August 2015

REPORT

Little Manitou Lake Diversion Engineering Design Concept

Submitted to:
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Report Number: 1404020/5500

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Golder Associates

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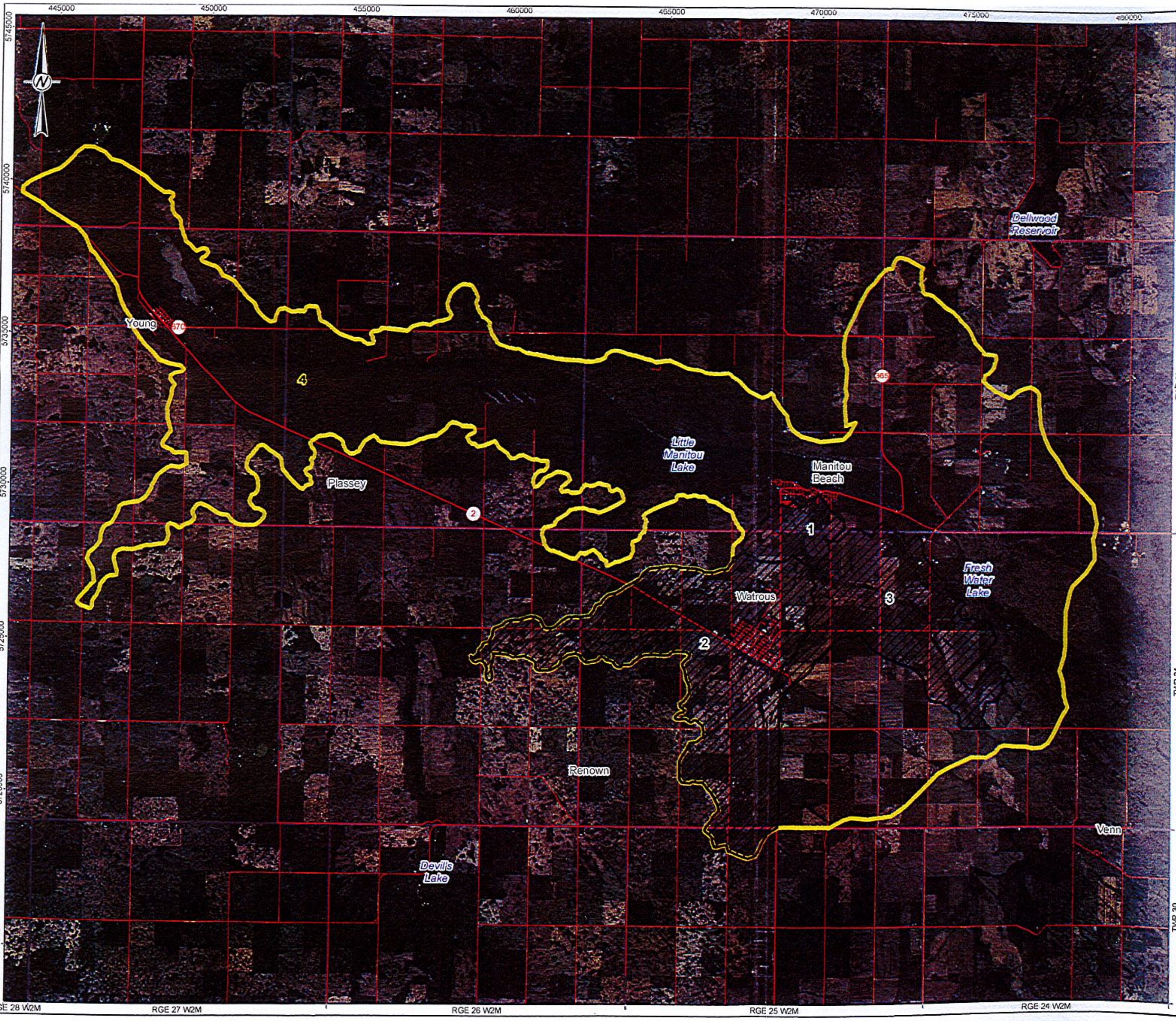
1.0 INTRODUCTION

Golder Associates Ltd. (Golder) was retained by the Saskatchewan Water Security Agency (WSA) to evaluate flood management options for Little Manitou Lake, where high lake levels are threatening the village of Manitou Beach. Golder (2014) described existing conditions and options for reducing the inflow to Little Manitou Lake as a means of managing the lake level. The assessment was based on existing topographic information and reconnaissance level field inspections and surveying.

Golder (2014) identified three options that could potentially limit water level increases in Little Manitou Lake. Two of the options involve the diversion of surface water toward the Boulder Lake drainage system; an adjacent drainage system that ultimately flows to Last Mountain Lake. The diversion is partly facilitated by redirecting flows along natural flow pathways to an existing channel that was constructed in the early 1960's that links to the Boulder Lake inflow channel. The third option involved the construction of a dam at the west end of Little Manitou Lake. However, this option offered only a small benefit at substantial expense and was not pursued further.

Little Manitou Lake and its effective drainage areas are shown on Figure 1. The drainage areas that can reasonably be diverted from the lake are shown as diversion areas 1, 2 and 3 on the figure, and combined will redirect runoff from about 70 km^2 away from Little Manitou Lake. While the diversion of these areas is not large enough to lower water levels under the current wet climatic conditions, they are expected to slow water level increases by reducing a portion of the surface water inflow.



LEGEND

BASIN AREA

PROPOSED DIVERTED AREA

0 2.5 5

1:125,000 KILOMETRES

NOTES
1. PROPOSED DIVERTED AREA: 5 KM^2
2. PROPOSED DIVERTED AREA: 30 KM^2
3. PROPOSED DIVERTED AREA: 35 KM^2
4. BASIN EFFECTIVE DRAINAGE AREA (215.5 KM^2) INCLUDES AREAS 1, 2 AND 3.

REFERENCE
CANVEC BASE DATA: © DEPARTMENT OF NATURAL RESOURCES CANADA, 2014. ALL RIGHTS RESERVED.
FLYSASK ORTHOIMAGERY, © SGIC PUBLIC WMS, 2008-2011
DRAINAGE AREA PROVIDED BY WATER SECURITY AGENCY, 2014
NAD 83 UTM ZONE 13

CLIENT
WATER SECURITY AGENCY

PROJECT
LITTLE MANITOU LAKE FLOOD MANAGEMENT

TITLE
PROPOSED DIVERTED AREAS FROM LITTLE MANITOU DRAINAGE AREA

CONSULTANT
Golder Associates

YYYY-MM-DD	2015-07-22
PREPARED	VGV
DESIGN	SM
REVIEW	BT
APPROVED	LG

PROJECT No	PHASE	Rev	FIGURE
1404020	5500	0	1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

25mm

2.0 SCOPE OF WORK

This study expands on the initial assessment (Golder 2014) by preparing an initial feasibility level design for the preferred option. The work included topographic surveys, a hydrotechnical and geotechnical investigation, and preliminary engineering.

The following tasks were undertaken:

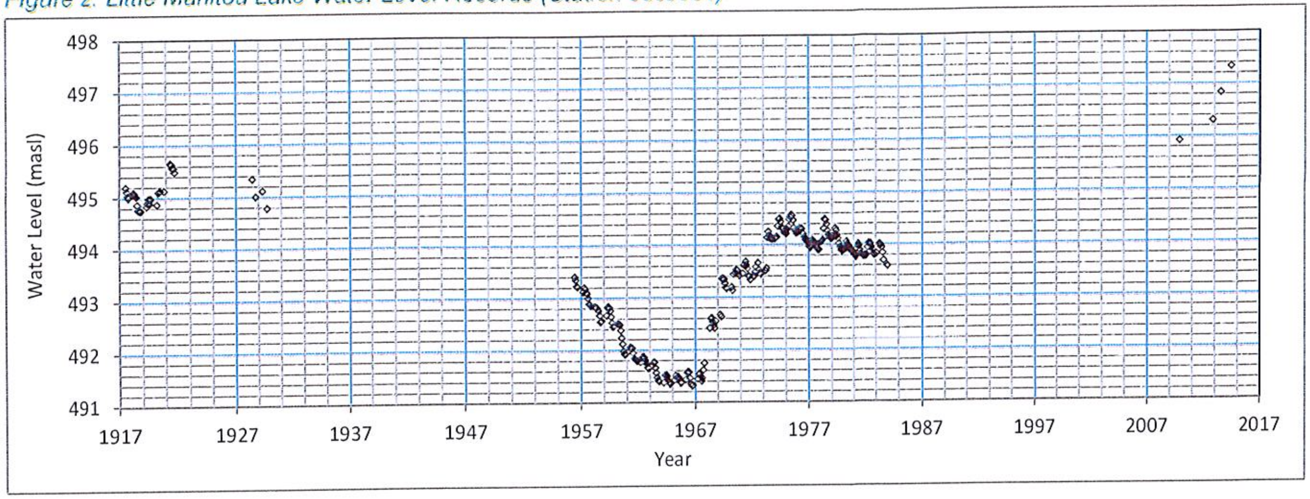
- geotechnical investigation of proposed dyke locations (drilling was only undertaken at the proposed location for the upstream dyke as the landowner would not allow access last fall);
- Real Time Kinematics (RTK) topographic survey of the proposed dyke and diversion channel alignments;
- RTK topographic survey of the natural channel pathways and along the existing drainage channel;
- laboratory testing of soils;
- geometric design of embankments;
- hydraulic design for the constructed channel and recommendations for a control structure at the dykes to allow return flow to Little Manitou Lake under future drier conditions;
- pump and pipe sizing to transfer accumulated groundwater from Wellington Creek Pond;
- conceptual design drawings; and
- bill of quantities and conceptual cost estimate.

3.0 EXISTING CONDITIONS

Little Manitou Lake is a saline lake located within a former glacial meltwater channel in central Saskatchewan, about 4.6 kilometres (km) north of the Town of Watrous. The Resort Village of Manitou Beach is located along the southeast shore of the lake. The average surface area of the lake is about 13.3 square kilometres (km^2), with an average depth of 3.8 m. Preliminary estimates provided by WSA, indicate that Little Manitou Lake receives most of its inflow via groundwater, while the remainder is supplied by direct precipitation and runoff from local drainage areas. Little Manitou Lake is an intermittently terminal basin with no outflow for at least 100 years. The natural drainage outlet is towards Last Mountain Lake. An examination of topographic data indicates that Little Manitou Lake would need to rise more than 6 m from the existing condition to reach the spill point, and begin flow southeast to the Last Mountain Lake drainage basin.

Water levels have been recorded periodically since 1918, with Water Survey Canada (WSC) operating a water level recorder from 1957 to 1984. After 1984 the monitoring station was discontinued, but water levels were measured in November 2010 and October 2013. WSA re-installed a staff gauge on Little Manitou Lake in June 2014 and levels on Jun 19, 2014 and May 14, 2015 were recorded. Lake water level fluctuations from 1918 to 2014 are shown on Figure 2. The highest recorded level was observed in May 14, 2015 at 497.33 metres above sea level (masl), while the lowest level occurred in the mid-1960's (491.4 masl). The observed value in June 19 of 2014 was 496.83 masl, showing a level increase of 0.5 m in one year. Dramatic water level increases have also been noted for other near-terminal basin lakes in the region since 2005, corresponding with a relatively wet period.

Figure 2: Little Manitou Lake Water Level Records (Station 05JJ001)



Rising water levels have been an ongoing concern to the local public due to the threat of flood damage to existing buildings, roadways and other infrastructure. Some shoreline infrastructure has been damaged and a section of Highway 365 east of the village of Manitou Beach has been submerged. Recent efforts to limit the flood risk to the Village of Manitou Beach and Camp Easter Seal, include the construction of containment dykes in 2011. Additional dyke sections were built along the highway road bed and shoulders. The crest of the dykes was constructed to an elevation of 497.6 masl. In the fall of 2014, a temporary structure was constructed to prevent waves from overtopping the dyke. This consisted of compacted earth wrapped in Rubber Gard (EPDM Membrane) placed along the length of the dyke to provide an additional 0.5 m of protection.

4.0 DESIGN BASIS

4.1 Lake Levels

A firm design basis has not been selected for a target water level. The intent is to re-direct water away from Little Manitou Lake for the purpose of slowing or perhaps stopping future lake level rise. A practical cost-effective limit for water diversions from the lake tributaries to other water bodies has been selected. The previous report describes the assessment of opportunities and selection of a preferred option.

4.2 Diversion Capacity

The selected design flow for hydraulic structure conveyance capacity is the 25-year return period flood peak, including new channels, dykes and cross-drainage structures. The existing natural channels where the diversion flow is redirected are assumed to have the required conveyance capacity, but some flooding along the channel margins is likely once the diversion structures are in place. Most of the land is privately owned, though an existing constructed channel passes through publicly-owned PFRA pasture.

4.3 Design Flow

Design flow for the diversion structures is based on a regional flood frequency analysis derived from historical records at three Water Survey Canada (WSC) Stations in the Little Manitou Lake area. The selected stations are summarized in Table 1. The regional flood frequency curve was obtained as the median for the [T-year-flood] / [mean-annual-flood] ratio values for the three hydrometric stations at various recurrence interval. Results of the regional flood frequency analysis are illustrated on Figure 3. The mean annual flood for the ungauged diversion drainage areas was estimated as a function of the effective drainage area as indicated on Figure 4. The regional curve is used to estimate the total runoff inflow to Little Manitou Lake, then peak flows for the smaller sub-basins selected for diversion are estimated based on the following relationship;

$$Q_{sl} = Q_{lm}\left({A_{sl}}/{A_{lm}}\right)^{b}$$

Where: Q represents discharge in cubic metres per second (m^3/s); A represents area in km^2; and "lm" and "sl" refer to entire Little Manitou Lake and the sub basin at the selected location, respectively. The exponent "b" accounts for the relatively higher unit peak flows occurring in smaller drainage areas; a recommended value range from 0.7 to 1. In this assessment a value of 0.85 was used.

