REGIONAL MUNICIPALITY OF WOOD BUFFALO



FORT MCMURRAY FLOOD PROTECTION
CONCEPTUAL DESIGN

nhc
northwest hydraulic consultants

FORT McMURRAY FLOOD PROTECTION CONCEPTUAL DESIGN

Submitted to:

Regional Municipality of Wood Buffalo

Fort McMurray, Alberta

Submitted by:

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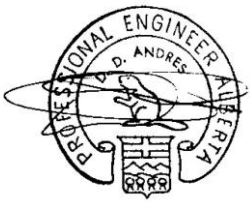
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August 2014

APEGGA Permit P00654

NHC project # 100165

EXECUTIVE SUMMARY

This report presents an evaluation of flood risks and preliminary conceptual designs for a flood protection system for the Lower Townsite, Waterways, and Ptarmigan Court within Fort McMurray in the Regional Municipality of Wood Buffalo. The objective is to provide flood protection up to the 100-year flood hazard for these areas of Fort McMurray for both ice-related and open water floods.

An updated assessment of the ice-related flood risks due to breakup on the Athabasca River indicates that the ice jam flood frequency curve adopted in 1991 has not changed in spite of somewhat severe ice jam events in 1997 and 2013. The 100-year ice-related flood level remains at elevation 250.0 m. The 1874 flood, which is the largest flood on record with an estimated elevation of 252.0 m is approximately the 500-year flood.

Analyses of open water flood risks for the Clearwater and Hangingstone rivers, indicate that water levels at the 100-year floods are within the banks of both streams at Fort McMurray. Ice-related flooding dominates along the margins of the Clearwater River and along the Hangingstone River downstream of King Street. Upstream of King Street and in the vicinity of Grayling Terrace, the 100-year open water flood on the Hangingstone River exceeds the ice-related flood level, but the 100-year levels of both types of flood are below the level of the terrace.

Four flood protection structure types have been adopted to provide a structural flood protection system that integrates with the existing development: (i) earthen dikes and retaining walls, (ii) raised roadways, (iii) floodwalls, and (iv) floodgates. Protection for the Lower Townsite extends along the Clearwater and Hangingstone rivers from MacDonald Drive to King Street. This protection would be composed mostly of dikes, raised roadways (Prairie Loop Boulevard), and floodwalls – selected on a reach by reach basis to fit into the existing and proposed development. Waterways would be protected with a combination of flood walls and dikes paralleling Saline Creek Drive. Ptarmigan Court would be protected with a high floodwall located along the margins of the Hangingstone River and Saline Creek because there is limited space to construct an earthen dike. The flood wall would tie into Tolen Road.

The three zones of flood protection – Lower Townsite, Waterways, and Ptarmigan Court – are differentiated on the basis of the elevations of existing local roads and the need to accommodate the Hangingstone River. Approximately 6.2 km of structure will be required for the Lower Townsite, 2.7 km for Waterways, and 0.6 km for Ptarmigan Court. Depending on the options chosen, the cost of protecting the entire area would be between $141 million and $155 million, including engineering costs and contingencies but not including inflationary costs and owner costs over the duration of the construction. Approximately 80 percent of the costs would be allocated to the Lower Townsite, 15 percent to Waterways, and 5 percent to Ptarmigan Court.

There are only a limited number of opportunities for a staged approach to providing flood protection. While a flood damage cost-benefit type of analysis has not been undertaken herein, the greatest flood damages would occur in the Lower Townsite, followed by Waterways and Ptarmigan Court. From a damage prevention and development perspective, the Lower Townsite would likely have priority. From an implementation perspective, Waterways would be the easiest to undertake with the least impact on local residents. Flood protection for Ptarmigan Court would be more intrusive and would require some public consultation.

While the dikes, floodwalls, and flood gates have been located in the most practicable way possible given what development would be reasonably expected to occur, not all the issues have been resolved. Some areas simply cannot be protected in a practicable way. The Coast Guard property may have some historical value, but it cannot be protected in its entirety. Also, concerns will remain about flood-related dangers to people and infrastructure outside of the flood protection, including the development along the Snye, the Horse Pasture, and rural residences southeast of Waterways. In some locations (Riverwalk Villas) floodgates will be required to allow access to areas adjacent to the Clearwater River. These will need to be installed for a few days in advance of a severe breakup. Effort will still need to be made each year to forecast the timing and severity of flooding and to warn residents of the impending floods.

Flood protection for Lions Park may be problematical from a flow conveyance perspective and because of its low elevation. It is situated lower than the design flood by up to three metres and would be inundated by at least one metre during the design open water flood on the Hangingstone River. The area would be classified as “floodway” and potential flood mitigation works in the park could increase water levels upstream – especially since the floodplain in the area of Heritage Park would be diked off. Furthermore, construction of a dike would require a large footprint and substantially reduce connectivity between the park and the Hangingstone River. Based upon current land use and hazard levels, flood protection for Lions Park is not recommended.

With respect to private lands, the issues become a little more complex. No protection will be provided for the vacant and forested property located east of Prairie Loop Boulevard and north of Franklin Avenue between the Clearwater River and Longboat Landing. Furthermore, discussions with owners of flood proofed properties that the proposed flood protection structures will tie into need to be undertaken to develop a consensus on how to proceed with the construction.

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1 INTRODUCTION

In the last number of years there has been a heightened recognition of the flood threat to Fort McMurray and Waterways – the urban area of the Regional Municipality of Wood Buffalo (RMWB) – designated herein as Fort McMurray. This increased sensitivity has developed in part due to ice-related and open water flood events that occurred in 1997 and 2013. Furthermore, significant flood damages elsewhere in Alberta in 2013 have led to a renewed incentive to develop and implement a flood protection plan.

In 2000, Trillium Engineering and Hydrographics Inc. (Trillium, 2000) examined the feasibility of constructing dikes to reduce the flooding potential in Fort McMurray. The study confirmed the 40-year ice jam flood elevation to be 248.5 m and the 100-year ice jam flood elevation as 250.0 m. The study identified reasonable flood protection alignments, given the streetscapes of the day, and recommended a staged flood mitigation approach that would ultimately result in providing protection up to the 100-year ice jam level, including 0.5 m of freeboard. The potential for interim protection up to the 40-year flood level was also assessed with a plan to compartmentalize the flood protection during the period over which the protection would have been brought up to the recommended 100-year level.

In 2013, RMWB formally adopted the 100-year flood elevation [1] as the design flood protection elevation and proposed a new preliminary flood protection concept based on considerations of existing and future developments, both of which are substantially different than those expected in 2000. Northwest Hydraulic Consultants Ltd. (NHC) was retained to update the Trillium analysis and develop conceptual designs based on updated information. NHC subcontracted Associated Engineering Ltd. (AE) to assist with the concept design and cost estimation.

The objectives of this report are as follows.

(1) Provide an assessment of the potential to provide an equal level of flood protection from flooding via the Athabasca, Clearwater, and Hangingstone rivers for all the existing development in Fort McMurray.
(2) Update the ice jam flood frequency curve.
(3) Perform an open-water hydrologic analysis along the Clearwater and Hangingstone rivers and identify the 100-year open water flood levels along each of them.
(4) Develop feasible flood protection concepts that take advantage of the existing flood proofing, current roadways, and positive topographic features to minimize construction costs.
(5) Provide preliminary pre-design cost estimates of the flood protection system.

[1] John Buchko, personal communication.

The following sections summarize the work that has been undertaken to address the above objectives. Included in the report are figures illustrating the results of the hydrologic and hydraulic analysis, plans showing recommended dike alignments, photos showing existing conditions along the proposed alignment, and drawings illustrating the flood protection concepts. Tables summarizing the estimated costs of the various flood protection alternatives are also provided.

2 DESIGN FLOOD LEVELS

2.1 DESIGN ICE JAM FLOOD LEVELS

2.1.1 PREVIOUS STUDIES

Flooding from high water levels due to ice jams during breakup has been a significant factor at Fort McMurray since the earliest fur traders arrived at the confluence of the Clearwater and Athabasca rivers in 1870 (***Figure 1***). Severe ice jams have caused water levels to exceed 247.5 m five times since that date. These severe floods, which occurred in 1875, 1885, 1928, 1936, and 1977, all caused significant concern and/or damage. In the modern era, the highest ice jam level occurred in 1977 when water levels peaked at 247.9 m at the mouth of the Clearwater River where it enters the Athabasca River. Another particularly alarming flood occurred in 1997 when the river peaked at an elevation of 247.5 m (***Figure 2***).

Substantial work has been undertaken to study the breakup processes and to investigate methods to reduce the ice jam-related flood damages within Fort McMurray. Blench (1964) undertook the first review of the situation. Based upon historical ice jam records, but on a somewhat limited appreciation of the breakup processes, he suggested that the jams were caused in part by the outflow of water up the Clearwater River (as the ice jam surge moved past the mouth) and the subsequent loss of conveyance in the Athabasca River channel downstream. He recommended the construction of the Snye Dike to reduce the outflow of water. This structure was constructed in the middle 1960s.

The dike was constructed to an elevation of 252.0 m and it effectively blocked off the Snye Channel from direct communication with the Athabasca River. Although ineffective in preventing ice jams, the dike reduced the ice jam levels in the Clearwater River by about one metre owing to the fact that the effective backwater levels from the Athabasca River were moved downstream a distance of about 2.5 km.

Interest in ice jam flooding increased after the 1977 event. The Fort McMurray Flood Damage Abatement Technical Committee comprised of personnel from the Fort McMurray, Alberta Environment, Alberta Transportation and Utilities, and Alberta Municipal Affairs was established to investigate flood mitigation measures. In addition to updating the flood risks and identifying

the damages that resulted from the 1977 event, a number of flood mitigation/protection schemes were examined. These included the following.

(1) Channel modification on the Athabasca River downstream to prevent ice jams from occurring.
(2) Diking along the Clearwater River to contain the high water levels.
(3) Improved flood forecasting and disaster management.
(4) Various flood proofing schemes to minimize flood damages.
(5) An ice control structure upstream to prevent ice from flowing past the Fort McMurray and potentially accumulating at the mouth of the Clearwater River.

However, most of the ice control schemes proved to be either ineffective or too costly to implement. Only diking and flood proofing appeared to warrant more investigation. These were re-examined in the early 1980's. Stage damage curves were derived for the urban area, flood damages were defined, and a more detailed design of the dikes was carried out. In 1985, it was estimated that the average annual cost of flooding was $5.8 million, with damages for the 1985 versions of the 25, 50, and 100 year floods to be $35 million, $119 million, and $220 million respectively. The capital costs of providing diking to protect to an elevation of 252.0 m (the adopted 100-year design flood level at the time) was estimated to be $48 million in 1982 dollars. The chosen dike alignment followed along low lying land near the Clearwater River. This would have required large quantities of fill and extensive bank protection works that likely would not to be practical today, given current sensitivities about maintaining natural systems in as pristine state as possible.

The huge impact that the dikes would have made on the landscape and the high cost of diking ultimately made the diking option unattractive, even though cost benefit studies at the time suggested that the dikes would be good investment. Instead, a rigorous flood plain management plan was implemented, with flood proofing to an elevation of 249 m or higher being required for all new development and backwater valves, etc. provided for all existing development.

In addition to examining methods to reduce flood damages, a more rigorous flood forecasting scheme was implemented after the 1977 flood. Alberta Environment, in co-operation with the Alberta Research Council began systematically monitoring breakup and measuring ice jams when they formed. A good understanding of the basin-wide breakup process, from the Pembina River down through the upper Athabasca River between Athabasca Town and Fort McMurray, was developed. The hydromechanical characteristics of the ice jams were measured and ice jam models were calibrated so that ice jam levels could be simulated for a wide range of flows during breakup. Although work is still required to develop a procedure to forecast snowmelt runoff in the Athabasca River during breakup, the installation of continuous monitoring stations upstream of Fort McMurray provides from two to twenty-four hours of advanced notice of breakup to residents.

The flood situation was re-examined as part of the Canada-Alberta Flood Damage Reduction Program in 1991 (AENV, 1991). Using alternative analytical techniques and an updated hydrologic record, the ice jam flood level frequency curve was re-defined. The new 100-year flood level was estimated to be at an elevation of 250.0 m (two metres below the previous value) and the 50-year flood level was lowered also by about two metres to 248.9 m.

The updated flood frequency curve also affected the calculation of the average annual flood damages. In 1994, the annual flood damages were estimated to be $5.9 million in 1992 dollars, while the capital cost of the lower dike was estimated to be $48 million. The reduction in cost due to the lower dike was offset by the increase in the cost of construction and land. As in the previous planning exercise, there was a lack of commitment to the dike because of the large capital cost and the huge effect that the dike would have on the landscape. Regardless, in terms of economics alone, it was re-affirmed that diking to protect against the 100-year flood was still a viable option.

2.1.2 ICE JAM FLOOD LEVEL FREQUENCY CURVE UPDATE

The last frequency analysis of ice jam levels was undertaken by Trillium (2000) using data gathered up to 1999, including the historical (pre-1977) data. The analysis was based on the conventional approach, which weights the historical data according to the time period that the data represents and on the basis of a critical elevation for which historical floods below that elevation would not be recorded. The adopted statistical parameters (mean, standard deviation, and skew) are weighted according to the length of record associated with the selected critical elevation and the frequency curve is calculated.

For the present study, the data set used by Trillium (2000) was extended to 2013 and the ice jam frequency curve was updated. The updated peak ice jam levels at Fort McMurray over the historical period between 1875 and 2013 are shown in ***Figure 2*** and the ice jam frequency curve for the updated data set is shown in ***Figure 3***. It should be noted that, consistent with the Trillium (2000) analysis, the historical ice jam levels observed prior to the construction of the Snye Dike have been lowered by one metre to reflect the effects of the dike.

While the addition of the recent data has changed the shape of the curve at the shorter return periods, it has little impact on the upper end of the curve because it is dominated by the high historical levels experienced in the 1800s and mid to late 1900s. The results of the 2000 analysis, the 2013 analysis, and the recommended flood levels for a range of return periods are summarized in ***Table 1***. Since there has not been a big change in the flood levels relative to the Trillium analysis, and that analysis did not provide a significant enough departure from the frequency curve developed by Alberta Environment (AENV, 1991), it is again recommended that the AENV 1991 frequency curve be adopted for planning purposes, as shown in ***Table 1***.

Table 1 Ice jam flood level frequencies at Fort McMurray

Annual Exceedance Probability (percent)	Return Period (years)	Water Levels along Clearwater River (m)		
		Results of 2000 Analysis [1]	Results of 2013 Analysis	Recommended Levels [2]
1	100	249.8	249.6	250.0
2	50	248.7	248.6	248.9
2.5	40	248.4	248.2	248.5
5	20	247.2	247.1	247.2
10	10	246.1	246.0	246.0
50	2	243.2	242.9	243.2

[1] Trillium (2000)
[2] AENV (1991)

2.2 OPEN WATER FLOOD LEVELS

Open water flooding along the Athabasca and Clearwater rivers is not problematical given the extreme ice-related water levels that develop on the Athabasca River, and that subsequently produce extreme backwater levels on the Clearwater River and lower Hangingstone River. However, open water flood levels can be higher on the Hangingstone River upstream of about King Street. To provide design flood levels for the upper Hangingstone River and to provide context, this report provides estimates of the open water flood risks on the Clearwater River and the Hangingstone River based on frequency analyses of the Water Survey of Canada (WSC) flood peaks on the Athabasca, Clearwater, and Hangingstone rivers. Corresponding flood levels on the Clearwater and Hangingstone rivers were computed the HEC-RAS modelling framework. The modelled area extends along the Clearwater River from its confluence with the Athabasca River to Draper and along the Hangingstone River from its confluence with the Clearwater River to a point upstream of Grayling Terrace (***Figure 1***).

The hydraulic models were calibrated against measured water levels at existing and discontinued WSC hydrometric stations and against highwater mark surveys carried out in 2013 by NHC and Alberta Environment and Sustainable Resource Development (ESRD). It should be noted that the elevations of the ESRD highwater marks are 0.56 m higher than both the NHC highwater marks and the WSC peak water level. This difference cannot be reconciled with any other topographic, bathymetric, and water level surveys. It appears that the datum used in the recent ESRD highwater mark surveys is higher than that adopted for all previous surveys in the area. The open water flood levels along the Hangingstone River should be viewed as preliminary, pending datum reconciliation by ESRD.

2.2.1 CLEARWATER RIVER

Open water flood levels on the Clearwater River are complex because they can be produced by three mechanisms – (i) high flows only on the Athabasca River that can cause water levels to rise on the lower Clearwater River, (ii) high flows only on the Clearwater River, and (iii) medium to high flows occurring simultaneously on both the Athabasca and Clearwater rivers. The historical variability in the flood peaks for the two rivers is shown in ***Figure 4***. As expected, the peaks on the Athabasca River are much higher than those on the Clearwater, notwithstanding that the Clearwater flows contribute somewhat to the Athabasca peaks. It also is interesting that the two data sets exhibit similar cyclic trends between high and low flow periods even though the flows on the two streams originate from two different geographic areas and the flows on the two rivers are essentially independent of each other (***Figure 5***).

Figure 6 contains the flood frequency curve for the Athabasca River at the WSC gauge downstream of the confluence of the Clearwater River where the flows are composed of the sum of the flows on the Clearwater River and flows on Athabasca River upstream of the confluence. This frequency curve represents the likelihood of experiencing a given flow at the confluence. The likelihood of a particular water level at the confluence being exceeded would be reflected in this curve. The flood frequency curve for the Clearwater River at Draper is shown in ***Figure 7***. This curve represents the probability of experiencing a certain inflow into the study area and would have a bearing on the likelihood of experiencing a particular water level along the Clearwater River upstream of where backwater influences from the Athabasca River typically would vanish. ***Table 2*** contains a summary of the flood frequencies for both of the rivers.

Table 2 Open water flood frequencies at Fort McMurray – Athabasca and Clearwater rivers

Annual Exceedance Probability (percent)	Return Period (years)	Instantaneous Peak Flow (m^3/s)	
		Athabasca River Downstream of Confluence	Clearwater River Upstream of Confluence
1	100	5240	866
2	50	4830	795
5	20	4260	696
10	10	3800	615
50	2	2440	379

The likelihood of some combination of medium to high flows occurring on the Clearwater and Athabasca rivers producing a 100-year event can be estimated by undertaking a joint probability analysis. There are various ways to do this, but the simplest is to construct a matrix that reflects

the probability of experiencing a flow on one river within a given range when the flow is within a given range on the other river. Such a table is quite large and will not be reproduced herein; however, it provides for the construction of a subsequent table that summarize the cumulative joint probabilities and the estimate of various flow combinations that would represent a particular return period or probability of occurrence each year. Estimates of these flows for the 20, 50, and 100-year events are summarized in ***Table 3***.

Table 3 Typical coincident flows on the Athabasca and Clearwater rivers that would represent a range of joint probabilities and corresponding return periods

Athabasca River Flow (m^3/s)	Clearwater River Flow (m^3/s)		
	5 Percent or Return Period of 20 years	2 Percent or Return Period of 50 years	1 Percent or Return Period of 100 years
5240 (1)	-	-	360
4350	400	540	580
3350	-	-	640
2750	440	560	-
2550	-	-	780
2150	-	740	-
1950	-	-	-
1750 (1)	560	-	866

(1) Hydraulic analysis indicates that the most severe combinations of events are the 100-year flood of 5240 m^3/s on the Athabasca River with a corresponding flow of 360 m^3/s on the Clearwater River and a 100-year flood on the Clearwater River of 866 m^3/s and a corresponding flow of 1750 m^3/s on the Athabasca River – see ***Figure 10*** for the most severe water levels.

WSC has established two sets of historical water level records on the Clearwater River - at the old NTCL docks and at Draper. The gauge at the old NTCL docks (termed Clearwater River below Waterways) operated between 1950 and 1975 and is now discontinued. It only provided water level measurements. The gauge at Draper has been operating since 1958 and provides both water level and discharge measurements. The relationship of the water levels measured at the old NTCL docks to discharges measured at Draper and discharges of the Athabasca River is illustrated in ***Figure 8***. It indicates that the water levels at the old NTCL docks are affected significantly by backwater from the Athabasca River. Water levels at Draper are not affected by backwater from the Athabasca River during open water periods, but during periods of high ice-related water levels on the Athabasca River, water levels at Draper rise more or less in concert with those on the Athabasca River.

The computed open water levels along the Clearwater River for a range of water levels on the Athabasca River and a range of Clearwater River flows are shown in ***Figure 9***. The simulated water surface profiles compared well with the measured water levels at the two gauges when using Manning roughness coefficients between 0.025 and 0.028 – with the roughness typically increasing as the flows increase and the Clearwater River bed forms become more significant. Even so, the bed roughness is quite low for a sand bed river.

Figure 10 contains the water surface profiles for the 100-year floods on the Athabasca and Clearwater rivers with a corresponding low flow on the other. The figure also shows the upper envelope of the highest water levels associated with a number of 100-year events as derived from the joint probabilities of experiencing high flows concurrently on both of the rivers. The backwater effects from the Athabasca River extend upstream on the Clearwater River to about Penhorwood Street when the Clearwater flows are low. Upstream of there, the 100-year flood level is reflective of peak flows on the Clearwater River only. ***Table 4*** is a summary of the water levels along the Clearwater River between the confluence and Draper at the composite 100-year flood.

Table 4 Water levels along the Clearwater River for the most severe 100-year flow combination on the Athabasca and Clearwater rivers

Distance Upstream of Confluence [(1)] (m)	Location	100-year Water Level (m)
2,260	Inlet to Snye	243.15
3,410	Alberta Drive	243.18
3,740	Hospital Street	243.18
4,020	Queen Street	243.19
4,480	Marshall Street	243.22
6,390	Hangingstone River	243.73
7,430	Tomlinson Street	244.04
7,650	Horse Pasture	244.06

[(1)] See ***Figure 10*** for the composite water surface profile.

2.2.2 HANGINGSTONE RIVER

Given the dominance of the ice jam floods in the area, a flood hazard study has not been undertaken relative to severe open water flows on the Hangingstone River. However, events in 2013 demonstrated that riparian areas along the left bank downstream of Tolen Drive could be at risk during the 100-year flood event in the absence of ice-related flood mitigation.

The Hangingstone River has been gauged by WSC since 1965 (see ***Figure 1***). The gauge is located along the left bank between Tolen Drive and Hwy 63. ***Figure 11*** contains a representation of the historical flood peaks at the WSC gauge in the period from 1965 to 2013. Note that at the time of the analysis, 2012 and 2013 data had not yet been finalized by WSC and only estimated values were used. Since then, the 2012 peak has been finalized at 34.6 m^3/s – higher than the 24.1 m^3/s used in the analysis. This change will not effect the estimate of the 100-year flood. The June 2013 flood is the highest on record and it is important to include it in the analysis to produce a defensible frequency analysis. ***Figure 12*** is an illustration of the flood frequency curve and ***Table 5*** provides a summary of the flood frequencies. While the statistical analysis suggests that the 100-year flood peak would be 186 m^3/s, it would likely be more defensible to adopt the 2013 flood peak of 197 m^3/s – say 200 m^3/s – as the design flood. This somewhat arbitrary but conservative assumption would increase the design water level at the WSC gauge by about 0.06 m or 60 mm – not a significant amount.

Table 5 Flood frequencies at Fort McMurray – Hangingstone River

Annual Exceedance Probability (percent)	Return Period (years)	Instantaneous Peak Flow (m^3/s)
1	100	186
2	50	159
5	20	123
10	10	96.0
50	2	35.8

The Hangingstone River channel is quite steep and more or less rectangular in shape. Three separate cross sections surveys have been undertaken over the last ten years or so. AE surveyed cross sections during the winter in support of the design of the Prairie Loop Boulevard Bridge. The survey extended from Tolen Drive downstream to the location of the then proposed Saline Creek Drive bridge. NHC surveyed cross sections to be used to support the design of the Saline Creek Drive bridge. The NHC survey extended from the mouth of river at the Clearwater River upstream to the pedestrian footbridge at Ptarmigan Trailer Park. Just recently in 2013, NHC surveyed cross sections in the reach from Tolen Drive upstream to the upstream end of Grayling Terrace.

The quality of the cross sections surveyed by AE are not adequate for hydraulic analysis since the survey was conducted in the winter and ice conditions prevented a rigorous definition of the channel bed. That data were adjusted to define better more realistic channel bed widths that reconciled with later surveys and observed channel characteristics. Nevertheless, when these three surveys are combined they provide a reasonable characterization of the Hangingstone River over its entire length within the developed portion Fort McMurray – notwithstanding the

channel changes that occurred during the 2013 flood. These data, along with the 2013 highwater marks and water levels and flows at the WSC gauge, were used to create a HEC-RAS model for hydraulic analysis.

The credibility of the hydraulic analysis is limited to a certain extent by the lack of a measured discharge at the peak of the 2013 flood that would provide an estimate of the discharge associated with the surveyed highwater marks. The only available calibration data upon which to calibrate the hydraulic model are located at the WSC gauge. The recent highest measured flow and associated water level are 98.6 m^3/s and 248.96 m respectively [2] (***Figure 13).*** The HEC-RAS model was calibrated against that measurement (***Figure 14***) using a Manning roughness of 0.033. The discharge-water level relationship was extended upward to the peak water level at the gauge, determined in part from the highwater mark surveys, to calculate the 2013 peak discharge, assuming that the same roughness would apply at the higher discharge. The extrapolation required to reach the design flood is significant, but the shape of the extrapolated rating curve is reasonable (although different than the WSC shape as might be expected). The simulated water levels elsewhere along the Hangingstone River agree well with the highwater marks.

It should be noted also that joint probabilities of coincident floods on the Clearwater and Hangingstone rivers are also somewhat of a concern. However, as shown in ***Figure 14*** the slope of the Hangingstone River is steep enough (and the 100-year open water level on the Clearwater river is low enough) that the 100-year flood level on the Clearwater River of 243.8 m water at the mouth of the Hangingstone River only extends upstream on the Hangingstone River for a distance of about 250 m. This is well within the bounds of where the ice-jam related water levels would still dominate the flood level.

As shown in ***Figure 14***, the peak historical flows were for the most part within bank. The design flood of 200 m^3/s goes overbank significantly in the vicinity of the Clearwater River and between Prairie Loop Boulevard and Tolen Drive in the vicinity of Heritage Park on the left bank and Lions Park on the right bank. The water would also overtop the bank upstream of Hwy 63, but because most of the development (in Grayling Terrace, for example) is located on a slightly higher terrace level (***Figure 15***), the extent of the design flood would be limited to the margins of the river. A more rigorous analysis along the lines of a conventional flood hazard study would better define the extent of the design flood. This is not within the scope of this study. Given the benign nature of the open water floods upstream of the diked reaches the additional effort would not be worthwhile.

The 100-year open water flood level on the Hangingstone River exceed the 250.0 m ice-related 100-year water level at a point just a few metres downstream of the Hwy 63 bridge. So, while

[2] The gauge height for that measurement is 3.907 m, and its geodetic elevation is determined by adding 245.040 m, which is the recently surveyed "gauge zero" elevation.

the ice jam floods dominate the flood risks downstream of Hwy 63, the open water floods on the Hangingstone River dominate the flood risks upstream of Hwy 63 and throughout Grayling Terrace. ***Table 6*** summarizes the estimated design open water and ice-related levels along the Hangingstone River at various locations.

The cross section shown in ***Figure 15*** illustrates the susceptibility of Grayling Terrace to the 100-year open water flood. It is evident that the level of the terrace upon which the subdivision is situated is about one metre above the design flood level. This provides sufficient freeboard to accommodate uncertainties in the estimated design flood and its corresponding water levels. That being said, slumping of the valley wall along the right bank of the Hangingstone River opposite the subdivision could exacerbate the flood potential, even at lower magnitude floods. It would be useful to undertake an analysis of the geotechnical stability of the valley wall because if it should fail, the flows would be forced out of the river channel and into Grayling Terrace. It is unlikely that any mitigative measures taken on the terrace would prevent significant flood-related damages from occurring. Measures to mitigate this phenomenon should be considered only after the completion of the geotechnical studies.

Table 6 Design open-water and ice-related levels along the Hangingstone River

Distance Upstream of Confluence [(1)] (m)	Location Description	100-year Ice Jam Level (m)	Design Open Water Level (m)
930	Saline Creek Drive	250.0	245.29
1230	Ptarmigan Court bridge	250.0	245.31
1590	Prairie Loop Boulevard	250.0	247.77
1840	Extension of Penhorwood Street	250.0	248.47
2070	Downstream end of Tolen Drive	250.0	249.29
2150	WSC gauge	250.0	249.80
2210	Downstream end of Hwy 63 bridges	250.0	250.0
2260	Downstream end of Grayling Terrace	-	250.47
2730	Upstream end of Grayling Terrace	-	252.30

[(1)] See ***Figure 14*** for the water surface profile.

3 FLOOD PROTECTION SYSTEM DESIGN

3.1 DESIGN PARAMETERS

The design parameters include factors that must be met to ensure that the flood protection system provides the necessary level of protection for Fort McMurray. For a given design flood level, it is important that the flood protection structures can be maintained in a manner consistent with the land use around it, that appropriate freeboard is provided, and that storm water management provided along the structure is consistent with the existing storm sewer capacities.

The ultimate alignment, shape, and elevation depend upon a number of economic, planning, operational, and design constraints. These constraints have been identified on the basis of discussions with RMWB, considerations of good engineering practice, and reasonable economic forecasts. The following design parameters have been selected.

(1) The 100-year ice jam elevation of 250.0 m is the adopted design flood level for the area along the Clearwater River and Hangingstone River.

(2) The adopted design open water flood on the Hangingstone River is 200 m^3/s. The corresponding water levels exceed the 250.0 m ice jam elevation upstream of Hwy 63. Analysis herein indicates that flood protection upstream of Hwy 63 is not required since all current development is above both the ice-related and open water design levels.

(3) At least 0.5 m freeboard is recommended to guard against settlement and unforeseen flood events. However, RMWB dictated that the design shall not include freeboard [3]. The 100-year ice-jam elevation of 250.0 m will be adopted herein as the design top elevation of any structure. Clearly, the lack of freeboard is somewhat problematical. The fact that flooding along the Clearwater River will be due to backwater tends to reduce the variability in water levels that typically occur in flowing streams, and that cannot be captured by hydraulic analysis, and because the flow velocity will be very low, the need for a conservative application of freeboard is reduced. Furthermore, to address the potential settlement associated with earthen structures, it is recommended that (i) rigorous monitoring of the condition of the dikes/floodwalls be carried out each fall and (ii) structural repairs are undertaken immediately prior to the onset of winter to ensure that the integrity of the structures are maintained over the long term.

(4) Where possible, the structures will be integrated into the long term vision of the landscape. It is important to maintain access to the Clearwater River and to construct the flood protection system to accommodate future land use.

[3] A directive provided by the executive branch of RMWB - John Buchko, personal communication.

(5) The layout of the flood protection structures will be determined in part by the locations of the existing high ground, flood proofed areas, and/or roads. These so-called anchor points will provide a basis to reduce the cost of the flood protection system and to compartmentalise the flood protection into reaches that are defined according to the characteristics of the existing development and RMWB's City Centre Area Redevelopment Plan. Anchor points such as the Snye Dike, Borealis Park, Tolen Road, King Street, and Hwy 63 provide end points with elevations in excess of the design protection level.

(6) The need for bank protection on either the Clearwater or Hangingstone rivers will be minimized by judiciously locating the dike away from the top of bank. In situations where bank protection is deemed necessary to maintain structure integrity over the long term, it would be provided on an as needed basis when the erosion becomes problematical.

(7) Stormwater management will provide protection at least up to the level of service provided by the existing system.

(8) Potential seepage under the flood protection structures and local surface drainage that might collect inside the structures will be collected and directed to the various stormwater outfalls.

3.2 FLOOD PROTECTION CONCEPTS

The alignment of the flood protection system, which at that time was composed of dikes, as proposed by Trillium (2000), followed either road allowances or the abandoned railway right of way. A revised preliminary concept was proposed by Mr. John Buchko of AE, working on behalf of RMWB in 2013 (***Appendix A***). This concept, termed the "RMWB Initial Alignment" and shown in ***Figure A1***, considered recent development, site condition constraints, recent functional requirements, and reasonably well-established future development scenarios as laid out in the RMWB City Centre Area Redevelopment Plan dated February 2012. In that plan, the municipality had set a priority on providing a mix of active and passive recreation opportunities in the downtown major redevelopment zone that included considerations for sensitive and sustainable landscaping. The alignment was divided into multiple reaches featuring different types of structures (***Figures A2*** to ***A9***) that included the following.

(1) Elevated trails
(2) Urban terraces
(3) Prairie Loop Boulevard
(4) Constricted areas (stream banks and riparian zones)
(5) Elevated park trails
(6) Elevated boardwalks
(7) Non-accessible berms

These concepts were designed to achieve the adopted design flood elevation of 250.0 m, and mainly consisted of a combination of retaining walls and earth berms with a trails along the tops

of the structures. The concepts were meant to accommodate a mix of waterfront land uses, and were tied to Prairie Loop Boulevard to limit the impact of the berms on park space and private property. However, to close some the gaps and to account for unsuitable terrain, NHC provided an alternative alignment (***Figure A10***) that set the stage for further optimizations.

Based on the RMWB concept and a more detailed analysis, NHC and AE developed an alternative concept of the flood protection system (***Appendix B***) as described in the following sections. This concept was developed, for the most part, with sensitivity to the RMWB redevelopment objectives. However, in some areas it would be physically (economically) impractical to maintain the objectives of the plan at the feasibility-level type of analysis that is described herein. Further integration may be possible during the detailed design by tailoring reach specifics to the redevelopment plan.

While the new flood protection alignments generally follow the RMWB initial alignment, it deviates over several reaches to minimize the cost and impact of the structures on roadway access, other park developments, and the Clearwater and Hangingstone rivers. As shown in ***Figure 16***, major changes occur in the vicinity of Centennial Drive, Longboat Landing, and Saline Creek Drive. In general, the RMWB Initial Alignment in those areas was too close to the banks of the Clearwater and Hangingstone rivers and was somewhat impractical. ***Appendix E*** contains hand held oblique photographs that illustrate existing conditions along the proposed alignment.

Overall, the design concepts for the flood protection system borrow heavily from concepts in the RMWB Initial Alignment. The proposed design includes combinations of 3H:1V (horizontal:vertical) sloped earthen dikes with various top widths, retaining walls to hold back banked earth, and free standing floodwalls. While the adopted 3H:1V side slope will increase the footprint of the earthworks and their cost, that slope was selected mainly for lawn/vegetation maintenance purpose, while also improving visual aesthetics and accessibility.

The proposed flood protection system can be divided into three distinct sections, based on the areas to be protected: (i) Lower Townsite, (ii) Waterways, and (iii) Ptarmigan Court. The Lower Townsite is divided into nine separate reaches (Reach 1 to Reach 9) as shown in ***Figure 17***. These reach designations correspond to the RMWB Initial Alignment. Note that some locations like Reaches 2 and 3 there is no structural differentiation because of the rationalization of the initial alignment and the simplification of the flood mitigation layouts. Waterways (Reaches 10 and 11) and Ptarmigan Court are distinct, separated by the Hangingstone River and Saline Creek, and stand alone. Two options are proposed for the Lower Townsite – Lower Townsite Alternative 1 and Lower Townsite Alternative 2 – with the latter improving on the former by taking into account concerns raised by local stakeholders and by incorporating Prairie Loop Boulevard into the flood mitigation scheme. One option only is provided for Waterways, since the land use there is relatively straightforward. Two options are provided for Ptarmigan Court due to the difficulty in constructing physical flood mitigation works in that neighbourhood. These options are described in subsequent sections.

3.2.1 LOWER TOWNSITE ALTERNATIVE 1 – MODIFIED INITIAL ALIGNMENT

The design features are described below and further illustrated in the design drawings contained in ***Appendix B***.

(1) **Reach 1 – Elevated Trail.** This reach is located between MacDonald Drive and the abutment of the south plaza of the proposed pedestrian bridge. It is a 550 m long asphalt trail situated on the top of an earthen berm. The asphalt trail is 3 m wide. The berm has 3H:1V side slopes and a top width of 4 m. Note that construction of the bridge is not required to maintain the integrity of the dike. The dike can be forced through proposed footprint of the plaza to connect with either Borealis Park or whatever structure is adopted for Reach 2.

(2) **Reach 2 – Urban Terrace.** This reach extends a distance of about 520 m along the Snye Channel from the south plaza of the pedestrian bridge to the proposed Snye Point Park. It consists of a 16.5 m wide stone paved promenade and a lower 5 m wide asphalt paved terrace. The promenade and terrace are separated by a 2 m high retaining wall which can be integrated with the RMWB concepts for in the City Centre Redevelopment Plan.

(3) **Reach 3 – Urban Terrace.** The 200 m long reach extends from Hardin Street to Snye Point Park. It consists of the same structure types as Reach 2. Side slopes of 3H:1V have been provided on both the river and City sides of the structure in the interim. Once the City Centre Redevelopment Plan is enabled, the City side of the structure will tie into redeveloped area at an elevation of 250.0 m.

(4) **Reach 4 – Road Tie-In North of Riverwalk Villas.** This reach parallels Prairie Loop Boulevard from Syne Point Park to Riverwalk Villas near Riedel Street. The current proposed grade of Prairie Loop Boulevard in this reach is below 250.0 m, and a dike attached to the river side of Prairie Loop Boulevard is meant to prevent the roadway from being overtopped. The rationale for this layout was to reduce costs by constructing an earthen dike rather than raising the entire footprint of Prairie Loop Boulevard. The dike is about 375 m long and consists of a berm with asphalt trail on the top – the same as in Reach 1. The dike will extend from Snye Point Park and tie into the embankment upon which Riverwalk Villas is situated, and will be constructed immediately beside the proposed sidewalk along Prairie Loop Boulevard. A flood gate will be required to provide access to the parking area behind the buildings.

(5) **Reach 5 – Riverwalk Villas.** The Riverwalk Villas present a challenge because of the close proximity of the buildings to both the Clearwater River and to Prairie Loop Boulevard. This prevents the construction of an earthen berm between the river and Riverwalk Villas and makes the raising of Prairie Loop Boulevard very difficult.

However, the main floor of the buildings is at 250.0 m elevation and so it is possible to transition from berm to a combination of a berm and a free standing concrete floodwall that will connect to the existing buildings on the north side of Prairie Loop Boulevard. The floodwall will skirt around the river side of the parking area at the end of Riedel Street and transition back to a berm at Prairie Loop Boulevard. The total length of this reach is about 140 m.

(6) **Reach 6 – Prairie Loop Boulevard**. This reach parallels Prairie Loop Boulevard for about 1960 m from Riverwalk Villas to the end of the south extension of Franklin Avenue at Denholm Gate. It primarily consists of dike similar to that in Reach 4, except the top of the dike will be 2 m wide, since it is an integral part of the structure of Prairie Loop Boulevard, complete with a floodwall to elevation 250.0 m. The dike is meant to be complementary to the roadway, and will have a walkway constructed on fill between the road and the dike. There is room towards the Clearwater River to increase the top width of the dike if necessary. At Marine Park, the dike will transition into a 2 m high retaining wall that will contain the north-bound lanes of Prairie Loop Boulevard which will be elevation 249.5 m between the retaining wall and Prairie Loop Boulevard. This has been provided to retain the current function and layout of Marine Park. A flood gate will also be required to maintain current access from Queen Street to Marine Park and its existing parking area.

(7) **Reach 7 – Elevated Trail.** This reach consists of a 480 m long berm paralleling the southeasterly extension of Franklin Avenue to the Clearwater River. The 3H:1V sloped berm will have a top width of 2 m wide. The top width of the dike was reduced in this area to minimize its footprint and reduce the volume of fill required for its construction. With a dike height of some six metres, it would need to extend onto private land along the Clearwater River.

(8) **Reach 8 – Elevated Trail.** This reach consists of a 600 m long dike running along the back side of the existing multifamily lots in Longboat Landing. The dike will extend from the end of the extension of Franklin Avenue to a high ground near the traffic circle at Denholm Gate and Saline Creek Drive. The berm will have a top width of 2 m with slope slopes of 3H:1V. The narrow top width was chosen to minimize the footprint to reduce the amount of encroachment onto private property. There would be a 150 m long section located very close to the Hangingstone River. The berm in that section would have a retaining wall structure at the river side to reduce the footprint to the berm and keep the side slope away from the bank slope of the river. Bank protection will be necessary where the structure comes close to the river.

(9) **Reach 9 – Elevated Trail.** This reach is located north of the Hangingstone River. It consists of a dike constructed over a distance of about 690 m from the north end of the Saline Creek pedestrian bridge plaza to Prairie Loop Boulevard and along the Hangingstone River from Prairie Loop Boulevard to King Street. The dike will be placed close to the roads in the area between the Saline Creek pedestrian bridge plaza and Prairie Loop Boulevard to minimize fill requirements and impacts on private lands. While this alignment appears to isolate the pumphouse, the structure has already been constructed to elevation 250.0 m and the adopted dike alignment does not sterilize the parking and storage area behind the pumphouse. Placing the dike closer to the Hangingstone River would require fill heights of up to 4 m compared to the 2 m fill along the selected alignment. A top width of 2.0 m was selected, for the most part, to minimize the footprint of the dike to reduce encroachment onto developed public lands and onto the Hangingstone River. Note that access is available along the dike on the adjacent roads. However, between Prairie Loop Boulevard and King Street, where the dike is mostly less than a metre high, a top width of 4 m (to accommodate a 3 m wide asphalt path) was selected. To allow maintenance (grass cutting, vehicle access, etc.), 3H:1V side slopes were maintained as in the other reaches.

3.2.2 LOWER TOWNSITE ALTERNATIVE 2 – RECOMMENDED ALIGNMENT

RMWB proposed a change to the Lower Townsite section after a review of the NHC draft report that presented the Lower Townsite Alternative 1 concept described above. The suggested Lower Townsite Alternative 2 was to raise Prairie Loop Boulevard road to form a section of the flood protection system, thereby eliminating the dike that ran parallel to the roadway.

Prairie Loop Boulevard is currently a two-lane road running along the north boundary of the Lower Townsite from Riedel Street to Hwy 63 near the Hangingstone River. The on-going Prairie Loop Boulevard project will widen the road to four lanes and extend it to the northwest from Riedel Street to Hardin Street. The alternative proposed by RMWB is to raise the road top between Snye Point Park and Franklin Avenue (***Figure 16***) to elevation 250.0 m so as to make use of the road embankment for flood protection. However, the grade is to be depressed to its current elevation at Riverwalk Villas so as not to degrade the streetscape at this location, and at Queen Street to allow level access to Marine Park. This will eliminate the need for a dike in Reach 4. Also, in Reach 6, the dike option would mostly become redundant except in the vicinity of Queen Street where combined dike-retaining wall-flood gate would be installed to provide access to Marine Park.

In addition, RMWB requested that the dike on the east side of Longboat Landing be located along the current drainage right of way – essentially constructed over a closed stormwater conduit that will replace the existing open ditch. RMWB also requested that the top width of the dikes in Reaches 8 and 9 be increased to 4 m to allow motorized access along the top of the dike. The rest of the flood protection system remains the same as Lower Townsite Alternative 1.

RMWB retained AECOM to investigate and provide cost estimate for this change. A summary of the AECOM report is provided in ***Appendix C***. The following provides a brief description of the Lower Townsite Alternative 2 features. Drawings of the flood control arrangements are contained in ***Appendix D*** and ***Appendix E*** contains a rendering of the structure layouts and how they fit into the landscape.

(1) **Reach 1 – Elevated Trail.** This reach is located between MacDonald Drive and the abutment of the south plaza of the proposed pedestrian bridge. It is a 550 m long asphalt trail situated on the top of an earthen berm. The asphalt trail is 3 m wide. The berm has 3H:1V side slopes and a top width of 4 m. Note that construction of the bridge is not required to maintain the integrity of the dike. The dike can be forced through proposed footprint of the plaza to connect with either Borealis Park or whatever structure is adopted for Reach 2. There would be no change from Alternative 1 for this reach.

(2) **Reach 2 – Urban Terrace.** This reach extends a distance of about 520 m along the Snye Channel from the south plaza of the pedestrian bridge to the proposed Snye Point Park. It consists of a 16.5 m wide stone paved promenade and a lower 5 m wide asphalt paved terrace. The promenade and terrace are separated by a 2 m high retaining wall which can be integrated with the RMWB concepts for in the City Centre Redevelopment Plan. There would be no change from Alternative 1 for this reach.

(3) **Reach 3 – Urban Terrace.** The 200 m long reach extends from Hardin Street to Snye Point Park. It consists of the same structure types as Reach 2. Side slopes of 3H:1V have been provided on both the river and City sides of the structure in the interim. Once the City Centre Redevelopment Plan is enabled, the City side of the structure will tie into redeveloped area at an elevation of 250.0 m. There would be no change from Alternative 1 for this reach.

(4) **Reach 4 – Prairie Loop Boulevard North of Riverwalk Villas.** Prairie Loop Boulevard will be raised to an elevation of at least 250.0 m for a distance of 840 m from Syne Point Park to a point just north of Riverwalk Villas near Riedel Street where the road grade will be gradually lowered to provide for a level crossing in front of Riverwalk Villas. A 105 m long dike will be constructed on the river side of Prairie Loop Boulevard and tie into the embankment upon which Riverwalk Villas is situated. A flood gate will be provided to provide access to the north parking lot behind Riverwalk Villas. The earthen dike will consists of a berm with asphalt trail on the top – the same as in Reach 1.

(5) **Reach 5 – Riverwalk Villas.** The Riverwalk Villas present a challenge because of the close proximity of the buildings to both the Clearwater River and to Prairie Loop

Boulevard. This prevents the construction of an earthen berm between the river and Riverwalk Villas and makes the raising of Prairie Loop Boulevard impractical. However, the main floor of the buildings is at 250.0 m elevation and so it is possible to transition from berm to a combination of a berm and a free standing concrete floodwall that will connect to the existing buildings at the end of Reidel Street. The 240 m floodwall/dike will skirt around the river side of the parking area at the end of Riedel Street and transition back to Prairie Loop Boulevard where the grade is at 250.0 m – about at the east extension of Alberta Drive.

(6) **Reach 6 – Prairie Loop Boulevard south of Riverwalk Villas**. Prairie Loop Boulevard will be raised from just south of Reidel all the way south to Franklin Avenue for a distance of about 1660 m. A retaining wall and floodwall will be provided at Queen Street to effect a level crossing to provide easy access to Marine Park area in order to retain the current function and layout of Marine Park. A flood gate will also be installed across Queen Street.

(7) **Reach 7 – Elevated Trail.** This reach consists of a 360 m long berm located on the existing stormwater right of way south of the intersection of Franklin Avenue and Prairie Loop Boulevard. The 3H:1V sloped berm will have a top width of 5 m with a 4 m wide paved surface.

(8) **Reach 8 – Elevated Trail.** This reach consists of a 600 m long dike running along the back side of the existing multifamily lots in Longboat Landing. The dike will extend from the end of the extension of Franklin Avenue to a high ground near the traffic circle at Denholm Gate and Saline Creek Drive. The berm will have a top width of 4 m to accommodate a 3 m wider asphalt surface with side slopes of 3H:1V. The top width was increased to allow for access along the top of the dike for routine maintenance and for monitoring during flood conditions. There would be a 150 m long section located very close to the Hangingstone River. The berm in that section would have a retaining wall structure at the river side to reduce the footprint to the berm and keep the side slope away from the bank slope of the river. Bank protection will be necessary where the structure comes close to the river.

(9) **Reach 9 – Elevated Trail.** This reach is located north of the Hangingstone River. It consists of a dike that extends over a distance of about 690 m from the north end of the Saline Creek pedestrian bridge plaza to Prairie Loop Boulevard and along the Hangingstone River from Prairie Loop Boulevard to King Street. The dike will be placed close to the roads in the area between the Saline Creek pedestrian bridge plaza and Prairie Loop Boulevard to minimize fill requirements and impacts on private lands. Placing the dike closer to the Hangingstone River would require fill heights of up to 4 m compared to the 2 m fill along the selected alignment. Again, at the request of RMWB, the top width of the dike was increased to 4 m to

accommodate a 3 m wider asphalt surface. To allow maintenance (grass cutting, vehicle access, etc.) 3H:1V side slopes have been adopted as in the other reaches.

3.2.3 WATERWAYS

Waterways is divided into two distinct reaches (Reaches 10 and 11) as shown in ***Figure 17***. The proposed design for the Waterways sections is described below and is illustrated in the design drawings contained in ***Appendix A***.

(1) **Reach 10 – Elevated Trail.** This reach runs along Saline Creek Drive with structures on either side of the road from the Saline Creek Drive Bridge on the Hangingstone River to the south. On the east side of Saline Creek Drive, it consists of a 120 m long retaining wall near the bridge connected to a 270 m long dike paralleling the road to the south. This dike is meant to prevent overtopping of Saline Creek Drive from the Clearwater River. The dike is intended to minimize costs by building a less expensive dike rather than raising the recently constructed road way. A dike top width of 2.0 m was adopted to minimize the footprint near the Hangingstone River. However, there would be room to expand the top width of the dike to a more ergonomic width to better accommodate pedestrians as it approaches McCormick Street. The dike will be tied into the natural ground that is above elevation 250 m just north of McCormick Street and then continue southward from a point south of McCormick Street to Park Street where Saline Creek Drive will be depressed to allow a level crossing for access to the Horse Pasture. A flood gate will be installed between across the Park Street opening.

On the west side of Saline Creek Drive, the dike will extend for a distance of about 150 m along Saline Creek Drive. It will start at a point just south of the pedestrian bridge for a distance of about 150 m before turning 90 degrees to the west and follow for a distance of about 320 m, along the tree line that separates Saline Creek from J. Howard Pew Memorial Park. The southeast end of this dike ties into high ground near Tolen Road. This dike will prevent water from the Hangingstone River and Saline Creek from moving southward into Waterways. The dike will 3H:1V side slopes and a 4 m top width to accommodate a 3.0 m wide asphalt trail. The dike height will be about 2.0 m high on its park side and more than 2.5 m high on its creek side.

(2) **Reach 11 – Elevated Trail**. This reach extends for a distance of about 1170 m from Park Street to the south along Saline Creek Drive, which is still under construction, to a point where Saline Creek Drive intersects the natural ground at elevation 250.0 m. A dike with a 2 m top width has been adopted along the Clearwater River side of Saline Creek Drive rather than raising the already established road grade. Saline Creek Drive north of Park Street has been constructed to a minimum elevation of 248.5 m but it rises as the ground level increases south of Park Street.

Note that it is intended that the road crossing of the Draper Connector would accommodate the 250.0 m elevation of the dike.

3.2.4 PTARMIGAN COURT

Ptarmigan Court is a mobile home park located north of Tolen Drive and is bounded on the north by the Hangingstone River and on the south by Saline Creek. It is on a somewhat higher terrace and is not be affected by open water flooding on either of the streams. However, it is at a nominal elevation of between 247 and 248 m and it would be severely inundated during the design ice-related flood. The subdivision contains 70 mobile homes that have become permanent fixtures over the last couple of decades. There are only two realistic options available to mitigate flood damages – (i) free standing floodwall around the entire community, (ii) raising of the landscape to elevation 250.0 m and replacing the structures and relate infrastructure, and (iii) outright purchase of all the properties and conversion to a land use that is unaffected by flooding.

