacustrine: Pertaining to, derived from, or deposited in glacial lakes; especially said of the deposits and landforms composed of suspended material brought by meltwater streams flowing into lakes bordering the glacier, such as deltas, kame deltas, and varved sediments.

Groundwater: Water that occurs beneath the land surface and fills the pore spaces of soil or rock below saturated zone.

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.

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.

Hydraulic Conductivity: Symbolized as K, is a property of vascular plants, soils and rocks, that describes the ease with which a fluid (usually water) can move through pore spaces or fractures. It depends on the intrinsic permeability of the material, the degree of saturation, and on the density and viscosity of the fluid.

Hydrogeology: The study of the interrelationships of geologic materials and processes with water, especially groundwater.

Invert (channel-): The stream bed or floor within a structure or channel.

Lacustrine: Of, or pertaining to, lakes; used in reference to soils deposited as sediments in a lake.

Piezometer: A piezometer is a device used to measure the pressure (more precisely, the piezometric head) of groundwater at a specific point.

Pool: A deep, slow-moving area of a stream; an artificially confined body of water above a dam or weir.

Recharge: Water added to an aquifer or the process of adding water to an aquifer.

Runoff: The flow of flood waters out of a drainage basin.

Shale: A clastic sedimentary rock that is made up of clay-size weathering debris. It typically breaks into thin flat pieces.

Stratigraphy: The science of rocks: it is concerned with the original succession and age relations of rock strata and their form, distribution, lithologic composition, fossil content, geophysical and geochemical properties-all characters and attributes of rocks as strata-and their interpretation in terms of environment and mode of origin and geologic history. Generic term referring to the sequential stacking of sediments / rocks in a region.

Till: An unstratified, unconsolidated mass of boulders, pebbles, sand and mud deposited by the movement or melting of a glacier.

Transmissivity: The rate of flow under a unit hydraulic gradient through a unit width of aquifer of thickness.

Turbidity: A measure of the relative clarity of water.

Water table: The upper surface of the zone of saturation in an unconfined aquifer.

Wetland: Land that is saturated with water long enough to promote wetland or aquatic processes as indicated by the formation of water altered soils, growth of water tolerant vegetation, and various kinds of biological activity that are adapted to wet environments (National Wetlands Working Group 1988).

Part 1: Introduction

1.0 PURPOSE AND SCOPE

The Groundwater Management Plan (GWMP) is a component of the overall Environmental Management Program (EMP) for the Lake Manitoba and Lake St. Martin Permanent Outlet Channel Project (the Project). This GWMP has been prepared for Manitoba Infrastructure (MI) to describe the groundwater management measures that will be implemented to mitigate or protect against impacts to groundwater or from groundwater during the construction and operation of the LMOC and LSMOC. These may include water level changes in aquifers, water quality changes, and changes in the relationship of the groundwater aquifer discharge to the surface water system. Adaptive measures are also identified for implementation if monitoring indicates the need for additional mitigation.

The GWMP is intended to be a living document that will be reviewed over the life of the Project and will be updated during preliminary and detailed design, incorporating applicable engagement feedback provided via regulatory review of the environmental assessment (EA), landowners and/or Indigenous Groups.

As the overall Project has two very distinct components (LMOC and LSMOC), different groundwater management approaches are required for each. The LMOC is primarily located near and through developed private farmland with drinking water and irrigation supply wells in proximity to the LMOC alignment. The LSMOC is primarily located in isolated, undeveloped Crown land used predominantly for hunting and fishing, with no agricultural activity or supply wells in the area. The local topography, geology and hydrogeology is also unique to each component of the project. Given the unique site characteristics of each of the channels, this GWMP is organized into three parts:

- Part 1 includes information that is common to both the Lake Manitoba and Lake St. Martin Outlet Channels.
- Part 2 includes information that is specific to the Lake Manitoba Outlet Channel.
- Part 3 includes information that is specific to the Lake St. Martin Outlet Channel.

1.1 Related Documents

The following project documents will also contain groundwater related topics and details, not necessarily included in this GWMP:

- The Construction Environmental Management Program (CEMP) will address Contingency and Emergency Response, including items related to groundwater.
- Detailed Design Documents will specify details of groundwater depressurization programs.
- A Groundwater Depressurization Plan will be developed by the Contractor in accordance with options provided in the Tender requirements.

- An Application for Temporary Authorization for Groundwater Construction Depressurization will be developed by the ESP and submitted to Manitoba Conservation and Climate Water Licensing, which will contain project specifics and an assessment of projected drawdown.
- General/specific conditions addressing groundwater issues from the CEAA 2012 Decision Statement and the Environment Act license for the project will also be incorporated into the project.

2.0 OBJECTIVES

The main objectives of the GWMP include:

- presenting an understanding of the hydrogeological conditions in the LMOC and LSMOC areas
- presenting groundwater depressurization plans for construction and operation scenarios
- identifying potential impacts on groundwater supply wells and required mitigation measures
- describing the planned monitoring to confirm effectiveness of mitigation measures

3.0 CRITERIA

Groundwater management controls for this GWMP will be designed, constructed and maintained in accordance with the terms and conditions of The Environment Act license, and conditions of the CEAA 2012 Decision Statement as effects may impact elements within federal jurisdiction, once the project is approved.

3.1 Discharge Criteria

Produced (pumped) groundwater will be discharged in accordance with the terms and conditions of any licences and approvals. If groundwater is discharged to surface water, it will be discharged into appropriate watercourses with the methods of containment, treatment and discharge performed according to measures outlined in Manitoba Water Quality Standards, Objectives and Guidelines (MWQSOG) Regulation (Reg. 196/2011). Discharges from site will comply with applicable Canadian Council of Ministers of the Environment (CCME) and MWQSOG criteria and assessment process for the Protection of Freshwater Aquatic Life (PAL).

3.2 Other Water Quality Criteria

Other water quality criteria will be used broadly within the project to interpret water quality data where required for detailed design or as required by any licences and approvals. Typical criteria include the Health Canada Canadian Drinking Water Guidelines (HC-CDWQG). For areas with groundwater surface water interactions the CCME Guidelines for Freshwater Aquatic Life may be pertinent as well.

3.3 Environmental Effects

Analyses of potential groundwater quality changes, or surface water quality changes as a result of short- or long-term discharges of groundwater to the surface water system, are not included in the detailed design, but may be included in The Environment Act licence. Additional evaluation criteria may be required at that stage of the project to assess any changes from background conditions. Traditional water quality analyses using methods such as Stiff diagrams and Durov plots, and including isotope analyses, will be applied to identify any meaningful changes to the surface water quality conditions with any addition of groundwater discharges to the surface water system.

Part 2: Lake Manitoba Outlet Channel

4.0 PROJECT INFORMATION

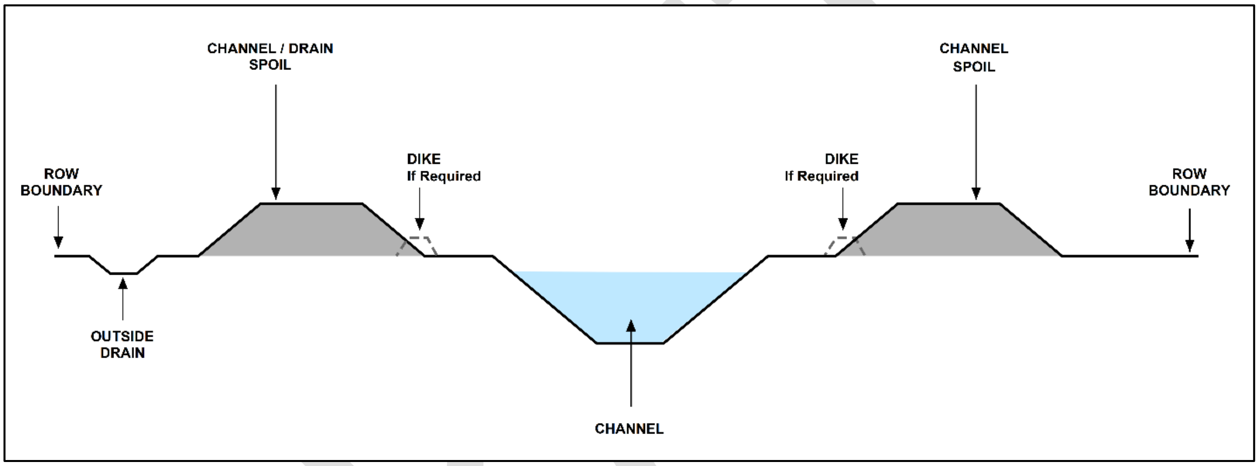
4.1 Project Description

The LMOC Project consists of an approximately 24 km long outlet channel, with the inlet positioned at Watchorn Bay on Lake Manitoba and outlet on the west side of Birch Bay on Lake St. Martin, as shown in Figure 1. The LMOC is designed to convey a flow of 212 m^3/s (7,500 cfs) at a Lake Manitoba water level of 248.11 m (812.5 ft) and a Lake St. Martin water level of 244.14 m (801 ft).

Figure 1: LMOC Project Area

The proposed channel will have an invert elevation of about 242.1 m at Watchorn Bay and about 239.3 m at Birch Bay. The channel will have a trapezoidal shape with a flat base varying in width from 12 m to 22 m and side slopes varying between 4H:1V to 5H:1V. Embankment dikes will be constructed on both sides of the channel in areas where existing ground levels are low. Spoil berms will be located behind the dikes on either side of the channel which will also be used to gain access to the channel for maintenance. An outside drain will be constructed and located on the west side of the channel to collect surface water runoff originating from the west and convey it into Lake Manitoba and Lake St. Martin. Drainage overflow structures may also be incorporated to allow flows in the outside drain during high local runoff periods to discharge into the LMOC. A typical cross section of the channel is provided in Figure 2.

Figure 2: Typical Cross-Section of the Lake Manitoba Outlet Channel



Inlet and outlet works will be required to allow for a smooth transition of flow from Watchorn Bay into the channel and from the channel into Birch Bay. The hydraulic profile of the channel will require the lake bottom to be excavated at the channel inlet and outlet to match the proposed channel invert elevations. The excavations will be tapered over a short distance out from the shoreline to meet natural lakebed elevations.

A water control structure (WCS) will be constructed at Iverson Road (approximately 21 km downstream of the inlet) to control flows through the LMOC while ensuring that Lake Manitoba water levels remain within their normal operating range when use of the channel is not required. A bridge will be integrated into the WCS to provide access across the channel. The preliminary design of the WCS consists of three 5.4 m wide sluice bays with vertical lift gates, upstream and downstream stoplogs, and a stilling basin with chute blocks, baffle blocks and an end sill.

The LMOC will intersect provincial highways and municipal roads. Realignment of PR 239 is required in order to accommodate the LMOC while still allowing for safe, economically feasible, and hydraulically efficient structures across the channel. Various sections of municipal road will also be realigned or extended for the purposes of maintaining residential access and agricultural activities.

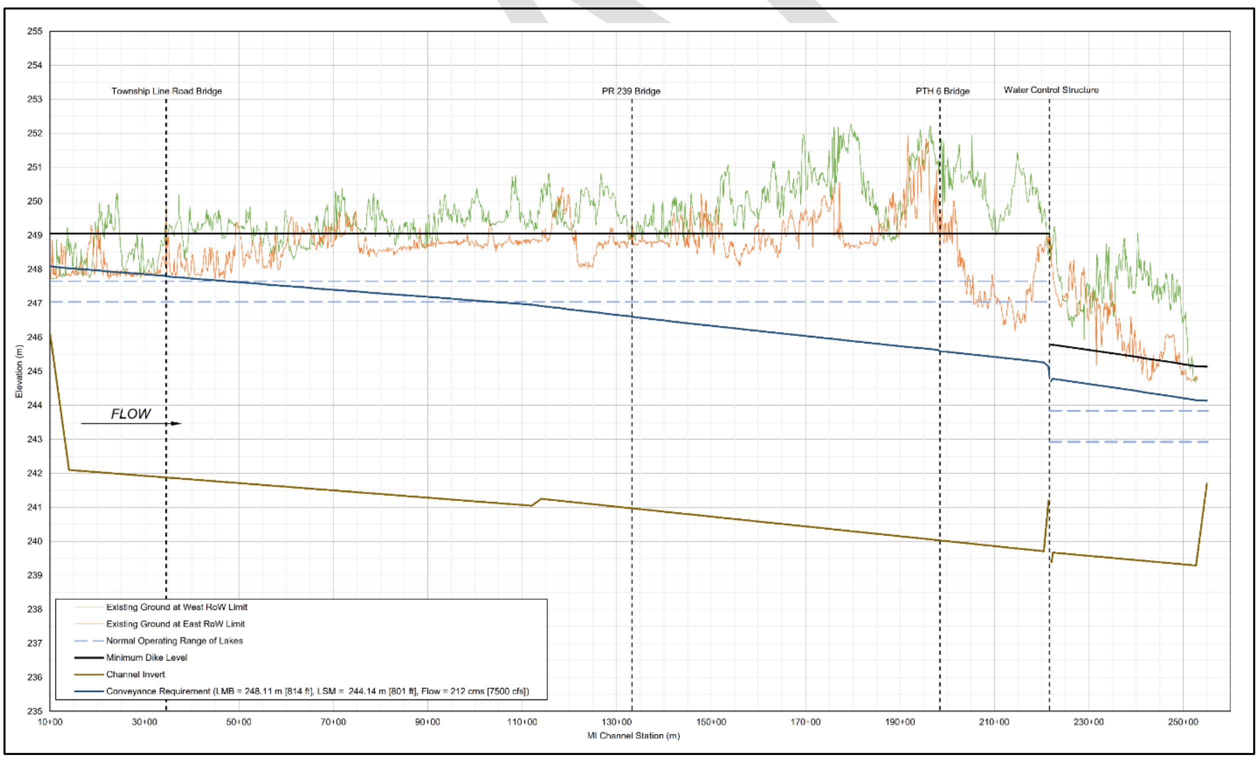
A total of four new bridges are planned to span the LMOC, of which one will be combined with the WCS as described above. The other three will be dedicated multispan bridges, constructed to maintain connectivity along the Township Line Road, realigned PR 239 (currently Carne Ridge Road) and PTH 6.

4.2 LMOC Operation

The LMOC will work in conjunction with the existing Fairford River WCS to regulate water levels on Lake Manitoba as established by the Operating Guidelines prepared for the Project. The LMOC will carry water directly into Lake St. Martin during periods when the water level on Lake Manitoba exceeds el. 247.65 m (812.5 ft), which is the top of its normal operating range.

The hydraulic profile for the LMOC is shown on Figure 3 for the normal operating range of the lakes (when the WCS gates are closed), as well as for the design conveyance condition of 212 m^3/s (7,500 cfs) in the channel with Lake Manitoba at el. 248.11 m (814 ft) and Lake St. Martin at el. 244.14 m (801 ft). Average velocities in the LMOC are expected to range between approximately 0.8 m/s and 1.0 m/s, with locally higher velocities occurring in the vicinity of the bridges and the WCS, during passage of the design conveyance condition.

Figure 3: LMOC Water Surface Profile



The LMOC is designed to be operated under both open water and ice covered conditions. The operation of the LMOC has been simulated by MI for a 103 year period from 1915-2017, based on historic lake levels and inflows. The simulation results indicate that the LMOC would have been used in 36 years over this period and been in operation for approximately 21% of the time on a daily basis.

4.3 Sequence of Construction

A preliminary construction sequencing plan is presently under development for the LMOC and will be provided in the preliminary engineering channel design report once it is complete. A brief high level overview of the general construction methodology is provided below.

4.3.1 Site Preparation

Site preparation will be the first activity to be undertaken, as it must be completed before construction can commence in all other work areas. This will include tree clearing, construction of drainage works, and establishment of bridge detours to facilitate bridge construction. Grubbing will not take place at the same time as tree clearing in order to minimize the risk of promoting the proliferation of invasive weed species, and thus will be part of individual construction contracts.

Tree clearing will be done in the winter months to avoid interference with the nesting window for migratory birds.

Permanent drainage to the west of the channel is needed in order to manage surface water runoff in the area and prevent it from flowing into the construction zones. Overland drainage from the west will be collected in a permanent outside drain located just to the west of the LMOC and routed to Lake Manitoba and Lake St. Martin. This drain will also be used to convey water from local construction dewatering and groundwater depressurization works along the LMOC.

Bridge detours would ideally be put in place during the construction season preceding bridge construction to avoid risk of delays.

4.3.2 Channel

The main consideration in the construction methodology and sequencing for the LMOC is managing the risks associated with basal heave and fracturing of the till aquitard, and/or slope instability, due to the high bedrock piezometric pressures that exist over the entire channel alignment. At present, it is anticipated that an active depressurization system will be used to lower the piezometric level in the vicinity of the LMOC to limit the risk of excavation basal heave during construction.

In order to reduce the required duration of active depressurization pumping, the construction methodology involves completing the channel excavation in several discrete segments that are separated from each other by a narrow natural land barrier (plug). Targeted depressurization pumping would then take place to lower the piezometric level within a particular segment and, once excavation of that segment is complete, thatsegment would be allowed to fill with water to restore weight to the till aquitard and thus no longer require active pumping to address basal heave risks.

Once excavation of each successive segments is complete, the plug that separates them would be removed. This will require flooding of the dry segment so as to equalize the water level on both sides of the plug, and thus prevent excessive erosive forces associated with the inrush of water that would otherwise occur into the dry segment when plug removal commences. Appropriate erosion and sedimentation controls, such as turbidity curtains, would be in place during the plug removal activities. A fish salvage will be required within the isolated area should fish be present.

Channel construction is envisioned to commence from each of the lakes and progress inland. This will allow each successively completed segment to then be opened to the lake, and thus use the lake water to restore weight to the till aquitard. At the upstream end, the work would be sequenced to allow construction activities for the inlet, Township Line Road bridge and the channel segment connecting them to be completed around the same time to allow this area to be opened to Lake Manitoba. Channel excavation segments would then be progressively advanced downstream towards the WCS, with the construction activities for the PR 239 bridge and PTH 6 bridge sequenced such that they are completed around the same time as the channel excavation segments at those locations. A similar strategy would be used at the downstream end of the LMOC where the channel excavation would be advanced from Lake St. Martin upstream towards the WCS. The channel segments around the WCS are likely to be the last sections to be excavated and these cannot be completed until construction of the WCS is complete.

Excavation activities within each segment are expected to advance in stages to further limit the duration of active depressurization pumping required, while managing the risks associated with basal heave and fracturing of the till aquitard. In general, initial excavation of a segment would be advanced to full width down to a level where the risk of basal heave is considered acceptable. This initial excavation would not require any depressurization pumping and thus could take place in either the winter or summer months. The remainder of the excavation within a segment would then be completed to the final geometry with active depressurization pumping in place, and ideally would be completed in the summer months so as to avoid the complications of having to pump and manage water in sub-freezing temperatures.

An alternate construction methodology is also under consideration that would involve limiting active depressurization to the bridges, water control structure, and potentially other discrete areas and accepting some risk of fracturing of the till aquitard. This would require a trench to be sub-cut into the base of the channel (below final grade) that would be backfilled with graded material to act as a filter. The trench would create a controlled path for groundwater seepage, as well as a location to divert and collect water that comes into excavation. This would greatly reduce the amount of depressurization pumping required and in turn, reduce the impacts to the regional groundwater system during construction.

4.3.3 Inlet and Outlet

It is presently assumed that construction of the inlet and outlet works will take place in the wet with the construction area isolated by a double turbidity curtain to prevent or minimize the migration of disturbed sediments into the lake. This work would take place in the summer, between July 1 and September 15, so as to be outside of the restricted spring (April 1 to June 15), summer (May 1 to June 30) and fall (September 15 to April 30) fish spawning windows. A fish salvage program will be required within the isolated area.

Alternate construction methods may also be considered, such as isolating the area with a cofferdam that would be constructed behind a turbidity curtain. In this case, only the construction and removal of the cofferdam would need to take place outside of the restricted spawning windows, however the overall construction time frame and impacted in-water area would be expected to be greater.

4.3.4 Bridges and Water Control Structure

Localized excavation and foundation preparation is required for the construction of the bridges and the WCS. It is expected that these work areas will be isolated from the rest of the channel with natural land plugs. These work areas would be kept small so as to limit the amount of pumping required to facilitate groundwater depressurization requirements and manage surface water runoff within the excavation. For the WCS, it is anticipated that pumping will need to continue for the full duration of its construction.

Detour roads will be established at each of the bridge locations and at the WCS to maintain traffic while those structures are being constructed.

5.0 OVERVIEW OF HYDROGEOLOGIC CONDITIONS

Site geological and hydrogeological information from previous and ongoing studies, were used to develop an understanding of the existing groundwater regime. The data will contribute to the preliminary and detailed design of the LMOC construction and operation depressurization systems and assist in informing and refining mitigation and monitoring programs.

