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PRELIMINARY DESIGN FOR REACH 2 OF THE LAKE ST. MARTIN OUTLET CHANNEL

Manitoba Infrastructure

KGS GROUP PROJECT
16-0300-005
Final - Rev 0

June 2017

Kontzamanis | Graumann | Smith | MacMillan | Inc.

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PRELIMINARY DESIGN FOR REACH 2 OF THE LAKE ST. MARTIN OUTLET CHANNEL REPORT

FINAL – REV 0

KGS Group 16-0300-005
June 2017

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June 23, 2017 File No: 16-0300-005

Manitoba Infrastructure
Water Management and Structures
2nd Floor 280 Broadway
Winnipeg, Manitoba
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ATTENTION: Mr. Jared Baldwin, P.Eng.
Project Manager

RE: Preliminary Design for Reach 2 of the Lake St. Martin Outlet Channel
Final Report – Rev 0

Dear Mr. Baldwin:

KGS Group is pleased to submit an electronic copy of the Preliminary Design for Reach 2 of the Lake St. Martin Outlet Channel Final Report. Four hard copies of the report will follow by courier next week and will include a USB memory stick with all data, including the GIS Database and Civil 3D files.

We appreciate the opportunity to have worked with MI on this project and look forward to our potential future involvement at the next stages of design and execution. If you have any questions or comments regarding the enclosed report, please contact the undersigned.

Sincerely,

Dave MacMillan, P.Eng.
Principal / Project Manager

PAL/ama
Enclosure

Cc: Mr. Mark Allard, P.Eng. Project Director (MI)
Mr. Colin Siepman, P.Eng. (KGS Group)
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EXECUTIVE SUMMARY

1. BACKGROUND

The Province of Manitoba announced in the fall of 2014 that it was proceeding with the Stage 2 Conceptual Design of the Lake St. Martin Outlet Channel with a design capacity of 326 m^3/s (11,500 cfs). The channel was separated into three distinct segments: Reach 1, Reach 2 and Reach 3. The conceptual design consisted of expanding the existing Reach 1 and Reach 3 emergency channels, extending Reach 3 to Lake Winnipeg, and construction of the Reach 2 segment located between Reach 1 and Reach 3.

After completing the Stage 2 Conceptual Design, Manitoba Infrastructure (MI) requested that KGS Group identify additional concept alternatives for Reach 2. This resulted in the development of four conceptual alternatives. Subsequently, MI selected KGS Group in a competitive process to undertake the Preliminary Design for Reach 2. KGS Group's team consisted of in-house engineers and scientists, external consulting firms ECOSTEM Ltd. and HATCH Ltd., and the input of Contractors.

This current study involved the evaluation of the four conceptual Reach 2 alternatives, the selection of the preferred alternative, and the Preliminary Design of the preferred Reach 2 option.

A helicopter supported field investigation program was conducted between September 12 and 16, 2016 to gather geotechnical, sub-surface water, topographic and bathymetric data along the four Reach 2 alignment options. Specific basis of designs were also developed for the four alignment options.

2. DESCRIPTION OF REACH 2 CHANNEL DESIGN FOR OPTIONS 1 TO 4

The four options for Reach 2 developed based on the concepts that were previously considered during the Stage 1 and 2 studies are described below:

- Option 1 follows essentially the same route was used for the emergency flood release from LSM in 2011/2012 and 2014/2015 and is based on the original concept was developed during the previous Stage 1 and 2 studies, including extending and deepening the Reach 1 channel. Flows enter the LSMOC at the inlet of Reach 1 and are carried north-easterly towards Big Buffalo Lake. Flows then travel through the peatland area surrounding Big Buffalo Lake and enter Buffalo Creek. However, contrary to emergency flood conditions, flows are then diverted into Reach 3 and discharge directly into Lake Winnipeg rather than into the Dauphin River.

- Option 2 is similar to Option 1 and was developed to address concerns regarding the potential for flotation of the peatland around Big Buffalo Lake. This option involves the excavation of a 200 m wide channel through the peatland along Buffalo Creek to ensure that the discharge capability of Reach 2 is not compromised by floating peat. However, the cost of Option 2 is more than Option 1, there exists the potential for additional environmental impacts, and there is a risk of floating islands forming. It was concluded early in this study that Option 2 was clearly less desirable than Option 1. As a result, Option 2 was eliminated from further consideration.

- Option 3 carries flows from the downstream end of the existing Reach 1 Channel, following an alignment around the peatland and Big Buffalo Lake to enter the upstream end of Reach 3. Dikes are constructed on both sides of the channel to avoid flooding of adjacent land.

- Option 4 is conceived as an alternate to Option 3 to reduce the combined Reach 1 and Reach 2 channel length and overall excavation quantities. Option 4 includes a new channel inlet at a location approximately 3.8 km to the east of the existing Reach 1 and follows a northerly direction to Reach 3. The downstream 6 km segment of the channel is essentially the same as Option 3. This option requires that the Reach 1 channel be decommissioned and re-vegetated.

Drop structures are required for all of the options to safely dissipate energy so that the excavated channels can have suitably mild gradients to avoid high velocities and potential erosion. The drop structures are proposed to be constructed of rockfill, with a sheet pile cutoff at the upstream crest. This concept assumes that a sufficient volume of rock of good quality will be available from the rock quarries within the region. Should detailed investigations prove the contrary, other concepts may have to be considered at the next stage of design.

Flow in the LSMOC will be controlled by a gated control structure. The concept for the inlet structure is unchanged from the Stage 2 Conceptual Design study. For Options 1, 2 and 3, the structure is proposed to be located in Reach 1 at or near the existing inlet location at LSM. For Option 4, it is assumed that the structure will be located in Reach 2, near the inlet location at LSM.

3. ASSESSMENT OF CONCERNS WITH OVERLAND FLOW THROUGH BIG BUFFALO LAKE PEATLAND AREA

The potential for floating peat or marsh islands to form in the inundated areas along the route of the LSMOC was identified early in the planning stages. KGS Group retained a peat specialist from ECOSTEM Ltd. to conduct a qualitative assessment of peatland conditions and the potential risks associated with overland flow in the area. The concern in the case of the LSMOC was that flotation of peat or marsh islands could potentially temporarily “clog” the outlet of the inundated zone surrounding Big Buffalo Lake. This could impede the reliable release of flood flows along the LSMOC during future high water conditions.

Of the four options considered in this report, Option 1 was the focus of the review of overland flow through the Buffalo Lakes wetland complex. Although the overall risk to hydraulic performance of Option 1 appears to be low, there is a real possibility that a mat large enough to block the Buffalo Creek inlet could be produced. Mitigation measures implemented in other regions with similar condition could be considered; but nevertheless, this option includes an operational risk, which does not exist for the other options.

4. EVALUATION OF OPTIONS

Each of the Reach 2 options were evaluated to identify the preferred alignment recommended to proceed to preliminary design. The categories for evaluation of the options were established in collaboration with MI and included:

- Constructability.

- Operability and performance.
- Environmental and Socio-economic considerations.
- Maintainability and Inspection.
- Resiliency.
- Cost.

Evaluation of the options culminated in a Technical Workshop where a panel of selected experts from the KGS Project team, MI and other outside experts conducted a comprehensive review of each of the options and of the results of the various assessments and comparisons summarized below.

Constructability Assessment

The terrain conditions, hydraulics, stratigraphy, and constructability are different for Option 1 compared to Options 3 and 4 since Option 1 requires significant construction in and through the Buffalo Lake wetland complex. Additional assessments with input from knowledgeable Contractors were conducted by KGS Group to better understand the issues related to constructability, the impact on cost and schedule and ultimately the selection of the preferred option.

For all options it was assumed that an all-season road will be constructed to permit year round (permanent) access for long-term operation and maintenance of the channel and the associated structures. This permanent road will be constructed to the site before construction of the channel commences. Although there are some differences between the options in how access will be provided to site during construction, each of the options was judged to be essentially equal with respect to access.

Each of the channel alignment options are located in the peatland area and will require surface water and groundwater management during construction. Based on Contractor input, excavation of the Reach 1 extension will be the most difficult segment to construct and will have higher construction risks compared to the other options.

Risk of schedule delays were also considered when comparing the options. For Option 1, the difficult construction conditions associated with the extension of Reach 1 could result in unforeseen schedule delays. Option 3 was considered to be the most vulnerable to unfavorable weather conditions as it has the longest construction footprint.

Operability and Performance Assessment

Operation of Reach 2 should occur without chronic problems related to sediment erosion, transport or deposition. From the perspective of erosion and sediment deposition, all options would be designed to be stable with minimal risk of erosion. If the design flows are exceeded, there would be some potential for erosion of the channel side slopes and base to occur. Option 3 has the largest surface area exposed to this risk, and also the largest potential volume of available sediment for transport as a result of the exposed side slopes following extended periods of operation.

The original route of the emergency channel to release flood flows from Lake St. Martin utilized the existing low lying areas and hydraulic conveyance through Big Buffalo Lake and downstream into Buffalo Creek. It is well within precedent that floating islands of bog material can occur in the channel for Option 1, which could significantly impede the ability of Option 1 to perform as desired. Neither Options 3 nor 4 cause any significant submergence of existing peatland and, therefore, the risk of causing floating islands is very low.

Operation under winter conditions is a requirement for the LSMOC. It is conceivable, depending on the magnitude of flow during winter, that some portions of the Reach 2 Channel could be partially or fully covered by the advancement of border ice from each side of the channel. However, this is not considered a significant problem since winter flows are expected to be considerably less than design flood conditions based on the proposed operating guidelines.

For all Reach 2 Channel options the groundwater seepage sources and associated groundwater impacts are considered the same. Impacts to the peat groundwater system are estimated to be nominal and regional bedrock aquifer water level impacts are not anticipated to be significant. Any of the Reach 2 Channel options, based on data available to date, are anticipated to perform quite similarly from a groundwater perspective in the long term.

Environmental and Socio-Economic Considerations

Operation of the proposed LSMOC will provide a permanent, long-term, positive effect by helping to alleviate flooding in the region. Construction and operation of these channels will, however, also result in a number of potential environmental and socio-economic impacts. A preliminary list of potential concerns for the various Reach 2 options was developed for the assignment and was qualitatively assessed and evaluated at the Technical Workshop. The categories of evaluation included the physical environment (surface water, groundwater, terrestrial environment, and aquatic habitat and resources) and socio-economic considerations (access, indigenous rights based activities, and commercial fisheries).

In general, Option 1 rated less favorably compared to Options 3 and 4 due to the alignment through the Big Buffalo Lake wetland complex and potential impacts related to widespread flooding of the area.

Maintainability and Inspection Assessment

An all-season road will be constructed to permit year round (permanent) access to the Lake St. Martin Outlet Channel for long-term operation and maintenance of the channel and the associated structures. Although there are some minor differences between options in how access will be provided to site for long-term operation and maintenance, each of the options was judged to have essentially comparable access.

All options have portions of channel side slopes vulnerable to poor vegetation growth as a result of prolonged operation. Options 1 and 3 have relatively high risks of excessive vegetation growth in Reach 1 due to shallow water depths, potentially requiring aggressive maintenance to prevent long-term loss of discharge capacity. Option 1 also has a relatively high risk of increased vegetation growth within the wetland complex surrounding Big Buffalo Lake due to the shallow water depths, as well as potentially in Reach 3 due to the additional source of nutrients. Overall, it is considered that Option 4 is superior in the category of maintenance of vegetation.

It is conceivable that during non-operative periods, wind-driven waves and currents in Lake St. Martin could cause movement of sediment located along shorelines. This risk is common for all options and should be investigated further at the next level of study.

Risks associated with operation of the LSMOC in winter conditions can be mitigated with the careful selection of channel geometry, not including low level water passages at drop structures, prohibiting opening the gates in the LSMOC control structure until the ice downstream has deteriorated, and operating the gates either fully open or fully closed during winter conditions.

Resiliency

The construction of the proposed channels at LSM and LMB would provide significant flood protection relief for the region. However, it is unclear how future climate change may affect flood potential in southern Manitoba. In consideration of this uncertainty, it is appropriate in the comparison of options to include an item that measures the ability of each option to be readily expanded in future. It was concluded that Option 4 offers a significant advantage over both Options 1 and 3 because the existence of a separate intake from LSM for Option 4 facilitates the possibility of reopening Reach 1 and using the discharge capacity available there, either in an emergency operation or permanently after appropriate preparation to avoid possible adverse impacts.

Capital, Maintenance and Risk Costs

Class “C” cost estimates were developed for each of the three Reach 2 options such that they could be incorporated into the evaluation and considered in the selection of a preferred alternative. Options 1 and 3 had similar costs, estimated at $302,690,000 and 301,630,000, respectively. The cost for Option 4 was less, estimated at $290,280,000.

Potential maintenance costs were evaluated for the purpose of comparing the options since the overall maintenance effort will vary between options based on length, design differences, and overall performance. Considering the overall differences in maintenance efforts between the options, Option 4 was assessed the lowest maintenance cost, and Option 1 the highest.

Cost risks that consider the potential for increases in the estimated cost of a given option due to added project requirements or unforeseen conditions were also considered. Cost risks were identified during the Technical Workshop, including socio-economic risks, the potential for further design optimization, environmental risks, construction risks, rock supply risks, and amortization risks. Option 1 was judged to have higher risks for unexpected increases in costs.

5. TECHNICAL WORKSHOP FOR SELECTION OF PREFERRED ALTERNATIVE

The Technical Workshop was held on December 15, 2016 to review the conceptual design of the channel alternatives, develop a set of evaluation criteria for comparing the options and then apply those criteria by rating the performance and suitability to the options to determine the preferred alternative. A total of 31 sub-criteria were defined, separated into 8 main categories. Each of the categories and sub-criteria were discussed in detail to ensure that the panel understood the implications of each sub-criteria. Weighting factors were established for each category and sub-criteria. The results of the workshop are summarized below.

Main Category	Score Subtotal		
	Option 1	Option 3	Option 4
1. Constructability	30	41	52
2. Operability & Performance	37	57	60
3. Physical Environmental Impacts	25	45	45
4. Social Economic Considerations	28	36	36
5. Maintainability and Inspection	27	33.5	36.5
6. Resiliency	10	15	25
7. Cost	27	28.5	30
8. Cost Risk	50	62	64
Total Score (out of 500)	**234**	**318**	**348.5**

Based on the results of the Technical Workshop, Option 4 had the highest score and was, therefore, identified as the preferred alternative.

6. PRELIMINARY DESIGN OF PREFERRED OPTION

The Preliminary Design of the Option 4 Reach 2 channel initially focused on a refinement of the channel alignment. Based on the results of the peat probe investigations, a revised alignment was adopted for this option and was used for the preliminary design. The remaining preliminary design efforts focused on the hydraulic design of the channel, the geotechnical design of the channel geometry, including dikes and spoil pile design, and the design of the drop structures.

The Reach 2 channel and associated structures were designed to comply with the hydraulic design criteria requirements of the project. The channel is proposed to have 4H:1V side slopes and a 0.0204% gradient, with the normal depth of flow in the channel estimated to be 4.5 m during passage of the design flow.

The location of the drop structures within the channel was selected to limit the volume of excavation for the channel by maintaining the water surface profile under the design flow condition as close to prairie level as possible, and to limit the amount of vegetation that tends to grow in the channel. Three drop structures are required to meet the design objectives. Each of the drop structures requires an upstream sheetpile cutoff to increase the robustness of the structure, to accommodate ice loading, to provide some insurance against loss of control of the channel in the event that rockfill is lost / displaced, and to limit seepage through and under the structure.

The preliminary design considers a water control structure that incorporates six vertical lift gates, 9 m wide bays and 2.5 m wide piers.

Optimization of the inlet configuration, control structure size and location, drop structure size and location, and channel design configuration should be conducted at the next stage of design.

Two drainage control structures are proposed on the southeast side of the channel to discharge flows from the south into the channel. To mitigate the impacts of a reduction in surface water runoff to the peatland area surrounding Big Buffalo Lake and Buffalo Creek, siphon(s) under Reach 2 could be considered instead of the two drainage structures.

A slope stability assessment was conducted to establish the side slope requirements for the Reach 2 LSMOC excavation and the dikes along the channel. The proposed channel cross section with 4H:1V excavation and dike side slopes meets the design criteria under the steady state long-term, end-of-construction and rapid drawdown cases.

The cost estimate for Option 4 was modified based on the revisions made as part of the Preliminary Design and was also updated to 2017 dollars. The cost estimate is considered to be a Class "C1" and includes a Contingency allowance of 20%. The total estimated cost is $ 295,450,000.

7. CONCLUSIONS AND RECOMMENDATIONS

A number of conclusions and recommendations were presented in the detailed report. Based on the results of the Technical Workshop Evaluation, which considered constructability, operability and performance, environmental and socio-economic considerations, maintainability and inspection, resiliency and cost, Option 4 was found to have the highest score and was therefore identified as the preferred alternative. The Preliminary Design of Option 4 involved the refinement of the channel alignment, preliminary hydraulic design, preliminary geotechnical design and preliminary design of drop structures. The preliminary design of Option 4 meets all of the identified design criteria and has an estimated cost of $295.5 million. The cost estimate is considered a Class C1 and is reported in 2017 dollars.

The key recommendation developed from this study is that Option 4 should be carried forward into final design, along with the other components of the LSMOC. Additional recommendations have been identified in the report and should also be considered for final design.

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1.0 INTRODUCTION

1.1 BACKGROUND

In 2011, record widespread flooding occurred across much of southwestern Manitoba, resulting in unprecedented inflows into Lake Manitoba and Lake St. Martin. These high flows extended well into the summer and overwhelmed the capacity of the existing flood control and protection infrastructure. In response to the flood conditions, the Province of Manitoba constructed the Lake St. Martin Emergency Outlet Channel (LSMEOC), which included the Reach 1 and Reach 3 channels. Subsequent to the flood, Kontzamanis Graumann Smith MacMillan Inc. (KGS Group) was retained by Manitoba Infrastructure (MI) to undertake a two-stage process to develop conceptual designs for permanent outlet channels from Lake Manitoba and Lake St. Martin. One of the fundamental scope items in the Stage 1 study was to identify outlet options for Lake Manitoba (LMB) and Lake St. Martin (LSM).

Based on screening criteria and economic analyses completed for each of the options identified within the Stage 1 study, the Province of Manitoba announced in the fall of 2014 that it was proceeding with the Stage 2 conceptual design of the preferred alternatives. The Stage 2 study was initiated in January of 2015, and final conceptual designs were completed for two Lake St. Martin Outlet Channel options with a design capacity of 326 m^3/s (11,500 cfs).

Both Lake St. Martin Outlet Channel options consisted of a channel connecting Lake St. Martin to Lake Winnipeg: one with its outlet located on Johnson Beach, and the other located east of Willow Point (Plate 1). The channel was separated into three distinct segments; Reach 1, Reach 2 and Reach 3. The concept consisted of expanding the existing Reach 1 and Reach 3 emergency channels, extending Reach 3 to Lake Winnipeg, and construction of the Reach 2 segment located between Reach 1 and Reach 3. The Reach 2 concept included extending the Reach 1 Channel, flooding of Big Buffalo Lake parkland area and the construction of a containment dike along Buffalo Creek. After completing the Stage 2 Conceptual Design, MI requested KGS Group to identify additional concept alternatives for Reach 2 and a total of four conceptual alternatives for Reach 2 were developed.

Subsequently, MI selected KGS Group to undertake the Preliminary Design for Reach 2 of the Lake St. Martin Outlet channels. This current study involved first the evaluation of the four conceptual Reach 2 alternatives, then recommendation of a preferred alternative, and it undertakes the Preliminary Design for the preferred Reach 2 option. Plates 2 to 6 show the proposed conceptual alignments of the four Reach 2 alternatives. A description of the concepts is included in Section 4.0.

1.2 SCOPE OF WORK

The scope of work for the assignment, which focused on Reach 2 of the Lake St. Martin Outlet Channel, was based on the study terms of reference and included:

- Field investigations and surveys.
- Constructability assessment considering access to site, surface and groundwater, material composition and bathymetric analysis.
- Operational risk assessment considering seepage, erosion, sediment transport and deposition, dislodged material from the Big Buffalo Lake peatlands, standing water at drop structures, and channel slope stabilities.
- Comparison of environmental impacts including sediment transport, fish passage and the potential for stranding, aquatic impacts, surface and groundwater impacts, and socio-economic considerations.
- Evaluation of maintenance and inspection costs that consider dike access, channel access, vegetation growth, sedimentation, and general maintenance costs.
- Class C engineer’s estimate.
- Evaluation of options including the development of a Technical Workshop and Decision Matrix.
- Recommendation of a preferred alignment and delivery of preliminary design details on the preferred alignment.

A team led by KGS Group was selected in a competitive process to carry out the scope of work identified above and worked collaboratively throughout the assignment on the various tasks of the project. KGS Group’s team consisted of in-house engineers and scientists, as well as external consulting firms ECOSTEM Ltd. and HATCH Ltd. ECOSTEM conducted a qualitative assessment of peatland conditions surrounding Big Buffalo Lake. Hatch was responsible for the preliminary design of the drop structure, assisted in executing the Technical Workshop, and assisted with the development of the preliminary hydraulic design of the preferred channel alternative. Consultations were also held with the two major construction firms, Sigfusson Northern Limited and Hugh Munro Construction Limited, that had successfully completed the emergency works in 2011.

2.0 FIELD INVESTIGATIONS

KGS Group conducted a helicopter supported field investigation program between September 12 and 16, 2016 that gathered geotechnical, sub-surface water, topographic and bathymetric data along the four Reach 2 alignment options. The program included:

- A topographic survey along the existing Reach 1 Emergency Channel using an unmanned aerial vehicle (UAV or drone) equipped with photogrammetric survey equipment. As well, a ground-truth survey of cross sections and water levels was conducted along the channel.
- Peat probes at approximately 250 m intervals on all four alignments, to measure the approximate depth of peat above the underlying till and obtain approximate sub-surface water levels.
- Test holes drilled via hand auger and soil samples of the till surface collected at approximately 2 km intervals along the proposed Option 3 and 4 alignments. Detailed sub-surface investigations were not conducted.
- A topographic and bathymetric survey along Buffalo Creek between the outlet of Big Buffalo Lake and approximately 2.5 km upstream of the Reach 3 inlet
- A Bathymetric survey on Big Buffalo Lake.
- An aerial and ground-truth site reconnaissance survey with Contractors.
- A site visit and peat investigations undertaken by a peat specialist.

In addition to the investigations outlined above, MI independently conducted a bathymetric survey of Lake St. Martin at the proposed inlet location of Option 4. The data collected during the field investigations is summarized on Plate 2. Also shown on Plate 2 is the data available from previous studies and investigations. Further details on each component of the field investigation program are summarized in Sections 2.1 to 2.6.

2.1 REACH 1 DRONE SURVEY

KGS Group retained Taiga Air Services to perform a topographic survey of the existing Reach 1 Channel, overbank, and spoil piles using an Unmanned Aerial Vehicle (UAV). Photo targets were installed and surveyed every 750 m on both sides of the Reach 1 Channel to verify the UAV survey data. The UAV captured 5 cm imagery and photogrammetric topography data to derive point cloud data at a resolution of 25 to 30 points per square metre. Prior to the completion of the UAV survey, KGS Group undertook a topographic survey along Reach 1, capturing cross sections that defined the natural ground, spoil piles, overbank, main channel, channel bottom, and water levels, at every kilometre. These cross sections were used to ground-truth the UAV point cloud data. The area surveyed by KGS Group is shown on Plate 2.

The surveyed topographic and bathymetric data was used to prepare a Digital Elevation Model (DEM) of Reach 1, which is included in Appendix A. The DEM does not include any information along the bottom of the Reach 1 Channel, as standing water in Reach 1 precluded the UAV from measuring any channel bottom information. The DEM was developed using a 0.5 m grid spacing, and was found to have a mean elevation error of +/- 0.1 m, with a standard deviation of 0.2 m. The DEM was then used to update the estimated quantities of excavation in Reach 1 and also provided information used during the constructability assessment discussed in Section 7.0.

2.2 GEOTECHNICAL INVESTIGATIONS

KGS Group undertook a geotechnical investigation program over three days that included peat probes and the drilling of test holes using hand augers.

The peat probes were conducted at 250 m intervals along the proposed Option 3 and 4 channel alignments, along the proposed containment dike for Options 1 and 2, and along Buffalo Creek between Big Buffalo Lake and approximately 2.5 km upstream of the Reach 3 inlet. The approximate depth of peat above the underlying till was measured as well as the approximate sub-surface water level. Observations of the soil characteristics of the underlying till were also recorded. Along the proposed Option 3 and 4 alignments, additional peat probe cross sections were also conducted at 8 locations, each being approximately 1 km wide transects perpendicular to the proposed channel alignment. A total of approximately 240 peat probes were conducted, with the depth of peat ranging from approximately 0.1 m to over 3 m, for the most part averaging between 1.5 m and 2.0 m.

The test holes were drilled using hand augers at locations of the peat probe transects along the proposed Option 3 and 4 alignments. The test holes were typically drilled 0.20 m into the underlying till to assess the soil conditions below the peat, with the actual drilling depth being governed by the denseness of the till. Soil samples were collected for visual classification according to the Unified Soil Classification System (USCS). More detailed investigations to depths below the design invert of the channel utilizing full size drill rigs should be conducted at the next stage of design to confirm the various geotechnical, groundwater and hydraulic assumptions described in this report and to provide a better understanding of sub-surface conditions.

All peat probe and hand auger locations are shown in Plate 2. Data from the Geotechnical Investigations is attached in Appendix B. Profiles showing the various peat depths along the options are provided in Section 4.0.

2.3 BUFFALO CREEK AND BIG BUFFALO LAKE GIS SURVEY

KGS Group undertook a topographic and bathymetric survey along Buffalo Creek between Big Buffalo Lake and Buffalo Creek approximately 2.5 km upstream of the Reach 3 inlet. The survey collected topographic and bathymetric cross sections, at approximately 250 m intervals along Buffalo Creek, to define the top of the peat elevation, the channel bank elevation, and the channel invert elevation. As well, several cross sections were surveyed that defined the hydraulic control at the outlet of the peatland area.

Survey activities also included a sonar survey of Big Buffalo Lake. The survey was conducted by boat and covered an area of approximately 35 ha. The location of the surveyed cross sections and extent of sonar survey is shown on Plate 2. All of the GIS survey data is attached in Appendix C and has been incorporated into the various profiles of the options provided in Section 4.0.

2.4 CONTRACTOR SITE VISIT

An aerial and ground-truth site reconnaissance survey along the four proposed Reach 2 alignment options was conducted by KGS Group Engineers and representatives of Contractors having previous experience with the Reach 1 and Reach 3 emergency channels. The survey was conducted to make observations and obtain general information on the existing site conditions. The input from the Contractors was then incorporated into the constructability assessment and project cost estimates. Specific constructability concerns noted by the Contractor representatives are discussed in Section 7.0.

2.5 PEAT SPECIALIST SITE VISIT AND INVESTIGATIONS

KGS Group retained a peat specialist from ECOSTEM Ltd. to conduct a qualitative assessment of peatland conditions and the potential risks associated with overland flow in the area. A one-day site visit and investigation was conducted to collect detailed information regarding the composition, stratigraphy, and hydraulic characteristics of the peat areas near the project site. Peat cores were drilled using a hand auger to assess the stratigraphy and composition of the peat at key locations near the project, and visual observations of the overall condition and type of peat at several other locations. The results of the investigations and ensuing assessments are discussed in Section 5.3.

2.6 BATHYMETRIC SURVEY AT CHANNEL INLET LOCATIONS

In addition to the investigations outlined above, MI independently conducted a bathymetric survey of Lake St. Martin at the proposed inlet location of Option 4. The survey extended from the lake shore to approximately 500 m into the lake and is attached in Appendix D.

3.0 BASIS OF DESIGN OF CHANNELS

3.1 DESIGN DISCHARGES AND LAKE LEVELS

The discharge capacities for open water in the LMB and LSM Outlet channels were based on outflows required to be passed during high water levels on each lake, as originally defined in 2011 as part of the *Analysis of Options for Emergency Reduction of Lake Manitoba and Lake St. Martin Levels* studies (KGS Group and AECOM, 2011). The selected high water levels for the design condition are shown in Table 1.

TABLE 1
SELECTED HIGH LAKE LEVELS FOR DESIGN OF OUTLET CHANNEL

Lake	Selected Water Level
Lake Manitoba	248.1 m (814 ft)
Lake St. Martin	244.1 m (801 ft)

As described in the Stage 2 Study Report (KGS Group, 2016), the Province of Manitoba committed to a discharge capacity of 212 m^3/s (7,500 cfs) in the outlet channel for LMB at a lake level of 248.1 m (814 ft). Similarly, a commitment was made for a discharge capacity of 326 m^3/s (11,500 cfs) in the LSMOC at a LSM lake level of 244.1 m (801 ft).

In consideration of these discharge capacities and high water levels, preliminary operation guidelines for the LSMOC were developed in 2016 by MI, and were proposed to include:

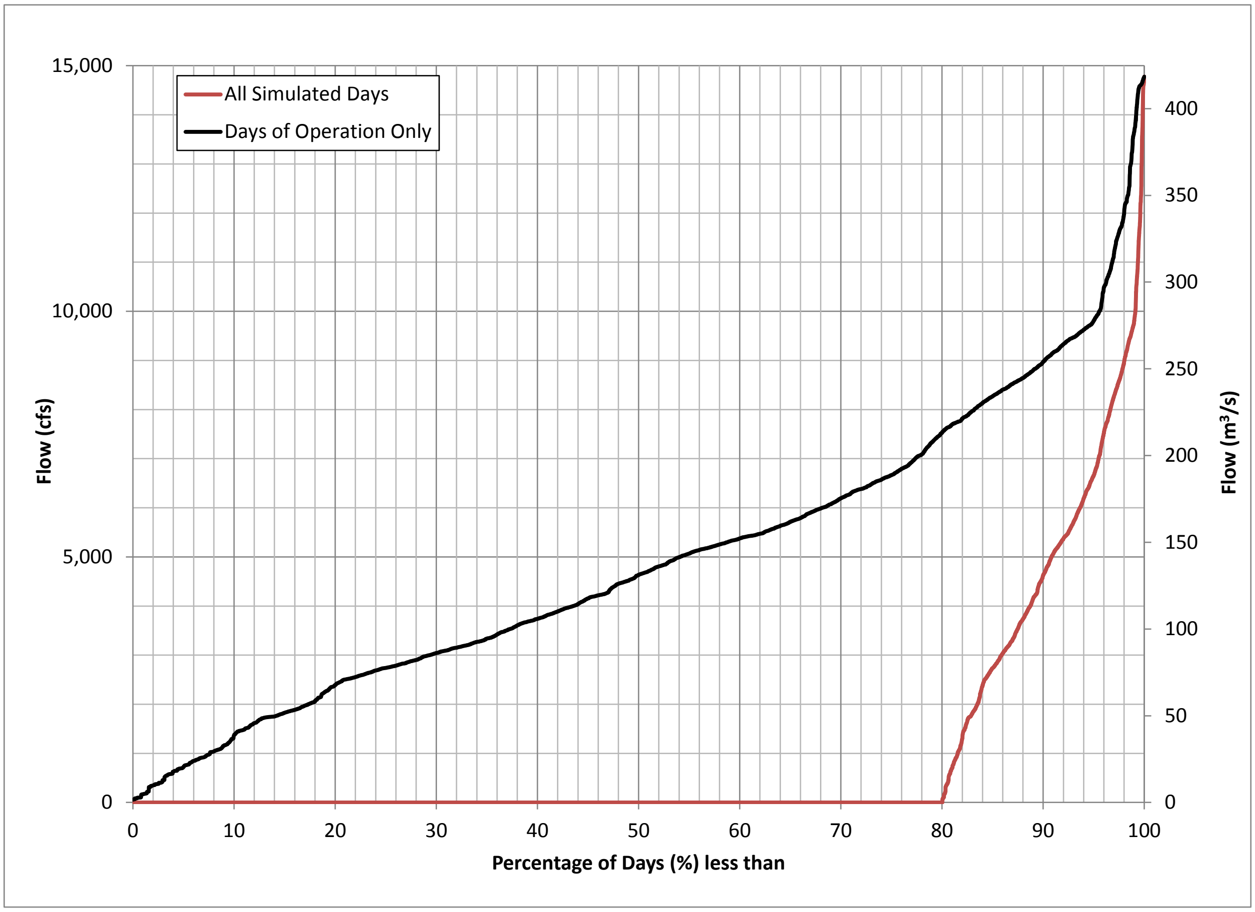
- The target regulation range for Lake St. Martin is El 797-800 ft.
- The LSMOC will be opened to full discharge capacity when the water level on Lake St. Martin rises above El 800 ft or when the Lake Manitoba Outlet is opened for initial operation and the water level on Lake St. Martin is above El 797 ft.
- During recovery from high water conditions when the lake level decreases below El 800 ft, the outflow from the LSMOC will be reduced to the greater of either 50% of channel capacity, or the outflow required to ensure that the total outflow from Lake St. Martin matches the total inflow from the Fairford River and Lake Manitoba Outlet Channel.
- If the Lake Manitoba Outlet is in operation in November, the Lake St. Martin Outlet Channel should be operated so that the total outflow from Lake St. Martin, insofar as

possible, matches inflow from the Fairford River and Lake Manitoba Outlet Channel during winter.

- The LSMOC will be closed fully when the water level on Lake St. Martin recedes below El 798 ft during the period from when ice cover has cleared out of the channel in the spring to October 31st.
- During the spring freshet, the LSMOC will be operated if the Lake Manitoba Outlet Channel has been in operation over the winter under the following conditions:
  - If the Dauphin River outflow plus the discharge capacity of the LSMOC is less than the total inflow into Lake St. Martin, then the LSMOC will be open to full discharge capacity.
  - Otherwise, the LSMOC should be operated so that the total outflow from Lake St. Martin, insofar as possible, matches inflow from the Fairford River and Lake Manitoba Outlet Channel.
- Initial operation of the outlet control structure shall not be initiated during the period in which there is solid ice cover in the channel (typically from Dec 1st – April 30th).

It is acknowledged that in future flood events, the flow in the channels will at times be less than the design discharge and will possibly exceed the selected discharge capacity of 326 m^3/s (11,500 cfs) in the LSMOC, depending on the water levels on the lakes at the time. Based on the operating guidelines, MI conducted flood routing studies of the system with the outlet channels in place. Figure 1 shows the range of flows that would occur if the channels had existed throughout the historical record of inflows (1915-2016).

FIGURE 1
SIMULATED FLOWS OF THE LAKE ST. MARTIN OUTLET CHANNEL



Statistical analyses by MI of the data summarized in Figure 1 have indicated that 326 m^3/s (11,500 cfs) is equivalent to a flood with an annual probability of being exceeded of approximately 1 in 90. The flood peak that would have an annual probability of being exceeded of 1 in 200 has been estimated to be approximately 382 m^3/s (13,500 cfs). Repetition of the flood of record (the 2011 event) would result in a flow of approximately 420 m^3/s (14,800 cfs) in the LSM channel. This estimate is based on an assumption that flows would not be cut back by partially closing the control structure.

Based on input from MI, it was agreed that for the current assignment, the Reach 2 Channel design capacity should be based on a flow of 326 m^3/s (11,500 cfs), as this was the capacity committed to by the Province of Manitoba. Similarly, the same capacity was assumed to apply to both Reaches 1 and 3 for the purposes of this study. Flows above 326 m^3/s (11,500 cfs) were assumed to be accommodated with a lower factor of safety. Acceptance of a lower factor of safety or, alternatively, potential increases in costs to address peak flows above the 326 m^3/s (11,500 cfs) capacity should be addressed at the next stage of design in parallel with design optimization.

The ultimate discharge capacity (maximum allowable capacity) of the channels is anticipated to be more than the selected design discharge described above. However, identification of the magnitude of the ultimate discharge capacity has not been defined at this phase of study.

3.2 CHANNEL GEOMETRY

The hydraulic design of the outlet channels was based on an assumed uniform trapezoidal cross sectional shape, with 4H:1V side slopes and a flat channel base.

Design to minimize the potential for erosion is a prerequisite. Doing so does not appear to conflict with any of the other demands on the channel performance, and has been addressed without compromising other features of the channel. This is defined in more detail in Section 3.3.

The selection of other aspects of the channel geometry was based on an optimal design between several conflicting issues:

- Maintaining low water levels in the channel during winter would tend to minimize the footprint area and extent of large thick ice sheets that could move during spring activation of the channel. On the other hand, persistently low water levels in winter would expose large areas of the channel side slopes where aufeis (ice forming in layers due to the successive cycle of water flowing and then freezing above the previous ice sheet) could grow due to seepage of local groundwater. Low water levels would also encourage the deposition of snow due to wind drifting, further exacerbating the ice development both in the channel and on the side slopes.
- Low water levels in the channel would maximize the exposure of the channel side slopes where vegetation may have been damaged or destroyed during preceding flood periods. Erosion of the side slopes during spring and summer rainstorms would be expected in these conditions.

- Conversely, relatively high water levels in the channels throughout the winter would minimize the exposure of bare soil on the side slopes, but maximize the development of a thick ice sheet that could be capable of causing damage in spring to the drop structures.
- Installation of culverts through the drop structures could facilitate fish movement, but in low flow conditions would cause drawdown of water levels that would exacerbate the vegetation issues described above. This drawdown is considered to be a significant negative effect on the channel performance with respect to vegetative growth and would clearly increase the costs of annual maintenance.

Based on the conceptual design developed during the Stage 2 Study, a design depth of flow of 3m was selected for the Reach 1 and Reach 2 channels to ensure a fair comparison of the options. However, considering the various issues regarding channel geometry identified above, the depth of the channel for the preferred option would be selected to be the maximum practical, so as to fulfill several objectives:

- Maintaining a depth of flow that will permit fish that may choose to winter in the channel to avoid being seriously impacted by ice growth throughout the full depth. A base flow will be required in the channel to ensure that anoxic conditions do not occur.
- Combined with appropriate crest lengths and crest elevations of the drop structures along Reach 2, the depth of flow will permit the maximum practical extent of submergence of the channel side slopes for extended durations. This is intended to minimize the surface areas of the channel side slopes, thereby minimizing erosion potential during rainstorms in non-flood periods.
- Minimizing excavation quantities, since a narrow deep channel is generally hydraulically superior and more cost effective than a wide shallow channel.
- Depths of water in both operative and non-operative periods of at least 1 m would be targeted to minimize the potential for uncontrolled growth of aquatic vegetation that would potentially reduce the hydraulic conveyance of the channel and adversely affect the discharge capacity. It will avoid shallow depths of water that would freeze over the full depth and encourage very thick aufeis deposits to form on the base of the channel, as well as on the exposed side slopes. While the areal extent of surface ice may be the greatest with the deep channels, the deep water will limit the thickness of ice growth to that normally associated with lakes and rivers (maximum of approximately 1 m typically).
- The configuration of the channel must permit the free transmission of any frazil ice that may be generated on the surface or within the flow in the channel. This may result in accumulation of a hanging dam at the downstream end of Reach 3. Preliminary analyses indicate that this accumulation would not cause serious impacts in Reach 3. Further discussion of this issue is provided in Section 8.5.

The channel depth and slope have been selected so as to minimize volumes of excavation as much as practical. Ideally, the Basis of Design would require incising the channel to the extent that the maximum water surface profile in the channel would be below the natural ground level over the length of the channel to minimize the requirements for dikes and potential risks of dike failures, as well as to minimize potential for overland flooding adjacent to the channel. However, preliminary analyses of such profiles revealed that achieving this criterion would result in an increased volume of excavation. Consequently, a practical alternative for the Basis of Design has been selected that would allow the maximum water surface profiles in the channels, generally over short segments, to exceed the outside ground levels at some locations.

To contain flows within the outlet channel, water retaining dikes have been incorporated into the design. Based on the conceptual design developed during the Stage 2 studies, a minimum 1.0 m (3.3 ft) freeboard above the 326 m^3/s (11,500 cfs) water level has been assumed to provide a greater safety margin for the dikes in consideration of flows that may exceed the design condition. The flood discharge that would permit a minimum freeboard of 0.6 m (2ft) has been estimated to be approximately 382 m^3/s (13,500 cfs). At the peak flow of approximately 420 m^3/s (14,800 cfs) during a repetition of the flood of record (the 2011 event), the dikes would have a freeboard of approximately 0.3 m (1 ft) above the maximum water surface profile. As discussed in Section 3.1, acceptance of a lower factor of safety or, alternatively, potential increases in costs to address peak flows above the 326 m^3/s (11,500 cfs) capacity will be addressed at the next stage of design in parallel with design optimization and input from MI.

Optimization of the channel design considering costs, excavation quantities, dike height, material types, control and drop structures, and utilities should also be undertaken following a process similar to what was done for the Red River Floodway Expansion Project. Studies of the Floodway Expansion indicated that savings of many tens of millions of dollars were estimated to be possible by applying an optimization method compared to a simple design that would maintain the same channel width throughout the channel. The method of optimization combined all the relevant primary factors of the channel design, and identified the design configuration that would minimize the overall cost of the project and should be applied to the Lake Manitoba Channel.

3.3 MAXIMUM ALLOWABLE VELOCITY OF FLOW IN CHANNEL

The limitation of flow velocities and shear stresses in the channel was based on KGS Group's extensive hydraulic experience in channel design and on a literature review of the maximum permissible non-scouring velocity and shear stress for the type of material that constitutes the channel bed.

As described in Section 2.2, test holes were drilled along Options 3 and 4 of the Reach 2 alignment using hand augers to a depth of approximately 0.20 m below the bottom of the peat. The material that was observed appeared consistent with what currently forms the channel bed on the existing Reach 1 Emergency Channel. A similar material also forms the channel bed of the Reach 3 Emergency Channel, with the exception of a short segment where fractured bedrock was encountered. On this basis, it was assumed that the bed material along Reach 2 would be consistent with that present in Reach 1 and Reach 3, although additional investigations and material testing will be necessary to more precisely confirm the material properties of the till and depths to bedrock. Based on the investigation results from the Stage 2 Conceptual Design Study, this material can generally be classified as a silt till to silty clay till, sometimes referred to as an unsorted glacial till. Undisturbed, the material is relatively compact and either cemented or with enough clay to be cohesive in nature.

Estimated maximum shear stresses and velocities for a non-eroding condition in different types of materials have been summarized in Table 2.

TABLE 2
MAXIMUM PERMISSIBLE SHEAR STRESS AND VELOCITIES FOR DIFFERENT BED MATERIAL

Bed Material	Maximum Shear Stress	Maximum Velocity	Source
Shales and Hardpans	32 N/m^2 (0.67 lb/ft^2)	1.8 m/s (6 ft/s)	Ven te Chow, 1959, Open Channel Hydraulics
Graded Silts to cobbles	21 N/m^2 (0.43 lb/ft^2)	1.2 m/s (4 ft/s)	Ven te Chow, 1959, Open Channel Hydraulics
Graded loam to cobbles	18 N/m^2 (0.38 lb/ft^2)	1.1 m/s (3.75 ft/s)	Ven te Chow, 1959, Open Channel Hydraulics
Compact Sandy Clay	(14 N/m^2) (0.3 lb/ft^2)	-	USDA 2007, National Engineering Handbook Part 654
Silt Clay	-	1.1 m/s (3.5 ft/s)	USACE 1991, EM 1110-2-1601,
Glacial Till	4.23 N/m^2 (0.09 lb/ft^2)	-	Mier & Garcia, Journal of Great Lakes Research 37 (2011) 399-410

As shown on Table 2, there is a relatively wide range of values to be considered as the maximum permissible shear stress or velocity depending on the originating source and the type of material that is selected. Since the conditions of the tests and material properties upon which these values have been based are unknown, it is difficult to associate with certainty the type of bed material on Reach 2 with a single value provided in Table 2. On this basis, the design of the Reach 2 Channel was based on maximum permissible values within the lower portion of the range and design velocities between 1.2 m/s to 1.4 m/s; and shear stresses less than 10 N/m^2 were targeted. This was judged to be a reasonable approach, based on our extensive experience with this type of material, while ensuring a relatively conservative design criterion at this stage of the design.

For comparison purposes, average velocities measured in Reach 1 during the Emergency Operation in 2011/2012 and 2014/2015 were in the range of approximately 1.2 m/s. Since recent observations of the Reach 1 Channel bed did not show signs of erosion, similar conditions in Reach 2 are not expected to result in erosion. Nonetheless, verification of the acceptable threshold values should be considered at the next stage of design based on additional research, comparisons with other channels with similar known conditions, or by conducting field or laboratory testing of the bed material.

3.4 HYDRAULIC GRADIENTS

The estimated head loss in the channel and the selected gradient of the invert of the channel were based on application of the Manning's equation. Manning's "n" values selected for the channel design were based on typical values as defined by Ven Te Chow (Chow, 1959). All four channel options assumed an n-value of 0.028 (channel bed in glacial till).

The design recognizes that growth of aquatic vegetation will typically be concentrated in areas where the depth of water is less than approximately 1 m. As noted in Section 3.2, the depth of water in the channel under non-operating conditions will be typically greater than 1 m and will inhibit the potential for growth of aquatic vegetation. The estimated head losses must acknowledge that along the sides of the channel where the depth would be less than 1 m, there may be heavy growth of vegetation. Future optimization of the design should anticipate that the effective hydraulic roughness in these shallow portions of the channel cross section will be relatively high. A Manning's n-value in the range of 0.04 to 0.12 should be considered to represent the anticipated heavy growth of vegetation in these shallow portions of the channel.

It is possible that under some conditions of relatively low flow during winter, an ice cover may develop in some low velocity zones in the channel. Border ice may form and advance laterally to cover the full width of the channel. For these conditions, it has been assumed that hydraulic gradients along the ice covered reaches could be approximated assuming a Manning's n-value of the undersurface of the ice of 0.025. This is described further in Section 8.5.

3.5 DROP STRUCTURES

3.5.1 Rationale for Incorporating Drop Structures

Options 1 and 2

There is a portion of Reach 2 for Option 1 that would pass through the upper end of Buffalo Creek where the gradient of the channel bed exceeds 1 m per 500 m. This is the same route that diverted flows followed in 2011/2012 and 2014/2015 during the emergency diversion of floodwaters from Lake St. Martin. The flows during the two emergencies ranged between approximately 40 m^3/s and 215 m^3/s (1,400 cfs and 7,600 cfs), which is considerably less than the current design flow of 326 m^3/s (11,500 cfs) for the permanent outlet channel. Nevertheless, extensive erosion in upper Buffalo Creek occurred during those diversions of floodwaters. Release of flows in the future along this route would be expected to continue to cause erosion.

Shear stresses along the channel have been estimated to be in excess of 80 pa during passage of the design flood. By comparison, it is known, for example, that flood flows through the Red River Floodway at the peak of the "flood of the century" in 1997 were approximately 8 pa in the upstream reaches. That did not incur erosion in the grass lined portion of the channel, but appeared to have caused significant scour of the unprotected clay bed of the Low Flow Channel in the Floodway. Indeed, literature on channel bed scour, such as what has been referenced in Section 3.3, lists the shear stress at which erosion can be expected to commence to be 8 pa for clay and as much a 35 pa for dense glacial till. The shear stresses to be expected in Buffalo Creek for Option 1 are estimated to be significantly greater than these thresholds. It is difficult to predict with any accuracy how the erosion would develop, expand or stabilize. But it is clear that substantial erosion of the channel would take place.

While erosion of the existing Buffalo Creek Channel occurred during the emergency conditions encountered in 2011/2012 and 2014/2015, continuation of this process is not considered acceptable for a permanent system of flood diversion. It was concluded that including drop structures to dissipate energy in concentrated, protected zones would be the most viable and economic option to avoid significant erosion.

Options 3 and 4

The existing ground surface within the last 3 km of the proposed Option 3 and 4 alignments also has a gradient of approximately 1 m per 500 m. Drop structures will, therefore, also be required to safely dissipate energy so that the excavated channels can have suitably mild slopes to avoid high velocities and potential erosion.

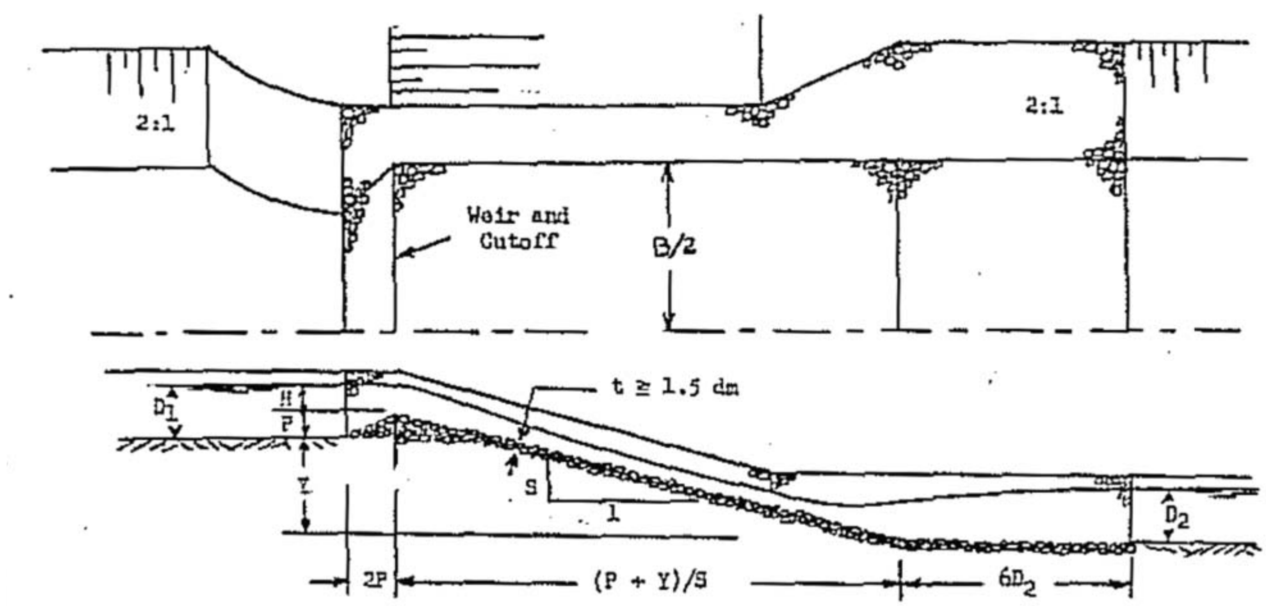
3.5.2 Design Basis for Drop Structures

The purposes of this stage of preliminary design of all options are to:

- Confirm that rock-fill drop structures are appropriate.
- Refine the design of the structures considering the competing and conflicting design requirements (i.e. ice, vegetation, and fish passage).

The design of the rock-fill drop structures for Reach 2 of the Lake St. Martin Outlet Channel is based on the guidance provided in the textbook by C.D. Smith entitled "Hydraulic Structures", 1995 edition (Chapter 8, Section E). The general arrangement of the structure that was developed by C.D. Smith was based on theory, model studies and experience, and is as shown in Figure 2.

FIGURE 2
CONCEPTUAL LAYOUT OF TYPICAL DROP STRUCTURE
(ADAPTED FROM SMITH, 1995)



The assumptions adopted for the initial design of the drop structures were:

- Design flow of 326 m^3/s (11,500 cfs).
- Typical spring freshet flow of 10 m^3/s (353 cfs).
- Typical riparian fish passage flow of 1 m^3/s (35.3 cfs).
- Channel longitudinal slope of approximately 0.0204%.
- Side slopes of the channel and the drop structure set at 4H:1V.
- Manning's n-value for the channel of 0.028.
- Maximum d_{50} of available riprap of 500 mm, with a specific gravity of 2.6.
- Typical vertical drop of 2 m (from upstream channel bed to downstream channel bed).
- 2H:1V upstream slope of drop structure weir crest.
- Riprap protection extends 5 m upstream of base of rockfill weir.
- Rockfill thickness of 3xd_{50} immediately downstream of weir crest provided.
- Rockfill thickness of 2xd_{50} on chute of drop structure.
- Riprap extends 1 m above design water levels.
- Riprap protection extends downstream of toe of chute slope for a distance equal to six times the downstream flow depth (D2).

3.6 CONTROL STRUCTURE

Flow in the LSMOC would be controlled by a gated control structure. Since developing the preliminary design of the control structure was not included in the scope of work for the current study, it was assumed that the concept would remain unchanged from the Stage 2 Conceptual Design study. The assumed structure has six 9 m wide bays that incorporate six vertical gates with a maximum opening of 6 m. The control structure also serves as a bridge to cross the outlet channel.

For Options 1, 2 and 3, the structure was proposed to be located in Reach 1 at or near the existing inlet location at LSM. For Option 4, it was assumed that the structure would also be located in Reach 2, also near the inlet location at LSM (see Section 4.0). Optimization of the structure design and location to reduce cost would be undertaken at the next stage of design for the preferred Reach 2 alternative.

3.7 PROTECTION AGAINST EROSION

In spite of the inclusion of drop structures, protection against erosion would still be required in the channel in local areas subject to high velocities or wave action. Revegetation of disturbed areas with exposed soils would also be required. Riprap armouring may also be required at the channels' inlet and outlet areas, at bridges and control structures, at drop structure locations, as well as at various locations along Buffalo Creek (Options 1 and 2).

A conceptual design for revegetation was developed in conjunction with Scatliff+Miller+Murray Inc. and is described in the Stage 2 Conceptual Design Report. It was largely based on the existing conditions observed at the LSM Emergency Outlet Channel. Further considerations regarding revegetation are discussed in Section 10.2.

3.8 FISH PASSAGE

The design of the LSMOC was developed such that fish will not be able to swim upstream from Lake Winnipeg through Reach 3 of the LSMOC under any conditions whether operating or non-operating to minimize potential aquatic impacts. The high velocities and large differential in water levels through the downstream drop structure of Reach 3 will impede the movement of fish in the upstream direction from Lake Winnipeg. However, since fish and fish habitat currently exist within Buffalo Creek and Big Buffalo Lake (Options 1 and 2), and since fish may be able to move downstream into the LSMOC from Lake St. Martin when the control structure is in operation (for all options, although accommodation of the LSMOC Control Structure for fish passage is not a requirement of the design criteria), the design criteria considers that fish must be able to escape from the LSMOC to the maximum extent practical after flood operations are curtailed (i.e. control structure gates closed).

Considerations with regards to fish passage that were included in the design of the LSMOC to achieve the proposed design criteria are listed below. Further review of the proposed criteria and assumed design conditions will be required at the next stage of design with input from the environmental approval process.

During Non-flood Periods with the Gates Closed in the LSMOC Control Structure:

- Fish should not be able to move upstream past the LSMOC Control Structure for any of the options (i.e. the closed gates impede the movement of fish).
- The design must accommodate the movement of fish in Buffalo Creek upstream past the diversion structure of Options 1 and 2 (see Section 4.1 for description of diversion structure). This structure will release flow into the natural waterway of lower Buffalo Creek. Options 3 and 4 do not require this control structure; and this restriction does not, therefore, apply to them.
- Similarly, the design must accommodate the movement of fish upstream and downstream past the drop structures located in Buffalo Creek along the route of Options 1 and 2.
- Along the route of Options 3 and 4, the design must accommodate the movement of fish downstream past any of the drop structures. This will minimize the potential for fish stranding after flood operations end in any particular year when the LSMOC is used.

During Flood Periods with the LSMOC Control Structure Gates Fully or Partially Open:

- Fish may be able to move upstream through the LSMOC Control Structure with the gates in a fully open condition. However, under almost all partial gate openings, fish will not be able to pass upstream through the control structure due to excessive velocities.
- Fish will not be able to swim upstream through the diversion structure of Options 1 and 2 due to high velocities through the culvert of the diversion structure and the large differential in water levels.
- Fish may be able to move downstream past the drop structures of all options, but may not be able to move upstream at these structures due to the high velocities and large differential in water levels.

3.9 CHANNEL SLOPES, DIKES AND SPOIL PILES

The following additional considerations were included in the Basis of Design for the LSM Outlet Channels:

- Long-term condition (after construction): minimum estimated geotechnical factor of safety (FS) of 1.5 for both the outlet channel and dike slope stability at steady state conditions, must be maintained under either full channel flow condition, or no water (dry channel conditions).

- Short term condition (during construction): must maintain a minimum estimated factor of safety (FS) of 1.3 for outlet channel and dike slope stability under dry channel conditions.
- Short term condition: minimum estimated factor of safety (FS) of 1.2 for outlet channel and dike slope stability under rapid drawdown conditions (during operation with Open or Closed Gate Conditions).
- The existing peat should be removed on either side of the channel excavation such the entire base of the dike is constructed on top of Till. This is to ensure a tight seal between the dike and foundation soils and to serve as a cut-off for seepage through the existing peat layer. The dike fill would be silt and clay till materials from composite excavation.
- Final dike elevations at the end of construction should be overbuilt by 0.3 m (1 ft) to overcome the long-term estimated settlements (i.e. in addition to the recommended 1.0 m (3.3 ft) freeboard at the design flow of 362 m^3/s (11,500 cfs) discussed in Section 3.2).
- The top of dike should be at a minimum 0.6 m (2 ft) above the ground surface (top of peat) to isolate the phreatic surface in the saturated peat from the open channel and to ensure surface water drainage is permitted to enter the channel only at predetermined locations.

The criteria for minimum estimated FS were based on current Manitoba Provincial Guidelines for dike stability (MIT, 2012) and are consistent with the Canadian Dam Association (CDA) Dam Safety Guidelines (CDA, 2007).

4.0 DESCRIPTION OF REACH 2 CHANNEL DESIGN FOR OPTIONS 1 TO 4

The release of flood waters from Lake St. Martin is planned to be achieved through a channel that exits the lake at its north end and passes overland to release into Lake Winnipeg. Plate 1 shows the general location of the diversion route.

The LSMOC concept that was developed as part of the Stage 1 and 2 studies was comprised of three distinct reaches: Reach 1 extending approximately 6 km from LSM to the peatland area surrounding Big Buffalo Lake; Reach 2 extending approximately 10 km to 13 km from the end of Reach 1 to Reach 3; and Reach 3, which passes overland approximately 10 km from Buffalo Creek to Lake Winnipeg.

This current assignment has focused on a comparison of four possible options for Reach 2, working from the concepts that were previously considered during the Stage 1 and 2 studies. The final planning and design of the preferred alternative for Reach 2, as well as for Reaches 1 and 3 is proposed by MI to be carried out after the selection of the preferred Reach 2 alignment option has been made. Each option for Reach 2 is described in Sections 4.1 through 4.4, and subsequent sections of this report address the key issues that were considered in a systematic evaluation and selection of the preferred route.

A permanent access road is planned to be constructed to the area before construction in any of the channel reaches commences. Further details on site access for the construction period as well as for the long-term are provided in Sections 7.1 and 10.1.

4.1 REACH 2 OPTION 1

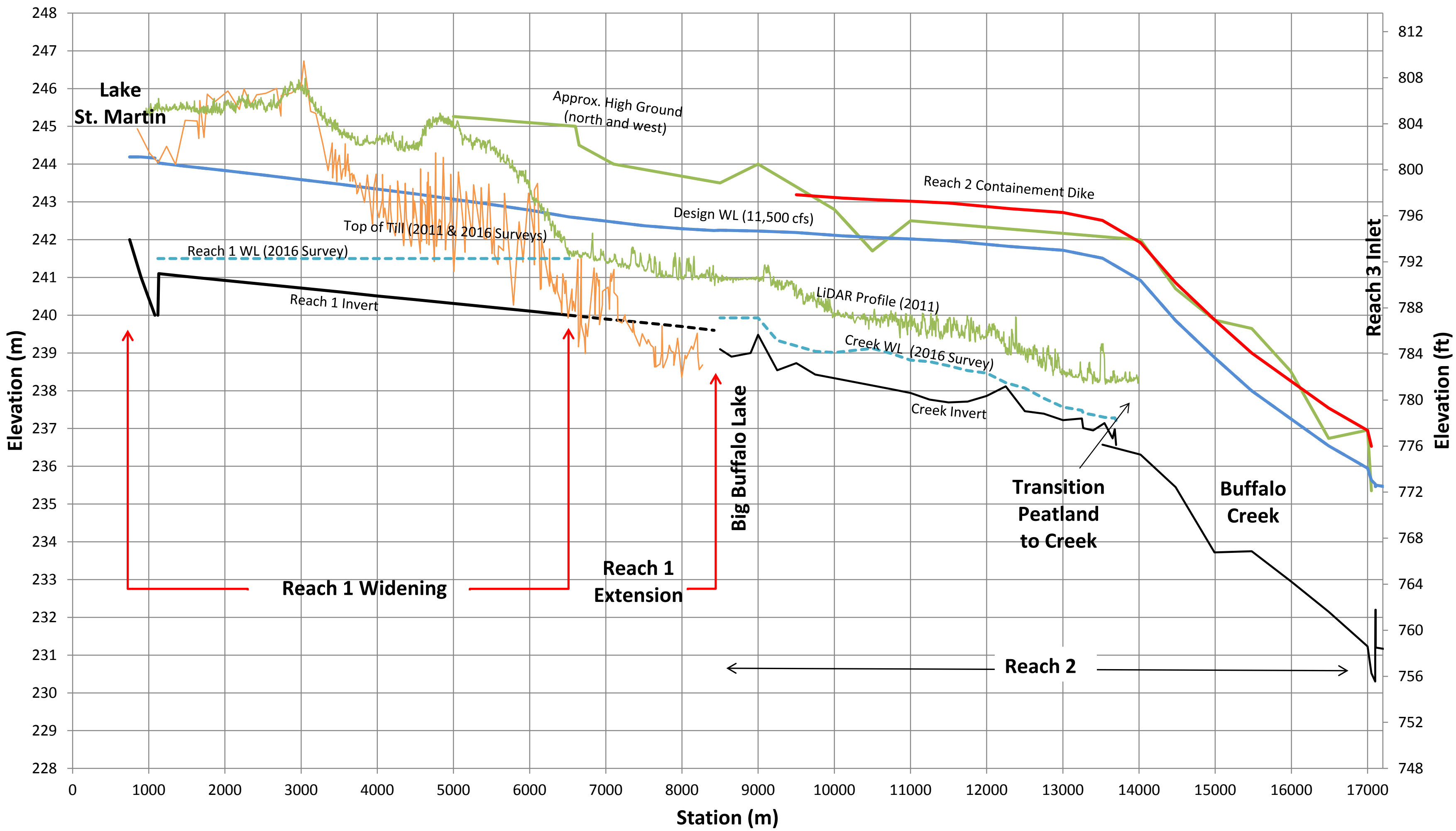
Reach 2, Option 1 follows essentially the same route that was used for the emergency flood release from LSM in 2011/2012 and 2014/2015 and is based on the original concept that was developed during the previous Stage 1 and 2 studies. Flows would enter the LSMOC at the inlet of Reach 1 and be carried north-easterly towards Big Buffalo Lake. Flows would then travel through the peatland area surrounding Big Buffalo Lake and enter Buffalo Creek. However, contrary to emergency flood conditions, flows would then be diverted into Reach 3 and would discharge directly into Lake Winnipeg rather than into the Dauphin River.

The following features were incorporated into the concept of Option 1:

- The existing Reach 1 that was constructed in 2011 would be expanded from a 45-m base width to 100 m.
- Reach 1 would also be extended an additional 2 km into the peatland area up to Big Buffalo Lake. This is necessary to achieve the hydraulic design capacity requirements stated in Section 3.1. The spoil pile would be concentrated on the west (left) bank of the channel to allow flows to continue to travel overland within the upland peatland area on the east side of the channel.
- A control structure would be constructed at the upstream end of Reach 1 to permit regulation of the outflow from LSM and to provide access across the channel.
- An approximately 11 km long powerline would be constructed to provide permanent power to the control structure and for construction, as shown on Plate 1.
- A containment dike would be constructed on the north side of Big Buffalo Lake to prevent “end runs” of flow during extreme floods
- Three drop structures would be included along Buffalo Creek to avoid excessive erosion that would otherwise be expected to occur in that steep part of the channel route. Further descriptions of these drop structures as well as ones required for the other options are located in Section 4.5.
- Additional erosion protection would be incorporated along the banks of Buffalo Creek in selected areas to protect steep and exposed side slopes against erosion.
- A vegetation clearing program would be undertaken to minimize the risk of debris floating and moving downstream during operation.
- A diversion structure would be constructed on Buffalo Creek to divert flows into Reach 3 during periods of operation and to release flow into the natural waterway of the lower Buffalo Creek as per the design criteria for fish passage (Section 3.8).
- A bridge structure would be included near the inlet of Reach 3 to provide long-term access to the diversion structure, as well as the containment dike and Buffalo Creek drop structures.

Plate 3 shows a map of the general alignment and key features of Option 1. The arrangement of the access road for construction and long-term operation and maintenance, discussed in detail in Sections 7.1 and 10.1, is also shown. Figure 3 shows a profile of Reaches 1 and 2 for Option 1. The profile includes channel invert and natural river/lake bed profiles, estimated water surface profiles for the design flood event of 326 m^3/s (11,500 cfs), a profile of the containment dike, profiles of existing ground levels and of the till surface that underlays the peat along the alignment, and approximate high ground levels to the north and west of the diversion route.

FIGURE 3
PROFILE OF OPTION 1



Note: Drop structure concept in Buffalo Creek not shown. Further discussion included in Section 4.5.1.

4.2 REACH 2 OPTION 2

A major concern with Option 1 is that the concept results in extensive flooding of the peatland surrounding Big Buffalo Lake. Large areas of the peat would be inundated during the passage of floodwaters. This is expected to cause a potential for floatation of the peat and/or marsh, possibly adversely affecting the discharge capacity of the diversion route.

That concern led to the development of a variation of Option 1 involving excavation of a 200 m wide channel through the peatland along Buffalo Creek to ensure that the discharge capability of Reach 2 would not be compromised by floating of the peat. This concept was originally developed as it was considered it could be more cost effective than an option that followed a new or modified alignment. The excavation depth would vary between approximately 2 and 3 m depending on the depth of peat down to the existing creek invert and/or the top of till. With the exception of this channel that would be located within the peatland, the remaining features of Option 2 would be as described for Option 1 (Section 4.1). Plate 4 shows a map of the general alignment of Option 2.

The concern regarding floatation of portions of the peatlands and the potential impacts to the hydraulic capacity of Reach 2 is a significant concern for bot options that discharge through the peatland. This issue is addressed in more detail, and is described more fully in Section 5.0. It was concluded that this risk was a significant disadvantage for Options 1 and 2 when compared to Options 3 and 4. Furthermore, it was concluded that the following aspects of Option 2 would make it less desirable as a solution compared to Option 1:

- Although excavation within the peat would assist in avoiding loss of discharge capacity along this route, it would still not prevent the risks associated with an influx of floating islands of peat or marsh that could clog the outlet into Buffalo Creek or at constrictions downstream. Options 3 and 4 (described below) would provide that security.
- Excavation in the peatland would be more difficult and expensive than Option 1.
- Dewatering of the peatland for construction would likely result in environmental impacts difficult to quantify.

In summary, considering that the overall cost of Option 2 would be more than Option 1, due to the added excavation works within the peatland area, that there would be potential additional environmental impacts, and that there would still be a risk of floating islands forming, it was concluded early in this study that Option 2 was clearly less desirable than Option 1 and, therefore, could be eliminated from further consideration. This concept was reviewed in a meeting between KGS Group and MI on October 6, 2016. It was agreed at that meeting that Option 2 should be rejected and study efforts devoted towards assessment of the other three options.

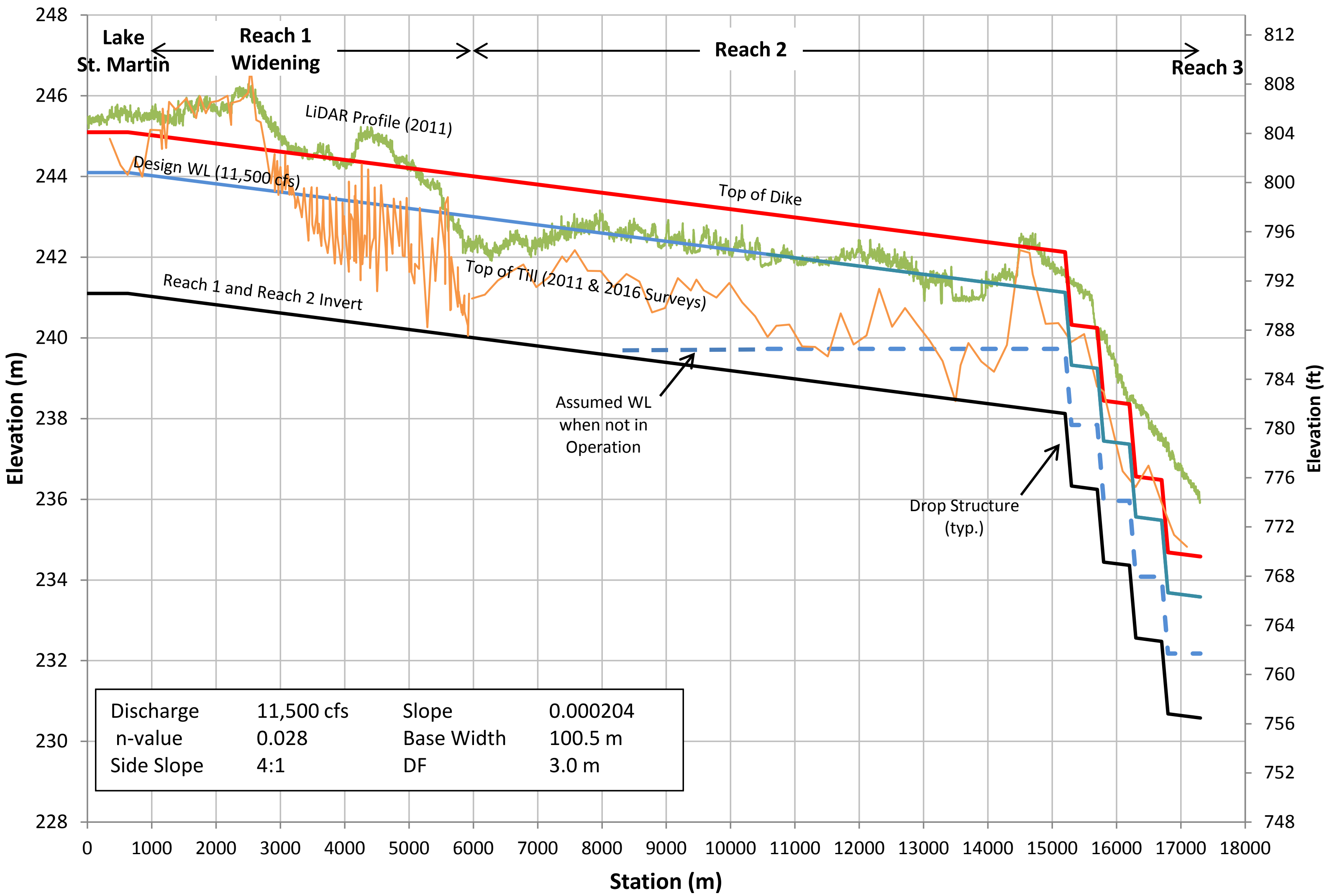
4.3 REACH 2 OPTION 3

The concerns for reliance on the route through the peatland area surrounding Big Buffalo Lake, including constructability, as well as environmental and operational risk, led to development of a channel orientation that would avoid inundation of the peatland area. Option 3 was developed to carry flow from the downstream end of the existing Reach 1 Channel (expanded in width as described for Option 1), following an alignment that would route around the peatland and Big Buffalo Lake and enter the upstream end of Reach 3 without adding floodwaters into Big Buffalo Lake or Creek.

Plate 5 shows a map of the general alignment and key features of Option 3. The arrangement of the access road for construction and long-term operation and maintenance is also shown. Figure 4 shows a profile of Reaches 1 and 2 for Option 3, including channel invert and top of dike profiles, estimated water surface profiles for the design flood event of 326 m^3/s (11,500 cfs) and under non-operating conditions, and profiles of existing ground levels and of the till surface that underlays the peat along the diversion route.

The Reach 2 Channel for Option 3 would extend approximately 11.1 km in length and would be similar to the expanded width of the existing channel in Reach 1, with a base width of approximately 100 m. The channel would be excavated through the surface peat material down into glacial till, and dikes would be constructed on both sides of the channel to avoid flooding of adjacent land. The dikes would also form the means of permanent access for inspection and maintenance, as discussed in Sections 7.1 and 10.1. Option 3 would include a control structure at the upstream end of Reach 1, similar to Option 1, which would also serve as a bridge. Now, however, a secondary bridge structure on Reach 3 would not be required (contrary to Option 1).

FIGURE 4
PROFILE OF OPTION 3



The channel for Option 3 would avoid the need to pass flood flow from LSM into Buffalo Creek, and therefore would also avoid the construction of the containment dike and Diversion Structure at the entrance of Reach 3. However, similar to Options 1 and 2, it would require drop structures to dissipate energy. The design of these structures is discussed in more detail in Section 4.5.

4.4 REACH 2 OPTION 4

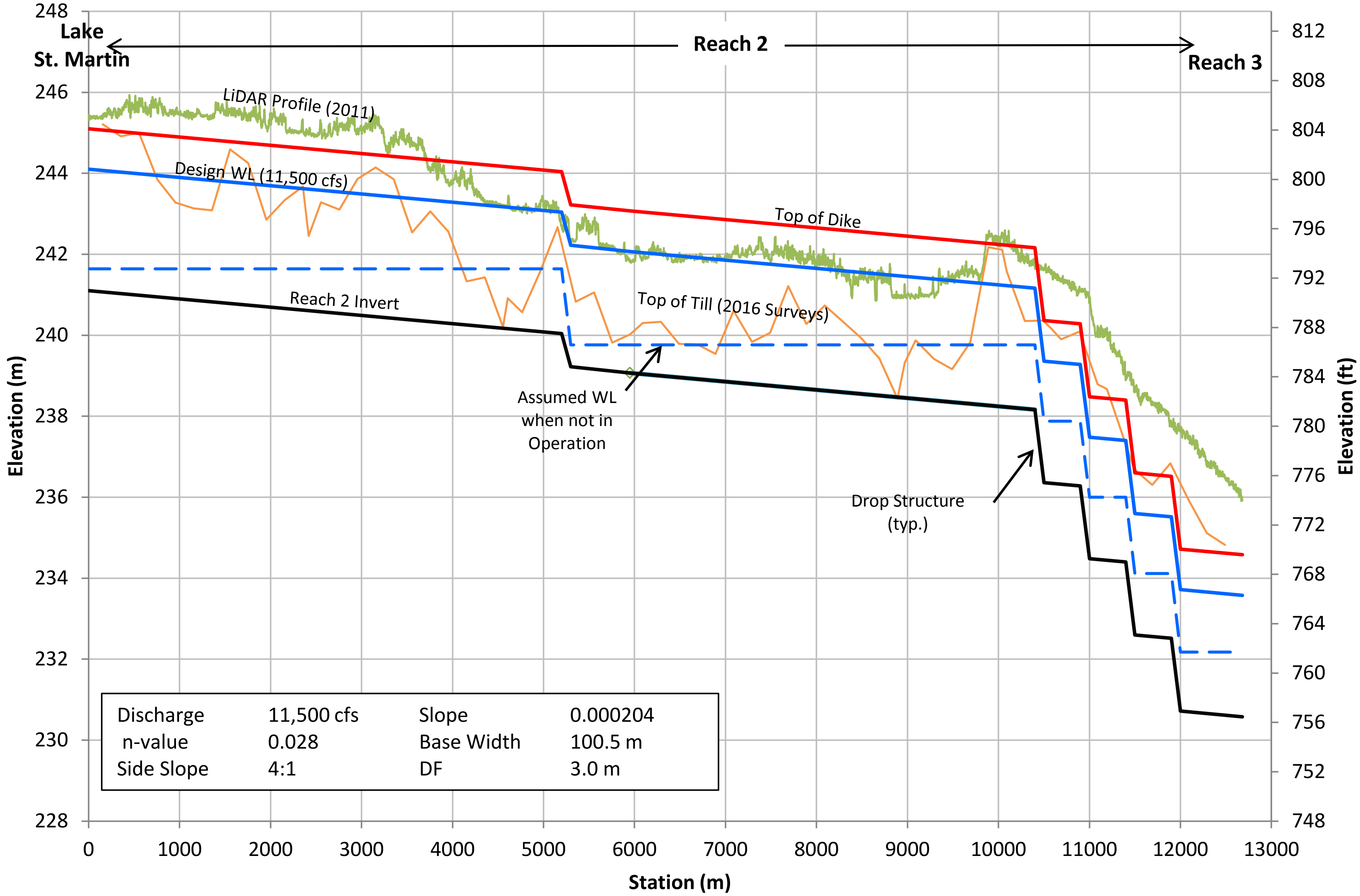
Option 4 was conceived as an alternate to Option 3 to reduce the combined Reach 1 and Reach 2 Channel length and overall excavation quantities. Option 4 considers a new intake for the channel at a location approximately 3.8 km to the east of the existing Reach 1, and it then follows a northerly direction to Reach 3. The downstream 6 km segment of the channel would essentially be the same as Option 3.

Plate 6 shows a map of the general alignment and key features of Option 4. The arrangement of the access road for construction and long-term operation and maintenance is also shown. Figure 5 shows a profile of Reach 2, as it would be needed with Option 4, including channel invert and top of dike profile, estimated water surface profiles for the design flood event of 326 m^3/s (11,500 cfs), and profiles of existing ground levels and of the till surface that underlays the peat along the diversion route.

The Reach 2 Channel for Option 4 would extend approximately 12.7 km in length and would be similar to Option 3, with a base width of approximately 100 m. The channel would be excavated through the surface peat material down into glacial till, and dikes would be constructed on both sides of the channel to avoid flooding of adjacent land in areas where ground surface is below the design water surface profile. The dikes would also form the means of permanent access for inspection and maintenance, as discussed in Sections 7.1 and 10.1. Contrary to Option 1, a bridge structure on Reach 3 would not be required.

A permanent control structure would be located at the upstream end of the channel for Option 4 and would also serve as a bridge to provide access on both sides of the channel and to Reach 1. As discussed in Section 3.6, the design concept for the control structure was assumed to be the same as that proposed for Option 1. However, the proposed 24 kv powerline would be approximately 4 km longer in order to extend to the control structure.

FIGURE 5
PROFILE OF OPTION 4



The channel for Option 4 would avoid the need to pass flood flow from LSM into Buffalo Creek, and, therefore, would also avoid construction of the containment dike and diversion structure at the entrance of Reach 3. However, similar to other options, it would require drop structures to dissipate energy. The design of these structures is discussed in more detail in Section 4.5.

The channel in Reach 1 would be decommissioned and re-vegetated. Decommissioning would consist of re-shaping the side slopes of the existing channel and spoil pile as required, improving local drainage within and along the perimeter of the channel, and enhancing the closure dike at the inlet. Opportunities to re-purpose Reach 1 to enhance aquatic and/or terrestrial habitat in the region, to provide a base flow from Lake St. Martin to the Big Buffalo Lake peatland area, and/or for other mitigation strategies would be considered at the next stage of design. In the event of a flood on Lake St. Martin during construction, emergency operation of Reach 1 could be considered with minimal impact to the construction schedule, resulting in a potential benefit compared to the other alignment options. Similarly, long-term additional emergency capacity would potentially be available with minimal effort by re-opening Reach 1 if necessary.

4.5 DROP STRUCTURES

The steep sections of Reach 2 do not provide hydraulic conditions that would prevent erosion of the channel bed. Drop structures within the diversion route are required to dissipate energy, as well as mitigate high velocities and potential erosion.

The drop structures are proposed to be constructed of rockfill, with a sheet pile cutoff at the upstream crest. As discussed in Section 7.4 and based on the results of previous field investigations, this concept assumes that a sufficient volume of rock of good quality will be available from the rock quarries within the region. Should detailed investigations prove the contrary, other concepts may have to be considered.

4.5.1 Drop Structures for Option 1

As discussed in Section 4.1, the portion of Buffalo Creek between Big Buffalo Lake and the inlet of Reach 3 will require measures to reduce velocities associated with passage of the design flow and thus limit future erosion in the channel. The acceptable design velocity during passage of the design flow is considered to be between 1.2 and 1.4 m/s, as identified in the Basis of Design for the channel.

Hydraulic modeling of this steep reach has shown that construction of drop structures alone will not be practical to limit erosion in this area as the existing channel cross section is too narrow to accommodate the design flow. Either channel deepening (which would also help reduce the longitudinal slope) and/or channel widening, along with construction of drop structures would be required to lower velocities sufficiently. As this is an existing waterway, such construction efforts would require a significant amount of in-water work.

Based on preliminary calculations and hydraulic modelling results, construction of drop structures that are at least 6 m in height would be required to reduce velocity in the channel to the desirable range. However, this height of structure would block a significant portion of the main creek channel. This blockage would result in much of the flow being forced onto the overbanks. Thus, the higher water levels will likely require an increase in the crest elevation of the containment dike on the northwest side, and may also require the construction of a dike on the south side to avoid flows going around the drop structures, as well as to avoid extensive overland flooding.

Fish passage is required in Buffalo Creek in both the upstream and downstream directions. This requires that the heights for the drop structures must be reduced significantly, or an alternate fish passage structure (such as a pool and riffle structure) be provided at each drop structure location. Incorporation of fish passage will further increase the costs associated with each of the drop structures required in Buffalo Creek. For the height of drop structures under consideration, the fish passage structures would need to be relatively long to provide the velocities and head differentials required to meet the fish passage criteria.

Considering the complex energy dissipation requirements for Option 1 (Buffalo Creek), detailed designs of the structure were not attempted at this level of study. Based on the preliminary assessment, it is evident that drop structures for Buffalo Creek with the same cross section and general design parameters as those considered for the Options 3 and 4 channels (described in Section 4.5.2) would require significantly greater volumes of rock per structure on Buffalo Creek.

4.5.2 Drop Structures for Options 3 and 4

The design of drop structures suitable for Options 3 and/or 4 was undertaken in an iterative manner based on the assumptions and criteria identified in Section 3.5. Several different arrangements were considered to assess the sensitivity of the design to changes in key parameters (structure widths and weir heights), as well as the impact these changes on these parameters could have on the quantity of rock required to construct the drop structure.

Several options for the channel geometry were under consideration at the time the initial drop structure design work was undertaken. The channel widths considered in the analysis of the drop structures ranged from 40 m to 450 m. Although a wide channel with long crest lengths at the structure would reduce the variability in water levels upstream of the structure, these wider channel configurations were concluded to be impractical due to the large quantities of excavation required to provide adequate transition lengths. Thus, channel and drop structure widths were restricted to less than 100 m. This width was found to strike a reasonable balance between cost, and the need to minimize the variation of water level between conditions during operation and conditions when no flood diversion was required (as explained in Section 3.2). For each conceptual layout of the drop structure, flow characteristics over the crest of the structure were computed, as well as on the chute and in the downstream channel.

Volume of Rock Required

Rockfill volumes were estimated for each of the channel/drop structure combinations considered, and are shown graphically on Figure 6. The volume of rock required was estimated for the 40 m wide drop structure placed in a channel with a 40 m base width, assuming 0.5 m median diameter rock with a specific gravity of 2.6 is 14,200 m^3. The estimated volume of rock for the 100 m wide drop structure in the 100 m wide channel is 10,200 m^3.

FIGURE 6
RELATIONSHIP BETWEEN VOLUME OF ROCK AND STRUCTURE WIDTHS

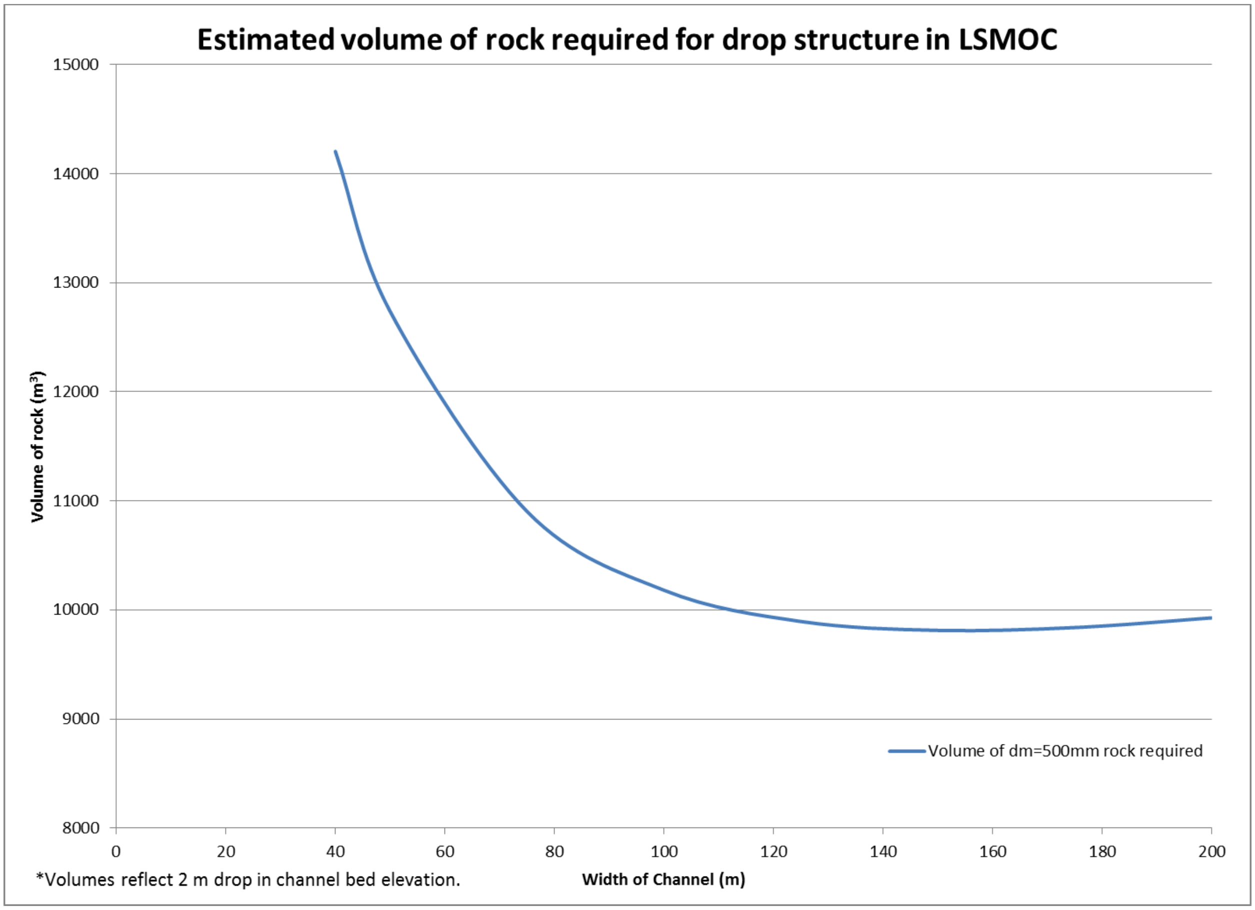


Figure 6 shows that the volume of rock per drop structure would be minimized for a channel and drop structure that are approximately 150 m wide. However, such a structure would require considerably more channel excavation in the transitions approaching and downstream of the structure, which would offset some of the minimal cost saving of the rock. As shown on Figure 6, the difference in volume of rock between a 150 m wide and 100 m wide drop structure is relatively small, in the order of 4%. A width of 100 m was, therefore, selected for the purposes of this study. However, further optimization is recommended in the next stage of design.

Ice Considerations

It is desirable that the head over the crest of the drop structure not be so great as to permit large, competent ice masses to be swept over the structure and damage either the drop structure or the channel downstream. The design assumes that increases in flow in the spring by raising the control gates would not occur until the end-of-winter ice on the channel has dissipated. A typical flow during the spring freshet (before the ice has dissipated) was assumed to be approximately 10 m^3/s (350 cfs). At this modest flow, the head over the crest of the structure would be considerably less than the thickness of the ice, and release of the ice cover over the crest would not be likely to occur until the ice reached a late stage of decay and melt. All of the options considered for the drop structure would prevent premature release of ice over the crest.

Sheet Pile Cutoff

Sheet piles (or some other type of upstream cutoff membrane) are proposed to be provided to avoid passing most, if not all, of the riparian flow through the rockfill, rather than over the crest of the structure. A sheet pile cutoff would also provide additional benefits, which include:

- Providing some insurance against loss of control of the channel in the event that rockfill is lost/displaced (possibly due to high flow events, or ice damage).
- Increasing the robustness of the structure to accommodate ice loading (either impact or ice jam accumulation), and possibly debris loading.
- Acting as a cutoff against seepage under the structure/piping (would allow for greater drop heights to be utilized).

Considerations for Fish Passage

The drop structures in Options 3 and 4 are required to provide downstream fish passage.

Several methods were examined for providing downstream fish passage over the structures. The most practical appears to be provision of a notch in the drop structure weir as well as provision of a small riparian flow through the outlet channel that would provide the necessary fish passage flows / water depths throughout the year, regardless of flood conditions.

Other options considered briefly included a low-level conduit, fish passage turnout (i.e. a gated culvert that would drain the upstream pool of water and fish before winter sets in), and a pool/riffle structure. While these options do provide downstream fish passage, the addition of a notch into the structure was deemed to meet the requirements; and it is much simpler and less expensive to construct, as well as easier to maintain while requiring no operation over the life of the structure.

The characteristics of the notch in the drop structures are summarized in Table 3. The design flow that was used to size the notch was a riparian flow of 1 m^3/s which would be provided at all times. This flow would either come from groundwater flow or surface runoff, and would be augmented as required by releases from the proposed Lake St. Martin Control Structure.

TABLE 3
CHARACTERISTICS OF NOTCHES
TO PROVIDE FISH PASSAGE THROUGH THE DROP STRUCTURES

Case	Depth of flow at 1 m^3/s	Width of Notch (at weir crest)
V-Notch, 1:1 side slope	0.88 m	1.76 m
V-Notch, 2:1 side slope	0.67 m	2.67 m
Trapezoidal, 5 m base, 2:1 side slope	0.23 m	5.92 m
Trapezoidal, 18.5 m base width, 2:1 side slope	0.1 m	18.85 m

The results in Table 3 show that only a relatively small V-notch is required to pass the minimum riparian flow of 1 m^3/s (35 cfs) with a head on the notch between 0.67 and 0.88 m. The depth of flow over the chute portion of the notch would decrease by between 0.03 and 0.1 m, depending on the slope of the chute and assuming that no flow percolates into the rocks. Downstream of the sheet pile wall and crest of the structure, flow through the rocks in the vicinity of the fish passage area would be limited by blending small gravel-sized stones with the rockfill to reduce the volume of voids, or by partially grouting the rockfill in this area. This detail would be resolved in final design.

Under the design flow condition, the notch for fish passage would be exposed to a discharge per unit width exceeding that on the rest of the crest. This increase is expected to be in the range of 10-20% and would require that the median diameter of rock increase from 0.5 m to 0.6 m for that section. This may be accomplished by selective placement of the larger rocks onto this notched portion of the structure and associated chute section. It is noted that the thickness of the riprap layer in this area would need to be increased to meet the $3xd_{50}$ and $2xd_{50}$ requirements. As noted previously, the placement of grout and/or mixing of smaller size gravel on this section would reduce flow through the rocks, and thus would help maintain sufficient depth of flow on the chute.

Another issue that requires further consideration at the next stage of design is how effective the fish passage notch and downstream chute area of the drop structure will perform during winter when aufeis may form within the notch, as well as on the slope downstream. If a large portion of the notch forms ice, this may reduce the conveyance through the notch and result in an increase in upstream water level required to pass the riparian flow. If higher water levels prevail, then there would be the possibility of sheet flow occurring over the full width of the drop structure, which could result in the formation of aufeis on the downstream chute in these areas. Given that relatively shallow depths of flow will occur on the downstream slope (either in the vicinity of the notch or over the full width of the structure), this may subject the riprap in this area to freeze/thaw and displacement. Using well graded material for the drop structures can reduce the impact of this, however, routine inspection and maintenance may be required to ensure that the structure does not lose its integrity. The need to provide downstream fish passage during the winter months should be reviewed before final design issues of this nature are addressed.

5.0 ASSESSMENT OF CONCERNS WITH OVERLAND FLOW THROUGH BIG BUFFALO LAKE PEATLAND AREA

5.1 BACKGROUND

The potential for floating peat or marsh islands to form in the inundated areas along the route of the LSMOC was identified early in the planning stages. Flooded peat mats floating up to the water surface (i.e. peat resurfacing) has been known to be a problem on similar reservoirs in Manitoba such as Cedar Lake (Grand Rapids Generating Station) on the Saskatchewan River, the reservoir formed by Manitoba Hydro's Kettle Dam on the Nelson River, as well as at similar inundated areas in northern Quebec. Less extensive floating marsh islands have been known to have occurred on Lake of the Woods and along the Winnipeg River. The concern in the case of the LSMOC was that flotation of peat or marsh islands could potentially clog temporarily the outlet of the inundated zone surrounding Big Buffalo Lake. This could impede the reliable release of flood flows along the LSMOC during future episodes of high water conditions.

This issue was raised as a concern that could affect the selection of the diversion route for Reach 2, as Option 1 for Reach 2 would cause varying extents of flooding (Plates 7 and 8), and as a result, varying potential for peat resurfacing to form floating peat islands. A scientific review by a peatland specialist was completed to assist in determining whether this could be a serious problem and whether selection of the diversion route should be influenced by this factor. The remainder of Section 5.0 addresses this issue.

5.2 EARLY REVIEW OF POTENTIAL CONCERNS

Expertise in the scientific aspects of floating bog islands is not widespread. KGS Group retained the services of a local expert, Dr. James Ehnes, who has had extensive experience in observing and predicting the phenomena associated with peat resurfacing. Section 5.3 is devoted to the advice provided after a site visit to the study area by Dr. Ehnes.

Initially KGS Group developed a list of concerns that, if they occurred, would pose serious operational problems for the LSMOC. These concerns included:

- Flotation and movement of individual bog islands would not be desirable, but it would only be a critical issue from the perspective of hydraulic performance of the LSMOC if the aerial extent of each island was greater than approximately 30 m in average diameter.
- Flotation and simultaneous movement of bog islands in large groups would be a serious concern, even if the islands were relatively small in diameter (less than 30 m). Jamming within the channel at the downstream end of the bog could be an issue.
- The thickness of floating bog islands would also be a factor. Thicknesses in excess of 1.5 m would almost certainly be a serious concern and could potentially significantly block the narrow channel at the outlet of the bog. On the other hand, islands of such thickness may not be able to reach the channel.
- Thin islands of less than 0.75 to 1 m in thickness would be a modest concern, but would not likely be capable of fully blocking the channel for an extended period.
- Flotation of bog islands unable to shift from their original location because they are too thick (more than 1.5 to 2 m) and the depth of flow within the bog is too shallow, would not in general be a concern. On the other hand, if the floated areas cover more than about 50% of the total bog area, this could evolve into a more serious concern. This would introduce a hydraulic bottleneck that would reduce the discharge capacity of the bog itself.

Section 5.3 summarizes the findings and conclusions of these considerations.

5.3 QUALITATIVE ASSESSMENT OF PEATLAND CONDITIONS

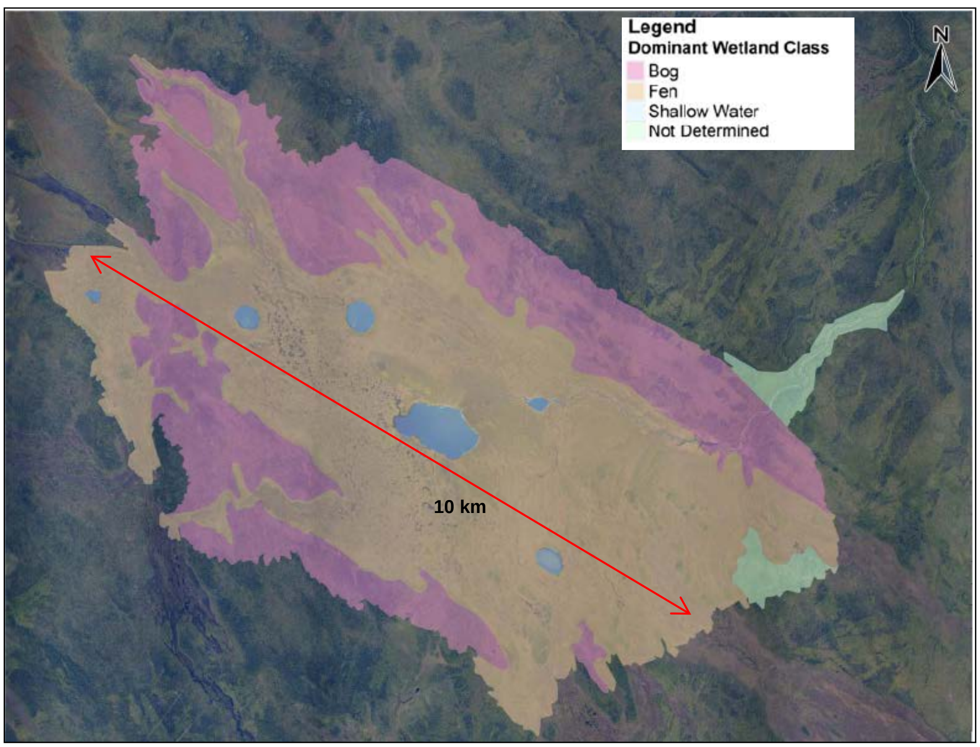
Of the four options considered in this report, Option 1 was the focus of the expert review of overland flow through the Buffalo Lakes wetland complex. Details of Dr. Ehnes' review are provided in Appendix E and are summarized below.

Human-induced flooding or water regulation can have a variety of effects on wetlands. Those of interest for hydraulic performance in Option 1 are processes generating floating peat or marsh islands. Floating marsh islands can be created when rising water levels or waves detach portions of a marsh. Floating peat islands can be generated by either of two peatland disintegration processes, which are referred to as peat resurfacing and shoreline peat breakdown. In peat resurfacing, portions of flooded peatlands float up to the water surface. In shoreline peat breakdown, waves or water level fluctuations break off portions of intact peatlands along the waterbody shoreline created by flooding. In other boreal regions, peatland disintegration produced many floating peat islands under some conditions, and some of these islands were transported over long distances by wind or current. Floating peat islands can be much larger than 100 m in diameter.

The first step in investigating potential risks to the hydraulic performance of Option 1 was development of an understanding of the effects to date of the construction of the Lake St. Martin Emergency Outlet Channel (LSMEOC) in 2011 and the subsequent operation. Essential elements for developing this understanding were mapping the wetland composition of the Buffalo Lakes wetland complex and relating this to LSMEOC construction and operation to date.

Based on coarse mapping completed for this study, fen was the most abundant wetland type in the Buffalo Lakes wetland complex prior to construction of the LSMEOC. Most of the remaining area was bog, as shown on Figure 7. The bog was predominantly blanket and veneer bog. The fen was predominantly horizontal fen.

FIGURE 7
DOMINANT WETLAND CLASS SURROUNDING BIG BUFFALO LAKE PRIOR TO LSMEOC



Construction of the LSMEOC and its operation to date have primarily affected pre-existing fens and associated waterbodies. Construction activities removed a very small proportion of the wetlands within the complex. In contrast, available information suggested that operation of the LSMEOC in 2011/2012 and 2014/2015 had flooded about half of the wetland complex during the open water season. It also appeared that only a small proportion of the bog was flooded during the open water season.

Operation of the LSMEOC has reduced the amount of fen in the Buffalo Lakes wetland complex. Flooding and flows have caused some mortality of pre-existing vegetation and/or peat breakdown, as well as mineral sediment deposition on top of the fen. In many locations, tall emergent vegetation (primarily comprised of cattails and common reed) is now growing in mineral sediment deposited on top of former fen (referred to as marsh-like vegetation). This marsh-like vegetation could produce floating marsh islands if Option 1 were implemented.

Floating peat islands have not been observed to occur during past LSMEOC operation, which suggests that peat resurfacing has not occurred. This is quite possible and could be the result of a variety of factors, including the following:

- The peat was frozen during initial flooding (which increases anchoring).
- Water depths increased rapidly during initial flooding.
- The dominant types of bog in the Buffalo Lakes wetland complex have relatively low buoyancy.
- The bogs were elevated above the maximum water levels during the open water season.
- Fens in the area have a relatively thin surface layer (i.e. lightly decomposed or fibric).
- The submerged peat was weighted down by mineral sediment deposition.

The following are the key observations by Dr. Ehnes regarding potential wetland responses if Option 1 were to be implemented:

1. There is a risk that bogs will generate some floating peat islands through peat resurfacing or shoreline peat breakdown when flows are relatively high. At their upper range, water levels for Option 1 could be considerably greater than experienced to date, particularly during the open water season. Most of the bog within the wetland complex would be flooded at design flows of 326 m^3/s (11,500 cfs) (Plate 7). In addition, predicted water depths would be sufficiently shallow to allow peat resurfacing throughout the flooded area.

2. On the other hand, the actual amount of peat resurfacing may be limited, even at high water levels. Comparison with other studies of the dominant bog types (veneer and blanket bog) in the Buffalo Lakes wetland complex show that less than 6% of their area has resurfaced. Veneer and blanket bogs tend to be thinner and more strongly attached than the remaining bog types. In addition, it is expected that the fetches (lengths of open water) in the flooded area will be too short to generate sufficient wave energy to create many floating islands from bogs.

3. To the extent that floating peat islands may be generated with Option 1, several factors limit the likelihood or frequency that these floating peat islands could substantially reduce the hydraulic performance of the outlet channel in Reach 2 or block the inlet to Buffalo Creek. These factors include:

   - Water levels will generally be too low to produce floating peat islands at the lower half of the potential flow range.
   - Even at higher flows, some proportion of floating islands will be in water depths that are too shallow for the islands to become mobilized.
   - Much of the bog area that could potentially produce mobile floating islands is situated in the areas furthest from the main flow through the Buffalo Lakes wetland complex. Longer travel distances to the main flow zone tend to create more opportunities for the floating peat islands to be trapped before reaching the main flow or the inlet to Buffalo Creek.
   - Some proportion of mobile floating islands are expected to sink.
   - Some proportion of mobile floating islands are expected to become beached by high winds.
   - Even if some floating peat islands would reach the main flow zone, the majority could be less than 100 cm thick (note, however, that this prediction is based on the limited available peat stratigraphy data).

4. However, the duration and frequency of water level changes will ultimately be a key driver for determining the degree to which the above factors limit the number of peat islands that enter the main flow zone or make their way to the Buffalo Creek inlet.

5. There is clearly a risk that floating marsh islands will be generated through the entire range of flows with Option 1. Nutrient deposition from outlet channel operation could increase the likelihood that this will occur in Option 1. There is also a risk that floating marsh islands may enter the main flow zone of Reach 2, and/or block the inlet to Buffalo Creek.

In summary, while the overall risk to hydraulic performance of Option 1 appears to be low, there is, however, a real possibility that a mat large enough to block the Buffalo Creek inlet could be produced. Mitigation measures that have been implemented in other regions could be implemented; but nevertheless, this option includes this operational risk that does not exist for other options.

6.0 EVALUATION OF OPTIONS

As described in Section 1.2, the scope of work for the assignment included the evaluation of the various Reach 2 options to identify the preferred alignment recommended to proceed to preliminary design. Sections 7.0 to 12.0 describe the various assessments conducted by KGS Group for the evaluation of the options and the comparison of the performance as well as the pros and cons of each potential channel alignment. The categories for evaluation of the options were developed in collaboration with MI and included:

- Constructability (Section 7.0).
- Operability and performance (Section 8.0).
- Environmental and Socio-economic considerations (Section 9.0).
- Maintainability and Inspection (Section 10.0).
- Resiliency (Section 11.0).
- Cost (Section 12.0).

The evaluation of the options culminated in a Technical Workshop held on December 15, 2016 where a panel of selected experts from the KGS Project team, MI and other outside experts conducted a comprehensive review of each of the options and of the results of the various assessments and comparisons summarized in Sections 7.0 to 12.0. A detailed description of the Technical Workshop process and results is included in Section 13.0.

7.0 CONSTRUCTABILITY ASSESSMENT

The terrain conditions, hydraulics, stratigraphy, and constructability are different for Option 1 or 2 compared to Options 3 and 4 because Option 1 requires significant construction in and through the Buffalo Lake wetland complex. Although the costs of dealing with these varying and difficult conditions were reflected in previous cost estimates, additional assessments and consultations with knowledgeable Contractors were conducted by KGS Group to better understand the issues related to the constructability, their impact on cost and schedule and ultimately the selection of the preferred option.

The assessment was based on the results of the investigations described in Section 2.0, which included geotechnical investigations and an aerial and ground-truth site reconnaissance survey by KGS Group Engineers and Contractor representatives. Additional input from Contractors was incorporated based on their first-hand experience with the local conditions during construction of the Reach 1 and Reach 3 Emergency Outlet Channels. The findings of the assessment and comparison between options, considering access to site, surface and groundwater management, material composition, bathymetric conditions and schedule are described in Sections 7.1 to 7.5.

7.1 ACCESS TO SITE

For all options, an all-season road will be constructed to permit year round (permanent) access for long-term operation and maintenance of the channel and associated structures. This permanent road, as shown on Plate 1, will be constructed to the site before construction of the channel reaches commences. The planned arrangements of the access roads for each of the Reach 2 options are shown on Plates 3 to 6.

For each of the LSM Outlet Channel alignment options, the all-season road will include upgrading an existing seasonal forestry road to an all-season single-lane gravel road. The road is approximately 61 km in length extending from Spearhill, Manitoba. An existing winter road that is approximately 19 km in length and extending from the end of the forestry road to Reach 1 will also be upgraded to a single-lane all-season gravel road.

For Option 1, an additional 16 km winter road that now extends to Reach 3 near Buffalo Creek would be upgraded for permanent access. This separate road would be necessary to permit construction of the containment dike and to access drop structure locations on Buffalo Creek.

The existing Reach 1 Channel banks will serve as access for either the widening of Reach 1 (Options 1 and 3) or the decommissioning of Reach 1 (Option 4). A temporary cofferdam (discussed in Section 7.2) at the downstream end of Reach 1 would serve as access for the proposed Reach 1 extension.

For Option 3, Reach 2 would be accessed from Reach 1 the same as for Option 1. For Option 4, Reach 2 would be accessed directly from the all-season road and would be extended to Reach 1 for the decommissioning. Temporary winter road access would also be available from Reach 3 for both Options 3 and 4.

Although there are some differences between options in how access will be provided to site during construction, each of the options was judged to have essentially equal access. All options will have a permanent all-season road prior to construction, and each option will require some level of planning to coordinate construction seasonally and/or between reaches. The cost implications associated with the different lengths of the all-season road has been incorporated into the cost estimates of the project described in Section 12.0.

7.2 SURFACE AND GROUNDWATER MANAGEMENT

Each of the channel alignment options is located in peatland area and will require surface water and groundwater management during construction. As discussed in Section 7.3, a significant portion of the channel excavation for each of the options is within a peat layer that varies between 0.1 m to 3 m in depth depending on location. During the 2016 field investigations, the existing water surface was generally at or near the peat surface along most portions of all channel options. Similar wet conditions have been experienced during other field surveys conducted as part of other studies in the area since 2011. Furthermore, there was up to 1.5 m of standing water within the Reach 1 Channel, as well as approximately a 1 m to 2 m depth of water in Big Buffalo Lake. As shown on Plate 1, Buffalo Creek and several other small streams are also located within the project area.

Option 1

As discussed in Section 4.1, Option 1 consists of widening the existing Reach 1 Channel, extending that channel into Big Buffalo Lake, constructing erosion protection along Buffalo Creek (riprap and drop structures), localized channel improvements, plus construction of a long containment dike. The layout is shown on Plate 3.

Construction of the Reach 1 extension is anticipated to proceed first to allow for more effective dewatering of the existing Reach 1 Channel during its widening. By completing the extension first, it should allow for gravity flow dewatering for the widening of the existing Reach 1 Channel.

As was shown on Figure 3 (Section 4.1), the existing Reach 1 Channel was terminated where the bottom of the channel reached the top of till (at the periphery of the peatland area). It was assumed that water would spill from there into the peatland surrounding Big Buffalo Lake and stage until it drained out of Buffalo Creek. Figure 3 also shows that in 2016 the water level in the channel was at the same level as the peatland even though the channel was not in operation.

It will be necessary to isolate the Reach 1 extension with upstream and downstream cofferdams before the excavating and pumping required to complete the excavation. This methodology of constructing the channel in cells is very similar to the methodology utilized in 2011 under emergency conditions. Once that is completed, however, then standing water in the existing Reach 1 Channel will flow into Big Buffalo Lake directly.

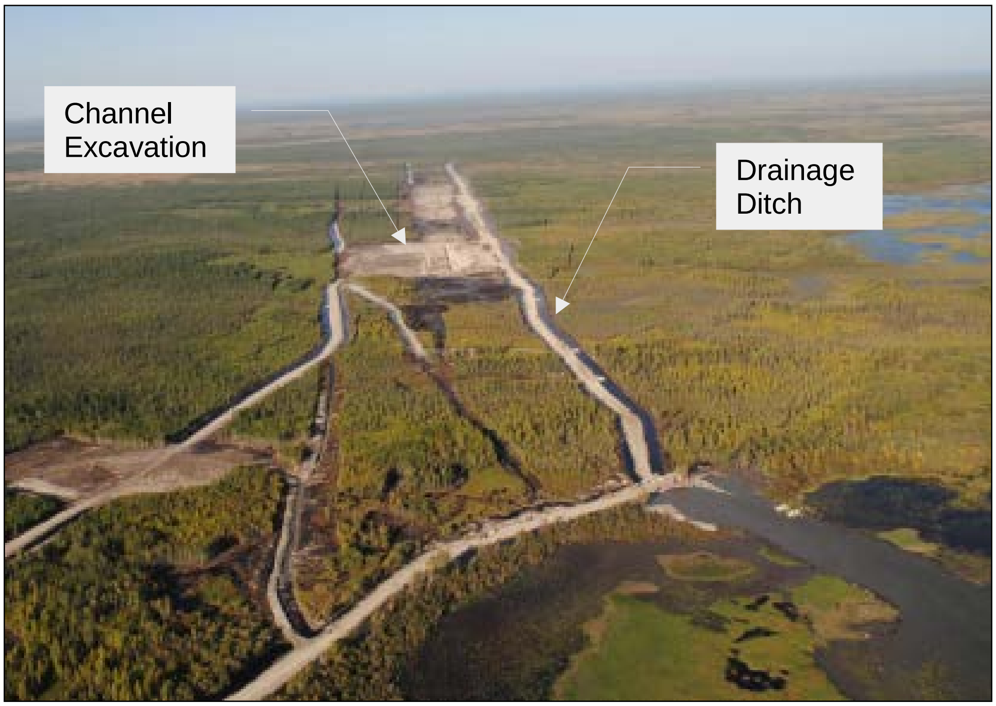
Based on Contractor input, excavation of the Reach 1 extension will be the most difficult segment of any other section of all options and will have higher construction risks compared to the other Reach 2 Options due to the proximity of Big Buffalo Lake and difficulties with dewatering.

