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Alberta Government







REPORT

Feasibility Study - Athabasca River Basins

Submitted to Government of Alberta - Flood Recovery Task Force
by IBI Group and Golder Associates

May 2014

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May 2014

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Appendix G – Structural Mitigation Options – Whitecourt
Appendix H – Potential Environmental Impacts Evaluation
Appendix I – Assessment and Consultation Summary Report
Appendix J – Reference List



EXECUTIVE SUMMARY

Executive Summary

Background

Flooding is a concern in the Athabasca River Basin. Significant urban flooding occurs in a number of centres along the main stem of the Athabasca River. In addition, major tributaries, especially the Pembina and Lesser Slave Rivers, contain large areas of productive farmland which are also subject to periodic flooding.

The Southern Alberta Flood Recovery Task Force (SAFRTF), through Alberta Transportation, initiated a Feasibility Study for Athabasca River Basins to provide recommendations for future water management projects based on an analysis of relevant background data and a review of proposed projects. The project will provide water management recommendations including:

- estimated costs associated with implementation of the proposed projects;
- timelines and conceptual scope of work for the projects; and
- benefit/cost analyses associated with the proposed mitigation projects.

Accordingly, in January of 2014 Golder Associates and IBI Group were retained to undertake the Feasibility Study for the Athabasca River Basins.

Purpose

The primary purpose of the feasibility study is to develop a water (floodplain) management plan for the flood affected areas within the Athabasca Basins based on a benefit/cost analysis of identified flood mitigation measures.

Context

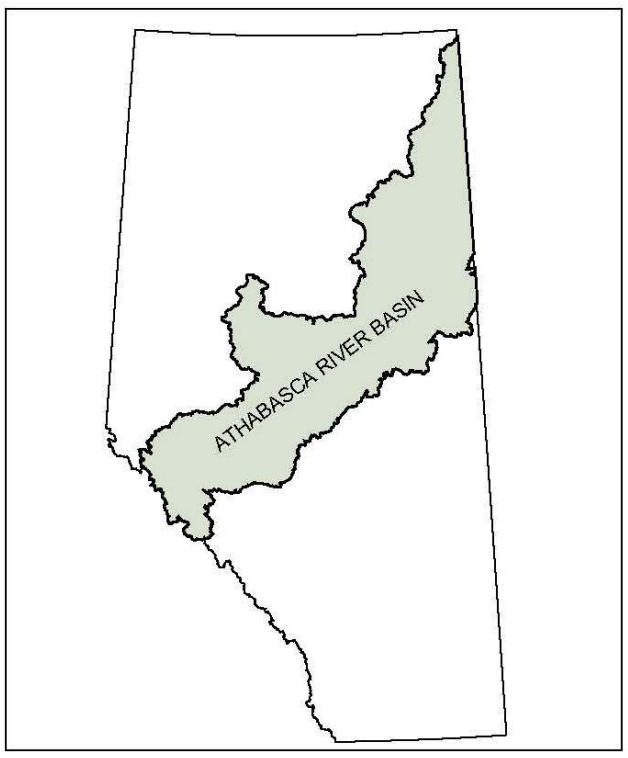
The Athabasca River drains an area of approximately 138,000 km^2, and flows nearly 1,400 km from its headwaters to the Peace-Athabasca Delta and Lake Athabasca. The Athabasca River Basins include a total of 94 rivers, over 150 named creeks, numerous unnamed creeks, and 153 lakes (Regional Aquatics Monitoring Program, RAMP). The headwaters result from the melting snow and ice of the Athabasca Glacier in Jasper National Park. The Athabasca River flows northeast across Alberta into the Peace-Athabasca Delta and Lake Athabasca. Approximately 90% of the Athabasca watershed is located within Alberta, with 10% falling within Saskatchewan[1] (see **Exhibit 2.1**).

The Athabasca River Basin is comprised of 10 sub-basins including:

- Upper Athabasca
- McLeod
- Pembina
- Central Athabasca – upper
- Central Athabasca – lower
- La Biche
- Clearwater
- Lower Athabasca
- Lake Athabasca
- Lesser Slave

[1] Hatfield Consultants Partnership, *Athabasca Watershed Council, State of the Watershed Report: Phase 1, Final Report*, March 2011.

Athabasca Basin





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Feasibility Study - Athabasca River Basins

May 2014

EXHIBIT 2.1

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These are illustrated in **Exhibit 2.2**. **Exhibit 2.3** illustrates the 25 separate jurisdictions within the basin.

Approach and Methodology

The approach and methodology to the study is described in considerable detail in Section 3 of the main report. The highlights of the approach are briefly described hereinafter.

Floodplain Mapping

During the 1990s floodplain mapping was produced for communities throughout Alberta under a federal-provincial initiative known as the Canada-Alberta Flood Damage Reduction Program (CAFDRP). The objective of the program was to identify and map the flood hazard areas in urban communities with a documented history of flooding and to encourage these communities to implement floodplain management practices and policies to regulate future development. The CAFDRP adopted the 1:100 year flood (i.e., a flood event with an average return period of 100 years and a 1% probability of occurrence each year) as the design flood event along with the two zone floodway - flood fringe approach as represented in **Exhibit 3.7**.

The available study reports and hydraulic model files for the following Athabasca River Basin communities included in the CAFDRP were obtained from Alberta Environment and Sustainable Resources (ESRD);Fort McMurray, Slave Lake, Whitecourt, Athabasca, Hinton, Barrhead, Rochester and Sangudo.

Assessment of Flood Damages

In a flood event, direct damages can occur both to buildings and infrastructure because of the inundation (hydrostatic effects) and action of the moving water (hydrodynamic effects).

For the Athabasca Basins Study, direct flood damages to residential dwellings includes both content and structural damages as well as the internal clean up costs. Flood damages for commercial properties includes damage to inventory, equipment, and buildings in addition to clean up costs. As with the residential component, these damages are generally calculated separately for contents and structures.

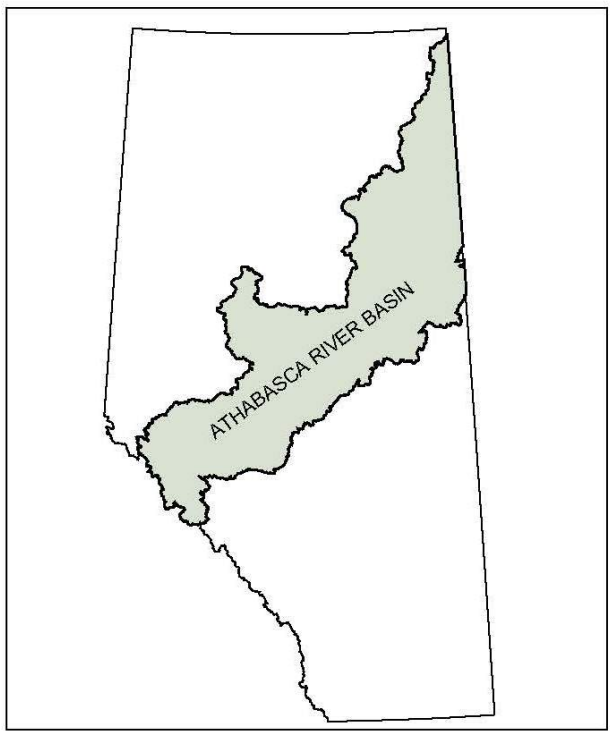
The commercial structures, due to the nature, range, and diversity of business, do not demonstrate the same uniformity in terms of damage per unit as residential structures. Consequently, categorization is a much more complicated procedure, and the grouping of similar functions for the purposes of estimating flood damages is done in order to maintain study costs within economic reason.

In a first principles approach, damages for residential and commercial/industrial units are estimated employing synthetic depth-damage curves developed for general usage in Alberta. These curves are based on a statistical sampling of structures in Fort McMurray and Calgary. On an ongoing basis, curves are indexed to current values employing Consumer Price and Construction Cost Indices ratios that allow for the conversion of the original values to present values. In the current study, detailed damage estimates previously developed for communities within the Athabasca Basins were updated by prorating the values employing the previously identified indices.

Where available, relevant aerial photography allowed for updating of the structural inventory within the flood risk areas.

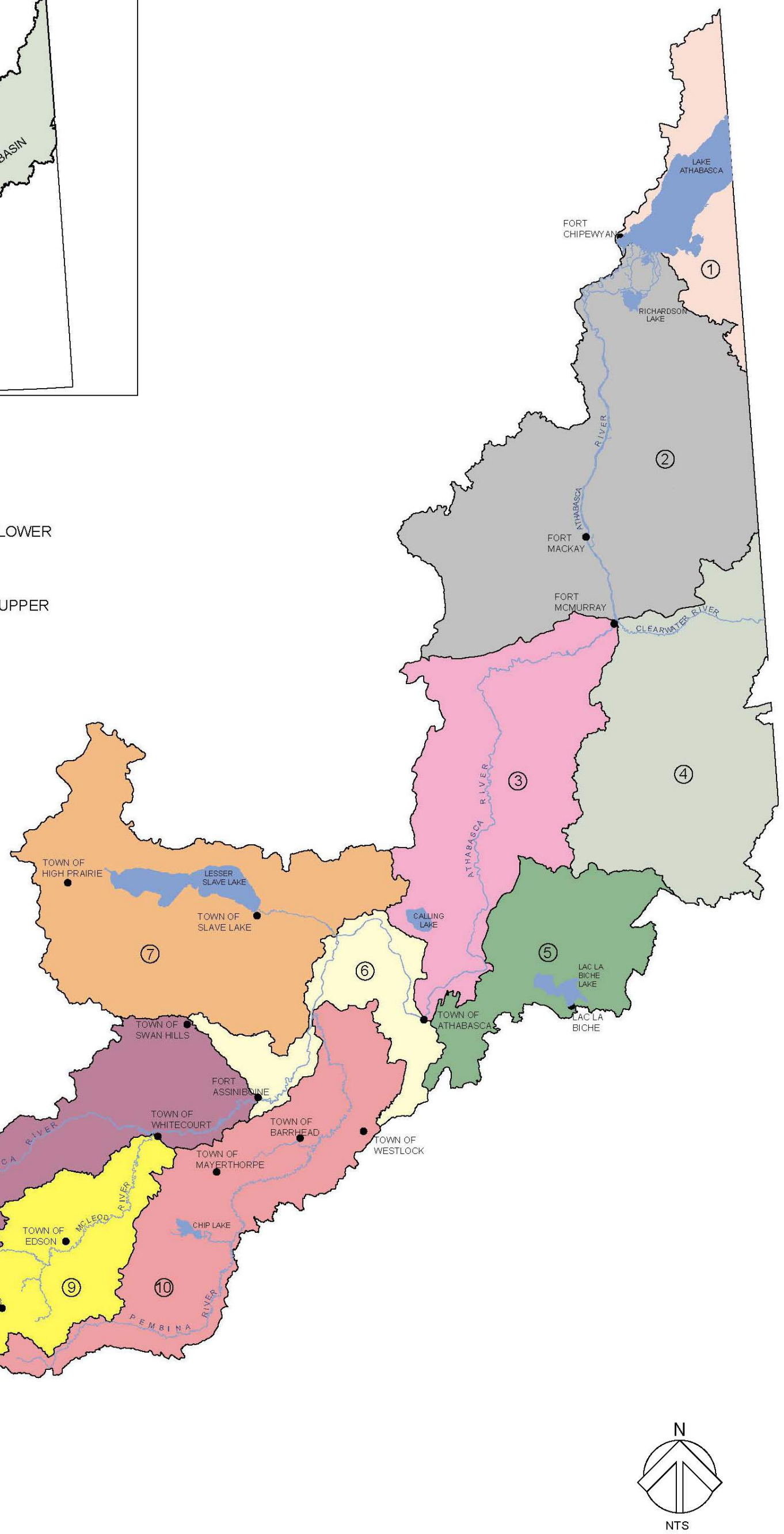
Flood events also cause indirect damages. These damages generally include such things as costs of evacuation, alternative accommodation during the flood event, loss of wages and business income due to disruption of business establishments and transportation routes, administrative costs, flood fighting costs, general inconvenience, and general clean up.

Athabasca Sub-Basins



LEGEND

1. LAKE ATHABASCA
2. LOWER ATHABASCA
3. CENTRAL ATHABASCA - LOWER
4. CLEARWATER
5. LA BICHE
6. CENTRAL ATHABASCA - UPPER
7. LESSER SLAVE
8. UPPER ATHABASCA
9. MCLEOD
10. PEMBINA



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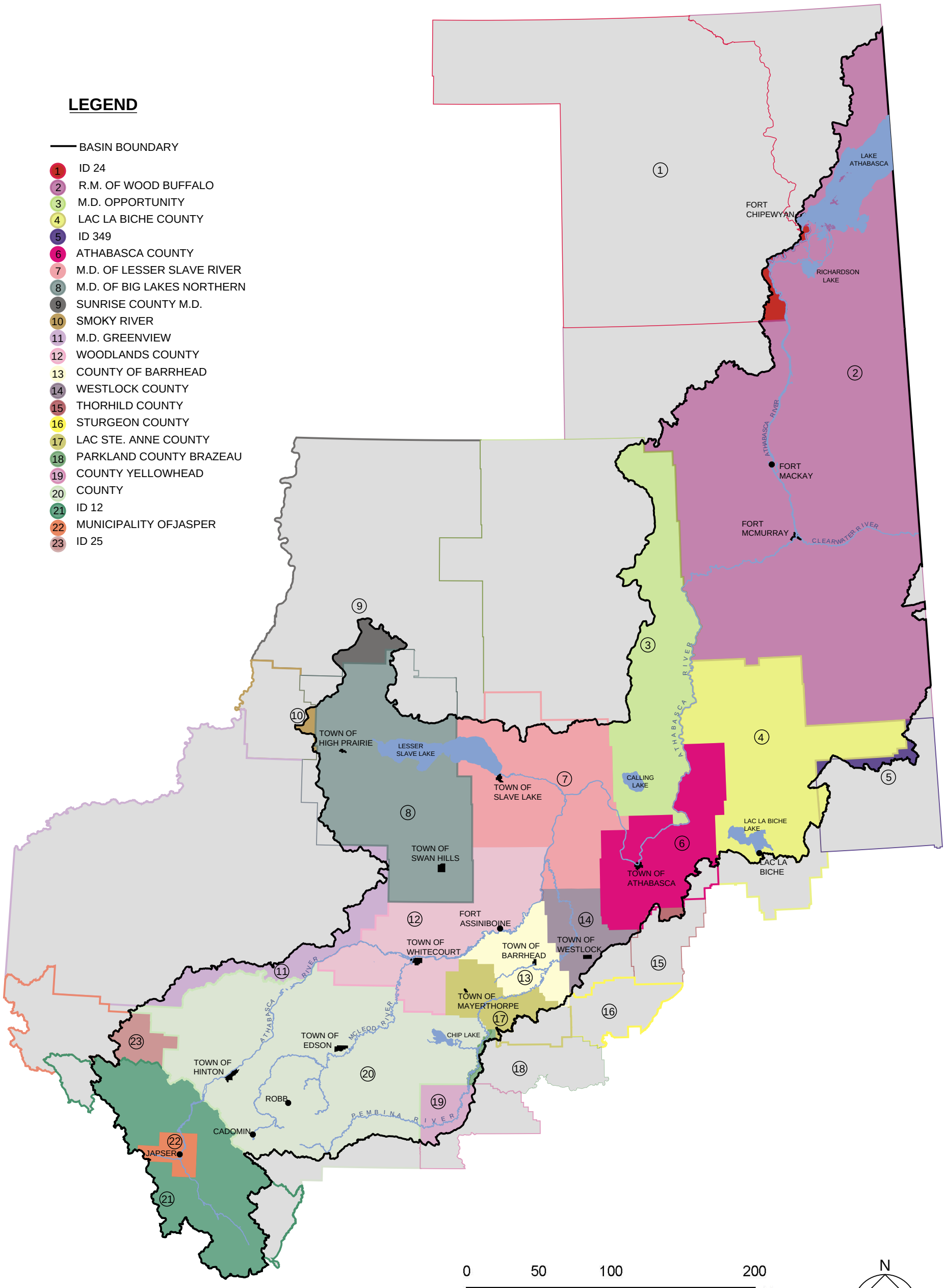
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EXHIBIT 2.2