Table 1: Selected Regional Gauging Stations for Design Flow Estimates

Stream	Station	ST- No	Period of Records	Discharge Location (UTM) – Zone 13		GDA (km^2)	EDA (km^2)
				East (m)	North (m)		
Lanigan Creek	Lanigan Creek above Boulder Lake	05JJ003	1958-2014	483588	5722076	2283.0	429.7
Bright water Creek	Bright water Creek near Kenaston	05HG002	1960-2013	395968	5713447	864.5	193.0
Lewis Creek	Lewis Creek near Imperial	05JH005	1972-2014	473431	5683318	464.4	143.3

UTM = Universal Transverse Mercator Coordinate System; km^2 = square kilometres; m = metres
GDA = gross drainage area; EDA = effective drainage estimated

Figure 3: Regional Flood Frequency Curve

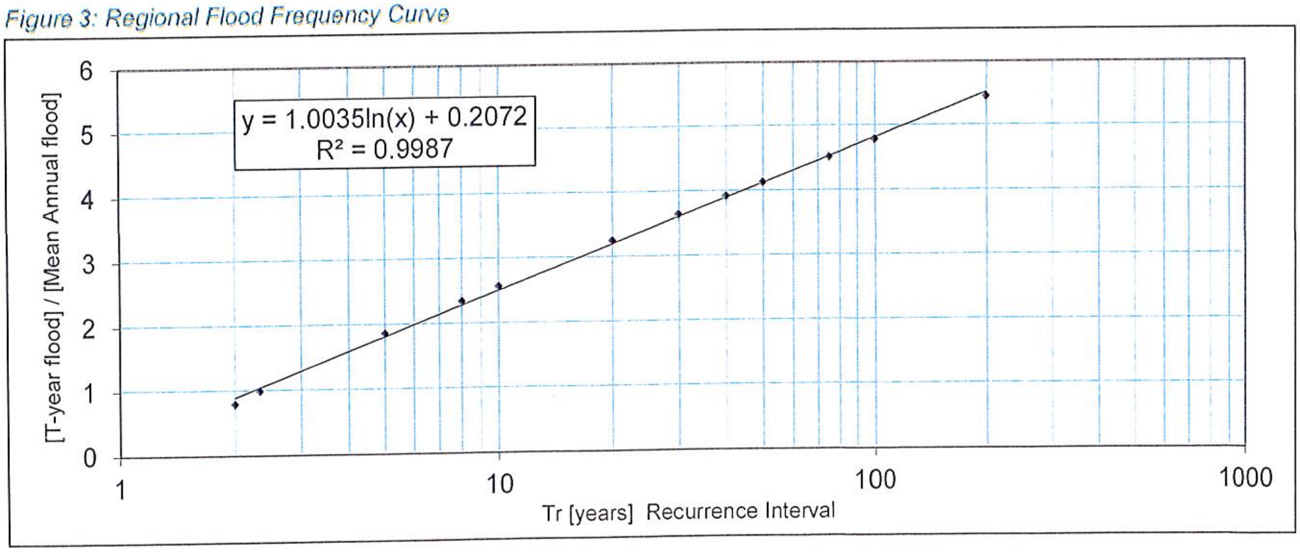
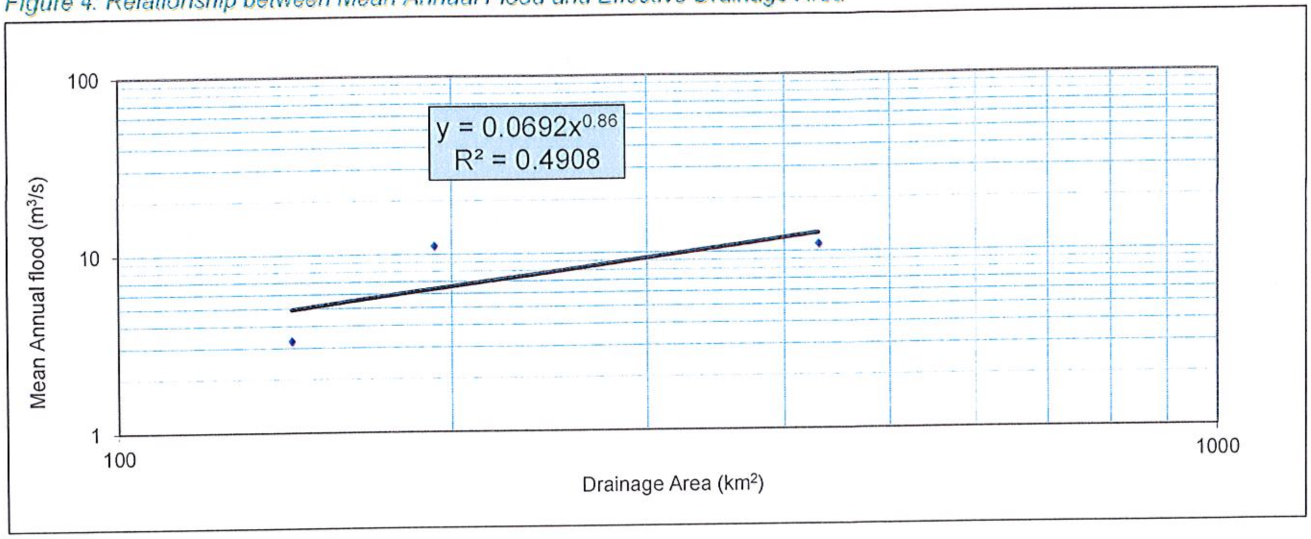


Figure 4: Relationship between Mean Annual Flood and Effective Drainage Area



Flood magnitude was estimated for three selected locations along the diversions:

- Location 1 - the proposed 100 m long earthen dyke constructed across Wellington Creek northwest of the Watrous Lagoons and the 250 m long redirect channel;
- Location 2 - the proposed 60 m long earthen dyke with a control structure constructed across the Freshwater Lake inflow channel immediately downstream where the existing constructed diversion channel connects to the natural channel flowing to Freshwater Lake, and
- Location 3 - the 60 m diameter pond pumping source location.

The effective drainage area for Little Manitou Lake was provided by WSA (215.5 km²), while the effective drainage areas for the three selected sub-basins proposed for diversion were based on a subsequent drainage area interpretation and field reconnaissance. Geographic coordinates and effective drainage areas for the three selected locations are summarized in Table 2. The flood magnitude and frequency estimated for the three selected locations and for selected recurrence intervals are indicated in Table 3.

Table 2: Selected Locations for Flood Magnitude Estimates

Item	Name	Type	Location UTM - Zone 13		EDA km²
			East [m]	North [m]	
Selected Location 1	Earthen dyke near Watrous Lagoons	Natural	469,756	5,727,351	30.4
Selected Location 2	Dyke and control structure west end of the existing channel	Natural	476,645	5,723,903	65.3[(a)]
Selected Location 3	Proposed pump station	Natural	469,918	5,729,350	5.0

This locations are shown in Appendix A, drawing 1404020/001; km² = square kilometres.

(a) Location 2 is downstream of location 1 once the dyke near the Watrous Lagoon is in place, thus the drainage area at location 2 combines the contributing areas of both drainages.

Table 3: Estimated Flood Peak for Selected Locations

Return Period (years)	Exceedance Probability [%]	Flood Peak [m³/s]		
		Watrous Lagoons (Location 1)	West End of the Existing Constructed Channel (Location 2)	Surface Water and Groundwater Spring (Location 3)
2	50	1.1	2.0	0.2
5	20	2.5	4.8	0.5
10	10	3.4	6.6	0.7
25	5	4.6	8.9	1.0
50	2	5.5	10.5	1.2

m^3/s = cubic metres per second;% = percentage; for instantaneous peak the daily peak discharge will be increased using a 1.3 factor

4.4 Discharge Surveys

Stream flow surveys were undertaken at two locations during the 2015 spring freshet to support peak flow estimates and to help verify regional estimates. The measured flow at Watrous Lagoons and Fresh Water Lake inflow are the two main discharges to Little Manitou Lake. Freshet flow conditions in March 2015 are shown on Figure 5 and Figure 6. Survey results are summarized in Table 4. The two discharge locations are representative of drainage areas DA-2 (Wellington Creek at the proposed location for the low earthen dyke and redirect channel near the Watrous Lagoons) and DA-3 (upstream of Freshwater Lake near the diversion dyke and existing channel). The flow measured on March 15, 2015 at Wellington Creek near the Watrous Lagoons was 1.39 m^3/s. According to spring 2015 runoff estimates provided by the Water Security Agency, runoff was expected to be normal to above normal in the Watrous area, which is approximately equivalent to a peak flow of 1.1 m^3/s for a 1:2-yr return period at Location 1.

Table 4: Discharge Surveys at Selected Locations – Spring Freshet 2015 (m^3/s)

Location	Mar-15	Mar-30
DA-2 Wellington Creek at Watrous Lagoons (Location 1)	1.39	0.148
DA-3 Fresh Water Lake Inflow (Location 2)	1.60	0.175

Figure 5: Wellington Creek near DA-2 (upstream of the Watrous Lagoons), March 15, 2015. Discharge is 1.39 m^3/s.

Figure 6: Freshwater Lake inflow near DA-3, March 15, 2015. Discharge is 1.60 m^3/s.

5.0 PROPOSED DIVERSION WORKS

The arrangement of proposed diversion works is provided in Appendix A on drawing 1402020/001. Conceptual design details are provided on drawings 1402020/002 to 008.

5.1 Overview

The proposed diversion would utilize existing natural drainage pathways where possible and an existing diversion channel to divert water to Boulder Lake. The diversion also considers pumping from a pond along the lower portion of Wellington Creek up to a diversion dyke. The pond is a groundwater discharge location that appears to be active most of the year. The diversion structures would consist of two containment dykes, and a pump with approximately 2,200 metres (m) of pipe. Additional works include minor channel excavation, culvert installation and a road grade raise.

The proposed drainage works are summarized as follows:

- A pump installed in an existing 60 m diameter pond that acts as a sump for surface and groundwater inflows. The pond is located along Wellington Creek near the Village of Manitou Beach immediately south of Wellington Park.
- A 2,200 metre (m) long pipeline that would carry water from the pond, up out of the Wellington Creek valley. The pipe will terminate near the northeast corner of the Watrous Lagoons and discharge into the existing ditch along the northeast side of the lagoons (drawing 1404020/002). This ditch drains southeastward through the grid road and down a natural drainage pathway.
- An earthen dyke would be constructed across Wellington Creek northwest of the Watrous Lagoon over a length of about 100 m (drawing 1404020/003, 004 and 007). This dyke would be placed to prevent runoff from draining further downslope toward Manitou Lake and would direct water toward the 250 m long proposed constructed channel that would convey water to the northeast corner of the sewage lagoon and into an existing ditch.
- A 250 m long section of constructed channel would redirect runoff from Wellington Creek to the north corner of the Watrous Lagoon to discharge into the existing ditch at the northeast side of the lagoons (drawing 1404020/003 and 007).
- An earthen embankment with a control structure (dyke and control structure) constructed across the Freshwater Lake inflow channel immediately below the confluence with the existing diversion channel that connects to the Boulder Lake inflow channel (drawing 1404020/001 and 006). The control structure consists of a 900 mm diameter CSP with a sluice gate on the upstream end. The CSP will be installed in the dyke at the low point in the channel profile. The purpose of the CSP is to maintain flow through the dam during dry periods when flow to Little Manitou Lake will be needed to maintain the lake level. During wet periods the gate will remain closed. The water management criteria for the gated culvert would be based on water level at Little Manitou Lake. It is proposed that the gate remain open for water levels below or equal to 495 masl; however the Village of Manitou Beach may have an alternative water level target level.

- A culvert upgrade and road grade raise east of the Watrous lagoon is required to accommodate the additional flow from Wellington Creek. At this location, the existing small culvert will be replaced with three 1000 mm diameter corrugated steel pipes (CSP) and a grade raise of 0.6 m along a low section of the grid road is required (drawing 1404020/003, 007 and 008). Treated effluent is periodically released and would also pass through CSPs, though it is believed the volumes are quite small.

- Reclaim two existing 1300 mm diameter CSPs located at the cattle crossing approximately 1200 m downstream (east) from the dyke which have been blocked in the past (drawing 1404020/001). The type of reclamation required for this crossing would be defined following an inspection of the pipes in the crossing. It appears the pipes have been blocked with plywood and local fill material

5.2 Pumping and Pipe Capacity

Following the construction of the diversion works, the drainage area reporting to the 60 m diameter pond which occurs along the Wellington Creek channel about 300 m upstream of the Village of Manitou Beach is about 5 km^2. The pond is the proposed pumping location that when combined with the upstream diversion, will substantially reduce flows to the lake from Wellington Creek. The 1:2 year peak flows (0.2 m^3/s) estimated from this drainage (Table 3) is used as a reference for the pumping requirements. Annual peak flows are expected to occur in April or May and last for several weeks while in the remaining of the months flows would be reduced. To manage potentially higher flows during the freshet and following heavy rains it is proposed that the pump capacity be 0.3 m^3/s. In combination with the diversion dyke further upstream near the Watrous Lagoon, this pumping capacity should be sufficient to eliminate most of the inflow that now passes into Little Manitou Lake via Wellington Creek.

The pipeline route would roughly follow the Wellington Creek flow pathway between the pump location and the sewage lagoons as illustrated in drawing 1402020/002.

The pumping system recommended for this portion of the design is a HL250M Dri Prime electric pump and 10" DR 17 HDPE pipe. This pump has the capacity to meet the required flow of up to 0.3 m^3/s for the 2,200 m distance and elevation change from about 488 to 497 metres. This pump is most cost-effective when it is run on electricity; therefore, an electrical hookup will be required near the pond location.