5.1 Site Characterization

The study area lies within the Lake Manitoba and Lake Winnipeg drainage basins. The lakes within the Manitoba lowland collect drainage from the southern portion of the Province, which is directed through Lake Winnipeg into the Nelson River system, and ultimately discharges into Hudson Bay.

The proposed LMOC is located within the Interlake area of the Manitoba lowland physiographic region. The Manitoba lowland is a region of gentle relief situated east of the Manitoba Escarpment. The lowland is underlain by gently southwestward dipping Paleozoic and Mesozoic sediments consisting of carbonate rocks, with minor clastic and argillaceous units. The bedrock is predominantly overlain by tills, proglacial lacustrine sediments, and more recent organic deposits found in low-lying areas. An overview of the regional and local surficial geology is provided in Figure 4.

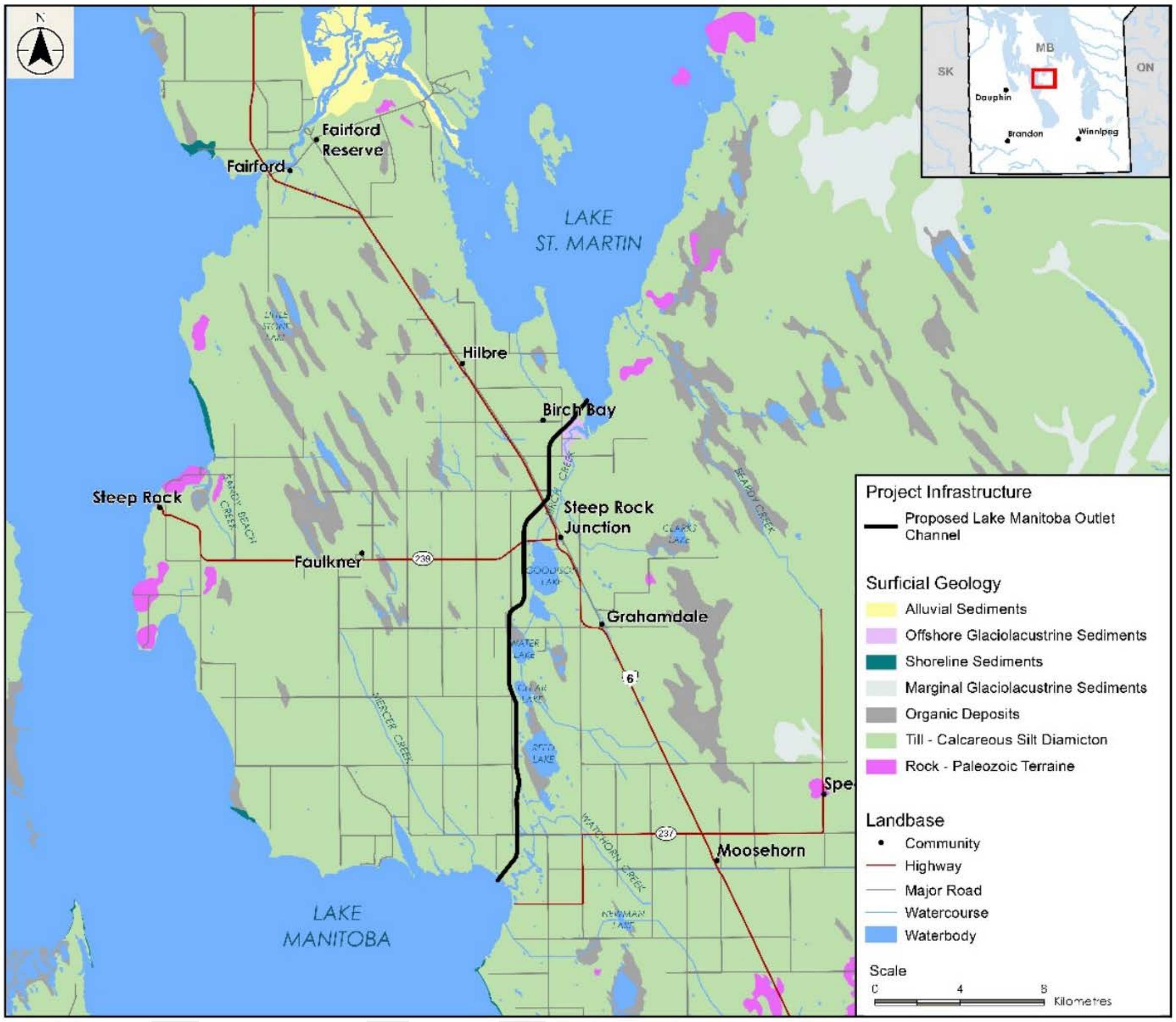
There are few areas of bedrock present near or at the surface, particularly in proximity to the LMOC alignment. Although the aquifer is confined by till along the LMOC alignment, there are recharge areas to the east and west of the Project. Topography in the area is relatively flat, and the terrestrial environment is diverse including agricultural areas, grasslands, forested areas, small lakes and larger regions of wetlands. Regional and local geology of the LMOC region will described in detail in the preliminary engineering report.

The Interlake region features one main aquifer that is associated with the extensive Paleozoic Carbonate Evaporite Unit covering mid Ordovician to Devonian strata (Betcher et. al.,1995). The Carbonate-Evaporite Unit is a thick sequence of Paleozoic carbonates (dolostones and limestones) with minor shales, sandstones and evaporites.

The upper carbonate aquifer has an effective depth of 15-30 m and is described as the most active zone of groundwater movement and storage of the carbonate aquifer (Simpson 1987). Transmissivities in the Interlake area are recorded with considerable variations ranging from <10 m2/day to 10,000 m2/day (Rutulis 1987; Render 1970). The primary recharge area for the aquifer lies in the central part of the Interlake with flow occurring outwards towards Lake Manitoba on the west and Lake Winnipeg on the east (Betcher 1997).

Additional details on regional stratigraphy and groundwater systems are discussed in Section 3.2.

Figure 4: Surficial Geology Within the LMOC Region



5.2 Geologic Units and Aquifers

5.2.1 Site Geological Stratigraphy

A geological model was developed based on subsurface, topography and GIS data. The geological units of the overburden were based on more than 1600 boreholes from previous reports (KGS 2017b), publicly accessible well data from GWDrill that included data from the Groundwater Information Network from 1903 to 2017 (GWDrill 2018), previous investigations by Manitoba Infrastructure (Tetra Tech EBA, 2016), as well as borehole logs from the 2019 field drilling program and hydrogeological field program (Table 1).

Table 1: Sources of Borehole Data used in Geological Model

	Num[illegible] les i[illegible]
GWDrill[a]	1508
Existing Project Related Data[b]	28
2016 Lake Bottom Stratigraphy [c]	9
2019 Team Drilling Program [d]	57

[a] GWDrill 2018, [b] KGS 2017, [c] TetraTech 2016, [d] TREK 2020

A generalized view of the LMOC stratigraphy along the LMOC project (see Figure 1), is provided in Appendix 2A- Plate 1. In general, site stratigraphy consists of five Quaternary overburden units underlain by carbonate bedrock. The chronological order of the lithologies is Peat-Topsoil at the surface, followed by Clay, Upper Sand and Gravel, Till, Lower Sand and Gravel and Bedrock.

Peat-Topsoil

Peat-topsoil was observed at surface along the majority of the LMOC project site. The peat-topsoil is relatively evenly distributed in areas with very low relief as they accumulated in fen, bog, swamp, and marsh settings (Matile, 2004). It is made up of peat and muck deposits in wetland areas and topsoil on fields. Its thickness ranges from <0.1 to 3 m, averaging 0.5 m.

Clay

Clay deposits in the LMOC area are observed at surface in some areas or below the peat-topsoil deposits. Matile (2004) describes the deposits as clay, silt and minor sand, very low relief massive and laminated deposits. These sediments were deposited from suspension in offshore, deep water of glacial Lake Agassiz and commonly sourced and homogenized by icebergs. The thickness of this sediment generally ranges from 1 to 5 m, averaging 2.67 m.

Till

The Quaternary till / glacial diamicton deposits are composed of calcareous silt diamicton and are predominately derived from Paleozoic dolomite and limestone (Matile 2004). They are observed at surface in some areas or below the peat-topsoil, clay and/or upper sand and gravel deposits. Their thickness generally ranges between 1 and 15 m, and averages 8.6 m.

Till was encountered in every historical and recent investigation program. Sand and gravel lenses are present below, within and above the till unit. Parts of the till are overlain by sand and gravel deposits, clay and organic material such as peat and topsoil.

Upper and Lower Sand and Gravel

The upper and lower sand and gravel deposits are represented by preglacial, marginal glaciolacustrine and postglacial shoreline sediments. The glaciolacustrine deposits are composed of sand and gravel, formed by waves at the margin of glacial Lake Agassiz and are found as beach ridges, spits, bars or littoral sand and gravel. The shoreline sediments were formed by waves at the margins of modern Lake St. Martin and Lake Manitoba (Matile 2004). These deposits are observed at surface in some areas or below peat-topsoil and/or the clay deposits in other areas. The lower Sand and Gravel unit represents unconsolidated preglacial sediments lying within or underlying the less permeable till unit and show limited areal distribution (Betcher 1995). These deposits have the potential to host a sand and gravel aquifer at the bedrock-till interface (Betcher 1995).

A few boreholes showed sand and gravel deposits within the till unit, but they had limited thickness and lateral extent. The thicknesses of these sediments vary from 1 to 6 m, averaging 2.5 m for Upper Sand and Gravel. The Lower Sand and Gravel deposits generally range from 1 to 8 m in thickness, averaging 5.5 m thick.

Bedrock

The bedrock in the region consists of sedimentary rocks of Paleozoic age which are primarily carbonates with minor clastics and evaporite sequences. The project area is underlain by fossiliferous dolomite of the Silurian Interlake Group in the northeast and Devonian rocks in the southwest. The Devonian rocks are subdivided into argillaceous dolomite and dolomitic shales of the Ashern Formation in the northeast and mottled limestones of the Elm Point Formation in the southwest. The Devonian Ashern and Elm Point Formations and Silurian Interlake Group underly all of the above-mentioned units and is considered the principal aquifer in the region.

5.2.2 Groundwater Systems - Aquifers and Aquitard

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

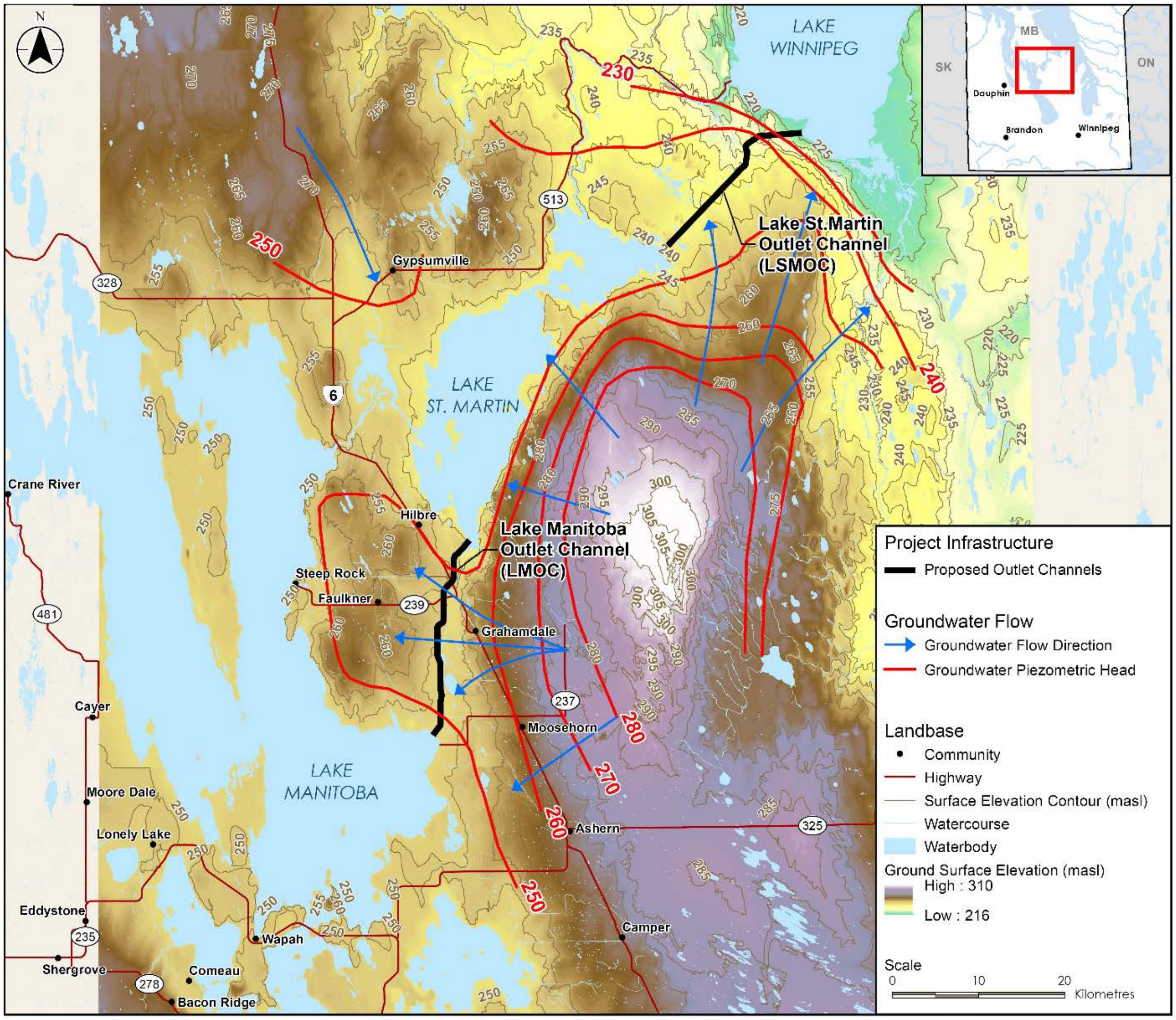
- surficial aquifer - relatively thin, discontinuous, composed of soils, peat and isolated thin sand layers; related to wetlands
- aquitard - undifferentiated till; this is the principal geological component in which the Project will be embedded. Intertill lenses composed of till occur with greater proportions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

The carbonate (bedrock) aquifer is overlain by a till aquitard at the LMOC. The fluted morphology of the till surface is particularly apparent with the distribution of low-lying organic deposits (wetlands) within till troughs. Those wetlands are believed to be fed with water from precipitation trapped within these low-lying depressions.

Domestic and livestock wells are generally fed by the carbonate aquifer in the LMOC area. Livestock wells are often flowing or artesian wells.

A generalized view of groundwater flow and piezometric head conditions in the LMOC area, based on pre-2019 data, is provided in Figure 5. The regional carbonate bedrock aquifer is confined and underlies the LMOC. The carbonate aquifer recharge occurs in the upland areas (Figure 5) under unconfined conditions where bedrock elevations are relatively high, above 280 masl, and sediment cover is thin to non-existent.

Figure 1: Regional Groundwater Flow and Piezometric Head Conditions

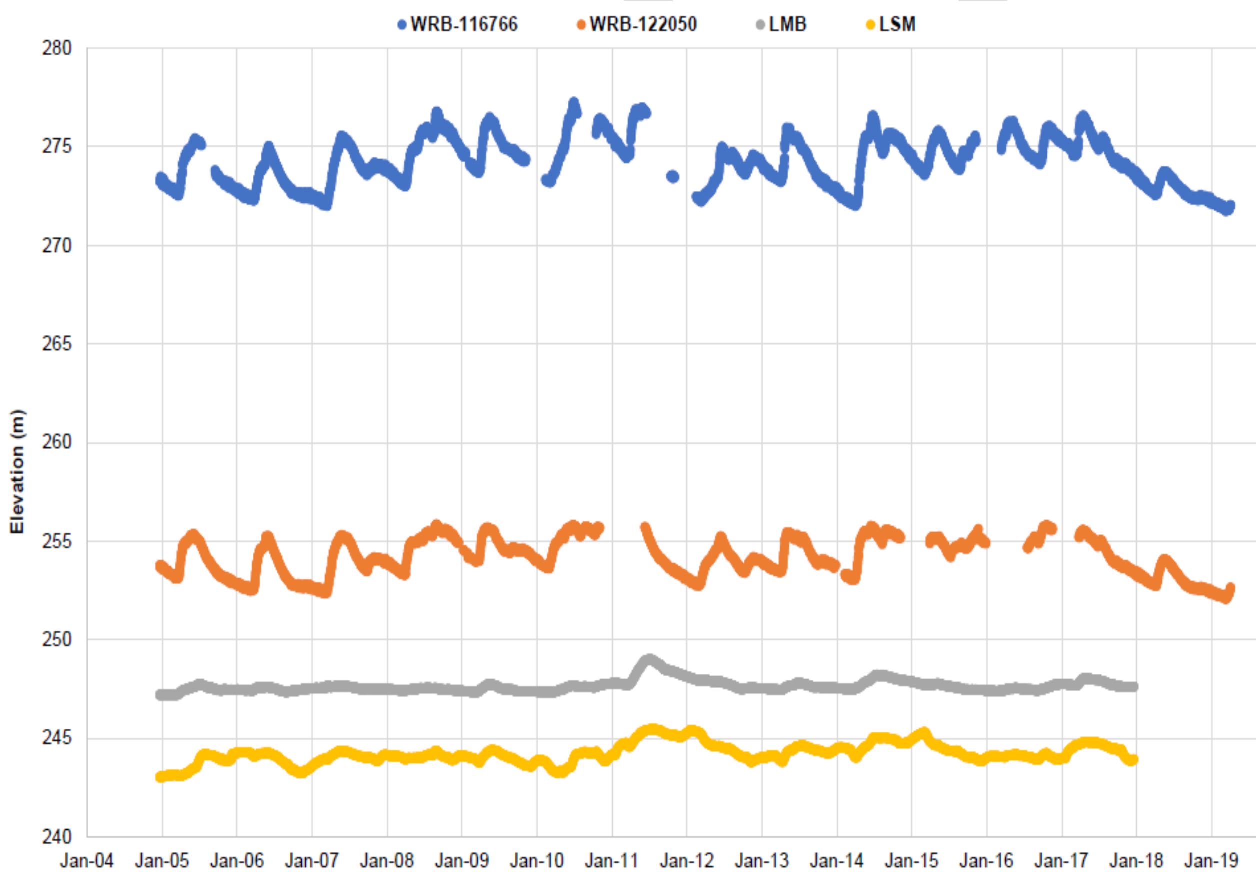


The groundwater flow radiates out from the uplands in all directions towards the major lakes (St. Martin, Manitoba and Winnipeg). In general, the uppermost 10 m of the carbonate bedrock aquifer exhibits some karsticity: this is the most productive horizon of the aquifer. The aquifer likely discharges 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 occur. Discharge occurs under a flowing artesian 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 masl (Figure 3 3), rising after spring snow melt and dropping over the winter, indicating that recharge is occurring in the uplands at elevations above 277 masl.

The carbonate aquifer in the LMOC area 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 masl to 250 masl. The piezometric head in this area, ranging from 249 masl to 255 masl, 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 masl and 256 masl (Figure 6). Typical seasonal piezometric head varies 2.5 m to 3 m per year in the aquifer in the LMOC area. The water levels (elevation) of Lake Manitoba and Lake St. Martin are lower than the groundwater in the area (Figure 6) indicating groundwater flow in the carbonate aquifer would be from the LMOC area towards the lakes. piezometric head varies between 272 and 277 masl (Figure 3 3), rising after spring snow melt and dropping over the winter, indicating that recharge is occurring in the uplands at elevations above 277 masl.

Figure 2: Piezometric Water Elevations in the Carbonate Aquifer and Water Elevations in Lake Manitoba (LMB) and Lake St. Martin (LSM) (2005-2019)



5.3 Baseline Groundwater Monitoring

In 2019, the Hatch Team (Hatch, Stantec and Trek Geotechnical) conducted a number of field programs including: test hole and well installation, instrumentation, pumping tests, groundwater monitoring and water quality sampling. The following sections provide a summary of these programs.