Widening of the existing Reach 1 Channel will require excavation and removal of existing spoil piles along the left channel for the entire reach. This means that approximately half of the previously excavated channel material will have to be excavated and moved again. That material is not sorted and will consist of trees, peat, and overburden material, as described in

Section 7.3.2. It is anticipated, therefore, that construction may again require the excavation and construction in cells similar to the 2011 construction methods.

An aerial photo of early construction activities on Reach 1 taken from Lake St. Martin shows isolated segments of channel excavation in progress (background of Photo 1). Drainage ditches on either side of the proposed channel, extending a distance downstream towards the background of the photo, are also visible.

PHOTO 1
CONSTRUCTION OF REACH 1 EMERGENCY CHANNEL



Hydraulic improvements in Buffalo Creek will include channel excavation, rockfill drop structures plus riprap in select areas. Work will require construction in water or dewatering of the area and will therefore require to avoid the fisheries window. Large runoff events during construction could result in a significant increase in water management efforts or potentially in significant delays to the construction schedule.

The Reach 2 containment dike will be located on high ground, such that less surface and groundwater management will be required for this component of the project. It will require, however, access across Buffalo Creek, plus development of construction access sufficient for hauling of material and dike construction, as discussed in Section 7.1.

Options 3 and 4

Similar to Option 1, widening of Reach 1 for Option 3 is anticipated to occur after Reach 2 construction is complete to take advantage of increased downstream drainage. However, should drainage alone be insufficient to completely dewater Reach 1, or should widening of Reach 1 proceed first or simultaneously with Reach 2 construction, a cofferdam would be constructed near the outlet, and the channel dewatered with temporary pumping.

Based on Contractor input, the preferred method of constructing Reach 2 for Options 3 and 4 would also consist of excavating the channel in 200 m to 300 m long segments, in order to isolate the excavation area from the groundwater and to allow dike construction under drier conditions. Construction of temporary drainage ditches in advance along both outside edges of the channel work area will reduce the impact of groundwater but not eliminate it. Construction of the ditching should proceed well in advance of main construction. This could occur during winter, while temporary access is available to Reach 3, as discussed in Section 7.1. If access to the downstream end is available during construction, then Contractors will have the option of beginning channel excavation from the outlet end such that construction water will drain by gravity. Even so, excavation will probably require construction in segments depending on the effectiveness of temporary outside drainage ditches. Photo 2 illustrates the pilot channel concept during construction of the Reach 1 Emergency Outlet Channel in 2011.

PHOTO 2
DRAINAGE PILOT CHANNEL DURING CONSTRUCTION OF REACH 1 EMERGENCY CHANNEL

7.3 MATERIAL COMPOSITION

7.3.1 Stratigraphy

Based on the results of the peat probes and hand auger investigations described in Section 2.2, the substrate material along the Reach 2 alignment was similar for all options. As shown on the profiles included in Section 4.0, the stratigraphy in the region typically consists of a peat layer ranging between 1 m to 3 m in depth overlying a till material that is a dense silty to clayey silt till matrix, which also contained cobbles and boulders.

Bedrock elevations have not been defined at this stage; but they have been assumed to be located below the proposed channel invert along each of the Reach 2 alignment options based on the limited additional investigations previously conducted on Reach 1, Reach 3, and the nearby access road. For context, regionally available bedrock surface elevation information is as follows:

- Approximately El 220 m in the immediate vicinity of the Lake Saint Martin narrows, rising to Approximately El 260 m along the northwestern most side of Lake St. Martin along Provincial Road 513, which provides access to Dauphin River.
- Between approximately El 215 m and El 225 m in the Community of Dauphin River.
- Between approximately El 228 m and El 230 m along the Reach 3 Channel (between approximately Sta. 21+000 and Sta. 22+000). This occurred along a noticeable southeast to northwest trending "ridge" of localized higher ground, with ground surface elevations >El 232 m to El 234 m
- At approximately El 220 m to approximately <El 215 m along the Willow Point Reach 3 Channel discharge option.

The carbonate bedrock within the Interlake is an example of strata that has undergone paleokarst processes. This condition is defined by solutioning or karstification that occurred at an earlier geologic time, which is subsequently buried and made inactive by later deposition of overlying sediments and/or changes in groundwater flows. The carbonate rock within the Interlake was deposited in a shallow marine environment, with periodic hiatuses in deposition and subaerial exposure in advance of any pre-glacial or glacial depositional periods.

During periods in time where carbonate bedrock deposition was slowed or stopped (i.e. a depositional hiatus), relatively fresh surface water undersaturated with respect to carbonate was available to flow into pre-existing discontinuities of the rockmass, and over time rock wall solutioning processes widened and eroded these discontinuities into larger features.

In general, bedrock topography will vary with the severity and extent of paleokarst processes. This geologic process was followed by physical weathering and erosion that occurred with glaciation and start-up of the incipient surface drainage system in the region, including the establishment of the postglacial lakes that have evolved and matured into the waterbodies observed in the present day. Thereafter and to the present time, postglacial weathering processes have largely occurred in areas of bedrock outcrop or bedrock areas with relatively thin sediment cover. As a result of this complex geologic history, areas of low surface topography, such as along lakes and surface drainages, are often (but not always) associated with pronounced bedrock surface depressions.

In the proposed areas of the Reach 2 Channel options, the local ground surface is comprised largely of the lowland areas surrounding Big Buffalo Lake, at topographic elevations of generally

<El 246 m (nearest Lake St. Martin), and <El 242 m in the areas immediately surrounding the Big Buffalo Lake basin. The Reach 3 inlet is at an elevation of approximately El 236 m. Based on available regional bedrock information, none of which is in the immediate vicinity of the Reach 2 Channel option alignments, it is estimated that the bedrock surface will occur between approximately El 215 m to El 225 m; however, this is expected to vary due to the complex geologic history outlined above and is considered a generalized and qualitative estimate.

Additional field investigations should be conducted at the next stage of design for the preferred alignment option to confirm assumptions and provide a better understanding of sub-surface conditions and possible locations of relatively shallow bedrock. Should bedrock be encountered along the channel, this is not considered to be a significant construction risk. If the rock is of poor quality, it could likely be excavated with minimal effort, whereas if it is of good quality, the material could be utilized as riprap for erosion protection at the drop structure locations. Rock encountered in isolated short segments of the emergency Reach 3 Channel was generally of poor quality.

7.3.2 Channel Excavation

Photo 3 illustrates the construction methodology used to construct Reach 1 in emergency conditions in 2011. The methodology consisted of forming cells along the alignment by pushing and constructing temporary diking around a work area. Pumping was then able to allow excavation of the main channel to proceed.

PHOTO 3
EXCAVATION DURING CONSTRUCTION OF REACH 1 EMERGENCY CHANNEL

Permanent construction will include sufficient time to construct access roads to site at both ends and to allow for construction of pre-drainage ditches parallel to the channel alignment. Nevertheless, it will still likely be necessary to excavate the main channel cell by cell as shown previously on Photo 3.

The cofferdams required for construction, as well as the various dikes required depending on the options, will be constructed with the excavated till material from the channel. Optimization of the channel earthworks will be essential, particularly for Options 3 and 4, to ensure sufficient material is available for dike construction while minimizing haul distances. For Option 1, hauling of the till material from Reach 1 will be required to construct the cofferdam for the Reach 1 Channel extension. Hauling will also be required to construct the Reach 2 containment dike likely from nearby borrow pits. The additional effort associated with hauling for Option 1 was incorporated into the cost estimates of the project as the added construction effort will result in additional costs compared to the other options for this component of the work.

On Reach 1, widening of the channel (Options 1 and 3) is proposed to be located on the north-west side only. Results of the drone survey, discussed in Section 2.1, indicated that the spoil pile on that side was smaller than the opposite, which would result in a lower overall excavation quantity for this reach. However, based on the input from the Contractors, handling of the existing Reach 1 spoil pile will require additional effort since the material is likely denser, unsorted, and may be full of debris. Although most of the excavated peat and vegetated debris was reported to have been disposed of on the south-east side of the Reach 1 Emergency Outlet Channel in 2011, a smaller amount of debris may still have been disposed of on the north-west side. In addition, some of the excavated material may have been disposed of directly on top of existing vegetation due to the emergent nature of the project. Consideration of the additional effort associated with handing the spoil pile material for Options 1 and 3 was incorporated into the cost estimates for the project. Should either Option 1 or 3 proceed to the next stage of design, field investigations should be conducted to provide a better understanding of the composition of the Reach 1 spoil pile material.

Given that a significant volume of rock is required for the construction of the drop structures for all of the options, as discussed in Section 4.5, there may be an opportunity to sort excavated till material to obtain an additional source of rock for riprap. A similar process was undertaken in 2012 during the construction of the Reach 3 Emergency Outlet Channel. Further analyses are necessary to assess whether this sorting process would be cost effective and yield a sufficient volume or rock in comparison to other rock source alternatives. At this stage of design, it was assumed based on the results of previous field investigations documented in the Stage 2 Conceptual Design Report that a sufficient volume of rock of good quality will be available from the rock quarries identified for the project.

7.4 BATHYMETRIC CONDITIONS

Big Buffalo Lake

Bathymetric data was collected on Big Buffalo Lake, complimented with cross sections downstream on Buffalo Creek within the peatland area, as discussed in Section 2.3. A profile of the area was included in Section 4.1. The results of the survey indicated that there was a short section of Buffalo Creek near the outlet of Big Buffalo Lake, which controls water levels in the lake. A number of other sections further downstream also control water levels in the creek where it exits the peatland area. Although a number of beaver dams were removed from Buffalo Creek in 2011 to help lower water levels within the peatland area for construction of the Reach 1 Emergency Channel, draining the peatland area and Big Buffalo Lake to improve constructability of the Reach 1 extension, beyond what was done in 2011, would require excavating or lowering a portion of the Buffalo Creek Channel. This was not considered a feasible solution considering lack of access, difficult constructability conditions in the peatland adjacent to the creek, and environmental concerns.

Lake St. Martin Inlet

Each of the options will include an inlet location at Lake St. Martin that will allow the flow to enter the channel. For Options 1 and 3 the inlet location would be at the existing Reach 1 entrance. For Option 4, the inlet location would be approximately 3.8 km south-east, as shown on Plate 6.

Based on the bathymetric surveys conducted at the inlet of Option 4, and information available from the record drawings of the Reach 1 Emergency Channel, the lake bottom elevation about 300 m to 400 m from shore is approximately 242.9 m (797 ft) at both locations. Given that the proposed channel invert elevation is 241 m (790.7 ft) for each of the options, excavation at the entrance will be required to minimize headlosses and ensure a smooth transition of flows into the channel.

A 2015 test hole drilled as part of the Stage 2 Conceptual Design study along the Reach 1 Channel approximately 500 m from the inlet indicated that the bedrock was well below the ground surface. On this basis, it was assumed that bedrock would not be encountered as part of the inlet works for Options 1 and 3. For Option 4, since there was no additional information available at the inlet, bedrock was also assumed to be located well below ground surface based on our understanding of regional geological conditions. Detailed sub-surface investigations will be necessary at the next stage of design at the inlet location of the preferred option to confirm assumed conditions.

For Option 1, due to the limited conveyance capacity through the peatland complex downstream of Reach 1, there will be limited opportunity to optimize the channel design by increasing the headloss at the inlet to reduce excavation within the Lake. For Options 3 and 4, since the channel extends further downstream and avoids the peatland area, there is greater opportunity to optimize the channel design and reduce excavation within the lake if it is considered a cost effective solution or if unforeseen conditions (e.g. bedrock) are encountered.

7.5 SCHEDULING

Construction of the LSMOC is tentatively expected to occur over a period of approximately three years and may be tendered in one or multiple contracts. For example, one contract could be awarded for the control structure and inlet works, with separate individual contracts for excavation of Reaches 1, 2 and 3. Duration of construction for each individual contract will depend on the channel length and the total volume of excavation per contract, and may vary depending on the construction strategy adopted by the Contractor.

Risk of schedule delays were considered when comparing the options. For Option 1, the difficult construction conditions associated with the extension of Reach 1 could result in unforeseen schedule delays. Unfavorable weather conditions could also impact project schedule. Option 3 was considered to be the most vulnerable to unfavorable weather conditions as it has the longest construction footprint.

High water levels and flooding on Lake St. Martin could result in construction delays if Reach 1 must be operated in an emergency situation. This could affect the schedule for Options 1 and 3 as they both require widening of the Reach 1 Channel. For Option 4, the Reach 2 alignment is separated from Reach 1; therefore, Option 4 benefits from having the ability to operate Reach 1 in an emergency during construction with minimal impact to the construction schedule.

8.0 OPERABILITY AND PERFORMANCE ASSESSMENT

8.1 CHANNEL DIKES AND SLOPES

The channel dikes and slopes for Options 1, 3 or 4 will perform in a similar manner as each option has been designed for a stable channel and slopes as per the design criteria set out in Section 3.0 of this report. All diking along each of these options must be placed directly on top of the underlying till materials to ensure a tight seal between the dike and foundation soils and to serve as a cut-off for seepage from the surrounding peatlands into the channel. Stability of the channel slopes and the associated stability analyses are discussed in Section 14.3.

8.2 EROSION, SEDIMENT TRANSPORT AND DEPOSITION

Operation of the flood diversion through Reach 2 must be achievable without chronic problems related to sediment erosion, transport or deposition. The expected performance of each option in this regard is described below. In all cases, the expected sediment content in the water released from Lake St. Martin will be very low.

Option 1

The widening and extension of the existing Reach 1 would be designed to be non-erodible during operation. Based on the concept presented in Section 4.0, the channel mean velocity at the design flow of 326 m^3/s (11,500 cfs) is estimated to be equal to approximately 1.0 m/s, and shear stresses are estimated to be less than 6 N/m^2. Both values are less than the established threshold limits described in Section 3.3 for the type of material that will form the channel bed. It is expected that when the channel side slopes are protected by a cover of deep-rooted vegetation, sediment will neither erode from the submerged surfaces of the channel, nor cause deposition to occur. It is possible, however, that the design flow may at some point in the future be exceeded. If that occurs, there may be some potential for erosion of the side slopes and base of the channels. It is estimated that the surface area of the channel in Reach 1 (including both the widening and the extension) that may be affected by such erosion potential would be in the order of 100 ha.

On the other hand, there is greater potential for channel side slopes to be vulnerable to erosion in areas where vegetation growth is inhibited, particularly during intense rainstorms when runoff occurs on the channel side slopes. This vulnerability may occur if revegetation after construction is slow to take effect or during periods immediately after long periods of operation. Extended operation (many months) would cause the upper surfaces of the channel, its pre-existing vegetation, and its root system to die, as described in Section 10.2. This could increase the potential for erosion of those surfaces to occur. Furthermore, the eroded material could potentially deposit within the submerged portion of the channel, and could affect the hydraulic performance of the channel in subsequent years. It is expected that eventually natural vegetation will be established on these surfaces, which will provide erosion protection, but that could take years to occur to a reliable extent.

This vulnerability exists for all the options and for this reason, the areal extent of this vulnerability has been estimated for each option for comparison purposes. It is estimated that the surface area of the Reach 1 extension exposed to this risk would be approximately 12 ha.

Downstream of the Reach 1 extension, the Reach 2 segment along the steep portion of Buffalo Creek is expected to erode uncontrollably if left unprotected. It has been concluded that protection would be required with a series of drop structures and with the installation of riprap along selected areas of steep and exposed side slopes, as discussed in Section 4.0, to avoid any significant extent of erosion. However, similar to Reach 1, the design flow may be exceeded during extraordinary future flood events. Erosion of the channel surfaces could occur in those rare events. The surface area so affected along Buffalo Creek would be approximately 25 ha. In addition, the surface area of the side slopes above the permanently wetted portion of the channel could be vulnerable to the same process of erosion during rainstorms or snowmelt, as described above for Reach 1.

Option 3

Similar to Option 1, the channels for Option 3 would be designed to be non-erodible during operation. Four drop structures are proposed for inclusion within the channels of Option 3 to provide for safe non-erodible dissipation of energy. If future flood events cause flows that exceed the selected design magnitude, erosion of the surfaces of the channel could occur. It is estimated that there would be approximately 210 ha of channel surface area that could be so affected.

Similar to Option 1, the upper, unsubmerged portions of the channel side slopes could be exposed to erosion during rainstorms or snowmelt in periods following extended operations when the vegetation cover on those side slopes could be killed. The surface area that could be affected would be considerably less than for Option 1 and is estimated to amount to only 31 ha.

Option 4

As for Options 1 and 3, the channels for Option 4 would be designed to be non-erodible during operation. Five drop structures are proposed to be included within the channels of Option 4 to provide for safe non-erodible dissipation of energy. If future flood events cause flows that exceed the selected design magnitude, erosion of the surface of the channel could occur. It is estimated that approximately 160 ha of channel surface area that could be so affected.

Also similar to Option 1, the upper, unsubmerged portions of the channel side slopes could be exposed to erosion during rainstorms or snowmelt in periods following extended operations when the vegetation cover on those side slopes could be killed. The surface area that could be affected would be considerably less than for Option 1, and is estimated to amount to only 14 ha.

Comparison of Alternatives

From the perspective of erosion and sediment deposition, all options would be designed to be stable with minimal risk of erosion. Given that the incoming sediment load from Lake St. Martin would be negligible, it is expected then that deposition within the channel would be limited in extent.

If the design flows are exceeded, there would be some potential for erosion of the channel side slopes and base to occur. Option 3 would have the largest surface area exposed to this risk.

Option 3 also has the largest potential volume of available sediment for transport as a result of exposed side slopes following extended periods of flood diversion.

8.3 FLOW THROUGH BUFFALO LAKES WETLAND COMPLEX

The original route of the emergency channel to release flood flows from Lake St. Martin utilized the existing low lying areas and hydraulic conveyance through Big Buffalo Lake and downstream into Buffalo Creek. Although that diversion, and the subsequent diversion in 2014, did not appear to cause problems, there has been an on-going concern about continued use of that route. The concern is based on precedents where submergence of peatlands has led to the floatation of large contiguous masses of peat material that have been carried into waterways. The concern in the case of Lake St. Martin is that the formation of such floating islands could lead to partial blocking of the diversion channel and a reduction of the effectiveness of the diversion exactly at the time that it is needed the most. This has prompted the retention of a consultant, Dr. James Ehnes, who has extensive experience with bogs in northern Canada. His report, included in Appendix E and summarized in Section 5.0, supports the concern that there is the potential for floatation of large floating islands in the area surrounding Big Buffalo Lake. The anticipated performances of each of the options in this regard are discussed below.

Option 1

Option 1 builds on the existing discharge capability in the emergency channel. That route includes Big Buffalo Lake and the surrounding area, as described in Section 4.1.The submerged area is estimated to be as much as 4,000 ha under design flood conditions (Plate 7). The probability of the formation of floating peat islands that would be large enough to cause serious blockage in the diversion route downstream is considered to be relatively low, as described in Section 5.0. However, the occurrence of such an event is well within precedent and could significantly impede the ability of Option 1 to perform as desired. Ultimately, effective control of Lake St. Martin may not be achievable if such an event were to occur. This is clearly an uncertainty for Option 1 and would have to be considered a disadvantage of that scheme. There are also a number of potential environmental concerns associated with the flow through the wetland complex. These are discussed in Section 9.0.

Options 3 and 4

Neither Options 3 nor 4 cause any significant submergence of existing peatland. Neither option have any significant chance of causing floating islands, and, therefore, have a significant advantage over Option 1 in this respect.

8.4 DROP STRUCTURES

The drop structures proposed for Options 3 and 4 would perform to a very similar standard. Both options require up to five structures of similar size to be placed in the excavated channel. As discussed in Section 4.5, they each have the same requirements for promoting establishment and retention of vegetation in the channel upstream, as well as for performance under ice conditions, and for passage of fish. It was determined that rockfill drop structures can be designed to meet these requirements for both Option 3 and 4.

Drop structures for Option 1 in Buffalo Creek present challenges related to upstream fish passage and channel configuration that are not present in Options 3 and 4. While it is possible to design drop structures to meet the requirements for this section of the channel, they would be considerably larger, potentially more difficult to construct, and costlier than drop structures placed in the engineered and excavated channels that make up Options 3 and 4.

8.5 OPERATION IN WINTER CONDITIONS

Operation under winter conditions is a requirement for the LSMOC. This will provide the maximum ability to control lake levels during years when flood inflows are otherwise unmanageable. Simulations of Lake Manitoba/Lake St. Martin using historical streamflow and runoff records have shown that, on average, the LSMOC will be required to release significant flows during approximately 15% to 20% of winters. Climate change may affect that percentage, and the frequency of winter operation is anticipated to change in the future, possibly increasing the frequency of winter operations.

The experience in 2011-2012 with the emergency outlet channel at LSM showed that only modest volumes of frazil ice were generated within the flow along the diversion route from LSM to the Dauphin River. Ice generation was sporadic and did not cause any problems, which may be partly attributed to the mild conditions of that winter. There may have been more ice generated in the more severe winter of 2014, but again there was no evidence of any serious issues arising. This same performance is expected to be prevalent with the proposed new LSM channels.

As described in the Basis of Design in Section 3.2, the channels are proposed to be designed such that any frazil ice generated during winter would be carried freely downstream. It is expected that the ice could eventually accumulate as a hanging dam at the lower end of Reach 3. KGS Group has estimated the volume of ice that could be generated as a worst case scenario. It is expected that, even with such a worst case, the rise in water level at the lower end of Reach 3 would be only a few metres, which is significantly less than the approximately 15m head drop existing within Reach 3. This process is not expected to cause adverse effects.

It is conceivable, depending on the magnitude of flow during the winter, that some portions of the Reach 2 Channel (or other portions of the LSM diversion route) could be partially or fully covered by the advancement of border ice from each side of the channel. This could cause local accumulations of frazil ice and create extended ice covered lengths in the channel. This is not considered a problem since winter flows are expected to be considerably less than design flood conditions based on the proposed operating guidelines. Rises in water level due to ice coverage is not expected to exceed the open water design condition for all of the options evaluated.

8.6 GROUNDWATER MANAGEMENT

Stratigraphy in the region of the Reach 2 Channels is interpreted to be as follows (based on the results of the field investigations described in Section 2.0 and data from previous studies such as the hand auger/probe work, and stratigraphy observed along the Reach 3 Emergency Channel, during construction in 2011/2012):

- Typically 1.0 m to 2.0 m of saturated peat (varies from 0.1 m to 3.0 m in thickness in the region of the Reach 2 Channels).
- 0.5 m to 2.5 m of grey silty clay in places.
- 0.3 m to 1.0 m of typical buff colored carbonate silty till, with cobbles and boulders.

- 0.9 m to 2.0 m of hard basal till/boulder till. Generally the contact between the overlying silt till and basal till is noted by a boulder layer; and the lower till unit grades downward from the boulder layer to the very dense, well indurated basal till. The hardest basal tills occur within approximately 1.0 m of the bedrock surface.

Table 4 summarizes the characteristics of the tills observed during construction of the Reach 3 Emergency Outlet Channel.

TABLE 4
CHARACTERISTICS OF THE TILL MATERIAL OBSERVED DURING CONSTRUCTION OF REACH 3 EMERGENCY OUTLET CHANNEL

Sample ID	Material	Depth (m)	Unified Classification	Moisture Content %	Liquid Limit %	Plastic Limit %	Plasticity Index %	% Gravel	% Sand	% Silt	% Clay
TP12-02	Buff clayey silt till	3.0	ML	9	17	14	3	28	29	27	16
TP12-03	Buff clayey silt till	2.1	CL	12	22	14	8	11	18	35	36
TP12-06	Grey hard basal till	3.5	GM	8	16	13	3	69	7	16	8

During construction of Reach 3, approximately 0.9 m of dense basal till was noted above the newly exposed bedrock between approximately Sta. 21+600 and 21+650. As well, the jointed top of the bedrock was observed to be till injected. Based on these observations, it is expected that the uppermost bedrock limestone slabs, separated along sub-vertical to vertical joints and horizontal bedding plane partings in some areas may be separated from the underlying bedrock surface by thin layers (i.e. 0.1 m or less) of injected basal till. In addition, it is possible for large bedrock slabs to be entrained within the very base of the basal till. It is anticipated that this type of condition will only exist within approximately 0.8 m to 1.2 m of the top of the bedrock surface. In cored boreholes along the Reach 3 alignment, the “transition” from a purely till condition to a purely bedrock condition was typically less than approximately 0.8 m. Under this type of scenario, large till-entrained slabs of limestone bedrock and/or slabs of bedrock with till injected between joints and bedding plane partings can occur at the top of the bedrock.

The stratigraphy described above is important, as there are two distinct groundwater systems within the region of the Reach 2 Channels, including:

1. The upper, saturated peat unit 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, where 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 will be at ground surface, up to perhaps 0.1 m below ground surface.
2. The lower, confined carbonate bedrock aquifer isolated from the peat unit by the clays 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. 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 Saint Martin narrows. In the region of the Reach 2 Channels in the Dauphin River area or in any location in proximity to Lake Winnipeg, the confined piezometric pressure within the bedrock aquifer will be very near, to above, ground surface. This occurs because Lake Winnipeg is a key discharge area for the bedrock aquifer; and as such, a strong upward gradient for discharge will occur in areas close to Lake Winnipeg, including within the region of the Reach 2 Channels.

Work completed by KGS Group in the community of Dauphin River included in-well groundwater level measurements of approximately 19 community bedrock wells, Confined bedrock aquifer piezometric pressures ranged from approximately 2.4 m below ground surface to approximately 2.4 m above ground surface. Flowing artesian conditions (aquifer levels at or above ground surface) were observed at 14 of the 19 measured wells. According to local residents, groundwater pressures increase and are at peak conditions during spring / summer (approximately May to mid-July). This seasonal relationship of aquifer water levels is expected, as the aquifer piezometric pressures will rise in response to spring recharge and fall during the remainder of the year (e.g. during a “dry” summer and fall period), punctuated only by short duration, intense periods of seasonal rainfall.

During construction of the Reach 2 Channels, excavation and isolation of the peat groundwater system, along with gravity drainage of the developing excavation, will be necessary to isolate and control groundwater seepage to the work. As the Reach 2 Channels are excavated into the tills, seepage is expected to occur as well from the following additional sources:

- General seepage from the tills and any inter-till granular zones. These seepage contributions are likely to be minimal and may decrease with time, unless there are pervious granular inter-till zones in direct interconnection with the underlying bedrock aquifer.
- Seepage from the bedrock, via hydraulically fractured ("blown out") till, which may occur where the channel excavation is relatively deep, and/or where the bedrock surface is relatively high, and where in particular the bedrock aquifer piezometric pressures are elevated.
- Direct seepage from the bedrock, should the channel be excavated to/into the bedrock surface.

For all Reach 2 Channel options currently under development, the groundwater seepage sources, and associated groundwater impacts, are considered the same and as described above. Impacts to the peat groundwater system are estimated to be nominal; and regional bedrock aquifer water level impacts, while measurable within localized areas, are not anticipated to contribute a significant impact. Gradients for seepage discharge within the bedrock are likely to be maintained with the Project, and there are no local well users who may be affected by Reach 2 construction. The nearest community well users within Dauphin River are hydraulically isolated from the Reach 2 aquifer areas by the Dauphin River. All Reach 2 Channel options will be designed to minimize the risks of seepage and blowouts, and standing water upstream of the drop structures will assist in mitigating the quantity of groundwater seepage to any of the channel options. Any of the Reach 2 Channel options, based on data available to date, are interpreted to perform very similarly from the groundwater perspective in the long term.

9.0 ENVIRONMENTAL AND SOCIO-ECONOMIC CONSIDERATIONS

Operation of the proposed LSMOC will provide a permanent, long-term and large positive effect by helping to alleviate flooding in the region. Construction and operation of these channels will, however, also result in a number of potential environmental and socio-economic impacts. A preliminary qualitative assessment was conducted as part of the Stage 1 Study and Stage 2 Conceptual Design. This preliminary assessment acknowledged the likelihood of particular environmental concerns from a general perspective and focused on localized effects along the original outlet channel options to qualitatively assess the relative difference between them.

Based on the results of the Stage 1 Study and Stage 2 Conceptual Design, as well as additional information recently collected by MI as part of a baseline study lead by M. Forster Enterprises, a preliminary list of potential concerns for the various Reach 2 options was developed for the current assignment and subdivided into a number of categories, as described in sections 9.1 and 9.2. Each of the concerns were assessed qualitatively and then evaluated at the Technical Workshop (see Section 13.0) based on input from a panel of selected experts from the KGS Project team, MI, and other outside experts, which included engineers, environmental scientists and biologists. Each of the options was then assigned a rating for each of the categories described in Sections 9.1 and 9.2, based on the methodology prescribed in Section 13.0. The sections that follow provide a comparison of the environmental and socio-economic concerns focusing on the differences.

9.1 PHYSICAL ENVIRONMENT

9.1.1 Surface Water

Surface water concerns are associated with potential impacts on surface water quality (i.e. TSS, Mercury, etc.) and quantity (i.e. flow rates, flow volumes, water levels, and seasonality). As described below, Option 1 has a number of concerns, which would be considered a disadvantage compared to Options 3 and 4.

Operation of the LSMOC will result in altered rate and seasonality of flow on the Dauphin River for all of the Reach 2 options. For Option 1, operation of the LSMOC will result in widespread flooding and flow rates in Big Buffalo Lake and Buffalo Creek that are 10 to 100 times above natural conditions. These impacts on flow rates would likely continue over multiple seasons upon closure of the LSMOC due to saturation of the wetland complex and increased groundwater levels. Impacts on flow rates for Options 3 and 4 would be different and attributable to a reduction in surface water runoff feeding the wetland complex as a result of channel construction. The surface drainage area of Big Buffalo Lake and Buffalo Creek impacted by the proposed channel construction is shown on Plate 9. It is estimated that approximately 65% of the area draining towards Big Buffalo Lake and the wetland complex would be cut off by the outlet channel for Option 3, compared to approximately 60% for Option 4. The impact of flow alteration could be reduced or mitigated with the construction of siphon(s) under Reach 2 at locations of existing streams for both Options 3 and 4. For Option 4, provision of a base flow from Lake St. Martin via Reach 1 could also be considered as a mitigation solution.

Operation of the LSMOC will result in widespread flooding of the wetland complex and of the upper Buffalo Creek for Option 1, which may result in leaching and decomposition of organic material. These flooding conditions could reduce dissolved oxygen and pH levels in the water and increase concentrations of select metals, including methylation of mercury, that are transported downstream. The channel dikes of Options 3 and 4 will minimize flooding of the wetland complex and the associated potential resultant impact to water quality.

Dewatering, dredging, and excavation activities will be required for all options during construction that could result in localized mobilization of sediment affecting water quality in waterbodies the watercourse in close proximity to the project. The risk of sediment mobilizing downstream is greater for Option 1 compared to Options 3 and 4 due to the proximity of construction on Big Buffalo Lake and Buffalo Creek. Although the channel will be designed to minimize the risk of erosion, as described in Section 8.2, poor vegetation growth on the channel banks, extreme flood events that exceed the design criteria, or other unforeseen conditions could result in unexpected erosion during operation, which may affect water quality. The potential impact to water quality would include areas of Lake Winnipeg at the outlet of Reach 3 for all options, but would also include Buffalo creek, Dauphin River, and Sturgeon Bay for Option 1.

9.1.2 Groundwater

As described in Section 8.6, groundwater impacts are expected to be similar for all options, both during construction and long-term during operation. Blowout of basal soils may occur if the groundwater pressure exceeds the pressure of overburden mass. This could result in groundwater discharge into surface water for all options, potentially influencing the surface water quality. Any risk of groundwater under the direct influence of surface water (GUDI) conditions is not expected to be of concern since there are no drinking water wells in the region.

Inundation of Buffalo Creek and the wetland complex surrounding Big Buffalo Lake for Option 1 and construction of the channel through the peatland area for Options 3 and 4 could also result in groundwater impacts in the unconfined / shallow peat layer. As described in Section 8.6, any of the Reach 2 Channel options, based on data available to date, are interpreted to perform very similarly, from the groundwater perspective.

9.1.3 Terrestrial Environment

Potential impacts to the terrestrial environment include vegetation and land cover, as well as associated impacts to wildlife and terrestrial habitat. All options will require vegetation clearing for channel and dike construction. Options 3 will require clearing an estimated area of approximately 410 ha, which is the largest proposed area to be cleared due to its longer channel length. For comparison, Option 4 will require clearing an estimated area of approximately 380 ha, and Option 1 approximately 175 ha.

Overland flow within the wetland complex for Option 1, as well construction of drop structures in Buffalo Creek, has the additional potential to impact the terrestrial environment of an area exceeding 4,000 ha. As discussed in Section 5.3, changes to the existing vegetation cover in the wetland complex has already occurred as a result of the emergency operation in 2011/2012 and 2014/2015. Emergency operation has also altered the terrestrial environment of Buffalo Creek. Similar potential impacts are not expected for Options 3 and 4 since the alignment of both options avoids the wetland complex and Buffalo Creek. However, there could be some potential impacts to the vegetation cover within the wetland complex for both Options 3 and 4 due to the potential changes in groundwater conditions, as described in Section 9.1.2.

Based on information from the baseline study in the region, there are two species of bat identified in the project area that are protected under the Species at Risk Act (SARA). As such a SARA permit will likely be required for work in the area for disturbance to Winter Hibernacula through blasting, vibrations and cave collapse and for the disturbance to the summer roosting trees (large trees or snags) from traffic disturbance and tree clearing. These concerns are common to all options and therefore results in the same potential impacts to Options 1, 3 and 4.

9.1.4 Aquatic Habitat and Resources

As described in the Basis of Design (Section 3.8), accommodation of the channel design for fish passage during operation would not be required for the LSMOC. However since fish may be able to move into the LSMOC from Lake St. Martin when in operation, a number of design considerations have been incorporated into the concepts of all the options to minimize potential impacts to the aquatic habitat. For example, provision of riparian flow and inclusion of a notch at the top of each drop structure will provide downstream passage for fish at all times when the channel is not in operation to minimize the risk of fish stranding within the channels. Provision of riparian flow and a deep pool upstream of the drop structures also reduces the potential risk of mortality for fish that may overwinter in the channel.

Option 1, however, has a number of additional concerns related to potential changes to existing fish and fish habitat within Buffalo Creek and Big Buffalo Lake, which significantly disadvantages the option with respect to aquatic impacts. As well, there is a risk of fish stranding in the wetland complex surrounding Big Buffalo Lake for Option 1 as a result of operation and inundation of the area. These concerns for Option 1 may require maintenance programs, such as fish salvage operations, and/or other potential mitigation measures.

Excavation and construction of drop structures in Buffalo Creek would result in destruction or alteration of fish habitat for Option 1. Similar structures in Buffalo Creek are not required for Options 3 and 4. Although fish passage for the period when the channel is not in operation would be incorporated into the design of the drop structures in Buffalo Creek, the structures would not be designed for fish passage during periods of channel operation and, therefore, could result in a temporary loss of fish habitat in Buffalo Creek and Big Buffalo Lake for Option 1. Furthermore, changes in flow patterns in Buffalo Creek downstream of the Reach 3

Diversion Structure as a result of operation could result in potential additional aquatic impacts for Option 1.

9.2 SOCIO-ECONOMIC CONSIDERATIONS

Evaluation of the options considered the short- and long-term impacts of the project to affected stakeholders and surrounding communities, including First Nations and Métis. Socio-economic factors were sub-divided into three sub-criteria for the evaluation, which included access, indigenous rights bases activities, and commercial fisheries.

As discussed in Section 7.1, a permanent all-season road will provide construction and long-term access to the project site for all options. Increased access to the area may be either a benefit or a concern to the current users in the area such as existing hunters, fisherman, First Nations and Métis. A gated system would be included on the access road to limit unauthorized access to the area. Although access would be provided on both sides of the channel for all of the options, as discussed in Section 10.1, access across the channel would only be available at the control structure/bridge location near the inlet for all options, and at the Reach 3 bridge location for Option 1. Overall, however, the benefits and concerns with access to the site would be similar for all options.

Potential impacts to traditional land use activities such as fishing, hunting and trapping were considered as part of the Indigenous Rights Base Activities sub-criteria. Construction and operation may result in potential impact to traditional land use and activities for all of the options. However, inundation of the Big Buffalo Lake wetland complex will result in a larger area of impact for Option 1 compared to Options 3 and 4.

Construction and operation of the LSMOC may also result in potential impact to the commercial fisheries in the region. Although a number of design considerations have been included in the project to minimize impacts to fish and fish habitat, as defined in the basis of design for the project (Section 3.8), the concerns with commercial fisheries are mostly related to the potential impacts on productivity and revenue. This concern is common for all options, however, is much greater for Option 1 since the alignment through Big Buffalo Lake and Buffalo Creek has the potential to result in additional aquatic impacts, as discussed in Section 9.1.4.

10.0 MAINTAINABILITY AND INSPECTION ASSESSMENT

10.1 ACCESS TO SITE

As described in Section 7.1, an all-season road will be constructed to permit year round (permanent) access to the Lake St. Martin Outlet Channel for long-term operation and maintenance of the channel and associated structures. Plate 1 shows the alignment of the proposed all-season road. In addition, access will be provided on top of all dikes on both sides of the channel for all options with the provision of a 6 m wide gravel top.

For Option 1, there would be two different access points from the all-season road, as shown on Plate 3. On Reach 1, the water control structure would serve as a bridge to access the north-west side of the channel. On Reach 3, a bridge would be constructed to access the north-west side of the channel and also to access the Reach 2 containment dike and Buffalo Creek Drop Structures.

For Options 3 and 4, the gravel roads on both sides of the channel, located on top of the adjacent dike channel banks, would be continuous, extending from Lake St. Martin to Lake Winnipeg, and accessed from the all-season road at a single point, as shown on Plates 5 and 6. The water control structure would serve as a bridge to access the north/west side of the channel.

Although there are some differences between options in how access will be provided to site for long-term operation and maintenance, as described above, each of the options was judged to have essentially equal access. The cost implications associated with the different road lengths and bridge requirement are described in Section 12.0.

10.2 VEGETATION GROWTH

Two key aspects of vegetation growth affect the performance of each option and have differing impacts on maintainability. They are:

1. Exposure of the side slopes of the channel after a flood event. As explained in Section 3.0, extended operation periods could cause the vegetation that would inhabit

the channel side slopes to die and leave exposed bare soil in the zone that was submerged during flood releases. This could lead to erosion in subsequent flood periods or erosion due to runoff from intense rainstorms or during snowmelt.

2. Shallow depths of water are conducive to the establishment and flourishing of dense aquatic vegetation such as cattails. This can cause a serious reduction in the hydraulic discharge capability of the channel if the vegetation occupies a significant portion of the wetted perimeter of the channel.

Both aspects need inspection and maintenance in the future to ensure continued good performance of the channel with respect to minimized erosion potential and maximum discharge capacity. Maintenance would include efforts to promote rapid revegetation that would protect the bare soil followed by cutting of heavy vegetation growth to ensure hydraulic efficiency. The characteristics of each option pertaining to these key factors are described below.

Option 1

Along the proposed Reach 1 widening, a large portion of the channel side slopes would be exposed as a result of prolonged operation and, therefore, would be vulnerable to erosion. The potentially affected surface area is estimated to be 12 ha in this zone. A large portion of the channel bottom would also have shallow water depths (less than 1 m) during non-flood periods. This is expected to affect almost the entire length of Reach 1, depending on the water level that persists in Big Buffalo Lake, increasing the risk of vegetation growth that could affect the capacity of the channel.

Within the Reach 1 extension and in the wetland complex surrounding Big Buffalo Lake, there would be similar exposure of the channel side slopes and vulnerability to shallow depths of flow. Prolonged periods of operation within the wetland complex could also result in increased or changes in vegetation growth, potentially exacerbating operability concerns within the peatland area, as described in Section 5.0, and/or resulting in environmental impacts difficult to quantify. There would, in addition, be a potential for the inundated wetland complex to release nutrients downstream thereby exacerbating unwanted vegetation growth in Buffalo Creek and in Reach 3.

In Buffalo Creek, it is anticipated that there would be an initial vegetation cleanup program in this area during construction to minimize the risk of debris floating and moving downstream during operation. However, on-going inspection in this area would be required. The drop structures would be designed to minimize the variation in water level between non-operative and flood release periods. Although vegetation established in natural conditions has greater resilience to perturbations like flooding than does newly established vegetation, it is anticipated that some portion of the channel side slopes would require efforts to revegetate after prolonged periods of flood releases.

Option 3

Option 3 would have similar concerns of poor vegetation growth on the side slopes as a result of prolonged operation. It is estimated that a total area of approximately 31 ha would be affected in Reaches 1 and 2. Similarly control from downstream drop structures may reduce the area relative to Option 1 that would have shallow depths of flow in non-operative periods. Only 6 km of Reach 1 would be vulnerable to depths of water of less than 1 m during inoperative periods. The inundation of the wetland area would be eliminated versus Option 1 and would minimize the issue of enhanced nutrient supply to the downstream areas.

Option 4

The issues for Option 4 are similar to Option 3, but the affected areas would be less. For example, the exposure of side slopes due to prolonged operation would be reduced to 14 ha. Similarly there would be only limited areas where the depths of water in non-operative periods would be less than 1 m, thereby minimizing the potential for cattails and similar vegetation to flourish.

Comparison of Options

Options 1 and 3 have relatively high risks of vegetation growth in Reach 1 that would require aggressive maintenance to prevent long-term loss of discharge capacity. The need for maintenance of this type could be lessened by over-excavating the channel in Reaches 1 and 2. However, over-excavating requires a substantial increase in cost, which would likely not be recovered in the reduced annual maintenance costs. This aspect could be examined in more detail if either Options 1 or 3 advance as the preferred alternative.

Option 1 has a relatively high risk of increased vegetation growth within the wetland complex surrounding Big Buffalo Lake due to the shallow water depths, as well as potentially in Reach 3 due to the additional source of nutrients.

Option 3 is estimated to have the largest potential area of channel side slopes vulnerable to poor growth or survival of vegetation, and Options 1 and 4 are similar in this regard.

Potentially more effort would be required for Option 1 than for Options 3 or 4 to address the debris floatation and impacts on downstream areas during flood releases.

Overall, it is considered that Option 4 is superior in the category of maintenance of vegetation.

10.3 SEDIMENTATION

The sediment content in the water of Lake St. Martin is estimated to be negligible during periods when there is passage of flood flows into the diversion channel. If there is any movement of sediment within any of the channels of the three options, the sources would be exclusively along the channel routes. As described in Section 8.2, the channels will all be designed to be non-erodible for normal operating conditions, and sediment erosion would only be expected if the design flood flow was exceeded in some extreme event in the future.

All channels may be prone to erosion along the upper zones of the channel side slopes following extended periods of flood operations where high water levels persist and cause the vegetative cover on those side slopes to die.

If erosion along the channel routes occurs, there is the potential for deposition as follows:

- Option 1 – in the low velocity zones in and around Big Buffalo Lake, in the channels upstream of drop structures, and at the outlet of Reach 3 in Lake Winnipeg.
- Option 3 and 4 – in the channel upstream of drop structures, and at the outlet of Reach 3 in Lake Winnipeg.

It is conceivable that during non-operative periods, wind-driven waves and currents in Lake St. Martin could cause movement of sediments located along the shorelines. It is possible that material transported in these wind events could cause deposition in the approach area to the inlets to each of the options. Whether or not this process would be of concern would require field reconnaissance of the shoreline material in the area and possibly observations during future wind storm events.

It is the opinion of KGS Group that movement of sediment along the shoreline of Lake St. Martin is unlikely to occur to an extent that will affect the channel inlet area significantly. Nevertheless, this process should be investigated further at the next level of study.

If subsequent planning and engineering of the selected Option shows that this is a serious concern, it could be addressed by one of the following strategies:

- If observations in the next level of planning and design cannot conclusively resolve whether this process is a serious concern, a strategy of "wait and watch" could be followed. If significant deposition occurs during the watch period, a dredge could be mobilized to remove the material in advance of release of flood flows through the channel.
- If observations in the next level of planning and design conclusively demonstrate that deposition in the approach areas to the channel occurs to an extent that reduces the discharge capacity into the channel, then construction of protective groins could be included in the final design. These groins would extend the approach area into deep water of Lake St. Martin and avoid deposition that could affect the discharge capacity.

The three options are similar in expected performance from a maintenance perspective. Option 1 has a larger potential area of deposition in Big Buffalo Lake than the other two. This is not considered a serious maintenance issue but does impact significant areas of terrestrial habitat.

10.4 OPERATION IN WINTER CONDITIONS

A concern voiced by MI in their RFP for this phase of engineering related to the potential damage to the channel and drop structures due to ice mobilized by the flow, either in spring or during winter operations. The "battering ram" effect that could ensue has been experienced on other similar facilities in Manitoba owned by MI. To some extent, the risk of this type of potential damage cannot be entirely eliminated. However, four factors are expected to significantly reduce the potential for serious damage to the diversion facilities on LSM:

1. The drop structures along Reach 2 will not include low level water passages. As described in Section 4.5.2, all flow releases will occur over the crests of the weirs. This will permit a deep pool of water to persist during winter and allow a stable lake-type ice cover to form.

2. As described in Section 3.0, the channel geometry has been selected to be as deep and narrow as practical, with wide rockfill weirs (drop structures) at the downstream end of each reach. This will serve two purposes:

   a) It will minimize the variation in water level and exposure of the side slopes of the channel above the prevalent water surface. This will in turn minimize the potential for aufeis formation on the exposed side slopes that tend to form due to the seepage from the surrounding groundwater system.

   b) It will maintain relatively deep pools within the channel reaches, and in combination with the absence of low level water passages (see Point 1 above), will allow a stationary lake-type ice cover to form without freezing to the channel bottom. This will avoid the potential for excessively thick aufeis that could develop in the shallow depths of a wide, shallow channel. Aufeis has been known to thicken uncontrollably to several metres and become a contributor to structural damage when it eventually floats up and drifts during spring operations of the channel. In contrast, lake-type ice on a deep channel would typically be between 0.7 to 1.2 m in thickness. Such relatively thin ice would be expected to deteriorate to a harmless mass much more quickly in spring than much thicker aufeis.

3. The rules of operation will prohibit the opening of the gates in the LSMOCS control structure (from a fully closed position) until the ice on the surface of the channel downstream has substantially deteriorated or melted entirely. This will minimize the risk of ice that has formed in the channel over the winter from mobilizing and drifting as a "battering ram" to cause damage to the channel or to the structures within it.

4. The gates in the LSMOCS will not be operated for extended periods of time as a partial opening in winter, to avoid the impact of ice floes that could drift from LSM into the structure. If release of flow occurs, it will be a continuation from the start of the winter. Movement of the gates in the winter will be allowed, if necessary, but the gates will each be either fully open or fully closed. Passage of very low riparian flows in winter from LSM, if necessary, may be possible with small gate openings in one bay of the control structure, or possibly with the use of a small gated orifice within the body of one gate. Further study of this will be required in the next level of study and design.

11.0 RESILIENCY

The construction of the proposed channels at LSM and Lake Manitoba would provide significant flood protection relief for the region. However, it is unclear how future climate change may affect flood potential in southern Manitoba, and whether the current efforts to enhance flood protection will prove to be fully satisfactory in future decades. In consideration of this uncertainty, it is appropriate in the comparison of options to include an item that measures the ability of each option to be readily expanded in future, if the need arises. This item has been referred to as "resiliency".

In this regard, all options have the ability to convey flows that exceed the design capacity of 326 m^3/s (11,500 cfs), however with a reduced freeboard, as discussed in Section 3.2, For Option 1, the hydraulic conveyance within the wetland complex surrounding Big Buffalo Lake limits the ability to increase flows much beyond the design peak without conducting additional excavation works in Reach 1 or within the wetland complex itself. Option 1 was, therefore, considered to perform less favorably compared to Options 3 and 4 in the category of resiliency.

It was concluded that Option 4 offers a significant advantage over both Options 1 and 3 because the existence of a separate intake from LSM for Option 4 facilitates the possibility of reopening Reach 1 and using the discharge capacity available there, either in an emergency operation or after appropriate preparation to avoid possible adverse impacts. The fact that Reach 1 might, under future circumstances be re-deployed, could mean infilling the excavated channel is not in the scope of construction for Option 4.

12.0 CAPITAL, MAINTENANCE AND RISK COSTS

12.1 CAPITAL COST ESTIMATE

Capital cost estimates were developed for each of the three Reach 2 options such that they could be incorporated into the evaluation and considered in the selection of a preferred alternative. To ensure that the cost estimates would be consistent with previous cost estimates for the overall project, the same methodology developed as part of the Stage 2 Conceptual Design was adopted. Although the focus of the assignment was Reach 2, the cost estimates presented here-in are inclusive of all components of the LSMOC, and include updates to other project components, such as Reach 1 and Reach 3, necessary to ensure a true comparison between options.

The cost estimate is considered to be a Class "C" estimate based on semi-detailed unit costs sufficient for budget authorization. The cost estimate was prepared assuming that the work will be divided into a number of contracts managed by MI or their designate. This contracting philosophy is consistent with MI's methodology for executing large projects. Although the level of effort to manage the work will be increased compared to a single large contract, the total overall cost should be significantly less. It is likely that the final contract execution strategy will involve First Nation's "set aside" requirements as part of the process. The estimate has not provided a specific allowance for this process, as it would best be addressed when these requirements are clear with adjustments made to the estimate as appropriate.

KGS Group has developed a hydraulic structures and earthworks cost database from our involvement in a number of recent construction projects. Unit prices are routinely updated based on market conditions and other factors as deemed necessary. Unit prices from our database formed the basis of the cost estimates described herein and were updated based on the input of Contractors as a part of the constructability assessment, as described in Section 7.0. The basis for the estimate for each of the project components is outlined in Sections 12.1.1 to 12.1.7. A summary of the cost estimate follows in Section 12.1.8; and the details of the estimate, including quantities, are provided in Appendix G.

12.1.1 Reach 1 Earthworks

The Reach 1 earthworks contract considered widening of the existing channel (Options 1 and 3) and decommissioning of Reach 1 (Option 4). Extension of Reach 1 for Option 1 was considered in the Reach 2 earthworks contract and is discussed in Section 12.1.2.

The following section describes how the costs for each component of the Reach 1 earthworks were developed for the various options and includes unit measures and pricing for updated project components that were not discussed in previous studies. Earthworks unit prices were assumed to include all of the Contractors' direct and indirect costs, bonding and insurance, as well as allowances for overhead and profit.

Excavation

The excavation quantities for widening Reach 1 for Options 1 and 3 were based on the quantities and unit prices from the Stage 2 Conceptual Design. Only the general excavation quantities and unit costs were updated as follows:

- Undisturbed material – quantities were based on the results of this Stage 2 Conceptual Design, which were based on LIDAR and channel cross sections and calculated using Civil 3D. The unit cost for unclassified earth excavation, including peat excavation was $\$10/m^3$.
- Existing spoil pile – quantities were based on the results of the UAV survey described in Section 2.1. Based on the results of the constructability assessment and feedback from the Contractors, as discussed in Section 7.3, it was judged that the unit cost for excavating the existing spoil pile should be increased from $\$10/m^3$ to $\$15/m^3$ due to the additional effort of handling material that is denser, unsorted and may be full of debris.

For Option 4, although decommissioning of Reach 1 does not require widening the channel, a quantity for general excavation was included in the estimate to re-shape the existing channel banks prior to revegetation and as an allowance for any excavation that may be required to address existing surface water drainage.

Inlet and outlet Works

Excavation of the Reach 1 inlet area will be required for Options 1 and 3, but not for Option 4. Similarly, dewatering of Reach 1 is only required for Options 1 and 3. As such, the estimated costs for the outlet cofferdam, construction dewatering, and inlet works were only included for Options 1 and 3 and were based on the quantities from the Stage 2 Conceptual Design.

Option 4 included a lump sum value estimated at $500,000 for the Inlet Closure Dike, which isolates Reach 1 from Lake St. Martin.

Construction Camp

The construction camp estimates were based on an assumed 5% of the subtotal of all direct earthworks costs as described in the Stage 2 Conceptual Design Report. The 5% value is intended to reflect the appropriate construction schedules and size of the construction camp relative to the size and complexity of each option.

Revegetation

Revegetation was based on an assumed rate of $11,500/ha as described in the Stage 2 Conceptual Design Report. This rate considers that revegetation of the LSM Outlet Channels will mostly require site specific native species. For Options 1 and 3, the total revegetation costs were calculated based on an assumed 75% of the total footprint area of the channel and spoil pile since revegetation will not be required on the channel bottom or lower side slopes that will always remain under water. However, for Option 4, the revegetation costs were calculated based on the entire footprint area of the existing Reach 1 Channel and spoil pile, since revegetation of the areas under water may also be desirable depending on the decommissioning strategy that will be further defined at the next stage of design.

12.1.2 Reach 2 Earthworks

The Reach 2 earthworks contract considered the segment of the LSMOC extending from Reach 1 to Reach 3 (Options 1 and 3) and from LSM to Reach 3 for Option 4.

The following section describes how the costs for each component of the Reach 2 earthworks were developed for the various options and includes unit measures and pricing for updated project components that were not discussed in previous studies. Earthworks unit prices were assumed to include all of the Contractors' direct and indirect costs, bonding and insurance, as well as allowances for overhead and profit.

Excavation

The excavation quantities for constructing Reach 2 were based on LiDAR, as well as the channel cross sections and profiles presented in Section 4.0. For Option 1, excavation volumes for the Reach 1 Channel extension were updated, as discussed in Section 7.3, such that the full depth of peat along the proposed channel alignment be removed during construction. The unit cost for unclassified earth excavation, including peat excavation was $\$10/m^3$.

Dikes

Fill quantities for the containment dike of Option 1 were based on the Stage 2 Conceptual Design, which assumed a dike geometry with an 8 m (26 ft) top width and 4:1 side slopes, with quantities updated considering the additional requirements associated with the proposed drop structures in Buffalo Creek. Dike quantities for Options 3 and 4 were not estimated as these were assumed to already be part of the general channel excavation quantities. The assumed unit price for peat excavation and dike fill were $\$10/m^3$ and $\$20/m^3$, respectively. Clearing and Grubbing was not included in the estimate as it was assumed they are already be included within the unit rate for peat excavation.

Cofferdam and Construction Dewatering

A lump-sum value of $1,000,000 was included for contract items requiring dewatering during construction based on engineering judgement and experience. A discussion of surface and groundwater management during construction is included in Section 7.2.

Since the cofferdams for Options 3 and 4 will be constructed with the till material excavated from the channel, and since it will also become an integral part of the channel dikes, an additional quantity for cofferdam was not included for these two options.

For Option 1, a quantity for the cofferdam that would be required to extend Reach 1 into the peatland area was included in the estimates since the material would be hauled from the Reach 1 widening. Quantities developed as part of the Stage 2 Conceptual Design were updated to consider the requirements for long-term access on the north side of the channel, as discussed in Section 10.1. Considering the additional efforts of working in wet conditions and the cost premium of having to haul material extended distances, a unit rate of $20/m^3 was adopted, based on the input of the contractors during the constructability assessment.

Inlet Works

Excavation of the Reach 2 inlet area in LSM will be required for Option 4. As discussed in Section 7.4, bathymetric conditions at the inlet of Option 4 are expected to be similar to conditions at the Reach 1 inlet. As such, the estimated costs for the placement and removal of the inlet cofferdam, and for the inlet excavation were based on the same quantities and unit rates as for Options 1 and 3 discussed in Section 12.1.1.

Drop Structures

The assumed unit rate for the rock riprap cost estimate was not modified from the Stage 2 Conceptual Design. The rate of $90/m^3 assumed that a sufficient volume of rock of good quality will be available from the rock quarries identified within the region. The assumed volume of riprap required per structure for Options 3 and 4 was 11,000 m^3 to be consistent with the assumptions of Reach 3. For Option 1, the structures would be larger, as described in Section 4.5, and a volume of 22,000 m^3 per structure was assumed.

A unit cost of $1,000 /m^2 was assumed for sheet piling based KGS Group's recent experience on other projects. An area of 800 m^2 per structure was assumed at this preliminary stage of comparison based on a width of 100 m and depth of 8 m.

Buffalo Creek Enhancements

Buffalo Creek enhancements would only be required for Option 1. In addition to construction dewatering and channel excavation already discussed, the Buffalo Creek enhancements would also include erosion protection of vulnerable channel banks, and a vegetation cleanup to minimize the risk of debris floating and moving downstream during operation of the LSMOC. The vegetation clearing program was assumed to cover the approximate extents of the flooded area within Buffalo Creek, and a unit rate of $16,500/ha was assumed. Estimates for erosion protection were based on the total length of the creek banks that would be vulnerable to erosion, (i.e. in sharp bends or areas of exposed side slopes), and a unit rate of $3,000/lm as defined during the Stage 2 Conceptual Design was assumed. This unit rate assumes a 10m width of riprap would be placed on the channel slope and includes the cost for shaping the channel bank.

Big Buffalo Lake Wetland Complex

Option 1 may require the province to designate the Big Buffalo Lake wetland complex as a Designated Reservoir Area (DRA) or a Provincial Water Way (PWW). A lump sum of $1,000,000 was, therefore, included for this option based on MI input and was assumed to cover costs such as signage, fences, gates, boom, etc.

Construction Camp

The construction camp estimates were based on an assumed 5% of the subtotal of all direct earthworks costs as defined in the Stage 2 Conceptual Design Report. The 5% value is intended to reflect the appropriate construction schedules and size of the construction camp relative to the size and complexity of each option.

Revegetation

Revegetation was based on an assumed rate of $11,500/ha as described in the Stage 2 Conceptual Design Report. This rate considers that revegetation of the LSM Outlet Channels requires mostly site specific native species. For Options 3 and 4, the total revegetation costs were calculated based on an assumed 75% of the total footprint area of the channel and spoil pile since revegetation is not required on the channel bottom or lower side slopes that will always remain under water. For Option 1, the revegetation quantities were based on the total footprint area of the containment dike and of the left dike / spoil pile (north-west side) of the Reach 1 Channel extension.

12.1.3 Reach 3 Earthworks

Although Reach 3 was not included in the scope of work of the current assignment, some modifications were necessary to the Reach 3 cost estimates in order to compare the options. In general, all of the cost items, quantities and unit rates for Options 1, 3 and 4 are identical to the Stage 2 Conceptual Design estimates with the exception of the following items:

- The excavation quantities and the revegetation area were reduced by 5% for Options 3 and 4 due to the shorter Reach 3 Channel length.
- The cost for the diversion structure and inlet weir was not included for Options 3 and 4. However, an assumed lump sum of $1,000,000 was included as an allowance for a dike structure upstream of Reach 3 to stop backwater into Buffalo Creek, and for other miscellaneous items such as the potential decommissioning of the Reach 3 Emergency Channel segment that would no longer be required.

For the purpose of this assignment, the cost estimates presented are for the Reach 3 option with outlet east of Willow Point. Based on the results of the Stage 2 Conceptual Design, the cost estimates for the option with an outlet at Johnson Beach would be approximately $14 million less.

12.1.4 Control Structures

As described in Section 3.6, it was assumed for this assignment that the conceptual design of the control structure would remain unchanged from the Stage 2 Conceptual Design study. The estimated cost of the control structure is therefore the same for each option and based on the same contract items, quantities and unit rates as those developed during the Stage 2 Conceptual Design. Although unit prices developed as part of the Stage 2 Conceptual Design were reported in 2014 dollars, the unit prices were not updated for the purpose of comparing the options. The cost was, however, updated to 2017 dollars for the preferred alternative as part of the Preliminary Design, as described in Section 14.5. It was judged that these nominal cost updates would not affect the comparison of alternatives.

12.1.5 Access Road and Gravel Topping

The cost estimate assumes that an all-season road will be required to permit year round access to the project site for construction and also in the future for the purpose of operating the control structure, maintaining the revegetation components of the project, and general maintenance to the structure and channel. As discussed in Section 7.1, the access road will require upgrading an existing forestry road as well as the existing winter road to various extents, depending on the option. It is estimated that upgrading the forestry road to a single-lane, gravel road will cost approximately $100,000/km, and upgrading the current winter road access to a single-lane, gravel road will cost approximately $500,000/km based on input from MI during the Stage 2 Conceptual Design.

It is assumed that long-term access will be provided along both banks of each of the channels for all options, as well as on the containment dike, as described in Section 10.1. An allowance for gravel topping has, therefore, been included for all options assuming a 6 m wide roadway, a 0.3 m thickness, and a unit cost of $45/m^3.

12.1.6 Bridges

Option 1 would include a bridge to access the left bank of Reach 3 as well as the containment dike and Reach 3 diversion structure. The estimated bridge cost was calculated based on the footprint area of the bridge assuming a width of 12 m and length of 40 m. A unit rate of $7,000/m^2 was used for the bridge, assuming the bridge could require design standards similar to PTH bridges. A $0.5 million allowance was also included for the approaches.

12.1.7 Electrical Power Supply Estimates

As described in the Stage 2 Conceptual Design Report, a temporary power supply will be required during construction of the LSMOC control structure. A permanent power supply will also be required for long-term operation. The cost estimates for electrical power supply were based on input from Manitoba Hydro, as described in the Stage 2 Conceptual Design report, with only the length of the proposed powerline from PR 513 to the control structure differing between options. For Options 1 and 3, approximately 11 km of overhead line cut through the existing undeveloped terrain will be required, whereas an additional 4 km will be required for Option 4 due to the alternate location of the control structure further south. The estimated cost is approximately $150,000/km and assumes there will be no issues with First Nations or land acquisition.

12.1.8 Cost Summary

The total costs of the LSMOC for the different Reach 2 alignment options are summarized in Tables 5, 6 and 7. This cost summary is based on the project components for each option as described in the previous sections with the detailed estimates shown on the tables provided in Appendix G.

Costs associated with proposed best practices to mitigate effects during construction, such as control of surface water and groundwater (dewatering, ditching, silt fences and settling ponds) have been included in the construction cost estimate as part of the unit price for excavation. Mitigation and compensation costs that have not been accounted for in the cost estimate of specific works include costs for long-term monitoring, compensation for damage to fish habitat, compensation to fishermen, or any additional mitigation and compensation measures that may come from Regulator requirements determined during the advancement of the licensing and permitting process for the channel. These costs have, however, been estimated as 5% of the direct project costs, which is consistent with the Stage 2 Conceptual Design estimates.
Also consistent with the Stage 2 Conceptual Design estimates, the total costs include a 20% allowance for engineering, administration and approvals as well as a 20% contingency. It is recommended that, at the next stage of design, project contingencies be updated based on a Risk-Cost approach, considering risk consequences, risk probability and residual risk, to ensure adequate cost allowances for risk are included in the project estimates. Cost risks were only considered for the purpose of comparing the options at this stage of design and are discussed in Section 12.3.

TABLE 5
TOTAL COST SUMMARY – OPTION 1

Construction Component	Estimated Cost	
Earth Works		
Reach 1	$	33,884,000
Reach 2 (Option 1)	$	50,861,000
Reach 3 (with outlet east of Willow Point)	$	42,162,000
Control Structure		
Spillway	$	23,139,000
Gates, Guides and Hoists	$	15,351,000
Access		
Reach 1 Access Road	$	15,600,000
Reach 3 Access Road	$	8,000,000
Gravel Topping (Reaches 1, 2, 3)	$	3,579,000
Reach 3 Bridge	$	3,860,000
Electrical Power Supply		
Permanent Power	$	1,720,000
Construction Power	$	3,636,000
Sub-total	**$**	**201,790,000**
Mitigation Cost (5%)	$	10,089,500
Engineering, Contract Admin., Approvals (20%)	$	40,358,000
Sub-total	**$**	**252,240,000**
Contingency Cost (20%)	$	50,448,000
TOTAL	**$**	**302,690,000**

TABLE 6
TOTAL COST SUMMARY – OPTION 3

Construction Component		Estimated Cost
Earth Works		
Reach 1	$	33,884,000
Reach 2 (Option 3)	$	64,014,000
Reach 3 (with outlet east of Willow Point)	$	39,288,000
Control Structure		
Spillway	$	23,139,000
Gates, Guides and Hoists	$	15,351,000
Access		
Reach 1 Access Road	$	15,600,000
Gravel Topping (Reaches 1, 2, 3)	$	4,456,000
Electrical Power Supply		
Permanent Power	$	1,720,000
Construction Power	$	3,636,000
Sub-total	**$**	**201,090,000**
Mitigation Cost (5%)	$	10,055,000
Engineering, Contract Admin., Approvals (20%)	$	40,218,000
Sub-total	**$**	**251,360,000**
Contingency Cost (20%)	$	50,272,000
TOTAL	**$**	**301,630,000**

TABLE 7
TOTAL COST SUMMARY – OPTION 4

Construction Component	Estimated Cost	
Earth Works		
Reach 1	$	4,802,000
Reach 2 (Option 4)	$	85,686,000
Reach 3 (with outlet east of Willow Point)	$	39,288,000
Control Structure		
Spillway	$	23,139,000
Gates, Guides and Hoists	$	15,351,000
Access		
Reach 1 Access Road	$	15,600,000
Gravel Topping (Reaches 2,3)	$	3,701,000
Electrical Power Supply		
Permanent Power	$	2,320,000
Construction Power	$	3,636,000
Sub-total	**$**	**193,520,000**
Mitigation Cost (5%)	$	9,676,000
Engineering, Contract Admin., Approvals (20%)	$	38,704,000
Sub-total	**$**	**241,900,000**
Contingency Cost (20%)	$	48,380,000
TOTAL	**$**	**290,280,000**

12.2 GENERAL MAINTENANCE COSTS

Potential maintenance costs were evaluated for the purpose of comparing the options since the overall maintenance effort will vary between options based on length, design differences, and overall performance.

Characteristics of the channel inlet and the control structure are similar for all options and, therefore, maintenance costs for those components of the design are not expected to be any different for one option compared to another. Within the channel, all options have a risk of excessive vegetation growth in locations of shallow water and/or a risk of poor vegetation growth on the channel banks as a result of extended submergence during flood operation, as discussed in Section 10.2. The risks associated with vegetation growth could result in increased maintenance costs, and would be of greater concern for Options 1 and 3 due to the increased channel length and shallower standing water conditions in Reach 1. Option 1 also has the risk of fish stranding, which could result in increased maintenance efforts during and after flood operations, as discussed in Section 9.1, and the operational risks through the wetland complex that were discussed in Section 6.0. Options 3 and 4 do not have similar disadvantages.

Considering the overall differences in maintenance efforts between the options as described above, a potential average annual maintenance cost was estimated for each of the options based on a percentage amount of the total direct construction costs. It was judged, that Option 1 requires the most maintenance effort, and the potential average annual maintenance cost was estimated at $6 million based on an assumed value equal to 2% of the capital cost of the option. The potential average annual maintenance cost for Option 3 was estimated at $4.8 million based on an assumed value equal to 1.6% of the capital cost, and estimated at $4.4 million for Option 4 based on an assumed value equal to 1.5% of the capital cost.

12.3 COST RISKS

The capital cost estimates presented in Section 12.1 could go up or down as the project advances to detailed design and construction. Cost risk considers the potential for increases in the estimated cost of a given option could change due to added project requirements or unforeseen conditions. A total of six cost risk items were identified at the Technical Workshop (described in Section 13) for the purpose of the comparison of options as described below:

1. **Social Risk** – As described in Section 9.2, Option 1 was judged to have additional socio-economic concerns due to its alignment going through the wetland complex and Buffalo Creek. The alignment of Options 3 and 4 avoid the wetland complex and Buffalo Creek altogether, minimizing the socio-economic risks compared to Option 1.

2. **Optimization** – Based on a review of the channel geometry and excavation quantities, it was estimated that a deeper, narrower and straighter channel could provide the opportunity for approximately $5 million in cost savings for Option 1 compared to approximately $15 million in cost savings for Options 3 and 4.

3. **Environmental** – As described in Section 9.1, Option 1 has potential additional environmental mitigation requirements to address concerns regarding flooding the wetland complex and Buffalo Creek, which could result in increased cost. The alignment of Options 3 and 4 avoids the wetland complex and Buffalo Creek altogether, minimizing the risks associated with environmental mitigation requirements compared to Option 1.

4. **Construction** – As described in Section 7.0, the Reach 1 extension for Option 1 has higher construction risks through the peatland area, based on Contractor input, which could result in unexpected increases in costs. Also, unknown spoil conditions for Reach 1 widening (Options 1 and 3) could result in unexpected increases in costs. Option 4 is also benefited due to the potential ability to operate Reach 1 during construction with minimal impact to the construction schedule.

5. **Rock Supply** – As described in Section 12.1, the cost of rock for riprap and drop structures will depend on the ability to obtain the necessary rock quantity and quality from nearby quarries. Although there is a limited amount of data on the overall quality and quantity of rock available for the project, differences in total rock quantity required is not substantially different between options.

6. **Amortization** – "Writing-off" the amortization of Reach 1 as part of decommissioning for Option 4 may result in cost differences compared to other options. Based on input from MI, since the design assumes the channel would be used in the future for riparian flow and/or emergency capacity due to climate change, "writing-off" the amortization is not anticipated to be a requirement. On this basis, cost differences are not expected between options for this item.

13.0 TECHNICAL WORKSHOP FOR SELECTION OF THE PREFERRED ALTERNATIVE

As discussed in Section 6.0, evaluation of the options included a Technical Workshop that was held on December 15, 2016 at the KGS Group office. The workshop was attended by project team members and a technical panel of experts and senior engineers from KGS Group, MI and other external consultants. The purpose of the workshop was to review the conceptual design of the channel alternatives, develop a set of evaluation criteria for comparing the options and apply those criteria by rating the performance and suitability to the options to determine the preferred alternative.

Prior to evaluating the alternatives, a summary project overview was presented at the workshop to ensure that all attendees were familiar with the nuances of the design and the differences between each option. This presentation included a review of the design information and available data for each of the channel alternatives. Minutes of the workshop including a copy of the presentation slides, are attached in Appendix F.

13.1 EVALUATION CRITERIA

During the Technical Workshop, attendees were invited to discuss the evaluation criteria and the group reached a consensus on the meaning and relative importance of each of the criteria. In summary, a total of 31 sub-criteria were defined, separated into 8 main categories. Each of the categories and sub-criteria were discussed in detail to ensure that the panel understood the implications of each sub-criteria. The final criteria and their definitions are described in Table 8.

TABLE 8
EVALUATION CRITERIA DEFINITIONS
(This table is located at the end of report)

As part of the workshop process, weighting factors were established for each category and sub-criteria. The final weighting scheme is provided in Section 13.2. Further detail on the development of the criteria and weighting is provided in the minutes from the Technical Workshop in Appendix F.

13.2 RATING OF OPTIONS AND RECOMMENDATION OF PREFERRED ALTERNATIVE

The evaluation process included a comprehensive review and rigorous comparison of the options. The merits and disadvantages of Options 1, 3 and 4 were each discussed in the context of all 31 sub-criteria listed in Table 8. As noted in Section 4.2, Option 2 was eliminated early in the study process and therefore was not considered at the Technical Workshop. A summary comparison of the options which lists the key information discussed in Sections 7.0 to 12.0 of this report, for each of the three options in each of the sub-criteria categories, is included in Table 9.

TABLE 9
SUMMARY COMPARISON OF OPTIONS
(This table is located at the end of report)

One sub-criteria at a time, the workshop attendees then rated each of the options based on a scale of 5 points. A rating of 5 was selected when the option was judged to exceed the requirements of the criteria, and/or performed best when compared to the other options. A rating of 1 was selected when the option was judged to perform less favorably and/or had disadvantages compared to the other options. A score was then calculated for each sub-criteria by multiplying the category's weight by the rating. The total score was then computed, and the option with the highest total score was identified as the preferred option. Table 10 summarizes the rating awarded to each option per sub-criteria as well as the final score calculated for the Options.

TABLE 10
TECHNICAL WORKSHOP EVALUATION RESULTS
(This table is located at the end of report)

Based on the results of the Technical Workshop, Option 4 had the highest score and was, therefore, identified as the preferred alternative. It received a score of 69.7 out of 100. Option 3 scored 63.6 out of 100 and placed second while Option 1 scored 46.8 out of 100 and placed third. The relatively low score for Option 1 was primarily attributed to the alignment through Big Buffalo Lake wetland complex, and associated concerns with constructability, long term operational risk, and the environment. Upon completion of the Technical Workshop, the project team recommended that Option 4 be advanced to the next phase of design. After reviewing the results of this workshop, MI concurred with the recommendation and provided the project team with permission to proceed with advancing the design details of Option 4.

14.0 PRELIMINARY DESIGN OF PREFERRED OPTION

14.1 OVERVIEW

The Preliminary Design of the Option 4 channel initially focused on a preliminary refinement of the channel alignment. As discussed in Section 4.0, the original alignment was selected to route around the peatland area surrounding Big Buffalo Lake. However, based on the results of the peat probe investigations discussed in Section 2.2, and the findings from the constructability assessment described in Section 7.0, it was concluded that a straight alignment of the Option 4 channel, instead of the one that was originally contemplated and shown on Plate 6, would perform equally well in all of the evaluation sub-criteria described in this report, while being shorter and, therefore, less costly due to lower excavation volumes. As a result, a revised alignment was adopted for this option and was used as the basis for the preliminary design and Civil-3D modeling. Plates 10 and 11 show the alignment adopted for the Option 4 channel. As shown on Plate 11, the Reach 2 Channel outlets into Reach 3 approximately 1.2 km from Buffalo Creek. This reduces the extent of excavation work required for Reach 3 and also reduces the number of bends in the channel alignment. Further refinements of the channel alignment should be considered at the next stage of design during the optimization process considering excavation quantities and the results of additional geotechnical investigations in the area.

The remaining preliminary design efforts were focused on the hydraulic design of the channel, the geotechnical design of the channel geometry, including dikes and spoil pile design, and the design of the drop structures. The preliminary design details are described in Sections 14.2 to 14.4. The findings of the assessments conducted for the evaluation of the options described in Sections 7.0 through 12.0 have been incorporated into the preliminary design where applicable. A plan view and cross sections of the channel alignment, developed based on a Civil 3D model of the option, are provided on Plates 10 to 14. The preliminary design of the drop structures is shown on Plate 15.

14.2 HYDRAULIC DESIGN

The channel, the inlet control structure, and the drop structures were designed to allow the LSMOC to comply with the hydraulic design criteria requirements of the project, as discussed in Section 3.0, while attempting to minimize the amount of excavation required. A 1-dimensional hydraulic model developed with the HEC-RAS software was analyzed to confirm that the channel design adequately complied with the hydraulic requirements. The model included the alignment of the channel for Option 4 from the inlet area at Lake St. Martin to the upstream end of Reach 3. A 44 m channel base width and 100 m wide drop structure (crest) were selected as the basis for the channel design. Exceptions include the channel inlet, the transitions at the drop structures, and the final 15 m of the channel where the channel widens to a base width of 49 m to comply with the water level requirement at the upstream end of the Reach 3 Channel. The channel is proposed to have 4H:1V side slopes and a 0.0204% channel slope. The normal depth of flow in the channel is estimated to be 4.5 m during passage of the design flow. These and other key aspects are summarized in Table 11.

TABLE 11
KEY DESIGN ASSUMPTIONS FOR OPTION 4

Parameter	Value
Typical channel bottom width	44 m
Side slopes	4H:1V
Channel longitudinal slope	0.0204%
Manning's roughness, *n*	0.028
Total channel length	12,856 m
Design discharge	326 cms (11,500 cfs)
Upstream (lake) water level	244.1 m (801 ft)
Downstream water level at design discharge	235.0 m

The hydraulic design was developed with the goal of achieving a lake level of El 244.1 m (801 ft) while passing a flow of 326 m^3/s (11,500 cfs). The water level at the downstream end of the numerical model was set to El 235.0 m (El 771 ft) at the design discharge, which corresponds to the estimated water level in Reach 3 at the outlet of Reach 2 during the design event. A Manning's roughness "n" value of 0.028 was chosen for the channel.

14.2.1 Channel Inlet and Control Structure

The inlet control structure is located approximately 620 m from the shoreline of LSM (approximately Station 0+620 on Plate 10). This structure is very similar in concept to the one previously considered for Reach 1 (Options 1 and 3). It is a sluice-type structure with an approximate invert elevation of 239.5 m. It would contain six, 9 m wide bays with five, 2.5 m wide piers separating them. The structure incorporates six vertical lift gates with a maximum opening of 6 m. For the analyses using HEC-RAS, the structure was only modelled with the gates fully open at the design flow. Since the control structure also serves as a bridge providing long-term access to the left banks of the Reach 2 Channel and also to Reach 1, the location of the control structure was assumed to be aligned with the proposed access road. Optimization of the channel design, considering alternate locations and sizes for the control structure should be conducted at the next stage of design.

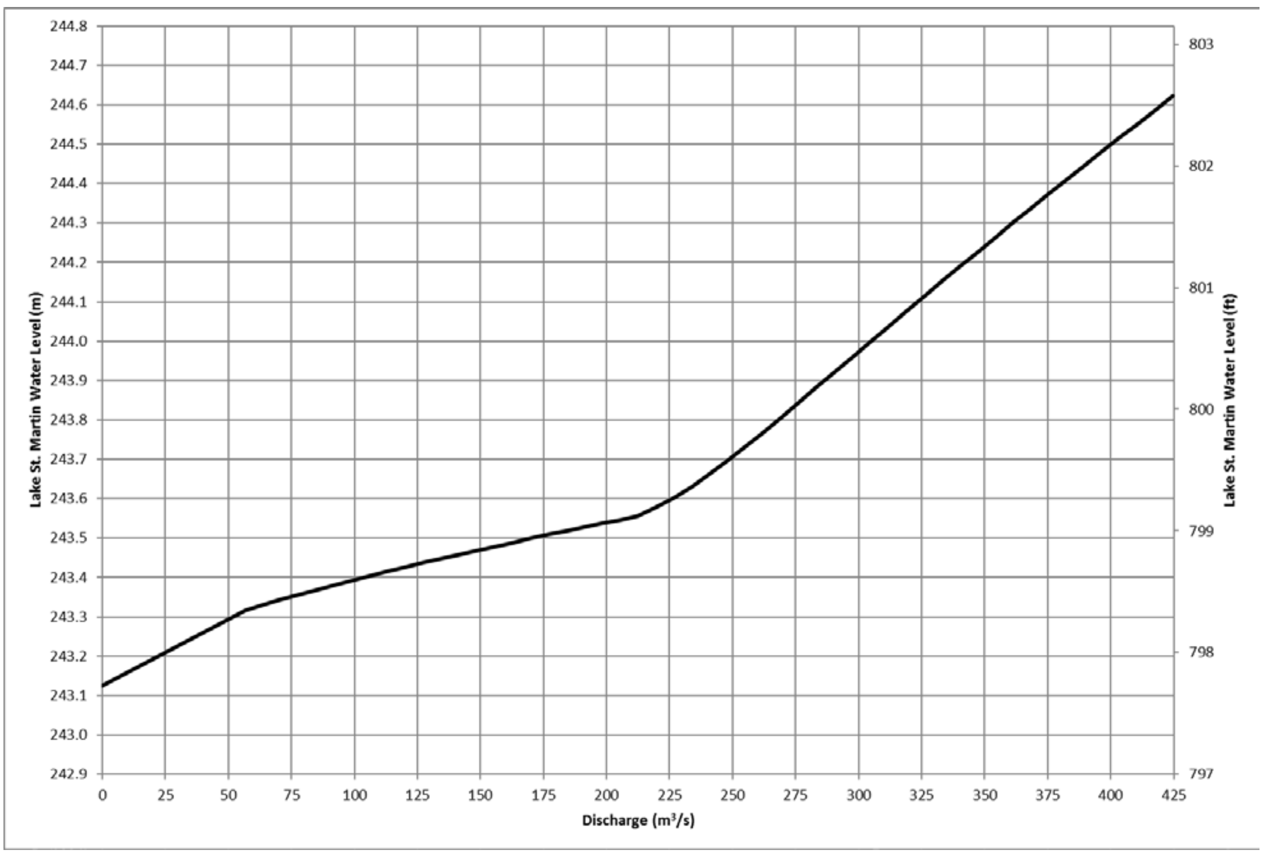
Upstream of the inlet control structure (from Station 0+000 to 0+620), the channel configuration was based on an assumed 100 m base width, side slopes of 4H:1V, and a channel slope of 0.0204%. This configuration was selected to be consistent with the design assumptions that were adopted for the control structure during the Stage 2 Conceptual Design study. At the upstream end of the channel (approximately Station 0 + 000), excavation into the lake is necessary to minimize headloss at the entrance of the channel. The required length of excavation is, therefore, adjusted in the preliminary design to meet the water level requirement for LSM of El 244.1 m (801 ft) during passage of the design flow and a 5 longitudinal to 1 lateral transition rate, with a 1% vertical slope, were assumed for the design. Based on the preliminary analysis, the limit of excavation required extends beyond the upstream limit of the currently available bathymetric data in LSM (Appendix D). Additional bathymetric data should, therefore, be collected at the next stage of design to confirm inlet conditions. Higher ground elevations than those observed in the surveys could result in increased excavation costs at the inlet.

Optimization of the inlet configuration, control structure size and location, drop structure size and location, and channel design configuration should be conducted at the next stage of design to reduce the extent of construction works in locations that may be more expensive (e.g. excavation in LSM) in favor of potentially lower cost alternatives (e.g. widening of the channel downstream).

Downstream of the inlet control structure, the base width of the channel contracts from 100 m to 44 m at a rate of 5 longitudinal to 1 lateral (the base width of the channel reaches 44 m at approximately Station 0+770 m).

The stage discharge relationship for the channel with a fully open inlet control structure is shown in Figure 8. The curve shows that when the control structure is fully open, for flows up to approximately 200 m^3/s (7,000 cfs), conditions at the inlet control how much flow enters the channel for a given Lake St. Martin water level. For flows greater than 200 m^3/s, the channel configuration downstream of the inlet (and the first drop structure) controls flows entering the channel for a given Lake St. Martin water level.

FIGURE 8
LAKE ST. MARTIN OUTLET CHANNEL STAGE DISCHARGE CURVE



14.2.2 Drop Structures

The location of the structures within the channel was selected to achieve two objectives. The first was to limit the volume of excavation for the channel by maintaining the water surface profile under the design flow condition as close to prairie level as possible throughout the channel. The second objective was to limit the amount of vegetation that tends to grow in the channel. Limitation of the vegetation growth was intended to be achieved by maintaining a water depth of 1 m or more at all times.

Three drop structures are required to meet the design objectives. The upstream-most drop structure (Drop Structure 1) is proposed to be located at approximately Station 4+606m and provides a head differential of 1.23 m from the upstream invert elevation of the channel bed to the downstream elevation of the channel bed. The next downstream structure (Drop Structure 2) is proposed to be located at Station 10+716 and provides a head differential of approximately 2.6 m. The final structure (Drop Structure 3) is proposed to be located at Station 12+186 and provides a head differential of 2.5 m at that location. Design details of the drop structures, and discussion of other associated design considerations are included in Section 14.4.

The channel transitions gradually from a base width of 44 m upstream of each drop structure to a width of 100 m at the crest of the drop structure and contract back to a channel width of 44 m in the downstream channel. These transitions can be achieved using the same 5:1 transition rate (longitudinal to lateral) adopted for the rest of the channel design.

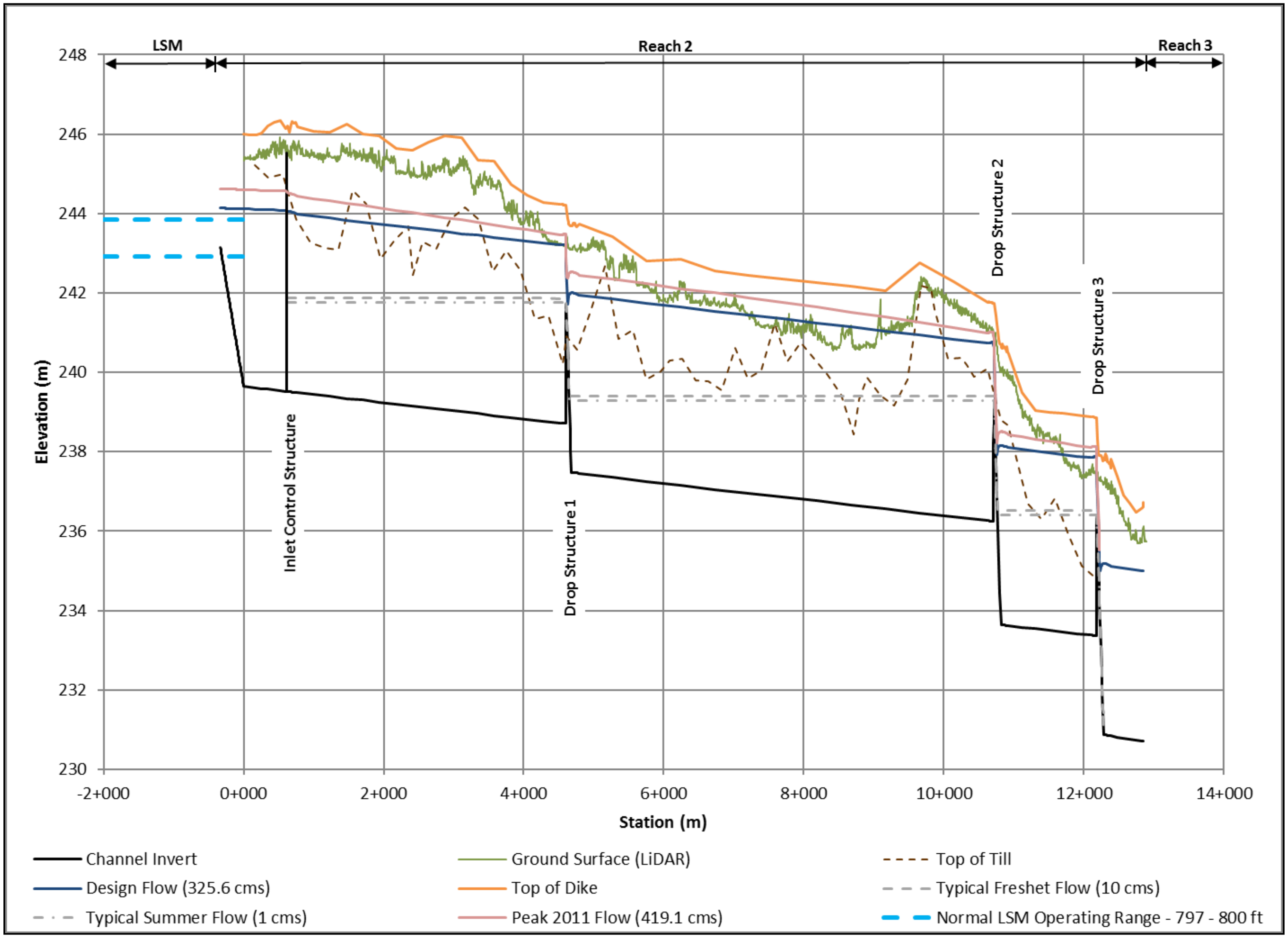
14.2.3 Numerical Modeling

Numerical model simulations were performed at the design flow of 326 m^3/s (11,500 cfs). The resulting water surface profile is shown on Figure 9**Error! Reference source not found.**. A boundary condition that assumes normal depth of flow was used in the model to simulate the downstream boundary with Reach 3. On that basis, the channel width was adjusted to 49 m to meet the downstream water level requirement of El 235.0 m (El 771 ft). Should the design of the Reach 3 Channel change in the future from that proposed in the Stage 2 Conceptual Design study, the portion of Reach 2 between Drop Structure 3 and the upstream limit of Reach 3 may require additional optimization.

An additional simulation was performed with a flow of 419 m^3/s (14,800 cfs) to check the ability of the channel to function under conditions similar to those occurring in a repetition of the 2011 flood event. The results of this simulation are also shown on Figure 9. It was found that there was an average freeboard of 1.36 m available for this condition, and that the minimum freeboard was 0.55 m. As discussed in Section 3.0, acceptance of a lower factor of safety, or alternatively, potential increases in costs to address peak flows above the 326 m^3/s (11,500 cfs) capacity would be addressed at the next stage of design in parallel with design optimization.

Also shown on Figure 9 are the assumed typical freshet flow and summer flow conditions. Water levels for those conditions are based on the design of the drop structures discussed in Section 14.4. Downstream of Drop Structure 3, the water levels depend on design conditions in Reach 3 that were not defined during the Stage 2 Conceptual Design, which, therefore, were not included on the profile.

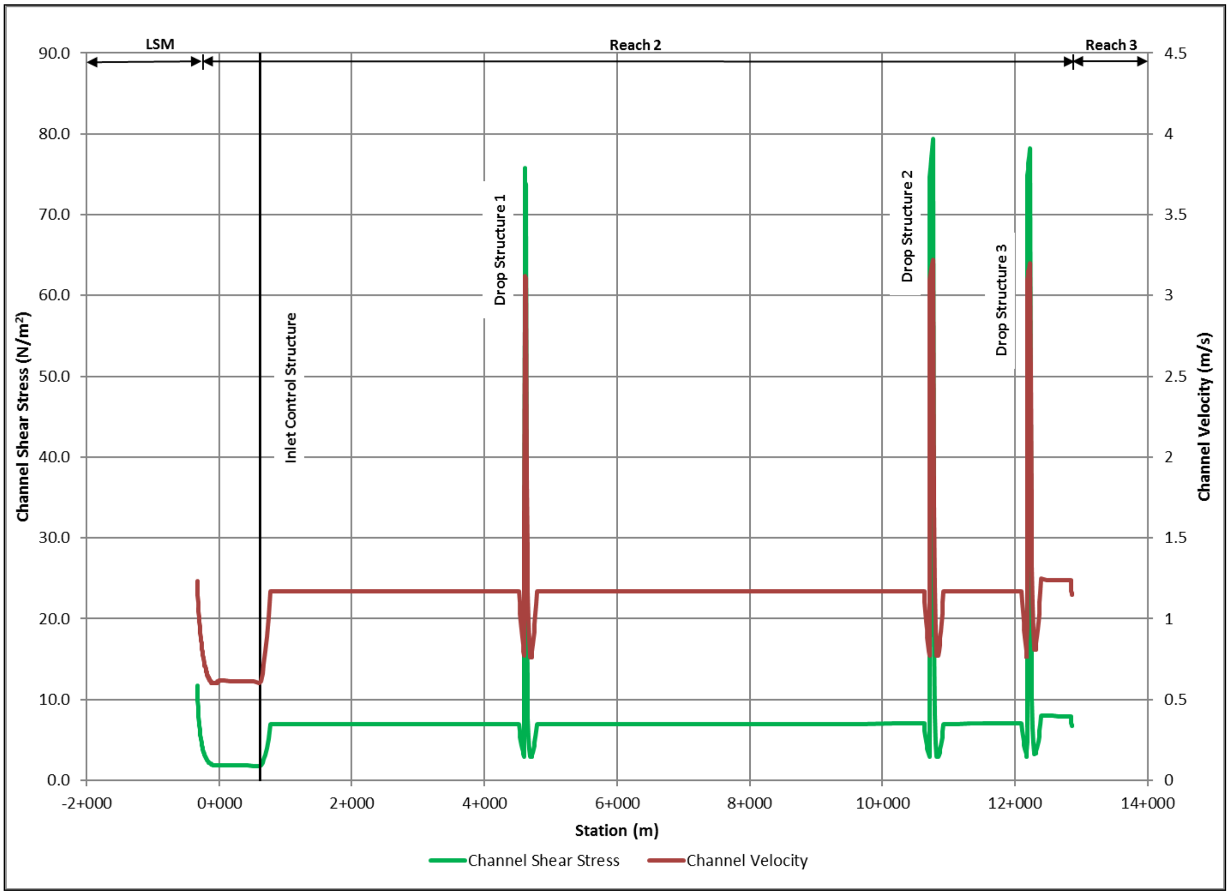
FIGURE 9
PRELIMINARY DESIGN PROFILE OF REACH 2 OF THE LAKE ST. MARTIN OUTLET CHANNEL



14.2.4 Velocity and Shear Stress

Profiles of channel velocity and shear stress are shown in Figure 10. It can be seen that the channel has a relatively constant shear stress (near 7 N/m^2) and an average velocity (1.2 m/s) for the reaches between the drop structures at the design discharge. Under a repetition of the 2011 flood event, the average velocity increases to approximately 1.4 m/s, while the shear stress increases to 9 N/m^2. For a flow of 198 m^3/s (7,000 cfs), the average velocity decreases to approximately 0.9 m/s and the shear stress to 4.5 N/m^2 in the channel between drop structures. The velocities and shear stresses within the channel are, therefore, within the targeted values identified in the Basis of Design in Section 3.3. At the drop structures, both velocities and shear stress values are greater, but those structures are designed to withstand these more intense hydraulic conditions.

FIGURE 10
PROFILES OF VELOCITY AND SHEAR STRESS



14.2.5 Surface Water Drainage

As shown on Plates 10 and 11, two drainage control structures are required along the channel, the first near Station 4+000 and the second near Station 6+600. The structures, assumed to consist of culverts and a gate system, will allow the discharge of surface runoff from the south-east side of the LSMOC into the channel while minimizing backwater from the channel into the adjacent land during periods of operation. In general, surface runoff will flow naturally above and/or through the peat until the discharge points at the drainage control structures.

An outside drain could be considered on the south-east side of the channel, if deemed necessary, in locations where peat depths are shallow. Shallow peat depths ensure that most of the drain can be excavated in till rather than peat. If constructed in peat, there is a concern that the side slopes could collapse and plug the drain, or that peat material could deteriorate overtime, resulting in the floatation or movement of peat material into the drain.

To mitigate the impacts of a reduction in surface water runoff to the peatland area surrounding Big Buffalo Lake and Buffalo Creek, siphon(s) under Reach 2 could be considered instead of the two drainage structures. Alternatively, a provision for a base flow from Lake St. Martin via Reach 1 could be considered as a mitigation solution, as discussed in Section 9.1.1.

14.3 GEOTECHNICAL DESIGN

The proposed channel for Reach 2 follows along the alignment as shown on Plates 10 and 11. The proposed channel cross section is shown on Plates 12, 13, and 14. Along the channel, removal of the existing peat down to the underlying till material is necessary for the construction of the channel dikes to the proposed grade. Placement of the dikes on the underlying mineral soil (till) will provide a cutoff to seepage through the existing peat layer as well as providing a suitable long-term foundation for the dikes.

14.3.1 Stratigraphy

KGS Group undertook a reconnaissance level geotechnical investigation program along Option 4. The program was comprised of peat probes, to determine the peat thickness, and of hand auger holes drilled through the peat into the underlying soils to assess their condition. Details of the investigation program are presented in Section 2.0 of this report.

Based on the peat probes, it was found that the depth of peat ranged from approximately 0.1 m to over 3 m, with an average peat thickness between 1.5 m and 2.0 m. All peat probe and hand auger locations are shown in Plate 2. Data from the Geotechnical Investigations is attached in Appendix B. Since the alignment of Option 4 was modified for the preliminary design, as described in Section 14.1, the results of the field investigations were projected to the channel centerline. A profile showing the peat depth along Reach 2 is provided in Figure 9 (Section 14.2.3).

As previously stated, additional detailed investigations completed to greater depths should be conducted at the next stage of design to confirm the various geotechnical, groundwater and hydraulic assumptions described in this report and to provide a better understanding of sub-surface conditions.

14.3.2 Groundwater Conditions

Groundwater conditions observed during the investigation program along Reach 2 found that the groundwater levels were at or just below ground surface virtually everywhere within the existing peat layer. This was as anticipated as the Reach 2 alignment is located within or adjacent to a large peatland area. While monitoring wells were not installed as a part of this investigation program, an upward gradient is anticipated from underlying till into the peat. Monitoring wells should be installed along the proposed channel alignment to confirm the potential presence and magnitude of an upward gradient that should be incorporated in the design of the Reach 2 Channel.

14.3.3 Reach 2 LSM Outlet Channel Slope Stability

A slope stability assessment was conducted to establish the side slope requirements for the Reach 2 LSM Outlet Channel excavation and the dikes along the channel. Three conditions were examined to determine the side slope requirements:

Case 1 Long-term condition (after construction): minimum estimated factor of safety (FS) of 1.5 for outlet channel and dike slope stability at steady state conditions.

Case 2 Short term condition (during construction): minimum estimated factor of safety (FS) of 1.3 for outlet channel and dike slope stability under dry channel conditions.

Case 3 Short term condition: minimum estimated factor of safety (FS) of 1.2 for outlet channel and dike slope stability under rapid drawdown conditions (during operation with Open or Closed Gate conditions).

The slope stability assessment assumed a shear strength of parameter cohesion of c' = 2.5 kPa and an internal angle of friction of ϕ' = 30^{o}. These strengths are assumed to be a conservative estimate of shear strengths and can be further refined at the next stage of the design. Totally saturated groundwater conditions (worst case conditions) were assumed along with the inclusion of an upward hydraulic gradient, "i", of 0.2.

Two cross sections were analyzed as a part of the stability assessment, Section A (Sta. 2+500) where the design water level in the channel was at or below the contact between the peat and underlying till and Section B (Sta. 7+500) where the Design Water Level (DWL) was at or above the ground surface, (i.e. above the peat). At each section the total height of the slope (from channel invert to crest of dike) ranges from approximately 5.0 m to 6.0 m with Section B having slightly higher slopes necessary to contain the design water level while also maintaining the necessary freeboard above the saturated peat.

14.3.4 Results of Slope Stability Assessment

Based upon the results of the stability analysis at both sections analyzed, the proposed channel cross section with 4H:1V excavation and dike side slopes meets the design criteria under the steady state long-term, end-of-construction and rapid drawdown cases. The results of the stability assessment are provided in Table 12. Slope Stability Sections are included in Appendix H.

TABLE 12
ESTIMATED FACTOR OF SAFETY
REACH 2 – SECTIONS A AND B

STATION	ESTIMATED FACTOR OF SAFETY				
	Case 1	Case 2	Case 2 with Upward gradient, i = 0.2	Case 3	Case 3 with Upward gradient, i = 0.2
A (2+500)	2.63	1.66	1.44	1.72	1.64
B (7+500)	2.78	1.61	1.56	1.65	1.68

Notes:
1. Till Shear Strength - c' = 2.5 kPa and $\phi' = 30$

The following is recommended for Reach 2:

- The proposed channel geometry for Reach 2, as shown on Plates 12 through 14, is recommended to proceed to the next stage of design with 4H:1V channel and dike slopes.
- Additional detailed investigations completed to greater depths should be conducted at the next stage of design to confirm the various geotechnical, groundwater and hydraulic assumptions described in this report and to provide a better understanding of sub-surface conditions. These additional investigations will also help confirm the soil conditions assumed in the stability analysis and potential optimization of the channel cross section.

Within the footprint of the channel dikes, all peat should be excavated for placement of the dikes on the underlying mineral soil (till). This will provide a cutoff to seepage through the existing peat layer as well as providing a suitable long-term foundation for the dikes.

14.4 DESIGN OF DROP STRUCTURES

The drop structures were designed according to the preliminary hydraulic design and model of the Reach 2 Channel. During the hydraulic design process, it was determined that three drop structures were required, with drop heights of 1.23 m, 2.6 m, and 2.5 m, respectively. These structures allow the channel to generally follow the natural topography of the region and limit the amount of excavation required for the channel. The configuration of these drop structures is shown in Table 13.

TABLE 13
PRELIMINARY DESIGN DROP STRUCTURE CONFIGURATIONS FOR REACH 2

Drop Height (Y)	Width of Weir Crest (B)	Head on crest at design flow (H)	Head on crest at 10 cms (spring freshet)	Rock d_{50}	Slope of Drop Structure Chute	Length* of Structure	Weir Height required (P)
1.23 m	100 m	1.5 m	0.16 m	0.5 m	18H:1V	208 m	3.0 m
2.6 m	100 m	1.5 m	0.16 m	0.5 m	18H:1V	232 m	3.0 m
2.5 m	100 m	1.5 m	0.16 m	0.5 m	18H:1V	231 m	3.0 m

Note: * from beginning of upstream channel transition to end of downstream channel transition

The following values correspond to the definition sketch provided in the Basis of Design for drop structures in Figure 2 from Section 3.5:

- D1 – 4.50 m – this corresponds to normal depth in 44 m wide channel with 0.028 Manning's n roughness value.
- P – 3.0 m.
- H – 1.50 m.
- Y – 1.23, 2.6, and 2.5 m.
- S – 18.
- t – 1 m (2*d_{50}).
- D2 – 4.50 m – this corresponds to normal depth in 44 m wide channel with 0.028 Manning's n roughness value.
- B – 100 m.

For the design drop structures, the head over the structure at the typical spring freshet flow is about 16 cm (0.5 feet). The characteristics of the fish passage section that will be implemented into the weir and chute sections of the drop structure are identified in Table 14.

TABLE 14
FISH PASSAGE CHARACTERISTCS OF THE DROP STRUCTURES

Notch type	Head on Notch at 1 m^3/s	Width of Notch (at the crest of Drop Structure)
V-Notch, 2:1 side slope	0.61 m	2.67 m

The estimated volume of rock required for the 100 m wide drop structures placed in the 44 m wide channel is 14,500 m^3, 17,100 m^3 and 16,900 m^3 for 1.23 m, 2.6 m and 2.5 m for the heights of the drop structures, respectively. A plan and profile view of the drop structure, including the channel transitions and stilling basin, for a drop height of 2.5 m is shown on Plate 15.

As noted in Section 4.5, each of the drop structures requires an upstream sheetpile cutoff to increase the robustness of the structure, to accommodate ice loading, to provide some insurance against loss of control of the channel in the event that rockfill is lost / displaced, and to limit seepage through and under the structure. This sheetpile should be placed in line with the crest of the drop structure. The depth of sheetpile required to prevent seepage under the structure will need to be confirmed in later phases of the design by conducting more detailed soil testing in the area of the drop structures and by performing seepage analyses for various flow conditions. At this phase of design, a sheet pile depth equal to twice the weir height was assumed to be sufficient. Thus, a sheet pile length equal to three times the weir height will be required at each drop structure. This will result in approximately 900 m^2 of sheet pile being required at each structure (9 m deep by 100 m wide).

14.5 UPDATED CLASS C COST ESTIMATE

Based on the results of the Preliminary Design of the Reach 2 channel described in Sections 14.1 to 14.4, the capital cost for the Lake St. Martin Outlet Channel presented in Section 12.1 was updated as described below. A detailed discussion on the basis of the cost estimate for the project has been included in Sections 12.1.1 to 12.1.8.

- General excavation quantities for the Reach 2 earthworks contract were updated based on the updated alignment and the results of the Civil 3D model.
- Inlet excavation quantities for the Reach 2 earthworks contract were updated based on the results of the hydraulic analyses.
- Riprap and sheet piling quantities for the Reach 2 earthworks contract were updated based on the preliminary design of the drop structures
- Although not part of our scope, a quantity for sheet piling was added to the cost estimate of the drop structures for the Reach 3 earthworks contract based on the preliminary design requirements established for the Reach 2 drop structures for consistency in the cost estimate.
- Two drainage control structures were added to the Reach 2 earthworks contract cost estimate to address surface water drainage. The lump sum value of $1,000,000 per structure was included based on engineering judgement and experience.

- General excavation quantities and revegetation area for the Reach 3 earthworks contract were updated based on the revised Reach 2 alignment. The quantities from the Stage 2 Conceptual Design were reduced by 10% due to the shorter Reach 3 channel length.

In addition to the updated quantities as described above, the total cost estimate was updated to be representative of existing market conditions based on our experience on a number of recent construction projects as well as input from Contractors, and has been reported in 2017 dollars. Earthworks construction pricing is in large driven by both fuel costs and labour market availability. Since the previous estimates developed as part of the Stage 2 Conceptual Design (reported in 2014 dollars), fuel prices have been generally stable whereas the local labour market availability has increased significantly due to the downturn in Alberta's economy. In general, the Manitoba market has benefitted such that current 2017 pricing is typically similar, and at times lower compared to 2014 pricing. In contrast mark-up on material costs has remained steady at approximately 2.5% increase per year since 2014, with contractor employee wages also increasing to attract the available labour market migrating to Manitoba from Western Canada. On this basis, and based on the input from local Contractors and our experience with other large scale project throughout the Province, the unit pricing for the earthworks contract from the Stage 2 Conceptual Design were not increased for the Preliminary Design.

For the control structure and electrical power supply, although the available labour market and fuel prices also influence unit prices, increases in material costs and increased competition in this area have a much greater impact. On this basis, the estimated costs from the Stage 2 Conceptual Design for the control structure spillway, gates, guides and hoists, as well as for the construction and permanent electrical power supply were escalated assuming a 5% increase from 2014 dollars to 2017 dollars.

The unit pricing for the access road from the Stage 2 Conceptual Design were updated to 2017 dollars based on Input from MI. It is estimated that upgrading the forestry road to a single-lane, gravel road will cost approximately $180,000/km, and upgrading the current winter road access to a single-lane, gravel road will cost approximately $500,000/km.

Table 15 summarizes the revised estimate (Class C1) for the Lake St. Martin Outlet Channel with outlet East of Willow Point. Details of the estimate are provided in Appendix G.

TABLE 15
TOTAL COST SUMMARY – LAKE ST. MARTIN OUTLET CHANNEL WITH OUTLET EAST OF WILLOW POINT

Construction Component	Estimated Cost	
Earth Works		
Reach 1	$	4,802,000
Reach 2 (Option 4)	$	76,091,000
Reach 3 (with outlet east of Willow Point)	$	45,401,000
Control Structure		
Spillway	$	24,296,000
Gates, Guides and Hoists	$	16,119,000
Access		
Reach 1 Access Road	$	20,480,000
Gravel Topping (Reaches 2 and 3)	$	3,645,000
Electrical Power Supply		
Permanent Power	$	2,320,000
Construction Power	$	3,818,000
Sub-total	**$**	**196,970,000**
Mitigation Cost (5%)	$	9,848,500
Engineering, Contract Admin., Approvals (20%)	$	39,394,000
Sub-total	**$**	**246,210,000**
Contingency Cost (20%)	$	49,242,000
TOTAL (2017 Dollars)	**$**	**295,450,000**

As shown on Table 15 and discussed in Section 12.1, the project estimate includes a 20% contingency. It is recommended that at the next stage of design, project contingencies be updated based on a Risk-Cost approach, considering risk consequences, risk probability and residual risk, to ensure adequate cost allowances for risk are included in the project estimates. Cost risks were only considered for the purpose of comparison the options at this stage of design and are discussed in Section 12.3. Furthermore, the cost estimate developed at this stage does not incorporate interest during construction. Future estimates should be updated considering the anticipated construction schedule and that construction will occur over multiple years.

15.0 CONCLUSIONS

Specific basis of designs have been developed for four conceptual alternatives for Reach 2 of the Lake St. Martin Outlet Channel. The options were evaluated considering a set of criteria and one alignment (Option 4) was recommended to proceed to preliminary design. Conclusions of the basis of design and evaluation of the options which lead to the selection of Option 4 as the preferred alternative are identified below. Additional conclusions for Option 4 based on the results of the Preliminary design follows.

15.1 BASIS OF DESIGN

- To contain flows within the outlet channel, water retaining dikes have been incorporated into the design. Based on the conceptual design developed during the Stage 2 studies, a minimum 1.0 m (3.3ft) freeboard above the 326 m^3/s (11,500 cfs) water level has been assumed for the dikes.
- A range of maximum permissible velocities and shear stress values were identified based on the type of bed material anticipated along Reach 2. The design of the Reach 2 channel was based on maximum permissible values within the lower portion of the range and design velocities between 1.2 m/s to 1.4 m/s and shear stresses less than 10 N/m^2 were targeted.
- While erosion of the existing Buffalo Creek Channel occurred during the emergency conditions encountered in 2011/2012 and 2014/2015, continuation of this process is not considered acceptable for a permanent system of flood diversion. Including drop structures within Buffalo Creek to dissipate energy in concentrated, protected zones would be the most viable and economic option to avoid significant erosion for Options 1 and 2.
- The alignments of Options 3 and 4 are also located in a zone where the ground surface has a steep gradient. Drop structures will therefore also be required to safely dissipate energy so that the excavated channels can have suitably mild slopes to avoid high velocities and potential erosion.
- Sheet piling (or some other type of upstream cutoff membrane) are proposed to be included in the drop structure design in order to avoid passing most, if not all, of the riparian flow through the rockfill rather than over the crest of the structure. A sheet pile cutoff would also provide some additional benefits.
- Fish passage is not a requirement of the design criteria of LSMOC Control Structure. The design criteria considers that fish must be able to escape from the LSMOC to the maximum extent practical after flood operations are curtailed (i.e. once the control structure gates are closed.

- The criteria for minimum estimated FS were based on current Manitoba Provincial Guidelines for dike stability (MIT, 2012) and are consistent with the Canadian Dam Association (CDA) Dam Safety Guidelines (CDA, 2007).

15.2 EVALUATION OF OPTIONS

The categories for evaluation of the options were developed in collaboration with MI and included:

- Constructability
- Operability and performance
- Environmental and Socio-economic considerations
- Maintainability and Inspection
- Resiliency
- Cost

Key conclusions in each of the categories are provided below.

Constructability

- Although there are some differences between options in how access will be provided to site during construction, as described above, each of the options was judged to have essentially equal access.
- Based on contractor input, the preferred method of constructing Reach 2 for Options 3 and 4 would consist of excavating the channel in 200 m to 300 m long segments, in order to isolate the excavation area from the groundwater and to allow dike construction under drier conditions.
- Draining the peatland area and Big Buffalo Lake to improve constructability of the Reach 1 extension (Option 1), beyond what was done in 2011, would require excavating the Buffalo Creek channel. This was not considered a feasible solution considering lack of access, difficult constructability conditions in the peatland adjacent to the creek, and environmental concerns.
- Construction of the LSMOC is tentatively expected to occur over a period of approximately 3 years and may be tendered in one or multiple contracts.
- While it is possible to design drop structures that will meet the requirements for the Option 1 section of the channel, they would be considerably larger, potentially more

difficult to construct, and costlier than drop structures placed in the engineered and excavated channels that make up Options 3 and 4.

Operability and Performance

- The potential for floating peat or marsh islands to form in the inundated areas along the route of the LSMOC (Options 1 and 2) was identified early in the planning stages. Flooded peat mats floating up to the water surface (i.e., peat resurfacing) has been known to be a problem on similar reservoirs in Manitoba such as Cedar Lake (Grand Rapids Generating Station) on the Saskatchewan River, the reservoir formed by Manitoba Hydro's Kettle Dam on the Nelson River
- Considering that the overall cost of Option 2 would be more than Option 1 due to the added excavation works within the peatland area, that there would be potential additional environmental impact, and that there would still be a risk of floating islands forming, it was concluded early in this study that Option 2 would not emerge as a preferred alternative.
- While the overall risk for floating peat or marsh islands affecting the hydraulic performance of Option 1 appears to be low, there is a real possibility that a mat large enough to block the Buffalo Creek inlet could be produced. Mitigation measures that have been implemented in other regions could be implemented but nevertheless this option includes this operational risk that does not exist for other options.
- Rises in water level due to the ice coverage is not expected to exceed the open water design condition for all of the options evaluated.