5.3 Earthen Dyke West of Watrous Lagoons and Redirect Channel

Following the diversion works, runoff from about 30 km^2 of the Wellington Creek drainage area would be diverted. A low earthen dyke will be placed across Wellington Creek channel, west of the sewage lagoons, to prevent runoff for draining further downslope to Little Manitou Lake. This diverted flow would be redirected toward a 250 m long shallow constructed channel that will convey water to the north corner of the sewage lagoon where an existing channel would be used to convey the flow along the north side of the lagoons to the grid road. The stream flow for the 1:25-yr return period event was estimated to be 4.6 m^3/s (Table 3), while the instantaneous peak is estimated to be about 6.0 m^3/s after applying a factor of 1.3 based on instantaneous peaks flows recorded at regional hydrometric stations. The earthen dyke and channel downstream are designed to contain and redirect the 1:25-yr instantaneous peak flow. Should flows exceed this value, a lowered section of the dyke will allow some flow to spill over and continue downslope along the existing Wellington Creek channel. The proposed alignment for the earthen dyke and redirect channel are provided in Appendix A, 1404020/003, while profiles and typical sections drawings 1404020/004 and 007, respectively.

The 100 m long earthen dyke will be placed across Wellington Creek channel as shown on drawing 1404020/003. The Dyke crest elevation is 499.0 masl. The dyke will have a 20 m long lowered section to allow overflow to discharge to the Wellington Creek channel during extreme peak flows. The overflow invert elevation will be at 489.5 masl and 3:1 side slope to provide sufficient height for the flow depth on the overflow invert and freeboard. The overflow section of the dyke and the drop/chute section will be armoured by using rip-rap with a median diameter of 150 mm and thickness of 0.3 m. A stilling basin will be located at the foot of the chute. This basin will be place to dissipate energy to assist with erosion control at the overflow. The stilling basin will be approximately 5 m length and 3 m wide, with a bottom depth elevation of at least 0.5 m lower than the invert of the natural channel. The basin will be also lined following the same riprap used in the overflow section.

The constructed redirect channel will join the earthen dyke, with the upstream end beginning approximately at the half length of the dyke where the invert of the natural channel of Wellington Creek occurs. The upstream end invert of the constructed channel will be at least 2.0 m lower than the top of the earthen dyke, i.e. at the overflow section the depth will be 1.5 m. The redirect channel will initially flow northeast, turning southeast to redirect the flow into the sewage lagoon ditch. The curve will have a radius of about 30m. The constructed channel will have a trapezoidal cross-section of 2 m wide base with 3:1 side slopes. The length of the proposed channel will be about 250 m and the invert slope would be about 0.43%. Preliminary calculations indicate that for an average slope of 0.43%, the depth for the design discharge (6.0 m^3/s) is estimated to be 1.22 m.

The constructed channel will discharge to the existing ditch along the north side of the sewage lagoons. According to the survey information, the existing ditch at the sewage lagoons has a trapezoidal section of 2 m width, 3:1 side slope, the depth referenced to the top of the embankment shaping the sewage lagoons is about 2 m. Therefore, the sewage lagoons ditch would not require an upgrade to convey the design flow.

The constructed channel would be excavated in natural ground. Water velocity in the constructed channel is expected to be 0.9 m/s under the design discharge event. Soil natural conditions are expected to have the erosion resistance for this velocity magnitude, but erosion resistance to the channel would be enhanced using turf reinforcement matting and seeding.

The Town of Watrous is planning an expansion of their lagoons in 2017. Their preliminary plan is shown in Appendix A, drawing 1404020/002. The location of the proposed lagoon expansion means that the dyke and redirect channel will need to be moved in two years. The Town of Watrous and their engineering firm are amenable to working with the WSA and the Village of Manitou Beach for future diversion plan adjustments. These adjustments would have some associated costs that will need to be addressed once the final expansion plan is available.

5.4 Road Crossing East of Watrous Lagoons

Once the flow passes through the ditch along the sewage lagoons, it will drain to the grid road, where there is currently only a small corrugated streel pipe (CSP) to convey the flow. With a substantially larger flow from Wellington Creek and the pumped volume from further downstream on the Wellington Creek drainage, cross-drainage at the grid road immediately east of sewage lagoons needs to be improved to convey the peak flow that will be redirected to the crossing. According to the previous section, for the design criteria, an instantaneous peak flow of about 6.0 m^3/s plus 0.3 m^3/s from the pump, i.e., 6.3 m^3/s must be conveyed through the grid road.

For the upgrade of this crossing, a 3x1000-mm CSP are recommended. At a flow rate of 6.3 m³/s, and the pipes installed with a 0.38% slope, the calculated headwater is estimated to be 1.84 m. The available headwater at the crossing will be a function of the minimum road elevation, but limited by the minimum elevation at the sewage lagoons embankment minus 0.3 m for a freeboard. With the crest elevation on the sewage lagoons berm at about 498.1 masl, the proposed invert for the culvert is at 495.58 masl, while the road grade is proposed to be raised to 497.18 masl (0.6 m above the crown of the pipes). Under this configuration, the road would likely be overflowed for discharges larger than about 5.0 m³/s. The calculation for the three CSPs using the Culvert Master application solved for headwater elevation and 5.0 m³/s is included in Table 5. The alternative of overflowing the road would be preferable to having an additional grade raise because higher backwater levels at the crossing may have an adverse effect in the sewage lagoons embankment. The road grade raise detail can be found on drawings 1404020/003 and 005).

Erosion protection is recommended near the culvert outlet. A riprap apron should extend 5 m downstream of the outlet and 1 m upstream of the inlet, with a minimum thickness of 0.3 m consisting of 150 mm median diameter rock, based on an estimated design velocity of 2.7 m/s using the following formula (Smith 1995):

$$d_m = 0.019\,V^2$$

where: d_m = median stone size (m)
V = average outlet velocity (m/s)

Table 5: Culvert Calculation Summary

Culvert Summary					
Allowable headwater (HW) elevation	498.10	m	Headwater depth/Height	1.49	
Computed HW elevation	497.07	m	Discharge	5.0000	m³/s
Inlet control HW Elev.	496.95	m	Tailwater elevation	495.52	m
Outlet control HW Elev.	497.07	m	Control type	Outlet Control	
Grades					
Upstream Invert	495.58	m	Downstream invert	495.52	m
Length	15.00	m	Constructed slope	0.003800	m/m
Hydraulic Profile					
Profile	CompositeM2PressureProfile		Depth, downstream	0.74	m
Slope type	Mild		Normal depth	N/A	m
Flow regime	Subcritical		Critical depth	0.74	m
Velocity downstream	2.66 m/s		Critical slope	0.020127	m/m
Section					
Section shape	Circular		Mannings coefficient	0.024	
Section material	CSP Helical		Span	1.000	m
Section size	1000 mm.		Rise	1.000	m
Number of sections	3				
Outlet control properties					
Outlet control HW Elev.	497.07	m	Upstream velocity head	0.23	m
Ke	0.90		Entrance loss	0.21	m

Inlet control properties					
Inlet control HW Elev.	496.95	m	Flow control	Transition	
Inlet type	Projecting		Area full	2.4	m²
K	0.03400		HDS 5 chart	2	
M	1.50000		HDS 5 scale	3	
C	0.05530		Equation form	1	
Y	0.54000				

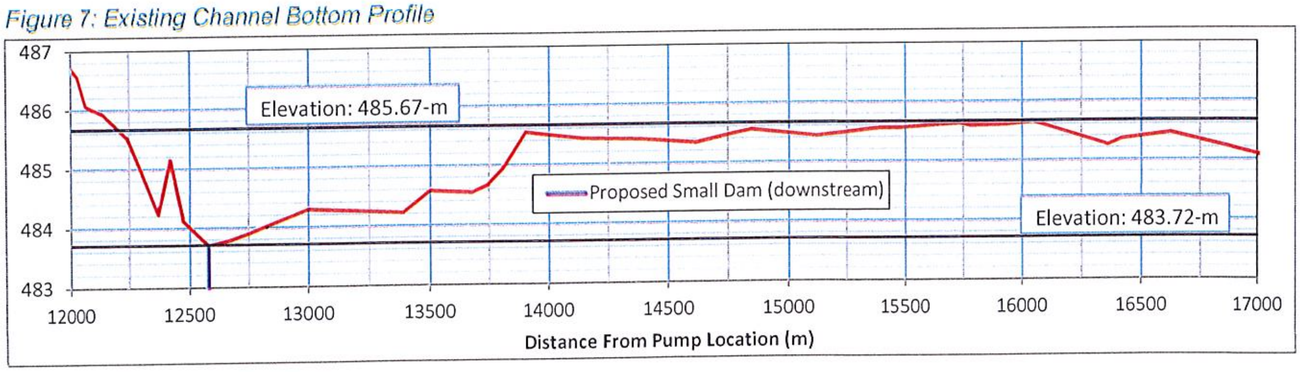
5.5 Dyke and Control Structure across Channel to Freshwater Lake

Runoff from Wellington Creek, including the pumped volume, will comprise most of the water passing around the Watrous Lagoon (sewage lagoons) where it will combine with additional natural runoff and drain to the southeast, eventually turning northeast near road grid (Twp Rd 312) and finally to the northwest to become part of the inflow to Freshwater Lake, which ultimately drains to Little Manitou Lake (Appendix A, drawing 1404020/001). To prevent much of this flow from entering Freshwater Lake, a low dyke is required across the natural channel, upstream of Fresh Water Lake. As headwater builds on the dyke, flow will drain east along an existing channel that is connected to the Boulder Lake drainage system.

The channel elevations at the proposed dyke location are shown on Figure 7, indicating flow by gravity eastward along the existing constructed channel for headwater above 485.67 m. Therefore, a minimum headwater of 1.95 m is required at the dyke for the eastward flow to occur by gravity.

During future dry periods, it may be desirable to have the water continue flowing to Freshwater Lake, and further downstream to Little Manitou Lake. To facilitate this bypass, a sluice gate culvert will be installed in the dyke. The sluice gate culvert will be open only when the diversion is not required. The culvert invert will be placed at approximately the current invert elevation of the existing natural channel at the dyke location. A 1 x 900-mm CSP with a sluice gate installed in a precast concrete headwall at the upstream side (south side of the dyke) will be used. It has not been determined who would be responsible for operation the bypass structure, i.e., Village of Manitou Beach, Water Security Agency, or the R.M. of Morris.

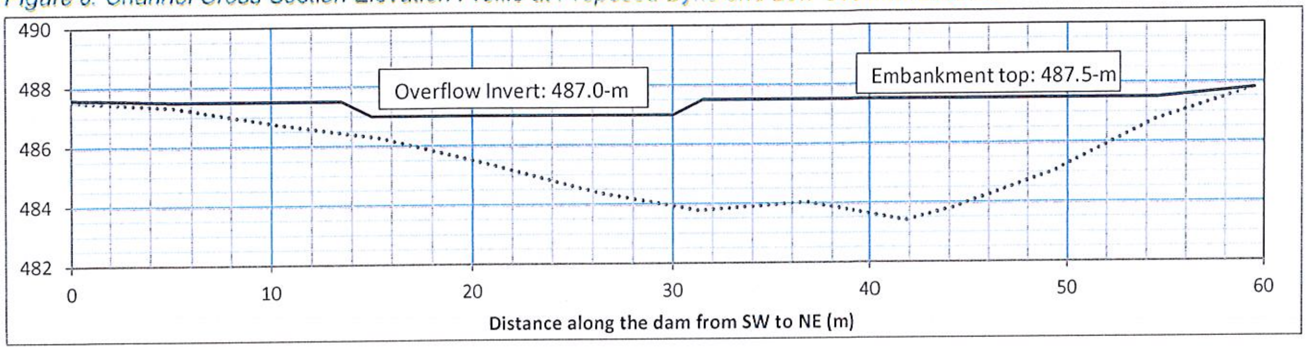
Figure 7: Existing Channel Bottom Profile



A cross section surveyed at the proposed location for the dyke and control structure is illustrated on Figure 8. A dyke embankment top at 487.5 m seems reasonable according to the surveyed cross-section at the dyke location. An armored low overflow at the dyke will be required to protect the dyke embankment under the occurrence of high flow conditions. The overflow (spillway) invert elevation will be at 487.0 masl with a width (weir length) of 15 m and 3:1 side slope to provide sufficient height for the flow depth on the overflow invert and freeboard. The dotted line on Figure 6 indicates the existing topography at the cross section and the dark continuous line illustrates the proposed top of the dyke embankment and invert elevation for the overflow section.

Following the dyke installation, backwater effects are expected to flood small areas upstream of this proposed structure. During dry periods, flow through the existing diversion channel would cease; therefore, under no flow conditions and the gated culvert closed, the minimum ponding elevation at the dyke would be the maximum bottom elevation of the existing constructed channel (i.e., at 485.67 m). The extent of the flood due to backwater effects would be a function of the headwater at the dyke. High flow rates, thus high headwater, are expected during the spring freshet and or under extreme rainfall events.