A free standing perimeter floodwall around the community would tie into Tolen Road north and south of the community. The top of the floodwall will be at elevation 250.0 m and at its highest the top of the wall will be three metres above the existing ground. This design is shown in the drawings contained in ***Appendix B***. The design will change the ambiance of Ptarmigan Court considerably – likely not for the better.

Raising the landscape will require removal and restoration of existing utilities, services, and roads; and temporary relocation of the residents for the duration of the construction period. There is a concern that the mobile homes presently located in the community may not be able to be moved without incurring significant damage.

Purchase of the properties and conversion to an alternative land use would mean that about 70 families would be relocated and new housing would need to be created for them. Clearly, this could only be achieved over a fairly long time frame given the current pace of development and the escalating demands for housing in the region.

3.2.5 PRIVATE LANDS

Attempts have been made to minimize encroachment onto privately held properties. For example, in Reach 1 the alignment of the dike was adjusted to fit between the west property line and the bank of the Snye. Within Reaches 2, 3, and 4 the dike/roadway follows an established road allowance and the structure will remain on public property. In Reach 5, diking and a floodgate will need to be installed within the development itself, and a floodwall will need to be constructed within the parking lot located across Reidel Street. The structures within Reach 6 will be built entirely on public land.

The flood protection in Reaches 7 and 8 will affect the largest are of private land. The dike along the south extension of Franklin Avenue may infringe slightly on the private property to the east.

At the back of Longboat Landing, the footprint of the dike will encroach on all the lots extending back from Fountain Crescent. Along Reach 9, the dike will cross the vacant property west of Prairie Loop Boulevard, run along the rear property line of the housing complex south of Mills Avenue at the end of Penhorwood Street, and extend along the Hangingstone River past Heritage Park to King Street. Although the Heritage Park lands appear to be public property, the Fort McMurray Historical Society has concerns about the placement of the dike and the sterilization of potential park land.

The flood protection works along Reaches 10 and 11 in Waterways are all on public land – either old railway right-of-way, existing road allowance, or park land. The floodwall option in Ptarmigan Court was chosen to minimize encroachment on private property and it is intended that its footprint be entirely on public land along either the Hangingstone River or Saline Creek.

The area of the land occupied by the flood mitigation structures outside of the transportation right-of-ways within each of the 11 reaches was estimated using land title information obtained from the Alberta Land Titles Spatial Information System (SPIN 2). It is clear that no part of the flood mitigation footprint lies on provincial lands. However, the explicit ownership could not be identified, nor could it be determined if the land was held privately or owned by the municipality without an inspection of individual ownership records – something that is beyond the scope of this report. The areas outside of the transportation right-of-ways upon which the flood mitigation structures could infringe are summarized in ***Table 7***. The estimated total area required would be about 9 ha.

Table 7 Private land requirements

Reach	Dike Footprint (ha)
1	-
2	0.42
3	0.06
4	0.98
5	0.002
6	0.58
7	0.17
8	1.78
9	0.48
10	3.18
11	1.67
Total	**9.32**

Appendix F provides the Land Identification Numeric Code of the each effected areas along with a description of the extent of structure occupation. The estimated ownership of each parcel (public or private) is also provided.

3.3 SPECIAL ISSUES

There are several areas which present special concerns or that fall into constricted areas. These are as follows.

(1) **Promenade** (Reaches 2 and 3). Concern has been raised that it may not be possible to construct the infrastructure that would be complementary to the promenade in the near future. As such the extensive fill required to construct the promenade would not be practical at this time. One contingency would be to replace the promenade with a dike like that proposed for Reach 1 – 3H:1V side slopes with a top width of 4 m and a 3 m wide asphalt surface. Costs for this option are provided in later sections of the report.

(2) **Riverwalk Villas on Riedel Street** (Reach 5). Due to constraints of the existing site condition, it is recommended that a concrete wall be built for this section and tied into the existing buildings. Additionally, a flood gate will be required to maintain vehicle access to the parking area behind the buildings. Due to the proximity of the Clearwater River, the parking lots southeast of the complex will likely lose some stalls and may need to be remarked.

(3) **Marine Park** (Reach 6). No flood protection for the Marine Park is planned. The park is lower than the design flood level by up to 3 m and is situated very close to the Clearwater River. A flood gate will be required to allow vehicle access if the retaining wall concept is adopted.

(4) **Franklin Street Outfall and Ditch** (Reach 7). The existing ditch will be filled. A 1500 mm concrete pipe and new outfall will be required to maintain stormwater drainage. It appears that the entire footprint of the dike will fit within the right-of-way of the south extension of Franklin Avenue and no private land will be affected.

(5) **Longboat Landing** (Reach 8). The berm will follow the perimeter of the development. It appears that there is limited space between the Hangingstone River and the lot boundaries. The will be a need to accommodate the footprint of the berm into the grading/construction plans of any future phases of this development.

(6) **Slope Stability** (Reach 8, 9 and 10). Several sections of the proposed flood protection alignment are very close to the bank line of the Hangingstone River. Further assessment and bank erosion protection may be required in those areas.

(7) **Heritage Park and Lions Park** (Reach 9). The proposed berms protecting Heritage Park are located within the 100-year open-water floodway of the Hangingstone River. Since the Heritage Park is a significant asset, flood protection will be provided for the structures within the park. An approval by ESRD for floodplain encroachment may be required, which will require additional assessment of its potential impacts on upstream and downstream flood levels. Alternatively, it is recommended that Lions Park not be protected. The park is some three metres below the design flood level. While it could be protected by a perimeter dike tying into Tolen Road at the north and south ends of the park, the high dike would require a large footprint and essentially destroy the connectivity of the park to the Hangingstone River. Furthermore, taken in consort with the dike across the river at Heritage Park, the Lions Park dike could constrict the floodplain to the point where it would increase open water flood levels on the Hangingstone River upstream of the park. Analysis would need to be undertaken to assess the effects of the constriction on upstream water levels.

4 COST ESTIMATES AND STAGING OPTIONS

AE provided the cost estimates for the two alternative flood protection system as described in ***Section 3*** and as illustrated in ***Appendices B*** and ***D***. These costs are detailed in ***Tables 8 and 9*** for the Lower Townsite, ***Table 10*** for Waterways, and ***Table 11*** for Ptarmigan Court. ***Appendix G*** contains a brief description of the costing procedures employed by AE. The tables provide detailed cost breakdowns along with quantities and unit costs for each of the components of the various alternatives. All of the cost estimates are Class 'D', which is defined as an estimate based on unit cost analysis and a comprehensive list of project requirements and assumptions that shall be revisited with cost planners before finalizing.

4.1 LOWER TOWNSITE

4.1.1 ALTERNATIVE 1 – MODIFIED INITIAL ALIGNMENT

The cost breakdown for Alternative 1 is provided in ***Table 8***. The estimated total is $126,760,000. The following items are considered in the cost estimate for this alternative, along with general caveats.

(1) **Future Landscaping.** With the majority of the flood protection system consisting of earthen berms near populated areas, the berms should be incorporated into future landscaping and site beautification plans. In addition to the basic structural costs that include clearing and grubbing, hauling and placing of fill, site grading, structure construction, topsoil placement and seeding to prevent surface erosion, landscaping costs have also been estimated. These landscaping costs have been

termed “landscaping enhancements” since they are not fundamental to providing flood protection, but they serve to incorporate the flood protection structures into the surrounding landscape. These costs of these landscaping enhancements are based on a lineal metre of flood protection and include (i) paved trails, (ii) benches, stairs, access pathways, trees and shrubs, and railings (called “plants and site furnishings”), and (iii) lighting. Based on recent bids for the construction of Reach 1, the unit lineal cost of the paved trails has come in at $430/m, the costs of benches, vegetation, and other fixtures came in at $750/m, and the cost of lighting came in at $300/m. These unit costs were applied to all reaches despite differing dike heights and footprint areas.

(2) **Flood Gates.** Providers of drop-in flood gate systems indicate that a four metre wide gate is estimated to cost $50,000 and an eight metre wide gate would cost $80,000. These costs were reviewed further and it was found that the combined procurement and installation costs would vary significantly with the type of gate, its storage facility, and its installation procedure (located off site and installed prior to the flood, kept on site and deployed semi-automatically, etc.). To account for these vagaries and to provide flexibility in the final implementation plan, a lump sum cost of $200,000 for each gate was assumed. Clearly, this cost will need to be defined in detail design.

(3) **Retaining and Floodwalls.** The requirements for retaining walls and stand-alone floodwalls vary throughout the system. Retaining walls are proposed in various reaches to reduce the footprint of the dikes. Their heights would vary from one to three metres and consequently the estimated costs would vary with height and range between $3,000 to $5,000 per m^2. Floodwalls are proposed in Reach 6, and the cost per unit length there is estimated to be $900 per linear metre. The attraction of the floodwalls is their small footprint, their striking architecture, and the fact that they can be designed to fit the aesthetics of an area. Note that a $500,000 allowance has been provide to accommodate the connection of the retaining wall to the south end of the Riverwalk Villas complex in Reach 5.

(4) **Connecting Streets**. An allowance of $10,000,000 has been included in the cost estimate to allow for adjustments of existing road intersections during and after the construction of the flood protection system. This allowance will likely be required for Reidel Street, Queen Street, McCormick Street, Park Street and a yet to be located boat launch in Reach 11. This allowance includes the costs to raise and repave roads, re-align utilities, and for signage. Note that this allowance was not applied to the Lower Townsite reaches for Alternative 2 – it was assumed that this would be accommodated in the costs of raising Prairie Loop Boulevard.

(5) **Allowance for Prairie Loop Boulevard** (Reach 4). An $18,000,000 allowance has been included in the cost estimate to account for changes to Prairie Loop Boulevard. This amount was provided by RMWB in a cost estimate dated September 5, 2013. In Alternative 2, this cost would comprise part of the costs of raising Prairie Loop Boulevard.

(6) **Stormwater Management Allowance**. An allowance of $10,000,000 has been included in the cost estimate to allow for changes to the existing stormwater management system - $8,000,000 for the Lower Townsite and $2,000,000 for Waterways. Potential costs include new outfalls, catch basins, manhole adjustments, ditching, and piping.

(7) **Mobilization and De-mobilization**. The cost estimate does not include mobilization and de-mobilization costs.

(8) **Topsoil Availability**. The cost estimate assumes that topsoil is available within 2 km of the work area.

(9) **Bank Stability – Hangingstone River.** The cost estimate assumes that Class II riprap will be used to protect river banks on an as needed basis. The costs are based on $250 per m^2 and include geotextile. Further investigation to confirm the appropriate slope stabilization requirement should be undertaken in detailed design.

Table 8 Class D cost estimate for Lower Townsite Alternative 1

Item	Description	Unit	Quantity	Unit Price	Extension
1.0	**Reach 1 Elevated Trail (488m)**				
1.1	Haul, place fill and site grading	m3	24,800	$80	$1,984,000
1.2	Clearing and grubbing/topsoil removal	m2	15,200	$25	$380,000
1.3	Erosion Protection - topsoil and seed	m2	14,800	$30	$444,000
1.4	Landscaping Enhancement				
1.4.1	Asphalt paving	LM	488	$430	$209,840
1.4.2	Plants and site furnishings	LM	488	$750	$366,000
1.4.3	Lighting	LM	488	$300	**$146,400**
	Subtotal - Reach 1				**$3,531,000**

Item	Description	Unit	Quantity	Unit Price	Extension
2.0	**Reach 2 and 3 Urban Terrace (720m)**				
2.1	Haul, place fill and site grading	m3	131,250	$80	$10,500,000
2.2	Retaining wall (2m height)	m2	720	$4,000	$2,880,000
2.3	Clearing and grubbing/topsoil removal	m2	40,220	$25	$1,005,500
2.4	Erosion protection - topsoil and seed	m2	25,260	$30	$757,800
2.5	Landscaping Enhancement				
2.5.1	Paving - stone	m2	11,880	$300	$3,564,000
2.5.2	Asphalt paving	LM	720	$430	$309,600
2.5.3	Plants and site furnishings	LM	720	$750	$540,000
2.5.4	Lighting	LM	720	$300	$216,000
	Subtotal - Reach 2 and 3				**$19,773,000**
3.0	**Reach 4 - Road Tie In (280m)**				
3.1	Haul, place fill and site grading	m3	19,100	$80	$1,528,000
3.2	Clearing and grubbing/topsoil removal	m2	5,900	$25	$147,500
3.3	Erosion protection - topsoil and seed	m2	5,700	$30	$171,000
3.4	Prairie Loop Boulevard		see RMWB		$18,000,000
3.5	Landscaping Enhancement				
3.5.1	Asphalt paving	LM	280	$430	$120,400
3.5.2	Plants and site furnishings	LM	280	$750	$210,000
3.5.3	Lighting	LM	280	$300	$84,000
	Subtotal - Reach 4				**$20,261,000**
4.0	**Reach 5 - Riverwalk Villas (620m)**				
4.1	Haul, place fill and site grading	m3	4,500	$80	$360,000
4.2	Clearing and grubbing/topsoil removal	m2	1,650	$25	$41,250
4.3	Retaining wall (1.5m)	LM	300	$3,500	$1,050,000
4.4	Vehicle floodgate (4 m long)	each	1	$200,000	$200,000
4.5	Allowance for flood wall tie-in to structure	each	1	$500,000	$500,000
4.6	Erosion protection - topsoil and seed	m2	900	$30	$27,000
4.7	Landscape enhancement				
4.7.1	Plants and site furnishings	LM	620	$750	$465,000
4.7.2	Lighting	LM	620	$300	$186,000
	Subtotal - Reach 5				**$2,830,000**

Item	Description	Unit	Quantity	Unit Price	Extension
5.0	**Reach 6 - Prairie Loop Boulevard (1780m)**				
5.1	Haul, place fill and site grading	m3	58,400	$80	$4,672,000
5.2	Clearing and grubbing/topsoil removal	m2	29,000	$25	$725,000
5.3	Erosion protection - topsoil and seed	m2	31,200	$30	$936,000
5.4	Retaining wall (1m)	m2	270	$3,000	$810,000
5.5	Vehicle floodgate (8m long)	each	1	$200,000	$200,000
5.6	Floodwall (0.5m)	LM	365	$900	$328,500
5.7	Landscaping Enhancement				
5.7.1	Asphalt paving	LM	1,780	$430	765,400
5.7.2	Plants and site furnishings	LM	1,780	$750	$1,335,000
5.7.2	Lighting	LM	1,780	$300	$534,000
	Subtotal - Reach 6				**$10,306,000**
6.0	**Reach 7 - Elevated Trail (450m)**				
6.1	Haul, place fill and site grading	m3	39,500	$80	$3,160,000
6.2	Clearing and grubbing/topsoil removal	m2	27,500	$25	$687,500
6.3	Erosion Protection - topsoil and seed	m2	33,000	$30	$990,000
6.4	Re-align storm outfall	LS	1	$2,000,000	$2,000,000
6.5	1500 mm concrete pipe	LM	225	$3,500	$787,500
6.6	Outfall	each	1	$250,000	$250,000
6.7	Landscape Enhancements				
6.7.1	Asphalt paving	LM	450	$430	$193,500
6.7.2	Plants and site furnishings	LM	450	$750	$337,500
6.7.3	Lighting	LM	450	$300	$135,000
	Subtotal - Reach 7				**$8,541,000**
7.0	**Reach 8 - Elevated Trail (620m)**				
7.1	Haul, place fill and site grading	m3	59,000	$80	$4,720,000
7.2	Clearing and grubbing/topsoil removal	m2	48,500	$25	$1,212,500
7.3	Stream bank protection with vegetation	m2	2,250	$150	$337,500
7.4	Erosion Protection - topsoil and seed	m2	57,400	$30	$1,722,000
7.5	Storm Sewer Upgrades	LS	1	$3,000,000	$3,000,000
7.6	Retaining wall (3m)	m2	435	$5,000	$2,175,000
7.7	Class 2 Rip Rap and geotextile	m2	420	$250	$105,000
7.8	Landscaping Enhancements				
7.8.1	Asphalt paving	LM	620	$430	266,600
7.8.2	Plants and site furnishings	LM	620	$750	465,000
7.8.3	Lighting	LM	620	$300	186,000
	Subtotal - Reach 8				**$14,190,000**

Item	Description	Unit	Quantity	Unit Price	Extension
8.0	**Reach 9 - Elevated Trail (660m)**				
8.1	Haul, place fill and site grading	m3	12,800	$80	$1,024,000
8.2	Clearing and grubbing/topsoil removal	m2	5,700	$25	$142,500
8.3	Stream bank protection with vegetation	m2	6,200	$150	$930,000
8.4	Erosion protection – top soil and seed	m2	5,800	$30	$174,000
8.5	Class 2 Rip Rap and geotextile	m2	810	$250	$202,500
8.6	Landscaping Enhancements				
8.6.1	Asphalt paving	LM	430	$430	$64,500
8.6.2	Plants and site furnishings	LM	430	$750	$322,500
8.6.3	Lighting	LM	430	$300	$129,000
	Subtotal - Reach 9				**$3,110,000**
9.0	**Storm Water Drainage Allowance**				
9.1	Allowance for storm water management and street modifications not identified above	LS	1	$8,000,000	**$8,000,000**
	Subtotal				**$90,542,000**
	Engineering Fees (10%)				$9,900,000
	Contingency (30%)				$27,163,000
	ESTIMATED TOTAL (2013 dollars)				**$126,760,000**

4.1.2 ALTERNATIVE 2 – RECOMMENDED ALIGNMENT

As described in ***Section 3.2.2***, Alternative 2 will replace the berms and retaining walls within Reaches 4 and 6 with a raised Prairie Loop Boulevard. The associated costs (including engineering fees and contingencies) of this alternative were estimated by AECOM to be between $37,690,000 if Queen Street is at its present elevation of 248.5 m and $40,980,000 if the intersection is raised to 250.0 m. Details of the AECOM cost estimate are shown in ***Appendix C***. Note that neither of the road profiles at Queen Street shown in ***Appendix C*** is representative of these adopted conditions. The estimated cost of the dikes, flood gates, and flood walls, etc. ancillary to the raising of Prairie Loop Boulevard is $80,878,000 (as shown in ***Table 9***) for a total cost of between $118,568,000 and $121,858,000. This would be between 4 and 6 percent less expensive than Alternative 1, but it may result in some challenges with respect landscaping, road connections, and vehicle access to properties located east of Prairie Loop Boulevard.

Table 9 Class D cost estimate for Lower Townsite Alternative 2 – ancillary to the raising of Prairie Loop Boulevard to 250.0 m

Item	Description	Unit	Quantity	Unit Price	Extension
1.0	**Reach 1 Elevated Trail (488m)**				
1.1	Haul, place fill and site grading	m3	24,800	$80	$1,984,000
1.2	Clearing and grubbing/topsoil removal	m2	15,200	$25	$380,000
1.3	Erosion Protection - topsoil and seed	m2	14,800	$30	$444,000
1.4	Landscaping Enhancement				
1.4.1	Asphalt paving	LM	488	$430	$209,840
1.4.2	Plants and site furnishings	LM	488	$750	$366,000
1.4.3	Lighting	LM	488	$300	$146,400
	Subtotal - Reach 1				**$3,531,000**
2.0	**Reach 2 and 3 Urban Terrace (720m)**				
2.1	Haul, place fill and site grading	m3	90,757	$80	$7,260,560
2.2	Retaining wall (2m height)	m2	720	$4,000	$2,880,000
2.3	Clearing and grubbing/topsoil removal	m2	36,220	$25	$905,500
2.4	Erosion protection - topsoil and seed	m2	20,260	$30	$607,800
2.5	Landscaping Enhancement				
2.5.1	Paving - stone	m2	8,580	$300	$2,574,000
2.5.2	Asphalt paving	LM	720	$430	$309,600
2.5.3	Plants and site furnishings	LM	720	$750	$540,000
2.5.4	Lighting	LM	720	$300	$216,000
	Subtotal - Reach 2 and 3				**$15,294,000**
3.0	**Reach 4 - Road Tie In (280m)**				
3.1	Haul, place fill and site grading	m3	3,000	$80	$240,000
3.2	Clearing and grubbing/topsoil removal	m2	2,000	$25	$50,000
3.3	Erosion protection - topsoil and seed	m2	2,100	$30	$63,000
3.4	Prairie Loop Boulevard		see Reach 6 for AECOM cost estimate		
3.5	Landscaping Enhancement (not required)				
	Subtotal - Reach 4				**$353,000**

Item	Description	Unit	Quantity	Unit Price	Extension
4.0	**Reach 5 - Riverwalk Villas (620m)**				
4.1	Haul, place fill and site grading	m3	3,000	$80	$240,000
4.2	Clearing and grubbing/topsoil removal	m2	750	$25	$18,750
4.3	Retaining wall (1.5m)	LM	236	$3,500	$824,250
4.4	Vehicle floodgate (4 m long)	each	1	$200,000	$200,000
4.5	Allowance for flood wall tie-in to structure	each	1	$500,000	$500,000
4.6	Erosion protection - topsoil and seed	m2	600	$30	$18,000
4.7	Landscape enhancement				
4.7.1	Plants and site furnishings	LM	620	$750	$465,000
4.7.2	Lighting	LM	620	$300	$186,000
	Subtotal - Reach 5				**$2,452,000**
5.0	**Reach 6 - Prairie Loop Boulevard (1780m)**				
5.1	Haul, place fill and site grading	m3	7,000	$80	$560,000
5.2	Clearing and grubbing/topsoil removal	m2	3,800	$25	$95,000
5.3	Erosion protection - topsoil and seed	m2	4,000	$30	$120,000
5.4	Retaining wall (1m)	m2	92	$3,000	$276,000
5.5	Vehicle floodgate (8m long)	each	1	$200,000	$200,000
5.6	Floodwall (0.5m)	LM	365	$900	$328,500
5.7	Landscaping Enhancement				
5.7.1	Asphalt paving	LM	not required		
5.7.2	Plants and site furnishings	LM	365	$750	$273,800
5.7.2	Lighting	LM	365	$300	$109,500
	Subtotal - Reach 6				**$1,635,000**
6.0	**Reach 7 - Elevated Trail (450m)**				
6.1	Haul, place fill and site grading	m3	35,500	$80	$2,840,000
6.2	Clearing and grubbing/topsoil removal	m2	24,700	$25	$617,500
6.3	Erosion Protection - topsoil and seed	m2	30,000	$30	$900,000
6.4	Re-align storm outfall	LS	1	$2,000,000	$2,000,000
6.5	1500 mm concrete pipe	LM	225	$3,500	$787,500
6.6	Outfall	each	1	$250,000	$250,000
6.7	Landscape Enhancements				
6.7.1	Asphalt paving	LM	450	$430	$193,500
6.7.2	Plants and site furnishings	LM	450	$750	$337,500
6.7.3	Lighting	LM	450	$300	$135,000
	Subtotal - Reach 7				**$8,061,000**

Item	Description	Unit	Quantity	Unit Price	Extension
7.0	**Reach 8 - Elevated Trail (620m)**				
7.1	Haul, place fill and site grading	m3	70,800	$80	$5,664,000
7.2	Clearing and grubbing/topsoil removal	m2	48,500	$25	$1,243,500
7.3	Stream bank protection with vegetation	m2	2,250	$150	$337,500
7.4	Erosion Protection - topsoil and seed	m2	57,400	$30	$1,759,200
7.5	Storm Sewer Upgrades	LS	1	$3,000,000	$3,000,000
7.6	Retaining wall (3m)	m2	435	$5,000	$2,175,000
7.7	Class 2 Rip Rap and geotextile	m2	420	$250	$105,000
7.8	Landscaping Enhancements				
7.8.1	Asphalt paving	LM	620	$430	266,600
7.8.2	Plants and site furnishings	LM	620	$750	465,000
7.8.3	Lighting	LM	620	$300	186,000
	Subtotal - Reach 8				**$15,202,000**
8.0	**Reach 9 - Elevated Trail (660m)**				
8.1	Haul, place fill and site grading	m3	12,800	$80	$1,228,800
8.2	Clearing and grubbing/topsoil removal	m2	5,700	$25	$164,500
8.3	Stream bank protection with vegetation	m2	6,200	$150	$930,000
8.4	Erosion protection – top soil and seed	m2	5,800	$30	$200,400
8.5	Class 2 Rip Rap and geotextile	m2	810	$250	$202,500
8.6	Landscaping Enhancements				
8.6.1	Asphalt paving	LM	430	$430	$64,500
8.6.2	Plants and site furnishings	LM	430	$750	$322,500
8.6.3	Lighting	LM	430	$300	$129,000
	Subtotal - Reach 9				**$3,242,000**
9.0	**Storm Water Drainage Allowance**				
9.1	Allowance for storm water management not identified above (street modifications not required)	LS	1	$8,000,000	**$8,000,000**
	Subtotal				**$57,770,000**
	Engineering Fees (10%)				$5,777,000
	Contingency (30%)				$17,331,000
	ESTIMATED TOTAL (2013 dollars)				**$80,878,000**

4.1.3 ALTERNATIVE 2 – REACH 2 AND 3 ELEVATED TRAIL OPTION

Given the time that it may take to redevelop the lands adjacent to Reaches 2 and 3 (between the proposed MacDonald Island Bridge and Hardin Street) and before the urban terrace concept can become a reality, there may be a need to construct a simple dike complete with an elevated

trail like that proposed for Reach 1 to provide interim flood protection. The smaller footprint of the structure will produce savings over the near term, while yet providing the required flood protection. The configuration of this structure would be similar in cross section to that shown in ***Figure D2*** of ***Appendix D***, although the height of the elevated trail would be somewhat higher to reflect the lower ground elevations shown in ***Figure D3***. The costs of this optional structure are estimated to be $11,575,000, including engineering fees and contingencies, as summarized in ***Table 10***. This option would cost about 60 percent less than the urban terrace, while still providing the same level of flood protection.

Table 10 Class D cost estimate for elevated trail option - Lower Townsite Reach 2 and 3

Item	Description	Unit	Quantity	Unit Price	Extension
2.0	**Reach 2 and 3 - Elevated Trail (720m)**				
2.1	Haul, place fill and site grading	m3	73,226	$80	$5,858,080
2.2	Clearing and grubbing/topsoil removal	m2	29,470	$25	$736,750
2.3	Erosion Protection - topsoil and seed	m2	20,260	$30	$607,800
Landscaping enhancements					
2.4	Asphalt paving	LM	720	$430	$309,600
2.5	Plants and site furnishings	LM	720	$750	$540,000
2.8	Lighting	LM	720	$300	$216,000
	Subtotal - Reach 2 and 3				**$8,269,000**
	Engineering Fees (10%)				$827,000
	Contingency (30%)				$2,480,700
	ESTIMATED TOTAL (2013 dollars)				**$11,577,000**

4.2 WATERWAYS

The estimated total cost for the Waterways section is $20,386,000. The cost breakdown is provided in ***Table 11***, which also includes quantities and unit costs. The estimate is based on the same assumptions as for the Lower Townsite section. A flood gate has been provided at Park Street and a short floodwall and a long dike with a 2 m top width has been prescribed along the Clearwater River side of Saline Creek Drive to accommodate its proposed grade of 248.5 m.

Table 11 Class D cost estimate for Waterways

Item	Description	Unit	Quantity	Unit Price	Extension
1.0	**Reach 10 - Road Tie In (1550m)**				
1.1	Haul, place fill and site grading	m3	73,500	$80	$5,880,000
1.2	Clearing and grubbing/topsoil removal	m2	7,700	$25	$192,500
1.3	Erosion Protection - topsoil and seed	m2	9,300	$30	$279,000
1.4	Class 2 Riprap and geotextile	m2	750	$250	$187,500
1.5	Vehicle flood gate (8 m long)	each	1	$200,000	$200,000
1.6	Landscaping Enhancements				
1.6.1	Asphalt paving	LM	550	$430	$236,500
1.6.2	Plants and site furnishings	LM	550	$750	$412,500
1.6.3	Lighting	LM	550	$300	$165,000
	Subtotal - Reach 10				**$7,553,000**
2.0	**Reach 11 - Road Tie In (1170m) – no landscaping**				
2.1	Haul, place fill and site grading	m3	28,300	$80	$2,264,000
2.2	Clearing and grubbing/topsoil removal	m2	9,600	$25	$240,000
2.3	Erosion Protection - topsoil and seed	m2	16,800	$30	$504,000
	Subtotal - Reach 11				**$3,008,000**
3.0	**Connecting Streets**				
3.1	Street modifications for Saline Creek Drive interface not included above	LS	1	$2,000,000	**$2,000,000**
4.0	**Storm Water Drainage Allowance**				
4.1	Allowance for storm water management not identified above	LS	1	$2,000,000	**$2,000,000**
	Subtotal				**$14,561,000**
	Engineering Fees (10%)				$1,456,000
	Contingency (30%)				$4,369,000
	Estimated TOTAL (2013 dollars)				**$20,386,000**

4.3 PTARMIGAN COURT

Table 12 summarizes the estimated costs for the proposed flood protection design for Ptarmigan Court as described in Section 3.2.5. The cost estimate is based on the same assumptions/unit prices adopted above. The design requires floodwalls that will vary in height from one two three metres over a length of about 600 m. The estimated cost is $8,512,000.

Raising the landscape to the design flood level of 250.0 m will require compacted/engineered fill tapered to the natural ground level around the perimeter of the subdivision with a 3H:1V side

slope. The total fill volume is estimated to be about 71,500 m^3 and when all the other cost items are accounted for, the expected cost of this item would be $37,982,000. The cost of the outright purchase of the properties is estimated by RMWB to be approximately $25,000,000 [4] or about $34,000,000 when transaction fees and contingencies are factored in. This works out to a cost of between $360,000 and $465,000 net (not including transaction fees) per residence – likely insufficient to purchase a replacement property within the urban area of RMWB.

Table 12 Class D cost estimates for Ptarmigan options

Item	Description	Unit	Quantity	Unit Price	Extension
1.0	**Floodwall – Option 1**				
1.1	Floodwall (3 m height)	m2	950	$5,000	$4,750,000
1.2	Floodwall (2 m height)	m2	160	$4,000	$640,000
1.3	Floodwall (1.5 m height)	m2	90	$3,500	$315,000
1.4	Floodwall (1 m height)	m2	80	$3,000	$240,000
1.5	Clearing and grubbing/topsoil removal	m2	1,800	$25	$45,000
1.6	Misc. - signs, bench, hand rails/low fencing	LM	600	$150	$90,000
	Subtotal - Floodwall				**$6,080,000**
	Engineering Fees (10%)				$608,000
	Contingency (30%)				$1,824,000
	Estimated TOTAL (2013 dollars)				**$8,512,000**
2.0	**Fill – Option 2**				
2.1	Haul, place fill and site grading	M^3	71,500	$80	$5,720,000
2.2	Clearing and grubbing/topsoil removal	M^2	40,000	$25	$1,000,000
2.3	Erosion Protection – topsoil and seed	M^2	10,000	$30	$300,000
2.4	Removal/restoration of services	LS	1	$17,500,000	$17,500,000
2.5	Temporary relocation of residents (1 yr)	each	70	$36,000	$2,520,000
2.6	Misc. – signs, bench, hand rails/low fencing	LM	600	$150	$90,000
	Subtotal - Fill				**$27,130,000**
	Engineering Fees (10%)				$2,713,000
	Contingency (30%)				$8,139,000
	Estimated TOTAL (2013 dollars)				**$37,982,000**

[4] Communication from John Buchko after consultation with RMWB officials.

Item	Description	Unit	Quantity	Unit Price	Extension
3.0	**Buyout – Option 3**				
3.1	Purchase the properties	each	70	$360,000	$25,200,000
	Subtotal – Buyout				**$25,200,000**
	Transaction Fees (5%)				$1,260,000
	Contingency (30%)				$7,560,000
	Estimated TOTAL (2013 dollars)				**$34,020,000**

4.4 COST SUMMARY

Table 13 provides a summary of the overall costs, differentiated by the two options for the Lower Townsite. Note that while one of the options for Ptarmigan Court is to purchase the properties and repurpose the land, only the cost of the flood protection option is presented in the table. It is evident that the cost differentials for the two Lower Townsite alternatives are not too different. Ultimately the choice of alternatives can be based more on what makes sense vis-a-vis the landscape as opposed to a strictly cost-based decision. The overall estimated cost of the flood protection is estimated to be about $121,858,000 for the Lower Townsite, $20,386,000 for Waterways, and $8,512,000 for Ptarmigan Court.

Table 13 Summary Class D cost estimate for flood protection system

Location	Cost ($)	
	Alternative 1	**Alternative 2**
Lower Townsite	$126,760,000	$121,858,000 [(1)]
Waterways	$20,386,000	$20,386,000
Ptarmigan Court	$8,512,000 [(2)]	$8,512,000 [(2)]
Lower Townsite + Waterways + Ptarmigan	$155,658,000 [(3)]	$150,756,000 [(3)]

[(1)] The total costs for the Lower Townsite - Alternative 2 range between $118,568,000 and $121,858,000 depending on which option for the raising of Prairie Loop Boulevard is selected – see ***Appendix C***.
[(2)] Assumes the cost of the floodwall only.
[(3)] These costs could be reduced by about $16,105,000 and $9,835,000 for Alternatives 1 and 2 respectively if the urban terrace in Reach 2 and 3 is replaced with a conventional dike.

4.5 ECONOMIC CONSIDERATIONS

As mentioned previously the last rigorous economic analysis of flood control options – undertaken in 1994 – confirmed that diking was the least expensive flood mitigation option and that a diking program was justifiable on the basis of a cost-benefit analysis. An economic

(cost/benefit) analysis has not been undertaken herein. However, if it assumed that the costs of flood damages and the costs of providing diking have increased in the same proportion (likely a conservative assumption given the scale of development in the Lower Townsite and Waterways), and in view of the $24,000,000 damages experienced by the relatively small footprint of the 2013 flood, construction of the flood protection identified herein would be justified from an economic perspective. Protecting the community against the 100-year flood continues to be a viable option from both an economic perspective and perhaps more importantly from a public safety perspective.

4.6 FLOOD COMPARTMENTALIZATION AND STAGING OPPORTUNITIES

The current design compartmentalizes the flood protection into three zones – Lower Townsite, Waterways, and Ptarmigan Court. This has been achieved by taking advantage of the elevations of existing local roads and the need to accommodate the Hangingstone River. Approximately 6.2 km of structures will be required for the Lower Townsite, 2.7 km for Waterways, and 0.6 km for Ptarmigan Court. Should the protective perimeter be breached at any location while water levels are near the design level, extensive areas of highly dense development would suffer flood damages. Previous studies (Trillium, 2000) have identified a desire to construct internal controls (say by raising streets or judiciously managing floodproofing/infilling) so that the extent of the flooding can be limited to smaller area should a breach occur. It is recommended that additional studies be undertaken to assess the potential for future additional flood compartmentalization in a synergistic way with the proposed future developments in the Lower Townsite and Waterways.

The topography behind the dike is extremely flat and does not allow for the creation of smaller zones that can be easily protected in the short term. Therefore, there are only a limited number of opportunities for a staged approach to providing flood protection. While a flood damage cost-benefit type of analysis has not been undertaken herein, it is clear that the greatest flood damages will occur in the Lower Townsite, followed by either Waterways or Ptarmigan Court. It is beyond the scope of this report to determine priorities in how the overall flood protection is implemented. However, from a damage prevention and development perspective the Lower Townsite would likely have priority. From an implementation perspective, Waterways would be the easiest to undertake with the least impact on local residents. Flood protection for Ptarmigan Court, on the other hand, would be more intrusive, it would require some public consultation, and it may be difficult to implement.

5 OUTSTANDING ISSUES

The concept design and cost estimate for the flood protection system have been undertaken within constrained terms of reference. This preliminary overview of opportunities to construct flood protection in Fort McMurray has identified a number of planning-related issues that should be addressed before final design is undertaken.

At this point, recognizing that flood protection is feasible, there is a need to finalize the strategy within the context of the City Centre Area Redevelopment Plan. It is recommended that RMWB place a high priority on the allocation of land to accommodate the flood protection structures. This will include developing privately held land and the reconciliation of the designs of other projects with the proposed flood protection system.

While the locations of dikes, floodwalls, and flood gates have been located in the most practicable way possible given what development would be reasonably expected to occur, not all the issues have been resolved. Some areas simply cannot be protected by the schemes that have been evaluated. Lands that appear to be of concern include the following.

(1) The Coast Guard property may have some historical value, but it cannot be protected in its entirety. It may be possible to adjust the alignment of the dike slightly and move the most valuable structures back from the river and inside the dike so that they can be protected. Clearly, there needs to be some compromise on both these fronts.

(2) There are concerns about flood-related dangers to people and infrastructure outside of the dike, including the development along the Snye, some of the sports fields in Waterways, the Horse Pasture, and rural residences southeast of Waterways. Efforts will still need to be made each year to forecast the timing and severity of flooding and to warn residents of the impending floods to ensure that appropriate action can be undertaken to mitigate the effects of the flooding.

(3) Flood protection for Lions Park is not recommended. The park is located on the floodplain of the Hangingstone River immediately downstream of the Tolen Drive. It is situated lower than the design flood by up to three metres and would be inundated by at least one metre during the design open water flood on the Hangingstone River. This would lead to its classification as “floodway” that would likely preclude significant flood protection. While it would be structurally possible to protect the park with dikes, they would certainly have to encroach into the floodway to be effective.

With respect to private lands, the issues become a little more complex. Some key items that should be resolved prior to the final engineering include the following.

(1) No protection will be provided for the Marine Park.

(2) No protection will be provided for the vacant and forested property located east of Prairie Loop Boulevard and north of Franklin Avenue between the Clearwater River and Longboat Landing.

(3) Discussions with the owners of flood proofed properties that the proposed flood protection structures will tie into need to be undertaken to develop a consensus on how to proceed with the construction. There will be a significant modification to the landscape around some of these locations that may impact parking or even access to the site. Although the flood protection works will benefit these properties, input from the owners is crucial prior to undertaking the final design.

In addition to the above, once an alignment has been agreed upon, a number of technical issues need to be resolved before final design can begin. The following should be undertaken.

(1) Borehole data may be required in selected locations to assess the geotechnical characteristics of the dikes foundation.

(2) Flood gates will be required at several locations to provide regular vehicle access. Site conditions should be inspected to confirm the feasibility and gate design options.

(3) Options for stormwater management during floods should be investigated. There is not much information available in Canada on stormwater management during floods. Design criteria should be investigated.

(4) When the flood protection alignment is finalized, locations prone to river bank erosion should be assessed.

(5) Ice jam flooding has limited impacts on flood levels along the Hangingstone River. Open-water hydraulic analysis results presented in this report are preliminary and should be vetted by ESRD to ensure that the modelling procedures are consistent with the protocols established for provincial flood hazard studies. Also, it is important for ESRD to take the lead on reconciling the survey datums adopted for the various topographic, bathymetric, and water level surveys on the Hangingstone River.

Finally, it must be noted that the Clearwater River is a natural and historic part of the RMWB. Access to the river should be preserved at all costs. Brute force flood protection should not compromise access to the river. However, the design and landscaping of the protection works can achieve flood control without reducing access to the river. One of the design principals should be to blend the works into the landscape as much as possible and to provide easy access across the works in as many locations as possible.

6 CONCLUSIONS

This report has described concept designs of perimeter flood protection systems that will provide flood protection up to the 100-year event for the Lower Townsite, Waterways, and Ptarmigan Park within Fort McMurray in the RMWB. As part of this work, the ice jam flood frequency curve has been updated to reaffirm the design flood level, open-water flood frequencies and flood levels along the Clearwater and Hangingstone rivers have been estimated, criteria for the design and placement of the flood protection structures have been developed on the basis of local concerns and existing and future development, and an optimal layout has been identified.

The ice jam flood frequency curve that was derived in 1991 by ESRD has not changed in spite of somewhat severe ice jams in 1997 and 2013. The 100-year ice jam flood level remains at an elevation of 250.0 m. The 1875 flood, which is the largest flood on record with an estimated elevation of 252.0 m, has an estimated return period of about 500 years. Taking account of current flood management trends in Alberta, the RWWB has adopted the 100-year flood level of 250.0 m as its design level (without freeboard) for all its urban infrastructure.

Analysis of open water flood risks for the Clearwater and Hangingstone rivers, indicates that water levels at the 100-year floods are within the banks of both streams. Ice-related flooding dominates along the margins of the Clearwater River and along Hangingstone River downstream of about King Street. Upstream of that point, in the vicinity of Grayling Terrace, the 100-year open water flood on the Hangingstone River exceeds the ice-related flood level, but the 100-year levels of both types of flood are below the level of the terrace.

Several types of flood protection structure have been adopted to provide a structural flood protection system that integrates with the existing development: (i) earthen dikes and retaining walls, (ii) raised roadways, and (iii) floodwalls and floodgates. Protection for the Lower Townsite and Waterways is composed mostly of dikes, raised roadways (Prairie Loop Boulevard), and floodwalls – selected on a reach by reach basis to fit into the existing and proposed development, and extending along the Clearwater and Hangingstone rivers from MacDonald Drive to King Street. Waterways is protected with a combination of dikes and raised roadways (Saline Creek Drive), while protection for Ptarmigan Court include floodwalls along the Hangingstone River and Saline Creek that tie into Tolen Drive.

The three zones of flood protection – Lower Townsite, Waterways, and Ptarmigan Court – are differentiated on the basis of the elevations of existing local roads and the need to accommodate the Hangingstone River. Approximately 6.2 km of structure will be required for the Lower Townsite, 2.7 km for Waterways, and 0.6 km for Ptarmigan Court. Depending on the options chosen, the cost of protecting the entire system could range from $141 million to $155 million, including engineering costs and contingencies but not including inflationary costs and owner costs over the duration of the construction. Approximately 80 percent of the costs

would be allocated to the Lower Townsite, 15 percent to Waterways, and 5 percent to Ptarmigan Court.

While the dikes, floodwalls, and flood gates have been located in the most practicable way possible given what development would be reasonably expected to occur, not all the issues have been resolved. Some areas simply cannot be protected in a practicable way. The Coast Guard property may have some historical value, but it cannot be protected in its entirety. Also, concerns will remain about flood-related dangers to people and infrastructure outside of the flood protection, including the development along the Snye, the Horse Pasture, and rural residences southeast of Waterways. In some locations (Riverwalk Villas) floodgates will be required to allow access to areas adjacent to the Clearwater River. These will need to be installed for a few days in advance of a severe breakup. Efforts will still need to be made each year to forecast the timing and severity of flooding and to warn residents of the impending floods.

Flood protection for Lions Park is not recommended. It is situated lower than the design flood by up to three metres and would be inundated by at least one metre during the design open water flood on the Hangingstone River. This would lead to its classification as "floodway" that would likely preclude significant flood protection. With respect to private lands, the issues become a little more complex. No protection will be provided for the vacant and forested property located east of Prairie Loop Boulevard and north of Franklin Avenue between the Clearwater River and Longboat Landing. Furthermore, discussions with the owners of flood proofed properties that the proposed flood protection structures will tie into need to be undertaken to develop a consensus on how to proceed with the construction.

In addition to the above, once appropriate options have been selected, a number of technical issues need to be resolved before final design can begin. Borehole data may be required in selected locations to assess the geotechnical characteristics of the dikes foundation. Options for stormwater management over a period of one to two weeks in April when ice-related water levels are high should be investigated. This report has only done a cursory examination of the need for and costs of bank protection along the Hangingstone River. More work is required there.

Ice jam flooding has limited impacts on flood levels along the Hangingstone River. Open-water hydraulic analysis results presented in this report are preliminary and should be vetted by ESRD to ensure that the modelling procedures are consistent with the protocols established for provincial flood hazard studies. Also, it is important for ESRD to take the lead on reconciling the survey datums adopted for the various topographic, bathymetric, and water level surveys on the Hangingstone River.

Finally, it must be noted that the Clearwater River is a natural and historic part of the City. Access to the river should be preserved at all costs. Brute force flood protection should not compromise access to the river. However, the design and landscaping of the protection works

can achieve flood control without reducing access to the river. One of the design principals should be to blend the works into the landscape as much as possible and to provide easy access across the works in as many locations as possible.

7 REFERENCES

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FIGURES



No.	Date	Revision	
0	30 October 2013	Issued for Review	DDA
No.	Date	Revision	ENG.