5.3.1 Instrument Installation

Vibrating wires

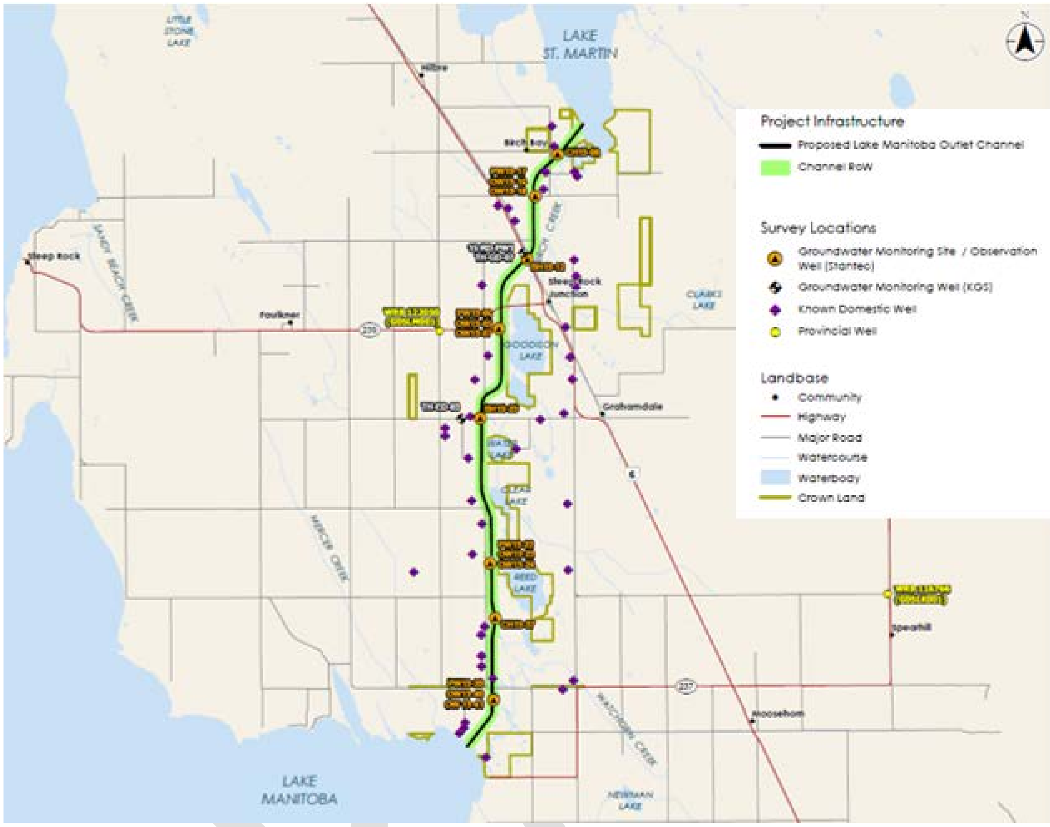
A total of 87 vibrating wire piezometers were installed within various stratigraphic units at 50 drilled test holes along the LMOC alignment. A high-level summary of the vibrating wire instrumentation is as follows:

- Till – 41 installations
- Sand – 7 installations
- Bedrock – 39 installations.

Bedrock Monitoring Wells

Long-term monitoring wells are equipped with transducers to continuously monitor and log groundwater level, electrical conductivity, and temperature data. Pump wells were selected for long-term groundwater level monitoring along with two wells developed in earlier studies (KGS 2017a). Location of groundwater monitoring wells are plotted on Figure 7 as follows: PW19-06, PW19-17, PW19-22, PW19-39, TH-ED-01W (TH-ED-01P), and 15-RD-PW1 (TH-GD-07).

Figure 3: LMOC 2019 Groundwater Level Monitoring and Sampling Locations



5.3.2 Pumping Tests and Calculation of Aquifer Parameters

Pumping test data were analyzed using a 2D analytical approach (AQTESOLV) and a 3-D numerical model (FEFLOW) to determine the hydraulic properties of the aquifer. The details of the pumping test methods and analyses will be provided in the preliminary engineering channel design report once it is complete.

Table 2 shows a summary of the aquifer properties estimation used in the analytical and numerical analyses of the pumping tests. For the analytical solutions where both methods (Cooper-Jacob and Theis (recovery)) were used, the mean of the two values was selected as the hydraulic conductivity. Literature values for maximum and minimum hydraulic conductivity and storativity for fractured bedrock are also shown in Table 2. Different values of the fractured bedrock were selected and applied to the numerical model for calibration.

Table 2: Estimated Fractured Bedrock Hydraulic Properties Using Analytical and Numerical Approach

PW19-17	AQTESOLV	6.60×10^{-6}	----
	FEFLOW	4.05×10^{-6}	1.00×10^{-5}
PW19-06	AQTESOLV	3.11×10^{-5}	1.60×10^{-6}
	FEFLOW	2.13×10^{-5}	1.57×10^{-6}
PW19-22	AQTESOLV	5.93×10^{-5}	2.75×10^{-6}
	FEFLOW	2.90×10^{-5}	1.00×10^{-6}
PW19-39	AQTESOLV	---	---
	FEFLOW	1.50×10^{-5}	1.00×10^{-6}
Literature (Domenico et. al (1990))		1.00×10^{-9} to 1.00×10^{-2}	1.00×10^{-6} to 1.00×10^{-4}

5.3.3 Groundwater Level Monitoring

Groundwater level monitoring was conducted in conjunction with groundwater quality sampling during the 2019 field season. The groundwater monitoring was completed from the north reach of the proposed channel at PW19-17 to the south reach of the proposed channel at PW19-39 in the summer (June 24-28, 2019) and fall (October 2019) field campaigns.

A total of six locations, including four pumping test locations and two long term monitoring wells developed in earlier studies (KGS 2017a), were selected for groundwater level monitoring. Table 3 lists the six monitoring sites used for the 2019 level monitoring program in the LMOC area and the purpose of each well.

Table 3: Summary of Existing and Newly Drilled Groundwater Wells Monitored in 2019

Pumping Test Well ID	Observation Well ID	UTM Easting	UTM Northing	Ground Elevation (masl)	Purpose	Comment
Newly Drilled Wells						
PW19-17		5701488	532294	248.876	Pumping Test; Long Term Level Monitoring	Flowing; Data Logger # C30274
	OW19-16	5701488	532344	248.785	Observation; Long Term Quality Sampling	Flowing
	OW19-18	5701488	532304	248.924	Observation	Flowing
PW19-06		5696645	531018	250.472	Pumping Test; Long Term Level Monitoring	Flowing; Data Logger #C30288
	OW19-05	5696655	531019	250.472	Observation; Long Term Quality Sampling	Flowing
	OW19-07	5696695	531010	250.743	Observation	Flowing
PW19-22		5688122	530695	248.514	Pumping Test; Long Term Level Monitoring	Flowing; Data Logger# C30065
	OW19-23	5688132	530695	248.701	Observation; Long Term Quality Monitoring	Flowing
	OW19-24	5688174	530694	249.171	Observation	Flowing
PW19-39		530823	5683152	247.811	Pumping Test; Long Term Level Monitoring	Flowing; Data Logger# C30351
	OW19-40	530823	5683152	247.909	Observation; Long Term Quality Sampling	Flowing
	OW19-41	530823	5683152	247.844	Observation	Flowing
Existing Wells						
	TH-ED-01W (TH-ED-01P) KGS WELL	530503	5692376	249.49	Long Term Level Monitoring	Groundwater Hydrographs from 2016 to present
	15-RD-PW1 (TH-GD-07) KGS WELL	531900	5699454	252.05	Long Term Level Monitoring	Groundwater Hydrographs from 2017 to present

Methods, data QA/QC and results of the 2019 groundwater level monitoring program will be described in the preliminary engineering report along with baseline groundwater level conditions.

5.3.4 Groundwater Quality Sampling

Existing groundwater quality in the LMOC area was characterized using data collected for the project from 2016 to 2019. The purpose was to:

- develop a preconstruction baseline of the groundwater quality so that changes occurring during or after construction can be identified

- assess the potential effects of groundwater being discharged to the surface during depressurization on surface water quality

In the LMOC area, groundwater quality monitoring to date includes programs conducted between 2016 and 2018 (KGS 2017a, 2017b, 2018) and monitoring completed by the Hatch Team (Stantec) in 2019 as part of the ongoing pre-construction monitoring program. In 2019, groundwater sampling was conducted at 13 sites (BH19-12, BH19-29, CH-19-08, CH19-11, CH19-37, OW19-05, OW19-16, OW19-18, OW19-23, OW19-40, PW19-06, PW19-17, PW19-22; Figure 7).

Results from these programs will establish the baseline groundwater quality conditions in the LMOC area. Reference comparisons to applicable CCME and MWQSOG criteria and assessment process for the Protection of Freshwater Aquatic Life (PAL) were made. Comparisons to HC-CDWQG were also made as the aquifer is a source of drinking water in the LMOC area.

Monitoring indicates that the aquifer currently provides good quality drinking water. The groundwater quality generally meets applicable CCME and MWSQSOG criteria and is comparable to the existing surface water quality in the area with the exception of a few parameters (such as dissolved oxygen).

The range of field chemistry measurements collected during the March and June 2019 baseline monitoring events are summarized in Table 4. Detailed field chemistry measurements and the results of laboratory analysis for all monitoring wells sampled will be provided in the Final Design Report.

Table 4: Range of Baseline Groundwater Field Chemistry Measurements

	Minimum	Maximum
pH	7.2	8.1
Electrical Conductivity (µs/cm)	518.7	784.0
Dissolved Oxygen (mg/L)	0.98	10.80
Oxygen Reduction Potential (mV)	-157.2	127.1

6.0 GROUNDWATER MANAGEMENT

6.1 General Considerations

Groundwater conditions along, and in the vicinity of, the LMOC are complex and driven by the regional groundwater aquifer system in the Interlake (i.e., between Lake Manitoba and Lake Winnipeg). Management of the groundwater conditions is critical for the successful construction and long-term operation of the project as discussed below.

6.1.1 Flowing Artesian Conditions in the Bedrock Aquifer

A confined carbonate bedrock aquifer is present in the LMOC area, which is overlain by 5 m to 18 m of till. Flowing artesian pressures are present in the vicinity of the LMOC, with piezometric heads that can typically be up to 5 m above the ground surface. The bedrock aquifer is recharged via rainfall and snowmelt regionally. Groundwater recharge areas local to the LMOC are from upland areas as well as from local recharge zones to the east and west of the LMOC. Groundwater flow in the carbonate aquifer is interpreted to be from the LMOC area towards Lake Manitoba and Lake St. Martin.

Construction and operation of the LMOC will result in potential changes to the existing groundwater conditions within the till and confined aquifer piezometric pressure conditions along the LMOC between Lake Manitoba and Lake St. Martin. These may include water level (pressure) changes in aquifers and changes in the relationship of the groundwater aquifer discharge to Lake Manitoba and Lake St. Martin.

In areas where the bedrock aquifer pressures are elevated relative to the thickness of the confining till aquitard units, and in particular during channel excavation and unloading of the confining aquitard units, there is a risk of basal heave/hydraulic fracturing of the till. This may induce a connection of the bedrock aquifer to discharge at the base of the excavation, possibly producing some uncontrolled groundwater discharge into the channel.

6.1.2 Groundwater Seepage Into the LMOC

The creation of new groundwater discharge pathways into the LMOC will locally increase the direct connection of exfiltrating groundwater to channel surface water, originating from the underlying bedrock aquifer. Groundwater modeling in the LMOC area is ongoing and will be described further in preliminary design. Groundwater currently flows towards Lake Manitoba and Lake St. Martin under the existing pre-project conditions. Based on the long-term simulations, the operation of the channel (with WCS gates open or closed) will not alter the groundwater flow direction towards the lakes. A fraction of the bedrock groundwater flow that would have otherwise outflowed into the lakes will be captured by the depressurization wells and reverse drain and be transported to the lakes via the LMOC. The regional groundwater flow direction will remain consistent; although, the gradients and velocity may be locally increased by the project depressurization. Further analyses and details will be provided during preliminary design.

6.1.3 Groundwater Level and Quality Changes to Groundwater Supply Wells

The impact of depressurization on the surrounding groundwater regime will be monitored, as identified in Section 8.0, and assessed to inform the implementation of mitigation measures and adaptive management strategies.

Groundwater Quality

The key mitigation to protect groundwater quality in the LMOC area was siting the LMOC to take advantage of local artesian conditions and reduce the risk of surface water influences on groundwater quality. While construction and operation of the LMOC will require depressurization of the aquifer to reduce the risk of slope failure and basal heave, the bedrock aquifer in the LMOC area will remain under positive pressure and groundwater will continue to flow upwards from the aquifer during LMOC construction and operation. Regular monitoring of the aquifer in the region will be conducted during, and post-construction.

Effects and Mitigation for Domestic and Livestock Wells

The LMOC is located on the west side of Birch Creek valley. The piezometric head in this area, ranging from 249 masl to 255 masl, is up to 5 m above ground level and the bedrock aquifer is entirely saturated. The high artesian pressures continue across the Birch Creek valley for 5-7 km to the east of the LMOC and, as the ground elevation is lower along Birch Creek, the existing artesian head may be 8 to 10 m above ground in these areas.

Currently the groundwater aquifer is recharged in the uplands between Lake Manitoba and Lake Winnipeg (or in recharge areas away from the channel) and discharges into Lake Manitoba and Lake St. Martin. With the construction dewatering and long-term depressurization in place, the aquifer will continue to recharge in the same areas, feed the domestic and livestock wells in the area (although at a reduced pressure), and discharge to both Lake Manitoba and Lake St Martin either directly or via the LMOC.

In all areas along the channel and for several kilometers to each side, the pressure head will remain above the bedrock. As all registered wells in the LMOC area for domestic or livestock consumption draw from the bedrock aquifer, the static groundwater elevation in the wells will remain above the bedrock well bottom. This will allow the well to continue to supply water as long as the well is pumped and the pump intake is placed low enough in the well. If the pump intake is not low enough, or the well capacity is insufficient, the well operation may be impaired, and mitigation would be necessary.

The construction and long-term depressurization system planned for the LMOC will reduce the groundwater pressure head in the LMOC area. Throughout the Birch Creek valley area where flowing artesian wells exist (5-7 km east of the LMOC), the artesian pressure will be reduced, and in most of this area flowing artesian pressure will be lost. This will have a direct effect on artesian-dependent well operation and some wells will not operate without pumping.

Mitigation measures to be implemented may include:

- Domestic wells
  - Short term: Provide water tanks or other alternate supply to affected well users until long term solutions can be put in place.
  - Long-term:
    - Lower existing pump intake if feasible
    - Supply new pumps
    - Drill new wells or extend existing well
- Artesian livestock wells
  - Short-term (during construction): Transfer water from construction dewatering or depressurization wells to dugouts by pipe or truck.
  - Long-term: Supply pumps for these wells, similar to domestic wells.

Implementing the mitigation measures will involve working with affected well users on a case by case basis. A database of information on local wells including location, elevation, depth, and the type of operation (pumped or artesian) is under development. The well information will be compared to model-predicted groundwater drawdown results to identify and contact potentially affected landowners to confirm appropriate mitigation measures.

Additional observation wells will be installed prior to construction depressurization to monitor the effects in the area during dewatering of each section during construction. Mitigation measures may be modified during the depressurization to respond to the site-specific data from observation wells and local well users.

6.1.4 Effects on Wetlands

There is no direct evidence that the small lakes and wetlands along Birch Creek, to the east of the LMOC, are fed by artesian springs. Therefore, it is not expected that the water balance of the small lakes and wetlands will be affected directly by groundwater depressurization. However, they will be affected by the Project as the LMOC will intercept the drainage in the Birch Creek watershed to the west of the LMOC. This will cause a reduction in flow through the wetland as discussed in the Surface Water Management Plan (SWMP). During low flow conditions, water levels may be reduced beyond previous natural seasonal variations in these waterbodies. To mitigate this effect, consideration will be given to diverting flows from groundwater depressurization into these waterbodies to supplement flows during low flow conditions.

6.2 Design Considerations

The effect of hydrogeologic conditions on construction and long-term operation of the LMOC is being considered in its design. In particular, the bedrock aquifer pressure head will be reduced to a target level (which will vary along the LMOC alignment) to meet geotechnical design constraints for channel slope stability and basal heave. More detail regarding these design considerations will be provided in the preliminary engineering channel design report once it is complete.

6.3 Aquifer Depressurization During Construction

6.3.1 Overview

A construction sequencing plan is under development for the preliminary design of the LMOC. This construction plan will require temporary bedrock depressurization at construction locations specific to each construction contract. Because depressurization requirements for one contract area have the potential to influence another, the timing of a group of construction contracts needs to be considered in order to optimize the depressurization plan. Accordingly, active aquifer depressurization plans will be developed for each year of construction, which will involve the installation of temporary depressurization wells near the construction area perimeter(s) to reduce groundwater pressure to the required targets. Groundwater quality will be monitored and mitigated as required prior to discharge to surface (See Section 8.2). Mitigation for local area wells is discussed in Section 8.1.3.2.

As the channel is built, the long-term (operation) depressurization measures (Section 7.4) for the section of the channel under construction will be installed. Therefore, the long-term (post-construction) and short-term (construction) depressurization effects will need to be considered. Also, mitigation measures for domestic or livestock wells (i.e. pumping or drilling new wells as required) during construction (see Section 8.1.3.2) may need to remain in place for the long-term.

6.3.2 LMOC depressurization

Preliminary design work related to the depressurization measures that are required during construction of the LMOC is ongoing. In general, these measures are expected to consist of the installation of temporary wells that will be actively pumped during construction of the LMOC and its associated structures to protect against uncontrolled groundwater discharge and basal heave in open excavations. More detail regarding depressurization measures for construction of the LMOC will be provided in the preliminary engineering channel design report once it is complete.

The Contractor will be responsible for developing a construction depressurization system to achieve the design requirements and other specifications listed in the tender. Activities to be conducted by the Contractor may include:

- Design and location of drilling and testing programs to further define aquifer conditions. Analysis of associated pump test results (in consultation with the Contract Administrator).
- Development of pumping system configuration for required combined total pump flow rate and individual flow rates, and discharge water requirements and associated handling of discharge groundwater (in consultation with the Contract Administrator).
- Development of a groundwater depressurization plan to be approved by the Contract Administrator.
- Supply, installation and testing of bedrock pumping wells and associated observation wells according to types, sizes, materials and construction specifications, as required in the tender documents or otherwise approved by the Contract Administrator for the WCS.

- Supply, installation and testing and commissioning of a bedrock groundwater depressurization pumping system at the WCS, including such items as pumps, power supply, drop piping, wellhead connections, well system header discharge piping, well caps and flow meters.
- Bedrock groundwater depressurization system operation including preparation of discharge area for erosion control and aeration at discharge header outlet.
- On-site monitoring (flow and water levels) in the area of work.

In addition, to monitoring the environmental effects of the construction phase depressurization program, the Resident Contract Administrator will conduct the following activities:

- Oversight and verification of Contractor monitoring in work area.
- Water quality testing of the WCS depressurization system pump discharge water during pump test and depressurization operations.
- Regional monitoring of groundwater elevations.

6.3.3 Well Decommissioning

Temporary depressurization wells required during construction, may be decommissioned as part of the construction contracts or maintained for future use in long-term monitoring programs.

6.4 Operations Aquifer Depressurization

6.4.1 Design of Operation Depressurization Plan

Aquifer depressurization is also required to reduce the risk of post-construction basal heave and slope instability within the channel. A long-term target level for pressure head is being developed that meets these requirements while reducing impacts to the regional groundwater system.

To depressurize the bedrock aquifer along the LMOC a hydraulic connection to the surface is required. Two depressurization options are being investigated in preliminary design:

- Depressurization wells
- Depressurization reverse drains

Depressurization Wells

Depressurization wells will be placed along the LMOC with each well releasing groundwater from the confined aquifer (thereby reducing aquifer pressure) into the channel. These wells would remain under artesian pressure and therefore flow upward year-round. These wells will act as a discharge zone for the aquifer. As a result, a portion of the aquifer water, currently discharging into Lake Manitoba or Lake St. Martin continuously, will be discharged to the LMOC through these wells. The positive pressure in the aquifer depressurization wells would protect against aquifer contamination.

Depressurization Reverse Drains

In some reaches of the LMOC the excavation of the channel will intersect the bedrock directly (i.e. at the water control structure) or only a relativity thin layer of till will remain between the channel invert and the top of bedrock. In these areas pressure relief can be effectively provided by excavating to the bedrock and infilling with coarse material. The material will act as a cover and provide the higher hydraulic conductivity required to allow water to flow upward from the bedrock aquifer. This will provide the passive depressurization along, and perpendicular to, the channel.

As with the depressurization wells, the reverse drains along the channel will flow year-round under positive pressure. The reverse drain would not pose a threat of contaminating the aquifer as they will be installed in aquifer discharge zone(s) not recharge zone(s).

6.4.2 Operations and Maintenance Plan

An operations and maintenance plan will be developed for groundwater management components such as monitoring wells and depressurization works as part of long-term operations and maintenance activities.

7.0 MONITORING

Groundwater monitoring will be conducted over three phases of the LMOC project.