Figure 8: Channel Cross Section Elevation Profile at Proposed Dyke and Low Overflow Location



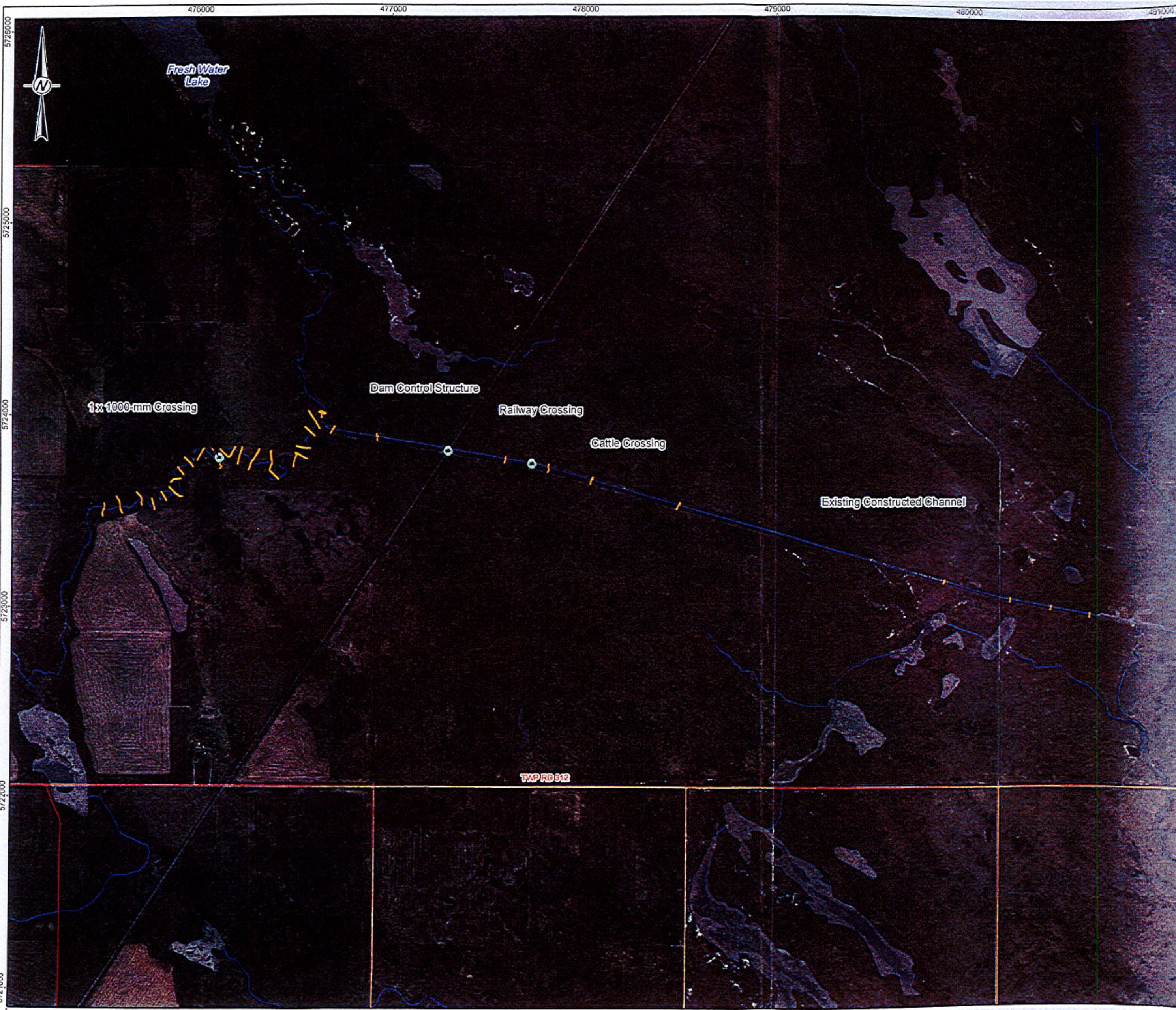
To estimate the flood extent upstream of the proposed dyke and shoreline inundation (if any) under selected discharges through the natural channel flowing to Freshwater Lake, a one-dimensional steady flow hydraulic assessment was undertaken using the River Analysis Modeling System (HEC-RAS) developed at the U.S. Corp of Engineers. The hydraulic model analysis extends over a distance of 1.6 km from upstream of the dyke to the wetland area north of the grid road 312, and then follows the existing constructed channel to the east over a distance of 4.1 km for a total modeling reach length of approximately 5.5 km. The geometric model data for the natural channel and the constructed channel were recreated based on 32 surveyed cross sections.

There are three culvert crossings along the reach: (1) a 1x1000-mm CSP located at a farm trail, about 750 m upstream of the dyke, (2) a 2x1300-mm pipe about 700 m (railway crossing) eastward along the existing constructed channel from the proposed dyke, and (3) a 2x1300-mm pipe about 1200 m (cattle crossing) eastward along the existing constructed channel from the proposed dyke. A section of the reach showing the locations of the hydraulic structures is shown on Figure 9.

A dyke with a low overflow as illustrated on Figure 8 was included in the modeling setup to represent the dyke overflow section and to simulate the potential flow to Freshwater Lake. The invert of the overflow was set at 487.0 m, a bottom width of 15 m using a side slope 3:1 to gradually lower the elevation from the top of the dyke, 487.5 masl, to the invert of the overflow.

The upstream boundary condition for the simulations was set to a specific flow discharge and the boundary was also set to be at normal flow depth to perform mixed flow analyses. The normal flow depth condition for the upstream end (required only in case of mixed flow) was chosen as a reasonable approach due to flat geometry conditions at this end location. The downstream condition was set at the normal flow depth. This boundary condition is considered reasonable since the downstream end location is sufficiently far away to affect results near the dyke.

The top of the dyke should be at least 487.5 masl for a 25 year return period peak daily flow of 5.3 m^3/s. The estimated diversion and dyke overflow rates are summarized in Table 6.



LEGEND

CULVERT LOCATION

MODELLING CROSS SECTION

0 400 800

1:20,000 METRES

REFERENCE
CANVEC BASE DATA: © DEPARTMENT OF NATURAL RESOURCES CANADA, 2014. ALL RIGHTS RESERVED.
FLYSASK ORTHOIMAGERY: © SGIC PUBLIC WMS, 2008-2011
NAD 83 UTM ZONE 13

CLIENT
WATER SECURITY AGENCY

PROJECT
LITTLE MANITOU LAKE FLOOD MANAGEMENT

TITLE
REACH USED FOR THE HEC-RAS MODELLING ANALYSIS

CONSULTANT

Golder Associates

YYYY-MM-DD	2015-08-11
PREPARED	VGV
DESIGN	SM
REVIEW	BT
APPROVED	LG

PROJECT No	PHASE	Rev.	FIGURE
1404020	5500	1	9

Table 6: Dyke Structure Hydraulic Results

Total Flow [m³/s]	Flow redirected to the constructed channel [m³/s]	Flow to Freshwater Lake [m³/s]	Water Elevation [masl]	Depth on Overflow [m]	Flow Area on Overflow [m²]	Mean Velocity [m/s]	Freeboard [m]
1.0	1.00	0	486.63	0.00	0	-	0.87
1.5	1.50	0	486.85	0.00	0	-	0.65
2.0	1.93	0.07	487.03	0.03	0.39	0.18	0.47
2.5	2.08	0.42	487.09	0.09	1.32	0.32	0.41
3.0	2.19	0.81	487.13	0.13	2.04	0.40	0.37
3.4	2.27	1.13	487.16	0.16	2.55	0.44	0.34
4.0	2.39	1.61	487.21	0.21	3.24	0.50	0.29
5.0	2.50	2.5	487.28	0.28	4.37	0.57	0.22
5.3	2.55	2.75	487.29	0.29	4.67	0.59	0.21
6.8	2.82	3.98	487.37	0.37	6.02	0.66	0.13

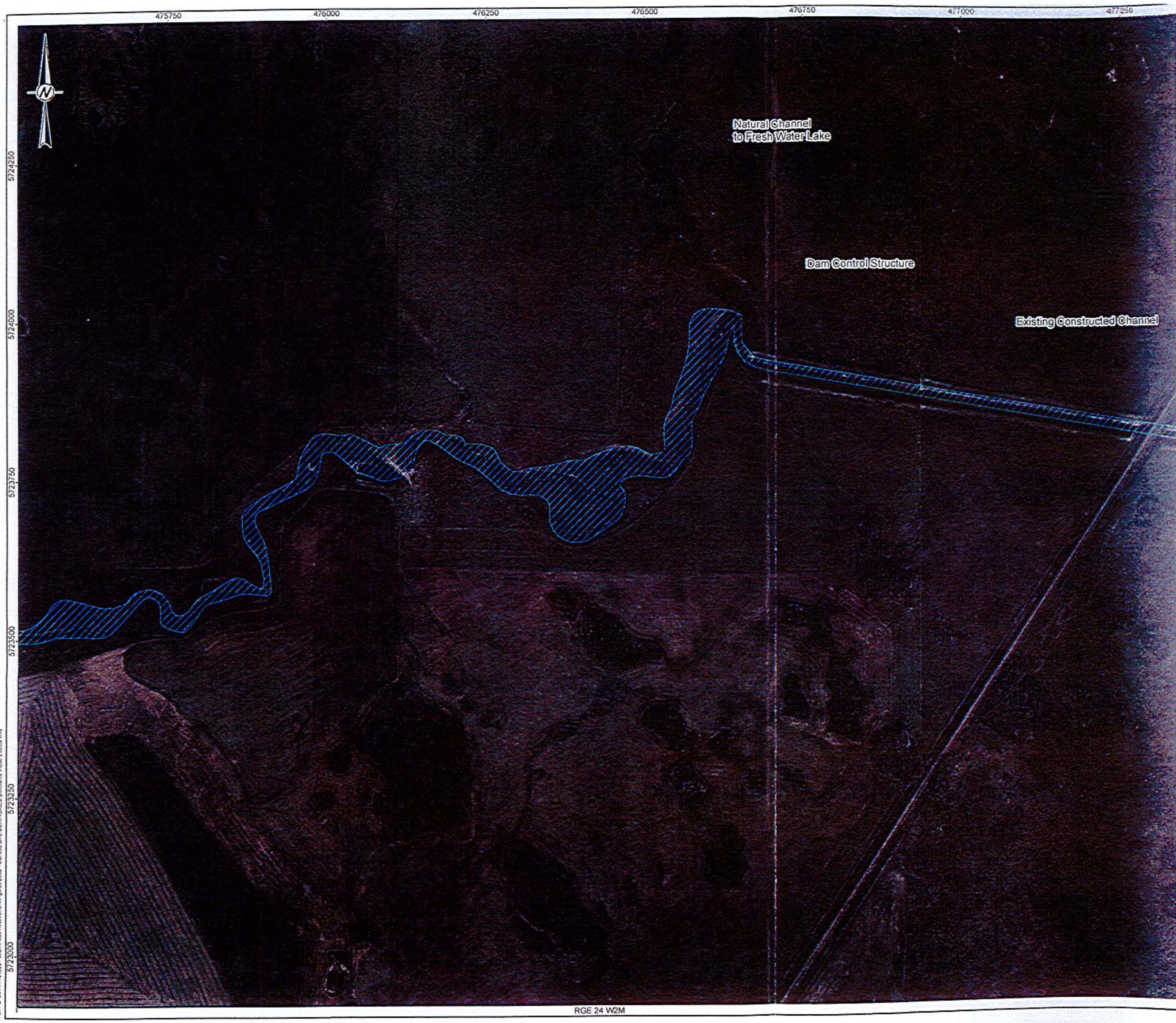
m^3/s = cubic metres per second; m = metres; masl = metres above sea level.

A preliminary analysis using the Culvert Master Application shows that the culvert would be able to convey about 2.1 m^3/s (Table 7), given water levels at the overflow elevation and assuming a 1x900-mm CSP pipe, 30 m length and 0.67% invert slope for the culvert.

Table 7: Gated Culvert Rating Curve – 1x900-mm CSP pipe, 30-m length and 0.67% slope

Discharge [m³/s]	Water Elevation at the Dyke [m]
0	483.82
0.5	484.51
1.0	484.92
1.5	485.74
2.0	486.81
2.1	487.0

The expected flood area once the water level reaches the invert elevation of the low overflow is illustrated on Figure 10. For the most part, the flow is well contained in the channel valley, which is primarily pasture land. Overflow to Freshwater Lake would begin to occur for discharges larger than 2 m^3/s.



LEGEND

SIMULATED FLOODED AREA

0 150 300

1:6,000 METRES

REFERENCE
CANVEC BASE DATA: © DEPARTMENT OF NATURAL RESOURCES CANADA, 2014. ALL RIGHTS RESERVED.
FLYSASK ORTHOIMAGERY: © SGIC PUBLIC WMS, 2008-2011
NAD 83 UTM ZONE 13

CLIENT
WATER SECURITY AGENCY

PROJECT
LITTLE MANITOU LAKE FLOOD MANAGEMENT

TITLE
SIMULATED FLOOD EFFECTS LIKELY TO OCCUR ONCE THE OVERFLOW INITIATES AT THE DAM CONTROL STRUCTURE

CONSULTANT

Golder Associates

YYYY-MM-DD	2015-07-31
PREPARED	LMS
DESIGN	SM
REVIEW	BT
APPROVED	LG

PROJECT No	PHASE	Rev	FIGURE
1404020	5500	0	10

6.0 ESTIMATED PERFORMANCE OF DIVERSION WORKS

6.1 Little Manitou Lake Level

The diversion works are intended to substantially reduce runoff from a 70.3 km² effective drainage area that reports to Little Manitou Lake through Wellington Creek and Freshwater Lake, and redirects the flow to an adjacent drainage area. The diversion is expected to slow water level increases during a continuation of the recent wet climate conditions. The change in Little Manitou Lake water level will depend on the prevailing climate in a particular year. The estimated future performance of the diversion works is based on the reduction of inflow volume that occurs by diverting a portion of the inflow.

The diverted volume for average year inflows (1:2 year) and wet year inflows (1:25 year) are converted to an equivalent water depth over the surface area of the lake to demonstrate the potential effect on water level. The regional annual volume frequency curve was obtained as the median for the [t-year-volume] / [mean-annual-volume] ratio values for the three stations at each recurrence interval following the procedure for developing a regional flood frequency curve described in Dunne and Leopold (1978). Results for the regional volume flood frequency curve are illustrated on Figure 11. The mean annual volume for the ungauged basins is estimated as a function of the effective drainage area as indicated on Figure 12. The regional curve was used to estimate magnitude of volumes for the entire Little Manitou effective drainage area (215.5 km²) and then the magnitude of the volume for selected Little Manitou sub-basins is calculated based on the magnitude volume for the entire Little Manitou Lake drainage by using area ratios incorporating the ratio of the basin yields as recommended in SaskWater (1993) for estimating annual high flow volumes at ungauged stations, i.e.:

$$V_{sb} = V_{lm} \left({A_{sb}}/{A_{lm}} \right) Y_r$$

Where: V represents annual water volumes; A represents area; "lm" and "sb" refer to entire Little Manitou Lake and the selected sub basin, respectively; and Y_r represents the ratio of basin yields, i.e., the yield of the entire Little Manitou compared with the yield of the diverted area.