REGIONAL MUNICIPALITY OF WOOD BUFFALO

nhc northwest hydraulic consultants

RM OF WOOD BUFFALO

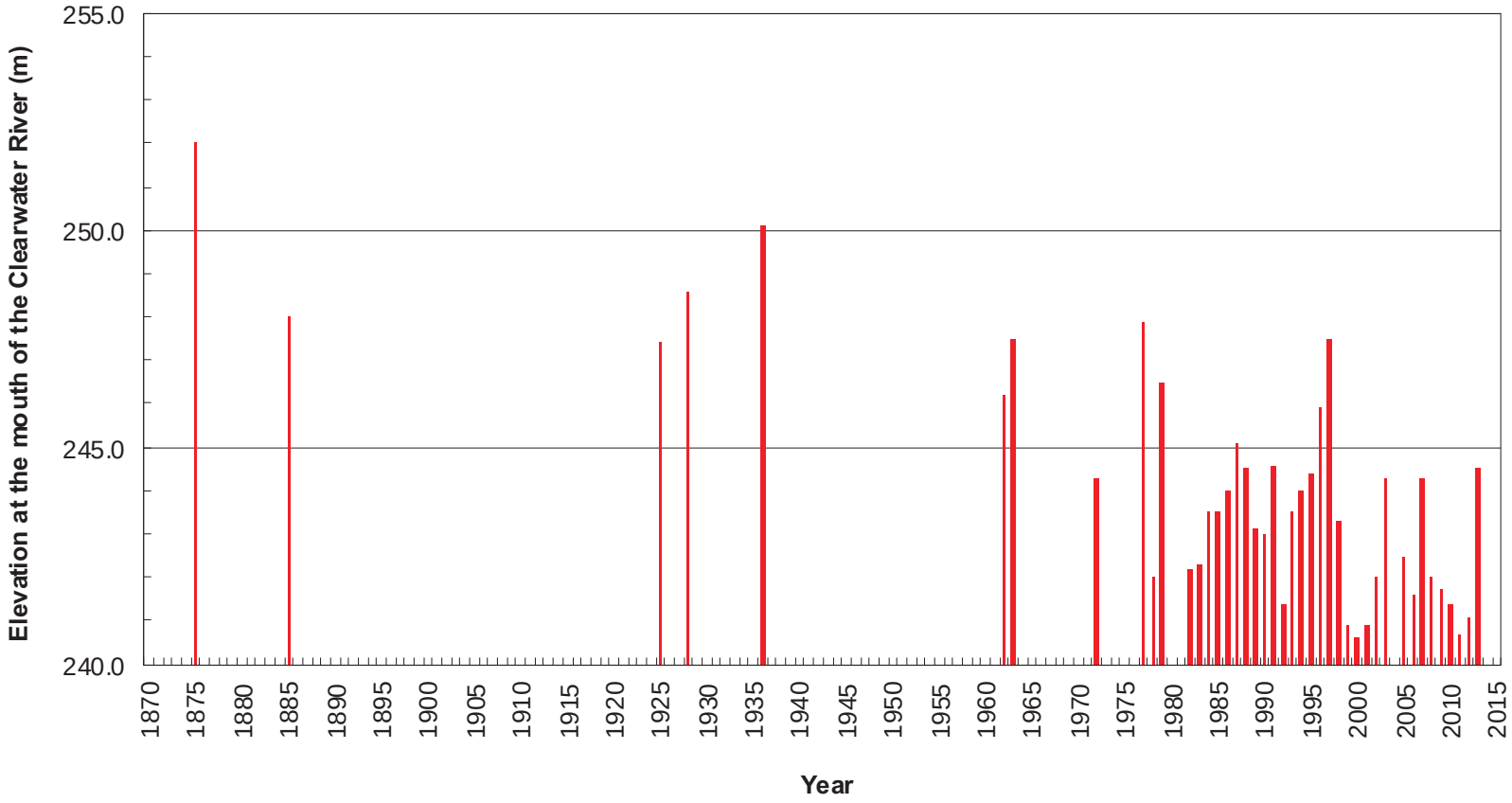
FORT McMURRAY FLOOD PROTECTION

LOCATION PLAN

Dwg. 100165-101	30 OCTOBER 2013	**Figure 1**

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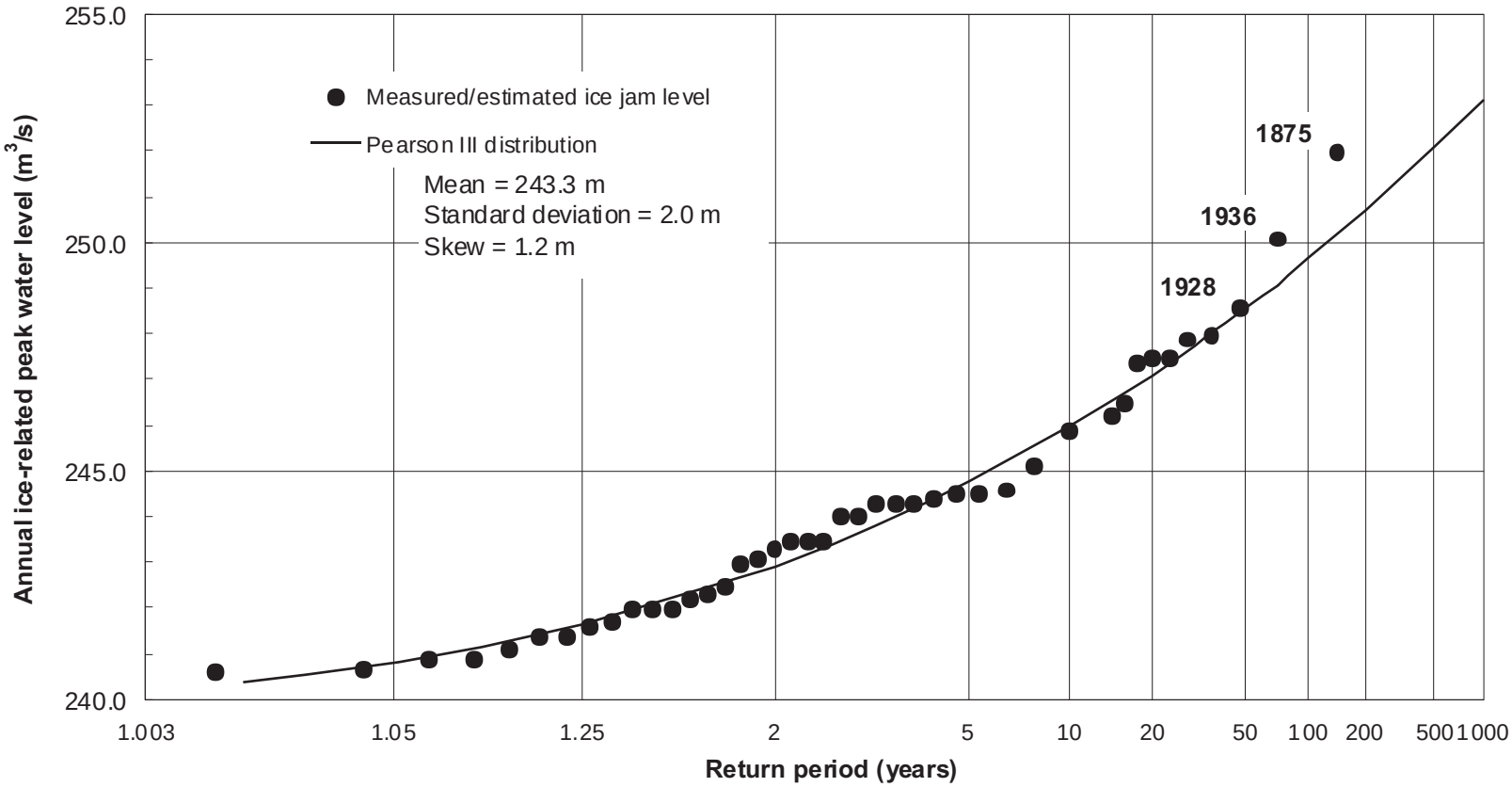
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FORT McMURRAY FLOOD PROTECTION

RECORDED ICE JAM LEVELS FOR ATHABASCA RIVER AT CLEARWATER RIVER MOUTH

Project 100165	November 2013	**Figure 2**

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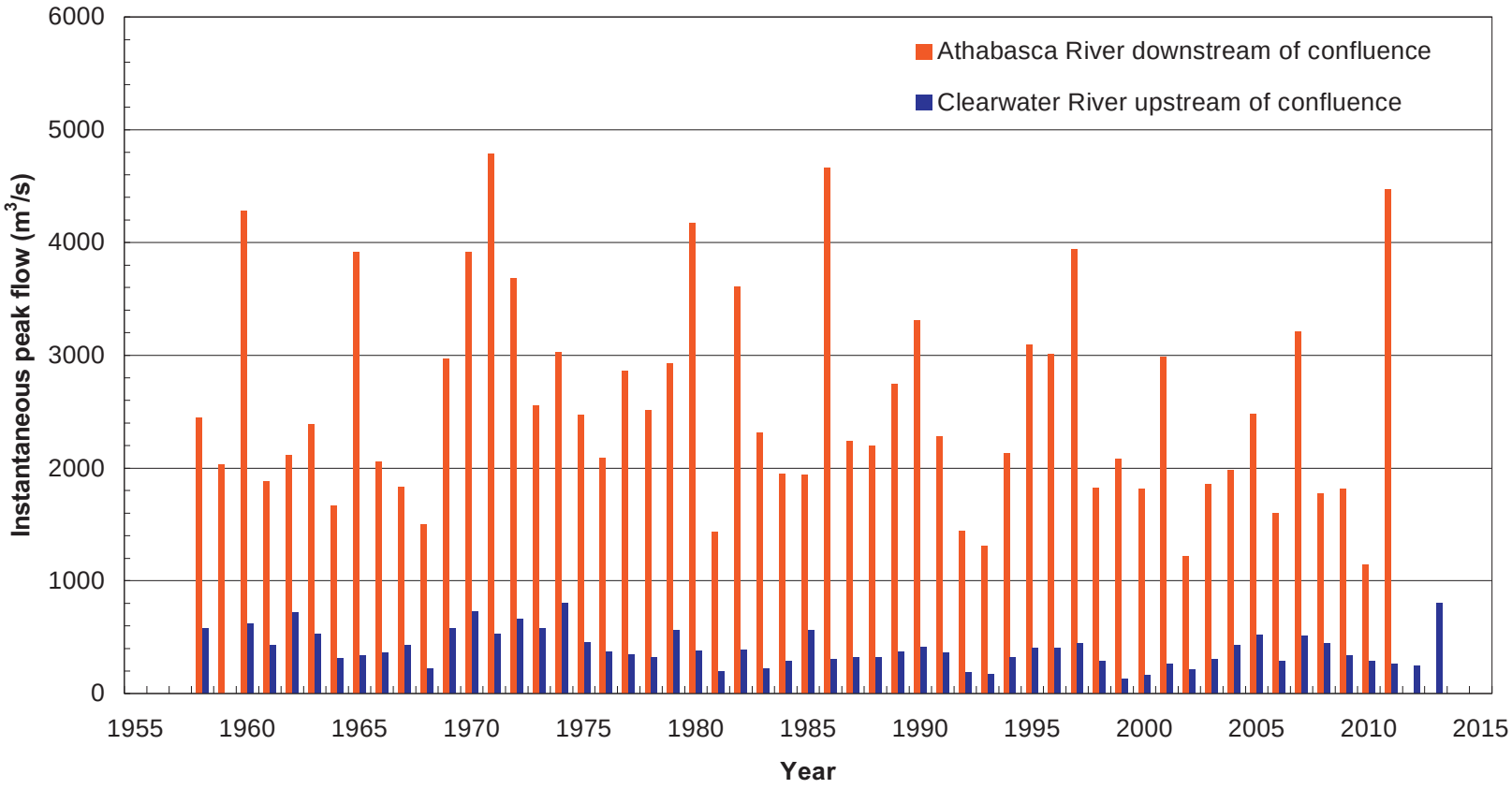
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FORT McMURRAY FLOOD PROTECTION

FREQUENCY CURVE OF PEAK ICE JAM FLOOD LEVELS FOR ATHABASCA RIVER AT CLEARWATER RIVER MOUTH

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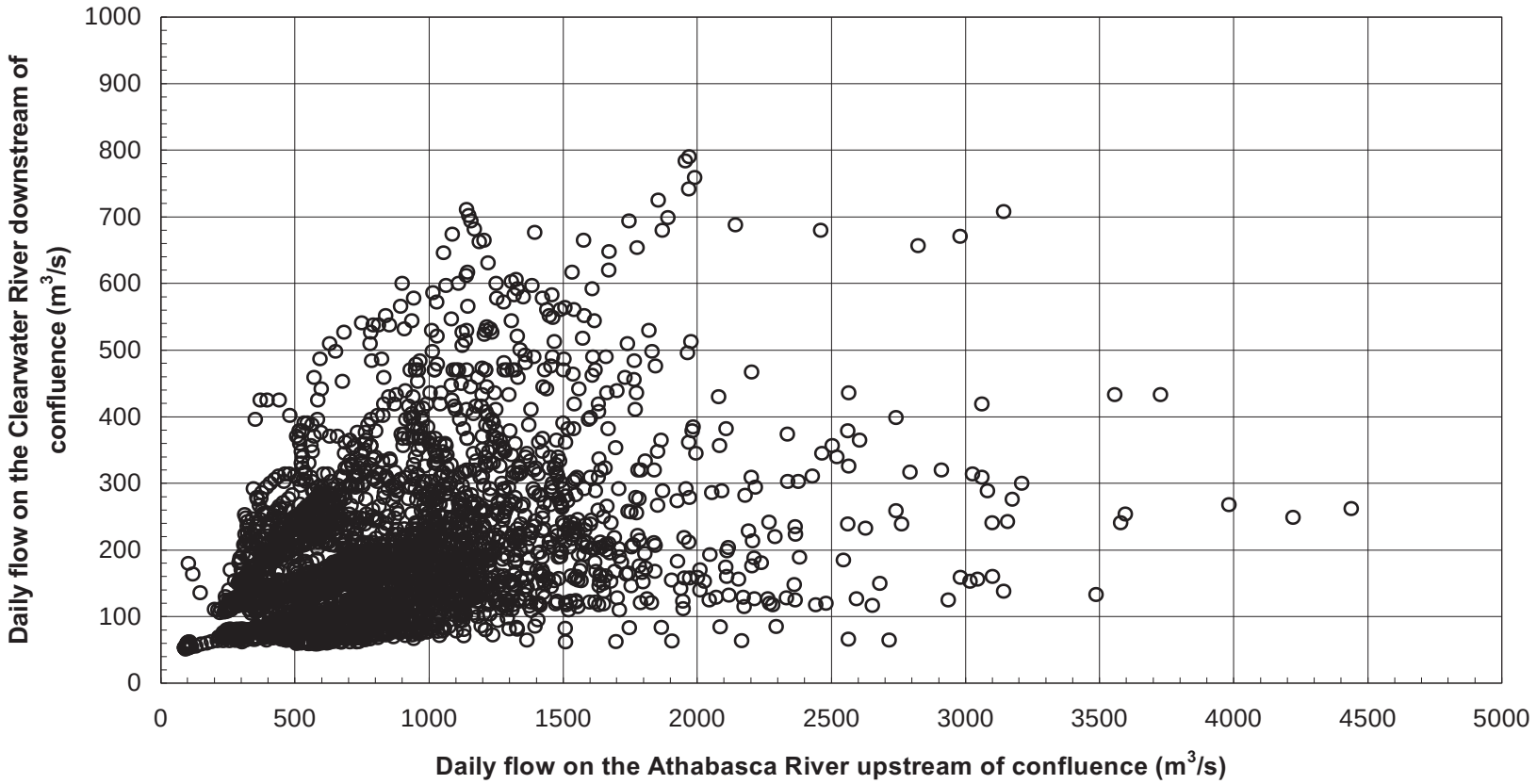
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FORT McMURRAY FLOOD PROTECTION

FLOOD PEAKS
ATHABASCA AND CLEARWATER RIVERS

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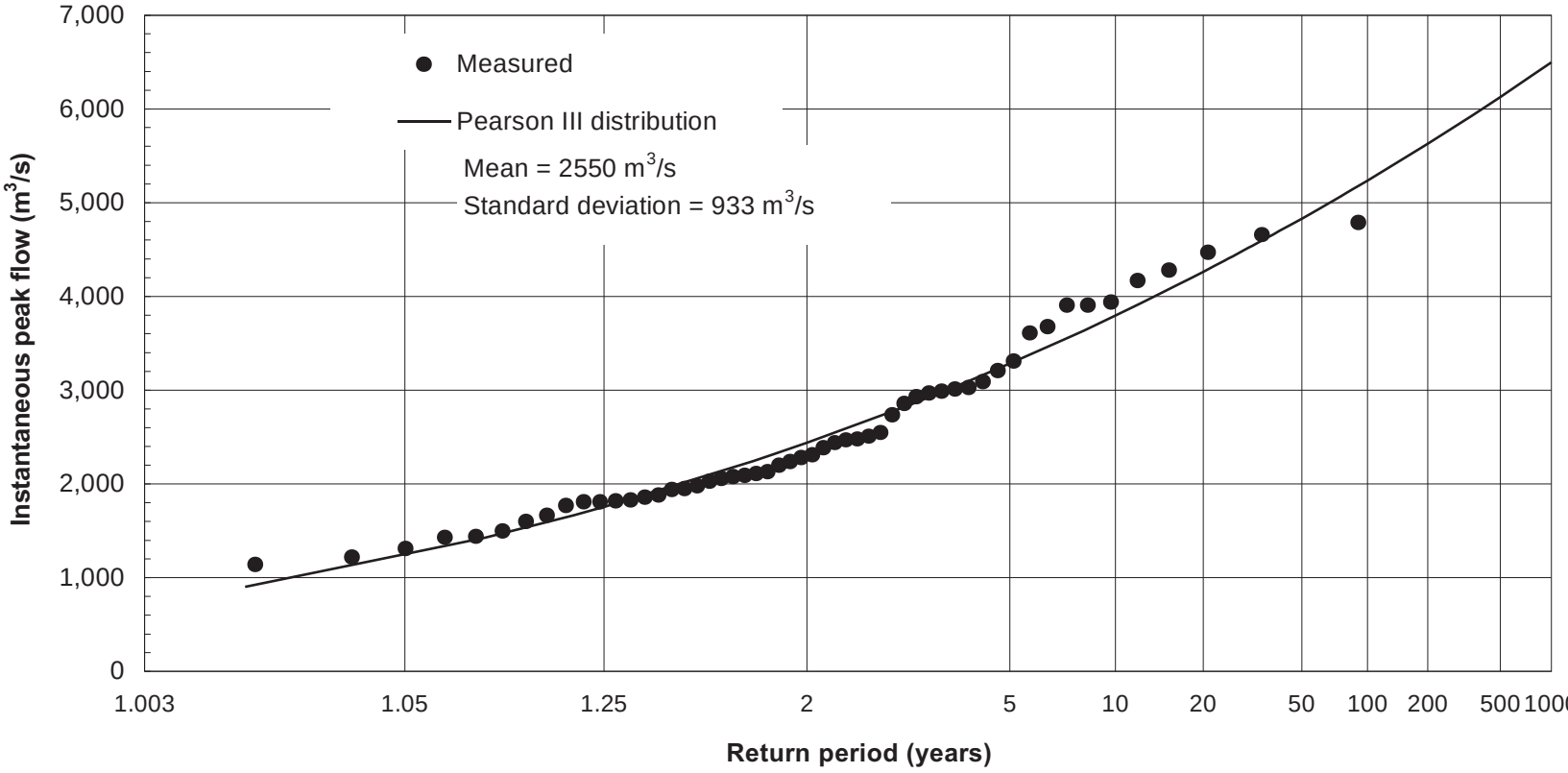
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FORT McMURRAY FLOOD PROTECTION

COMPARISON BETWEEN UPPER ATHABASCA AND CLEARWATER RIVER FLOWS

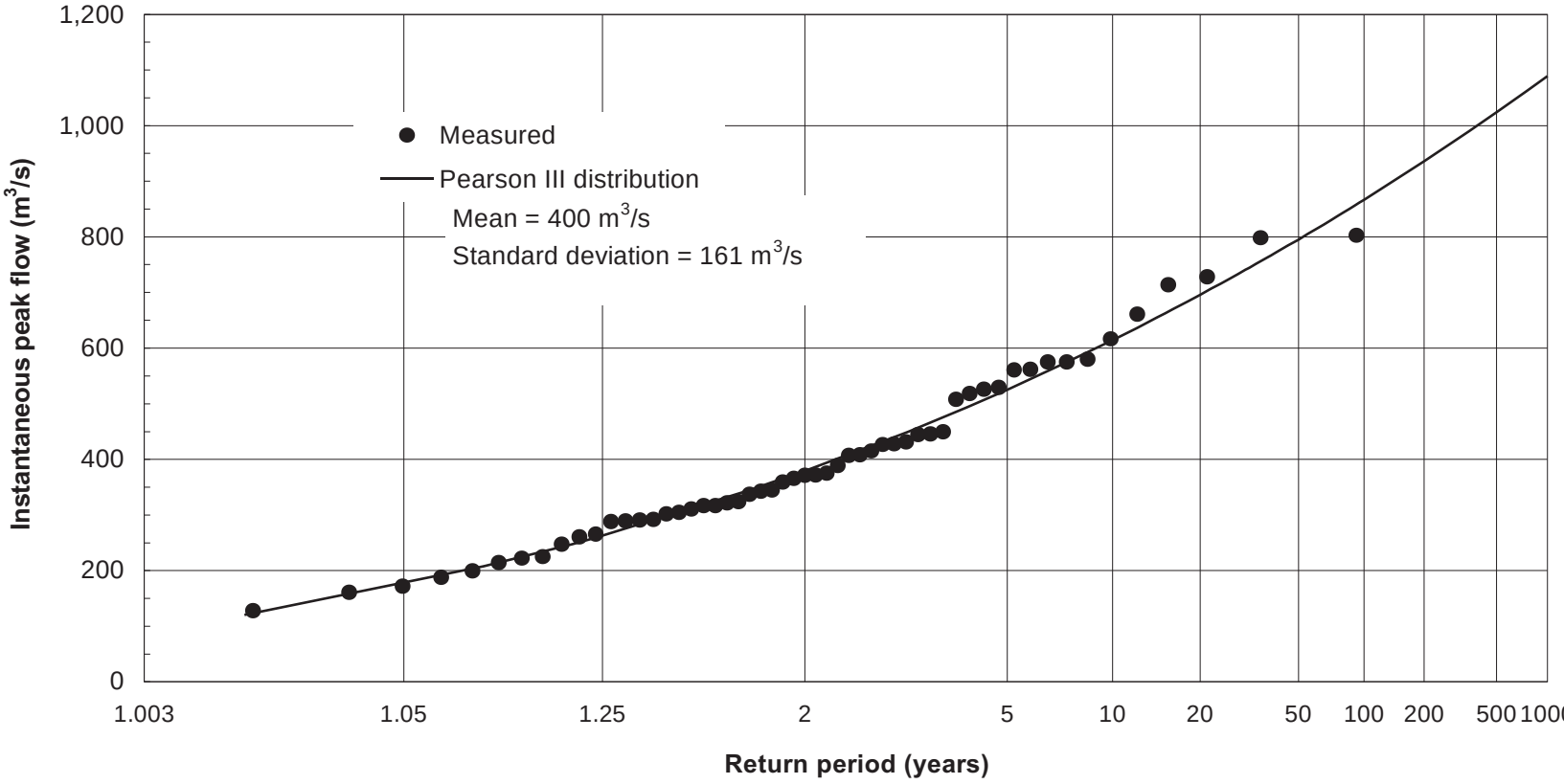
Project 100165	November 2013	**Figure 5**

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RM OF WOOD BUFFALO		
FORT McMURRAY FLOOD PROTECTION		
FREQUENCY CURVE OF FLOOD PEAKS ATHABASCA RIVER BELOW FORT MCMURRAY		
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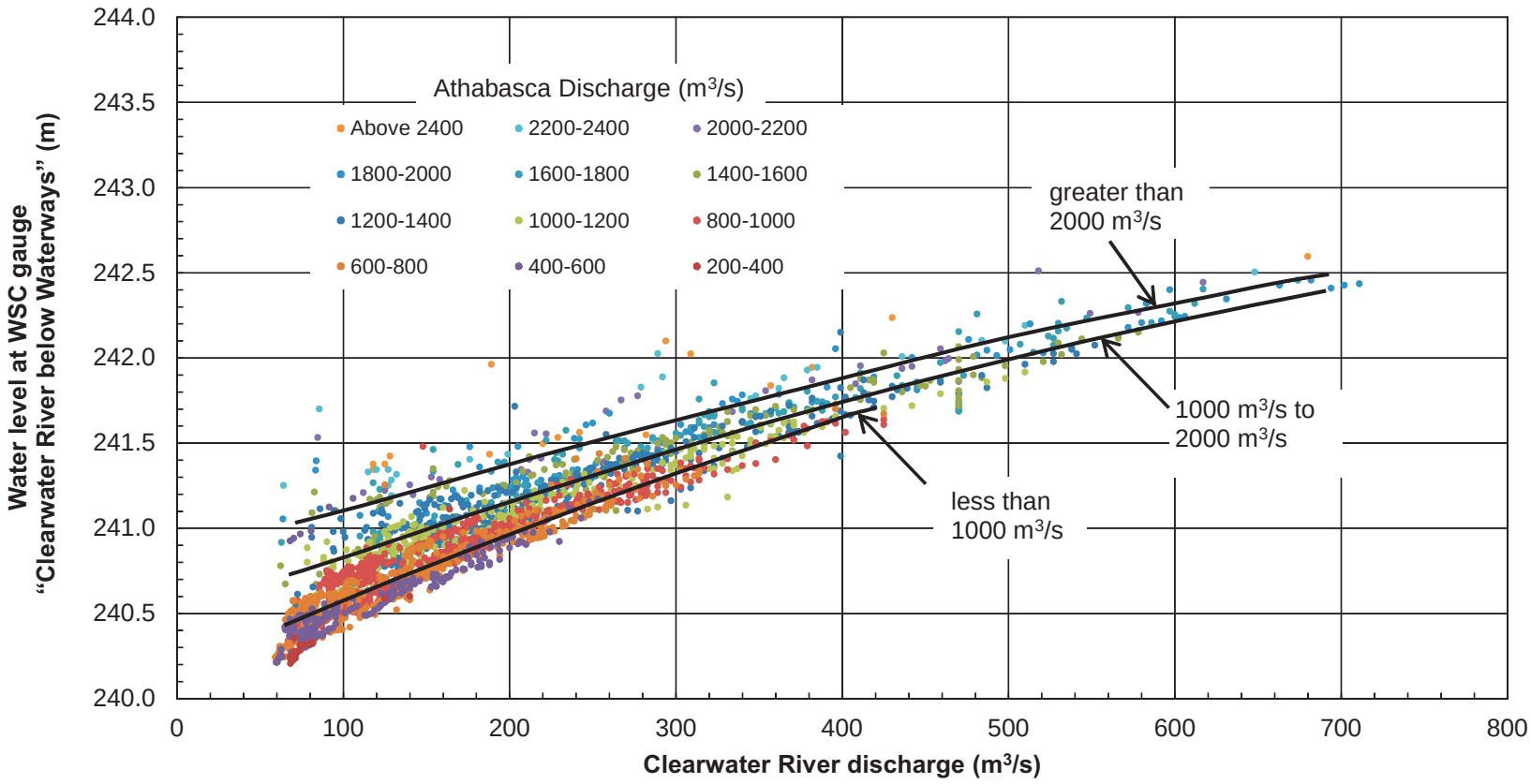
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FORT McMURRAY FLOOD PROTECTION

FREQUENCY CURVE OF FLOOD PEAKS
CLEARWATER RIVER
AT DRAPER

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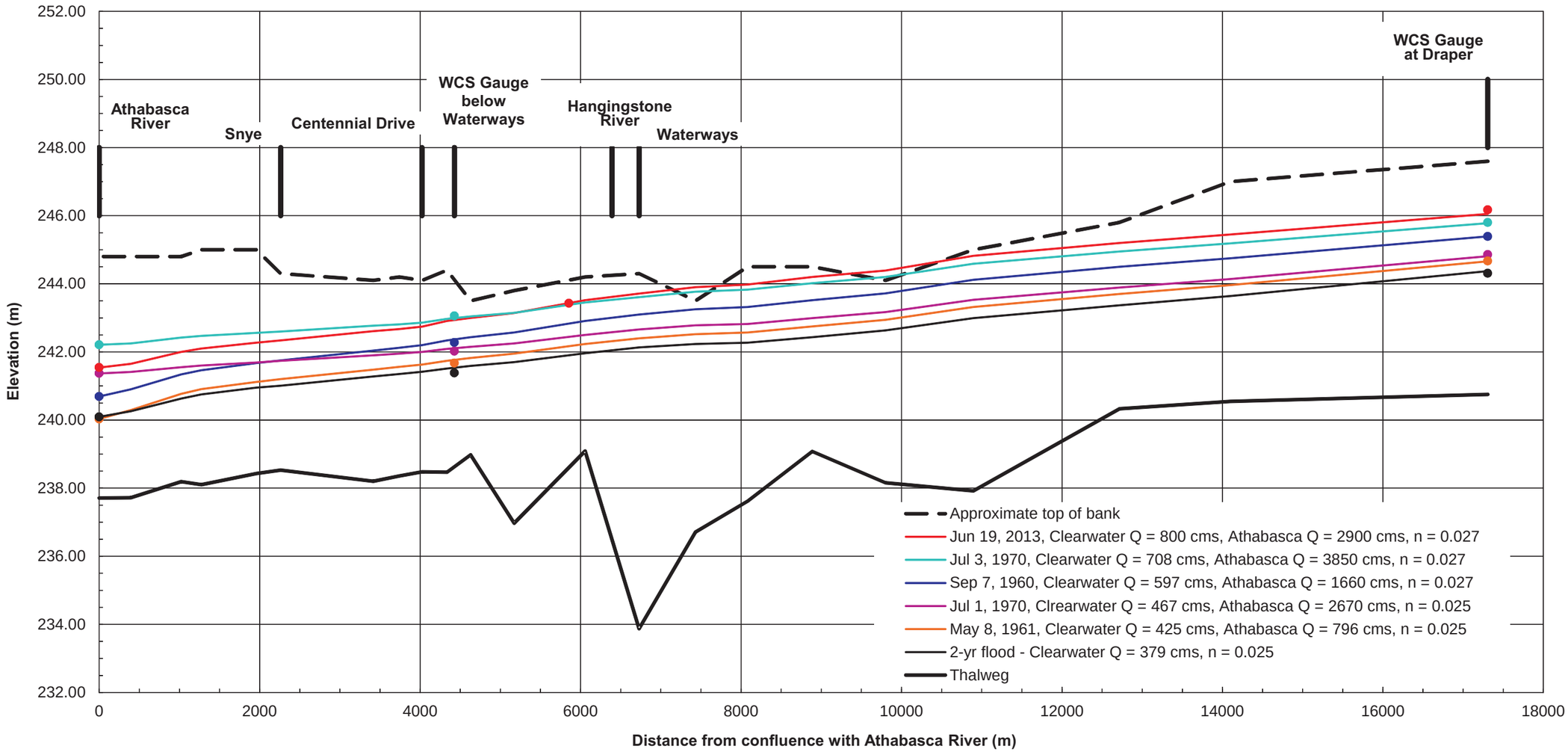
FORT McMURRAY FLOOD PROTECTION

EFFECTS OF ATHABASCA RIVER FLOWS ON CLEARWATER RIVER WATER LEVELS

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Figure 7 Simulated Water Surface Profiles - HEC-RAS Model Calibrations for Flood Flows on Clearwater River



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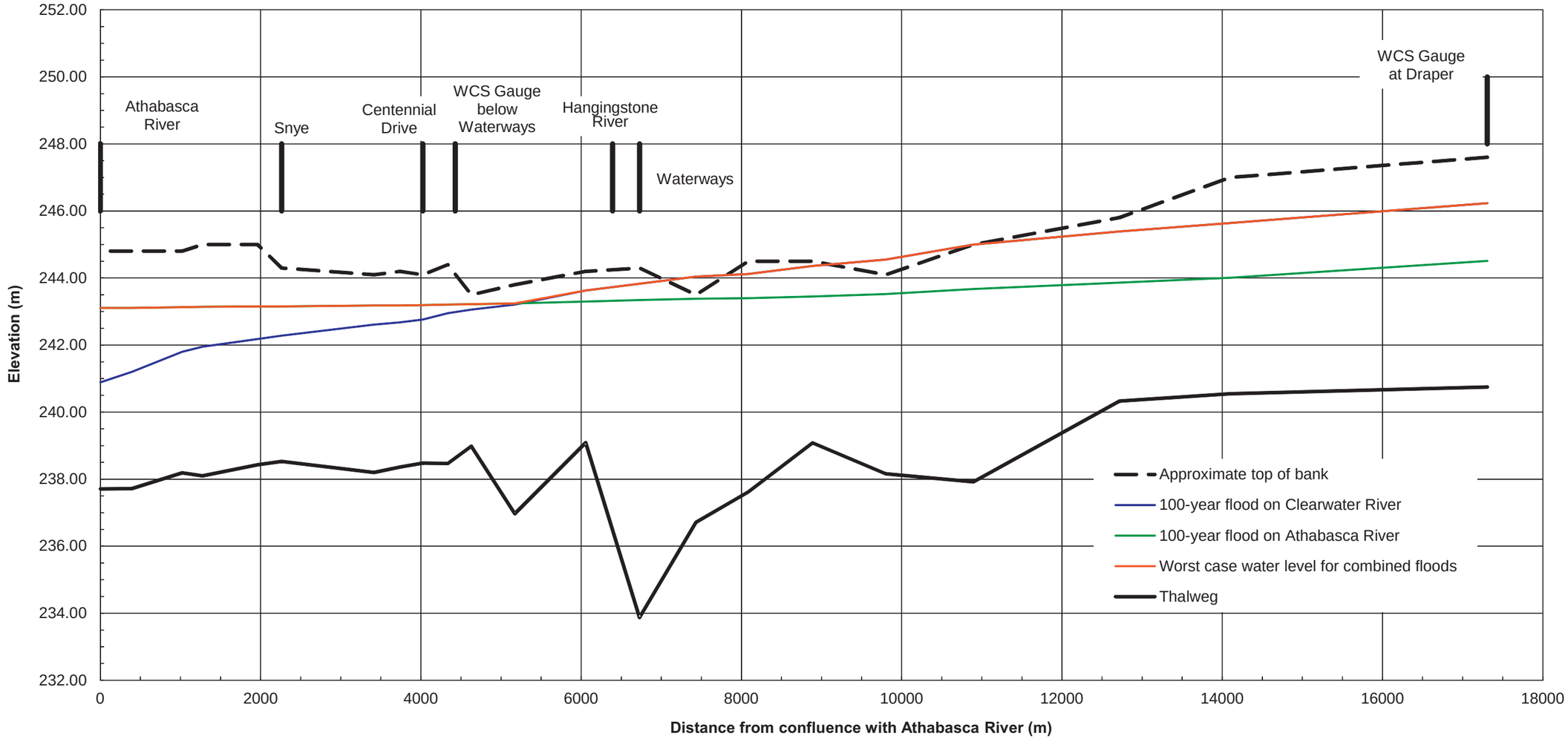
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FORT McMURRAY FLOOD PROTECTION

HEC-RAS WATER SURFACE PROFILES CLEARWATER RIVER

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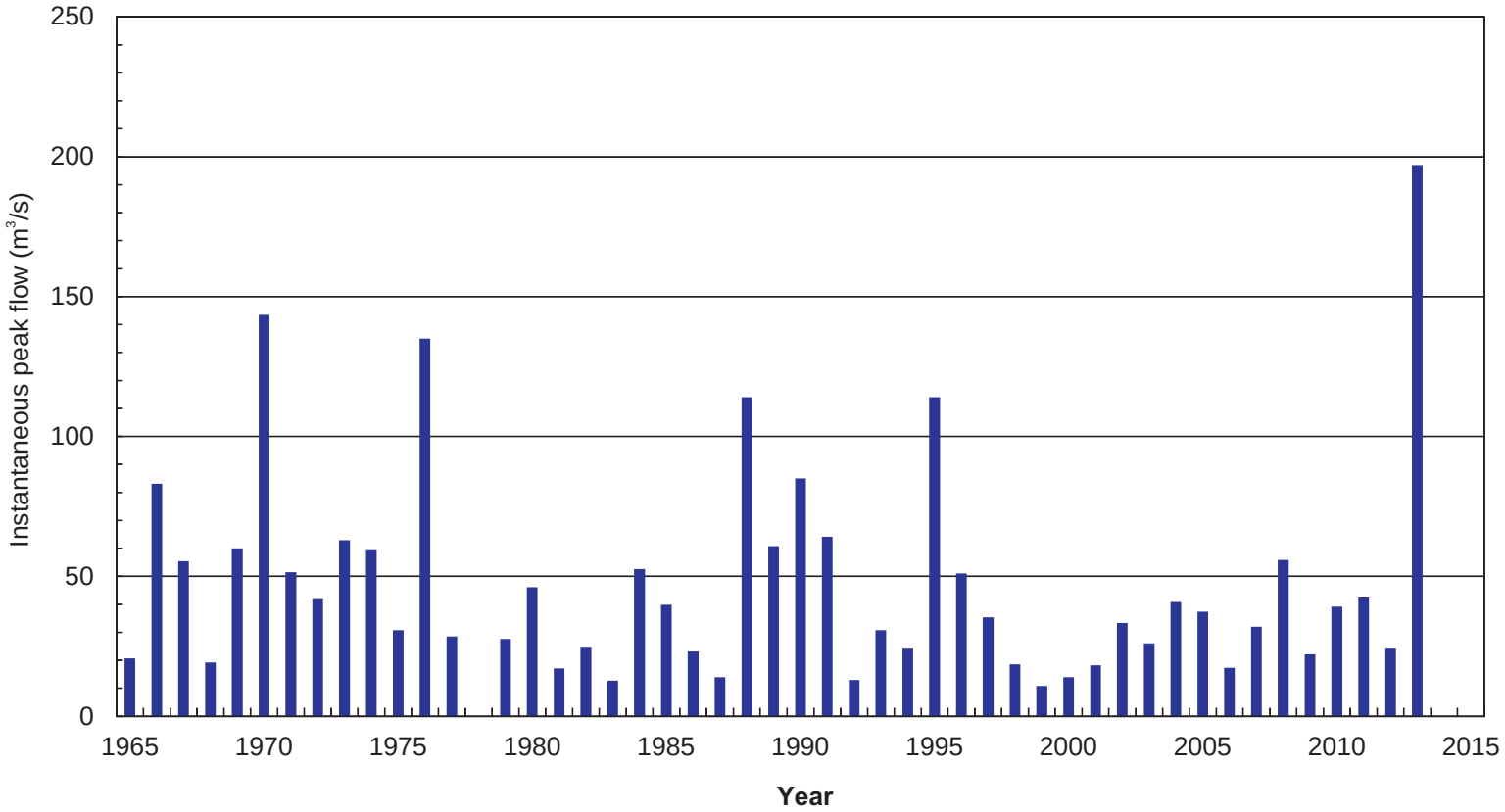
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FORT McMURRAY FLOOD PROTECTION

HEC-RAS 100 OPEN WATER PROFILES CLEARWATER RIVER

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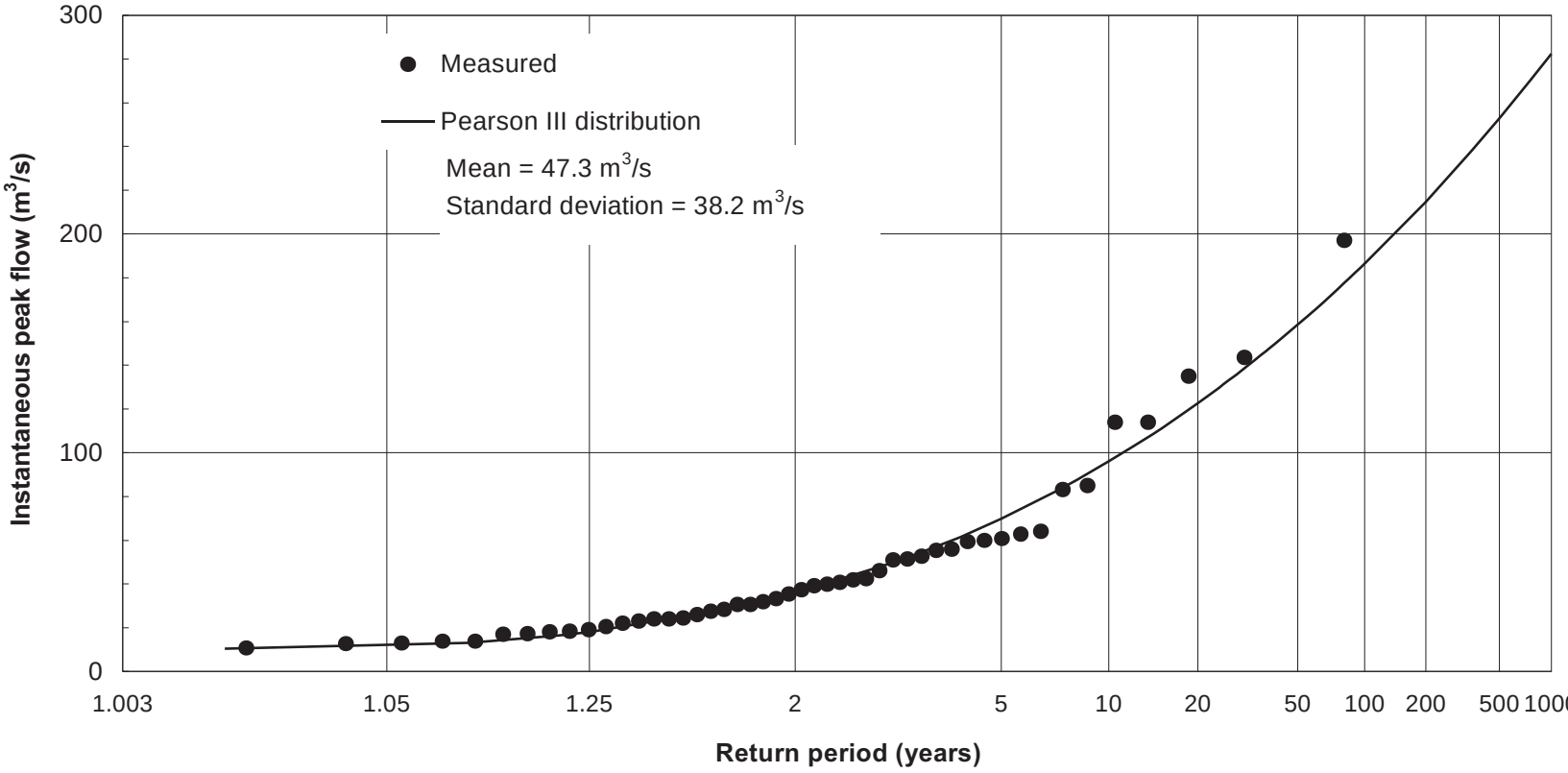
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FORT McMURRAY FLOOD PROTECTION

HANGINGSTONE RIVER FLOOD PEAKS

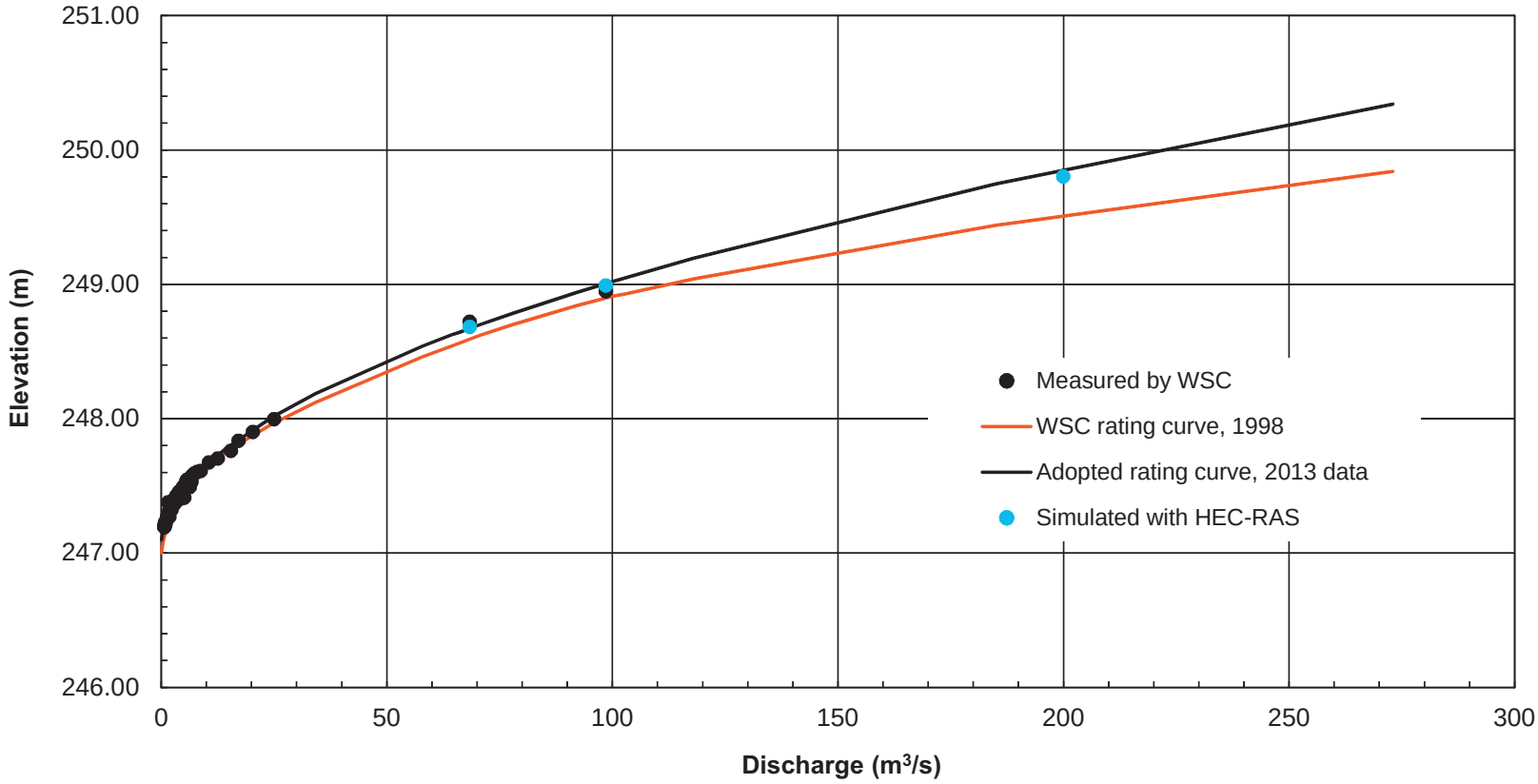
Project 100165	November 2013	**Figure 11**

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RM OF WOOD BUFFALO		
FORT McMURRAY FLOOD PROTECTION		
FREQUENCY CURVE OF FLOOD PEAKS FOR HANGINGSTONE RIVER AT FORT McMURRAY		
Project 100165	November 2013	**Figure 12**
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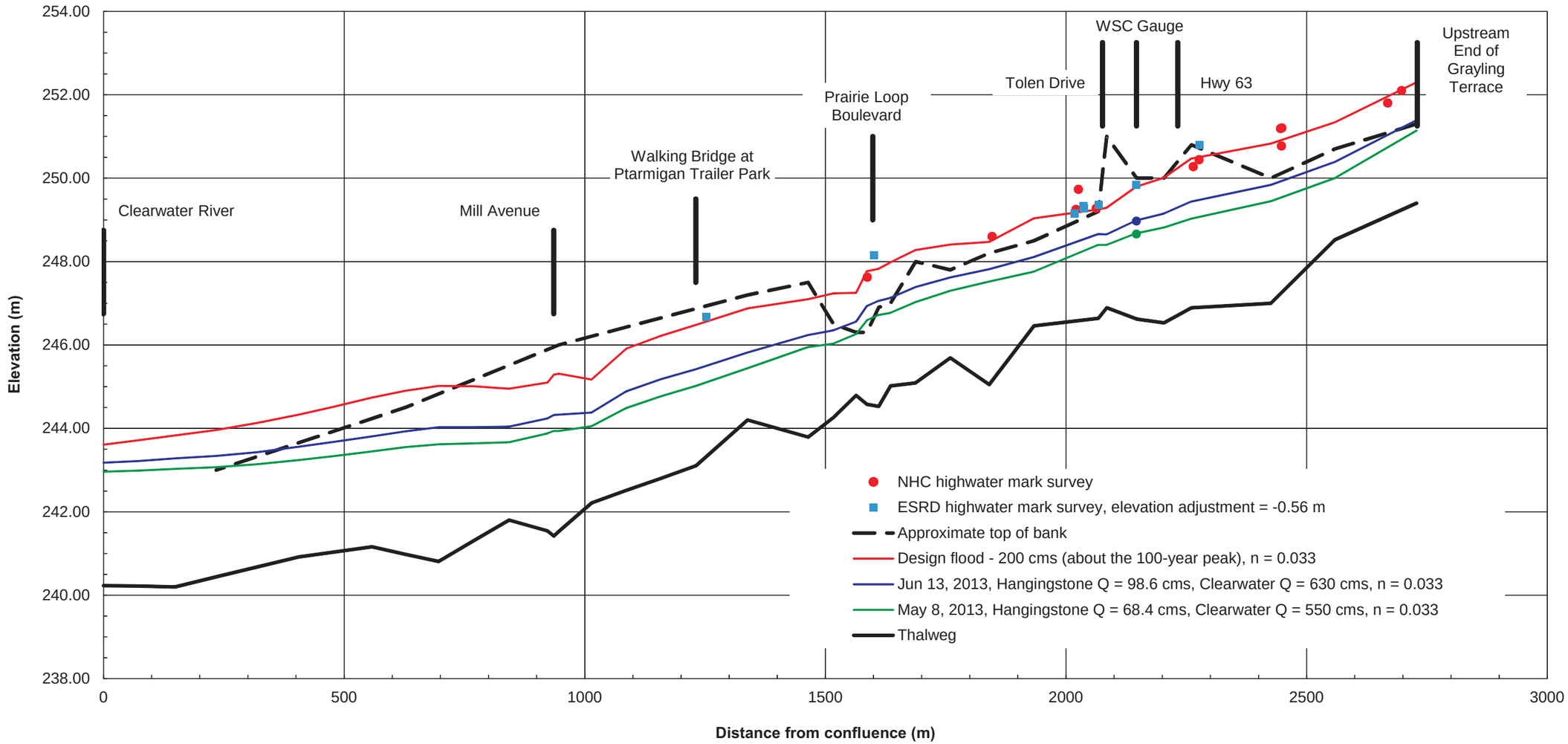
RM OF WOOD BUFFALO

FORT McMURRAY FLOOD PROTECTION

WSC RATING CURVE
HANGINGSTONE RIVER

Project 100165	November 2013	**Figure 13**

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RM OF WOOD BUFFALO

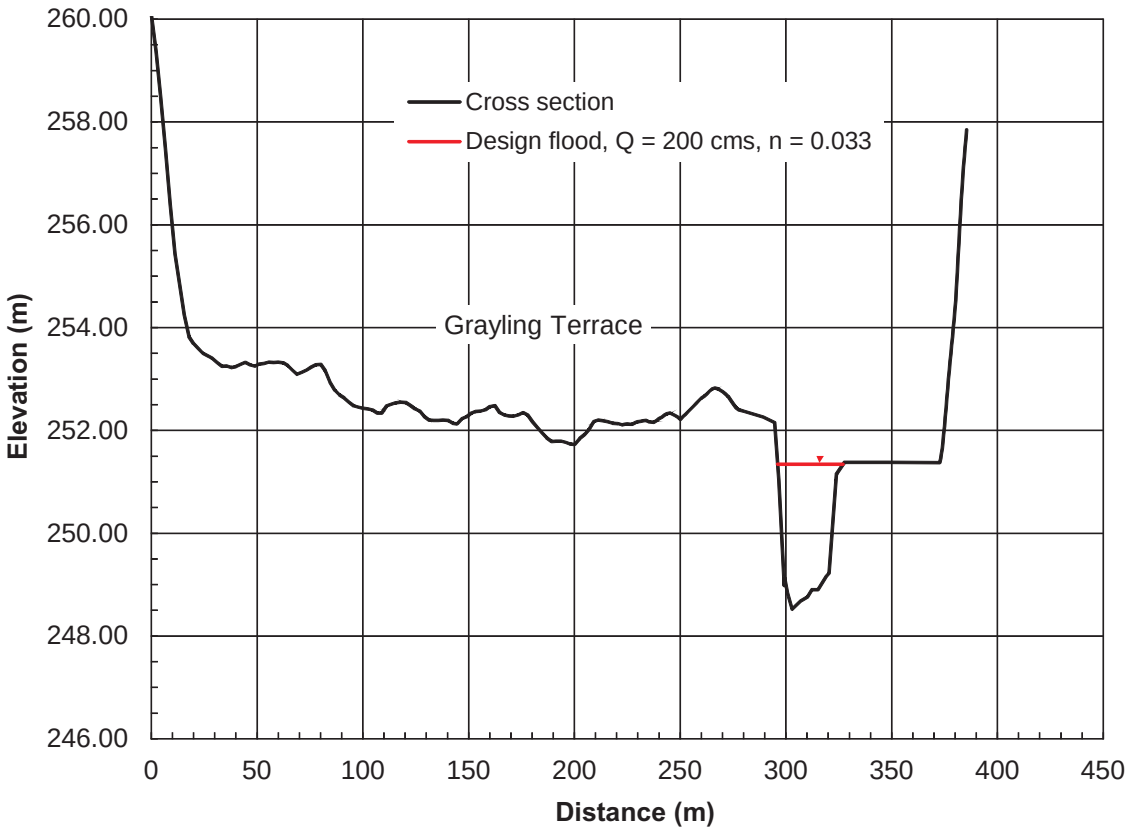
FORT McMURRAY FLOOD PROTECTION

HEC-RAS WATER SURFACE PROFILES 2013 FLOOD AND DESIGN FLOOD

Project 100165	November 2013	**Figure 14**

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RM OF WOOD BUFFALO

FORT McMURRAY FLOOD PROTECTION

TYPICAL CROSS SECTION GRAYLING TERRACE

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LEGEND:

FLOOD PROTECTION:

- 2013 PROPOSED ALIGNMENT - ALTERNATIVE 1
- 2013 PROPOSED ALIGNMENT - ALTERNATIVE 2
- AREA ABOVE EL. 250 m

PROPOSED SNYE POINT PARK

RIVERWALK VILLAS

SNYE

CLEARWATER RIVER

LOWER TOWNSITE

LONG BOAT LANDING

TIES TO EXISTING GROUND @ EL. 250.00 m

WILL EXTEND TO HIGH GROUND @ EL. 250.00 m

GRAYLING TERRACE

PTARMIGAN COURT

WATER WAYS

HIGHWAY 63

MACDONALD DRIVE

MAIN STREET

HARDIN ST.

FATHER MERCREDI ST.

MORRISON ST.

FRASER AVE.

MCLEOD ST.

RIEDEL ST.

HOSPITAL ST.

QUEEN ST.

CENTENNIAL DR.

KING ST.

MANNING AVE.

FRANKLIN AVE.

PENHORNWOOD ST.

HOSPITAL STREET

PRAIRIE LOOP BOULEVARD

SALINE CREEK DR.

MCCORMICK DR.

OMUNSON ST.

HUSGARD ST.

250

250 0 250 500 m

SCALE 1:12,500

No.	Date	Revision	ENG.
1	28 February 2014	Issued for Review	KZ
0	14 November 2013	Issued for Review	KZ

REGIONAL MUNICIPALITY OF WOOD BUFFALO

nhc northwest hydraulic consultants

RM OF WOOD BUFFALO

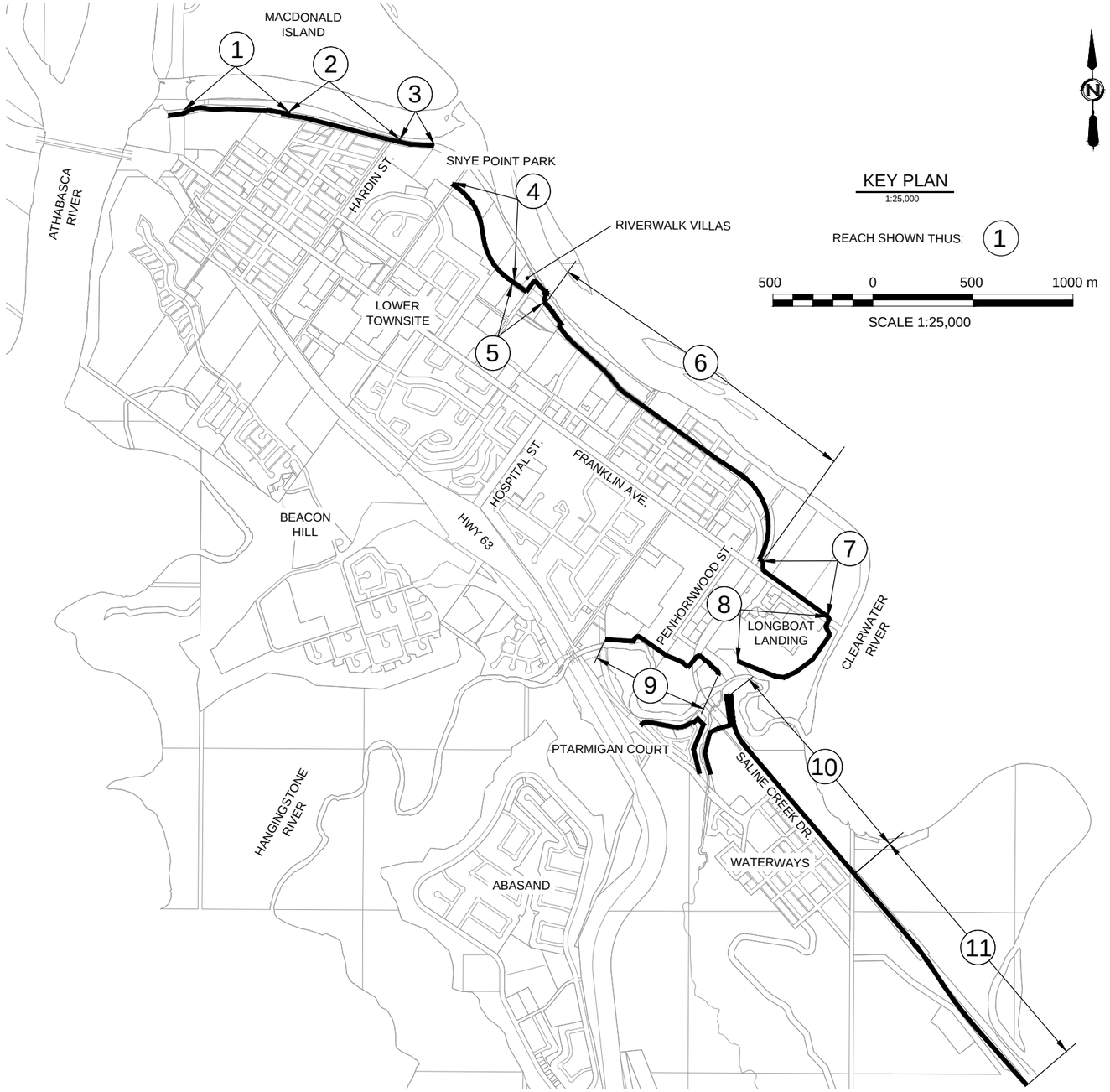
FORT McMURRAY FLOOD PROTECTION

2013 PROPOSED DIKING ALIGNMENTS

Dwg. 100165-102	28 FEBRUARY 2014	**Figure 16**

northwest hydraulic consultants ltd.