Environmental and Socio-Economic Considerations

- The potential impacts to water quality would include areas of Lake Winnipeg at the outlet of Reach 3 for all options, but would also include Buffalo creek, Dauphin River, and Sturgeon Bay for Option 1.
- Each of the Reach 2 channel options, based on data available to date, is expected to not have significant concerns and is interpreted to perform very similarly, from the groundwater perspective. There are no local well users who may be affected by Reach 2 construction.
- Overland flow within the wetland complex for Option 1, as well construction of drop structures in Buffalo Creek, has the additional potential to impact the terrestrial environment of an area exceeding 4,000 ha.
- Excavation and construction of drop structures in Buffalo Creek would result in destruction or alternation of fish habitat for Option 1. Similar structures in Buffalo Creek are not required for Options 3 and 4.
- For Option 4, opportunities to re-purpose Reach 1 to enhance aquatic and/or terrestrial habitat in the region, to provide a base flow from Lake St. Martin to the Big Buffalo Lake

peatland area, and/or for other mitigation strategies would be considered at the next stage of design.

Maintainability and Inspection

- Neither Options 3 nor 4 cause any significant submergence of existing peatland. Neither Option would have any significant chance of causing floating islands, and therefore have significant advantage over Option 1 in this respect.
- From the perspective of erosion and sediment deposition, all options would be designed to be stable with minimal risk of erosion. Given that the incoming sediment load from Lake St. Martin would be negligible, it is expected then that deposition within the channel would be limited in extent.
- Overall, it is considered that Option 4 would be superior in the category of maintenance of vegetation.
- A concern voiced by MI was that potential damage that could be done by ice that could be mobilized by the flow, either in spring or during winter operations. To some extent, the risk of this type of potential damage cannot be entirely eliminated. However, a number of design features proposed are expected to significantly reduce the potential for serious damage to the diversion facilities on LSM.

Resiliency

- For Option 4, the Reach 2 alignment is separated from Reach 1, and therefore Reach 1 benefits from having the ability to be operated in an emergency during construction with minimal impact to construction schedule.

Cost

- The total cost estimates of the LSMOC with outlet east of Willow Point for the different Reach 2 alignment options are summarized as follows:
    - Option 1 – $302.7 million
    - Option 3 – $301.6 million
    - Option 4 – $290.3 million
- It was judged, that Option 1 would require the most maintenance effort, and the potential average annual maintenance cost was estimated at $6 million based on 2% of the capital costs of the option. The potential average annual maintenance cost for Option 3 was estimated at $4.8 million based on 1.6% of the capital cost, and estimated at $4.4 million for Option 4 based on 1.5% of the Capital Costs.

15.3 PREFERRED OPTION PRELIMINARY DESIGN

- Based on the results of the Technical Workshop, Option 4 had the highest score and was therefore identified as the preferred alternative. It received a score of 69.7 out of 100. Option 3 scored 63.6 out of 100 and placed second while Option 1 scored 46.8 out of 100 and placed third.
- The Preliminary Design of Option 4 involved the refinement of the channel alignment, preliminary hydraulic design, preliminary geotechnical design and preliminary design of drop structures. The preliminary design of Option 4 meets all of the identified design criteria and has an estimated cost of $295.5 million. The cost estimate is considered a Class C1 and reported in 2017 dollars.

16.0 RECOMMENDATIONS

The key recommendation developed from this study is that Option 4 should be carried forward into final design, along with the other components of the LSMOC. There are also a series of recommendations that should be considered in the next steps of engineering:

1. The diversion channel should adopt a deep, narrow cross section wherever practical.
2. Use of rockfill drop structures should be included in the design to allow safe dissipation of energy and protect the channel from erosion.
3. Sheet piling should be used in the crest of the structure.
4. The justification for inclusion of facilities that permit movement of fish through the system in winter should be established. If such movement is a clear design objective, the means to provide that capability should be reviewed and finalized.
5. The potential for sediment deposition and infilling at the inlet to Option 4 at LSM during non-operative periods should be examined using field observations and surveys. If there is a chance that a serious loss of long-term discharge capacity is possible, means to address that should be finalized. Options include either construction (now along with the construction of the rest of Option 4 elements, or at some future juncture) of isolating groins in the lake, or planning to excavate any impeding deposits using a dredge on similar excavation equipment.
6. Final design should be based on more intensive sub-surface investigations than have been practical to date along the proposed channel route, as well as in the inlet extending into LSM. Additional bathymetric surveys should also be considered at the inlet.
7. Provision of access to the entire length of the channel should be considered to facilitate future inspection and maintenance. Gravel-topped roads should be considered on both sides of the channel.
8. Optimization of the design of the channel should be carried out and focus on the following to develop the lowest overall cost for the LSMOC:
   - Location and size of control structure, including number and size of control gates.
   - Locations of drop structures.
   - Location and depth of channel.
   - Balance of earthworks.
   - Extent that the design water surface profile can be allowed to exceed surrounding ground levels (in combination with retaining dikes).
   - Optimization of the excavation in Lake St. Martin at the channel inlet to reflect updated bathymetric information.
   - Peak flows above the 326 m^3/s (11,500 cfs) capacity.
9. Details of the tie-in of the downstream end of Reach 2 with the upstream end of Reach 3 should be developed and finalized.

10. Revegetation of the channel excavated in Reach 1 should be undertaken. Infilling of the channel should be avoided so that the route can be mobilized again in the future if climate change intensifies and exacerbates flood potential.

11. Facilities to permit a modest amount of riparian inflow into Reach 1 should be considered to mitigate the potential reduction of surface runoff into the Big Buffalo Lake wetland complex due to construction of the LSMOC.

12. The proposed channel geometry for Reach 2, as shown on Plates 12 through 14, is recommended to proceed to the next stage of design with 4H:1V channel and dike slopes.

13. Additional detailed investigations completed to greater depths should be conducted at the next stage of design to confirm the various geotechnical, groundwater and hydraulic assumptions described in this report and to provide a better understanding of sub-surface conditions. These additional investigations will also help confirm the soil conditions assumed in the stability analysis and potential optimization of the channel cross section.

14. Within the footprint of the channel dikes, all peat should be excavated for placement of the dikes on the underlying mineral soil (till). This will provide a cutoff to seepage through the existing peat layer as well as providing a suitable long-term foundation for the dikes.

17.0 STATEMENT OF LIMITATIONS AND CONDITIONS

17.1 THIRD PARTY USE OF REPORT

This report has been prepared for Manitoba Infrastructure to whom this report has been addressed and any use a third party makes of this report, or any reliance on or decisions made based on it, are the responsibility of such third parties. KGS Group accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions undertaken based on this report.

17.2 GEOTECHNICAL INVESTIGATION STATEMENT OF LIMITATIONS

The geotechnical investigation findings and recommendations of this report were prepared in accordance with generally accepted professional engineering principles and practice. The findings and recommendations are based on the results of field and laboratory investigations, combined with an interpolation of soil and groundwater conditions found at and within the depth of the test holes drilled by KGS Group at this site. If conditions encountered during construction appear to be different from those shown by the test holes drilled by KGS Group or if the assumptions stated herein are not in keeping with the design, this office should be notified in order that the recommendations can be reviewed and modified if necessary.

17.3 CAPITAL COST ESTIMATE STATEMENT OF LIMITATIONS

The cost estimates included with this report have been prepared by KGS Group using its professional judgment and exercising due care consistent with the level of detail required for the stage of the project for which the estimate has been developed. These estimates represent KGS Group's opinion of the probable costs and are based on factors over which KGS Group has no control. These factors include, without limitation, site conditions, availability of qualified labour and materials, present workload of the Bidders at the time of tendering and overall market conditions. KGS Group does not assume any responsibility to Manitoba Infrastructure, in contract, tort or otherwise in connection with such estimates and shall not be liable to Manitoba Infrastructure if such estimates prove to be inaccurate or incorrect.

18.0 REFERENCES

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TABLES

TABLE 8
EVALUATION CRITERIA DEFINITIONS

Main Category	Definition	Sub-Criteria	Definition
1. Constructability	• Ability to achieve project schedule and complete project on time. • Ability to complete project on budget. • Ability to execute the project and complete construction as planned and as per design specifications. • Construction risks associated with potential cost overruns. • Construction risks that may result to changes in project concept and/or design. • Overall ease of construction.	**1.1 Access to Site**	• Ease of access for construction. • Ability to execute multiple contracts if required. • Reliance on construction staging and/or seasonal factors.
		1.2 Surface and Groundwater Management	• Ease of drainage for construction. • Cofferdam requirements. • Reliance on construction staging and/or seasonal factors. • Risk of blowouts and basal heave conditions. • Risk of increased costs due to unforeseen conditions.
		1.3 Material Composition	• Ease of excavation. • Source and quality of material for dike construction. • Source and quality of material for drop structures and erosion protection. • Risk of increased costs due to unforeseen conditions.
		1.4 Bathymetric Conditions	• Extents of underwater excavation required for construction. • Depth of excavation under water. • Risk of increased costs due to unforeseen conditions.
		1.5 Scheduling	• Ability to manage risk of flooding during construction. • Risk of schedule delays due to weather or construction timing restrictions.
2. Operability & Performance	• Relative ease and level of effort to operate channel. • Overall ability of the project to achieve its intended purpose (i.e. probability of success). • Ability of the project to perform as intended over the short and long term without additional environmental impacts, or increased maintenance & inspection requirements. • Performance under extreme or less than optimal conditions (i.e. reliance on optimal conditions).	**2.1 Channel Dikes and Slopes**	• Long term stability of the channel dikes and slopes. • Available freeboard above the dikes.
		2.2 Erosion, Sediment Transport and Deposition	• Risk of erosion as a result of operation. • Risk of sediment transport and deposition as a result of operation.
		2.3 Flow Through Buffalo Lakes Wetland Complex	• Risk associated with flotation and movement of individual bog or marsh islands, or marsh/bog islands in large groups. • Risk of floating islands blocking channel(s). • Risk of conveyance loss as a result of floating bog or marsh that remains in place. • Ability to maintain the wetland complex as a designated Provincial Waterway or a Designated Reservoir Area.
		2.4 Drop Structures	• Ability of the drop structures to dissipate energy as intended for the range of flow conditions.
		2.5 Operation in Winter Conditions	• Ability to operate channel in winter conditions and manage formation of ice.
		2.6 Groundwater Management	• Ability to manage risk of seepage and groundwater blowouts.
3. Physical Environmental Impacts	• Short and long term impacts of the project to the physical environment during both the construction and operation phases. • Ease of obtaining approvals from regulators and environmental agencies to proceed with construction.	**3.1 Surface Water**	• Potential impacts on surface water quality (i.e. TSS, Mercury, etc.) • Potential impacts on surface water quantity (i.e. flow rates, flow volumes, water levels, and seasonality).
		3.2 Groundwater	• Potential risks associated with GUDI (Groundwater under the direct influence of surface water). • Potential impacts to water levels in adjacent aquifers. • Potential impacts to groundwater quality.
		3.3 Terrestrial Environment	• Potential impacts on existing vegetation and land cover. • Potential impacts on existing wildlife and habitat.
		3.4 Aquatic Habitat & Resources	• Potential impacts to aquatic species and habitat. • Potential impacts to spawning and migration of fish species.

TABLE 8 (CONTINUED)
EVALUATION CRITERIA DEFINITIONS

Main Category	Definition	Sub-Criteria	Definition
4. Social Economic Considerations	• Short and long term impacts of the project to affected stakeholders and surrounding communities, including First Nations and Metis. • Impacts of project considering socio-economic factors. • Ease of obtaining approvals from regulators and environmental agencies to proceed with construction.	**4.1 Access**	• Potential impacts to access in the area.
		4.2 Indigenous Rights Based Activities	• Potential impacts to traditional land use activities such as fishing, hunting and trapping.
		4.3 Commercial Fisheries	• Potential impacts on the commercial fisheries.
5. Maintainability and Inspection	• Ability to maintain infrastructure in working conditions. • Ability to inspect infrastructure to confirm condition and performance. • Overall ease of conducting maintenance and inspection activities. • Ease of rehabilitation in the future.	**5.1 Access to Site**	• Ease of access for maintenance and inspection. • Reliance on seasonal factors, and/or operating conditions.
		5.2 Vegetation Growth	• Ability to grow and maintain vegetation cover on the channel and dike slopes to manage risk of erosion. • Risk of thick aquatic vegetation growth within the channel that impacts discharge capacity of the channel.
		5.3 Sedimentation	• Risk of sedimentation occurring within or downstream of the channel.
		5.4 Operation in Winter Conditions	• Risk that the movement of ice in the channel during channel operation, or during the spring freshet when the channel is closed, results in damages to the channel and structures.
6. Resiliency	• Ability to adapt project in the future to changing conditions such as climate change & increased runoff.	**6.1 Adaptability for Additional Capacity**	• Ability to adapt channel design in the future for increased capacity. • Ability to increase channel capacity in the event of an emergency.
7. Cost	• Overall project costs including capital costs and long term maintenance and inspection.	**7.1 Capital Costs**	• Total project costs, including: mitigation costs; engineering fees; contract administration; approvals; contingencies.
		7.2 General Maintenance Costs	• Long term maintenance cost over entire life expectancy of project.
8. Cost Risk	• Potential for changes in cost due to added project requirements or unforeseen conditions	**8.1 Social Risk**	• Potential for socio-economic factors to affect project cost.
		8.2 Optimization	• Potential for reduction in cost by optimization of final design.
		8.3 Environmental	• Potential for increased cost due to added environmental mitigation requirements.
		8.4 Construction	• Potential for increased cost as a result of unfavorable construction conditions.
		8.5 Rock Supply	• Ability to obtain necessary rock quantity / quality for drop structure and riprap requirements.
		8.6 Amortization	• Cost differences as a result of decommissioning Reach 1.

TABLE 9
SUMMARY COMPARISON OF OPTIONS

Main Category	Sub-Criteria	Option 1	Option 3	Option 4	Summary Comparison
1. Constructability	1.1 Access to Site	• **Reach 1 widening:** permanent access road completed prior to construction. • **Reach 1 extension:** access from Reach 1. • **Reach 2 containment dike:** access from Reach 3 must cross Buffalo Creek. • **Buffalo Creek enhancements:** access from Reach 2 containment dike &/or Reach 3. • **Reach 3:** permanent access road completed prior to construction.	• **Reach 1 widening:** permanent access road completed prior to construction. • **Reach 2:** access from Reach 1. • **Reach 3:** temporary winter access only until Reach 2 construction completed.	• **Reach 1 decommissioning:** permanent access road completed prior to construction. • **Reach 2:** permanent access road completed prior to construction. • **Reach 3:** temporary winter access only until Reach 2 construction completed.	• Option 1 has two separate permanent access points (Reach 1 and Reach 3). • Options 3 & 4 have a single permanent access point (Reach 1) and a potential secondary winter access to Reach 3.
	1.2 Surface and Groundwater Management	• **Reach 1 widening:** standing water in channel; cofferdam & pumping required or provision of drainage downstream into Big Buffalo Lake. • **Reach 1 extension:** water level in peat at or near surface; cofferdam & pumping required. o Level of effort dependent on downstream conditions in Big Buffalo Lake. • **Reach 2 containment dike:** constructed on high ground and requires minimal surface and groundwater management. • **Buffalo Creek enhancements:** cofferdam and pumping required for construction of Drop Structures and channel excavation.	• **Reach 1 widening:** standing water in channel; cofferdam & pumping required or provision of drainage downstream by constructing Reach 2 first. • **Reach 2:** water level in peat at or near surface; cofferdam & pumping required. o Channel dikes included as part of Reach 2 design. Construction of dikes reduces cofferdam requirements. o Level of effort reduced with provision of drainage downstream. o Opportunity to start construction at Reach 3. Starting construction at downstream end improves drainage.	• **Reach 1 decommissioning:** minimal dewatering required for construction. • **Reach 2:** water level in peat at or near surface; cofferdam & pumping required. o Channel dikes included as part of Reach 2 design. Construction of dikes reduces cofferdam requirements. o Level of effort reduced with provision of drainage downstream. o Opportunity to start construction at Reach 3. Starting construction at downstream end improves drainage.	• All options require some level of construction drainage & dewatering, including cofferdam construction with pumping. Dewatering efforts incorporated into cost estimates. • Higher construction risks for Option 1 based on contractor input due to difficulties with dewatering Reach 1 extension and proximity of Big Buffalo Lake. • Risk of blowouts and basal heave conditions similar for all options and can be managed by pumping, downstream drainage, or with passive depressurization system.
	1.3 Material Composition	• **Reach 1 widening:** existing Reach 1 spoil pile material is dense, unsorted and contains widespread debris. o Most unsorted material may be located on right side (south-east side). o Undisturbed area includes combination of peat and till excavation. • **Reach 1 extension:** constructed in peat only and excavated to the surface of till. o Material more difficult to handle. o Hauling of till material from Reach 1 required for construction of cofferdams. • **Reach 2 containment dike:** constructed in undisturbed area; requires vegetation removal and peat excavation. o Till material for dike construction to be obtained from nearby borrow pits. • **Buffalo Creek enhancements:** Hauling of riprap required for construction of drop structures and erosion protection measures.	• **Reach 1 widening:** existing Reach 1 spoil pile material denser, unsorted and full of debris. o Most unsorted material may be located on right side (south-east side). o Undisturbed area includes combination of peat and till excavation. • **Reach 2:** constructed in undisturbed area and includes combination of peat and till excavation. o Till material from channel excavation used for dike and cofferdam construction. o Hauling of Riprap required for construction of drop structures.	• **Reach 1 decommissioning:** re-shaping of till surface required prior to re-vegetation. • **Reach 2:** constructed in undisturbed area and includes combination of peat and till excavation. o Till material from channel excavation used for dike and cofferdam construction. o Hauling of Riprap required for construction of drop structures.	• Material type in undisturbed areas similar for all options. Material for Reach 1 extension more difficult to handle. • Reach 1 widening for Options 1&3 requires increased excavation effort due to composition of existing spoil pile material. • Hauling of riprap required for all options.

TABLE 9 (CONTINUED)
SUMMARY COMPARISON OF OPTIONS

Main Category	Sub-Criteria	Option 1	Option 3	Option 4	Summary Comparison
1. Constructability (continued)	**1.4 Bathymetric Conditions**	• **Lake St. Martin Inlet**: Excavation required to minimize headloss upstream of control structure. o Limited potential to reduce inlet excavation requirements, if necessary, by optimization of the channel design due to the limited conveyance capacity through the wetland complex surrounding Big Buffalo Lake. • **Big Buffalo Lake**: Bathymetric conditions in Buffalo Creek control water levels in Big Buffalo Lake; impacts dewatering for construction of Reach 1 extension.	• **Lake St. Martin Inlet**: Excavation required to minimize headloss upstream of control structure. o Potential to reduce inlet excavation requirements, if necessary, by optimization of the channel design.	• **Lake St. Martin Inlet**: Excavation required to minimize headloss upstream of control structure. o Potential to reduce inlet excavation requirements, if necessary, by optimization of the channel design.	• Excavation required to minimize headloss upstream of control structure for all options. • Potential to reduce inlet excavation requirements for Options 3&4 but not Option 1. • Conditions in Buffalo Creek and Big Buffalo Lake results in potential additional construction challenges on Option 1.
	1.5 Scheduling	• Emergency operation of Reach 1 during construction in the event of high water levels on LSM may result in significant construction delays on Reach 1, Buffalo Creek and the Reach 2 containment Dike.	• Emergency operation of Reach 1 during construction in the event of high water levels on LSM may result in significant construction delays on Reach 1 only. • Most vulnerable to unfavorable weather conditions due to longest construction footprint (i.e. longest channel length).	• Reach 1 has the ability to be operated in an emergency during construction with minimal impact to construction schedule in the event of high water levels on LSM.	• Option 4 has ability to operate Reach 1 during construction in an emergency if required, with minimal impact to construction schedule, whereas not Options 1&3.
2. Operability & Performance	**2.1 Channel Dikes and Slopes**	• **Reach 1 widening:** No dikes required. • **Reach 1 extension:** Access road constructed on left bank with minimum 1m freeboard above 11,500 cfs profile. • **Reach 2 containment dike:** Minimum 1m freeboard above 11,500 cfs profile. • **Buffalo Creek enhancements:** erosion protection measures included to protect existing creek banks and slopes in vulnerable areas.	• **Reach 1 widening:** No dikes required. • **Reach 2:** Dikes required along a portion of the channel. Minimum 1m freeboard above 11,500 cfs profile.	• **Reach 1 decommissioning:** upgrades to closure dike at the channel inlet included in the design. • **Reach 2:** Dikes required along a portion of the channel. Minimum 1m freeboard above 11,500 cfs profile.	• All options designed with stable channel dikes and slopes as per design criteria and therefore are intended to perform equally (4:1 slopes and a Factor of Safety of 1.5 for normal conditions and 1.3 under rapid drawdown conditions).

TABLE 9 (CONTINUED)
SUMMARY COMPARISON OF OPTIONS

Main Category	Sub-Criteria	Option 1	Option 3	Option 4	Summary Comparison
2. Operability & Performance (continued)	**2.2 Erosion, Sediment Transport and Deposition**	• **Reach 1 widening and extension:** Channel designed to be non-erodible during operation (velocity ~1.0 m/s and shear stress ~ 6 Pa at 11,500 cfs). o Potential for exposed side slopes as a result of poor vegetation growth (see item 5.2) increases risk for erosion due to runoff; effects approximately 12 ha surface area of Reach 1. • **Buffalo Creek enhancements:** Combination of drop structures and channel excavation required to mitigate high velocities and risk of erosion due to the steep slope of the creek. • Potential volume of sediment available for transport based on a wetted surface area of approximately 100 ha upstream of Big Buffalo Lake and approximately 25 ha upstream of Reach 3.	• **Reach 1 widening and Reach 2:** Channel designed to be non-erodible during operation (velocity ~1.0 m/s and shear stress ~ 6 Pa at 11,500 cfs). • 4 drop structures incorporated into design to dissipate energy and to maintain non-erodible design condition. • Potential volume of sediment available for transport based on a wetted surface area of approximately 210 ha upstream of Reach 3. • Potential for exposed side slopes as a result of poor vegetation growth (see item 5.2) increases risk for erosion due to runoff; effects approximately 31 ha surface area of Reach 1 & Reach2.	• **Reach 2:** Channel designed to be non-erodible during operation (velocity ~1.0 m/s and shear stress ~ 6 Pa at 11,500 cfs). • 5 drop structures incorporated into design to dissipate energy and to maintain non-erodible design condition. • Potential volume of sediment available for transport based on a wetted surface area of approximately 160 ha upstream of Reach 3. • Potential for exposed side slopes as a result of poor vegetation growth (see item 5.2) increases risk for erosion due to runoff; effects approximately 14 ha surface area of Reach 2.	• All options designed to be non-erodible as per design criteria and are therefore intended to perform equally. • Option 3 has largest potential volume of available sediment for transport as a result of operation based on the wetted surface area of the channel, followed by Option 4, then Option 1. • Option 3 has largest potential volume of available sediment for transport as a result of exposed side slopes based on the potential surface area of poor vegetation growth. Options 1 & 4 have similar area of exposed side slopes.
	2.3 Flow Through Buffalo Lakes Wetland Complex	• Potential for loss of conveyance concentrated in bog and marsh areas. • Potential risk for floating bog/marsh islands depend on a combination of factors including depth of flooding, duration, timing… • Additional concerns with maintaining Big Buffalo Lake and surrounding wetland complex as a Provincial Waterway or a Designated Reservoir Area.	• No concerns due to flow avoiding Buffalo Lakes wetland complex.	• No concerns due to flow avoiding Buffalo Lakes wetland complex.	• Option 1 has potential risks and concerns associated with flow through the bog and marsh areas. • Options 3 and 4 do not have similar disadvantages.
	2.4 Drop Structures	• Drop structures design to accommodate peak flows and provide upstream and downstream fish passage in Buffalo Creek when channel not in operation.	• Drop structures design to accommodate peak flows and provide downstream fish passage when channel not in operation.	• Drop structures design to accommodate peak flows and provide downstream fish passage when channel not in operation.	• All options intended to perform equally as per design criteria. • More complex structure required for Option 1 to provide upstream fish passage in Buffalo Creek . Upstream fish passage not required for Options 3 & 4.

TABLE 9 (CONTINUED)
SUMMARY COMPARISON OF OPTIONS

Main Category	Sub-Criteria	Option 1	Option 3	Option 4	Summary Comparison
2. Operability & Performance (continued)	**2.5 Operation in Winter Conditions**	• Frazil ice formation is expected at some distance downstream of the Lake St. Martin Inlet during operation. • Potential volume of frazil ice produced based on a surface area of approximately 100 ha upstream of Big Buffalo Lake and approximately 105 ha upstream of outlet into Lake Winnipeg. • Design criteria include objectives that would maximize the potential for safe and effective management of the ice. • Operating guidelines include provision to avoid initial operation during period when a competent ice cover is present in the channel.	• Frazil ice formation is expected at some distance from the Lake St. Martin Inlet during operation. • Potential volume of frazil ice produced based on a surface area of approximately 295 ha upstream of outlet into Lake Winnipeg. • Design criteria include objectives that would maximize the potential for safe and effective management of the ice. • Operating guidelines include provision to avoid initial operation during period when a competent ice cover is present in the channel.	• Frazil ice formation is expected at some distance from the Lake St. Martin Inlet during operation. • Potential volume of frazil ice produced based on a surface area of approximately 245 ha upstream of outlet into Lake Winnipeg. • Design criteria include objectives that would maximize the potential for safe and effective management of the ice. • Operating guidelines include provision to avoid initial operation during period when a competent ice cover is present in the channel.	• All options would be designed to minimize risks associated with winter conditions as per design criteria and therefore are intended to, and are expected to, perform equally well. • Differences in potential volume of frazil ice production between options are not expected to result in a significant variance in performance between options.
	2.6 Groundwater Management	• Seepage and groundwater inflow expected and are not anticipated to result in significant impacts.	• Seepage and groundwater inflow expected and are not anticipated to result in significant impacts. o Standing water upstream of the drop structures reduce seepage and groundwater inflow.	• Seepage and groundwater inflow expected and are not anticipated to result in significant impacts. o Standing water upstream of the drop structures reduce seepage and groundwater inflow.	• All options would be designed to minimize risks of seepage and blowouts and are therefore intended to perform equally. • Impacts not expected to be significant.

TABLE 9 (CONTINUED)
SUMMARY COMPARISON OF OPTIONS

Main Category	Sub-Criteria	Option 1	Option 3	Option 4	Summary Comparison
3. Physical Environmental Impacts	**3.1 Surface Water**	• Altered rate and seasonality of flow on the Dauphin River. • Operation of the outlet channel and conveyance through Reaches 1 and 2 will result in altered rate and seasonality of flow to Big Buffalo Lake and Buffalo Creek. o Operation expected to occur on average once every 3 years. o Residual impacts on flow rates may continue over multiple seasons upon closure of the channel due to saturation of the wetland complex and increased groundwater levels. • Flooding of the wetland complex and of upper Buffalo Creek as a result of operation may lead to leaching and decomposition of organic material, reducing dissolved oxygen and pH, and increasing concentrations of select metals including methylation of mercury. • Dewatering, dredging and excavation in proximity to waterbodies or watercourses could result in localized mobilization of sediment, affecting water quality. Proximity of construction to Big Buffalo Lake and Buffalo Creek increases potential for mobilization downstream. • Potential for erosion as a result of operation may affect water quality within the channel, in Big Buffalo Lake, Buffalo Creek, Dauphin River, Sturgeon Bay, and in Lake Winnipeg at the outlet of Reach 3. • Potential erosion at Buffalo Lake outlet as a result of operation could lower water levels permanently.	• Altered rate and seasonality of flow on the Dauphin River. • Altered rate and seasonality of flow to Big Buffalo Lake and Buffalo Creek as a result of Reach 2 construction. o 65% of the Buffalo Lakes wetland complex watershed cutoff by Reach 2. o Impacts of flow alteration can be reduced or mitigated with construction of siphon(s) under Reach 2. • Channel dikes minimize flooding into adjacent land. • Dewatering, dredging and excavation in proximity to waterbodies or watercourses could result in localized mobilization of sediment, affecting water quality • Potential for erosion as a result of operation may affect water quality within the channel and in Lake Winnipeg at the outlet of Reach 3.	• Altered rate and seasonality of flow on the Dauphin River. • Altered rate and seasonality of flow to Big Buffalo Lake and Buffalo Creek as a result of Reach 2 construction. o 60% of the Buffalo Lakes wetland complex watershed cutoff watershed cutoff by Reach 2. o Impacts of flow alteration can be reduced or mitigated with construction of siphon(s) under Reach 2 or provision of base flow from Lake St. Martin via Reach 1. • Channel dikes minimize flooding into adjacent land. • Dewatering, dredging and excavation in proximity to waterbodies or watercourses could result in localized mobilization of sediment, affecting water quality. • Potential for erosion as a result of operation may affect water quality within the channel and in Lake Winnipeg at the outlet of Reach 3.	• Altered rate and seasonality of flow on the Dauphin River for all options. • Altered rate and seasonality of flow to Big Buffalo Lake and Buffalo Creek for all Options. Potential impacts more severe with Option 1 due to the magnitude of alteration. Potential mitigation strategies identified for Options 3&4. • Flooding of wetland complex and upper Buffalo Creek as a result of operation once every 3 years for Option 1, whereas Options 3&4 have dikes that minimize flooding into land adjacent to channel. • Additional number of locations with potential impacts to water quality as a result of operation for Option 1 compared to Options 3 & 4. • Increased potential of mobilization of sediment during construction for Option 1 compared to Options 3 & 4.

TABLE 9 (CONTINUED)
SUMMARY COMPARISON OF OPTIONS

Main Category	Sub-Criteria	Option 1	Option 3	Option 4	Summary Comparison
3. Physical Environmental Impacts (continued)	3.2 Groundwater	• Groundwater discharge into surface water could result in changes to surface water quality. • Blowout of basal soils may occur if groundwater pressure exceeds pressure of overburden mass. o GUDI not expected to be of concern as there are no drinking water wells in the region. • Seepage of groundwater in outlet channel could lower water levels in aquifer, whereas inundation of Buffalo Creek and the wetland complex surrounding Big Buffalo Lake could increase water levels in aquifer. o Changes in aquifer water levels could impact surrounding vegetation.	• Groundwater discharge into surface water could result in changes to surface water quality. • Blowout of basal soils may occur if groundwater pressure exceeds pressure of overburden mass. o GUDI not expected to be of concern as there are no drinking water wells in the region. • Seepage of groundwater in outlet channel could lower water levels in aquifer. o Changes in aquifer water levels could impact surrounding vegetation.	• Groundwater discharge into surface water could result in changes to surface water quality. • Blowout of basal soils may occur if groundwater pressure exceeds pressure of overburden mass. o GUDI not expected to be of concern as there are no drinking water wells in the region. • Seepage of groundwater in outlet channel could lower water levels in aquifer. o Changes in aquifer water levels could impact surrounding vegetation.	• Blowout of basal soils may occur if groundwater pressure exceeds pressure of overburden mass. • Potential groundwater impacts (confined layer) similar for all options. • Construction of channel through peatland area for Options 3 & 4 may result in additional groundwater impacts (shallow / unconfined layer).
	3.3 Terrestrial Environment	• Flow over the Big Buffalo Lake wetland complex has the potential to result in changes to the existing vegetation and land cover. Inundated area approximately 4,000ha at the 11,500 cfs design flow event. o Emergency operation of the Reach 1 channel has already altered the wetland complex. • Construction of drop structures in Buffalo Creek will result in long-term inundation of the existing vegetation, directly impacting an area of approximately 25 ha. o Flow in Buffalo Creek has the potential to result in changes to the existing vegetation and land cover. o Emergency operation of the Reach 1 channel has already altered Buffalo Creek. • Channel and dike construction will require "new" vegetation clearing along Reach 1 and Reach 2, covering and area approximately 175 ha.	• Channel and dike construction will require "new" vegetation clearing along Reach 1 and Reach 2, covering an area approximately 410ha. • Potential direct impacts to vegetation cover in wetland complex as a result of changes in shallow / unconfined groundwater conditions.	• Channel and dike construction will require "new" vegetation clearing along Reach 1 and Reach 2, covering an area approximately 380ha. • Potential direct impacts to vegetation cover in wetland complex as a result of changes in shallow / unconfined groundwater conditions.	• Option 1 has the largest potential area of direct impacts to terrestrial environment due to inundation of wetland complex. • Option 3 directly impacts slightly larger area then Option 4 due to longer channel length. • Area of indirect impacts uncertain for all options.

TABLE 9 (CONTINUED)
SUMMARY COMPARISON OF OPTIONS

Main Category	Sub-Criteria	Option 1	Option 3	Option 4	Summary Comparison
3. Physical Environmental Impacts (continued)	**3.4 Aquatic Habitat & Resources**	• Accommodation of channel design for fish passage during operation not required as per design criteria. • Fish passage to be incorporated into drop structure design in Buffalo Creek for period when channel not in operation. • Risk of fish stranding in wetland complex surrounding Big Buffalo Lake as a result of operation, may result in additional maintenance cost to conduct fish salvage program. • Excavation and construction of drop structures in Buffalo Creek will result in destruction or alteration of Fish Habitat. • Loss of fish habitat in Buffalo Creek and Big Buffalo Lake when channel in operation. • Changes in flow patterns in Buffalo Creek downstream of Reach 3 Diversion structure as a result of operation has the potential to result in additional aquatic impacts.	• Accommodation of channel design for fish passage during operation not required as per design criteria. • Provision of riparian flow and inclusion of notch at top of drop structures will provide downstream passage for fish at all times when channel not in operation to minimize risk of fish stranding. • Provision of riparian flow and deep pool upstream of drop structures reduces potential risk of fish kill for fish that overwinter in the channel.	• Accommodation of channel design for fish passage during operation not required as per design criteria. • Provision of riparian flow and inclusion of notch at top of drop structures will provide downstream passage for fish at all times when channel not in operation to minimize risk of fish stranding. • Provision of riparian flow and deep pool upstream of drop structures reduces potential risk of fish kill for fish that overwinter in the channel.	• Risk of fish stranding for Option 1 whereas this is addressed as part of design criteria for Options 3 & 4. • Destruction or alteration of Fish Habitat in Buffalo Creek for Option 1. Options 3 & 4 avoid Buffalo Creek altogether. • Impediment to fish migration in Buffalo Creek and Big Buffalo Lake for Option 1 during operation whereas not for Options 3 & 4. • Option 1 has potential for additional aquatic impacts on Buffalo Creek and Dauphin River downstream of Reach 3 diversion structure.
4. Social Economic Considerations	**4.1 Access**	• Increased access to the area may be a benefit and a concern to current users (i.e existing hunters, fisherman, First Nation, etc…). • Decreased access within the site due to the channel may be a concern • Gated system will be included on access road to limit unauthorized access.	• Increased access to the area may be a benefit and a concern to current users (i.e existing hunters, fisherman, First Nation, etc…) • Decreased access within the site due to the channel may be a concern • Gated system will be included on access road to limit unauthorized access.	• Increased access to the area may be a benefit and a concern to current users (i.e existing hunters, fisherman, First Nation, etc…) • Decreased access within the site due to the channel may be a concern • Gated system will be included on access road to limit unauthorized access.	• Benefits and concerns with access to the site similar for all options.
	4.2 Indigenous Rights Based Activities	• Construction and operation may result in potential impacts to traditional land use and activities in the area, such as fishing, trapping and hunting. • Inundation of the Big Buffalo Lake Wetland Complex results in a larger area of impact.	• Construction and operation may result in potential impacts to traditional land use and activities in the area, such as fishing, trapping and hunting.	• Construction and operation may result in potential impacts to traditional land use and activities in the area, such as fishing, trapping and hunting.	• Additional concerns for Option 1.
	4.3 Commercial Fisheries	• Construction and operation may result in potential impacts to commercial fisheries in the region. • Alignment through Big Buffalo Lake and Buffalo Creek has the potential to result in additional aquatic impacts affecting Commercial Fisheries.	• Construction and operation may result in potential impacts to commercial fisheries in the region.	• Construction and operation may result in potential impacts to commercial fisheries in the region.	• Additional concerns for Option 1.

TABLE 9 (CONTINUED)
SUMMARY COMPARISON OF OPTIONS

Main Category	Sub-Criteria	Option 1	Option 3	Option 4	Summary Comparison
5. Maintainability and Inspection	**5.1 Access to Site**	• Design includes permanent access road to Reach 1 & Reach 3. • Bridge included in design to provide access across Reach 3 and to the Reach 2 containment dike. • Gravel topping included on top of all dikes and on both sides of the channel.	• Design includes permanent access road to Reach 1. • Gravel topping included on top of all dikes and on both sides of the channel.	• Design includes permanent access road to Reach 1. • Gravel topping included on top of all dikes and on both sides of the channel.	• All options have access included on all dikes and along both sides of the entire channel as per design criteria and therefore are intended to perform equally.
	5.2 Vegetation Growth	• **Reach 1 widening:** Portion of channel side slopes vulnerable to poor vegetation growth as a result of prolonged operation; effects approximately 12 ha surface area of Reach 1. o Standing water in channel less than 1m in depth vulnerable to aquatic vegetation growth at the bottom. Entire length of Reach 1 channel (6km) may be affected depending on Big Buffalo Lake water levels. • **Reach 1 extension and wetland complex:** Additional nutrient source from flowing through wetland complex and Buffalo Creek can increase risk of vegetation growth downstream in Reach 3. o Potential for increased or changes in vegetation growth within wetland complex as a result of operation. • **Buffalo Creek:** Additional maintenance potentially required in addition to initial vegetation cleanup program during construction to address risk of debris floating and moving downstream during operation. o Standing water upstream of the drop structures designed to minimize portion of channel side slopes vulnerable to poor vegetation growth. o Vegetation established in natural conditions has greater resilience to perturbations like flooding, than does newly established vegetation.	• **Reach 1 widening and Reach 2:** Portion of channel side slopes vulnerable to poor vegetation growth as a result of prolonged operation; effects approximately 31 ha surface area of Reaches 1 and 2. o Standing water upstream of the drop structures designed to exceed 1m in depth to minimize heavy aquatic vegetation growth at the bottom of the channel and to minimize portion of channel side slopes vulnerable to poor vegetation growth and slow recovery after flood operations. o Approximately 6km of channel (existing Reach 1) may have standing water less than 1m in depth due to its distance away from the nearest drop structure.	• **Reach 2:** Portion of channel side slopes vulnerable to poor vegetation growth as a result of prolonged operation; effects approximately 14 ha surface area of Reach 2. o Standing water upstream of the drop structures designed to exceed 1m in depth to minimize heavy aquatic vegetation growth at the bottom of the channel and to minimize portion of channel side slopes vulnerable to poor vegetation growth and slow recovery after flood operations.	• Options 1 & 3 have increased risk of vegetation growth within the Reach 1 channel. • Option 1 has increased risk of vegetation growth within wetland complex and Reach 3. • Option 3 has largest potential area of channel banks vulnerable to poor vegetation growth, whereas Options 1 & 4 perform similarly. • Additional maintenance effort potentially required for Option 1 to address risk of debris floating and moving downstream during operation.

TABLE 9 (CONTINUED)
SUMMARY COMPARISON OF OPTIONS

Main Category	Sub-Criteria	Option 1	Option 3	Option 4	Summary Comparison
5. Maintainability and Inspection (continued)	**5.3 Sedimentation**	• Sediment input into channel expected to be minimal. • Potential deposition areas include the Buffalo Lakes wetland complex, the channel upstream of drop structures, and/or Lake Winnipeg. • Potential for sedimentation at the channel inlet dependent on shoreline conditions and coastal processes and can be managed with construction of rockfill groins or implementing future maintenance program.	• Sediment input into channel expected to be minimal. • Potential deposition areas include the channel upstream of drop structures, and/or Lake Winnipeg. • Potential for sedimentation at the channel inlet dependent on shoreline conditions and coastal processes and can be managed with construction of rockfill groins or implementing future maintenance program.	• Sediment input into channel expected to be minimal. • Potential deposition areas include the channel upstream of drop structures, and/or Lake Winnipeg. • Potential for sedimentation at the channel inlet dependent on shoreline conditions and coastal processes and can be managed with construction of rockfill groins or implementing future maintenance program.	• Potential for deposition similar for all options. • Option 1 has additional location of potential deposition in wetland complex.
	5.4 Operation in Winter Conditions	• Operating guidelines include provision to avoid initial operation during period when a solid ice cover is present in the channel. • Deep standing water upstream of the drop structures reduces risk of aufeis growth and possibly growth due to snow influx/ retention; reduces risk of ice damaging channel and structures in the spring in Buffalo Creek. • Risks associated with aufeis growth and possibly growth due to snow influx/ retention in Reach 1 due to shallow standing water in the channel expected to be insignificant due to the presence of Big Buffalo Lake and surrounding wetland complex at the outlet of Reach 1.	• Operating guidelines include provision to avoid initial operation during period when a solid ice cover is present in the channel. • Deep standing water upstream of the drop structures reduces risk of aufeis growth and possibly growth due to snow influx/ retention; reduces risk of ice damaging channel and structures in the spring.	• Operating guidelines include provision to avoid initial operation during period when a solid ice cover is present in the channel. • Deep standing water upstream of the drop structures reduces risk of aufeis growth and possibly growth due to snow influx/ retention; reduces risk of ice damaging channel and structures in the spring.	• All options designed to minimize risks associated with winter conditions as per design criteria and are therefore expected to perform equally well.
6. Resiliency	**6.1 Adaptability for Additional Capacity**	• **Reach 1 widening and extension in wetland complex:** Conveyance in wetland complex surrounding Big Buffalo Lake limit ability to increase flows beyond design peak without conducting additional excavation works. • **Reach 2 containment dike and Buffalo Creek:** Flows above design peak encroach on dike freeboard.	• **Reach 2:** Flows above design peak encroach on dike freeboard.	• **Reach 2:** Flows above design peak encroach on dike freeboard. • **Reach 1 decommissioning:** Potential additional emergency capacity available with minimal effort by re-opening Reach 1.	• Option 1 has limited ability to provide additional capacity. • Option 4 most adaptable for additional capacity.

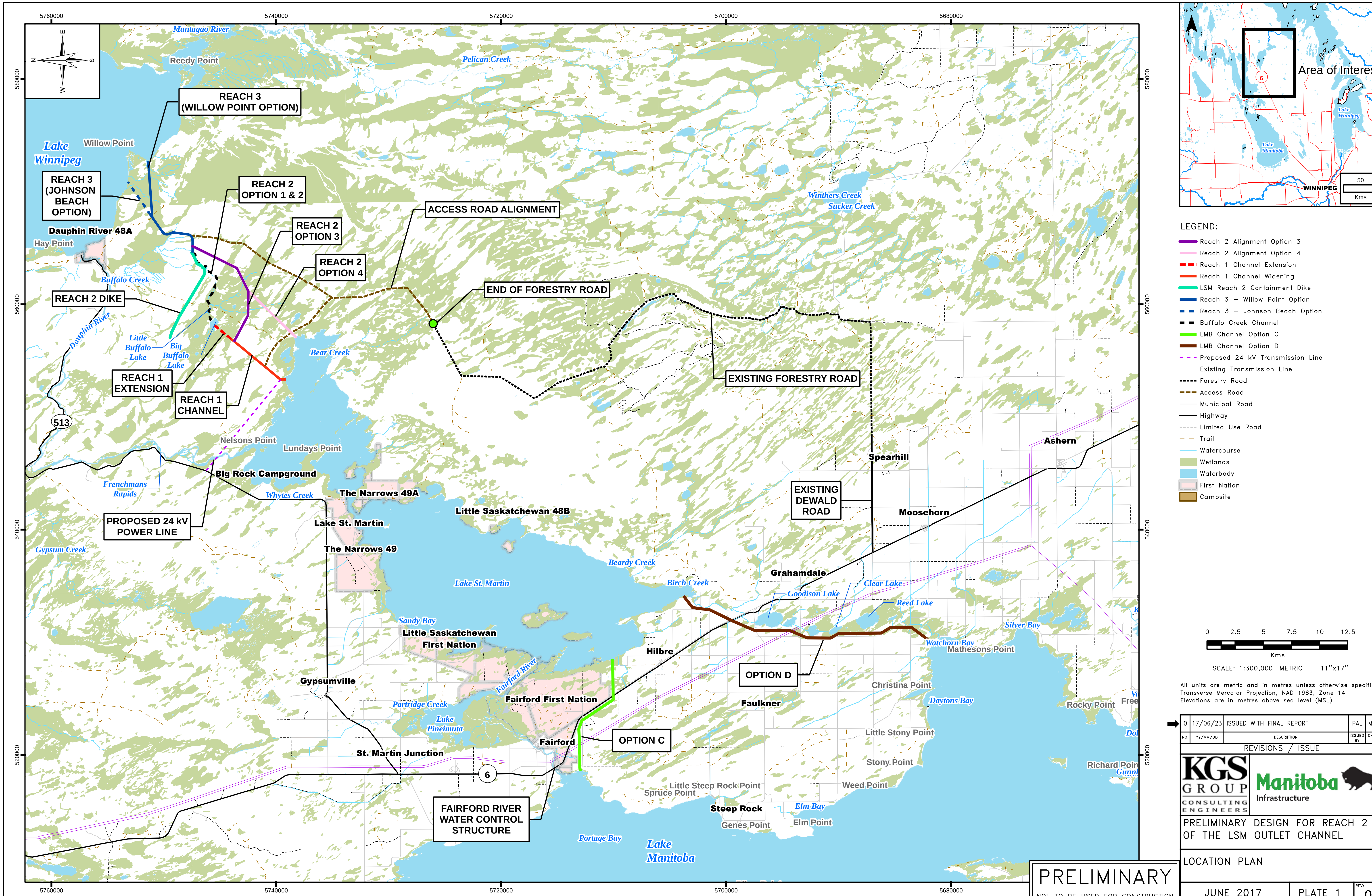
TABLE 9 (CONTINUED)
SUMMARY COMPARISON OF OPTIONS

Main Category	Sub-Criteria	Option 1	Option 3	Option 4	Summary Comparison
7. Cost	7.1 Capital Costs	• Preliminary Class C estimate (+/- 30%) approximated at $ 300 million (All-inclusive for Reaches 1 2 & 3 combined – with outlet east of Willow Point)	• Preliminary Class C estimate (+/- 30%) approximated at $ 300 million (All-inclusive for Reaches 1 2 & 3 combined – with outlet east of Willow Point)	• Preliminary Class C estimate (+/- 30%) approximated at $ 290 million (All-inclusive for Reaches 1 2 & 3 combined – with outlet east of Willow Point)	• All Options have similar estimated capital costs, with Option 4 slightly less costly.
	7.2 General Maintenance Costs	• Estimated average annual maintenance costs based on 2% of Capital Costs: $ 6 million.	• Estimated average annual maintenance costs based on 1.6% of Capital Costs: $ 4.8 million.	• Estimated average annual maintenance costs based on 1.5% of Capital Costs: $ 4.4 million.	• Option 1 has highest estimated maintenance costs mostly due to risk of fish stranding, increased risk of vegetation growth within the channel and operation risks through the wetland complex. • Option 3 has slightly larger estimated maintenance cost compared to Option 4 due to increased risk of vegetation growth within the channel and risk of poor vegetation growth on the channel banks.
8. Cost Risk	8.1 Social Risk	• Additional socio-economic concerns due to alignment through wetland complex and Buffalo Creek	• Alignment avoids wetland complex and Buffalo Creek altogether, minimizing socio-economic risks compared to Option 1.	• Alignment avoids wetland complex and Buffalo Creek altogether, minimizing socio-economic risks compared to Option 1.	• Additional socio-economic concerns with Option 1
	8.2 Optimization	• Deeper, narrower channel provides opportunity for approximately $5 million cost savings.	• Deeper, narrower and straighter channel provides opportunity for approximately $15 million cost savings.	• Deeper, narrower and straighter channel provides opportunity for approximately $15 million cost savings.	• Options 3 & 4 have larger potential cost savings than Option 1.
	8.3 Environmental	• Potential additional environmental mitigation requirements to address concerns with flooding the wetland complex and Buffalo Creek could result in increased cost.	• Alignment avoids wetland complex and Buffalo Creek altogether, minimizing risks associated with environmental mitigation requirements compared to Option 1.	• Alignment avoids wetland complex and Buffalo Creek altogether, minimizing risks associated with environmental mitigation requirements compared to Option 1.	• Additional risks with Option 1.
	8.4 Construction	• Higher construction risks for Option 1 (Reach 1 extension), based on contractor input, could result in unexpected increases in costs. • Unknown spoil conditions (Reach 1 widening) could result in unexpected increases in costs.	• Unknown spoil conditions (Reach 1 widening) could result in unexpected increases in costs.	• Ability to operate Reach 1 during construction with minimal impacts to construction schedule.	• Option 4 performs best. • Option 1 has higher risks for unexpected increases in costs.
	8.5 Rock Supply	• Hauling of riprap required for construction of drop structures and for erosion protection. • Limited amount of data on overall quality and quantity of rock available for the project.	• Hauling of riprap required for construction of drop structures and for erosion protection. • Limited amount of data on overall quality and quantity of rock available for the project.	• Hauling of riprap required for construction of drop structures and for erosion protection. • Limited amount of data on overall quality and quantity of rock available for the project.	• Differences in total rock quantity required not substantially different between options.
	8.6 Amortization	• "Writing-off" the amortization of Reach 1 not a requirement for this option.	• "Writing-off" the amortization of Reach 1 not a requirement for this option.	• "Writing-off" the amortization of Reach 1 as part of decommissioning may result in cost differences compared to other Options. • Design assumes channel used in the future for riparian flow and/or emergency capacity due to climate change. "Writing-off" the amortization therefore not required.	• No cost differences expected between options.

TABLE 10
TECHNICAL WORKSHOP EVALUATION RESULTS

Main Category	Weight	Sub-Criteria	Weight	Option 1		Option 3		Option 4	
				Rating	Score	Rating	Score	Rating	Score
1. Constructability	13	1.1 Access to Site	2.0	3	6.0	3	6.0	3	6.0
		1.2 Surface and Groundwater Management	4.0	2	8.0	4	16.0	4	16.0
		1.3 Material Composition	2.0	2	4.0	3	6.0	4	8.0
		1.4 Bathymetric Conditions	2.0	3	6.0	3.5	7.0	3.5	7.0
		1.5 Scheduling	3.0	2	6.0	2	6.0	5	15.0
2. Operability & Performance	15	2.1 Channel Dikes and Slopes	2.0	3	6.0	4	8.0	4	8.0
		2.2 Erosion, Sediment Transport and Deposition	3.0	2	6.0	3	9.0	4	12.0
		2.3 Flow Through Buffalo Lakes Wetland Complex	5.0	2	10.0	5	25.0	5	25.0
		2.4 Drop Structures	1.5	3	4.5	3	4.5	3	4.5
		2.5 Operation in Winter Conditions	2.0	3	6.0	3	6.0	3	6.0
		2.6 Groundwater Management	1.5	3	4.5	3	4.5	3	4.5
3. Physical Environmental Impacts	15	3.1 Surface Water	5.0	1	5.0	3	15.0	3	15.0
		3.2 Groundwater	2.0	4	8.0	3	6.0	3	6.0
		3.3 Terrestrial Environment	4.0	2	8.0	3	12.0	3	12.0
		3.4 Aquatic Habitat & Resources	4.0	1	4.0	3	12.0	3	12.0
4. Social Economic Considerations	12	4.1 Access	4.0	3	12.0	3	12.0	3	12.0
		4.2 Indigenous Rights Based Activities	4.0	2	8.0	3	12.0	3	12.0
		4.3 Commercial Fisheries	4.0	2	8.0	3	12.0	3	12.0
5. Maintainability and Inspection	10	5.1 Access to Site	2.0	3	6.0	4	8.0	4	8.0
		5.2 Vegetation Growth	3.0	2	6.0	3	9.0	4	12.0
		5.3 Sedimentation	3.0	3	9.0	3.5	10.5	3.5	10.5
		5.4 Operation in Winter Conditions	2.0	3	6.0	3	6.0	3	6.0
6. Resiliency	5	6.1 Adaptability for Additional Capacity	5.0	2	10.0	3	15.0	5	25.0
7. Cost	10	7.1 Capital Costs	7.0	3	21.0	3	21.0	3	21.0
		7.2 General Maintenance Costs	3.0	2	6.0	2.5	7.5	3	9.0
8. Cost Risk	20	8.1 Social Risk	3.0	2	6.0	3	9.0	3	9.0
		8.2 Optimization	4.0	3	12.0	4	16.0	4	16.0
		8.3 Environmental	3.0	2	6.0	3	9.0	3	9.0
		8.4 Construction	4.0	2	8.0	2.5	10.0	3	12.0
		8.5 Rock Supply	2.0	3	6.0	3	6.0	3	6.0
		8.6 Amortization	4.0	3	12.0	3	12.0	3	12.0
		Total Score (out of 500)	500		234.0		318.0		348.5
		Total Score (out of 100)	100		46.8		63.6		69.7

PLATES



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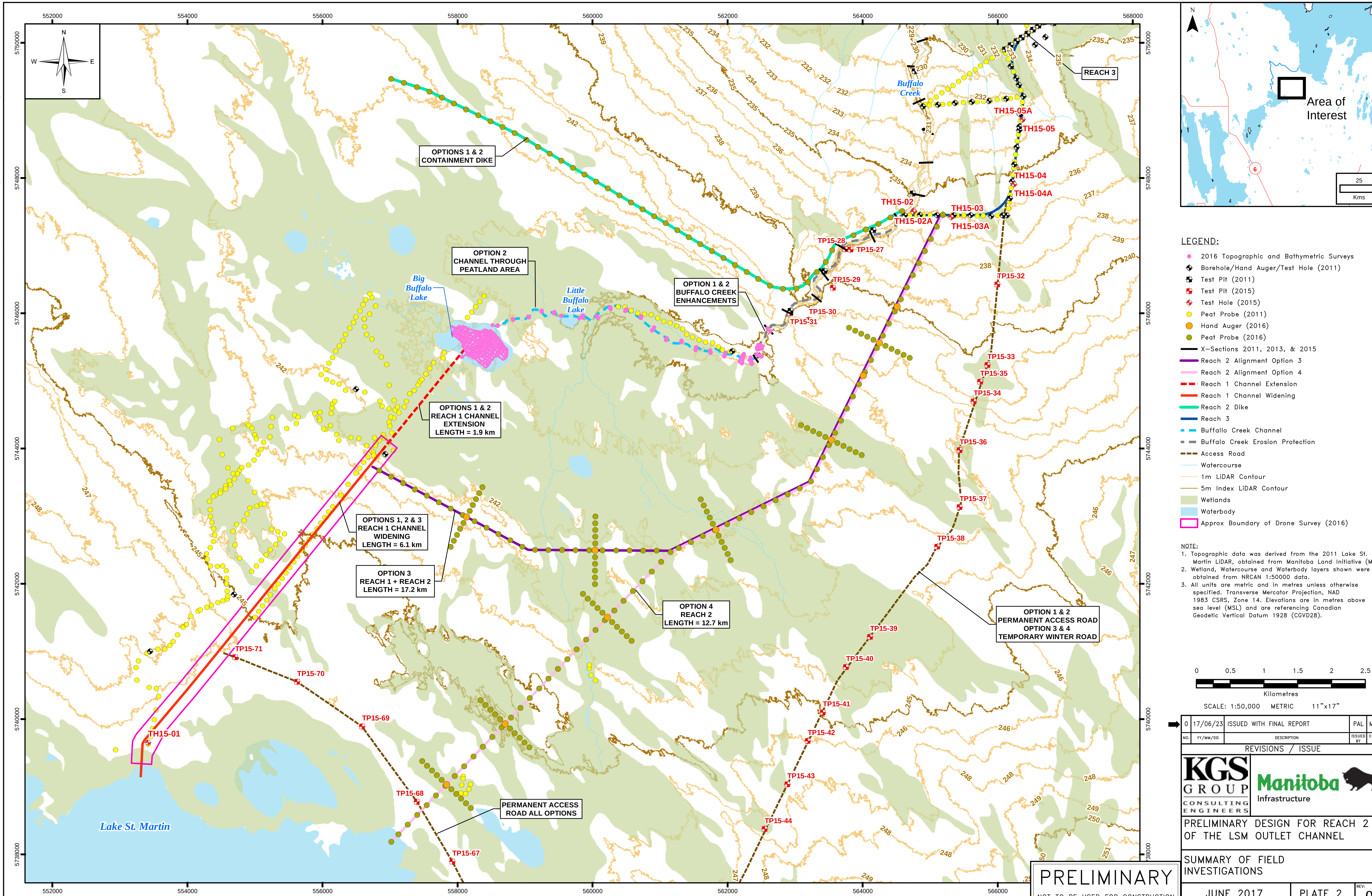

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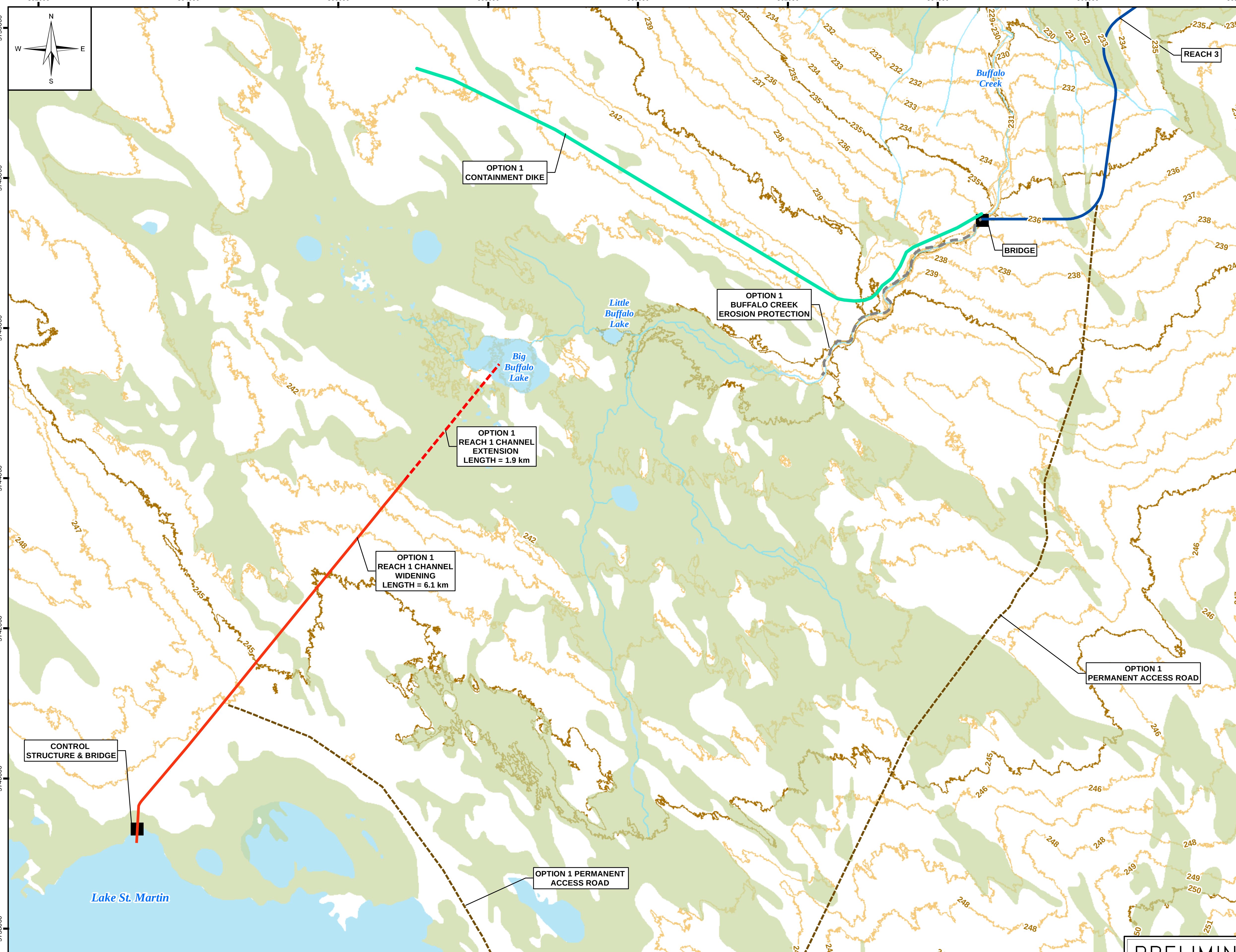

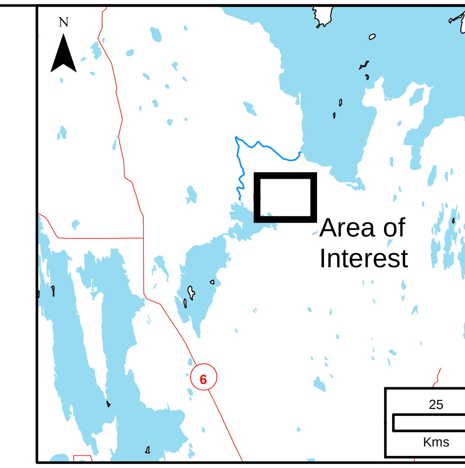

LEGEND:

- Reach 1 Channel Extension
- Reach 1 Channel Widening
- Reach 2 Dike
- Reach 3
- Buffalo Creek Erosion Protection
- Access Road
- Watercourse
- 1m LiDAR Contour
- 5m Index LiDAR Contour
- Wetlands
- Waterbody

NOTE:
1. Topographic data was derived from the 2011 Lake St. Martin LiDAR, obtained from Manitoba Land Initiative (MLI).
2. Wetland, Watercourse and Waterbody layers shown were obtained from NRCAN 1:50000 data.
3. All units are metric and in metres unless otherwise specified. Transverse Mercator Projection, NAD 1983 CSRS, Zone 14. Elevations are in metres above sea level (MSL) and are referencing Canadian Geodetic Vertical Datum 1928 (CGVD28).

0 0.5 1 1.5 2 2.5
Kilometres
SCALE: 1:50,000 METRIC 11"x17"

NO.	YY/MM/DD	DESCRIPTION	ISSUED BY	CHECK BY
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KGS GROUP CONSULTING ENGINEERS

Manitoba Infrastructure

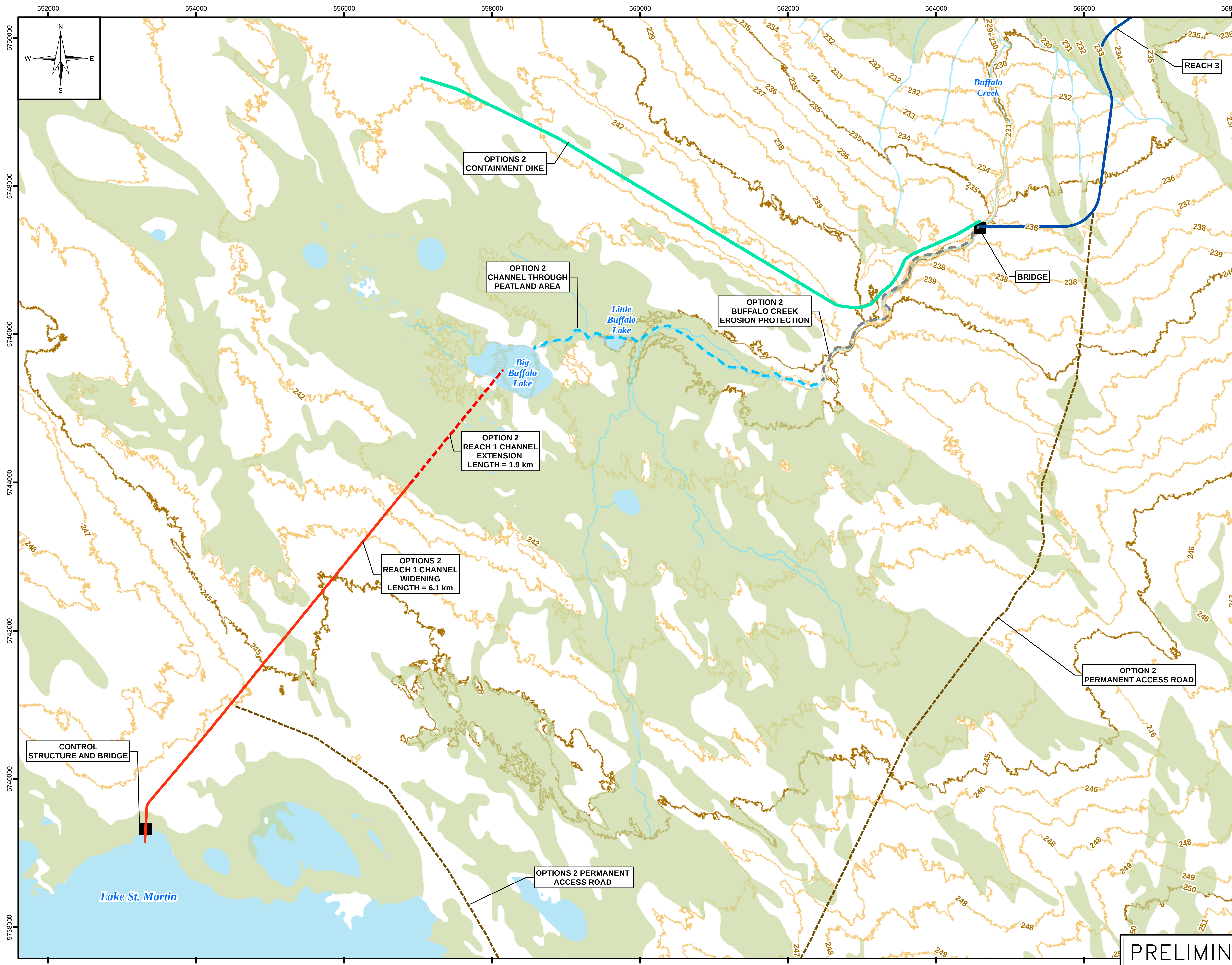
PRELIMINARY DESIGN FOR REACH 2 OF THE LSM OUTLET CHANNEL

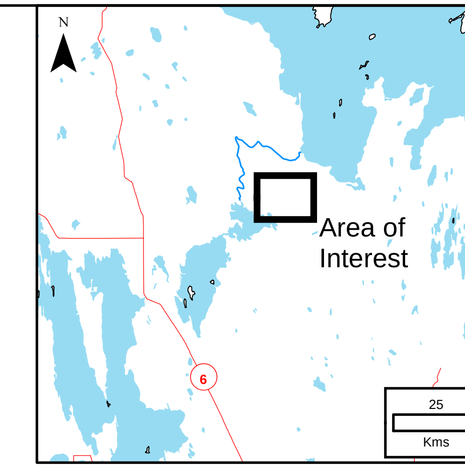
OPTION 1

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

JUNE 2017 | PLATE 3 | REV: 0

FileName:P:\Projects\2016\16-0300-005\Dwg\GIS\MXDs\Rev0\Alignment Options\16-0300-005_P3_Rev0.mxd
11"x17" PLOT SCALE 1:1





LEGEND:

- Reach 1 Channel Extension
- Reach 1 Channel Widening
- Reach 2 Dike
- Reach 3
- Buffalo Creek Channel
- Buffalo Creek Erosion Protection
- Access Road
- Watercourse
- 1m LiDAR Contour
- 5m Index LiDAR Contour
- Wetlands
- Waterbody

NOTE:

1. Topographic data was derived from the 2011 Lake St. Martin LiDAR, obtained from Manitoba Land Initiative (MLI).
2. Wetland, Watercourse and Waterbody layers shown were obtained from NRCAN 1:50000 data.
3. All units are metric and in metres unless otherwise specified. Transverse Mercator Projection, NAD 1983 CSRS, Zone 14. Elevations are in metres above sea level (MSL) and are referencing Canadian Geodetic Vertical Datum 1928 (CGVD28).

0 0.5 1 1.5 2 2.5
Kilometres

SCALE: 1:50,000 METRIC 11"x17"

NO.	YY/MM/DD	DESCRIPTION	ISSUED BY	CHECK BY
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KGS GROUP CONSULTING ENGINEERS — Manitoba Infrastructure

PRELIMINARY DESIGN FOR REACH 2 OF THE LSM OUTLET CHANNEL

OPTION 2

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

JUNE 2017 | PLATE 4 | REV: 0

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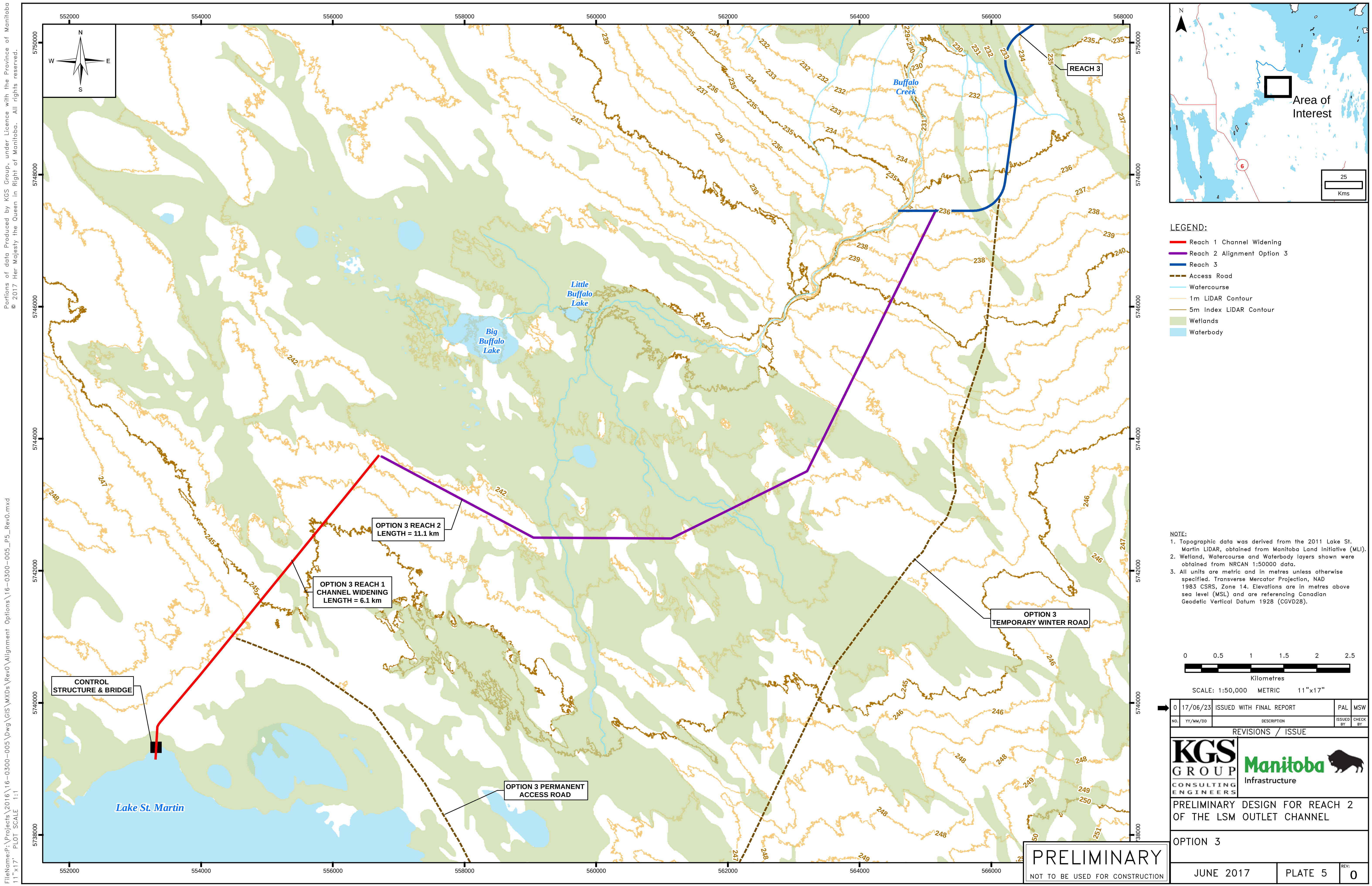
11"x17" PLOT SCALE 1:1



Buffalo Creek
Little Buffalo Lake
Big Buffalo Lake
Lake St. Martin
REACH 3
OPTION 3 REACH 2
LENGTH = 11.1 km
OPTION 3 REACH 1
CHANNEL WIDENING
LENGTH = 6.1 km
CONTROL
STRUCTURE & BRIDGE
OPTION 3 PERMANENT
ACCESS ROAD
OPTION 3
TEMPORARY WINTER ROAD
Area of
Interest
Kms
LEGEND:
Reach 1 Channel Widening
Reach 2 Alignment Option 3
Reach 3
Access Road
Watercourse
1m LiDAR Contour
5m Index LiDAR Contour
Wetlands
Waterbody
NOTE:
1. Topographic data was derived from the 2011 Lake St. Martin LiDAR, obtained from Manitoba Land Initiative (MLI).
2. Wetland, Watercourse and Waterbody layers shown were obtained from NRCAN 1:50000 data.
3. All units are metric and in metres unless otherwise specified. Transverse Mercator Projection, NAD 1983 CSRS, Zone 14. Elevations are in metres above sea level (MSL) and are referencing Canadian Geodetic Vertical Datum 1928 (CGVD28).
Kilometres
SCALE: 1:50,000 METRIC 11"x17"
0 17/06/23 ISSUED WITH FINAL REPORT PAL MSW
NO. YY/MM/DD DESCRIPTION ISSUED BY CHECK BY
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Manitoba Infrastructure
PRELIMINARY DESIGN FOR REACH 2 OF THE LSM OUTLET CHANNEL
OPTION 3
JUNE 2017
PLATE 5
REV: 0
PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION
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11"x17" PLOT SCALE 1:1

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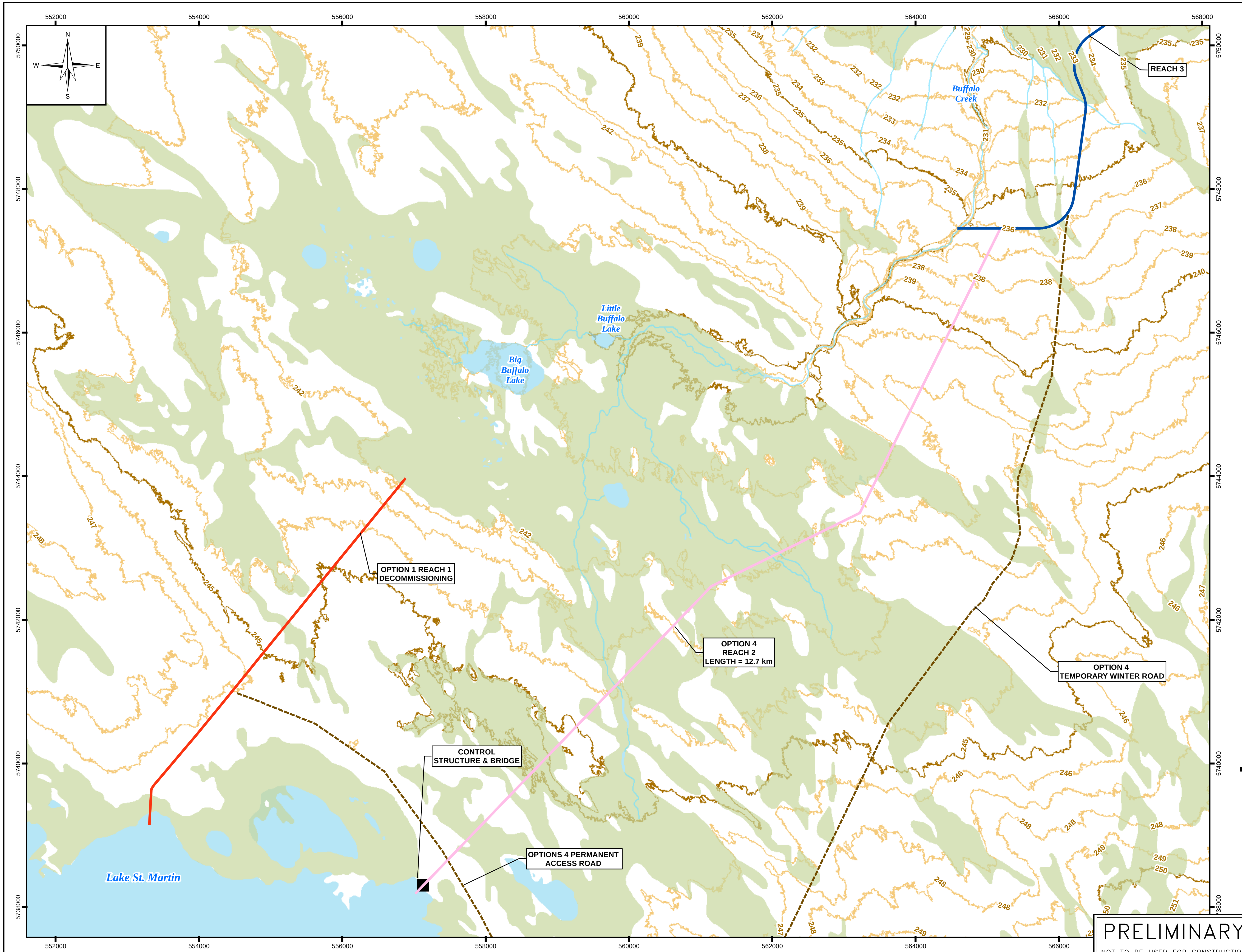
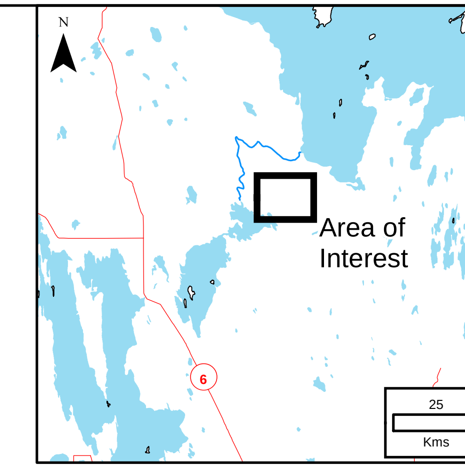
11"x17" PLOT SCALE 1:1





LEGEND:

- Reach 2 Alignment Option 4
- Reach 1 Channel
- Reach 3
- Access Road
- Watercourse
- 1m LiDAR Contour
- 5m Index LiDAR Contour
- Wetlands
- Waterbody

NOTE:
1. Topographic data was derived from the 2011 Lake St. Martin LiDAR, obtained from Manitoba Land Initiative (MLI).
2. Wetland, Watercourse and Waterbody layers shown were obtained from NRCAN 1:50000 data.
3. All units are metric and in metres unless otherwise specified. Transverse Mercator Projection, NAD 1983 CSRS, Zone 14. Elevations are in metres above sea level (MSL) and are referencing Canadian Geodetic Vertical Datum 1928 (CGVD28).

0 0.5 1 1.5 2 2.5
Kilometres

SCALE: 1:50,000 METRIC 11"x17"

NO.	YY/MM/DD	DESCRIPTION	ISSUED BY	CHECK BY
0	17/06/23	ISSUED WITH FINAL REPORT	PAL	MSW

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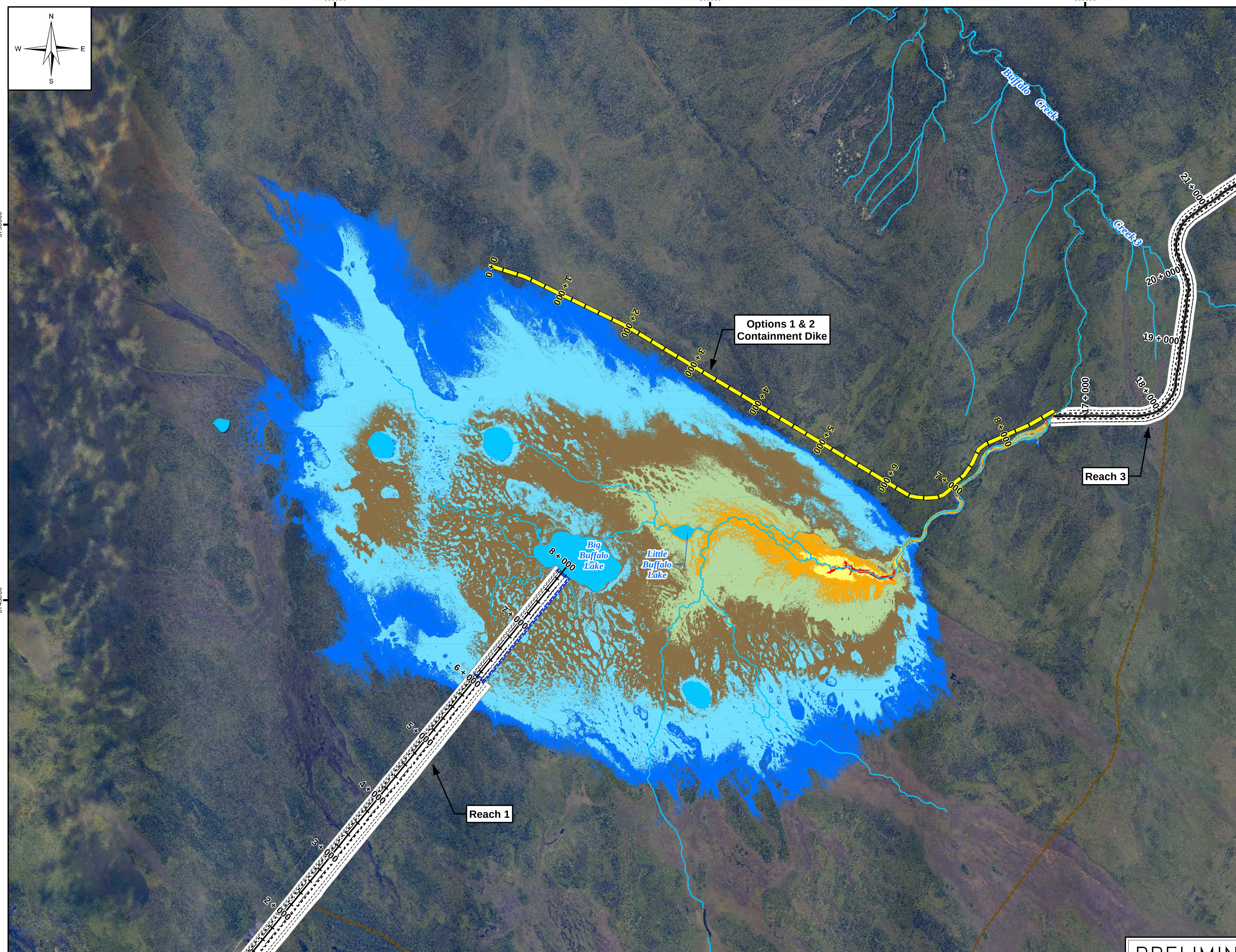
Manitoba Infrastructure

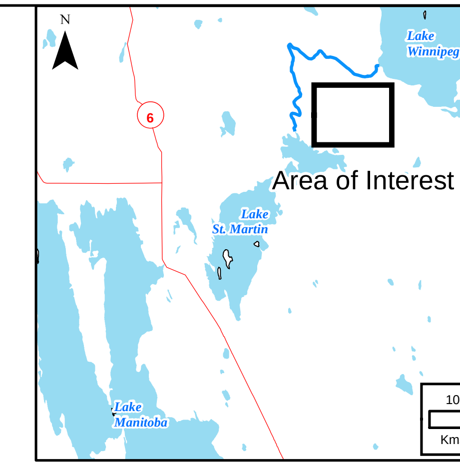
PRELIMINARY DESIGN FOR REACH 2 OF THE LSM OUTLET CHANNEL

OPTION 4

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

JUNE 2017 | PLATE 6 | REV: 0





LEGEND:

Options 1 & 2 Containment Dike

Channel Linework
- Channel Alignment
- Cofferdam
- Toe of Channel
- Top of Spoil
- Top of Expanded Channel Footprint
- Right of Way Footprint
- Access Road

Water Features
- River/Stream
- Waterbody

Depth of Flooding (m)
- 0 – 0.5
- 0.5 – 1.0
- 1.0 – 1.5
- 1.5 – 2.0
- 2.0 – 2.5
- 2.5 – 3.0
- >3

NOTES:
1. Imagery is dated 2011 and supplied by the Province of Manitoba.

0 500 1,000 1,500 2,000 2,500
Meters

SCALE: 1:50,000 METRIC 11"x17"

All units are metric and in metres unless otherwise specified.
Transverse Mercator Projection, NAD 1983, Zone 14
Elevations are in metres above sea level (MSL)

NO.	YY/MM/DD	DESCRIPTION	ISSUED BY	CHECK BY
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Manitoba Infrastructure

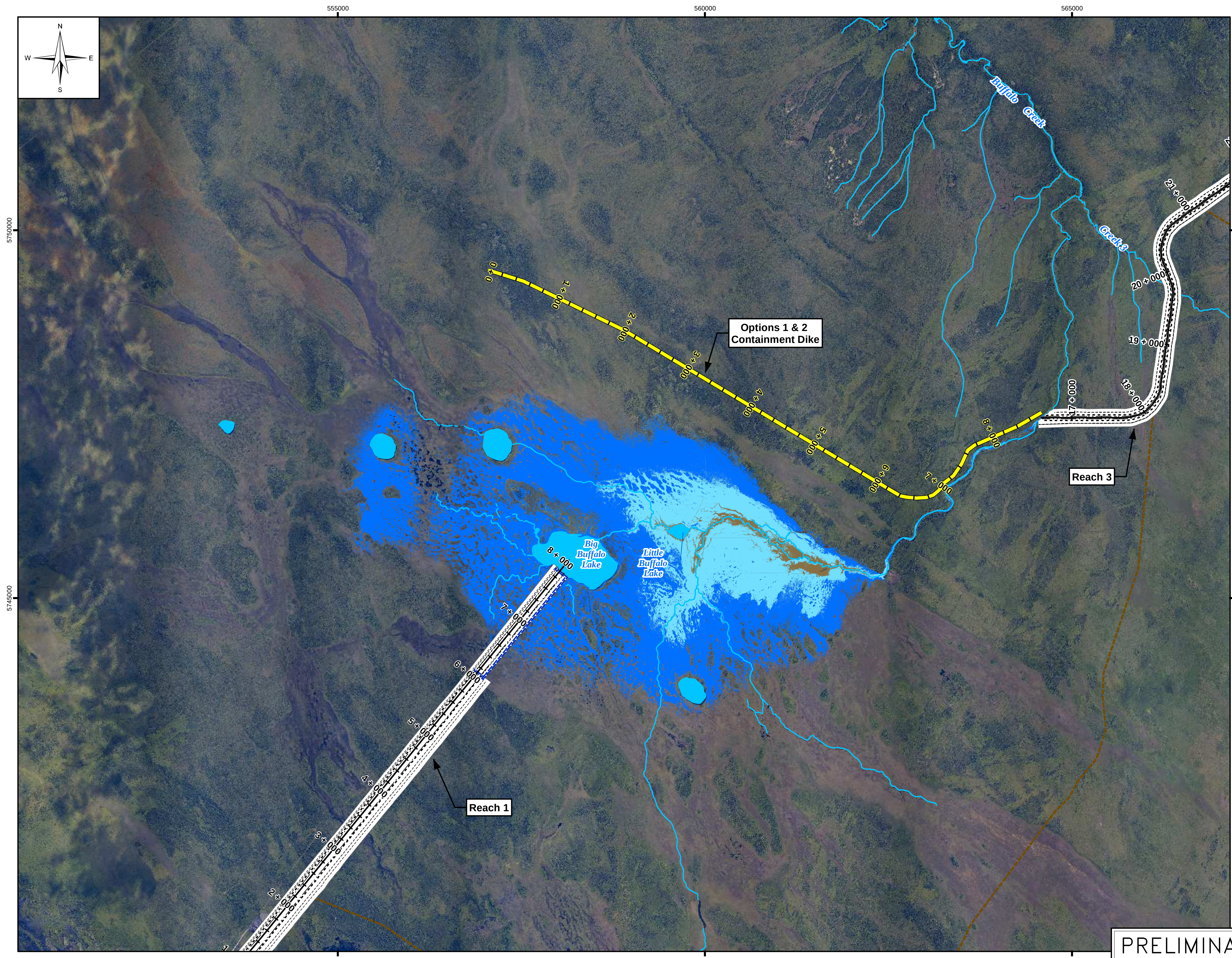
PRELIMINARY DESIGN FOR REACH 2 OF THE LSM OUTLET CHANNEL

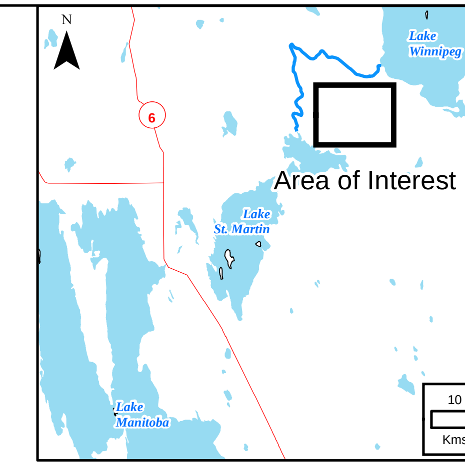
DEPTH OF FLOODING SURROUNDING BIG BUFFALO LAKE AREA – 11500 CFS

JUNE 2017 | PLATE 7 | REV: 0

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

FileName: P:\Projects\2016\16-0300-005\Dwg\GIS\MXDs\Rev0\Alignment Options\16-0300-005_P7_Rev0.mxd
11"x17" PLOT SCALE 1:1





LEGEND:

- Options 1 & 2 Containment Dike

Channel Linework
- Channel Alignment
- Cofferdam
- Toe of Channel
- Top of Spoil
- Top of Expanded Channel Footprint
- Right of Way Footprint
- Access Road

Water Features
- River/Stream
- Waterbody

Depth of Flooding (m)
- 0 – 0.5
- 0.5 – 1.0
- 1.0 – 1.5
- 1.5 – 2.0
- 2.0 – 2.5
- 2.5 – 3.0
- >3

NOTES:

1. Imagery is dated 2011 and supplied by the Province of Manitoba.

0 500 1,000 1,500 2,000 2,500

Meters

SCALE: 1:50,000 METRIC 11"x17"

All units are metric and in metres unless otherwise specified.
Transverse Mercator Projection, NAD 1983, Zone 14
Elevations are in metres above sea level (MSL)

NO.	YY/MM/DD	DESCRIPTION	ISSUED BY	CHECK BY
0	17/06/23	ISSUED WITH FINAL REPORT	PAL	MSW

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Manitoba Infrastructure

PRELIMINARY DESIGN FOR REACH 2 OF THE LSM OUTLET CHANNEL

DEPTH OF FLOODING SURROUNDING BIG BUFFALO LAKE AREA – 2500 CFS

JUNE 2017 | PLATE 8 | REV: 0

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

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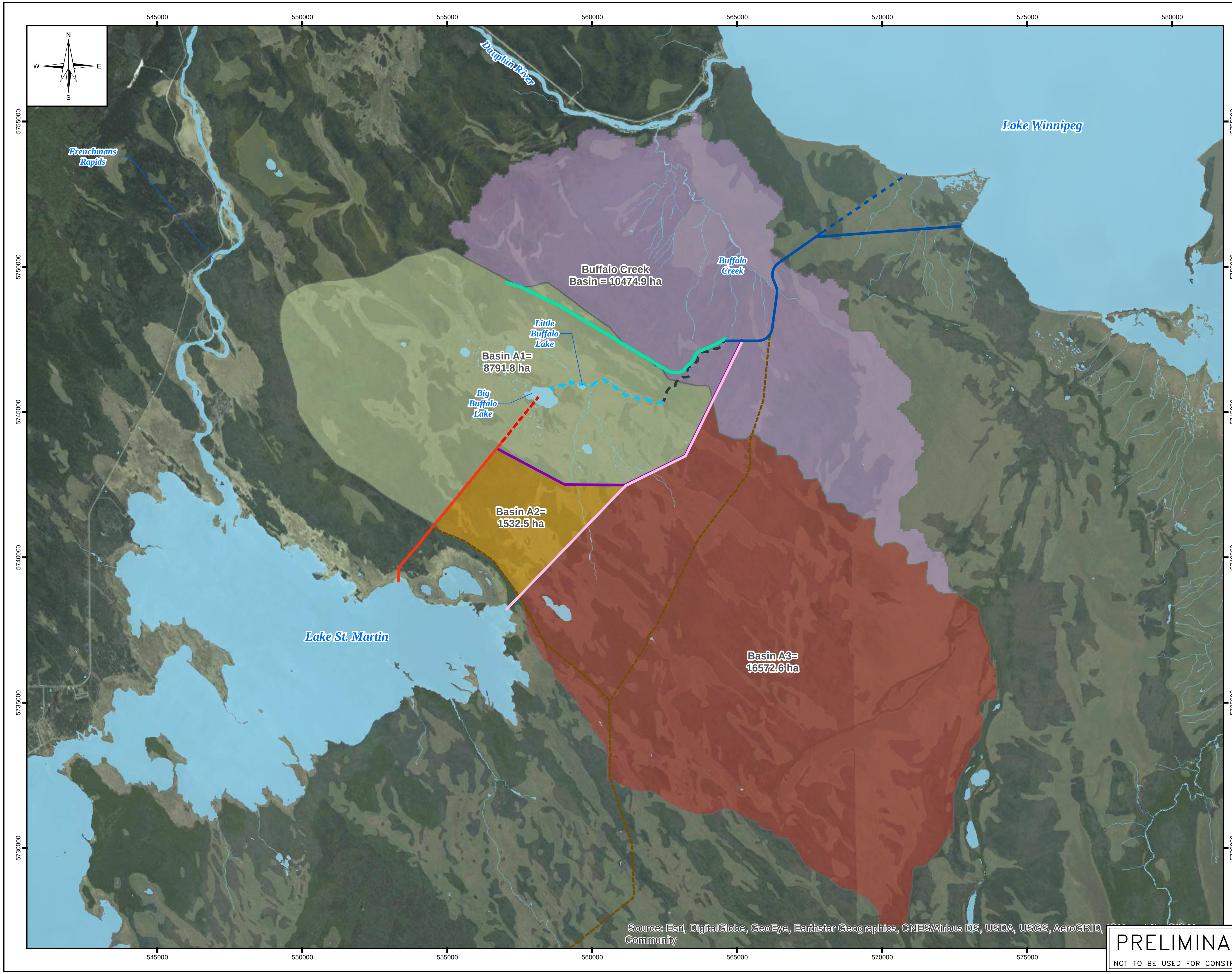
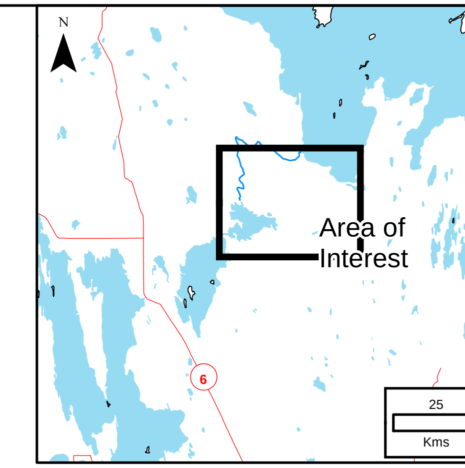
11"x17" PLOT SCALE 1:1





LEGEND:

- Reach 2 Alignment Option 3
- Reach 2 Alignment Option 4
- Reach 1 Channel Extension Option 1
- Reach 1 Channel Widening Option 1 & 3
- Reach 2 Containment Dike (Option 1)
- Reach 3
- Buffalo Creek Channel
- Buffalo Creek Channel Enhancements Option 1
- Access Road
- Watercourse
- Waterbody
- Wetlands
- Buffalo Creek Basin
- Buffalo Lake Basin A1
- Buffalo Lake Basin A2
- Buffalo Lake Basin A3

NOTE:

1. Wetland, Watercourse and Waterbody layers shown were obtained from NRCAN 1:50000 data.
2. All units are metric and in metres unless otherwise specified. Transverse Mercator Projection, NAD 1983 CSRS, Zone 14. Elevations are in metres above sea level (MSL) and are referencing Canadian Geodetic Vertical Datum 1928 (CGVD28).

0 1 2 3 4 5

Kilometres

SCALE: 1:125,000 METRIC 11"x17"

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Manitoba Infrastructure

PRELIMINARY DESIGN FOR REACH 2 OF THE LSM OUTLET CHANNEL

SURFACE WATER DRAINAGE BASIN MAP

PRELIMINARY

NOT TO BE USED FOR CONSTRUCTION

JUNE 2017 | PLATE 9 | REV: 0

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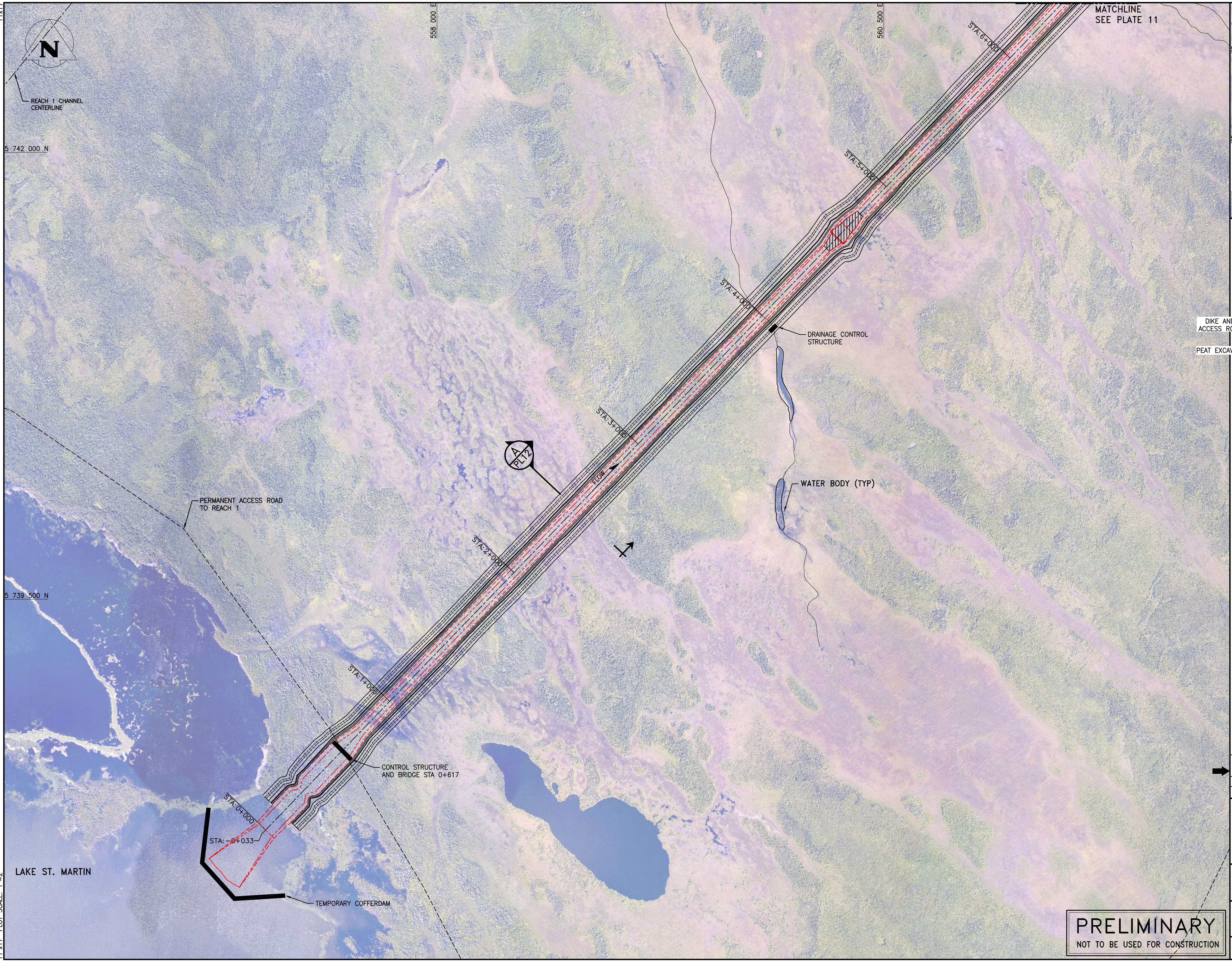
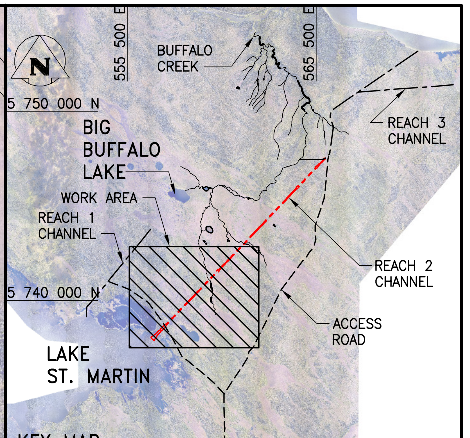
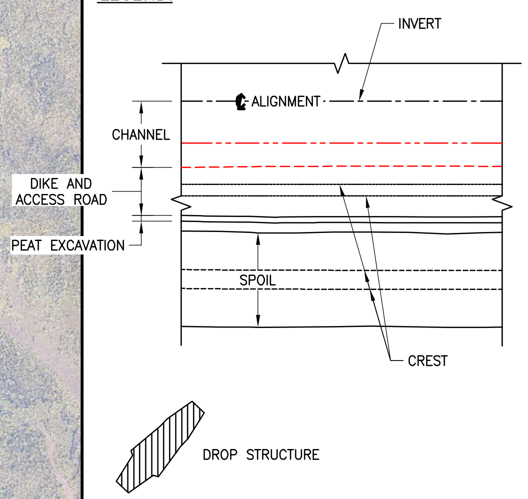




KEY MAP

LEGEND:



NOTES:

1. ALL UNITS ARE METRIC AND IN METRES UNLESS OTHERWISE SPECIFIED. TRANSVERSE MERCATOR PROJECTION, AND 1983 CSRS, ZONE 14. ELEVATIONS ARE IN METRES ABOVE SEA LEVEL (MSL) AND ARE REFERENCING CANADIAN GEODETIC VERTICAL DATUM 1928 (CGVD28).
2. IMAGERY IS DATED 2011 AND SUPPLIED BY THE PROVINCE OF MANITOBA.

200 0 200 400 600 800 m

SCALE: 1:10000

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0	17/06/23	ISSUED WITH FINAL REPORT	SKB (HATCH)	PAL (KGS)

REVISIONS / ISSUE

KGS GROUP CONSULTING ENGINEERS

Manitoba Infrastructure

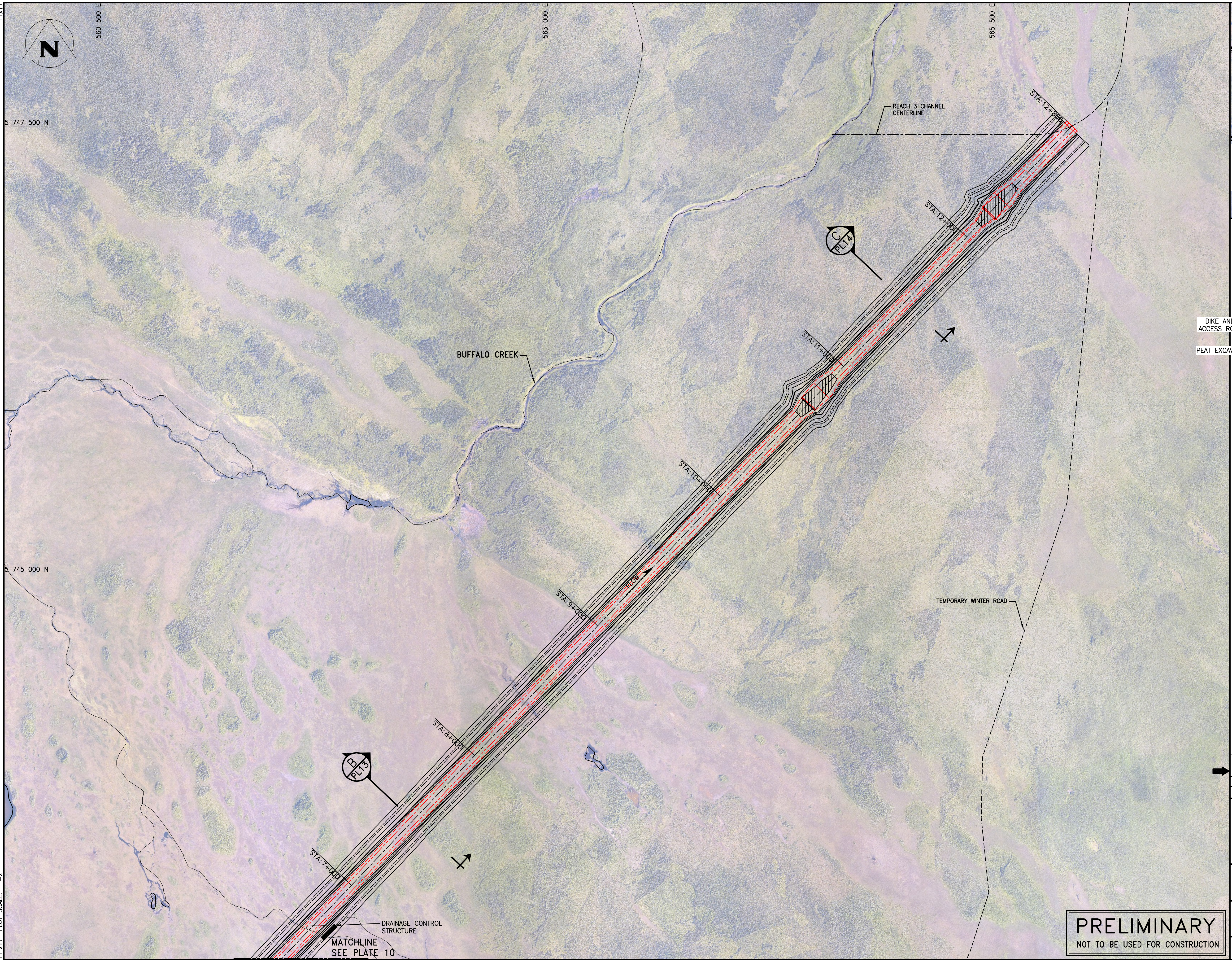
PRELIMINARY DESIGN FOR REACH 2 OF THE LAKE ST. MARTIN OUTLET CHANNEL

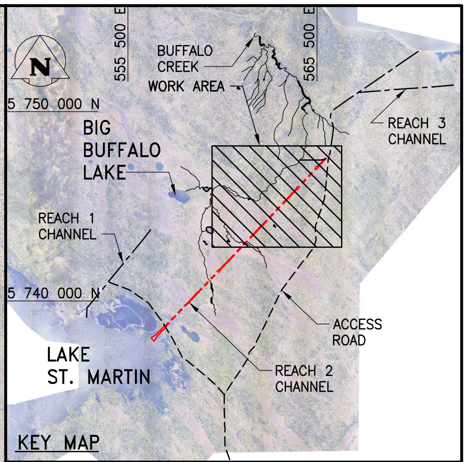
PLAN VIEW OF REACH 2 CHANNEL OPTION 4 (SHEET 1 OF 2)

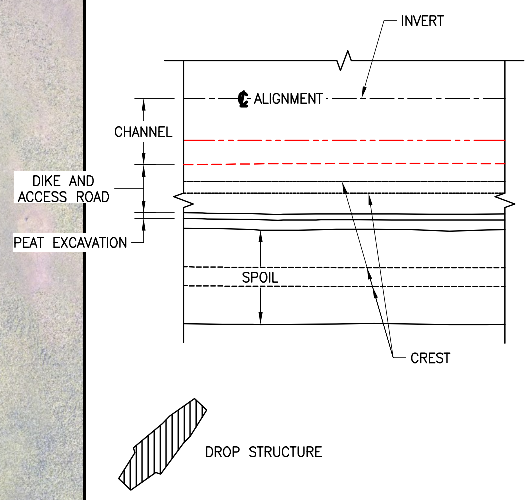
JUNE 2017 | PLATE 10 | REV: 0

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

FileName: C:\Users\gasp56924\Documents\RGaspar\CAD420AV\InRoads Modeling Studies\GMM\nn-nnnn-nnn_Plate 10_11-190717a.dwg - Tab: Layout1 Plotted By: GASP56924 17/06/19 [Mon 8:40am]
11"x17" PLOT SCALE: 1"=2"
11x17







NOTES:

1. ALL UNITS ARE METRIC AND IN METRES UNLESS OTHERWISE SPECIFIED. TRANSVERSE MERCATOR PROJECTION, AND 1983 CSRS, ZONE 14. ELEVATIONS ARE IN METRES ABOVE SEA LEVEL (MSL) AND ARE REFERENCING CANADIAN GEODETIC VERTICAL DATUM 1928 (CGVD28).
2. IMAGERY IS DATED 2011 AND SUPPLIED BY THE PROVINCE OF MANITOBA.