7.1 Pre-Construction Monitoring

Additional geotechnical and groundwater monitoring activities will occur during the preliminary and detailed design phase of the project in order to finalize the engineering design prior to project tendering and construction. These activities include monitoring of existing instrumentation and further drilling investigations to confirm the presence and thickness of inter-till sands and depths to bedrock at select locations.

Additional monitoring activities beyond these events may be conducted as design progresses. The details of all pre-construction monitoring will be reported in annual monitoring reports.

Continuous level monitoring gauges will be maintained, and new wells will be developed as required for construction depressurization monitoring. Continued monitoring of groundwater level and quality at existing and new sites will be undertaken during spring, summer and fall with reporting completed annually.

Groundwater monitoring in the LMOC area will generally be conducted quarterly between spring and fall prior to, during, and following construction. In 2019 groundwater quality and/or levels were monitored in conjunction with geotechnical testing conducted for the LMOC preliminary design at four existing wells and 12 new well locations along the LMOC route. Collected samples were analyzed for parameters listed in Table 5. to describe baseline groundwater quality conditions.

Table 5: Groundwater Quality Parameters Included in Pre-Construction Monitoring Program

Field Monitoring	temperature, pH, electrical conductivity, dissolved oxygen, oxygen reduction potential,
Potable Water	electrical conductivity, hardness, pH, total dissolved solids, turbidity, alkalinity, bicarbonate, carbonate, fluoride, hydroxide, nitrate and nitrite (as Nitrogen), nitrate (as Nitrogen), nitrite (as Nitrogen), sulfate
Dissolved Metals	aluminum, antimony, arsenic, barium, beryllium, bismuth, boron, cadmium, calcium, cesium, chromium, cobalt, copper, iron, lead, lithium, magnesium, manganese, molybdenum, nickel, phosphorus, potassium, rubidium, selenium, silicon, silver, sodium, strontium, sulfur, tellurium, thallium, thorium, tin, titanium, tungsten, uranium, vanadium, zinc, zirconium
BTEX and Petroleum Hydrocarbons	Benzene, Toluene, Ethylbenzene, Xylenes, and Hydrocarbon Fractions
Microbiological	*E.Coli*, total coliforms

Construction works will interfere with existing pre-construction monitoring wells. These wells will be either decommissioned or replaced/relocated, if required, to enable continued collection of water quality and level (head) data during construction and operation phases.

The specific details of the monitoring plan will be worked out during detailed design prior to construction with consideration of input from local affected landowners. Results of the updated modelling will be used to inform and adapt the monitoring program and mitigation measures as outlined in the GWMP. Objectives of the groundwater monitoring program are discussed below:

- Continued monitoring of groundwater levels and quality near the Project.
- Groundwater quality and elevation monitoring locations will be located within the right of way (or at a re-established location) near the project.
- Monitoring of groundwater levels and quality away from the Project near local well users.
- Locations and numbers of wells will be determined based on model predictions and in discussion with landowners. These wells will monitor water quality and/or pressure head.
- Monitoring of groundwater levels (head) near the wetlands along Birch Creek in the bedrock and in the till.
- Locations and numbers of wells will be determined based on model predictions.
- Monitoring of groundwater quality in select domestic wells

Groundwater quality will be monitored in select domestic wells based on location and proximity to the project as part of the ongoing domestic well monitoring program.

7.2 Construction Monitoring

Groundwater levels will be monitored and results used to modify depressurization activities and adapt mitigation measures through interactions with landowners and dewatering contractor as required during construction. Continuous level monitoring gauges will be maintained, and groundwater quality monitoring will continue annually in spring, summer and fall during construction with reporting completed annually.

7.3 Operations Groundwater Monitoring

Operations groundwater monitoring is currently planned as follows:

Post-construction phase – Continuous level monitoring gauges will be maintained, and groundwater quality monitoring will continue three times per year frequency for spring, summer and fall for at least two years. Annual reporting of results will be developed.

Collection of groundwater quality samples and groundwater level measurements at previously established baseline sites will continue following construction of the LMOC. This monitoring will initially be carried out during the first two years post-construction; however, the duration may be extended depending on the monitoring results, environmental conditions present, success of revegetation and the frequency of use of the LMOC.

The frequency and locations of the groundwater quality monitoring conducted during the operation phase will be based on specific environmental conditions present and may be adjusted based on the monitoring results. Operation phase water quality monitoring parameters are expected to be consistent with those monitored for during the pre-construction phase, as summarized in Section 8.1.

8.0 ADAPTIVE MANAGEMENT AND FOLLOW-UP

8.1 General

A follow up process is a form of adaptive management to improve practices by learning about their effects and then making changes in those practices as new information is available. The federal Impact Assessment Act defines a follow up program as "a program for verifying the accuracy of the impact assessment of a designated project and determining the effectiveness of any mitigation measures." An associated Operational Policy Statement (https://www.canada.ca/content/dam/iaac-acei/documents/ops/ops-follow-up-programs-2011.pdf) indicated that "a follow-up program is used to:

- verify predictions of environmental effects identified in the environmental assessment
- determine the effectiveness of mitigation measures in order to modify or implement new measures where required
- support the implementation of adaptive management measures to address previously unanticipated adverse environmental effects
- provide information on environmental effects and mitigation that can be used to improve and/or support future environmental assessments including cumulative environmental effects assessments, and
- support environmental management systems used to manage the environmental effects of projects."

In the context of groundwater management for this project the design will be implemented while managing risks with monitoring, as generally described in Section 8.1. As described in Section 12.4.1.1 of the EIS, the objective of the groundwater follow-up and monitoring program is to determine whether there are changes to the volume and accessibility or quality of the groundwater in the groundwater LAA as a result of construction or operations and update and implement mitigation measures and responses accordingly. The predicted residual effects during construction and operation of the Project include a change in local groundwater flow due to dewatering operations, and a change in groundwater–surface water interaction due to surficial drainage diversion and bedrock aquifer depressurization. The monitoring and analysis program will provide information to better predict and quantify potential effects and confirm which locations of the groundwater LAA should be further monitored during aquifer depressurization. Domestic water wells, because of their purpose, will be monitored for their quality. Knowledge obtained from field performance will be used to modify programs as necessary as construction progresses. Any proposed changes to the GWMP and monitoring as part of adaptive management would be discussed with MI and Manitoba Conservation and Climate as necessary and documented.

8.2 Follow up Response

Follow up response will be designed based on the groundwater effects predicted from depressurization during preliminary and detailed design. The range of management threshold for each monitoring well will be based on baseline data and model predictions, dependent upon location and depressurization stage.

Monitoring programs implemented for the Project will produce data that will be assessed to evaluate environmental impact. Based on the results, changes in the monitoring program locations, analysis parameters or frequency may be warranted. The monitoring program will be designed with this flexibility in mind.

If monitoring programs indicate effects in excess of the management threshold ranges (to be established) then the pumping rates and locations may be reduced/increased to modify the effects and monitored via the monitoring program to determine the need for additional adaptive management measures. Other mitigation measures may be developed based on further investigation and monitoring data collected during the project construction.

There will be active feedback during depressurization programs as monitoring data is collected to verify that required drawdown is properly achieved in the work area. Pumping rates will be adjusted or additional wells will be installed to maintain that drawdown locally while attempting to reduce off-site drawdown. Adjustments to the pumping rates may be made over time as well.

Construction methods will be modified as required to achieve the goals of the channel excavation process in providing controlled groundwater pressure relief.

9.0 CONTINGENCY MEASURES AND EMERGENCY RESPONSE

Contingency measures and emergency response will be included for unforeseen events or circumstances related to groundwater in various planning documents for the program. These will be developed and finalized prior to construction.

Groundwater Depressurization Plan – The Groundwater depressurization plan will include contingency measures for loss of power during depressurization and will include provisions to increase pumping rates if possible or longer-term measures such as additional wells to provide additional depressurization if needed.

Health and Safety Plan – The health and safety plan for the project and individual contractors must address all hazards associated with channel and deeper excavations where uncontrolled discharge of groundwater may occur in an emergency situation.

Construction Environmental Management Program – The CEMP will provide specific measures to address the potential contamination of groundwater from hazardous materials and waste, including materials and waste management and emergency spill response and reporting procedures. [MI TO CONFIRM THIS IS APPLICABLE]

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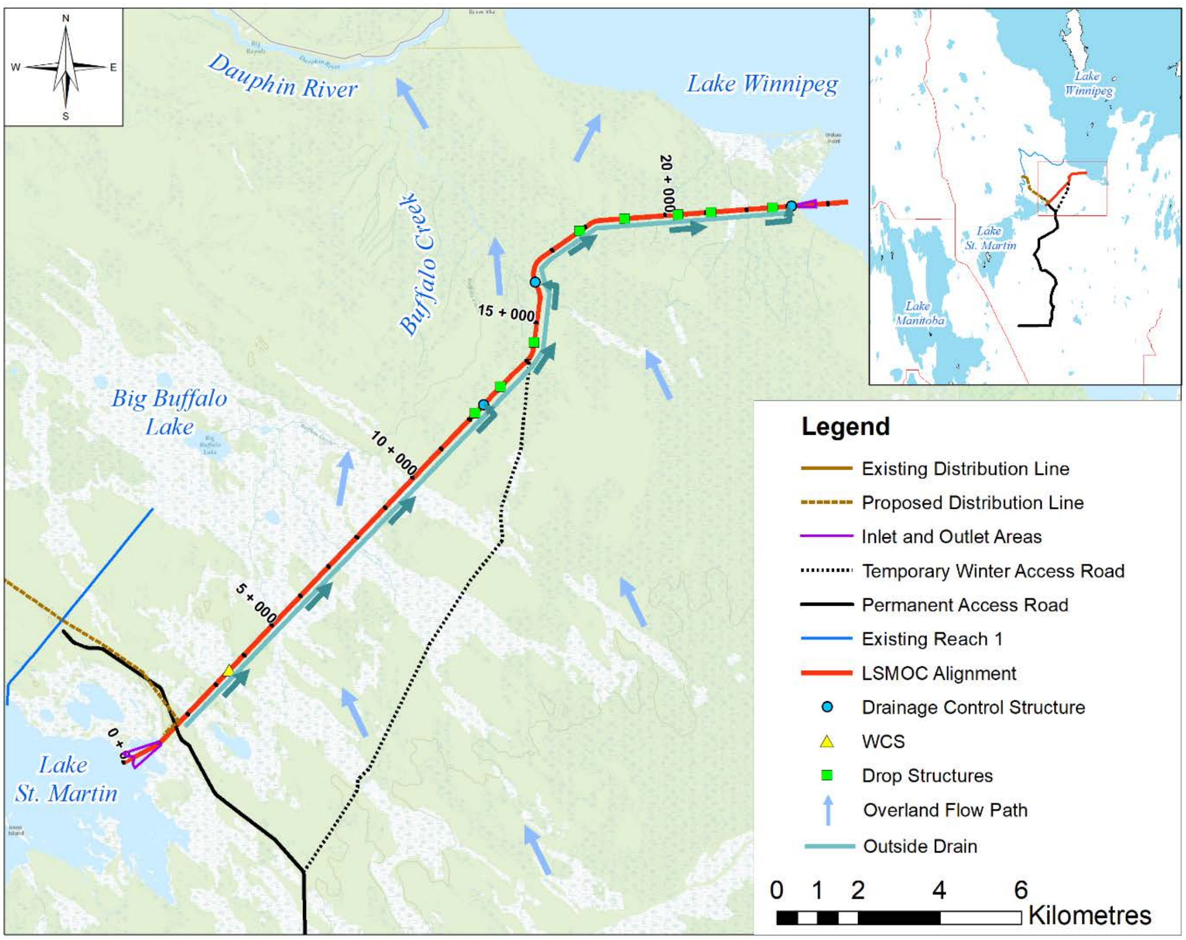
Part 3: Lake St. Martin Outlet Channel

11.0 PROJECT INFORMATION

11.1 Project Description

The LSMOC Project consists of an approximately 23 km long outlet channel, with the inlet positioned at the east end of the north basin of Lake St. Martin and outlet south of Willow Point on Sturgeon Bay of Lake Winnipeg. A plan showing the LSMOC and key project infrastructure is provided in Figure 8.

Figure 8: Overview Plan of the LSMOC



The LSMOC will have a capacity of 326 m3/s at a Lake St. Martin south basin water elevation of 244.14 m and will be designed to convey flows up to the Inflow Design Flood (IDF), considering the intent of the Canadian Dam Association (CDA) Dam Safety Guidelines. A 1:1000 year flood event has been assumed for the IDF and will be updated at detailed design based on the results of a detailed dam safety classification and dam breach assessment.

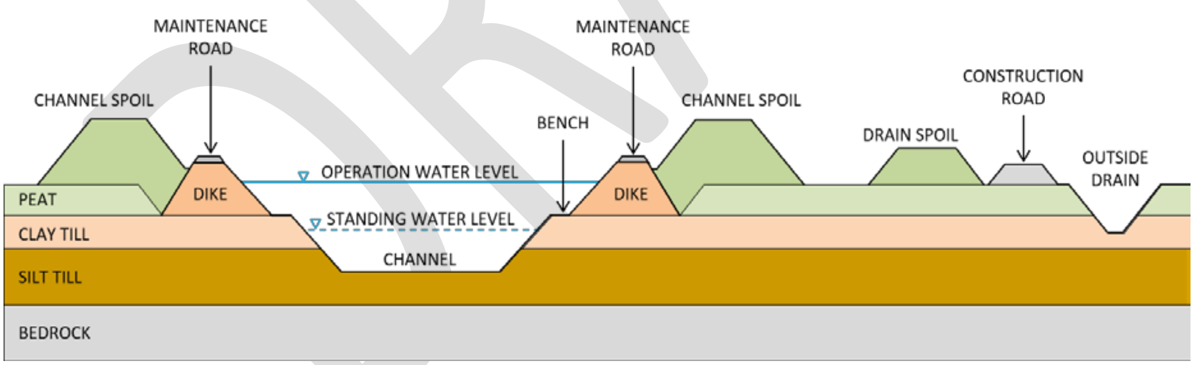
The proposed channel will have an invert elevation (El.) of approximately El. 241 m at Lake St. Martin and approximately El. 213 m at Lake Winnipeg and is designed to limit erosion. The design is based on a trapezoid shaped channel with a flat base approximately 42 m wide, 6 to 8 m depth and 4H:1V to 4.5H:1V side slopes. The hydraulic profile of the channel will require the lake bottoms to be excavated at the channel inlet and outlets to match proposed channel invert elevations. The excavations will be tapered over a short distance out from shoreline to meet natural lake bed elevations.

Permanent water retaining dikes will be located on both sides of the excavated channel to contain design flows within the LSMOC and to isolate the surface water and the upper saturated perched peat system from the excavated channel. Spoil piles for the excavated material will be located outside of the channel dikes.

An outside drain will be constructed on the east side of the project to intercept the surface water runoff flowing towards the LSMOC. The design of the outside drain is described in more detail in the SWMP.

Access for long term maintenance and inspection will be available via maintenance roads located on top of the dikes on both sides of the LSMOC for the entire 23 km. A typical cross section for the LSMOC is provided in Figure 9.

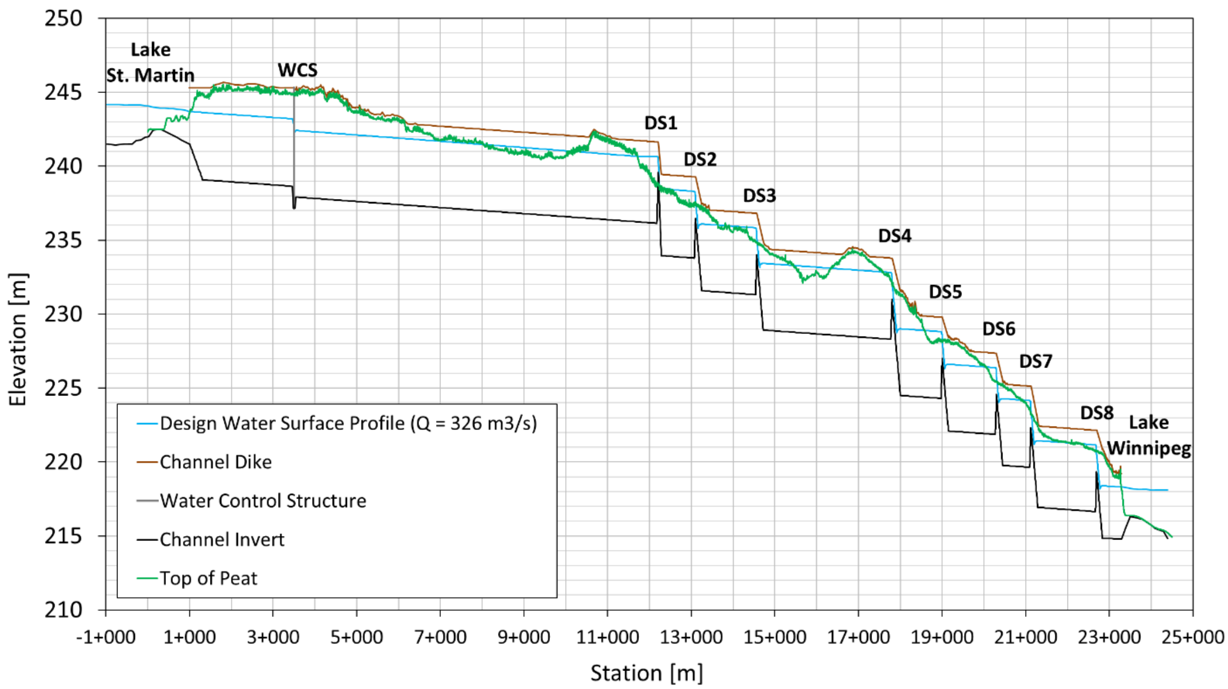
Figure 9: Typical Cross Section



A water control structure is required to control flows through the LSMOC while ensuring that Lake St. Martin water levels remain within their planned range. The control structure will be constructed near the inlet, although the exact location of the structure will be confirmed at Detailed Design, as described in the Preliminary Design Report. It will also act as a bridge to provide access to both sides of the channel. The water control structure will be a concrete structure with sluice bays, guides and sill beams for upstream stoplogs, vertical lift gates and downstream stoplogs.

As shown on the hydraulic profile in Figure 10, the LSMOC will require approximately 8 drop structures to minimize channel flow velocity and erosion in areas of steep sloping terrain. The drop structures will be constructed of rockfill, with a sheet pile cutoff at the upstream crest. When the water control structure gates are closed, a minimum one metre depth of water will be maintained in the channel to minimize the growth of aquatic vegetation. Near the drop structures, the minimum water depth during non-operation will be at least 2.0 m to maintain a pool of water below the surface ice cover during the winter, to minimize potential impacts to aquatic habitat (fish). A base flow will be provided through the water control structure to maintain appropriate water quality conditions (oxygen levels).

Figure 10: Hydraulic Profile of the LSMOC



11.2 LSMOC Operation

The LSMOC will be operated to help maintain water levels in the south basin of Lake St. Martin within the target regulation range of 242.9 - 243.8 m. Table 6 summarizes the range of water levels in the south basin of Lake St. Martin for different return periods and corresponding flows in the channel.

Table 6: Range in Lake St. Martin Water Levels and LSMOC Flows

1:4 year	243.84	251
1:10 year	243.98	290
1:35 year	244.14	326
1:100 year	244.40	367
1:200 year	244.59	395
1:300 year	244.72	413
(2011 Flood of Record)		
1:1000 year	245.06	460

The corresponding water level in the north basin of Lake St. Martin will be lower due to headlosses through the narrow channel which separates the basins. Additional analyses to quantify the headloss through the narrows and document water levels in the north basin are ongoing and will be incorporated at Detailed Design.