Figure 11: Regional Frequency Curve for Estimating Annual Runoff Volumes

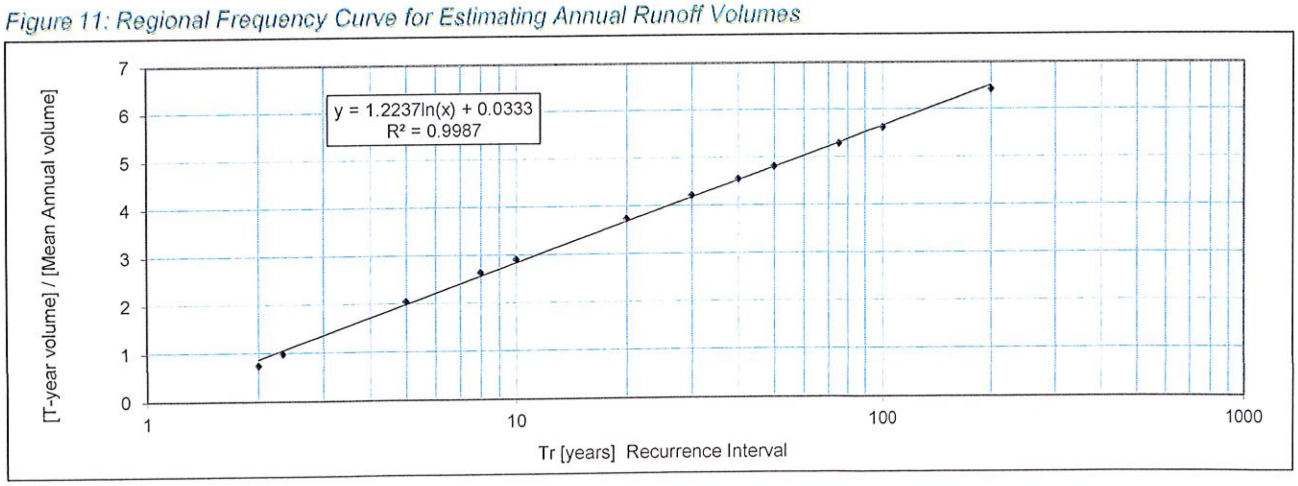
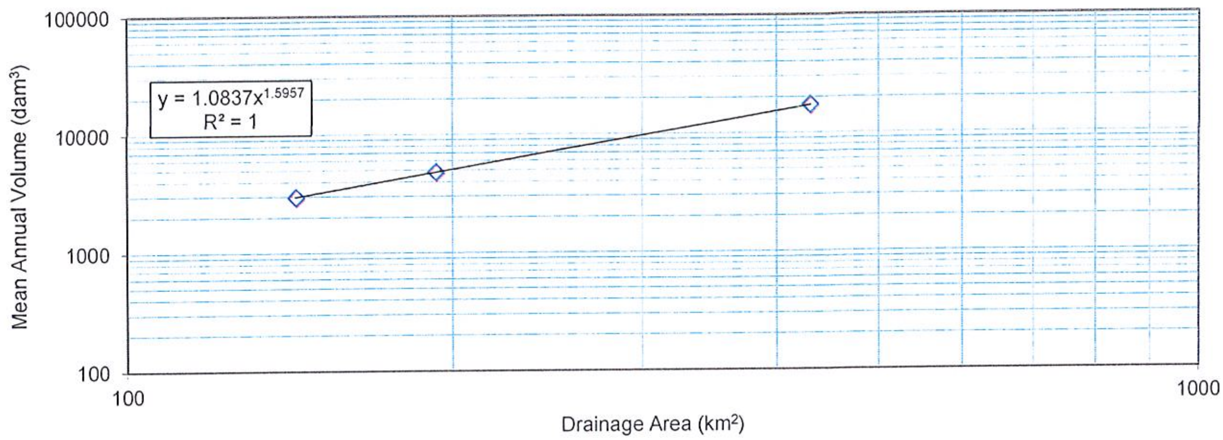


Figure 12: Mean Annual Volume versus Effective Drainage Area



The Wellington Creek drainage, with its deeply incised channels through some sections seems to convey more runoff than other flow pathways and streams that report to Little Manitou Lake. Even when other streams cease to flow, it is observed that Wellington Creek seems to continue to drain baseflow that collects in the lower reaches of the channel. Consequently, it is expected that for average climate years most of the surface water discharges to the lake through this tributary and the runoff on per unit basis for the area drained by this tributary would be substantially larger than the rest of the area; however for wet years, e.g., 1:50-yr, runoff on per unit basis may be to be more uniform for the entire basin. In this assessment, the assumption is that for 1:2-yr annual volume the yield ratio of Wellington Creek compared with the rest of the area would be 2, while for 1:50-yr the yield ratio would be 1. For recurrence intervals between 1:2-yr and 1:50-yr the yield ratio is assumed to be linear.

Little Manitou Lake has an effective drainage area 215.5 km^2, as shown on Figure 1. Of the total effective drainage area, drainage areas #2 (30.4 km^2) and #3 (34.9 km^2) can be diverted to the Boulder Lake drainage, though a portion (5 km^2) of drainage area #2 must be pumped before it can drain by gravity. Combined, the drainage areas selected for diversion occupy 70.3 km^2, which is about 33% of the total effective drainage area of Little Manitou Lake.

The estimated annual volumes from the proposed diverted areas are indicated in Table 8 for selected recurrence intervals. The table also includes the potential effect on lake level assuming that all the runoff could be diverted.

The estimated volume potentially diverted for 1:2 recurrence interval (close to average conditions) is about 2,900 cubic decametres (dam^3) or 0.2 m depth in Little Manitou Lake over a lake area of 13.3 km^2, while for the 1:25 year recurrence interval (wet year) the estimated potential volume to be diverted is about 11,400 dam^3, which is equivalent to 0.86 m depth in Little Manitou Lake.

Table 8: Estimated Annual Volume from Proposed Diversion

Return Period (years)	Exceedance Probability [%]	Little Manitou (dam^3/year)	Yield ratio (p.u.)	Diverted Area (dam^3/year)	Manitou Lake Equivalent Depth (m)
2	50	4,333	2	2,827	0.21
5	20	11,819	1.9	7,470	0.56
10	10	16,775	1.8	10,032	0.75
25	4	23,037	1.5	11,429	0.86

dam^3: cubic decametres; p.u.: per unit bases; depth is calculated based on a lake area of 13.3 km^2.

6.2 Diversion Efficiency

With the diversion works in place, most of the diverted flow will be redirected to the dyke adjacent to the existing channel and subsequently to Boulder Lake via the existing channel; however, the actual flow that is redirected to the existing channel is less than the potential volume. This is because the flow redirected to the current constructed channel is governed by the configuration of the dyke and the existing channel invert elevation and slope. Some flow will overtop the spillway toward Freshwater Lake during discharges larger than 1.9 m³/s (Table 6). Example hydrographs are provided on Figure 13 and Figure 14 to illustrate the loss of some peak diversion flow due to overtopping.

Figure 13: Expected Diversion Discharge for 1:2 Year Annual Volume

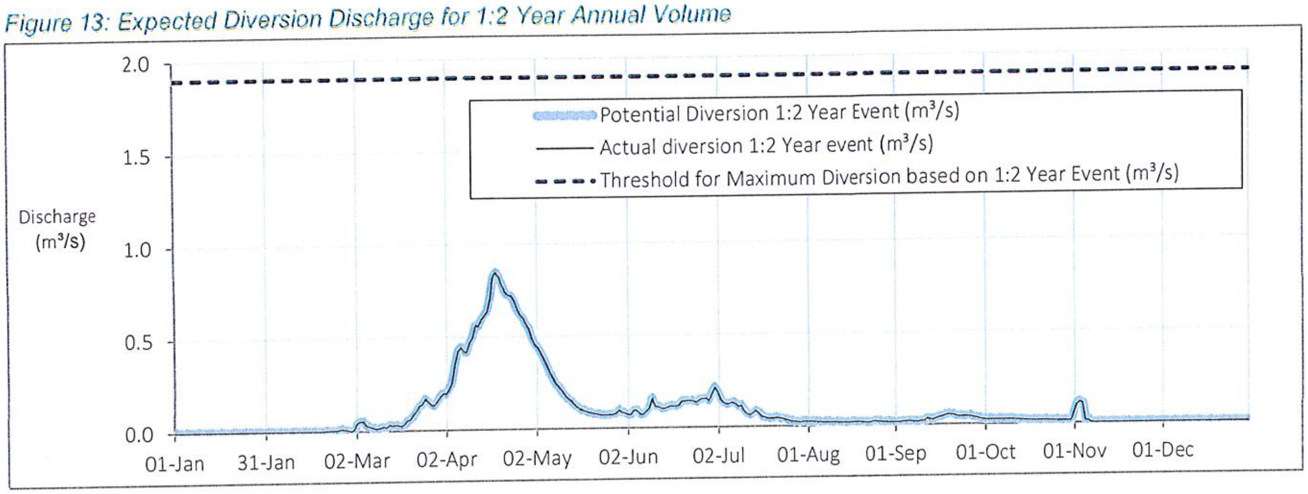


Figure 14: Expected Diversion Discharge for 1:25 Year Annual Volume

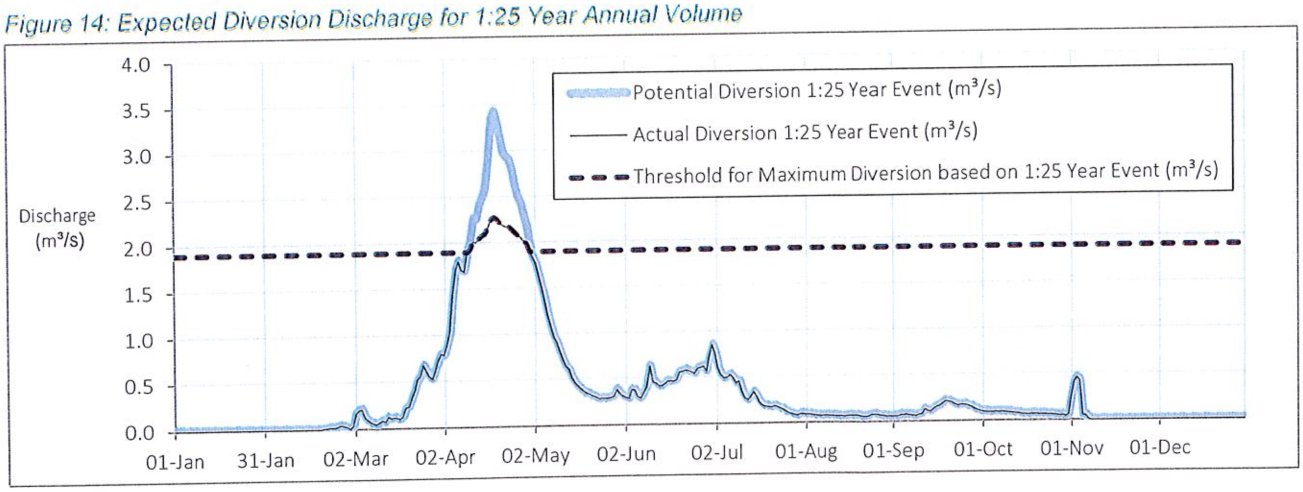


Table 9: Effective diversion for 1:2 year and for 1:25 annual volumes

Variable	1:2 Year Event		1:25 Year Event	
	Potential Diversion	Effective Diversion	Potential Diversion	Effective Diversion
Volume [dam³/year]	2,827	2,827	11,429	10,447
Equivalent Depth[(a)] [m/year]	0.21	0.21	0.86	0.79

(a) The equivalent depth is based on 13.3 km² lake area.

7.0 ESTIMATED CAPITAL COST

The estimated capital cost for the Little Manitou Lake water inflow management plan is about $1,236,410, assuming a 30% contingency. The cost is summarized in Table 10. An estimated annual operating cost of $26,000 is expected to cover maintenance and electrical costs for eight months per year. Additional costs that may be associated with land control or future diversion plan adjustments have not been included. A breakdown of the cost assumptions are provided in the following tables:

- Table 11: Pump and Pipe Construction;
- Table 12: Wellington Creek Dyke and Channel Extension;
- Table 13: Road Culvert Upgrade; and
- Table 14: Diversion Dyke and Control Structure.