200 0 200 400 600 800 m

SCALE: 1:10000

NO.	YY/MM/DD	DESCRIPTION	ISSUED BY	CHECKED BY
0	17/06/23	ISSUED WITH FINAL REPORT	SKB (HATCH)	PAL (KGS)

REVISIONS / ISSUE

KGS GROUP CONSULTING ENGINEERS

Manitoba Infrastructure

PRELIMINARY DESIGN FOR REACH 2 OF THE LAKE ST. MARTIN OUTLET CHANNEL

PLAN VIEW OF REACH 2 CHANNEL OPTION 4 (SHEET 2 OF 2)

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

JUNE 2017 | PLATE 11 | REV: 0

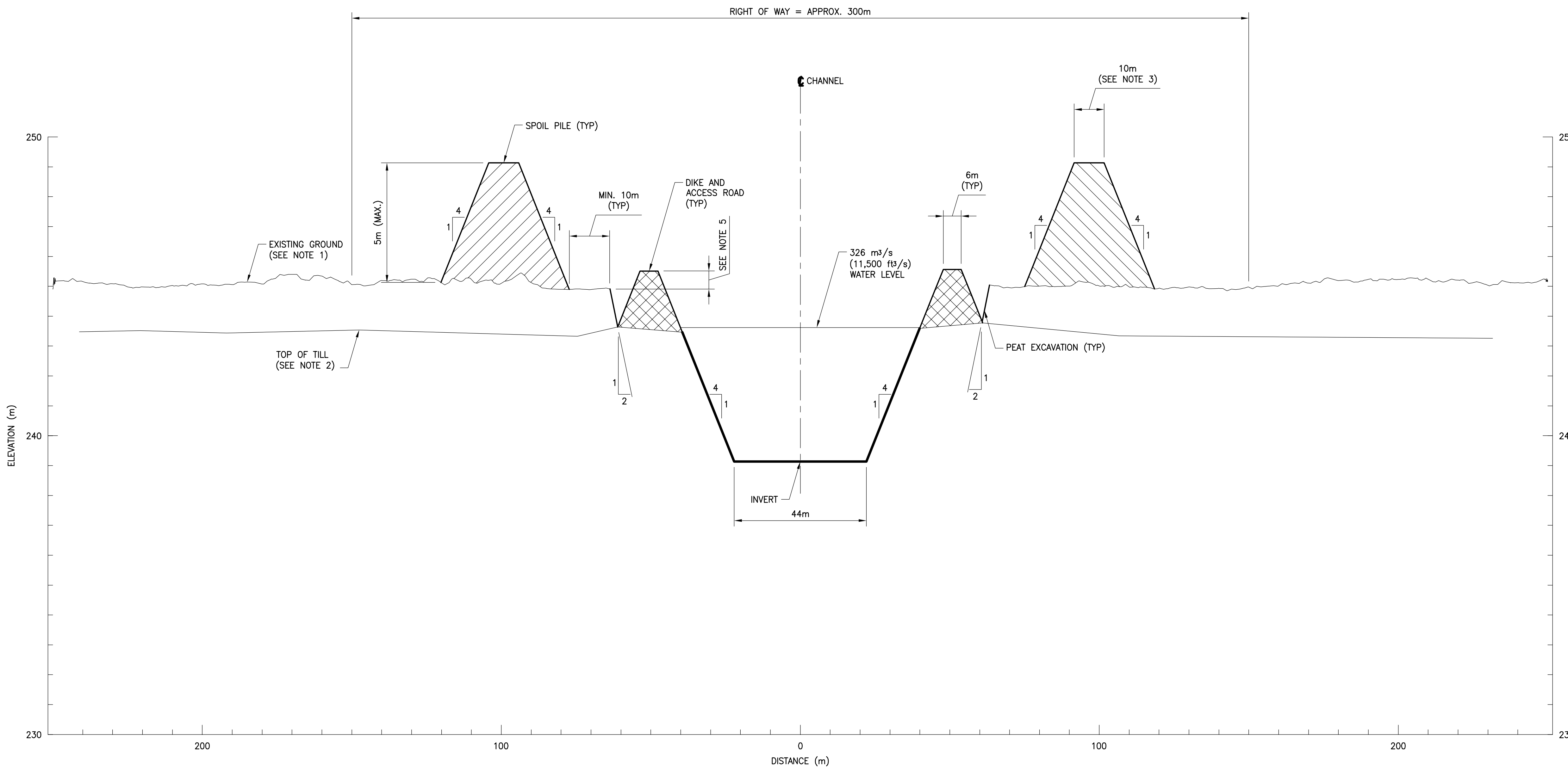
11"x17" PLOT SCALE: 1"=2"

FileName: C:\Users\gasp56924\Documents\RGaspar\CAD42AY\nRoads Modeling Studies\GMM\nn-nnnn-nnn_Plate 10_11-190717a.dwg - Tab: Layout1 Plotted By: GASP56924 17/06/19 [Mon 8:39am]

11x17

NOTES:

1. EXISTING GROUND SURFACE BASED ON LIDAR (2011).
2. TOP OF FILL APPROXIMATE AND BASED ON 2016 PEAT PROBE SURVEY PROJECTED TO CHANNEL CENTERLINE.
3. SPOIL PILE SHOWN DOES NOT INCLUDE ADJUSTMENTS FOR MATERIAL HANDLING AND ASSUMES CONSTANT WIDTH AND HEIGHT ALONG ENTIRE CHANNEL LENGTH.
4. ALL UNITS ARE METRIC AND IN METRES UNLESS OTHERWISE SPECIFIED. TRANSVERSE MERCATOR PROJECTION, AND 1983 CSRS, ZONE 14. ELEVATIONS ARE IN METRES ABOVE SEA LEVEL (MSL) AND ARE REFERENCING CANADIAN GEODETIC VERTICAL DATUM 1928 (CGVD28).
5. TOP OF DIKE BUILT TO MINIMUM 0.6 m ABOVE TOP OF PEAT OR MINIMUM 1.0 m ABOVE DESIGN WATER LEVEL, WHICHEVER IS GREATER.



CROSS SECTION (STA 2+500)

PL10

1:800 HOR SCALE
1:80 VER SCALE

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Manitoba Infrastructure

PRELIMINARY DESIGN FOR REACH 2 OF THE LAKE ST. MARTIN OUTLET CHANNEL

CROSS SECTION A (STA 2+500) REACH 2 CHANNEL OPTION 4

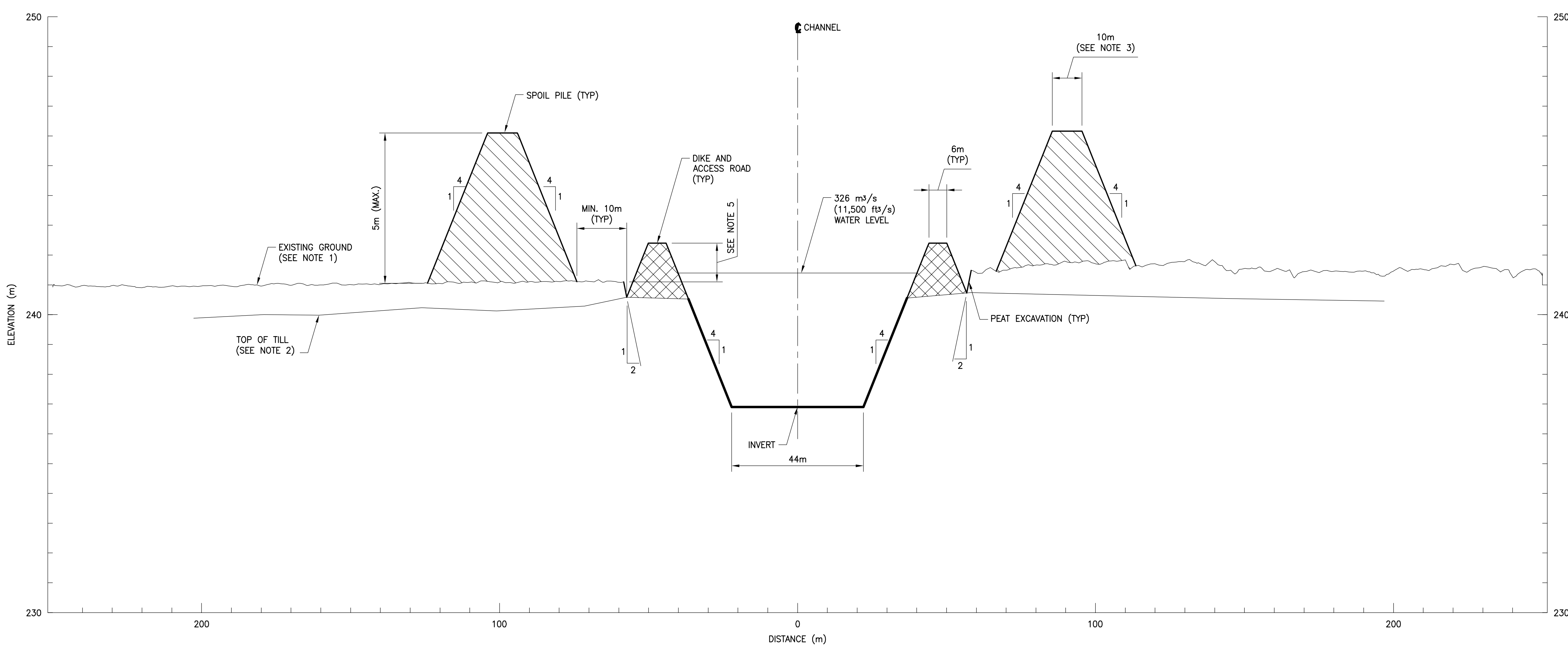
PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

JUNE 2017 | PLATE 12 | REV: 0

11x17

NOTES:

1. EXISTING GROUND SURFACE BASED ON LIDAR (2011).
2. TOP OF FILL APPROXIMATE AND BASED ON 2016 PEAT PROBE SURVEY PROJECTED TO CHANNEL CENTERLINE.
3. SPOIL PILE SHOWN DOES NOT INCLUDE ADJUSTMENTS FOR MATERIAL HANDLING AND ASSUMES CONSTANT WIDTH AND HEIGHT ALONG ENTIRE CHANNEL LENGTH.
4. ALL UNITS ARE METRIC AND IN METRES UNLESS OTHERWISE SPECIFIED. TRANSVERSE MERCATOR PROJECTION, AND 1983 CSRS, ZONE 14. ELEVATIONS ARE IN METRES ABOVE SEA LEVEL (MSL) AND ARE REFERENCING CANADIAN GEODETIC VERTICAL DATUM 1928 (CGVD28).
5. TOP OF DIKE BUILT TO MINIMUM 0.6 m ABOVE TOP OF PEAT OR MINIMUM 1.0 m ABOVE DESIGN WATER LEVEL, WHICHEVER IS GREATER.



B / PL11 SECTION (STA 7+500)

1:800 HOR SCALE
1:80 VER SCALE

NO.	YY/MM/DD	DESCRIPTION	ISSUED BY	CHECKED BY
0	17/06/23	ISSUED WITH FINAL REPORT	SKB (HATCH)	DEA (KGS)

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PRELIMINARY DESIGN FOR REACH 2 OF THE LAKE ST. MARTIN OUTLET CHANNEL

CROSS SECTION B (STA 7+500)
REACH 2 CHANNEL OPTION 4

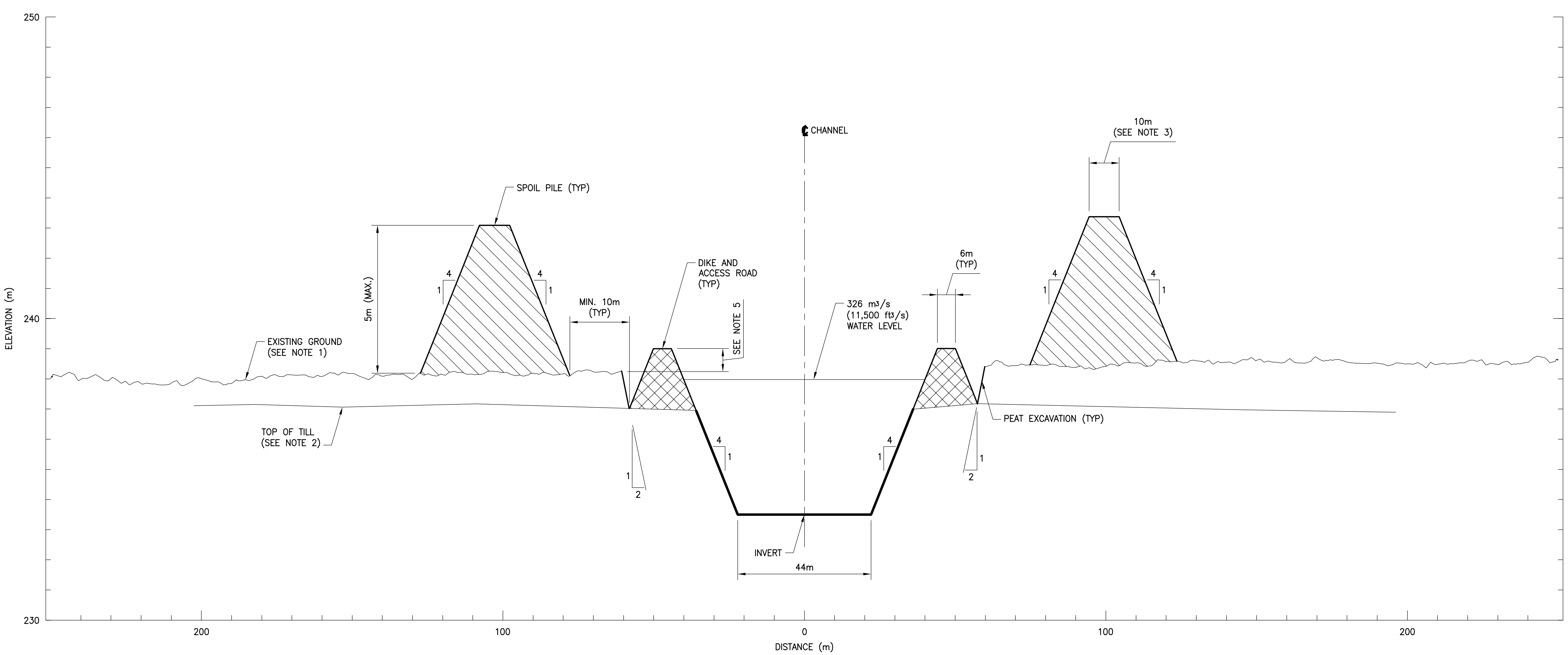
PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

JUNE 2017 | PLATE 13 | REV: 0

11x17

NOTES:

1. EXISTING GROUND SURFACE BASED ON LIDAR (2011).
2. TOP OF FILL APPROXIMATE AND BASED ON 2016 PEAT PROBE SURVEY PROJECTED TO CHANNEL CENTERLINE.
3. SPOIL PILE SHOWN DOES NOT INCLUDE ADJUSTMENTS FOR MATERIAL HANDLING AND ASSUMES CONSTANT WIDTH AND HEIGHT ALONG ENTIRE CHANNEL LENGTH.
4. ALL UNITS ARE METRIC AND IN METRES UNLESS OTHERWISE SPECIFIED. TRANSVERSE MERCATOR PROJECTION, AND 1983 CSRS, ZONE 14. ELEVATIONS ARE IN METRES ABOVE SEA LEVEL (MSL) AND ARE REFERENCING CANADIAN GEODETIC VERTICAL DATUM 1928 (CGVD28).
5. TOP OF DIKE BUILT TO MINIMUM 0.6 m ABOVE TOP OF PEAT OR MINIMUM 1.0 m ABOVE DESIGN WATER LEVEL, WHICHEVER IS GREATER.



C / PL11 SECTION (STA 11+500)
1:800 HOR SCALE
1:80 VER SCALE

NO.	YY/MM/DD	DESCRIPTION	ISSUED BY	CHECKED BY
0	17/06/23	ISSUED WITH FINAL REPORT	SKB (HATCH)	DEA (KGS)

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PRELIMINARY DESIGN FOR REACH 2 OF THE LAKE ST. MARTIN OUTLET CHANNEL

CROSS SECTION C (STA 11+500) REACH 2 CHANNEL OPTION 4

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

JUNE 2017 | PLATE 14 | REV: 0

FileName: C:\Users\gasp56924\Documents\RGaspar\CAD42DAY\InRoads Modeling Studies\GMM\nn-nnnn-nnn_Plate 12_13_14-190717a.dwg - Tab: Layout1 Plotted By: GASP56924 17/06/19 [Mon 8:38am]
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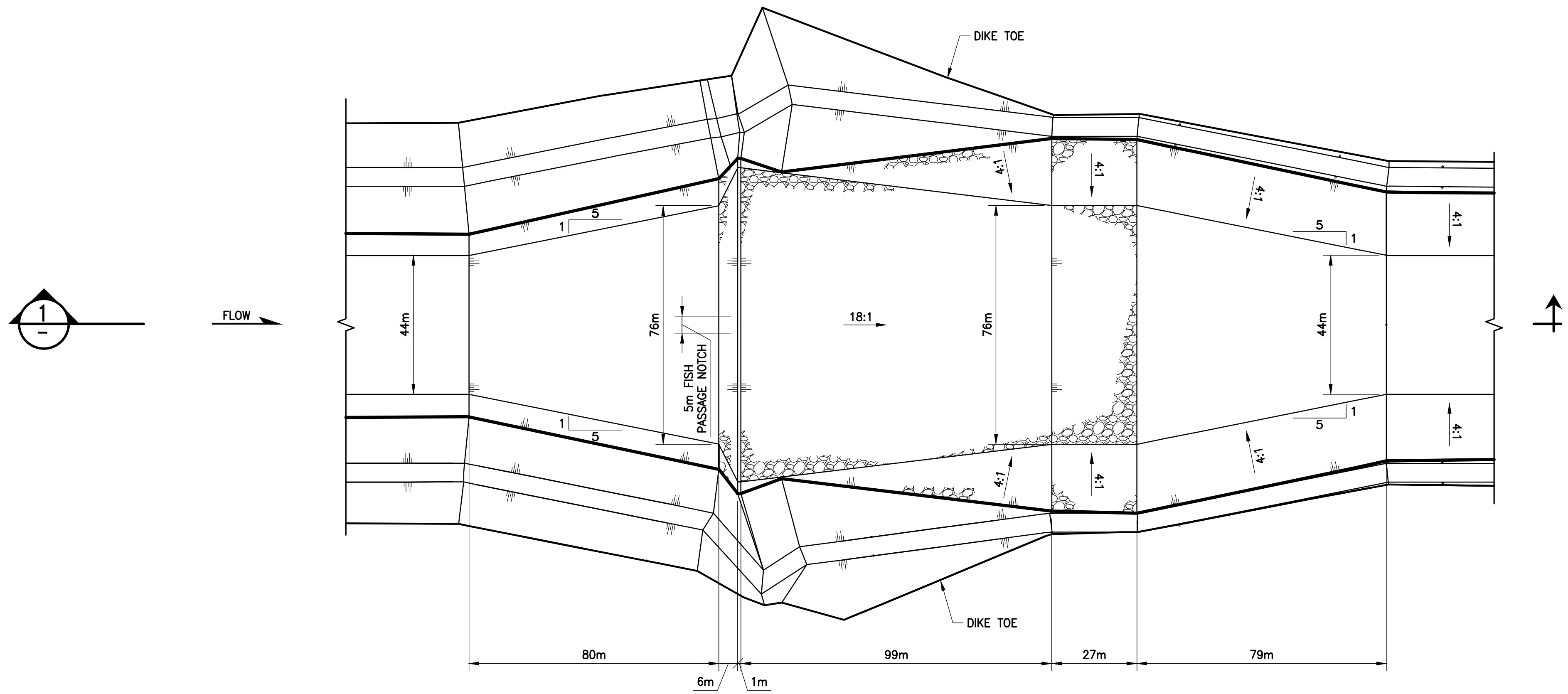
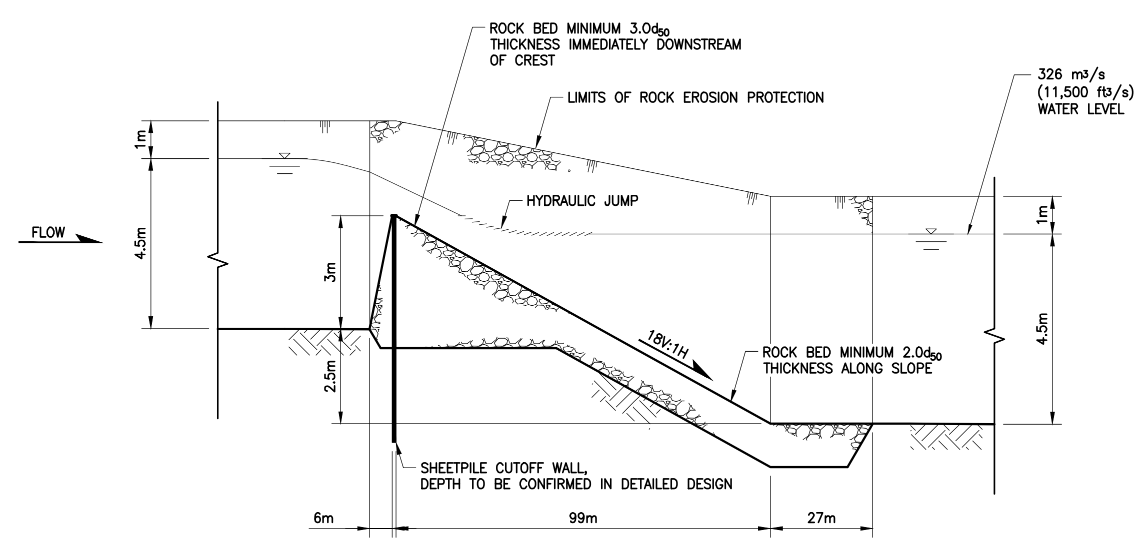


PLAN

SCALE: 1:1000



SECTION (10X EXAGGERATED VERTICAL SCALE)

SCALE: 1:1000

NOTES:

1. ALL UNITS ARE METRIC AND IN METRES UNLESS OTHERWISE SPECIFIED. TRANSVERSE MERCATOR PROJECTION, AND 1983 CSRS, ZONE 14. ELEVATIONS ARE IN METRES ABOVE SEA LEVEL (MSL) AND ARE REFERENCING CANADIAN GEODETIC VERTICAL DATUM 1928 (CGVD28).

NO.	YY/MM/DD	DESCRIPTION	ISSUED BY	CHECKED BY
0	17/06/23	ISSUED WITH FINAL REPORT	SKB (HATCH)	AJB (HATCH)

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PRELIMINARY DESIGN FOR REACH 2 OF THE LAKE ST. MARTIN OUTLET CHANNEL

PLAN & PROFILE OF TYPICAL DROP STRUCTURE ON REACH 2 CHANNEL OPTION 4

JUNE 2017 | PLATE 15 | REV: 0

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

APPENDIX A

UAV DRONE SURVEY OF REACH 1

KGS GROUP CONSULTING ENGINEERS

MEMORANDUM

TO: Colin Siepman, P. Eng.

FROM: Mark Wilcox, C.E.T.
Brooke Irving, C.E.T.

DATE: June 23, 2017

FILE NO: 16-0300-005

RE: Preliminary Design for Reach 2 of the Lake St. Martin Outlet Channel
UAV and DEM Development QA/QC for the Reach 1 Existing Channel

1.0 INTRODUCTION

KGS Group was retained by Manitoba Infrastructure (MI) to undertake a UAV (unmanned aerial vehicle) capture and survey to define the as-built conditions (at time of capture) of the Lake St. Martin Reach 1 Outlet Channel. In collaboration with Taiga Air Services, this work was completed in the fall of 2016 and is described in this document. This component of work is part of the extensive field investigation program that gathered geologic, topographic and bathymetric data along the alignments of the various preliminary design options considered as part of this project.

2.0 PROJECT DATA CAPTURE

2.1 UAV Capture

Taiga Air Services was responsible for the capture of data using a SenseFly Ebee with a 18.2 megapixel Sony WX220 with a 4mm focal length. This is a survey grade UAV photogrammetric drone with post-processing capabilities. Prior to the UAV flight, KGS Group established horizontal and vertical survey control in the area, and set up photo control locations. 17 photo control locations were established and the methodology is described in further detail in Section 2.2. Five flights were flown by Taiga, and commenced at 12:38pm on September 13th, 2016 and were completed at 3:44pm on the same day. Mission 3 was spilt into 2 flights due to battery life and wind conditions but the flights were processed together because it covered the same area. These flights covered the entire length of the channel (approximately 5.5 kilometres), and covered a width of approximately 300 metres (on average) of the channel. Taiga post-processed the collected data and provided KGS Group with calibrated, raw LAS files of the collected, unclassified point cloud and .tif files of the digital ortho imagery (DOI).

2.2 Survey Data Collection

KGS Group GIS/Geomatics personnel provided ground support survey services to a 1 day drone flight along the Reach 1 channel, Lake St. Martin, Manitoba. Representative cross sections of the channel were captured at approximately 1 km intervals and photo targets were set at approximately 750m intervals along REACH 1. This survey was completed on September 12th, 2016, one day prior to the drone flight. The cross sections included a shot of channel bottom passed the water level, a water level shot and ground shots up and over the embankments on both sides of the channel. The photo targets included a surveyed shot of 3 points – the corner and ends of the photo targets.

All survey information was completed in Universal Transverse Mercator (UTM) NAD83 CSRS Zone 14 projection and CGVD28 elevation datum. All topographical survey capture was completed using Global Positioning System (GPS) Real Time Kinematic (RTK) and Post Processing Kinematic (PPK) style surveying. Stop and go kinematic occupations of three or more epochs were used for the topographic survey. Positions were collected by using real time correction with UHF radio links that communicate between the rover and the base. The accuracy of the topographic points is within +/- 1.0 cm in horizontal and +/- 1.5 cm in vertical.

Geodetic project control benchmark, LSM_KGS1, was established in the field by having a GPS receiver collect static data on established project benchmarks AL_CP001 and 95R503. Control point LSM_KGS1, a 1.22 metre piece of rebar, was installed at site and also a 0.152 metre nail was set as a temporary check point to ensure QA/QC and repeatability throughout the day. Static occupations on the survey control were performed by L1/L2 dual constellation (GPS and GLONASS) GPS receivers using post-processing procedures. The static data was post-processed in the office. The accuracy of these networks was +/- 0.5 cm in the horizontal and +/- 1.0 cm in the vertical, in accordance with the standard followed by KGS Group. Statistics and confidence levels were provided for all control points established.

3.0 PROJECT DATA PROCESSING & DEM DEVELOPMENT

3.1 DATA PROCESSING & QUALITY CONTROL

Using the calibrated LAS files provided by Taiga Air Services, KGS Group began processing the tiled flights to create a bare-earth digital elevation model (DEM) of the as-built conditions of the Reach 1 channel. KGS Group assessed the point density and coverage of the UAV data to ensure there were no large gaps in the data. After assessing the data, KGS Group determined that the missions had overflown targets resulting in some distortion of the data towards the end of the mission flight lines. KGS Group clipped back the point cloud data to be within 75m of photo control locations, to ensure no distortion of the data was present. Data between missions still overlapped and this clip back of the data did not result in any data voids. As the drone used by Taiga Air Services is a survey grade, photogrammetric UAV, the point cloud data received is not classified (like a traditional LiDAR point cloud would be). The drone is not able to capture true ground conditions in areas with thick tree canopy and vegetation and the drone auto-triangulation does not represent the surface of the water properly. KGS reclassified the data that represented ground conditions. Areas with thick vegetation and tree canopy, along with the water in the channel remain unclassified in the point cloud.

Prior to building the bare earth DEM, KGS Group assessed the raw point data to determine the vertical and horizontal accuracy of the raw LAS point cloud data and digital ortho imagery and the survey data collected by KGS Group at the photo control locations (using the corner point of the photo control). These results have been summarized in the table below:

TABLE 1
RAW UAV TARGET DATA QUALITY ASSESSMENT (VERTICAL & HORIZONTAL)

Point ID	Northing	Easting	Code	Survey Elevation	UAV Elevation	Difference in Elevation	Difference in Horizontal	Mission
JWM1001	5739873.803	553448.638	TARGET	246.597	246.581	0.016	0.000	Mission 1
JWM1021	5740466.073	553943.072	TARGET	247.251	247.409	-0.158	0.000	Mission 1
JWM1043	5741036.611	554408.301	TARGET	248.456	248.387	0.069	0.000	Mission 2
JWM1062	5741625.293	554890.055	TARGET	247.012	247.069	-0.057	0.090	Mission 2
JWM1080	5742228.483	555368.093	TARGET	247.330	247.348	-0.018	0.090	Mission 3
JWM1097	5742800.752	555839.175	TARGET	247.377	247.436	-0.059	0.000	Mission 3
JWM1115	5743362.350	556307.050	TARGET	245.295	245.279	0.016	0.000	Mission 4
JWM1130	5743927.781	556746.532	TARGET	243.184	243.108	0.076	0.050	Mission 4
ALW1002	5739807.605	553520.244	TARGET	246.100	246.279	-0.179	0.000	Mission 1
ALW1012	5740395.992	554047.513	TARGET	247.032	247.149	-0.117	0.080	Mission 1
ALW1024*	5740981.127	554521.982	TARGET	247.068	247.218	-0.150	N/A	Mission 2
ALW1037	5741544.817	555001.026	TARGET	246.730	246.797	-0.067	0.030	Mission 2
ALW1047	5742144.631	555461.694	TARGET	246.762	246.814	-0.052	0.050	Mission 3
ALW1059	5742723.548	555943.423	TARGET	247.740	247.756	-0.016	0.050	Mission 3
ALW1071	5743288.003	556401.737	TARGET	245.754	245.795	-0.041	0.150	Mission 4
ALW1081**	5743860.929	556866.931	TARGET	241.975	242.050	-0.075	N/A	Mission 4
ALW1089	5739664.809	553330.196	TARGET	245.487	245.371	0.116	0.050	Mission 1

Note:
*Damaged Target
**Poor Image Quality

TABLE 2
SUMMARY OF THE RAW UAV DATA QUALITY ASSESSMENT

Survey vs UAV LAS Stats	
-0.041	Average
0.083	Standard Deviation
0.042	+/-
0.116	Max
-0.179	Min
17	Count

Table 2 is a statistical breakdown of the points shown on Table 1. These points are of the photo control locations, and are located along the top of the dike spoil piles.

3.2 DIGITAL ELEVATION MODEL (DEM) BUILD AND QA/QC

After completing the QA/QC on the raw LAS points, KGS Group proceeded with building a 0.5m bare-earth DEM in Universal Transverse Mercator (UTM) NAD83 Zone 14 projection, using only the points that had been reclassified as ground. Though there were a total of 4 LAS files provided by Taiga Air Services, KGS proceeded with a single, initial DEM build using all four mission datasets. The DEM was then clipped to the limits of the edge of vegetation to ensure no additional interpolation was present in the DEM outside the area of interest.

KGS Group then proceeded with QA/QC on the initial bare earth DEM, comparing the DEM to the topographic survey cross sections that were collected by KGS Group's surveyors on September 12, 2016. Any survey points that fell outside the edge of vegetation or within the channel (for example, water level and bottom of channel survey points) were removed for the purpose of this analysis. Please see the table below of the ArcGIS analysis on these points:

TABLE 3
SUMMARY OF THE DEM DATA QUALITY ASSESSMENT

Survey vs DEM Stats	
-0.108	Average
0.205	Standard Deviation
0.103	+/- From a Mean
-0.512	Max
0.343	Min
102	Count

KGS Group also completed an analysis on the raw LAS point cloud data, the bare earth DEM, and the survey points to ensure that the shape of the DEM accurately represents the earth at that point. 2 cross sections have been generated for two locations along the Reach 1 channel and are shown in Appendix A.

Using the initial bare earth DEM, KGS Group developed a 3D breakline along the edge of water and used a water level 3D breakline along with channel design breaklines (bottom toes and CL of channel) to develop an "underwater" TIN. This TIN was then exported to a raster format and was fused to the initial bare earth DEM.

Due to limitations of UAV point cloud data capturing top of vegetation, KGS needed to develop backslopes along the spoil piles so that the as-built conditions would transition smoothly to the original ground conditions, captured by the LiDAR in 2011. A 3D breakline was developed along the top shoulder of the spoil pile, and was used to create an outer toe/bottom of slope 3D breakline, graded at a 4:1 slope (as in the design). Using this data, a TIN was created for the spoil backslopes. The TIN was exported to a raster format and merged to the bare-earth/design channel DEM. This is the final product at time of memo publication.

Based on the above observations and quality control processes, the DEM has an accuracy of +/- 0.1 metres.

4.0 STATEMENT OF LIMITATIONS AND CONDITIONS

4.1 THIRD PARTY USE OF REPORT

This report has been prepared for Manitoba Infrastructure to whom this report has been addressed and any use a third party makes of this memorandum, or any reliance on or decisions made based on it, are the responsibility of such third parties. KGS Group accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions undertaken based on this report.

Prepared By:

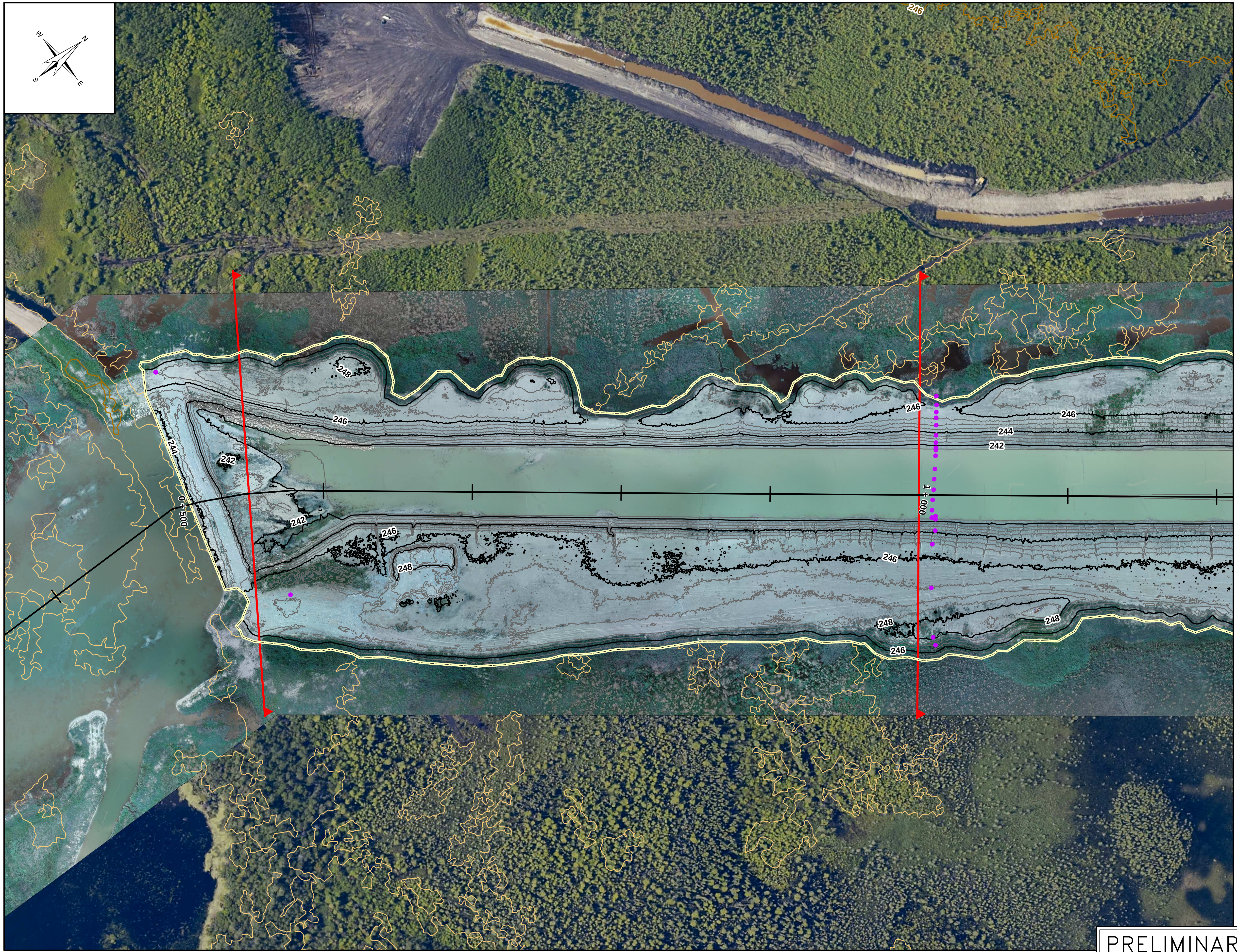
Brooke Irving, C.E.T.
GIS Technologist

Approved By:

Mark Wilcox, C.E.T.
Senior Geomatics Specialist

BI/ama
Enclosure

FIGURES



LEGEND:

- KGS Survey Data (September 2016)
- Cross Section
- Channel Alignment
- 2m Index UAV Contour (2016)
- 0.5m UAV Contour (2016)
- 2m Index LiDAR Contour (2011)
- 0.5m LiDAR Contour (2011)
- Limit of UAV DEM

25 0 25 50 75 100

Meters

SCALE: 1:2,500 METRIC 11"x17"

All units are metric and in metres unless otherwise specified.
Transverse Mercator Projection, NAD 1983, Zone 14
Elevations are in metres above sea level (MSL)

NO.	YY/MM/DD	DESCRIPTION	ISSUED BY	CHECK BY
0	17/06/23	ISSUED WITH UAV QA/QC MEMO	BJI	MSW

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PRELIMINARY DESIGN FOR REACH 2 OF THE LSM OUTLET

REACH 1 SITE OVERVIEW (SHEET 1 OF 7)

JUNE 2017 | FIGURE 01.01 | REV: 0

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

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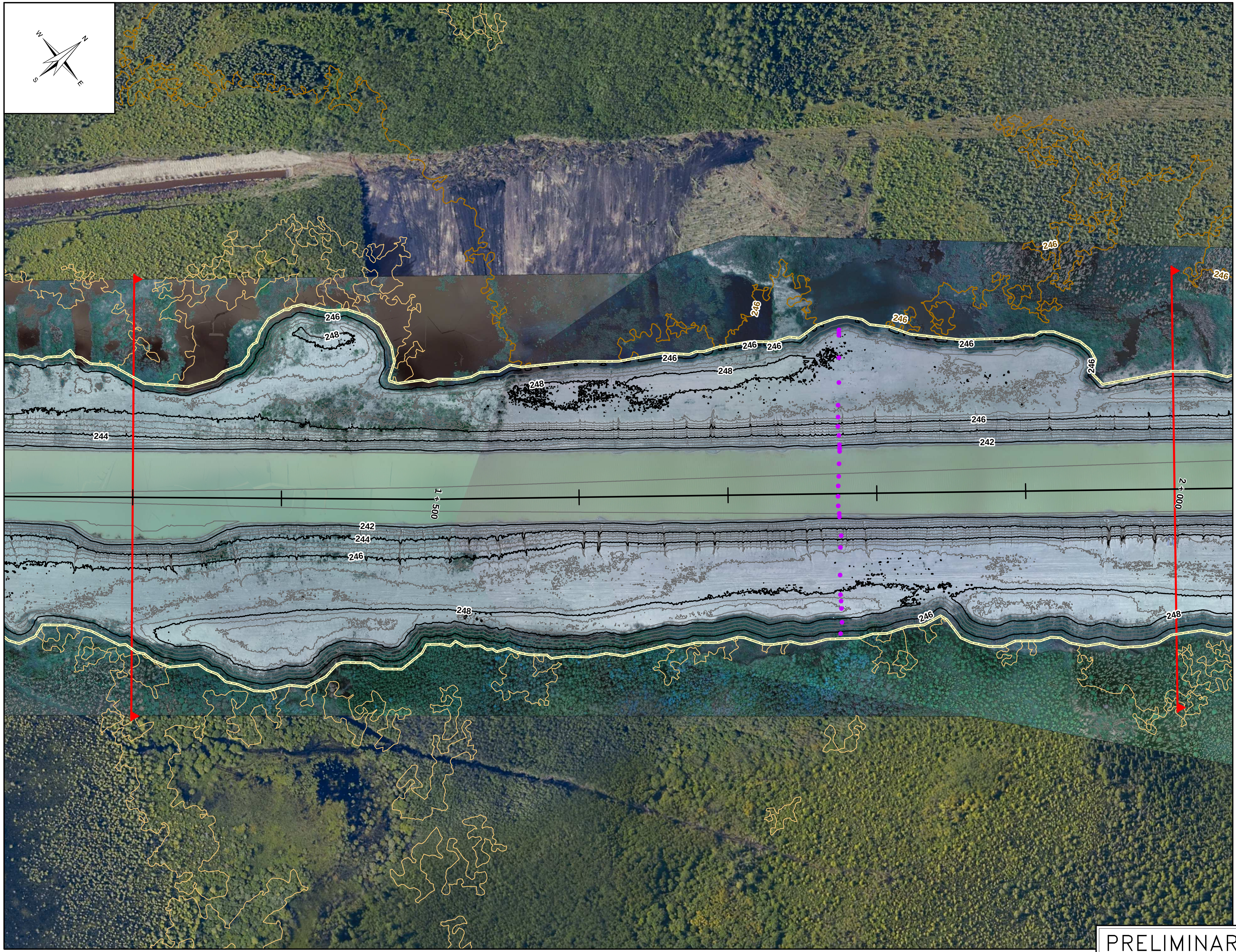
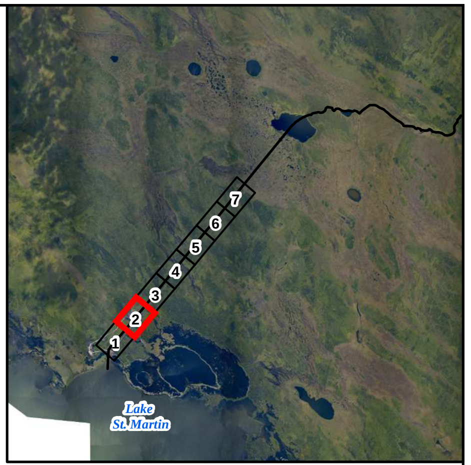
11"x17" PLOT SCALE 1:1





LEGEND:

- KGS Survey Data (September 2016)
- Cross Section
- Channel Alignment
- 2m Index UAV Contour (2016)
- 0.5m UAV Contour (2016)
- 2m Index LiDAR Contour (2011)
- 0.5m LiDAR Contour (2011)
- Limit of UAV DEM

25 0 25 50 75 100
Meters

SCALE: 1:2,500 METRIC 11"x17"

All units are metric and in metres unless otherwise specified.
Transverse Mercator Projection, NAD 1983, Zone 14
Elevations are in metres above sea level (MSL)

NO.	YY/MM/DD	DESCRIPTION	ISSUED BY	CHECK BY
0	17/06/23	ISSUED WITH UAV QA/QC MEMO	BJI	MSW

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PRELIMINARY DESIGN FOR REACH 2 OF THE LSM OUTLET

REACH 1 SITE OVERVIEW (SHEET 2 OF 7)

JUNE 2017 FIGURE 01.02 REV: 0

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

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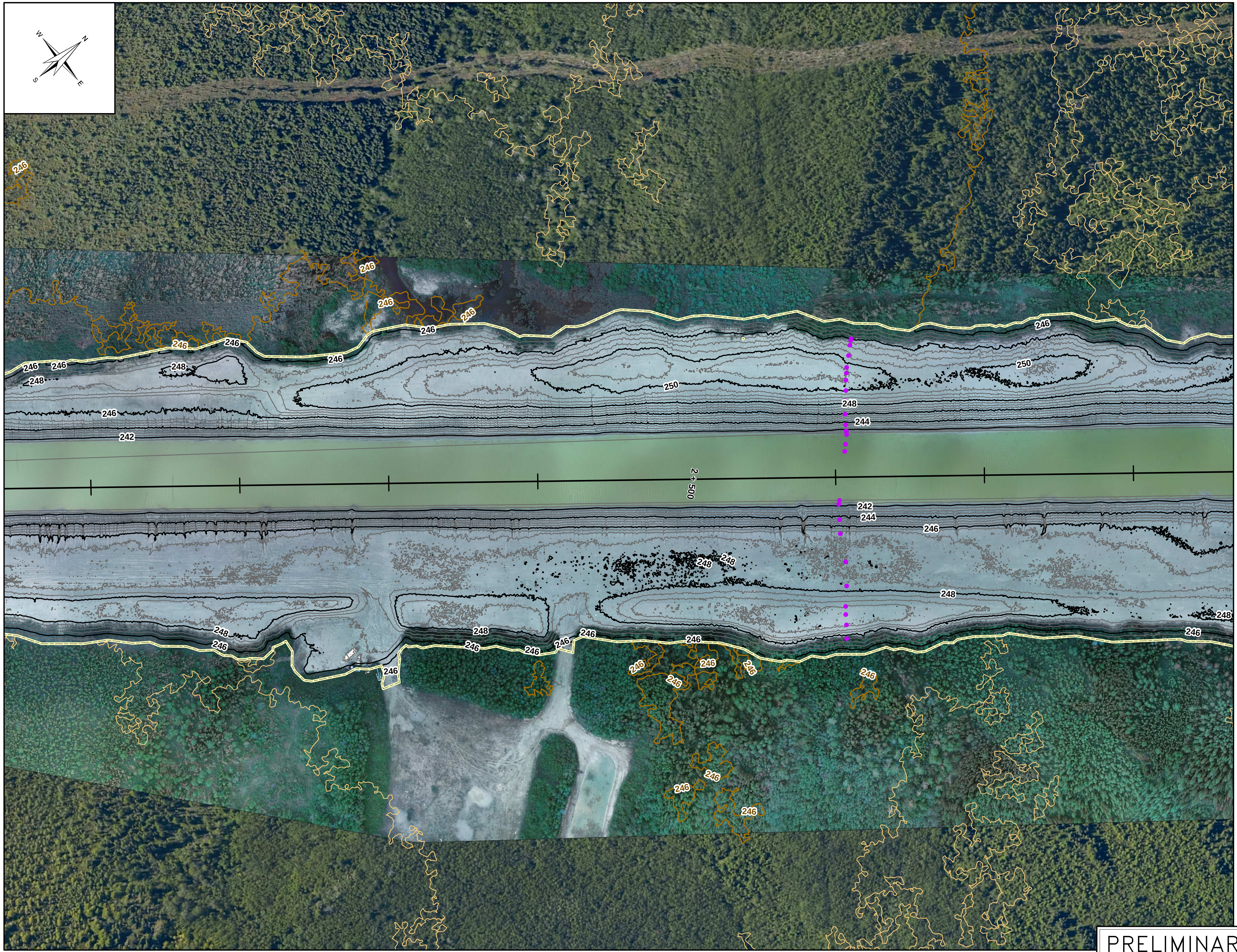

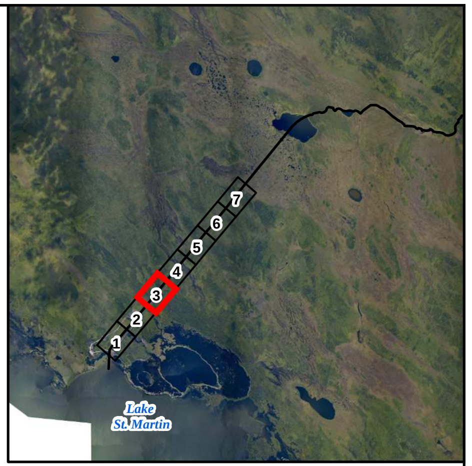

LEGEND:

- KGS Survey Data (September 2016)
- Cross Section
- Channel Alignment
- 2m Index UAV Contour (2016)
- 0.5m UAV Contour (2016)
- 2m Index LiDAR Contour (2011)
- 0.5m LiDAR Contour (2011)
- Limit of UAV DEM

25 0 25 50 75 100

Meters

SCALE: 1:2,500 METRIC 11"x17"

All units are metric and in metres unless otherwise specified.
Transverse Mercator Projection, NAD 1983, Zone 14
Elevations are in metres above sea level (MSL)

NO.	YY/MM/DD	DESCRIPTION	ISSUED BY	CHECK BY
0	17/06/23	ISSUED WITH UAV QA/QC MEMO	BJI	MSW

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Manitoba Infrastructure

PRELIMINARY DESIGN FOR REACH 2 OF THE LSM OUTLET

REACH 1 SITE OVERVIEW (SHEET 3 OF 7)

JUNE 2017 | FIGURE 01.03 | REV: 0

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

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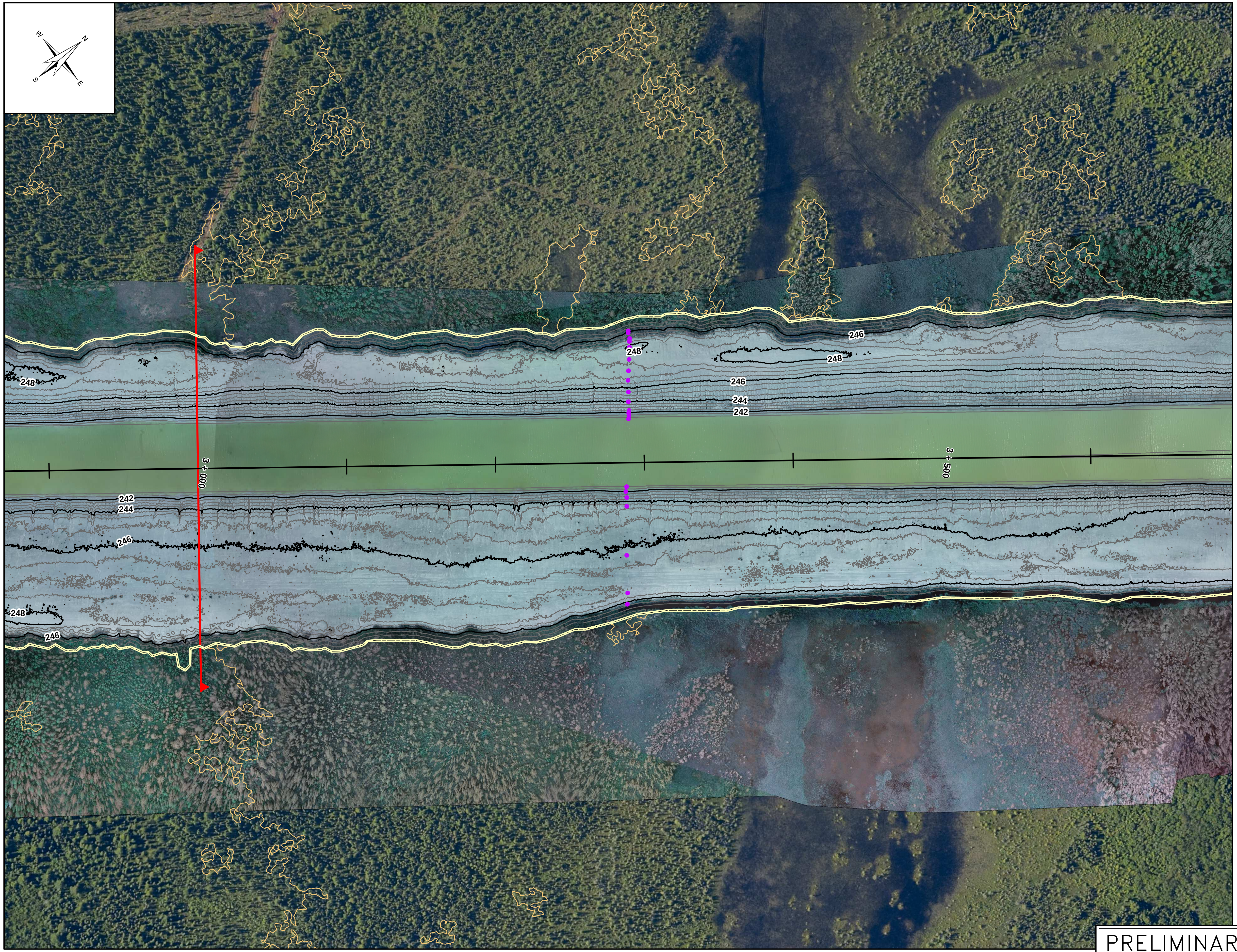

LEGEND:

- KGS Survey Data (September 2016)
- Cross Section
- Channel Alignment
- 2m Index UAV Contour (2016)
- 0.5m UAV Contour (2016)
- 2m Index LiDAR Contour (2011)
- 0.5m LiDAR Contour (2011)
- Limit of UAV DEM

25 0 25 50 75 100

Meters

SCALE: 1:2,500 METRIC 11"x17"

All units are metric and in metres unless otherwise specified.
Transverse Mercator Projection, NAD 1983, Zone 14
Elevations are in metres above sea level (MSL)

NO.	YY/MM/DD	DESCRIPTION	ISSUED BY	CHECK BY
0	17/06/23	ISSUED WITH UAV QA/QC MEMO	BJI	MSW

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PRELIMINARY DESIGN FOR REACH 2 OF THE LSM OUTLET

REACH 1 SITE OVERVIEW (SHEET 4 OF 7)

JUNE 2017 | FIGURE 01.04 | REV: 0

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

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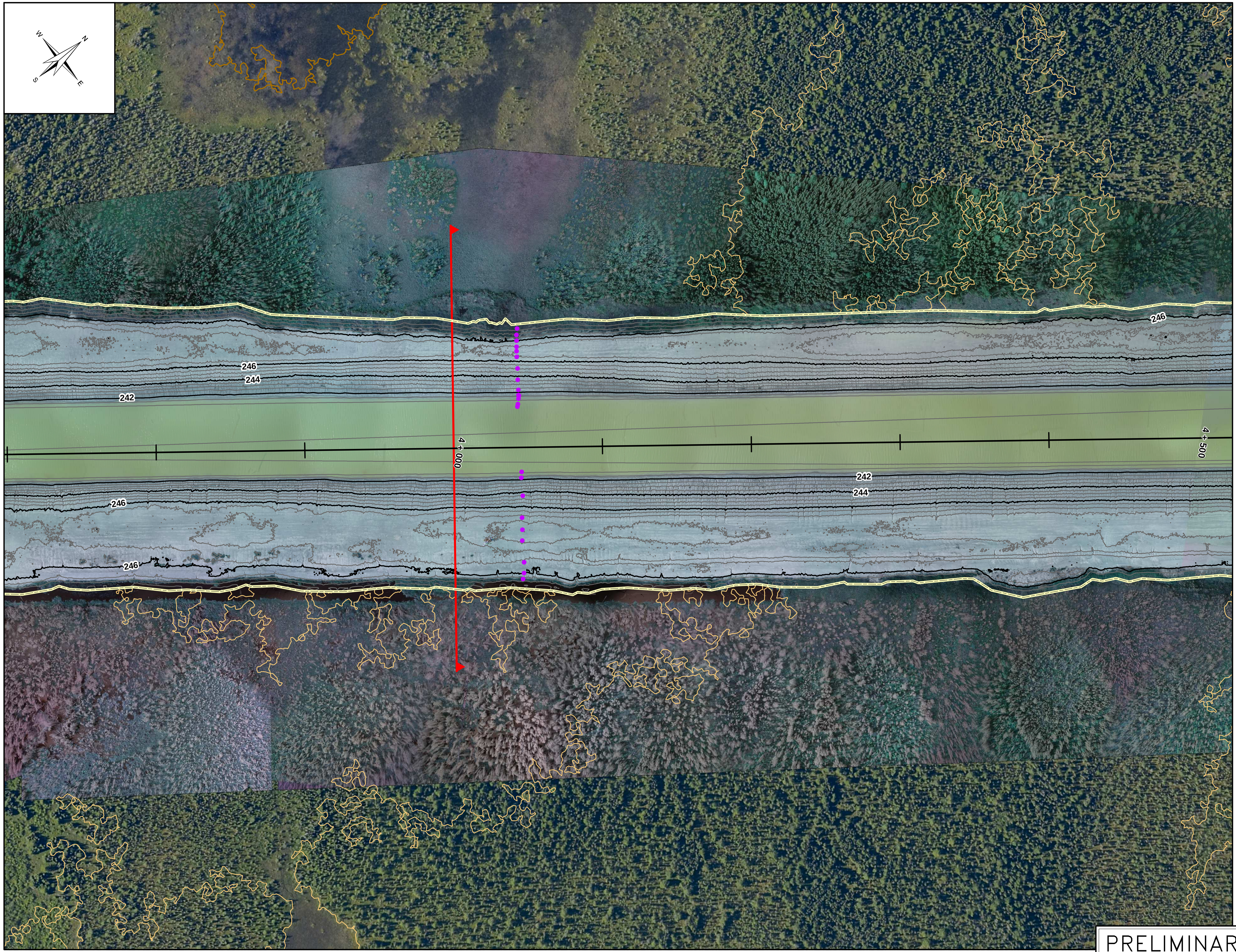

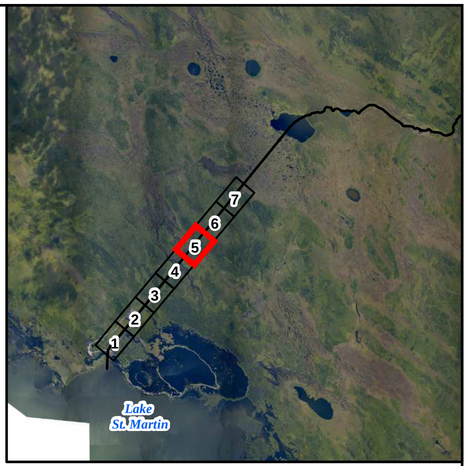

LEGEND:

- KGS Survey Data (September 2016)
- Cross Section
- Channel Alignment
- 2m Index UAV Contour (2016)
- 0.5m UAV Contour (2016)
- 2m Index LiDAR Contour (2011)
- 0.5m LiDAR Contour (2011)
- Limit of UAV DEM

25 0 25 50 75 100
Meters

SCALE: 1:2,500 METRIC 11"x17"

All units are metric and in metres unless otherwise specified.
Transverse Mercator Projection, NAD 1983, Zone 14
Elevations are in metres above sea level (MSL)

NO.	YY/MM/DD	DESCRIPTION	ISSUED BY	CHECK BY
0	17/06/23	ISSUED WITH UAV QA/QC MEMO	BJI	MSW

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PRELIMINARY DESIGN FOR REACH 2 OF THE LSM OUTLET

REACH 1 SITE OVERVIEW (SHEET 5 OF 7)

JUNE 2017 | FIGURE 01.05 | REV: 0

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

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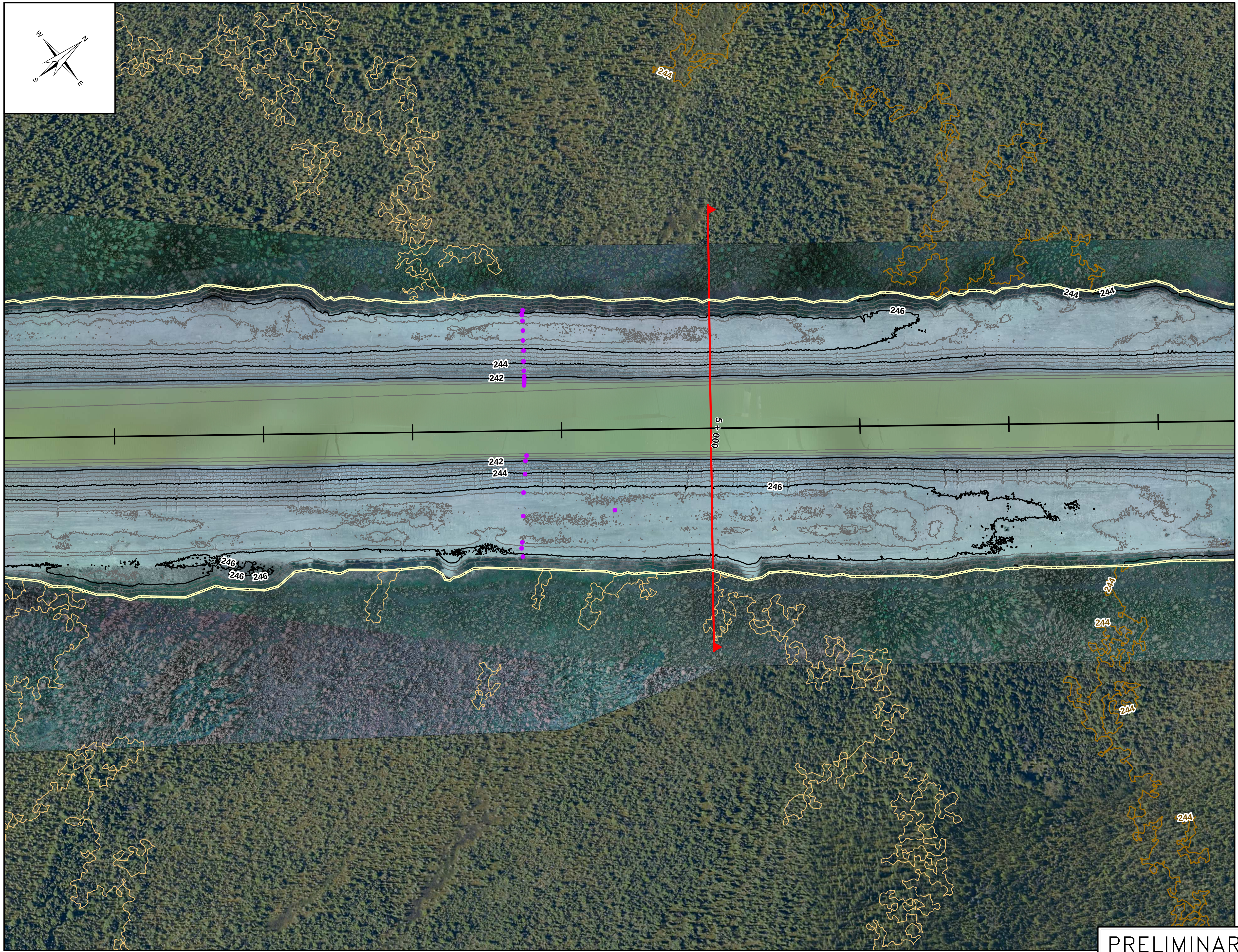

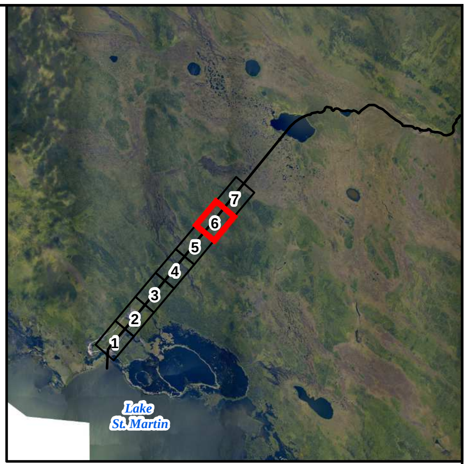

LEGEND:

- KGS Survey Data (September 2016)
- Cross Section
- Channel Alignment
- 2m Index UAV Contour (2016)
- 0.5m UAV Contour (2016)
- 2m Index LiDAR Contour (2011)
- 0.5m LiDAR Contour (2011)
- Limit of UAV DEM

25 0 25 50 75 100

Meters

SCALE: 1:2,500 METRIC 11"x17"

All units are metric and in metres unless otherwise specified.
Transverse Mercator Projection, NAD 1983, Zone 14
Elevations are in metres above sea level (MSL)

NO.	YY/MM/DD	DESCRIPTION	ISSUED BY	CHECK BY
0	17/06/23	ISSUED WITH UAV QA/QC MEMO	BJI	MSW

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PRELIMINARY DESIGN FOR REACH 2 OF THE LSM OUTLET

REACH 1 SITE OVERVIEW (SHEET 6 OF 7)

JUNE 2017 | FIGURE 01.06 | REV: 0

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

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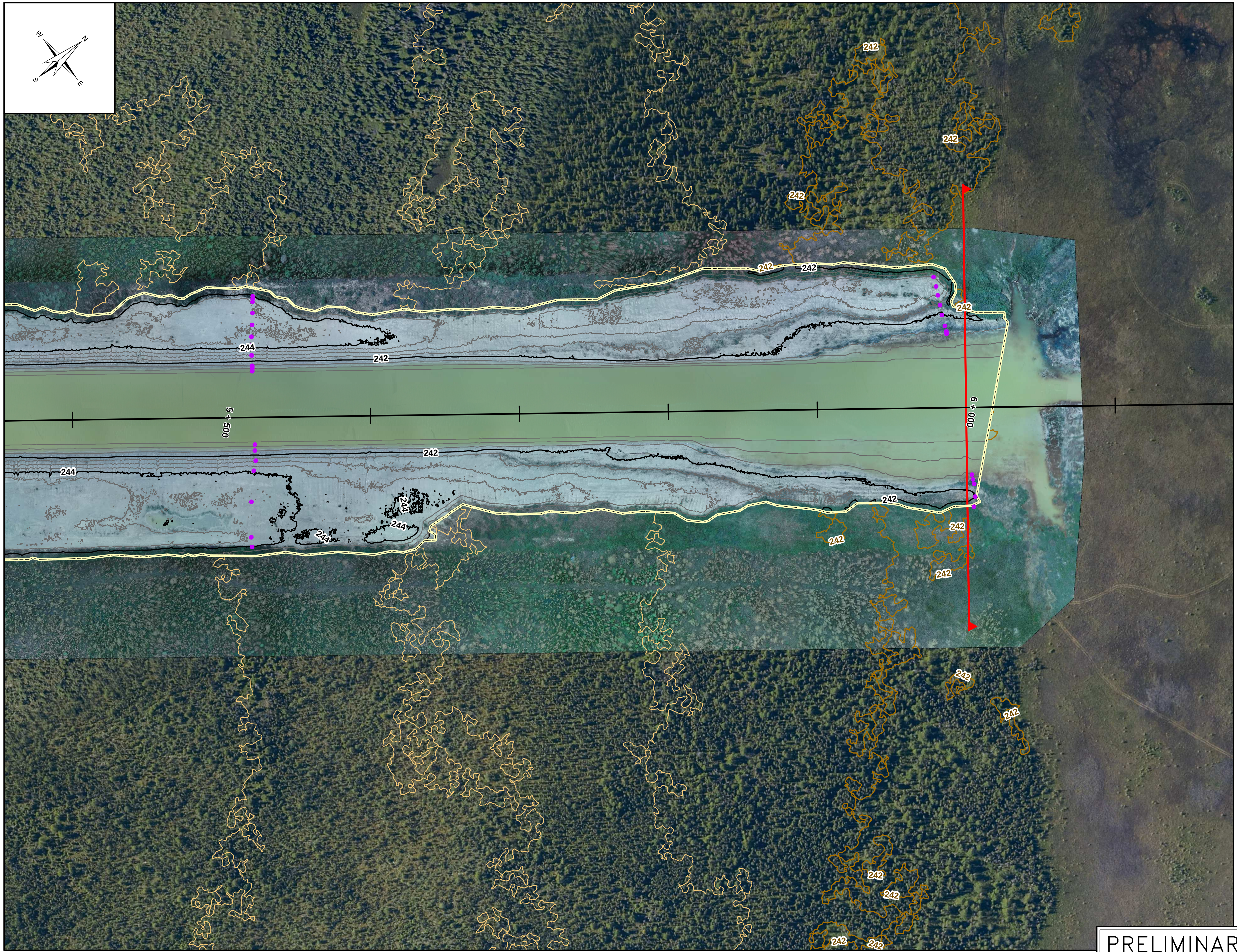
11"x17" PLOT SCALE 1:1



LEGEND:

- KGS Survey Data (September 2016)
- Cross Section
- Channel Alignment
- 2m Index UAV Contour (2016)
- 0.5m UAV Contour (2016)
- 2m Index LiDAR Contour (2011)
- 0.5m LiDAR Contour (2011)
- Limit of UAV DEM

25 0 25 50 75 100

Meters

SCALE: 1:2,500 METRIC 11"x17"

All units are metric and in metres unless otherwise specified.
Transverse Mercator Projection, NAD 1983, Zone 14
Elevations are in metres above sea level (MSL)

NO.	YY/MM/DD	DESCRIPTION	ISSUED BY	CHECK BY
0	17/06/23	ISSUED WITH UAV QA/QC MEMO	BJI	MSW

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Manitoba Infrastructure

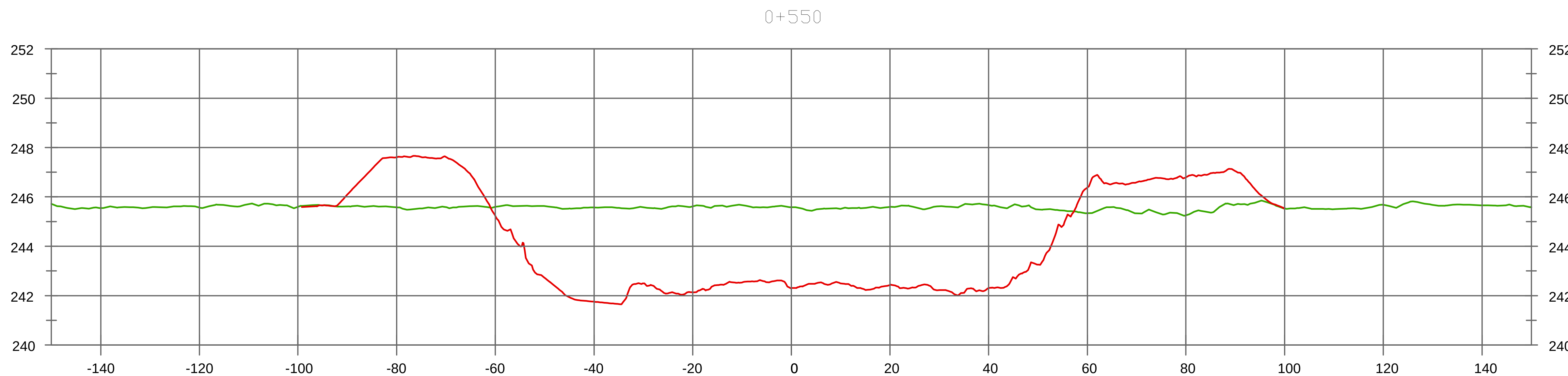
PRELIMINARY DESIGN FOR REACH 2 OF THE LSM OUTLET

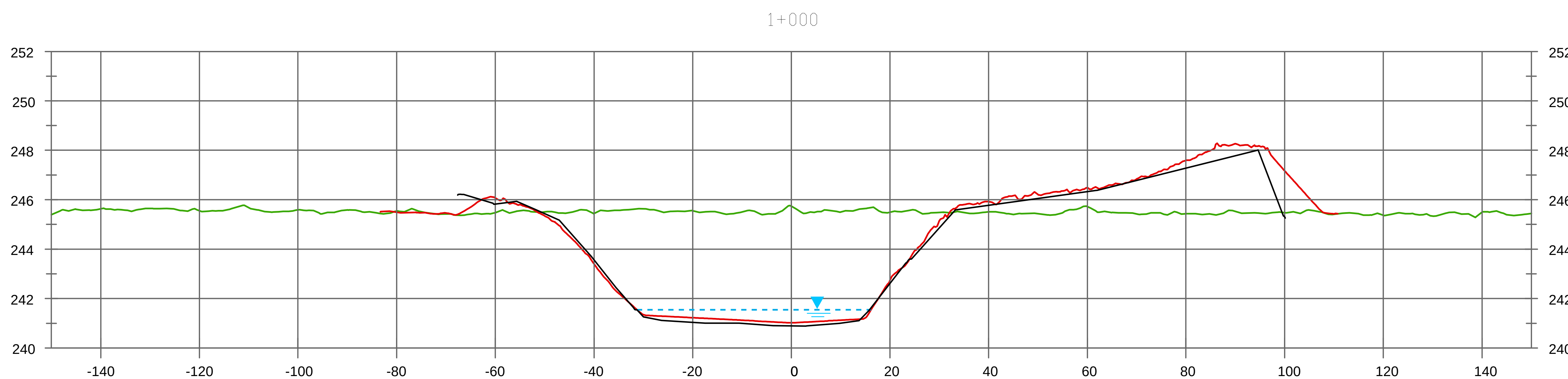
REACH 1 SITE OVERVIEW (SHEET 7 OF 7)

JUNE 2017 | FIGURE 01.07 | REV: 0

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

FileName: P:\Projects\2016\16-0300-005\Dwg\GIS\MXDs\Rev0\UAV_QAQC_Memo\16-0300-005_Fig01_Rev0.mxd
11"x17" PLOT SCALE 1:1





LEGEND:

- UAV As–Built (September 2016)
- KGS Survey Section (September 2016)
- LiDAR Original Ground (2011)
- Water Level (September 2016)

NOTES:
1. Water Level: 241.52m (September 2016).
2. Sections shown with survey data are interpolated within 50m.

10 0 10 20 30 40
Meters
HORIZONTAL SCALE: 1:1,000 METRIC 11"x17"

2 0 2 4 6 8
Meters
VERTICAL SCALE: 1:200 METRIC 11"x17"

All units are metric and in metres unless otherwise specified.
Transverse Mercator Projection, NAD 1983, Zone 14
Elevations are in metres above sea level (MSL)

NO.	YY/MM/DD	DESCRIPTION	ISSUED BY	CHECK BY
0	17/06/23	ISSUED WITH UAV QA/QC MEMO	BJI	MSW

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PRELIMINARY DESIGN FOR REACH 2 OF THE LSM OUTLET

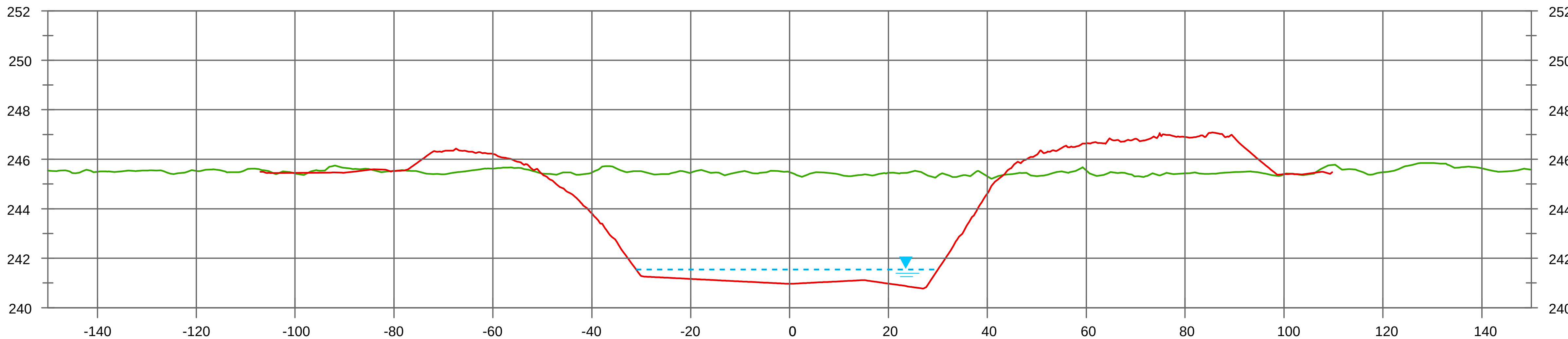
CROSS SECTION PLAN (SHEET 1 OF 4)

JUNE 2017 | FIGURE 02 | REV: 0

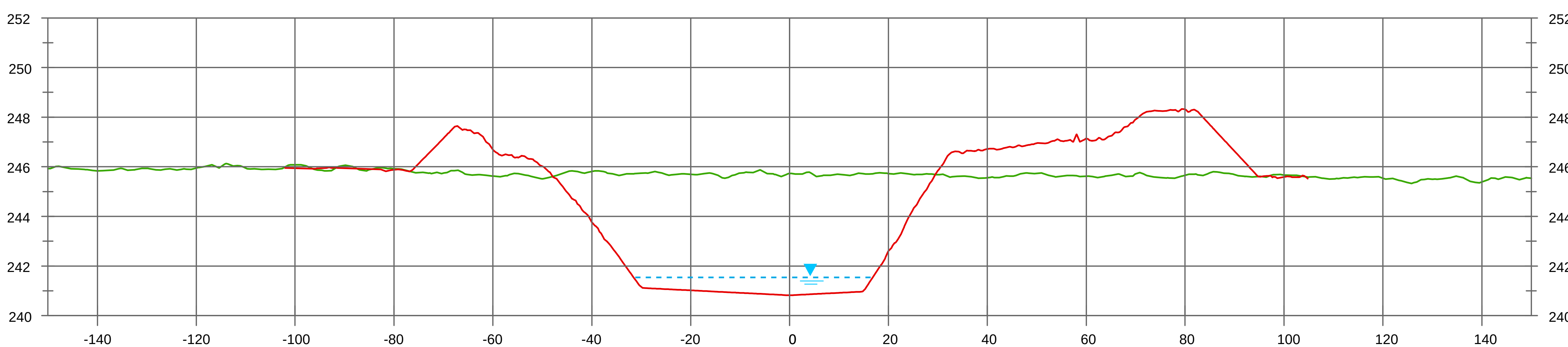
PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

FileName: P:\Projects\2016\16-0300-005\Dwg\GIS\MXDs\Rev0\UAV_QAQC_Memo\16-0300-005_Fig02_Rev0.mxd
11"x17" PLOT SCALE 1:1

1+300



2+000



LEGEND:

- UAV As-Built (September 2016)
- KGS Survey Section (September 2016)
- LiDAR Original Ground (2011)
- Water Level (September 2016)

NOTES:
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10 0 10 20 30 40
Meters
HORIZONTAL SCALE: 1:1,000 METRIC 11"x17"

2 0 2 4 6 8
Meters
VERTICAL SCALE: 1:200 METRIC 11"x17"

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Transverse Mercator Projection, NAD 1983, Zone 14
Elevations are in metres above sea level (MSL)

NO.	YY/MM/DD	DESCRIPTION	ISSUED BY	CHECK BY
0	17/06/23	ISSUED WITH UAV QA/QC MEMO	BJI	MSW

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PRELIMINARY DESIGN FOR REACH 2 OF THE LSM OUTLET

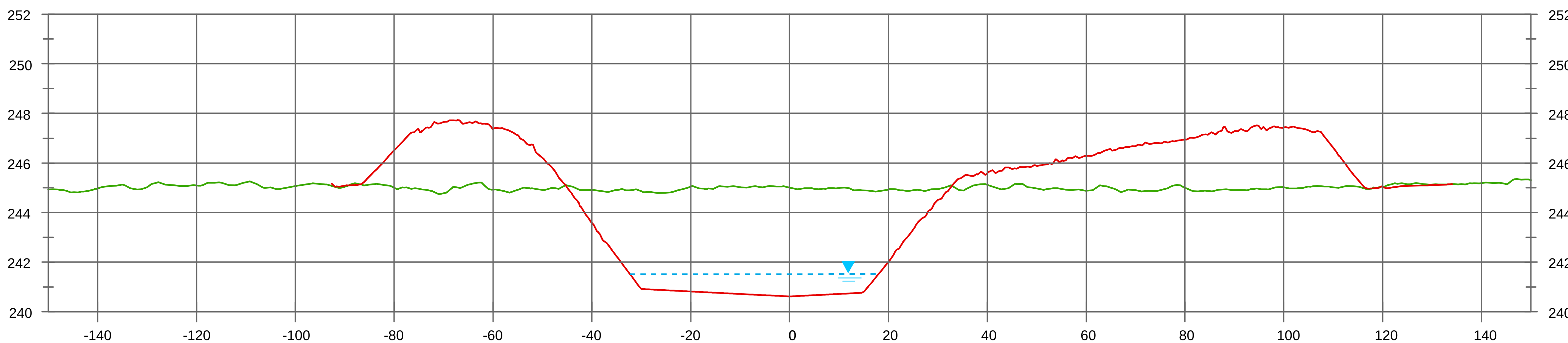
CROSS SECTION PLAN (SHEET 2 OF 4)

JUNE 2017 | FIGURE 02 | REV: 0

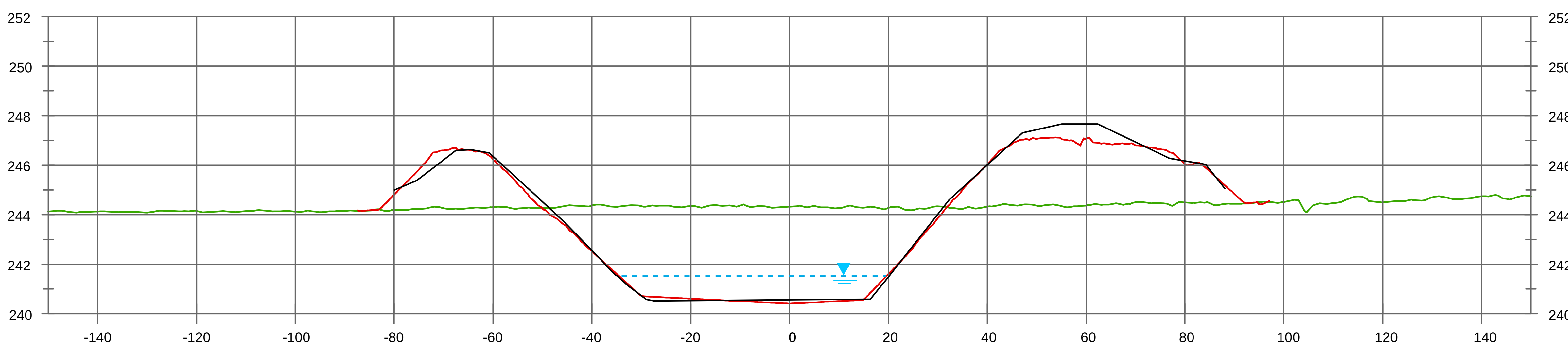
PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

FileName: P:\Projects\2016\16-0300-005\Dwg\GIS\MXDs\Rev0\UAV_QAQC_Memo\16-0300-005_Fig02_Rev0.mxd
11"x17" PLOT SCALE 1:1

3+000



4+000



LEGEND:

- UAV As-Built (September 2016)
- KGS Survey Section (September 2016)
- LiDAR Original Ground (2011)
- Water Level (September 2016)

NOTES:
1. Water Level: 241.52m (September 2016).
2. Sections shown with survey data are interpolated within 50m.

10 0 10 20 30 40
Meters
HORIZONTAL SCALE: 1:1,000 METRIC 11"x17"

2 0 2 4 6 8
Meters
VERTICAL SCALE: 1:200 METRIC 11"x17"

All units are metric and in metres unless otherwise specified.
Transverse Mercator Projection, NAD 1983, Zone 14
Elevations are in metres above sea level (MSL)

NO.	YY/MM/DD	DESCRIPTION	ISSUED BY	CHECK BY
0	17/06/23	ISSUED WITH UAV QA/QC MEMO	BJI	MSW

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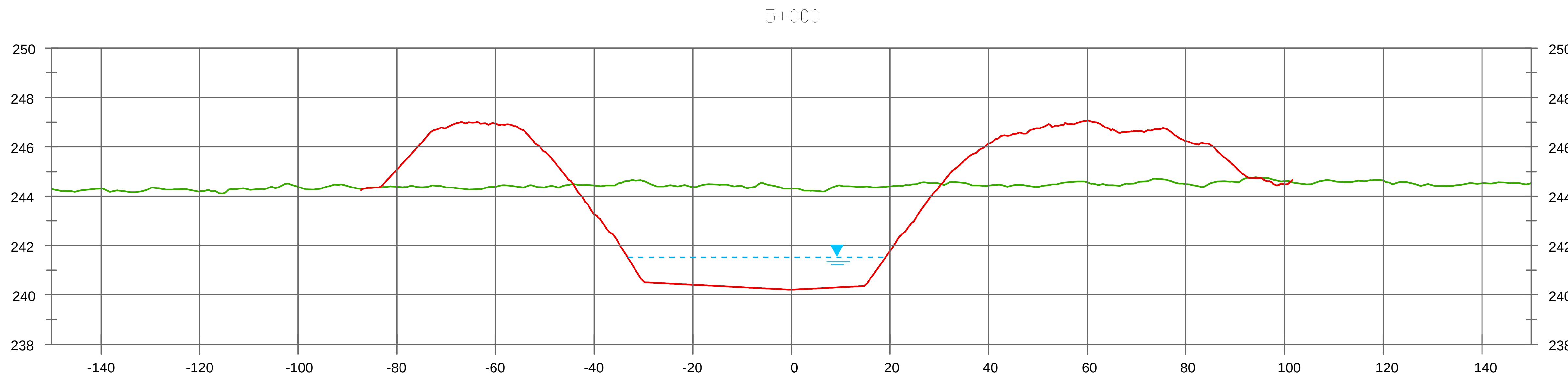
PRELIMINARY DESIGN FOR REACH 2 OF THE LSM OUTLET

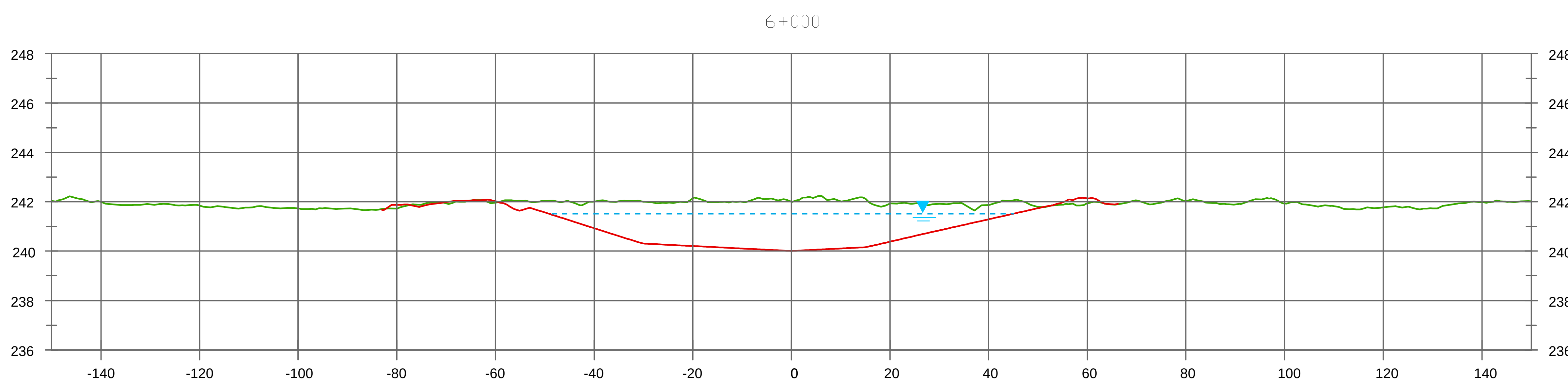
CROSS SECTION PLAN (SHEET 3 OF 4)

JUNE 2017 | FIGURE 02 | REV: 0

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

FileName: P:\Projects\2016\16-0300-005\Dwg\GIS\MXDs\Rev0\UAV_QAQC_Memo\16-0300-005_Fig02_Rev0.mxd
11"x17" PLOT SCALE 1:1





LEGEND:

- UAV As-Built (September 2016)
- KGS Survey Section (September 2016)
- LiDAR Original Ground (2011)
- Water Level (September 2016)

NOTES:
1. Water Level: 241.52m (September 2016).
2. Sections shown with survey data are interpolated within 50m.

10 0 10 20 30 40
Meters
HORIZONTAL SCALE: 1:1,000 METRIC 11"x17"

2 0 2 4 6 8
Meters
VERTICAL SCALE: 1:200 METRIC 11"x17"

All units are metric and in metres unless otherwise specified.
Transverse Mercator Projection, NAD 1983, Zone 14
Elevations are in metres above sea level (MSL)

NO.	YY/MM/DD	DESCRIPTION	ISSUED BY	CHECK BY
0	17/06/23	ISSUED WITH UAV QA/QC MEMO	BJI	MSW

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Manitoba Infrastructure

PRELIMINARY DESIGN FOR REACH 2 OF THE LSM OUTLET

CROSS SECTION PLAN (SHEET 4 OF 4)

JUNE 2017 | FIGURE 02 | REV: 0

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

FileName: P:\Projects\2016\16-0300-005\Dwg\GIS\MXDs\Rev0\UAV_QAQC_Memo\16-0300-005_Fig02_Rev0.mxd
11"x17" PLOT SCALE 1:1

APPENDIX B

2016 PEAT PROBES AND HAND AUGER DATA

Lake St Martin Peat Investigation

13-Sep-16 **15-Sep-16**

*Distances on plots are approximate

Hand Auger

Station	Site Descriptor	Date	Depth of Peat [m]	Depth to Water [m]	Auger Depth [m]	Soil Description	Location - UTM 14 U Easting - Northing	Notes
PP1	R2 Option 3	13-Sep-16	-	-		soft, silty material	14 U 565185 5747461	In Reach 3 excavated channel
PP2	R2 Option 3	13-Sep-16	1.7	0		silt on tip	14 U 565097 5747282	
PP3	R2 Option 3	13-Sep-16	1.75	0		clay till	14 U 565008 5747102	
PP4	R2 Option 3	13-Sep-16	1.6	0.3		clay till	14 U 564919 5746923	
PP5	R2 Option 3	13-Sep-16	0.95	0		silt till	14 U 564830 5746744	
PP6	R2 Option 3	13-Sep-16	2.05	0.3		clay till	14 U 564742 5746565	
PP7	R2 Option 3	13-Sep-16	2	0.15		silt till	14 U 564653 5746385	
PP8	R2 Option 3	13-Sep-16	1.5	0.2		silt till	14 U 564564 5746206	
HA-01	R2 Option 3	13-Sep-16	1.5	0.4	1.5 to 1.7	clay till-grey, moist, LP-IP, firm, some fg-cg sand. Pocket Pen = 1.0	14 U 564522 5746119	
PP9	R2 Option 3	13-Sep-16	1.4	0.15		silt till	14 U 564476 5746027	silt till at 1.4 to 1.5 m
PP10	R2 Option 3	13-Sep-16	1	0.1		silt till	14 U 564387 5745848	
PP11	R2 Option 3	13-Sep-16	1.5	0.2		silt till	14 U 564298 5745668	
HA-02	R2 Option 3	13-Sep-16	1.4	0.3	1.4 to 1.6	silt till - grey, moist, LP, some fg-cg sand. Pocket Pen = 2.0	14 U 564247 5745562	
PP12	R2 Option 3	13-Sep-16	1.3	0.3		Silt till	14 U 564209 5745489	
PP13	R2 Option 3	13-Sep-16	1.55	0.4		Silt till	14 U 564121 5745310	
PP14	R2 Option 3	13-Sep-16	0.7	0.4		Silt till	14 U 564032 5745131	
HA-03	R2 Option 3	13-Sep-16	0.4	0.4	0.4 to 0.6	Peat - increased organics with depth. Silt till - grey, moist, LP with fg-cg sand	14 U 564011 5745086	
PP15*	R2 Option 3	13-Sep-16	0.25	0.25		Silt till	14 U 563943 5744951	Peat - dam (topsoil/organics), silt powder on tip dry
PP16	R2 Option 3	13-Sep-16	1.75	0.45		Silt till	14 U 563855 5744772	
PP17	R2 Option 3	13-Sep-16	2.2	0.4		-	14 U 563766 5744593	
PP18	R2 Option 3	13-Sep-16	1.6	0		Silt till	14 U 563677 5744414	
PP19	R2 Option 3	13-Sep-16	1.1	0		Silt till	14 U 563588 5744234	
HA-04	R2 Option 3	13-Sep-16	1.96	0	2.0 to 2.2	0.2 silt till - grey, moist to wet, LP, some to with fg-cg sand	14 U 563536 5744127	
PP20	R2 Option 3	14-Sep-16	2.5	0		clay till	14 U 563500 5744055	Clay till 2.5-2.65 or softer till zone - higher sand content, silt till 2.65 (dense till)
PP21	R2 Option 3	14-Sep-16	2.05	0.5		silt till	14 U 563411 5743876	
PP22	R2 Option 3	14-Sep-16	1.5	1		--	14 U 563322 5743697	
PP23	R2 Option 3	14-Sep-16	1.3	0.3		silt till	14 U 563234 5743517	
PP24	R2 Option 3	14-Sep-16	1.2	0.3		silt till	14 U 563068 5743415	
PP25	R2 Option 3	14-Sep-16	1.5	0.3		silt till	14 U 562889 5743326	
PP26	R2 Option 3	14-Sep-16	1.05	0.8		silt till	14 U 562709 5743238	
PP27	R2 Option 3	14-Sep-16	1.8	0		silt till	14 U 562530 5743150	
PP28	R2 Option 3	14-Sep-16	2.2	0		silt till	14 U 562351 5743061	
PP29	R2 Option 3	14-Sep-16	1.5	0		silt till	14 U 562171 5742973	
PP30	R2 Option 3	14-Sep-16	2.3	0		silt till	14 U 561992 5742884	
PP31 **HA-05**	R2 Option 3	14-Sep-16	2.1	0	2.1 to 2.3	Clay till - Grey, moist , stiff, IP, some fg-cg sand. Pocket Pen = 1.5	14 U 561813 5742796	
PP32	R2 Option 3	14-Sep-16	2.2	0		silt till	14 U 561633 5742707	
PP33	R2 Option 3		1.7	0		silt till	14 U 561454 5742619	
PP34	R2 Option 3	14-Sep-16	1.6	0		silt till	14 U 561274 5742531	Silt till @1.6-1.8 m
			1.87	0		-		
PP34.1	R2 Option 3	15-Sep-16	1.8	0.2			14 U 561152 5742470	Clay till - trace clay with fg-mg sand, some cg sand
PP35	R2 Option 3	14-Sep-16	1.38	0		Clay till	14 U 560947 5742492	
PP36	R2 Option 3	14-Sep-16	1.4	0		Clay till	14 U 560747 5742493	
PP37	R2 Option 3	14-Sep-16	1	0		Clay till	14 U 560547 5742494	
PP38	R2 Option 3	14-Sep-16	1.52	0		Clay till	14 U 560347 5742495	Clay till - ML, grey, moist-wet, some clay, some fg-mg sand, trace cg sand
PP39	R2 Option 3	14-Sep-16	1.41	0		Clay till	14 U 560147 5742497	
HA-06	R2 Option 3	14-Sep-16	0.7	0		Clay Till	14 U 560036 5742497	Clay till - grey, some cg sand w/fg-mg sand, trace fg gravel, LP-IP
PP40	R2 Option 3	14-Sep-16	1.14	0		Clay till	14 U 559947 5742498	
PP41	R2 Option 3	14-Sep-16	0.93	0.3		Clay till	14 U 559747 5742499	Clay till - tan, wet, fg-mg sand, NP, some cg sand
PP42	R2 Option 3	14-Sep-16	1.55	0		Clay till	14 U 559547 5742500	Clay till - grey, wet, some fg-mg sand, trace cg sand
PP43	R2 Option 3	14-Sep-16	1.97	0		Silt till	14 U 559347 5742501	Silt till - tan, wet, LP, some fg-mg sand, trace cg sand
PP44	R2 Option 3	14-Sep-16	1.31	0.3		Silt till	14 U 559147 5742503	Silt till - grey, wet, some fg-mg sand, trace cg sand
PP45	R2 Option 3	14-Sep-16	1.14	0.85		Silty clay	14 U 558958 5742550	Silty clay - grey mottled w/ tan, trace fg-mg sand, LP-IP
PP46	R2 Option 3	14-Sep-16	1.19	-		Silty clay	14 U 558782 5742644	Silty clay - brown, LP, moist
PP47	R2 Option 3	14-Sep-16	1.45	0.2			14 U 558605 5742738	
PP48	R2 Option 3	14-Sep-16	1.21	0.01			14 U 558429 5742832	tan, trace cg-sand found
PP49	R2 Option 3	14-Sep-16	0.89	0.01		-	14 U 558252 5742926	fg- sand in peat
HA-07	R2 Option 3	13-Sep-16	0.76	-	0.76 to 0.96	Clay Till	14 U 558136 5742987	Clay till -beige/tan, trace inclusions of fg-cg gravel, some fg-cg sand
PP50	R2 Option 3	13-Sep-16	1	0		Clay Till	14 U 558076 5743020	Wet, grey, some fg-cg sand
PP51	R2 Option 3	13-Sep-16	0.95	0		Silt till	14 U 557899 5743114	fg sand above grey till
PP52	R2 Option 3	13-Sep-16	1.09	0.08		Silt till	14 U 557723 5743208	0.14 m thick sand & gravel deposit, grey
PP53	R2 Option 3	13-Sep-16	0.66	-		Silt till	14 U 557546 5743302	
PP54	R2 Option 3	13-Sep-16	0.722	-		Silt till	14 U 557370 5743396	brown silt till, trace clay, moist, peat wet
PP55	R2 Option 3	13-Sep-16	0.75	0.5		Silt till	14 U 557193 5743490	trace clay
PP56	R2 Option 3	13-Sep-16	1.13	0		Silt till	14 U 557017 5743584	
PP57	R2 Option 3	13-Sep-16	1.32	0		Silt till	14 U 556840 5743678	tan, wet
PP57.1	R2 Option 3	13-Sep-16					14 U 556705 5743754	

Lake St Martin Peat Investigation

13-Sep-16 **15-Sep-16**

*Distances on plots are approximate

Hand Auger

Station	Site Descriptor	Date	Depth of Peat [m]	Depth to Water [m]	Auger Depth [m]	Soil Description	Location - UTM 14 U Easting - Northing	Notes
PP58	R2 Option 4	15-Sep-16	2.4	-0.2			14 U 561014 5742328	
PP59	R2 Option 4	15-Sep-16	1.7	-0.1			14 U 560875 5742184	
PP60	R2 Option 4	15-Sep-16	1.5	-0.2			14 U 560736 5742040	
PP61	R2 Option 4	15-Sep-16	0.5	0			14 U 560597 5741896	
PP62	R2 Option 4	15-Sep-16	1.7	-0.1			14 U 560458 5741752	
PP63	R2 Option 4						14 U 560319 5741608	Could not reach PP63. Too much open water in bog to reach safely.
PP63A	R2 Option 4	15-Sep-16	2.55	-0.3			14U 560319 5741624	
HA-08	R2 Option 4	14-Sep-16	2.3	-0.1			14U 560217 5741500	
PP64	R2 Option 4	14-Sep-16	3	-0.2			14 U 560181 5741464	
PP65	R2 Option 4	14-Sep-16	1.9	0			14 U 560042 5741320	
PP66	R2 Option 4	14-Sep-16	2.5	0			14 U 559903 5741177	
PP67	R2 Option 4	14-Sep-16	1.25	0			14 U 559764 5741033	
PP68	R2 Option 4	14-Sep-16	1	0			14 U 559625 5740889	
PP69	R2 Option 4	14-Sep-16	2.2	0.2			14 U 559486 5740745	
PP70	R2 Option 4	14-Sep-16	1	0.3			14 U 559347 5740601	
PP71	R2 Option 4	14-Sep-16	1.2	-			14 U 559209 5740457	
PP72	R2 Option 4	14-Sep-16	1.2	1.2			14 U 559070 5740313	
PP73	R2 Option 4	14-Sep-16	2	0.3			14 U 558931 5740169	
PP74	R2 Option 4	14-Sep-16	1.9	0.1			14 U 558792 5740025	
HA-09	R2 Option 4	14-Sep-16	2.5	0			14U 558698 5739926	
PP75	R2 Option 4	14-Sep-16	1.65	0			14 U 558653 5739881	
PP76	R2 Option 4	13-Sep-16	1.95	0			14 U 558514 5739737	Edge of treed area close to bog. Coniferous.
PP77	R2 Option 4	13-Sep-16	2.3	-0.2			14 U 558375 5739593	Peat bog next to open pond.
PP78	R2 Option 4	13-Sep-16	1.05	0			14 U 558236 5739449	Treed area. Dense bush. Moderate to large coniferous trees. Some deciduous.
PP79	R2 Option 4	13-Sep-16	0.95	0			14 U 558098 5739305	Treed area. Coniferous. Large trees. Moderately dense.
PP80	R2 Option 4	13-Sep-16	2.3	0			14 U 557959 5739162	Peat bog.
PP81 **HA-10**	R2 Option 4	13-Sep-16	2.3	0	2.25 to 2.45	Light grey silty clay with organics and some fg-cg sand	14 U 557820 5739018	Peat bog.
PP82	R2 Option 4	13-Sep-16	2.2	0.2		light grey silty clay	14 U 557681 5738874	Edge of treed area close to bog. Coniferous.
PP83	R2 Option 4	13-Sep-16	1.7	0			14 U 557542 5738730	Marshy area with 6-foot + high bushes
PP84	R2 Option 4	13-Sep-16	0.8	0.2			14 U 557403 5738586	Treed area. Deciduous.
PP85	R2 Option 4	13-Sep-16	0.6	-			14 U 557264 5738442	Lightly treed area with grasses. Deciduous.
PP86	R2 Option 4	13-Sep-16	0.125	-		Dark grey.	14 U 557126 5738298	Grassy marshland near edge of Lake St. Martin
PP86.1	R2 Option 4	13-Sep-16	None	-0.7		Lake bottom with some rocks	14 U 557018 5738187	Station is in 0.7 m deep water in Lake St. Martin.
PP87	R2 - Opt 4 transects	13-Sep-16	1.25	0			14 U 557477 5739382	Very dense bush. Some deciduous trees.
PP88	R2 - Opt 4 transects	13-Sep-16	1.2	0			14 U 557548 5739312	Swamp. Bush with some trees (both coniferous and deciduous)
PP89	R2 - Opt 4 transects	13-Sep-16	1.7	0			14 U 557620 5739243	Edge of peat bog. Near bush and dead coniferous trees.
PP90	R2 - Opt 4 transects	13-Sep-16	1.3	0		Additional ~0.5 m penetration into grey silty clay till	14 U 557692 5739174	Peat bog.
PP91	R2 - Opt 4 transects	13-Sep-16	1.4	0		Additional ~0.6 m penetration into grey silty clay till	14 U 557764 5739104	Peat bog.
PP92	R2 - Opt 4 transects	13-Sep-16	2.8	0			14 U 557908 5738965	Near edge of treed area. Larger coniferous trees.
PP93	R2 - Opt 4 transects	13-Sep-16	2.3	0			14 U 557980 5738896	Peat bog. Near edge of moderately treed area (coniferous)
PP94	R2 - Opt 4 transects	13-Sep-16	2.3	0			14 U 558052 5738826	Peat bog. Near edge of lightly treed area (coniferous) with some bush.
PP95	R2 - Opt 4 transects	13-Sep-16	2.6	0			14 U 558124 5738757	Peat bog. Near edge of lightly treed area (coniferous) with some bush.
PP96	R2 - Opt 4 transects	13-Sep-16	2.8	0.15			14 U 558196 5738688	Swamp. Very dense smaller coniferous trees
PP97	R2 - Opt 4 transects	14-Sep-16	2.1	0.1			14 U 558342 5740279	
PP98	R2 - Opt 4 transects	14-Sep-16	1.8	0			14 U 558414 5740210	
PP99	R2 - Opt 4 transects	14-Sep-16	1.8	0			14 U 558486 5740140	
PP100	R2 - Opt 4 transects	14-Sep-16	2	0			14 U 558558 5740071	
PP101	R2 - Opt 4 transects	14-Sep-16	1.8	0			14 U 558630 5740001	
PP102	R2 - Opt 4 transects	14-Sep-16	2.15	0			14 U 558774 5739862	
PP103	R2 - Opt 4 transects	14-Sep-16	2.4	0			14 U 558846 5739793	
PP104	R2 - Opt 4 transects	14-Sep-16	1.8	0			14 U 558918 5739723	
PP105	R2 - Opt 4 transects	14-Sep-16	1.7	0.1			14 U 558990 5739654	
PP106	R2 - Opt 4 transects	14-Sep-16	2.1	0			14 U 559062 5739585	
PP107	R2 - Opt 4 transects	15-Sep-16	2.2	-0.2			14 U 559857 5741853	
PP108	R2 - Opt 4 transects	15-Sep-16	3	-0.2			14 U 559929 5741783	
PP109	R2 - Opt 4 transects	15-Sep-16	3	-0.2			14 U 560001 5741714	
PP110	R2 - Opt 4 transects	15-Sep-16	2.1	-0.2			14 U 560073 5741645	
PP111	R2 - Opt 4 transects	15-Sep-16	2.3	-0.2			14 U 560145 5741575	
PP112	R2 - Opt 4 transects	15-Sep-16	2	-0.1			14 U 560289 5741436	
PP113	R2 - Opt 4 transects	15-Sep-16	2.7	-0.2			14 U 560361 5741367	
PP114	R2 - Opt 4 transects	15-Sep-16	2.7	-0.2			14 U 560433 5741297	
PP115	R2 - Opt 4 transects	15-Sep-16	2.3	-0.1			14 U 560505 5741228	
PP116	R2 - Opt 4 transects	15-Sep-16	2.1	-0.15			14 U 560577 5741158	

Lake St Martin Peat Investigation

13-Sep-16 **15-Sep-16**

*Distances on plots are approximate

Hand Auger

Station	Site Descriptor	Date	Depth of Peat [m]	Depth to Water [m]	Auger Depth [m]	Soil Description	Location - UTM 14 U Easting - Northing	Notes
PP117	R2 - Opt **3** transects	13-Sep-16	1.155	0		Silt till	14 U 557898 5742548	tan
PP118	R2 - Opt **3** transects	13-Sep-16	1.035	0		-	14 U 557945 5742637	Tough entry, gritty
PP119	R2 - Opt **3** transects	13-Sep-16	2.01	0		-	14 U 557992 5742725	
PP120	R2 - Opt **3** transects	13-Sep-16	1.175	0		Silt till	14 U 558039 5742813	tan with fg-mg sand and trace cg sand
PP121	R2 - Opt **3** transects	13-Sep-16	1.135	0		Clay till	14 U 558086 5742901	
PP122	R2 - Opt **3** transects	14-Sep-16	1.19	0.01		Clay Till	14 U 558180 5743078	Clay till - ML, tan, moist, L-N plasticity, some fg-mg sand
PP123	R2 - Opt **3** transects	13-Sep-16	1.075	0		Silt till	14 U 558227 5743166	Grey silt till with pockets of wet fg sand in peat
PP124	R2 - Opt **3** transects	14-Sep-16	1.18	0		Silt till	14 U 558274 5743254	Silt till - grey, some fg-mg sand, NP, trace cg-sand
PP125	R2 - Opt **3** transects	13-Sep-16	1.37	0		Clay till	14 U 558321 5743343	Grey clay till with some fg-cg sand, IP
PP126	R2 - Opt **3** transects	13-Sep-16	1.7	0		Clay till	14 U 558368 5743431	grey, moist, LP-IP, some fg-mg sand and trace cg sand
PP127	R2 - Opt **3** transects	14-Sep-16	1.4	0		Clay till	14 U 560034 5741997	
PP128	R2 - Opt **3** transects	14-Sep-16	1.13	0		Clay till	14 U 560035 5742097	
PP129	R2 - Opt **3** transects	14-Sep-16	1.37	0		Clay till	14 U 560035 5742197	
PP130	R2 - Opt **3** transects	14-Sep-16	1.22	0		Clay till	14 U 560036 5742297	
PP131	R2 - Opt **3** transects	14-Sep-16	0.98	0		Clay till	14 U 560036 5742397	
PP132	R2 - Opt **3** transects	14-Sep-16	1.31	0		Clay till	14 U 560038 5742597	
PP133	R2 - Opt **3** transects	14-Sep-16	1.42	0		Clay till	14 U 560038 5742697	
PP134	R2 - Opt **3** transects	14-Sep-16	1.45	0		Clay till	14 U 560039 5742797	
PP135	R2 - Opt **3** transects	14-Sep-16	1.32	0		Clay till	14 U 560039 5742897	
PP136	R2 - Opt **3** transects	14-Sep-16	1.55	0		Clay till	14 U 560040 5742997	
PP137	R2 - Opt **3** transects	14-Sep-16	2.45	0		silt till	14 U 561603 5743250	
PP138	R2 - Opt **3** transects	14-Sep-16	2.6	0		silt till	14 U 561647 5743160	Higher sand content
PP139	R2 - Opt **3** transects	14-Sep-16	2.25	0		silt till	14 U 561691 5743071	
PP140	R2 - Opt **3** transects	14-Sep-16	2.2	0		silt till	14 U 561736 5742981	Silt til 2.2 to 2.35 m
PP141	R2 - Opt **3** transects	14-Sep-16	3	0		silt till	14 U 561780 5742891	
PP142	R2 - Opt **3** transects	14-Sep-16	2.1	0		silt till	14 U 561868 5742712	
PP143	R2 - Opt **3** transects	14-Sep-16	2.15	0		silt till	14 U 561912 5742622	
PP144	R2 - Opt **3** transects	14-Sep-16	2.15	0		silt till	14 U 561957 5742532	
PP145	R2 - Opt **3** transects	14-Sep-16	1.8	0		--	14 U 562001 5742443	
PP146	R2 - Opt **3** transects	14-Sep-16	1.9	0.2		--	14 U 562045 5742353	
PP147	R2 - Opt **3** transects	14-Sep-16	2.5	0		silt till	14 U 563984 5743906	
PP148	R2 - Opt **3** transects	14-Sep-16	2.55	0		silt till	14 U 563894 5743950	
PP149	R2 - Opt **3** transects	14-Sep-16	2.65	0		silt till	14 U 563804 5743995	
PP150	R2 - Opt **3** transects	14-Sep-16	2.4	0		clay till	14 U 563715 5744039	Clay till 2.4 to 2.65
PP151	R2 - Opt **3** transects	14-Sep-16	2.3	0		silt till	14 U 563625 5744083	
PP152	R2 - Opt **3** transects	14-Sep-16	2.75	0		silt till	14 U 563446 5744172	
PP153	R2 - Opt **3** transects	14-Sep-16	2.15	0		silt till	14 U 563356 5744216	
PP154	R2 - Opt **3** transects	14-Sep-16	2.05	0		silt till	14 U 563267 5744261	
PP155	R2 - Opt **3** transects	14-Sep-16	2.45	0		silt till	14 U 563177 5744305	
PP156	R2 - Opt **3** transects	14-Sep-16	2.5	0.4		silt till	14 U 563087 5744349	
PP157	R2 - Opt **3** transects	13-Sep-16	1.6	0.4		Silt till	14 U 564695 5745344	
PP158	R2 - Opt **3** transects	13-Sep-16	1.5	0.3		Silt till	14 U 564605 5745389	
PP159	R2 - Opt **3** transects	13-Sep-16	1.3	0.3		Silt till	14 U 564516 5745433	
PP160	R2 - Opt **3** transects	13-Sep-16	1.4	0.3		Silt till	14 U 564426 5745477	Peat probe penetrated 0.1 m into silt till
PP161	R2 - Opt **3** transects	13-Sep-16	1.3	0.1		Silt till	14 U 564336 5745522	Peat probe penetrated 0.1 m into silt till
PP162	R2 - Opt **3** transects	13-Sep-16	0.9	0.2		Silt till	14 U 564157 5745610	
PP163	R2 - Opt **3** transects	13-Sep-16	1	0.3		-	14 U 564067 5745655	
PP164	R2 - Opt **3** transects	13-Sep-16	2.1	0.3		Silt till	14 U 563978 5745699	Peat probe went 0.2 m into silt till
PP165	R2 - Opt **3** transects	13-Sep-16	1.05	0.3		-	14 U 563888 5745743	
PP166	R2 - Opt 3 transects	13-Sep-16	0.3	Dry		Silt till	14 U 563799 5745788	

Lake St Martin Peat Investigation

13-Sep-16 **15-Sep-16**

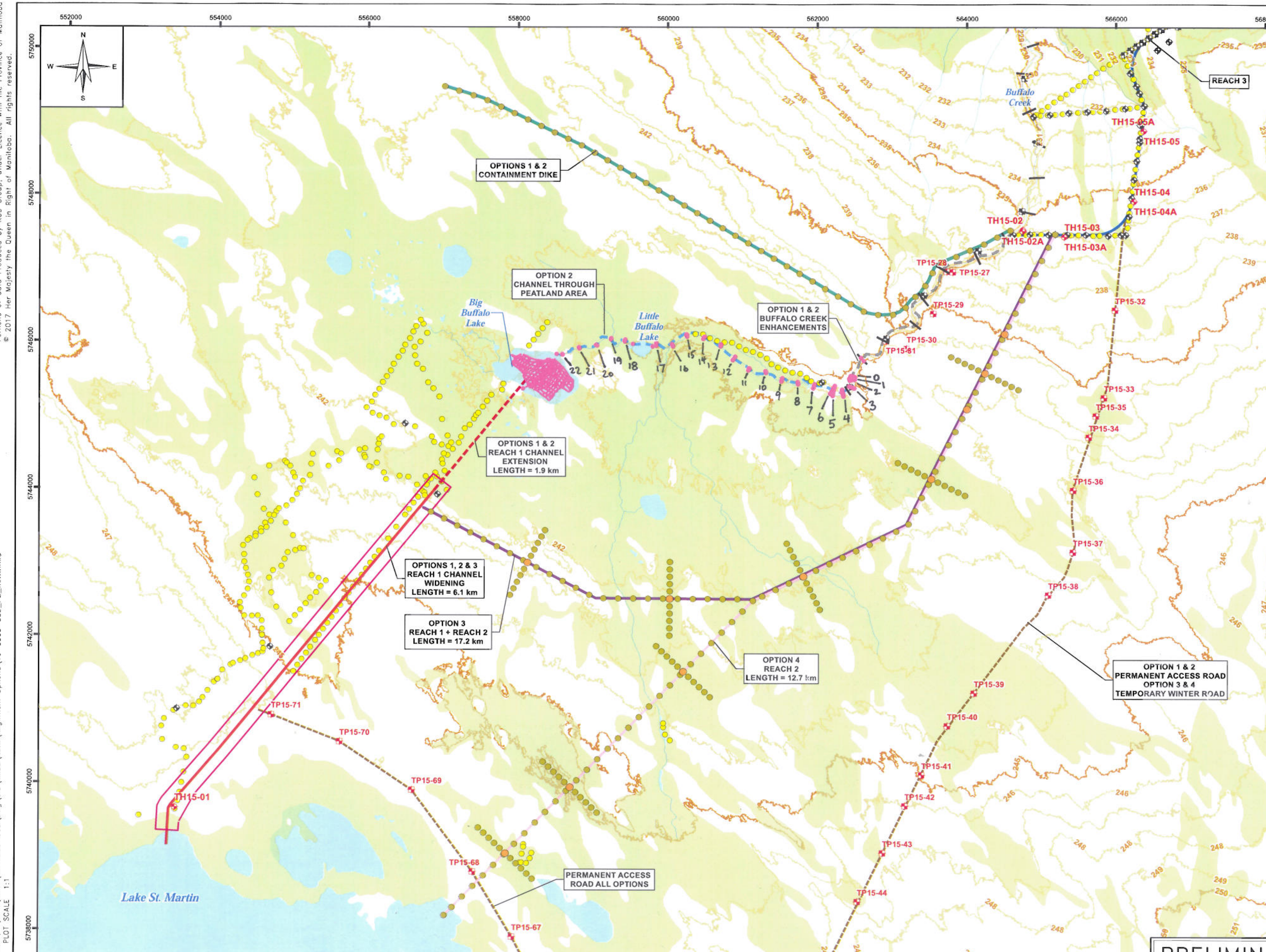
*Distances on plots are approximate

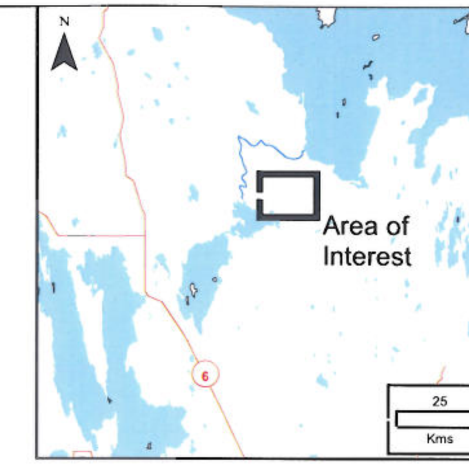
Hand Auger

Station	Site Descriptor	Date	Depth of Peat [m]	Depth to Water [m]	Auger Depth [m]	Soil Description	Location - UTM 14 U Easting - Northing	Notes
CD1	Contain Dyke (Opt 1)	15-Sep-16	0.86	0			14 U 564585 5747513	
CD2	Contain Dyke (Opt 1)	15-Sep-16	0.85	0			14 U 564410 5747416	
CD3	Contain Dyke (Opt 1)	15-Sep-16	0.9	0			14 U564233 5747321	
CD4	Contain Dyke (Opt 1)	15-Sep-16	0.63	0			14 U 564049 5747239	
CD5	Contain Dyke (Opt 1)	15-Sep-16	0.5	0			14 U 563865 5747153	
CD6	Contain Dyke (Opt 1)	15-Sep-16	0.18	0			14 U 563681 5747075	
CD7	Contain Dyke (Opt 1)	15-Sep-16	1	0			14 U 563548 5746934	
CD8	Contain Dyke (Opt 1)	15-Sep-16	0.92	0			14 U 563454 5746758	
CD9	Contain Dyke (Opt 1)	15-Sep-16	0.92	0			14 U 563320 5746611	
CD10	Contain Dyke (Opt 1)	15-Sep-16	0.2	0			14 U 563188 5746462	
CD11	Contain Dyke (Opt 1)	15-Sep-16	0.84	-			14 U 563019 5746365	
CD12	Contain Dyke (Opt 1)	15-Sep-16	0.55	0			14 U 562820 5746363	
CD13	Contain Dyke (Opt 1)	15-Sep-16	0.19	0			14 U 562627 5746408	
CD14	Contain Dyke (Opt 1)	15-Sep-16	0.17	0			14 U 562454 5746509	
CD15	Contain Dyke (Opt 1)	15-Sep-16	-	0			14 U 562282 5746612	
CD16	Contain Dyke (Opt 1)	15-Sep-16	0.71	0			14 U 562110 5746715	
CD17	Contain Dyke (Opt 1)	15-Sep-16	1.26	0			14 U 561939 5746817	
CD18	Contain Dyke (Opt 1)	15-Sep-16	0.79	0			14 U 561768 5746920	
CD19	Contain Dyke (Opt 1)	15-Sep-16	0.69	0			14 U 561597 5747023	
CD20	Contain Dyke (Opt 1)	15-Sep-16	0.26	0			14 U 561425 5747125	
CD21	Contain Dyke (Opt 1)	15-Sep-16	0.44	0			14 U 561254 5747229	
CD22	Contain Dyke (Opt 1)	15-Sep-16	0.49	0			14 U 561082 5747332	
CD23	Contain Dyke (Opt 1)	15-Sep-16	0.65	0			14 U 560911 5747435	
CD24	Contain Dyke (Opt 1)	15-Sep-16	1.13	0			14 U 560739 5747538	
CD25	Contain Dyke (Opt 1)	15-Sep-16	0.7	0.3	0.7 to 0.9	Clay till - grey, moist, firm, some sand	14 U 560568 5747640	
CD26	Contain Dyke (Opt 1)	15-Sep-16	1.05	0.35		Silt till	14 U 560396 5747743	Sitff surface @ 0.8 m.
CD27	Contain Dyke (Opt 1)	15-Sep-16	1.45	0.6		Silt till	14 U 560225 5747846	Sitff surface @ 0.9 m.
CD28	Contain Dyke (Opt 1)	15-Sep-16	1.6	0.5		Silt till	14 U 560053 5747949	Sitff surface @ 0.95 m.
CD29	Contain Dyke (Opt 1)	15-Sep-16	1.1	0.2		Silt till	14 U 559881 5748052	Sitff surface @ 0.8 m.
CD30	Contain Dyke (Opt 1)	15-Sep-16	0.9	0.35	0.9 to 1.1 m	Silt till - grey, m oist, firm, LP, some sand	14 U 559709 5748154	Peat probe advanced to 1.35 m with resistance below 0.9 m.
CD31	Contain Dyke (Opt 1)	15-Sep-16	1.1	0.3		Silt till	14 U 559537 5748258	
CD32	Contain Dyke (Opt 1)	15-Sep-16	1.65	0.3		Silt till	14 U 559365 5748361	
CD33	Contain Dyke (Opt 1)	15-Sep-16	1.7	0.2		Silt till	14 U 559193 5748463	Difficult below 1.1 m.
CD34	Contain Dyke (Opt 1)	15-Sep-16	1.55	0.5		Silt till	14 U 0559022 5748566	
CD35	Contain Dyke (Opt 1)	15-Sep-16	0.7	0.3	0.7 to 0.85	Silt till - grey, moist, firm, LP, some fg-cg sand	14 U 558848 5748665	
CD36	Contain Dyke (Opt 1)	15-Sep-16	1.2	0.1		Silt till	14 U 558668 5748752	
CD37	Contain Dyke (Opt 1)	15-Sep-16	1.95	0.2		Silt till	14 U 558488 5748840	
CD38	Contain Dyke (Opt 1)	15-Sep-16	1.7	0.1		Silt till	14 U 558307 5748928	
CD39	Contain Dyke (Opt 1)	15-Sep-16	1.6	0.3		Silt till	14 U 558127 5749015	
CD40	Contain Dyke (Opt 1)	15-Sep-16	1.1	0.3	1.1 to 1.3	Clay Till - grey, moist, firm, LP, some sand	14 U 557947 5749102	
CD41	Contain Dyke (Opt 1)	15-Sep-16	0.9	0.3		Silt till	14 U 557767 5749190	Silt till 0.9-1.1 m, hard at 1.1 m
CD42	Contain Dyke (Opt 1)	15-Sep-16	0.9	0.6		Silt till	14 U 557587 5749277	Silt till 0.9-1.1 m, hard at 1.1 m
CD43	Contain Dyke (Opt 1)	15-Sep-16	1.1	0.5		Silt till	14 U 557399 5749346	
CD44	Contain Dyke (Opt 1)	15-Sep-16	0.75	0.5		Silt till	14 U 557208 5749407	
CD45	Contain Dyke (Opt 1)	15-Sep-16	0.85	0.3	1.0 to 1.2	Silt till - grey, moist to wet, LP, some fg-cg sand, firm to stiff	14 U 557017 5749467	Peat probe advanced to 1.1 m
ALW PP001	Buffalo Creek	13-Sep-16	0.5	0		Clay	14 U 562183.643 5745297.757	
ALW PP002	Buffalo Creek	13-Sep-16	0.6	0.2		Silty clay	14 U 561948.281 5745362.835	
ALW PP003	Buffalo Creek	13-Sep-16	1.5	0		Clay	14 U 561746.534 5745417.827	
ALW PP004	Buffalo Creek	13-Sep-16	1.6	0.6		Clay	14 U 561525.445 5745455.836	
ALW PP005	Buffalo Creek	13-Sep-16	0.8			Clay	14 U 561317.621 5745570.602	
ALW PP006	Buffalo Creek	13-Sep-16	1.6			Clay	14 U 561093.888 5745634.61	
ALW PP007	Buffalo Creek	13-Sep-16	1	0.2		Clay	14 U 560908.492 5745791.516	
ALW PP008	Buffalo Creek	13-Sep-16	1.5	0.7		Clay	14 U 560720.773 5745959.472	
ALW PP009	Buffalo Creek	13-Sep-16	1.5	0.5		Clay/Silt	14 U 560480.641 5746033.031	
ALW PP010	Buffalo Creek	13-Sep-16	1.3	0.2		Clay	14 U 560266.223 5746064.3	
ALW PP011	Buffalo Creek	13-Sep-16	2	0.3		Clay	14 U 560076.688 5745930.407	
ALW PP012	Buffalo Creek	13-Sep-16	2.5	0.3		Clay	14 U 559850.893 5745974.355	
ALW PP013	Buffalo Creek	14-Sep-16	1	0		Clay	14 U 558519.319 5745823.671	
ALW PP014	Buffalo Creek	14-Sep-16	1.6	0.6		Clay	14 U 558815.905 5745915.405	
ALW PP015	Buffalo Creek	14-Sep-16	1.7	0.2		Clay	14 U 559043.296 5745949.079	
ALW PP016	Buffalo Creek	14-Sep-16	1.7	0.7		Clay	14 U 559245.351 5746037.424	
ALW PP017	Buffalo Creek	14-Sep-16	1.8	0.1		Clay	14 U 559433.573 5746019.844	

APPENDIX C

BUFFALO CREEK AND BIG BUFFALO LAKE CROSS SECTION AND BATHYMETRIC DATA





LEGEND:

- 2016 Topographic and Bathymetric Surveys
- Borehole/Hand Auger/Test Hole (2011)
- Test Pit (2011)
- Test Pit (2015)
- Test Hole (2015)
- Peat Probe (2011)
- Hand Auger (2016)
- Peat Probe (2016)
- X-Sections 2011, 2013, & 2015
- Reach 2 Alignment Option 3
- Reach 2 Alignment Option 4
- Reach 1 Channel Extension
- Reach 1 Channel Widening
- Reach 2 Dike
- Reach 3
- Buffalo Creek Channel
- Buffalo Creek Erosion Protection
- Access Road
- Watercourse
- 1m LiDAR Contour
- 5m Index LiDAR Contour
- Wetlands
- Waterbody
- Approx Boundary of Drone Survey (2016)

NOTE:

1. Topographic data was derived from the 2011 Lake St. Martin LiDAR, obtained from Manitoba Land Initiative (MLI).
2. Wetland, Watercourse and Waterbody layers shown were obtained from NRCAN 1:50000 data.
3. All units are metric and in metres unless otherwise specified. Transverse Mercator Projection, NAD 1983 CSRS, Zone 14. Elevations are in metres above sea level (MSL) and are referencing Canadian Geodetic Vertical Datum 1928 (CGVD28).