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No.	Date	Revision	ENG.
0	28 February 2014	Issued for Review	KJ

REGIONAL MUNICIPALITY OF WOOD BUFFALO

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FORT McMURRAY FLOOD PROTECTION

FLOOD PROTECTION ALIGNMENT REACHES

Dwg. 100165-203	28 FEBRUARY 2014	**Figure 17**

northwest hydraulic consultants ltd.

Filename: P:_Projects (Active)\100165 WOOD BUFFALO Flood Frequency Update\Drawings\100165-203-Alignment Reach.dwg 3/07/2014 9:52:48 AM

APPENDIX A

RMWB Initial Alignment

LEGEND:

FLOOD PROTECTION CONCEPT:

- 1 ELEVATED TRAIL
- 2 URBAN TERRACE
- 3 PRAIRIE LOOP BOULEVARD - ELEVATED
- 4 CONSTRICTED AREA
- 5a ELEVATED PARK TRAIL (1-3m)
- 5b ELEVATED PARK TRAIL (3-5m)
- 6 ELEVATED BOARDWALK
- 7 NON-ACCESSIBLE BERM
- TOPOGRAPHIC CONTOUR EL. 250 m

SECTION DESIGNATION:

- 1 REACH NUMBER

NOTES:

1. SHADED AREA INDICATES LAND ABOVE ELEVATION 250.0 m

CLEARWATER RIVER

FRASER AVE.

MANNING AVE.

FRANKLIN AVE.

HIGHWAY 63

MacDONALD DRIVE

MORRISON ST.

MAIN ST. WEST

HARDIN ST.

FATHER MERCREDI ST.

McLEOD ST.

RIEDEL ST.

HOSPITAL ST.

QUEEN ST.

CENTENNIAL DR.

KING ST.

PENHORWOOD ST.

HOSPITAL STREET

GRAYLING TERRACE

HANGINGSTONE RIVER

PTARMIGAN COURT

WATERWAYS

McCORMICK DR.

CORMORANT CRES.

MUGGABEE ST.

250

250 0 250 500 m

SCALE 1:12,500

No.	Date	Revision	ENG.
0	19 November 2013	Issued for Review	DDA

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FORT McMURRAY FLOOD PROTECTION

GENERAL LAYOUT
RMWB INITIAL ALIGNMENT
CONCEPT PLAN

Dwg. 100165-100	19 NOVEMBER 2013	**Figure A1**

northwest hydraulic consultants ltd.

Filename: P:_Projects (Active)\100165 WOOD BUFFALO Flood Frequency Update\Drawings\100165-100-R2 APPENDIX A.dwg 22/07/2014 11:10:58 AM

FIGURE A2 CONDITION 1 – ELEVATED TRAIL

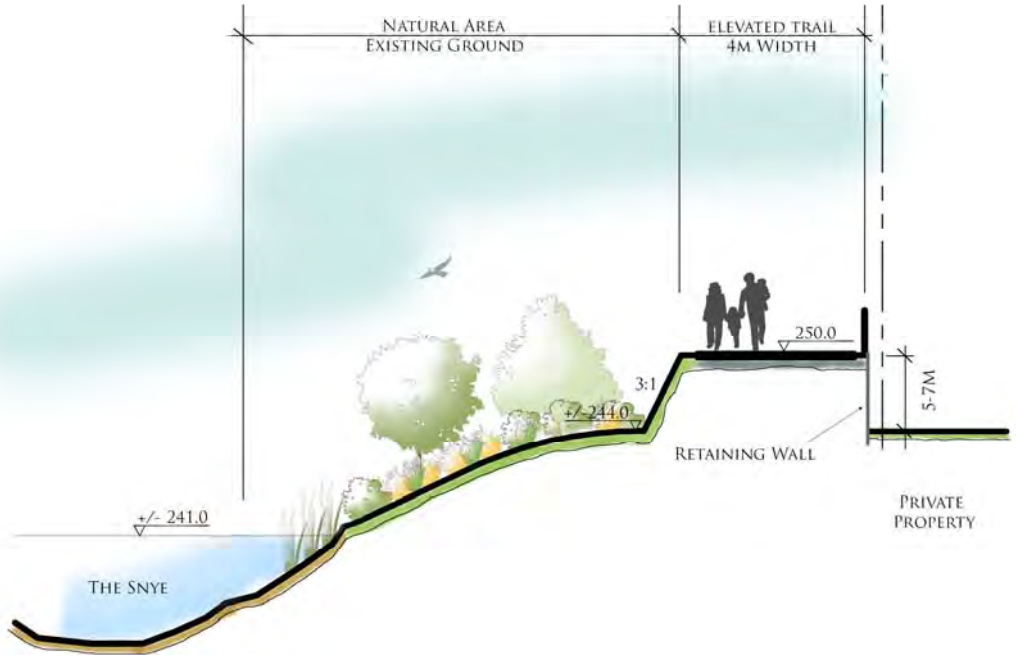


FIGURE A3 CONDITION 2 – URBAN TERRACE

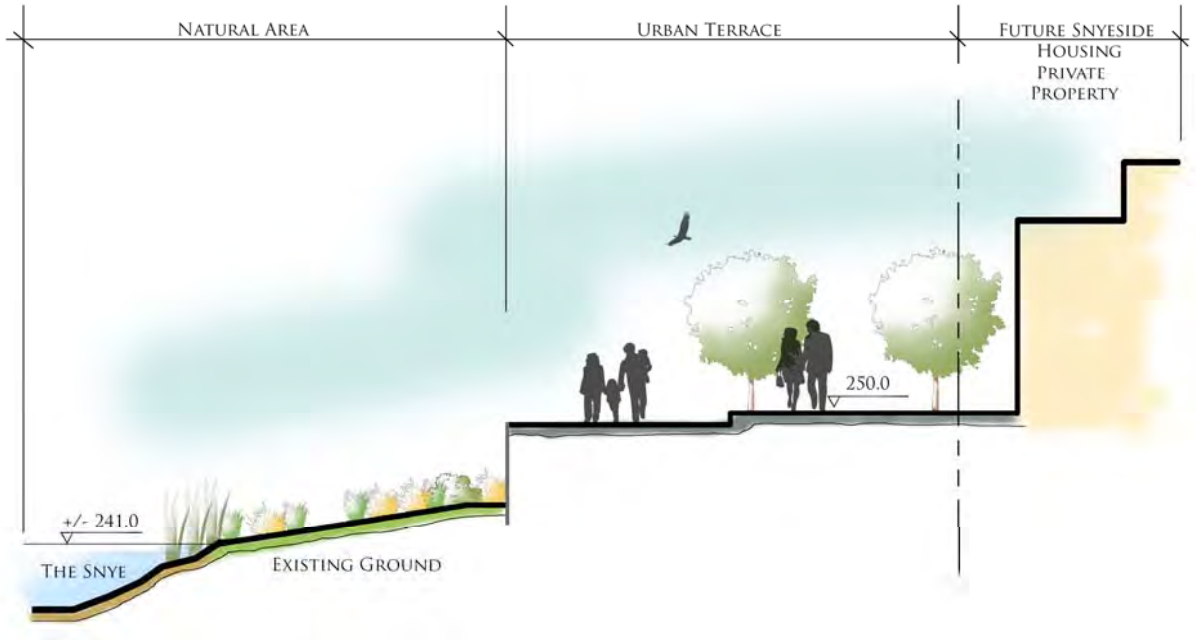


FIGURE A4 CONDITION 3 – ELEVATED PRAIRIE LOOP BOULEVARD

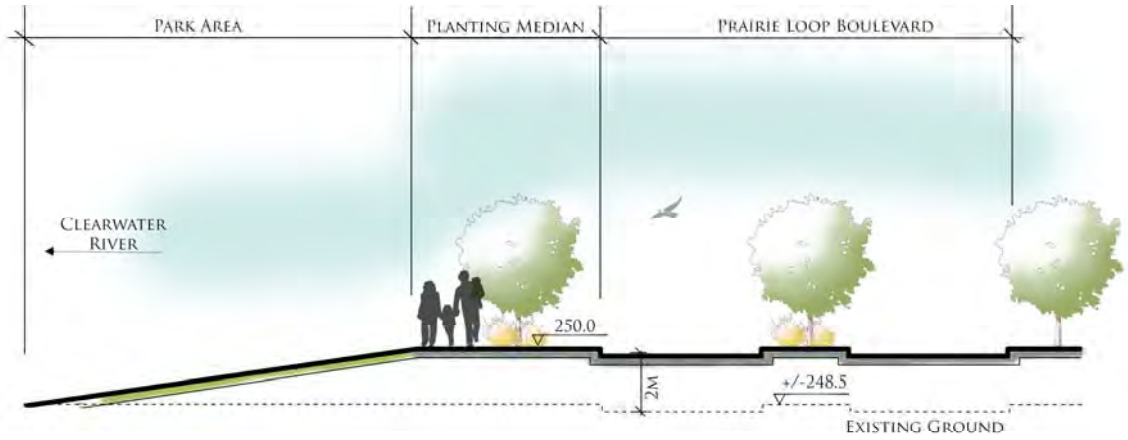


FIGURE A5 CONDITION 4 – CONSTRICTED AREA

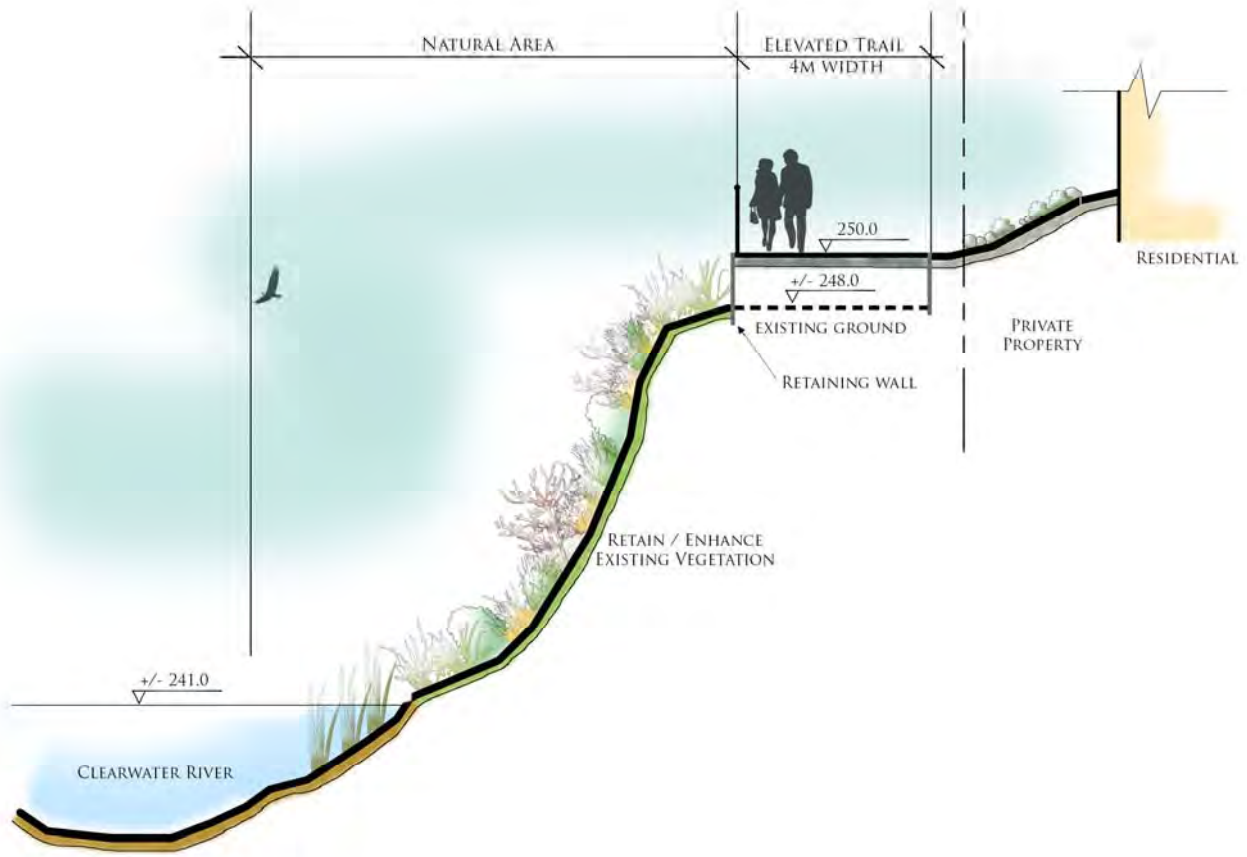


FIGURE A6 CONDITION 5A – ELEVATED TRAIL

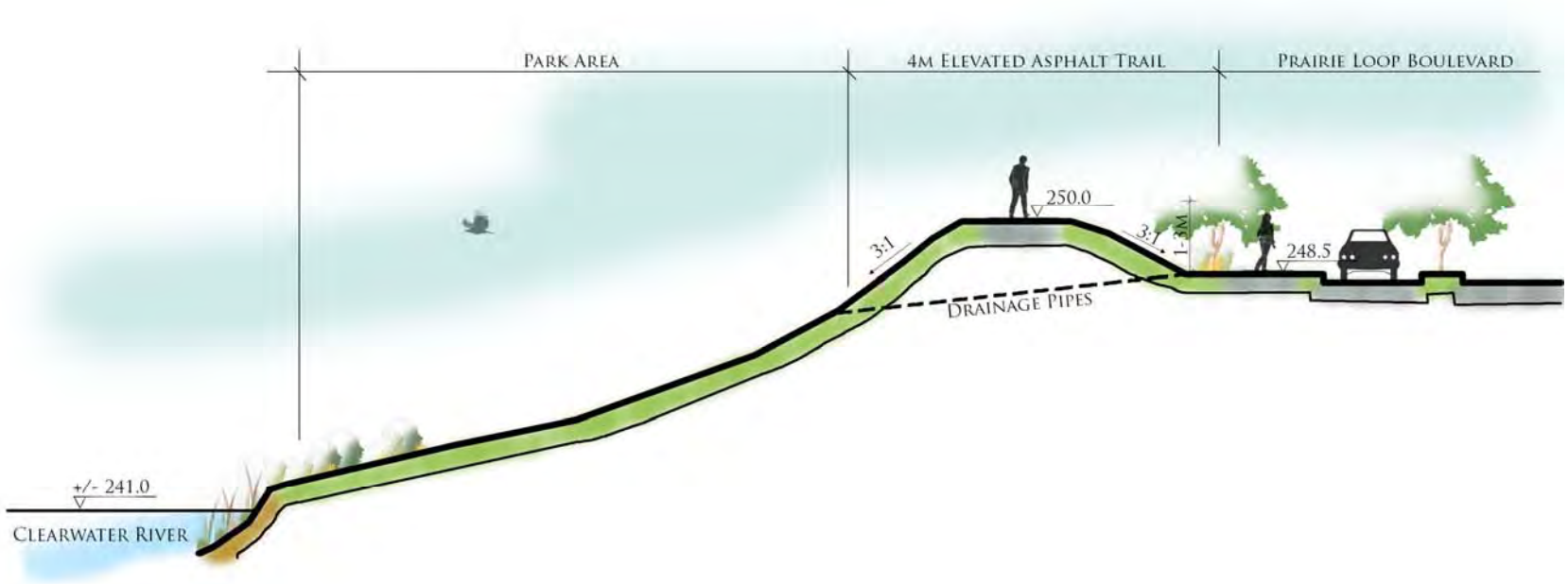


FIGURE A7 CONDITION 5B – ELEVATED TRAIL

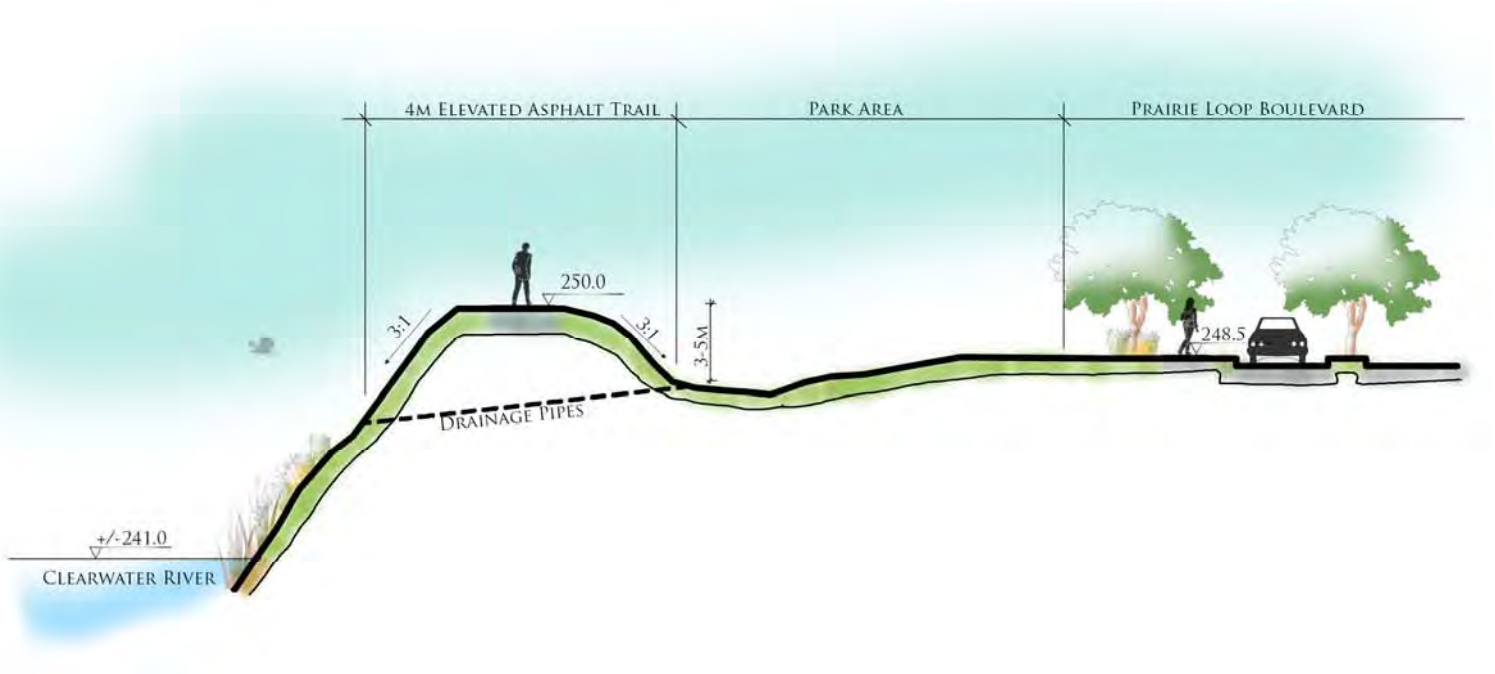


FIGURE A8 CONDITION 6 – ELEVATED BOARDWALK

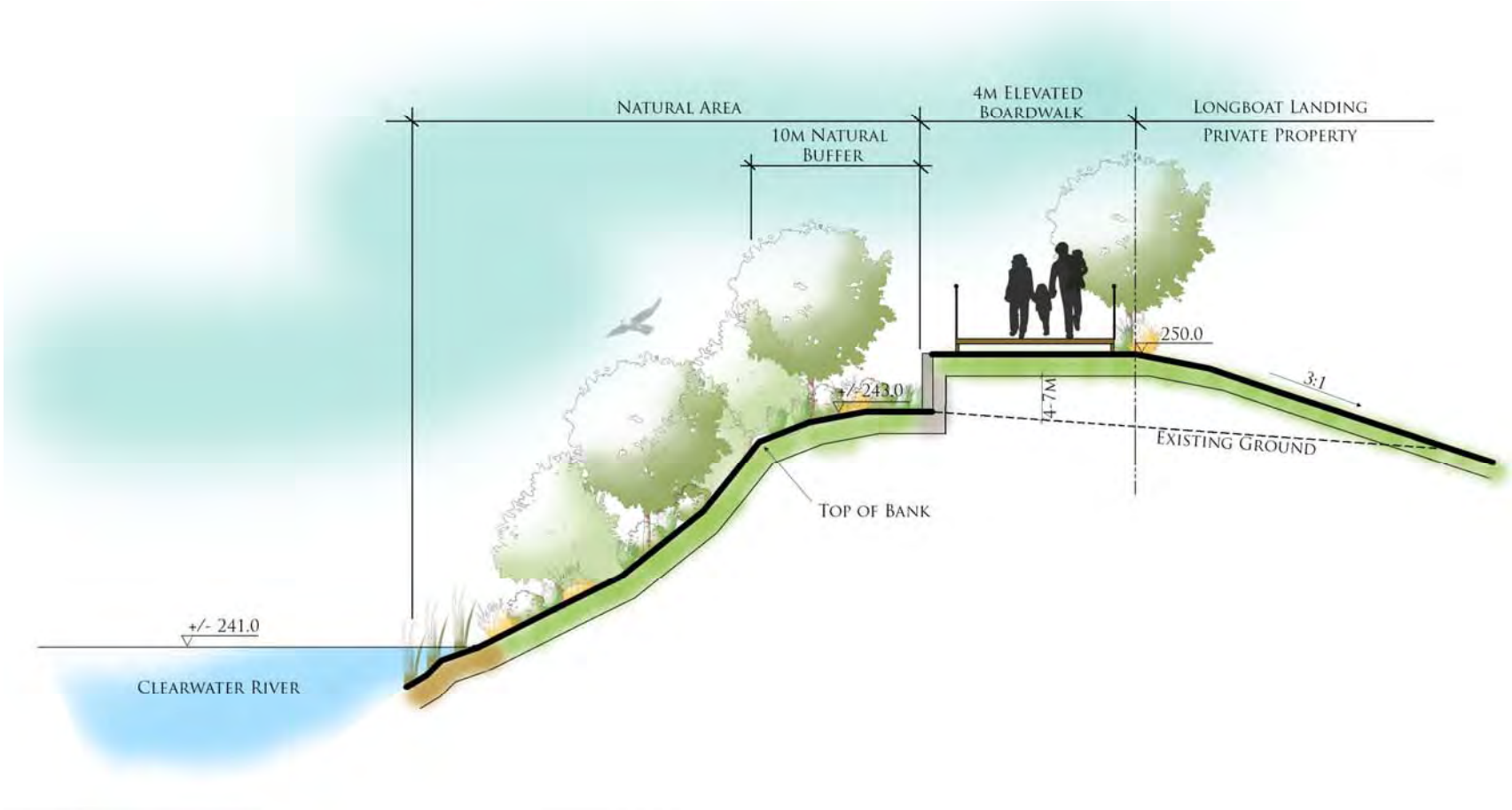
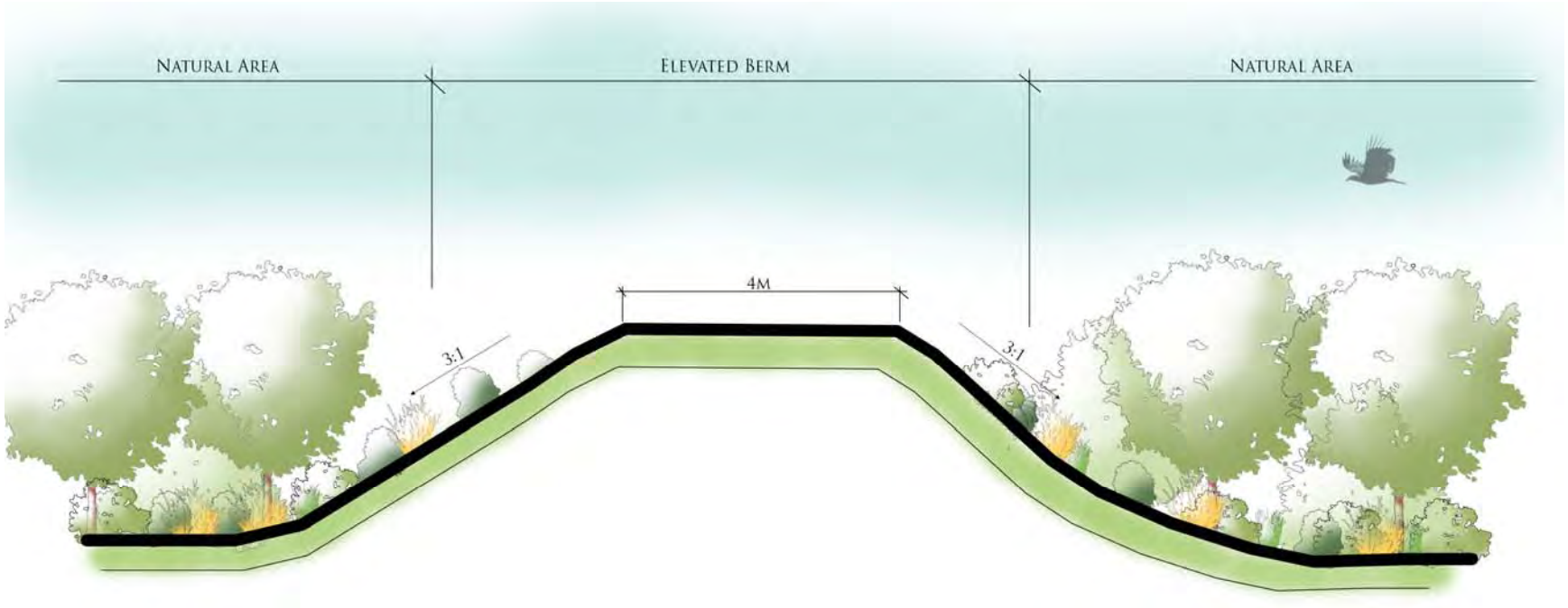


FIGURE A9 CONDITION 7 – NON-ACCESSIBLE BERM



LEGEND:

FLOOD PROTECTION:

- 2013 RMWB INITIAL CONCEPT
- 2013 ALTERNATIVE DIKING ALIGNMENT
- TOPOGRAPHIC CONTOUR EL. 250 m

REACH DESIGNATION:

- [1] REACH NUMBER

NOTES:

1. SHADED AREA INDICATES LAND ABOVE ELEVATION 250.0 m

CLEARWATER RIVER

HIGHWAY 63

FRASER AVE.

FRANKLIN AVE.

MANNING AVE.

MacDONALD DRIVE

MORRISON ST.

MAIN STREET

HARDIN ST.

FATHER MERCREDI ST.

McLEOD ST.

RIEDEL ST.

HOSPITAL ST.

QUEEN ST.

CENTENNIAL DR.

KING ST.

PENHORWOOD ST.

HOSPITAL STREET

GRAYLING TERRACE

HANGINGSTONE RIVER

PTARMIGAN COURT

McCORMICK DR.

COMMUNITY ST.

MUSKEG ST.

WATERWAYS

250

250 0 250 500 m

SCALE 1:12,500

No.	Date	Revision	ENG.
0	19 November 2013	Issued for Review	DDA

REGIONAL MUNICIPALITY OF WOOD BUFFALO

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RM OF WOOD BUFFALO

FORT McMURRAY FLOOD PROTECTION

GENERAL LAYOUT RMWB INITIAL AND ALTERNATIVE ALIGNMENTS

Dwg. 100165-100 | 19 NOVEMBER 2013 | **Figure A10**

northwest hydraulic consultants ltd.

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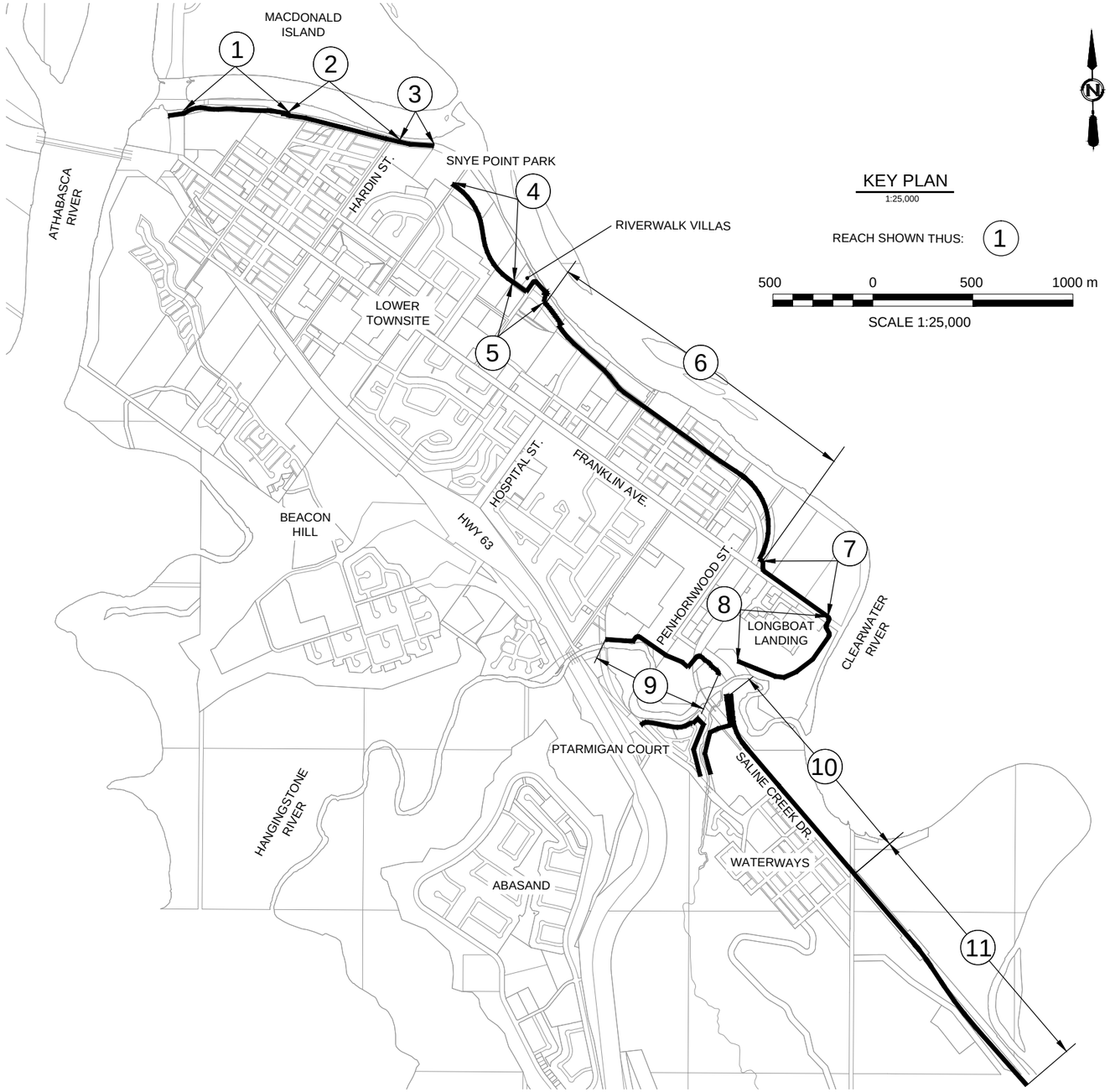
APPENDIX B

Design Drawings

Lower Townsite Alternative 1

Waterways

Ptarmigan Court



No.	Date	Revision	ENG.
0	28 February 2014	Issued for Review	KJ

REGIONAL MUNICIPALITY OF WOOD BUFFALO

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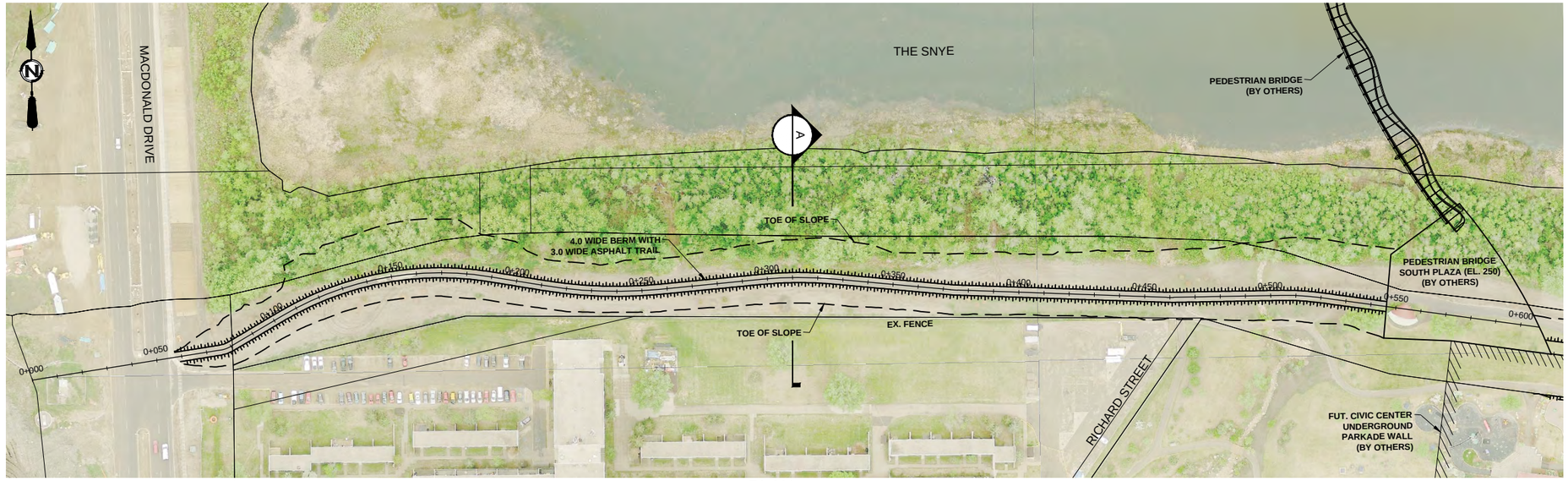
FORT McMURRAY FLOOD PROTECTION

ALTERNATIVE 1
FLOOD PROTECTION ALIGNMENT REACHES

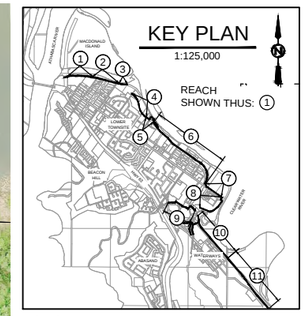
Dwg. 100165-203	28 FEBRUARY 2014	**Figure B1**

northwest hydraulic consultants ltd.

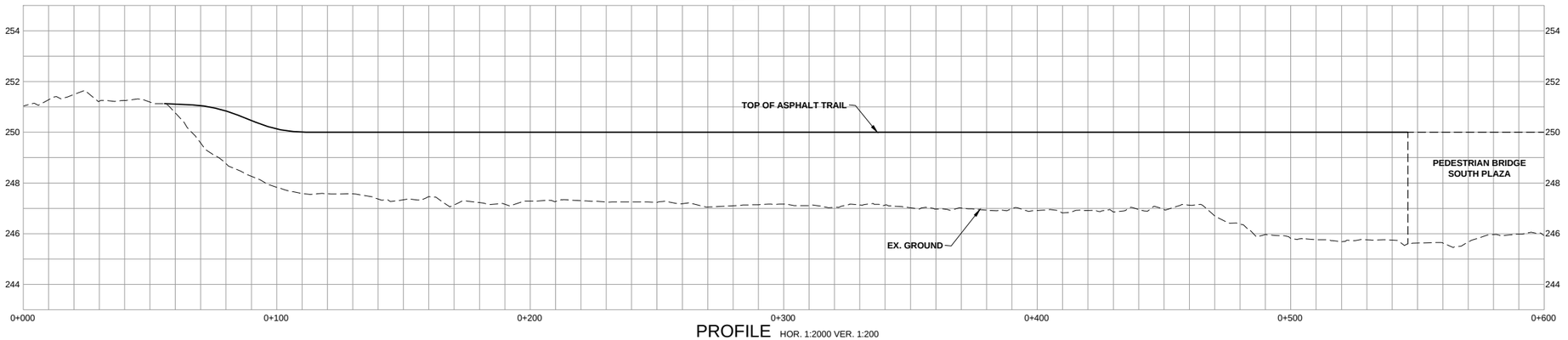
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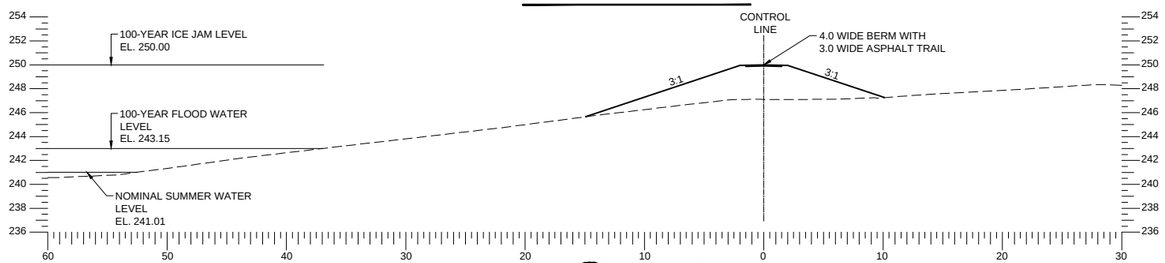
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NOTES:
1. AIRPHOTO DATED NOVEMBER 2011



PROFILE HOR. 1:2000 VER. 1:200



A SECTION 1:500

No.	Date	Revision	ENG.
0	28 February 2014	Issued for Review	KJ

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FORT McMURRAY FLOOD PROTECTION

LOWER TOWNSITE
ALTERNATIVE 1 - REACH 1
BERM WITH ASPHALT TRAIL

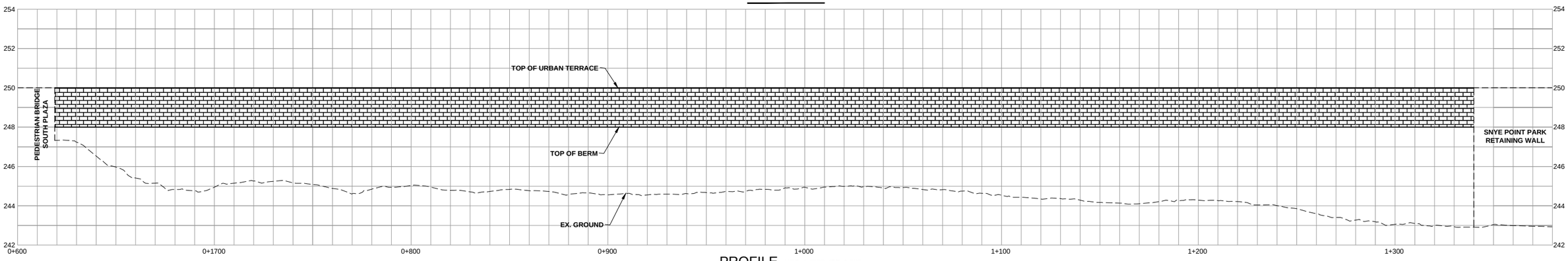
Dwg. 100165-203 | 28 FEBRUARY 2014 | **Figure B2**

northwest hydraulic consultants ltd.

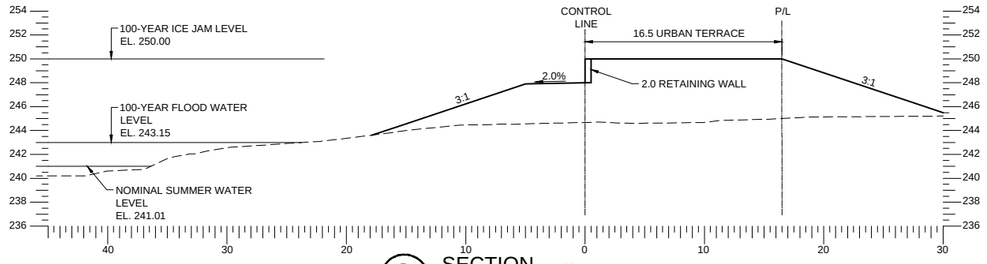
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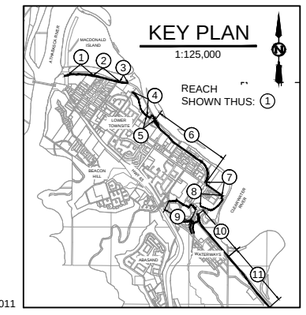
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B SECTION 1:500



NOTES:
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No.	Date	Revision	ENG.
0	28 February 2014	Issued for Review	KJ

REGIONAL MUNICIPALITY OF WOOD BUFFALO

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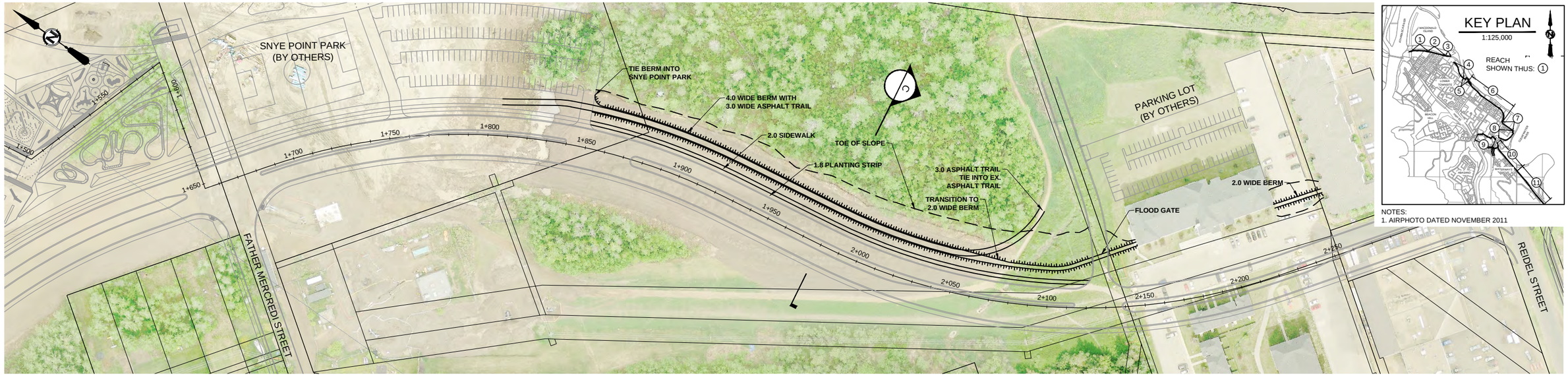
FORT McMURRAY FLOOD PROTECTION

LOWER TOWNSITE
ALTERNATIVE 1 - REACH 2 AND 3
URBAN TERRACE

Dwg. 100165-203 | 28 FEBRUARY 2014 | **Figure B3**

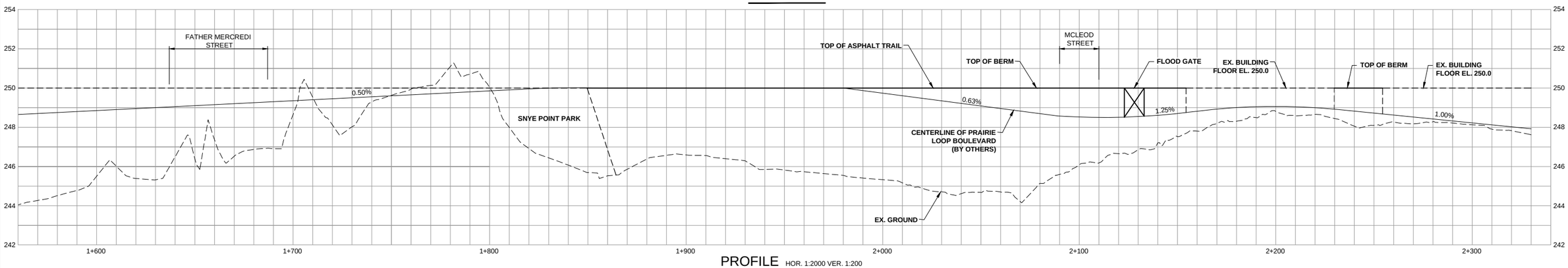
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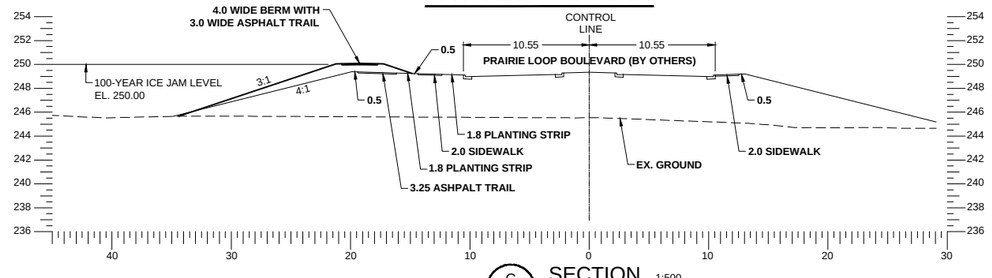


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1. AIRPHOTO DATED NOVEMBER 2011

PLAN 1:2000



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No.	Date	Revision	ENG.
0	28 February 2014	Issued for Review	KJ

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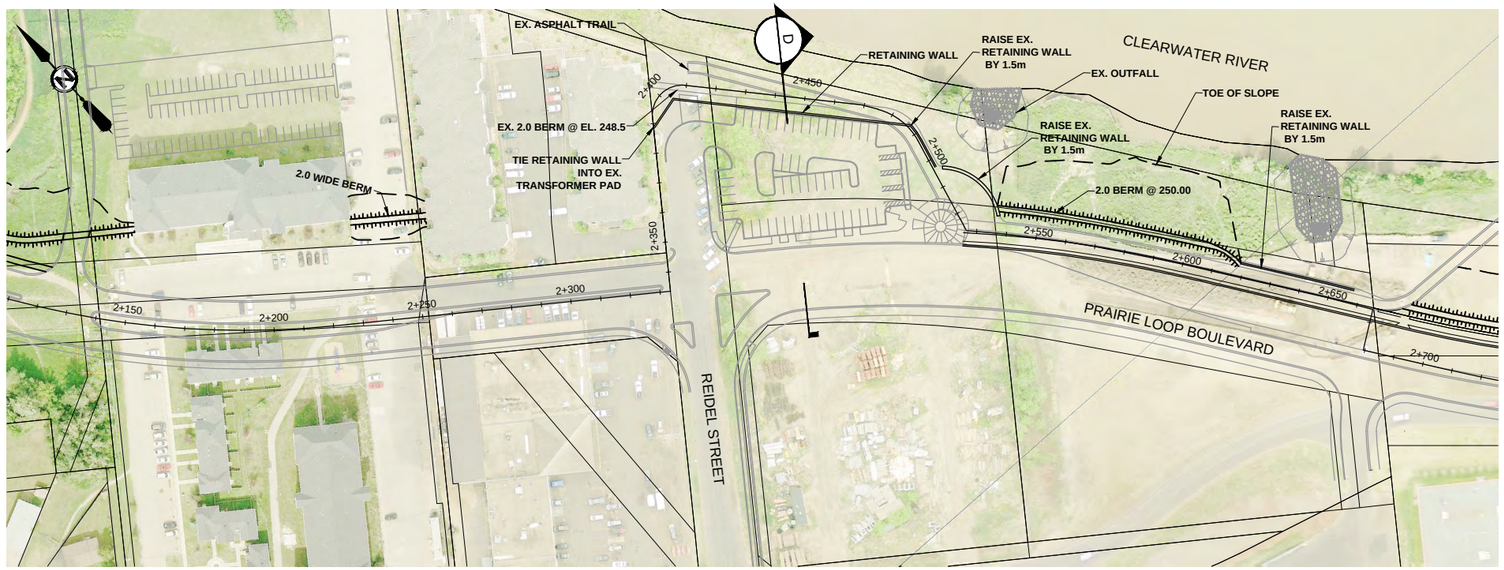
FORT McMURRAY FLOOD PROTECTION

LOWER TOWNSITE
ALTERNATIVE 1 - REACH 4 AND 5
BERM WITH PATH

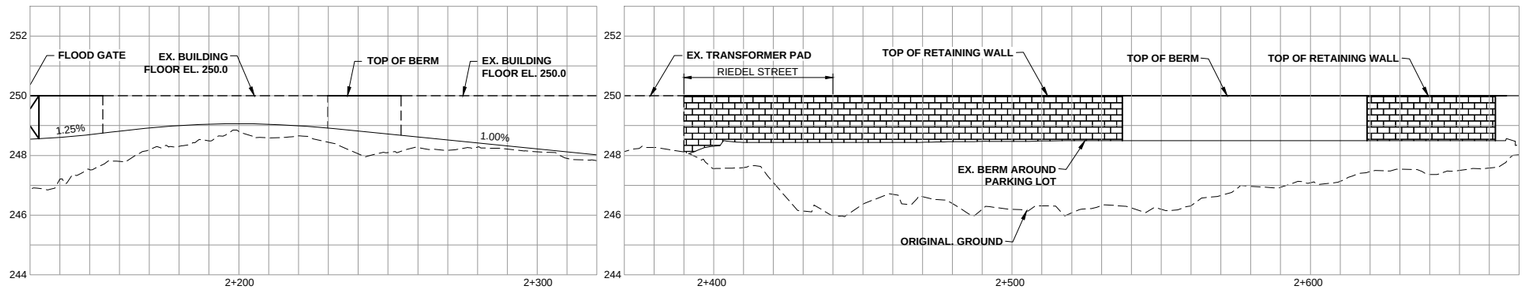
Dwg. 100165-203 | 28 FEBRUARY 2014 | **Figure B4**

northwest hydraulic consultants ltd.