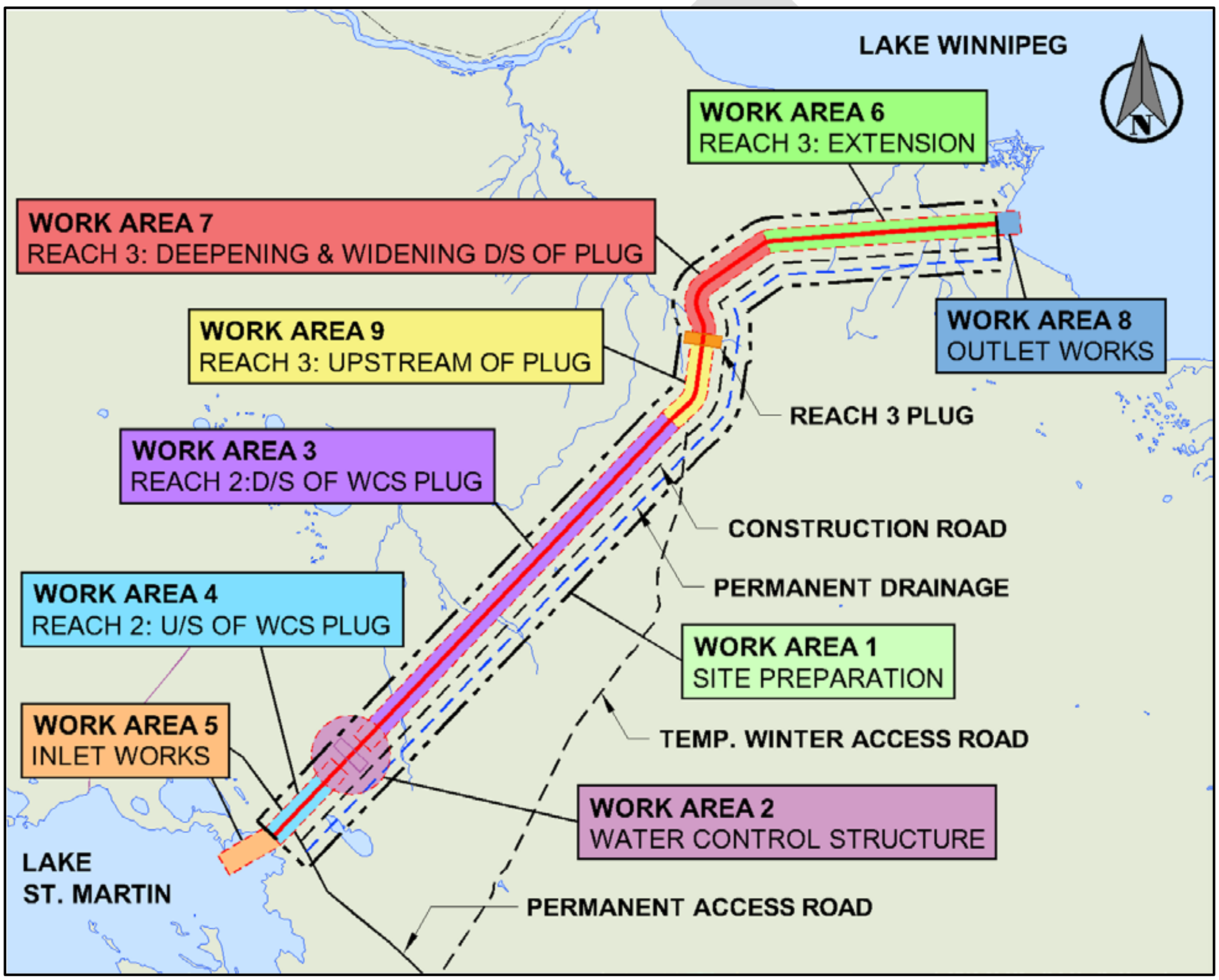
The LSMOC is designed to be operated in both open water and ice covered conditions. Based on historic lake levels and inflows, MI has simulated the operation of the LSMOC for the 103 year period from 1915-2018. Results indicate that the LSMOC would have been operated approximately 22% of the time, or operated in 38 years of the 103 year period. The average duration of operation was approximately one year and the average discharge in the channel during periods of operation was 130 m3/s.

11.3 Sequence of Construction

A preliminary construction sequencing plan has been developed for the project as part of Preliminary Design and is described in the Preliminary Design Report. A summary has been included below as it provides a basis for developing the GWMP for the construction phase of the project.

The project is subdivided into the nine work areas shown on Figure 11. The work areas were numbered considering the preliminary sequencing plan.

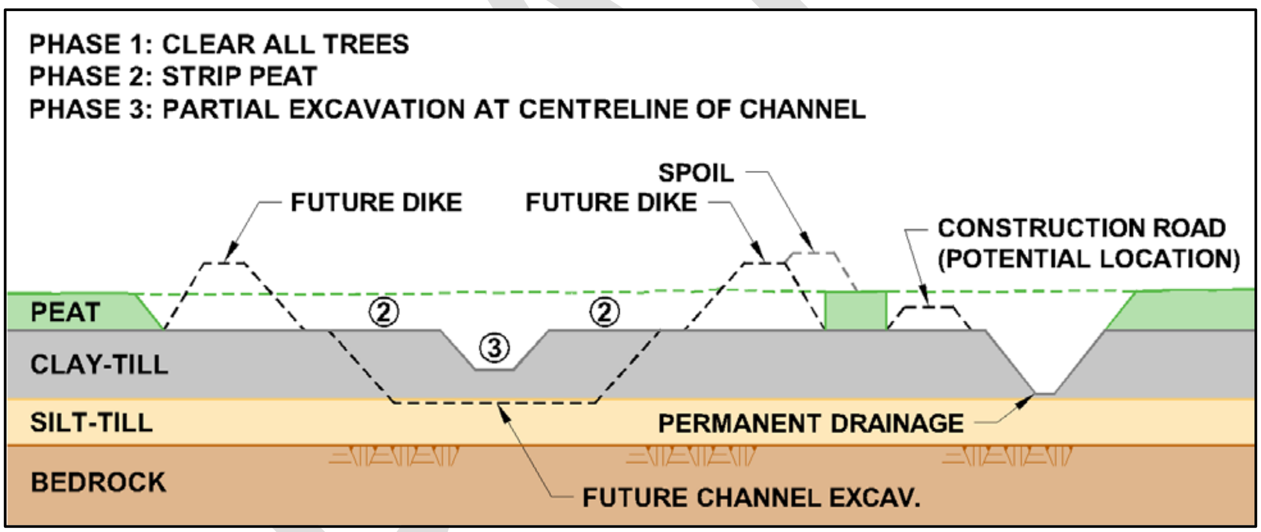
Figure 11: Overview of Work Areas for Construction



Work Area 1 – Site Preparation and Peat Excavation, must be tendered first. It is a critical path activity to be undertaken before construction can begin in the other work areas. Tree clearing, peat excavation, and construction access road development is best done in the winter months allowing for access over the peatland, simplifying water management requirements, and avoiding interference with the nesting window for migratory birds. It is important to construct permanent drainage to the east of the channel and excavate the peat within the channel/dike footprint early in construction to reduce (but not eliminate) surface water runoff and groundwater seepage into the work area, as well as to promote drainage within the channel construction limits thus improving access to the underlying mineral soils for subsequent excavations within other project earthworks contracts. Overland drainage from the east side will be collected in the permanent drainage ditch and routed towards Buffalo Creek during construction.

A partial pilot ditch along the centerline of the channel (within the mineral soil) is proposed to collect and drain seepage/surface runoff entering the excavation area during construction, particularly in Reach 2 and the Reach 3 Extension where there is currently no existing excavation. This will improve drainage of the materials underlying peat and promote better access conditions for the subsequent earthworks contracts. Figure 12 shows the assumed construction sequencing for Work Area 1.

Figure 12: Construction Sequencing for Work Area 1



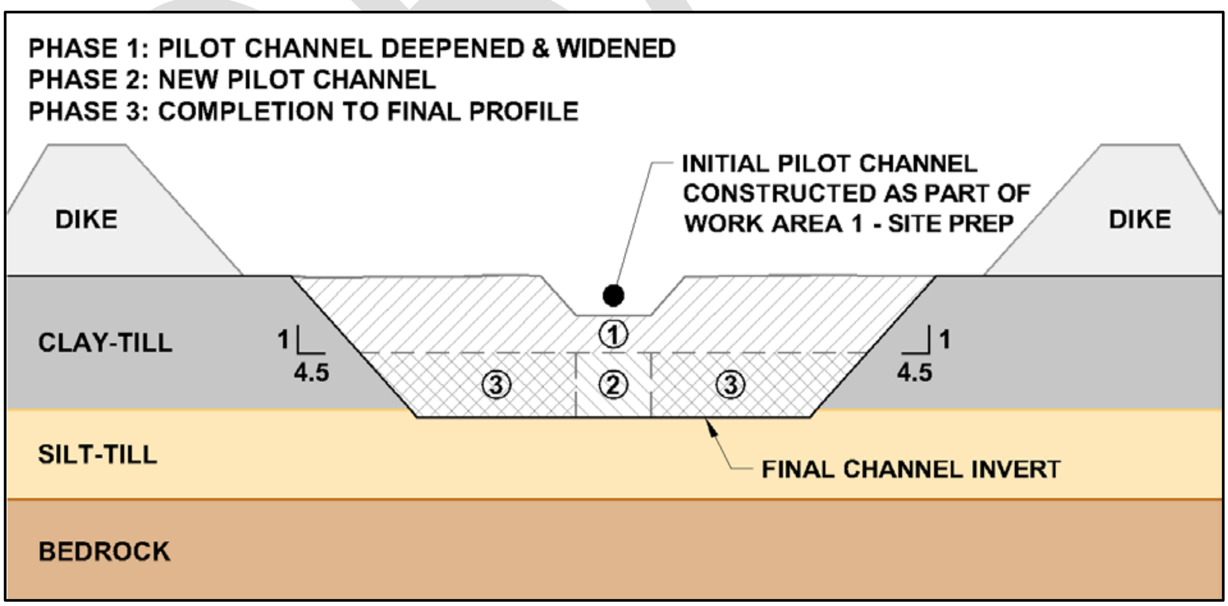
Work Area 2 - The Water Control Structure, will likely be tendered as a stand-alone contract due to the unique scope of work included. Localized excavation and foundation bedrock preparation are required for construction of the WCS. Due to high bedrock piezometric pressures (at times artesian) within the bedrock aquifer in this area, an active depressurization system will be required to limit the risk of excavation basal heave during excavations and to control, monitor and dewater the work area once the bedrock is exposed in the excavation, and as it is being prepared for the construction of the WCS.

Work Areas 3 to 9 - The remaining work areas (3 to 9) could be tendered separately, or in different combinations based on contractor capabilities and consideration of the increased complexity of managing multiple contracts.

Earthwork activities are planned to start at the downstream end of each construction reach, gradually progressing up the channel, to promote gravity drainage of the work areas. The existing plug in Reach 3 will facilitate the isolation of Work Areas 6, 7 and 8 from Work Areas 3 and 9 to help manage surface water and groundwater drainage during construction. The existing plug in Reach 3 maintains natural flow patterns towards Buffalo Creek and provides an opportunity to initiate channel excavation in Work Area 7 and Work Area 3 independently and simultaneously. Once Work Area 7 is completed, the plug in Reach 3 can be removed, allowing Work Area 9 to be dewatered (by gravity drainage) for construction.

Due to elevated confined bedrock piezometric pressures along the channel alignment, excavation activities are estimated to advance in stages to manage risks associated with basal heave and associated fracturing of the till aquitard. The estimated excavation sequence within the mineral soil (following peat excavation) is shown in the schematic on Figure 13. Stage 1 involves advancing channel excavation at full width to an invert where the factor of safety against the risk of basal heave is acceptable. Stage 2 involves advancing a new pilot channel to full channel completion depth along the channel centerline. The intent is to promote concentration of potential heaved or fractured till interconnections between the bedrock aquifer and channel invert along the centreline, while improving drainage to the remaining excavation areas moving toward the excavation slopes (i.e. Stage 3), and also reducing the underlying confined bedrock aquifer piezometric pressures due to drainage within the deepened pilot channel. Stage 3 involves expanding the new pilot ditch to full width, completing the excavation to the final geometry.

Figure 13: Channel Excavation Phases



Associated channel excavation spoil will be used as fill source for construction of the channel dikes. Dike construction will occur above freezing temperatures to facilitate subgrade preparation and proper material compaction. The remaining channel excavation activities may occur at any time of year. Construction of the drop structures may occur at the contractor's discretion during or after completion of channel excavation. Drainage control structures will be constructed at the same time as dike construction.

Upstream of the water control structure, construction of work area 4 is estimated to occur toward the end of the project to maintain access towards Reach 1, and until the water control structure is completed. this construction sequence also maintains a natural barrier between Lake St. Martin and the water control structure.

The inlet and outlet works (e.g. Work Areas 5 and 8) are estimated to start construction in the summer, outside of the restricted spring (April 1 to June 15), summer (May 1 to June 30) and fall (September 15 to April 30) fish spawning windows. The in-water works to be conducted outside of these restricted windows includes the installation and removal of the cofferdams. Construction activities in the area isolated from the lakes will then proceed at the discretion of the contractor for approximately a one-year period.

Each work area will have associated roadworks and revegetation, which can occur as soon as possible as channel excavation and dike construction advances.

12.0 OVERVIEW OF HYDROGEOLOGIC CONDITIONS

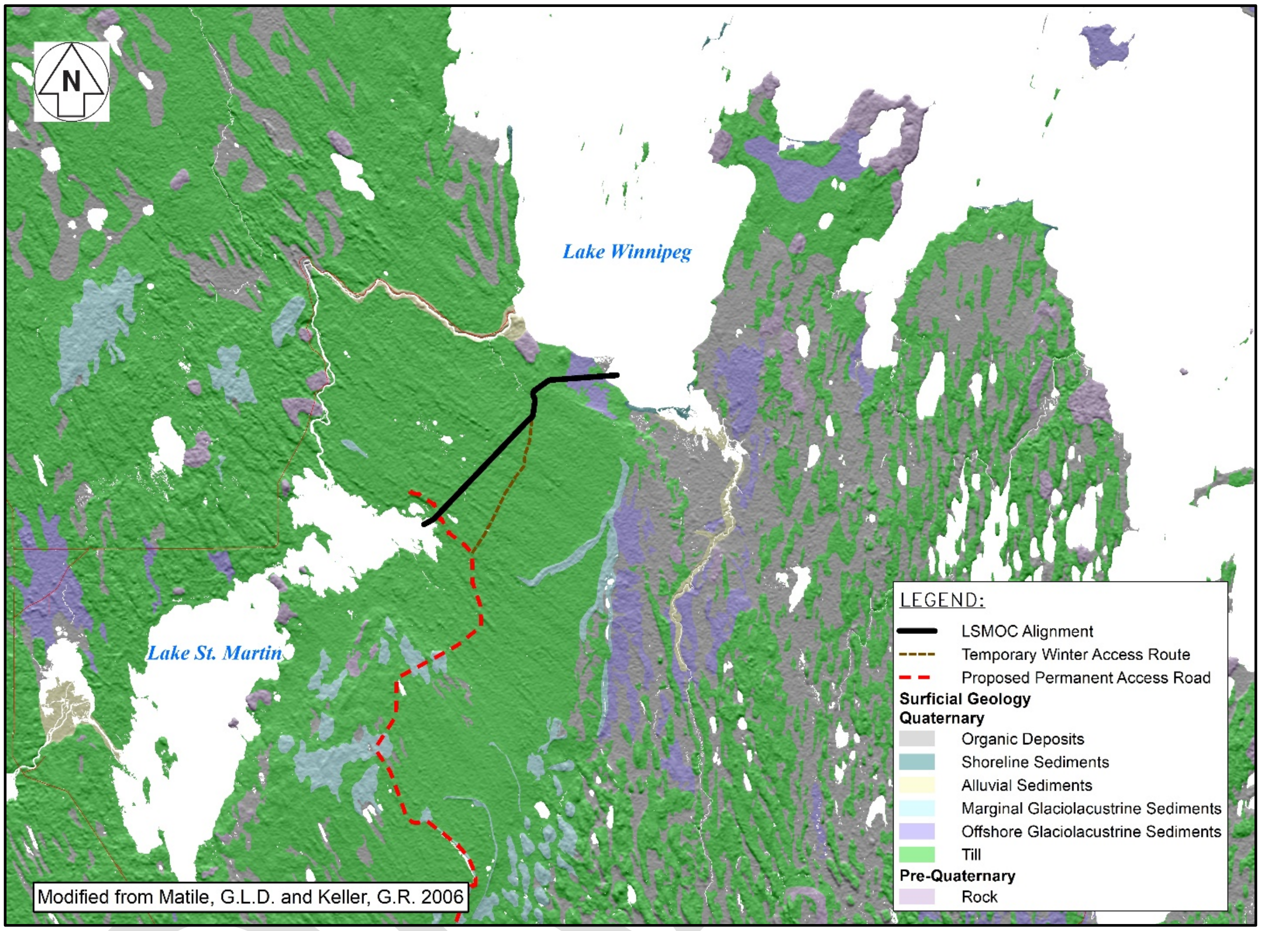
Hydrogeologic conditions of the LSMOC project area (project area) are interpreted from available information, previous field studies and the 2019 groundwater field program conducted by KGS Group as part of the Preliminary Design for the LSMOC.

12.1 Site Characterization

The study area lies within the Lake Manitoba and Lake Winnipeg drainage basins. The lakes within the Manitoba lowland collect drainage from the southern portion of the Province, which is directed through Lake Winnipeg into the Nelson River system. Discharge of the drainage system ultimately occurs at Hudson Bay.

The proposed LSMOC is located within the Interlake area of the Manitoba lowland physiographic region. The Manitoba lowland is a region of gentle relief situated east of the Manitoba Escarpment. The lowland is underlain by gently southwestward dipping Paleozoic and Mesozoic sediments consisting of carbonate rocks, with minor clastic and argillaceous units. The bedrock is predominantly overlain by tills, proglacial lacustrine sediments, and more recent organic deposits found in low-lying areas. An overview of the regional and local surficial geology modified from Matile and Keller (2006) is provided in Figure 14 below.

Figure 14: Surficial Geology Within the Region of the LSMOC



Two distinct groundwater systems are known to be present within the region of the LSMOC; an upper saturated peat, and a lower confined carbonate bedrock aquifer. Glaciolacustrine clays/clay tills, and silt tills form a low permeability aquitard between the perched peat groundwater flow system, and the underlying confined carbonate bedrock aquifer system.

Lake Winnipeg and Lake St. Martin are key discharge areas for the bedrock aquifer and flowing artesian conditions have been observed in the area due to confined piezometric pressure within the bedrock aquifer.

12.2 Geologic Units and Aquifers

12.2.1 Site Stratigraphy

Stratigraphy in the area of the LSMOC was interpreted based on the results of recent field investigations and from previous studies in the area including during the Reach 2 Preliminary Design studies and Stage 2

Conceptual Design studies. It was also interpreted based on stratigraphy observed along the Reach 3 Channel during construction in 2011/2012.

A generalized view of the LSMOC stratigraphy along the LSMOC project (see Figure 8), is provided in Appendix 3A- Plate 2. In general, the overburden layer in the LSMOC project location varies in thickness along the channel alignment from 1 m to 24 m. As described below, the stratigraphy encountered in the test holes drilled is generally peat over silty clay, glacial till (consisting of clay till and silt till) and isolated of sand, gravel, and cobble lenses, underlain by bedrock.

Peat

Peat was observed at surface along the majority of the LSMOC project site. The peat is generally described as black to dark brown in colour, moist to wet, and is fibrous to amorphous and ranges in thickness between about 0 m to 3.0 m (however, it is typically about 1.0 m to 2.0 m in thickness).

Silty Clay

A silty clay unit was observed below the peat surface and is most apparent downstream of the existing emergency Reach 3 channel towards Lake Winnipeg. The silty clay generally described as brown to grey in colour, moist, soft to stiff, intermediate to high plasticity (low plasticity in some instances), containing trace silt pockets, trace fine- to coarse-grained sand, trace gravel, and ranges in thickness between approximately 0.5 m to 4.0 m.

One additional zone of clay soil was encountered as an inter-till layer in one borehole advanced along the LSMOC. A 5.1 m thick zone of soft (putty-like) clay was encountered below the silt till and above the bedrock surface in TH19-KGS-04 (Sta. 3+500). The extent of this layer is undefined and requires additional investigations to determine whether this stratum is part of an isolated, discontinuous lens, or more prevalent and locally significant stratigraphic layer.

Clay Till

A clay till unit was generally observed either immediately below the peat, or below the silty clay, and above the silt till. The predominant grain size within the clay till varied spatially and with depth. The clay till is generally described as silty, brown to dark grey in colour, moist to wet, firm to stiff, intermediate to high plasticity (low plasticity in some instances), containing trace to some silt pockets, trace to some sand, trace gravel, trace cobbles, trace boulders, and ranges in thickness between about 0 m to 5.0 m.

Silt Till

A silt till unit was observed below either the silty clay or clay till units, and overlying the bedrock. The predominant grain size within the till varied spatially and with depth. The silt till is generally described as tan to grey in colour, dry to moist, dense to very dense, low plasticity, containing some to with clay, trace to some sand, trace to some gravel, trace to some cobbles and boulders, and ranges in thickness between about 1.5 m to 21.0 m. The silt till is generally thickest upstream of the existing Reach 3 emergency channel between Station 0+000 and 13+800, ranging from approximately 7.0 m to 21.0 m along this reach of the LSMOC. In the upstream section of the Reach 3 emergency channel itself (between approximately Sta.