DRAFT

0 0.5 1 1.5 2 2.5

Kilometres

SCALE: 1:50,000 METRIC 11"x17"

NO.	YY/MM/DD	DESCRIPTION	ISSUED BY	CHECK BY
A	17/05/29	ISSUED WITH DRAFT REPORT	PAL	MSW

REVISIONS / ISSUE

KGS GROUP CONSULTING ENGINEERS

Manitoba Infrastructure

PRELIMINARY DESIGN FOR REACH 2 OF THE LSM OUTLET CHANNEL

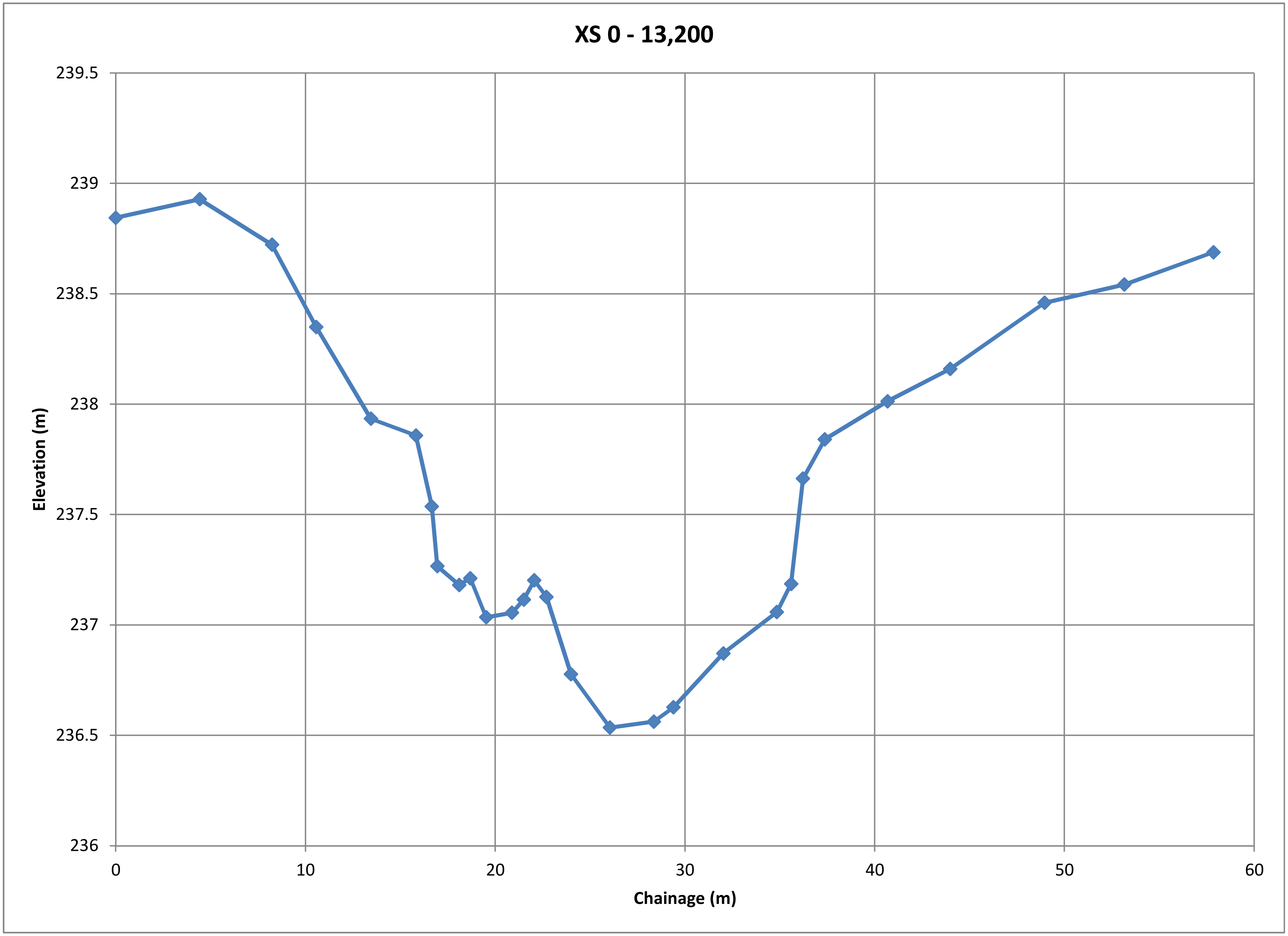
SUMMARY OF FIELD INVESTIGATIONS

MAY 2017 | PLATE 2 | REV: A

PRELIMINARY

NOT TO BE USED FOR CONSTRUCTION

FileName:P:\Projects\2016\16-0300-005\Dwg\GIS\MXDs\RevA\Alignment Options\16-0300-005_P2_RevA.mxd
11"x17" PLOT SCALE 1:1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238
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237
236.5
236
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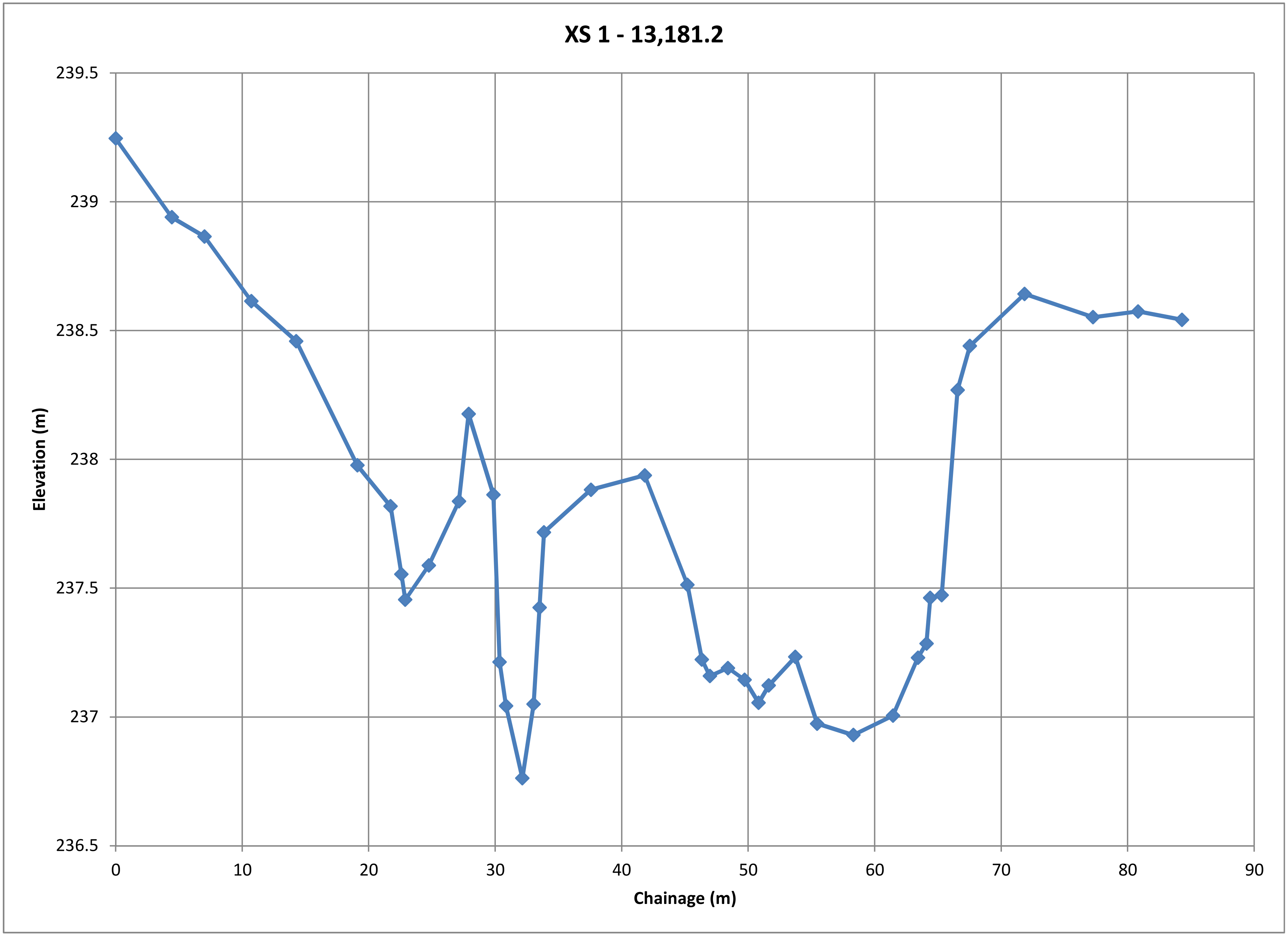
10
20
30
40
50
60
Chainage (m)



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238.5
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237.5
237
236.5
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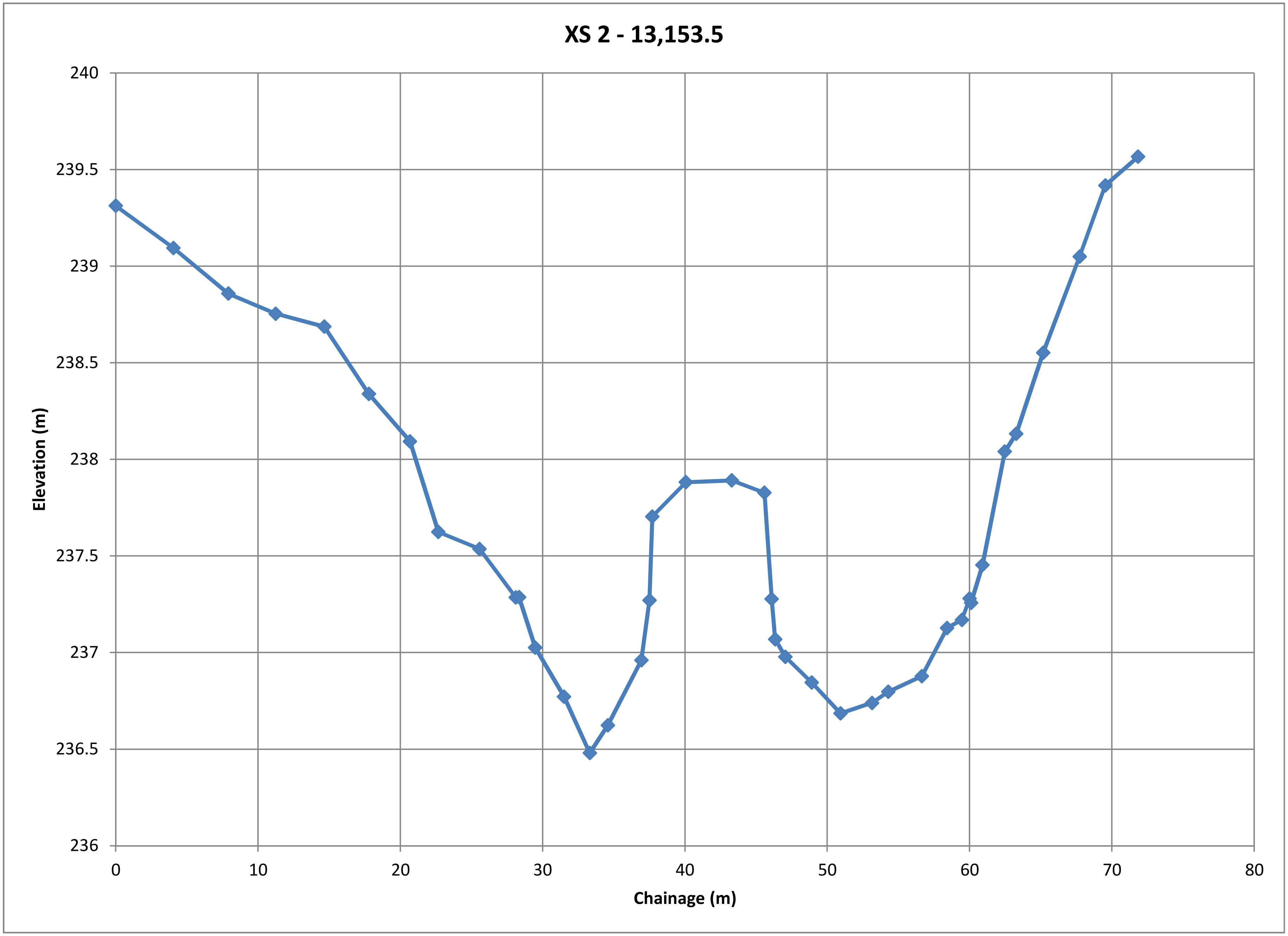
10
20
30
40
50
60
70
80
90
Chainage (m)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236.5
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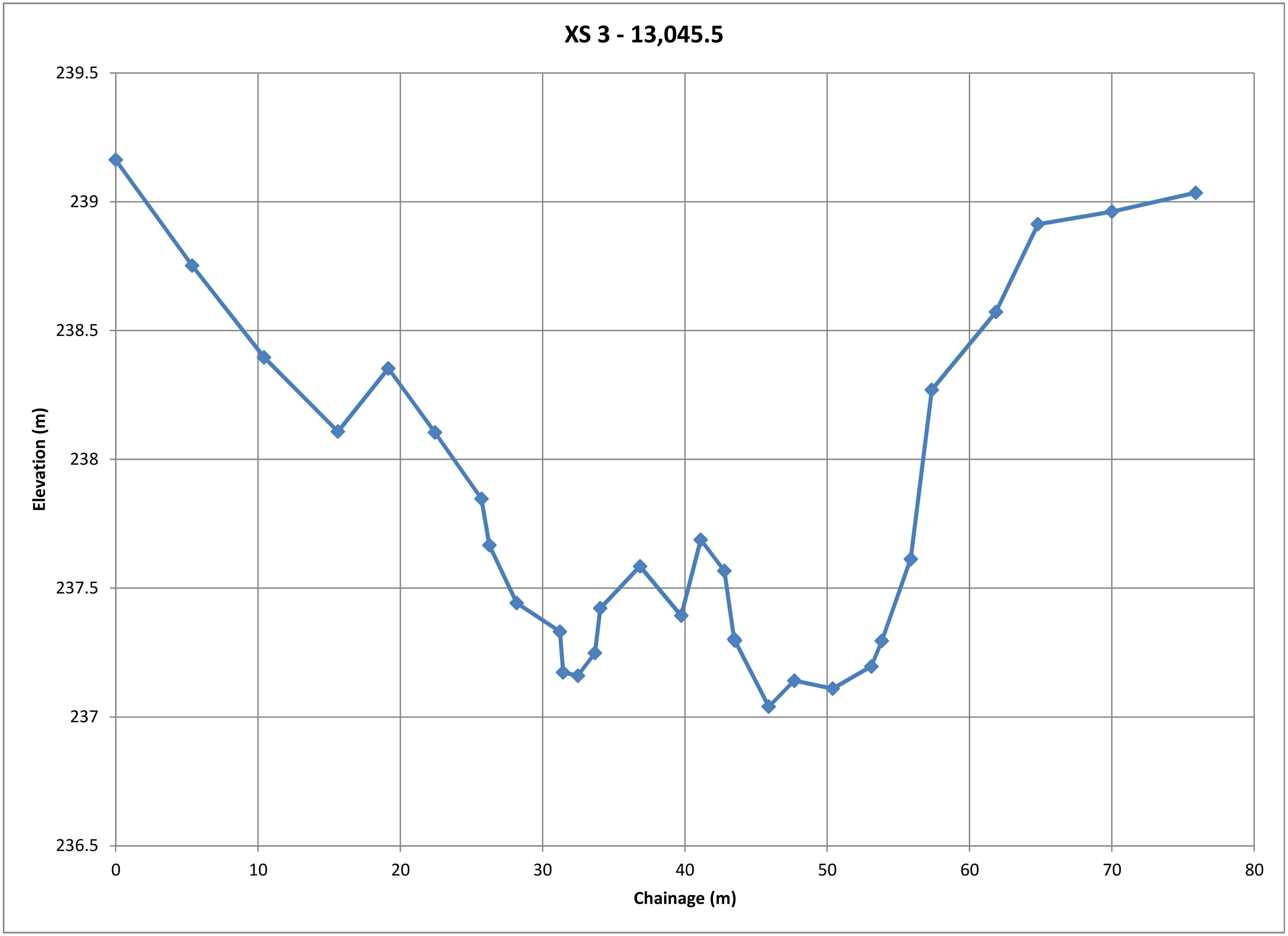
40
50
60
70
80
Chainage (m)



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238.5
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237.5
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236.5
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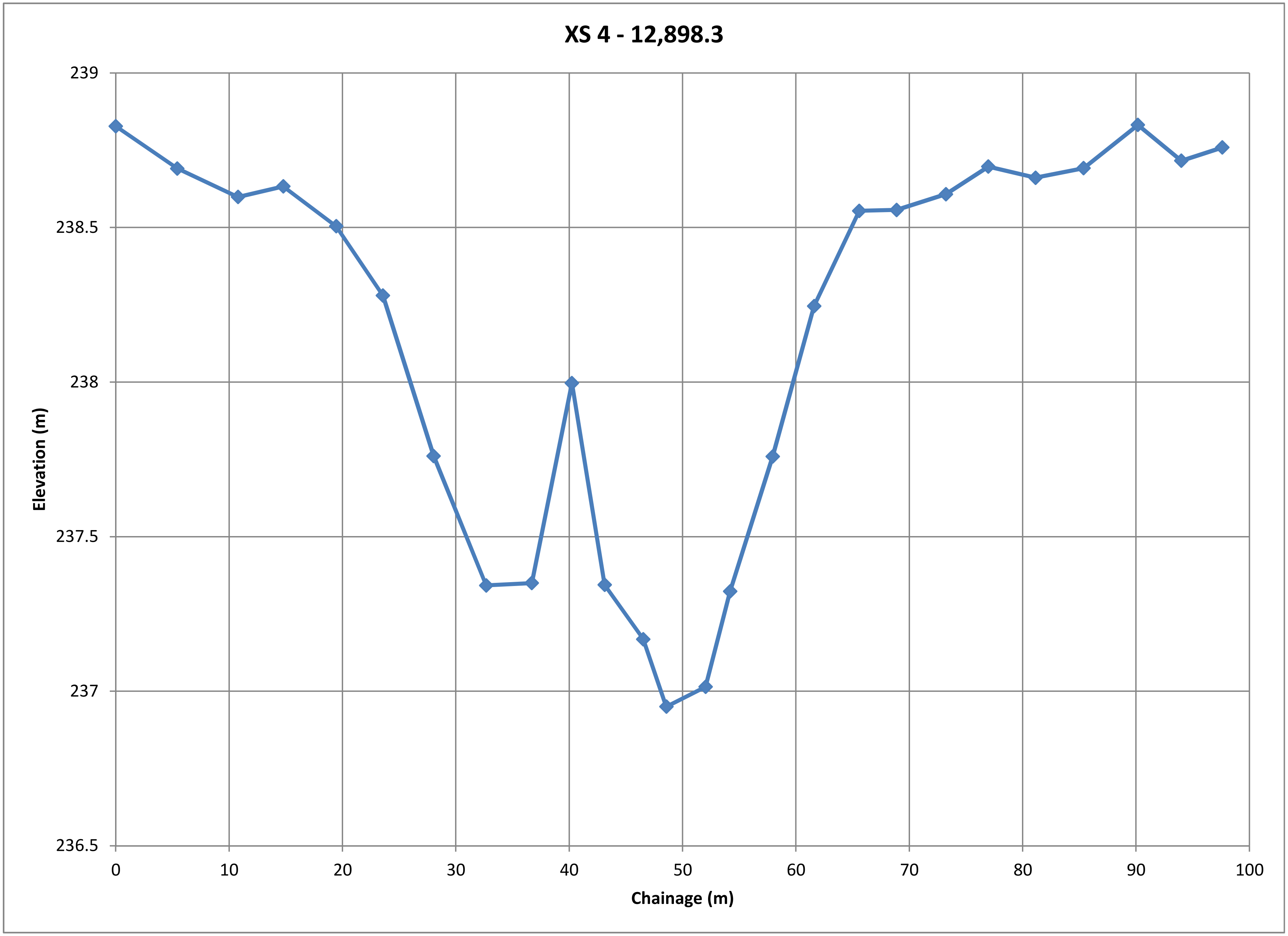
40
50
60
70
80
Chainage (m)



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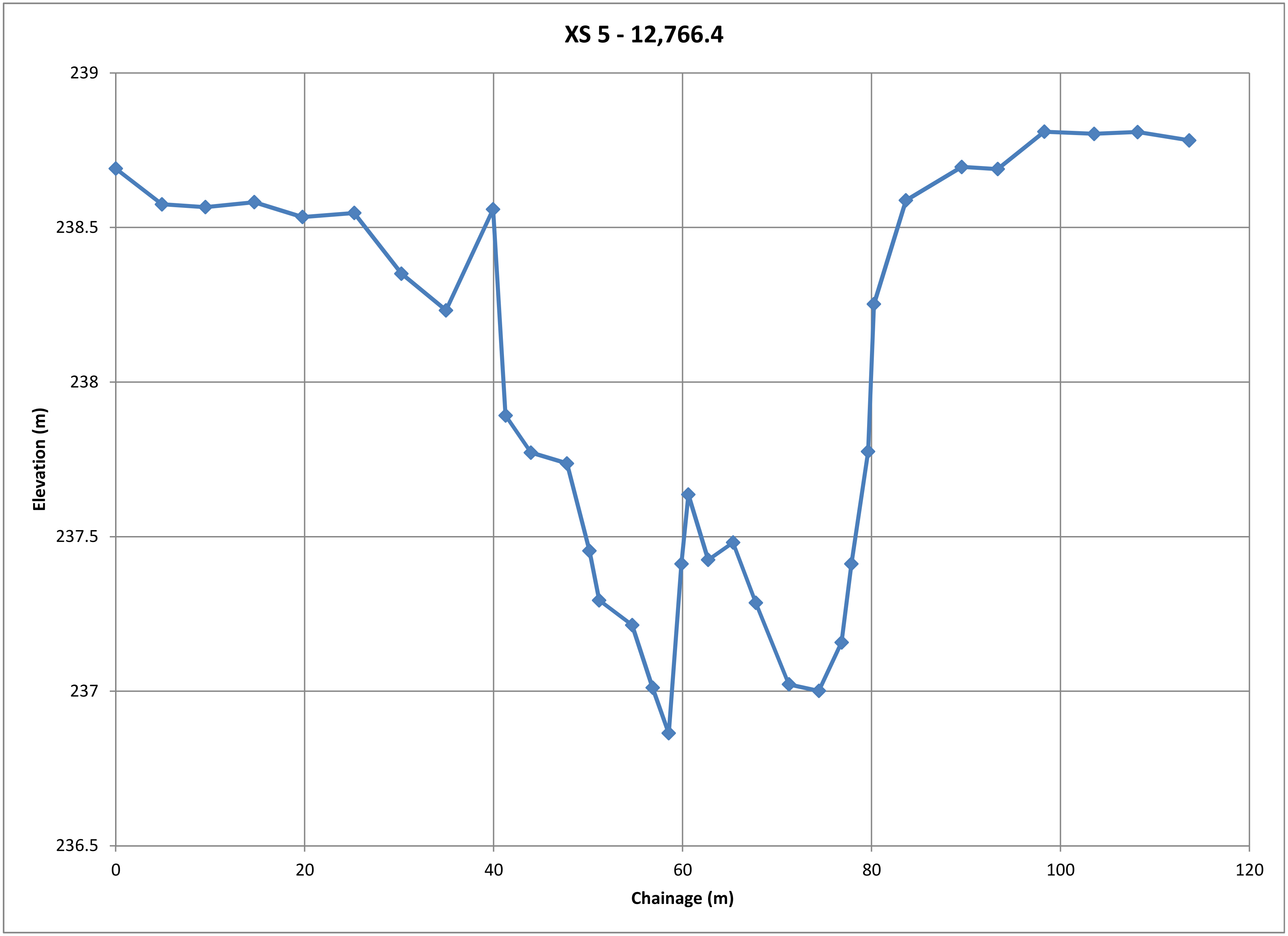
238.5
238
237.5
237
236.5
0
10
20
30
40
50
60
70
80
90
100
Elevation (m)
Chainage (m)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Elevation (m)
Chainage (m)
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237.5
237
236.5
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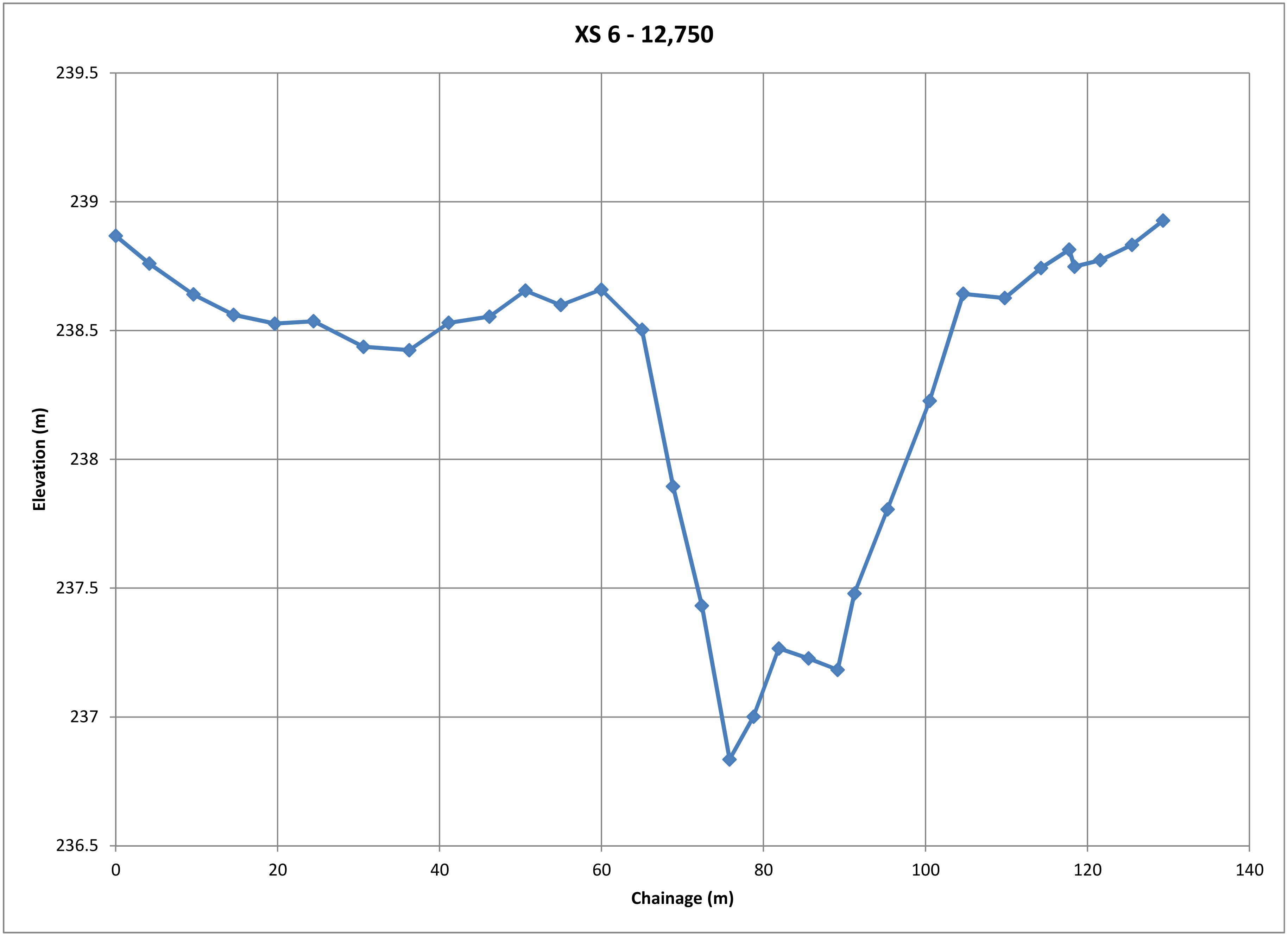
20
40
60
80
100
120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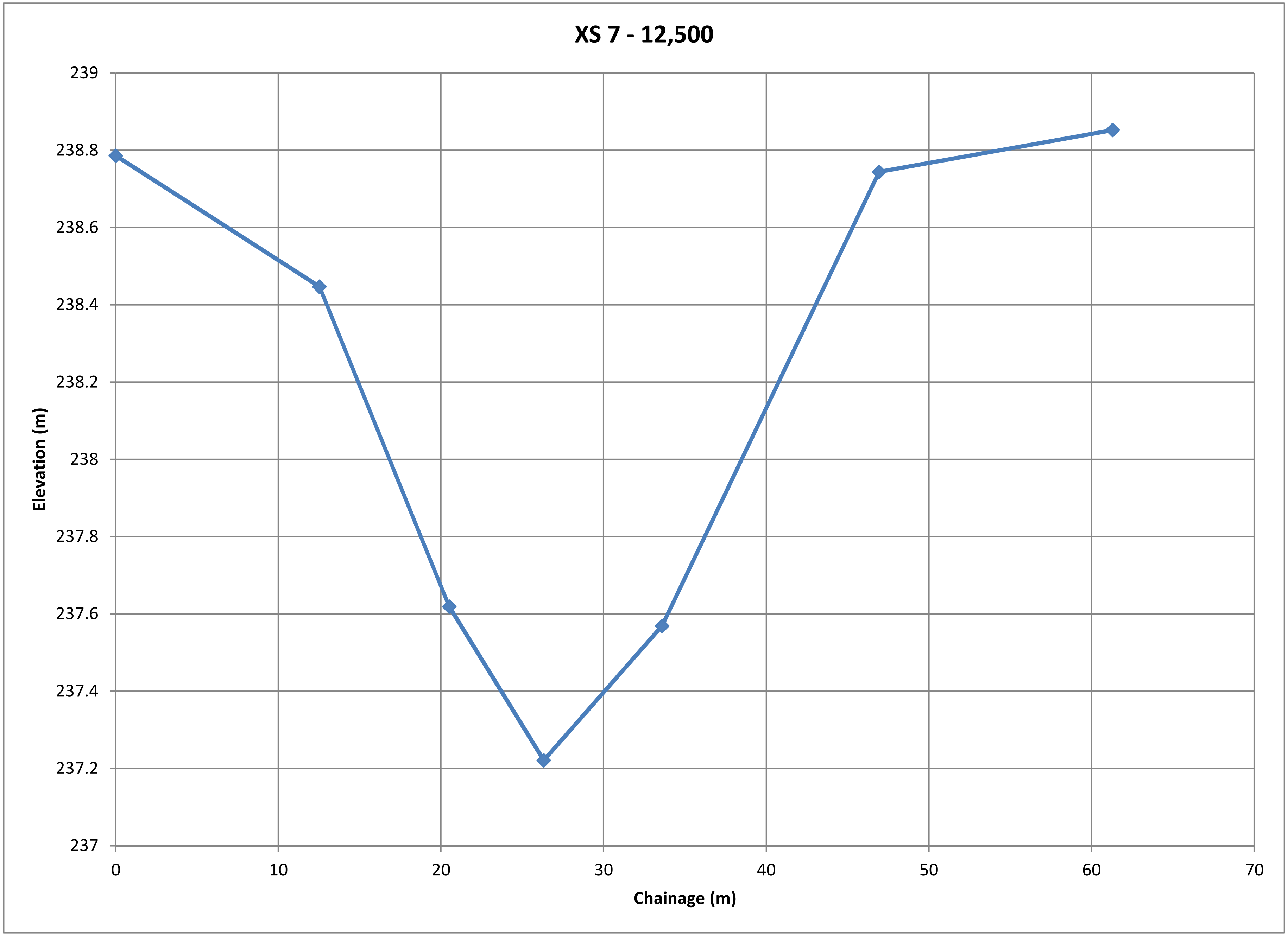
100
120
140
Chainage (m)



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237.4
237.2
237
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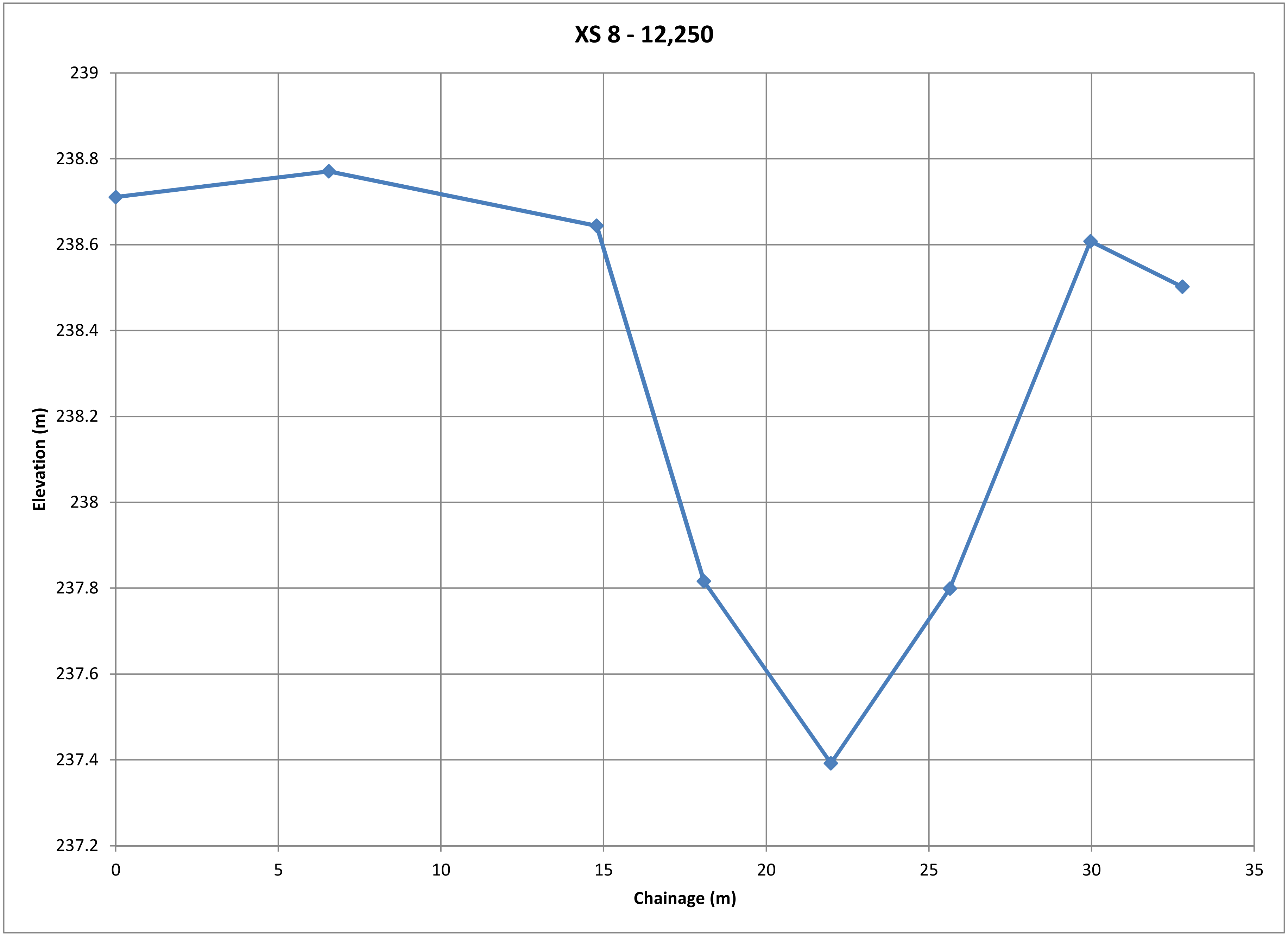
20
30
40
50
60
70
Chainage (m)



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238.2
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237.4
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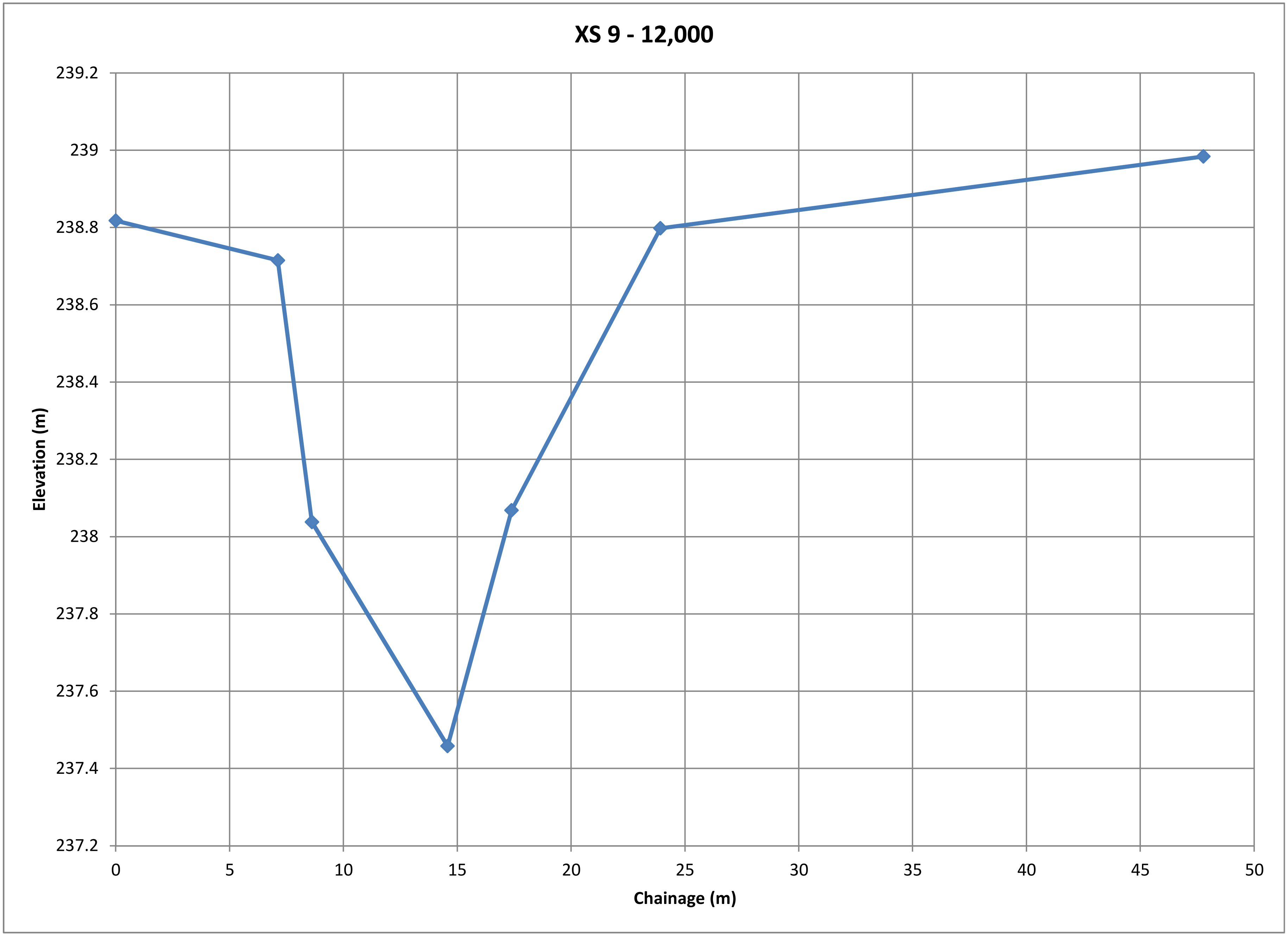
15
20
25
30
35
Chainage (m)



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238.8
238.6
238.4
238.2
238
237.8
237.6
237.4
237.2
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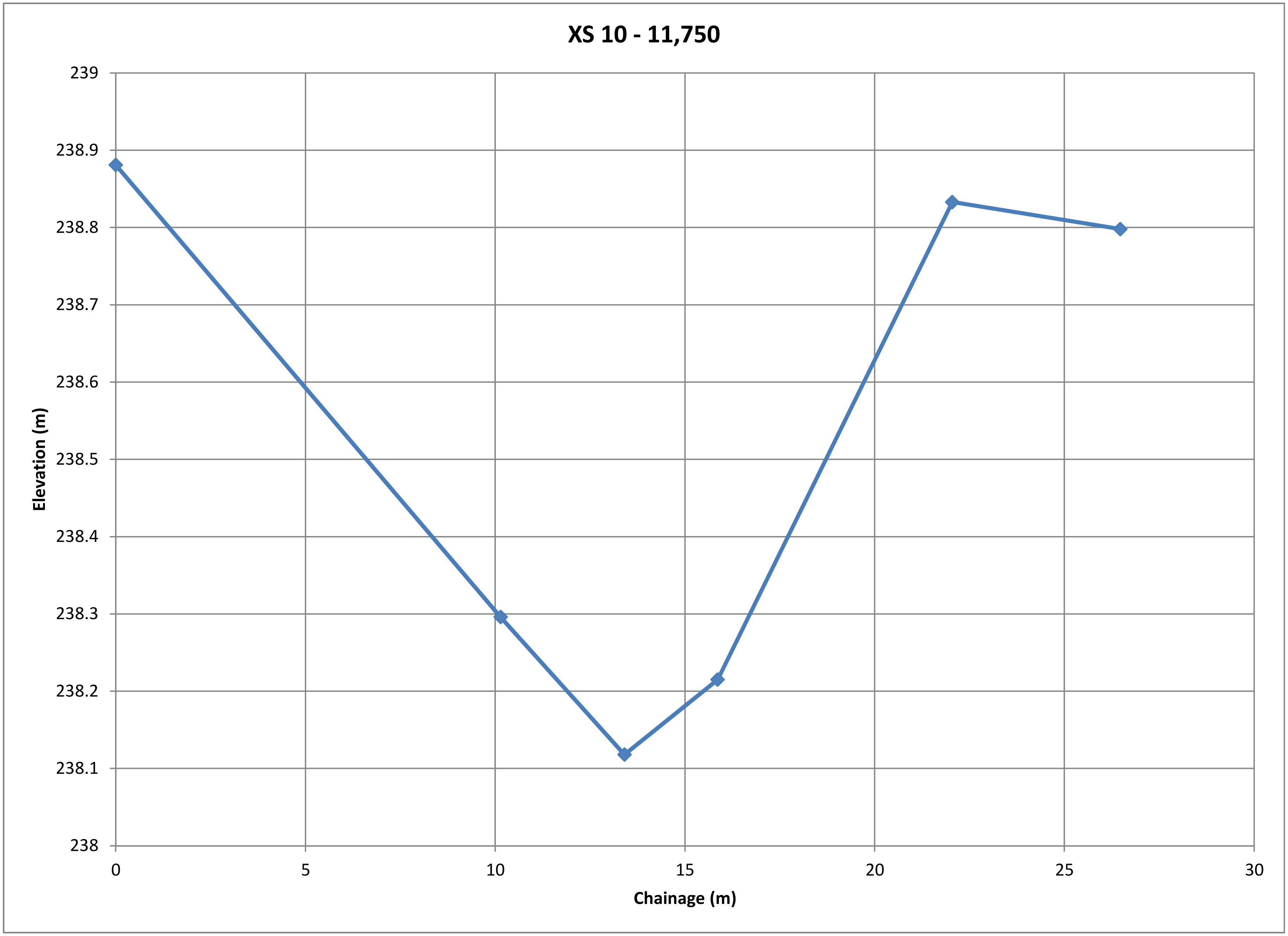
5
10
15
20
25
30
35
40
45
50
Chainage (m)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Chainage (m)
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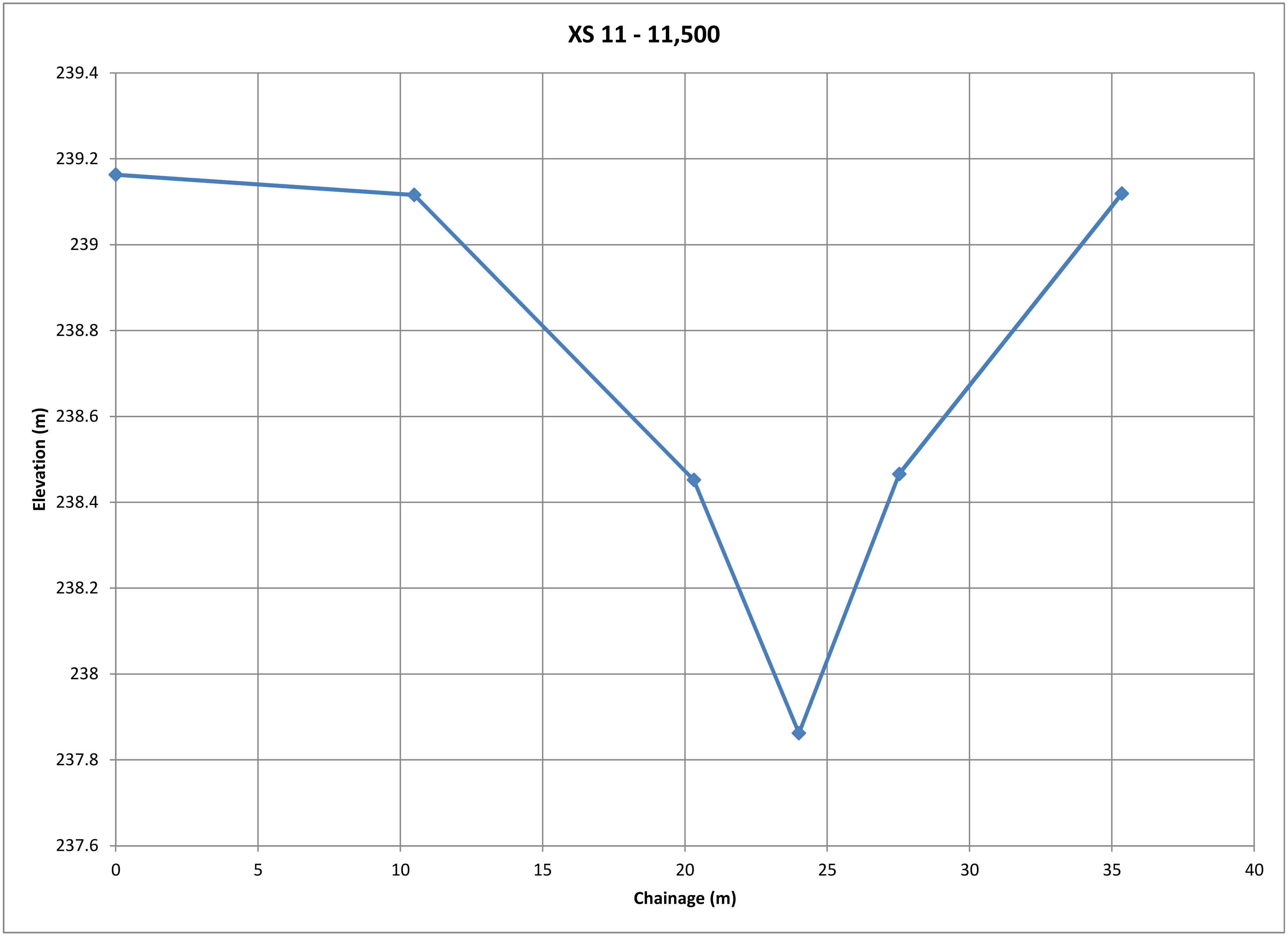
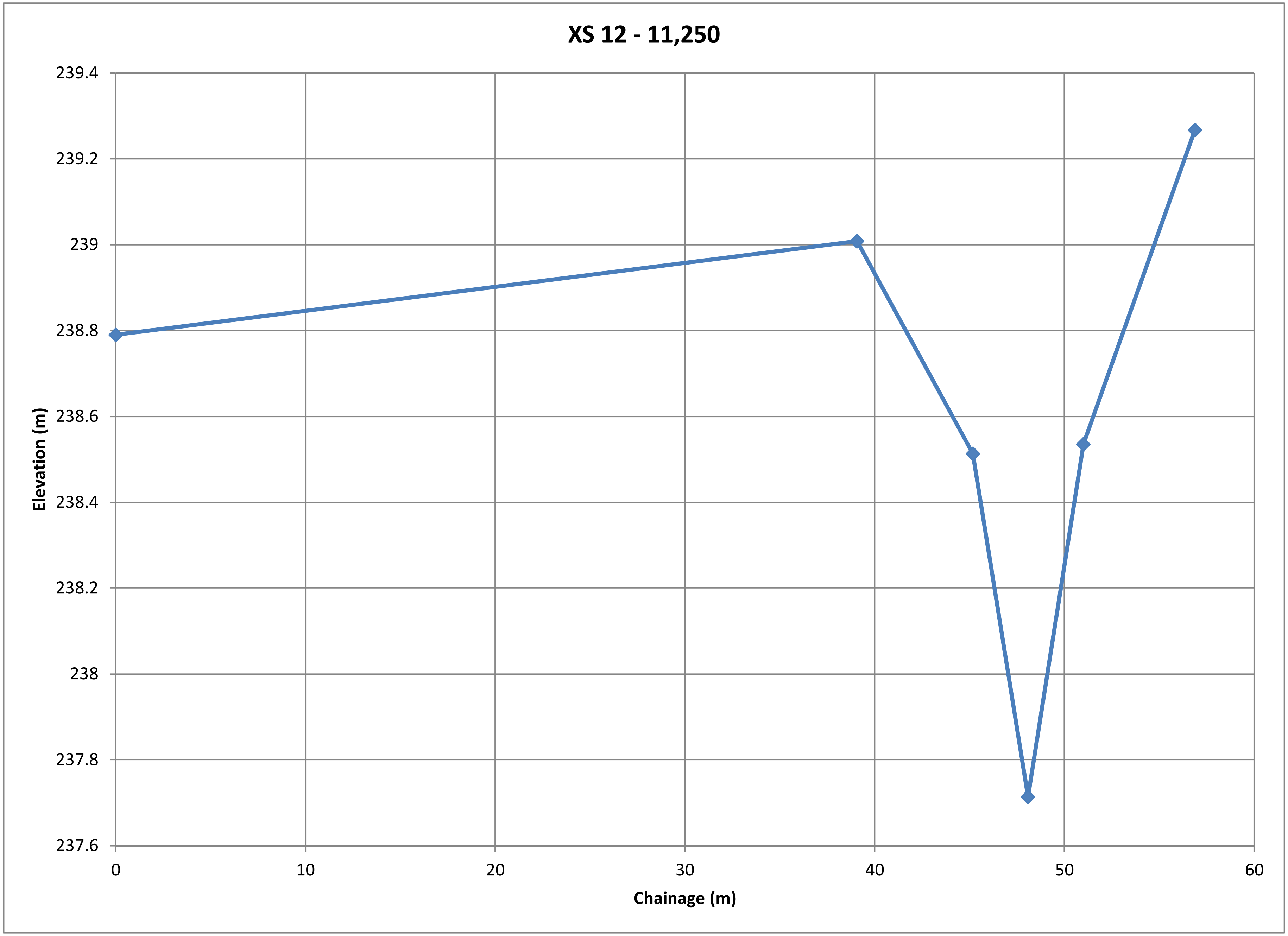
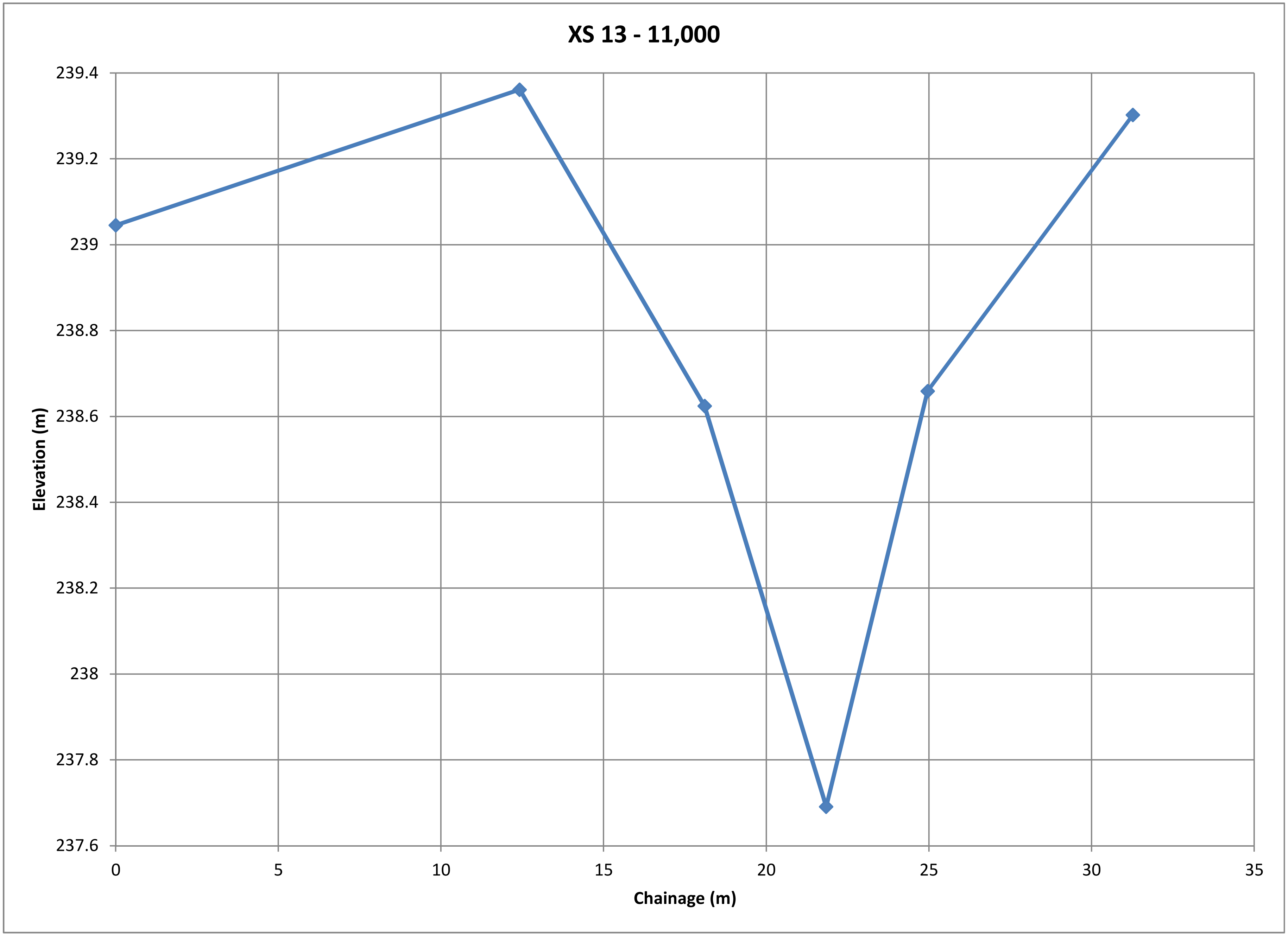
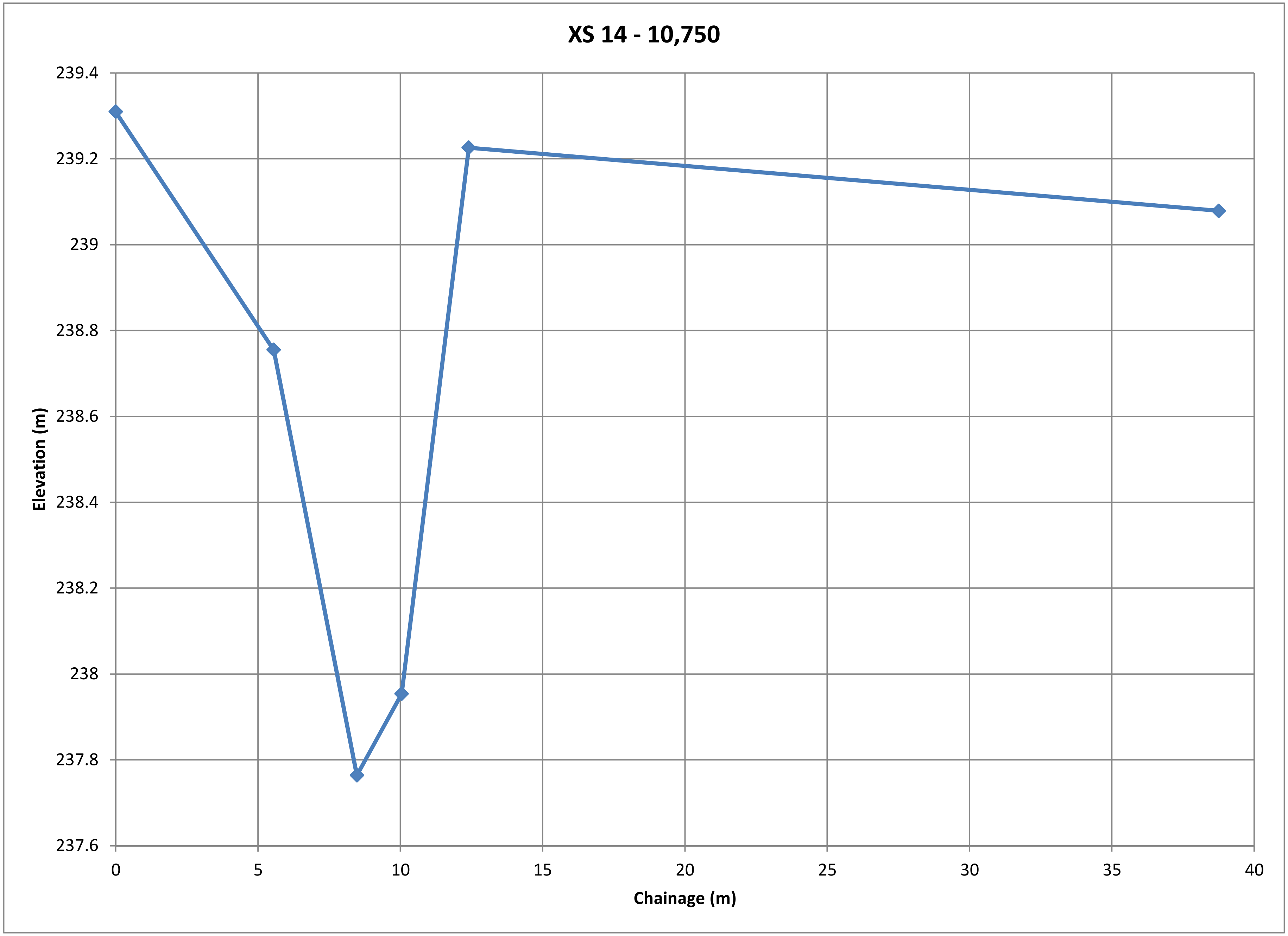
238.2
238.1
238
0
5
10
15
20
25
30



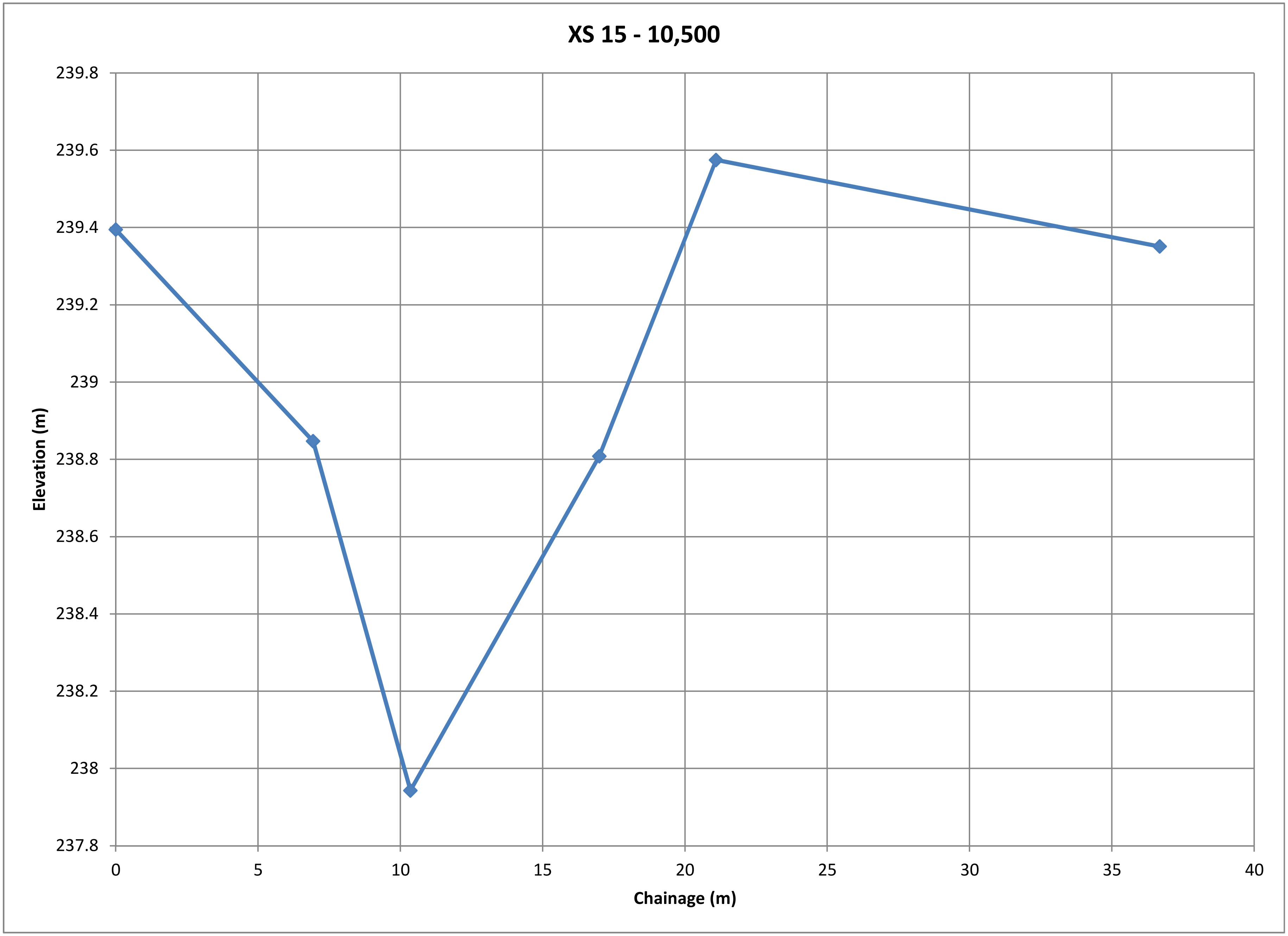
XS 11 - 11,500
239.4
239.2
239
238.8
238.6
238.4
238.2
238
237.8
237.6
Elevation (m)
0
5
10
15
20
25
30
35
40
Chainage (m)


XS 12 - 11,250
Elevation (m)
239.4
239.2
239
238.8
238.6
238.4
238.2
238
237.8
237.6
0
10
20
30
40
50
60
Chainage (m)

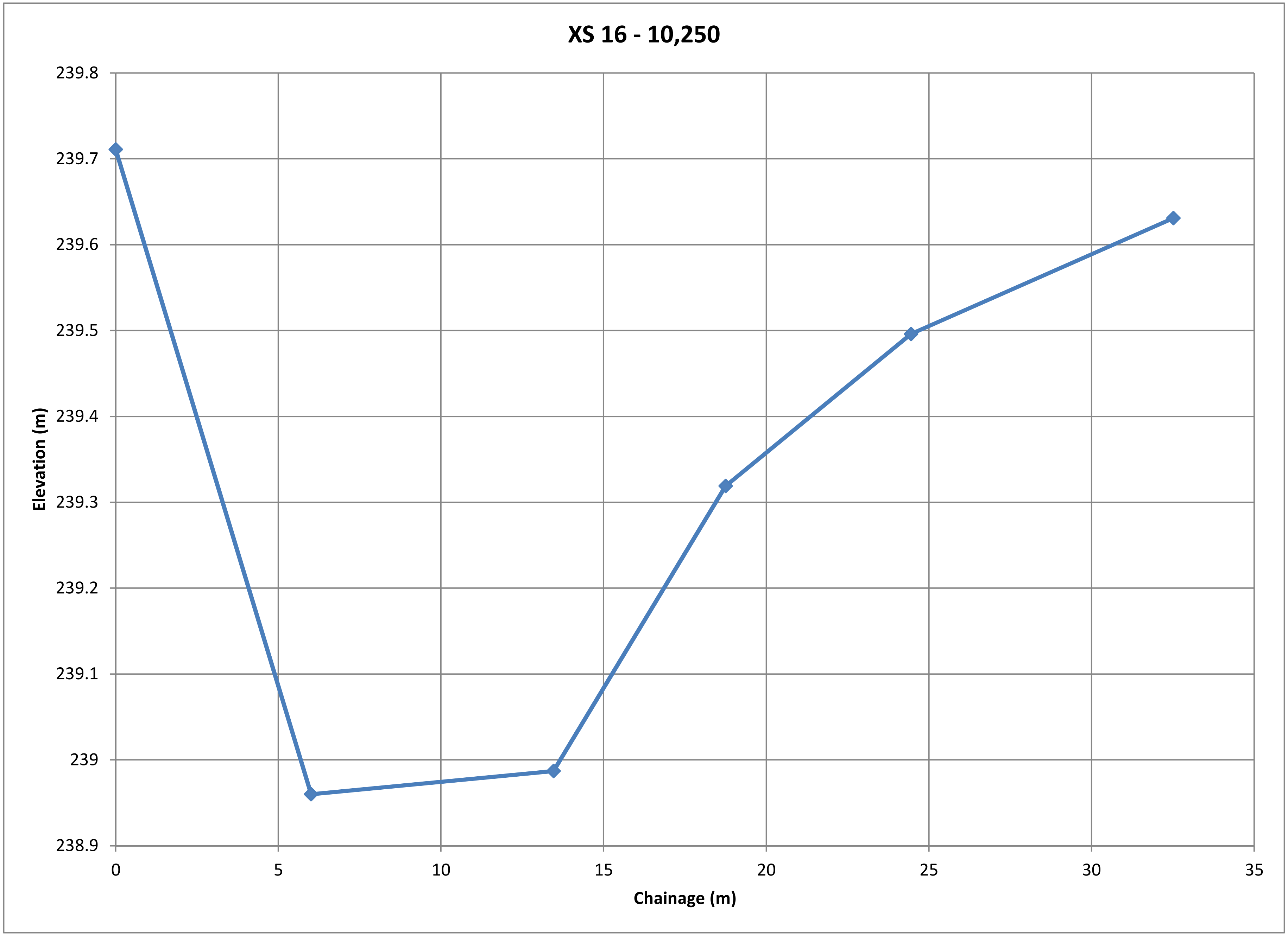

XS 13 - 11,000
Elevation (m)
239.4
239.2
239
238.8
238.6
238.4
238.2
238
237.8
237.6
0
5
10
15
20
25
30
35
Chainage (m)

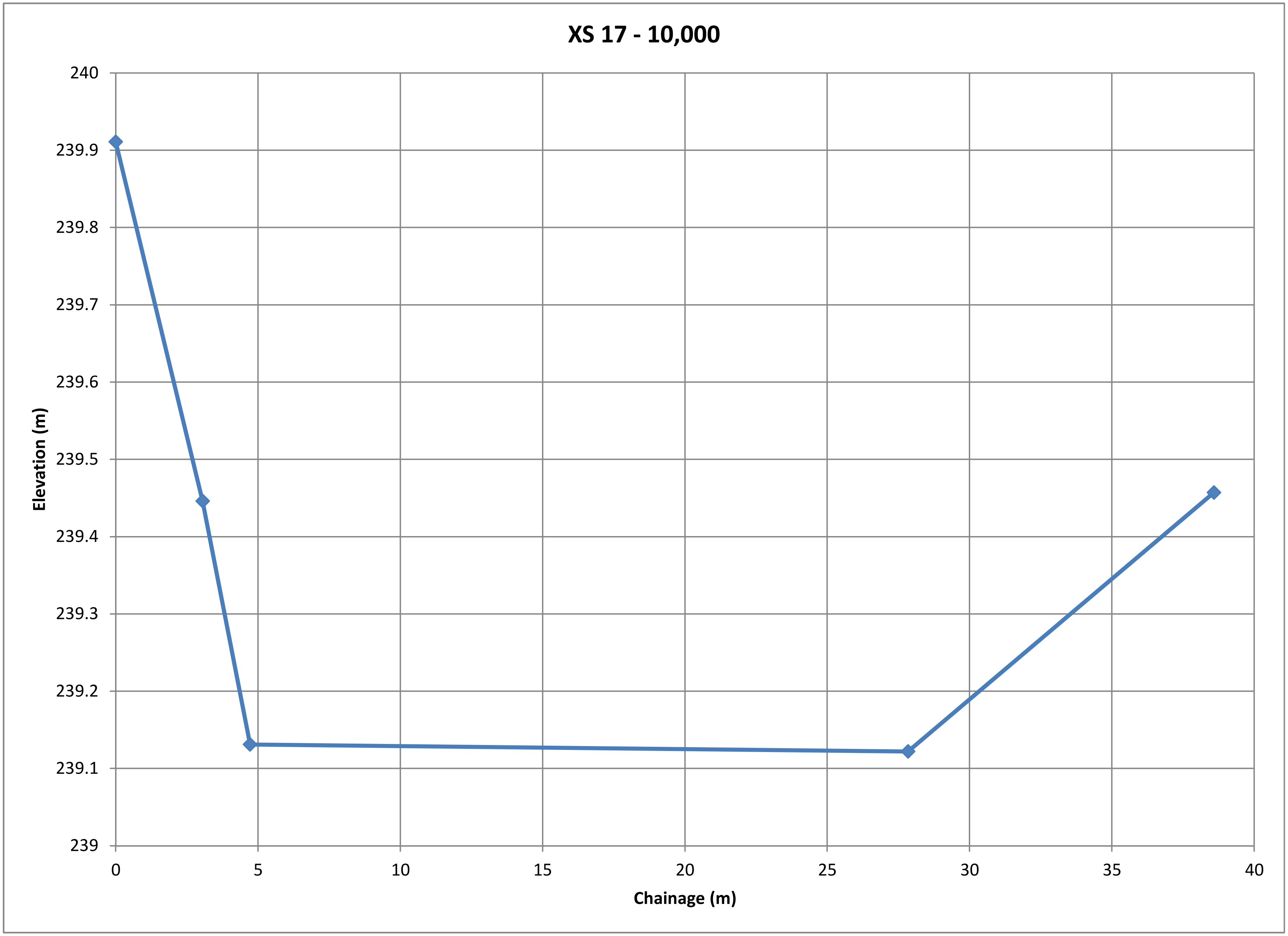


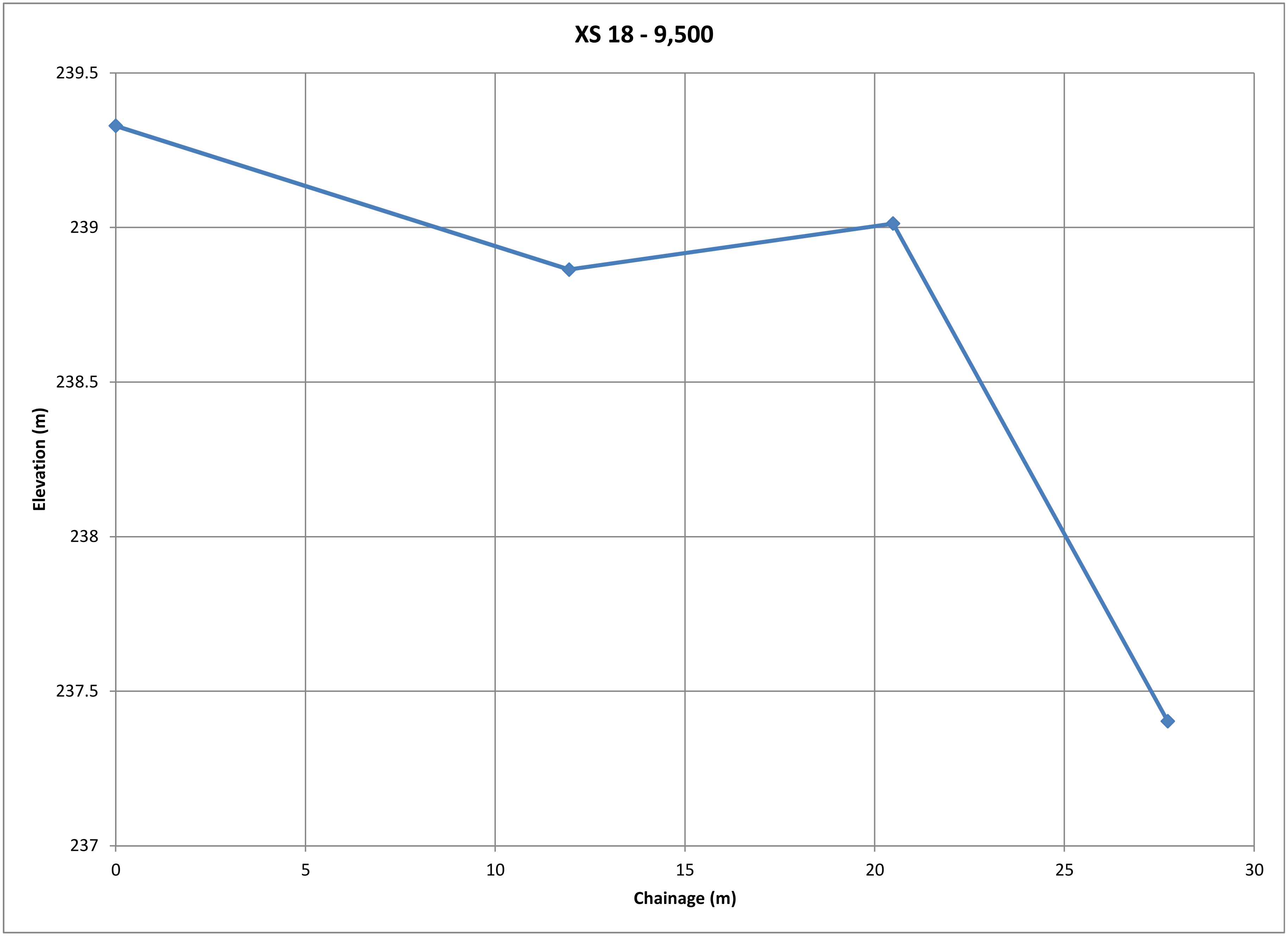
XS 14 - 10,750
Elevation (m)
239.4
239.2
239
238.8
238.6
238.4
238.2
238
237.8
237.6
0
5
10
15
20
25
30
35
40
Chainage (m)

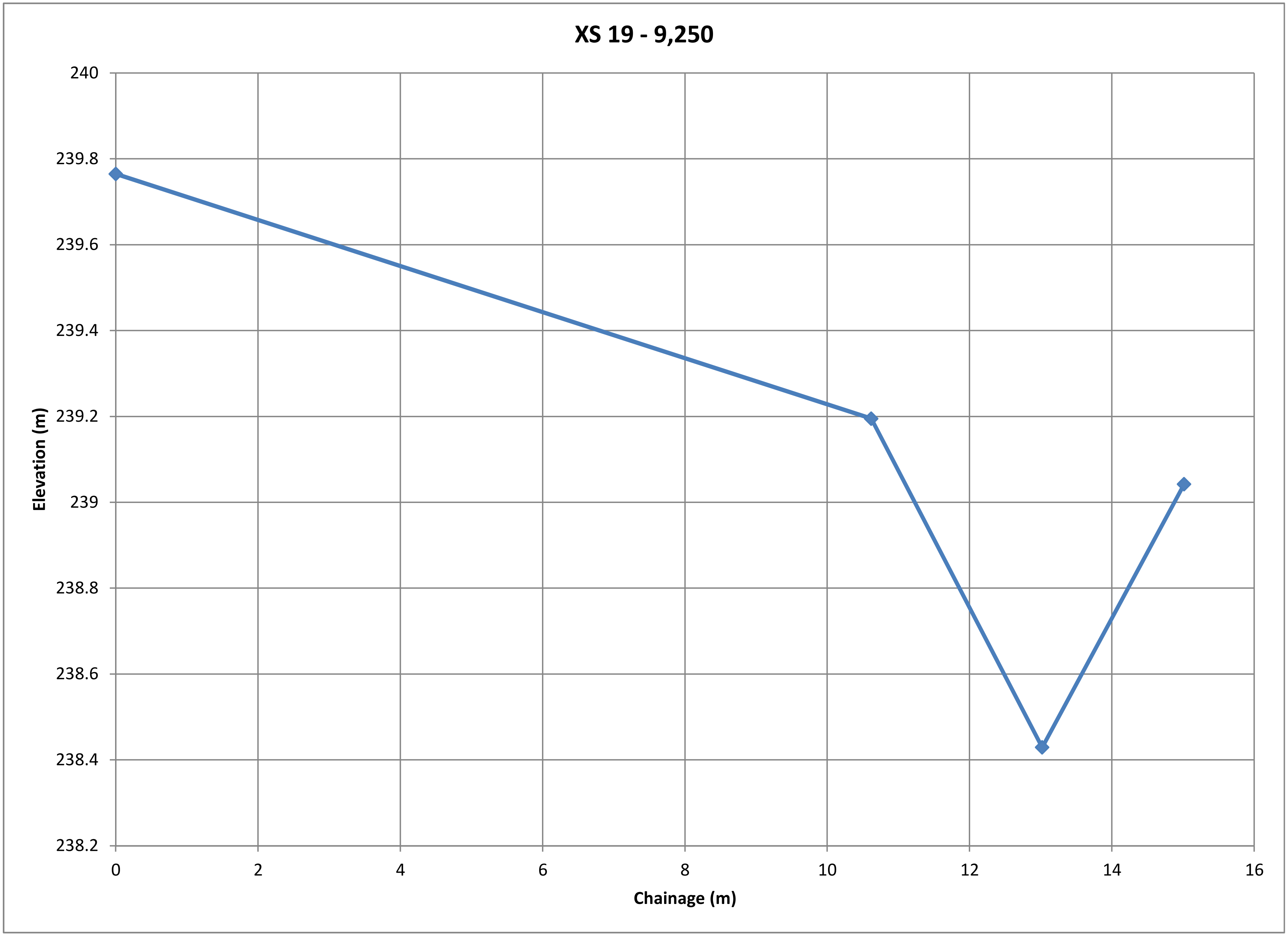


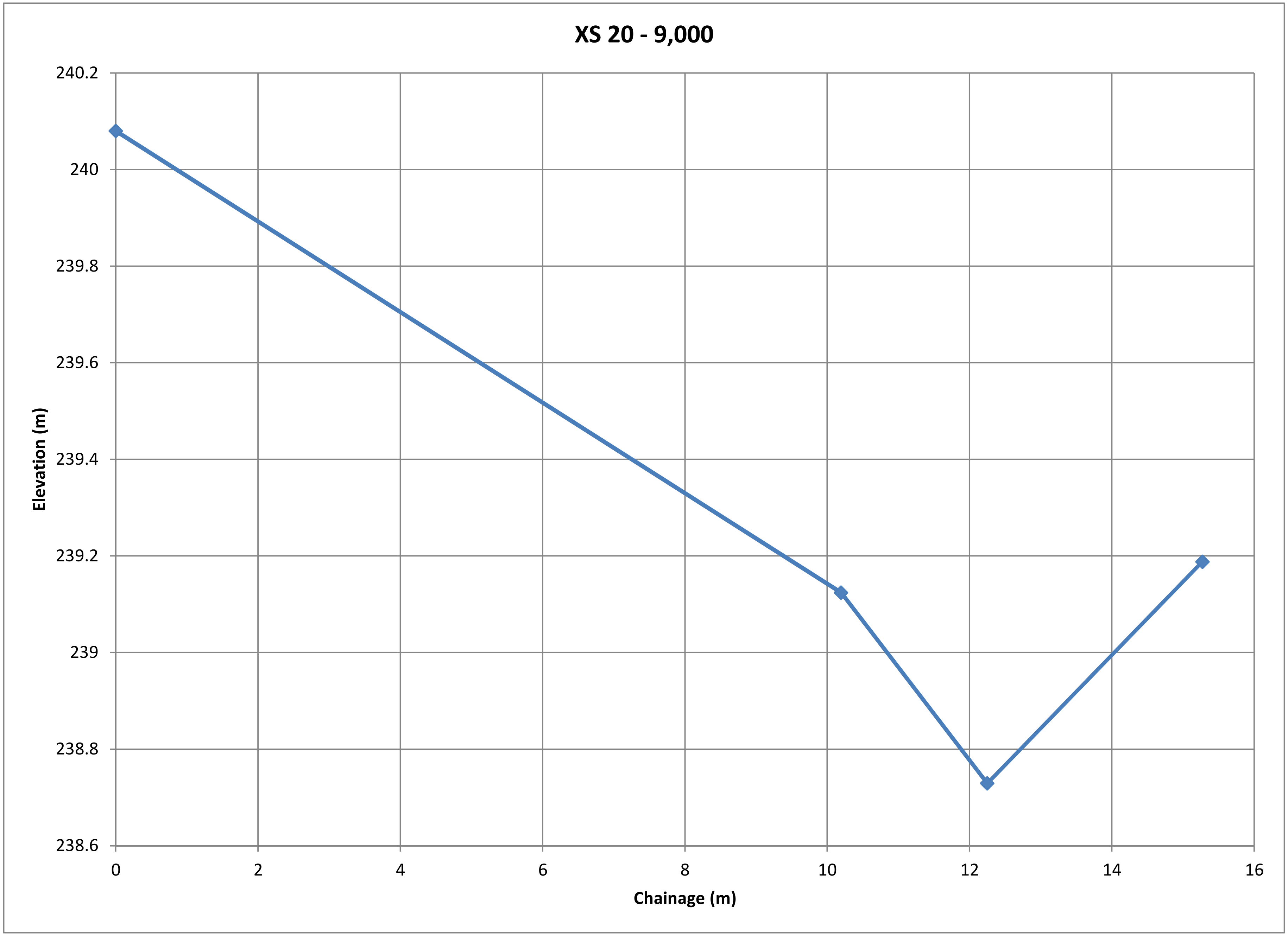
XS 15 - 10,500
Elevation (m)
239.8
239.6
239.4
239.2
239
238.8
238.6
238.4
238.2
238
237.8
0
5
10
15
20
25
30
35
40
Chainage (m)


XS 16 - 10,250
Elevation (m)
Chainage (m)
239.8
239.7
239.6
239.5
239.4
239.3
239.2
239.1
239
238.9
0
5
10
15
20
25
30
35

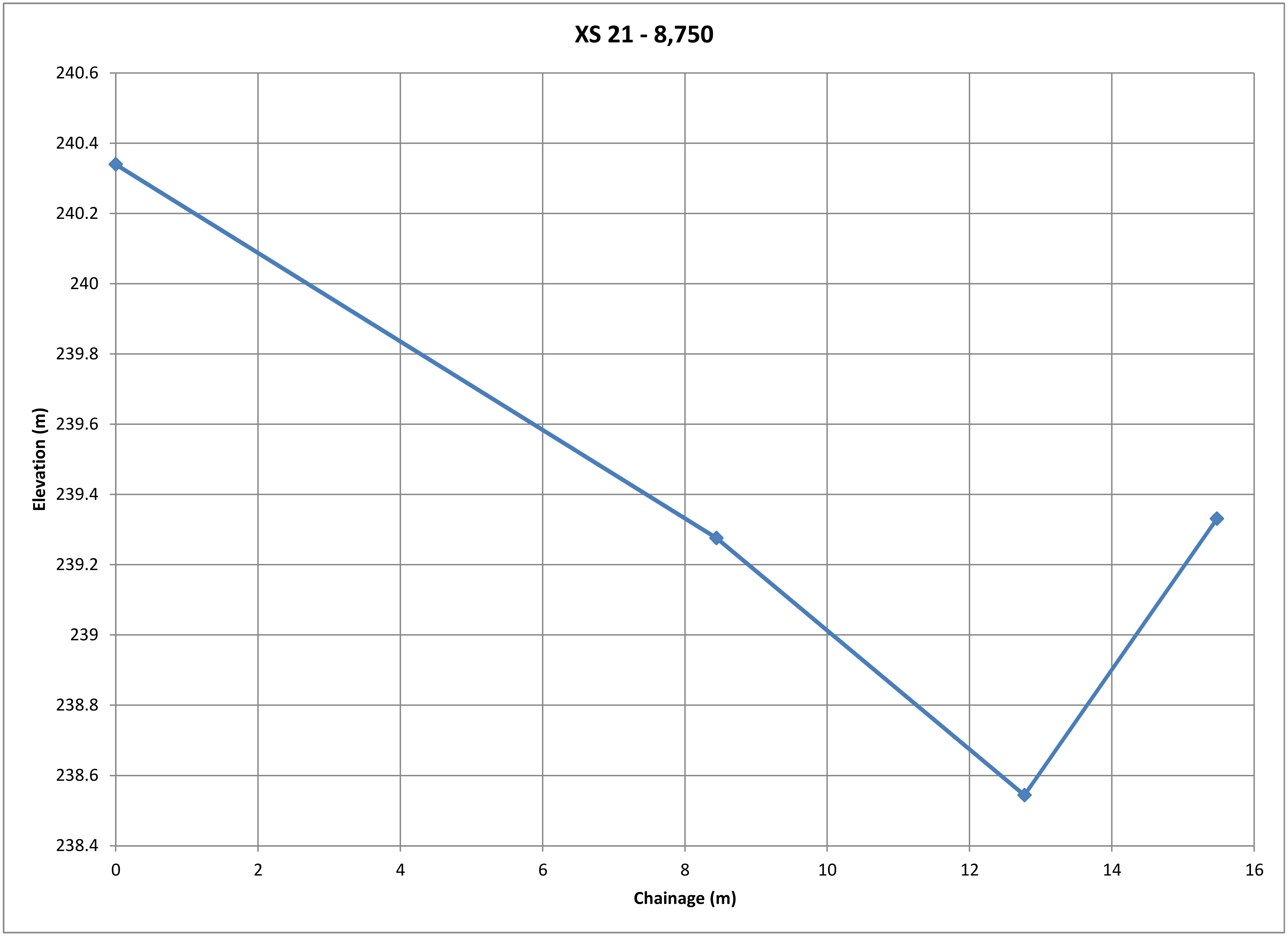

XS 17 - 10,000
Elevation (m)
240
239.9
239.8
239.7
239.6
239.5
239.4
239.3
239.2
239.1
239
0
5
10
15
20
25
30
35
40
Chainage (m)

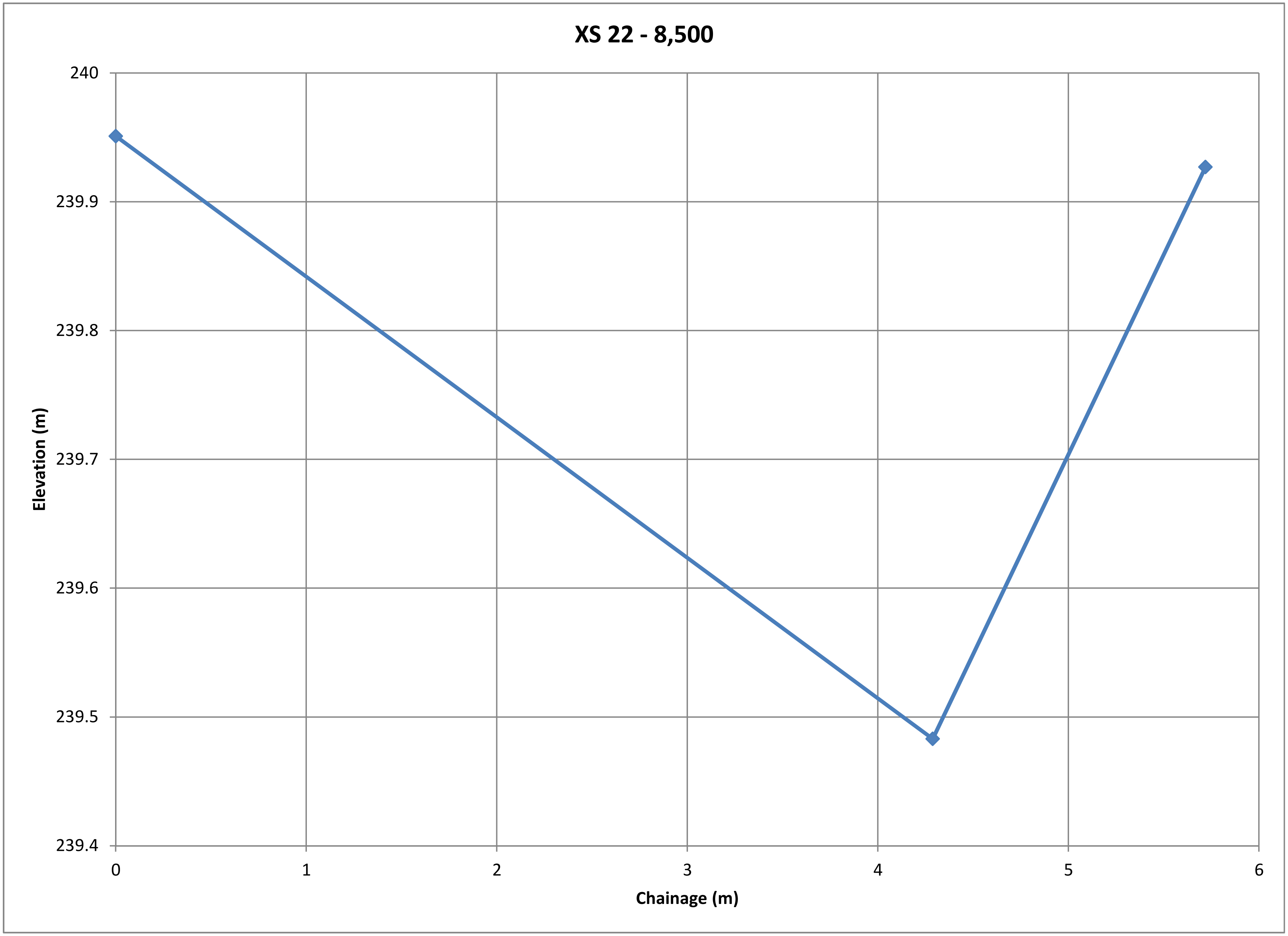

XS 18 - 9,500
239.5
239
238.5
238
237.5
237
Elevation (m)
0
5
10
15
20
25
30
Chainage (m)


XS 19 - 9,250
Elevation (m)
240
239.8
239.6
239.4
239.2
239
238.8
238.6
238.4
238.2
0
2
4
6
8
10
12
14
16
Chainage (m)



XS 20 - 9,000
Elevation (m)
240.2
240
239.8
239.6
239.4
239.2
239
238.8
238.6
0
2
4
6
8
10
12
14
16
Chainage (m)


XS 21 - 8,750
Elevation (m)
Chainage (m)
240.6
240.4
240.2
240
239.8
239.6
239.4
239.2
239
238.8
238.6
238.4
0
2
4
6
8
10
12
14
16



XS 22 - 8,500
240
239.9
239.8
239.7
239.6
239.5
239.4
Elevation (m)
0
1
2
3
4
5
6
Chainage (m)

XS 0 - 13200			
X	Y	CH (m)	Z (m)
562452	5745534	0.00	238.84
562456	5745532	4.43	238.93
562460	5745531	8.24	238.72
562462	5745531	10.57	238.35
562465	5745530	13.45	237.93
562467	5745530	15.82	237.86
562468	5745529	16.66	237.54
562468	5745529	16.95	237.27
562469	5745529	18.10	237.18
562470	5745529	18.69	237.21
562471	5745529	19.53	237.04
562472	5745528	20.88	237.06
562473	5745528	21.51	237.12
562473	5745528	22.06	237.20
562474	5745528	22.70	237.13
562475	5745527	24.00	236.78
562477	5745527	26.05	236.54
562479	5745526	28.36	236.56
562480	5745526	29.40	236.63
562483	5745525	32.02	236.87
562486	5745524	34.84	237.06
562486	5745524	35.60	237.19
562487	5745524	36.22	237.66
562488	5745524	37.37	237.84
562491	5745523	40.68	238.01
562494	5745523	43.98	238.16
562499	5745521	48.95	238.46
562503	5745521	53.16	238.54
562508	5745520	57.86	238.69

XS 1 - 13181.2			
X	Y	CH (m)	Z (m)
562432	5745495	0.00	239.25
562437	5745496	4.43	238.94
562439	5745497	7.03	238.87
562443	5745498	10.72	238.61
562446	5745498	14.27	238.46
562451	5745500	19.10	237.98
562453	5745500	21.73	237.82
562454	5745501	22.59	237.55
562454	5745501	22.89	237.46
562456	5745501	24.75	237.59
562458	5745502	27.14	237.84
562459	5745502	27.90	238.18
562461	5745502	29.86	237.86
562461	5745503	30.35	237.21
562461	5745503	30.86	237.04
562463	5745503	32.15	236.76
562464	5745503	33.04	237.05
562464	5745503	33.51	237.43
562464	5745504	33.86	237.72
562468	5745504	37.57	237.88
562472	5745504	41.82	237.94
562475	5745502	45.20	237.51
562476	5745503	46.34	237.22
562477	5745502	46.97	237.16
562478	5745503	48.40	237.19
562480	5745503	49.72	237.14
562480	5745504	50.83	237.06
562481	5745505	51.63	237.12
562482	5745506	53.73	237.23
562484	5745507	55.46	236.97
562486	5745507	58.31	236.93
562489	5745508	61.45	237.01
562491	5745509	63.42	237.23
562492	5745509	64.10	237.29
562492	5745509	64.40	237.46
562493	5745509	65.30	237.47
562494	5745510	66.56	238.27
562495	5745510	67.53	238.44
562499	5745511	71.85	238.64
562505	5745512	77.27	238.55
562508	5745512	80.83	238.57
562511	5745511	84.29	238.54

XS 2 - 13153.5			
X	Y	CH (m)	Z (m)
562439	5745470	0.00	239.31
562443	5745470	4.05	239.09
562446	5745471	7.92	238.86
562449	5745473	11.25	238.75
562452	5745475	14.66	238.69
562455	5745475	17.79	238.34
562458	5745476	20.68	238.09
562460	5745477	22.67	237.62
562463	5745477	25.57	237.54
562465	5745478	28.11	237.29
562465	5745478	28.35	237.29
562466	5745479	29.48	237.03
562468	5745479	31.51	236.77
562470	5745479	33.32	236.48
562471	5745480	34.59	236.62
562474	5745480	36.94	236.96
562474	5745480	37.51	237.27
562474	5745480	37.71	237.70
562477	5745480	40.07	237.88
562480	5745480	43.30	237.89
562482	5745481	45.59	237.83
562483	5745481	46.10	237.28
562483	5745481	46.34	237.07
562484	5745481	47.05	236.98
562486	5745481	48.91	236.85
562488	5745481	50.94	236.69
562490	5745481	53.15	236.74
562491	5745481	54.29	236.80
562493	5745481	56.66	236.88
562495	5745481	58.43	237.13
562496	5745481	59.46	237.17
562497	5745482	60.01	237.28
562497	5745482	60.11	237.26
562497	5745482	60.91	237.45
562499	5745482	62.48	238.04
562500	5745482	63.29	238.13
562502	5745482	65.18	238.55
562504	5745483	67.74	239.05
562506	5745482	69.55	239.42
562508	5745482	71.85	239.57

XS3 - 13045.5			
X	Y	CH (m)	Z (m)
562432	5745391	0.00	239.16
562436	5745388	5.38	238.75
562441	5745386	10.42	238.40
562446	5745385	15.61	238.11
562449	5745383	19.16	238.35
562452	5745382	22.43	238.11
562456	5745381	25.70	237.85
562456	5745381	26.26	237.67
562458	5745380	28.18	237.44
562461	5745379	31.22	237.33
562461	5745379	31.44	237.17
562462	5745379	32.47	237.16
562463	5745378	33.68	237.25
562463	5745378	34.05	237.42
562466	5745378	36.85	237.59
562469	5745377	39.74	237.39
562470	5745376	41.11	237.69
562472	5745376	42.78	237.57
562472	5745375	43.46	237.30
562472	5745375	43.52	237.30
562474	5745375	45.89	237.04
562476	5745374	47.68	237.14
562479	5745373	50.38	237.11
562481	5745372	53.10	237.20
562482	5745372	53.84	237.30
562484	5745371	55.87	237.61
562485	5745370	57.35	238.27
562489	5745369	61.86	238.57
562492	5745368	64.80	238.91
562497	5745366	70.01	238.96
562502	5745363	75.89	239.04

XS 4 - 12898.3			
X	Y	CH (m)	Z (m)
562338	5745348	0.00	238.83
562339	5745343	5.44	238.69
562340	5745338	10.78	238.60
562341	5745334	14.78	238.63
562341	5745329	19.45	238.50
562342	5745325	23.58	238.28
562343	5745321	28.05	237.76
562345	5745317	32.68	237.34
562345	5745313	36.70	237.35
562346	5745309	40.24	238.00
562347	5745306	43.13	237.34
562347	5745303	46.54	237.17
562348	5745301	48.57	236.95
562348	5745298	52.03	237.01
562349	5745296	54.20	237.32
562350	5745292	57.95	237.76
562350	5745288	61.61	238.25
562350	5745284	65.59	238.55
562351	5745281	68.89	238.56
562351	5745277	73.24	238.61
562353	5745273	76.97	238.70
562353	5745269	81.14	238.66
562354	5745265	85.38	238.69
562355	5745260	90.17	238.83
562356	5745257	94.00	238.72
562356	5745253	97.62	238.76

XS 5 - 12766.4			
X	Y	CH (m)	Z (m)
562225	5745373	0.00	238.69
562224	5745368	4.91	238.58
562225	5745363	9.49	238.57
562224	5745358	14.68	238.58
562223	5745353	19.76	238.53
562222	5745348	25.25	238.55
562222	5745343	30.24	238.35
562221	5745338	34.96	238.23
562220	5745333	39.94	238.56
562221	5745332	41.27	237.89
562221	5745329	43.96	237.77
562220	5745326	47.76	237.74
562219	5745323	50.15	237.45
562219	5745322	51.18	237.29
562218	5745319	54.67	237.21
562217	5745317	56.83	237.01
562216	5745316	58.55	236.86
562215	5745315	59.89	237.41
562216	5745314	60.62	237.64
562215	5745312	62.72	237.43
562215	5745309	65.34	237.48
562214	5745307	67.76	237.29
562214	5745304	71.26	237.02
562214	5745300	74.43	237.00
562215	5745298	76.84	237.16
562215	5745297	77.88	237.41
562214	5745295	79.64	237.78
562214	5745295	80.26	238.25
562213	5745291	83.65	238.59
562213	5745286	89.55	238.70
562212	5745282	93.36	238.69
562213	5745277	98.29	238.81
562212	5745272	103.58	238.80
562212	5745267	108.16	238.81
562210	5745262	113.63	238.78

XS 6 - 12750			
X	Y	CH (m)	Z (m)
562240	5745399	0.00	238.87
562239	5745395	4.15	238.76
562238	5745390	9.60	238.64
562236	5745385	14.54	238.56
562235	5745380	19.65	238.53
562233	5745376	24.43	238.54
562231	5745370	30.59	238.44
562230	5745365	36.26	238.42
562227	5745361	41.12	238.53
562224	5745357	46.16	238.55
562221	5745353	50.59	238.66
562219	5745350	54.96	238.60
562216	5745345	59.97	238.66
562213	5745341	65.01	238.50
562212	5745338	68.83	237.90
562210	5745335	72.38	237.43
562208	5745332	75.81	236.84
562207	5745329	78.77	237.00
562205	5745326	81.88	237.27
562203	5745323	85.56	237.23
562201	5745321	89.16	237.18
562200	5745319	91.24	237.48
562197	5745316	95.32	237.81
562193	5745312	100.52	238.23
562191	5745308	104.67	238.64
562188	5745304	109.80	238.63
562186	5745300	114.27	238.74
562184	5745298	117.75	238.81
562183	5745297	118.40	238.75
562181	5745295	121.57	238.77
562179	5745292	125.52	238.83
562177	5745289	129.35	238.93

XS 7 - 12500			
X	Y	CH (m)	Z (m)
561967	5745421	0.00	238.79
561963	5745409	12.53	238.45
561962	5745401	20.51	237.62
561960	5745395	26.32	237.22
561958	5745388	33.60	237.57
561956	5745375	46.94	238.74
561948	5745363	61.29	238.85

XS 8 - 12250			
X	Y	CH (m)	Z (m)
561743	5745450	0.00	238.71
561744	5745444	6.55	238.77
561745	5745435	14.79	238.64
561746	5745432	18.08	237.82
561746	5745428	21.99	237.39
561747	5745425	25.65	237.80
561748	5745420	29.97	238.61
561747	5745418	32.80	238.50

XS 9 - 12000			
X	Y	CH (m)	Z (m)
561537	5745502	0.00	238.82
561536	5745495	7.12	238.72
561536	5745493	8.62	238.04
561534	5745488	14.58	237.46
561533	5745485	17.38	238.07
561532	5745479	23.92	238.80
561525	5745456	47.77	238.98

XS 10 - 11750			
X	Y	CH (m)	Z (m)
561311	5745594	0.00	238.88
561317	5745586	10.14	238.30
561317	5745583	13.41	238.12
561318	5745581	15.86	238.22
561317	5745575	22.05	238.83
561318	5745571	26.47	238.80

XS 11 - 11250			
X	Y	CH (m)	Z (m)
561094	5745635	0.00	239.16
561099	5745625	10.49	239.12
561092	5745618	20.31	238.45
561090	5745615	24.01	237.86
561089	5745612	27.53	238.47
561085	5745605	35.35	239.12

XS 13 - 11000			
X	Y	CH (m)	Z (m)
560721	5745959	0.00	239.05
560720	5745947	12.42	239.36
560717	5745942	18.11	238.62
560715	5745939	21.84	237.69
560714	5745936	24.96	238.66
560712	5745930	31.27	239.30

XS 14 - 10750			
X	Y	CH (m)	Z (m)
560504	5746061	0.00	239.31
560498	5746059	5.55	238.76
560496	5746059	8.48	237.76
560495	5746058	10.05	237.95
560493	5746056	12.41	239.23
560481	5746033	38.76	239.08

XS 15 - 10500			
X	Y	CH (m)	Z (m)
560257	5746095	0.00	239.40
560260	5746088	6.94	238.85
560263	5746086	10.35	237.94
560258	5746082	16.99	238.81
560260	5746079	21.09	239.58
560266	5746064	36.68	239.35

XS 16 - 10250			
X	Y	CH (m)	Z (m)
560064	5745958	0.00	239.71
560066	5745953	6.01	238.96
560070	5745946	13.46	238.99
560074	5745943	18.75	239.32
560078	5745938	24.45	239.50
560077	5745930	32.52	239.63

XS 17 - 10000			
X	Y	CH (m)	Z (m)
559853	5745977	0.00	239.91
559853	5745974	3.05	239.45
559853	5745972	4.72	239.13
559852	5745949	27.84	239.12
559851	5745938	38.59	239.46

XS 18 - 9500			
X	Y	CH (m)	Z (m)
559434	5746021	0.00	239.33
559427	5746012	11.95	238.86
559426	5746003	20.49	239.01
559430	5745998	27.72	237.40

XS 19 - 9250			
X	Y	CH (m)	Z (m)
559246	5746038	0.00	239.77
559243	5746028	10.62	239.20
559243	5746026	13.02	238.43
559244	5746024	15.02	239.04

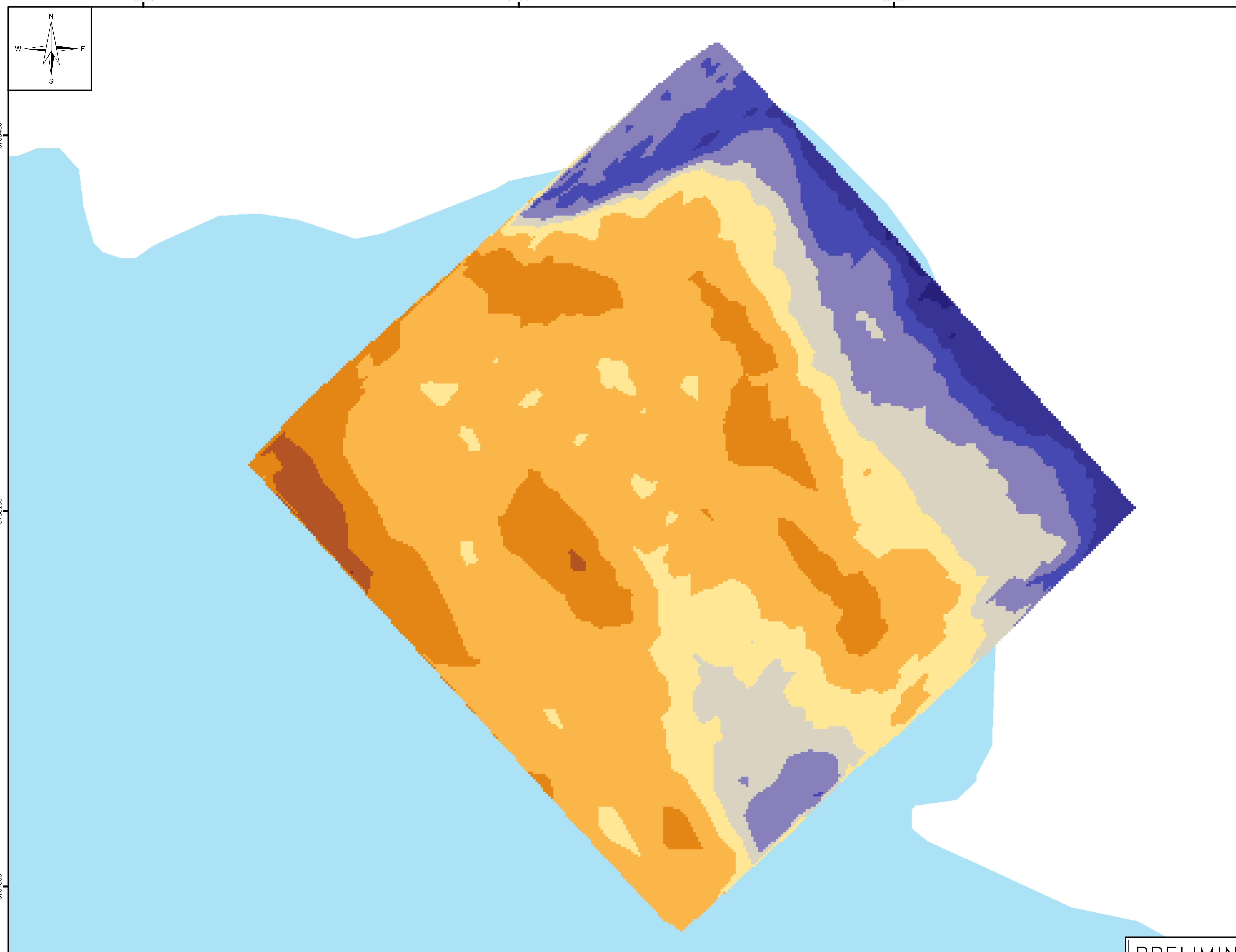
XS 20 - 9000			
X	Y	CH (m)	Z (m)
559044	5745950	0.00	240.08
559053	5745945	10.19	239.12
559055	5745944	12.25	238.73
559057	5745943	15.27	239.19

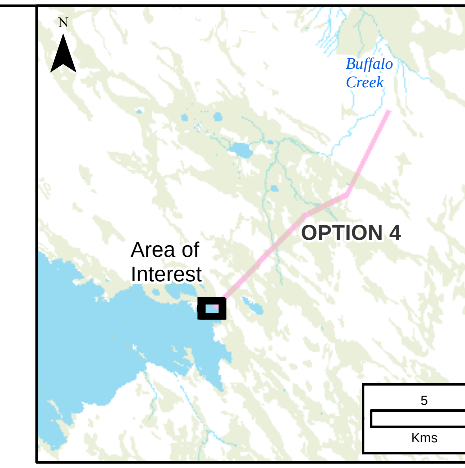
XS 21 - 8750			
X	Y	CH (m)	Z (m)
558817	5745916	0.00	240.34
558821	5745909	8.44	239.28
558821	5745905	12.77	238.54
558821	5745902	15.48	239.33

XS 22 - 8500			
X	Y	CH (m)	Z (m)
558596	5745822	0.00	239.95
558597	5745818	4.29	239.48
558598	5745817	5.72	239.93

APPENDIX D

BATHYMETRIC DATA AT INLET OF OPTION 4





LEGEND:

- Watercourse
- Waterbody

Inlet Bathymetry

- 242.89
- 242.9 – 243
- 243.01 – 243.2
- 243.21 – 243.4
- 243.41 – 243.6
- 243.61 – 243.8
- 243.81 – 244
- 244.01 – 244.2
- 244.21 – 244.4
- 244.41 – 244.51

NOTE:

1. The inlet bathymetry for option 4 collected in Fall 2016 and provided by Manitoba Infrastructure.
2. All units are metric and in metres unless otherwise specified. Transverse Mercator Projection, NAD 1983 CSRS, Zone 14. Elevations are in metres above sea level (MSL) and are referencing Canadian Geodetic Vertical Datum 1928 (CGVD28).