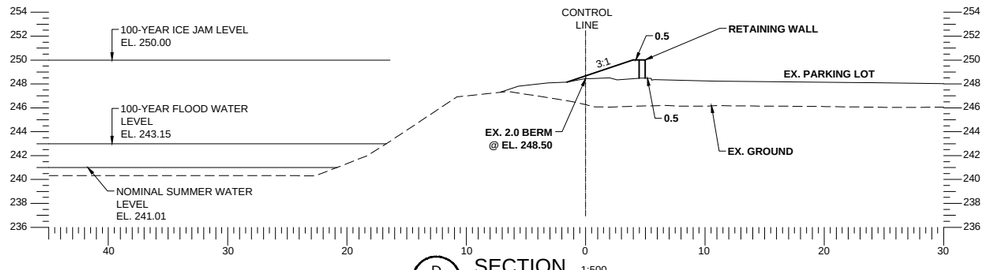
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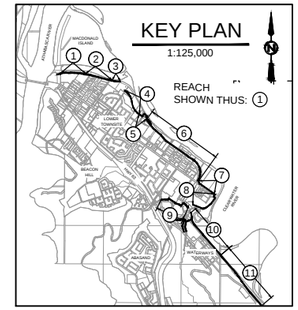
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NOTES:
1. AIRPHOTO DATED NOVEMBER 2011

No.	Date	Revision	ENG.
0	28 February 2014	Issued for Review	KJ

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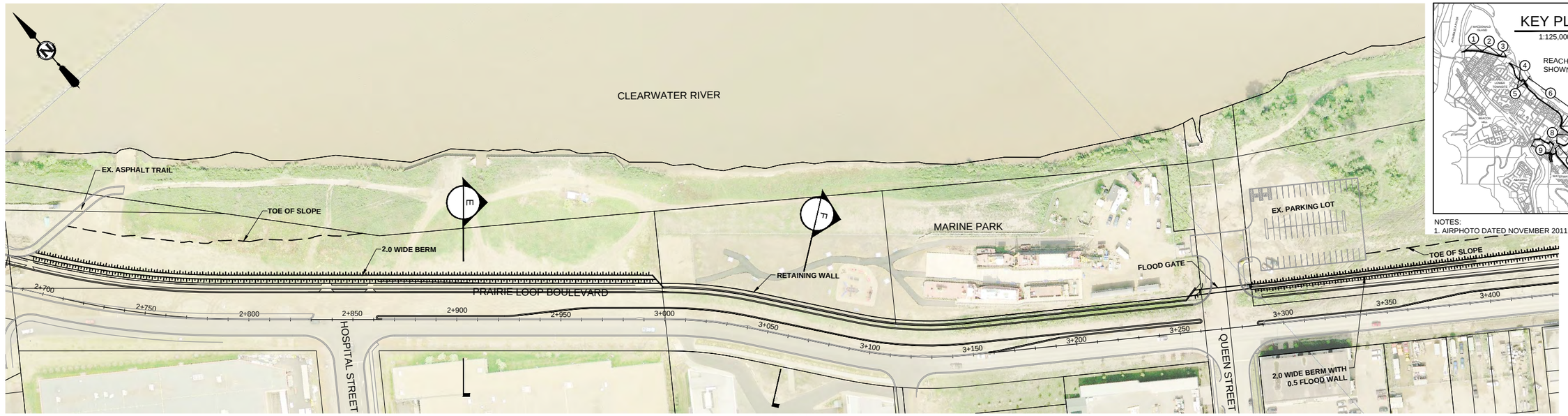
FORT McMURRAY FLOOD PROTECTION

LOWER TOWNSITE
ALTERNATIVE 1 - REACH 5
BERM AND WALL

Dwg. 100165-203 | 28 FEBRUARY 2014 | **Figure B5**

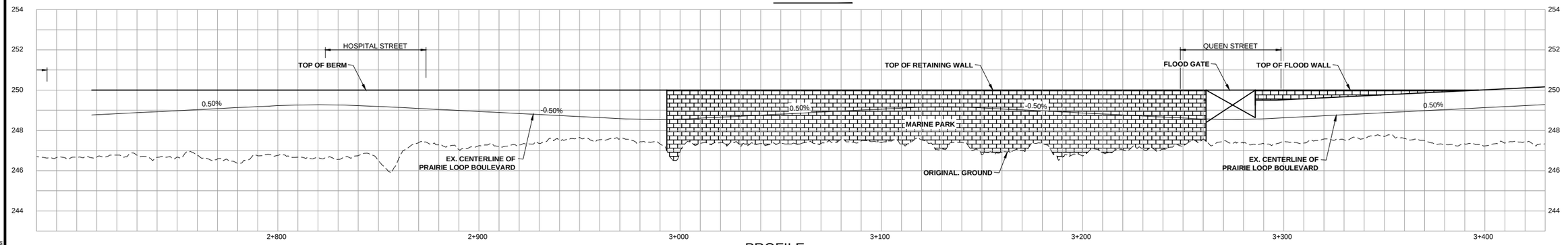
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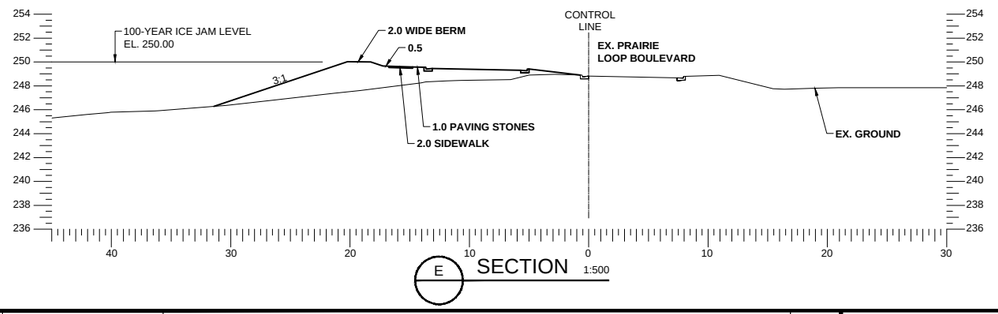


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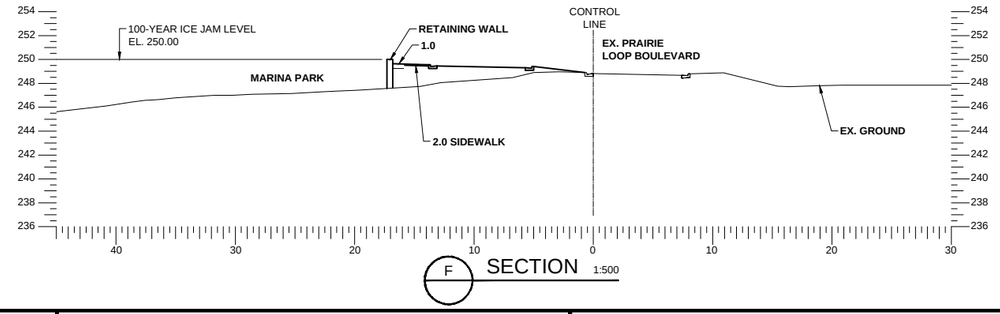
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1. AIRPHOTO DATED NOVEMBER 2011



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F SECTION 1:500

No.	Date	Revision	ENG.
0	28 February 2014	Issued for Review	KJ

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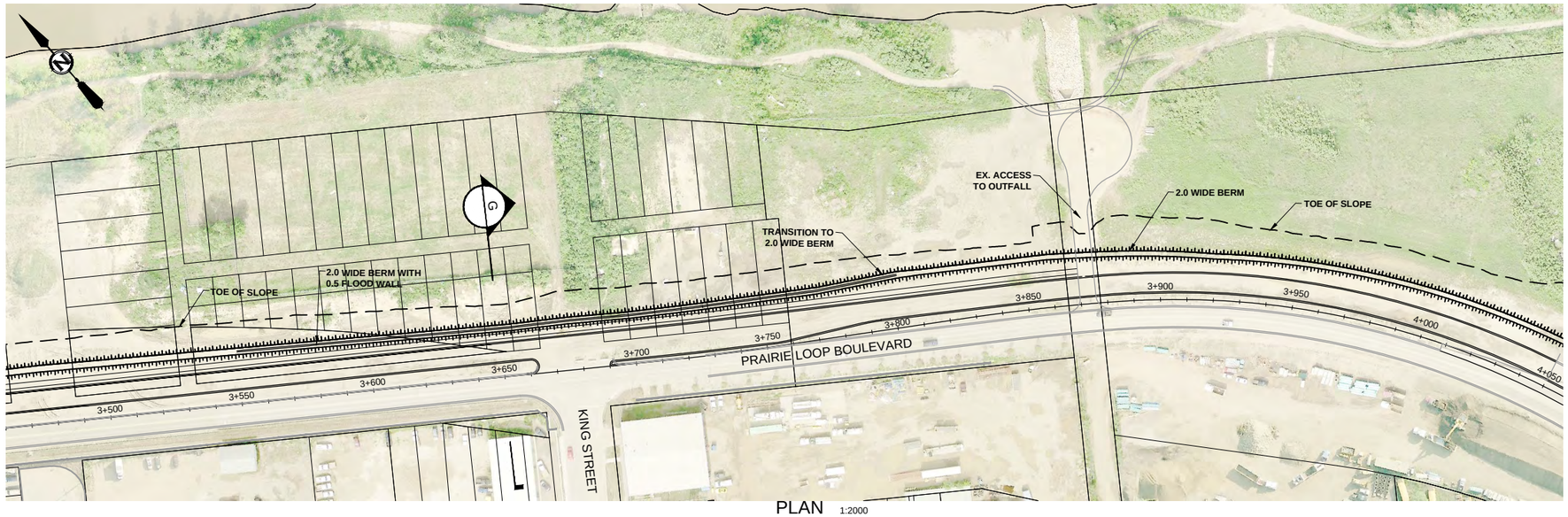
FORT McMURRAY FLOOD PROTECTION

LOWER TOWNSITE
ALTERNATIVE 1 - REACH 6
BERM AND WALL

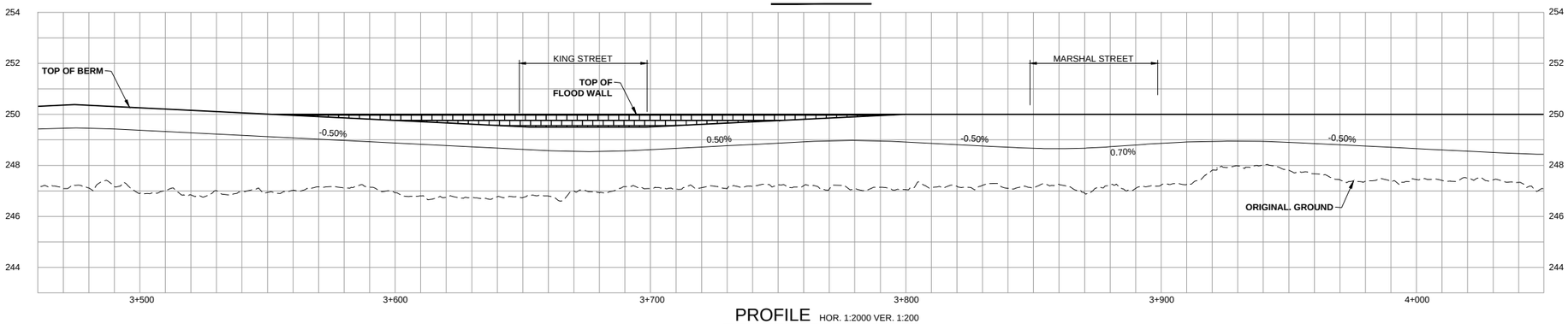
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northwest hydraulic consultants ltd.

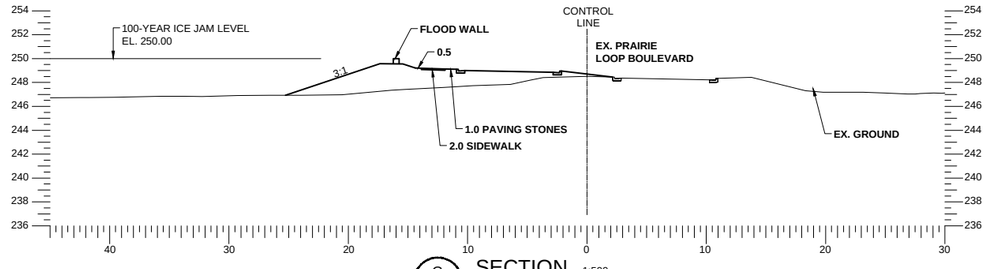
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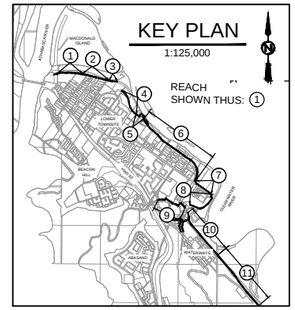
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G SECTION 1:500



NOTES:
1. AIRPHOTO DATED NOVEMBER 2011

No.	Date	Revision	ENG.
0	28 February 2014	Issued for Review	KJ

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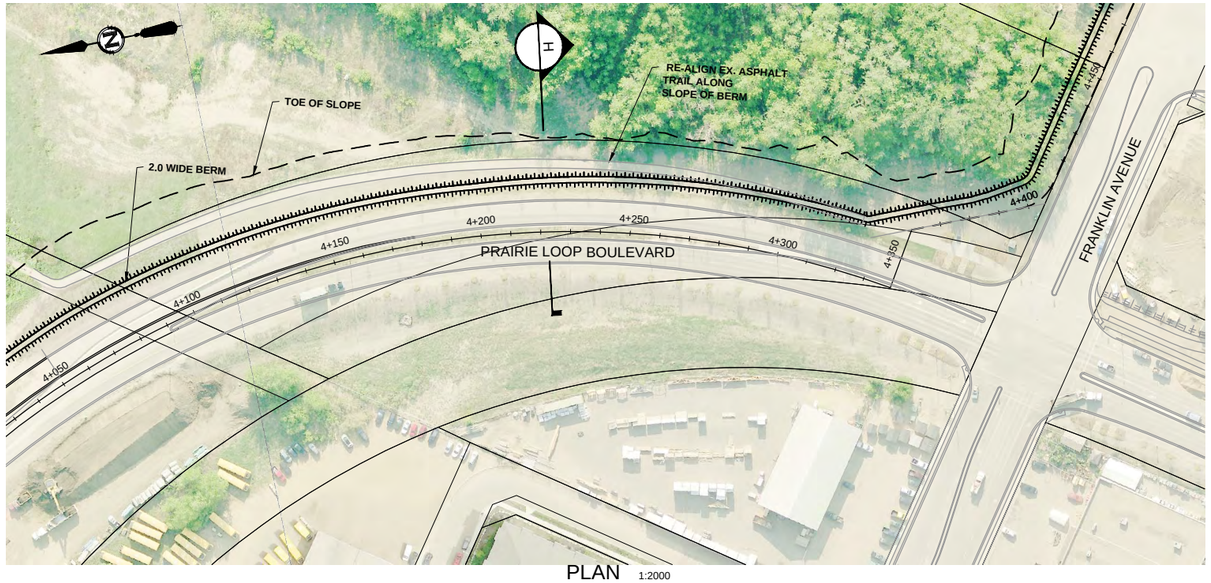
FORT McMURRAY FLOOD PROTECTION

LOWER TOWNSITE
ALTERNATIVE 1 - REACH 6
BERM AND WALL

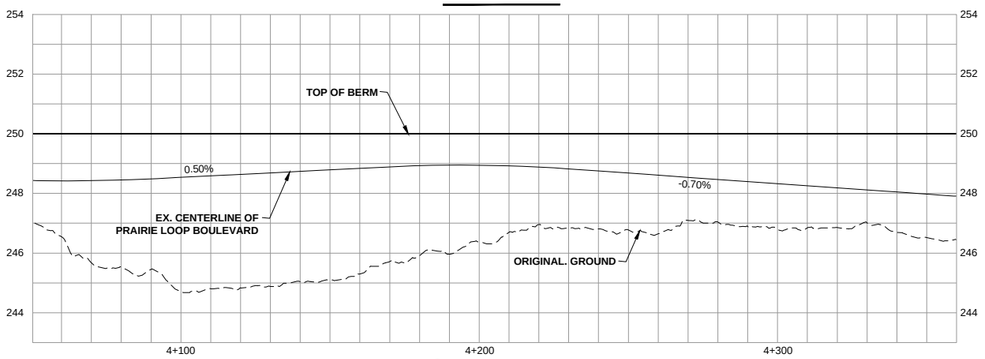
Dwg. 100165-203 | 28 FEBRUARY 2014 | **Figure B7**

northwest hydraulic consultants ltd.

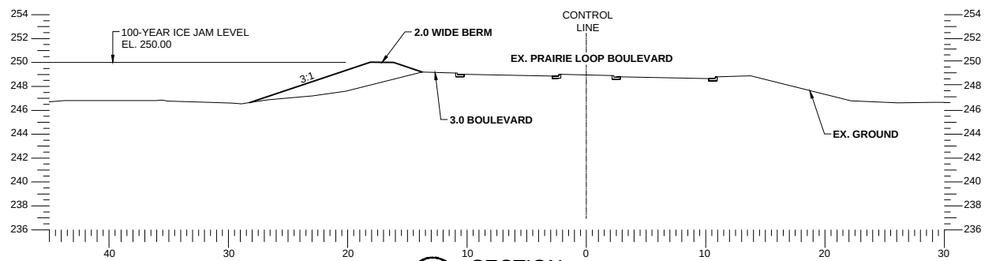
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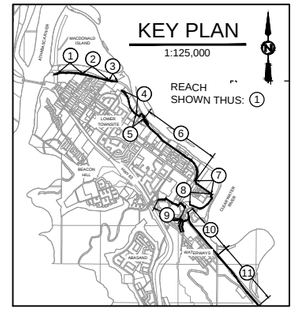
PLAN 1:2000



PROFILE HOR. 1:2000 VER. 1:200



H SECTION 1:500



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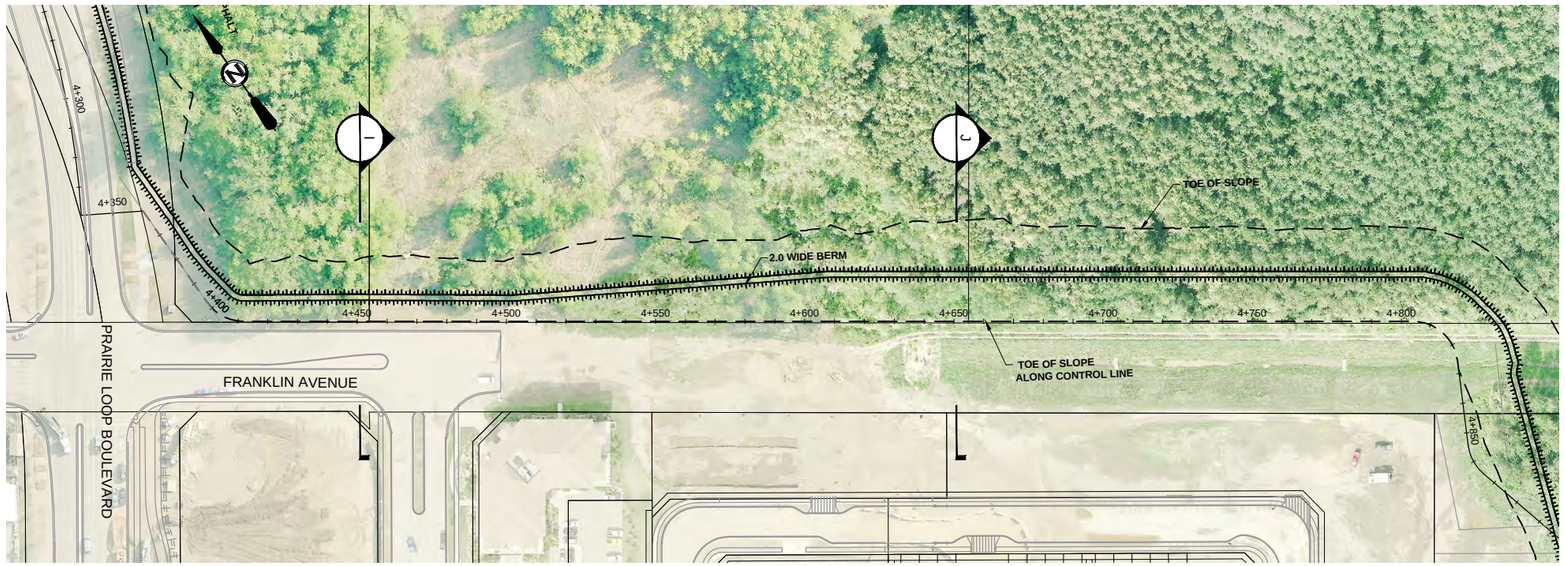
FORT McMURRAY FLOOD PROTECTION

LOWER TOWNSITE
ALTERNATIVE 1 - REACH 6
BERM

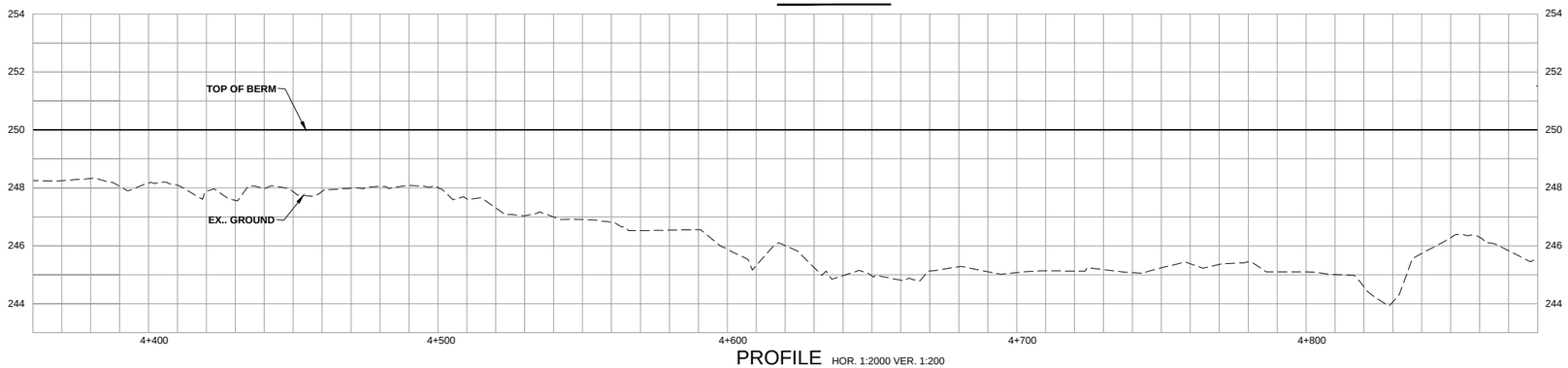
Dwg. 100165-203	28 FEBRUARY 2014	**Figure B8**

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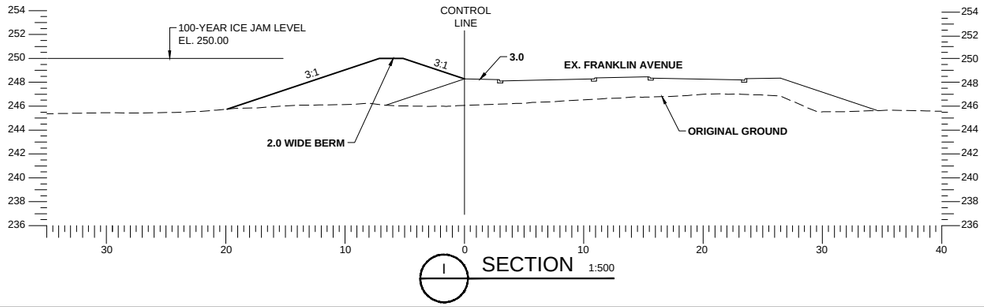
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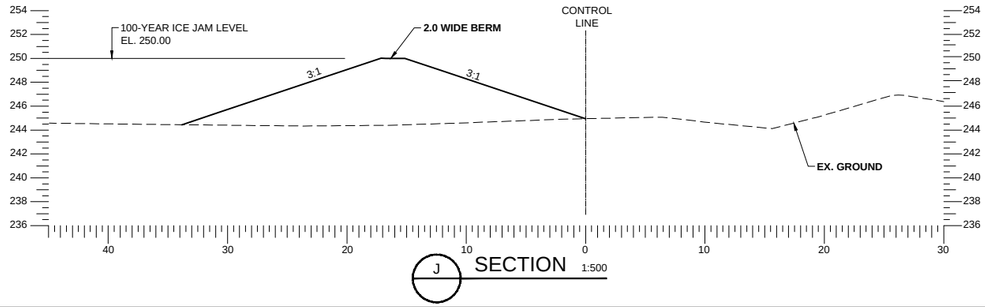
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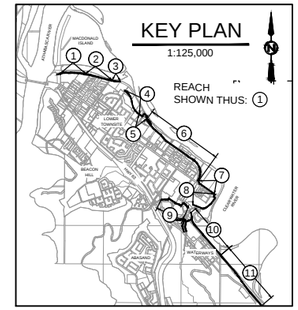
PROFILE HOR. 1:2000 VER. 1:200



I SECTION 1:500



J SECTION 1:500



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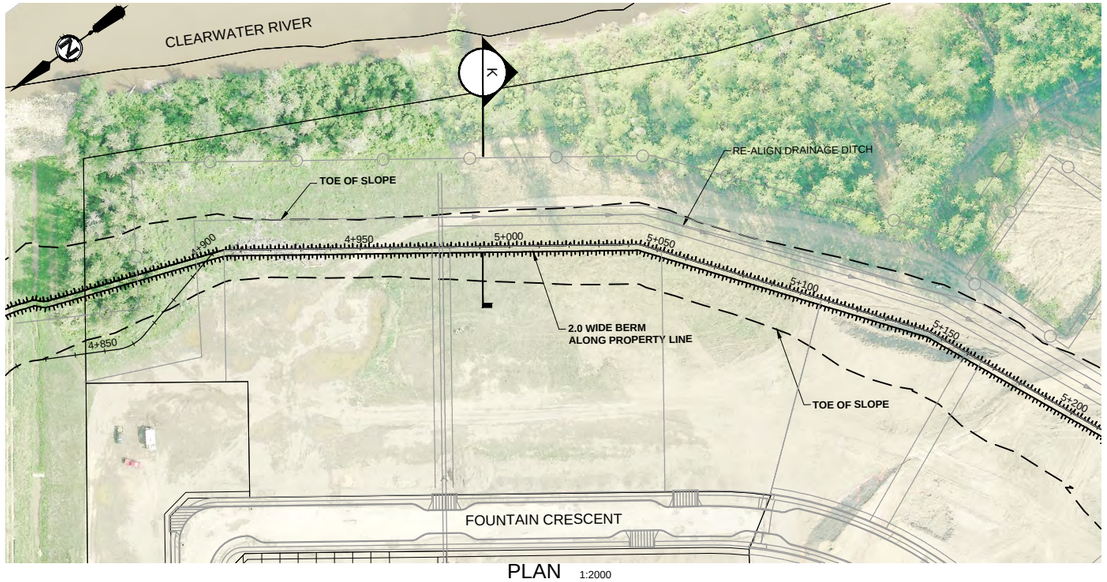
FORT McMURRAY FLOOD PROTECTION

LOWER TOWNSITE
ALTERNATIVE 1 - REACH 7
BERM

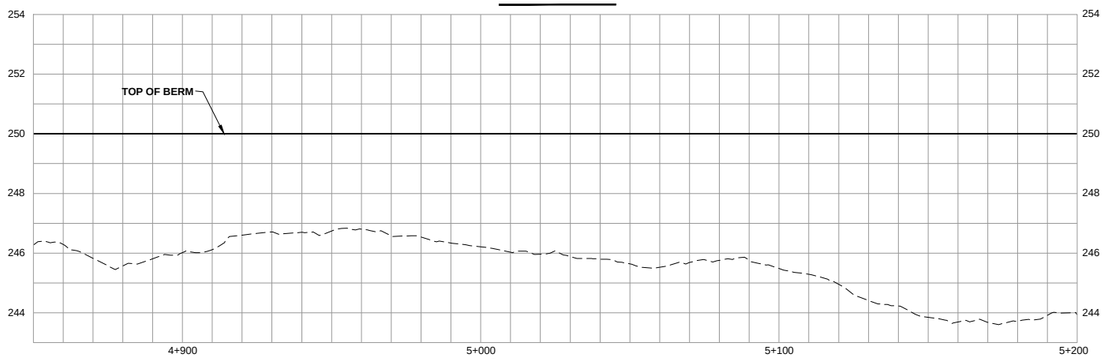
Dwg. 100165-203 | 28 FEBRUARY 2014 | **Figure B9**

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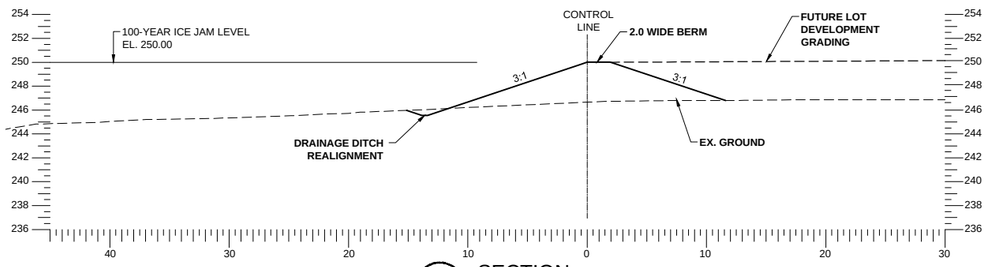
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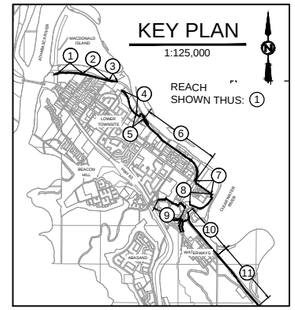
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K SECTION 1:500



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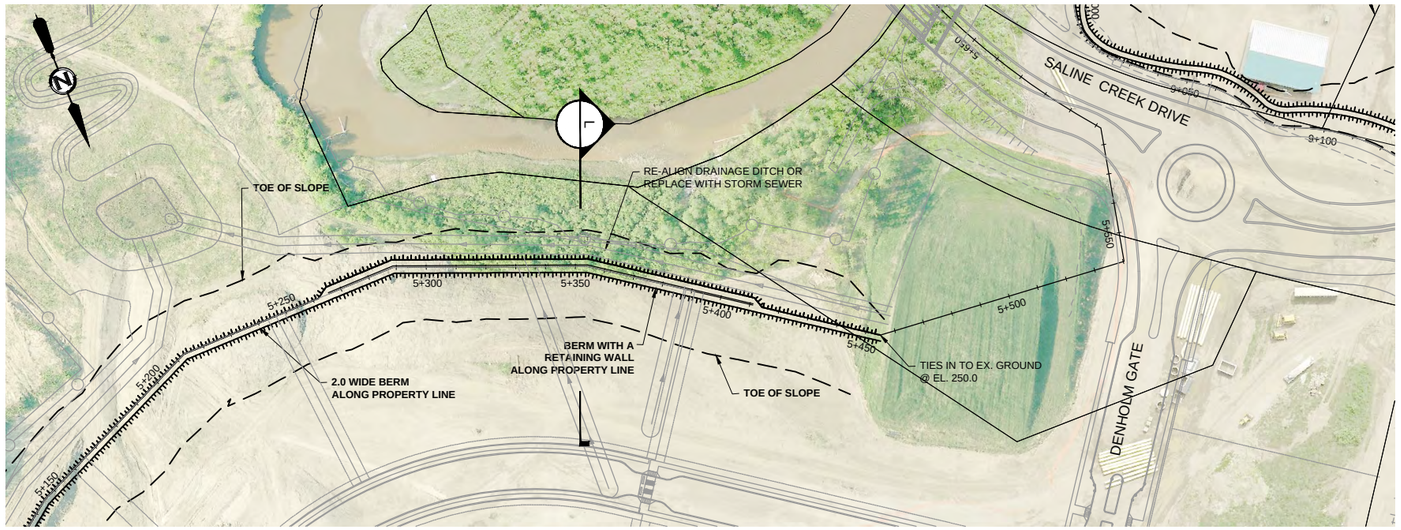
FORT McMURRAY FLOOD PROTECTION

LOWER TOWNSITE
ALTERNATIVE 1 - REACH 8
BERM

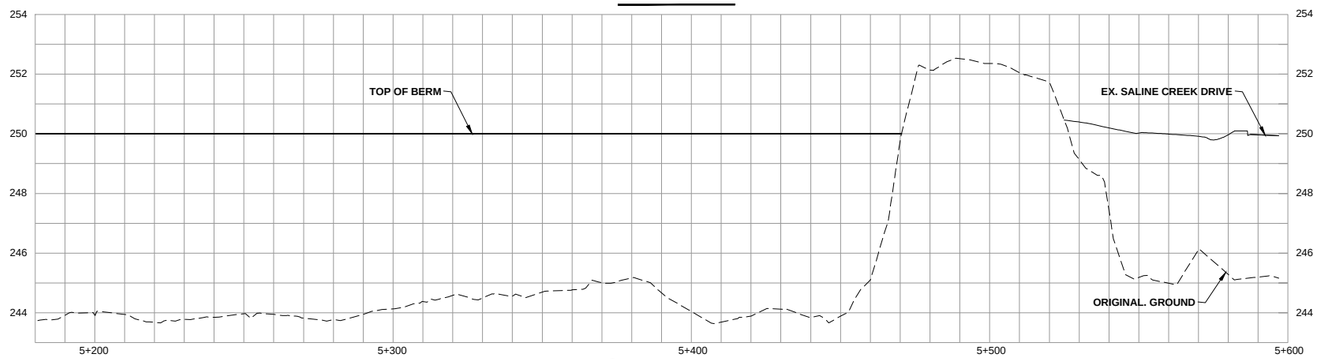
Dwg. 100165-203	28 FEBRUARY 2014	**Figure B10**

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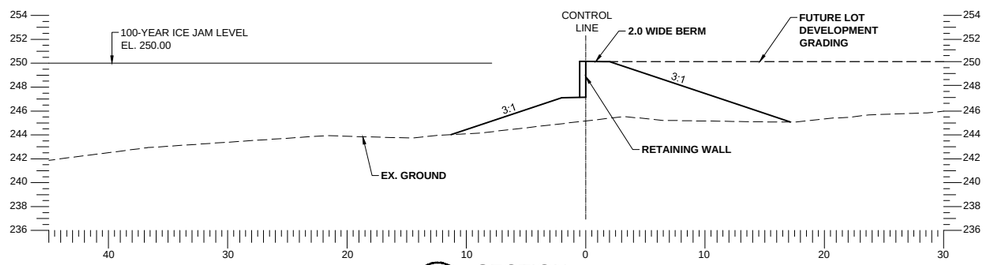
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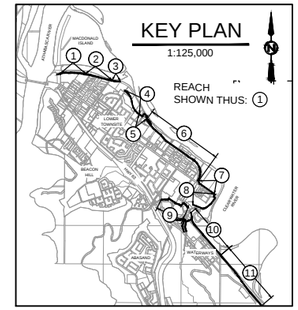
PLAN 1:2000



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L SECTION 1:500



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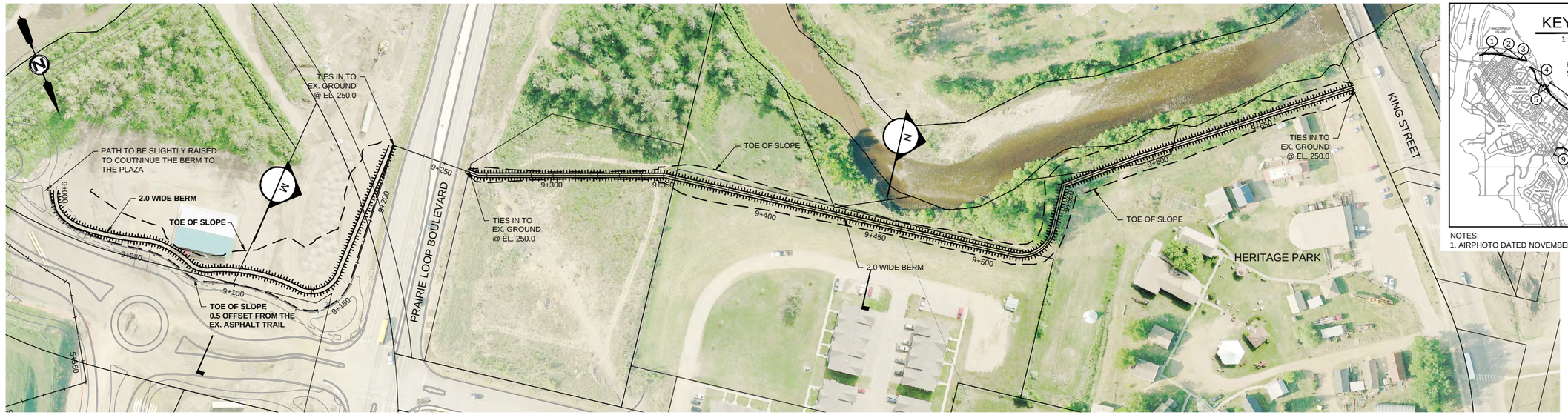
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LOWER TOWNSITE
ALTERNATIVE 1 - REACH 8
BERM

Dwg. 100165-203	28 FEBRUARY 2014	**Figure B11**

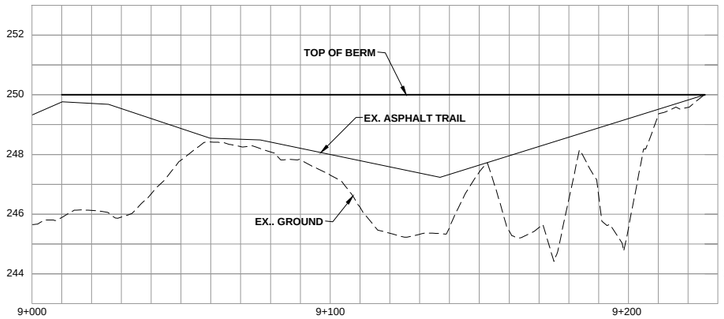
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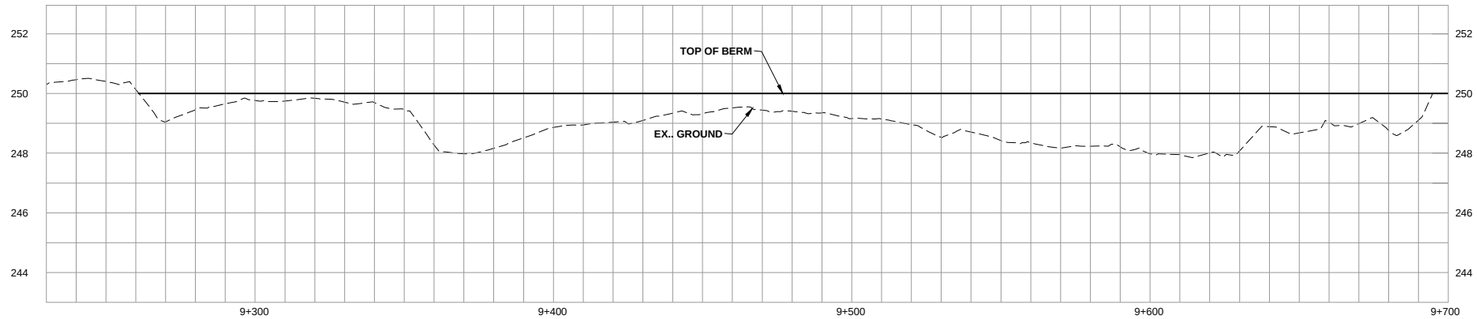
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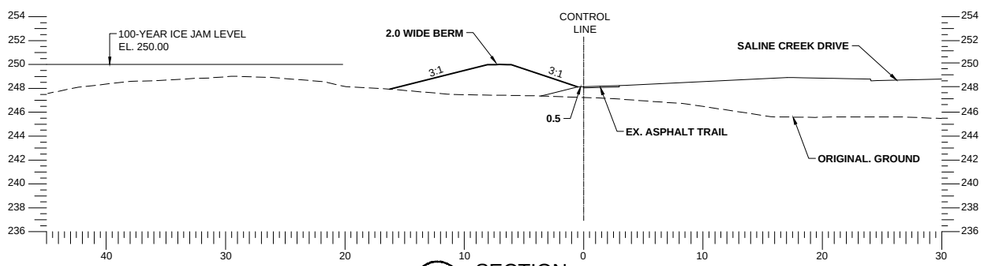
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1. AIRPHOTO DATED NOVEMBER 2011

PLAN 1:2000

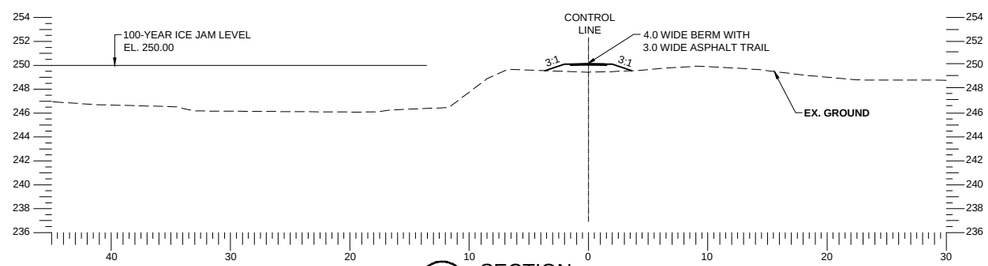




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M SECTION 1:500



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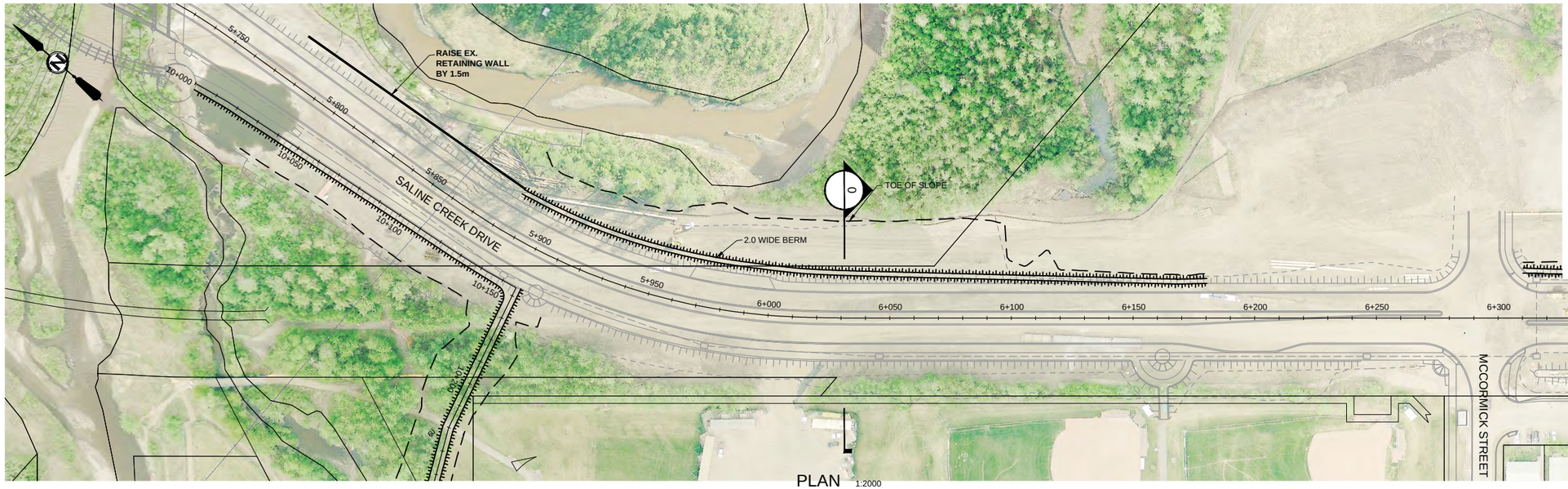
FORT McMURRAY FLOOD PROTECTION

LOWER TOWNSITE
ALTERNATIVE 1 - REACH 9
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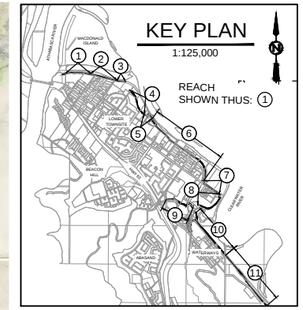
Dwg. 100165-203 | 28 FEBRUARY 2014 | **Figure B12**

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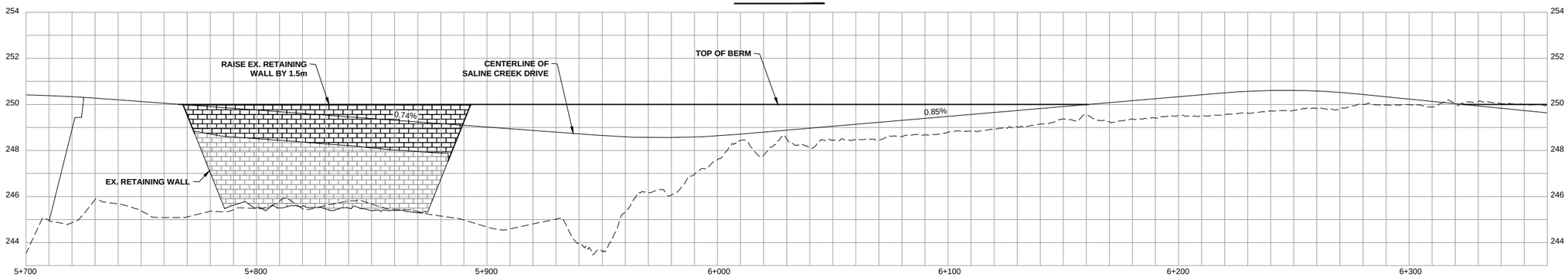
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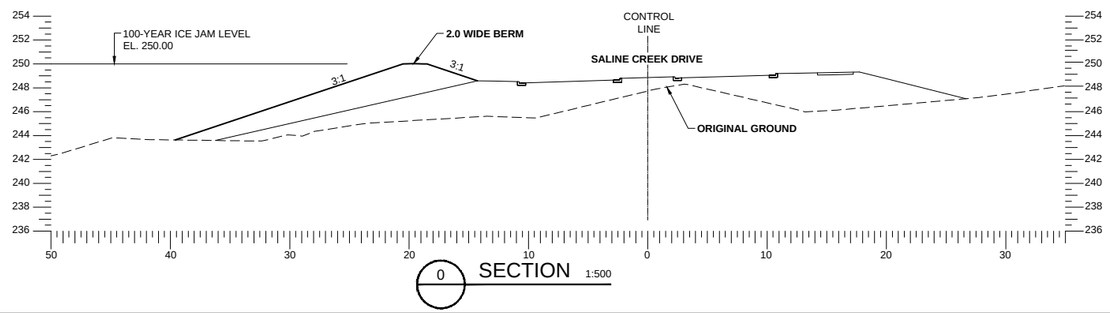
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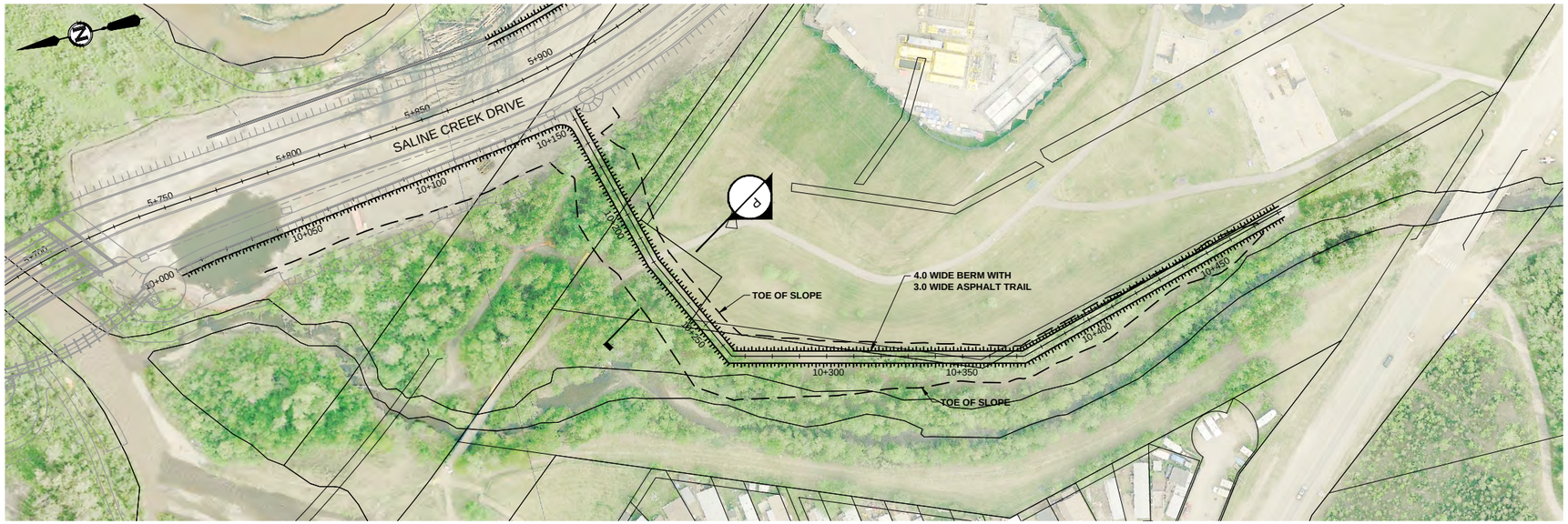
FORT McMURRAY FLOOD PROTECTION

WATERWAYS
REACH 10
BERMS

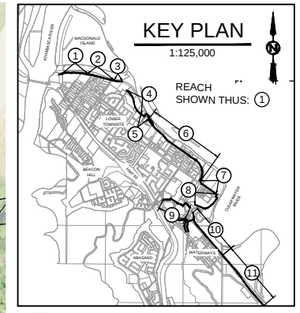
Dwg. 100165-203 | 28 FEBRUARY 2014 | **Figure B13**