Table 10: Cost Estimate Summary

Item	Description	Amount
1	Mobilization/ Demobilization	$100,000
2	Pump and Pipe Construction	$237,046
3	Road Raise & Culvert Installation	$71,369
4	Wellington Creek Earthen Dyke and Channel Construction	$142,795
5	Diversion Dyke and Control Structure	$158,115
6	Construction Management (10% of basic cost)	$91,718
7	Engineering (15% of capital cost)	$166,445
8	Surveying (1% of capital cost)	$8,010
9	Tendering (1% of capital cost)	$8,010
10	Contingency (30% of capital cost)	$240,313
GST (5%)		$58,877
TOTAL		$1,236,410

Table 11: Pump and Pipe Construction Costs

Item	Quantity	Unit	Rate	Cost
Pump (purchase)	1	L.S.	$130,000	$130,000
10" DR 17 HDPE Pipe	2,200	m	$41	$90,200
Pipe Anchors	1	L.S.	$1,000	$1,000
Pipe couplers, flanges, etc.	11	ea.	$150	$1,650
Electrical hook-up	1	L.S.	$1,000	$1,000
Pipe Installation	3	day	$2,500	$7,500
Culvert (CSP) - 1000 mm x 5m long	5	m	$139	$696
Freight	1	L.S.	$5,000	$5,000
Total				**$237,046**

Table 12: Wellington Creek Dyke and Channel Construction Costs

Item	Quantity	Unit	Rate	Cost
Clearing, grubbing, and stripping	0.16	ha	$2,000	$320
Embankment Dykes (Fill)	3,100	m^3	$25	$77,500
Non-Woven Geotextile Supply and Installation	900	m^2	$10	$8,750
Rip Rap – Spillway (overflow)	150	m^3	$200	$30,000
Channel Earthworks (Excavation)	200	m^3	$10	$1,900
Reinforced Turf Mat	900	m^2	$4	$3,600
Turf Mat Installation	275	hr	$75	$20,625
Turf Mat Staples	4	box	$50	$200
Total				**$142,795**

Table 13: Road Culvert Upgrade Costs

Item	Quantity	Unit	Rate	Cost
Topsoil/Traffic Gravel stripping	4,500	m^2	$4	$18,000
Scarify Road Surface	2,464	m^2	$4	$9,856
Excavation	112	m^3	$20	$2,240
Culvert (CSP) 3x1000 mm x15 m long	45	m	$241	$10,863
Embankment Fill	800	m^3	$25	$20,000
Backfill around new Culvert	60	m^3	$25	$1,500
Rip Rap Culvert Outlet	17	m^3	$200	$3,360
Traffic Gravel	185	m^3	$30	$5,550
Total				**$71,369**

m^2 = square metre.

Table 14: Diversion Dyke and Gated Culvert Costs

Item	Quantity	Unit	Rate	Amount
Clearing, grubbing, and stripping	0.18	ha	$2,000	$360
Earthworks (Excavation)	900	m^3	$6	$5,400
Embankment Dykes (Fill)	1,920	m^3	$25	$49,500
Non-Woven Geotextile Supply and Installation	1,140	m^2	$3	$3,420
Reinforced Turf Mat	1,140	m^2	$4	$4,560
Turf Mat Installation	57	hr	$75	$4,275
Turf Mat Staples	15	box	$50	$750
Rip Rap - Spillway	341	m^3	$200	$68,200
Culvert 900-mm	30	m	$105	$3,150
Culvert Installation	1	L.S.	$10,000	$10,000
Sluice Gate and Flange - (gated culvert)	1	NA	$8,500	$8,500
Subtotal				**$158,115**

8.0 CONCLUSION

The proposed diversion plan is intended to redirect some of the surface water inflow that normally reports to Little Manitou Lake into the larger Boulder Lake drainage system, which joins Lanigan Creek prior to discharging to Last Mountain Lake. The diversions would use mainly existing natural flow pathways and an existing constructed diversion channel to convey the flow to Boulder Lake. To accomplish the diversion, two low level dykes, one with a control structure, a large capacity pump and approximately 2,200 metres (m) pipe are proposed. Additional works include minor channel excavation, culvert installation and a road grade raise.

With the diversion works in place, most of the diverted flow will be redirected to the dyke adjacent to the existing channel and subsequently to Boulder Lake via the existing channel; however, the actual flow that is redirected to the existing channel is less than the potential volume which is governed by the configuration of the dyke and the existing channel invert elevation and slope. For discharges greater than about 2 m^3/s, part of the discharge begins to flow over the spillway and downstream to Freshwater Lake.

The daily hydrograph for the annual average and wet year indicate that during an average year almost 100% of the redirected flow can be diverted to the existing channel leading to Boulder Lake, while during wet years likely about 84% of the redirected flow can be diverted to the existing constructed channel. In a wet year, portions of the peak flow, mostly in April, will not be diverted but will pass over the spillway and downstream to Freshwater Lake.

The costs to proceed with the Little Manitou Lake water inflow management plan were estimated to be about $1,236,410. An annual estimated operating cost of $26,000 is expected to cover maintenance and electrical costs for eight months per year.

Report Signature Page

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Golder Associates Ltd.
Number C0230

Permission to Consult held by:

Discipline	Sk. Reg. No.	Signature
Water resources	13702	MB
Geotech	6087	

Golder Associates

LIMITATIONS

This report presents a preliminary conceptual design for a diversion to help control Little Manitou Lake levels. The design concept has been selected in part based on an analysis of the options and client preferences. The design is based on limited information, including a survey, field visits in July and August, 2014 and stream flow measurements in March 2015. The factual data, interpretations and recommendations are not applicable to any other project or site location. Any change of site conditions, purpose, development plans, or if the project is not initiated within twelve months of the report date may alter the validity of the report.

REFERENCES

Dunne, T., Leopold, L.P. 1978. Water in Environmental Planning. W.H. Freeman and Company. New York, NY.

Sask-Water 1993. Magnitude and Frequency of Peak Flows and Flow Volumes in Saskatchewan. Water Management Division Hydrology Branch, April 1993. Summary Report and Users Manual.

Golder 2014. Survey Results and Inspection of Drainages in the Vicinity of Little Manitou Lake and Options for Inflow Management. September 2014.

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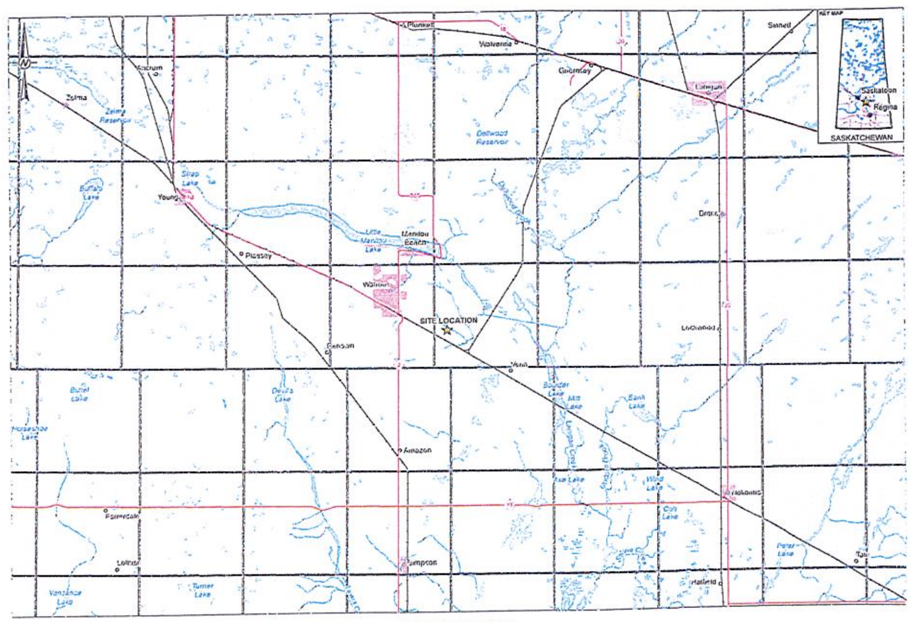
APPENDIX A

Drawings

WATER SECURITY AGENCY
MANITOU LAKE WATER MANAGEMENT DESIGN

SITE VICINITY
SCALE: NTS



SITE LOCATION
SCALE: NTS

DRAWING LIST TABLE	
CIVIL	
001	GENERAL ARRANGEMENT
002	PIPE ROUTE PLAN AND PROFILE
003	DIVERSION DYKE REDIRECT CHANNEL AND ROAD GRADE RAISE
004	DIVERSION DYKE AND REDIRECT CHANNEL PROFILES
005	ROAD GRADE RAISE AND CULVERT INSTALLATION PROFILE
006	PLAN VIEW AND CROSS SECTIONS FOR DYKE AND CONTROL STRUCTURE
007	TYPICAL SECTIONS FOR DIVERSION DAM, REDIRECT CHANNEL AND ROAD GRADE RAISE
008	TYPICAL SECTION FOR CULVERT INSTALLATION

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COVER SHEET

SAMPLING / MONITORING

- BOREHOLE LOCATION
- BOREHOLE LOCATION (BY OTHERS)
- BOREHOLE LOCATION (PROPOSED)
- MONITORING WELL LOCATION
- MONITORING WELL LOCATION (BY OTHERS)
- MONITORING WELL LOCATION (PROPOSED)
- PIEZOMETER LOCATION
- PIEZOMETER LOCATION (BY OTHERS)
- PIEZOMETER LOCATION (PROPOSED)
- TEST PIT LOCATION
- TEST PIT LOCATION (BY OTHERS)
- TEST PIT LOCATION (PROPOSED)
- SOIL SAMPLE
- HAND AUGER
- INCLINOMETER LOCATION (EXISTING)
- INCLINOMETER LOCATION (PROPOSED)
- CPT LOCATION (EXISTING)
- CPT LOCATION (PROPOSED)
- WATER WELL DRY
- WATER WELL - ELOG
- WATER WELL FIELD VERIFIED
- WATER WELL PRODUCING
- INJECTION WELL

SURVEY SYMBOLS

- BENCHMARK
- CONTROL POINT
- FOUND IRON PIN (FIP)
- DESIGN GRADE

GENERAL FEATURES & SYMBOLS

- CULVERT LOCATION (SMALL DIAMETER)
- CULVERT LOCATION (LARGE DIAMETER)
- LIGHT STANDARD
- MANHOLE
- CATCH BASIN
- FIRE HYDRANT
- SIGN
- POWERPOLE
- BREAKLINE
- DEPOSITION LOCATION
- FLOW DIRECTION
- GRADE INDICATOR
- SLOPE DIRECTION
- WATER SURFACE
- 1V 2H SLOPE LABEL
- PROJECT LOCATION STAR

LINETYPES - UTILITIES

ABANDONED EXISTING

- FO FIBER OPTIC LINE
- NG NATURAL GAS LINE
- NPW NON POTABLE WATER LINE
- OH OVERHEAD POWERLINES
- PW POTABLE WATER
- PWR POWERLINE
- SS SANITARY LINE
- ST STORM DRAIN
- TEL TELEPHONE LINE
- T TRANSMISSION LINE
- UG UNDERGROUND LINE
- WW WASTE WATER
- W WATER LINE

LINETYPES - PLAN FEATURES

EXISTING NEW

- X FENCE LINE
- DITCH
- SF SILT FENCE
- SB STRAW BALE
- SWALE
- GUARDRAIL
- TREELINE
- CENTERLINE (ALIGNMENT)
- DESIGN LINES
- 930 930 MAJOR CONTOUR
- 931 MINOR CONTOUR
- PERFORATED PIPING
- PIPELINE
- SOLID PIPING
- PROPERTY LINE
- RAIL LINE
- TMA BOUNDARY
- WORKING LIMITS

LINETYPES - SECTIONS / DETAILS / PROFILES

- EXISTING GROUND
- NATURAL / ORIGINAL GROUND
- FINISHED GRADE
- HATCH BOUNDARY
- HDPE HDPE LINER
- LINER LINER OTHER
- NON-WOVEN GEOTEXTILE
- PROJECTED EMBANKMENT
- STRIPPED GROUND
- SUBGRADE / SUBCUT
- TOPSOIL
- WOVEN GEOTEXTILE
- GW GROUNDWATER
- SOLID PIPING
- PERFORATED PIPING

HATCH PATTERNS

- ASPHALT
- CONCRETE
- FILL
- TRAFFIC GRAVEL
- GRANULAR BASE COURSE
- GRANULAR SUBBASE COURSE
- GRANULAR FILL
- RIPRAP - CLASS A
- RIPRAP - CLASS B
- RIPRAP - CLASS I
- RIPRAP - CLASS II
- SAND FILL
- TOPSOIL
- PEAT
- CLAY
- GABION
- TAILINGS
- OVERBURDEN
- BEDROCK

GENERAL LABELS

- MATCH LINE — MATCH LINE
- DETAIL BUBBLE
- 2+500 2+500 — ALIGNMENT STATION LABEL
- 1 203 — DETAIL CALLOUT
- A 203 — SECTION CALLOUT
- SCALE 1:100 VERT. SCALE 1:50 A 203 CROSS SECTION A-A — SECTION TITLE
- SCALE 1:100 1 203 DETAIL — DETAIL TITLE
- PROFILE SCALE 1:1000 — VIEW TITLE
- 1 — REV CLOUD & CALLOUT
- ELEV. 501.00m — ELEVATION LEVEL
- LT-11-05 — BOREHOLE IDENTIFIER
- CPT-LT-11-30 — CPT IDENTIFIER
- CPT Q_t CURVE
- CONDUCTIVITY CURVE