0 25 50 75 100 125

Metres

SCALE: 1:3,000 METRIC 11"x17"

NO.	YY/MM/DD	DESCRIPTION	ISSUED BY	CHECK BY
0	17/06/23	ISSUED WITH FINAL REPORT	PAL	MSW

REVISIONS / ISSUE

KGS GROUP CONSULTING ENGINEERS

Manitoba Infrastructure

PRELIMINARY DESIGN FOR REACH 2 OF THE LSM OUTLET CHANNEL

BATHYMETRY DATA AT INLET OF OPTION 4

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

JUNE 2017 | FIGURE D1 | REV: 0

FileName: P:\Projects\2016\16-0300-005\Dwg\GIS\MXDs\Rev0\Alignment Options\16-0300-005_FigD1_Rev0.mxd
11"x17" PLOT SCALE 1:1

APPENDIX E

POTENTIAL WETLAND RESPONSES TO LAKE ST. MARTIN OUTLET CHANNEL OPERATION IF OPTION 1 IS ADOPTED FOR REACH 2

LAKE MANITOBA FLOOD DIVERSION PROJECT

Potential Wetland Responses to Lake St. Martin Outlet Channel Operation if Option 1 is Adopted for Reach 2

Report Prepared for:

KGS Group

By

ECOSTEM Ltd.

May, 2017

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1.0 INTRODUCTION

1.1 BACKGROUND

In 2011, the Province of Manitoba constructed the Lake St. Martin Emergency Outlet Channel (LSMEOC) to relieve record widespread flooding occurring in southwestern Manitoba. LSMEOC structures were constructed from Lake St. Martin to the southwestern limit of the Buffalo Lakes wetland complex (*i.e.*, Reach 1), and from Buffalo Creek towards Lake Winnipeg (see Figure 1 in KGS Group 2017). Reach 1 and Buffalo Creek were connected by overland flow through to the Buffalo Lakes wetland complex (*i.e.*, Reach 2).

Subsequent to the 2011 flood, Kontzamanis Graumann Smith MacMillan Inc. (KGS Group) was retained by Manitoba Infrastructure to undertake a two-stage process to develop conceptual designs for permanent outlet channels from Lake Manitoba & Lake St. Martin.

Based on screening criteria and economic analyses completed within the Stage 1 study, the Province of Manitoba announced in the fall of 2014 that it was proceeding with the Stage 2 conceptual design of the preferred alternatives. The concept consisted of expanding the existing Reach 1 and Reach 3 emergency channels, extending Reach 3 to Lake Winnipeg, and construction of the Reach 2 segment located between Reach 1 and Reach 3. After completing the Stage 2 conceptual design, Manitoba Infrastructure requested KGS Group to identify additional concept alternatives for Reach 2.

Manitoba Infrastructure and KGS Group were evaluating four conceptual route options for Reach 2 (Figure 1-1) when this study was initiated in August, 2016. This was during the first stage of developing a recommendation regarding which of four alternatives was the preferred option. Option 1 of these four alternatives involves extending the Reach 1 channel to Big Buffalo Lake, and then having unconfined flow go through existing lakes and waterways as well as into the surrounding wetland complex, and then into Buffalo Creek.

1.2 ISSUES OF CONCERN

Early on during the consideration of Options 1 and 2, questions were raised about the potential for flooded peat to reduce the hydraulic performance of the permanent outlet channel in Reach 2. The primary concerns were that flooded peat mats could float up (*i.e.*, resurface) and produce floating islands that were sufficiently large to reduce outlet channel flows through Reach 2 and/or block the inlet to Buffalo Creek. The likelihood of such events occurring was unclear as none had been observed during past LSMEOC operation.

Based on an early review of the options, it became evident that Option 2 did not provide significant added benefits compared to Option 1 with respect to the risk and concerns associated with induced flooding of the wetlands described in this report. Option 2 was therefore not considered further. Analyses were therefore focused on Option 1.

ECOSTEM was retained in August, 2016 to investigate the potential for flooded peat to affect the hydraulic performance of the outlet channel through Reach 2 if Option was adopted. These were confirmed to be justified concerns at the outset of this investigation based on studies completed elsewhere in Manitoba and Quebec (Section 2.0).

To help scope this investigation, KGS then developed a preliminary list of “undesirable events” relative to the hydraulic performance of the outlet channel (see KGS Group 2017, Section 5.2). These undesirable events can be summarized as:

- Flotation and movement of individual bog islands or bog islands in large groups;
- Floating islands blocking the Reach 2 channel (or in Reach 3 downstream); or,
- Loss in conveyance as a result of floating bogs that remain in place.

This study also identified other wetland responses to human-induced flooding and water regulation that may pose issues for the hydraulic performance of the outlet channel or on the terrestrial environment. These issues related to organic sediment production and transport as well as to indirect effects on vegetation and soils due to altered groundwater characteristics.

1.3 OBJECTIVES

The objectives of this report are to:

- Provide an overview of wetland responses to human-induced flooding and water regulation;
- Report the results of a one day reconnaissance level survey of the Buffalo Lakes wetland complex;
- Provide qualitative observations on the potential for wetlands to reduce hydraulic performance of the outlet channel in Reach 2 if the Option 1 alignment is adopted; and,
- Identify other important wetland responses associated with the Option 1 alignment.

1.4 STUDY AREA

The study area included the Buffalo Lakes wetland complex and surrounding area, which is situated between Lake St. Martin and Lake Winnipeg (Figure 1-1). The study area is in the Boreal Plains Ecozone, near the western boundary of the Mid-Boreal Lowland Ecoregion and the Sturgeon Bay Ecodistrict (EcoRegions Working Group 1989). The Sturgeon Bay Ecodistrict is relatively large, including most of the north basin of Lake Winnipeg.

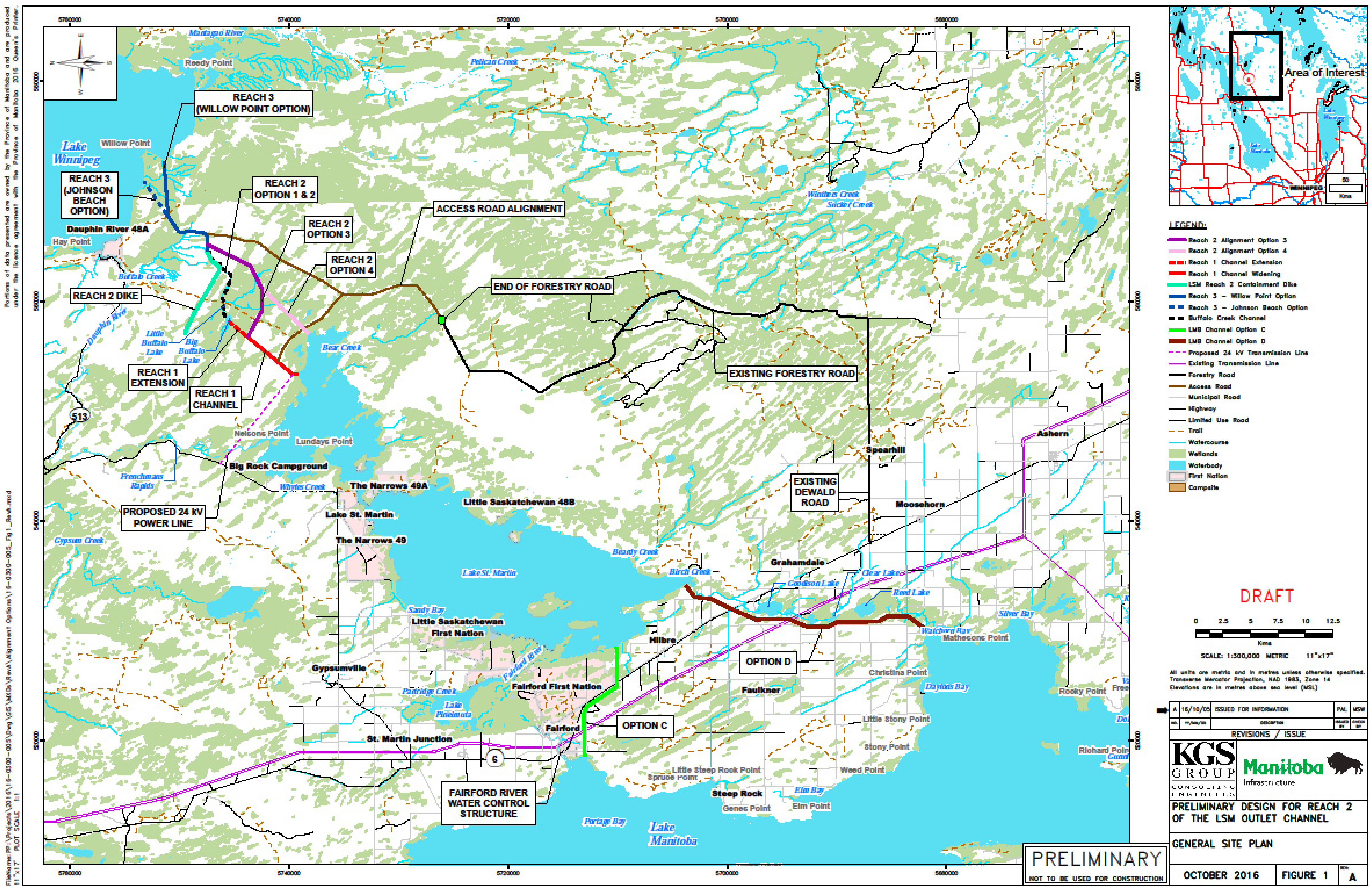


Figure 1-1. Project location and Reach 2 channel options (source KGS Group 2017).

1.5 OVERALL APPROACH

In the Canadian Wetland Classification System (National Wetlands Working Group 1997), a wetland is defined as: “land that is saturated with water long enough to promote wetland or aquatic processes as indicated by poorly drained soils, hydrophytic vegetation and various kinds of biological activity which are adapted to a wet environment.” Peatlands, which comprise two of the five wetland classes (*i.e.*, the most general subdivision of wetlands into types), include areas where dead organic material has thickly accumulated on the underlying mineral or bedrock material.

Peatlands dominate the Buffalo Lakes wetland complex (Section 4.2.1). As described in Section 1.2, there are concerns that wetlands flooded in Option 1 could substantively reduce the hydraulic performance of the outlet channel.

Numerous examples of how peatland dominated wetland complexes respond to human-induced flooding and/or water regulation are found in Manitoba and Quebec. A recent report documents such effects for northern Manitoba (Manitoba Conservation and Manitoba Hydro 2015). ECOSTEM (2012, 2013) provide a detailed examination of wetland responses to human-induced flooding and water regulation for several reaches of the Burntwood and Nelson River systems. Both reports include results that support predicting wetland responses human-induced flooding and/or water regulation. The former report includes a relevant quantitative, spatially explicit predictive model.

The overall approach to developing qualitative observations regarding potential wetland responses to future outlet channel operation if Option 1 is adopted for Reach 2 was to apply the wetland response dynamics demonstrated in other relevant flooded areas to the information available for the Buffalo Lakes wetland complex as of September, 2016.

2.0 OVERVIEW OF WETLAND RESPONSES TO HUMAN-INDUCED FLOODING AND WATER REGULATION

The following provides an overview of potential wetland responses to human-induced flooding and water regulation, with a focus on those that have implications for the hydraulic performance of the permanent outlet channel or on terrestrial ecosystems. For a detailed description of these responses in Manitoba, see Manitoba Conservation and Manitoba Hydro (2015), ECOSTEM (2012) and ECOSTEM (2013).

Human-induced flooding and/or water regulation can have a number of major direct or indirect effects on terrestrial ecosystems, including wetlands. Flooding removes some terrestrial areas. Over time, the waterbody created by flooding can expand due to peatland breakdown and mineral shoreline erosion, leading to further terrestrial losses. In some areas, affected peatlands can release large amounts of organic sediment, woody debris, methylated mercury and other materials of concern into the aquatic system. Carbon dioxide, methane and other greenhouse gases are released from flooded areas. Adjacent terrestrial areas are altered through groundwater and edge effects, potentially creating major changes to terrestrial ecosystems in some locations.

Of these general responses to human-induced flooding and/or water regulation, two may have major implications for the hydraulic performance of an outlet channel. First, portions of flooded peat mats float to the surface (peat resurfacing) and either remain in the same general area or are transported elsewhere, sometimes over large distances (Photo 2-1). Second, some of the intact peatlands along the shoreline of the waterbody created by flooding gradually break down. A portion of these become floating peat mats. Floating peat mats generated by shoreline peatland breakdown or resurfacing can either experience a net decrease or increase in volume, area and mass over given period. The net outcome depends on the balance between peat mat breakdown and new peat formation.

Note: Mobile crane at right side of photo provides a sense of photo scale. Source: ECOSTEM.

Photo 2-1: Floating peat mat that moved at least several km from its point of origin.

In this report, peatland disintegration refers to processes related to: peat resurfacing; breakdown of shoreline peatlands or resurfaced peatlands/peat mats; and, peat formation on peatlands or peat mats that have hydrological connections to the waterbody created by flooding. Peatland disintegration is a biological as well as a physical process because peat forms from living plants when conditions are favorable.

ECOSTEM (2012) identified the following three general types of peatland disintegration processes:

- Peat resurfacing
  - The uppermost layer of the flooded peat detaches from the lower peat layers. Detached mats may float to the surface (Photo 2-2), become suspended in the water column or sink quickly after detaching.
  - Floating and suspended detached mats either remain in the same general area or are transported elsewhere (Photo 2-1). There are anecdotal reports of floating peat mats moving more than 10 km in a few days.
- Shoreline and resurfaced mat breakdown
  - Shoreline or inland peatlands with hydrological connections to the waterbody created by flooding can either break down, expand or remain stable over a given time period.
  - Resurfaced peat mats can also either break down, expand or remain stable over a given time period.
- Peat formation
  - Peatlands can expand in area, volume and/or mass on a net basis in situations where dead plant material accumulation exceeds decomposition.

Source: ECOSTEM.

Photo 2-2: Large floating peat islands in the Eastmain Reservoir, Quebec.

ECOSTEM (2012, 2013) detail the drivers and pathways for wetland responses to human-induced flooding or water regulation. The following bullet points summarize the key information.

Some physical properties of peat that are important for peatland disintegration are:

- As water elevations fluctuate under natural conditions, some types of peatlands or peat mats move up and down with the water surface because they are already floating;
- The water table in a peatland is often elevated (or perched) above adjacent open water.
- Peat is elastic in the sense that anchored peat can “stretch” vertically and horizontally.
- Peat has a high water holding capacity.

The main drivers influencing peatland responses to flooding and water regulation are:

- Horizontal and vertical peat formation:
  - live vegetation on top of the peat creates more peat, which expands peat mats;
- Water level variability:
  - high water level variability inhibits organic material production from vegetation and/or removes peat and organic material;
- Waves:
  - waves physically fragment peat mat margins and/or inhibit peat mat expansion;
- Current:
  - current physically removes peat, organic material and/or peat forming vegetation;
- Ice blockages, or other obstructions or disturbances that create or increase current:
  - ice blockages can affect the location or magnitude of flows;
- Extreme water discharge or level events;
- Removal or disturbance of riparian vegetation:
  - reduces peat cohesion;
- Removal or disturbance of vegetation (e.g., clearing, fire, windthrow) in ice cored peatlands:
  - thaws ground ice which leads to peatland collapse;
- Changes to median depth to water table:
  - the rate of peat formation generally increases with decreasing depth to water table, all other things being equal;
- Changes to ground water nutrient status:
  - changes to nutrient availability for plants growing on the peat changes the rate of peat formation. Net effect is a complex interaction with other factors;
- Water depth:
  - hydrostatic pressure, which is linearly related to water depth, compresses flooded peat and forces out gas bubbles. This reduces flooded peat mat buoyancy. Other studies found that peat under water deeper than 6 m does not resurface, all other things being equal.
- Sedimentation:
  - mineral sediment accumulation counteracts flooded peat mat buoyancy;

- Vegetation clearing:
    - tree clearing tend to reduce the amount of peat mat breakup; and,
- Microbial decomposition of submerged peat:
    - gas bubbles produced by microbial decomposition increase peat buoyancy

Wetland responses to flooding occur in several stages including:

1. Initial direct responses to flooding;
2. Subsequent delayed responses to flooding as well as waterbody effects; and,
3. Subsequent indirect responses. Examples are sediment generation, debris generation, marsh formation

The three potential initial direct responses are that the peatlands: become submerged; “stretch” with rising water levels; or, some portions break away and float up with rising water.

For submerged peatlands, subsequent potential responses include remaining submerged or portions later detach and resurface. Peat resurfacing can continue for up to 10 years. Resurfaced mats can be very large (*e.g.*, Photo 2-1).

For floating peatlands, subsequent potential responses include remaining anchored, becoming highly mobile or becoming trapped by terrain or shallow water (*e.g.*, Photo 2-1)

Intact shoreline peatlands or resurfaced peat mats may subsequently break down or expand in area or volume. Peat breakdown can be offset by peat formation.

Photo 2-3 illustrates some of the peatland disintegration pathways for a peat plateau bog in northern Manitoba.

ECOSTEM (2012) developed a quantitative, spatial model to predict peatland disintegration in northern Manitoba. This peatland disintegration model predicts the locations and amounts of peat resurfacing, waterbody expansion due to peat disintegration, potential mobility of floating peat mats and organic sediment released into the aquatic system. The peatland disintegration model was developed using a time series analysis of historical air photos, a large number of soil stratigraphy samples and lab analysis to characterize the physical properties of peat.

Figure 2-1 is a schematic representation of the model for the blanket bog peatland type (a transition probability is attached to each pathway between states). Outputs from the peatland disintegration model have been successfully integrated with mineral bank erosion, sedimentation and aquatic habitat models. The model is applicable to the Buffalo Lakes wetland study based on research conducted to develop the model and available information for the study area.

Note: Arrows show pathway from intact peatland to floating peat mat to sunken peat mat.

Photo 2-3: Shoreline peatland breakdown in Kettle Generation Project reservoir.

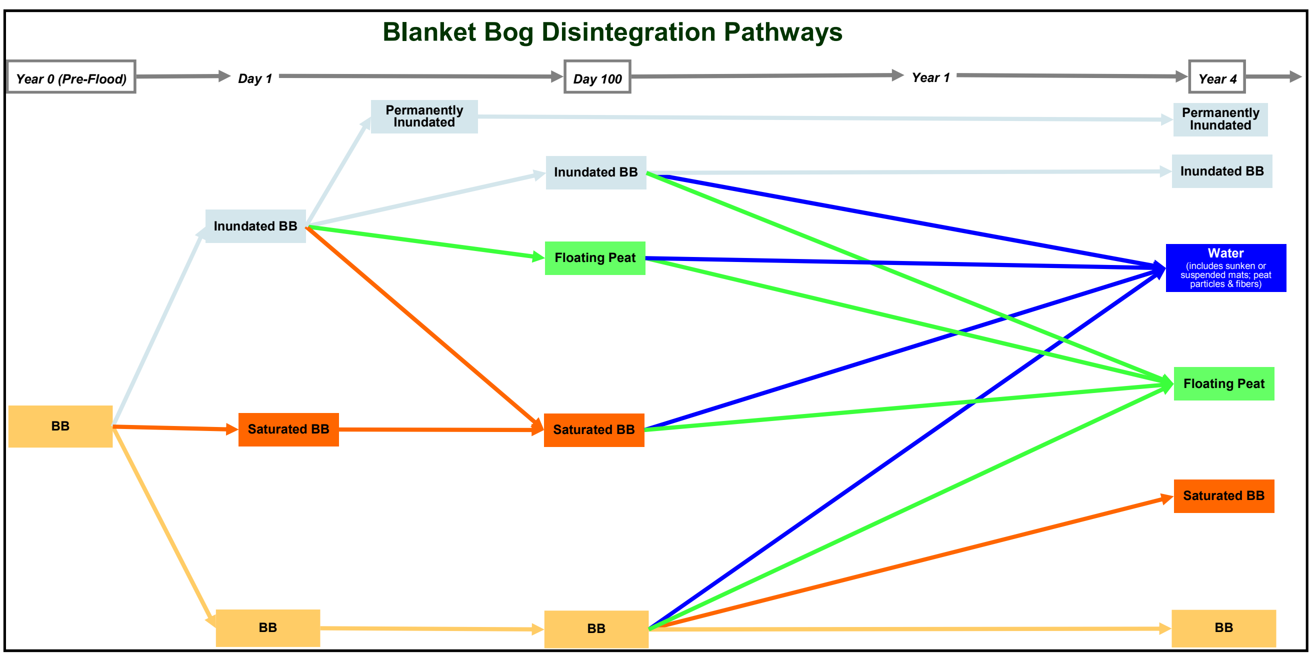


Figure 2-1: Schematic peatland disintegration pathway model for blanket bog.

The potential for peat resurfacing was a key interest of this study. The probability that a flooded peat mat will resurface is primarily determined by its buoyancy and the counteracting effects of mat anchoring and hydrostatic pressure.

Peat mat buoyancy is derived from its apparent saturated specific gravity and mat thickness. In general, only the slightly decomposed surface layer (*i.e.*, the Of, or fibric, layer) of a peat profile has a sufficiently low apparent saturated specific gravity to create adequate buoyancy to float the material to water surface. Once a peatland is flooded, it is typically only the surface Of layer that separates from the lower portions of the peat profile.

Lab analysis indicates that buoyancy of the Of layer does not vary with peatland type (ECOSTEM 2011). Peatland type is still important for characterizing wetland responses to flooding for two reasons. First, Of layer thickness is typically related to peatland type. Second, the degree of anchoring at the mat bottom or edge varies by peatland type. Veneer bogs are thought to have the strongest anchoring because they are the thinnest peatland type and therefore are more likely to have the peat and/or plant roots attached to the mineral soil.

As noted above, the counteracting effects of hydrostatic pressure are thought to be a linear function of water depth. Additionally, peat resurfacing generally does not occur when the water is deeper than 6 m.

It appears that peat resurfacing generally ceases within 10 years of flooding. The anaerobic microbial decomposition that generates gas bubbles in flooded peat (and thereby increases peat buoyancy) declines over time as microbes consume the labile material. Additionally, mineral sediment deposition weighs down the flooded peat mat and, along with the sustained effects of hydrostatic pressure, counteracts buoyancy.

The available literature suggests that the tendency for a floating peat mat to move is a function of many factors such as wave energy, current, wind characteristics (*e.g.*, direction, frequency and strength) and its location relative to waterbody morphology (*e.g.*, a mat in a bay with a narrow opening into the main waterbody will tend to be trapped in the bay). These factors can change the locations of floating peat mats as rapidly as from one day to the next. In other studies, floating peat mats in sheltered bays tended to be immobile, ostensibly because they were resting on the lake bottom or a beach and because they were somewhat more protected from wind. Additionally, floating peat mats were found in sheltered areas more often than in other areas, and peat mats could move several km or more within a few days.

3.0 METHODS

3.1 INTRODUCTION

This section describes the existing information and methods used to complete the study.

As noted in Section 1.4, the overall approach was to apply the wetland response dynamics documented in other relevant flooded areas to the information available for the Buffalo Lakes wetland complex as of September, 2016. The primary sources for documented wetland response dynamics were the ECOSTEM (2012) peatland disintegration model and the documented responses of terrestrial habitats to reservoir flooding and water regulation in northern Manitoba (ECOSTEM 2013). The available information used to meet the third study objective primarily included data and observations collected by the author during a one day reconnaissance survey, local information produced by or for KGS Group (see following subsections for details). Other relevant literature and information were also considered.

3.2 EXISTING INFORMATION

Existing information primarily used to develop the qualitative observations included the following items.

- Canvec 1:50,000 hydrography and saturated soil vector data. Available at https://www.nrcan.gc.ca/earth-sciences/geography/topographic-information/free-data-geogratis/11042
- 30 cm digital orthorectified imagery (UTM Zone 14, NAD83) created by ATLIS Geomatics from imagery captured in 2011 on July 24, 25, 26, 29, 30, 31, and August 13, 17, 18, 22.
- LiDAR data collected in 2011 prior to operation of the Lake St. Martin Emergency Outlet Channel.
- Aerial photos taken on various dates from 2011 to 2015.
- Peat depth data collected by KGS Group.
- Modeled flooding extent at 2,500 cfs.
- Modeled flooding extent at 11,500 cfs.

3.3 DATA COLLLECTION

A one day reconnaissance survey of the Buffalo Lakes wetland complex was completed on September 16, 2016. The objectives for this survey were to:

- familiarize the author with the ecological conditions within and surrounding this wetland complex;
- broadly characterize its wetland composition; and,
- confirm that the stratigraphy of the common peatland types found in the complex was consistent with that found in the flooded areas used to characterize wetland responses to human-induced flooding and water regulation.

The reconnaissance survey included helicopter-based aerial surveys of the wetland complex, ground traverses and peat profile sampling at a few strategic locations.

Map 1 shows the majority of the overflight routes. Portions of some routes are missing due to poor GPS reception. Georeferenced photos were taken during the aerial survey.

Soil stratigraphy sampling in the most common peatland types within the wetland complex was completed at 13 locations (Map 1). Ground traverses occurred in the general vicinity of these locations. Data collected at the soil stratigraphy locations included depth of surface organic material, thickness and type of surface horizon, dominant vegetation contributing to surface horizon (*e.g.*, sedges, Sphagnum mosses), whether the sampling reached the mineral substrate, mineral substrate texture and habitat type. Photos were taken of the ground cover at the sample point and of the surrounding habitat.

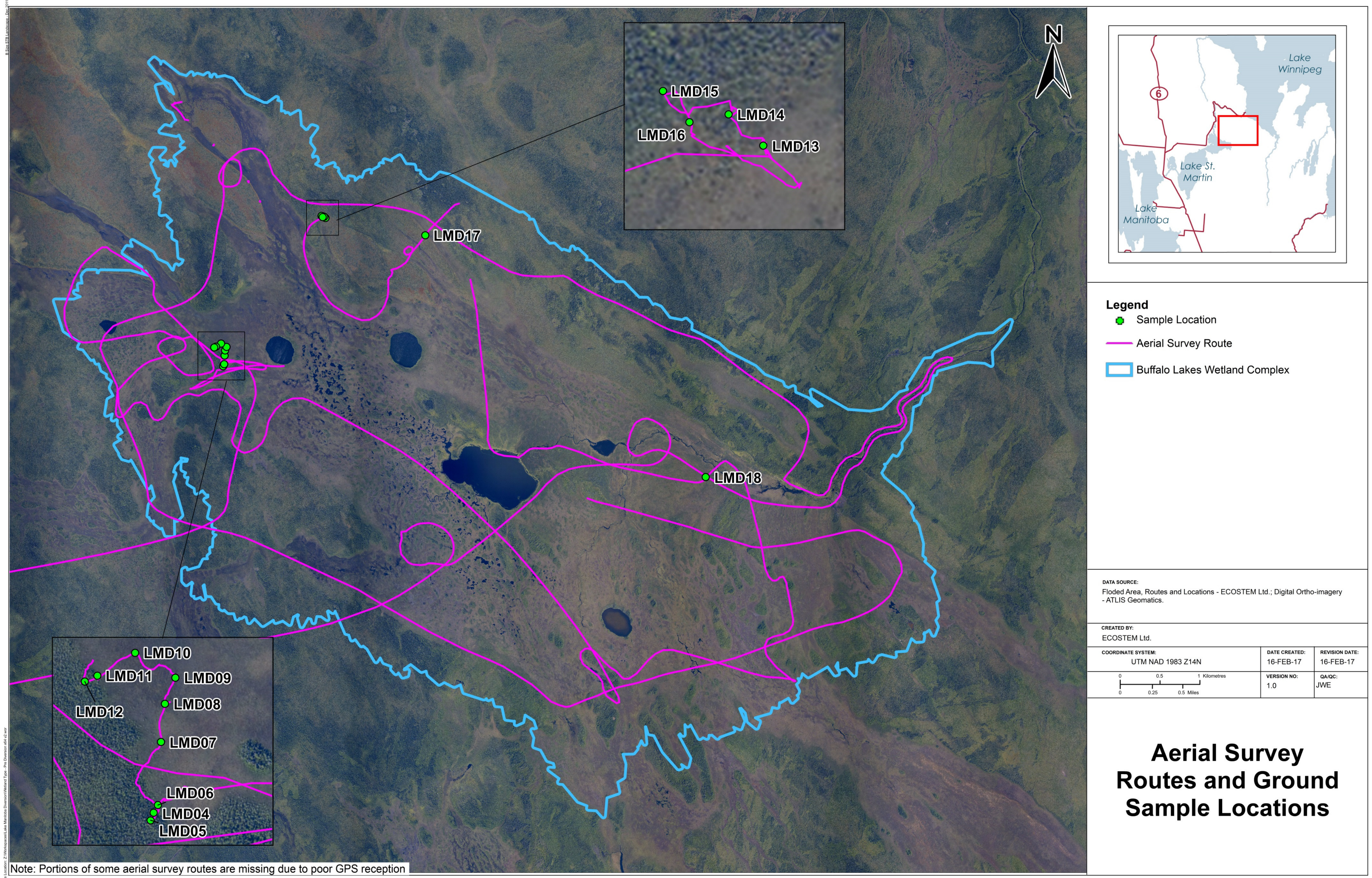
Test probing was completed at two additional locations to determine if the marsh mat was floating (see locations LMD17 and LMD18 in Map 1).

3.4 ANALYSIS

Two very generalized wetland class maps of the Buffalo Lakes wetland complex were created. The first was for conditions existing before LSMEOC construction while the second was for conditions as of 2016. This level of detail was sufficient for investigating the potential for flooded peat to affect the hydraulic performance of the outlet channel through Reach 2. The boundary of the Buffalo Lakes wetland mapping approximated the maximum potential extent of flooding (P. LeClerc, KGS Group, pers. comm., March 29, 2017).

The primary data sources used to create the pre-LSMEOC wetland map were the 30 cm DOI, aerial photos taken during the reconnaissance survey and the peat profile data collected by ECOSTEM and KGS Group. The Canvec saturated soil vector data (Section 3.2) provided a reasonable starting approximation for subdividing the wetland complex into very generalized wetland classes. These polygons were modified as needed in a GIS using the 2011 high resolution DOI as the base map for pre-LSMEOC conditions.

The post-LSMEOC wetland class map was created by modifying a copy of the pre-LSMEOC GIS dataset to reflect post-LSMEOC conditions as observed in 2016. Changes from 2011 were only made for those areas having sufficient helicopter-based aerial photo coverage.



Map 1: **Aerial survey routes and soil stratigraphy sample locations**

4.0 RESULTS

4.1 PEAT STRATIGRAPHY

The surface organic layer at the 13 locations sampled during the one day reconnaissance survey of the Buffalo Lakes wetland complex ranged from 70 cm to 220 cm thick (Table 4-1; see Appendix A for the data collected at each location). For three of the bog locations, the recorded maximum thickness was the minimum thickness since the coring stopped before reaching the underlying mineral layer. Coring was halted at some of the locations for several reasons. First, because the primary interest was the thickness of the Of layer, as this is typically the only organic layer to have sufficient buoyancy and cohesiveness to resurface after flooding (Section 2.0). Additionally, it was known that KGS Group had measured total peat depth at a large number of locations.

Table 4-1: Minimum and maximum thickness (cm) of the surface organic material and the Of (fibric) layer.

Peatland Type	N	Surface Organic Material		Of (fibric) Layer		
		Minimum	Maximum[1]	Minimum	Mean	Maximum
Bog	4	110	140	70	85	100
Fen	9	70	220	10	23	40
All	13	70	220	10	42	100

Notes: [1] Coring at three of the bog locations stopped before reaching the underlying mineral layer.

The Of layer in all of the bog locations was thicker than in the fen locations (Table 4-1). Additionally, the Of layer in the bog profiles was primarily derived from Sphagnum mosses, whereas that of the fen profiles was either primarily derived from sedges or a mixture of sedges and Sphagnum mosses.

Both of the preceding results were expected. The relatively oligotrophic rooting zone conditions that distinguish a bog from a fen also inhibit decomposition. Slower decomposition generally produces a thicker Of layer in bogs than in fens. As most lacustrine bogs originate from fens, Sphagnum moss colonization is often the driving factor that gradually reduces rooting zone nutrient availability, and eventually converts the fen into a bog (Zoltai et al. 1988).

The generalized peat stratigraphy at the sample locations was the same as found by the other studies used to characterize wetland responses to flooding and water regulation (Section 1.4). While there were variations in organic layer thicknesses, the sequence of layer types and their general state of decomposition were the same. This similarity was consistent with the lack of variability by peatland type previously observed for this parameter in other studies (Section 2.0).

4.2 WETLAND COMPOSITION

4.2.1 Prior to LSMEOC Operation

Prior to LSMEOC operation, fen was the most abundant wetland class in the 5,342 ha Buffalo Lakes wetland complex based on the very generalized wetland mapping created for this report (Map 2). In 2011, fen covered approximately 62% of total wetland complex area (Table 4-2). At approximately 33% of complex area, bog was the next most abundant wetland class by far. Shallow open water was the remaining wetland type mapped in 2011, and included Big Buffalo Lake, Little Buffalo Lake, four other small lakes and Buffalo Creek.

Table 4-2: Pre- and post-LSMEOC generalized wetland class composition of the Buffalo Lakes wetland complex.

Dominant Wetland Class[1]	Percentage of Total Area[2]		Total Area (ha) [2]		
	Pre-LSMEOC (2011)	Post-LSMEOC (2016)	Pre-LSMEOC (2011)	Post-LSMEOC (2016)	Difference (2016-2011)
Bog	33	33	1,751	1,741	-10
Fen	62	57	3,325	3,029	-296
Emergent on Fen	-	6	-	295	295
Shallow Water	2	2	100	100	0
LSMEOC Channel	-	~0	-	10	10
Not Determined	3	3	166	166	0
All	100	100	5,342	5,342	0

Notes: [1] Patches of other wetland classes occur within each total. [2] "-" indicates the type is absent; "~0" is a value that rounds to zero.

The mapped fen and bog included unmapped patches of marsh, swamp and either fen or bog, depending on the mapped type. Since the mapping was very generalized, some of these unmapped wetland patches could be large enough to meet the minimum size for affecting hydraulic performance (Section 3.4).

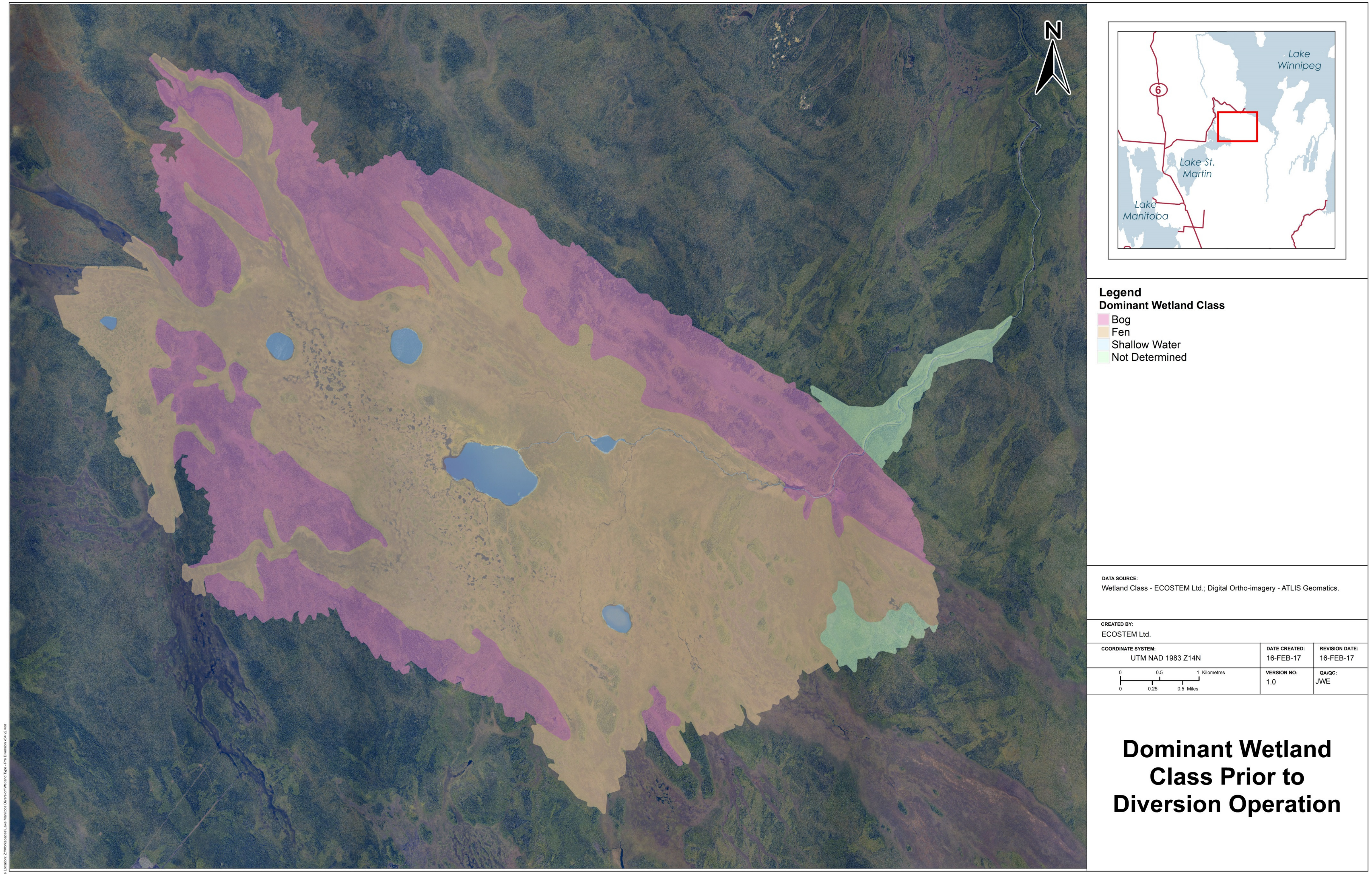
Mapped bog was concentrated in the north, south and west perimeter areas of the Buffalo Lakes wetland complex (Map 2). All of the mapped bog was predominantly situated on the higher ground within the wetland complex (Map 3).

The unmapped marsh appeared to be concentrated in the shallow water near the shorelines of the Buffalo lakes and Buffalo Creek. Unmapped swamp was scattered throughout the wetland complex but concentrated southeast of Buffalo lakes. A fen-bog-swamp sequence was frequently observed, particularly southeast of Buffalo lakes. In some instances, this sequence also included an upland zone.

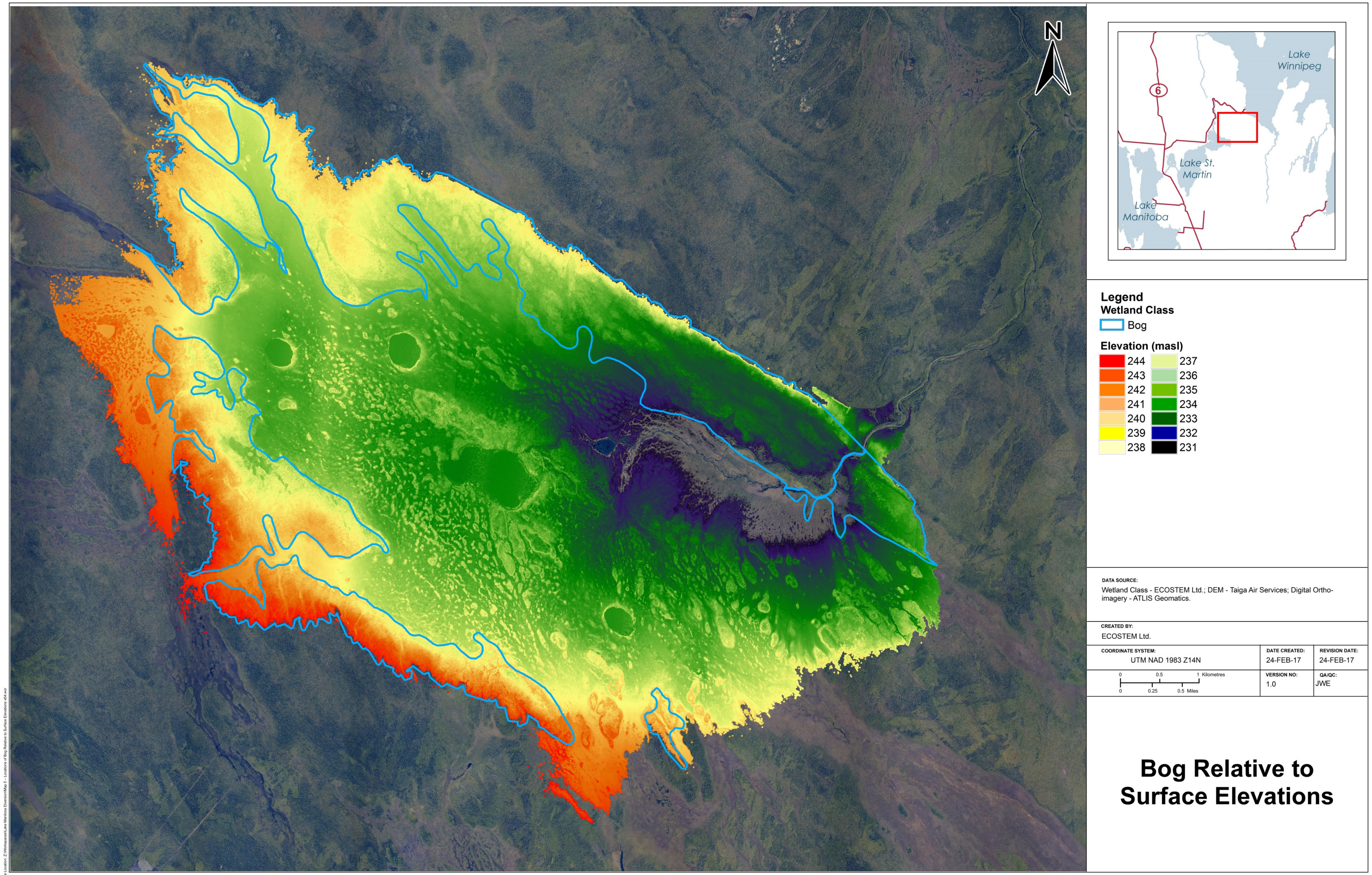
Using the Canadian Wetland Classification System (National Wetlands Working Group 1997), the bog was predominantly blanket and veneer bog, with the veneer bog being in a more elevated slope position than the blanket bog. Riparian bog comprised the majority of the remaining bog area.

The fen was predominantly of the horizontal form. Riparian fen comprised the majority of the remaining fen area.

String fen was also observed, but largely outside of the wetland complex. String fens typically indicate high unconfined groundwater flows. The observed fens, combined with the surface elevation provided by the DEM, suggest that unconfined groundwater flows have created and maintained the Buffalo Lakes wetland complex priori to LSMEOC operation.



Map 2: Generalized wetland class in the Buffalo Lakes wetland complex prior to LSMEOC construction and operation.



Map 3: **Location of pre-LSMEOC bogs relative to surface elevations.**

4.2.1 After LSMEOC Construction and Operation

Key past impacts of LSMEOC construction and operation on the Buffalo Lakes wetland complex include excavation, flooding, flow variation in space and time, water level variation and mineral sediment deposition.

Channel construction was complete prior to the start of LSMEOC operation. LSMEOC excavation within the wetland complex (Photo 4-1, Photo 4-2) removed about 10 ha of the 5,342 ha of wetlands in the complex (Table 4-2).

Up to September, 2016, the LSMEOC had been operated for two periods: November 1, 2011 to approximately November 21, 2012; and, July 2, 2014 to approximately August 14, 2015. Flooding, flow variation and water level variation were expected to dissipate over some period after each time that LSMEOC operation ceased.

LSMEOC flows through Reach 1 largely determined the proportion of and locations where the Buffalo Lakes wetland complex have been or would be flooded. The modeled 5^{th} to 95^{th} percentile range of flows for future outlet channel operation is 1,000 cfs to 11,000 cfs (see KGS Group 2017, Section 3.1). Map 4 shows the modeled flooded area when outlet channel flows are at either 2,500 cfs or 11,500 cfs.

Estimated actual flows during the two past periods of LSMEOC operation ranged from approximately 700 cfs to 7,600 cfs (KGS Group 2016). The highest flows occurred immediately after the LSMEOC was first opened during the winter of 2011/2012. The maximum estimated flow on any day after April, 2012 was approximately 4,400 cfs while the maximum on any day during the open water season was approximately 4,400 cfs.

During the first stage of investigating potential wetland responses to LSMEOC operation, the pre-LSMEOC generalized wetland class map was updated to September, 2016 conditions and compared with several degrees of flooding. Map 6 shows the very generalized wetland composition of the Buffalo Lakes wetland complex in 2016. Revisions to the pre-LSMEOC wetland class dataset were only made for areas having sufficient photo coverage from the September, 2016 helicopter-based aerial survey (see Section 3.4 for details).

At the time of the 2016 reconnaissance survey, it was clearly apparent that a large proportion of the Buffalo Lakes wetland complex had already undergone major alteration due to LSMEOC operaton. Based on modeled flooding at various flows and satellite imagery (*e.g.*, September 22, 2014 Landsat imagery), it was estimated that at least half of the peatlands within the complex had been flooded or otherwise affected by LSMEOC flows. Mineral sediment was present on top of former peatlands (Photo 4-6).

(Source: KGS Group)

Photo 4-1: LSMEOC excavation at the end of construction.

(Source: KGS Group)

Photo 4-2: LSMEOC excavation and flooding near outlet on August 13, 2014.

Based on the pre-LSMEOC wetland class mapping and available information (*e.g.*, Photo 4-3), the excavated wetlands were primarily bog. Given the generalized nature of this mapping, fen and possibly swamp were affected as well. It appeared that most, if not virtually all, of the LSMEOC-related flooding to date was on the mapped fen. It may be the case that very little of the bog was flooded during the open water season (*e.g.*, Photo 4-4).

(Source: Taiga Air Services)

Photo 4-3: Wetlands in LSMEOC area on June 23, 2011.

(Source: KGS Group)

Photo 4-4: Flooding in western portion of the wetland complex on April 17, 2012.

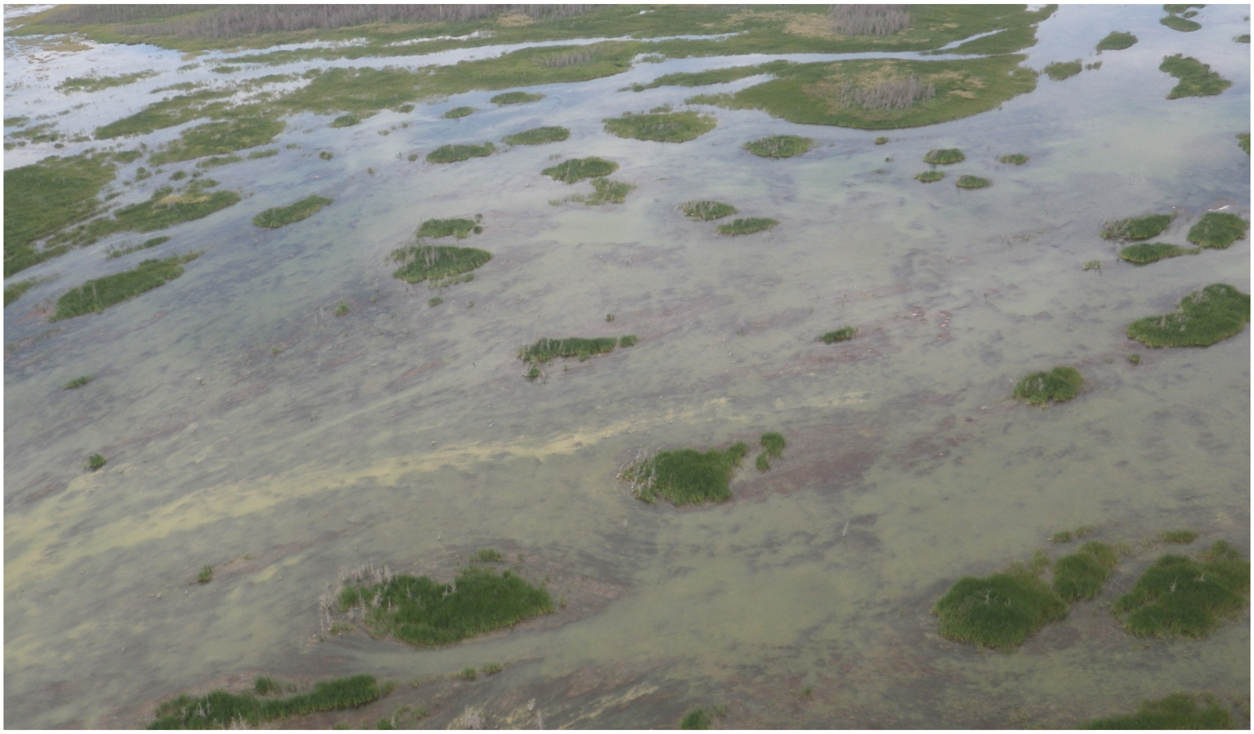
Map 5 shows actual flooding that was visible in Landsat 8 imagery acquired on September 22, 2014. Estimated flows on this day were approximately 3,550 cfs, which was about 80% of the maximum (approximately 4,400 cfs) during the open water seasons to date. The vast majority of bogs were not inundated at this flow. Additionally, the DEM illustrates that elevations within the bog areas increase substantially (Map 3), which limits how much additional area would be flooded at 4,400 cfs. And even less bog would be inundated if some of the bog peat “stretched” up with rising water, which is what has been observed in other regions. It is noted that, while there are bogs too small to map in the flooded fen area, their combined area is likely quite low, and the individual patches small.

Considerably higher flows were present immediately after the LSMEOC was first opened (*i.e.*, up to approximately 7,600 cfs), which was during the winter. Based on surface elevations, predicted flooding and observed flooding (see above), it was thought that only a portion of the bog would have been flooded during this period. Also, any flooded peatlands were frozen, which was expected to considerably reduce their potential for resurfacing (ECOSTEM 2012).

Some bog that was not flooded would have experienced other effects from LSMEOC operation. Vegetation and soils would have been affected by factors such as an elevated water table and nutrient-enriched groundwater.

Much of the fen observed during the September, 2016 reconnaissance survey was no longer “natural” due to inundation and mineral sediment deposition (Photo 4-5, Photo 4-6). Depending on the location, pre-existing plants had been killed.

In many locations, cattails (*Typha* spp.) and/or common reed (*Phragmites australis*), which are tall emergent plants often found in southern Manitoba marshes, had colonized and become established on top of a former fen (Photo 4-7), and were quite dense in some locations. It seemed likely that these emergent plants established shortly after the surface of the submerged fen reappeared after LSMEOC operation ceased and water levels dropped (Photo 4-8). Cattails have been widely observed growing on peatlands affected by human-induced flooding or water regulation elsewhere in central (Manitoba Conservation and Manitoba Hydro 2015) and southern (ECOSTEM unpublished information for the Winnipeg River) boreal regions of Manitoba.



(Source: KGS Group)

Photo 4-5: Flooded fen and mineral sediment on August 14, 2013.

(Source: KGS Group)

Photo 4-6: Mineral sediment on former fen at channel outlet.

(Source: ECOSTEM)

Photo 4-7: Emergents growing on former fen.

(Source: KGS Group)

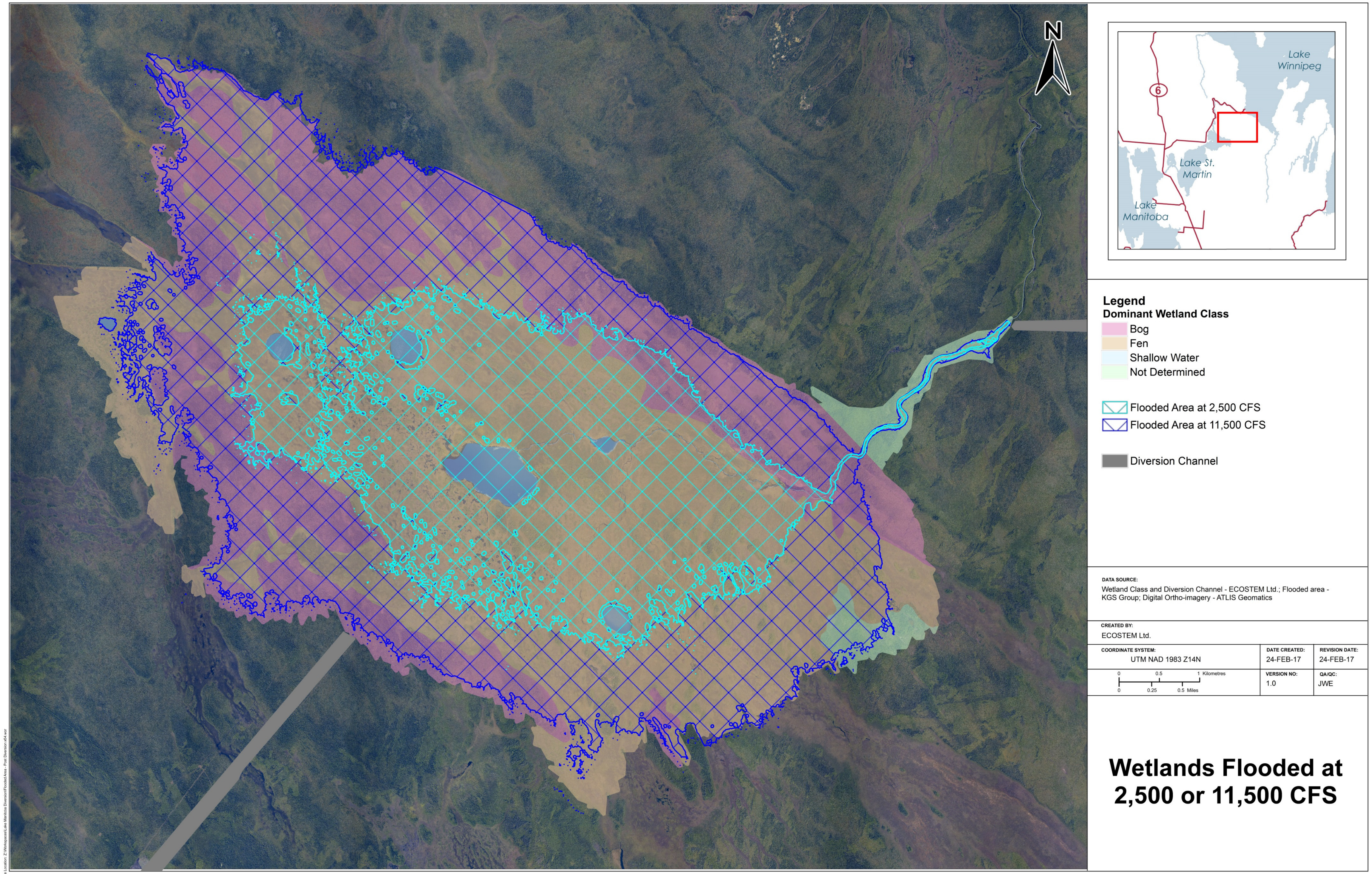
Photo 4-8: Dense emergents on August 14, 2013.

This report uses “marsh-like vegetation” to refer to emergent vegetation growing on fen that was submerged during LSMEOC operation. Such vegetation was considered to be marsh-like rather than true marsh since this type is rarely seen under natural boreal conditions, particularly with respect to events that create high mineral sedimentation on top of a fen. Additionally, the Canadian Wetland Classification System does not include human modified types.

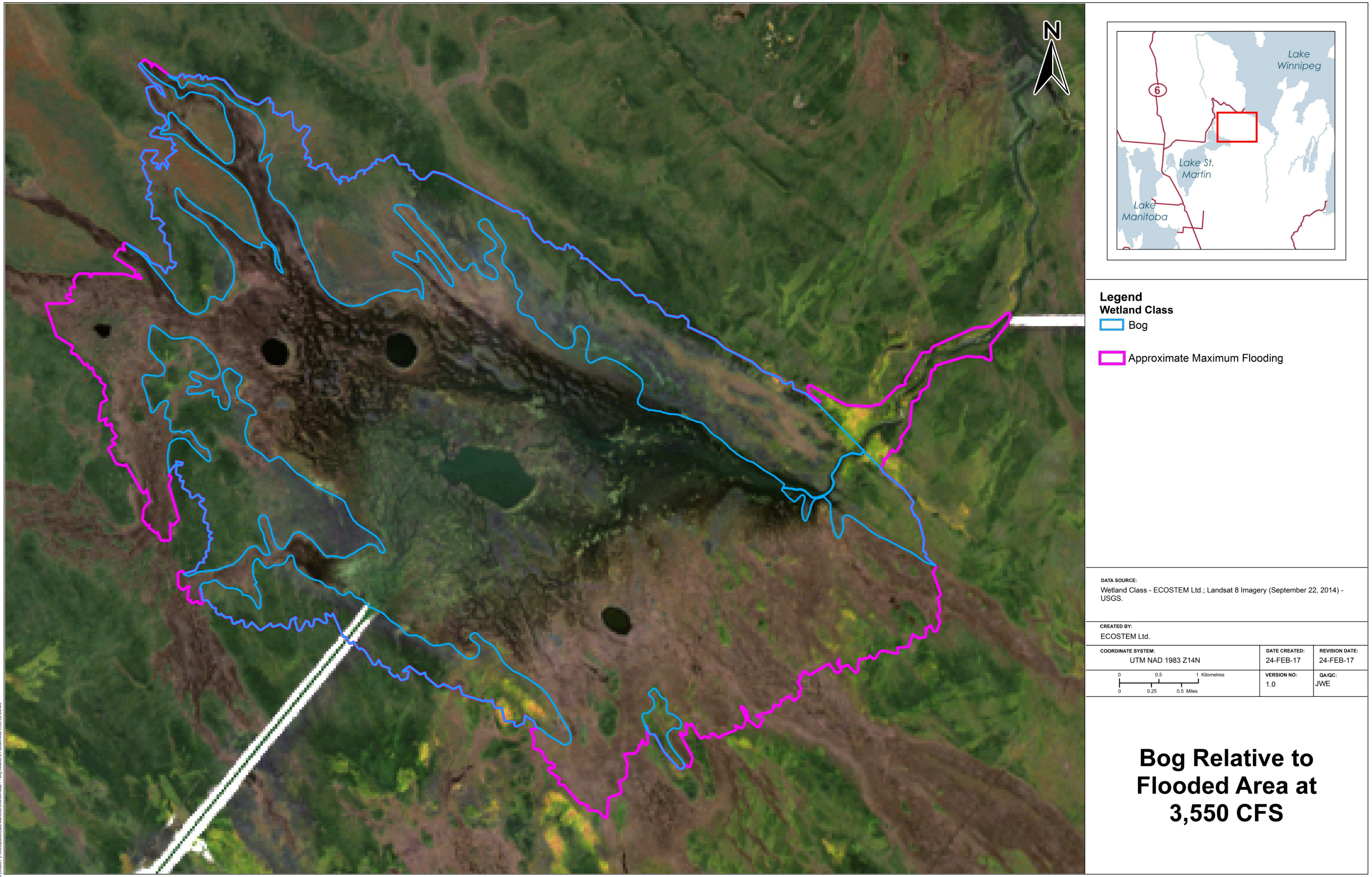
Marsh or marsh-like vegetation was observed in many locations during the September, 2016 reconnaissance survey. The total area with marsh or marsh-like vegetation appeared to be considerably higher than it was prior to LSMEOC operation based on available remote sensing (*i.e.*, aerial photos and high resolution DOIs). Increased emergent vegetation was likely facilitated by the nutrient additions from the LSMEOC water and from mineral sediment deposition. The extent to which emergent vegetation on fen became more abundant could not be determined since the available remote sensing only covered a portion of the wetland complex. Additionally, the substrate type could not be determined in many locations because it was submerged.

To the extent that the generalized wetland class mapping could be updated, results indicated that the percentage of total wetland complex area that was natural fen decreased by at least 5%, or from approximately 62% to 57% of total area (Table 4-2). Given the limitations of the mapping, this was expected to be a substantial underestimate of the total amount of fen alteration.

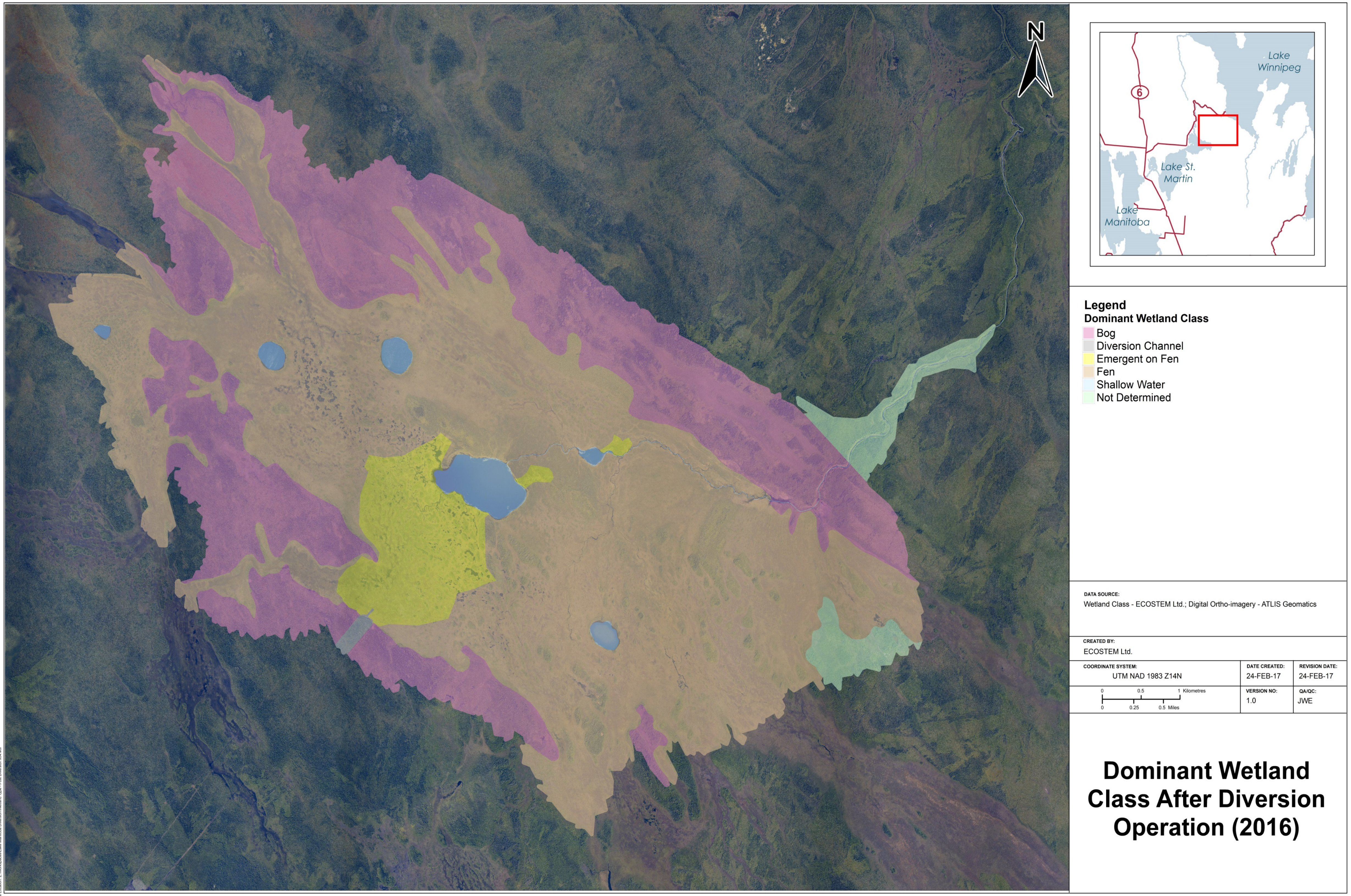
All of the mapped fen alteration consisted of conversion to marsh-like vegetation (Table 4-2). These alterations were situated between the LSMEOC channel outlet and Big Buffalo Lake, immediately east of Big Buffalo Lake and immediately east of Little Buffalo Lake.



Map 4: **Wetlands flooded when modeled outlet channel flows are 2,500 or 11,500 cfs in Option 1.**



Map 5: **Location of bog relative to flooded area in Landsat imagery on September 22, 2014, at outlet channel flows of 3,550 cfs.**



Note: Changes from Map 2 were only made in areas with suitable helicopter-based aerial photo coverage.

Map 6: **Generalized wetland class in the Buffalo Lakes wetland complex in 2016, which is after LSMEOC construction and operation.**

5.0 QUALITATIVE OBSERVATIONS ON WETLAND RESPONSES

This section of the report provides qualitative observations on potential wetland responses to outlet channel operation if Option 1 is adopted for Reach 2. The focus is on risks to hydraulic performance, as this was the concern that initiated the study. Observations are also provided for organic sediment transport and long-term changes to vegetation and soils from groundwater alterations.

It is noted that all observations are based on limited amounts of fieldwork and analysis by the author. This study was simply intended to determine the nature of risks to help inform evaluation of all four options being considered during Stage 2 design.

5.1 RISKS TO HYDRAULIC PERFORMANCE IN REACH 2

Concerns were raised during Stage 1 design that flooded wetlands might pose potential risks to the hydraulic performance of the outlet channel if Option 1 becomes the adopted alignment in Reach 2 (Section 1.2). To provide some background, Section 2.0 included an overview of potential wetland responses to human-induced flooding and water regulation. In brief, peat resurfacing (*i.e.*, flooded peat mats rise to the water surface) and shoreline peat breakdown are the two forms of peatland disintegration that could generate floating peat islands that either reduce conveyance through Reach 2 or block the inlet to Buffalo Creek.

During the course of this study, marsh and marsh-like vegetation were identified as another potential risk to hydraulic performance if Option 1 is adopted for Reach 2. It is possible that some proportion of these wetlands would also generate floating islands.

5.1.1 Peat Resurfacing

Peat resurfacing is the wetland response having the highest potential to reduce hydraulic performance. When a peatland is flooded, the surface Of (*i.e.*, fibric) layer is the only one that typically has the potential to separate from the lower portions of the peat profile, all other things being equal (Section 2.0). The key factors determining Of layer resurfacing potential are Of layer thickness, degree of peat mat anchoring and water depth over the flooded peat.

It appeared that, to date, only a small proportion of the total bog area was flooded by LSMEOC operation during the open water season (Section 4.2.1). And even in the areas where surface elevations generate modeled flooding, the peat may have stretched up with the rising water and remained otherwise intact. Additionally, given the types of bog found in the wetland complex, less than 10% of the bog area was expected to resurface if their response was similar to that observed in other regions.

Peat resurfacing that produced persistent floating islands has not been observed during LSMEOC operation to date. This could be largely explained by the following factors[1]:

[1] Given the limited amount of monitoring information, it is possible that floating islands were produced but sank before they could be observed.

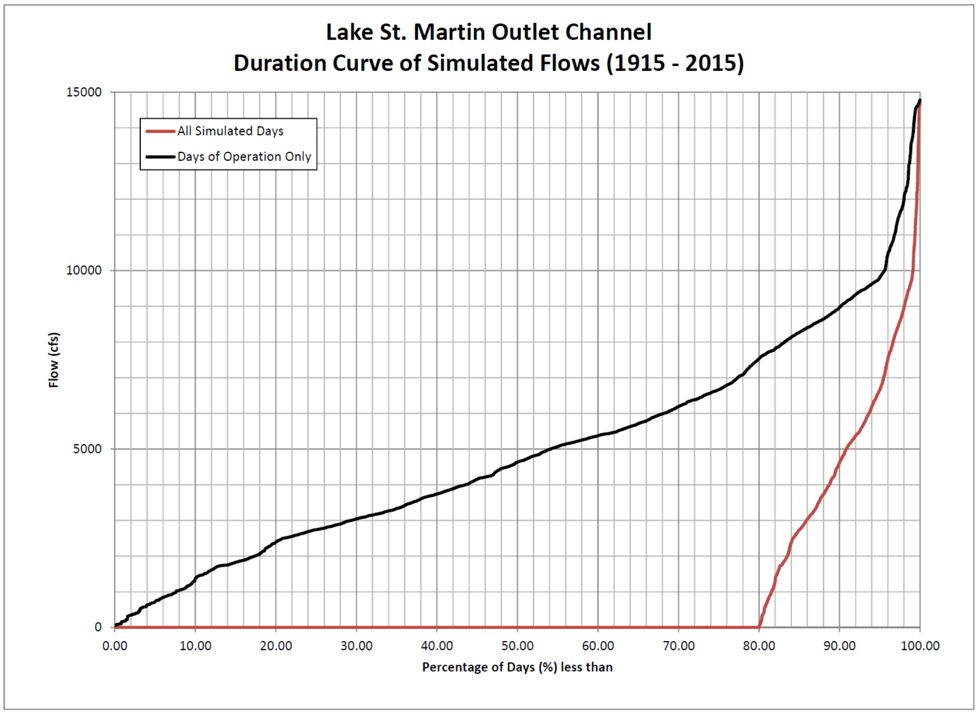
- For fens:
  - Most flooded patches lacked sufficient buoyancy and cohesiveness to resurface as a mat because their Of layer was too thin (Section 4.1); and,
  - Where the Of layer was sufficiently thick, buoyancy was counteracted upon by the fen being frozen during initial flooding (which increases anchoring), water depth increasing rapidly during initial flooding (P. LeClerc, KGS Group., pers. comm. March 29, 2017) and many patches receiving mineral sediment deposition.
- For bogs:
  - The vast majority of bog was outside of the LSMEOC open water season flooding;
  - Some of the flooded bog stretched up with rising water levels; and,
  - Water levels that were sufficiently high to flood portions of bogs were only present during the winter when the peatlands were frozen. Frozen peat has a much lower resurfacing potential due to higher cohesiveness and substrate attachment.

In contrast, there still are future risks to hydraulic performance from peat resurfacing if Option 1 is adopted for Reach 2. Most of the bog within the wetland complex would be flooded at design flows of 11,500 cfs (Map 4). This contrast with past conditions in which flows after the first few months of operation have always been below the 50th percentile of flows simulated from historical conditions (Figure 5-1; flood routing studies conducted by the Province of Manitoba simulating historic conditions assuming the Lake Manitoba and Lake Sat. Martin Outlet Channels are in operation; see KGS Group 2017, Section 3.1).

Additionally, predicted water depths are too shallow to prevent peat resurfacing. Hydrostatic pressure is a linear function of water depth, thought to range from 0 m to 6 m in other studies. Predicted water depths are considerably less than 6 m in all areas. If none of the bog initially stretched up the rising water, water depths over 83% of the mapped bog would be less than 2 m, and 53% would be in water less than 1 m deep (Table 5-1). Many of the deep areas are in pre-existing waterbodies.

Nevertheless, the actual amount of peat resurfacing when flooding is at its maximum may be quite low. ECOSTEM (2011, 2012) found that the veneer and blanket bog types have the lowest resurfacing potential amongst the studied peatland types. Additionally, after considering all the driving factors, it is estimated that an average of 1% of veneer bog and 6% of blanket bog resurface after flooding.

However, even at relatively low outlet channel flows of 2,500 cfs, there is a small risk that peat resurfacing could reduce hydraulic performance in Reach 2 with Option 1. At these flows, there are bogs in the flooded fen area (Map 5) that were too small to map. These bogs likely pose a small risk to hydraulic performance, primarily for two reasons. They often occur in patches smaller than the 30 m diameter. Many of these bog patches have had mineral sediment deposited on them during past operation, which reduces their resurfacing potential.



Source: KGS Group (2017).

Figure 5-1: Lake St. Martin outlet duration curve.

Table 5-1: Modeled water depths within the Buffalo Lakes wetland complex at outlet channel flows of 11,500 cfs, by wetland class.

Water Depth (cm) [2]	Bog	Fen	Emergent on Fen	Shallow Water	Channel	Not Determined	All
0	11	6	-	2	37	13	7
1 - 50	11	8	0	2	23	0	8
51 - 100	31	8	1	0	34	4	15
101 - 150	21	27	42	1	7	25	25
151 - 200	9	30	55	86	-	20	25
201 - 250	12	12	0	0	-	8	11
251 - 300	3	7	2	5	-	7	5
301 - 350	1	2	0	1	-	3	2
351 - 400	0	0	-	0	-	1	0
> 400	0	0	-	2	-	20	1
All	100	100	100	100	100	100	100

Notes: "-" indicates the type is absent; "~0" is a value that rounds to zero.

5.1.1 Shoreline Peat Breakdown

In the Buffalo Lakes wetland complex, most of the predicted waterbody shoreline at the upper range of flooding will occur in bog or bog transitioning into swamp or upland soils. This peat shoreline would include anchored peat mats. It would also include peat mats that move up with rising water levels become part of the waterbody shoreline.

Shoreline peat could also break down and generate peat islands (Section 2.0). Other studies have shown that portions of bogs will move up with rising water levels, detach and then become floating peat islands. Some of these islands could be larger than 30 m in diameter. Intact, anchored mats have also been seen to detach and become floating, similar to peat resurfacing.

The primary driving factors for shoreline breakdown are peatland type, wave energy and water level variability (Section 2.0). Blanket and veneer bog were thought to be the predominant shoreline peatland types at the upper half of the possible flow range. At these flows, fetches in the flooded area will be too short to generate sufficient wave energy to create floating islands from shoreline blanket or veneer bog. Water level variability, which cannot be predicted with confidence, will be a key factor determining the degree to which shoreline peat generates peat islands.

5.1.1 Floating Peat Islands

Peat resurfacing and shoreline peat breakdown are expected to generate floating peat islands. Several factors limit the likelihood or frequency that these peat islands could substantially reduce the hydraulic performance of the permanent outlet channel in Reach 2 with Option 1. These factors are:

- Some proportion of floating islands will be in water that is too shallow for them to be mobile;
- Much of the bog area that could potentially produce mobile floating islands is situated in the areas furthest from the main flow through the Buffalo Lakes wetland complex. The distance that must be travelled provides opportunities for floating peat islands to be trapped before reaching the main flow or the inlet to Buffalo Creek. That is, shallow areas between where the islands originate and the main flow zone create barriers that trap floating islands;
- Some proportion of mobile floating islands are expected to sink;
- Some proportion of mobile floating islands are expected to become beached by high winds;
- Even if some floating peat islands are generated, the vast majority could be less than 100 cm thick based on the limited available stratigraphy data. Maximum Of thickness was 40 cm in all of the fen sample locations (23 cm on average; n=9) and 100 cm in the blanket bog locations (85 cm on average; n=4).; and,
- Water levels will be too low to produce floating peat islands at the lower half of the predicted range of flows.

The duration and frequency of water level changes will be a key driver for determining the degree to which the above factors limit the number of peat islands that enter the main flow zone or makes its way to the Buffalo Creek inlet.

5.1.2 Marsh Islands

The intertwined roots of marsh plants such as cattails can trap sufficient gases and be sufficiently cohesive to create floating marsh mats. Where factors such as waves, wind or highly variable water levels detach these mats, they can become mobile floating islands.

The amount of marsh or marsh-like vegetation in the Buffalo Lakes wetland complex appeared to have increased substantially with LSMEOC operation (Section 4.2.1). The two marsh-like vegetation locations sampled during the one day reconnaissance survey were both floating. Some of the marsh or marsh-like vegetation may generate floating marsh islands that affect hydraulic performance. Based on the observed increases to date, nutrient deposition from future outlet channel operation could increase the probability this will occur by increasing the number and size of areas that produce marsh mats.

5.1.3 Possible Mitigation

There are possible methods to reduce the risk that peat islands or marsh mats will create blockages or reduce conveyance. If even a single occurrence of a blockage or major flow reduction was deemed unacceptable, some of mitigation methods could be investigated for their feasibility for implementation during construction rather than after they occur. Examples of preventative or post-event mitigation are:

- Excavate areas prior to flooding;
- Break up islands/mats prior to flooding;
- Deposit excavated mineral spoil material from other areas prior to flooding;
- Construct an ice boom to protect the inlet to Buffalo Creek;
- Pull floating islands/mats with boats; or,
- Dynamite blockages.

As emergent vegetation abundance is strongly affected by water levels, water level manipulation is another possible option to limit the amount of marsh or marsh-like vegetation.

This report does not explore these mitigation options further since this was intended to be the first stage of investigations. Some options may not be technically feasible or economically viable for the local conditions.

5.2 ORGANIC SEDIMENT PRODUCTION AND TRANSPORT

Peatland disintegration produces peat fragments and fibers. This material can remain on the bottom of the waterbody created by flooding, or become either floating or suspended for some period of time. Eventually the floating or suspended material sinks to the bottom or washes ashore. As observed elsewhere in Manitoba’s boreal ecozone following human-induced flooding or water regulation, floating or suspended organic material is often transported by current and wind.

The peatland types found in the Buffalo Lakes wetland complex are expected to generate peat fragments and fibers that would float on the surface or be suspended in the water column for some period of time. Some fraction of the floating or suspended material would be transported by current and wind, possibly downstream into Buffalo Creek. Qualitative observations regarding the potential amounts or locations of organic sediment production and transport are not made since this was beyond the scope of this report.

5.3 VEGETATION AND SOIL EFFECTS FROM GROUNDWATER ALTERATIONS

Surface elevations (Map 3) and peatland composition (4.2.1) suggested that unconfined groundwater flows have created and maintained the Buffalo Lakes wetland complex priori to LSMEOC operation. Of particular note is the presence of string fens, which typically indicates high unconfined groundwater flows.

Indirect effects on vegetation and soils are expected regardless of which of the four options is chosen for the Reach 2 alignment due to unavoidable impacts on groundwater flow characteristics (*e.g.*, magnitude, pathway or nutrient content). These impacts could indirectly alter vegetation, soils and wildlife habitat over large areas. Qualitative observations regarding the potential amounts or locations of indirect effects on vegetation and soils are not made since this was beyond the scope of this report.

6.0 SUMMARY OF KEY OBSERVATIONS

The following are the key observations regarding Buffalo Lakes wetlands and LSMEOC construction and operation to date.

- It appeared that unconfined groundwater flows created and maintained the Buffalo Lakes wetland complex prior to LSMEOC construction.
- Fen was the most abundant wetland type in the Buffalo Lakes wetland complex prior to LSMEOC construction. Most of the remaining area was bog.
- LSMEOC construction in 2011 removed a very small proportion of the wetlands within the complex.
- LSMEOC operation has reduced the amount of fen and created areas with marsh-like vegetation growing on top of former fen.
- To date, LSMEOC flooding has primarily affected pre-existing fens and waterbodies.
- Persistent floating peat islands have not been documented during past LSMEOC operation, which suggested peat resurfacing had not occurred. It was quite possible that this was the case due to a variety of factors such as peatland composition, the locations of flooding relative to peatland composition and the timing of initial flooding.

The following are the key observations regarding potential wetland responses to future outlet channel operation if Option 1 is the adopted alignment for Reach 2.

- There is a risk that floating peat islands will be generated by peat resurfacing or shoreline peat breakdown when flows are relatively high.
- There is a risk that floating marsh islands will be generated through the entire range of flows. Nutrient deposition from outlet channel operation could increase the probability this will occur.
- With Option 1, there is a risk that floating peat or marsh islands may enter the main flow zone of Reach 2, and/or block the inlet to Buffalo Creek.
- While the overall risk to hydraulic performance of the outlet channel in Reach 2 with Option 1 appears to be low, there still is the possibility that a mat large enough to block the Buffalo Creek inlet could be produced.
- Mitigation measures that have been implemented in other regions could reduce but not eliminate the risk to hydraulic performance of the outlet channel in Reach 2 with Option 1.
- Peatland disintegration will produce floating and suspended organic material, some of which may be transported into the main flow zone of Reach 2 and/or into Buffalo Creek.
- Indirect effects on vegetation and soils are expected regardless of which of the four options is chosen for the Reach 2 alignment due to unavoidable impacts on unconfined groundwater.

7.0 REFERENCES

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Zoltai, S.C., S. Taylor, J.K. Jeglum, G.F. Mills and J.D. Johnson. 1988. Wetlands of boreal Canada. pp. 100-154 in Wetlands of Canada. Ecological Land Classification Series No. 24, Environment Canada, Ottawa, Ontario, and Polyscience Publications, Montreal, Quebec. 452 pp.

8.0 APPENDICES

8.1 APPENDIX A

Table 8-1: Pedon and location data at sample locations.

Location	Peat-land Type	Peat Thickness (cm)	Of Thickness (cm)	Truncated[1]	Habitat Type	Peat Type	Mineral Substrate Texture	Comment
LMD04	Fen	100	30	0	Tamarack fen with *Myrica gale*	Mostly sedge	Clay	
LMD05	Fen	80	30	0	Tamarack fen	Mostly sedge	Clay	
LMD06	Fen	70	20	0	*Myrica*/sedge poor fen	Sedge	Clay	
LMD07	Fen	130	40	0	Sedge fen. Scattered tamarack	Sedge	Clay	Sand particles and limestone pebbles at bottom of hole
LMD08	Fen	210	20	0	Sedge fen. *Equisetum hyemale* or *fluviatale*, *Sarracenia purpurea*	Sedge	Clay	
LMD09	Fen	220	20	0	Sedge fen. *Equisetum hyemale* (or maybe *fluviatale*), *Sarracenia purpurea*	Sedge	Clay	
LMD10	Fen	150	20	0	Sedge fen. *Equisetum hyemale* or *fluviatale*, *Sarracenia purpurea*	Sedge	Clay	
LMD11	Fen	100	20	0	Sedge fen near edge of bog. Bog birch, bog bean, scattered tamarack	Sedge	Clay	
LMD12	Fen	90	10	0	Sphagnum/ bog birch/ Tamarack	Sedge	Clay	
LMD13	Bog	120	80	0	Sphagnum bog. Bog birch, sedges, *Equisetum, Kalmia polifolia*	Sphagnum	Clay	Thin water layer between peat and mineral
LMD14	Bog	140	100	1	Black spruce/ Sphagnum bog. *Kalmia polifolia, Sarracenia*	Sphagnum	unknown	

Location	Peat-land Type	Peat Thickness (cm)	Of Thickness (cm)	Truncated[1]	Habitat Type	Peat Type	Mineral Substrate Texture	Comment
					purpurea, Chamaedaphne calyculata			
LMD15	Bog	120	90	1	Black spruce/ Sphagnum bog. Bog birch, *Kalmia polifolia, Myrica gale*	Sphagnum	unknown	
LMD16	Bog	110	70	1	Sphagnum/ sedge bog/fen. Scattered Tamarack	Sphagnum	unknown	
Notes: [1] Coring stopped before reaching the underlying mineral substrate.								

APPENDIX F

MINUTES OF THE TECHNICAL WORKSHOP

KGS GROUP
CONSULTING ENGINEERS

MINUTES OF MEETING

PROJECT DESCRIPTION:
Preliminary Design for Reach 2 of the Lake St. Martin Outlet Channel

FILE NO:
16-0300-005

PREPARED BY:
Patrice Leclercq, Colin Siepman, & Steven Bohrn

ISSUED DATE:
January 3, 2017

MEETING DATE: December 15, 2016

LOCATION: KGS Group
895 Waverley Street

PRESENT:

Mark Allard (MI)
Jared Baldwin (MI)
Doug McMahon (MI)
Ron Richardson (MI)
Christine Baljko (MI)
Maureen Forster (M. Forster Ent.)
Dave MacMillan (KGS Group)
Bert Smith (KGS Group)
Rick Carson (KGS Group)
Rob Kenyon (KGS Group)
Patrice Leclercq (KGS Group)
Steve Offman (KGS Group)
Colin Siepman (KGS Group)
Warren Hoyle (Hatch)
Andrew Baryla (Hatch)
James Ehnes (ECOSTEM)
Don MacDonnell (North-South Cons.)
Steven Bohrn (Hatch)

ISSUED TO: All attendees

PURPOSE: To evaluate and rank the suitability of each option of the Reach 2 channel in meeting the objectives of the project and identify a preferred option to proceed with Preliminary Design.

ITEM	DETAILS	ACTION BY:
1.0	**Introduction and Review of Agenda**	
	• All attendees participated in round-table introductions to open the workshop.	
	• Dave M. reviewed the agenda for the day and emphasized that the day would be full and that it would be imperative to stick to the schedule.	
2.0	**Project Background/Review of Options**	
	• Patrice L. went over a review of the previous meeting, dismissed Option 2. The review focused on Options 1, 3, and 4.	
	• The review provided brief information on the options as well as	

ITEM	DETAILS	ACTION BY:
	updates since previous technical meeting. Details of the review are included in the presentation slides attached to these minutes.	
	• Maps of the options were provided as a handout, as well as profiles, and are attached to these minutes.	
	• Figure 2, which shows the alignment of each of the Reach 2 Options, was printed on a large size paper and pinned on the wall for reference throughout the workshop.	
	• An updated cost estimate was provided for the options. Option 1 was estimated at ~$303 million, which is approximately $55 million more than the Stage 2 study estimate. The extra cost is primarily attributed to increased effort to construct the Reach 1 extension than originally assumed, and the added cost of enhancements in Buffalo Creek (drop structures, channel excavation, riprap…) to address concerns with erosion.	
	• The total cost of Option 3 was estimated at approximately $300 million and approximately $290 million for Option 4.	
	• Mark A. noted that the Reach 1 right spoil pile may have the majority of the debris in it based on discussions with Triline Construction; this may have to be verified prior to construction.	
	• MI noted that the control structure bridge deck and bridge at Reach 3 for Option 1 must be capable of supporting heavy construction vehicles.	
	• James E. indicated that constructing the channel will likely raise the unconfined water table to the east of the channel and could convert the bog to fen and change the landscape significantly. It is uncertain what the sub-surface drainage in the area looks like so it is unclear what the impacts to that system will be. It was noted that there could be other positive impacts resulting from changing the landscape, i.e, more moose or bird habitat.	
3.0	**Overview of Workshop Process**	
	• Warren H. described the workshop process; a Decision Matrix incorporating a weighting and rating system was described. Each option is then scored by multiplying the rating by the weighting and the option with the highest total score is identified as the preferred alternative.	
	• Warren gave an example of the weighted criteria matrix process as it would be applied to selecting a trip.	
4.0	**Evaluation Criteria and Weighting Process**	
	• Patrice L. lead a review of the criteria that were defined by the project team prior to the evaluation workshop.	
	• The group stepped through the definitions of each category and criteria one at a time. Proposed modifications and updates to the definitions were discussed. Table 1, which summarized the criteria definition, was provided as a handout at the workshop. An updated version of the criteria, based on	

ITEM	DETAILS	ACTION BY:
	feedback from the meeting, is attached with these minutes.	
	• Based on the discussions, the sub-criteria “Schedule” was added to the Constructability category as Item 1.5. In addition, a new category was added, as Item 8: “Cost Risk”. Item 7.2. Cost Sensitivities, was moved to the Cost Risk category.	
	• After reviewing the definitions, each of the categories and sub-criteria were assigned a weight for use in the evaluation matrix. The final weight assigned to each category and sub-criteria is shown in the attached Table 3. Warren H. facilitated the weighting process as well as defining the rating scale (1 to 5) that was used to evaluate the options.	
	• The issue of how to maintain the wetland as a PWW or DRA was raised; there is a need to consider the costs of maintaining the area. Designating something a PWW means that the province owes money to the stakeholders in the area if they are impacted by use of the waterway.	
	• Mark A. mentioned that he had correspondence with Eugene K. stating that a legal property plan for the reservoir is not required since the area is surrounded by crown land. If a legal plan is made for the reservoir, the project team would need to define 100 or 200 year flooded area that is affected.	
	• Mark A. indicated that the environmental license will indicate the area that will be impacted during operations. If the flooded area extends outside that, additional compensation would be required.	
	• It was noted the access road to the project area can be a positive or negative for the local stakeholders in the project. It provides better access for traditional users but also could increase non-traditional use of the area.	
5.0	**Comparison of Options and Rating**	
	• Patrice L. lead a summary review of how the alternatives compared for each criteria, followed by discussions. Table 2, which provides a comparison of the options for each sub-criteria, was provided as a handout. An updated version of the comparison, incorporating comments and suggestions from the workshop, is attached with these minutes.	
	• Based on the discussions, Category 4 “Social Impacts” was modified to “Socio Economic Concerns”. The sub criteria were then modified to: 4.1 Access, 4.2 Impacts on Indigenous Rights, and 4.3 Commercial Fisheries.	
	• The sub-criteria for Category 8 “Cost Risk” were defined as 8.1 Social Risk, 8.2 Optimization, 8.3 Environmental Approvals, 8.4 Weather, Unforeseen Conditions and Oher Unknown Environmental Requirements, 8.5 Rock Supply, and 8.6 Amortization.	
	• Each sub-criteria was assigned a rating throughout the process. The Final rating is summarized in the attached	

ITEM	DETAILS	ACTION BY:
	Table 3.	
6.0	**Results of the Evaluation**	
	• Based on the rankings and weightings that were determined during the workshop, the total scores for each of the options were totaled. The results were presented at the workshop for review prior to selecting the preferred alternative. The results are summarized below as well as in the attached Table 3.	

Main Category	Score Subtotal		
	Option 1	**Option 3**	**Option 4**
1. Constructability	30	41	52
2. Operability & Performance	37	57	60
3. Physical Environmental Impacts	25	45	45
4. Social Economic Considerations	28	36	36
5. Maintainability and Inspection	27	33.5	36.5
6. Resiliency	10	15	25
7. Cost	27	28.5	30
8. Cost Risk	50	62	64
Total Score (out of 500)	**234**	**318**	**348.5**
Total Score (out of 100)	**46.8**	**63.6**	**69.7**

ITEM	DETAILS	ACTION BY:
	• Based on the results of the evaluation that was carried out at the workshop, Option 4 was identified as the preferred alternative.	
7.0	**Wrap-up / Next Steps**	
	• Before the results were announced, Mark A. commented on amortization – if Reach 1 is going to be used in the future (i.e. riparian flow and/or emergency capacity due to climate change), it would not require any writing down of the amortization.	
	• The group reviewed the remaining “parking lot” items that had been identified during the day. It was agreed that all items had been previously addressed and that additional discussion would not affect the workshop conclusions, therefore no further action was required.	
	• Based on the outcome of the workshop, **Option 4 has been recommended as the preferred option to proceed with to Preliminary Design.**	
	• Meeting Minutes (this document) will be used to document the results of the Workshop	KGS

ITEM	DETAILS	ACTION BY:
	• KGS Group will begin refining the preliminary design details associated with the preferred alternative upon approval from MI (i.e. after review and acceptance of the Meeting Minutes).	MI
	• A detailed description of the workshop process and results will be documented in the final report.	KGS

It is believed that these minutes accurately reflect the discussion held in the meeting. Please advise if there are errors or omissions.

Prepared By:

Patrice Leclercq, P.Eng.
Water Resources Engineer

PAL/ama

TABLE 1
REACH 2 DECISION MATRIX – CRITERIA DEFINITIONS

Main Category	Definition	Sub-Criteria	Definition
1. Constructability	• Ability to achieve project schedule and complete project on time. • Ability to complete project on budget. • Ability to execute the project and complete construction as planned and as per design specifications. • Construction risks associated with potential cost overruns. • Construction risks that may result to changes in project concept and/or design. • Overall ease of construction.	1.1 Access to Site	• Ease of access for construction. • Ability to execute multiple contracts if required. • Reliance on construction staging and/or seasonal factors.
		1.2 Surface and Groundwater Management	• Ease of drainage for construction. • Cofferdam requirements. • Reliance on construction staging and/or seasonal factors. • Risk of blowouts and basal heave conditions. • Risk of increased costs due to unforeseen conditions.
		1.3 Material Composition	• Ease of excavation. • Source and quality of material for dike construction. • Source and quality of material for drop structures and erosion protection. • Risk of increased costs due to unforeseen conditions.
		1.4 Bathymetric Conditions	• Extents of underwater excavation required for construction. • Depth of excavation under water. • Risk of increased costs due to unforeseen conditions.
		1.5 Scheduling	• Ability to manage risk of flooding during construction. • Risk of schedule delays due to weather or construction timing restrictions.
2. Operability & Performance	• Relative ease and level of effort to operate channel. • Overall ability of the project to achieve its intended purpose (i.e. probability of success). • Ability of the project to perform as intended over the short and long term without additional environmental impacts, or increased maintenance & inspection requirements. • Performance under extreme or less than optimal conditions (i.e. reliance on optimal conditions).	2.1 Channel Dikes and Slopes	• Long term stability of the channel dikes and slopes. • Available freeboard above the dikes.
		2.2 Erosion, Sediment Transport and Deposition	• Risk of erosion as a result of operation. • Risk of sediment transport and deposition as a result of operation.
		2.3 Flow Through Buffalo Lakes Wetland Complex	• Risk associated with flotation and movement of individual bog or marsh islands, or marsh/bog islands in large groups. • Risk of floating islands blocking channel(s). • Risk of conveyance loss as a result of floating bog or marsh that remains in place. • Ability to maintain the wetland complex as a designated Provincial Waterway or a Designated Reservoir Area.
		2.4 Drop Structures	• Ability of the drop structures to dissipate energy as intended for the range of flow conditions.
		2.5 Operation in Winter Conditions	• Ability to operate channel in winter conditions and manage formation of ice.
		2.6 Groundwater Management	• Ability to manage risk of seepage and groundwater blowouts.
3. Physical Environmental Impacts	• Short and long term impacts of the project to the physical environment during both the construction and operation phases. • Ease of obtaining approvals from regulators and environmental agencies to proceed with construction.	3.1 Surface Water	• Potential impacts on surface water quality (i.e. TSS, Mercury, etc.) • Potential impacts on surface water quantity (i.e. flow rates, flow volumes, water levels, and seasonality).
		3.2 Groundwater	• Potential risks associated with GUDI (Groundwater under the direct influence of surface water). • Potential impacts to water levels in adjacent aquifers. • Potential impacts to groundwater quality.
		3.3 Terrestrial Environment	• Potential impacts on existing vegetation and land cover. • Potential impacts on existing wildlife and habitat.
		3.4 Aquatic Habitat & Resources	• Potential impacts to aquatic species and habitat. • Potential impacts to spawning and migration of fish species.
4. Social Economic Considerations	• Short and long term impacts of the project to affected stakeholders and surrounding communities, including First Nations and Metis. • Impacts of project considering socio-economic factors.	4.1 Access	• Potential impacts to access in the area.
		4.2 Indigenous Rights Based Activities	• Potential impacts to traditional land use activities such as fishing, hunting and trapping.

Main Category	Definition	Sub-Criteria	Definition
	• Ease of obtaining approvals from regulators and environmental agencies to proceed with construction.	4.3 Commercial Fisheries	• Potential impacts on the commercial fisheries.
5. Maintainability and Inspection	• Ability to maintain infrastructure in working conditions. • Ability to inspect infrastructure to confirm condition and performance. • Overall ease of conducting maintenance and inspection activities. • Ease of rehabilitation in the future.	5.1 Access to Site	• Ease of access for maintenance and inspection. • Reliance on seasonal factors, and/or operating conditions.
		5.2 Vegetation Growth	• Ability to grow and maintain vegetation cover on the channel and dike slopes to manage risk of erosion. • Risk of thick aquatic vegetation growth within the channel that impacts discharge capacity of the channel.
		5.3 Sedimentation	• Risk of sedimentation occurring within or downstream of the channel.
		5.4 Operation in Winter Conditions	• Risk that the movement of ice in the channel during channel operation, or during the spring freshet when the channel is closed, results in damages to the channel and structures.
6. Resiliency	• Ability to adapt project in the future to changing conditions such as climate change & increased runoff.	6.1 Adaptability for Additional Capacity	• Ability to adapt channel design in the future for increased capacity. • Ability to increase channel capacity in the event of an emergency.
7. Cost	• Overall project costs including capital costs and long term maintenance and inspection.	7.1 Capital Costs	• Total project costs, including: mitigation costs; engineering fees; contract administration; approvals; contingencies.
		7.2 General Maintenance Costs	• Long term maintenance cost over entire life expectancy of project.
8. Cost Risk	• Potential for changes in cost due to added project requirements or unforeseen conditions	8.1 Social Risk	• Potential for socio-economic factors to affect project cost.
		8.2 Optimization	• Potential for reduction in cost by optimization of final design.
		8.3 Environmental	• Potential for increased cost due to added environmental mitigation requirements.
		8.4 Construction	• Potential for increased cost as a result of unfavorable construction conditions.
		8.5 Rock Supply	• Ability to obtain necessary rock quantity / quality for drop structure and riprap requirements.
		8.6 Amortization	• Cost differences as a result of decommissioning Reach 1.

TABLE 2
REACH 2 DECISION MATRIX – BACKGROUND INFORMATION FOR COMPARISON OF OPTIONS

Main Category	Sub-Criteria	Option 1	Option 3	Option 4	Summary Comparison
1. Constructability	1.1 Access to Site	• **Reach 1 widening:** permanent access road completed prior to construction. • **Reach 1 extension:** access from Reach 1. • **Reach 2 containment dike:** access from Reach 3 must cross Buffalo Creek. • **Buffalo Creek enhancements:** access from Reach 2 containment dike &/or Reach 3. • **Reach 3:** permanent access road completed prior to construction.	• **Reach 1 widening:** permanent access road completed prior to construction. • **Reach 2:** access from Reach 1. • **Reach 3:** temporary winter access only until Reach 2 construction completed.	• **Reach 1 decommissioning:** permanent access road completed prior to construction. • **Reach 2:** permanent access road completed prior to construction. • **Reach 3:** temporary winter access only until Reach 2 construction completed.	• Option 1 has two separate permanent access points (Reach 1 and Reach 3). • Options 3 & 4 have a single permanent access point (Reach 1) and a potential secondary winter access to Reach 3.
	1.2 Surface and Groundwater Management	• **Reach 1 widening:** standing water in channel; cofferdam & pumping required or provision of drainage downstream into Big Buffalo Lake. • **Reach 1 extension:** water level in peat at or near surface; cofferdam & pumping required. o Level of effort dependent on downstream conditions in Big Buffalo Lake. • **Reach 2 containment dike:** constructed on high ground and requires minimal surface and groundwater management. • **Buffalo Creek enhancements:** cofferdam and pumping required for construction of Drop Structures and channel excavation.	• **Reach 1 widening:** standing water in channel; cofferdam & pumping required or provision of drainage downstream by constructing Reach 2 first. • **Reach 2:** water level in peat at or near surface; cofferdam & pumping required. o Channel dikes included as part of Reach 2 design. Construction of dikes reduces cofferdam requirements. o Level of effort reduced with provision of drainage downstream. o Opportunity to start construction at Reach 3. Starting construction at downstream end improves drainage.	• **Reach 1 decommissioning:** minimal dewatering required for construction. • **Reach 2:** water level in peat at or near surface; cofferdam & pumping required. o Channel dikes included as part of Reach 2 design. Construction of dikes reduces cofferdam requirements. o Level of effort reduced with provision of drainage downstream. o Opportunity to start construction at Reach 3. Starting construction at downstream end improves drainage.	• All options require some level of construction drainage & dewatering, including cofferdam construction with pumping. Dewatering efforts incorporated into cost estimates. • Higher construction risks for Option 1 based on contractor input due to difficulties with dewatering Reach 1 extension and proximity of Big Buffalo Lake. • Risk of blowouts and basal heave conditions similar for all options and can be managed by pumping, downstream drainage, or with passive depressurization system.
	1.3 Material Composition	• **Reach 1 widening:** existing Reach 1 spoil pile material is dense, unsorted and contains widespread debris. o Most unsorted material may be located on right side (south-east side). o Undisturbed area includes combination of peat and till excavation. • **Reach 1 extension:** constructed in peat only and excavated to the surface of till. o Material more difficult to handle. o Hauling of till material from Reach 1 required for construction of cofferdams. • **Reach 2 containment dike:** constructed in undisturbed area; requires vegetation removal and peat excavation. o Till material for dike construction to be obtained from nearby borrow pits. • **Buffalo Creek enhancements:** Hauling of riprap required for construction of drop structures and erosion protection measures.	• **Reach 1 widening:** existing Reach 1 spoil pile material denser, unsorted and full of debris. o Most unsorted material may be located on right side (south-east side). o Undisturbed area includes combination of peat and till excavation. • **Reach 2:** constructed in undisturbed area and includes combination of peat and till excavation. o Till material from channel excavation used for dike and cofferdam construction. o Hauling of Riprap required for construction of drop structures.	• **Reach 1 decommissioning:** re-shaping of till surface required prior to re-vegetation. • **Reach 2:** constructed in undisturbed area and includes combination of peat and till excavation. o Till material from channel excavation used for dike and cofferdam construction. o Hauling of Riprap required for construction of drop structures.	• Material type in undisturbed areas similar for all options. Material for Reach 1 extension more difficult to handle. • Reach 1 widening for Options 1&3 requires increased excavation effort due to composition of existing spoil pile material. • Hauling of riprap required for all options.