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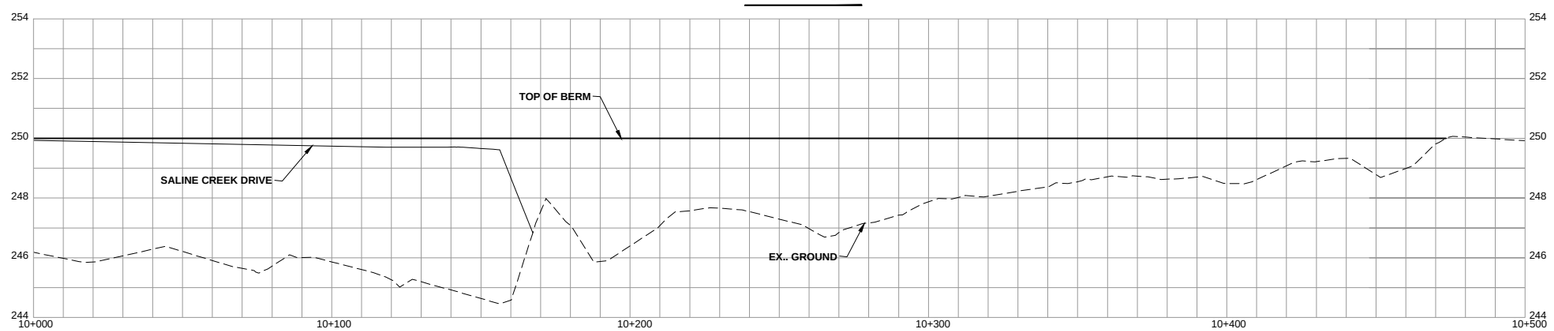
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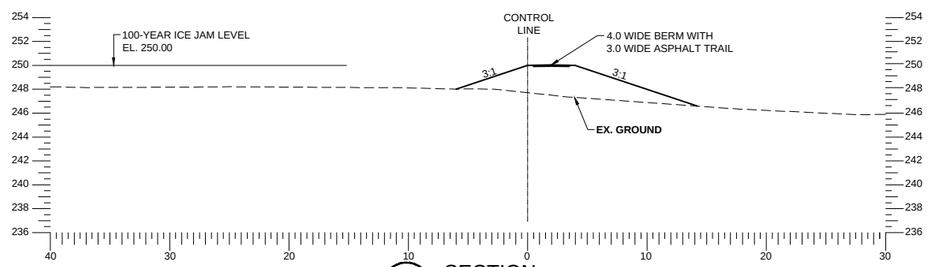
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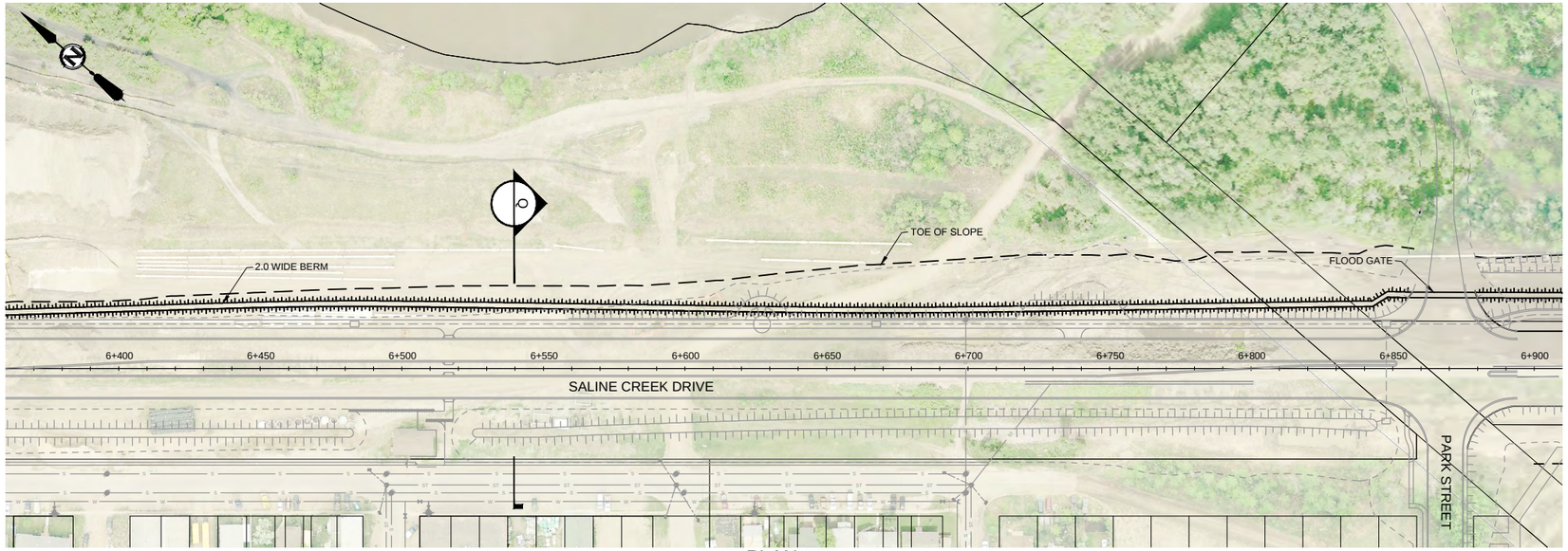
FORT McMURRAY FLOOD PROTECTION

WATERWAYS
REACH 10
BERMS

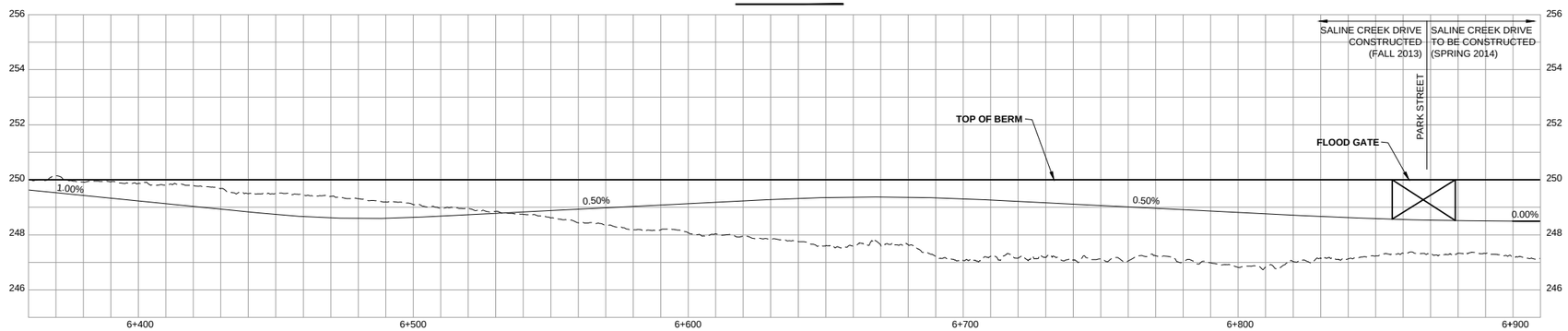
Dwg. 100165-203 | 28 FEBRUARY 2014 | **Figure B14**

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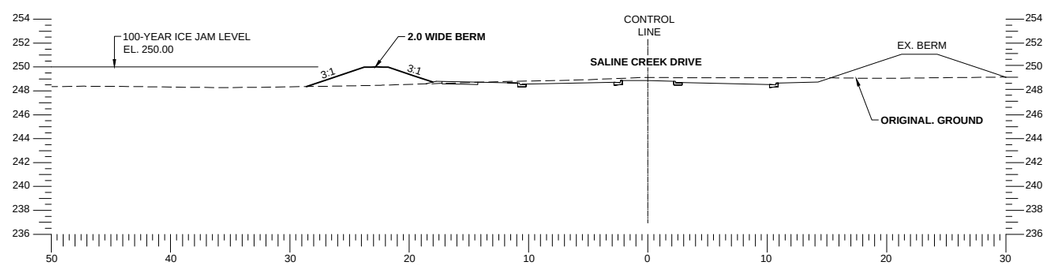
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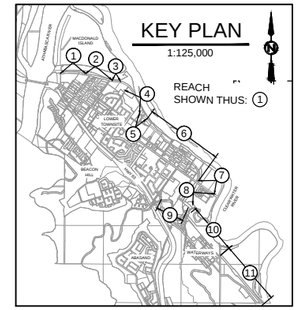
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Q SECTION 1:500



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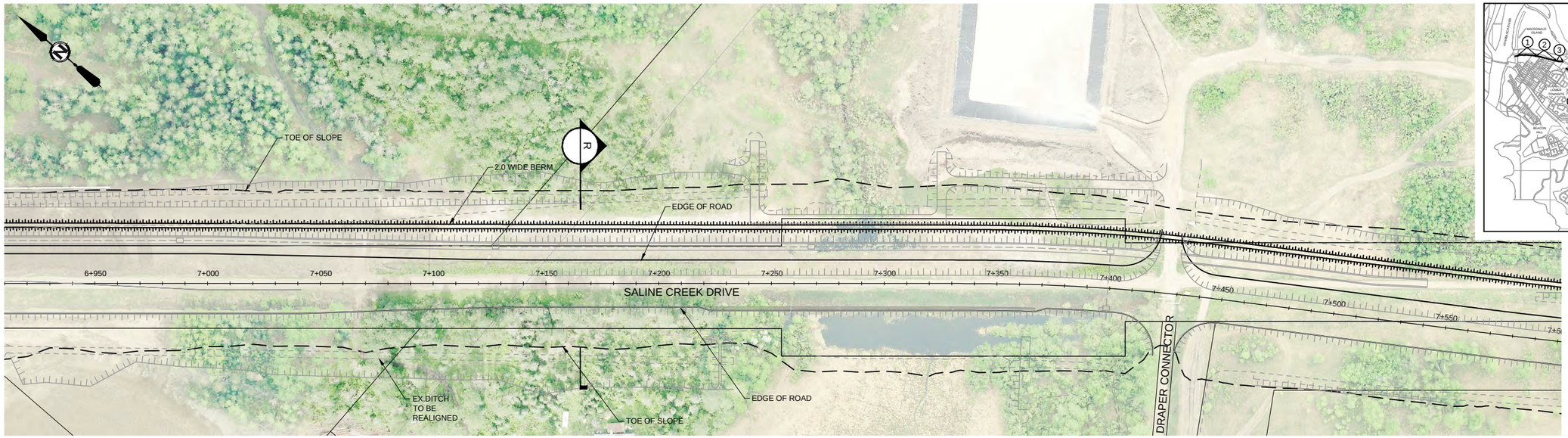
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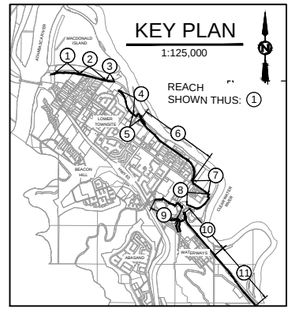
WATERWAYS
REACH 10
BERM

Dwg. 100165-203	28 FEBRUARY 2014	**Figure B15**

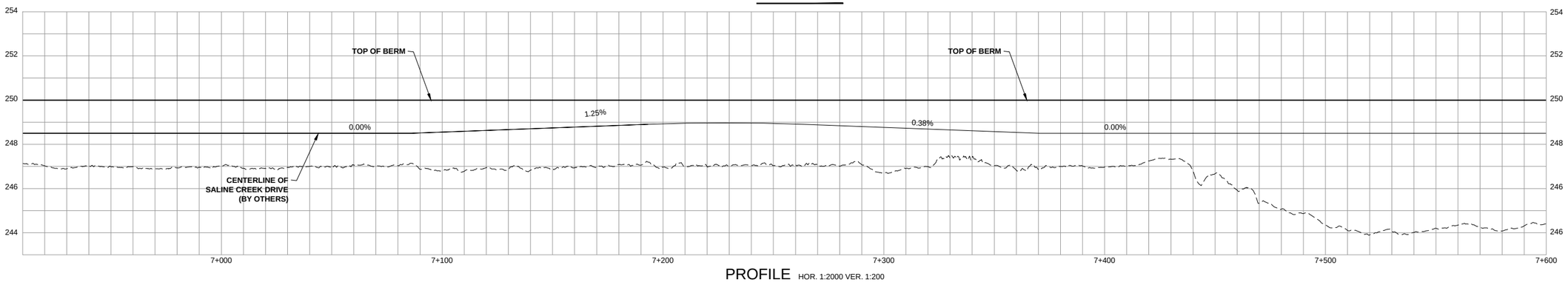
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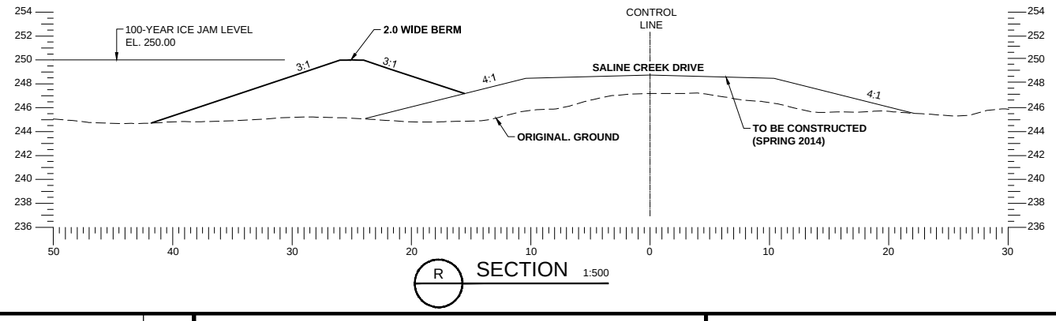




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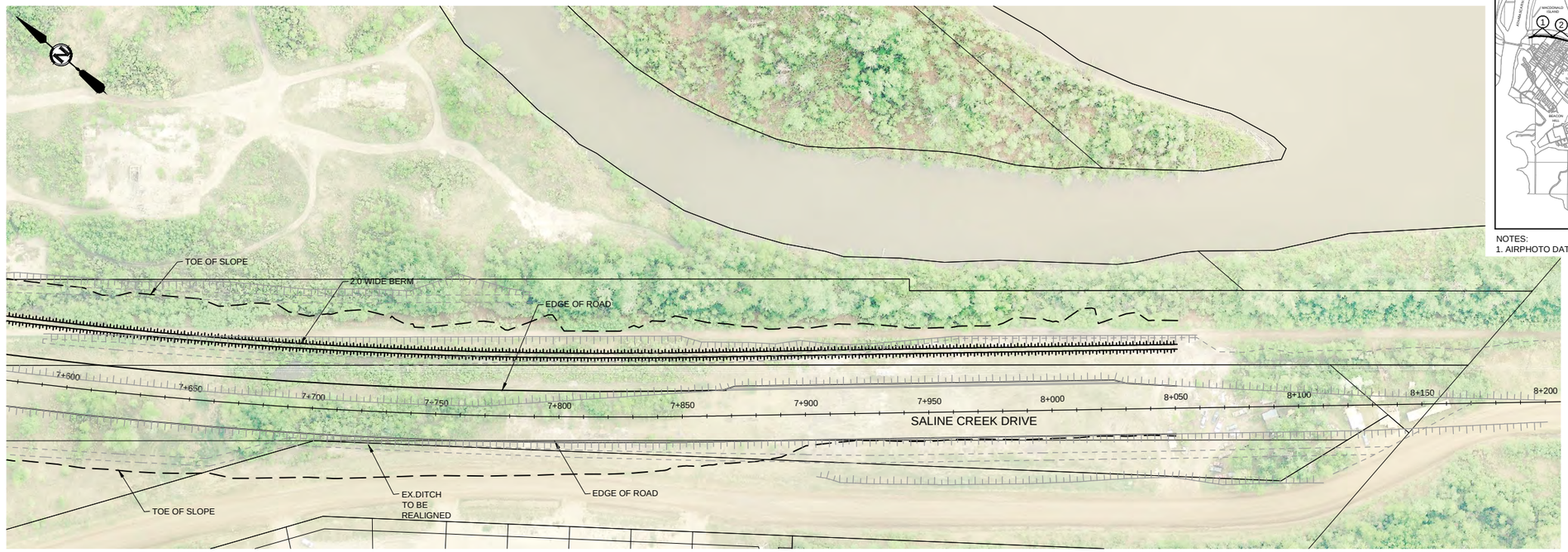
FORT McMURRAY FLOOD PROTECTION

WATERWAYS
REACH 11
RAISING SALINE CREEK DRIVE

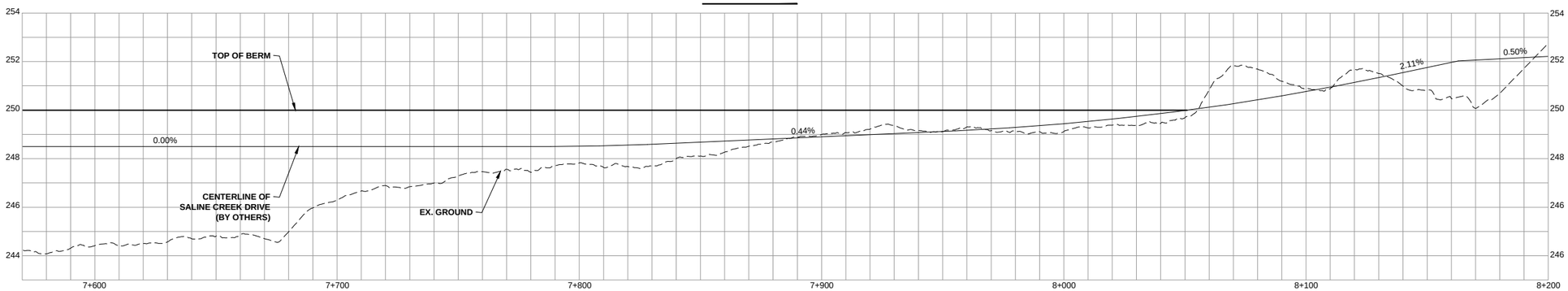
Dwg. 100165-203	28 FEBRUARY 2014	**Figure B16**

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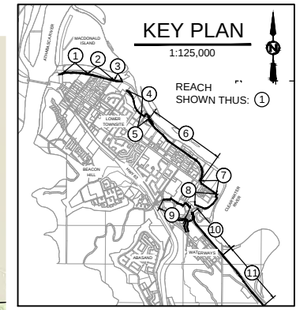
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PLAN 1:2000



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WATERWAYS
REACH 11
RAISING SALINE CREEK DRIVE

Dwg. 100165-203	28 FEBRUARY 2014	**Figure B17**

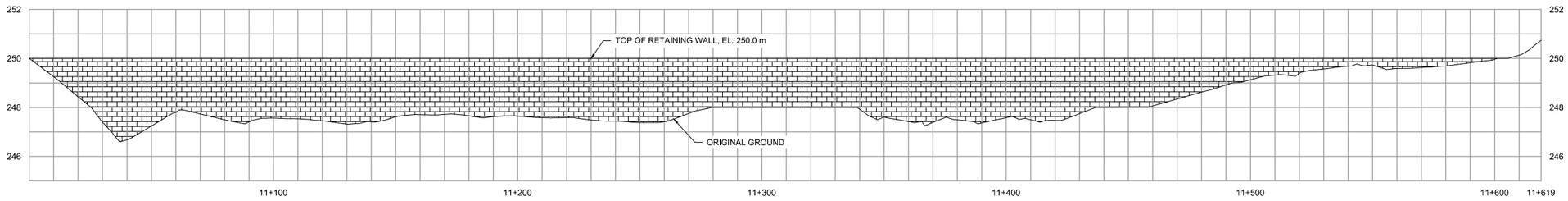
northwest hydraulic consultants ltd.

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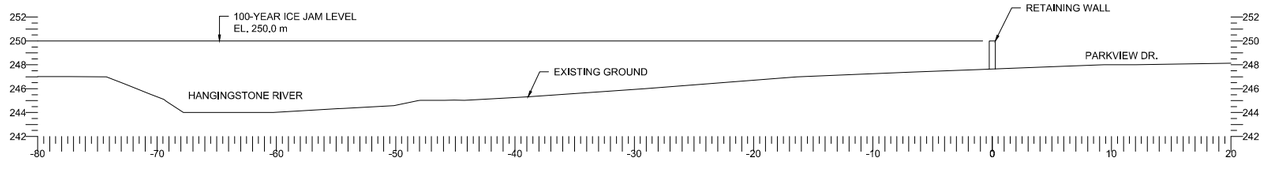


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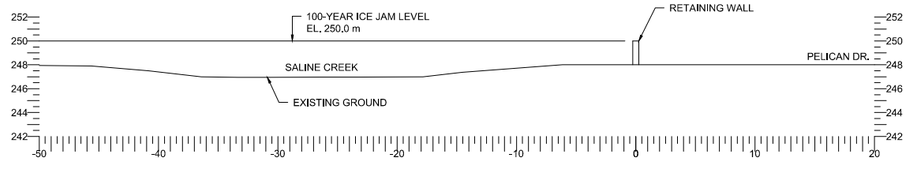
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PTARMIGAN COURT RETAINING WALL

Dwg. 100165-200 | 24-FEBRUARY-2014 | **Figure B18**

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APPENDIX C

Excerpt from AECOM's Final Memorandum Entitled "Study of Evaluation of Raising Prairie Loop Boulevard to 250 m Elevation"

prepared for

Kashif Khan, P. Eng.
Regional Municipality of Wood Buffalo
March 13, 2014

Table 1- 'Additional Cost' Summary to Raise Prairie Loop Boulevard to 250.0m

Additional Cost For Option 1 with Queen St Intersection at 250.0 M Elevation		
Phase 1-Riedel St to McLeod St	$	275,000
Phase 2-McLeod St to Hardin St	$	3,430,000
Phase 3 –Riedel St to Franklin Ave with Option 1 (Queen St at 250.0 M Elevation)	$	21,650,000
Phase 4 –Morrison St to Hardin St	$	3,350,000
City Side Flood Pumping and Misc.	$	2,340,000
Estimated Total Additional Cost to Original PLB Design	**$**	**31,045,000 ($ 31.0M)**
Engineering Fee	$	3,105,000
	$	**34,150,000 ($ 34.2M)**
Contingency	$	6,830,000
TOTAL ADDITIONAL COST (OPTION 1)	**$**	**40,980,000 ($ 41.0M)**

Additional Cost For Option 2 with Queen St Intersection at 248.5 M Elevation		
Phase 1-Riedel St to McLeod St	$	275,000
Phase 2-McLeod St to Hardin St	$	3,430,000
Phase 3 –Riedel St to Franklin Ave with Option 2 (Queen St at Original Design 248.5m Elevation)	$	19,156,000
Phase 4 –Morrison St to Hardin St	$	3,350,000
City Side Flood Pumping and Misc.	$	2,340,000
Estimated Total Additional Cost To Original PLB Design	**$**	**28,551,000 ($ 28.5M)**
Engineering Fee	$	2,855,000
	$	**31,406,000 ($ 31.4M)**
Contingency	$	6,281,000
TOTAL ADDITIONAL COST (OPTION 2)	**$**	**37,690,000 ($ 37.7M)**

Table 2: Total Additional Cost Summary to Raise PLB to 250.0m min Elevation

PRAIRIE LOOP BOULEVARD	TOTAL (250.0M OPTION 1)	TOTAL (250.0 M OPTION 2)
Phase 1-Riedel St to Mcleod St	$363,000	$363,000
Phase 2-Mcleod St to Hardin St	$4,528,000	$4,528,000
Phase 3-Riedel St to Franklin Ave	$28,578,000	$25,286,000
Phase 4-Hardin St to Morrison St	$4,422,000	$4,422,000
City Side Flood Pumping and Miscellaneous Items (Allowances)	$3,089,000	$3,089,000
Total	$40,980,000	$37,690,000

- The costs include engineering fee and contingencies

Appendix A (Estimate of Additional Cost to Raise PLB to 250.0m Min)

Project Name:	**Prairie Loop Boulevard**	**Date Prepared:**	**February 11, 2014**	**(Rev: Mar 13, 2014)**
Owner:	**Regional Municipality of Wood Buffalo**	**Prepared By:**	WZ/SP	
Project No:	**60190853-402**	**Checked By:**	ZB/NB	

Subject: **Estimate of Additional Cost to Raise PLB to 250.0 m Min**

PHASE 1
RIEDEL ST TO MCLEOD ST ~371m

Item	Description	Unit	Quantity	Unit Price	Extension
1.0	**Removals**				
1.1	Removal of Ex Concrete Structures	l.m.	0	$ 95	$ -
1.2	Removal of Ex Rd Structures	sq.m.	0	$ 42	$ -
2.0	**Additional Fill Volume**				
2.1	Additional Road Fill Volume	cu.m.	0	$ 50	$ -
2.2	Additional Road Side Slope Volume	cu.m.	0	$ 50	$ -
3.0	**Additional Roadworks**				
3.1	Road Structures	sq.m.	0	$ 110	$ -
3.2	Concrete Works	l.m.	0	$ 294	$ -
4.0	**Additional Retaining Wall on City Side Roadway w Barrier Fence**	l.m.	0	$ 3,500	$ -
5.0	**Additional Landscaping Works**	l.s.	1	$ 75,000	$ 75,000
6.0	**Additional Utilities**				
6.1	Underground Allowances-Storm Sewer/Sanitary/Water Adjustment	l.s.	1	$ 100,000	$ 100,000
6.2	Franchise Utilities Allowances (Electric, Gas, Cable)	l.s.	1	$ 100,000	$ 100,000
7.0	***Flood Control dyke***				*NA*
	TOTAL				**$ 275,000**

Appendix A (Estimate of Additional Cost to Raise PLB to 250.0m Min)

Project Name:	**Prairie Loop Boulevard**	**Date Prepared:**	**February 11, 2014**	**(Rev: Mar 13, 2014)**
Owner:	**Regional Municipality of Wood Buffalo**	**Prepared By:**	WZ/SP	
Project No:	**60190853-402**	**Checked By:**	ZB/NB	

Subject: **Estimate of Additional Cost to Raise PLB to 250.0 m Min**

PHASE 2
MCLEOD ST TO HARDIN STREET ~770m

Item	Description	Unit	Quantity	Unit Price	Extension
1.0	**Removals**				
1.1	Removal of Ex Concrete Structures	l.m.	0	$ 95	$ -
1.2	Removal of Ex Rd Structures	sq.m.	0	$ 42	$ -
2.0	**Additional Fill Volume**				
2.1	Additional Road Fill Volume	cu.m.	37,000	$ 50	$ 1,850,000
2.2	Additional Road Side Slope Volume	cu.m.	14,000	$ 50	$ 700,000
3.0	**Road Embankment Flood Side Liner**	sq.m.	4,000	$ 100	$ 400,000
4.0	**Additional Roadworks**				
4.1	Road Structures	sq.m.	0	$ 110	$ -
4.2	Concrete Works	l.m.	0	$ 294	$ -
5.0	**Additional Retaining Wall on City Side Roadway w Barrier Fence**	l.m.	80	$ 3,500	$ 280,000
6.0	**Additional Landscaping Works**	l.s.	0	$ -	$ -
7.0	**Additional Utilities**				
7.1	Underground Allowances-Storm Sewer/Sanitary/Water Adjustment	l.s.	1	$ 200,000	$ 200,000
7.2	Franchise Utilities Allowances (Electric, Gas, Cable)	l.s.	1	$ -	$ -
	TOTAL				**$ 3,430,000**

Appendix A (Estimate of Additional Cost to Raise PLB to 250.0m Min)

Project Name:	**Prairie Loop Boulevard**	**Date Prepared:**	**February 11, 2014**	**(Rev: Mar 13, 2014)**
Owner:	**Regional Municipality of Wood Buffalo**	**Prepared By:**	WZ/SP	
Project No:	**60190853-402**	**Checked By:**	ZB/NB	

Subject: **Estimate of Additional Cost to Raise PLB to 250.0 m Min**

PHASE 3
WIDENING TO FOUR LANES - RIEDEL ST TO FRANKLIN AVE ~1900 m

Riedel St to Hospital St ~440 m

Item	Description	Unit	Quantity	Unit Price	Extension
1.0	**Removals**				
1.1	Removal of Ex Concrete Structures	l.m.	880	$ 95	$ 83,600
1.2	Removal of Ex Rd Structures	sq.m.	3,600	$ 42	$ 151,200
2.0	**Additional Fill Volume**				
2.1	Additional Road Fill Volume	cu.m.	17,000	$ 50	$ 850,000
2.2	Additional Road Side Slope Volume	cu.m.	3,200	$ 50	$ 160,000
3.0	**Road Embankment Flood Side Liner**	sq.m.	800	$ 100	$ 80,000
4.0	**Additional Roadworks**				
4.1	Road Structures	sq.m.	4,400	$ 110	$ 484,000
4.2	Concrete Works	l.m.	880	$ 294	$ 258,720
5.0	**Additional Side Street Connection (Hospital St ~45m)**				
5.1	**Removals**				
5.1.1	Road Removal	sq.m	1,600	$ 42	$ 67,200
5.1.2	Concrete Removal	l.m.	90	$ 95	$ 8,550
5.2	**Imported Fill**	cu.m.	800	$ 50	$ 40,000
5.3	**New Construction**				
5.3.1	Road Structures	sq.m	1,600	$ 110	$ 176,000
5.3.2	Curb and Gutter w Sidewalk	l.m.	100	$ 800	$ 80,000
6.0	**Additional Side Street Connection (Alberta Ave ~35m)**				
6.1	**Removals**				
6.1.1	Road Removal	sq.m	450	$ 42	$ 18,900
6.1.2	Concrete Removal	l.m.	70	$ 95	$ 6,650
6.2	**Imported Fill**	cu.m.	300	$ 50	$ 15,000
6.3	**New Construction**				
6.3.1	Road Structures	sq.m	450	$ 110	$ 49,500
6.3.2	Curb and Gutter w Sidewalk	l.m.	90	$ 800	$ 72,000
7.0	**Additional Retaining Wall on City Side Roadway and Connecting Streets w Barrier Fence**	l.m.	250	$ 3,500	$ 875,000
8.0	**Additional Landscaping Works**	l.s.	1	$ 325,000	$ 325,000
9.0	**Additional Utilities**				
9.1	Underground Allowances-Storm Sewer/Sanitary/Water Adjustment	l.s.	1	$ 400,000	$ 400,000
9.2	Franchise Utilities Allowances (Electric, Gas, Cable)	l.s.	1	$ 300,000	$ 300,000
	TOTAL				**$ 4,501,000**

Appendix A (Estimate of Additional Cost to Raise PLB to 250.0m Min)

Project Name:	**Prairie Loop Boulevard**	**Date Prepared:**	**February 11, 2014**	**(Rev: Mar 13, 2014)**
Owner:	**Regional Municipality of Wood Buffalo**	**Prepared By:**	WZ/SP	
Project No:	**60190853-402**	**Checked By:**	ZB/NB	
Subject:	**Estimate of Additional Cost to Raise PLB to 250.0 m Min**			

Phase 3 Hospital St to Queen St~ 400 m (Option 1 with Queen St at 250.0 m Elevation)

Item	Description	Unit	Quantity	Unit Price	Extension
1.0	**Removals**				
1.1	Removal of Ex Concrete Structures	l.m.	800	$ 95	$ 76,000
1.2	Removal of Ex Rd Structures	sq.m.	3,200	$ 42	$ 134,400
2.0	**Additional Fill Volume**				
2.1	Additional Road fill Volume	cu.m.	21,000	$ 50	$ 1,050,000
2.2	Additional Road Side Slope Volume	cu.m.	5,500	$ 50	$ 275,000
3.0	**Road Embankment Flood Side Liner**	sq.m.	700	$ 100	$ 70,000
4.0	**Additional Roadworks**				
4.1	Road Structures	sq.m.	4,000	$ 110	$ 440,000
4.2	Concrete Works	l.m.	800	$ 294	$ 235,200
5.0	**Additional Side Street Connection (Queen St ~55m)**				
5.1	**Removals**				
5.1.1	Road Removal	sq.m	750	$ 42	$ 31,500
5.1.2	Concrete Removal	l.m.	110	$ 95	$ 10,450
5.2	**Imported fill**	cu.m.	600	$ 50	$ 30,000
5.3	**New Construction**				
5.3.1	Road Structures	sq.m	750	$ 110	$ 82,500
5.3.2	Curb and Gutter w Sidewalk	l.m.	130	$ 800	$ 104,000
6.0	**Condo Access Adjustment**				
6.1	**Removals**				
6.1.1	Road Structures	sq.m	800	$ 42	$ 33,600
6.1.2	Concrete Works	l.m.	150	$ 95	$ 14,250
6.2	**Imported Fill**	cu.m.	4,000	$ 50	$ 200,000
6.3	**New construction**				
6.3.1	Road Structures	sq.m	2,000	$ 110	$ 220,000
6.3.2	Curb and Gutter w Sidewalk	l.m.	250	$ 800	$ 200,000
6.3.3	Stairs w Handrails	l.s	1	$ 250,000	$ 250,000
7.0	**Additional Retaining Wall**				
7.1	Additional Retaining Wall on City Side w Barrier Fence	l.m.	475	$ 3,500	$ 1,662,500
7.2	Additional Retaining Wall on Boat Museum	l.m.	260	$ 2,500	$ 650,000
8.0	**Additional Landscaping Works**	l.s.	1	$ 250,000	$ 250,000
9.0	**Additional Utilities**				
9.1	Underground Allowances-Storm Sewer/Sanitary/Water Adjustment	l.s.	1	$ 450,000	$ 450,000
9.2	Franchise Utilities Allowances (Electric, Gas, Cable)	l.s.	1	$ 250,000	$ 250,000
	TOTAL				**$ 6,719,000**

Appendix A (Estimate of Additional Cost to Raise PLB to 250.0m Min)

Project Name:	**Prairie Loop Boulevard**	**Date Prepared:**	**February 11, 2014**	**(Rev: Mar 13, 2014)**
Owner:	**Regional Municipality of Wood Buffalo**	**Prepared By:**	WZ/SP	
Project No:	**60190853-402**	**Checked By:**	ZB/NB	

Subject: **Estimate of Additional Cost to Raise PLB to 250.0 m Min**

Phase 3 Hospital St to Queen St~ 400 m (Option 2 with Queen St at Original Design Elevation)

Item	Description	Unit	Quantity	Unit Price	Extension
1.0	**Removals**				
1.1	Removal of Ex Concrete Structures	l.m.	800	$ 95	$ 76,000
1.2	Removal of Ex Rd Structures	sq.m.	1,200	$ 42	$ 50,400
2.0	**Additional Fill Volume**				
2.1	Additional Road fill Volume	cu.m.	13,000	$ 50	$ 650,000
2.2	Additional Road Side Slope Volume	cu.m.	2,000	$ 50	$ 100,000
3.0	**Additional Roadworks**				
3.1	Road Structures	sq.m.	3,000	$ 110	$ 330,000
3.2	Concrete Works	l.m.	800	$ 294	$ 235,200
5.0	Additional Retaining Wall on Boat Museum	l.m.	400	$ 5,000	$ 2,000,000
6.0	Removable Non-Mechanical Flood gate at Queen St (1.5 mx9 m)	ea	1	$ 200,000	$ 200,000
7.0	**Additional Landscaping Works**	l.s.	1	$ 250,000	$ 250,000
8.0	**Additional Utilities**				
8.1	Underground Allowances-Storm Sewer/Sanitary/Water Adjustment	l.s.	1	$ 450,000	$ 450,000
8.2	Franchise Utilities Allowances (Electric, Gas, Cable)	l.s.	1	$ 250,000	$ 250,000
	TOTAL				**$ 4,592,000**

Appendix A (Estimate of Additional Cost to Raise PLB to 250.0m Min)

Project Name:	**Prairie Loop Boulevard**	**Date Prepared:**	**February 11, 2014**	**(Rev: Mar 13, 2014)**
Owner:	**Regional Municipality of Wood Buffalo**	**Prepared By:**	WZ/SP	
Project No:	**60190853-402**	**Checked By:**	ZB/NB	
Subject:	**Estimate of Additional Cost to Raise PLB to 250.0 m Min**			

Phase 3 Queen St to King St~400 m (Option 1 with Queen St at 250.0 m Elevation)

Item	Description	Unit	Quantity	Unit Price	Extension
1.0	**Removals**				
1.1	Removal of Ex Concrete Structures	l.m.	800	$ 95	$ 76,000
1.2	Removal of Ex Rd Structures	sq.m.	3,200	$ 42	$ 134,400
2.0	**Additional Fill Volume**				
2.1	Additional Road Fill Volume	cu.m.	21,000	$ 50	$ 1,050,000
2.2	Additional Road Side Slope Volume	cu.m.	5,800	$ 50	$ 290,000
3.0	**Road Embankment Flood Side Liner**	sq.m.	2,000	$ 100	$ 200,000
4.0	**Additional Roadworks**				
4.1	Road Structures	sq.m.	4,000	$ 110	$ 440,000
4.2	Concrete Works	l.m.	800	$ 294	$ 235,200
5.0	**Additional Side Street Connection (King St ~40 m)**				
5.1	**Removals**				
5.1.1	Road Removal	sq.m	550	$ 42	$ 23,100
5.1.2	Concrete Removal	l.m.	80	$ 95	$ 7,600
5.2	**Imported Fill**	cu.m.	400	$ 50	$ 20,000
5.3	**New Construction**				
5.3.1	Road Structures	sq.m	600	$ 110	$ 66,000
5.3.2	Curb and Gutter w Sidewalk	l.m.	100	$ 800	$ 80,000
6.0	**Additional Retaining Wall on City Side Roadway and Connecting Streets w Barrier Fence**	l.m.	430	$ 3,500	$ 1,505,000
7.0	**Additional Landscaping Works**	l.s.	1	$ 250,000	$ 250,000
8.0	**Additional Utilities**				
8.1	Underground Allowances-Storm Sewer/Sanitary/Water Adjustment	l.s.	1	$ 350,000	$ 350,000
8.2	Franchise Utilities Allowances (Electric, Gas, Cable)	l.s.	1	$ 200,000	$ 200,000
	TOTAL				**$ 4,927,000**

Appendix A (Estimate of Additional Cost to Raise PLB to 250.0m Min)

Project Name:	**Prairie Loop Boulevard**	**Date Prepared:**	**February 11, 2014**	**(Rev: Mar 13, 2014)**
Owner:	**Regional Municipality of Wood Buffalo**	**Prepared By:**	WZ/SP	
Project No:	**60190853-402**	**Checked By:**	ZB/NB	
Subject:	**Estimate of Additional Cost to Raise PLB to 250.0 m Min**			

Phase 3 Queen St to King St~400 m (Option 2 with Queen St at Original Design Elevation)

Item	Description	Unit	Quantity	Unit Price	Extension
1.0	**Removals**				
1.1	Removal of Ex Concrete Structures	l.m.	800	$ 95	$ 76,000
1.2	Removal of Ex Rd Structures	sq.m.	3,000	$ 42	$ 126,000
2.0	**Additional Fill Volume**				
2.1	Additional Road Fill Volume	cu.m.	19,000	$ 50	$ 950,000
2.2	Additional Road Side Slope Volume	cu.m.	5,000	$ 50	$ 250,000
3.0	**Road Embankment Flood Side Liner**	sq.m.	2,000	$ 100	$ 200,000
4.0	**Additional Roadworks**				
4.1	Road Structures	sq.m.	3,600	$ 110	$ 396,000
4.2	Concrete Works	l.m.	800	$ 294	$ 235,200
5.0	**Additional Side Street Connection (King St ~40 m)**				
5.1	**Removals**				
5.1.1	Road Removal	sq.m	550	$ 42	$ 23,100
5.1.2	Concrete Removal	l.m.	80	$ 95	$ 7,600
5.2	**Imported Fill**	cu.m.	400	$ 50	$ 20,000
5.3	**New Construction**				
5.3.1	Road Structures	sq.m	600	$ 110	$ 66,000
5.3.2	Curb and Gutter w Sidewalk	l.m.	100	$ 800	$ 80,000
6.0	**Additional Retaining Wall on City Side Roadway and Connecting Streets w Barrier Fence**	l.m.	380	$ 3,500	$ 1,330,000
7.0	**Additional Landscaping Works**	l.s.	1	$ 250,000	$ 250,000
8.0	**Additional Utilities**				
8.1	Underground Allowances-Storm Sewer/Sanitary/Water Adjustment	l.s.	1	$ 350,000	$ 350,000
8.2	Franchise Utilities Allowances (Electric, Gas, Cable)	l.s.	1	$ 200,000	$ 200,000
	TOTAL				**$ 4,560,000**

Appendix A (Estimate of Additional Cost to Raise PLB to 250.0m Min)

Project Name:	**Prairie Loop Boulevard**	**Date Prepared:**	**February 11, 2014**	**(Rev: Mar 13, 2014)**
Owner:	**Regional Municipality of Wood Buffalo**	**Prepared By:**	WZ/SP	
Project No:	**60190853-402**	**Checked By:**	ZB/NB	

Subject: **Estimate of Additional Cost to Raise PLB to 250.0 m Min**

Phase 3 King St to Franklin Ave~ 660 m

Item	Description	Unit	Quantity	Unit Price	Extension
1.0	**Removals**				
1.1	Removal of Ex Concrete Structures	l.m.	1,500	$ 95	$ 142,500
1.2	Removal of Ex Rd Structures	sq.m.	5,500	$ 42	$ 231,000
2.0	**Additional Fill Volume**				
2.1	Additional Road Fill Volume	cu.m.	30,000	$ 50	$ 1,500,000
2.2	Additional Road Side Slope Volume	cu.m.	8,000	$ 50	$ 400,000
3.0	**Road Embankment Flood Side Liner**	sq.m.	2,000	$ 100	$ 200,000
4.0	**Additional Roadworks**				
4.1	Road Structures	sq.m.	6,600	$ 110	$ 726,000
4.2	Concrete Works	l.m.	1,500	$ 294	$ 441,000
5.0	**Additional Retaining Wall on City Side Roadway w Barrier Fence**	l.m.	375	$ 3,500	$ 1,312,500
6.0	**Additional Landscaping Works**	l.s.	1	$ 300,000	$ 300,000
7.0	**Additional Utilities**				
7.1	Underground Allowances-Storm Sewer/Sanitary/Water Adjustment	l.s.	1	$ 100,000	$ 100,000
7.2	Franchise Utilities Allowances (Electric, Gas, Cable)	l.s.	1	$ 150,000	$ 150,000
	TOTAL				**$ 5,503,000**

Appendix A (Estimate of Additional Cost to Raise PLB to 250.0m Min)

Project Name:	**Prairie Loop Boulevard**	**Date Prepared:**	**February 11, 2014**	**(Rev: Mar 13, 2014)**
Owner:	**Regional Municipality of Wood Buffalo**	**Prepared By:**	WZ/SP	
Project No:	**60190853-402**	**Checked By:**	ZB/NB	

Subject: **Estimate of Additional Cost to Raise PLB to 250.0 m Min**

PHASE 4
HARDIN STREET TO MORRISON ST ~500m

Item	Description	Unit	Quantity	Unit Price	Extension
1.0	**Removals**				
1.1	Removal of Ex Concrete Structures	l.m.	0	$ 95	$ -
1.2	Removal of Ex Rd Structures	sq.m.	0	$ 42	$ -
2.0	**Additional Fill Volume**				
2.1	Additional Road Fill Volume	cu.m.	30,000	$ 50	$ 1,500,000
2.2	Additional Road Side Slope Volume	cu.m.	5,000	$ 50	$ 250,000
3.0	**Road Embankment Flood Side Liner**	sq.m.	1,300	$ 100	$ 130,000
4.0	**Additional Roadworks**				
4.1	Road Structures	sq.m.	0	$ 110	$ -
4.2	Concrete Works	l.m.	0	$ 294	$ -
5.0	**Additional Side Street Connection (Main St ~40 m)**				
5.1	**Removals**				
5.1.1	Road Removal	sq.m	550	$ 42	$ 23,100
5.1.2	Concrete Removal	l.m.	80	$ 95	$ 7,600
5.2	**Imported Fill**	cu.m.	400	$ 50	$ 20,000
5.3	**New Construction**				
5.3.1	Road Structures	sq.m	600	$ 110	$ 66,000
5.3.2	Curb and Gutter w Sidewalk	l.m.	100	$ 800	$ 80,000
6.0	**Additional Retaining Wall on City Side Roadway w Barrier Fence**	l.m.	250	$ 3,500	$ 875,000
7.0	**Additional Landscaping Works at Retaining wall**	l.s.	1	$ 160,000	$ 160,000
8.0	**Additional Utilities**				
8.1	Underground Allowances-Storm Sewer/Sanitary/Water Adjustment	l.s.	1	$ 170,000	$ 170,000
8.2	Franchise Utilities Allowances (Electric, Gas, Cable)	l.s.	1	$ 70,000	$ 70,000
	TOTAL				**$ 3,350,000**

Appendix A (Estimate of Additional Cost to Raise PLB to 250.0m Min)

Project Name:	**Prairie Loop Boulevard**	**Date Prepared:**	**February 11, 2014**	**(Rev: Mar 13, 2014)**
Owner:	**Regional Municipality of Wood Buffalo**	**Prepared By:**	WZ/SP	
Project No:	**60190853-402**	**Checked By:**	ZB/NB	

Subject: **Estimate of Additional Cost to Raise PLB to 250.0 m Min**

CITY SIDE FLOOD PUMPING AND MISCELLANEOUS ITEMS (ALLOWANCES)

Item	Description	Unit	Quantity	Unit Price	Extension
1.0	**Flood Pump for Major Drainage**	ea.	8	$ 250,000	$ 2,000,000
2.0	**Drainage collection for Pumps (City Side)**	ea	8	$ 30,000	$ 240,000
3.0	**Geotechnical Services (Field Testing)**	l.s.	1	$ 100,000	$ 100,000
	TOTAL				**$ 2,340,000**

Appendix A (Estimate of Additional Cost to Raise PLB to 250.0m Min)

Project Name:	**Prairie Loop Boulevard**	**Date Prepared:**	**February 11, 2014**	**(Rev: Mar 13, 2014)**
Owner:	**Regional Municipality of Wood Buffalo**	**Prepared By:**	WZ/SP	
Project No:	**60190853-402**	**Checked By:**	ZB/NB	

Subject: **Estimate of Additional Cost to Raise PLB to 250.0 m Min**

ADDITIONAL COST FOR OPTION 1 WITH QUEEN ST INTERSECTION AT 250.0 M ELEVATION		
PHASE 1 RIEDEL ST TO MCLEOD ST	$	275,000
PHASE 2 MCLEOD ST TO HARDIN ST	$	3,430,000
PHASE 3 RIEDEL ST TO FRANKLIN AVE WITH OPTION 1 (QUEEN ST AT 250.0 M ELEVATION)	$	21,650,000
PHASE 4 HARDIN ST TO MORRISON ST	$	3,350,000
CITY SIDE FLOOD PUMPING AND MISC	$	2,340,000
TOTAL ADDITIONAL COST TO ORIGINAL PLB DESIGN (OPTION 1)	$	31,045,000
ENGINEERING FEE	$	3,105,000
	$	34,150,000
CONTINGENCY	$	6,830,000
TOTAL COST (OPTION 1)	$	40,980,000

ADDITIONAL COST SUMMARY FOR OPTION 2 WITH QUEEN STREET INTERSECTION AT ORIGINAL DESIGN ELEVATION of 248.5M MIN		
PHASE 1 RIEDEL ST TO MCLEOD ST	$	275,000
PHASE 2 MCLEOD ST TO HARDIN ST	$	3,430,000
PHASE 3 RIEDEL ST TO FRANKLIN AVE WITH OPTION 2 (QUEEN ST AT ORIGINAL DESIGN ELEVATION)	$	19,156,000
PHASE 4 HARDIN ST TO MORRISON ST	$	3,350,000
CITY SIDE FLOOD PUMPING AND MISC	$	2,340,000
TOTAL ADDITIONAL COST TO ORIGINAL PLB DESIGN (OPTION 2)	$	28,551,000
ENGINEERING FEE	$	2,855,100
	$	31,406,100
CONTINGENCY	$	6,281,220
TOTAL COST (OPTION 2)	$	37,690,000

APPENDIX A (COST ESTIMATE ASSUMPTIONS)

Prepared By: NB/WZ
Reviewed By:NB/ZB

Notes: The following items to be noted with above estimated cost

- Phase 1:

1. An Additional allowance for landscaping of the flood berm where it joins to PLB, has been included in this estimate
2. Sanitary Sewer / Water adjustment will include adjusting the existing already in place structures, including Storm/ Sanitary manholes, valve boxes, catch basins etc.
3. An additional allowance for franchise utilities has been included for coordination and minor revisions (if any) with the Utility companies where the road transitions to 250.0 m

- Phase 2, 3 and 4:

1. Additional earth fill volume will be delivered to the site and the source of the material is not finalized.
2. The price of $50 per cubic meter for this estimate includes the following assumptions:
    - Material is supplied free of charge
    - Pricing includes borrow stripping of 6" and replacement
    - The cost of imported fill will vary depending on location, accessibility and haul distances.
    - The cost of $\$50/m^3$ is selected as a reasonable estimate based on the information and possible borrow sites considered at this time
3. Flood side liner was estimated to be a 5 meter wide strip of non-permeable liner to be installed on the river side to reduce the water seepage in the pavement structure.
4. The road structure was estimated as per the existing design (road structure as per sq. m and monolithic concrete curb / sidewalk as concrete works in lin.m.)
5. Retaining wall is calculated per linear meter. This includes a block (structural concrete) retaining wall of approximately 1.5 meters above the ground and 0.5 meter below the ground.
6. Barrier fence / Guard rail will be to road safety standards for the vehicular traffic.
7. Sanitary Sewer / Water adjustment allowances will include adjusting the existing already in place structures, including STM/ Sanitary manholes, valve boxes, catch basins etc. New catch basins and leads are required in some locations.
8. There are no additional Franchise Utility costs in Phase 2 as engineering design and construction has not been finalized.
9. Removable Non- Mechanical Flood Gate at Queens Street will be 1.50 meter high x 9.0 meter wide and will be specifically designed to act as a flood gate
10. Due to the additional elevations and requirement for retaining wall on the City side of PLB, additional landscaping costs are included in this estimate. An estimated average cost of $600/lin.m was utilized as a similar cost for landscaping designed on the river side of PLB.