Municipalities within the Athabasca Basin

LEGEND

- BASIN BOUNDARY
- 1 ID 24
- 2 R.M. OF WOOD BUFFALO
- 3 M.D. OPPORTUNITY
- 4 LAC LA BICHE COUNTY
- 5 ID 349
- 6 ATHABASCA COUNTY
- 7 M.D. OF LESSER SLAVE RIVER
- 8 M.D. OF BIG LAKES NORTHERN
- 9 SUNRISE COUNTY M.D.
- 10 SMOKY RIVER
- 11 M.D. GREENVIEW
- 12 WOODLANDS COUNTY
- 13 COUNTY OF BARRHEAD
- 14 WESTLOCK COUNTY
- 15 THORHILD COUNTY
- 16 STURGEON COUNTY
- 17 LAC STE. ANNE COUNTY
- 18 PARKLAND COUNTY BRAZEAU
- 19 COUNTY YELLOWHEAD
- 20 COUNTY
- 21 ID 12
- 22 MUNICIPALITY OFJASPER
- 23 ID 25



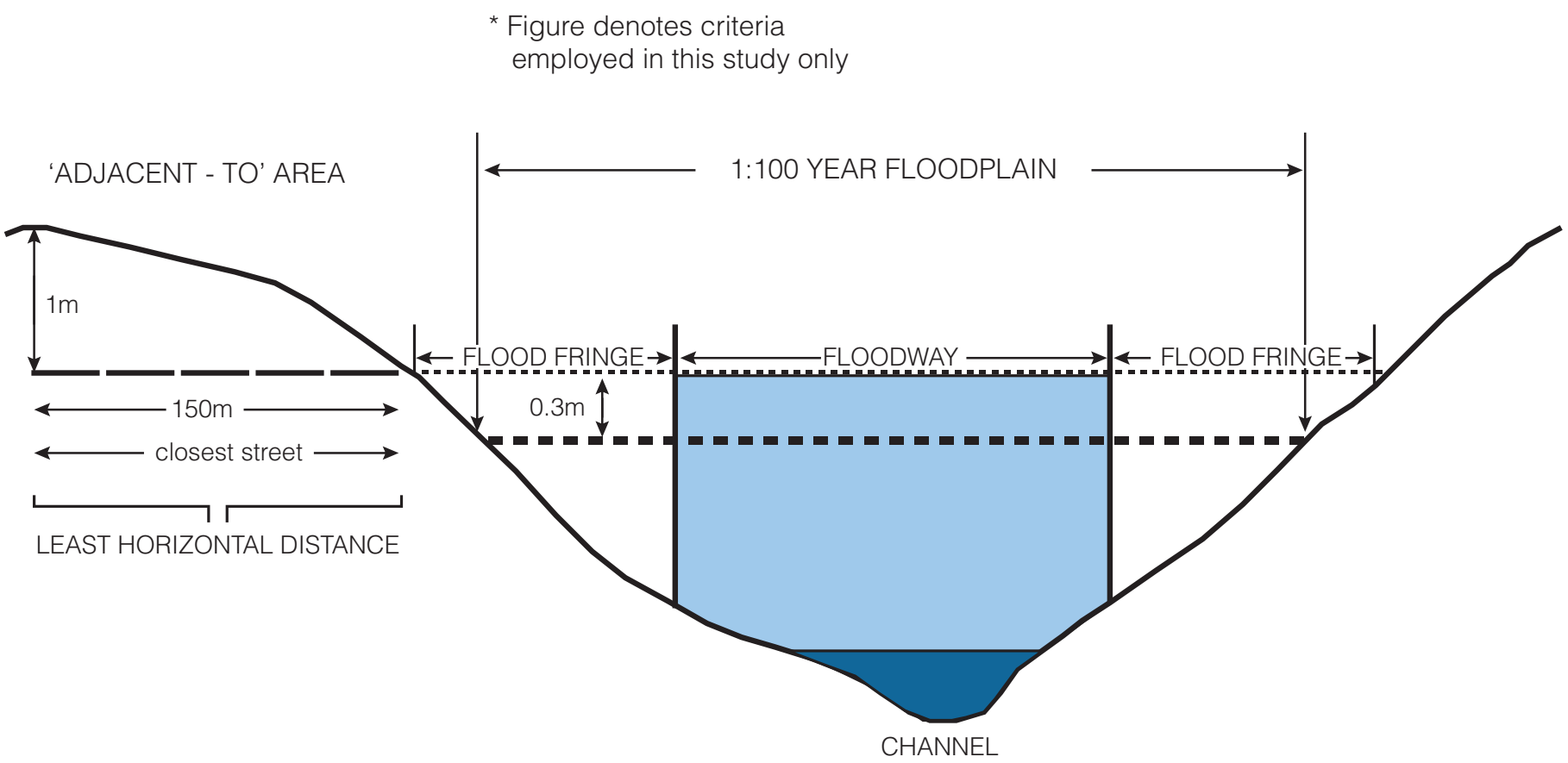
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May 2014

EXHIBIT 2.3

Floodway - Flood Fringe Delineation

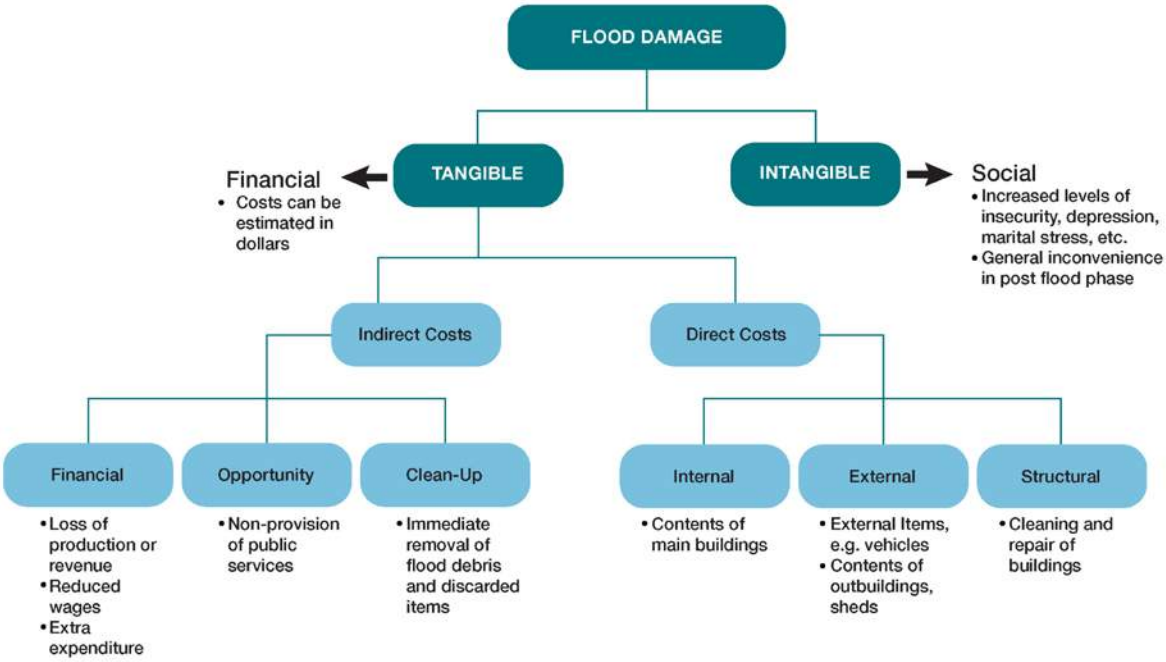


For the purpose of this study, the floodway is defined as:

1) the stream channel and that part of the floodplain required to convey the 1:100 year flood without raising the 1:100 year water surface elevation more than 0.3 m.
2) lies at a depth greater than 0.7 m below the 1:100 year water surface elevation.

Finally, and most importantly, flooding may represent a threat to human life and well-being, not only for those residing directly within the floodplain but also for those individuals who may work within the area as well as those volunteers who are involved in flood fighting activities (see below).

Types of Flood Damage



Estimated Flood Damages in 2014 Dollars

Community	1:100 Flood Event	Average Annual Damages
Fort McMurray	$385,000,000	$10,450,000
Whitecourt	$32,069,000[1]	n/a
Slave Lake	35,475,000[1]	$133,000
Athabasca	$600,000	n/a
Robb	$1,000,000	n/a
Pembina Valley	12,757,000[2]	n/a

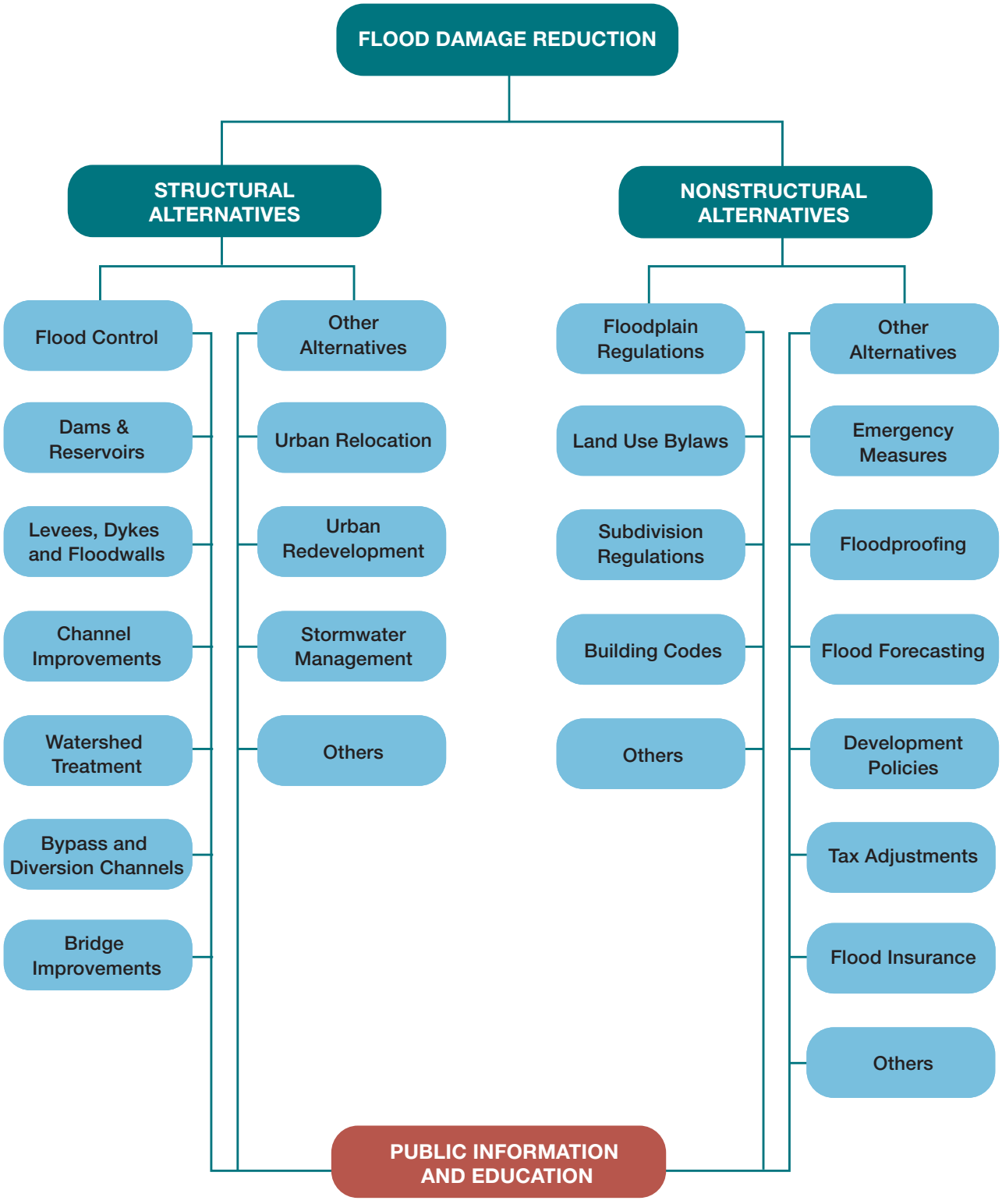
[1] Minimal to no damages until 1:100 year exceeded.

[2]1986 disaster assistance payment (uninsurable losses) in 2014 dollars.

Flood Damage Reduction Alternatives

There are two basic approaches to the problem of reducing flood damages. The first, structural alternatives, consists of methods to control the extent of flooding by construction of dams, reservoirs, dykes or other protective works. The second approach which limits the susceptibility of the developments to flood damages, is effected through a variety of non-structural alternatives, especially land use controls. **Exhibit 3.10** details the various types of flood damage reduction alternatives.

Flood Damage Reduction Alternatives



Stakeholder Engagement Process

The project team conducted the stakeholder engagement process employing the skills of land use planners and policy analysts over the course of February and March of 2014. A survey format and follow-up telephone discussion were typically employed. All stakeholder contacts were given the option of completing the survey by email or by discussion with the Project Team. Some stakeholders, particularly the First Nations groups, were also given the opportunity to meet in person with the Project Team and Task Force representatives if desired. The Project Team was assisted with identification of stakeholders and contacts with some groups, particularly the First Nations and Métis Settlements by The Flood Recovery Task Force stakeholder liaison members seconded from the Justice ministry for this study.

All stakeholders were contacted by email and telephone multiple times and encouraged to participate in the survey and collection of information necessary to the study. A copy of the list of stakeholders as well as the flood information surveys can be found in **Appendix B**.

Stakeholders were grouped into three distinct categories. These three categories are:

- Municipalities (total of 34 contacts);
- External Stakeholders (Government Department, Industry, etc.) 12 contacts; and
- First Nations and Métis Settlements (total of 33 contacts).

Key highlights from the consultations with the 34 municipalities include the following:

- The population of Fort McMurray (61,000) and the surrounding Municipal District of Wood Buffalo (55,000) accounts for one third of the population of the entire Athabasca River Basin geography.
- Eleven (11) municipalities experienced past urban flooding.
- Nine (9) experienced rural land flooding.
- All municipalities have non-structural flood mitigation practices (land use by-law development regulations).
- Historical urban flood areas have some level of mitigation infrastructure in place (dykes, channel improvements, bank stabilization, etc.).
- The most significant recent historical flood damage reported was in Fort McMurray related to 2013 flooding. The municipality is applying for $25 million from the Alberta Disaster Recovery program to repair damaged infrastructure.
- Other flood-related municipal damages typically reported in the survey process ranged from $1 million to $2 million primarily for road and bridge repairs. Very few flood-related damages were reported for municipal facilities.
- Based on the results of the surveys and discussion with the 34 municipalities, the level of risk for future flood damages was evaluated for each municipality. The risk levels are summarized as follows:
  - No Risk: 9 municipalities
  - Very Low Risk: 9 municipalities
  - Low Risk: 10 municipalities
  - Moderate Risk: 2 municipalities (Town of Whitecourt and Town of Slave Lake)
  - High Risk: 1 municipality (Fort McMurray)
  - No recent reliable information: 3 municipalities

Based on the results of the Municipal Stakeholder engagement process, there are only three municipalities with a moderate or high risk for damages arising from flooding across the Athabasca River Basin. These communities are Fort McMurray and the towns of Whitecourt and Slave Lake (see **Exhibit 3.5**).

Analysis by Community

Section 4 of the report contains a detailed analysis of flood damages, and potential mitigation alternatives including an evaluation of the alternatives and recommendations for implementation.

Development of Selected Mitigation Alternatives

Structural mitigation alternatives were developed where the potential for significant damages was expected to be high and in cases where non-structural measures were likely to be ineffective. Considerations included both the aerial extent of flooding as well as depth-velocity. In some communities, mitigation alternatives had been proposed in the past and where information was available from old study reports, previous designs were revisited and costs updated. In cases where mitigation alternatives had not been previously investigated, various options were considered and conceptual level designs were prepared for those deemed to be best suited to the magnitude of the problem and the specific site conditions.