Main Category	Sub-Criteria	Option 1	Option 3	Option 4	Summary Comparison
	1.4 Bathymetric Conditions	• **Lake St. Martin Inlet**: Excavation required to minimize headloss upstream of control structure. o Limited potential to reduce inlet excavation requirements, if necessary, by optimization of the channel design due to the limited conveyance capacity through the wetland complex surrounding Big Buffalo Lake. • **Big Buffalo Lake**: Bathymetric conditions in Buffalo Creek control water levels in Big Buffalo Lake; impacts dewatering for construction of Reach 1 extension.	• **Lake St. Martin Inlet**: Excavation required to minimize headloss upstream of control structure. o Potential to reduce inlet excavation requirements, if necessary, by optimization of the channel design.	• **Lake St. Martin Inlet**: Excavation required to minimize headloss upstream of control structure. o Potential to reduce inlet excavation requirements, if necessary, by optimization of the channel design.	• Excavation required to minimize headloss upstream of control structure for all options. • Potential to reduce inlet excavation requirements for Options 3&4 but not Option 1. • Conditions in Buffalo Creek and Big Buffalo Lake results in potential additional construction challenges on Option 1.
	1.5 Scheduling	• Emergency operation of Reach 1 during construction in the event of high water levels on LSM may result in significant construction delays on Reach 1, Buffalo Creek and the Reach 2 containment Dike.	• Emergency operation of Reach 1 during construction in the event of high water levels on LSM may result in significant construction delays on Reach 1 only. • Most vulnerable to unfavorable weather conditions due to longest construction footprint (i.e. longest channel length).	• Reach 1 has the ability to be operated in an emergency during construction with minimal impact to construction schedule in the event of high water levels on LSM.	• Option 4 has ability to operate Reach 1 during construction in an emergency if required, with minimal impact to construction schedule, whereas not Options 1&3.
2. Operability & Performance	**2.1 Channel Dikes and Slopes**	• **Reach 1 widening:** No dikes required. • **Reach 1 extension:** Access road constructed on left bank with minimum 1m freeboard above 11,500 cfs profile. • **Reach 2 containment dike:** Minimum 1m freeboard above 11,500 cfs profile. • **Buffalo Creek enhancements:** erosion protection measures included to protect existing creek banks and slopes in vulnerable areas.	• **Reach 1 widening:** No dikes required. • **Reach 2:** Dikes required along a portion of the channel. Minimum 1m freeboard above 11,500 cfs profile.	• **Reach 1 decommissioning:** upgrades to closure dike at the channel inlet included in the design. • **Reach 2:** Dikes required along a portion of the channel. Minimum 1m freeboard above 11,500 cfs profile.	• All options designed with stable channel dikes and slopes as per design criteria and therefore are intended to perform equally (4:1 slopes and a Factor of Safety of 1.5 for normal conditions and 1.3 under rapid drawdown conditions).

Main Category	Sub-Criteria	Option 1	Option 3	Option 4	Summary Comparison
	2.2 Erosion, Sediment Transport and Deposition	• **Reach 1 widening and extension:** Channel designed to be non-erodible during operation (velocity ~1.0 m/s and shear stress ~ 6 Pa at 11,500 cfs). o Potential for exposed side slopes as a result of poor vegetation growth (see item 5.2) increases risk for erosion due to runoff; effects approximately 12 ha surface area of Reach 1. • **Buffalo Creek enhancements:** Combination of drop structures and channel excavation required to mitigate high velocities and risk of erosion due to the steep slope of the creek. • Potential volume of sediment available for transport based on a wetted surface area of approximately 100 ha upstream of Big Buffalo Lake and approximately 25 ha upstream of Reach 3.	• **Reach 1 widening and Reach 2:** Channel designed to be non-erodible during operation (velocity ~1.0 m/s and shear stress ~ 6 Pa at 11,500 cfs). • 4 drop structures incorporated into design to dissipate energy and to maintain non-erodible design condition. • Potential volume of sediment available for transport based on a wetted surface area of approximately 210 ha upstream of Reach 3. • Potential for exposed side slopes as a result of poor vegetation growth (see item 5.2) increases risk for erosion due to runoff; effects approximately 31 ha surface area of Reach 1 & Reach2.	• **Reach 2:** Channel designed to be non-erodible during operation (velocity ~1.0 m/s and shear stress ~ 6 Pa at 11,500 cfs). • 5 drop structures incorporated into design to dissipate energy and to maintain non-erodible design condition. • Potential volume of sediment available for transport based on a wetted surface area of approximately 160 ha upstream of Reach 3. • Potential for exposed side slopes as a result of poor vegetation growth (see item 5.2) increases risk for erosion due to runoff; effects approximately 14 ha surface area of Reach 2.	• All options designed to be non-erodible as per design criteria and are therefore intended to perform equally. • Option 3 has largest potential volume of available sediment for transport as a result of operation based on the wetted surface area of the channel, followed by Option 4, then Option 1. • Option 3 has largest potential volume of available sediment for transport as a result of exposed side slopes based on the potential surface area of poor vegetation growth. Options 1 & 4 have similar area of exposed side slopes.
	2.3 Flow Through Buffalo Lakes Wetland Complex	• Potential for loss of conveyance concentrated in bog and marsh areas. • Potential risk for floating bog/marsh islands depend on a combination of factors including depth of flooding, duration, timing… • Additional concerns with maintaining Big Buffalo Lake and surrounding wetland complex as a Provincial Waterway or a Designated Reservoir Area.	• No concerns due to flow avoiding Buffalo Lakes wetland complex.	• No concerns due to flow avoiding Buffalo Lakes wetland complex.	• Option 1 has potential risks and concerns associated with flow through the bog and marsh areas. • Options 3 and 4 do not have similar disadvantages.
	2.4 Drop Structures	• Drop structures design to accommodate peak flows and provide upstream and downstream fish passage in Buffalo Creek when channel not in operation.	• Drop structures design to accommodate peak flows and provide downstream fish passage when channel not in operation.	• Drop structures design to accommodate peak flows and provide downstream fish passage when channel not in operation.	• All options intended to perform equally as per design criteria. • More complex structure required for Option 1 to provide upstream fish passage in Buffalo Creek . Upstream fish passage not required for Options 3 & 4.

Main Category	Sub-Criteria	Option 1	Option 3	Option 4	Summary Comparison
	2.5 Operation in Winter Conditions	• Frazil ice formation is expected at some distance downstream of the Lake St. Martin Inlet during operation. • Potential volume of frazil ice produced based on a surface area of approximately 100 ha upstream of Big Buffalo Lake and approximately 105 ha upstream of outlet into Lake Winnipeg. • Design criteria include objectives that would maximize the potential for safe and effective management of the ice. • Operating guidelines include provision to avoid initial operation during period when a competent ice cover is present in the channel.	• Frazil ice formation is expected at some distance from the Lake St. Martin Inlet during operation. • Potential volume of frazil ice produced based on a surface area of approximately 295 ha upstream of outlet into Lake Winnipeg. • Design criteria include objectives that would maximize the potential for safe and effective management of the ice. • Operating guidelines include provision to avoid initial operation during period when a competent ice cover is present in the channel.	• Frazil ice formation is expected at some distance from the Lake St. Martin Inlet during operation. • Potential volume of frazil ice produced based on a surface area of approximately 245 ha upstream of outlet into Lake Winnipeg. • Design criteria include objectives that would maximize the potential for safe and effective management of the ice. • Operating guidelines include provision to avoid initial operation during period when a competent ice cover is present in the channel.	• All options would be designed to minimize risks associated with winter conditions as per design criteria and therefore are intended to, and are expected to, perform equally well. • Differences in potential volume of frazil ice production between options are not expected to result in a significant variance in performance between options.
	2.6 Groundwater Management	• Seepage and groundwater inflow expected and are not anticipated to result in significant impacts.	• Seepage and groundwater inflow expected and are not anticipated to result in significant impacts. o Standing water upstream of the drop structures reduce seepage and groundwater inflow.	• Seepage and groundwater inflow expected and are not anticipated to result in significant impacts. o Standing water upstream of the drop structures reduce seepage and groundwater inflow.	• All options would be designed to minimize risks of seepage and blowouts and are therefore intended to perform equally. • Impacts not expected to be significant.

Main Category	Sub-Criteria	Option 1	Option 3	Option 4	Summary Comparison
3. Physical Environmental Impacts	3.1 Surface Water	• Altered rate and seasonality of flow on the Dauphin River. • Operation of the outlet channel and conveyance through Reaches 1 and 2 will result in altered rate and seasonality of flow to Big Buffalo Lake and Buffalo Creek. o Operation expected to occur on average once every 3 years. o Residual impacts on flow rates may continue over multiple seasons upon closure of the channel due to saturation of the wetland complex and increased groundwater levels. • Flooding of the wetland complex and of upper Buffalo Creek as a result of operation may lead to leaching and decomposition of organic material, reducing dissolved oxygen and pH, and increasing concentrations of select metals including methylation of mercury. • Dewatering, dredging and excavation in proximity to waterbodies or watercourses could result in localized mobilization of sediment, affecting water quality. Proximity of construction to Big Buffalo Lake and Buffalo Creek increases potential for mobilization downstream. • Potential for erosion as a result of operation may affect water quality within the channel, in Big Buffalo Lake, Buffalo Creek, Dauphin River, Sturgeon Bay, and in Lake Winnipeg at the outlet of Reach 3. • Potential erosion at Buffalo Lake outlet as a result of operation could lower water levels permanently.	• Altered rate and seasonality of flow on the Dauphin River. • Altered rate and seasonality of flow to Big Buffalo Lake and Buffalo Creek as a result of Reach 2 construction. o 65% of the Buffalo Lakes wetland complex watershed cutoff by Reach 2. o Impacts of flow alteration can be reduced or mitigated with construction of siphon(s) under Reach 2. • Channel dikes minimize flooding into adjacent land. • Dewatering, dredging and excavation in proximity to waterbodies or watercourses could result in localized mobilization of sediment, affecting water quality • Potential for erosion as a result of operation may affect water quality within the channel and in Lake Winnipeg at the outlet of Reach 3.	• Altered rate and seasonality of flow on the Dauphin River. • Altered rate and seasonality of flow to Big Buffalo Lake and Buffalo Creek as a result of Reach 2 construction. o 60% of the Buffalo Lakes wetland complex watershed cutoff watershed cutoff by Reach 2. o Impacts of flow alteration can be reduced or mitigated with construction of siphon(s) under Reach 2 or provision of base flow from Lake St. Martin via Reach 1. • Channel dikes minimize flooding into adjacent land. • Dewatering, dredging and excavation in proximity to waterbodies or watercourses could result in localized mobilization of sediment, affecting water quality. • Potential for erosion as a result of operation may affect water quality within the channel and in Lake Winnipeg at the outlet of Reach 3.	• Altered rate and seasonality of flow on the Dauphin River for all options. • Altered rate and seasonality of flow to Big Buffalo Lake and Buffalo Creek for all Options. Potential impacts more severe with Option 1 due to the magnitude of alteration. Potential mitigation strategies identified for Options 3&4. • Flooding of wetland complex and upper Buffalo Creek as a result of operation once every 3 years for Option 1, whereas Options 3&4 have dikes that minimize flooding into land adjacent to channel. • Additional number of locations with potential impacts to water quality as a result of operation for Option 1 compared to Options 3 & 4. • Increased potential of mobilization of sediment during construction for Option 1 compared to Options 3 & 4.

Main Category	Sub-Criteria	Option 1	Option 3	Option 4	Summary Comparison
	3.2 Groundwater	• Groundwater discharge into surface water could result in changes to surface water quality. • Blowout of basal soils may occur if groundwater pressure exceeds pressure of overburden mass. o GUDI not expected to be of concern as there are no drinking water wells in the region. • Seepage of groundwater in outlet channel could lower water levels in aquifer, whereas inundation of Buffalo Creek and the wetland complex surrounding Big Buffalo Lake could increase water levels in aquifer. o Changes in aquifer water levels could impact surrounding vegetation.	• Groundwater discharge into surface water could result in changes to surface water quality. • Blowout of basal soils may occur if groundwater pressure exceeds pressure of overburden mass. o GUDI not expected to be of concern as there are no drinking water wells in the region. • Seepage of groundwater in outlet channel could lower water levels in aquifer. o Changes in aquifer water levels could impact surrounding vegetation.	• Groundwater discharge into surface water could result in changes to surface water quality. • Blowout of basal soils may occur if groundwater pressure exceeds pressure of overburden mass. o GUDI not expected to be of concern as there are no drinking water wells in the region. • Seepage of groundwater in outlet channel could lower water levels in aquifer. o Changes in aquifer water levels could impact surrounding vegetation.	• Blowout of basal soils may occur if groundwater pressure exceeds pressure of overburden mass. • Potential groundwater impacts (confined layer) similar for all options. • Construction of channel through peatland area for Options 3 & 4 may result in additional groundwater impacts (shallow / unconfined layer).
	3.3 Terrestrial Environment	• Flow over the Big Buffalo Lake wetland complex has the potential to result in changes to the existing vegetation and land cover. Inundated area approximately 4,000ha at the 11,500 cfs design flow event. o Emergency operation of the Reach 1 channel has already altered the wetland complex. • Construction of drop structures in Buffalo Creek will result in long-term inundation of the existing vegetation, impacting and area of approximately 25 ha. o Flow in Buffalo Creek has the potential to result in changes to the existing vegetation and land cover. o Emergency operation of the Reach 1 channel has already altered Buffalo Creek. • Channel and dike construction will require "new" vegetation clearing along Reach 1 and Reach 2, covering and area approximately 175 ha.	• Channel and dike construction will require "new" vegetation clearing along Reach 1 and Reach 2, covering an area approximately 410ha. • Potential impacts to vegetation cover in wetland complex as a result of changes in shallow / unconfined groundwater conditions.	• Channel and dike construction will require "new" vegetation clearing along Reach 1 and Reach 2, covering an area approximately 380ha. • Potential impacts to vegetation cover in wetland complex as a result of changes in shallow / unconfined groundwater conditions.	• Option 1 has the largest potential area of impacts to terrestrial environment due to inundation of wetland complex. • Option 3 impact slightly larger area then Option 4 due to longer channel length.

Main Category	Sub-Criteria	Option 1	Option 3	Option 4	Summary Comparison
	3.4 Aquatic Habitat & Resources	• Accommodation of channel design for fish passage during operation not required as per design criteria. • Fish passage to be incorporated into drop structure design in Buffalo Creek for period when channel not in operation. • Risk of fish stranding in wetland complex surrounding Big Buffalo Lake as a result of operation, may result in additional maintenance cost to conduct fish salvage program. • Excavation and construction of drop structures in Buffalo Creek will result in destruction or alteration of Fish Habitat. • Loss of fish habitat in Buffalo Creek and Big Buffalo Lake when channel in operation. • Changes in flow patterns in Buffalo Creek downstream of Reach 3 Diversion structure as a result of operation has the potential to result in additional aquatic impacts.	• Accommodation of channel design for fish passage during operation not required as per design criteria. • Provision of riparian flow and inclusion of notch at top of drop structures will provide downstream passage for fish at all times when channel not in operation to minimize risk of fish stranding. • Provision of riparian flow and deep pool upstream of drop structures reduces potential risk of fish kill for fish that overwinter in the channel.	• Accommodation of channel design for fish passage during operation not required as per design criteria. • Provision of riparian flow and inclusion of notch at top of drop structures will provide downstream passage for fish at all times when channel not in operation to minimize risk of fish stranding. • Provision of riparian flow and deep pool upstream of drop structures reduces potential risk of fish kill for fish that overwinter in the channel.	• Risk of fish stranding for Option 1 whereas this is addressed as part of design criteria for Options 3 & 4. • Destruction or alteration of Fish Habitat in Buffalo Creek for Option 1. Options 3 & 4 avoid Buffalo Creek altogether. • Impediment to fish migration in Buffalo Creek and Big Buffalo Lake for Option 1 during operation whereas not for Options 3 & 4. • Option 1 has potential for additional aquatic impacts on Buffalo Creek and Dauphin River downstream of Reach 3 diversion structure.
4. Social Economic Considerations	4.1 Access	• Increased access to the area may be a benefit and a concern to current users (i.e existing hunters, fisherman, First Nation, etc…). • Decreased access within the site due to the channel may be a concern • Gated system will be included on access road to limit unauthorized access.	• Increased access to the area may be a benefit and a concern to current users (i.e existing hunters, fisherman, First Nation, etc…) • Decreased access within the site due to the channel may be a concern • Gated system will be included on access road to limit unauthorized access.	• Increased access to the area may be a benefit and a concern to current users (i.e existing hunters, fisherman, First Nation, etc…) • Decreased access within the site due to the channel may be a concern • Gated system will be included on access road to limit unauthorized access.	• Benefits and concerns with access to the site similar for all options. • Decreased access within the site is a greater concern for Options 3 & 4 since they do not include a bridge at Reach 3.
	4.2 Indigenous Rights Based Activities	• Construction and operation may result in potential impacts to traditional land use and activities in the area, such as fishing, trapping and hunting. • Inundation of the Big Buffalo Lake Wetland Complex results in a larger area of impact.	• Construction and operation may result in potential impacts to traditional land use and activities in the area, such as fishing, trapping and hunting.	• Construction and operation may result in potential impacts to traditional land use and activities in the area, such as fishing, trapping and hunting.	• Additional concerns for Option 1.
	4.3 Commercial Fisheries	• Construction and operation may result in potential impacts to commercial fisheries in the region. • Alignment through Big Buffalo Lake and Buffalo Creek has the potential to result in additional aquatic impacts affecting Commercial Fisheries.	• Construction and operation may result in potential impacts to commercial fisheries in the region.	• Construction and operation may result in potential impacts to commercial fisheries in the region.	• Additional concerns for Option 1.
5. Maintainability and Inspection	5.1 Access to Site	• Design includes permanent access road to Reach 1 & Reach 3. • Bridge included in design to provide access across Reach 3 and to the Reach 2 containment dike. • Gravel topping included on top of all dikes and on both sides of the channel.	• Design includes permanent access road to Reach 1. • Gravel topping included on top of all dikes and on both sides of the channel.	• Design includes permanent access road to Reach 1. • Gravel topping included on top of all dikes and on both sides of the channel.	• All options have access included on all dikes and along both sides of the entire channel as per design criteria and therefore are intended to perform equally.

Main Category	Sub-Criteria	Option 1	Option 3	Option 4	Summary Comparison
	5.2 Vegetation Growth	• **Reach 1 widening:** Portion of channel side slopes vulnerable to poor vegetation growth as a result of prolonged operation; effects approximately 12 ha surface area of Reach 1. o Standing water in channel less than 1m in depth vulnerable to aquatic vegetation growth at the bottom. Entire length of Reach 1 channel (6km) may be affected depending on Big Buffalo Lake water levels. • **Reach 1 extension and wetland complex:** Additional nutrient source from flowing through wetland complex and Buffalo Creek can increase risk of vegetation growth downstream in Reach 3. o Potential for increased or changes in vegetation growth within wetland complex as a result of operation. • **Buffalo Creek:** Additional maintenance potentially required in addition to initial vegetation cleanup program during construction to address risk of debris floating and moving downstream during operation. o Standing water upstream of the drop structures designed to minimize portion of channel side slopes vulnerable to poor vegetation growth. o Vegetation established in natural conditions has greater resilience to perturbations like flooding, than does newly established vegetation.	• **Reach 1 widening and Reach 2:** Portion of channel side slopes vulnerable to poor vegetation growth as a result of prolonged operation; effects approximately 31 ha surface area of Reaches 1 and 2. o Standing water upstream of the drop structures designed to exceed 1m in depth to minimize heavy aquatic vegetation growth at the bottom of the channel and to minimize portion of channel side slopes vulnerable to poor vegetation growth and slow recovery after flood operations. o Approximately 6km of channel (existing Reach 1) may have standing water less than 1m in depth due to its distance away from the nearest drop structure.	• **Reach 2:** Portion of channel side slopes vulnerable to poor vegetation growth as a result of prolonged operation; effects approximately 14 ha surface area of Reach 2. o Standing water upstream of the drop structures designed to exceed 1m in depth to minimize heavy aquatic vegetation growth at the bottom of the channel and to minimize portion of channel side slopes vulnerable to poor vegetation growth and slow recovery after flood operations.	• Options 1 & 3 have increased risk of vegetation growth within the Reach 1 channel. • Option 1 has increased risk of vegetation growth within wetland complex and Reach 3. • Option 3 has largest potential area of channel banks vulnerable to poor vegetation growth, whereas Options 1 & 4 perform similarly. • Additional maintenance effort potentially required for Option 1 to address risk of debris floating and moving downstream during operation.
	5.3 Sedimentation	• Sediment input into channel expected to be minimal. • Potential deposition areas include the Buffalo Lakes wetland complex, the channel upstream of drop structures, and/or Lake Winnipeg. • Potential for sedimentation at the channel inlet dependent on shoreline conditions and coastal processes and can be managed with construction of rockfill groins or implementing future maintenance program.	• Sediment input into channel expected to be minimal. • Potential deposition areas include the channel upstream of drop structures, and/or Lake Winnipeg. • Potential for sedimentation at the channel inlet dependent on shoreline conditions and coastal processes and can be managed with construction of rockfill groins or implementing future maintenance program.	• Sediment input into channel expected to be minimal. • Potential deposition areas include the channel upstream of drop structures, and/or Lake Winnipeg. • Potential for sedimentation at the channel inlet dependent on shoreline conditions and coastal processes and can be managed with construction of rockfill groins or implementing future maintenance program.	• Potential for deposition similar for all options. • Option 1 has additional location of potential deposition in wetland complex.

Main Category	Sub-Criteria	Option 1	Option 3	Option 4	Summary Comparison
	5.4 Operation in Winter Conditions	• Operating guidelines include provision to avoid initial operation during period when a solid ice cover is present in the channel. • Deep standing water upstream of the drop structures reduces risk of aufeis growth and possibly growth due to snow influx/ retention; reduces risk of ice damaging channel and structures in the spring in Buffalo Creek. • Risks associated with aufeis growth and possibly growth due to snow influx/ retention in Reach 1 due to shallow standing water in the channel expected to be insignificant due to the presence of Big Buffalo Lake and surrounding wetland complex at the outlet of Reach 1.	• Operating guidelines include provision to avoid initial operation during period when a solid ice cover is present in the channel. • Deep standing water upstream of the drop structures reduces risk of aufeis growth and possibly growth due to snow influx/ retention; reduces risk of ice damaging channel and structures in the spring.	• Operating guidelines include provision to avoid initial operation during period when a solid ice cover is present in the channel. • Deep standing water upstream of the drop structures reduces risk of aufeis growth and possibly growth due to snow influx/ retention; reduces risk of ice damaging channel and structures in the spring.	• All options designed to minimize risks associated with winter conditions as per design criteria and are therefore expected to perform equally well.
6. Resiliency	**6.1 Adaptability for Additional Capacity**	• **Reach 1 widening and extension in wetland complex:** Conveyance in wetland complex surrounding Big Buffalo Lake limit ability to increase flows beyond design peak without conducting additional excavation works. • **Reach 2 containment dike and Buffalo Creek:** Flows above design peak encroach on dike freeboard.	• **Reach 2:** Flows above design peak encroach on dike freeboard.	• **Reach 2:** Flows above design peak encroach on dike freeboard. • **Reach 1 decommissioning:** Potential additional emergency capacity available with minimal effort by re-opening Reach 1.	• Option 1 has limited ability to provide additional capacity. • Option 4 most adaptable for additional capacity.
7. Cost	**7.1 Capital Costs**	• Preliminary Class C estimate (+/- 30%) approximated at $ 300 million (All-inclusive for Reaches 1 2 & 3 combined – with outlet east of Willow Point)	• Preliminary Class C estimate (+/- 30%) approximated at $ 300 million (All-inclusive for Reaches 1 2 & 3 combined – with outlet east of Willow Point)	• Preliminary Class C estimate (+/- 30%) approximated at $ 290 million (All-inclusive for Reaches 1 2 & 3 combined – with outlet east of Willow Point)	• All Options have similar estimated capital costs, with Option 4 slightly less costly.
	7.2 General Maintenance Costs	• Estimated average annual maintenance costs based on 2% of Capital Costs: $ 6 million.	• Estimated average annual maintenance costs based on 1.6% of Capital Costs: $ 4.8 million.	• Estimated average annual maintenance costs based on 1.5% of Capital Costs: $ 4.4 million.	• Option 1 has highest estimated maintenance costs mostly due to risk of fish stranding, increased risk of vegetation growth within the channel and operation risks through the wetland complex. • Option 3 has slightly larger estimated maintenance cost compared to Option 4 due to increased risk of vegetation growth within the channel and risk of poor vegetation growth on the channel banks.
8. Cost Risk	**8.1 Social Risk**	• Additional socio-economic concerns due to alignment through wetland complex and Buffalo Creek	• Alignment avoids wetland complex and Buffalo Creek altogether, minimizing socio-economic risks compared to Option 1.	• Alignment avoids wetland complex and Buffalo Creek altogether, minimizing socio-economic risks compared to Option 1.	• Additional socio-economic concerns with Option 1
	8.2 Optimization	• Deeper, narrower channel provides opportunity for approximately $5 million cost savings.	• Deeper, narrower and straighter channel provides opportunity for approximately $15 million cost savings.	• Deeper, narrower and straighter channel provides opportunity for approximately $15 million cost savings.	• Options 3 & 4 have larger potential cost savings than Option 1.

Main Category	Sub-Criteria	Option 1	Option 3	Option 4	Summary Comparison
	8.3 Environmental	• Potential additional environmental mitigation requirements to address concerns with flooding the wetland complex and Buffalo Creek could result in increased cost.	• Alignment avoids wetland complex and Buffalo Creek altogether, minimizing risks associated with environmental mitigation requirements compared to Option 1.	• Alignment avoids wetland complex and Buffalo Creek altogether, minimizing risks associated with environmental mitigation requirements compared to Option 1.	• Additional risks with Option 1.
	8.4 Construction	• Higher construction risks for Option 1 (Reach 1 extension), based on contractor input, could result in unexpected increases in costs. • Unknown spoil conditions (Reach 1 widening) could result in unexpected increases in costs.	• Unknown spoil conditions (Reach 1 widening) could result in unexpected increases in costs.	• Ability to operate Reach 1 during construction with minimal impacts to construction schedule.	• Option 4 performs best. • Option 1 has higher risks for unexpected increases in costs.
	8.5 Rock Supply	• Hauling of riprap required for construction of drop structures and for erosion protection. • Limited amount of data on overall quality and quantity of rock available for the project.	• Hauling of riprap required for construction of drop structures and for erosion protection. • Limited amount of data on overall quality and quantity of rock available for the project.	• Hauling of riprap required for construction of drop structures and for erosion protection. • Limited amount of data on overall quality and quantity of rock available for the project.	• Differences in total rock quantity required not substantially different between options.
	8.6 Amortization	• “Writing-off” the amortization of Reach 1 not a requirement for this option.	• “Writing-off” the amortization of Reach 1 not a requirement for this option.	• “Writing-off” the amortization of Reach 1 as part of decommissioning may result in cost differences compared to other Options. • Design assumes channel used in the future for riparian flow and/or emergency capacity due to climate change. “Writing-off” the amortization therefore not required.	• No cost differences expected between options.

TABLE 3
REACH 2 DECISION MATRIX – RESULTS

Main Category	Weight	Sub-Criteria	Weight	Option 1		Option 3		Option 4	
				Rating	Score	Rating	Score	Rating	Score
1. Constructability	13	1.1 Access to Site	2.0	3	6.0	3	6.0	3	6.0
		1.2 Surface and Groundwater Management	4.0	2	8.0	4	16.0	4	16.0
		1.3 Material Composition	2.0	2	4.0	3	6.0	4	8.0
		1.4 Bathymetric Conditions	2.0	3	6.0	3.5	7.0	3.5	7.0
		1.5 Scheduling	3.0	2	6.0	2	6.0	5	15.0
2. Operability & Performance	15	2.1 Channel Dikes and Slopes	2.0	3	6.0	4	8.0	4	8.0
		2.2 Erosion, Sediment Transport and Deposition	3.0	2	6.0	3	9.0	4	12.0
		2.3 Flow Through Buffalo Lakes Wetland Complex	5.0	2	10.0	5	25.0	5	25.0
		2.4 Drop Structures	1.5	3	4.5	3	4.5	3	4.5
		2.5 Operation in Winter Conditions	2.0	3	6.0	3	6.0	3	6.0
		2.6 Groundwater Management	1.5	3	4.5	3	4.5	3	4.5
3. Physical Environmental Impacts	15	3.1 Surface Water	5.0	1	5.0	3	15.0	3	15.0
		3.2 Groundwater	2.0	4	8.0	3	6.0	3	6.0
		3.3 Terrestrial Environment	4.0	2	8.0	3	12.0	3	12.0
		3.4 Aquatic Habitat & Resources	4.0	1	4.0	3	12.0	3	12.0
4. Social Economic Considerations	12	4.1 Access	4.0	3	12.0	3	12.0	3	12.0
		4.2 Indigenous Rights Based Activities	4.0	2	8.0	3	12.0	3	12.0
		4.3 Commercial Fisheries	4.0	2	8.0	3	12.0	3	12.0
5. Maintainability and Inspection	10	5.1 Access to Site	2.0	3	6.0	4	8.0	4	8.0
		5.2 Vegetation Growth	3.0	2	6.0	3	9.0	4	12.0
		5.3 Sedimentation	3.0	3	9.0	3.5	10.5	3.5	10.5
		5.4 Operation in Winter Conditions	2.0	3	6.0	3	6.0	3	6.0
6. Resiliency	5	6.1 Adaptability for Additional Capacity	5.0	2	10.0	3	15.0	5	25.0
7. Cost	10	7.1 Capital Costs	7.0	3	21.0	3	21.0	3	21.0
		7.2 General Maintenance Costs	3.0	2	6.0	2.5	7.5	3	9.0
8. Cost Risk	20	8.1 Social Risk	3.0	2	6.0	3	9.0	3	9.0
		8.2 Optimization	4.0	3	12.0	4	16.0	4	16.0
		8.3 Environmental	3.0	2	6.0	3	9.0	3	9.0
		8.4 Construction	4.0	2	8.0	2.5	10.0	3	12.0
		8.5 Rock Supply	2.0	3	6.0	3	6.0	3	6.0
		8.6 Amortization	4.0	3	12.0	3	12.0	3	12.0
		Total Score (out of 500)	500		234.0		318.0		348.5
		Total Score (out of 100)	100		46.8		63.6		69.7

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Preliminary Design for Reach 2 of the Lake St. Martin Outlet Channels

Technical Workshop

December 15, 2016

Science | Imagination | Collaboration

Introduction

- Welcome
- Round Table Introductions

Workshop Agenda

8:00 AM - Pastries and Coffee

8:30 AM - Technical Workshop (Morning Session)

1.0 Goals/Objectives and Workshop Overview

2.0 Project Background / Review of Options

3.0 Description of Workshop Process

9:45 AM - Break

4.0 Evaluation Criteria & Weighting Process

12:00 PM - Lunch

Workshop Agenda

12:30 PM - Technical Workshop (Afternoon Session)

5.0 Comparison of Options & Rating

~2:00 PM - Break

5.0 Comparison of Options & Rating (continued)

6.0 Results

7.0 Wrap up / Next Steps

4:30 PM – Adjournment (Tentative)

Workshop Goals

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- Evaluate and rank the suitability of each option of the Reach 2 channel in meeting the objectives of the project.

- Identify a preferred option to proceed with Preliminary Design.

Overview of Workshop Process

1. Review of Background Information
2. Detailed Description of Workshop Process
3. Review Criteria Definitions / Weighting (morning)
    - Table 1 issued ahead of the workshop
    - Overview of definitions & open discussions
    - Weighting process – main categories followed by sub criteria
    - Interactive approach

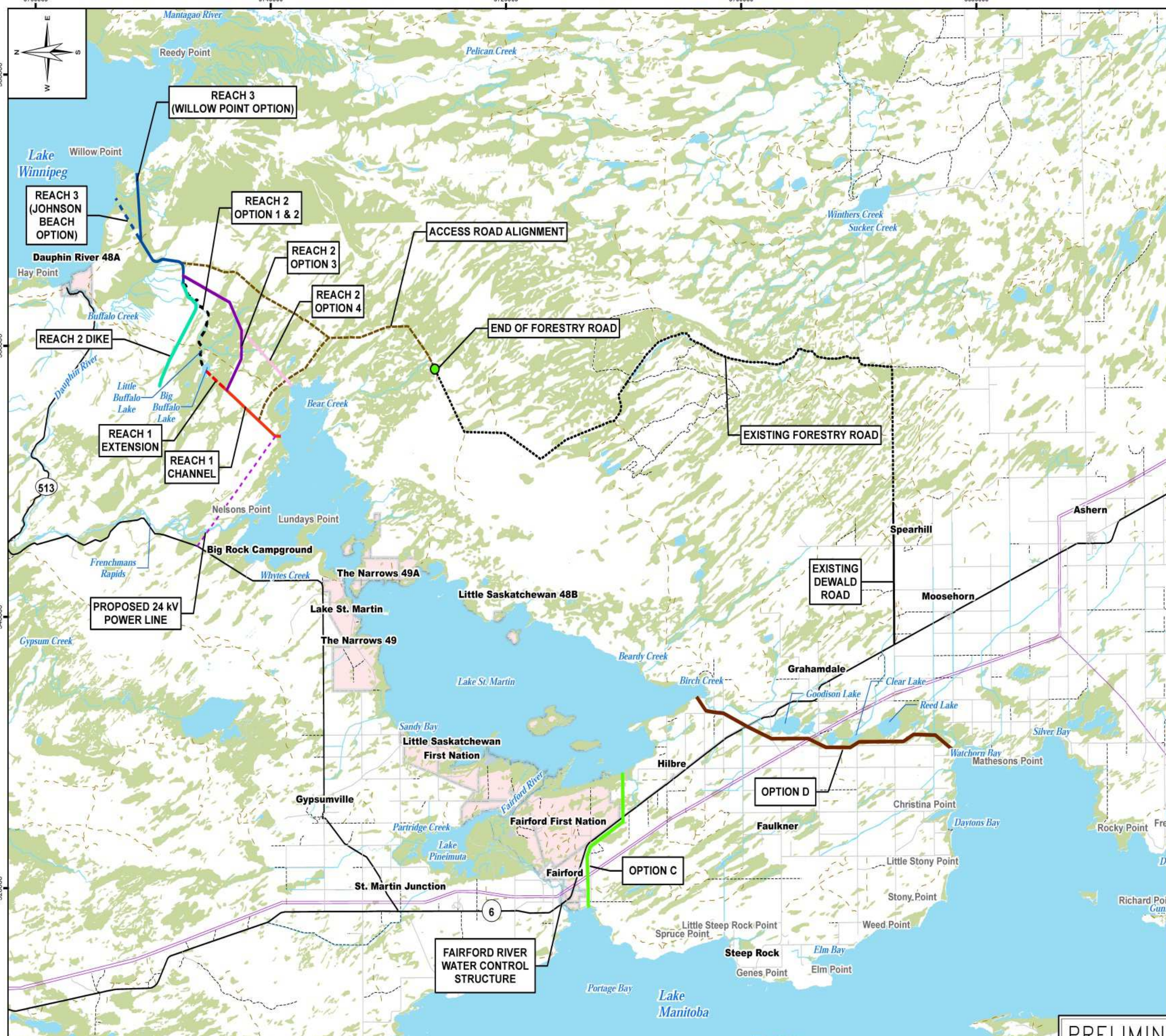
Overview of Workshop Process

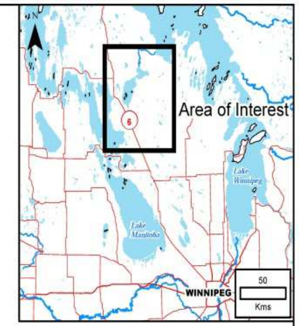
4. Comparison of Options /Rating (afternoon)
   - Table 2 issued ahead of the workshop
   - Comparison of options & open discussions
   - Rating system will be defined
   - Rating process criteria by criteria
   - Interactive approach
   - Opportunity to revisit “parking lot” items
5. Review of scoring results at the end of Workshop

2. Project Background

Project Background

- Details of Options 1 to 4 presented at early review meeting on October 6.
- Review to focus on Options 1, 3 & 4.
  - Option 2 previously dismissed – provides minimal added benefits to address concerns in wetland complex & of floating bog/marsh islands.
- Will also Focus on:
  - Necessary information for comparison
  - New & updated design components
  - More details during comparison process





LEGEND:

- Reach 2 Alignment Option 3
- Reach 2 Alignment Option 4
- Reach 1 Channel Extension
- Reach 1 Channel Widening
- LSM Reach 2 Containment Dike
- Reach 3 – Willow Point Option
- Reach 3 – Johnson Beach Option
- Buffalo Creek Channel
- LMB Channel Option C
- LMB Channel Option D
- Proposed 24 kV Transmission Line
- Existing Transmission Line
- Forestry Road
- Access Road
- Municipal Road
- Highway
- Limited Use Road
- Trail
- Watercourse
- Wetlands
- Waterbody
- First Nation
- Campsite

DRAFT

0 2.5 5 7.5 10 12.5
Kms

SCALE: 1:300,000 METRIC 11"x17"

All units are metric and in metres unless otherwise specified.
Transverse Mercator Projection, NAD 1983, Zone 14
Elevations are in metres above sea level (MSL)

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A	16/10/05	ISSUED FOR INFORMATION	PAL	MSW

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PRELIMINARY DESIGN FOR REACH 2 OF THE LSM OUTLET CHANNEL

GENERAL SITE PLAN

OCTOBER 2016 | FIGURE 1 | REV: A

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

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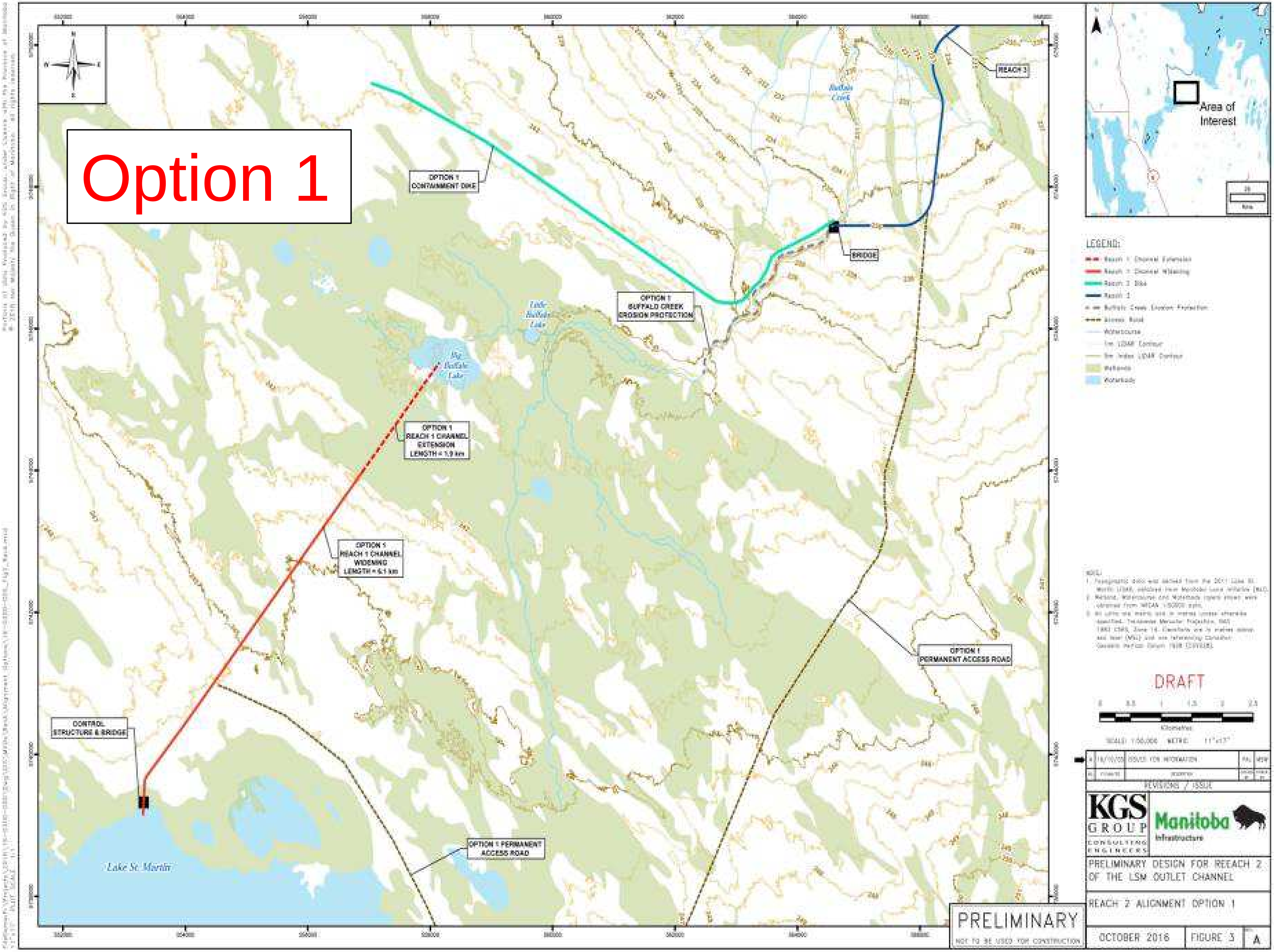
11"x17" PLOT SCALE 1:1


Option 1
OPTION 1 CONTAINMENT DIKE
REACH 3
Buffalo Creek
BRIDGE
OPTION 1 BUFFALO CREEK EROSION PROTECTION
Little Buffalo Lake
Big Buffalo Lake
OPTION 1 REACH 1 CHANNEL EXTENSION LENGTH = 1.9 km
OPTION 1 REACH 1 CHANNEL WIDENING LENGTH = 6.1 km
CONTROL STRUCTURE & BRIDGE
OPTION 1 PERMANENT ACCESS ROAD
OPTION 1 PERMANENT ACCESS ROAD
Lake St. Martin
Area of Interest
LEGEND:
DRAFT
Kilometres
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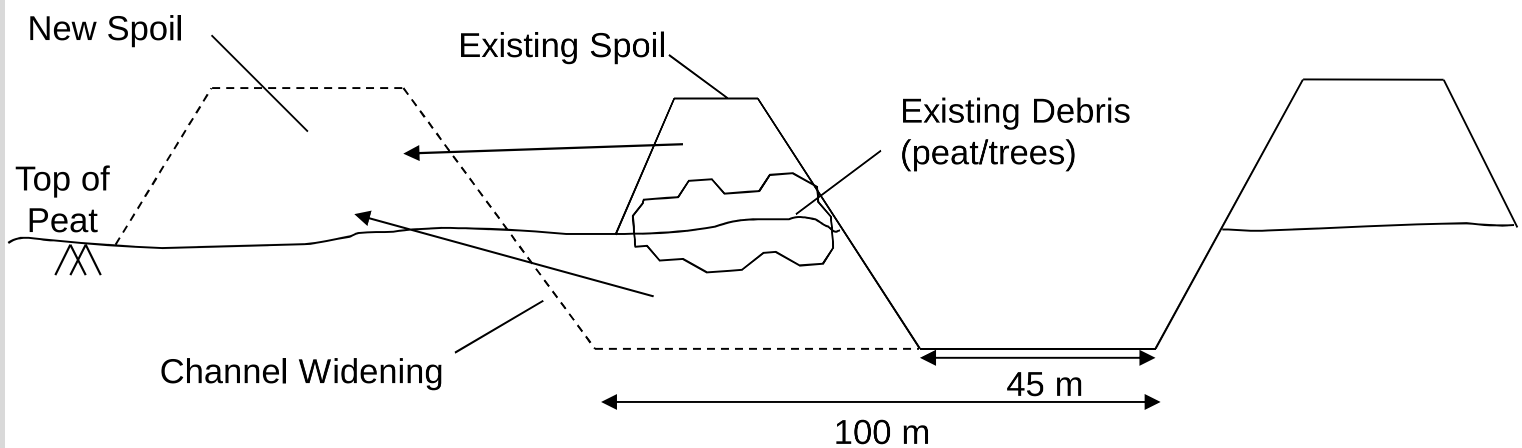
Infrastructure
PRELIMINARY DESIGN FOR REEACH 2 OF THE LSM OUTLET CHANNEL
REACH 2 ALIGNMENT OPTION 1
PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION
OCTOBER 2016
FIGURE 3
A

Option 1 (& Option 3)
Reach 1 Widening

- Access
  - Permanent access road to Reach 1 completed prior to construction
  - Gravel topping included on both sides of channel for long term access
- Constructability / Dewatering
  - Cofferdam & pumping required for construction or provision of drainage downstream

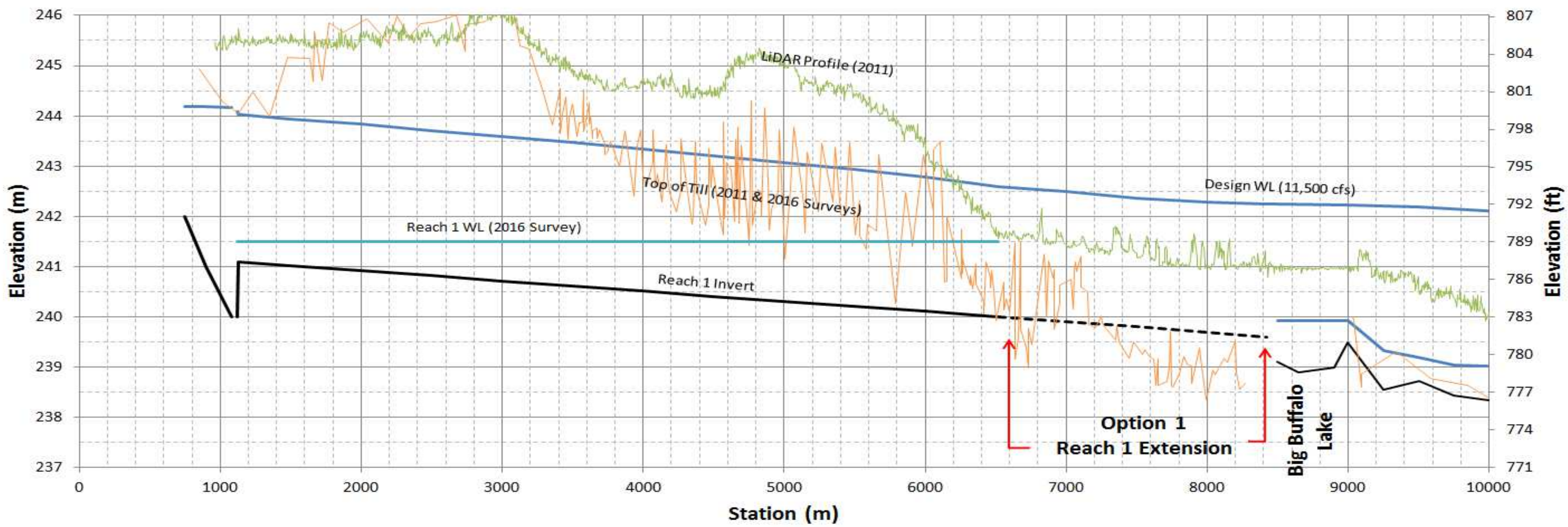
Option 1 (& Option 3)
Reach 1 Widening



- 2016 drone survey results:
  - Left spoil smaller than right spoil
  - Less volume than Stage 2 estimates
- Excavate channel – spoil on left side
  - debris / peat / trees under spoil - unsorted & wet material requires more excavation effort (addressed in cost estimates).

Option 1
Reach 1 Widening - Summary

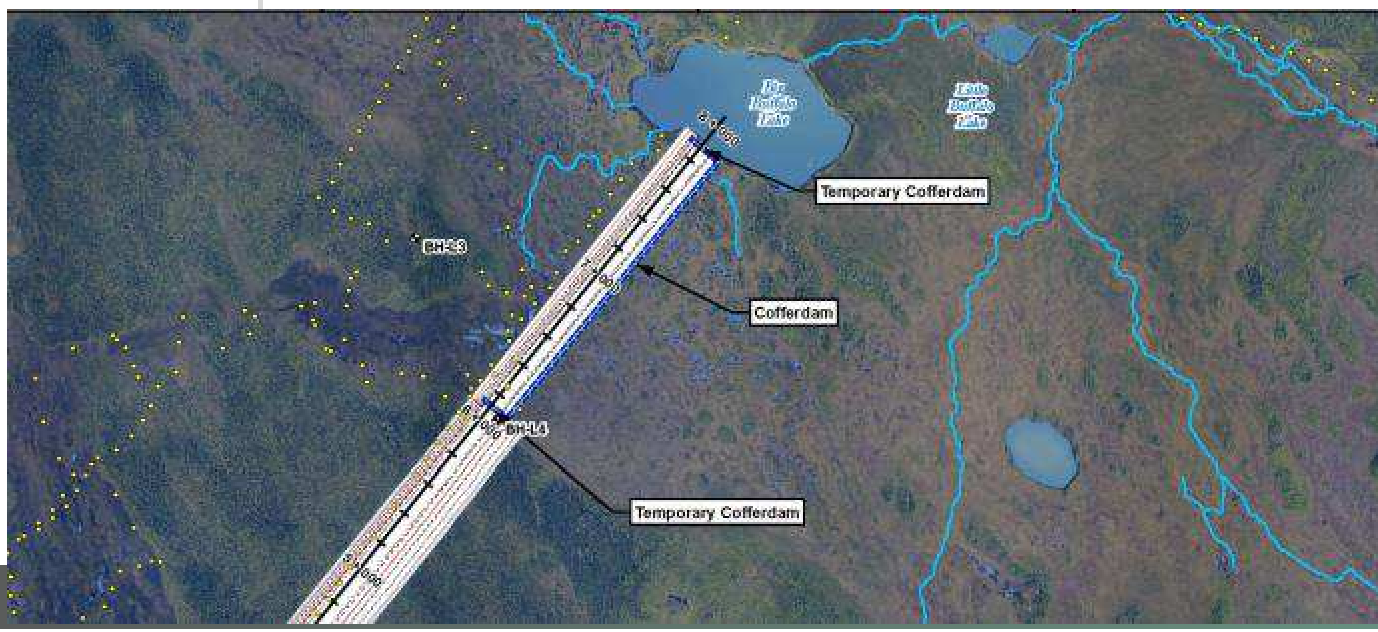
- Shallow depths of standing water when channel not in operation
  - Water levels dependent on Big Buffalo Lake
  - Increased risk of aquatic vegetation growth in channel
  - Increased portion of side slopes vulnerable to poor vegetation growth as a result of prolonged operation



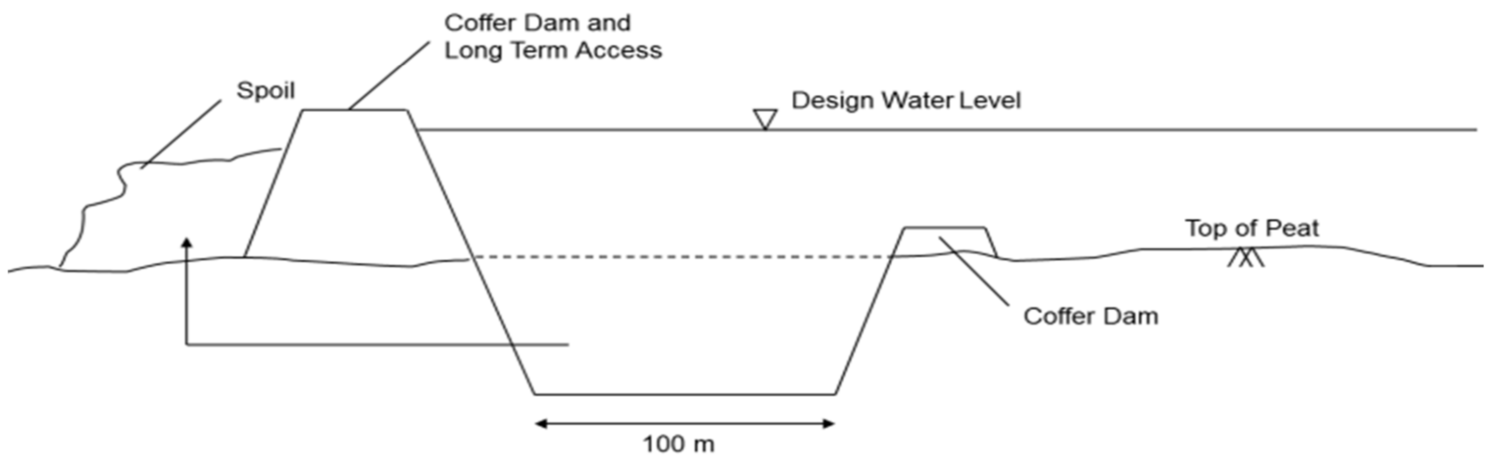
Option 1
Reach 1 Extension

Option 1
Reach 1 Extension

- Constructability / Dewatering
  - Construction of cofferdams requires hauling material from Reach 1 widening
  - Isolate in ~200 m – 300 m cells
  - Start downstream, working towards Reach 1



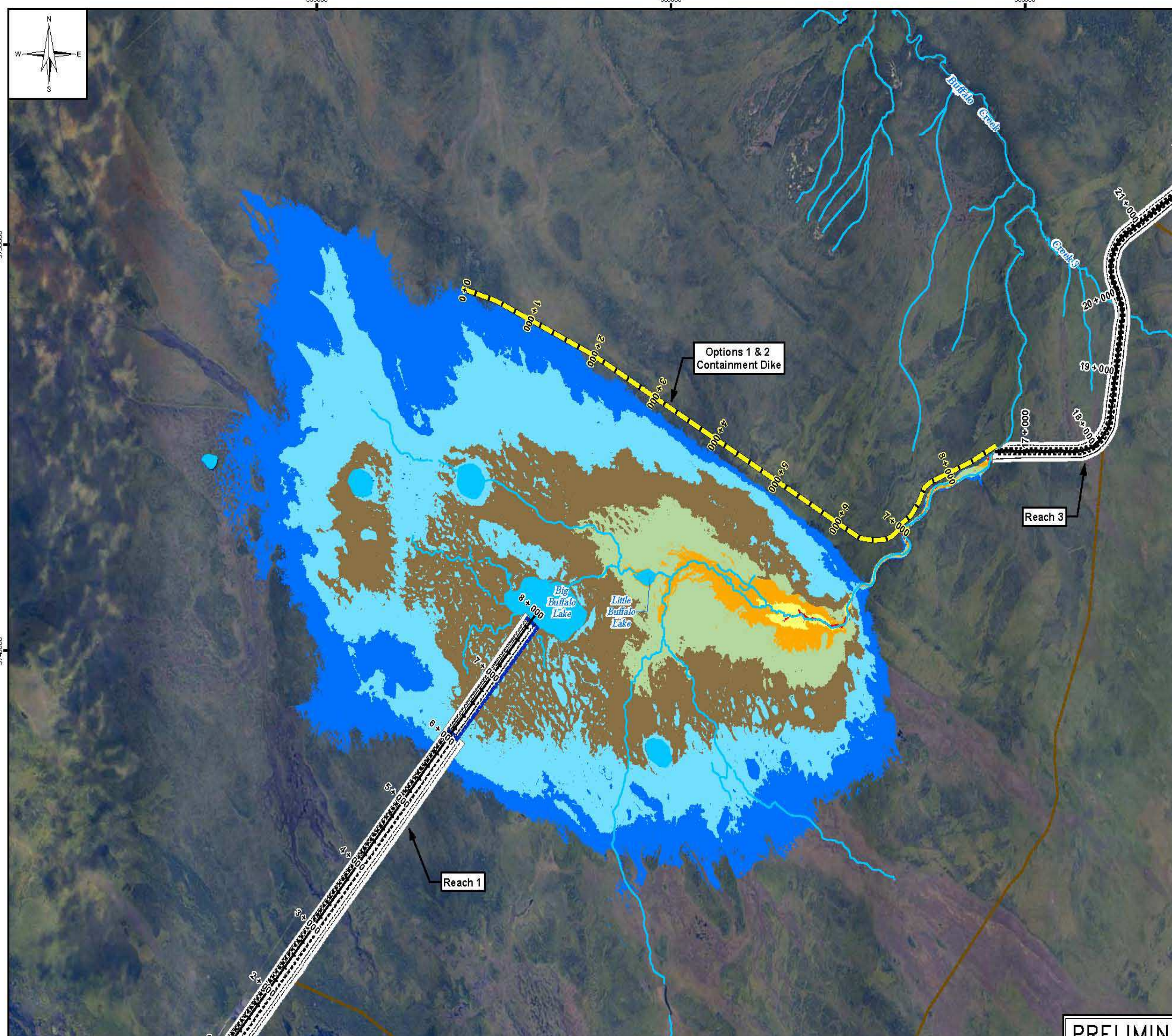
Option 1 - Reach 1 Extension

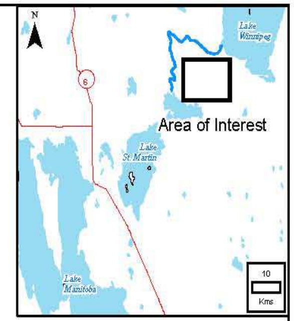


- Channel invert above till
  - Removal of peat required for construction
- Permanent access on left side
  - Increased volume compared to Stage 2 estimates
- Overall more effort per km compared to Options 3 & 4
  - addressed in the cost estimates

Option 1
Flow through Wetland Complex

- Engaged Dr. James Ehnes
  - Terrestrial Ecologist – ECOSTEM Ltd.
  - peatland / bog expert
- Potential loss of conveyance concentrated in bog or marsh areas
- Potential risk for floating bog/marsh islands depend on various factors





LEGEND:

- Options 1 & 2 Containment Dike
- Channel Linework
  - Channel Alignment
  - Cofferdam
  - Toe of Channel
  - Top of Spoil
  - Top of Expanded Channel Footprint
  - Right of Way Footprint
  - Access Road
- Water Features
  - River/Stream
  - Waterbody
- Depth of Flooding (m)
  - 0 – 0.5
  - 0.5 – 1.0
  - 1.0 – 1.5
  - 1.6 – 2.0
  - 2.0 – 2.5
  - 2.6 – 3.0
  - >3

NOTES:

1. Imagery is dated 2011 and supplied by the Province of Manitoba.

DRAFT

0 500 1,000 1,500 2,000 2,500

Metres

SCALE: 1:50,000 METRIC 11"x17"

All units are metric and in metres unless otherwise specified.
Transverse Mercator Projection, NAD 1983, Zone 14
Elevations are in metres above sea level (MSL)

NO.	YY/MM/DD	DESCRIPTION	ISSUED BY	CHECK BY
A	16/10/05	ISSUED FOR INFORMATION	PAL	MSW

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PRELIMINARY DESIGN FOR REEACH 2 OF THE LSM OUTLET CHANNEL

DEPTH OF FLOODING SURROUNDING BIG BUFFALO LAKE AREA – 11500 CFS

OCTOBER 2016 | FIGURE 7 | REV: A

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

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11"x17" PLOT SCALE 1:1

Option 1
Flow through Wetland Complex

- Various environmental concerns:
  - Altered rate and seasonality of flow
  - Leaching / decomposition of organic material
  - Change / impacts to terrestrial environment
  - Risk of fish stranding
- Long term maintenance required to convert into Provincial Waterway or Designated Reservoir Area
- Limited ability to adapt for additional future capacity
- Need for containment dike

Option 1
Buffalo Creek Enhancements

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- Erosion concerns discussed at early review meeting:
  - Inclusion of 3 drop structures
  - Requires increased height to containment dike & excavation works for additional capacity
  - Riprap protection required along banks in critical areas
  - Results in increased cost
- Aquatic impacts (fish passage requirements)
- Bridge across Reach 3 added to design for long term access + gravel topping on containment dike

Option 1
Cost Estimate Updates

- Reach 1 Widening has
  - Less volume but more effort per m^3
    - ~ $0M difference
- Reach 1 Extension:
  - Increased excavation volume to excavate down to till
    - ~ + $2M
  - Increased cofferdam/dike volume for access
    - ~ + $12M
- Flow through wetland complex:
  - Convert into a PWW or DRA
    - ~ + $1M

Option 1
Cost Estimate Updates

- Buffalo Creek Enhancements:
  - Drop structures, channel excavation, riprap, construction dewatering, etc…
    - ~ + $22M
- Containment Dike
  - Increased height along Buffalo Creek
    - ~ + $6M
- Access
  - Bridge across Reach 3
    - ~ + $6M
  - Gravel topping for access
    - ~ + $6M

Option 1
Cost Estimate Updates

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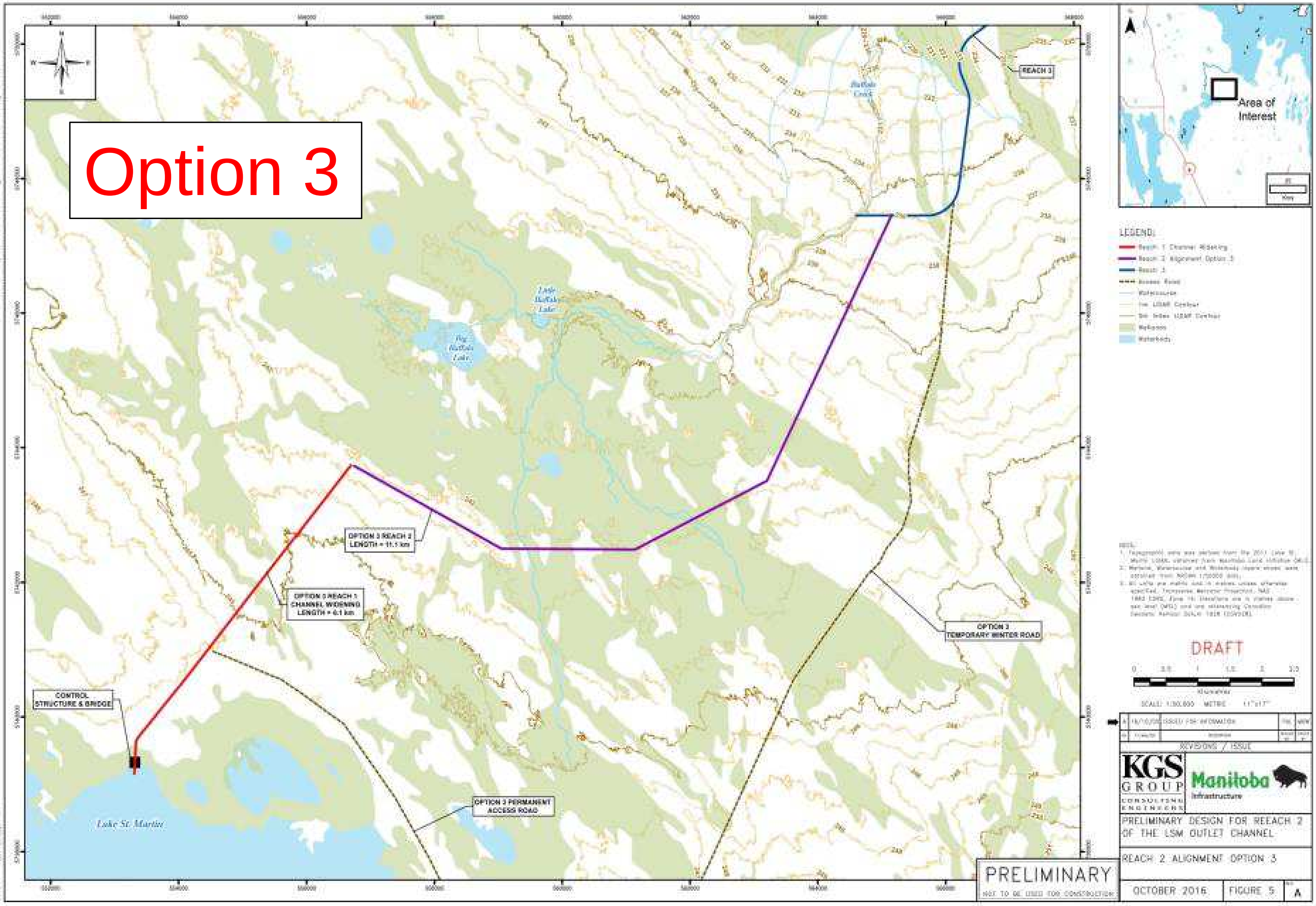
- Other
  - Mitigation, Engineering, Approvals, Contingencies…
    - Included in previous totals

- Updated Total
  - Reaches 1, 2, and 3 with outlet East of Willow Point
    - ~ + $55M
    - Now ~ $ 303 million up from ~ $ 248 million


Option 3
REACH 3
Buffalo Creek
Little Buffalo Lake
Big Buffalo Lake
Lake St. Martin
OPTION 3 REACH 2
LENGTH = 11.1 km
OPTION 3 REACH 1
CHANNEL WIDENING
LENGTH = 6.1 km
CONTROL
STRUCTURE & BRIDGE
OPTION 3 PERMANENT
ACCESS ROAD
OPTION 3
TEMPORARY WINTER ROAD
Area of
Interest
LEGEND:
DRAFT
Kilometres
REVISIONS / ISSUE
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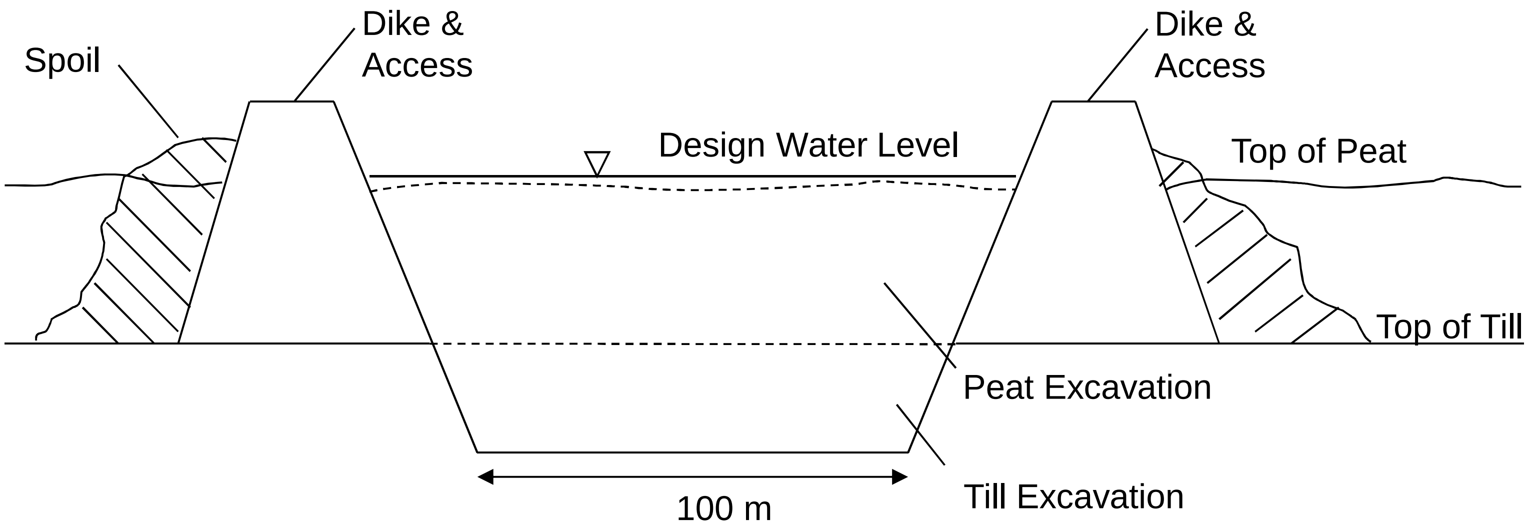
PRELIMINARY DESIGN FOR REEACH 2
OF THE LSM OUTLET CHANNEL
REACH 2 ALIGNMENT OPTION 3
OCTOBER 2016
FIGURE 5
A
PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

Option 3
Reach 2 channel

- Access
  - Permanent access road to Reach 1 completed prior to construction
  - Winter road access to Reach 3 for construction
  - Gravel topping included on both sides of channel for long term access
- Widening of Reach 1
  - Essentially same as Option 1

Option 3 (& Option 4) Reach 2 channel



- Constructability
  - Construction of drainage ditch starting at Reach 3 or alternatively at the upstream end
  - Excavated till used for cofferdams and dikes
  - Dewatering - Isolate in ~200m – 300m cells

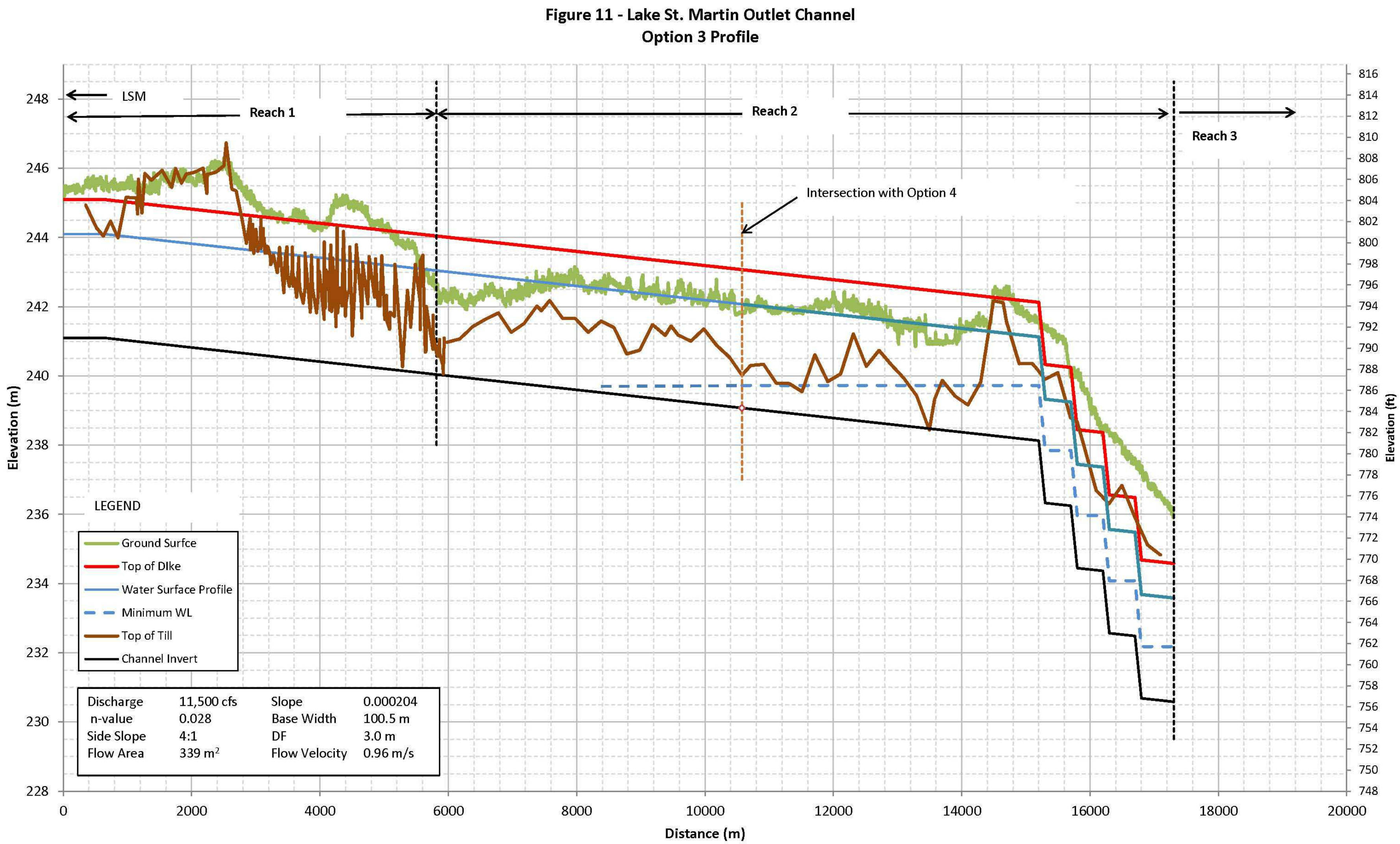
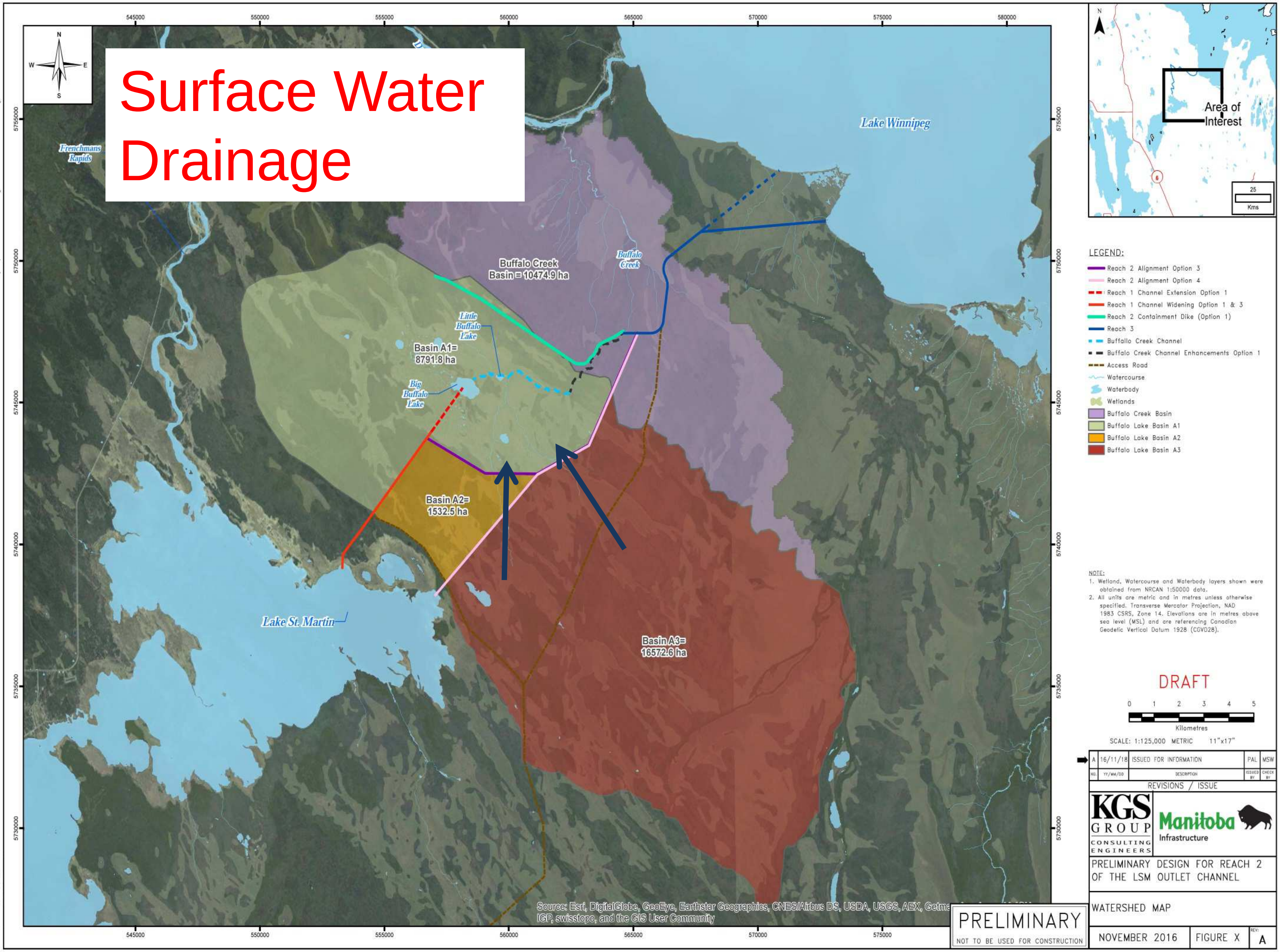


Figure 11 - Lake St. Martin Outlet Channel
Option 3 Profile
LSM
Reach 1
Reach 2
Reach 3
Intersection with Option 4
Elevation (m)
Elevation (ft)
Distance (m)
LEGEND
Ground Surfce
Top of DIke
Water Surface Profile
Minimum WL
Top of Till
Channel Invert
Discharge 11,500 cfs
n-value 0.028
Side Slope 4:1
Flow Area 339 m²
Slope 0.000204
Base Width 100.5 m
DF 3.0 m
Flow Velocity 0.96 m/s

Option 3
Drop Structures

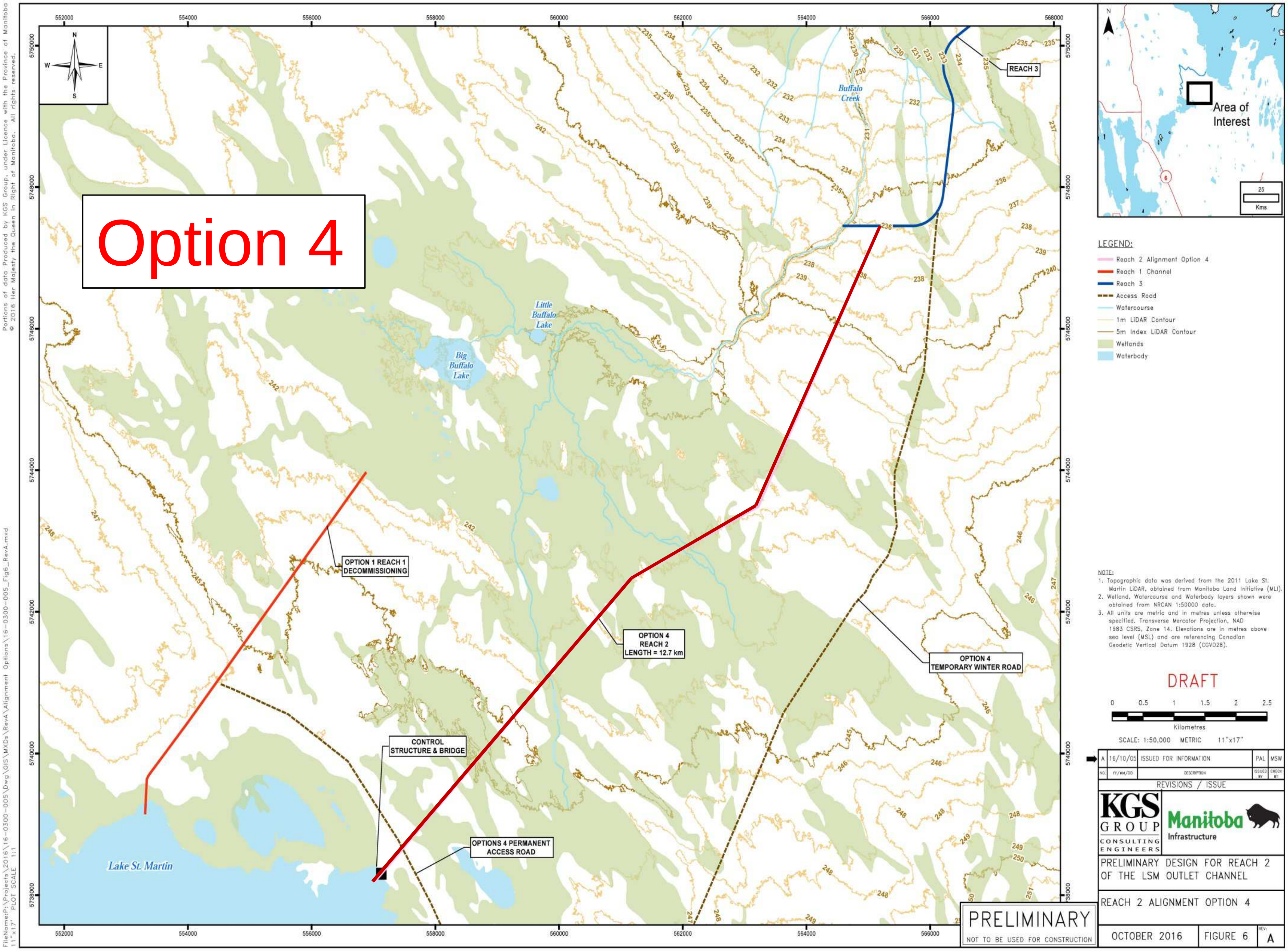
- Maximize depth of standing water upstream of structures:
  - Reduces concerns with vegetation growth in channel
  - Reduces area of channel banks exposed to poor vegetation growth
  - Minimizes risks associated with ice damage in the spring
- Provision of downstream fish passage
  - Notch at the crest of the structure
  - Provision of riparian flow

Surface Water Drainage



Option 3
Summary

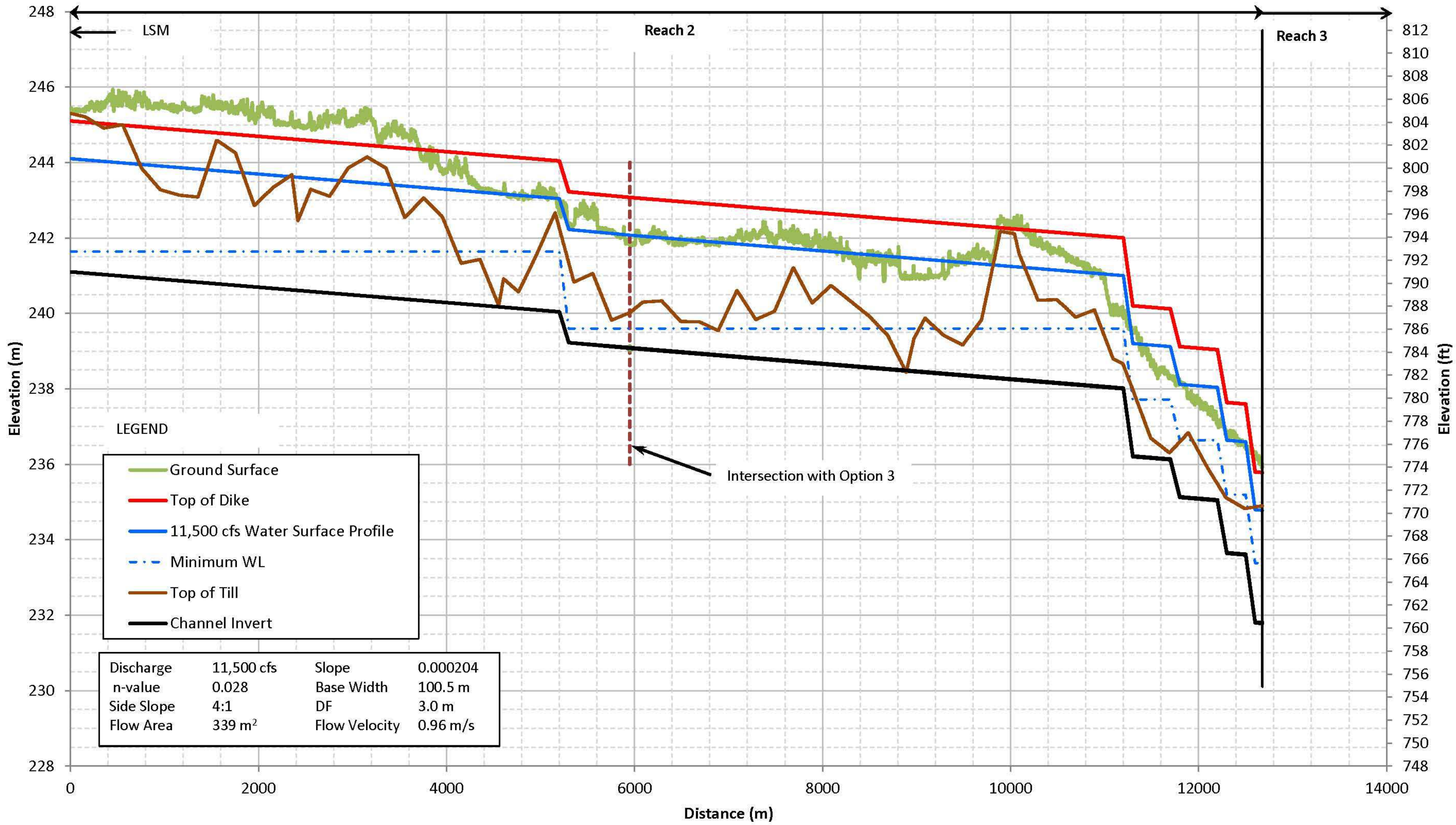
- Longest channel length
- Avoids wetland complex and Buffalo Creek
- Total cost approximately $300M
  - Options 1 & 3 have similar cost
- Opportunity for Optimization
  - Deeper, narrower, straighter channel


Option 4
REACH 3
Buffalo Creek
Little Buffalo Lake
Big Buffalo Lake
Lake St. Martin
OPTION 1 REACH 1 DECOMMISSIONING
OPTION 4 REACH 2 LENGTH = 12.7 km
OPTION 4 TEMPORARY WINTER ROAD
CONTROL STRUCTURE & BRIDGE
OPTIONS 4 PERMANENT ACCESS ROAD
Area of Interest
LEGEND:
Reach 2 Alignment Option 4
Reach 1 Channel
Reach 3
Access Road
Watercourse
1m LiDAR Contour
5m Index LiDAR Contour
Wetlands
Waterbody
NOTE:
1. Topographic data was derived from the 2011 Lake St. Martin LiDAR, obtained from Manitoba Land Initiative (MLI).
2. Wetland, Watercourse and Waterbody layers shown were obtained from NRCAN 1:50000 data.
3. All units are metric and in metres unless otherwise specified. Transverse Mercator Projection, NAD 1983 CSRS, Zone 14. Elevations are in metres above sea level (MSL) and are referencing Canadian Geodetic Vertical Datum 1928 (CGVD28).
DRAFT
Kilometres
SCALE: 1:50,000 METRIC 11"x17"
A 16/10/05 ISSUED FOR INFORMATION PAL MSW
REVISIONS / ISSUE
KGS GROUP CONSULTING ENGINEERS
Manitoba Infrastructure
PRELIMINARY DESIGN FOR REACH 2 OF THE LSM OUTLET CHANNEL
REACH 2 ALIGNMENT OPTION 4
PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION
OCTOBER 2016
FIGURE 6
A
Portions of data Produced by KGS Group, under Licence with the Province of Manitoba © 2016 Her Majesty the Queen in Right of Manitoba. All rights reserved.

Option 4

- Access similar to Option 3
- Channel design and construction method similar to Option 3 (excluding Reach 1)
- Drop structures
  - 1 additional structure – reduces concerns associated with vegetation growth

Figure 12 - Lake St. Martin Outlet Channel
Option 4 Profile



Option 4

- Channel inlet
  - Fall 2016 survey
  - All Options relatively shallow and assumed to require similar excavation works at inlet to minimize headloss
- Reach 1 decommissioning
  - Surface drainage, till shaping, revegetation…
  - Provision of base flow from Lake St. Martin potential mitigation strategy for wetland complex
  - Emergency capacity during construction & possibly long term

Option 4
Summary

- Shorter than Option 3
- Avoids wetland complex and Buffalo Creek
- Total cost approximately $290M
  - ~$10M less than Options 1 & 3.
- Opportunity for Optimization
  - Deeper, narrower, straighter channel
- Reach 1 decommissioning
- Emergency capacity

3. Description of Workshop Process

Decision Matrix

- In order to simplify the process, and because the information and rating system can be clearly defined, a Decision Matrix will be used for this process

- Decision Making process using weighted alternatives
  - Multiple criteria of different levels of importance

Method

1. Establish weight factors for each main category
2. Divide weights for each main category into respective sub-categories
3. Establish a numerical comparison scale
4. Rate each sub-criteria independently using priority scale
5. Multiply rating by weight to establish score
6. Option with the highest total score is the best

Example – Deciding on a trip

- Options: Trip A, Trip B, Trip C
- Criteria:
  - Travel cost
  - Total Cost
  - Novelty
  - Locations
  - Travel time
  - Safety
  - Accommodation
  - Travel quality

Weighting Factors Decision

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Criteria	Weight
Travel cost	0.25
Total Cost	0.2
Novelty	0.15
Locations	0.1
Travel time	0.1
Safety	0.1
Accommodation	0.05
Travel quality	0.05

Total: 1.00

Establish Numerical Comparison Scale

0 → Not suitable

1 → Moderately suitable

2 → Very suitable

Ratings for Each Sub-Criteria

	Trip A	Trip B	Trip C
Criteria	Rating	Rating	Rating
Travel cost	1	0	1
Total Cost	0	1	1
Novelty	2	1	2
Locations	1	0	2
Travel time	0	1	1
Safety	2	1	2
Accommodation	2	1	2
Travel quality	2	0	2

Establish Score

Score = Weight x Rating

		Trip A		Trip B		Trip C	
Criteria	**Weight**	**Rating**	**Score**	**Rating**	**Score**	**Rating**	**Score**
Travel cost	0.25	1	0.25	0	0	1	0.25
Total Cost	0.2	0	0	1	0.2	1	0.2
Novelty	0.15	2	0.3	1	0.15	2	0.3
Locations	0.1	1	0.1	0	0	2	0.2
Travel time	0.1	0	0	1	0.1	1	0.1
Safety	0.1	2	0.2	1	0.1	2	0.2
Accommodation	0.05	2	0.1	1	0.05	2	0.1
Travel quality	0.05	2	0.1	0	0	2	0.1

Total Scores and Make Decision

Option with highest total score is the best option → Trip C

		Trip A		Trip B		Trip C	
Criteria	**Weight**	**Rating**	**Score**	**Rating**	**Score**	**Rating**	**Score**
Travel cost	0.25	1	0.25	0	0	1	0.25
Total Cost	0.2	0	0	1	0.2	1	0.2
Novelty	0.15	2	0.3	1	0.15	2	0.3
Locations	0.1	1	0.1	0	0	2	0.2
Travel time	0.1	0	0	1	0.1	1	0.1
Safety	0.1	2	0.2	1	0.1	2	0.2
Accommodation	0.05	2	0.1	1	0.05	2	0.1
Travel quality	0.05	2	0.1	0	0	2	0.1
TOTAL			1.05		0.6		1.45
RANK			**2**		**3**		**1**

10min Break

4. Evaluation Criteria

Process

- Review Criteria Definitions
  - Table 1 of Handout Package
  - Main categories and sub-criteria
  - Open discussions : clarifications & suggestions
  - Target ~ 10min-15min per Category

- Weighting process at end
  - Target start time 11:30

Criteria Definition

- Main Categories:
  1. Constructability
  2. Operability & Performance
  3. Physical Environmental Impacts
  4. Social Impacts
  5. Maintainability and Inspection
  6. Resiliency
  7. Cost
- Sub-Criteria
  - 25 identified

Constructability

Main Category	Definition
1. **Constructability**	• Ability to achieve project schedule and complete project on time. • Ability to complete project on budget. • Ability to execute the project and complete construction as planned and as per design specifications. • Construction risks associated with potential cost overruns. • Construction risks that may result to changes in project concept and/or design. • Overall ease of construction.

Constructability

Sub-Criteria	Definition
1.1 Access to Site	• Ease of access for construction. • Ability to execute multiple contracts if required. • Reliance on construction staging and/or seasonal factors.
1.2 Surface and Groundwater Management	• Ease of drainage for construction. • Cofferdam requirements. • Reliance on construction staging and/or seasonal factors. • Risk of blowouts and basal heave conditions. • Risk of increased costs due to unforeseen conditions.
1.3 Material Composition	• Ease of excavation. • Source and quality of material for dike construction. • Source and quality of material for drop structures and erosion protection. • Risk of increased costs due to unforeseen conditions.
1.4 Bathymetric Conditions	• Extents of underwater excavation required for construction. • Depth of excavation under water. • Risk of increased costs due to unforeseen conditions.

Operability & Performance

Main Category	Definition
2. Operability & Performance	• Relative ease and level of effort to operate channel. • Overall ability of the project to achieve its intended purpose (i.e. probability of success). • Ability of the project to perform as intended over the short and long term without additional environmental impacts, or increased maintenance & inspection requirements. • Performance under extreme or less than optimal conditions (i.e. reliance on optimal conditions).

Operability & Performance

Sub-Criteria	Definition
2.1 Channel Dikes and Slopes	• Long term stability of the channel dikes and slopes. • Available freeboard above the dikes.
2.2 Erosion, Sediment Transport and Deposition	• Risk of erosion as a result of operation. • Risk of sediment transport and deposition as a result of operation.
2.3 Flow Through Buffalo Lakes Wetland Complex	• Risk associated with flotation and movement of individual bog or marsh islands, or marsh/bog islands in large groups. • Risk of floating islands blocking channel(s). • Risk of conveyance loss as a result of floating bog or marsh that remains in place.
2.4 Drop Structures	• Ability of the drop structures to dissipate energy as intended for the range of flow conditions.
2.5 Operation in Winter Conditions	• Ability to operate channel in winter conditions and manage formation of ice.
2.6 Groundwater Management	• Ability to manage risk of seepage and groundwater blowouts.

Physical Environmental Impacts

Main Category	Definition
3. Physical Environmental Impacts	• Short and long term impacts of the project to the physical environment during both the construction and operation phases. • Ease of obtaining approvals from regulators and environmental agencies to proceed with construction.

Physical Environmental Impacts

Sub-Criteria	Definition
3.1 Surface Water	• Potential impacts on surface water quality (i.e. TSS, Mercury, etc.) • Potential impacts on surface water quantity (i.e. flow rates, flow volumes, water levels, and seasonality).
3.2 Groundwater	• Potential risks associated with GUDI (Groundwater under the direct influence of surface water). • Potential impacts to water levels in adjacent aquifers.
3.3 Terrestrial Environment	• Potential impacts on existing vegetation and land cover. • Potential impacts on existing wildlife and habitat.
3.4 Aquatic Habitat & Resources	• Potential impacts to aquatic species and habitat. • Potential impacts to spawning and migration of fish species.

Social Impacts

Main Category	Definition
4. Social Impacts	• Short and long term impacts of the project to affected stakeholders and surrounding communities, including First Nations. • Impacts of project considering socio-economic factors. • Ease of obtaining approvals from regulators and environmental agencies to proceed with construction.

Social Impacts

Sub-Criteria	Definition
4.1 Land Use / Ownership	• Potential impacts to the physical land use and legal ownership in the area. • Potential impacts to traditional land use activities such as those protected under treaty rights (e.g. fishing, hunting, trapping).
4.2 Access	• Potential impacts as a result of construction all season access in the area.

Maintainability and Inspection

Main Category	Definition
5. Maintainability and Inspection	• Ability to maintain infrastructure in working conditions. • Ability to inspect infrastructure to confirm condition and performance. • Overall ease of conducting maintenance and inspection activities. • Ease of rehabilitation in the future.

Maintainability and Inspection

Sub-Criteria	Definition
5.1 Access to Site	• Ease of access for maintenance and inspection. • Reliance on seasonal factors, and/or operating conditions.
5.2 Vegetation Growth	• Ability to grow and maintain vegetation cover on the channel and dike slopes to manage risk of erosion. • Risk of thick aquatic vegetation growth within the channel that impacts discharge capacity of the channel.
5.3 Sedimentation	• Risk of sedimentation occurring within or downstream of the channel.
5.4 Flow Through Buffalo Lakes Wetland complex	• Ability to maintain the wetland complex as a designated Provincial Waterway or a Designated Reservoir Area.
5.5 Operation in Winter Conditions	• Risk that the movement of ice in the channel during channel operation, or during the spring freshet when the channel is closed, results in damages to the channel and structures.

Resiliency

Main Category	Definition
6. Resiliency	• Ability to adapt project in the future to changing conditions such as climate change & increased runoff.

Resiliency

Sub-Criteria	Definition
6.1 Adaptability for Additional Capacity	• Ability to adapt channel design in the future for increased capacity. • Ability to increase channel capacity in the event of an emergency.

Cost

Main Category	Definition
7. Cost	• Overall project costs including capital costs and long term maintenance and inspection.

Cost

Sub-Criteria	Definition
7.1 Capital Costs	• Total project costs, including: mitigation costs; engineering fees; contract administration; approvals; contingencies.
7.2 Cost Sensitivities	• Potential for reduction in cost by optimization of final design. • Potential for increased cost due to added project requirements or unforeseen conditions.
7.3 General Maintenance Costs	• Long term maintenance cost over entire life expectancy of project.

Consensus on Criteria

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- “Parking lot” items
- Final opportunity for editing criteria

Weighting Process

- Main Criteria
- Sub-criteria

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LUNCH!

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5. Comparison of Options

Comparison

- Purpose: to rate options for each sub-criteria such that the best decision is made to satisfy the goal
  - Evaluate options, and assign them values in terms of performance

Rating Scale

1. Poor Performance
2. Mediocre performance
3. Satisfactory Performance
4. Good Performance
5. Superior Performance

Rating Process

- Table 2 of Handout Package
- One criteria at a time
  - Summary comparison
  - Review performance of options if necessary
  - Rate the options
- Target ~5 min per criteria

Constructability

Sub-Criteria	Summary Comparison
1.1 Access to Site	• Option 1 has two separate permanent access points (Reach 1 and Reach 3); improves construction staging and scheduling. • Options 3 & 4 have a single permanent access point (Reach 1) and a potential secondary winter access to Reach 3.

Constructability

Sub-Criteria	Summary Comparison
1.2 Surface and Groundwater Management	• All options require some level of construction drainage & dewatering, including cofferdam construction with pumping. Dewatering efforts incorporated into cost estimates. • Higher construction risks for Option 1 based on contractor input due to difficulties with dewatering Reach 1 extension and proximity of Big Buffalo Lake. • Risk of blowouts and basal heave conditions similar for all options and can be managed by pumping, downstream drainage, or with passive depressurization system. • Option 4 has ability to operate Reach 1 during construction in an emergency if required, with minimal impact to construction schedule, whereas not Options 1&3.

Constructability

Sub-Criteria	Summary Comparison
1.3 Material Composition	• Material type in undisturbed areas similar for all options. • Reach 1 widening for Options 1&3 requires increased excavation effort due to composition of existing spoil pile material. • Hauling of riprap required for all options.

Constructability

Sub-Criteria	Summary Comparison
1.4 Bathymetric Conditions	• Excavation required to minimize headloss upstream of control structure for all options. • Potential to reduce inlet excavation requirements for Options 3&4 but not Option 1. • Conditions in Buffalo Creek and Big Buffalo Lake results in potential additional construction challenges on Option 1.

Operability and Performance

Sub-Criteria	Summary Comparison
2.1 Channel Dikes and Slopes	• All options designed with stable channel dikes and slopes as per design criteria and therefore are intended to perform equally (4:1 slopes and a Factor of Safety of 1.5 for normal conditions and 1.3 under rapid drawdown conditions).

Operability and Performance

Sub-Criteria	Summary Comparison
2.2 Erosion, Sediment Transport and Deposition	• All options designed to be non-erodible as per design criteria and are therefore intended to perform equally. • Option 3 has largest potential volume of available sediment for transport as a result of operation based on the wetted surface area of the channel, followed by Option 4, then Option 1. • Option 3 has largest potential volume of available sediment for transport as a result of exposed side slopes based on the potential surface area of poor vegetation growth. Options 1 & 4 have similar area of exposed side slopes.

Operability and Performance

Sub-Criteria	Summary Comparison
2.3 Flow Through Buffalo Lakes Wetland Complex	• Option 1 has potential risks and concerns associated with flow through the bog and marsh areas. • Options 3 and 4 do not have similar disadvantages.

Operability and Performance

Sub-Criteria	Summary Comparison
2.4 Drop Structures	• All options intended to perform equally as per design criteria. • More complex structure required for Option 1 to provide upstream fish passage in Buffalo Creek . Upstream fish passage not required for Options 3 & 4.

Operability and Performance

Sub-Criteria	Summary Comparison
2.5 Operation in Winter Conditions	• All options would be designed to minimize risks associated with winter conditions as per design criteria and therefore are intended to, and are expected to, perform equally well. • Differences in potential volume of frazil ice production between options are not expected to result in a significant variance in performance between options.

Operability and Performance

Sub-Criteria	Summary Comparison
2.6 Groundwater Management	• All options would be designed to minimize risks of seepage and blowouts and are therefore intended to perform equally. • Impacts not expected to be significant.

Physical Environmental Impacts

Sub-Criteria	Summary Comparison
3.1 Surface Water	• Altered rate and seasonality of flow on the Dauphin River for all options. • Altered rate and seasonality of flow to Big Buffalo Lake and Buffalo Creek for all Options. Potential impacts more severe with Option 1 due to the magnitude of alteration. Potential mitigation strategies identified for Options 3&4. • Flooding of wetland complex and upper Buffalo Creek as a result of operation once every 3 years for Option 1, whereas Options 3&4 have dikes that minimize flooding into land adjacent to channel. • Additional number of locations with potential impacts to water quality as a result of operation for Option 1 compared to Options 3 & 4. • Increased potential of mobilization of sediment during construction for Option 1 compared to Options 3 & 4.

Physical Environmental Impacts

Sub-Criteria	Summary Comparison
3.2 Groundwater	• Blowout of basal soils may occur if groundwater pressure exceeds pressure of overburden mass. • Potential groundwater impacts similar for all options.

Physical Environmental Impacts

Sub-Criteria	Summary Comparison
3.3 Terrestrial Environment	• Option 1 has the largest potential area of impacts to terrestrial environment due to inundation of wetland complex. • Option 3 impact slightly larger area then Option 4 due to longer channel length.

Physical Environmental Impacts

Sub-Criteria	Summary Comparison
3.4 Aquatic Habitat & Resources	• Risk of fish stranding for Option 1 whereas this is addressed as part of design criteria for Options 3 & 4. • Destruction or alteration of Fish Habitat in Buffalo Creek for Option 1. Options 3 & 4 avoid Buffalo Creek altogether. • Impediment to fish migration in Buffalo Creek and Big Buffalo Lake for Option 1 during operation whereas not for Options 3 & 4. • Option 1 has potential for additional aquatic impacts on Buffalo Creek and Dauphin River downstream of Reach 3 diversion structure.

10min Break

Social Impacts

Sub-Criteria	Summary Comparison
4.1 Land Use / Ownership	• Potential impacts similar for all options

Social Impacts

Sub-Criteria	Summary Comparison
4.2 Access	• Additional concerns for Option 1.

Maintainability and Inspection

Sub-Criteria	Summary Comparison
5.1 Access to Site	• All options have access included on all dikes and along both sides of the entire channel as per design criteria and therefore are intended to perform equally.

Maintainability and Inspection

Sub-Criteria	Summary Comparison
5.2 Vegetation Growth	• Options 1 & 3 have increased risk of vegetation growth within the Reach 1 channel. • Option 1 has increased risk of vegetation growth within wetland complex and Reach 3. • Option 3 has largest potential area of channel banks vulnerable to poor vegetation growth, whereas Options 1 & 4 perform similarly. • Additional maintenance effort potentially required for Option 1 to address risk of debris floating and moving downstream during operation.

Maintainability and Inspection

Sub-Criteria	Summary Comparison
5.3 Sedimentation	• Potential for deposition similar for all options. • Option 1 has additional location of potential deposition in wetland complex.

Maintainability and Inspection

Sub-Criteria	Summary Comparison
5.4 Flow Through Buffalo Lakes Wetland Complex	• Additional maintenance required for Option 1.

Maintainability and Inspection

Sub-Criteria	Summary Comparison
5.5 Operation in Winter Conditions	• All options designed to minimize risks associated with winter conditions as per design criteria and are therefore expected to perform equally well.

Resiliency

Sub-Criteria	Summary Comparison
6.1 Adaptability for Additional Capacity	• Option 1 has limited ability to provide additional capacity. • Option 4 most adaptable for additional capacity.

Cost

Sub-Criteria	Summary Comparison
7.1 Capital Costs	• All Options have similar estimated capital costs, with Option 4 slightly less costly.

Cost

Sub-Criteria	Summary Comparison
7.2 Cost Sensitivities	• Options 3 & 4 have slightly larger potential cost savings than Option 1. • Option 1 has higher risks for unexpected increases in costs. • Option 4 has additional potential cost differences compared to Option 1 & 3 associated with decommissioning of Reach 1.

Cost

Sub-Criteria	Summary Comparison
7.3 General Maintenance Costs	• Option 1 has highest estimated maintenance costs mostly due to risk of fish stranding, increased risk of vegetation growth within the channel and operation risks through the wetland complex. • Option 3 has slightly larger estimated maintenance cost compared to Option 4 due to increased risk of vegetation growth within the channel and risk of poor vegetation growth on the channel banks.

Results

- Preliminary Scoring Results
- “Parking Lot” Items
- Discussion

Wrap up / next steps

- Consensus of the preferred Reach 2 Option
- Are there any follow up items identified during the course of the workshop?
- Detailed documentation of Technical Workshop directly into final report
- Summary documentation with Minutes
- Tentative submission date of Draft Report in February.

Wrap up / next steps

KGS GROUP CONSULTING ENGINEERS

- Approval to proceed with refinement of preliminary design details of the preferred option:
  - Refinement of design (e.g. alignment, channel cross section, drop structures…)
  - Civil 3D layout and quantity estimate
  - Preliminary design drawings
  - Updated cost estimate

APPENDIX G

COST ESTIMATE DETAILS

APPENDIX G1

COST ESTIMATE DETAILS FOR COMPARISON OF OPTIONS

LAKE ST. MARTIN OUTLET CHANNEL
WITH OUTLET EAST OF WILLOW POINT

TOTAL COST SUMMARY - OPTION 1

Construction Component		**Estimated Cost**
Earth Works		
Reach 1	$	33,884,000
Reach 2	$	50,860,950
Reach 3	$	42,162,000
Control Structure		
Spillway	$	23,139,000
Gates, Guides and Hoists	$	15,351,000
Access		
Reach 1 Access Road	$	15,600,000
Reach 3 Access Road	$	8,000,000
Gravel Topping (Reaches 1, 2, 3)	$	3,578,580
Reach 3 Bridge	$	3,860,000
Electrical Power Supply		
Permanent Power	$	1,720,000
Construction Power	$	3,636,000
Sub-total	**$**	**201,790,000**
Mitigation Cost (5%)	$	10,089,500
Engineering, Contract Admin., Approvals (20%)	$	40,358,000
Sub-total	**$**	**252,240,000**
Contingency Cost (20%)	$	50,448,000
TOTAL	**$**	**302,690,000**

LAKE ST. MARTIN OUTLET CHANNEL
WITH OUTLET EAST OF WILLOW POINT

DETAILED COST ESTIMATE - OPTION 1

ITEM/CONTRACT	Unit	Quantity	Unit Cost	Cost (2015 $)
REACH 1 EARTHWORKS				
Mobilization/Demobilization	LS	1	$500,000	$500,000
Excavation (Widening Existing Channel)				
General Excavation - Existing Spoil Pile	m^3	699,500	$15	$10,492,500
General Excavation - Undisturbed Material	m^3	1,177,500	$10	$11,775,000
Outlet Cofferdam				
Placement	m^3	10,000	$20	$200,000
Removal	m^3	10,000	$20	$200,000
Construction Dewatering	LS	1	$500,000	$500,000
Inlet Works				
Cofferdam				
Placement (Earthfill)	m^3	85,000	$20	$1,700,000
Placement (riprap)	m^3	15,000	$90	$1,350,000
Removal (80%)	m^3	80,000	$20	$1,600,000
Inlet Excavation (includes dewatering)	m^3	70,000	$20	$1,400,000
Other				
Revegetation (75% of footprint area)	ha	222	$11,500	$2,553,000
Construction Camp (5% of total costs)			5%	$1,613,525
TOTAL				**$33,884,000**

Note:
1. Unit costs assumed to include all of the Contractors' direct and indirect costs, bonding and insurance, as well as allowances for overhead and profit.

LAKE ST. MARTIN OUTLET CHANNEL
WITH OUTLET EAST OF WILLOW POINT

DETAILED COST ESTIMATE - OPTION 1

ITEM/CONTRACT	Unit	Quantity	Unit Cost	Cost (2015 $)
REACH 2 EARTHWORKS				
Mobilization/Demobilization	LS	1	$500,000	$500,000
Dikes				
Peat Excavation	m^3	390,000	$10	$3,900,000
Earthfill	m^3	523,650	$20	$10,473,000
Extension to Big Buffalo Lake				
General Excavation	m^3	325,000	$10	$3,250,000
Outlet Cofferdam				
Placement (Earthfill)	m^3	5,000	$20	$100,000
Placement (riprap)	m^3	900	$90	$81,000
Removal	m^3	5,900	$20	$118,000
North & South Dikes/Cofferdams				
Placement (Earthfill)	m^3	640,000	$20	$12,800,000
Construction Dewatering	LS	1	$1,000,000	$1,000,000
Buffalo Creek Enhancements				
Channel Excavation	m3	300,000	$10	$3,000,000
Erosion Protection (riprap, bank shaping, filter fabric, etc…)	lm	1,000	$3,000	$3,000,000
Vegetation Clearing	ha	30	$16,500	$495,000
Construction Dewatering	LS	1	$1,000,000	$1,000,000
Buffalo Creek Drop Structures				
Riprap [1]	m^3	66,000	$90	$5,940,000
Sheet Piling	m^2	1,000	$1,000	$1,000,000
Other				
Big Buffalo Lake Wetland Complex PWW or DRA	LS	1	$1,000,000	$1,000,000
Revegetation (Dike)	ha	13	$11,500	$149,500
Revegetation (Extension)	ha	55	$11,500	$632,500
Construction Camp (5% of total costs)			5%	$2,421,950
TOTAL				**$50,860,950**

Notes:

1. Assumed three structures at 22,000 m^3 per structure.
2. Unit costs assumed to include all of the Contractors' direct and indirect costs, bonding and insurance, as well as allowances for overhead and profit.

LAKE ST. MARTIN OUTLET CHANNEL
WITH OUTLET EAST OF WILLOW POINT

DETAILED COST ESTIMATE - OPTION 1

ITEM/CONTRACT	Unit	Quantity	Unit Cost	Cost (2015 $)
REACH 3 TO WILLOW POIN				
Mobilization/Demobilization	LS	1	$500,000	$500,000
Excavation				
General Excavation	m^3	2,520,000	$10	$25,200,000
Construction Dewatering	LS	1	$1,000,000	$1,000,000
Outlet Works				
Cofferdam Closure Section				
Placement (Earthfill)	m^3	10,000	$20	$200,000
Placement (riprap)	m^3	5,000	$90	$450,000
Removal (80%)	m^3	12,000	$20	$240,000
Outlet Excavation (includes dewatering)	m^3	10,000	$20	$200,000
Diversion Structure & Inlet Weir				
Earthfill	m^3	9,000	$20	$180,000
Riprap	m^3	2,000	$90	$180,000
Culvert Structure & Misc.	LS	1	$2,000,000	$2,000,000
Drop Structures				
Riprap	m^3	85,000	$90	$7,650,000
Other				
Revegetation (75% of footprint area)	ha	205	$11,500	$2,354,625
Construction Camp (5% of total costs)				$2,007,731
TOTAL				**$42,162,000**

Note:
1. Unit costs assumed to include all of the Contractors' direct and indirect costs, bonding and insurance, as well as allowances for overhead and profit.