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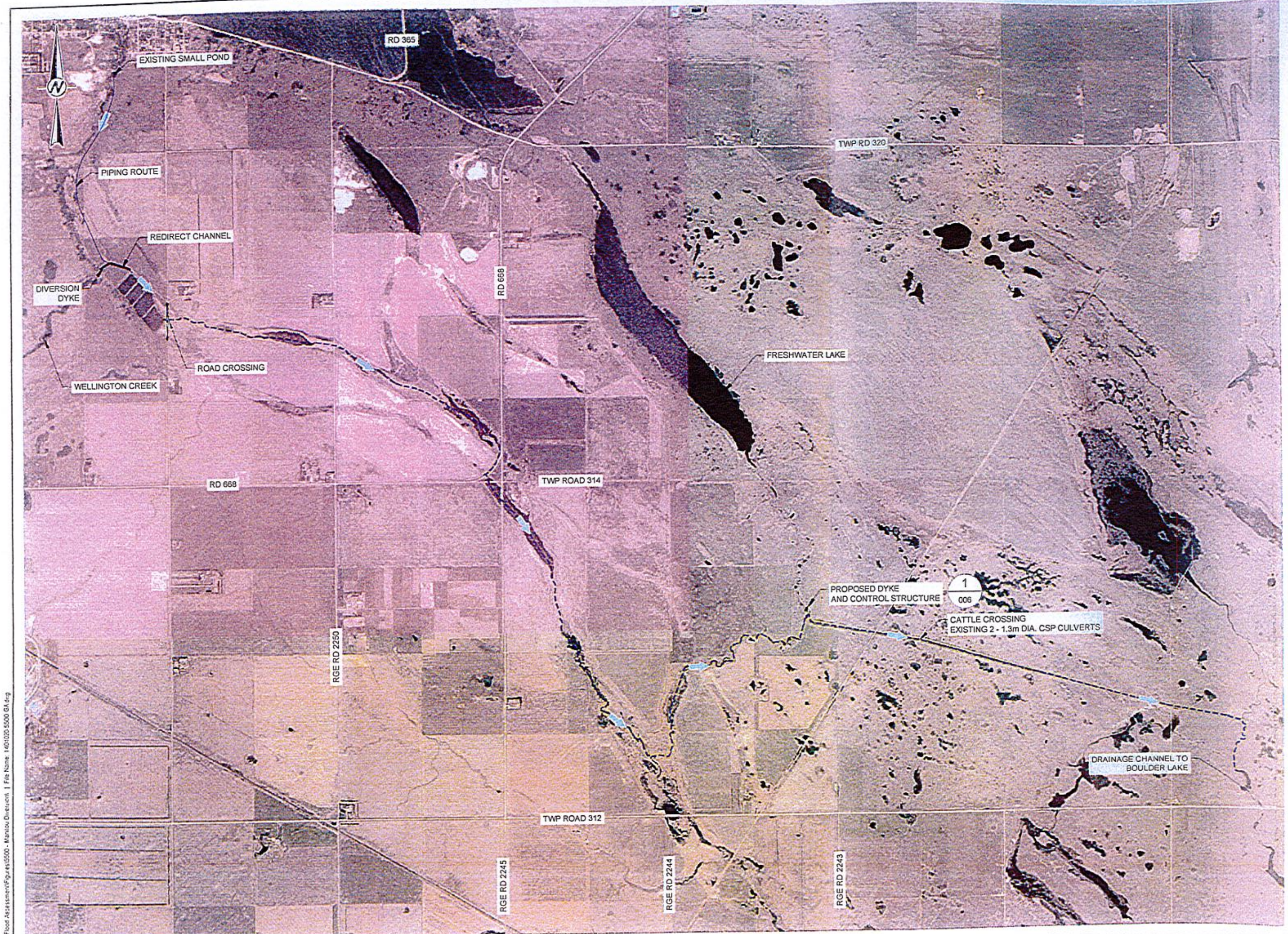
LEGEND SHEET



NOTES
1. VERTICAL DATUM: LOCAL DATUM
2. HORIZONTAL DATUM: LOCAL GRID
3. UNITS ARE METRES UNLESS OTHERWISE NOTED

0 1,000 2,000
1:20,000 METRES

Rev	YYYY-MM-DD	DESCRIPTION	PREPARED	DESIGN	REVIEW	APPROVED
A	2015-07-31	ISSUED FOR REVIEW	JDS	JDS	BT	LG

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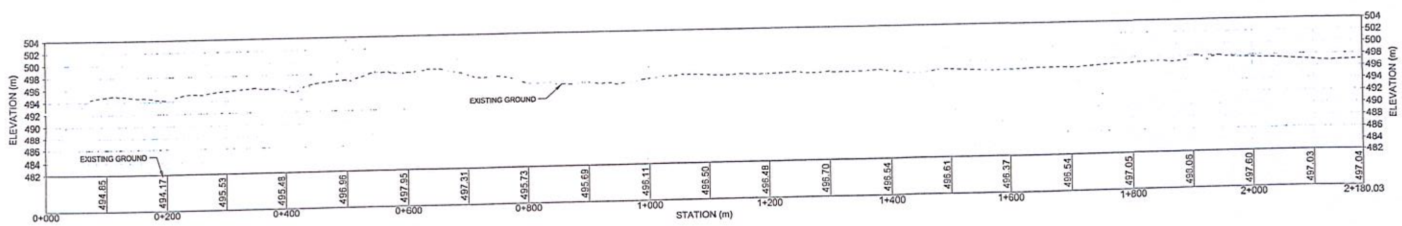
PROJECT
MANITOU LAKE WATER MANAGEMENT DESIGN

TITLE
GENERAL ARRANGEMENT

PROJECT No. 1404020
Rev A
001

PLAN VIEW
SCALE 1:4000



PROFILE
SCALE 1:4000
VERTICAL SCALE 1:400

NOTES
1. TOPOGRAPHIC SURFACE GENERATED FROM GOLDER SURVEY 2014-09 (4 DAYS).
2. VERTICAL DATUM: LOCAL DATUM.
3. HORIZONTAL DATUM: LOCAL GRID, UTM ZONE 13.
4. UNITS ARE METRES UNLESS OTHERWISE NOTED.
5. BLUE LINEWORK REPRESENTS THE PRELIMINARY EXPANSION PLAN FOR THE TOWN OF WATROUS LAGOONS.

0 20 40
1:400 METRES

0 200 400
1:4,000 METRES

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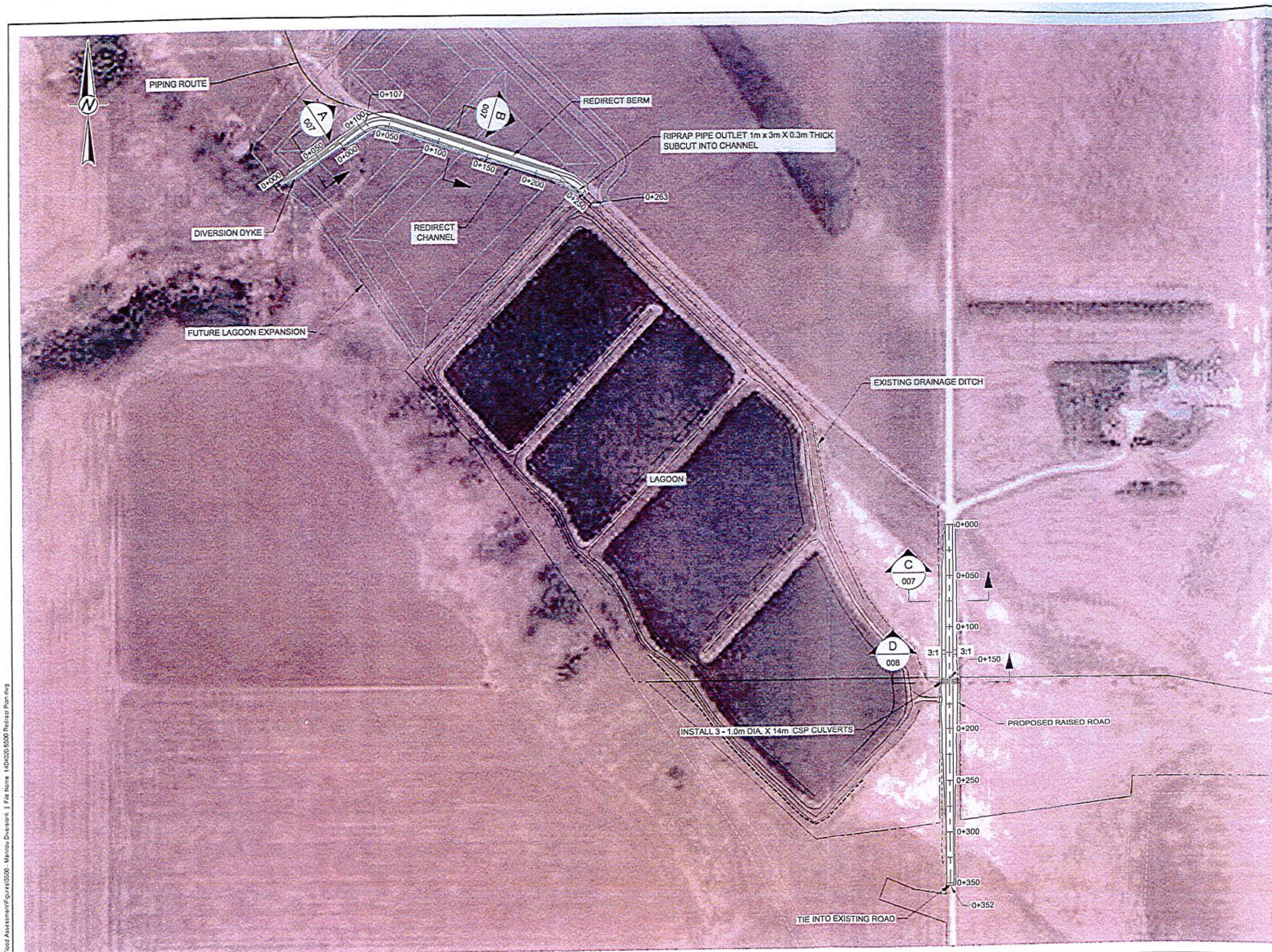
PROJECT
MANITOU LAKE WATER MANAGEMENT DESIGN

TITLE
PIPE ROUTE PLAN AND PROFILE

PROJECT No 1404020
Rev A
002

25 mm
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI D



NOTES

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2. VERTICAL DATUM: LOCAL DATUM
3. HORIZONTAL DATUM: LOCAL GRID, UTM ZONE 13
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5. BLUE LINEWORK REPRESENTS THE PRELIMINARY EXPANSION PLAN FOR THE TOWN OF WATROUS LAGOONS.

0 100 200
1:2,000 METRES

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PROJECT
MANITOU LAKE WATER MANAGEMENT DESIGN

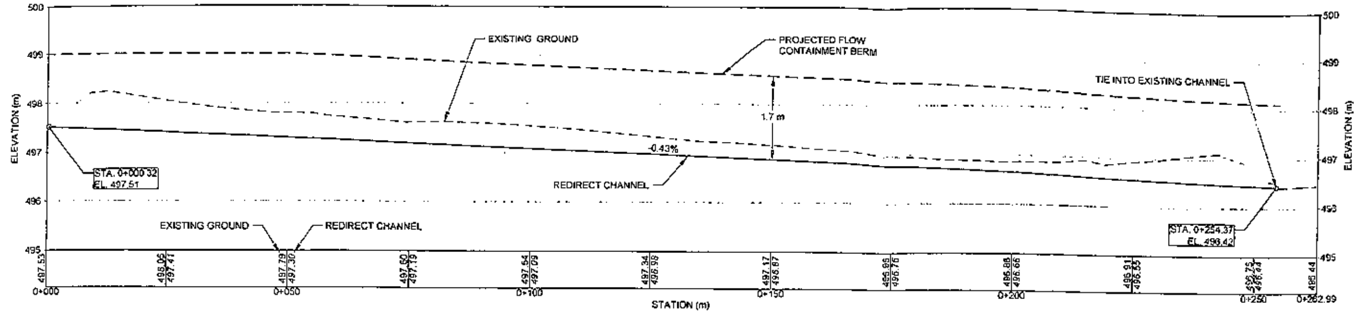
TITLE
DIVERSION DYKE REDIRECT CHANNEL AND ROAD GRADE RAISE

PROJECT No 1404020
Rev A
003

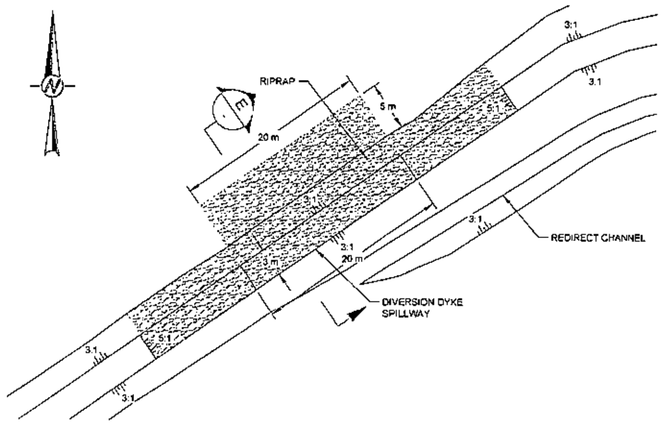
Path: \\golder.gds\gal\saskatoon\gis\2014\1404020 - WSA Flood Assessment\Figures\5500 - Manitou Diversion\ | File Name: 1404020-5500 Redirect Plan.dwg

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI D
25 mm

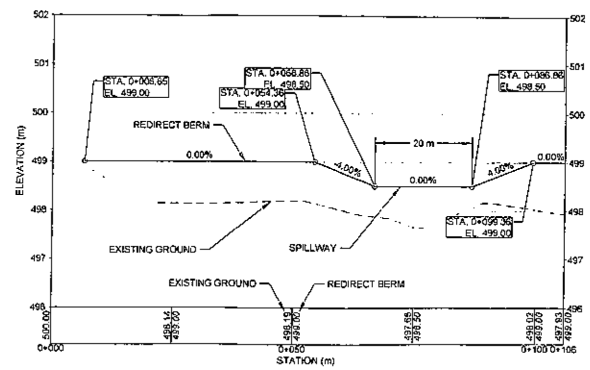
NOTES
1. TOPOGRAPHIC SURFACE GENERATED FROM GOLDER SURVEY 2014-09 (4 DAYS)
2. VERTICAL DATUM: LOCAL DATUM
3. HORIZONTAL DATUM: LOCAL GRID, UTM ZONE 13
4. UNITS ARE METRES UNLESS OTHERWISE NOTED.