Water Management Plan

Description of Plan

The accompanying exhibit (see **Exhibit 5.1A,B,C**) provides a summary description of the Water Management Plan proposed for the Athabasca River Basins on a community-by-community basis.

Schedule and Conceptual Scope of Work for Mitigation Projects

The accompanying exhibit (see **Exhibit 5.2**) details the type and scope of studies required to facilitate the various mitigation alternatives proposed for implementation within the Athabasca River Basins. It also outlines responsibility, estimated costs and schedule, including an estimated timeline for constructing the actual mitigation alternative.

Updating of Baseline Information

Assessment of Flood Damages

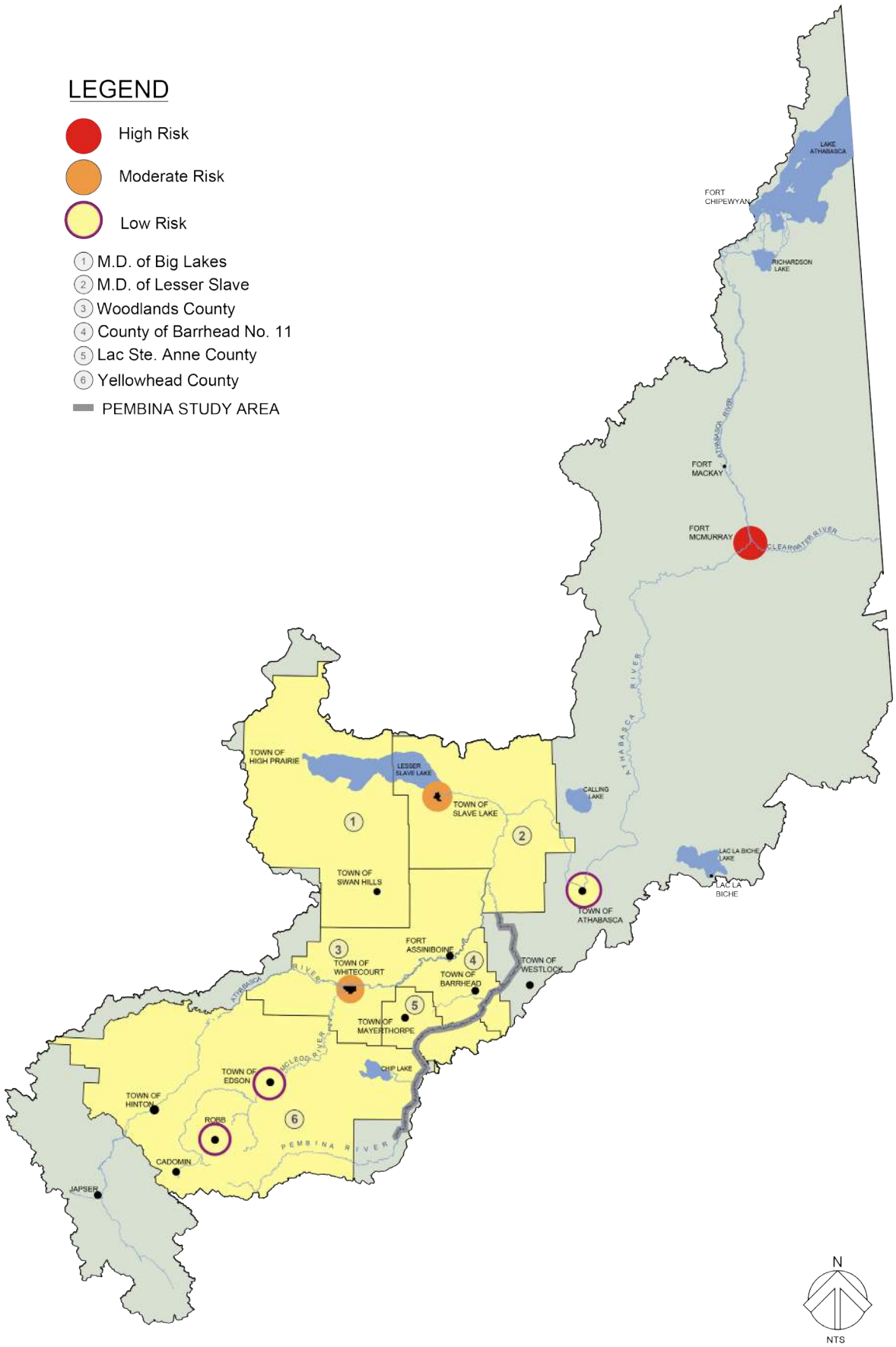
An update review of flood damage assessment methodologies was undertaken as part of this study to determine if any improvements or changes in best practice has occurred over the last thirty years. A general literature review of flood damage assessment showed that the approach developed by IBI Group/Ecos[2] is still relevant today. In the Canadian context no new methodology has been developed nationally, or provincially since the definitive studies were undertaken by the IBI Group/Ecos.

In the United States, the first flood damage evaluations were developed at the beginning of the 50s by Gilbert White[3] (father of floodplain management), and were followed by the development of guidelines and several sets of damage functions by the US Army Corps of Engineers. The

[2] Shawcross, S.W., and Ribeiro, A.R.V., "The development of residential stage-damage curves for application in Western Canada", (Flood Hazard Management in Government and the Private Sector, Proceedings of the Ninth Annual Conference of State Floodplain Managers, 100-105, 1985)

[3] White, G. F., "Choice of adjustment to floods", Department of geography research papers, edited by: Chicago, U. o., University of Chicago, Chicago, 150 pp., 1964

Future Flood Damage Potential Risk



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Feasibility Study - Athabasca River Basins

May 2014

EXHIBIT 3.5

Community	Population	Future Flood Damage Potential Risk	Recommended Mitigation	Estimated Capital Costs	B/C Ratio	Schedule	Responsibility	Discussion/Comments
Fort McMurray	61,374	High • Average annual damages: $10.4 million.	• Upgraded ring road/dyke to 1:100 year level of protection adjacent to Clearwater River currently being considered.	$26.3 million*	1.6	• The ring road/dyke is 50% complete. • Scheduled for completion in 2016. • The portion that is complete (2 of 4 lanes) runs from Riedel Street to Franklin Avenue. • Studies underway to increase level of protection to 1:100 year.	City of Fort McMurray	• In light of the study being undertaken to consider a 1:100 year ring road/dyke, design work has been put on hold. However, construction continues on the 1:40 year ring road/dyke. Reconstruction may need to take place if the 1:100 year design is approved.
			• Golder/IBI 2014 recommendation for ring road and secondary dykes with 1 m freeboard to provide protection for entire flood hazard area. • Municipal program to encourage the retrofitting of sewer backflow prevention devices. • Public awareness and education. • In reviewing Emergency Measures Plans, consideration should be given to the impact of events that exceed 1:100 year levels up to the 1:500 year level or 2 m above the 1:100 year level, whichever is greater.	$85.2 million	1.3	• Analysis and design studies proposed for 2015.		• It should be noted that the current alignment of the Prairie Loop Boulevard ring road and dyke does not provide protection for that area of the Lower Townsite west of Hardin Street, a significant area with high future damage potential. It is assumed that the ongoing study will give consideration to extending protection to this area and thereby provide 1:100 year flood protection for the entire Lower Townsite and Waterways areas. • Currently understood that Hangingstone River flood issues will be dealt with as part of the aforementioned assignment. • With only ring road dyke and no freeboard, substantial damages will be incurred in the areas outside the dyke and at flood levels above 1:100 year. It is estimated that the ring road/dyke alone only provides protection for half the buildings within the flood hazard area. Therefore, it is recommended that the freeboard option, along with secondary dyking, be considered to protect the entire flood risk area.
Whitecourt	10,574	Moderate • 100 year flood estimated at $32 million.	• Earthen berms to be constructed at spill areas in event of high return period floods. • Contingency plan details to be formalized for the above. • Alternatively consider dyking options through a more detailed design exercise. • Municipal program to encourage the retrofitting of sewer backflow prevention devices. • Public education and awareness.	$14.4 million	N/A	• Studies to be undertaken through 2014.	Town of Whitecourt ESRD	• It is recommended that with completion of the current detailed flood damage reduction study being undertaken by Northwest Hydraulics, damage estimates and benefit/cost be reassessed in detail. This analysis will allow for definitive conclusions to be drawn with respect to the permanent dyke alternatives.
Slave Lake	6,782	Moderate • 1:100 year flood estimated at $35 million. • Average annual damages: $133,000.	• Recommended that the Town of Slave Lake continue to apply land use regulations restricting development within the floodplain. • As part of a comprehensive contingency measures program, a more detailed analysis of overland spill areas to allow for the development of site-specific mitigation measures.	N/A	N/A	• Analysis and related studies through 2014.	Town of Slave Lake ESRD	• The current flood mitigation system provides protection up to the revised 1:100 year flood level. Above this level, there would be overland flow into the adjacent residential areas east of the creek bounded by Highway 88 and north of Township Road 725A. For events exceeding the 1:100 year flood level, it is anticipated that substantial basement flooding will occur in these areas.

*2000 estimate

Community	Population	Future Flood Damage Potential Risk	Recommended Mitigation	Estimated Capital Costs	B/C Ratio	Schedule	Responsibility	Discussion/Comments
Slave Lake			• Continue dyke and watershed management to control debris. • Municipal program to encourage the retrofitting of sewer backflow prevention devices. • Public awareness and education. • In reviewing Emergency Measures Plans, consideration should be given to the impact of events that exceed 1:100 year levels up to the 1:500 year level or 2 m above the 1:100 year level, whichever is greater.	N/A	N/A	• 2014.	Town of Slave Lake ESRD	
Athabasca	2,990	Low • Minimal damages for 1:100 year flood between $550,000 and $650,000.	• Land use regulations restricting development within the floodplain. • Contingency measures to include sandbagging of vulnerable commercial and residential structures. • Residential buildings at risk of basement flooding to install sewer backflow prevention devices. • Public education and awareness.	N/A		• 2014 – 2015.	Town of Athabasca ESRD	
Robb	183	Low • 1:100 year flood damages estimated at $1 million. • 15 to 16 units with basement flooding and 8 suffering first floor damage.	• 2001 Floodplain Study recommendations including culvert and bridge upgrades to be implemented. • Public education and awareness including recommendations for adjustments to use of structures.	N/A	N/A	• 2014 – 2015.	Yellowhead County ESRD	
Barrhead	4,432	Low • Minimal basement flooding.	• Land use regulations restricting development within the floodplain. • Contingency measures to include sandbagging of vulnerable commercial and residential structures. • Residential buildings at risk of basement flooding to install sewer backflow prevention devices. • Public education and awareness.	N/A	N/A	• 2014 – 2015.	Town of Barrhead	
Pembina River Valley	N/A	Low • $4.2 million paid out as a result of 1986 flood. • In 2014$ this equates to $12.7 million over an extensive reach ±110 km.	• Voluntary cost-sharing program of floodproofing of residences and farm buildings utilizing earthen berm. • Comprehensive contingency measures program. • Consideration for implementation of cost-shared mitigation program between Province and landowners.	$21.6 million $15.2 million	N/A	• Analysis of alternatives and structuring of program/ subsidies through 2014 – 2015.	Alberta Agriculture and ESRD	• Given the relatively low damages on a per acre basis and widely dispersed nature of flooding, coupled with the very high potential costs of only partially alleviating the damages, the “do nothing” alternative constitutes a potentially realistic option that should not be discounted in subsequent phases of this initiative. Any riverine environment possesses a known potential risk and owners who choose to risk farming in this area must bare some responsibility. • Damages confined primarily to crops with 147 farmsteads impacted. • Structural alternatives not feasible in this area on a benefit/cost basis.

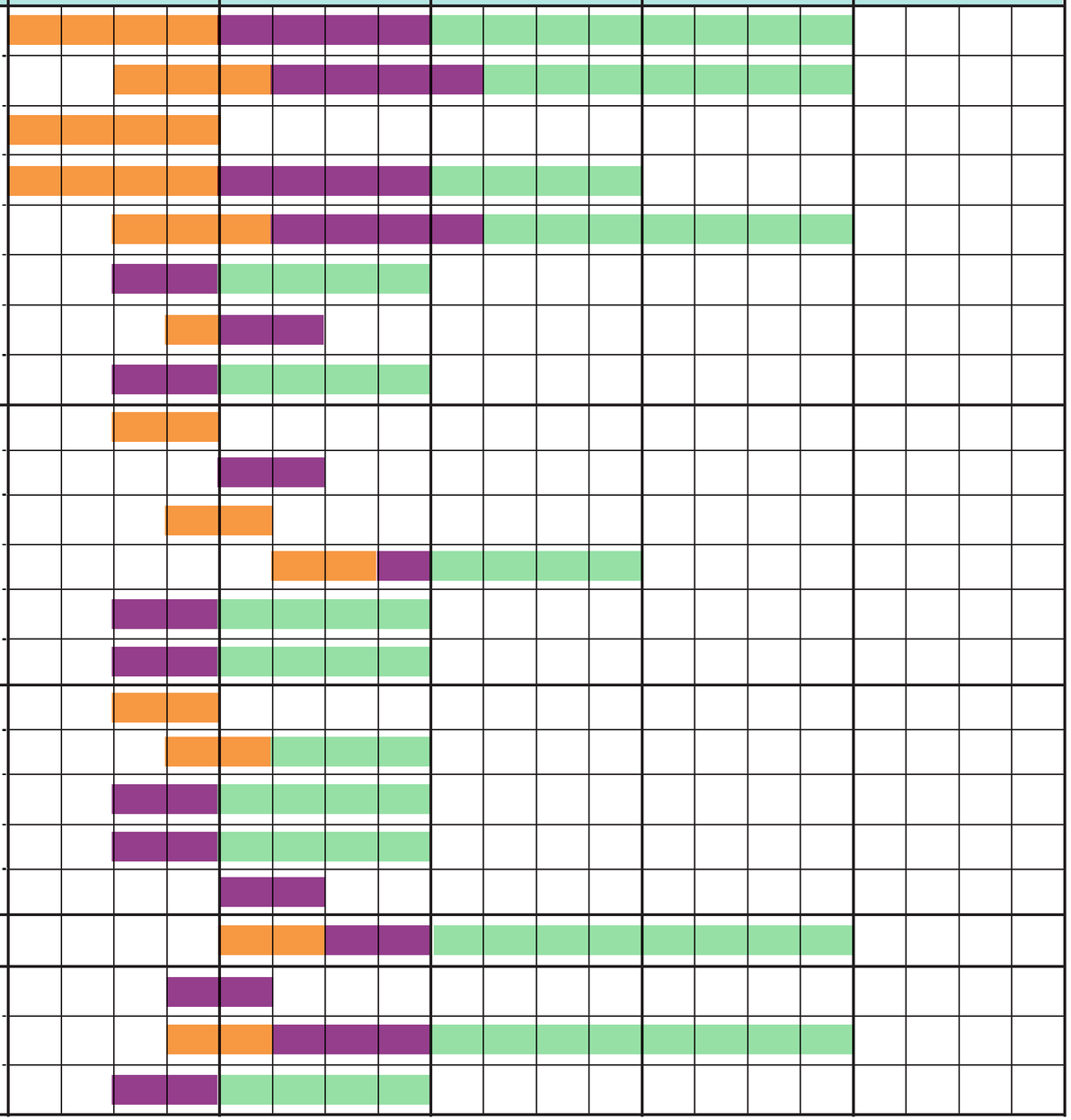
*2000 estimate

Community	Population	Future Flood Damage Potential Risk	Recommended Mitigation	Estimated Capital Costs	B/C Ratio	Schedule	Responsibility	Discussion/Comments
Town of Edson	8,646	Low	• Contingency measures and upgrading of local storm drainage systems.	N/A	N/A	• Ongoing.	Town of Edson	• Nuisance flooding primarily impacting municipal roads and culverts, agricultural land and isolated buildings.
Woodlands County	4,306	Low	• Contingency measures and upgrading of local storm drainage systems.	N/A	N/A	• Ongoing.	Woodlands County	• Nuisance flooding primarily impacting municipal roads and culverts, agricultural land and isolated buildings.
County of Barrhead	6,096	Low	• Contingency measures and upgrading of local storm drainage systems.	N/A	N/A	• Ongoing.	County of Barrhead	• Nuisance flooding primarily impacting municipal roads and culverts, agricultural land and isolated buildings.
Municipal District of Big Lakes	3,861	Low	• Contingency measures and upgrading of local storm drainage systems.	N/A	N/A	• Ongoing.	Municipal District of Big Lakes	• Nuisance flooding primarily impacting municipal roads and culverts, agricultural land and isolated buildings.
Lac Ste. Anne County	10,260	Low	• Contingency measures and upgrading of local storm drainage systems.	N/A	N/A	• Ongoing.	Lac Ste. Anne County	• Nuisance flooding primarily impacting municipal roads and culverts, agricultural land and isolated buildings.
Municipal District of Lesser Slave River	2,929	Low	• Contingency measures and upgrading of local storm drainage systems.	N/A	N/A	• Ongoing.	Municipal District of Lesser Slave River	• Nuisance flooding primarily impacting municipal roads and culverts, agricultural land and isolated buildings.
Yellowhead County	10,469	Low	• Contingency measures and upgrading of local storm drainage systems.	N/A	N/A	• Ongoing.	Yellowhead County	• Nuisance flooding primarily impacting municipal roads and culverts, agricultural land and isolated buildings.