13+800 to 17+000) the till thickness ranges between approximately 1.5 m and 12.0 m. The downstream section of the Reach 3 emergency channel (between approximately Sta. 17+000 to 18+300) is characterized by a bedrock high, and has a limited thickness of silt till ranging from approximately 0 m to 1.5 m. Downstream of the Reach 3 emergency channel (i.e. between approximately Sta. 18+300 to 24+000), the silt till thickness ranges from approximately 2 m to 9 m.

Sand / Gravel / Cobbles

Isolated sand, gravel, and cobble layers were encountered at various locations and depths along the channel alignment.

Sandy gravel and sand layers were observed on the lake bottom surface within Lake St. Martin in TH-17-LSMI-10 and -11, with thicknesses of 1.1 and 0.7 m, respectively. A near surface sand layer approximately 0.2m thick was observed beneath the peat in TP19-KGS-07 (Sta. 1+614).

A discontinuous inter-till sand unit was observed within the silt till, from 6.2 m to 7.4 m below grade, and also from 8.7 to at least 12.0 m below grade (end of test hole), in test hole TH19-KGS-07 (Sta. 5+606). Inter-till sand layers ranging in thickness from at least 0.6 m to 1.2 m were also encountered near Lake St. Martin in test holes TH-17LSMI-10 and -11 at depths of 10.7 m and 7.7 m, respectively. A cobble and gravel layer ranging in thickness from 0.5 m to 1.7 m was observed at the base of the silt till unit immediately above bedrock within Lake St. Martin and Lake Winnipeg in test holes TH-17LSMI-13, -14, and TH17-LWGO-16.

Bedrock

The bedrock encountered along the channel alignment was intersected at depths ranging from approximately 1.0 m to 24.0 m below grade based on drilled test holes. The bedrock is generally described as dolomite to dolomitic limestone. Layers of carbonaceous shale were observed at several test hole locations, generally downstream of approximate station 13+200.

12.2.2 Groundwater Systems

Two distinct groundwater systems are known to be present within the region of the LSMOC, within the upper saturated peat and the lower confined carbonate bedrock aquifer.

Perched Peat Flow System

The upper, saturated peat unit is perched above the clays (where present) and underlying till units. The peat is recharged directly from surface rainfall and snowmelt. Groundwater flows within the peat will be locally controlled. Small-scale flow systems develop from raised bog/peat mound areas, flowing radially outward toward relatively lower-lying depressions and other associated open water areas. The water table within the peat is at or near ground surface, with an overall hydraulic gradient, including surficial flow, to the east.

Aquitard

Glaciolacustrine clays/clay tills, and silt tills form a low permeability aquitard between the perched peat groundwater flow system, and the underlying confined carbonate bedrock aquifer system. Aside from regional surface water drainage patterns, the low permeability nature of the aquitard is a key element in maintaining perched water levels in the surficial peat and confined head in the bedrock aquifer and overlying silt till. Negligible recharge through the aquitard to the bedrock is expected, as recharge to the bedrock occurs regionally within bedrock outcrop areas, and/or where the bedrock topography is high, and the overlying till cover is thin.

Lower Carbonate Bedrock Aquifer

The lower, confined bedrock aquifer is comprised of a Paleozoic rock sequence commonly referred to in Manitoba as the “Carbonate Aquifer System”. This aquifer system is isolated from the peat unit by the upper clay zone and underling tills. The confined bedrock aquifer is recharged via rainfall and snowmelt regionally, with recharge areas occurring at locations of bedrock outcrop or in areas where the bedrock is covered by a thin overburden layer.

Well yields are highly variable in the region, a direct result of the fractured rock conditions. Water yields depend on the number of fractures intersected by a well, their size (aperture), extent, and interconnection to other fractures. East of Lake Manitoba the water quality is generally fresh, with Total Dissolved Solids (TDS) <1,000 mg/L. Water quality is generally Mg Ca-HCO_3 type, with TDS in the order of 400 mg/L to 650 mg/L. This water quality reflects the significant meteoric water, aquifer recharge zone noted within the Interlake area. Due to more complex geology and evaporate mineralogy in the Gypsumville area, water quality varies and is locally poorer with TDS concentrations up to 4,550 mg/L (Betcher, 1987).

12.2.3 Regional Trends

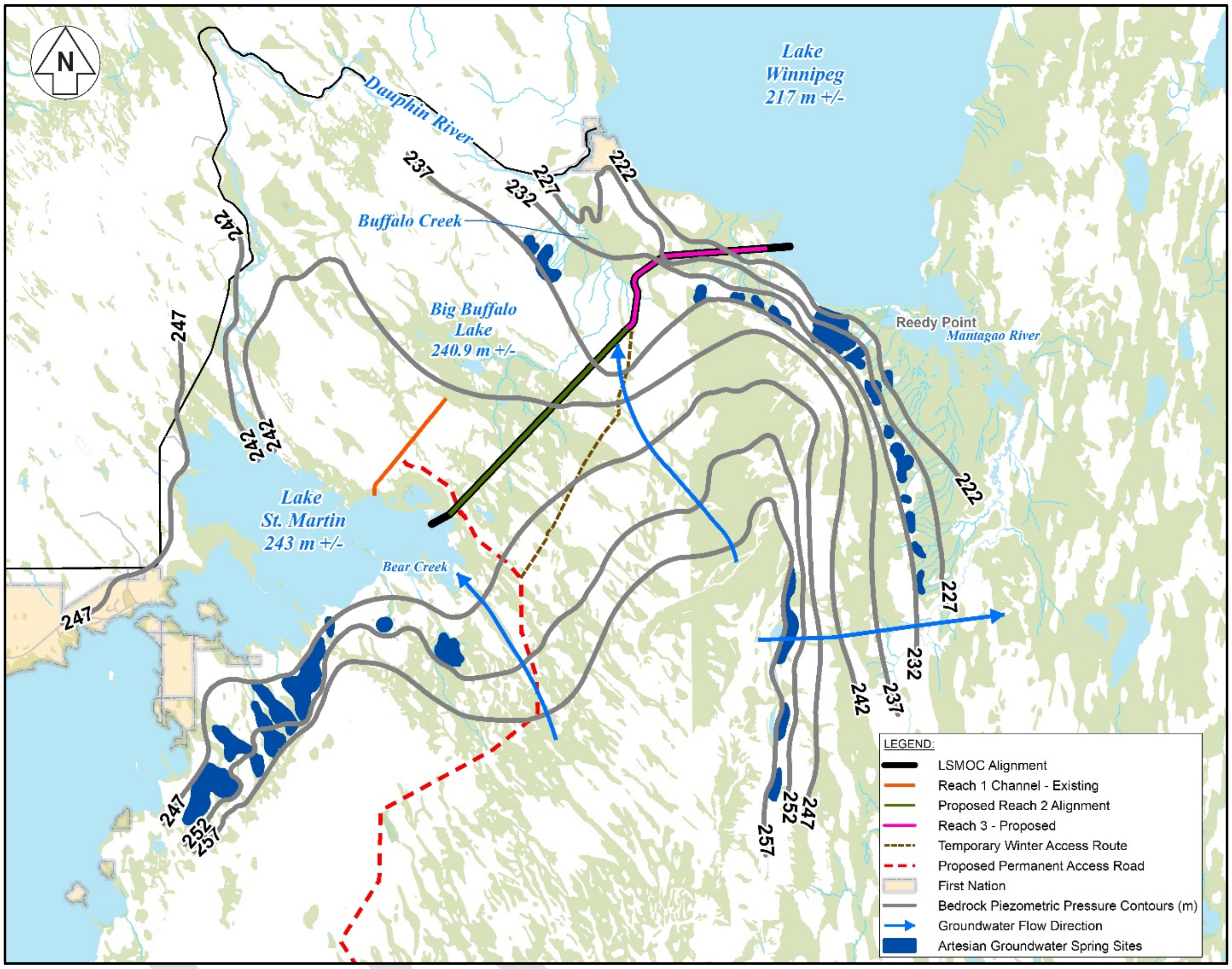
Key regional recharge areas of note for the confined bedrock aquifer occur near Gypsumville, and along outcrop areas that occur immediately to the north-northwest and south of the Lake St. Martin narrows. In addition, the high elevation bedrock bluff area approximately 10 km southeast of Lake St. Martin, also functions as a sub-regional bedrock aquifer recharge area, with the bedrock surface in this location situated well above the aquifer piezometric pressure surface. In the region of the LSMOC, in the Dauphin River area, or in any location in proximity to Lake Winnipeg or Lake St. Martin, the confined piezometric pressure within the bedrock aquifer has been observed to be very near, and in some cases above, the ground surface (i.e. flowing artesian). This occurs because Lake Winnipeg and Lake St. Martin, and associated near-lake low-lying wet areas, are key discharge areas for the bedrock aquifer. Because of this, a strong upward gradient for discharge is anticipated and has been observed to be present in areas close to Lake Winnipeg, including within the region of the Lake St. Martin Outlet Channel.

Detailed contours of the bedrock aquifer piezometric pressures observed in instrumented test holes and monitoring wells during 2019 monitoring activities have been contoured as part of Preliminary Design and a schematic of these contours is presented in Figure 15 below along with the locations of artesian groundwater spring sites as interpreted from aerial photography and field observations. Discharge of the confined bedrock aquifer in the form of artesian groundwater springs are noted in the region of the LSMOC as follows:

- As baseflow to Lake St. Martin and Lake Winnipeg, limited by the condition of the overlying till aquitard found below the recent lake sediments.
- As baseflow through exposed bedrock to the existing Reach 3 Channel.

- A series of flowing artesian springs draining northwestward to Lake St. Martin, and discharging at ground surface elevations between approximately El. 250 m to El. 255 m at the west toe of slope of the high ground area located immediately east-southeast of Lake St. Martin narrows.
- A series of flowing artesian springs draining northerly to Lake St. Martin in the vicinity of the north basin and forming tributaries of Bear Creek, and discharging at ground surface elevations of approximately El. 250 m at the west-northwest toe of slope of the high ground area located immediately east-southeast of Lake St. Martin narrows and the north basin of the lake.
- A series of flowing artesian springs draining easterly to the Mantagao River, and discharging at ground surface elevations of approximately El. 255 m at the easterly toe of slope of the high ground area located immediately east-southeast of Lake St. Martin narrows and the north basin of the lake.
- Based on the peat morphology and surface water elevation relationships of the Big Buffalo Lake Complex (El. 240.9 m to El. 241.5 m), and bedrock piezometric pressure conditions measured along the LSMOC channel in adjacent areas (e.g. minimum of El. 242.6 m), there is an inferred aquifer discharge condition at the Big Buffalo Lake Complex.
- A series of flowing artesian springs draining northeasterly, forming tributaries that connect to Big Buffalo Creek, and discharging at ground surface elevations of approximately El. 235 m and located north-northeast of the big Buffalo Lake Complex.
- A series of flowing artesian springs draining northeasterly to Lake Winnipeg and forming tributaries of the Mantagao River and discharging at ground surface elevations of approximately El. 220 m to El. 230 m, at the northern and northeasterly toe of slope located immediately along the shoreline of Lake Winnipeg, near Reedy Point.

Figure 15: Schematic of Regional Artesian Spring Sites and Contoured Bedrock Aquifer Piezometric Pressures



- Piezometric Pressure Conditions and Variability Along LSMOC.
- The confined karstic carbonate bedrock aquifer pressure condition, driven by infiltration within aquifer recharge areas of relatively high bedrock elevation and thin overburden cover, results in strong gradients for groundwater discharge, or exfiltration (to flowing artesian conditions) along the Lake St. Martin channel alignment, and with regional bedrock groundwater flows toward discharge at Lake St. Martin and Lake Winnipeg (Figure 15).
- Bedrock aquifer pressure conditions are broadly defined as follows, based on channel reaches (see Figure 8 for station locations).
- Lake St. Martin – Sta. 10+500: Between approximately El. 245.0 m (Sta. 1+618) - El. 242.6 m (Sta. 8+000); and in places exhibiting flowing artesian conditions; influenced by the surface water elevation at the Big Buffalo Lake Complex (El. 240.9 m – El. 241.5 m) and its possible interconnection to

the bedrock aquifer; vertical gradients within the bedrock aquifer are upward (i.e. a discharge condition), and vertical gradients between the bedrock aquifer and overlying till aquitard are also upward;

- Sta. 10+500 – Sta. 18+000: Between approximately El. 236.5 m (Sta. 11+716) - El. 230.5 m (Sta. 17+673); comparable in general to ground surface elevations; influenced by artesian spring discharges at ground surface elevations of approximately El. 235 m, and located north-northeast of the Big Buffalo Lake Complex; influenced by artesian spring discharges at ground surface elevations of approximately El. 230 m, and draining northeasterly to Lake Winnipeg and forming tributaries of the Mantagao River, and near Reedy Point; vertical gradients within the bedrock aquifer are upward (i.e. a discharge condition), and vertical gradients between the bedrock aquifer and overlying till aquitard are also upward, in particular within the existing Reach 3 channel area (however this can vary locally); and
- Sta. 18+000 – (Lake Winnipeg): Between approximately El. 222.5 m (Sta. 20+416) - El. 218.3 m (Sta. 22+490); typically well below ground surface elevations; influenced by artesian spring discharges at ground surface elevations of approximately El. 220 m, and draining northeasterly to Lake Winnipeg and forming tributaries of the Mantagao River, and near Reedy Point; vertical gradients within the bedrock aquifer are upward (i.e. a discharge condition), and while the bedrock aquifer remains confined by the till, vertical gradients between the bedrock aquifer and overlying till aquitard are in general downward, reflecting the enhanced decrease in piezometric pressure of the bedrock aquifer in the lower reaches of the channel alignment, and the strong influence of aquifer drainage through the artesian spring sites near Lake Winnipeg and the Mantagao River. However, where the bedrock is deeper, and in closest proximity to Lake Winnipeg, the vertical gradients between the bedrock and the overlying aquitard can be strongly upward, reflecting the strong exfiltration or discharge conditions for the bedrock aquifer at Lake Winnipeg.
- Flowing artesian well conditions from the bedrock aquifer system have also been observed in the Dauphin River area along the west slopes to Lake Winnipeg, and below Lake St. Martin and Lake Winnipeg, during drilling programs completed at the LSMOC inlet and outlet areas, by MI. These conditions are also consistent with the 2011 and 2015 field investigation results along the LSMOC by KGS Group where artesian flow conditions were encountered up to 1 m above ground surface.

Evaluation of Seasonal Variability in Bedrock Aquifer Conditions

Based on regionally available multi-year data and one season of data collection over the winter of 2019 through the spring freshet, bedrock aquifer piezometric pressure conditions in general fluctuate (rise) by approximately 1.0 m to 1.2 m during the spring freshet. The duration and timing of the aquifer rise can vary, but in general these pressure changes are noted to occur between approximately mid-March and about mid-May to the end of May, each year.

12.3 Baseline Groundwater Monitoring

Groundwater related investigations have been undertaken by KGS Group in the project area since 2011. A total of 12 Instrumented test holes were drilled during the 2015 investigations and instrumented with a total of 24 nested standpipe piezometers. Survey and monitoring of these instruments was completed as part of the 2019 field program.

In 2019 as part of the Preliminary Design Phase Monitoring Program, KGS Group conducted a number of baseline groundwater monitoring programs, including: test hole drilling and well installation, instrumentation, hydraulic conductivity testing, pump testing, groundwater monitoring and water quality sampling. The following sections provide a summary of the 2019 KGS Group field programs.

12.3.1 Instrument Installation

Test Holes

In 2019 KGS Group completed and surveyed 34 test holes along the LSMOC alignment. A series of nested piezometers were installed in the drilled test holes consisting of standpipe piezometers (SP) and vibrating wire piezometers (VW). A total of 34 SPs and 32 VWs were installed.

Pumping Wells

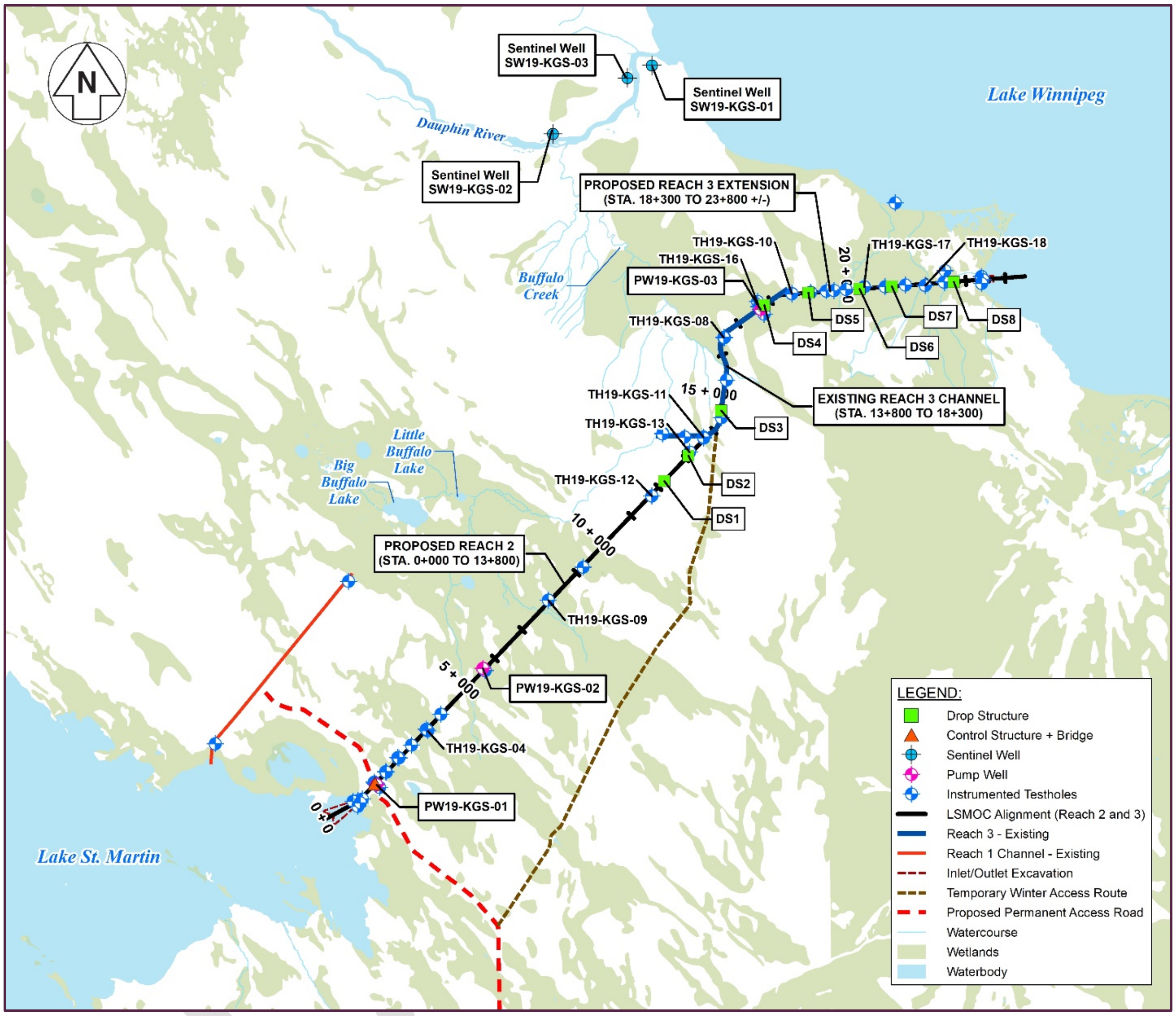
Bedrock pumping wells (125 mm diameter) were completed at 3 locations along the LSMOC alignment: near the inlet, in Reach 2 and in Reach 3. These locations are plotted on Figure 15 as follows: PW19-KGS-01 at Sta. 1+618 near the inlet, PW19-KGS-02 at Sta. 5+606 in Reach 2, and PW19-KGS-03 at Sta. 17+668, in Reach 3.

Sentinel Wells

Three sentinel wells (SW19-KGS-01 to 03) were drilled and installed within the Dauphin River First Nation community located approximately 6 km northeast of the LSMOC. The purpose of the sentinel wells is to collect baseline groundwater information (groundwater levels and water quality parameters) on the bedrock aquifer within the community and allow ongoing monitoring of conditions during the design and construction phases of the project. The sentinel wells were installed as an independent system separate from intrusive monitoring of the network of existing domestic wells.