- General:

1. Land Acquisition cost are not included
2. Cost of procurement/purchasing earth fill (borrow pit royalties) is not included
3. Allowance for additional landscaping has been included
4. Cost of the flood control dyke system where required on PLB, is not included
5. Cost of stormwater management to the City side is included as an allowance. This includes portable diesel driven flood pumps for emergency pumping.
6. Flood Pumps for Major Drainage are planned as Diesel Engine primed high volume pumps capable of pumping to 20 meter head. The cost includes procuring and installing the pump with a diesel engine drive. The pumps and the engine can be mounted on rails and made mobile to transfer between locations.
7. The cost of preparing drainage collection for emergency flood pumping and a platform for the pump/ engine is included as a separate line item in the estimate.
8. Geotechnical Services will include selection and testing of borrow fill material used for embankments to enhance flood protection

Appendix B (Original Design 248.5 m min- Cost Estimate _Phase 1-4, July 2013)

					Contingency				Total		
Summary	Total	District Heating	Road Works	Water Main	Percentage	District Heating	Road Works	Water Mains	District Heating	Road works	Water Mains
Phase 1	$ 15,250,645.68	$2,055,000.00	$13,195,645.68	$455,500.00	0.00%		$0.00	$0.00	$2,055,000.00	$13,195,645.68	$455,500.00
Phase 2	$ 19,168,946.54	$7,500,000.00	$11,668,946.54	$1,056,100.00	20.00%	$1,500,000.00	$2,333,789.31	$211,220.00	$9,000,000.00	$14,002,735.85	$1,267,320.00
Phase 3	$ 25,318,310.37	$12,075,000.00	$13,243,310.37		10.00%	$1,207,500.00	$1,324,331.04	$0.00	$13,282,500.00	$14,567,641.41	$0.00
Phase 4	$ 6,501,059.20	$2,055,000.00	$4,446,059.20	$248,000.00	30.00%	$616,500.00	$1,333,817.76	$74,400.00	$2,671,500.00	$5,779,876.96	$322,400.00
Fraser and McLeod	$ 1,133,340.52		$1,133,340.52		20.00%		$226,668.10	$0.00		$1,360,008.62	$0.00
Total	$ 67,372,302.31	$ 23,685,000.00	$ 43,687,302.31	$ 1,759,600.00		$ 3,324,000.00	$ 5,218,606.21	$ 285,620.00	$ 27,009,000.00	$ 48,905,908.52	$2,045,220.00

NOTES:

- Appendix B-(248.5m Min) Costs are previously submitted to RMWB in July 2013

- The Total Costs (248.5m) are approximate and required to be refined at detailed design stage

- Phase 2 and Phase 4 Costs are based on preliminary design information available at this time and may subject to change in detailed design phase

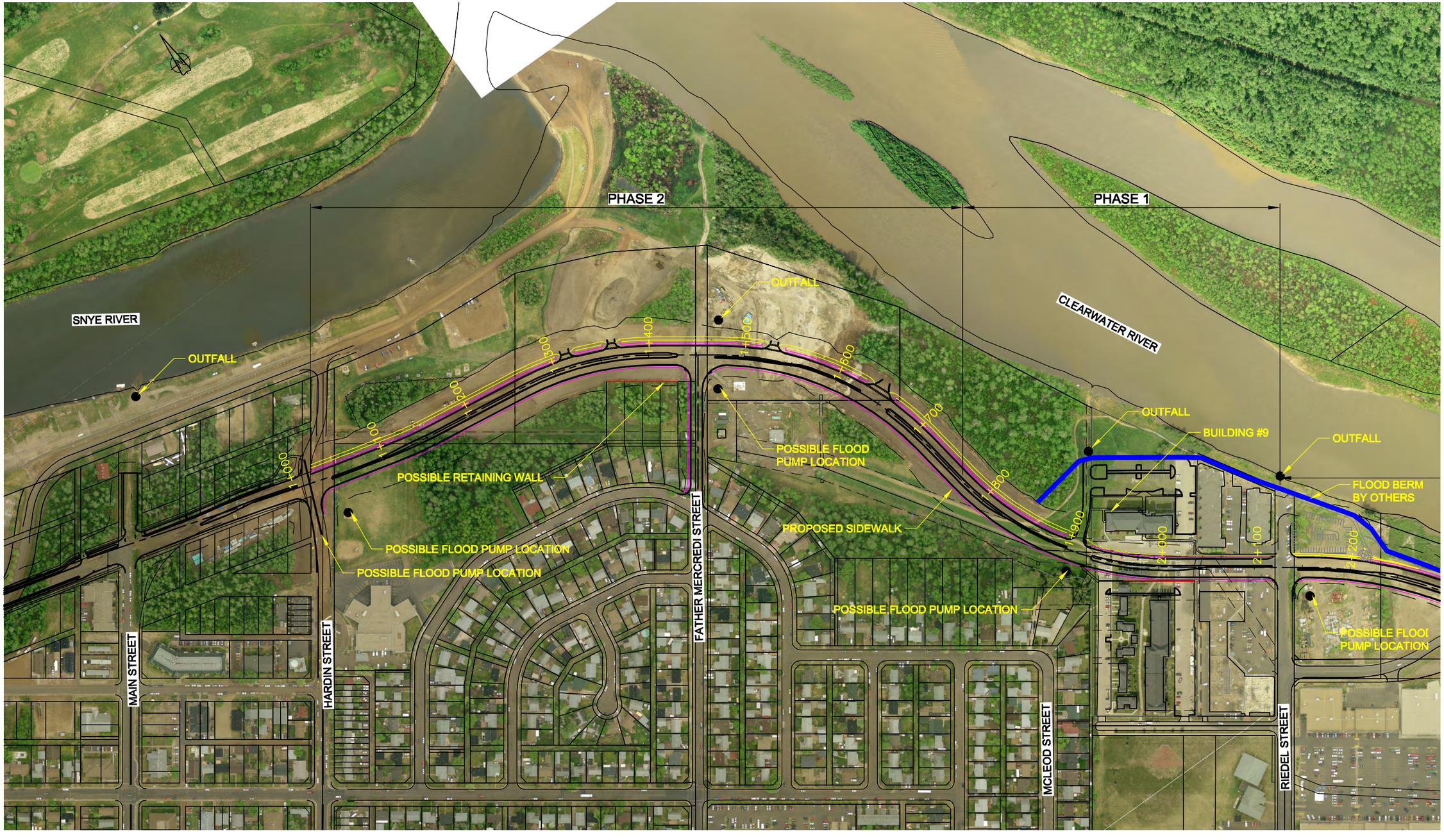
- Phase 4 Costs are from Hardin Street to Main Street (North of Gordon Ave) in this estimate (Appendix B)

B SIZE 11" x 17" (279.4mm x 431.8mm)

PLOT: 2/11/2014 2:21:05 PM

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AECOM FILE NAME:



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Regional Municipality of Wood Buffalo
Prairie Loop Boulevard
Study of Evaluation of Raising Prairie Loop Boulevard

Proposed Road Plan
Figure 1.1 (1 of 2)

B SIZE 11" x 17" (279.4mm x 431.8mm)

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AECOM FILE NAME:

PHASE 3

OUTFALL

POSSIBLE RETAINING WALL

PROPOSED CONDO ACCESS

OUTFALL

POSSIBLE FLOOD GATE

BOAT MUSEUM

CONDOMINIUM SITE

OUTFALL

CLEARWATER RIVER

FLOOD BERM BY OTHERS

2+100

2+500

2+600

2+700

2+800

2+900

3+000

3+100

3+200

3+300

3+400

3+500

3+600

3+700

3+800

3+900

4+000

4+039

POSSIBLE FLOOD PUMP LOCATION

POSSIBLE REGRADING WORK TO BE DONE TO EXISTING ROAD

POSSIBLE FLOOD PUMP LOCATION

POSSIBLE RETAINING WALL

POSSIBLE FLOOD PUMP LOCATION

POSSIBLE RETAINING WALL

POSSIBLE FLOOD PUMP LOCATION

POSSIBLE RETAINING WALL

POSSIBLE REGRADING WORK TO BE DONE TO EXISTING ROAD

PROPOSED SIDEWALK

ALBERTA DRIVE

HOSPITAL STREET

QUEEN STREET

CENTENNIAL DRIVE

KING STREET

MARSHALL STREET

FRANKLIN AVENUE

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Prairie Loop Boulevard
Study of Evaluation of Raising Prairie Loop Boulevard

Proposed Road Plan

Figure 1.2 (2 of 2)

B SIZE 11" x 17" (279.4mm x 431.8mm)

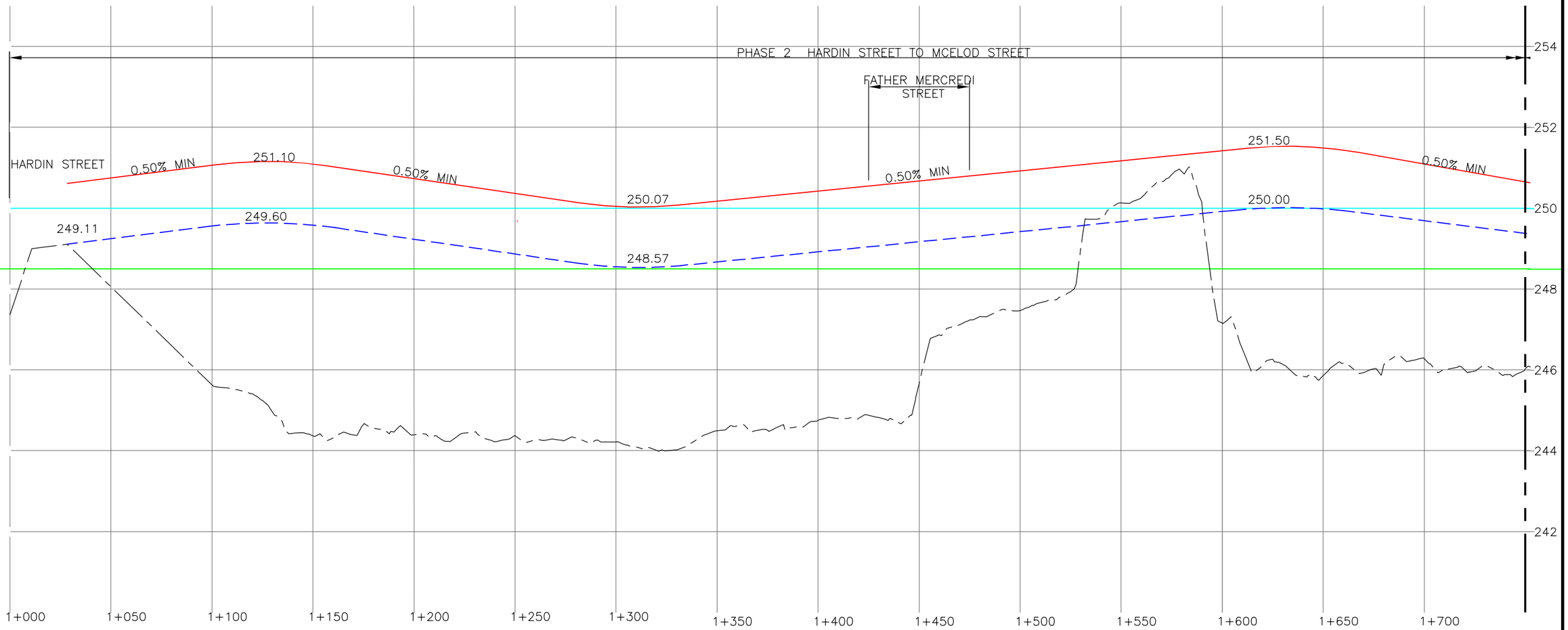
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LEGEND

- 250.00 m FLOOD ROAD ELEVATION
- ORIGINAL DESIGN ROAD ELEVATION
- OPTION 2– QUEEN STREET AT ORIGINAL DESIGN ELEVATION
- 250.00 m ELEVATION
- 248.5 m ELEVATION
- ORIGINAL GROUND



0 20 40 60 m H=1:2000
0 1 2 3 V=1:100

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Prairie Loop Boulevard
Study of Evaluation of Raising Prairie Loop Boulevard

Proposed Road Profile

Figure 2.1 (1 of 4)

B SIZE 11" x 17" (279.4mm x 431.8mm)

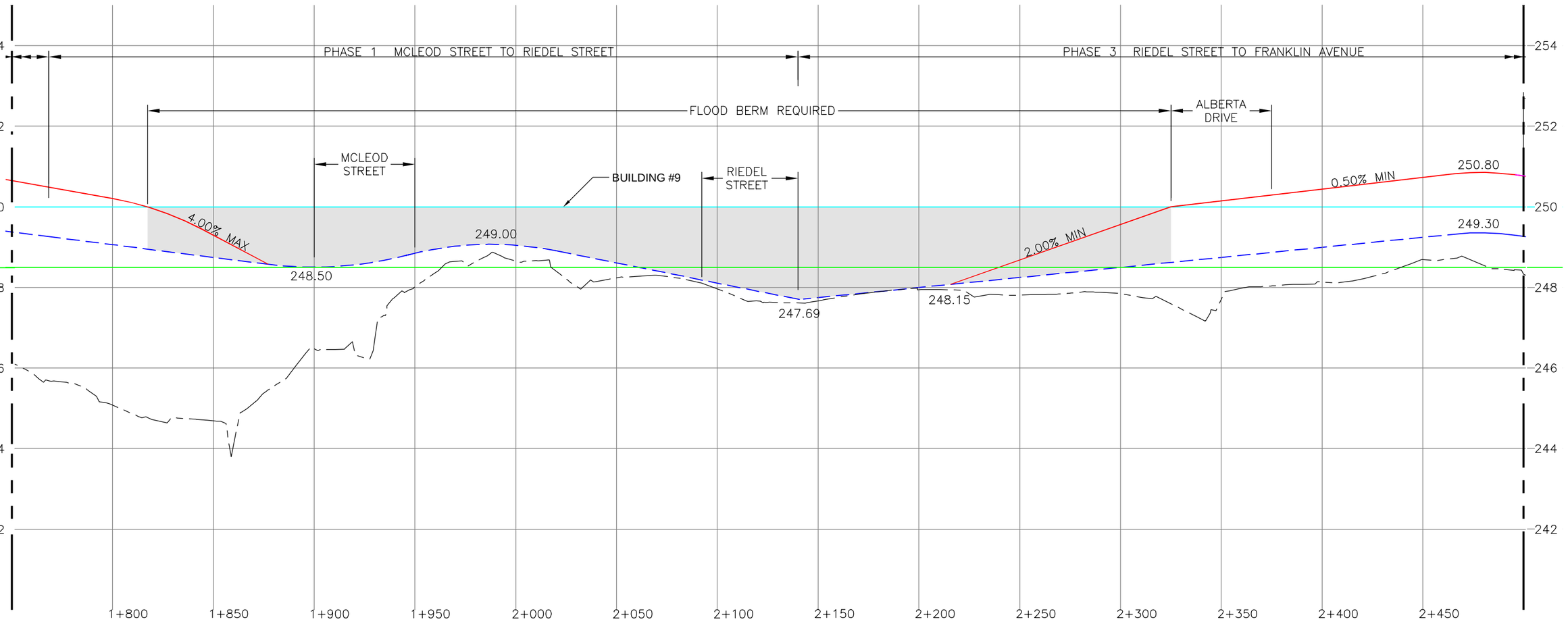
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- ORIGINAL DESIGN ROAD ELEVATION
- OPTION 2– QUEEN STREET AT ORIGINAL DESIGN ELEVATION
- 250.00 m ELEVATION
- 248.5 m ELEVATION
- ORIGINAL GROUND



0 20 40 60 m
0 1 2 3

H=1:2000
V=1:100

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Prairie Loop Boulevard
Study of Evaluation of Raising Prairie Loop Boulevard

Proposed Road Profile

Figure 2.2 (2 of 4)

B SIZE 11" x 17" (279.4mm x 431.8mm)

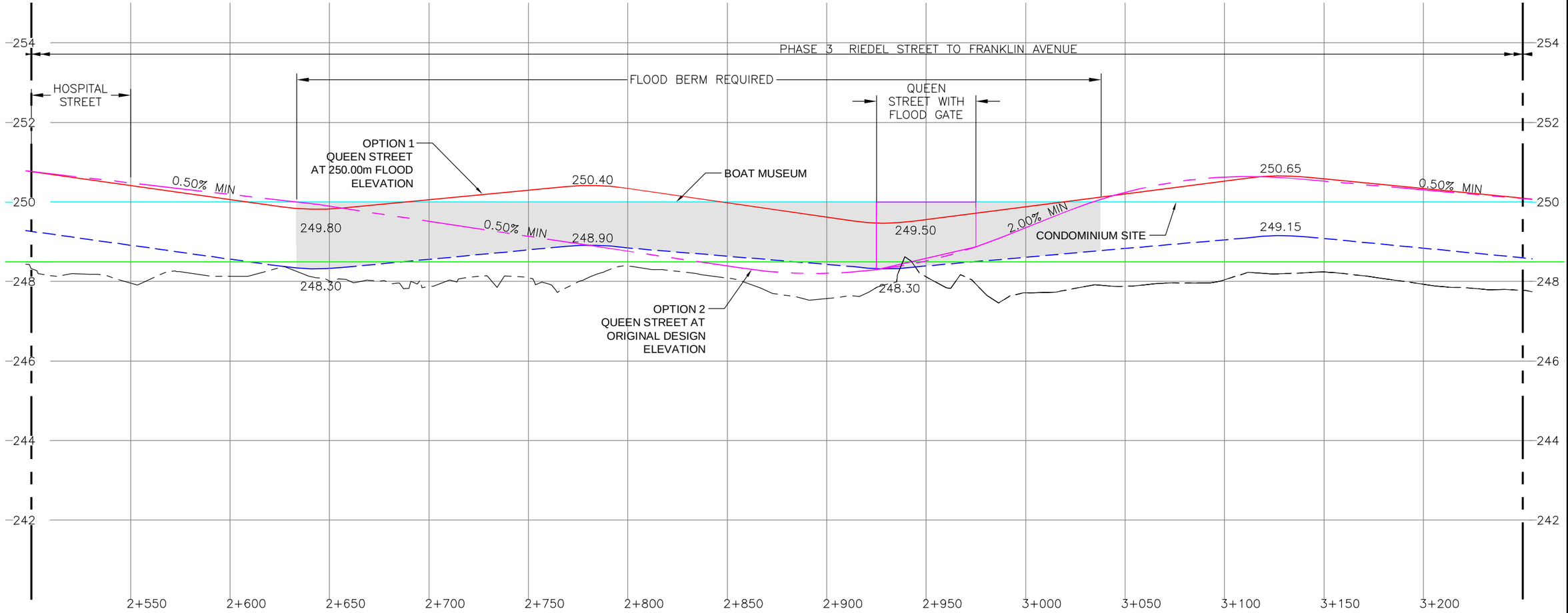
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LEGEND

- 250.00 m FLOOD ROAD ELEVATION
- ORIGINAL DESIGN ROAD ELEVATION
- OPTION 2– QUEEN STREET AT ORIGINAL DESIGN ELEVATION
- 250.00 m ELEVATION
- 248.5 m ELEVATION
- ORIGINAL GROUND



0 20 40 60 m
0 1 2 3

H=1:2000
V=1:100

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Prairie Loop Boulevard
Study of Evaluation of Raising Prairie Loop Boulevard

Proposed Road Profile

Figure 2.3 (3 of 4)

B SIZE 11" x 17" (279.4mm x 431.8mm)

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LEGEND

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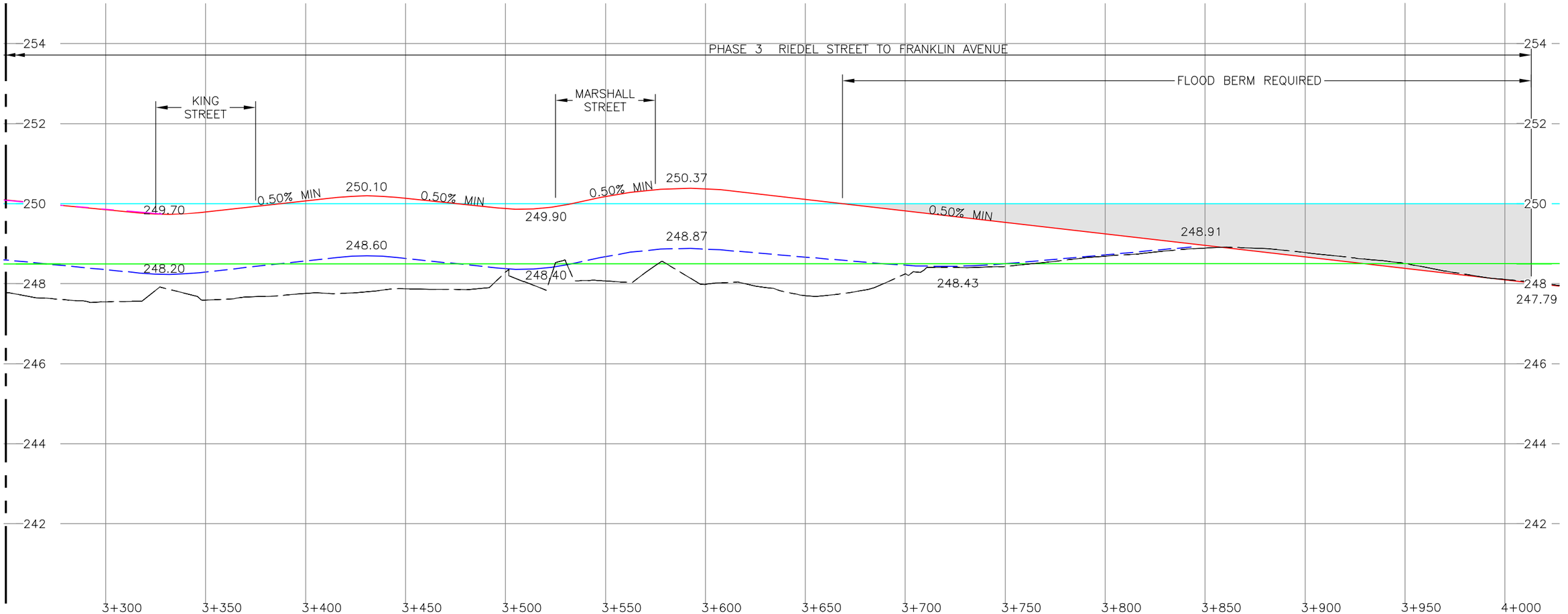
ORIGINAL DESIGN ROAD ELEVATION

OPTION 2– QUEEN STREET AT ORIGINAL DESIGN ELEVATION

250.00 m ELEVATION

248.5 m ELEVATION

ORIGINAL GROUND



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Prairie Loop Boulevard
Study of Evaluation of Raising Prairie Loop Boulevard

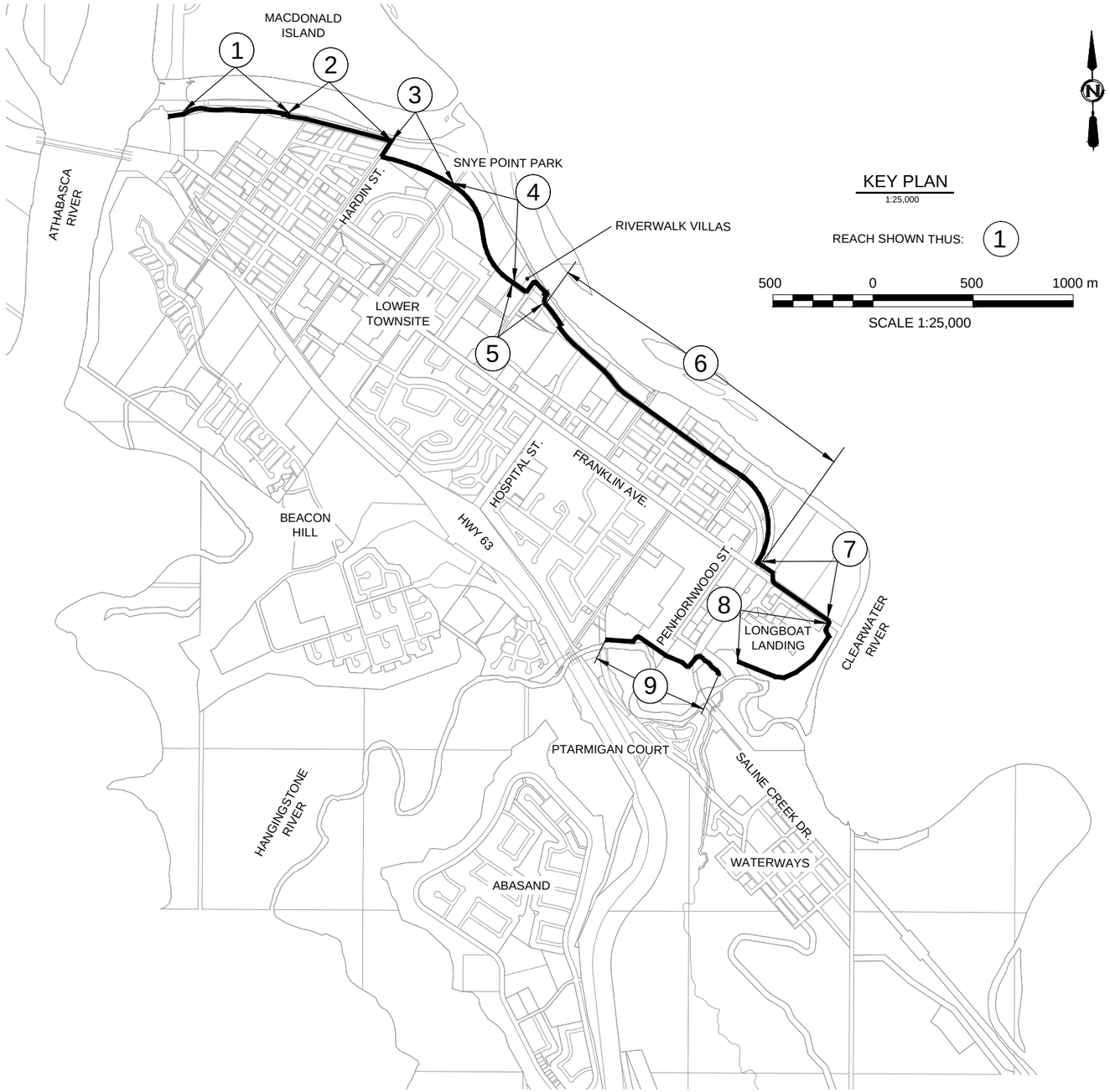
Proposed Road Profile

Figure 2.4 (4 of 4)

APPENDIX D

Design Drawings

Lower Townsite Alternative 2



No.	Date	Revision	
0	22 June 2014	Issued for Review	DA
No.	Date	Revision	ENG.

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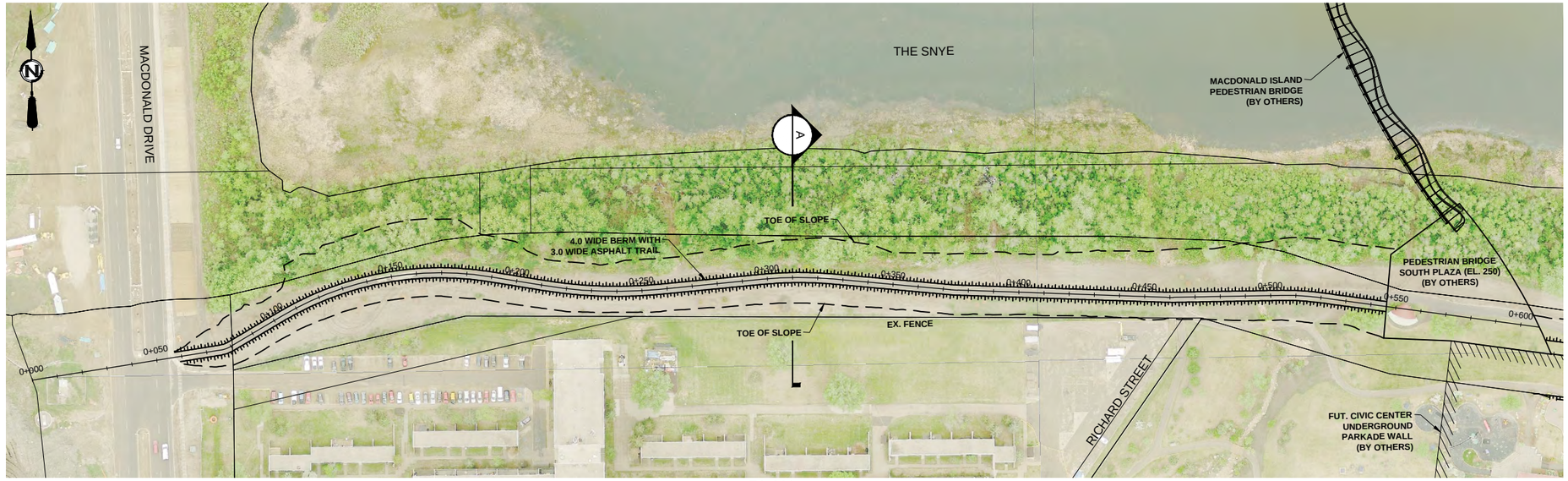
FORT McMURRAY FLOOD PROTECTION

LOWER TOWNSITE - ALTERNATIVE 2 FLOOD PROTECTION ALIGNMENT REACHES

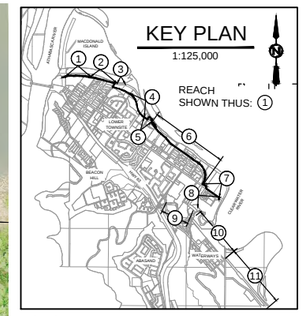
Dwg.100165-D-FG	22 JUNE 2014	**Figure D1**

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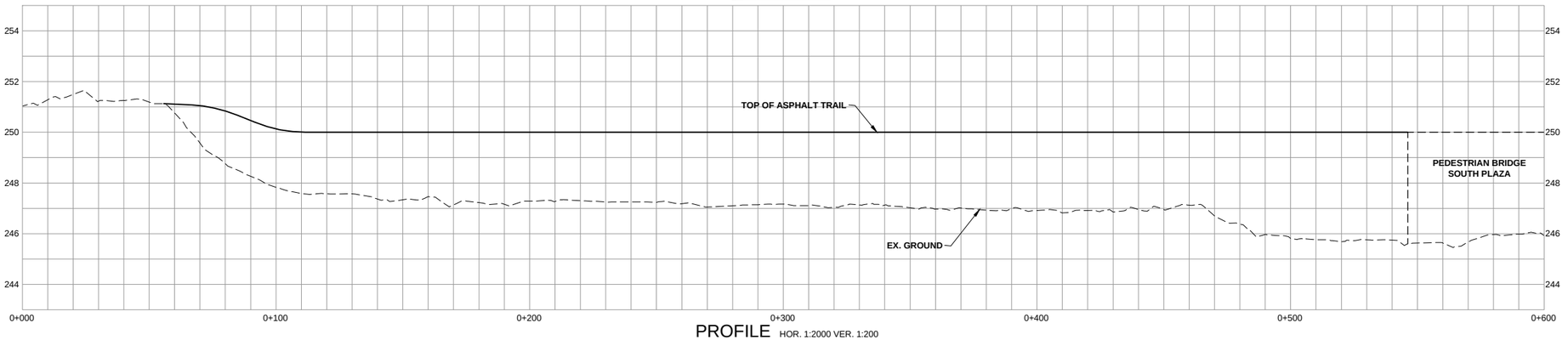
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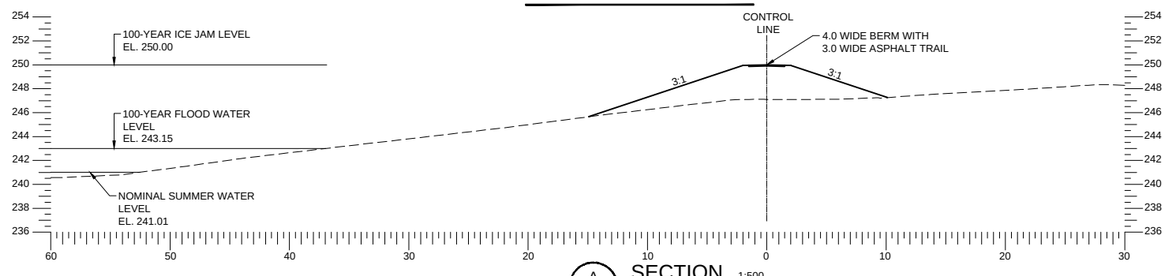
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NOTES:
1. AIRPHOTO DATED NOVEMBER 2011



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A SECTION 1:500

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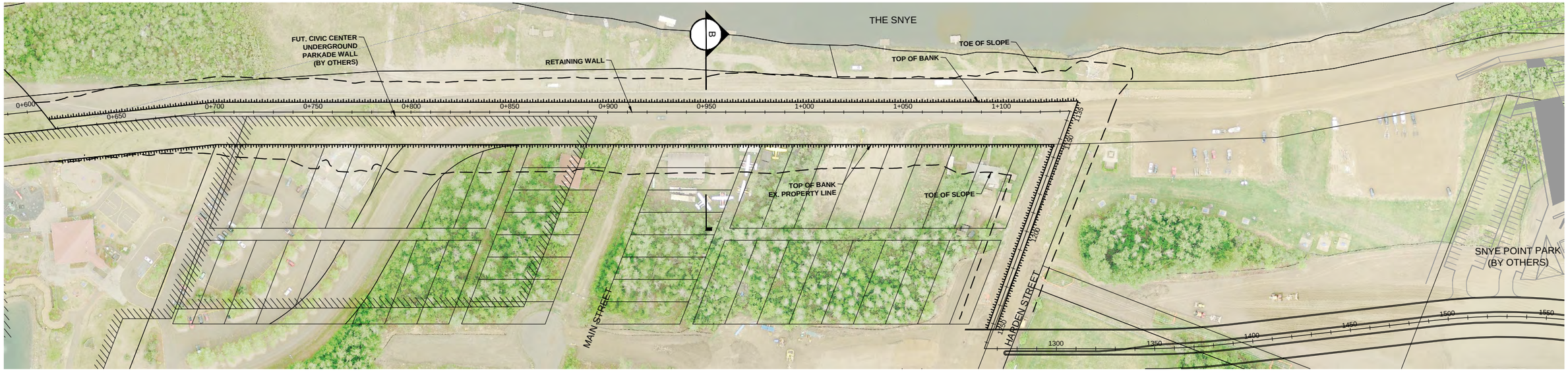
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LOWER TOWNSITE
ALTERNATIVE 2 - REACH 1
BERM WITH ASPHALT TRAIL

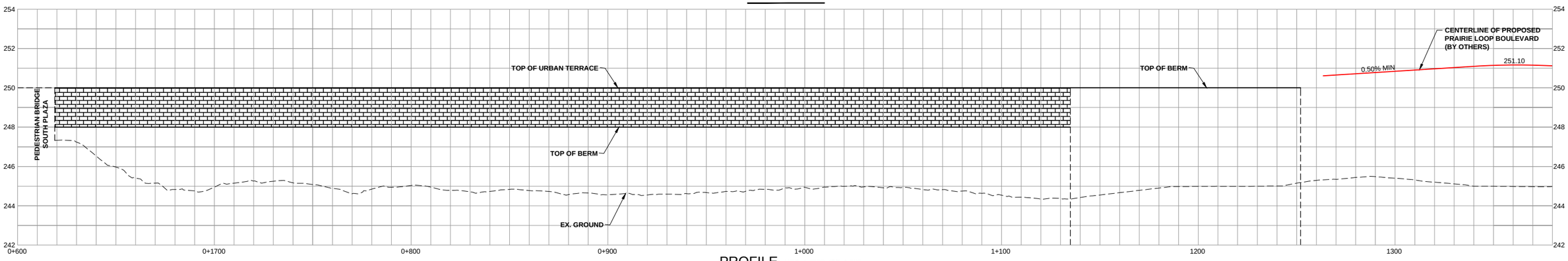
Dwg.100165-D-FG	22 JUNE 2014	**Figure D2**

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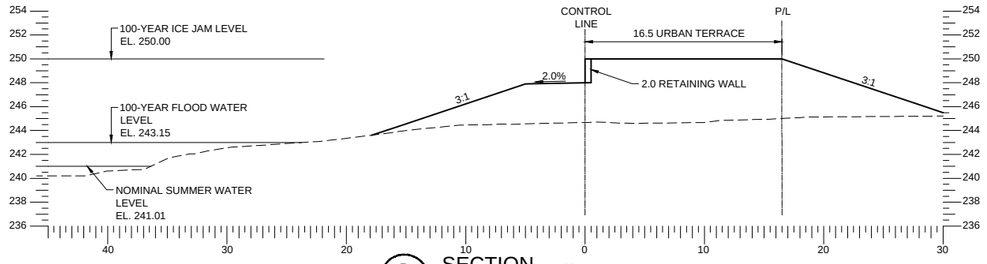
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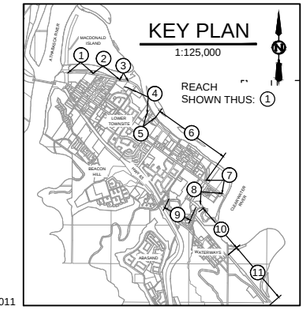
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B SECTION 1:500



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1. AIRPHOTO DATED NOVEMBER 2011

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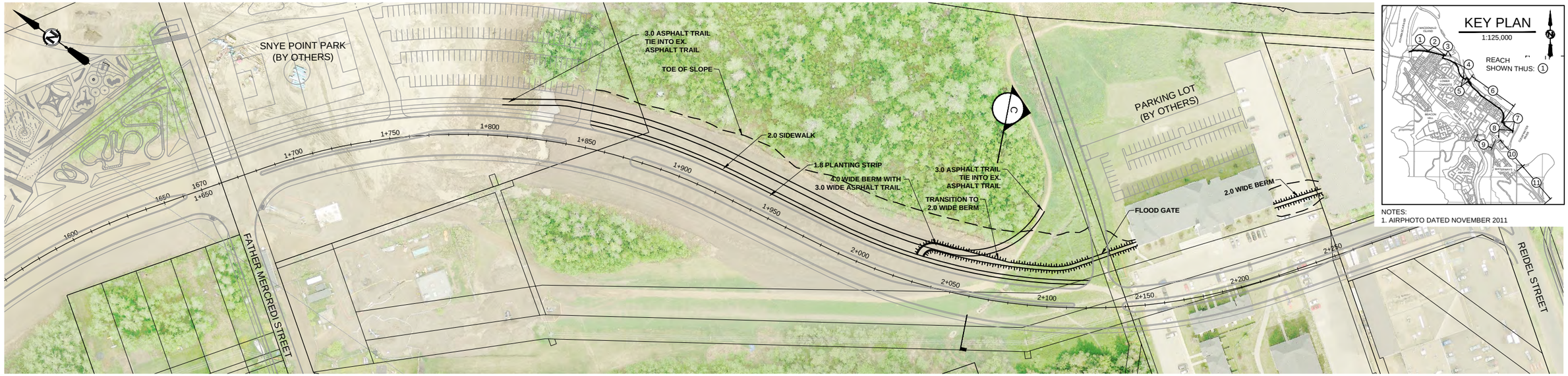
FORT McMURRAY FLOOD PROTECTION

LOWER TOWNSITE
ALTERNATIVE 2 - REACH 2 AND 3
URBAN TERRACE

Dwg.100165-D-FG	22 JUNE 2014	**Figure D3**

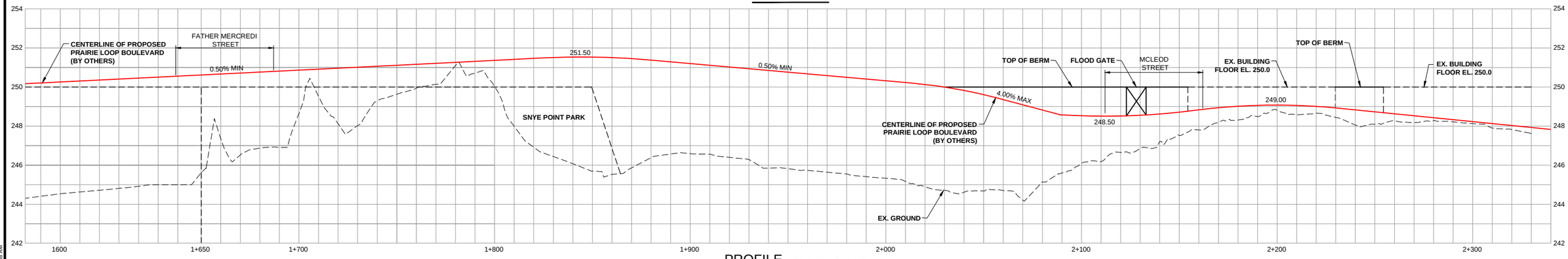
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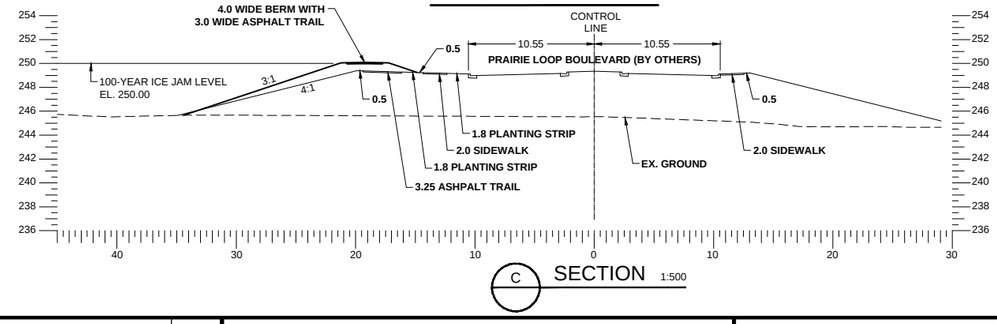


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1. AIRPHOTO DATED NOVEMBER 2011

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C SECTION 1:500

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No.	Date	Revision	ENG.

REGIONAL MUNICIPALITY OF WOOD BUFFALO

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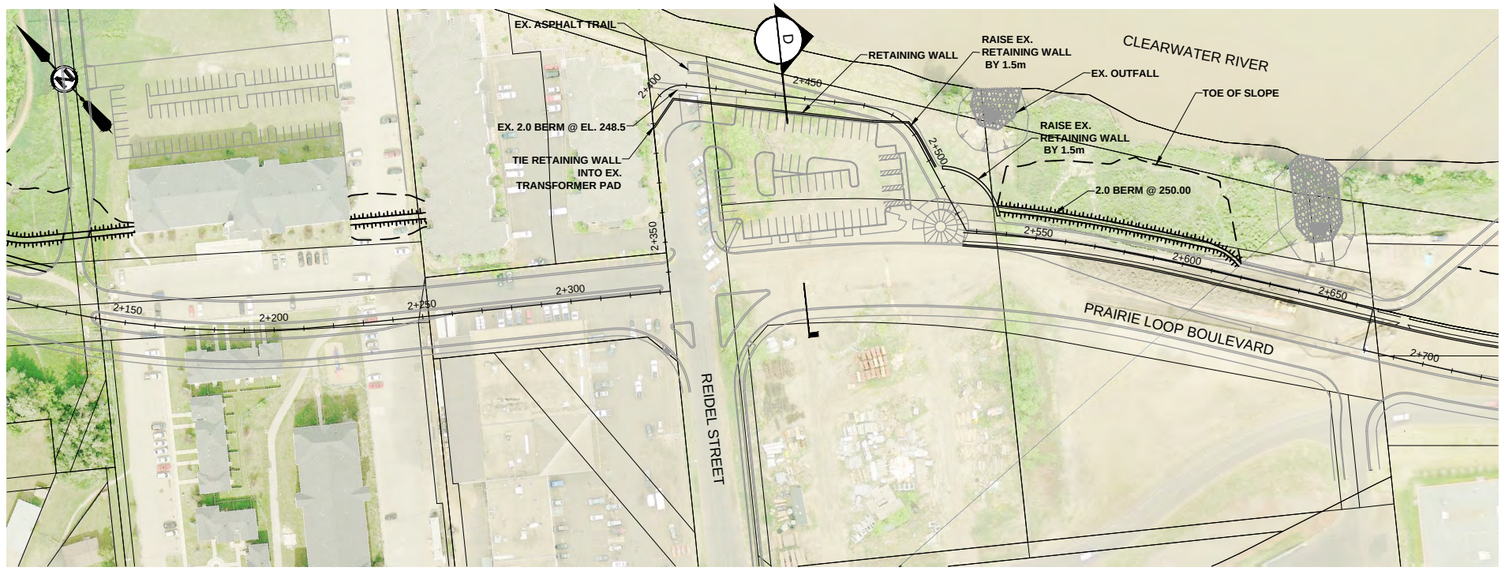
FORT McMURRAY FLOOD PROTECTION

LOWER TOWNSITE
ALTERNATIVE 2 - REACH 4 AND 5
BERM WITH PATH

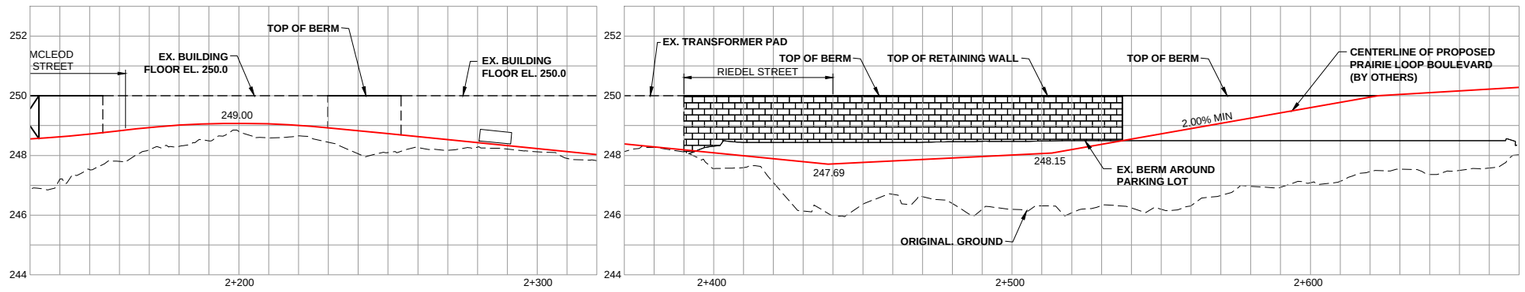
Dwg.100165-D-FG	22 JUNE 2014	**Figure D4**

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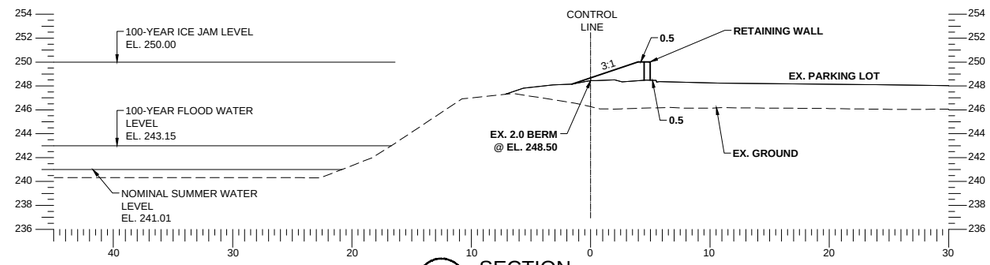
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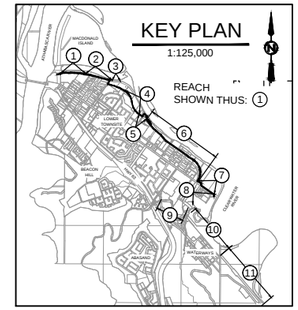
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D SECTION 1:500



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			ENG.

REGIONAL MUNICIPALITY OF WOOD BUFFALO

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RM OF WOOD BUFFALO

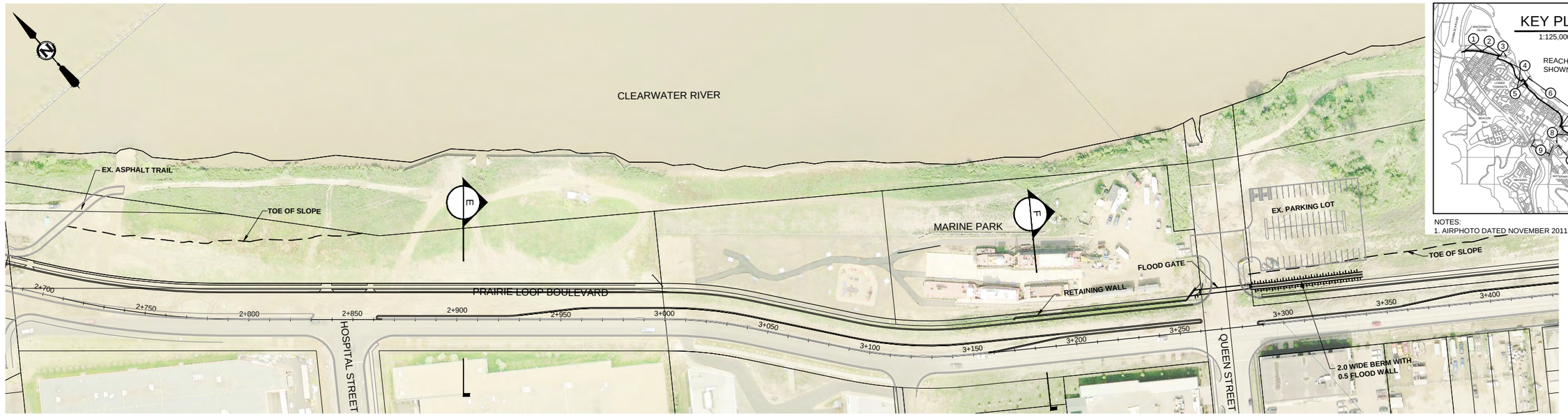
FORT McMURRAY FLOOD PROTECTION

LOWER TOWNSITE
ALTERNATIVE 2 - REACH 5
BERM AND WALL

Dwg.100165-D-FG | 22 JUNE 2014 | **Figure D5**

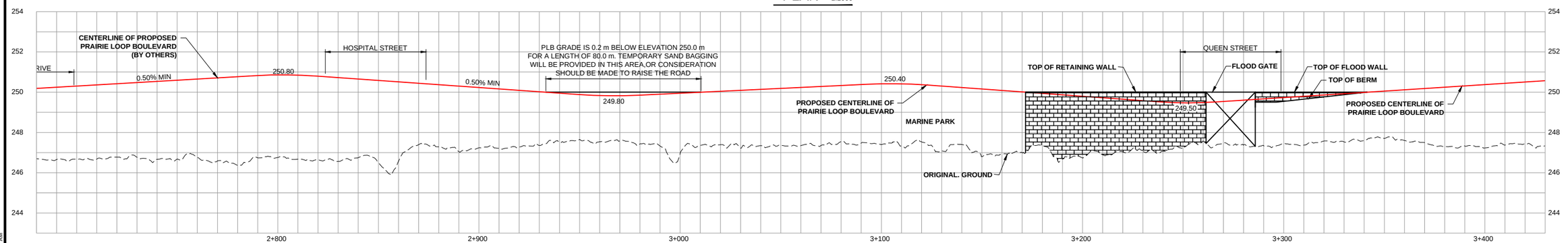
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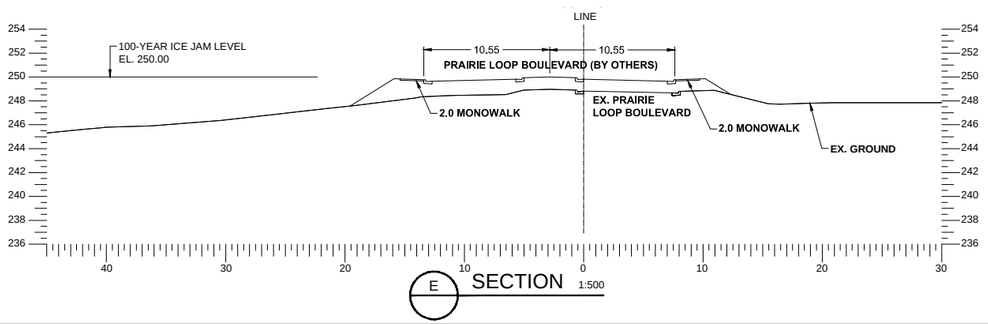


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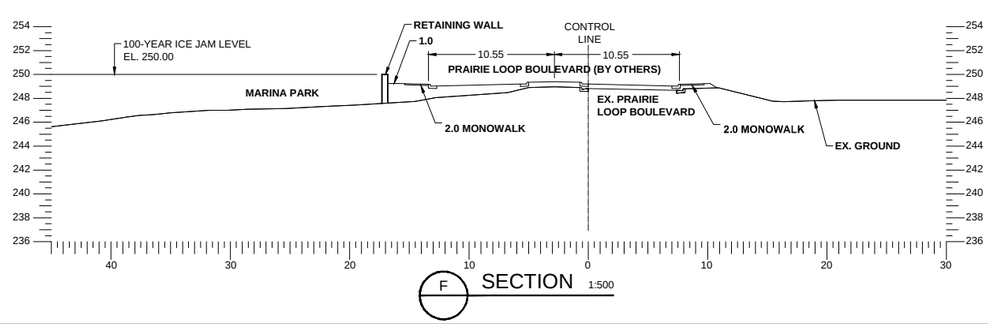
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E SECTION 1:500



F SECTION 1:500

No.	Date	Revision	
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No.	Date	Revision	ENG.