*2000 estimate

Water Management Plan: Mitigation Alternatives - Project Scope and Schedule

Community	Required Studies/Scope	Responsibility	Estimated Cost*	Schedule
Fort McMurray	• 1:100 dyke design study.	Regional Municipality of Wood Buffalo	Ongoing	
	• Study of mitigation alternatives to protect area west of Hardin Street.	Regional Municipality of Wood Buffalo	$75,000	
	• Flood risk mapping for Hangingstone River.	Regional Municipality of Wood Buffalo	$50,000	
	• Flood damage reduction study for Hangingstone River.	Regional Municipality of Wood Buffalo	$75,000	
	• Study of inclusion of secondary dykes with freeboard.	Regional Municipality of Wood Buffalo	$150,000	
	• Municipal program to encourage the retrofitting of sewer backflow prevention devices.	Regional Municipality of Wood Buffalo	$50,000	
	• Update of Contingency Measures Plan with consideration of events exceeding 1:100 year level.	Regional Municipality of Wood Buffalo	$50,000	
	• Public education and awareness.	Regional Municipality of Wood Buffalo	$100,000	
Whitecourt	• Analysis of spill areas.	Town of Whitecourt	$30,000	
	• Update of Contingency Measures Plan.	Town of Whitecourt	$25,000	
	• Update of damages in light of revised hydraulic studies.	Town of Whitecourt	$25,000	
	• Review of dyking alternative.	Town of Whitecourt	$60,000	
	• Municipal program to encourage the retrofitting of sewer backflow prevention devices.	Town of Whitecourt	$50,000	
	• Public education and awareness.	Town of Whitecourt	$30,000	
Slave Lake	• Analysis of spill areas.	Town of Slave Lake	$30,000	
	• Review of O&M of existing flood mitigation works.	Town of Slave Lake	$40,000	
	• Municipal program to encourage the retrofitting of sewer backflow prevention devices.	Town of Slave Lake	$50,000	
	• Update of Contingency Measures Plan.	Town of Slave Lake	$25,000	
	• Public education and awareness.	Town of Slave Lake	$30,000	
Pembina River Valley	• Study of voluntary cost-sharing options for floodproofing of residences and farm buildings.	Alberta Agriculture ESRD	Est. Cost: $75,000	
Remaining Low Risk Communities	• Update of Contingency Measures Program.	ESRD/Municipality	Est. Cost: TBD	
	• Upgrading of local storm drainage systems.	ESRD/Municipality	Est. Cost: TBD	
	• Public education and awareness.	ESRD/Municipality	Est. Cost: TBD	



* Costs for design and construction of mitigation measures to be determined.

Analysis Design Implementation / Construction

US Army Corps of Engineers[4] continues to develop and update regional depth-damage curves for use in the different states.

In Australia, the state of Queensland has adopted the "Best Practice Principles and Guidelines" on Flood Management in Australia[5] which uses a single stage damage curve for residential buildings and a set of stage damage curves on a unit area basis for commercial buildings. This approach is remarkably similar to that developed by IBI Group/Ecos for Alberta. However the Alberta approach is even more detailed in that separate curves were developed to account for different housing types and commercial uses.

If the IBI Group/Ecos flood damage assessment stage damage curves were updated to 2014, this model could be used throughout communities in Alberta to estimate potential direct tangible damages. Coupled with floodplain mapping, remote sensing and GIS, an approach could be developed that would allow for consistent and expeditious flood damage assessments in the province.

Accordingly, it is strongly recommended that consideration be given to updating the previously developed curves through first order research and further that going forward, a flood damage database management approach be developed for application on flood damage reduction studies.

[4] US Army Corps of Engineers, "Catalog of Residential Depth-Damage Functions used by the Army Corps of Engineers in Flood Damage Estimation", (IWR Report 92-R-3, May 1992)

[5] Jongman, B., et al., "Comparative flood damage model assessment: towards a European Approach", (Natural Hazards and Earth System Sciences, 12, 3733-3752, 2012)



1.0 INTRODUCTION

1 Introduction

1.1 Background

Flooding is a concern in the Athabasca River Basin. Significant urban flooding occurs in a number of centres along the main stem of the Athabasca River. In addition, major tributaries, especially the Pembina and Lesser Slave Rivers, contain large areas of productive farmland which are also subject to periodic flooding.

The Southern Alberta Flood Recovery Task Force (SAFRTF), through Alberta Transportation, initiated a Feasibility Study for Athabasca River Basins to provide recommendations for future water management projects based on an analysis of relevant background data and a review of proposed projects. The project will provide water management recommendations including:

- estimated costs associated with implementation of the proposed projects;
- timelines and conceptual scope of work for the projects; and
- benefit/cost analyses associated with the proposed mitigation projects.

Accordingly, in January of 2014 Golder Associates and IBI Group were retained to undertake the Feasibility Study for the Athabasca River Basins.

1.2 Purpose

The primary purpose of the feasibility study is to develop a water (floodplain) management plan for the flood affected areas within the Athabasca Basins based on a benefit/cost analysis of identified flood mitigation measures.

1.3 Scope

Time constraints, in part, dictated the scope of the exercise relative to the level of detail for certain of the components. The scope, by specific task, is elaborated upon in **Appendix A**.

1.4 Report Format

The report is subdivided into four primary components:

Section 2: Context

Section 3: Approach and Methodology

Section 4: Analysis by Community

Section 5: Water (Floodplain) Management Plan

The report is prefaced with an Executive Summary which highlights the key findings of the analysis and is supported by several technical appendices.



2.0 CONTEXT

2 Context

2.1 Study Area Boundaries

The Athabasca River drains an area of approximately 138,000 km^2, and flows nearly 1,400 km from its headwaters to the Peace-Athabasca Delta and Lake Athabasca. The Athabasca River Basins include a total of 94 rivers, over 150 named creeks, numerous unnamed creeks, and 153 lakes (Regional Aquatics Monitoring Program, RAMP). The headwaters result from the melting snow and ice of the Athabasca Glacier in Jasper National Park. The Athabasca River flows northeast across Alberta into the Peace-Athabasca Delta and Lake Athabasca. Approximately 90% of the Athabasca watershed is located within Alberta, with 10% falling within Saskatchewan[6] (see **Exhibit 2.1**).

Several urban centres are located along the Athabasca River including, Athabasca, Jasper, Edson, Whitecourt, Hinton and Fort McMurray. Economic activity in the upper portion of the watershed is dominated by agriculture and forestry, while oil sands developments dominate the lower portion of the watershed. Alberta has now set strict limits on how much water oil sands companies can remove from the Athabasca River. These limits have been set to balance the needs of the community and industry (ESRD, 2014).

The Athabasca River Basin is comprised of 10 sub-basins including:

- Upper Athabasca
- McLeod
- Pembina
- Central Athabasca – upper
- Central Athabasca – lower
- La Biche
- Clearwater
- Lower Athabasca
- Lake Athabasca
- Lesser Slave

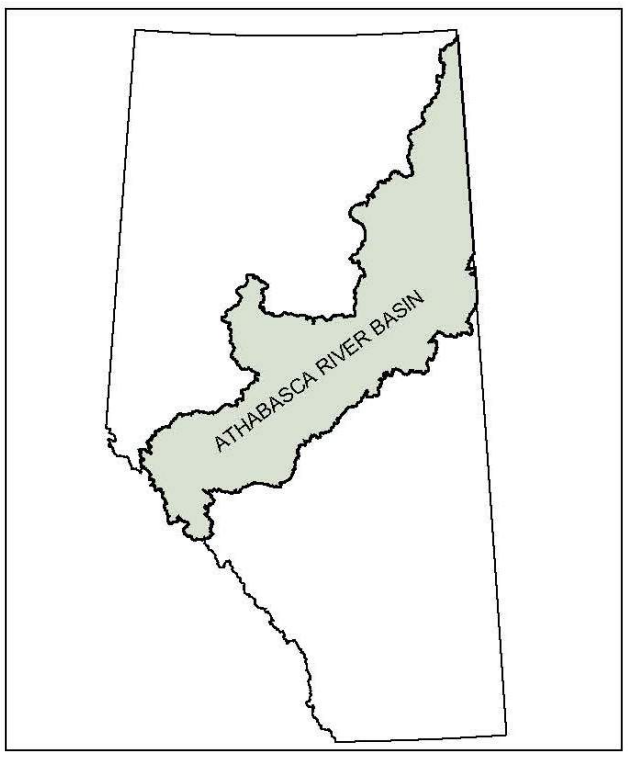
These are illustrated in **Exhibit 2.2**. **Exhibit 2.3** illustrates the 25 separate jurisdictions within the basin.

2.2 Basin Characteristics

The following map series (**Exhibits 2.4** to **2.12)** provides an overview of the salient characteristics of the Athabasca River Basins.

[6] Hatfield Consultants Partnership, *Athabasca Watershed Council, State of the Watershed Report: Phase 1, Final Report*, March 2011.

Athabasca Basin





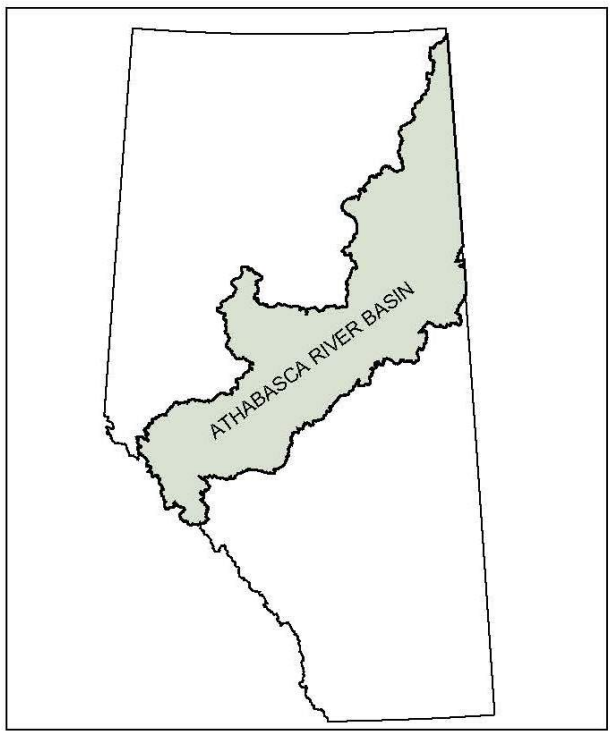
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Feasibility Study - Athabasca River Basins

May 2014

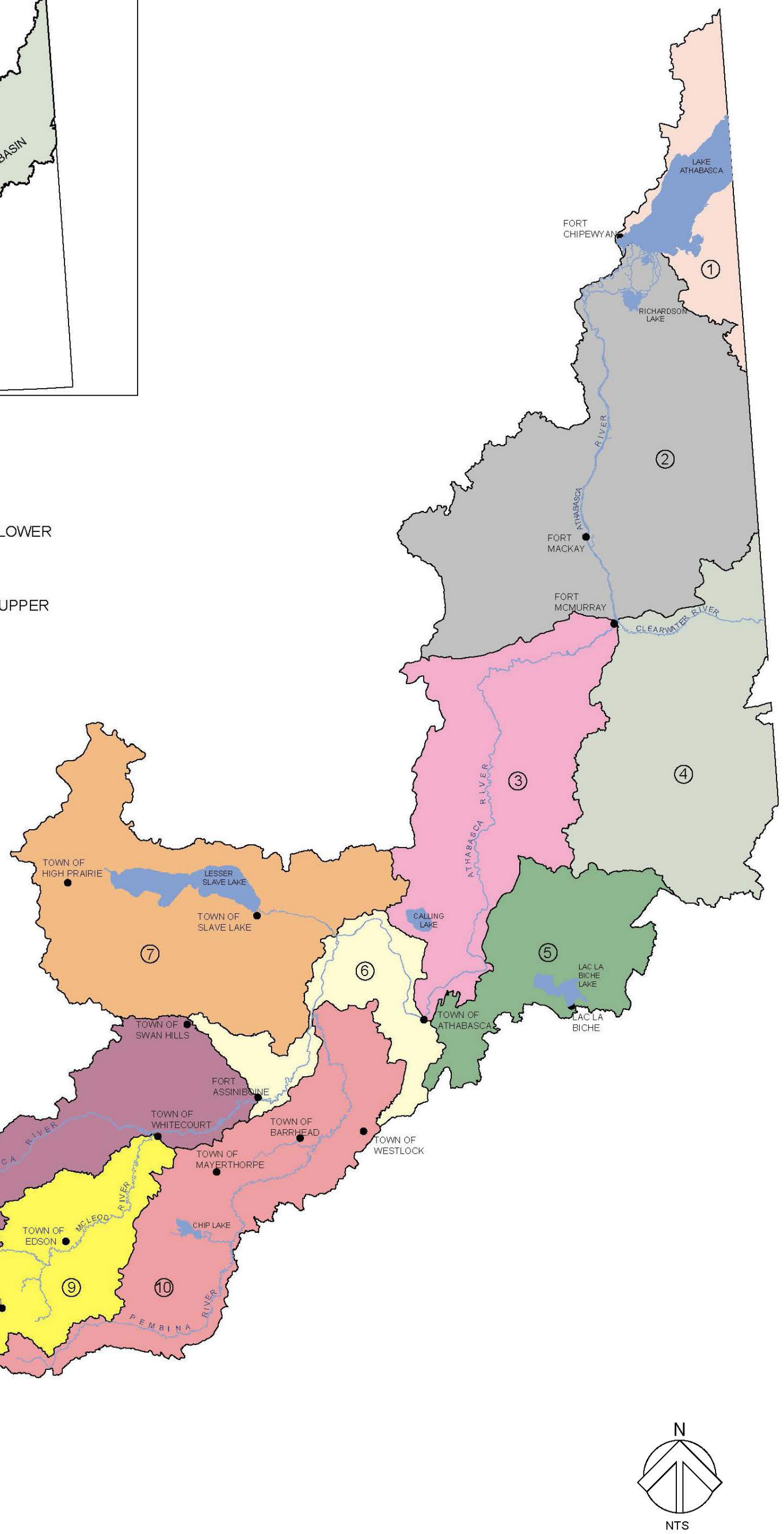
EXHIBIT 2.1

Athabasca Sub-Basins



LEGEND

1. LAKE ATHABASCA
2. LOWER ATHABASCA
3. CENTRAL ATHABASCA - LOWER
4. CLEARWATER
5. LA BICHE
6. CENTRAL ATHABASCA - UPPER
7. LESSER SLAVE
8. UPPER ATHABASCA
9. MCLEOD
10. PEMBINA