The location of the sentinel wells is shown on Figure 16. One sentinel well (SW19-KGS-01) is located on the south side of the Dauphin River near the southeastern edge of the First Nation boundary and serves as the nearest monitoring point between the community and the LSMOC site. Two wells (SW19-KGS-02 and 03) are situated on the north side of the Dauphin River within the network of existing domestic wells. Drilling and installation of the sentinel wells occurred in two stages; SW19-KGS-01 was installed in March 2019 via ice road across the Dauphin River, and SW19-KGS-02 and 03 were installed in September 2019 via road access.

Figure 16: Monitored Well and Test Hole Locations



The sentinel wells are equipped with transducers to continuously monitor and datalog water level, electrical conductivity, and temperature. Water quality sampling and testing was conducted following the drilling, installation, and development of each sentinel well. Additional water sampling of each sentinel well is planned during future groundwater monitoring events.

12.3.2 Instrumentation Locations

There are a total of 58 standpipe piezometers (SPs) (24 installed in 2015 and 34 in 2019) and 32 vibrating wire piezometers (VWs) installed within the 46 test holes along the LSMOC alignment (see Figure 16). A high-level summary of the instrumentation is as follows:

- Peat - 19 installations

- Silty Clay / Clay Till – 8 installations
- Silt Till - 36 installations
- Sand - 2 installations (local to Station 5+606)
- Bedrock - 25 installations

12.3.3 Field Permeability Testing

A total of 49 field permeability tests were conducted on standpipes installed along the LSMOC in order to estimate the range of hydraulic conductivities of the overburden soil units and the underlying confined bedrock aquifer. Tests were completed during the 2015 and 2019 investigation programs. Rising and/or falling head tests were conducted on the standpipes depending on factors including expected recharge or infiltration time, well freezing, and artesian well conditions. A summary of the test result ranges by material type is provided in Table 7 below.

Table 7: Summary of Field Permeability Test Results

Overburden Soil Unit	Number of Tests	Estimated Hydraulic Conductivity (m/sec)	
		Minimum	**Maximum**
Peat	9	$2x10^{-8}$	$5x10^{-5}$
Clay Till	4	$5x10^{-10}$	$9x10^{-8}$
Silt Till	22	$2x10^{-10}$	$8x10^{-7}$
Sand	1	$5x10^{-6}$	-
Bedrock	13	$1x10^{-9}$	$2x10^{-5}$

12.3.4 Pumping Tests and Calculation of Aquifer Parameters

Constant rate pumping tests were conducted at the three pumping wells (PW19-KGS-01 to PW19-KGS-03) along the LSMOC alignment between March 11 and 15, 2019. Each pumping well was pumped using a submersible pump for a period of seven hours. To obtain continuous groundwater level and piezometric measurements during pumping, pressure transducers were installed at monitoring wells and standpipes, and dataloggers were employed at vibrating wire piezometers. Periodic measurements of flow rates and field water quality parameters (EC, temperature, and pH) were also obtained.

Pumping test data were analyzed using AQTESOLV analytical software and the Cooper-Jacob straight line solution method. Time-drawdown, time-residual drawdown and distance drawdown straight line graphing methods were applied to estimate preliminary hydraulic properties of the local and regional hydrogeological flow regimes. The calculated transmissivity values of the bedrock aquifer from the pumping were found to be relatively low and estimated to be as low as of 7,500 USgpd/ft (80 m2/d). The upper limit of the calculated transmissivity ranges from measurements collected during the single well pumping tests were estimated to be less than approximately 35,000 USgpd/ft (360 m2/d). This range in values is considered representative of the aquifer within the region of the project. Based on all testing to date, there does not appear to be bedrock aquifer transmissivities that exceed approximately 50,000 USgpd/ft to 65,000 USgpd/ft (645 m2/d to 810 m2/d), however the transmissivity field within fractured bedrock aquifers will vary.

12.3.5 Piezometer Pressure Monitoring

Piezometric pressure (or groundwater level) monitoring was completed on instrumented test holes and pump wells from both the 2015 and 2019 investigations along the LSMOC. Two monitoring events were completed during the Preliminary Design phase of the project including one in March 2019 immediately following initial installation of the 2019 instruments and a second event in June 2019. The results of baseline piezometric pressure monitoring are summarized for bedrock aquifer monitoring installations in Table 8 below. Details of the 2015 and 2019 baseline monitoring programs will be provided in the Final Design Report.

Table 8: Summary of 2019 Baseline Bedrock Aquifer Piezometric Pressure Ranges

LSMOC Centerline Station Locations		Number of Bedrock Aquifer Monitoring Installations	Piezometric Pressure (m)	
			Minimum	**Maximum**
0+000	**5+000**	5	244.1	245.0
5+000	**10+000**	2	244.0 (Flowing)*	244.5 (Flowing)*
10+000	**15+000**	4	235.3	237.9
15+000	**20+000**	8	224.6	235.6
20+000	**Lake Winnipeg**	5	218.3	223.3

*Note: flowing signifies flowing artesian conditions at the time of the monitoring event.

An additional monitoring event was completed in October 2019 and June 2020 as part of the Detailed Design phase of the project which included the three sentinel wells in the Dauphin River First Nation. The results of this and any additional monitoring events will be provided in the Final Design Report.

12.3.6 Groundwater Quality Sampling

Two rounds of groundwater quality sampling and field observations were completed, in March and June 2019 during the Preliminary Design phase of the project for the purpose of obtaining baseline parameters to support environmental assessments for the project.

As part of this program, a total of 31 standpipes, three pump wells, and one sentinel well were sampled and analyzed for water chemistry. The other two sentinel wells were sampled when they were installed in September 2019. Water chemistry parameters analyzed in the field included temperature, pH, electrical conductivity (EC), dissolved oxygen (DO), and oxygen reduction potential (ORP). Parameters analyzed in the laboratory included potable water parameters, dissolved metals and environmental stable isotopes as follows.

Potable Water Parameters - electrical conductivity, hardness, pH, total dissolved solids, turbidity, alkalinity, bicarbonate, carbonate, fluoride, hydroxide, nitrate and nitrite (as N), nitrate (as N), nitrite (as N) and sulfate.

Dissolved Metals – aluminum, antimony, arsenic, barium, beryllium, bismuth, boron, cadmium, calcium, cesium, chromium, cobalt, copper, iron, lead, lithium, magnesium, manganese, molybdenum, nickel, phosphorus, potassium, rubidium, selenium, silicon, silver, sodium, strontium, sulfur, tellurium, thallium, thorium, tin, titanium, tungsten, uranium, vanadium, zinc and zirconium.

Environmental Stable Isotopes - deuterium, oxygen and tritium.

Bacteria analyses including E.Coli and total coliforms were also completed on select water samples, specifically the three pump wells, and also on the three sentinel wells.

The range of field chemistry measurements collected during the March and June 2019 baseline monitoring events are summarized in Table 9.

Table 9: Range of Baseline Groundwater Field Chemistry Measurements

Field Parameter	Range of 2019 Monitoring Results	
	Minimum	**Maximum**
pH	6.51	8.76
Electrical Conductivity (µS/cm)	436	1,888
Dissolved Oxygen (mg/L)	0.36	13.72
Oxygen Reduction Potential (mV)	-93.2	490

In June and fall 2019, additional groundwater quality and laboratory analysis were completed on a select number of test holes. Detailed field chemistry measurements and the results of laboratory analysis for all monitoring wells sampled will be provided in the Final Design Report.

13.0 GROUNDWATER MANAGEMENT

13.1 General Considerations

Groundwater conditions along and in the vicinity of the LSMOC are complex and driven by the regional groundwater aquifer system in the Interlake (i.e. between Lakes Manitoba and Winnipeg), and particularly between groundwater recharge and discharge areas associated with Lake St. Martin and Lake Winnipeg. Management of the groundwater conditions is critical for the successful construction of the project as discussed below.

13.1.1 Confined to Flowing Artesian Conditions in the Bedrock Aquifer

Confined to flowing artesian bedrock aquifer conditions are present in most areas of the LSMOC as shown by 2015 and 2019 groundwater elevation/pressure data that is shown on Figure 15.

In areas where the excess confined bedrock aquifer pressures are elevated relative to the thickness of the confining till and silty clay aquitard units, there is a risk of basal heave/hydraulic fracturing of the till. This risk is greater during channel excavation due to unloading of the confining aquitard units and may induce a connection of the bedrock aquifer to discharge at the base of the channel excavation. Under these conditions, there is a possibility of uncontrolled groundwater discharge to the channel excavation area(s). This condition is known to develop naturally and has been observed in the region of the LSMOC project where artesian spring sites are common (Figure 15). The total flow of groundwater from the bedrock aquifer to the LSMOC is anticipated to be limited by the low transmissivity of the fractured bedrock observed to date within existing exploration areas, and within the base of Reach 3. There remains potential for variability and localized karstic and higher transmissivity bedrock within other areas of the Project. Because these excess bedrock aquifer piezometric pressure conditions cannot be avoided in the region of the LSMOC, one of the project design considerations is that there will be some groundwater discharge to the channel excavation, originating from discrete, and somewhat limited source areas.

In general, consideration of groundwater piezometric pressures and any associated aquifer depressurization requirements during the design phases of the project will apply not only to the channel excavation, but also to the channel inlet/outlet excavations, the channel drop structure installations, and the channel WCS foundations (including associated long-term WCS uplift pressure mitigation measures).

In terms of geotechnical stability, groundwater discharge areas along the centerline and base of the channel may pose fewer short- and long-term challenges than if they were to occur near the channel sideslope, or near (or beneath) an engineered structure. Minimizing and mitigating groundwater discharges is being addressed as part of detailed design and in construction sequencing.

Active depressurization of high groundwater pressures with temporary groundwater depressurization systems pumping from bedrock wells are anticipated to be required to facilitate deep foundation excavations for construction of concrete structures (i.e. the WCS). Following construction, passive sub drains are planned to lower piezometric pressures beneath the base of the WCS to protect against uplift.

The channel is currently directly interconnected with the exposed bedrock in a portion of the existing Reach 3 channel. Additional interconnection will occur as the channel is deepened and widened through the Reach 3 area. Groundwater discharge will occur with this work; however, the degree of groundwater discharge will be controlled by the low bulk transmissivity of the bedrock encountered, which to date has been calculated based on water well pump testing results, and with measurement of baseflow along the existing Reach 3 channel. Contingencies will be explored to manage groundwater discharge during construction if higher transmissivity bedrock areas are encountered.

The excess bedrock piezometric pressures must also be considered for the excavation of the channel inlet, and outlet, within the cofferdam areas, depending on the depth of lake bottom excavation determined during design optimization. Seepage discharge areas may develop at the base of the excavation from the confined bedrock aquifer foundations or from Lake St. Martin and Lake Winnipeg via lake bottom deposits, and the resulting discharge must be managed.

Design of drop structures must also account for excess piezometric pressures, specifically within construction excavations, to ensure the hydraulic, geotechnical and constructability requirements are satisfied throughout the short and long-term timeframes.

13.1.2 Groundwater Level and Quality Changes to Groundwater Supply Wells

The nearest groundwater well users are at Dauphin River First Nation, 5 to 6 km north and northeast of the channel. The majority of the community wells are on the north side of the Dauphin River, which serves as a groundwater discharge, hydraulically isolating domestic wells on the north side. A few wells are located on the south side (i.e. project side) of the Dauphin River.

Although the LSMOC project development and operation is very unlikely to result in any temporary or permanent water quality or water level impacts to domestic wells in the region, protection of the regional groundwater aquifer must be considered as practicable during design optimization.

The monitoring of potential effects of the project on groundwater (levels and quality) is provided at Sentinel wells located in the community on both sides of the Dauphin River. Continuous monitoring of groundwater elevations will be provided to track any long-term groundwater elevation changes. Water quality monitoring in the Sentinel wells will establish baseline and long-term trends.

A strategy for mitigating any adverse effects to domestic wells is typically required by groundwater licences that will be issued for construction of the project.

Water levels within the perched peat wetlands are largely impacted by surface water measures and drainage modifications described within the SWMP. Any changes in bedrock piezometric pressures as a result of the LSMOC project are not estimated to cause any measurable effect on the peatlands as a whole in any areas in proximity to the LSMOC, due to the presence of the extensive silty clay and dense silt till aquitard.

Changes in groundwater piezometric pressures could possibly alter the total discharge of groundwater to wetlands that are directly interconnected via artesian springs, such as in proximity to Big Buffalo Lake, and along the shores of Lake Winnipeg near Willow Point. These possible changes in baseflow discharge to surface could potentially impact the associated aquatic and terrestrial habitat. There is no scenario, however, where these naturally occurring spring discharge sites would cease to flow entirely because of the LSMOC project.

13.1.3 Groundwater Seepage into and/or out of the Channel

The creation of new groundwater discharge pathways into the LSMOC channel will locally increase the direct connection of exfiltrating groundwater to channel surface water, originating from the underlying bedrock aquifer.

The bedrock aquifer in the region of the LSMOC is confined, and as such responds quickly in piezometric pressure to changes in aquifer boundary conditions (i.e. changes to water levels or pressure conditions at aquifer recharge and discharge areas). The LSMOC is situated in an area of high confined bedrock aquifer groundwater pressures, which drives groundwater discharge to the LSMOC channel as baseflow under virtually all scenarios of variability in aquifer boundary conditions. However, during certain times of channel operation, such as the rapid staging of surface water within the channel as it is opened, downward vertical gradients may be temporarily developed between the surface water within the operating channel and the underlying bedrock groundwater aquifer, resulting in short-term (hours) and localized infiltration of surface water to the bedrock aquifer. This will only occur in locations where there is a physical interconnection of the LSMOC channel to the bedrock through the till aquitard, or where the bedrock aquifer is directly exposed within the LSMOC channel base, and only during the limited period of time when the water level within the LSMOC channel is higher in elevation than the piezometric pressure of the underlying confined bedrock aquifer.

The bedrock aquifer piezometric pressure conditions will rise in response to the change in boundary conditions – specifically the staging or rise of surface water within the LSMOC channel in these interconnected channel areas; thus returning the bedrock aquifer system to a discharge (exfiltrating) condition at the channel in these interconnected channel areas, even with the channel full, and in operation. With repeated, short-lived pressure conditions favoring infiltration from the channel to the bedrock aquifer, development of a localized influx of infiltrated channel surface water, local to the channel and moving further down gradient in the bedrock aquifer groundwater system near the channel, is a possibility. These mixed surface and ground waters would migrate through the aquifer system to the next available discharge area, located either within the LSMOC channel itself, at an existing downgradient artesian spring site, or possibly in the longer term as baseflow to Lake Winnipeg.

Repeated infiltration of small quantities of surface water may cause local and short-lived water quality changes to the regional bedrock aquifer resource in close proximity to the LSMOC. It is important to distinguish that infiltration may only occur in areas where there is a physical connection from the channel to the bedrock aquifer. These interconnections are localized, and will occur only where the till aquitard has been fractured or heaved during excavation of the channel, or where bedrock is exposed within the channel (such as at Reach 3, currently). There are, however, no nearby domestic well users and the overall hydraulic gradient (groundwater flow direction) in the area is to the east northeast, with discharge to existing downgradient artesian spring sites, and ultimately into Lake Winnipeg.

The channel optimization will include consideration to mitigate the potential for any downward vertical gradients to the bedrock aquifer by minimizing the difference between the operating (staged) channel water level, and the current static piezometric pressure in the underlying bedrock aquifer, particularly in the exposed bedrock area of Reach 3.

13.1.4 Effects on Wetlands

Water levels within the perched peat wetlands adjacent to the LSMOC are largely impacted by local surface water conditions. Measures to address surface water drainage modifications are included in the SWMP. Any changes in bedrock piezometric pressures as a result of the construction and operation of the LSMOC are not expected to cause any measurable effect on the peatlands as a whole in any areas in proximity to the LSMOC, due to the presence of the extensive silty clay and dense silt till aquitard.

Changes in groundwater piezometric pressures could possibly alter the discharge of groundwater to wetlands that are directly interconnected via artesian springs, such as in close proximity to Big Buffalo Lake, and along the shores of Lake Winnipeg near Willow Point. These possible changes in baseflow discharge to surface have the potential to impact the associated aquatic and terrestrial habitat. However, there is no scenario where these naturally occurring spring discharge sites would cease to flow entirely as a result of the LSMOC project.

13.2 Design Considerations

The effect of the hydrogeologic conditions on construction and long-term operation of the outlet channel and structures has been considered in the design as described below. This includes consideration of the baseline groundwater flow system, and changes to the flow system estimated to be a result of LSMOC construction, and/or when the channel is operated.

13.2.1 Channel Works

The channel profile optimization process includes considerations to minimize the potential for interconnection of the channel invert with the bedrock aquifer groundwater system. The maximum channel water elevation within Reach 3 (where bedrock is exposed within the channel and is directly interconnected) has been constrained so that it is comparable to the current, naturally occurring piezometric pressure elevation of the bedrock aquifer at this location. Groundwater/surface water interconnections exist now and are expected to remain at Reach 3 due to exposed bedrock and thinner overburden conditions. Limiting the channel water elevation serves to minimize the potential for the development of short-term downward gradients from the surface water to the bedrock groundwater system in the Reach 3 area. Reducing the maximum channel water elevation at this location also lowers the risk of channel-induced increased bedrock aquifer piezometric pressures in down-channel areas, where the potential could be increased for uncontrolled groundwater discharge (i.e. artesian spring breakouts) in downstream areas, where the topography drops markedly to the east.

In the remainder of the channel, the proposed invert is based in till. However, areas are present along the channel where excavating to the design invert would result in an increased risk of basal heave and fracturing of the till in the base of the channel. This could result in uncontrolled groundwater discharge from the underlying bedrock aquifer.

Construction sequencing is proposed to help manage this risk by promoting interconnections in a concentrated, central channel, area, should they occur. Channel excavation will proceed such that full excavation to design invert in these higher risk areas would proceed using a central pilot ditch and progress outwards to the full channel excavation width, as detailed in Section 12.3.

This excavation staging will minimize the potential for uncontrolled discharge in large areas of the channel base, particularly in areas closer to the channel sideslopes, whose stability conditions are most sensitive in terms of overall channel excavation.

13.2.2 Inlet and Outlet Works

Excavation of the channel Inlet at Lake St. Martin and the channel Outlet at Lake Winnipeg will occur in the lake bottom till sediments. At the Inlet and Outlet works, groundwater discharge may occur within the construction area. If this area must be dewatered for ease of construction, any groundwater discharge will be directed to a sump and pumped out during construction. After construction, the water elevation of Lake St. Martin and Lake Winnipeg will mitigate the long-term rate of any groundwater discharge baseflow to the lakes. Since groundwater discharge baseflow is already occurring to both lakes from the surrounding regional bedrock aquifer, development of additional discharge zones within the inlet are considered to be acceptable where it cannot be avoided. There is no scenario where these naturally occurring groundwater baseflows to the lakes would cease to flow entirely as a result of the LSMOC project. Control of surface water within the cofferdams is discussed in the SWMP.

13.2.3 Water Control Structure

Active groundwater depressurization (i.e. bedrock aquifer depressurization pumping with wells) will be required during construction of deeper excavations at the WCS. Preliminary Design of the LSMOC is based on the WCS being located approximately 2.5 km down-channel from Lake St. Martin, thereby reducing bedrock aquifer depressurization requirements for the temporary pumping system, because of the thicker overlaying till deposit at this location. However, alternate locations will be considered at detailed design to improve structure foundations. If the structure is founded on bedrock, active pumping will be required to maintain the integrity of the soil base of excavation as it progresses to completion and exposure of the underlying bedrock, and thereafter to dewater the excavation and exposed bedrock, in preparation for, and throughout the WCS construction activity. Regardless of the location, the layout of the WCS will be refined in final design relative to the number of bays and the invert elevation of the base slab, which will influence aquifer depressurization requirements. Long-term subsurface passive drainage of groundwater beneath the foundation will be incorporated into the active depressurization pumping well design to relieve any long-term uplift pressures on the foundation from bedrock aquifer groundwater contributions.

13.2.4 Drop Structures

The drop structures incorporate a sheet pile seepage cut-off wall within the foundations, and across the width of the structure. The sheet pile wall also forms the crest, which acts as a weir to concentrate normal channel baseflow within the LSMOC. The sheet pile will extend beneath the channel invert and will be driven into a pre-excavated and clay backfilled trench. Open excavation of this trench will require groundwater control, anticipated to be achieved with pumping from surface sumps, or similar means. There is however, one exception to the above construction at DS4. The cut-off wall at DS4 will be comprised of a concrete weir founded on a shallow footing bearing directly on bedrock. Bedrock grouting may be required to limit seepage beneath this structure and will be evaluated further in Detailed Design.