REGIONAL MUNICIPALITY OF WOOD BUFFALO

nhc northwest hydraulic consultants

RM OF WOOD BUFFALO

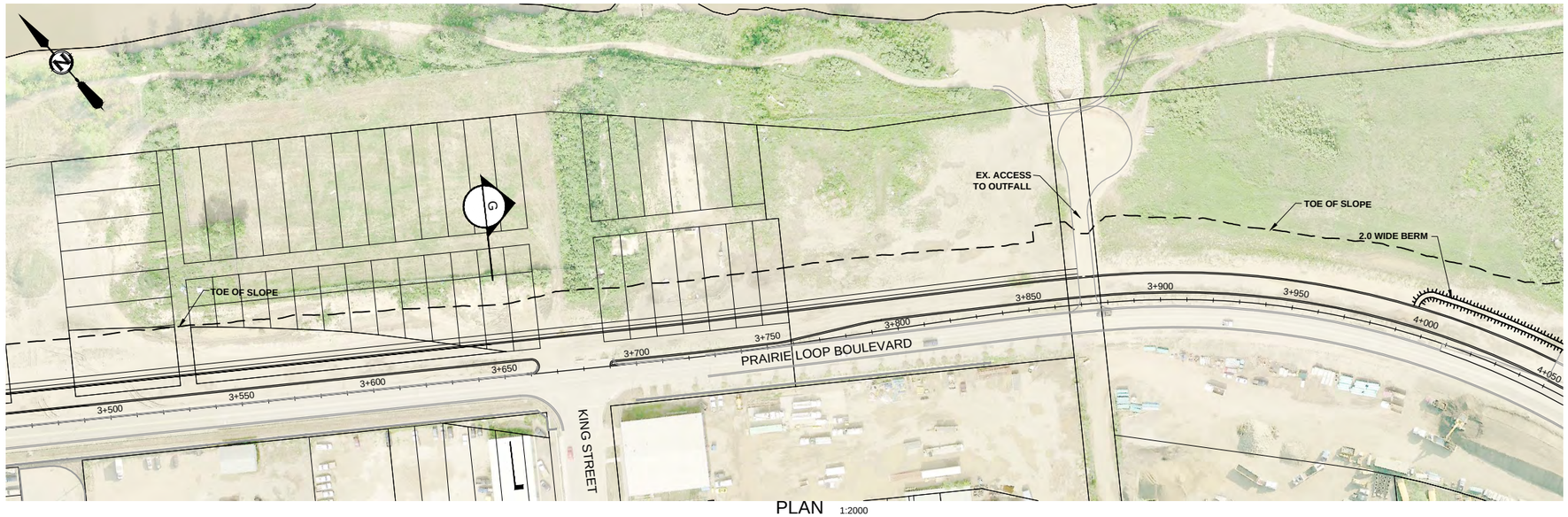
FORT McMURRAY FLOOD PROTECTION

LOWER TOWNSITE
ALTERNATIVE 2 - REACH 6
BERM AND WALL

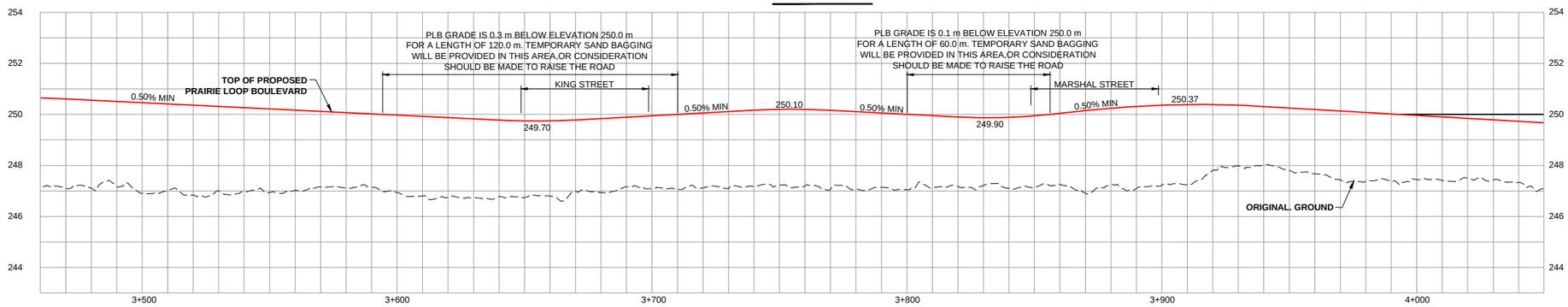
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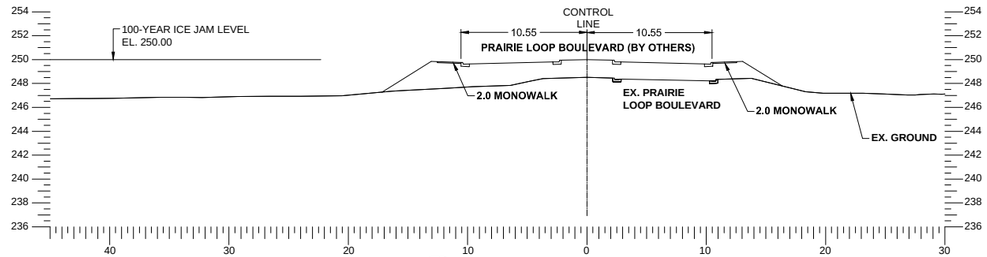
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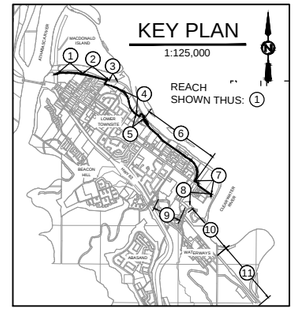
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G SECTION 1:500



NOTES:
1. AIRPHOTO DATED NOVEMBER 2011

No.	Date	Revision	
0	22 June 2014	Issued for Review	DA
No.	Date	Revision	ENG.

REGIONAL MUNICIPALITY OF WOOD BUFFALO

nhc northwest hydraulic consultants

RM OF WOOD BUFFALO

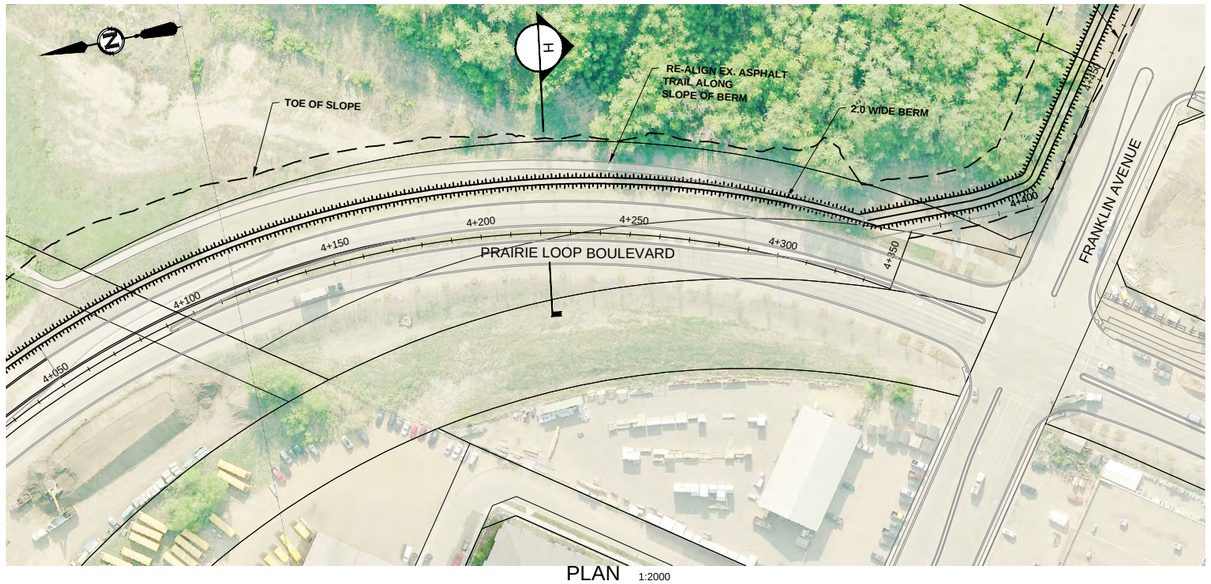
FORT McMURRAY FLOOD PROTECTION

LOWER TOWNSITE
ALTERNATIVE 2 - REACH 6
BERM AND WALL

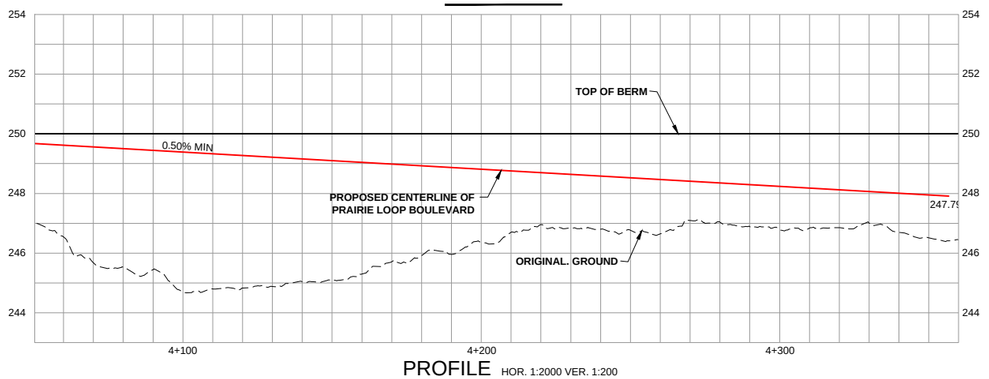
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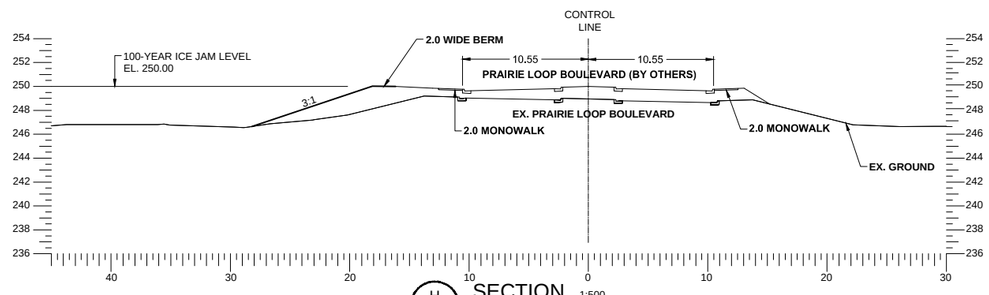
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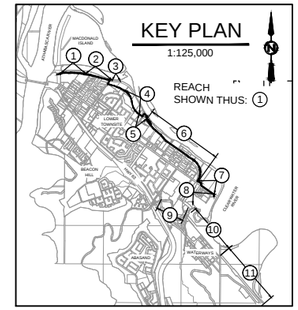
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H SECTION 1:500



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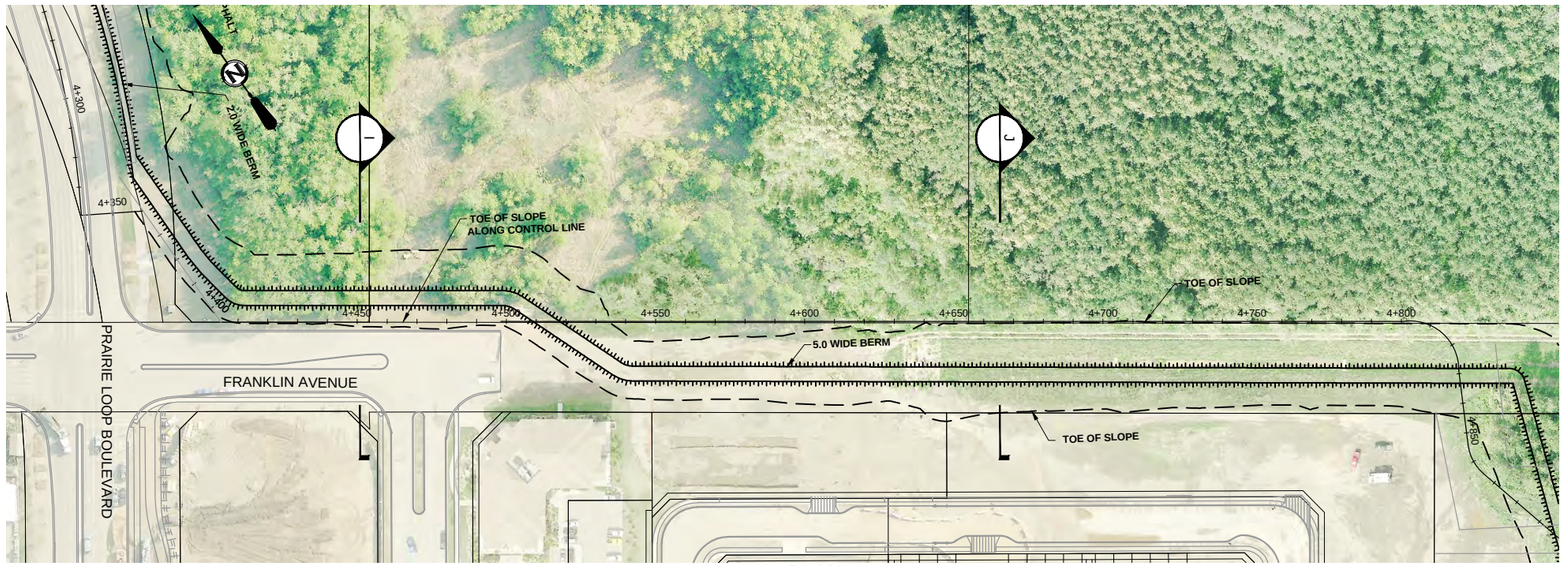
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LOWER TOWNSITE
ALTERNATIVE 2 - REACH 6
BERM

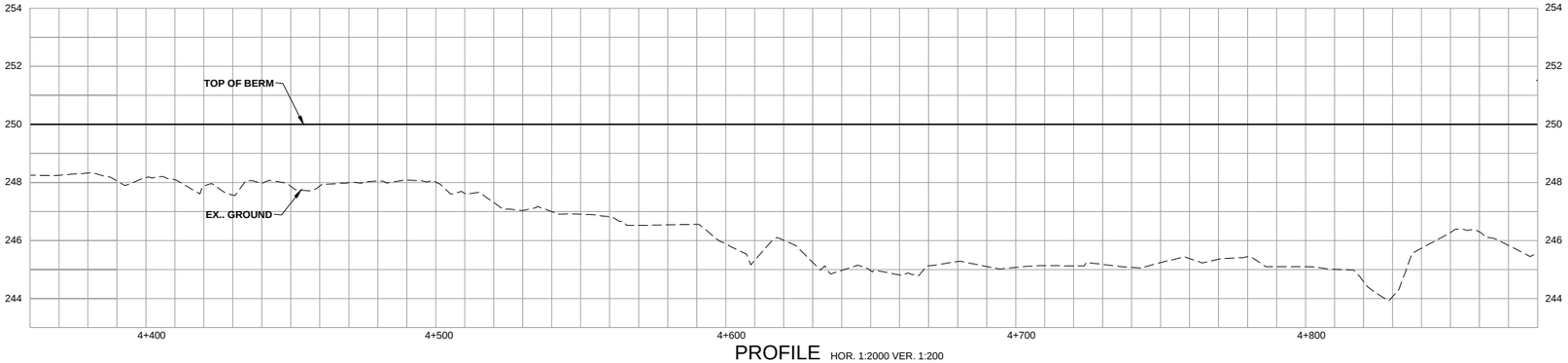
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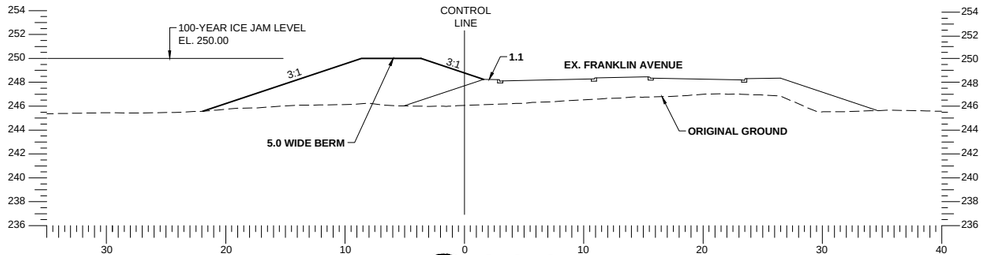
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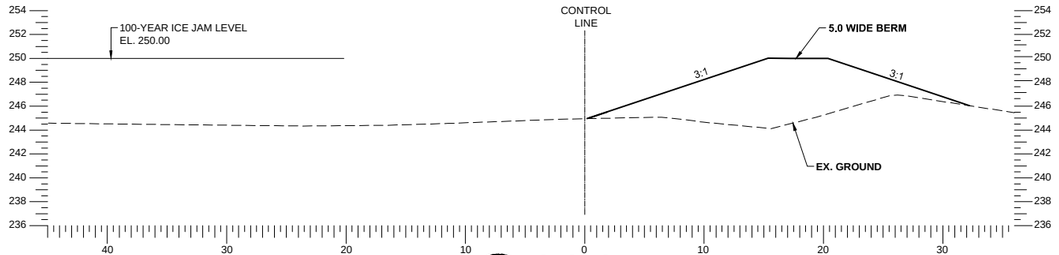
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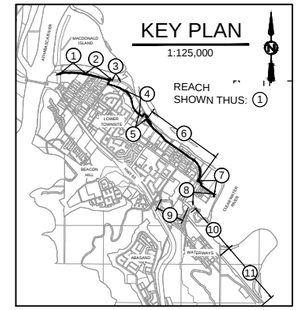
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J SECTION 1:500



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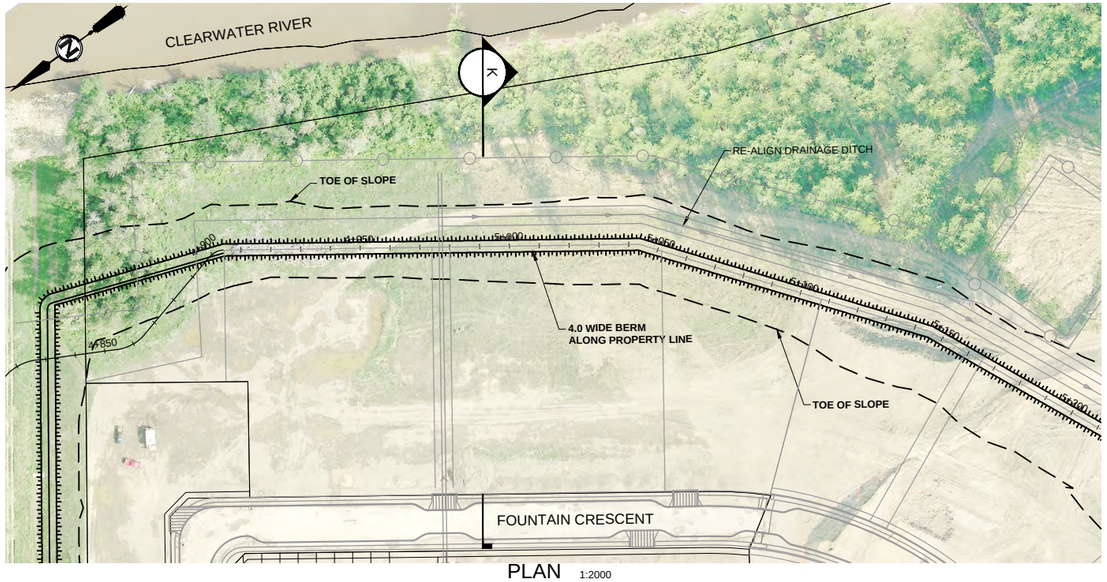
FORT McMURRAY FLOOD PROTECTION

LOWER TOWNSITE
ALTERNATIVE 2 - REACH 7
BERM

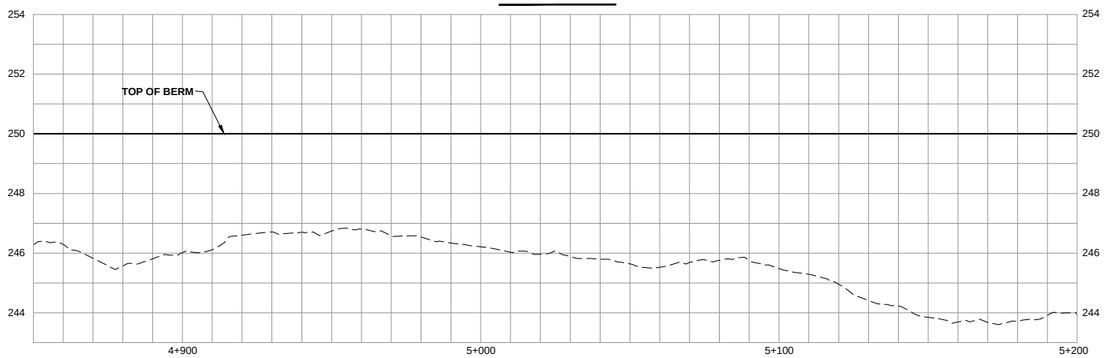
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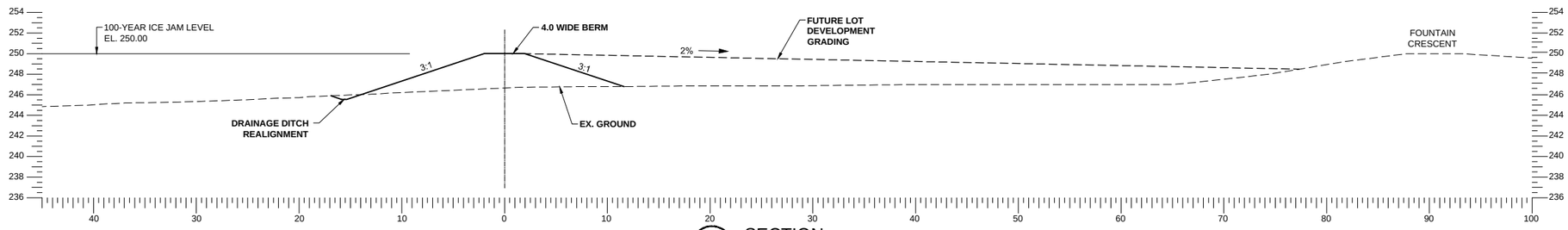
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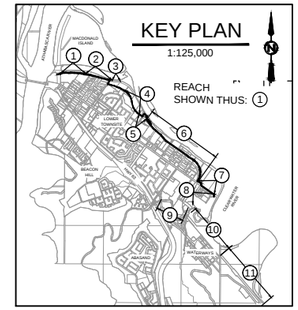
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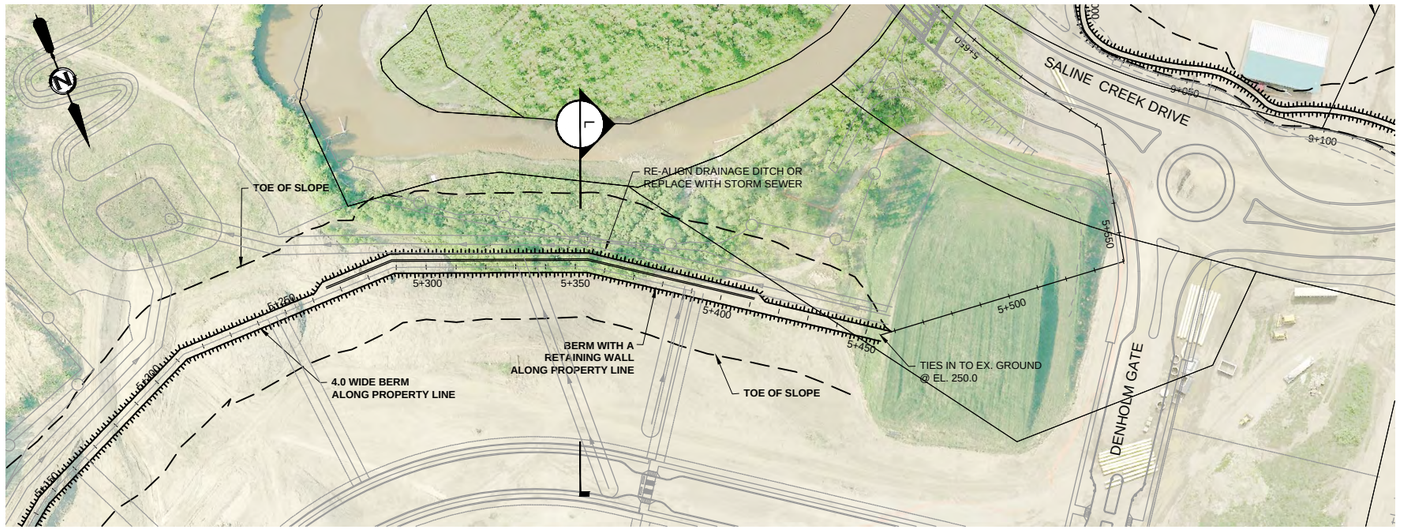
FORT McMURRAY FLOOD PROTECTION

LOWER TOWNSITE
REACH 8
BERM

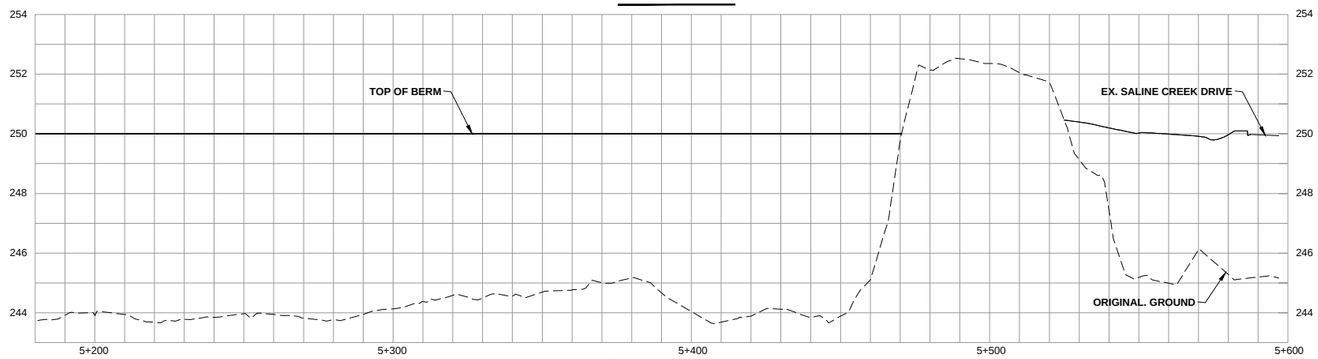
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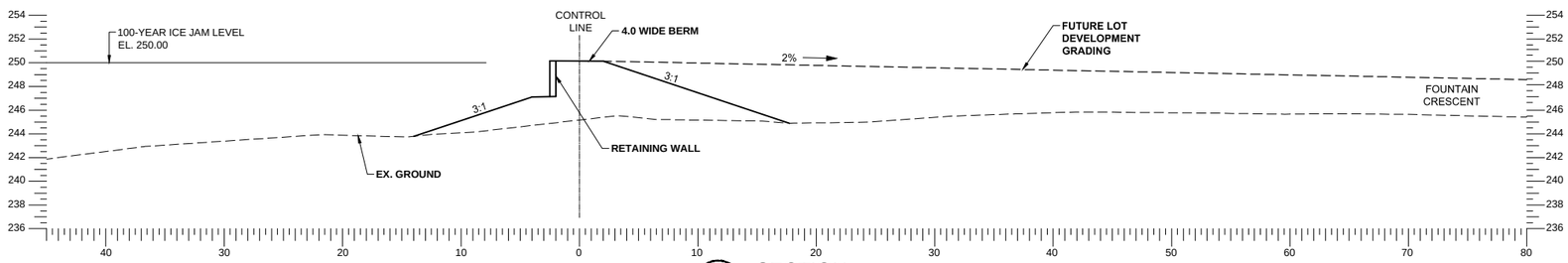
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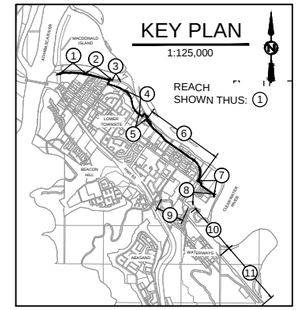
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L SECTION 1:500



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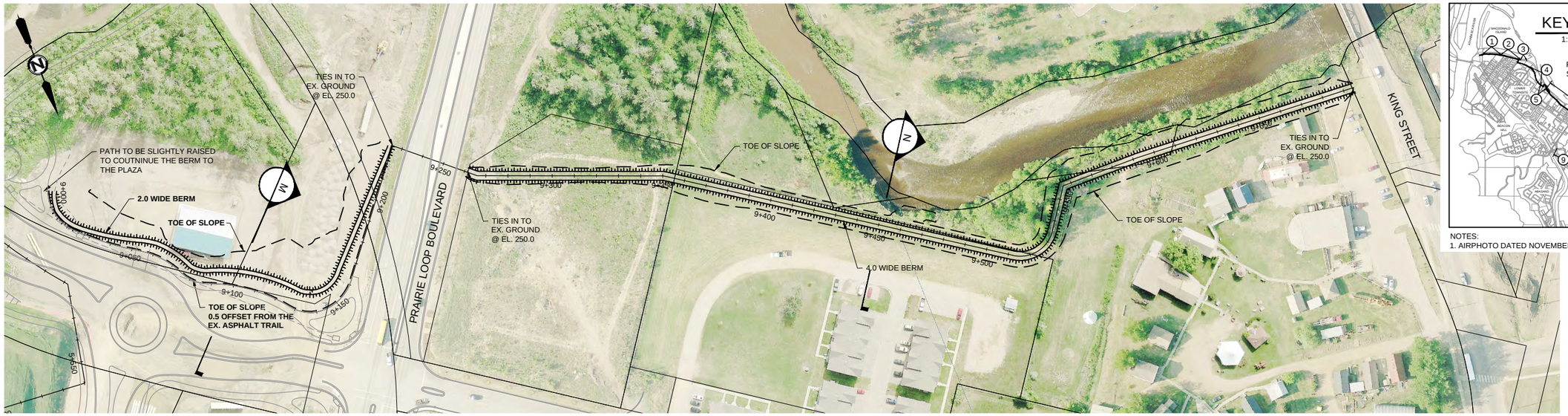
FORT McMURRAY FLOOD PROTECTION

LOWER TOWNSITE
REACH 8
BERM

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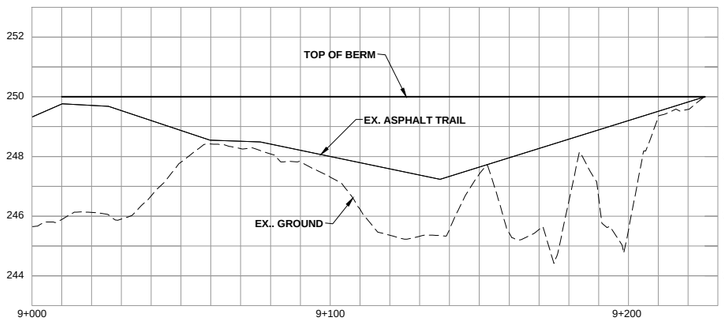
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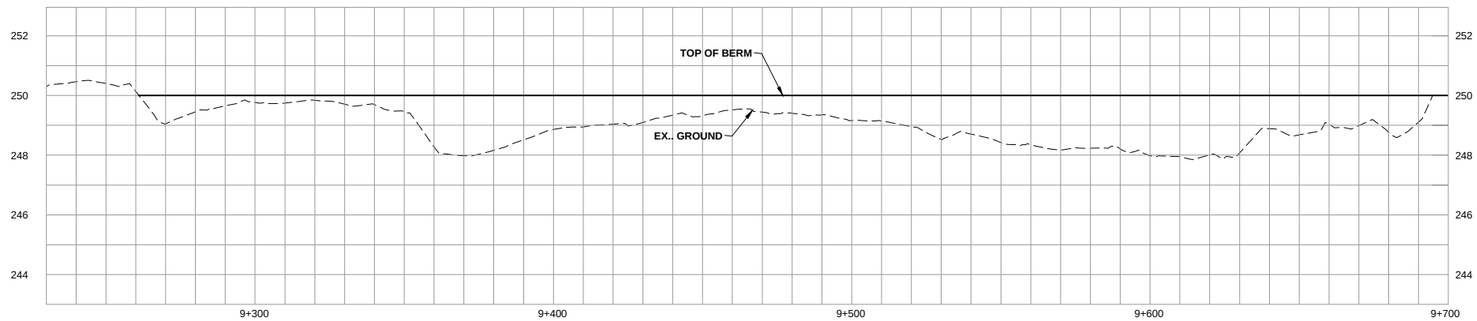
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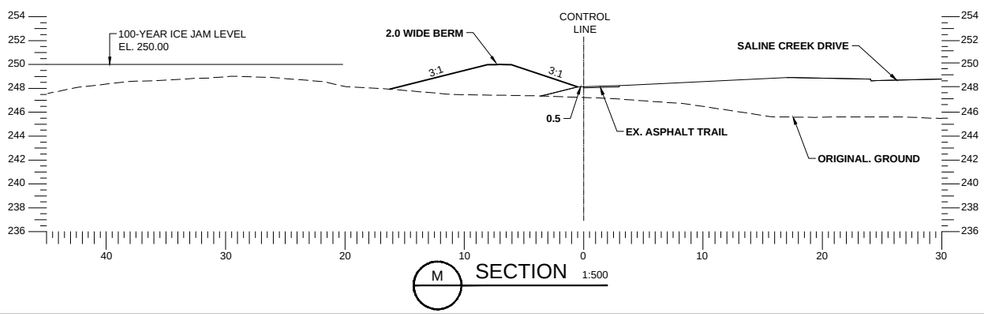
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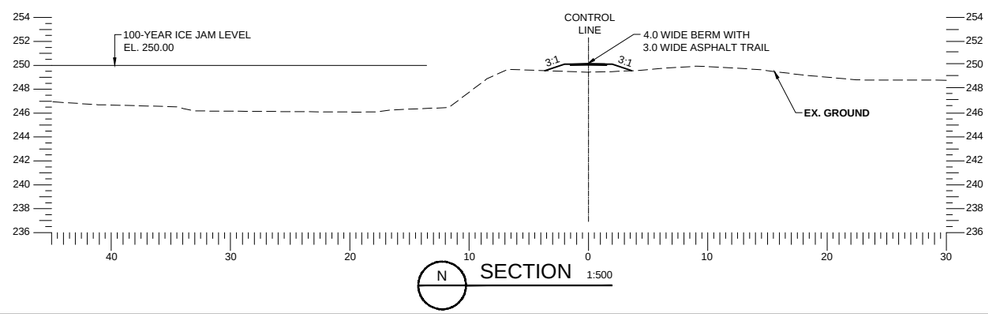




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REGIONAL MUNICIPALITY OF WOOD BUFFALO

nhc northwest hydraulic consultants

RM OF WOOD BUFFALO

FORT McMURRAY FLOOD PROTECTION

LOWER TOWNSITE
REACH 9
BERM

Dwg.100165-D-FG	22 JUNE 2014	**Figure D12**

northwest hydraulic consultants ltd.

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APPENDIX E
Rendered Flood Alternative2
Mitigation Measures
on 2013 Streetscape Photographs



Figure E1 Snye



Figure E2 Snye



Figure E3 Snye



Figure E4 Riverwalk Villas



Figure E5 Prairie Loop Boulevard



Figure E6 Marine Park



Figure E7 Prairie Loop Boulevard - Franklin Avenue



Figure E8 Longboat Landing



Figure E9 Hangingstone River



Figure E10 Heritage Park



Figure E11 Waterways



Figure E12 Saline Creek Drive South

APPENDIX F

Legal Land Descriptions

Structure Footprint Areas

Reach #	LINC #	Area (ha)	Parcel Description	Designation[1]
2	0020620688	0.014	Berm is to follow Morimoto Drive, but the slope enters this land parcel at station 0+610 and exits this parcel at station 0+700 at Main Street. There is a retaining wall at the top of this berm up to station 1+135.	Public
2	0027876812	0.082	Berm centerline is to follow Morimoto Drive, but the edge of berm slope enters this land parcel at station 0+715 and exits at station 0+800.	Public
2	0027876812	0.027	Berm centerline is to follow Morimoto Drive, but the edge of the berm slope enters this land parcel between a curved roadway on the west and Main Street on the east between stations 0+820 to 0+860.	Public
2	0030812283	0.009	Edge of berm slope enters this parcel between stations 0+860 and 0+870.	Public
2	0027876812	0.057	Edge of berm slope enters this parcel between stations 0+870 and 0+910 where it crosses Main Street.	Public
2	0021033501	0.062	Edge of berm slope enters this parcel between stations 0+935 and 0+975.	Public
2	0021033493	0.024	Edge of berm slope enters small parcel between stations 0+985 and 1+002.	Public
2	0010788058	0.041	Edge of berm slope enters small parcel between stations 1+002 and 1+034	Public
2	0010823185	0.020	Edge of berm slope enters small parcel between stations 1+034 and 1+050.	Public
2	0010823193	0.037	Edge of berm slope enters small parcel between stations 1+050 and 1+083.	Public
2	0010838373	0.046	Edge of berm slope enters small parcel between stations 1+083 and 1+115.	Public
3	0010823177	0.035	Berm centerline turns and follow Hardin Street and edge of berm slope enters this parcel between stations 1+155 and 1+200.	Public
3	0021685368	0.026	Berm centerline follows Hardin Street and edge of berm slope enters this parcel between stations 1+210 and 1+255. Berm then turns to follow what will be Prairie Loop Boulevard and the berm slopes end at station 1+255.	Public
4	0020276564	0.068	Berm centerline follows Prairie Loop Boulevard. Berm slope only required on north side. Edge of berm slope enters this parcel between stations 1+850 and 1+875.	Public
4	0013432208	0.843	Berm centerline follows Prairie Loop Boulevard. Berm slope only required on north side. Edge of berm slope enters this parcel between stations 1+855 and 2+140. Gap for flood gate between stations 2+120 and 2+130.	Public
4	0029335545	0.035	Berm centerline follows Prairie Loop Boulevard. Berm slope only required on north side. Edge of berm slope enters this parcel between stations 2+140 and 2+147.	Public

Reach #	LINC #	Area (ha)	Parcel Description	Designation[1]
4	0029335545	0.033	Berm is only required for a short stretch between two existing buildings and will run through a parking lot. Enters this parcel of land at the edge of the building at station 2+228 and exits parcel at station 2+252.	Public
5	0029081767	0.002	Berm is only required for a short stretch between two existing buildings, and will run through a parking lot. Enters this parcel of land at station 2+252 and ends at a building at station 2+255.	Public
6	0034515249	0.156	Berm begins at station 2+538 where it joins to an existing retaining wall around a parking lot. Berm extends to station 2+620 where it meets a section of Prairie Loop Boulevard that is at 250 m elevation. Berm centerline follows Prairie Loop Boulevard, only north slope is required.	Public
6	0036052405	0.191	Prairie Loop Boulevard is at or above 250 m elevation (no berm required) until retaining wall that follows Prairie Loop Boulevard from station 3+130 to a flood gate between stations 3+260 and 3+285. Berm starts at flood gate at station 3+285 and follows Prairie Loop Boulevard up to station 3+395.	Public
6	0033950262	0.231	Berm starts at station 4+180 where it meets high portion of Prairie Loop Boulevard. Centerline of berm follows Prairie Loop Boulevard, north slope of berm falls into this parcel and exits at station 4+455.	Public
7	0016977522	0.171	Berm follows Franklin Avenue. The edge of north berm slope enters parcel at station 4+455 and exits at station 4+535.	Public
7	0016977530	0.001	Berm follows Franklin Avenue. Small portion of north berm slope enters parcel at station 4+680 and exits at station 4+780.	Public
8	0035697945	1.726	Centerline of berm crosses parcel boundary at stations 4+844 and 5+441. Retaining wall on berm from 5+260 to 5+415.	Private
8	0034279760	0.050	Centerline of berm crosses parcel boundary at station 5+441 and berm ends at 5+454 where it ties into existing high ground.	Private
9	0034279760; 0928173	0.112	Centerline of berm starts in parcel at station 9+000 and exits parcel at station 9+073. Area of toe of slope is only considered to the south of berm centerline because of road on north side.	Public
9	0017776782	0.042	Centerline of berm starts in parcel at station 9+262 where it ties into existing high ground at edge of road and crosses edge of parcel at station 9+355.	Private

Reach #	LINC #	Area (ha)	Parcel Description	Designation[1]
9	0021318597	0.130	Centerline of berm crosses parcel at stations 9+355 and 9+520.	Private
9	0014128391	0.180	Centerline of berm starts in parcel at station 9+520 and ends where it ties into existing high ground at a road at station 9+694.	Public
10	0026434259	0.510	Berm centerline enters parcel at station 5+916 and ends where it ties into road at station 6+179.	Public
10	0031055529	0.433	Berm centerline ties into existing retaining wall (which will be raised) at station 5+884 and crosses out of parcel at station 5+916.	Public
10	0031055529	0.134	Berm is built on opposite side of Saline Creek Drive, across from retaining wall. Starts at station 10+030 and crosses parcel edge at station 10+138.	Public
10	0026434259	0.123	Berm centerline enters parcel at station 10+138 and exits at station 10+197. Runs along one side of Saline Creek Drive until turning sharply.	Public
10	0021145158	0.097	Berm centerline enters parcel at station 10+197 and exits at station 10+244.	Public
10	0021145158	0.270	Berm centerline enters parcel at station 10+244 and berm ends at station 10+472.	Public
10	0026637884	0.064	Two small corners and one long strip of berm slope enter this parcel.	Public
10	0026434259	1.551	Gap in berm where Saline Creek Drive is elevated between stations 6+179 and 6+310. Berm begins at station 6+310 and crosses out of parcel at station 6+832 at an existing road allowance.	Public
11	0023654859	0.695	Berm centerline lies within railway right of way. Berm slope falls into this parcel between stations 6+862 and 7+120.	Public
11	0026434274	0.669	Berm centerline follows railway right of way along Saline Creek Drive. Located within this parcel between stations 6+862 and 7+525.	Public
11	0010664613	0.307	Berm ends in this parcel. Slope of berm falls into this parcel while the centerline continues to follow railway right of way.	Public

[1] The parcel designation was deduced based on information from SPIN 2 Alberta Land Titles Spatial Information System and aerial photos. The public and private designations are preliminary and should be confirmed.

APPENDIX G

Associated Engineering

Cost Estimate Memorandum

Associated Engineering | GLOBAL PERSPECTIVE. LOCAL FOCUS.

Date:	November 11, 2013	**File:**	2013-3929
To:	Dave Andres, NHC		
From:	Associated Engineering		
Project:	Flood Mitigation		
Subject:	Cost Estimate and Preliminary Alignment		

MEMO

The purpose of this memorandum is to provide Northwest Hydraulics Consultant (NHC) a summary on the cost estimate based on the preliminary alignment discussion. This information will be incorporated into NHC report on flood mitigation update.

Flood Protection within Existing Redevelopment Concept

As laid out in Regional Municipality of Wood Buffalo's City Centre Area Redevelopment Plan date February 2012, the Municipality has set a priority on providing more active and passive recreation in the downtown major redevelopment zone. This includes considerations for sensitive and sustainable landscaping. The conceptual design for the flood mitigation measures has kept these considerations in mind when proposing several reaches. Further integration will be possible when during the detailed design by tailoring reach specifics to RMWB's concept for redevelopment.

Initially Proposed Alignment and Concept Design

The perimeter diking system was originally divided into separate and distinct reaches based on site limitations and functional requirements by John Buchko, RMWB. In his report, the different reaches were defined within the following classifications:

- Elevated Trail
- Urban Terrace
- Prairie Loop Boulevard
- Constricted Areas
- Elevated Park Trail (1-3m)
- Elevated Park Trail (3-5m)
- Elevated Boardwalk
- Non-Accessible Berm

The initial concept, designed to reach the 250m elevation, mainly consisted of a combination of retaining walls and 3:1 (horizontal:vertical) sloped earth berms with a trail on the top. The initial concept also takes into the consideration of the proposed waterfront development that is part of the City Centre Redevelopment Plan.

The initial alignment was focused on a mix of water front development and tying into Prairie Loop Boulevard in order to limit the impact of the berms on park space and private property.

Currently Proposed Alignment and Concept Design

The proposed alignment and concept design provided in this report represent limited, but significant changes from the initially proposed ones while still meeting the 250m elevation for flood protection.

While in principal, the new alignment follows the initial one, it deviates over several reaches by following Prairie Loop Boulevard or similar roads in order to minimize the cost and impact of the dyke system on other park developments.

CANADA'S BEST MANAGED COMPANIES

Specifically, changes in the alignment in the vicinity of Centennial Drive, Longboat Landing development and Saline Creek Drive.

Similarly, the concept design of the dyke system has been adapted from the initial design. The proposed concept design includes the use of 3:1 (horizontal:vertical) sloped berms, retaining walls to hold back banked earth and free standing flood walls. The 3:1 side slope was selected mainly for lawn or vegetation maintenance purpose. This provides both improved visual aesthetics and cost reduction for the entire dyke system. Overall, the new proposed designs can be classified by the following descriptions. Each description corresponds with the "Reach" shown in the attached drawings:

- Reach 1 – Elevated Trail. This reach is a 3:1 slope rising from both sides to a 4m wide top with asphalt trail. This reach starts at McDonald Drive and ends at the abutment of the south plaza pedestrian bridge.

- Reach 2 – Urban Terrace. This reach supports a 16.5m wide stone paved promenade and a lower 5m wide asphalt paved terrace. The promenade and terrace are separated by a 2m high retaining wall which can be designed to mix the RMWB concepts for in the City Centre Redevelopment Plan. Potential examples of the cast in place retaining walls are provided. The reach starts at the south plaza pedestrian bridge.

- Reach 3 – Urban Terrace. The reach is the same as Reach 2 in all aspects. The reach ends at the Syne Point Development.

- Reach 4 – Road Tie-In. This reach parallels Prairie Loop Boulevard from the Syne Point Development to Riedel Street area. The 3:1 sloped berm will start after the proposed sidewalk. The top will be 4m wide and will support a 3m wide asphalt trail. The river side will slope down to natural ground.

- Reach 5 – Constricted Area. The Riverwalk Villas present a challenge as their proximity to the river and to Prairie Loop Boulevard prohibits a berm; however, the buildings are at 250m elevation. The dyke system will transition from berm to free standing concrete flood wall which will connect to the existing buildings on the north side of Prairie Loop Boulevard, requiring one 4m wide flood gate for vehicle parking. The dyke will skirt around the river side of the parking lot at the end of Riedel Street using a combination of a berm and flood wall and transition back to a berm at Prairie Loop Boulevard.

- Reach 6 – Road Tie-In. The reach is similar to Reach 4 and continues until Prairie Loop Boulevard connects with Franklin Avenue. However, in order to retain the current function and layout of the Marine Park, an earth retaining wall will be required on the other side of the Prairie Loop Boulevard sidewalk as well as a flood gate. This allows the current access to the existing parking lot to function as is. Moving the entrance further south can also be considered as an option.

- Reach 7 – Elevated Trail. This reach consists of a berm paralleling Franklin Avenue with a 2m wide top.

- Reach 8 – Elevated Trail. This reach is a berm with a 2m wide top that runs along the back side of the existing multifamily lots. The reach ends at the high feature near the traffic circle of Denholme Gate and Saline Creek Drive. The reach ends at the Saline Creek Drive bridge. A retaining wall structure adjacent to the Hangingstone

River is considered for this reach to avoid the toe of berm extending into the slopes of the River bank.

- Reach 9 – Elevated Trail. This reach is a berm with a 2m wide top that starts at the north Saline Creek pedestrian bridge plaza and continues to Prairie Loop Boulevard. It then continues on the north side of the Hangingstone River until King Street.

- Reach 10 – Elevated Trail. This reach is consists of a berm, but will also require a retaining wall near the Saline Creek Drive bridge. In order to prevent Saline Creek Drive from flooding, the berm will parallel the east side of the drive until Park Street. A berm will also have to be constructed on the west side and will follow along the tree line in J. Howard Pew Memorial Park until the park reaches the 250m elevation.

- Reach 11 – Raised Road. In this reach, Saline Creek Drive, still under construction, will be raised until the road naturally reaches the 250m elevation. The berm from Reach 10 will need to be tied into the road to ensure continuity of protection.

Areas of Special Concern

There are several areas which present a special concern or are a constricted area:

Ptarmigan Trailer Park (No Reach assigned). This trailer park is below the 250m elevation and is very close to the Hangingstone Creek. In many sections, a height of approximately 3m must be attained. Whether achieved with walls or berms, this will very likely disrrupt the integrity of the community. Similarly, to raise the property to 250m will require approximately $8 million of fill, excluding the costs of the required sloping or retain walls, and approximately $18 million to reinstall utilities, rebuild roads and pilings, not including the requirement for temporary housing for the residents. Another option could be to relocate the community to higher ground. Overall, mitigation measures would need to be evaluated and determine the optimum protection. As such, no flood mitigation is planned in this report.

- Riverwalk Villas on Riedel Street (Reach 5). Due to a constricted site and the requirement to maintain parking, it is recommended that a concrete wall be built for this section and having it tied into the buildings. Additionally, a flood gate will be required to provide vehicle access. Due to the proximity to the bank, the parking lot of the south-east of the complex will likely lose parking stalls and may need to be remarked.

- Marine Park (Reach 6). A retaining wall is recommended between Prairie Loop Boulevard and the Marine Park. A vehicle gate will be required to allow vehicle access, however, the access and current parking will not need to be realigned.

- Franklin Street Outfall (Reach 7). The current outfall will be filled in, requiring a 1500mm concrete pipe and new outfall. Also this may a lease or land procurement to establish a Right-of-Way adjacent to Franklin Avenue to account for the toe of the berm.

- Longboat Landing (Reach 8). The berm will follow the perimeter of this development where currently constructed and in the lots where not constructed. It will require that the developers to incorporate the berm into their future

construction plans.

- Slope Stability (Reach 8, 9 and 10). Several sections of bank, such as along the Hangingstone River, may require further assessment and likely more work to ensure slope stability and stabilization.

- South-eastern Saline Creek (Reach 11). It is recommended that Saline Creek Drive be elevated to 250m, which will remove the requirement for a paralleled berm. With the construction of this section of Saline Creek being completed in spring 2014, the change order must be issued prior to the resumption of construction.

Requirement for Priority Land Allocation

It is critical for RMWB to place a high priority on the allocation of land to the flood mitigation project. This will include developing privately held land and the adaptation of other projects into the proposed dyke system, and not the reverse.

Cost Estimate

The Class D cost estimate for this project is $146,800,000. The cost breakdown is provided; however some considerations are:

1. Future Landscaping. With the majority of the dyke system consisting of berms with wide tops near populated areas, the dyke system should be incorporated into future landscaping plans. A landscaping plan should be developed to ensure proper vegetation to stabilize the banks and slopes as well as blend the functional nature of the dykes with the aesthetics of the immediate environment. Future landscaping is not included in the cost estimate.

2. Concept Flood Gates. The following are potential providers of drop in flood gate systems. A 4m wide gate is estimated at $50,000 and an 8m gate at $80,000. The detailed design should determine the suitability of these options. Below are some potential floodgate systems.

3. Retaining and Flood Walls. The requirement for retaining walls and stand-alone flood walls varies throughout the dyke system. Retaining walls are proposed in various reaches to reduce the footprint of the toe and vary in height from 1m to 3m at an estimated cost of $3,000 to $5,000 per m^2. Flood walls are proposed in reach 6 to reduce the footprint of the toe at a cost of $900 per linear metre. The retaining walls and flood wall can be designed as to fit the aesthetics of the area they are built in. Below are some examples of flood walls and retaining walls which could be used in urban and naturalized locations.

4. Connecting Streets. An allowance of $10,000,000 has been provided for to make adjustments of existing intersections during the construction of the dyke system. This allowance will likely be used on Reidel Street, Queen Street, McCormick Street, Park Street and a yet to be located boat launch in Reach 11. This allowance includes the cost to raise and repaved roads, re-align utilities and signage.

5. Prairie Loop Boulevard Allowance (Reach 4). An $18,000,000 allowance has been provided to account for the changes to Prairie Loop Boulevard as a result of the dyke construction. The value was estimated by RWMB in a

cost estimate dated 5th Sept, 2013. (more detail to be proved once determined)

6. Stormwater Management Allowance. An allowance of $10,000,000 has been provided for as a result of changes to the existing stormwater management system caused by the dyke system. Potential costs include new outfalls, catchbasins, manhole adjustments, ditching, and piping.

7. Mobilization and De-mobilization. This cost estimate does not include mobilization and de-mobilization costs.

8. Soil Availability. This cost estimate assumes soil material is available within 2km of site.

9. Slope Stability. This cost estimate assumes that class 2 rip rap will be used to stabilize vulnerable slopes. The cost is estimated at $250 per m2 and includes geotextile. The detailed design will require further investigation to confirm the appropriate slope stabilization requirement.