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Feasibility Study - Athabasca River Basins

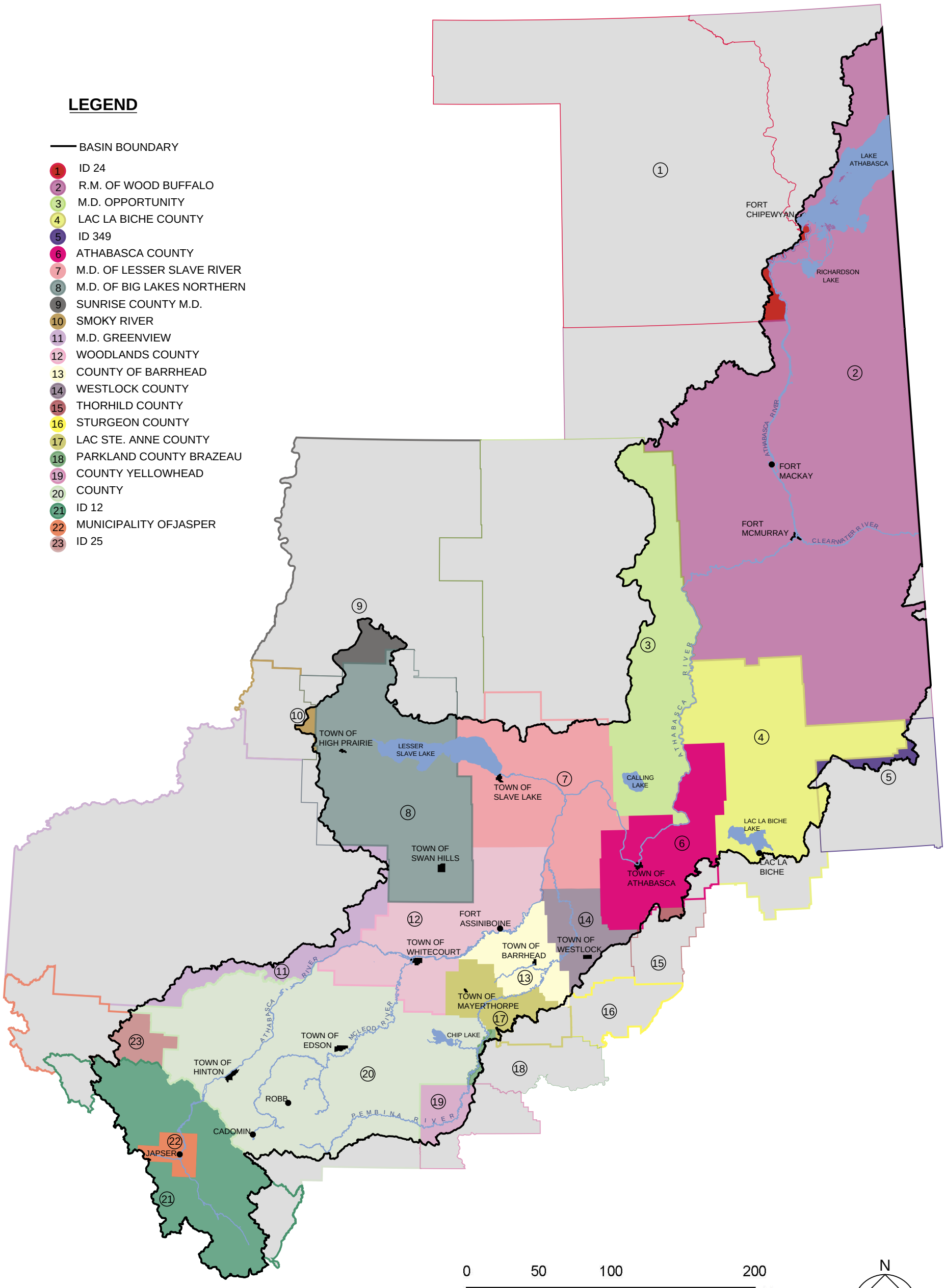
May 2014

EXHIBIT 2.2

Municipalities within the Athabasca Basin

LEGEND

- BASIN BOUNDARY
- 1 ID 24
- 2 R.M. OF WOOD BUFFALO
- 3 M.D. OPPORTUNITY
- 4 LAC LA BICHE COUNTY
- 5 ID 349
- 6 ATHABASCA COUNTY
- 7 M.D. OF LESSER SLAVE RIVER
- 8 M.D. OF BIG LAKES NORTHERN
- 9 SUNRISE COUNTY M.D.
- 10 SMOKY RIVER
- 11 M.D. GREENVIEW
- 12 WOODLANDS COUNTY
- 13 COUNTY OF BARRHEAD
- 14 WESTLOCK COUNTY
- 15 THORHILD COUNTY
- 16 STURGEON COUNTY
- 17 LAC STE. ANNE COUNTY
- 18 PARKLAND COUNTY BRAZEAU
- 19 COUNTY YELLOWHEAD
- 20 COUNTY
- 21 ID 12
- 22 MUNICIPALITY OFJASPER
- 23 ID 25



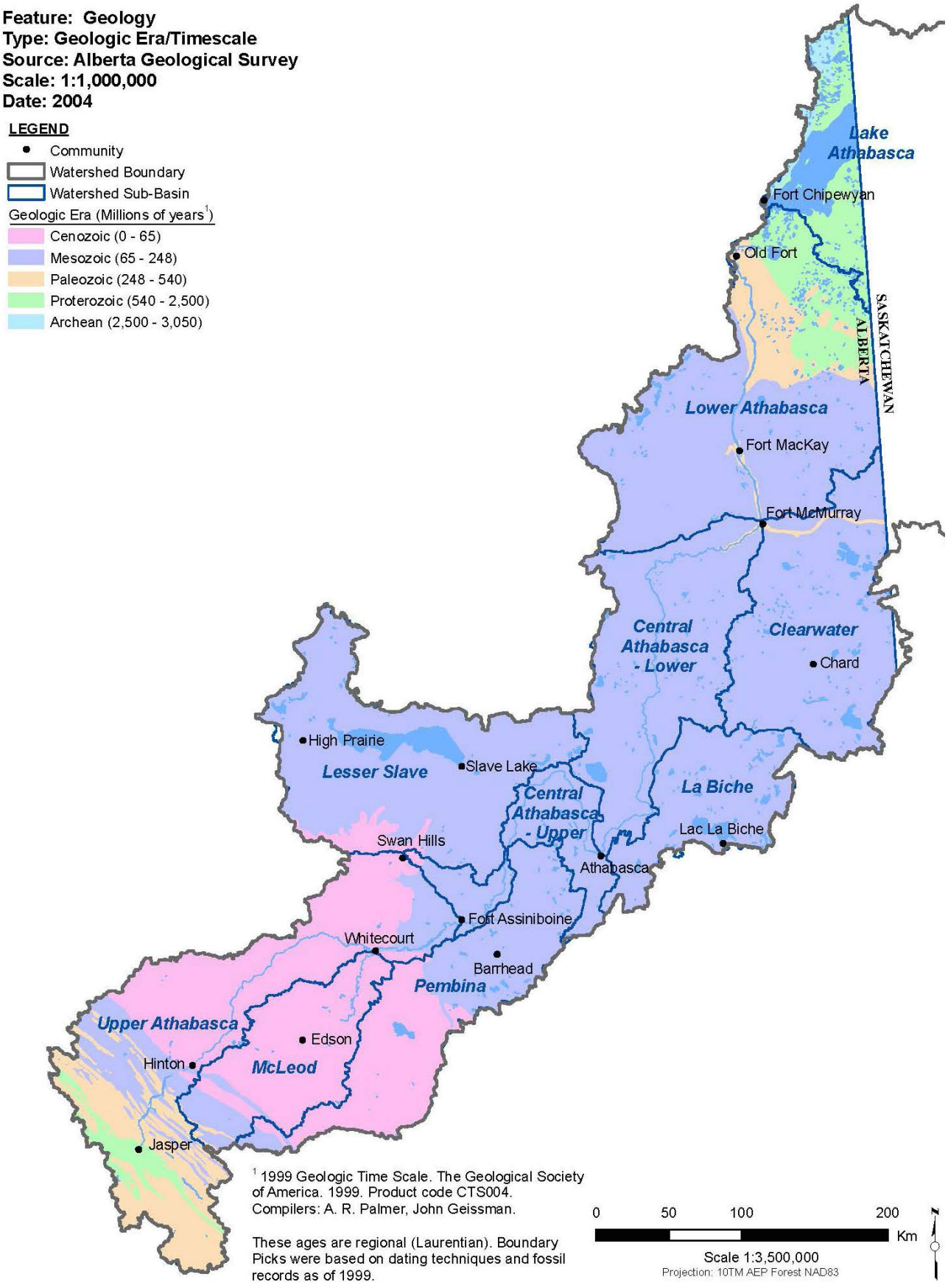
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Feasibility Study - Athabasca River Basins

May 2014

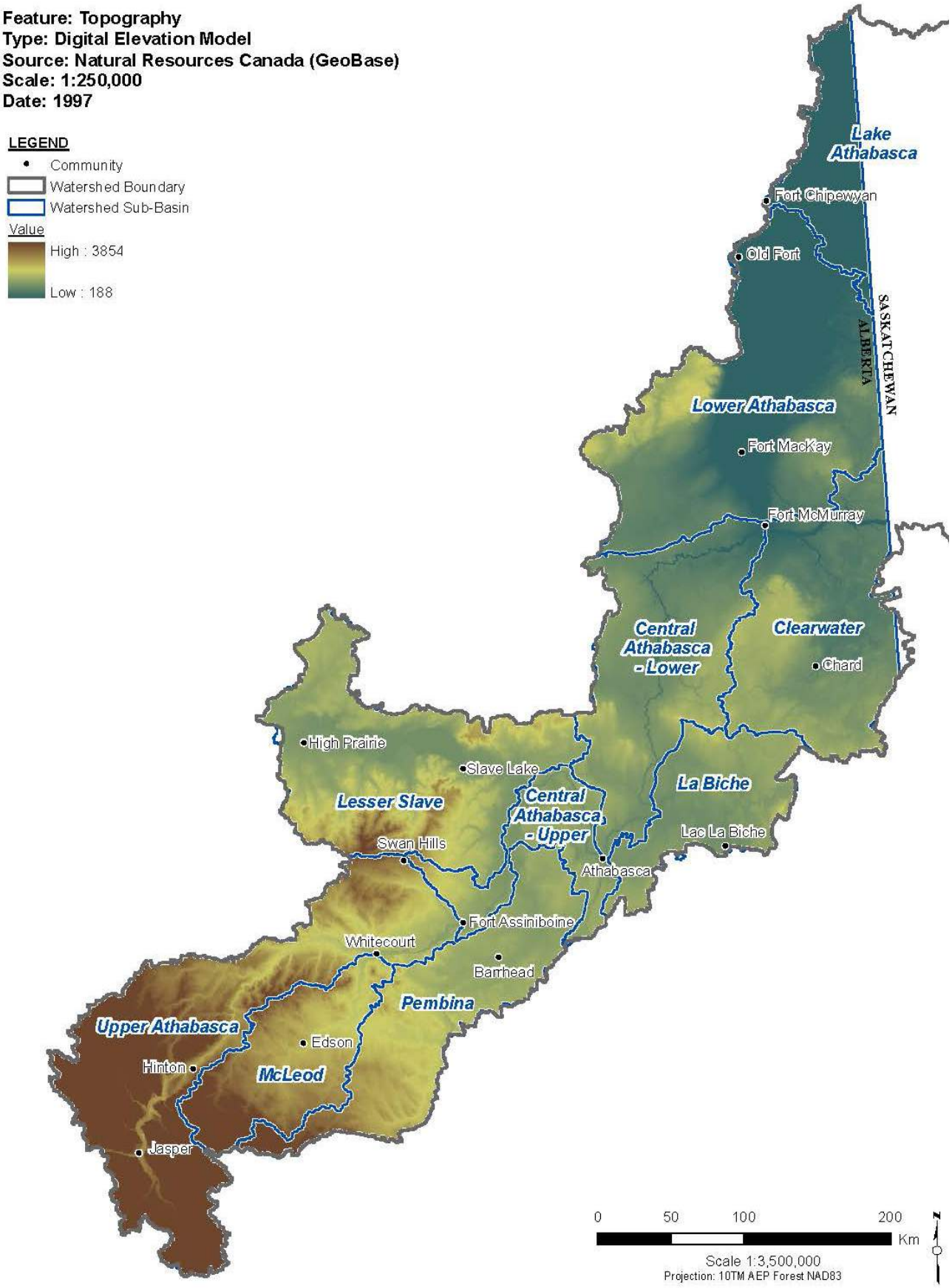
EXHIBIT 2.3

Geology


Feature: Geology
Type: Geologic Era/Timescale
Source: Alberta Geological Survey
Scale: 1:1,000,000
Date: 2004
LEGEND
Community
Watershed Boundary
Watershed Sub-Basin
Geologic Era (Millions of years[1])
Cenozoic (0 - 65)
Mesozoic (65 - 248)
Paleozoic (248 - 540)
Proterozoic (540 - 2,500)
Archean (2,500 - 3,050)
Lake Athabasca
Fort Chipewyan
Old Fort
SASKATCHEWAN
ALBERTA
Lower Athabasca
Fort MacKay
Fort McMurray
Central Athabasca - Lower
Clearwater
Chard
High Prairie
Lesser Slave
Slave Lake
Central Athabasca - Upper
La Biche
Lac La Biche
Swan Hills
Athabasca
Fort Assiniboine
Whitecourt
Barrhead
Pembina
Upper Athabasca
Edson
Hinton
McLeod
Jasper
[1] 1999 Geologic Time Scale. The Geological Society of America. 1999. Product code CTS004.
Compilers: A. R. Palmer, John Geissman.
These ages are regional (Laurentian). Boundary Picks were based on dating techniques and fossil records as of 1999.
0 50 100 200
Km
Scale 1:3,500,000
Projection: 10TM AEP Forest NAD83

Topography

Feature: Topography
Type: Digital Elevation Model
Source: Natural Resources Canada (GeoBase)
Scale: 1:250,000
Date: 1997