13.3 Aquifer Depressurization During Construction

Measures are required to mitigate groundwater pressures acting on the tills at the channel excavation base, and some associated structures during construction. These include:

Channel - Construction sequencing will use an initial central drainage channel to control and direct areas of groundwater discharge and allow for controlled pressure relief of the bedrock aquifer groundwater system. Bedrock aquifer discharge from the existing Emergency Reach 3 channel exists currently. Groundwater discharge from other portions of the channel may also occur, with construction of the LSMOC. Bedrock aquifer groundwater conditions will equilibrate beneath, and in the vicinity of, the LSMOC channel, creating a post-construction groundwater flow system that remains in an overall discharge condition to the LSMOC, and to Lake St. Martin, Lake Winnipeg, and associated artesian spring sites. Depending on the total amount of additional bedrock aquifer baseflow to the LSMOC, the piezometric pressure condition of the aquifer may decline locally, however the regional recharge-discharge relationships will remain the same.

Water Control Structure - Active ***temporary*** groundwater depressurization will use pumping wells installed in the bedrock aquifer. Subsurface passive drainage of groundwater piezometric pressures may also be required long term at the WCS to relieve uplift pressures on the foundation.

Drop Structures - Active ***temporary*** groundwater depressurization will be by pumping seepage from the open excavation for the sheet pile cutoff wall, during installation. No long-term measures are planned.

13.3.1 Regulatory Approval

Channel

The changes in groundwater discharge resulting from channel excavation were discussed in the Environmental Impact Statement for the project and will be covered under the final environmental licence.

Water Control Structure

A temporary authorization for construction groundwater depressurization will be required from Manitoba Conservation & Climate Water Licensing for the active depressurization well system at the WCS. The passive drainage system beneath the structure would also be discussed in that application; but would not require licensing because only limited discharge volumes are estimated.

Drop Structures

A temporary authorization for construction groundwater depressurization may be required from Manitoba Conservation & Climate Water Licensing for the active temporary groundwater depressurization during drop structure construction. The requirement for a temporary authorization will be determined in consultation with Manitoba Conservation & Climate during Detailed Design.

13.3.2 Water Control Structure

A temporary construction aquifer depressurization system consisting of pumping wells is anticipated to be required during construction of the WCS. This will be a temporary measure used to protect against uncontrolled groundwater discharge and basal heave in open excavations during the construction phase of the WCS.

Specific depressurization requirements in the work area will be established during the final design of the WCS and will be specified in the tender. It is possible that some field drilling and pumping programs may be conducted during final design to help define aquifer conditions over larger areas and reduce risk; however further exploratory drilling by the Contractor is typically also required. The Contractor would then be responsible for developing a system capable of meeting the design depressurization requirements.

Activities during the final design process will include those items needed to further define aquifer conditions, design depressurization target elevations and assess regional drawdown effects for the purpose of groundwater licensing. These may include:

- Finalize detailed design of the Water Control Structure, and depressurization requirements.
- Design and location of additional drilling and testing programs to further define aquifer conditions (to be determined).
- Analysis of associated pump test results.
- Design of depressurization target elevations.
- Specify discharge water requirements (discharge point, quality, quantity, and turbidity).
- Drawdown assessment in the area of work.
- Regional drawdown assessment.
- Preparation and submission of an Application for Temporary Aquifer Depressurization to Manitoba Conservation & Climate Water Licensing.
- Development of tender documents.

The Contractor will be responsible for developing a construction depressurization system to achieve the design requirements and other specifications listed in the tender. Activities to be conducted by the Contractor may include:

- Design and location of drilling and testing programs to further define aquifer conditions. Analysis of associated pump test results (in consultation with the Contract Administrator).
- Development of pumping system configuration for required combined total pump flow rate and individual flow rates, and discharge water requirements and associated handling of discharge groundwater (in consultation with the Contract Administrator).
- Development of a groundwater depressurization plan to be approved by the Contract Administrator.
- Supply, installation and testing of bedrock pumping wells and associated observation wells according to types, sizes, materials and construction specifications, as required in the tender documents or otherwise approved by the Contract Administrator for the WCS.
- Supply, installation and testing and commissioning of a bedrock groundwater depressurization pumping system at the WCS, including such items as pumps, power supply, drop piping, wellhead connections, well system header discharge piping, well caps and flow meters.
- Bedrock groundwater depressurization system operation including preparation of discharge area for erosion control and aeration at discharge header outlet.
- On-site monitoring (flow and water levels) in the area of work.

In addition, to monitoring the environmental effects of the construction phase depressurization program, the Resident Contract Administrator will conduct the following activities:

- Oversight and verification of Contractor monitoring in work area.
- Water quality testing of the WCS depressurization system pump discharge water during pump test and depressurization operations.
- Regional monitoring of groundwater elevations.

13.3.3 Drop Structures

A temporary construction aquifer depressurization system consisting of pumping from a sump within the excavation for the clay filled trench at each of the drop structures will be required. This is a temporary measure used to protect against uncontrolled groundwater discharge and basal heave in open excavations during the construction phase of the drop structures.

The specific depressurization requirements in the area of work will be defined during the final design and will be specified in the tender documents. The Contractor will be responsible for developing a system capable of meeting the design requirements.

Activities during the final design process will include those items needed to further define aquifer conditions, design depressurization target elevations and assess regional drawdown effects for the purpose of groundwater licensing. These may include:

- Design and location of additional drilling and testing programs (rising head tests) to define aquifer conditions (to be determined).
- Design of depressurization target elevations.
- Specify discharge water requirements (discharge point, quality, quantity and turbidity).
- Drawdown assessment in the work area.
- Regional drawdown assessment.
- Preparation and Submission of an Application for Temporary Aquifer Depressurization to Manitoba Conservation & Climate Water Licensing.
- Development of tender documents.

The contractor will be responsible for developing a construction depressurization system to achieve the design requirements and other specifications listed in the tender. Activities to be conducted by the Contractor may include:

- Development of a sump configuration and required combined flow rate and discharge water requirements and associated handling of discharge groundwater.
- Development of a groundwater depressurization plan to be approved by the contract administrator.
- Supply, installation and testing of sump materials, sump pumps according to types, sizes, materials and construction specifications, as required in the tender documents or otherwise approved by the contract administrator for the drop structure(s).
- Supply, installation, testing and commissioning of the sump dewatering system at the drop structure(s), including such items as sump pumps, power supply, piping, connections, discharge piping and flow meters.
- Sump dewatering system operation including preparation of discharge area for erosion control and aeration at discharge header outlet.
- On-site monitoring (flow and water levels) in the work area.

14.0 MONITORING

The groundwater monitoring program for the LSMOC is based on the project phases, including pre-construction, construction, and operation. The following sections provide a summary of the currently planned monitoring program for each phase, which may be revised and updated based on input from potentially affected Indigenous groups and the requirements of the Environment Act Licence and Federal Decision Statement Conditions.

14.1 Pre-Construction Monitoring

Additional geotechnical and groundwater monitoring activities are anticipated to occur during the Detailed Design Phase of the LSMOC project in order to finalize the engineering design prior to project tendering and construction. These activities include monitoring of existing instrumentation and installation of additional instrumentation to confirm geotechnical conditions and groundwater pressures at select locations, including the WCS, drop structures and possibly within other areas where construction activities may interact with groundwater conditions (e.g., where bedrock is exposed along the existing Reach 3 channel). Installation of at least one additional monitoring location in the Big Buffalo wetland complex to monitor for changes in water levels and quality is also anticipated to occur during pre-construction monitoring.

In October 2019, as part of pre-construction monitoring, additional instrumentation was installed at the WCS and monitoring was completed in areas local to the WCS. In June 2020, monitoring of all LSMOC instrumentation was conducted, including the collection of water elevation and piezometric pressure data and some water quality. Additional monitoring activities beyond these two events may be required as detailed design progresses. A summary of the field and laboratory analysis parameters included in the pre-construction monitoring program is presented in Table 10.

Table 10. Groundwater Quality Parameters Included in Pre-Construction Monitoring Program

Field Monitoring	temperature, pH, electrical conductivity, dissolved oxygen, oxygen reduction potential, overburden groundwater elevations, bedrock aquifer piezometric pressure
Potable Water	electrical conductivity, hardness, pH, total dissolved solids, turbidity, alkalinity, bicarbonate, carbonate, fluoride, hydroxide, nitrate and nitrite (as Nitrogen), nitrate (as Nitrogen), nitrite (as Nitrogen), sulfate
Dissolved Metals	aluminum, antimony, arsenic, barium, beryllium, bismuth, boron, cadmium, calcium, cesium, chromium, cobalt, copper, iron, lead, lithium, magnesium, manganese, molybdenum, nickel, phosphorus, potassium, rubidium, selenium, silicon, silver, sodium, strontium, sulfur, tellurium, thallium, thorium, tin, titanium, tungsten, uranium, vanadium, zinc, zirconium
Environmental Stable Isotopes	deuterium, oxygen, tritium
Microbiological	*E.Coli*, total coliforms (pumping wells and sentinel wells only)

14.2 Construction Monitoring

Construction groundwater aquifer monitoring events will be conducted by KGS Group during the LSMOC construction period. Currently nine monitoring events are planned according to the following schedule, which is based on channel excavation activities beginning in the fall of 2021:

Sampling Event	***Sampling Date***
Event 1	October 2021
Event 2	May 2022
Event 3	July 2022
Event 4	October 2022
Event 5	May 2023
Event 6	July 2023
Event 7	October 2024
Event 8	May 2024
Event 9	July/October 2024

The above monitoring schedule may be revised based on construction scheduling, but the intent is to have groundwater aquifer monitoring events in spring, summer and fall throughout the active construction period.

Monitoring will focus on identifying any local or regional effects of construction activities, such as active aquifer depressurization pumping, and/or channel excavation and basal heave or fracturing of the till aquitard which may have an effect on groundwater quality and levels. Apart from the three sentinel wells, many of the current monitoring well and instrumented test hole locations are located within the LSMOC alignment and will be decommissioned as construction progresses. Additional groundwater monitoring locations (groundwater monitoring wells and/or instrumented test holes), outside of the alignment, will be installed during the pre-construction phase to provide coverage of the channel and major structures at key locations, such as the WCS and in channel excavation areas of greater risk of basal heave/hydraulic fracturing of the till. The number and location of additional groundwater monitoring locations will be determined through discussion with MI during detailed design.

The exact water quality parameters to be monitored and analysed for during the construction phase will be based on the requirements of the Environment Act Licence and Federal Decision Statement Conditions, but are anticipated to be similar to those required during the pre-construction phase (Table 10).

Additional construction monitoring of the overburden groundwater levels and bedrock aquifer piezometric pressures for geotechnical purposes will be conducted separately, as required. Continuous level monitoring gauges will be maintained, and groundwater quality monitoring will continue annually in spring, summer and fall during construction with reporting completed annually.

14.3 Operation Monitoring

An initial operation phase groundwater monitoring program is currently planned for a period of two years following construction of the LSMOC. Six sampling events are planned for the 2-year post-construction period according to the following schedule.

Sampling Event	***Sampling Date***
Year 1 Event 1	May 2025
Year 1 Event 2	July 2025
Year 1 Event 3	October 2025
Year 2 Event 1	May 2026
Year 2 Event 2	July 2026
Year 2 Event 3	October 2026

Monitoring will focus on the effect of any passive long-term aquifer depressurization, and any channel surface water/groundwater interaction during initial channel operating and non-operating conditions. Monitoring locations and water quality parameters will be determined based on the requirements of the Environment Act Licence and Federal Decision Statement Conditions and the results of pre-construction and construction phase groundwater monitoring, Operation phase water quality monitoring parameters are expected to be consistent with those monitored during the pre-construction phase, as summarized in Section 15.1.

A plan for annual long-term operation groundwater monitoring beyond 2026 will be developed based on the previous monitoring data, an assessment of any possible LSMOC effects, and public engagement. The plan will include monitoring the effect of the channel on groundwater quality and water levels during channel operating and non-operating conditions. On-site and regional monitoring of the effects of any long-term passive aquifer depressurization will also be included in the plan.

15.0 ADAPTIVE MANAGEMENT AND FOLLOW-UP

15.1 General

A follow up process is a form of adaptive management to improve practices by learning about their effects and then making changes in those practices as new information is available. The federal Impact Assessment Act defines a follow up program as “a program for verifying the accuracy of the impact assessment of a designated project and determining the effectiveness of any mitigation measures.” An associated Operational Policy Statement (https://www.canada.ca/content/dam/iaac-acei/documents/ops/ops-follow-up-programs-2011.pdf) indicated that “a follow-up program is used to:

- verify predictions of environmental effects identified in the environmental assessment
- determine the effectiveness of mitigation measures in order to modify or implement new measures where required
- support the implementation of adaptive management measures to address previously unanticipated adverse environmental effects
- provide information on environmental effects and mitigation that can be used to improve and/or support future environmental assessments including cumulative environmental effects assessments, and
- support environmental management systems used to manage the environmental effects of projects.”

In the context of groundwater management for this project the design will be implemented while managing risks with monitoring, as generally described in Section 15.1. As described in Section 12.4.1.1 of the EIS, the objective of the groundwater follow-up and monitoring program is to determine whether there are changes to the volume and accessibility or quality of the groundwater in the groundwater LAA as a result of construction or operations and update and implement mitigation measures and responses accordingly. The predicted residual effects during construction and operation of the Project include a change in local groundwater flow due to dewatering operations, and a change in groundwater–surface water interaction due to surficial drainage diversion and bedrock aquifer depressurization. The monitoring and analysis program will provide information to better predict and quantify potential effects and confirm which locations of the groundwater LAA should be further monitored during aquifer depressurization. Domestic water wells, because of their purpose, will be monitored for their quality. Knowledge obtained from field performance will be used to modify programs as necessary as construction progresses. Any proposed changes to the GWMP and monitoring as part of adaptive management would be discussed with MI and Manitoba Conservation and Climate as necessary and documented.

15.2 Follow up Response

Follow up response will be designed based on the groundwater effects predicted from depressurization during preliminary and detailed design. The range of management threshold for each monitoring well will be based on baseline data and model predictions, dependent upon location and depressurization stage.

Monitoring programs implemented for the Project will produce data that will be assessed to evaluate environmental impact. Based on the results, changes in the monitoring program locations, analysis parameters or frequency may be warranted. The monitoring program will be designed with this flexibility in mind.

If monitoring programs indicate effects in excess of the management threshold ranges (to be established) then the pumping rates and locations may be reduced/increased to modify the effects and monitored via the monitoring program to determine the need for additional adaptive management measures. Other mitigation measures may be developed based on further investigation and monitoring data collected during the project construction.

There will be active feedback during depressurization programs as monitoring data is collected to verify that required drawdown is properly achieved in the work area. Pumping rates will be adjusted or additional wells will be installed to maintain that drawdown locally while attempting to reduce off-site drawdown. Adjustments to the pumping rates may be made over time as well.

Construction methods will be modified as required to achieve the goals of the channel excavation process in providing controlled groundwater pressure relief.

16.0 CONTINGENCY MEASURES AND EMERGENCY RESPONSE

Contingency measures and emergency response will be included for unforeseen events or circumstances related to groundwater in various planning documents for the program. These will be developed and finalized prior to construction.

Groundwater Depressurization Plan – The Groundwater depressurization plan will include contingency measures for loss of power during depressurization and will include provisions to increase pumping rates if possible or longer-term measures such as additional wells to provide additional depressurization if needed.

Health and Safety Plan – The health and safety plan for the project and individual contractors must address all hazards associated with channel and deeper excavations where uncontrolled discharge of groundwater may occur in an emergency situation.

Construction Environmental Management Program – The CEMP will provide specific measures to address the potential contamination of groundwater from hazardous materials and waste, including materials and waste management and emergency spill response and reporting procedures. Some general measures regarding groundwater quality are outlined below.

Adverse impacts to surface water quality in the project area associated with groundwater discharges to surface water are not anticipated as the system has adapted to this natural interaction, which are known to occur in the region through natural springs. Groundwater quality in the project area may be adversely affected during construction from leaks and accidental spills or release of fuels or other hazardous substances. There are no groundwater wells in the immediate vicinity of the proposed development. Typical mitigation to prevent leaks, spills and releases includes providing secondary containment for fuel and hazardous material storage, requiring drip trays for equipment, refueling and conducting maintenance only when equipment is an appropriate distance from water, providing spill clean-up equipment and materials, and providing an emergency (spill) response plan.

If a spill should occur, the contractor would be responsible to provide notification through the emergency response line at (204) 944-4888, which is monitored by Manitoba Conservation & Climate, and to document the event with an incident report. Follow-up may include periodic inspection for leaks, spills and releases, and periodic updates to the emergency (spill) response plan.

17.0 REFERENCES

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Additional Sources

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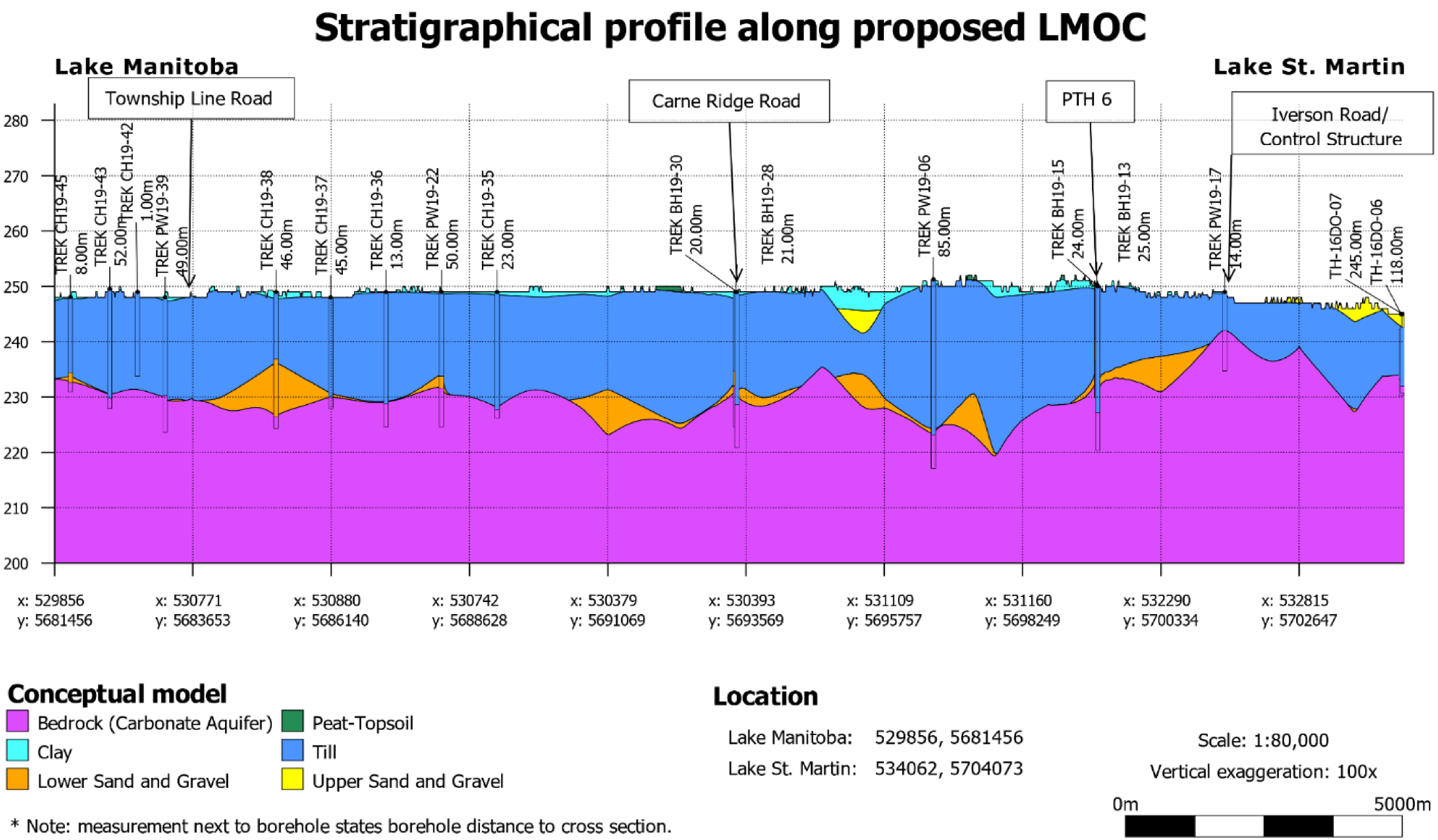
APPENDIX 2A

Lake Manitoba Outlet Channel Stratigraphic Profile

Figure 2A-1: Cross section of the geological model along the proposed LMOC. Selected boreholes and structures are indicated. Vertical exaggeration is 100x.



APPENDIX 3A

Lake St. Martín Outlet Channel Stratigraphic Profile

Figure 3A-1: Stratigraphic Profile of Proposed LSMOC as Interpreted from Borehole Logs