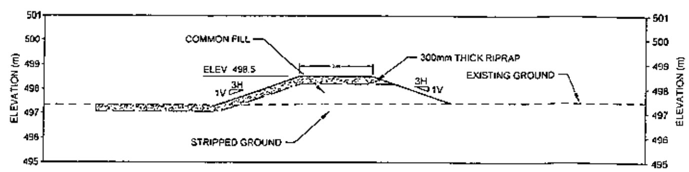
REDIRECT CHANNEL AND BERM - PROFILE
HORIZONTAL SCALE 1:500
VERTICAL SCALE 1:50



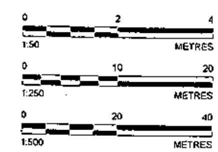
SPILLWAY - PLAN
SCALE 1:250



DIVERSION DYKE - PROFILE
HORIZONTAL SCALE 1:500
VERTICAL SCALE 1:50



SCALE 1:100 E CROSS SECTION E



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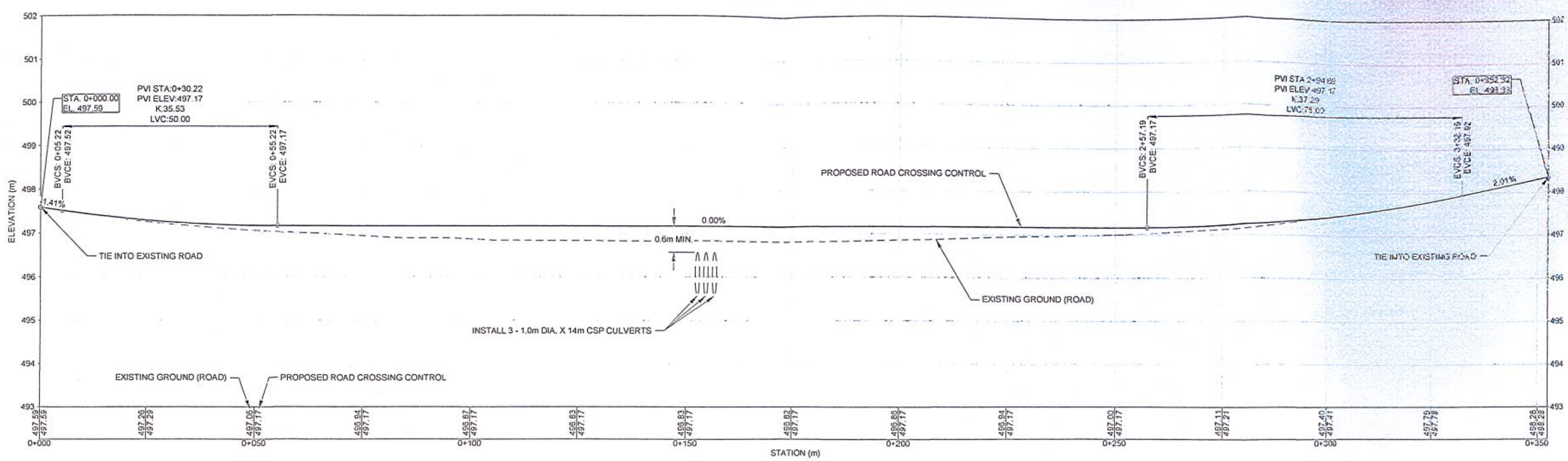
PROJECT
MANITOU LAKE WATER MANAGEMENT DESIGN

TITLE
DIVERSION DYKE AND REDIRECT CHANNEL PROFILES

PROJECT No 1404020
Rev A
004



PROPOSED ROAD CROSSING - PROFILE
HORIZONTAL SCALE 1:500
VERTICAL SCALE 1:50

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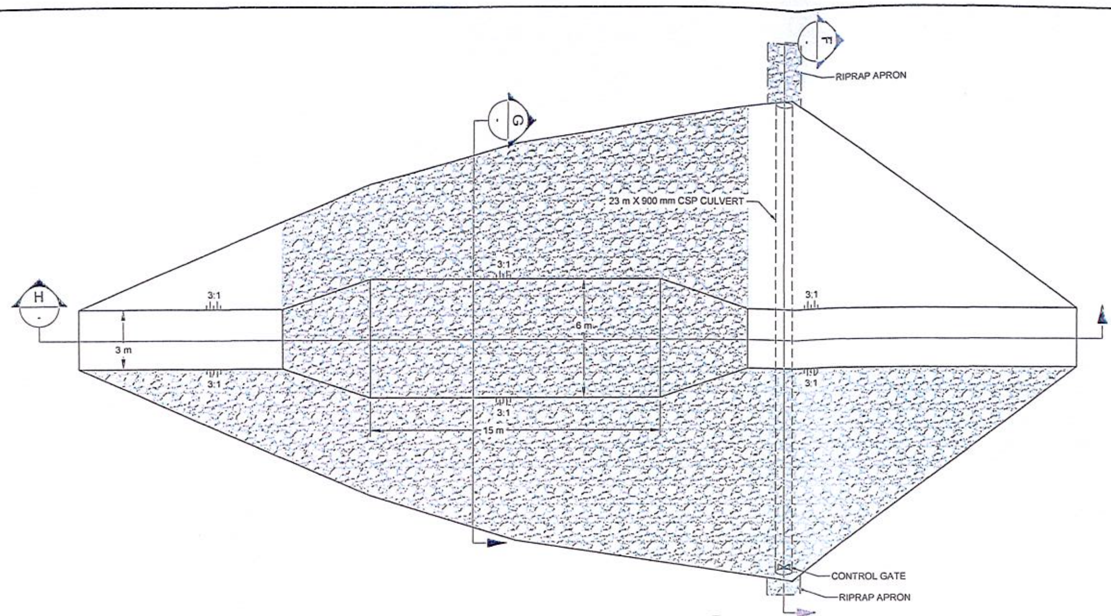
PROJECT
MANITOU LAKE WATER MANAGEMENT DESIGN

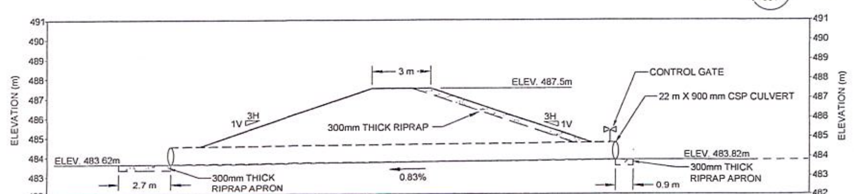
TITLE
ROAD GRADE RAISE AND CULVERT INSTALLATION PROFILE

PROJECT No 1404020
Rev A
005

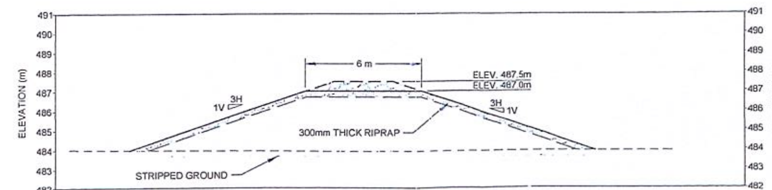
NOTES
1. UNITS ARE METRES UNLESS OTHERWISE NOTED.



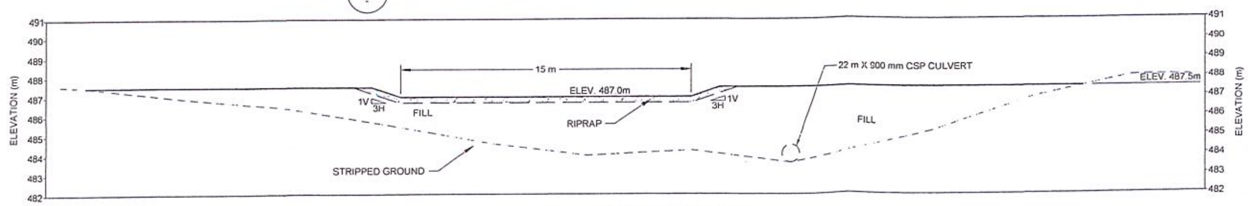
SCALE 1:125 1 / 001 PROPOSED DYKE



SCALE 1:125 F CROSS SECTION F



SCALE 1:125 G CROSS SECTION G



SCALE 1:125 H CROSS SECTION H

0 5 10
1:125 METRES

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PROJECT
MANITOU LAKE WATER MANAGEMENT DESIGN

TITLE
PLAN VIEW AND CROSS SECIONS FOR DYKE AND CONTROL STRUCTURE

PROJECT No 1404020
Rev A
006

NOTES
1. TOPOGRAPHIC SURFACE GENERATED FROM GOLDER SURVEY 2014-09 (4 DAYS).
2. VERTICAL DATUM: LOCAL DATUM
3. HORIZONTAL DATUM: LOCAL GRID
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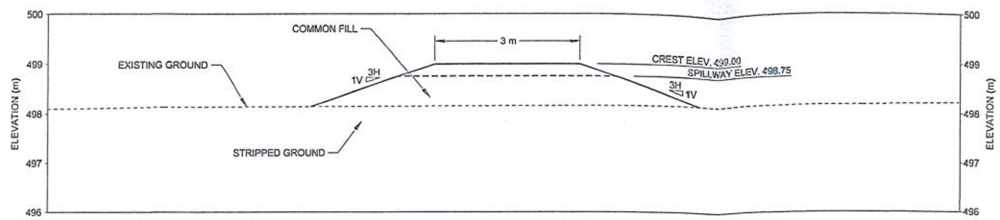
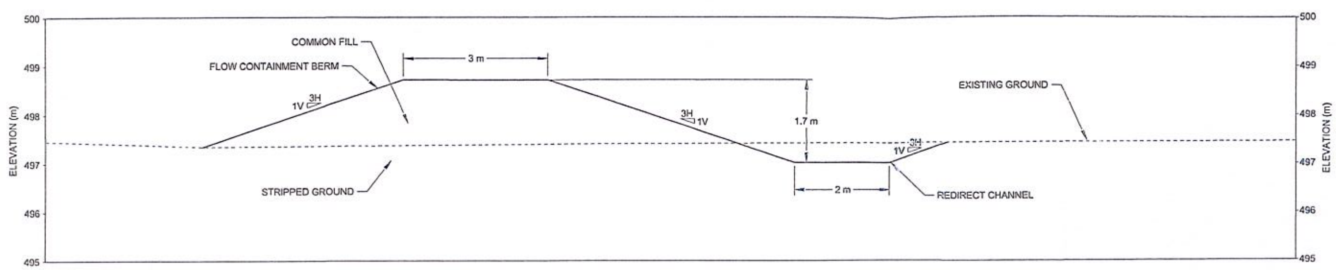
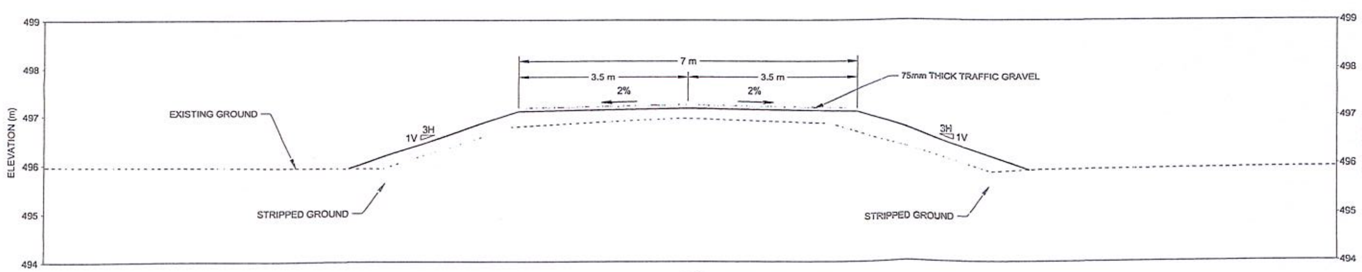


SCALE 1:50 A 003 CROSS SECTION A



SCALE 1:50 B 003 CROSS SECTION B



SCALE 1:50 C 003 CROSS SECTION C

0 2 4
1:50 METRES

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PROJECT
MANITOU LAKE WATER MANAGEMENT DESIGN

TITLE
TYPICAL CROSS SECTIONS FOR DIVERSION DYKE, REDIRECT CHANNEL AND ROAD GRADE RAISE

PROJECT No 1404020
Rev A
007

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI D
25 mm

NOTES
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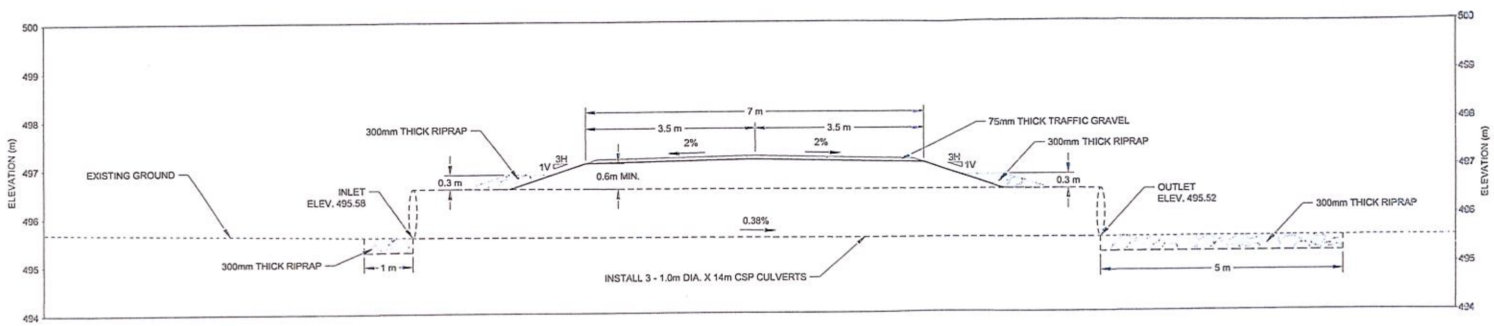

SCALE 1:50 D 003 CROSS SECTION D

0 2 4
1:50 METRES

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PROJECT
MANITOU LAKE WATER MANAGEMENT DESIGN

TITLE
TYPICAL CROSS SECTION FOR CULVERT INSTALLATION

PROJECT No 1404020 Rev A 008

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