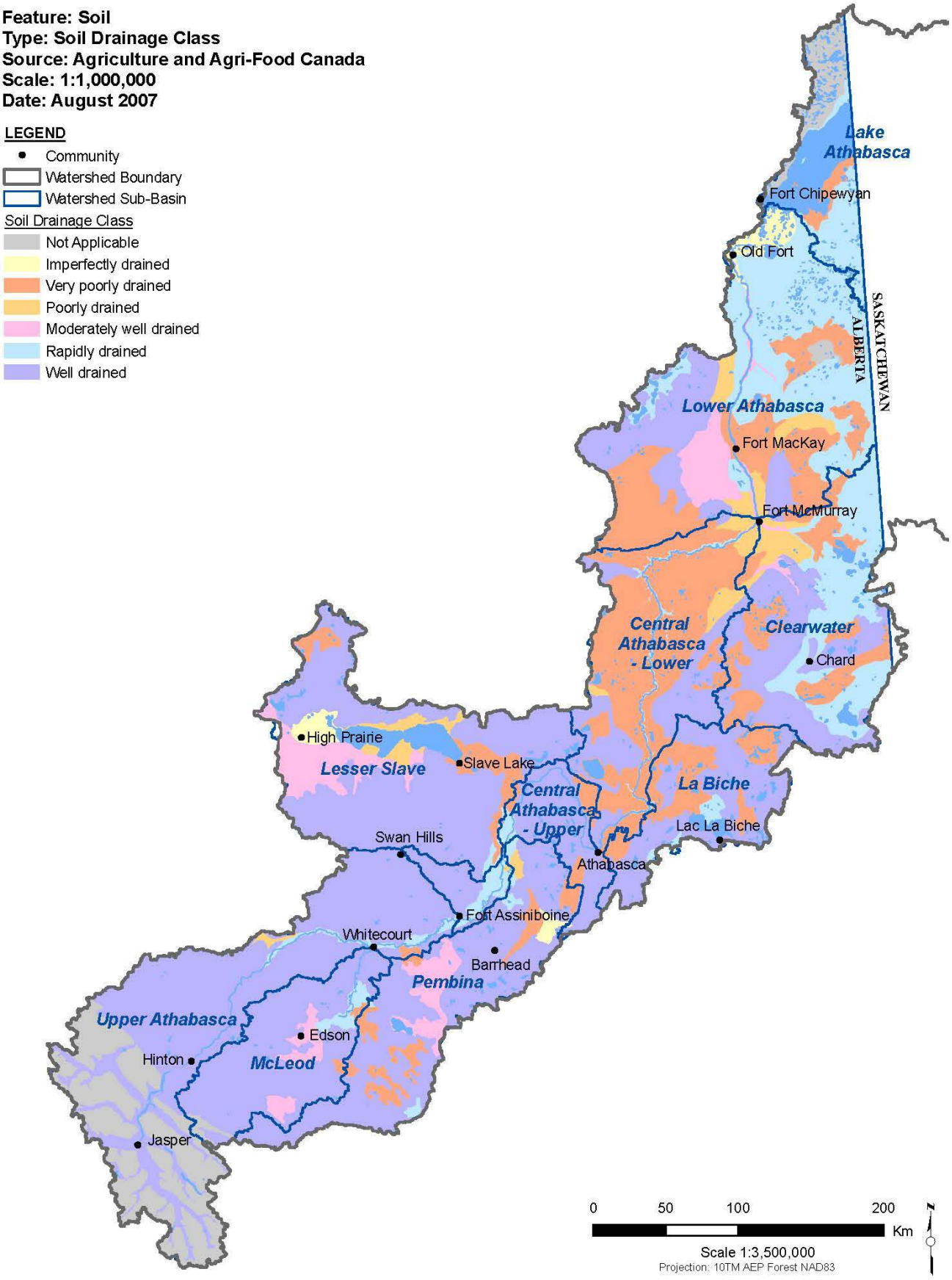


Topography

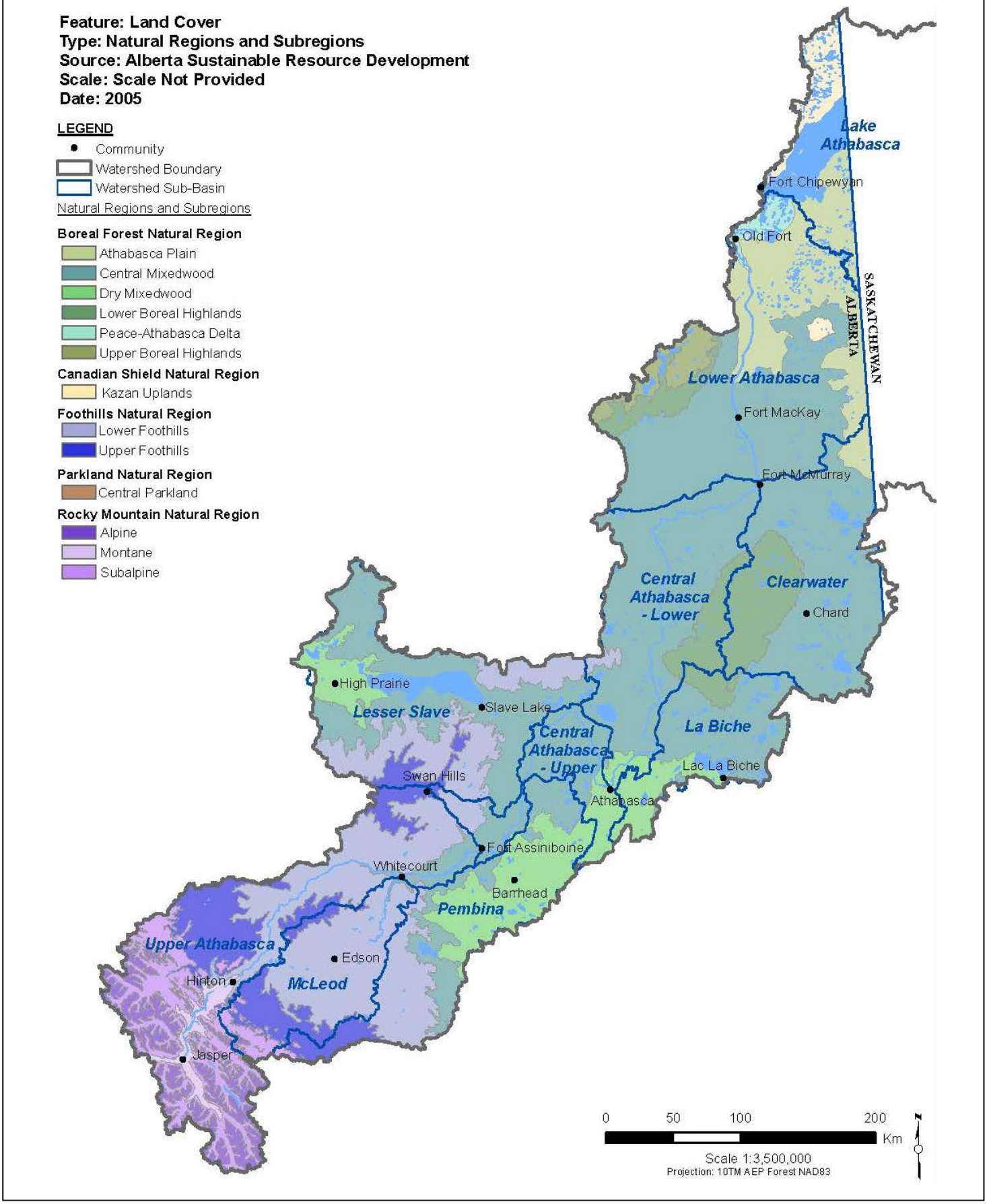

Feature: Topography
Type: Hillshade (derived from Digital Elevation Model)
Source: Natural Resources Canada (GeoBase)
Scale: 1:250,000
Date: 1997
LEGEND
Community
Watershed Boundary
Watershed Sub-Basin
Lake Athabasca
Fort Chipewyan
Old Fort
SASKATCHEWAN
ALBERTA
Lower Athabasca
Fort MacKay
Fort McMurray
Central Athabasca - Lower
Clearwater
Chard
High Prairie
Lesser Slave
Slave Lake
Central Athabasca - Upper
La Biche
Lac La Biche
Swan Hills
Athabasca
Fort Assiniboine
Whitecourt
Barrhead
Pembina
Upper Athabasca
Edson
Hinton
McLeod
Jasper
0
50
100
200
Km
Scale 1:3,500,000
Projection: 10TM AEP Forest NAD83

Soil

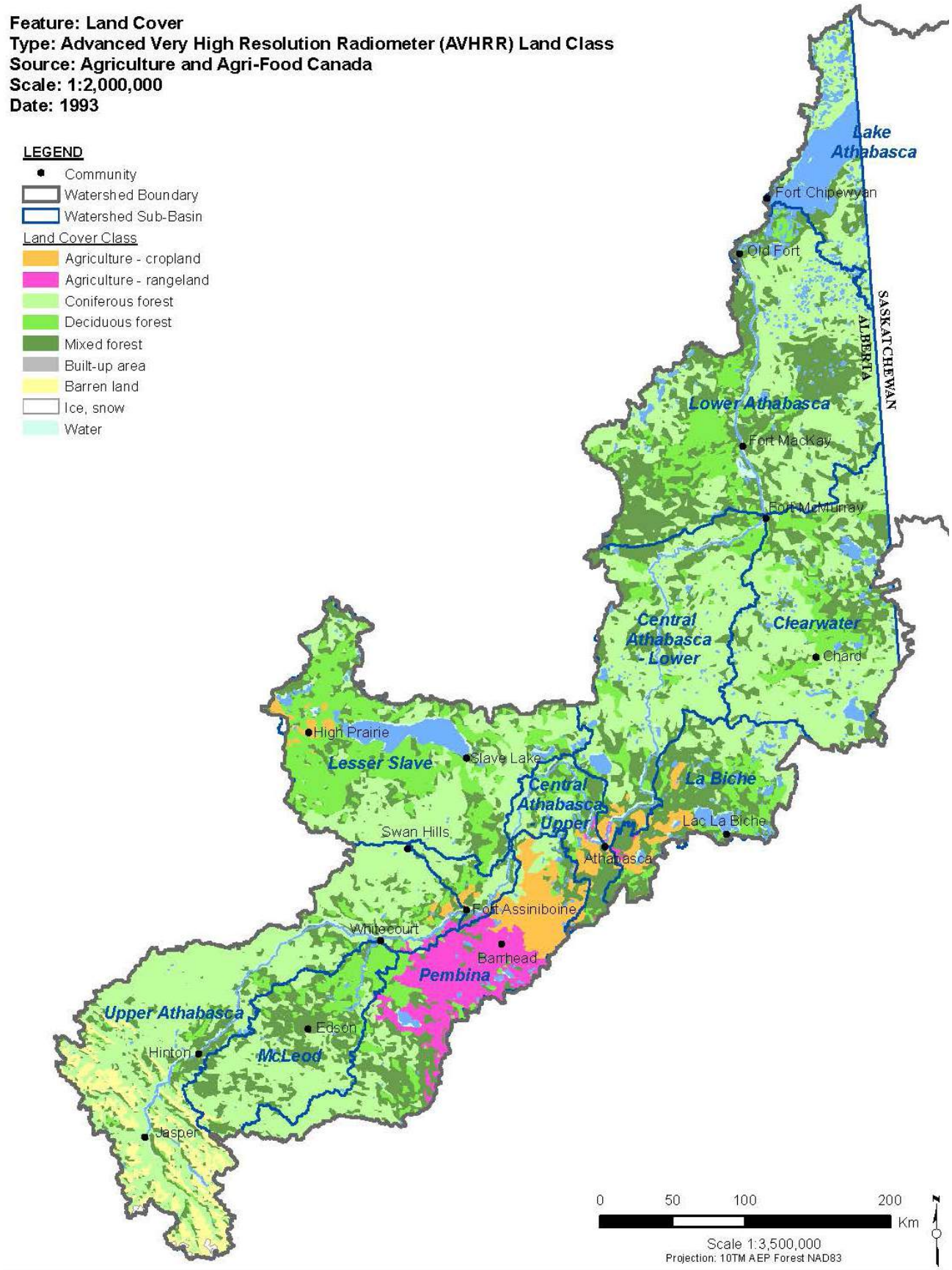
Feature: Soil
Type: Soil Drainage Class
Source: Agriculture and Agri-Food Canada
Scale: 1:1,000,000
Date: August 2007



Land Cover

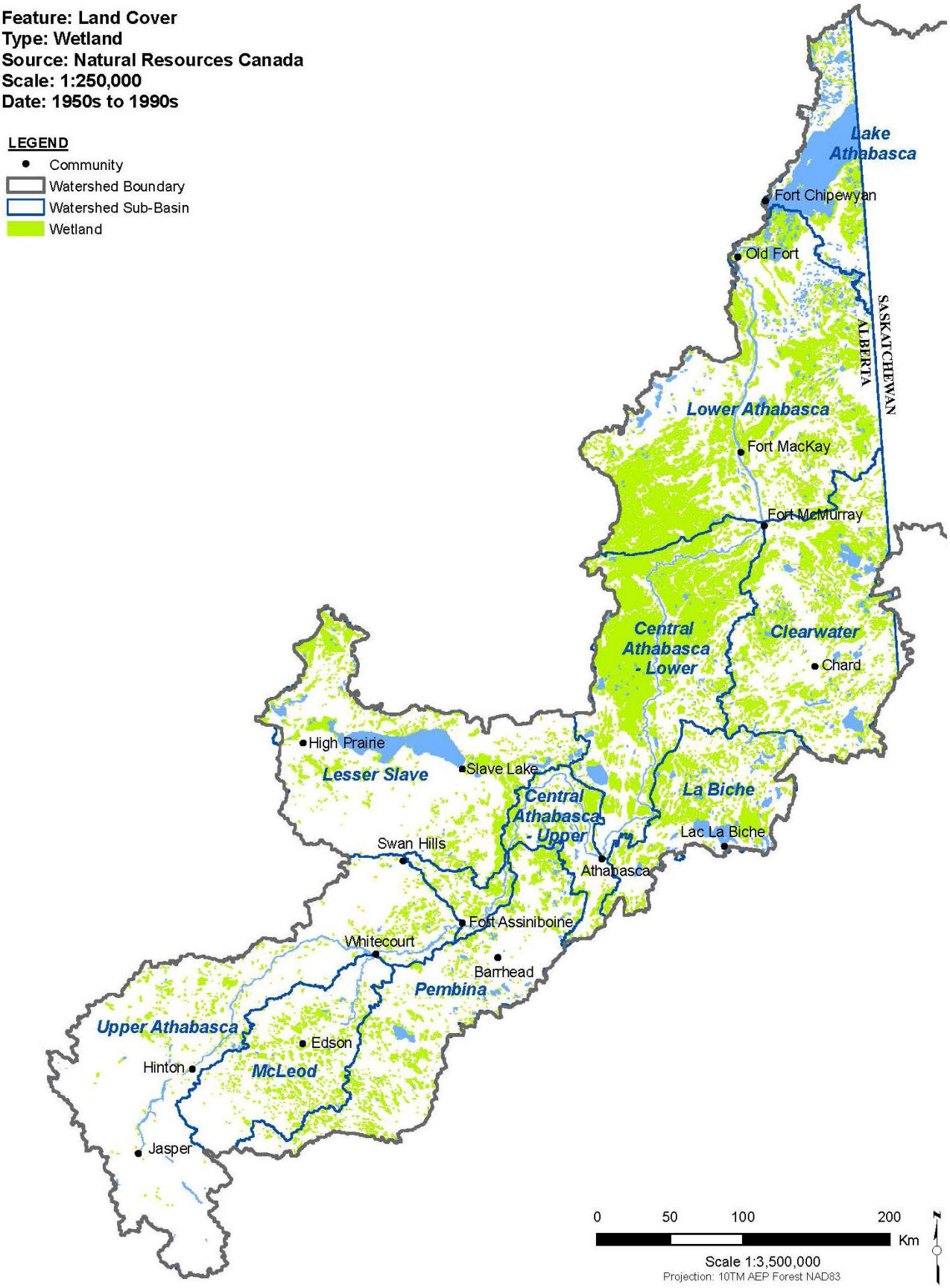

Feature: Land Cover
Type: Natural Regions and Subregions
Source: Alberta Sustainable Resource Development
Scale: Scale Not Provided
Date: 2005
LEGEND
Community
Watershed Boundary
Watershed Sub-Basin
Natural Regions and Subregions
Boreal Forest Natural Region
Athabasca Plain
Central Mixedwood
Dry Mixedwood
Lower Boreal Highlands
Peace-Athabasca Delta
Upper Boreal Highlands
Canadian Shield Natural Region
Kazan Uplands
Foothills Natural Region
Lower Foothills
Upper Foothills
Parkland Natural Region
Central Parkland
Rocky Mountain Natural Region
Alpine
Montane
Subalpine
Lake Athabasca
Fort Chipewyan
Old Fort
SASKATCHEWAN
ALBERTA
Lower Athabasca
Fort MacKay
Fort McMurray
Central Athabasca - Lower
Clearwater
Chard
High Prairie
Lesser Slave
Slave Lake
Central Athabasca - Upper
La Biche
Lac La Biche
Swan Hills
Athabasca
Fort Assiniboine
Whitecourt
Barrhead
Pembina
Upper Athabasca
Edson
Hinton
McLeod
Jasper
0 50 100 200
Km
Scale 1:3,500,000
Projection: 10TM AEP Forest NAD83