LAKE ST. MARTIN OUTLET CHANNEL
WITH OUTLET EAST OF WILLOW POINT

DETAILED COST ESTIMATE - OPTION 1

ITEM/CONTRACT	Unit	Quantity	Unit Cost	Cost (2015 $)
CONTROL STRUCTURE				
SITEWORK & STRUCTURE				
Foundation Preparation				
- Spillway Structure	m^2	1,300	$20	$26,000
Approaches and Traffic Control	LS	1	$3,000,000	$3,000,000
Reinforced Concrete				
Main Spillway	m^3	4,500	$1,700	$7,650,000
D/S Wing Walls	m^3	120	$2,300	$276,000
U/S Wing Walls	m^3	40	$2,300	$92,000
Genset Pad	m^3	20	$1,000	$20,000
Precast Concrete Bridge	m^2	680	$2,500	$1,700,000
Miscellaneous Steel Items				
U/S Walkway and Bridge	kg	15,000	$15	$225,000
Stair Towers	kg	8,500	$15	$128,000
Guardrails	kg	15,000	$15	$225,000
Downstream Walkway and Bridge	kg	15,000	$15	$225,000
Gate, Guide, and Hoist Installation	LS	1	$2,050,000	$2,050,000
Miscellaneous Embedded and Non-Embedded Items	LS	1	$600,000	$600,000
Backfill / Slope Protection				
Rip Rap	m^3	1,995	$90	$180,000
TOTAL DIRECT COSTS				**$16,397,000**
Indirect Costs			20%	$3,279,000
General Contractor Travel & Camp			5%	$984,000
TOTAL CONTROL STRUCTURE CONSTRUCTION COSTS				**$20,660,000**
General Contractor Bonding			1%	$206,600
General Contractor Insurance			1%	$206,600
General Contractor Overhead and Profit			10%	$2,066,000
TOTAL				**$23,139,000**

GATES GUIDES AND HOISTS (Design and Supply Only)				
Main Spillway Gates	kg	132,000	$18	$2,376,000
U/S Stoplogs	kg	12,000	$12	$144,000
D/S Stoplogs	kg	6,000	$12	$72,000
Main Gate Guides	kg	24,000	$23	$540,000
U/S Stoplog Guides	kg	19,200	$19	$360,000
D/S Stoplog Guides	kg	19,200	$19	$360,000
Steel Gate Hoist Superstructure	kg	62,000	$12	$744,000
Pre Fabricated Hoist Housing	m^2	250	$1,900	$475,000
Main Gate Hoists & Controls	LS	6	$900,000	$5,400,000
U/S Stoplog Monorail Crane c/w Follower	LS	1	$1,200,000	$1,200,000
Maintenance Hoist	LS	1	$400,000	$400,000
	LS	1	$1,000,000	$1,000,000
Downstream stoplog hoist superstructure	kg	32,000	$12	$384,000
Supporting M&E Equipment	LS	1	$500,000	$500,000
TOTAL GATES, GUIDES AND HOISTS CONSTRUCTION COST				**$13,955,000**
General Contractor Overhead and Profit			10%	$1,395,500
TOTAL				**$15,351,000**

LAKE ST. MARTIN OUTLET CHANNEL
WITH OUTLET EAST OF WILLOW POINT

DETAILED COST ESTIMATE - OPTION 1

ITEM/CONTRACT	Unit	Quantity	Unit Cost	Cost (2015 $)
ACCESS ROAD				
Reach 1				
Upgrade Forestry Road	km	61	$100,000	$6,100,000
Construct All-season Road	km	19	$500,000	$9,500,000
Reach 3				
Construct All-season Road	km	16	$500,000	$8,000,000
TOTAL				**$23,600,000**

GRAVEL TOPPING				
Reach 1	m^3	21,600	$45	$972,000
Reach 2 (Reach 1 Extension)	m^3	3,600	$45	$162,000
Reach 2 Dike	m^3	15,804	$45	$711,180
Reach 3	m^3	38,520	$45	$1,733,400
TOTAL				**$3,578,580**

BRIDGE				
Reach 3				
Bridge Construction	m^2	480	$7,000	$3,360,000
Approaches and Traffic Control	1	LS	$500,000	$500,000
TOTAL				**$3,860,000**

ELECTRICAL POWER SUPPLY				
Permanent Power				
Integration to Existing Manitoba Hydro Line	km	11	$150,000	$1,650,000
750 kVA Pad Mount	LS	1	$70,000	$70,000
Construction Power				
Generator Rental	LS	1	$1,098,000	$1,098,000
Mobilization/Demobilization	LS	1	$119,000	$119,000
Maintenance Cost	LS	1	$138,000	$138,000
Operating Cost	LS	1	$2,281,000	$2,281,000
TOTAL				**$5,356,000**

LAKE ST. MARTIN OUTLET CHANNEL
WITH OUTLET EAST OF WILLOW POINT

TOTAL COST SUMMARY - OPTION 3

Construction Component	**Estimated Cost**
Earth Works	
Reach 1	$ 33,884,000
Reach 2	$ 64,014,000
Reach 3	$ 39,288,000
Control Structure	
Spillway	$ 23,139,000
Gates, Guides and Hoists	$ 15,351,000
Access	
Reach 1 Access Road	$ 15,600,000
Gravel Topping (Reaches 1, 2, 3)	$ 4,455,810
Electrical Power Supply	
Permanent Power	$ 1,720,000
Construction Power	$ 3,636,000
Sub-total	**$ 201,090,000**
Mitigation Cost (5%)	$ 10,054,500
Engineering, Contract Admin., Approvals (20%)	$ 40,218,000
Sub-total	**$ 251,360,000**
Contingency Cost (20%)	$ 50,272,000
TOTAL	**$ 301,630,000**

LAKE ST. MARTIN OUTLET CHANNEL
WITH OUTLET EAST OF WILLOW POINT

DETAILED COST ESTIMATE - OPTION 3

ITEM/CONTRACT	Unit	Quantity	Unit Cost	Cost
REACH 1 EARTHWORKS				
Mobilization/Demobilization	LS	1	$500,000	$500,000
Excavation (Widening Existing Channel)				
General Excavation - Existing Spoil Pile	m^3	699,500	$15	$10,492,500
General Excavation - Undisturbed Material	m^3	1,177,500	$10	$11,775,000
Outlet Cofferdam				
Placement	m^3	10,000	$20	$200,000
Removal	m^3	10,000	$20	$200,000
Construction Dewatering	LS	1	$500,000	$500,000
Inlet Works				
Cofferdam				
Placement (Earthfill)	m^3	85,000	$20	$1,700,000
Placement (riprap)	m^3	15,000	$90	$1,350,000
Removal (80%)	m^3	80,000	$20	$1,600,000
Inlet Excavation (includes dewatering)	m^3	70,000	$20	$1,400,000
Other				
Revegetation (75% of footprint area)	ha	222	$11,500	$2,553,000
Construction Camp (5% of total costs)				$1,613,525
TOTAL				**$33,884,000**

Note:
1. Unit costs assumed to include all of the Contractors' direct and indirect costs, bonding and insurance, as well as allowances for overhead and profit.

LAKE ST. MARTIN OUTLET CHANNEL
WITH OUTLET EAST OF WILLOW POINT

DETAILED COST ESTIMATE - OPTION 3

ITEM/CONTRACT	Unit	Quantity	Unit Cost	Cost
REACH 2 EARTHWORKS				
Mobilization/Demobilization	LS	1	$500,000	$500,000
Excavation				
General Excavation	m^3	4,800,000	$10	$48,000,000
Construction Dewatering	LS	1	$1,000,000	$1,000,000
Drop Structures				
Riprap [1]	m^3	44,000	$90	$3,960,000
Sheet Piling	m^2	2,400	$1,000	$2,400,000
Dikes [2]				
Peat Excavation	m^3		$10	$0
Clearing/Grubbing	ha		$16,500	$0
Earthfill	m^3		$20	$0
Other				
Revegetation (75% of footprint area)[5]	ha	444	$11,500	$5,106,000
Construction Camp (5% of total costs)				$3,048,300
TOTAL				**$64,014,000**

Notes:

1. Assumed 4 structures at 11,000 m^3 per structure.
2. Dike construction part of general excavation quantities.
3. Unit costs assumed to include all of the Contractors' direct and indirect costs, bonding and insurance, as well as allowances for overhead and profit.

LAKE ST. MARTIN OUTLET CHANNEL
WITH OUTLET EAST OF WILLOW POINT

DETAILED COST ESTIMATE - OPTION 3

ITEM/CONTRACT	Unit	Quantity	Unit Cost	Cost
REACH 3 TO WILLOW POINT				
Mobilization/Demobilization	LS	1	$500,000	$500,000
Excavation				
General Excavation [1]	m^3	2,394,000	$10	$23,940,000
Construction Dewatering	LS	1	$1,000,000	$1,000,000
Outlet Works				
Cofferdam Closure Section				
Placement (Earthfill)	m^3	10,000	$20	$200,000
Placement (riprap)	m^3	5,000	$90	$450,000
Removal (80%)	m^3	12,000	$20	$240,000
Outlet Excavation (includes dewatering)	m^3	10,000	$20	$200,000
Diversion Structure & Inlet Weir [2]				
Earthfill	m^3		$20	$0
Riprap	m^3		$90	$0
Culvert Structure & Misc.	LS	1	$1,000,000	$1,000,000
Drop Structures				
Riprap	m^3	85,000	$90	$7,650,000
Other				
Revegetation (75% of footprint area) [1]	ha	195	$11,500	$2,236,894
Construction Camp (5% of total costs)				$1,870,845
TOTAL				**$39,288,000**

Notes:
1. Assumed 5% savings due to shorter channel length.
2. Not required. $1M allowance is for dike structure upstream of Reach 3 to stop backwater into Buffalo Creek.
3. Unit costs assumed to include all of the Contractors’ direct and indirect costs, bonding and insurance, as well as allowances for overhead and profit.

LAKE ST. MARTIN OUTLET CHANNEL
WITH OUTLET EAST OF WILLOW POINT

DETAILED COST ESTIMATE - OPTION 3

ITEM/CONTRACT	Unit	Quantity	Unit Cost	Cost
CONTROL STRUCTURE				
SITEWORK & STRUCTURE				
Foundation Preparation				
- Spillway Structure	m^2	1,300	$20	$26,000
Approaches and Traffic Control	LS	1	$3,000,000	$3,000,000
Reinforced Concrete				
Main Spillway	m^3	4,500	$1,700	$7,650,000
D/S Wing Walls	m^3	120	$2,300	$276,000
U/S Wing Walls	m^3	40	$2,300	$92,000
Genset Pad	m^3	20	$1,000	$20,000
Precast Concrete Bridge	m^2	680	$2,500	$1,700,000
Miscellaneous Steel Items				
U/S Walkway and Bridge	kg	15,000	$15	$225,000
Stair Towers	kg	8,500	$15	$128,000
Guardrails	kg	15,000	$15	$225,000
Downstream Walkway and Bridge	kg	15,000	$15	$225,000
Gate, Guide, and Hoist Installation	LS	1	$2,050,000	$2,050,000
Miscellaneous Embedded and Non-Embedded Items	LS	1	$600,000	$600,000
Backfill / Slope Protection				
Rip Rap	m^3	1,995	$90	$180,000
TOTAL DIRECT COSTS				**$16,397,000**
Indirect Costs			20%	$3,279,000
General Contractor Travel & Camp			5%	$984,000
TOTAL CONTROL STRUCTURE CONSTRUCTION COSTS				**$20,660,000**
General Contractor Bonding			1%	$206,600
General Contractor Insurance			1%	$206,600
General Contractor Overhead and Profit			10%	$2,066,000
TOTAL				**$23,139,000**

GATES GUIDES AND HOISTS (Design and Supply Only)				
Main Spillway Gates	kg	132,000	$18	$2,376,000
U/S Stoplogs	kg	12,000	$12	$144,000
D/S Stoplogs	kg	6,000	$12	$72,000
Main Gate Guides	kg	24,000	$23	$540,000
U/S Stoplog Guides	kg	19,200	$19	$360,000
D/S Stoplog Guides	kg	19,200	$19	$360,000
Steel Gate Hoist Superstructure	kg	62,000	$12	$744,000
Pre Fabricated Hoist Housing	m^2	250	$1,900	$475,000
Main Gate Hoists & Controls	LS	6	$900,000	$5,400,000
U/S Stoplog Monorail Crane c/w Follower	LS	1	$1,200,000	$1,200,000
Maintenance Hoist	LS	1	$400,000	$400,000
D/S Stoplog Hoist	LS	1	$1,000,000	$1,000,000
Downstream stoplog hoist superstructure	kg	32,000	$12	$384,000
Supporting M&E Equipment	LS	1	$500,000	$500,000
TOTAL GATES, GUIDES AND HOISTS CONSTRUCTION COST				**$13,955,000**
General Contractor Overhead and Profit			10%	$1,395,500
TOTAL				**$15,351,000**

LAKE ST. MARTIN OUTLET CHANNEL
WITH OUTLET EAST OF WILLOW POINT

DETAILED COST ESTIMATE - OPTION 3

ITEM/CONTRACT	Unit	Quantity	Unit Cost	Cost
ACCESS ROAD				
Reach 1				
Upgrade Forestry Road	km	61	$100,000	$6,100,000
Construct All-season Road	km	19	$500,000	$9,500,000
Reach 3				
Construct All-season Road	km		$500,000	$0
TOTAL				**$15,600,000**

GRAVEL TOPPING				
Reach 1	m^3	21,600	$45	$972,000
Reach 2 - Option 3	m^3	40,824	$45	$1,837,080
Reach 3 [1]	m^3	36,594	$45	$1,646,730
TOTAL				**$4,455,810**

ELECTRICAL POWER SUPPLY				
Permanent Power				
Integration to Existing Manitoba Hydro Line	km	11	$150,000	$1,650,000
750 kVA Pad Mount	LS	1	$70,000	$70,000
Construction Power				
Generator Rental	LS	1	$1,098,000	$1,098,000
Mobilization/Demobilization	LS	1	$119,000	$119,000
Maintenance Cost	LS	1	$138,000	$138,000
Operating Cost	LS	1	$2,281,000	$2,281,000
TOTAL				**$5,356,000**

Notes:
1. Assumed 5% savings due to shorter channel length.

APPENDIX G2

UPDATED COST ESTIMATE DETAILS FOR LAKE ST. MARTIN OUTLET CHANNEL WITH OUTLET EAST OF WILLOW POINT

LAKE ST. MARTIN OUTLET CHANNEL
WITH OUTLET EAST OF WILLOW POINT

TOTAL COST SUMMARY - OPTION 4

Construction Component	**Estimated Cost**
Earth Works	
Reach 1	$ 4,802,000
Reach 2	$ 85,686,000
Reach 3	$ 39,288,000
Control Structure	
Spillway	$ 23,139,000
Gates, Guides and Hoists	$ 15,351,000
Access	
Reach 1 Access Road	$ 15,600,000
Gravel Topping (Reaches 2,3)	$ 3,700,890
Electrical Power Supply	
Permanent Power	$ 2,320,000
Construction Power	$ 3,636,000
Sub-total	**$ 193,520,000**
Mitigation Cost (5%)	$ 9,676,000
Engineering, Contract Admin., Approvals (20%)	$ 38,704,000
Sub-total	**$ 241,900,000**
Contingency Cost (20%)	$ 48,380,000
TOTAL	**$ 290,280,000**

LAKE ST. MARTIN OUTLET CHANNEL
WITH OUTLET EAST OF WILLOW POINT

DETAILED COST ESTIMATE - OPTION 4

ITEM/CONTRACT	Unit	Quantity	Unit Cost	Cost
REACH 1 EARTHWORKS - BASIC DECOMISSIONING				
Mobilization/Demobilization	LS	1	$500,000	$500,000
Excavation (Bank Shapping and Surface Drainage)				
General Excavation [1]	m^3	240,000	$10	$2,400,000
Outlet Cofferdam [2]				
Placement	m^3		$20	$0
Removal	m^3		$20	$0
Construction Dewatering [2]	LS		$500,000	$0
Inlet Works[2]				
Cofferdam				
Placement (Earthfill)	m^3		$20	$0
Placement (riprap)	m^3		$90	$0
Removal (80%)	m^3		$20	$0
Inlet Excavation (includes dewatering)	m^3		$20	$0
Drop Structures[2]				
Riprap	m^3		$90	$0
Other				
Inlet Closure Structure	LS	1	$500,000	$500,000
Revegetation [3]	ha	102	$11,500	$1,173,000
Construction Camp (5% of total costs)				$228,650
TOTAL				**$4,802,000**

Notes:
1. Bank shapping assumes 1 foot depth of excavation, 40m width on both sides of channel. Surface drainage assumes 4m wide, 1m deep drainage ditch on both sides of the channel.
2. Not required
3. Revegetation assumes entire footprint area of channel and spoil pile.
4. Unit costs assumed to include all of the Contractors' direct and indirect costs, bonding and insurance, as well as allowances for overhead and profit.

LAKE ST. MARTIN OUTLET CHANNEL
WITH OUTLET EAST OF WILLOW POINT

DETAILED COST ESTIMATE - OPTION 4

ITEM/CONTRACT	Unit	Quantity	Unit Cost	Cost
REACH 2 EARTHWORKS				
Mobilization/Demobilization	LS	1	$500,000	$500,000
Excavation				
General Excavation	m^3	6,000,000	$10	$60,000,000
Construction Dewatering	LS	1	$1,000,000	$1,000,000
Inlet Works				
Cofferdam				
Placement (Earthfill)	m^3	85,000	$20	$1,700,000
Placement (riprap)	m^3	15,000	$90	$1,350,000
Removal (80%)	m^3	80,000	$20	$1,600,000
Inlet Excavation (includes dewatering)	m^3	70,000	$20	$1,400,000
Drop Structures				
Riprap [1]	m^3	55,000	$90	$4,950,000
Sheet Piling	m^2	4,000	$1,000	$4,000,000
Dikes [2]				
Peat Excavation	m^3		$10	$0
Clearing/Grubbing	ha		$16,500	$0
Earthfill	m^3		$20	$0
Other				
Revegetation (75% of footprint area)	ha	444	$11,500	$5,106,000
Construction Camp (5% of total costs)				$4,080,300
TOTAL				**$85,686,000**

Notes:

1. Assumed 5 structures at 11,000 m^3 of Riprap and 800m^2 of Sheet Pile per structure .
2. Dike construction part of general excavation quantities.
3. Unit costs assumed to include all of the Contractors' direct and indirect costs, bonding and insurance, as well as allowances for overhead and profit.

LAKE ST. MARTIN OUTLET CHANNEL
WITH OUTLET EAST OF WILLOW POINT

DETAILED COST ESTIMATE - OPTION 4

ITEM/CONTRACT	Unit	Quantity	Unit Cost	Cost
REACH 3 TO WILLOW POINT				
Mobilization/Demobilization	LS	1	$500,000	$500,000
Excavation				
General Excavation [1]	m^3	2,394,000	$10	$23,940,000
Construction Dewatering	LS	1	$1,000,000	$1,000,000
Outlet Works				
Cofferdam Closure Section				
Placement (Earthfill)	m^3	10,000	$20	$200,000
Placement (riprap)	m^3	5,000	$90	$450,000
Removal (80%)	m^3	12,000	$20	$240,000
Outlet Excavation (includes dewatering)	m^3	10,000	$20	$200,000
Diversion Structure & Inlet Weir [2]				
Earthfill	m^3		$20	$0
Riprap	m^3		$90	$0
Culvert Structure & Misc.	LS	1	$1,000,000	$1,000,000
Drop Structures				
Riprap	m^3	85,000	$90	$7,650,000
Other				
Revegetation (75% of footprint area) [1]	ha	195	$11,500	$2,236,894
Construction Camp (5% of total costs)				$1,870,845
TOTAL				**$39,288,000**

Notes:
1. Assumed 5% savings due to shorter channel length.
2. Not required. $1M allowance is for dike structure upstream of Reach 3 to stop backwater into Buffalo Creek.
3. Unit costs assumed to include all of the Contractors' direct and indirect costs, bonding and insurance, as well as allowances for overhead and profit.

LAKE ST. MARTIN OUTLET CHANNEL
WITH OUTLET EAST OF WILLOW POINT

DETAILED COST ESTIMATE - OPTION 4

ITEM/CONTRACT	Unit	Quantity	Unit Cost	Cost
CONTROL STRUCTURE				
SITEWORK & STRUCTURE				
Foundation Preparation				
- Spillway Structure	m^2	1,300	$20	$26,000
Approaches and Traffic Control	LS	1	$3,000,000	$3,000,000
Reinforced Concrete				
Main Spillway	m^3	4,500	$1,700	$7,650,000
D/S Wing Walls	m^3	120	$2,300	$276,000
U/S Wing Walls	m^3	40	$2,300	$92,000
Genset Pad	m^3	20	$1,000	$20,000
Precast Concrete Bridge	m^2	680	$2,500	$1,700,000
Miscellaneous Steel Items				
U/S Walkway and Bridge	kg	15,000	$15	$225,000
Stair Towers	kg	8,500	$15	$128,000
Guardrails	kg	15,000	$15	$225,000
Downstream Walkway and Bridge	kg	15,000	$15	$225,000
Gate, Guide, and Hoist Installation	LS	1	$2,050,000	$2,050,000
Miscellaneous Embedded and Non-Embedded Items	LS	1	$600,000	$600,000
Backfill / Slope Protection				
Rip Rap	m^3	1,995	$90	$180,000
TOTAL DIRECT COSTS				**$16,397,000**
Indirect Costs			20%	$3,279,000
General Contractor Travel & Camp			5%	$984,000
TOTAL CONTROL STRUCTURE CONSTRUCTION COSTS				**$20,660,000**
General Contractor Bonding			1%	$206,600
General Contractor Insurance			1%	$206,600
General Contractor Overhead and Profit			10%	$2,066,000
TOTAL				**$23,139,000**

GATES GUIDES AND HOISTS (Design and Supply Only)				
Main Spillway Gates	kg	132,000	$18	$2,376,000
U/S Stoplogs	kg	12,000	$12	$144,000
D/S Stoplogs	kg	6,000	$12	$72,000
Main Gate Guides	kg	24,000	$23	$540,000
U/S Stoplog Guides	kg	19,200	$19	$360,000
D/S Stoplog Guides	kg	19,200	$19	$360,000
Steel Gate Hoist Superstructure	kg	62,000	$12	$744,000
Pre Fabricated Hoist Housing	m^2	250	$1,900	$475,000
Main Gate Hoists & Controls	LS	6	$900,000	$5,400,000
U/S Stoplog Monorail Crane c/w Follower	LS	1	$1,200,000	$1,200,000
Maintenance Hoist	LS	1	$400,000	$400,000
D/S Stoplog Hoist	LS	1	$1,000,000	$1,000,000
Downstream stoplog hoist superstructure	kg	32,000	$12	$384,000
Supporting M&E Equipment	LS	1	$500,000	$500,000
TOTAL GATES, GUIDES AND HOISTS CONSTRUCTION COST				**$13,955,000**
General Contractor Overhead and Profit			10%	$1,395,500
TOTAL				**$15,351,000**

LAKE ST. MARTIN OUTLET CHANNEL
WITH OUTLET EAST OF WILLOW POINT

DETAILED COST ESTIMATE - OPTION 4

ITEM/CONTRACT	Unit	Quantity	Unit Cost	Cost
ACCESS ROAD				
Reach 1				
Upgrade Forestry Road	km	61	$100,000	$6,100,000
Construct All-season Road	km	19	$500,000	$9,500,000
Reach 3 [1]				
Construct All-season Road	km		$500,000	$0
TOTAL				**$15,600,000**

GRAVEL TOPPING				
Reach 1 [1]	m^3	0	$45	$0
Reach 2 - Option 4	m^3	45,648	$45	$2,054,160
Reach 3 [2]	m^3	36,594	$45	$1,646,730
TOTAL				**$3,700,890**

ELECTRICAL POWER SUPPLY				
Permanent Power				
Integration to Existing Manitoba Hydro Line [3]	km	15	$150,000	$2,250,000
750 kVA Pad Mount	LS	1	$70,000	$70,000
Construction Power				
Generator Rental	LS	1	$1,098,000	$1,098,000
Mobilization/Demobilization	LS	1	$119,000	$119,000
Maintenance Cost	LS	1	$138,000	$138,000
Operating Cost	LS	1	$2,281,000	$2,281,000
TOTAL				**$5,956,000**

Notes:
1. Not required
2. Assumed 5% savings due to shorter channel length.
3. Assumed 4 km longer than Base Case.

LAKE ST. MARTIN OUTLET CHANNEL
WITH OUTLET EAST OF WILLOW POINT

REVISED TOTAL COST SUMMARY FOR PRELIMINARY DESIGN - OPTION 4

Construction Component	**Estimated Cost**
Earth Works	
Reach 1	$ 4,802,000
Reach 2	$ 76,091,000
Reach 3	$ 45,401,000
Control Structure	
Spillway	$ 24,296,000
Gates, Guides and Hoists	$ 16,119,000
Access	
Access Road - Reach 1	$ 20,480,000
Gravel Topping (Reaches 2,3)	$ 3,645,000
Electrical Power Supply	
Permanent Power	$ 2,320,000
Construction Power	$ 3,818,000
Sub-total	**$ 196,970,000**
Mitigation Cost (5%)	$ 9,848,500
Engineering, Contract Admin., Approvals (20%)	$ 39,394,000
Sub-total	**$ 246,210,000**
Contingency Cost (20%)	$ 49,242,000
TOTAL (2017 Dollars)	**$ 295,450,000**

LAKE ST. MARTIN OUTLET CHANNEL
WITH OUTLET EAST OF WILLOW POINT

REVISED TOTAL COST SUMMARY FOR PRELIMINARY DESIGN - OPTION 4

ITEM/CONTRACT	Unit	Quantity	Unit Cost	Cost
REACH 1 EARTHWORKS - BASIC DECOMISSIONING				
Mobilization/Demobilization	LS	1	$500,000	$500,000
Excavation (Bank Shapping and Surface Drainage)				
General Excavation [1]	m^3	240,000	$10	$2,400,000
Outlet Cofferdam [2]				
Placement	m^3		$20	$0
Removal	m^3		$20	$0
Construction Dewatering [2]	LS		$500,000	$0
Inlet Works[2]				
Cofferdam				
Placement (Earthfill)	m^3		$20	$0
Placement (riprap)	m^3		$90	$0
Removal (80%)	m^3		$20	$0
Inlet Excavation (includes dewatering)	m^3		$20	$0
Drop Structures[2]				
Riprap	m^3		$90	$0
Other				
Inlet Closure Structure	LS	1	$500,000	$500,000
Revegetation [3]	ha	102	$11,500	$1,173,000
Construction Camp (5% of total costs)				$228,650
TOTAL (2017 Dollars)				**$4,802,000**

Notes:
1. Bank shapping assumes 1 foot depth of excavation, 40m width on both sides of channel. Surface drainage assumes 4m wide, 1m deep drainage ditch on both sides of the channel.
2. Not required
3. Revegetation assumes entire footprint area of channel and spoil pile.
4. Unit costs assumed to include all of the Contractors' direct and indirect costs, bonding and insurance, as well as allowances for overhead and profit.

LAKE ST. MARTIN OUTLET CHANNEL
WITH OUTLET EAST OF WILLOW POINT

REVISED TOTAL COST SUMMARY FOR PRELIMINARY DESIGN - OPTION 4

ITEM/CONTRACT	Unit	Quantity	Unit Cost	Cost
REACH 2 EARTHWORKS				
Mobilization/Demobilization	LS	1	$500,000	$500,000
Excavation				
General Excavation	m^3	5,170,000	$10	$51,700,000
Construction Dewatering	LS	1	$1,000,000	$1,000,000
Inlet Works				
Cofferdam				
Placement (Earthfill)	m^3	85,000	$20	$1,700,000
Placement (riprap)	m^3	15,000	$90	$1,350,000
Removal (80%)	m^3	80,000	$20	$1,600,000
Inlet Excavation (includes dewatering)	m^3	160,000	$20	$3,200,000
Drop Structures				
Riprap	m^3	33,110	$90	$2,979,900
Sheet Piling	m^2	2,700	$1,000	$2,700,000
Dikes [1]				
Peat Excavation	m^3		$10	$0
Clearing/Grubbing	ha		$16,500	$0
Earthfill	m^3		$20	$0
Other				
Drainage Control Stuctures	LS	2	$1,000,000	$2,000,000
Revegetation (75% of footprint area)	ha	325	$11,500	$3,737,500
Construction Camp (5% of total costs)				$3,623,370
TOTAL (2017 Dollars)				**$76,091,000**

Notes:
1. Dike construction part of general excavation quantities.
2. Unit costs assumed to include all of the Contractors' direct and indirect costs, bonding and insurance, as well as allowances for overhead and profit.

LAKE ST. MARTIN OUTLET CHANNEL
WITH OUTLET EAST OF WILLOW POINT

REVISED TOTAL COST SUMMARY FOR PRELIMINARY DESIGN - OPTION 4

ITEM/CONTRACT	Unit	Quantity	Unit Cost	Cost
REACH 3 TO WILLOW POINT				
Mobilization/Demobilization	LS	1	$500,000	$500,000
Excavation				
General Excavation [1]	m^3	2,268,000	$10	$22,680,000
Construction Dewatering	LS	1	$1,000,000	$1,000,000
Outlet Works				
Cofferdam Closure Section				
Placement (Earthfill)	m^3	10,000	$20	$200,000
Placement (riprap)	m^3	5,000	$90	$450,000
Removal (80%)	m^3	12,000	$20	$240,000
Outlet Excavation (includes dewatering)	m^3	10,000	$20	$200,000
Diversion Structure & Inlet Weir [2]				
Earthfill	m^3		$20	$0
Riprap	m^3		$90	$0
Culvert Structure & Misc.	LS	1	$1,000,000	$1,000,000
Drop Structures				
Riprap	m^3	85,000	$90	$7,650,000
Sheet Piling	m^2	7,200	$1,000	$7,200,000
Other				
Revegetation (75% of footprint area) [1]	ha	184	$11,500	$2,119,163
Construction Camp (5% of total costs)				$2,161,958
TOTAL (2017 Dollars)				**$45,401,000**

Notes:
1. Assumed10% savings due to shorter channel length.
2. Not required. $1M allowance is for dike structure upstream of Reach 3 to stop backwater into Buffalo Creek.
3. Unit costs assumed to include all of the Contractors' direct and indirect costs, bonding and insurance, as well as allowances for overhead and profit.

LAKE ST. MARTIN OUTLET CHANNEL
WITH OUTLET EAST OF WILLOW POINT

REVISED TOTAL COST SUMMARY FOR PRELIMINARY DESIGN - OPTION 4

ITEM/CONTRACT	Unit	Quantity	Unit Cost	Cost
CONTROL STRUCTURE				
SITEWORK & STRUCTURE				
Foundation Preparation				
- Spillway Structure	m^2	1,300	$20	$26,000
Approaches and Traffic Control	LS	1	$3,000,000	$3,000,000
Reinforced Concrete				
Main Spillway	m^3	4,500	$1,700	$7,650,000
D/S Wing Walls	m^3	120	$2,300	$276,000
U/S Wing Walls	m^3	40	$2,300	$92,000
Genset Pad	m^3	20	$1,000	$20,000
Precast Concrete Bridge	m^2	680	$2,500	$1,700,000
Miscellaneous Steel Items				
U/S Walkway and Bridge	kg	15,000	$15	$225,000
Stair Towers	kg	8,500	$15	$128,000
Guardrails	kg	15,000	$15	$225,000
Downstream Walkway and Bridge	kg	15,000	$15	$225,000
Gate, Guide, and Hoist Installation	LS	1	$2,050,000	$2,050,000
Miscellaneous Embedded and Non-Embedded Items	LS	1	$600,000	$600,000
Backfill / Slope Protection				
Rip Rap	m^3	1,995	$90	$180,000
TOTAL DIRECT COSTS				**$16,397,000**
Indirect Costs			20%	$3,279,000
General Contractor Travel & Camp			5%	$984,000
TOTAL CONTROL STRUCTURE CONSTRUCTION COSTS				**$20,660,000**
General Contractor Bonding			1%	$206,600
General Contractor Insurance			1%	$206,600
General Contractor Overhead and Profit			10%	$2,066,000
TOTAL (2014 Dollars)				**$23,139,000**
TOTAL (2017 Dollars)				**$24,296,000**

GATES GUIDES AND HOISTS (Design and Supply Only)				
Main Spillway Gates	kg	132,000	$18	$2,376,000
U/S Stoplogs	kg	12,000	$12	$144,000
D/S Stoplogs	kg	6,000	$12	$72,000
Main Gate Guides	kg	24,000	$23	$540,000
U/S Stoplog Guides	kg	19,200	$19	$360,000
D/S Stoplog Guides	kg	19,200	$19	$360,000
Steel Gate Hoist Superstructure	kg	62,000	$12	$744,000
Pre Fabricated Hoist Housing	m^2	250	$1,900	$475,000
Main Gate Hoists & Controls	LS	6	$900,000	$5,400,000
U/S Stoplog Monorail Crane c/w Follower	LS	1	$1,200,000	$1,200,000
Maintenance Hoist	LS	1	$400,000	$400,000
D/S Stoplog Hoist	LS	1	$1,000,000	$1,000,000
Downstream stoplog hoist superstructure	kg	32,000	$12	$384,000
Supporting M&E Equipment	LS	1	$500,000	$500,000
TOTAL GATES, GUIDES AND HOISTS CONSTRUCTION COST				**$13,955,000**
General Contractor Overhead and Profit			10%	$1,395,500
TOTAL (2014 Dollars)				**$15,351,000**
TOTAL (2017 Dollars)				**$16,119,000**

LAKE ST. MARTIN OUTLET CHANNEL
WITH OUTLET EAST OF WILLOW POINT

REVISED TOTAL COST SUMMARY FOR PRELIMINARY DESIGN - OPTION 4

ITEM/CONTRACT	Unit	Quantity	Unit Cost	Cost
ACCESS ROAD				
Reach 1				
Upgrade Forestry Road	km	61	$180,000	$10,980,000
Construct All-season Road	km	19	$500,000	$9,500,000
Reach 3 [1]				
Construct All-season Road	km		$500,000	$0
TOTAL (2017 dollars)				**$20,480,000**

GRAVEL TOPPING				
Reach 1 [1]	m^3	0	$45	$0
Reach 2 - Option 4	m^3	46,325	$45	$2,084,616
Reach 3 [2]	m^3	34,668	$45	$1,560,060
TOTAL (2017 dollars)				**$3,644,676**

ELECTRICAL POWER SUPPLY				
Permanent Power				
Integration to Existing Manitoba Hydro Line [3]	km	15	$150,000	$2,250,000
750 kVA Pad Mount	LS	1	$70,000	$70,000
Construction Power				
Generator Rental	LS	1	$1,098,000	$1,098,000
Mobilization/Demobilization	LS	1	$119,000	$119,000
Maintenance Cost	LS	1	$138,000	$138,000
Operating Cost	LS	1	$2,281,000	$2,281,000
TOTAL (2014 Dollars)				**$5,956,000**
TOTAL (2017 Dollars)				**$6,254,000**

Notes:
1. Not required
2. Assumed 10% savings due to shorter channel length.
3. Assumed 4 km longer than Base Case.

APPENDIX H

SLOPE STABILITY SECTIONS

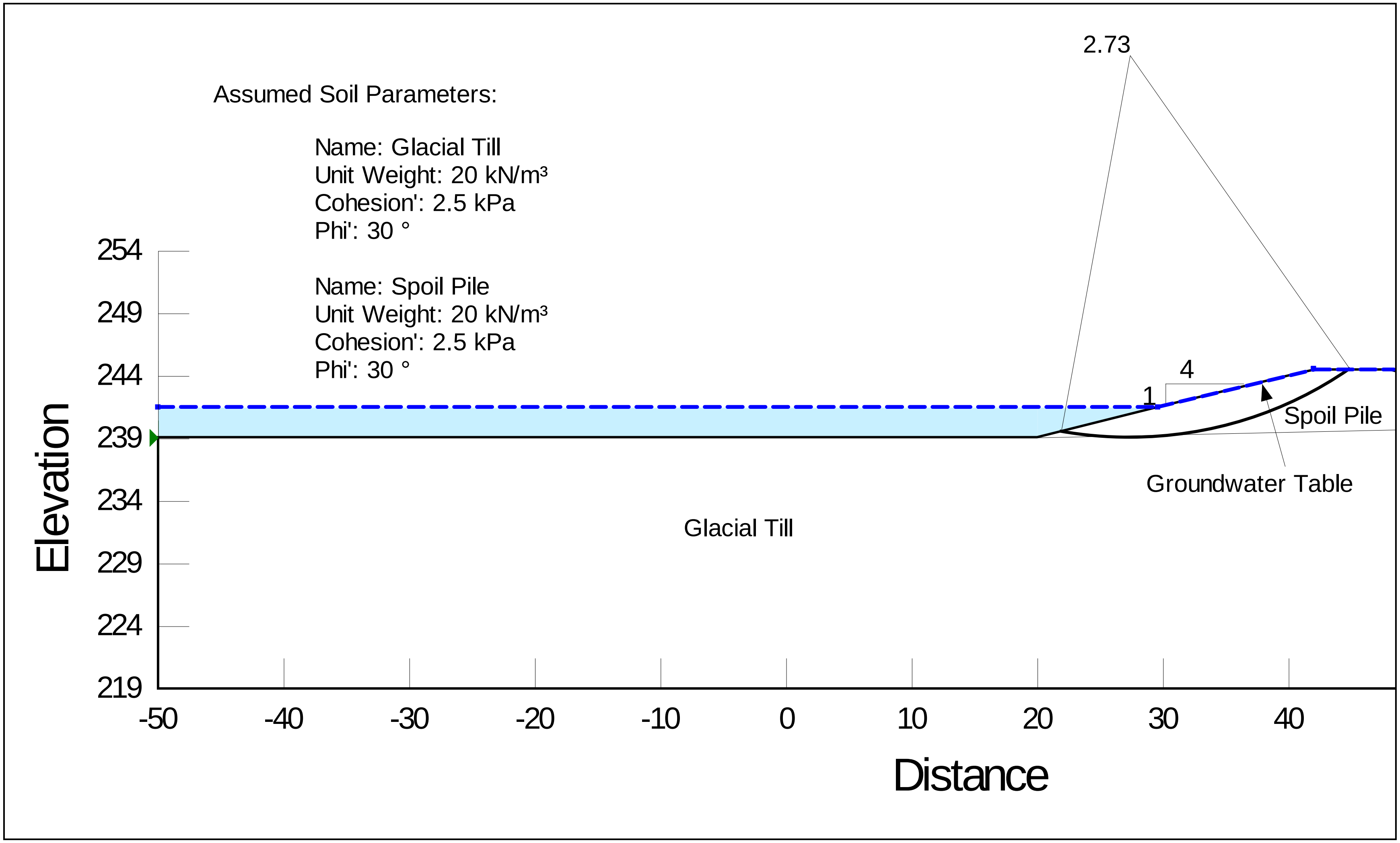

FIGURE H – 11

OPTION 4 – STATION 2+500. Case (1)

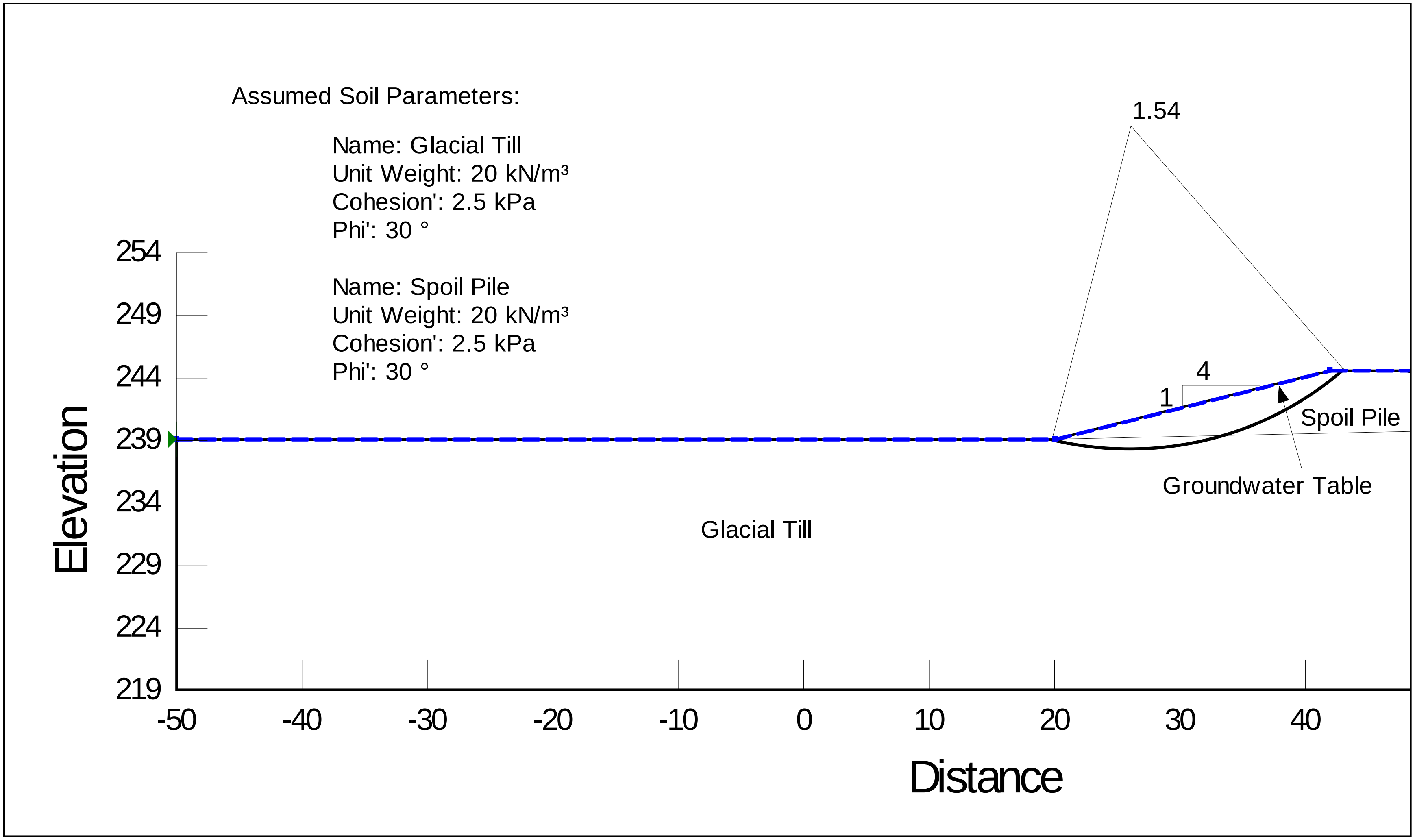

FIGURE H – 12

OPTION 4 – STATION 2+500. Case (2)

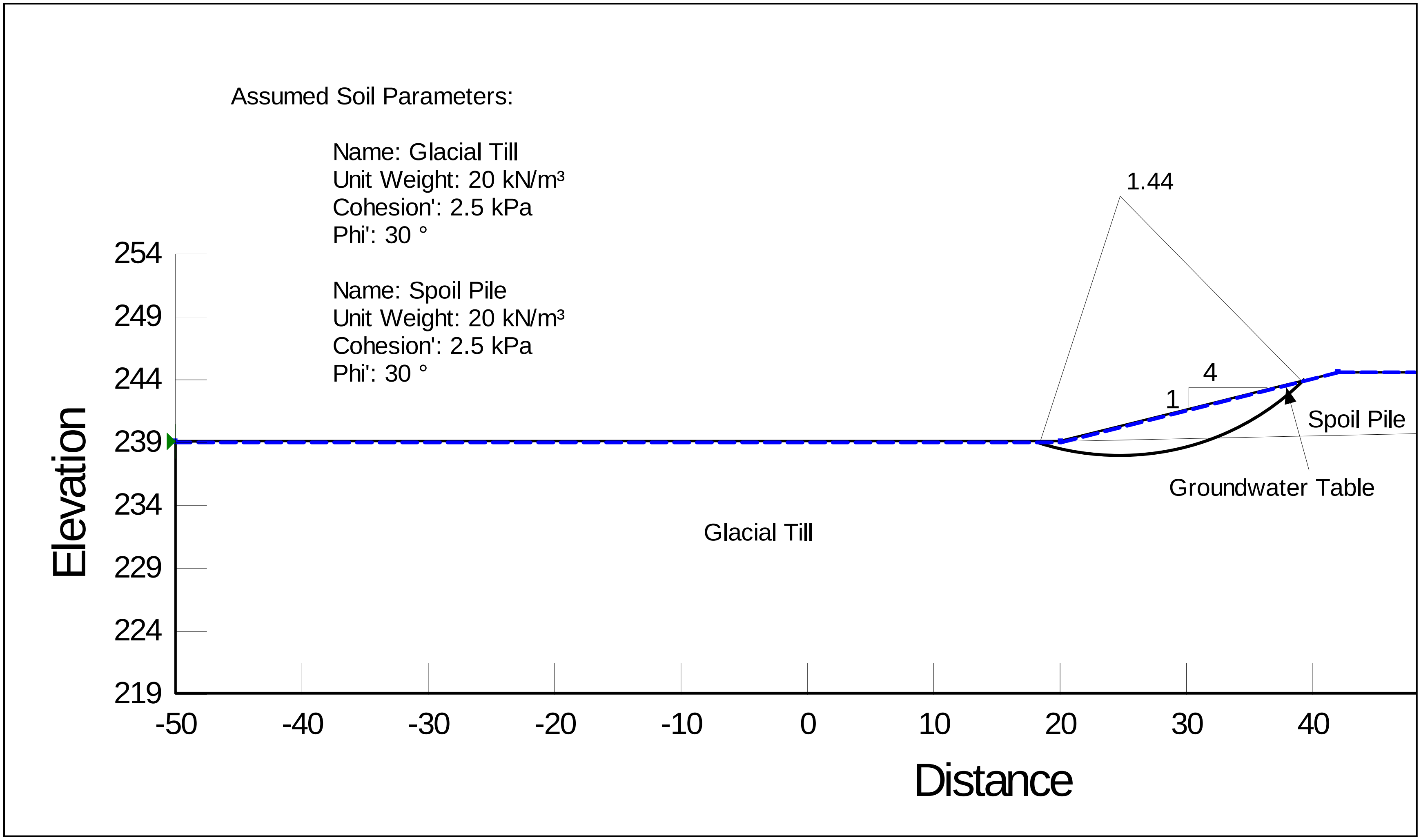

FIGURE H – 13

OPTION 4 – STATION 2+500. Case (2i)

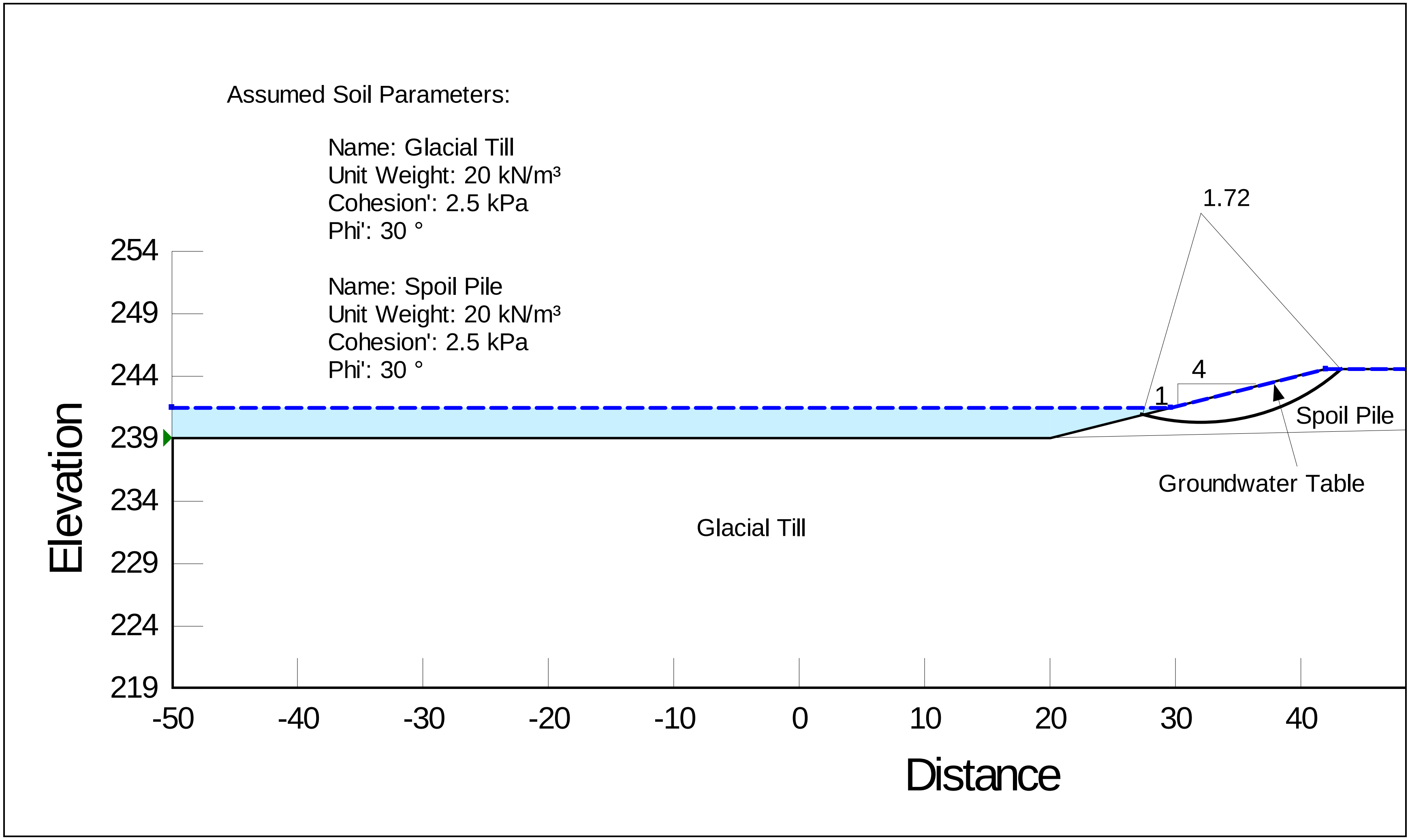

FIGURE H – 14

OPTION 4 – STATION 2+500. Case (3)

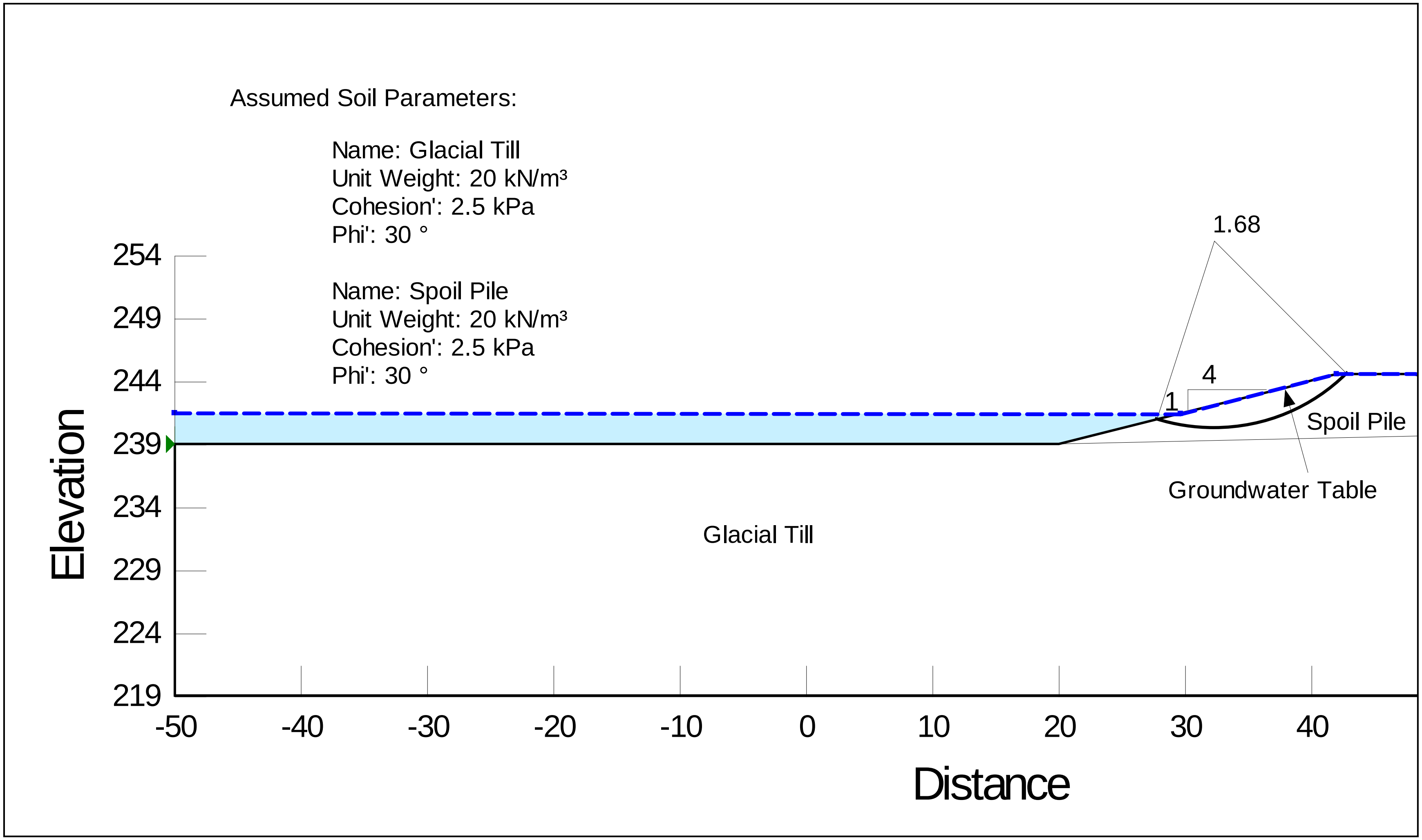

FIGURE H – 15

OPTION 4 – STATION 2+500. Case (3i)

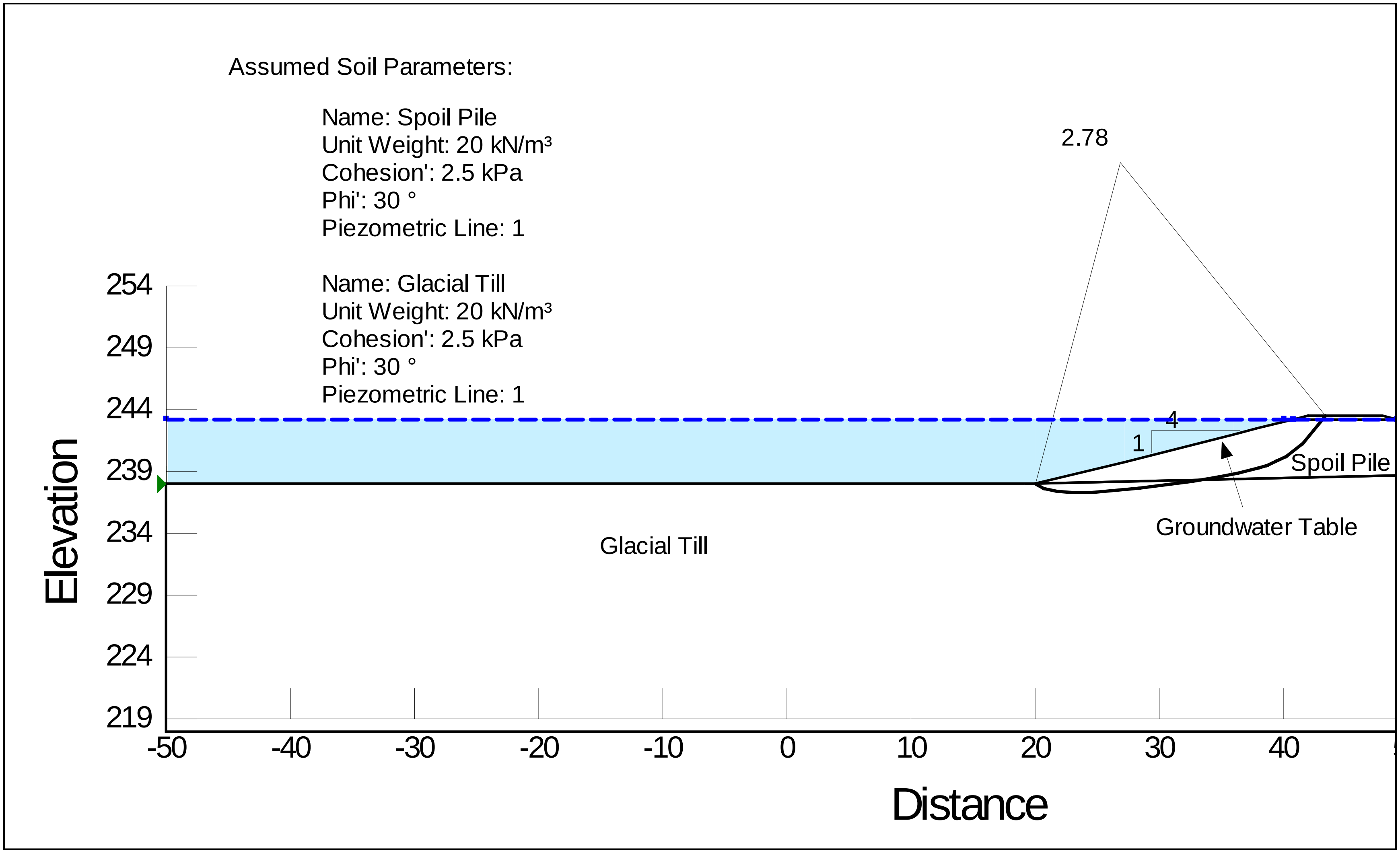

FIGURE H – 16

OPTION 4 – STATION 7+500. Case (1)

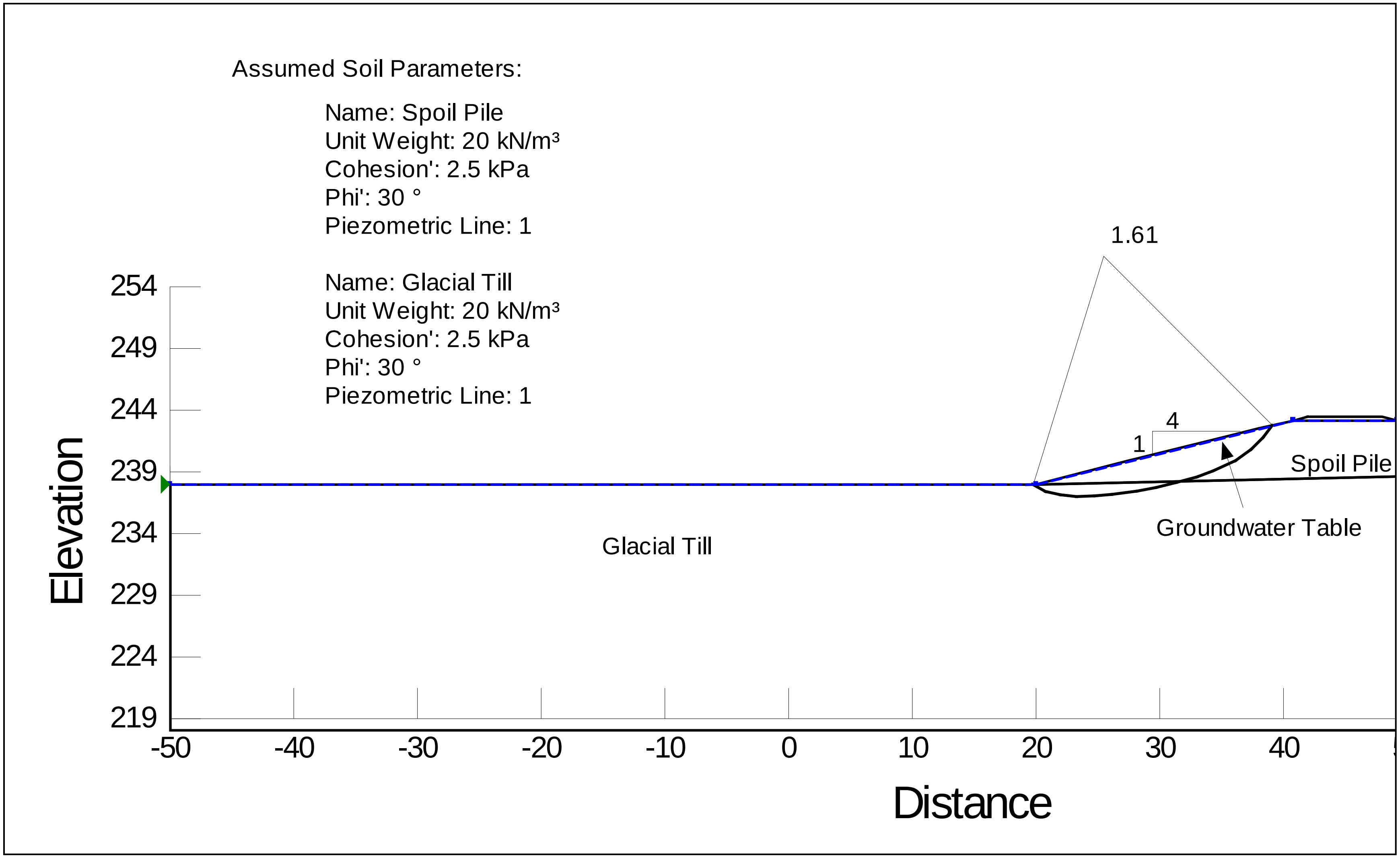

FIGURE H – 17

OPTION 4 – STATION 7+500. Case (2)

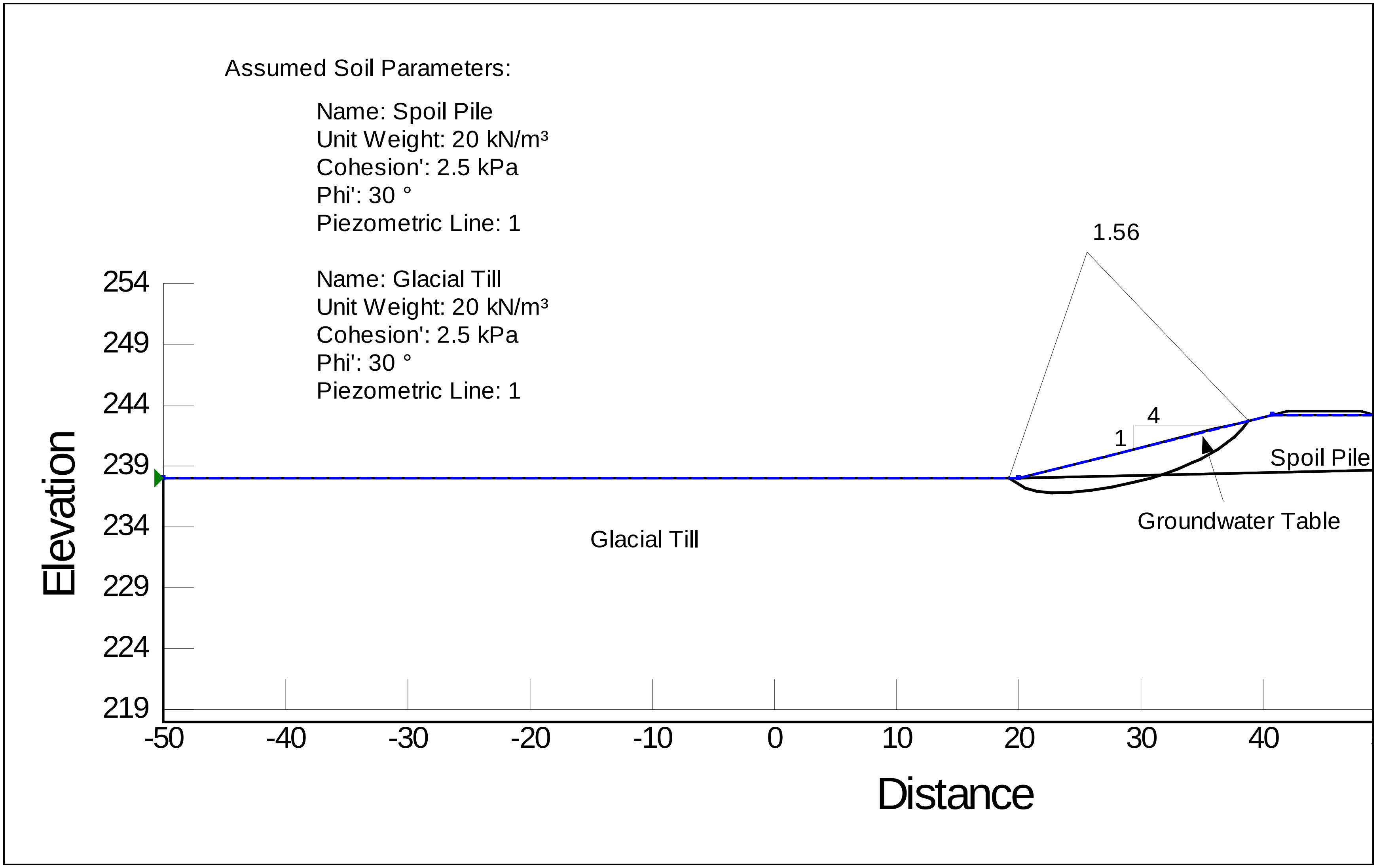

FIGURE H – 18

OPTION 4 – STATION 7+500. Case (2i)

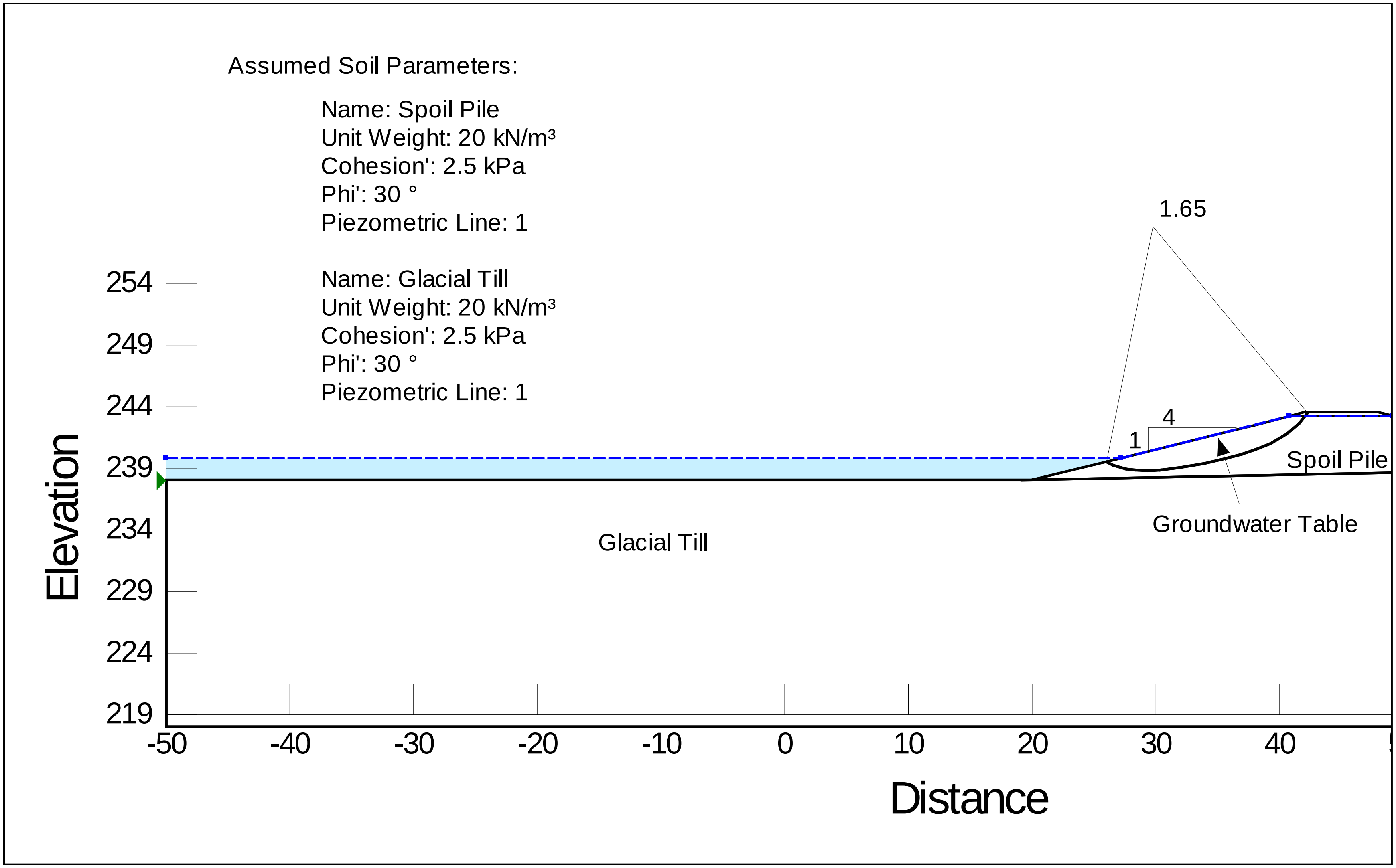

FIGURE H – 19

OPTION 4 – STATION 7+500. Case (3)

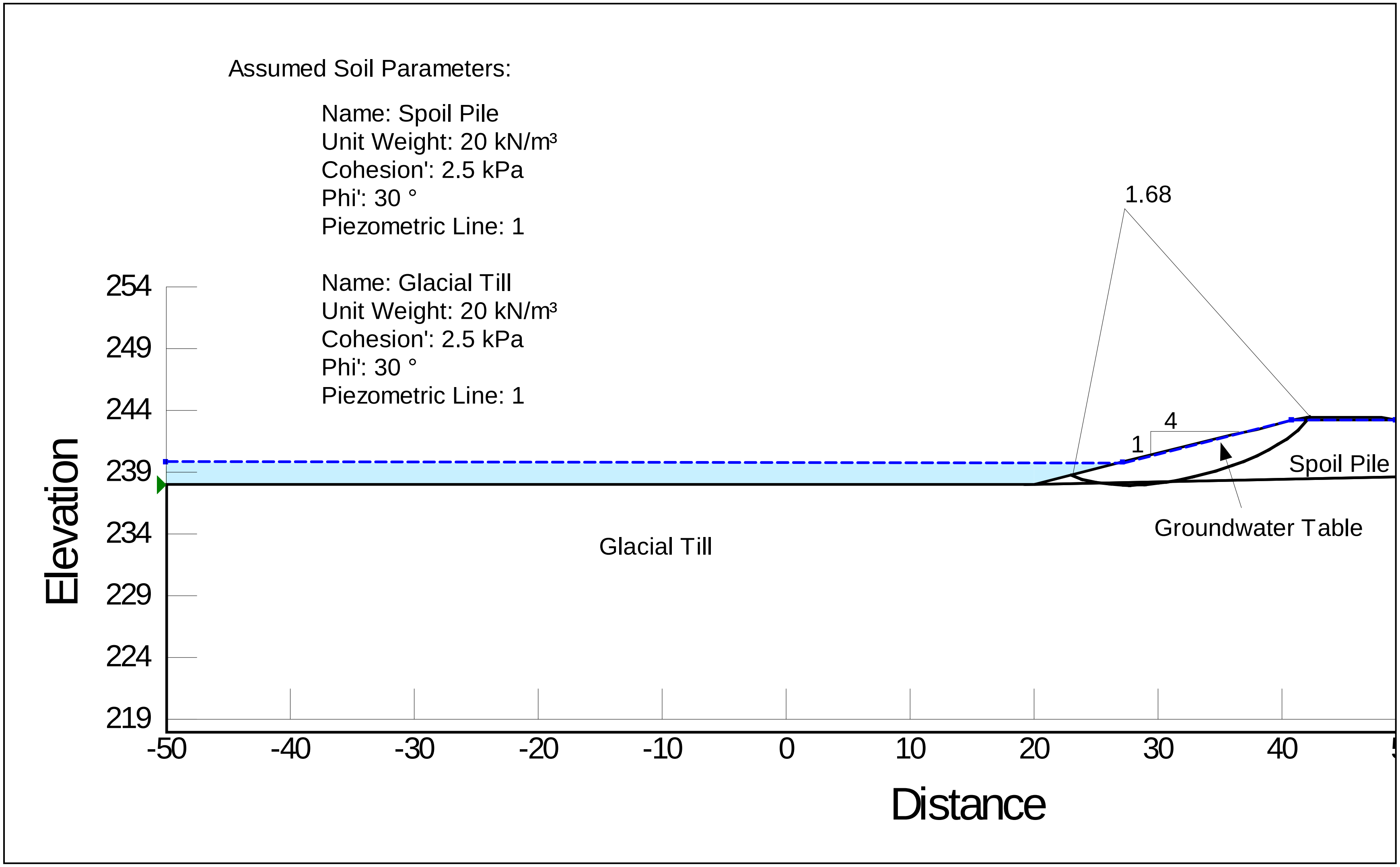

FIGURE H – 20

OPTION 4 – STATION 7+500. Case (3i)

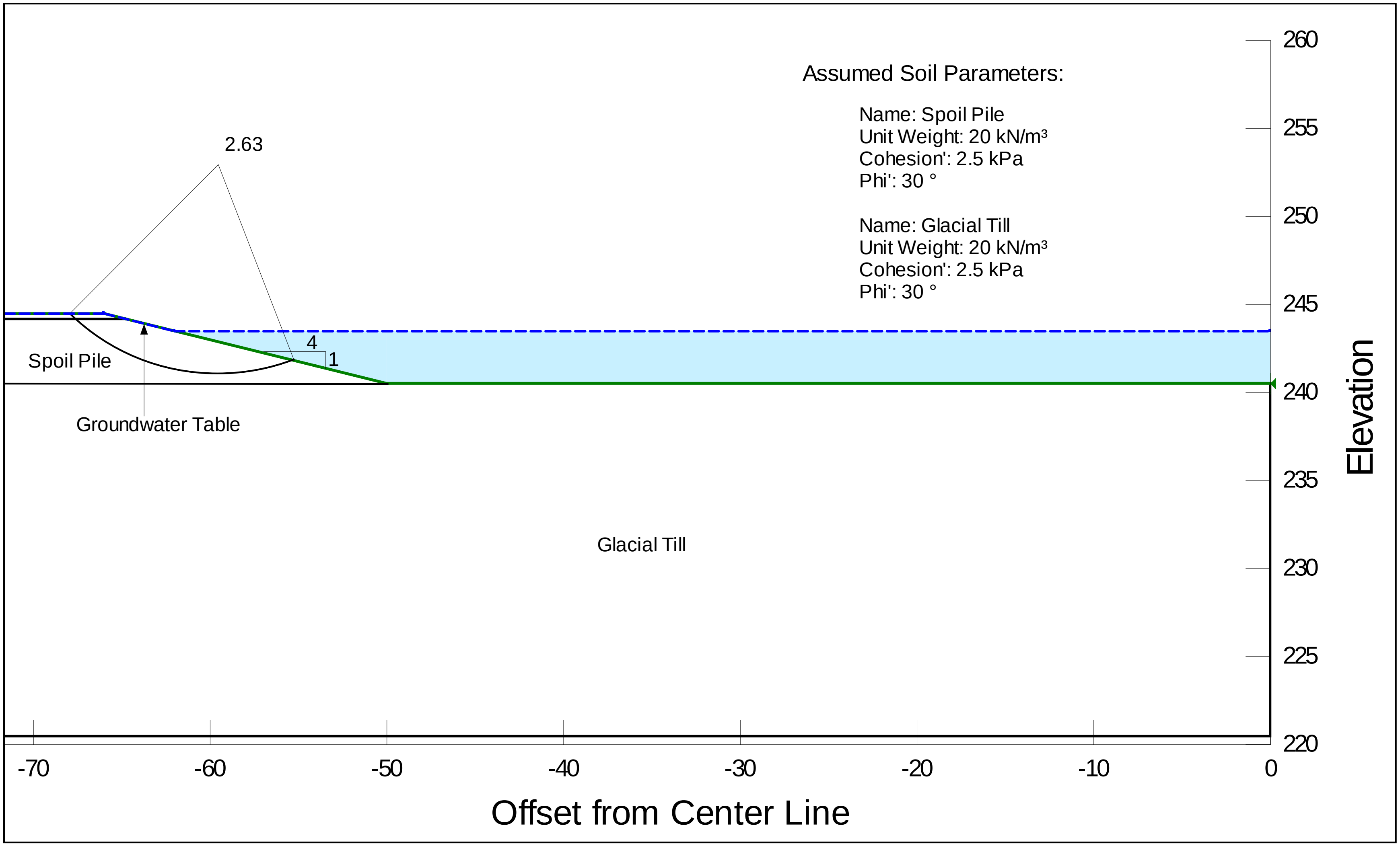

FIGURE H – 1

OPTION 4 – STATION 2+500. Case (1)

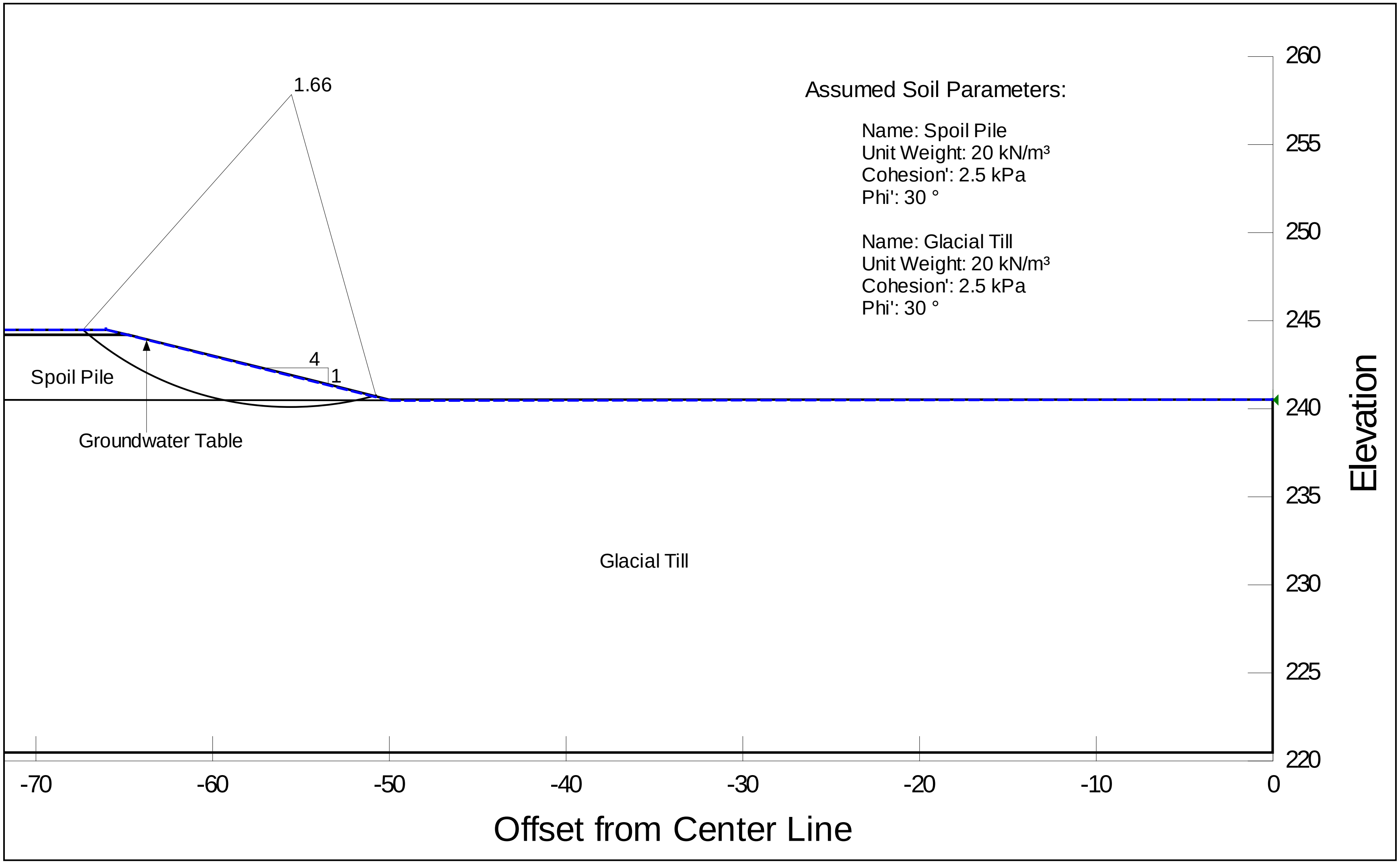

FIGURE H – 2

OPTION 4 – STATION 2+500. Case (2)

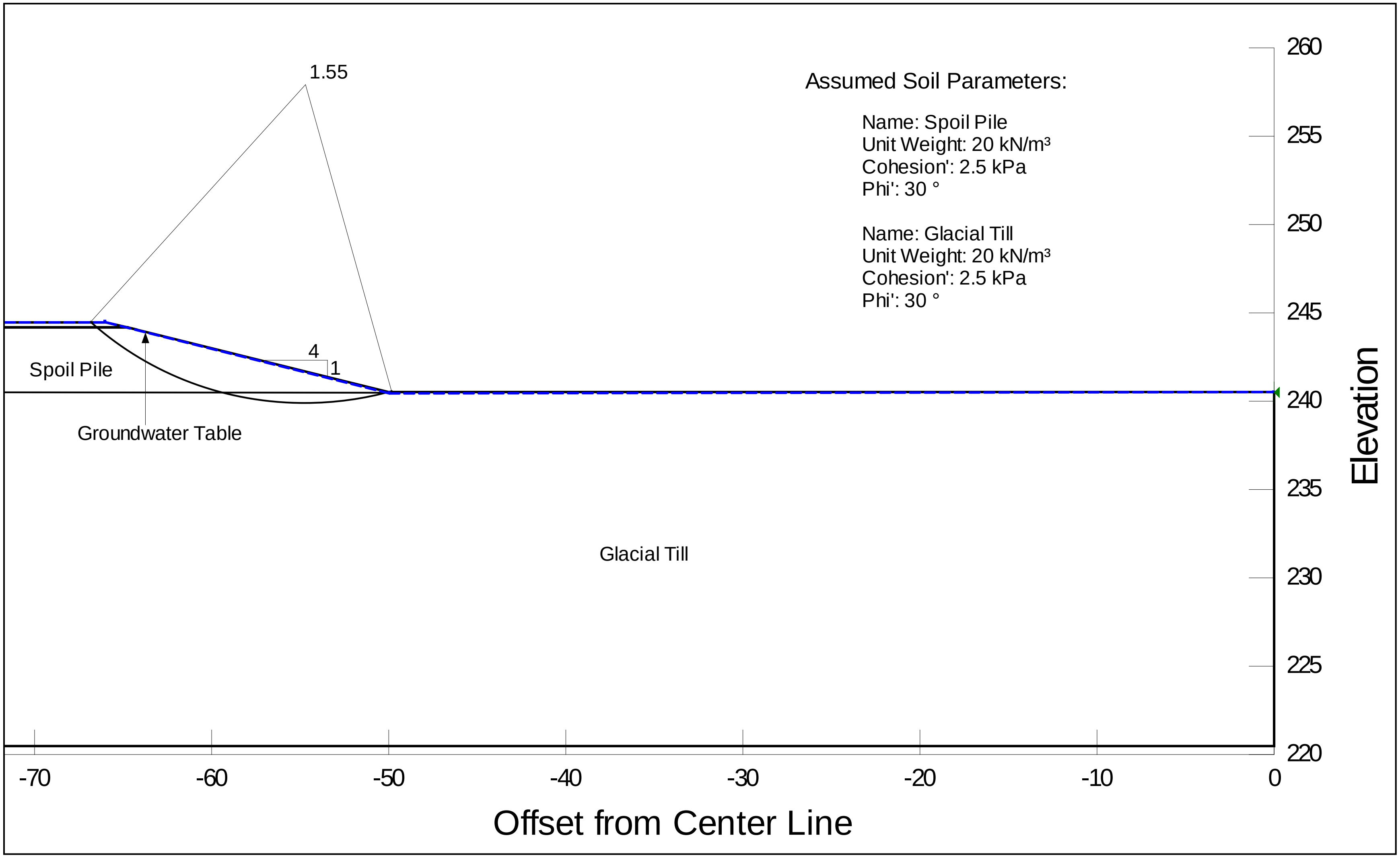

FIGURE H – 3

OPTION 4 – STATION 2+500. Case (2i)

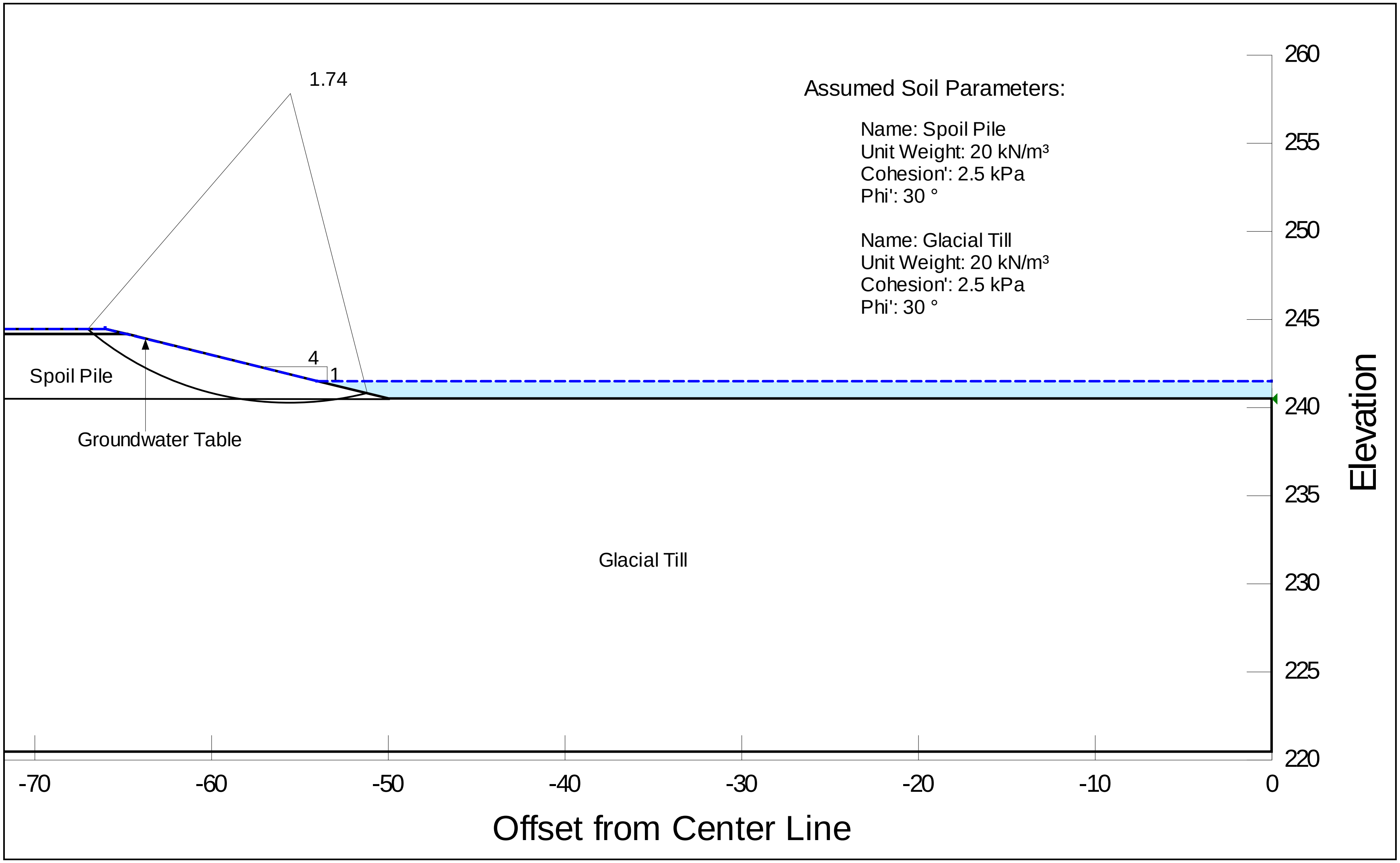

FIGURE H – 4

OPTION 4 – STATION 2+500. Case (3)

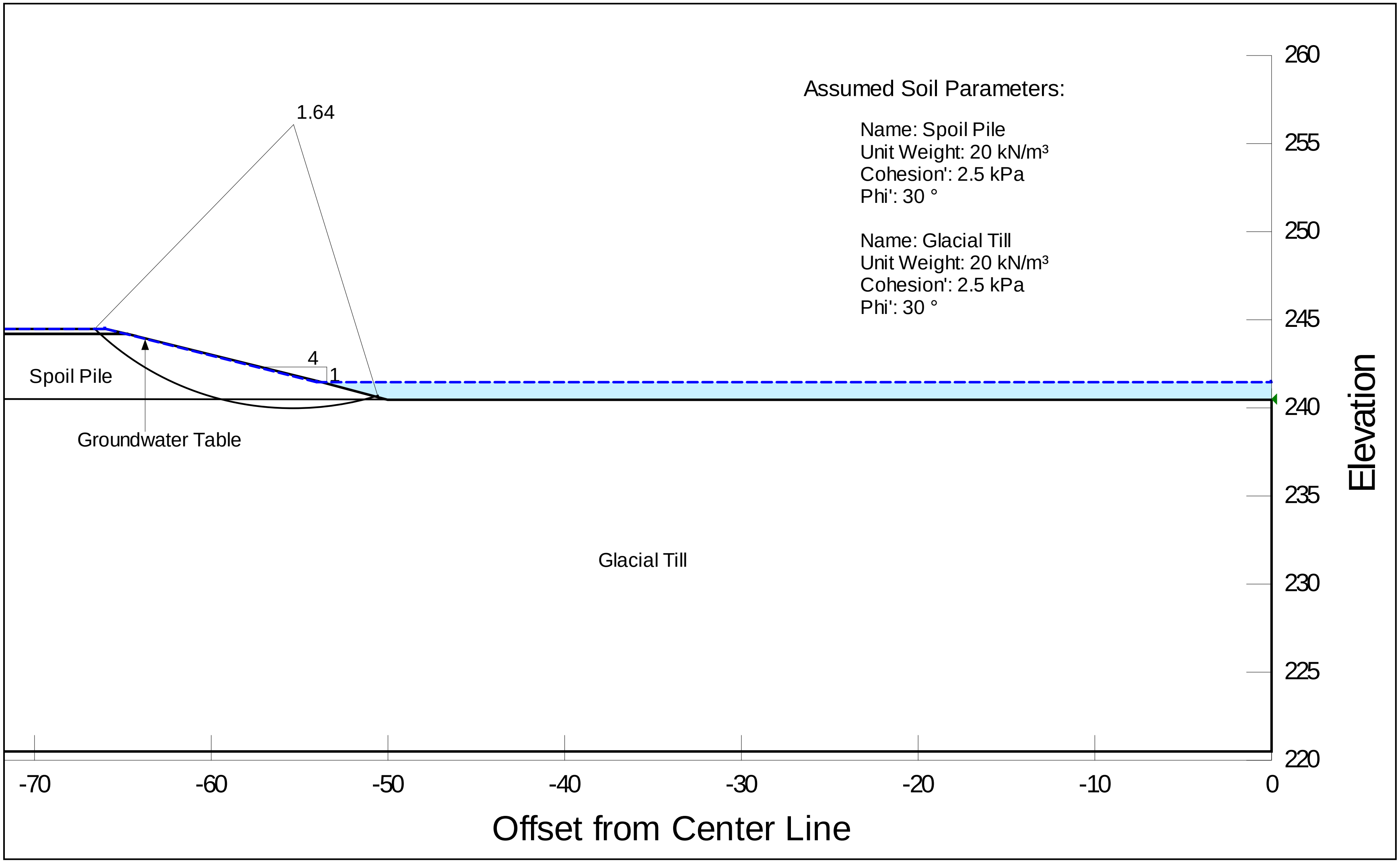

FIGURE H – 5

OPTION 4 – STATION 2+500. Case (3i)

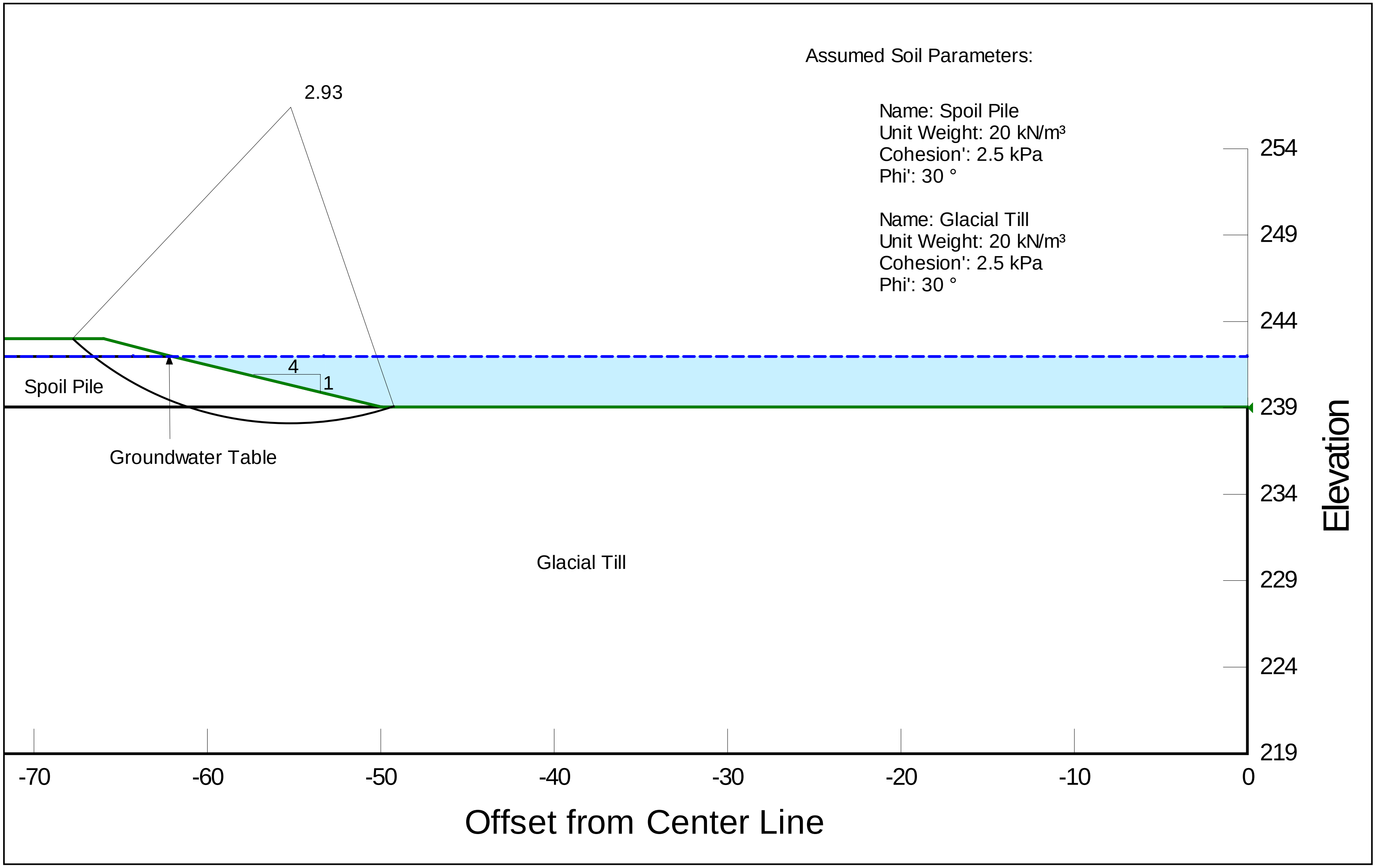

FIGURE H – 6

OPTION 4 – STATION 7+500. Case (1)

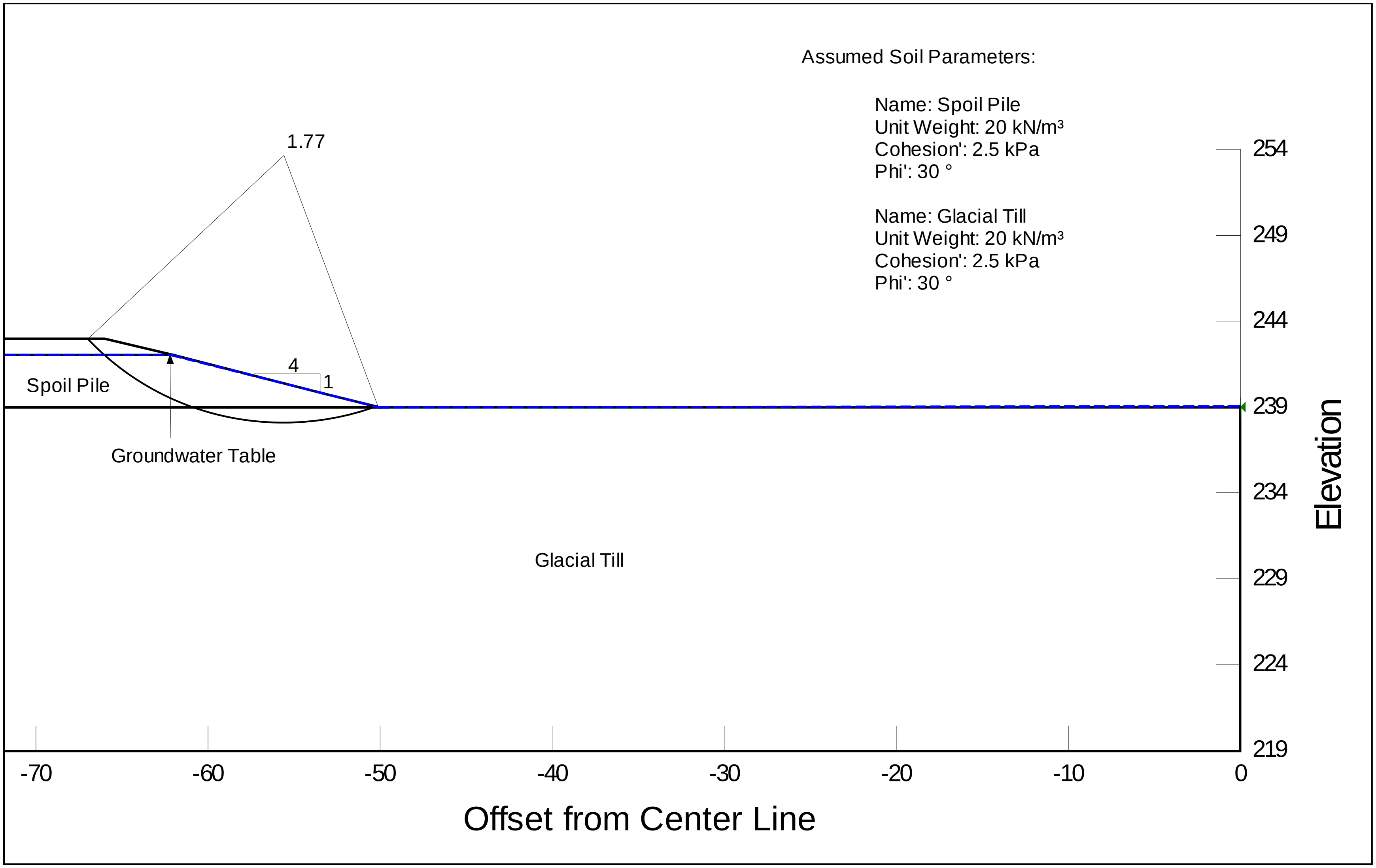

FIGURE H – 7

OPTION 4 – STATION 7+500. Case (2)

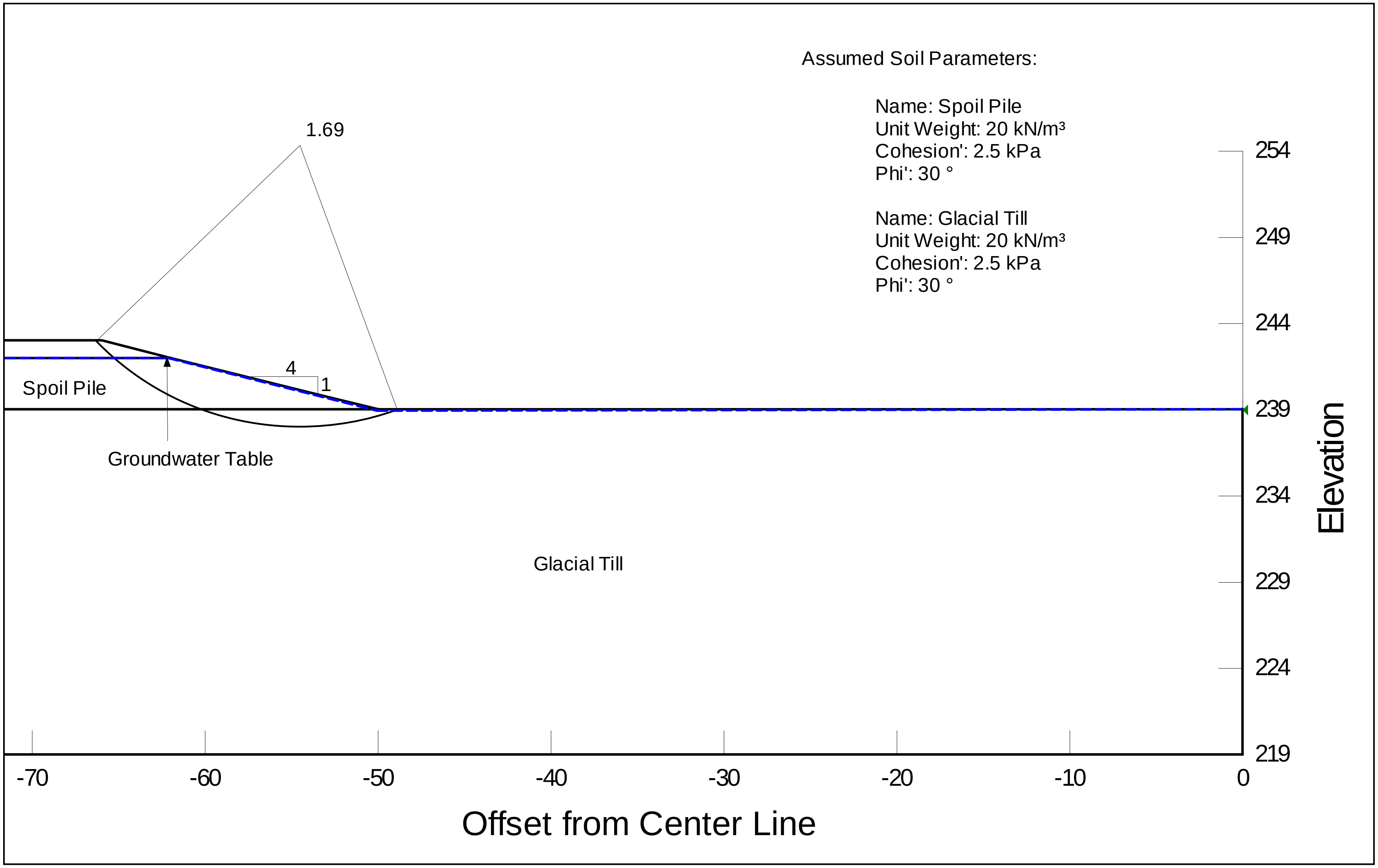

FIGURE H – 8

OPTION 4 – STATION 7+500. Case (2i)

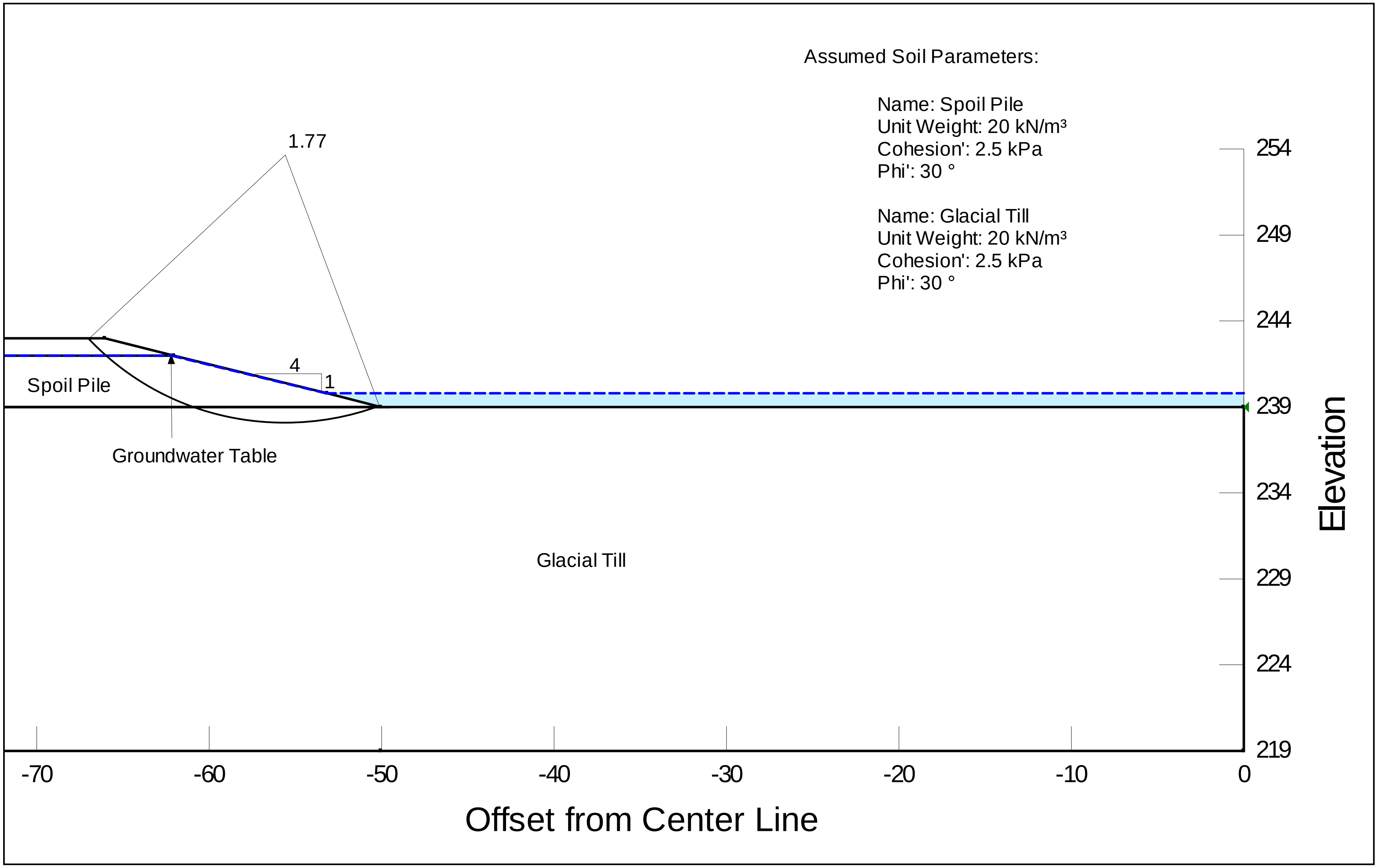

FIGURE H – 9

OPTION 4 – STATION 7+500. Case (3)

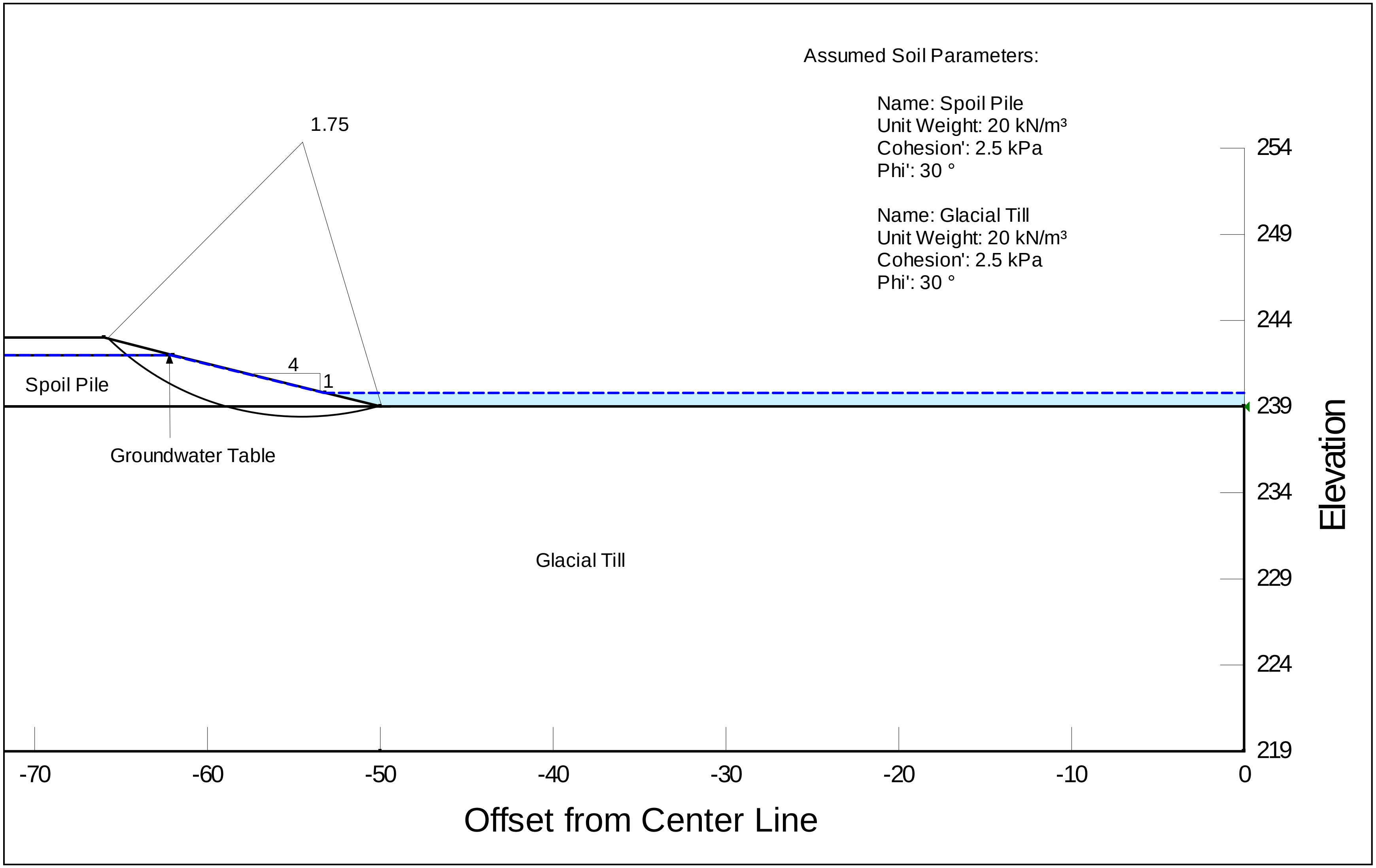

FIGURE H – 10

OPTION 4 – STATION 7+500. Case (3i)


KGS
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CONSULTING
ENGINEERS