Land Cover


Feature: Land Cover
Type: Advanced Very High Resolution Radiometer (AVHRR) Land Class
Source: Agriculture and Agri-Food Canada
Scale: 1:2,000,000
Date: 1993
LEGEND
Community
Watershed Boundary
Watershed Sub-Basin
Land Cover Class
Agriculture - cropland
Agriculture - rangeland
Coniferous forest
Deciduous forest
Mixed forest
Built-up area
Barren land
Ice, snow
Water
Lake Athabasca
Fort Chipewyan
Old Fort
SASKATCHEWAN
ALBERTA
Lower Athabasca
Fort MacKay
Fort McMurray
Central Athabasca - Lower
Clearwater
Chard
High Prairie
Lesser Slave
Slave Lake
Central Athabasca - Upper
La Biche
Lac La Biche
Swan Hills
Athabasca
Fort Assiniboine
Whitecourt
Barrhead
Pembina
Upper Athabasca
Edson
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McLeod
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Scale 1:3,500,000
Projection: 10TM AEP Forest NAD83

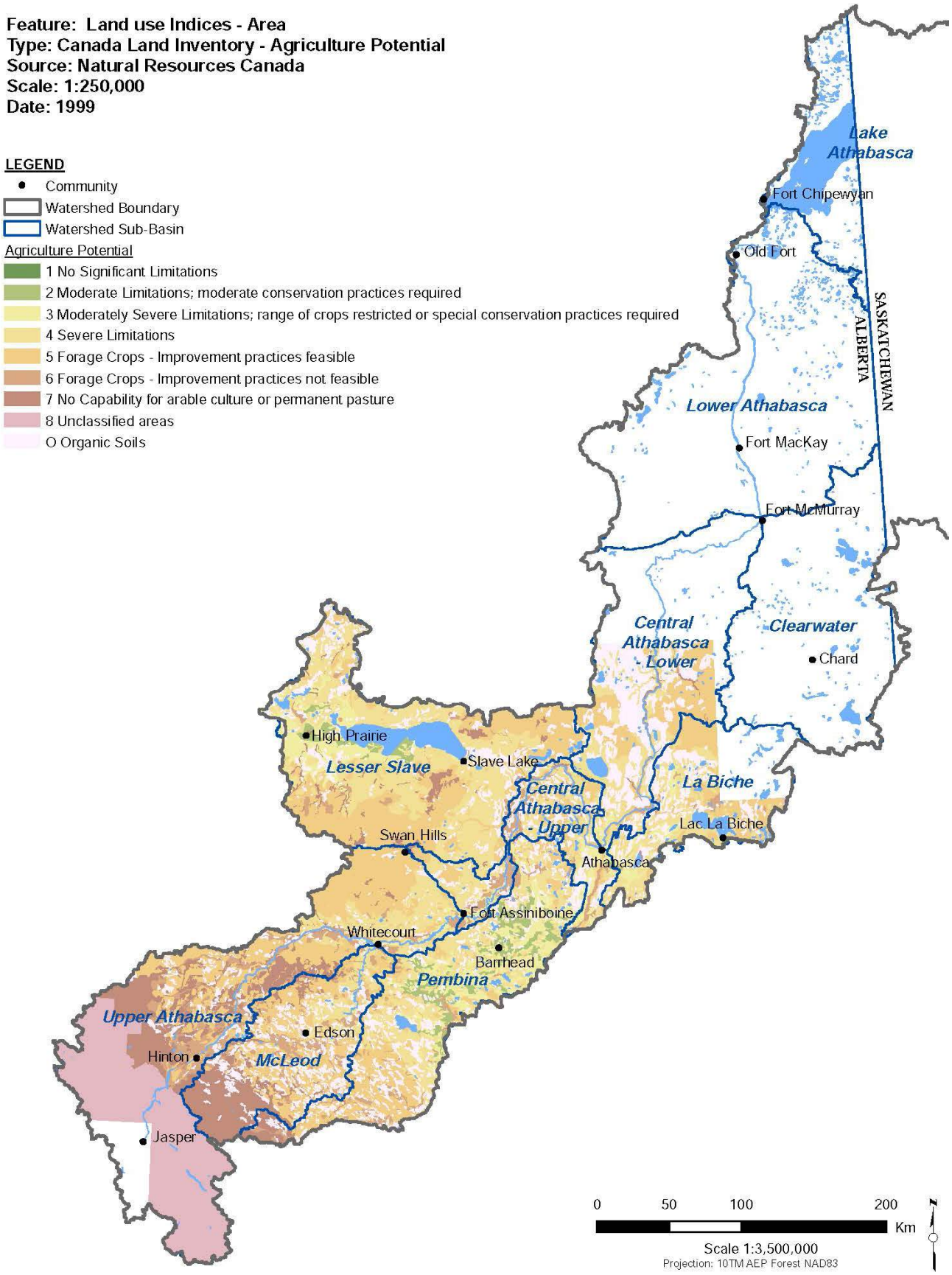
Land Cover

Feature: Land Cover
Type: Wetland
Source: Natural Resources Canada
Scale: 1:250,000
Date: 1950s to 1990s



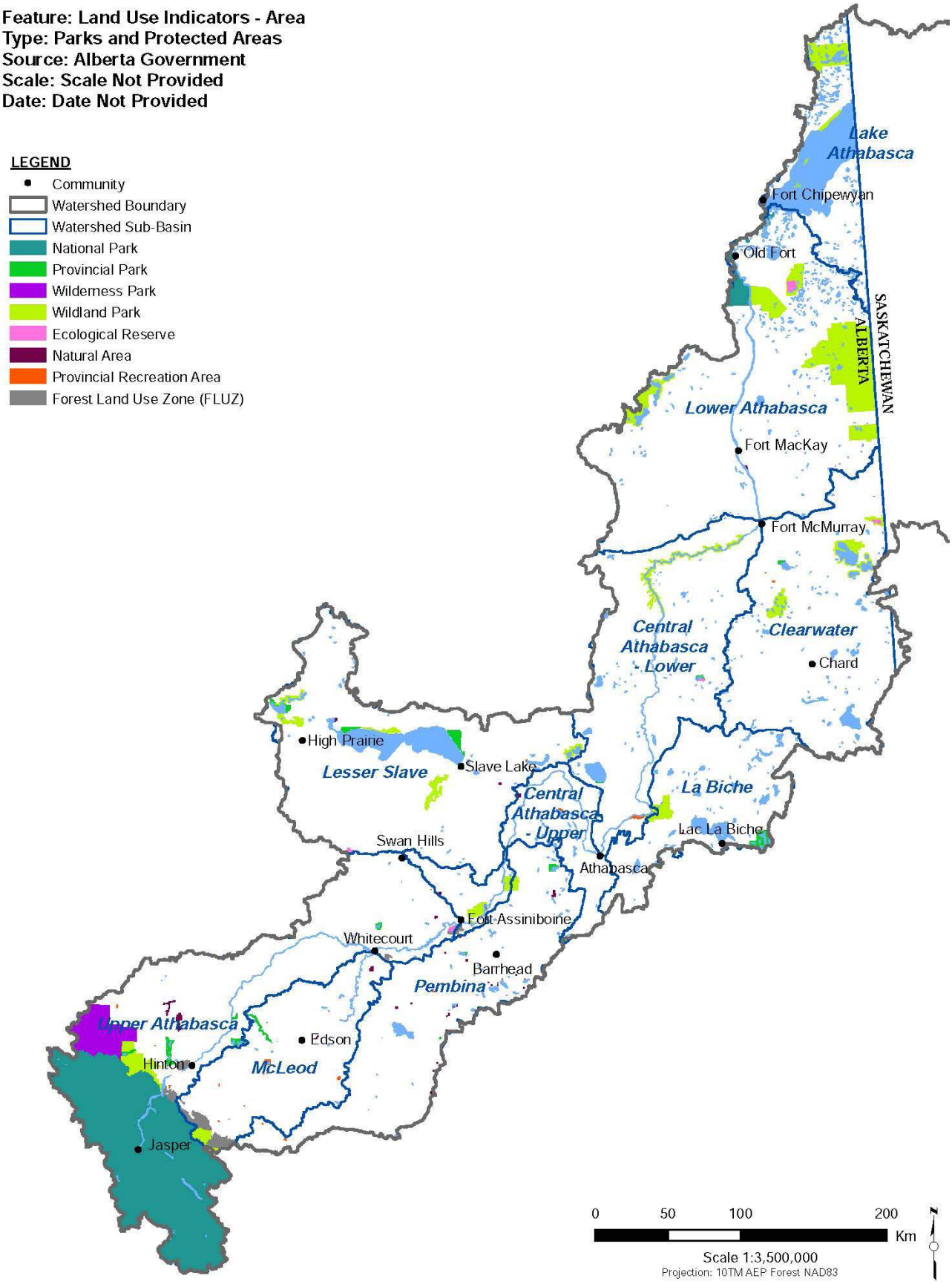
Land Use Indices - Area

Feature: Land use Indices - Area
Type: Canada Land Inventory - Agriculture Potential
Source: Natural Resources Canada
Scale: 1:250,000
Date: 1999



Land Use Indicators - Area

Feature: Land Use Indicators - Area
Type: Parks and Protected Areas
Source: Alberta Government
Scale: Scale Not Provided
Date: Date Not Provided





3.0 APPROACH AND METHODOLOGY

3 Approach and Methodology

3.1 Background Data Compilation and Review by Community

For each of the flood affected communities background data and historical records were collected from a variety of sources along with review of relevant reports and stakeholder interviews. Due to budget, data and scheduling limitations, only limited field surveys were undertaken during this investigation.

3.1.1 Stakeholder Engagement Process

3.1.1.1 Overview

The stakeholder engagement process is an essential means of obtaining flood damages and risk information from a variety of sources. Surveys and discussions with stakeholders provide information necessary to identify historical flood events and flood-related damages, as well as existing and proposed mitigation measures to reduce flood risks and associated potential damages. Stakeholders were also an important source of mapping, particularly within municipalities, and information regarding policies and regulatory efforts enacted to reduce flood risk of damages to communities within the Athabasca River Basin.

The Project Team conducted the stakeholder engagement process employing the skills of land use planners and policy analysts over the course of February and March of 2014. A survey format and follow-up telephone discussion were typically employed. All stakeholder contacts were given the option of completing the survey by email or by discussion with the Project Team. Some stakeholders, particularly the First Nations groups, were also given the opportunity to meet in person with the Project Team and Task Force representatives if desired. The Project Team was assisted with identification of stakeholders and contacts with some groups, particularly the First Nations and Métis Settlements by The Flood Recovery Task Force stakeholder liaison members seconded from the Justice ministry for this study.

All stakeholders were contacted by email and telephone multiple times and encouraged to participate in the survey and collection of information necessary to the study. A copy of the list of stakeholders as well as the flood information surveys can be found in **Appendix B**.

Stakeholders were grouped into three distinct categories. These three categories are:

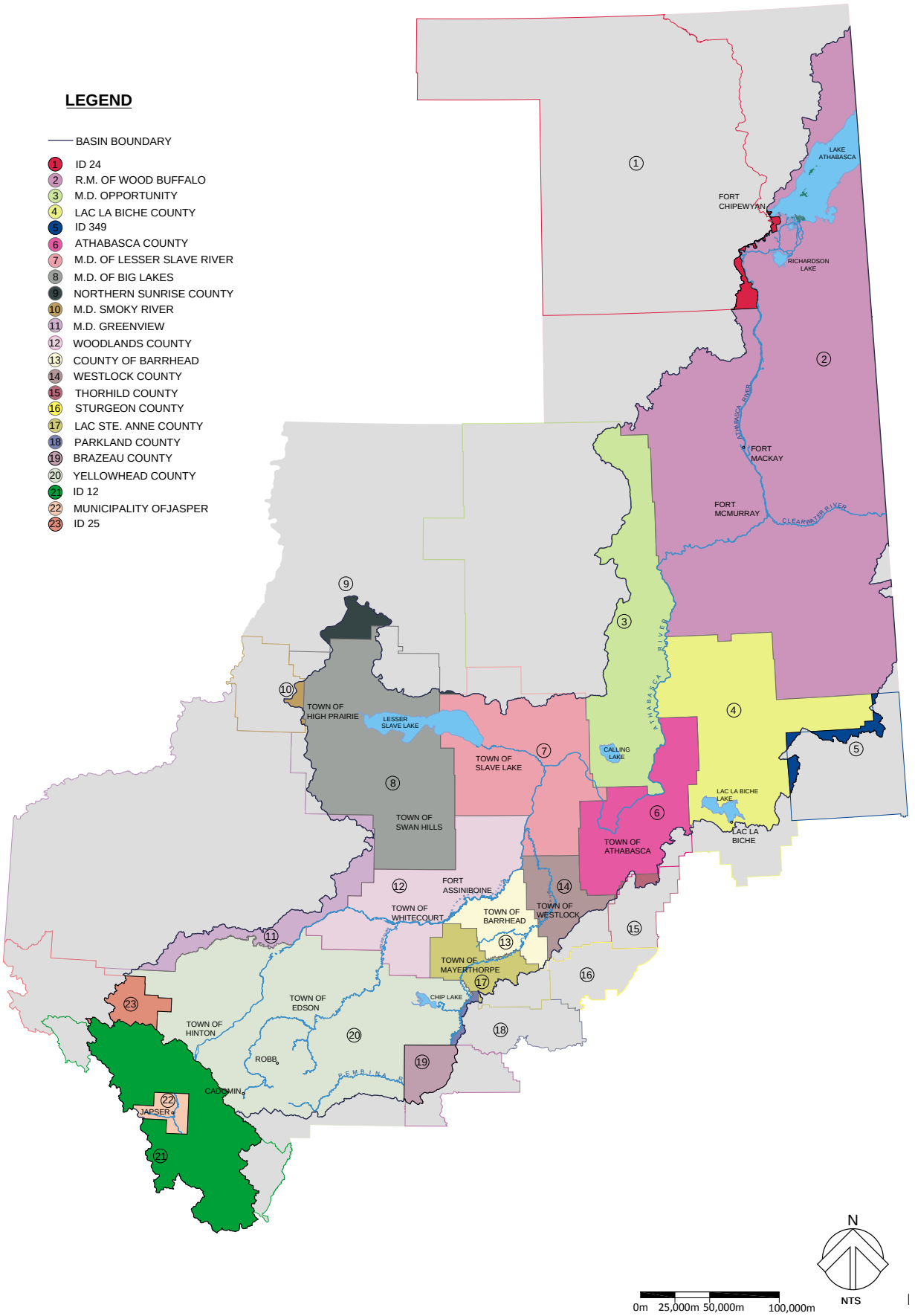
- Municipalities (total of 34 contacts);
- External Stakeholders (Government Department, Industry, etc.) 12 contacts; and
- First Nations and Métis Settlements (total of 33 contacts).

3.1.1.2 Municipalities or Internal Stakeholders

Internal stakeholders are those groups that are directly affected by flooding within the Athabasca River Basin. That is all municipalities within the basin are considered stakeholders and were contacted for their participation in the survey seeking information for this study. A total of 34 municipalities were identified as stakeholders within the Athabasca River Basin (see **Exhibit 3.1**). The communities included locations such as the Town of Jasper near the origin of the basin as well as Whitecourt, Slave Lake, and of course, Fort McMurray. All municipal districts and counties within the basin were also identified as stakeholders.

The results of the municipal stakeholder engagement process are summarized in **Exhibit 3.2A,B,C,D** entitled Athabasca River Basin Municipal Stakeholders – Flood Summary Table

Municipalities within the Athabasca Basin



IBI GROUP | Golder Associates | Alberta Government

Feasibility Study - Athabasca River Basins

May 2014

EXHIBIT 3.1

Athasbasca River Basins Municipal Stakeholders - Flood Summary Table

Municipality	Pop`n	Flood Years	History of Urban Flooding	Communities Affected by Past Flooding	Communities at Risk of Future Flooding	History of Agricultural Flooding	Infrastructure Affected by Past Flooding	Flood Damages	Existing Flood Mitigation Measures	Planned and/or Proposed Flood Mitigation Measures	Future Flood Damage Potential	Other Comments
Town of Jasper	5,236	None	No	None	N/A	N/A	None	None known	None	None needed	No risk	The river is situated at a lower elevation than the townsite. There is no risk of flooding.
Yellowhead County	10,469	1942, 1950, 1980,1982, 1989, 2011	No	Cadomin	Hamlets of Peers, and Robb and Seabolt Estates subdivision	Yes	Yes, repair to road surfaces and bridges	2011: $1 million mostly for road repairs	Land Use Bylaw includes restrictions on development within the floodplain. Emergency Management Plan provides flood related emergency measures	None needed	Low	Intermittent flooding of agricultural land (overland drainage) and are cautious about risks of flooding. For the Hamlet of Cadomin, the *Athabasca River Basin Planning Program* study (1988) determined that other than natural open space lands within the floodplain, there were only three private residential properties that could be affected by a flood and none of the principle buildings on these properties infringed on the floodplain. The study concluded that there was virtually no potential for future increases in flood damages in the Hamlet of Cadomin.
Town of Edson	8,646	2002 was last flood; potentially earlier incidences	Yes	Town of Edson	N/A	N/A	No significant damages. Mostly residential sewer back-ups and some road flooding on south side of Town	2002: $1 million in damages to municipal infrastructure	Municipal Development Plan includes restrictions on development within the floodplain. Other flood mitigation measures include the dredging of the creeks	None needed	Low	Stormwater management is key mitigation measure in newer developed areas of Town.
Town of Hinton	9,640	1960s & 1970s; 1988	Yes	Town of Hinton	N/A	N/A	Crescent Valley School, some commercial buildings along Hardisty Creek; Seniors Hall	No information available	Culvert crossings	Future update to development policies proposed	Very Low	Will update Municipal Development Plan (MDP) and Land Use Bylaw. The *Hinton Flood Risk Mapping Study* (1994) reported that there was a need for culvert crossing improvements along Happy and Hardisty creeks to prevent overtopping of roadways. According to the Town, occurrences of flooding subsided once a culvert was built under Hardisty Avenue to prevent the road/bridge from washing out.
Municipal District of Greenview	5,299	None Known	No	Smoky River when Big Smoky River came over the bridge	Grande Cache, Valleyview, Little Smoky (risk is low)	Yes	Thought golf course was flooded once in Little Smoky. Possibly water crested bridge on Little Smoky once near DeBolt	None known	DeBolt Drainage System (weir and large track canal ditches)	Future update to development policies proposed	Very Low	No risk to infrastructure from normal flooding during spring. Any repairs to infrastructure related to normal wear.
Woodlands County	4,306	1943;1963;1980; 1986; 2005; 2011; 2012	No	Hamlet of Blue Ridge	Town of Whitecourt; any community within a floodplain is at risk	Yes	Roadway erosion, culvert repairs and ditch refurbishment; bridge washed away	2012: $565,000 in damages. 2011: $505,000	Land Use Bylaw includes restrictions on development within the floodplain. Emergency Management Plan provides flood related emergency measures	Restricting development in floodplain through Land Use Bylaw (LUB)	Low	1980 was the significant flood event and used as the 50 year flood marker. Town of Whitecourt area flooded (confluence of the McLeod and Athabasca rivers).
Town of Whitecourt	10,574	2012; 2011; 1996; 1986; 1980; 1963; 1960; 1958; 1954; 1950-1948; 1948; 1943; 1940; 1926	Yes	Town of Whitecourt	N/A	N/A	1996: moved some mobile homes only; 2011 & 2012 damage to golf course and recreational park. 2013 significant bank erosion (potentially from 2011 & 2012 floods)	2012: $458,000 in damages. 2011: $800,000 (half of costs to repair stormwater outfalls)	Water treatment plant and waste water treatment plant raised above 1:100 flood line. Land Use Bylaw includes restrictions on development within the floodplain. Emergency Management Plan provides flood related emergency measures. The Beaver Creek diversion was built in approximately 1989 to prevent flood damage to a mobile home park	None to date	Moderate	Recent floods resulted in need to repair to stormwater outfalls (utility infrastructure). Since 1996, highwater has resulted in some bank erosion.

Athasbasca River Basins Municipal Stakeholders - Flood Summary Table

Municipality	Pop`n	Flood Years	History of Urban Flooding	Communities Affected by Past Flooding	Communities at Risk of Future Flooding	History of Agricultural Flooding	Infrastructure Affected by Past Flooding	Flood Damages	Existing Flood Mitigation Measures	Planned and/or Proposed Flood Mitigation Measures	Future Flood Damage Potential	Other Comments
Lac Ste. Anne County	10,260	2012; 2011; either 1987 or 1989	No	No communities affected	None identified within the County; potentially Town of Barrhead	Yes	Localized road flooding only; in 3 days the waters recede. Road repairs needed. Flooding is confined to agricultural property only. 1987 Pembina flood affected a campground and ball diamond and park in river valley.	2012: $500,000 damages. 2011: $1.5M damages. Mostly gravel road repairs, replacement of washed-out culverts	The County's Land Use Bylaw includes restrictions on development within the floodplain but updating LUB now. Emergency Management Plan provides flood related emergency measures. Structural flood mitigation measures include the Paddle River Dam and dykes along the Paddle River	Very cautious about potential development in floodplain. Updating Land Use Bylaw now.	Low	Paddle River dam has made a huge difference. The Pembina river has topped the banks since construction. Have not stopped development - but are very cautious about risks of flooding. The *Athabasca River Basin Planning Program* study (1988) determined that the Hamlet of Sangudo had a low potential for flood damage. Although there were areas which would be affected, there were few facilities or buildings on them. Also, it was considered that there was limited potential for development on these parcels.
Town of Mayerthorpe	1,398	2012 (overland drainage issue from rainfall)	No	None	N/A	N/A	Only incident was potential of river flooding the landfill site.	None from river flooding. Rainfall resulted in some flooded basements.	2008/09 bank stabilization project. Replacement of undersized culverts. Focus on stormwater management.	Want to examine bank stabilization	Very Low	Town is built on south side of river. The north river bank's elevation is lower. Town feels any river flooding would affect agricultural land on the north side of the river rather than flood the banks on the south side.
County of Barrhead S	6,096	2011; 2012	No	Hamlet of Fort Assiniboine (near the bridge)	Hamlet of Minola	Yes	2011 flooded est. 8,000 acres of agricultural land. No houses or structures affected. Confined to western edge of County. Mostly road erosion damages.	2011: $15,000; 2012: $120,000 in damages related to roadway repair; culvert replacement, etc.	Land Use Bylaw includes restrictions on development within the floodplain. Emergency Management Plan provides flood related emergency measures. Dykes on the Paddle River	Restrict development in floodplain through Land Use Bylaw	Low	Extensive flood damage to crops and pasture land in 2011; 2012 from overland flooding causing damage/erosion to County roads.
Town of Barrhead	4,432	1974; 1982; 1994; 1997	Yes	Town of Barrhead	N/A	N/A	In 1974 golf course damaged, washed out bridge. 1986 no Town land affected, just County rural land	No information available	Emergency Management Plan provides flood related emergency measures. Water comes from Paddle River (well-controlled). New weir for water treatment plant in 2011	Restrict development in floodplain through Land Use Bylaw and Municipal Development Plan	Low	No residential development permitted since the 1950s in the river valley. No homes have ever been affected by flooding.
Municipal District of Big Lakes	3,861	1971; 1988; 1996; 2011; 2013	No	Hamlets of Joussard & Kinuso	None identified within the County	Yes	No public facilities at risk now that dykes constructed in 1988 (Kinuso was most at risk)	Disaster relief claims made in 1996 and 1988, 2011 and 2013. 2011: $2 million in damages. 2013: $300,000 in damages	Dyke construction.	Ongoing upsizing of culverts paid for by MD	Low	Possible project east of High Prairie intended to divert water into a creek to minimize flooding on agricultural land in the area (two homesteads).
Town of High Prairie	2,600	No flooding since 1967	Yes	Town of High Prairie	N/A	N/A	No public facilities at risk.	No damages	Straightened and deepened channel in late 1960s and again in the 1970s and 1980s.	Stormwater management plan update.	Very Low	No issues with flooding since channel straightening. Only mild ponding at a few intersections. Hospital site planning considered potential for flooding from stormwater.
Town of Swan Hills	1,465	No flooding history	No	None	N/A	N/A	None	None known	None	None needed	No risk	
Westlock County	7,644	1986 was most recent flood	No	No communities affected	Hamlet of Jarview; potentially Hamlet of Fawcett	Yes	Schools, community halls and churches (risk area defined by County)	No information available	None known; Do have Emergency Disaster Plan	Revise current Land Use Bylaw	Very Low	Minor flooding since 1986 involves minor spring flooding in creeks and drainage ditches.
Town of Westlock	4,823	No past flooding	No	None	N/A	N/A	None	None known	None	None needed	No risk	Flooding has never been an issue in this community.

Athasbasca River Basins Municipal Stakeholders - Flood Summary Table

Municipality	Pop`n	Flood Years	History of Urban Flooding	Communities Affected by Past Flooding	Communities at Risk of Future Flooding	History of Agricultural Flooding	Infrastructure Affected by Past Flooding	Flood Damages	Existing Flood Mitigation Measures	Planned and/or Proposed Flood Mitigation Measures	Future Flood Damage Potential	Other Comments
Athabasca County	7,662	2012	Yes	Baptist Lake (2012)	Villages of Boyle; Colinton, Rochester (summer villages)	None described	Boat launches and day use areas along Athabasca River. Possibly two bridge crossings.	No information available	Municipal Development Plan and Land Use Bylaw restrict development in the flood plain.	Aware of a bridge replacement in Town of Athabasca	Very Low	Damaged bridge to be removed in Town of Athasbasca, which will reduce ice jams in winter along the river. The *Tawatinaw River at Rochester Flood Risk Mapping Study* (1997) determined that the Tawatinaw River, in proximity of Rochester, was confined to the main river valley within a relatively narrow undeveloped floodplain. Specifically, the study identified only one farm house property that was located within the Tawatinaw River flood fringe.
Town of Athabasca	2,990	1991, 1971, 1963, 1956, 1954, 1944, 1936, 1932, 1914	Yes	Town of Athabasca	N/A	N/A	Flooding about every 5 years when water tops the river banks and deposits silt and debris onto a park. Lift station & generator; playground & parks. Campsite affected in late 1970s or early 1980s.	No damages reported. Costs are related solely to general maintenance.	With the exception of a reference to trailer parks, there are no flood mitigation restrictions in the current Land Use Bylaw. Municipal Development Plan includes policies restricting development within the 1:100 year floodplain. Sandbags for lift station and generator.	Raise elevation of parking lot when repaved. No additional measures planned or proposed.	Low	Frequent (every 5 yr), although minor, local flooding. Some potential for flooding of lift station and generator as well as downtown if there was a very severe flood.
Municipal District of Lesser Slave River	2,929	Flooding every year	Yes	Eating Creek; Mooney Creek; Marten Beach; Canyon Creek	No other communities identified	None described	Dry hydrant facility in Marten Beach. No other facilities identified. Bridge and road repairs required.	Unknown	Land Use Bylaw includes restrictions on development within the floodplain. Emergency Management Plan provides flood related emergency measures. Included policies in Poplar Lane Area Structure Plan	None planned	Low	Summer villages surrounding Slave Lake most at risk. Flooding accepted as common occurrence in the MD
Town of Slave Lake	6,782	2011, 1990, 1988, 1986, 1983, 1979, 1978, 1975, 1974, 1972, 1968, 1961, 1959 or 1958, 1935, 1920	Yes	Town of Slave Lake	N/A	N/A	Dike failed in 1988. Flooding in SE and NE sectors of the Town. 2011 resulted in some sewer back-ups; storm ponds overflowed; required pump out of storm sewers.	Extensive damage in 1988, but no costs available.	Structural flood mitigation measures include flood control channel, cutoffs, dykes and debris control structure. Land Use Bylaw includes restrictions on development within the floodplain. Emergency Management Plan provides flood related emergency measures.	Existing measures thought adequate. Participated in Flood Reduction Program 1989	Moderate	The flood of 1988 is identified to have been particularly destructive as the dyke constructed to minimize flooding failed due to debris jams along the creek. In response, a debris trap was built along the creek and in turn the most recent flood in 2011 was relatively minor
Municipal District of Opportunity	3,061	1984	Yes	Hamlet of Wabasca Desmarais	No other communities identified	N/A	No flood damages since 1984. The highway was raised to avoid damage. No evacuations or other property damaged.	No damages reported.	Highway 754 was raised and flood damage is no longer an issue.	None planned	Very Low	No flooding issues in the County (Hamlet of Wabasca Desmarais) since Highway was raised.
Lac La Biche County	12,200	None	No	None	None	No	None	None known	None	None needed	No risk	The County reviewed their records and they did not find any instances of flooding.
Regional Municipality of Wood Buffalo (excludes Fort McMurray urban area)	55,033	No recent reliable information	Yes	Conklin	Draper (though no history of any flooding reported)	No	Highway 881 as a result of heavy rainfall in Morris Creek and Christina River	No recent reliable information	Land Use Bylaw includes restrictions on development within the floodplain. Emergency Management Plan provides flood related emergency measures.	No recent reliable information	Very Low	Conklin experiences high water levels during periods of heavy rainfall (specific areas of concern include around the Jackfish River Bridge where the river feeds Christina Lake)

Athasbasca River Basins Municipal Stakeholders - Flood Summary Table

Municipality	Pop`n	Flood Years	History of Urban Flooding	Communities Affected by Past Flooding	Communities at Risk of Future Flooding	History of Agricultural Flooding	Infrastructure Affected by Past Flooding	Flood Damages	Existing Flood Mitigation Measures	Planned and/or Proposed Flood Mitigation Measures	Future Flood Damage Potential	Other Comments
Fort McMurray urban area	61,374	2013, 1997, 1993, 1986, 1978, 1977, 1972, 1963, 1962, 1936, 1928, 1925, 1885, 1881, 1875, 1835	Yes	Fort McMurray	N/A	N/A	Several structures in Fort McMurray: Keyano College; includes the Athletic & Wellness Syncrude Centre at Keyano College; sportsfields and parks	2013: Applied for $25 million from the Disaster Recovery Program for repairs to municipal infrastructure	Earth dyke across the west end of the Syne at the Athabasca River. A dual function ring road and dyke and flood proofing are being implemented for protection against 1:40 year floods. Land Use Bylaw includes restrictions on development within the floodplain. Emergency Management Plan provides flood related emergency measures.	RM now considering improving dual function ring road and dyke to protect against 1:100.	High	Flooding has mainly been a result of ice jams in the Athabasca River. Fort McMurray witnessed a significant flood in 2013 as a result of heavy rain fall and subsequent high flows in the Hagingstone River.
Northern Sunrise County	2,525	None in past two years	No	None	None	No	None	None known	None	No	No risk	For the portion of the municipality within the Athabasca Basins, there has been no history of flooding.
MD of Smoky River	2,459	2013, 2011, 2008, 2007, usually every two to three years	No	None	None	Yes	2013: culverts, bridges and roads	2013: Applied for $2 million from the Disaster Recovery Program for the entire municipality. Note that only a small portion of the municipality is within the Athabasca Basins boundary	Land Use Bylaw includes restrictions on development within the floodplain. Emergency Management Plan provides flood related emergency measures. For portion of municipality within Athabasca Basins boundary, a canal and weirs between Winagami Lake (within Athabasca Basins) and Kimiwan Lake (outside of Athabasca Basins)	No	Low	Only Maurice Lake and Winagmi Lake are within the Athabasca Basins Boundary. A canal and weirs were constructed in the 1960s between Winagami Lake (within Athabasca Basins) and Kimiwan Lake (outside of Athabasca Basins) to consolidate the water in the area. Water can flow either direction between the Lakes. The 2013 flood affected infrastructure and agricultural land southwest of Winagmi Lake and north of Maurice Lake.
Brazeau County	7,201	No recent reliable information	No recent reliable information	None	None	No recent reliable information	No recent reliable information	No recent reliable information	No recent reliable information	No recent reliable information	No recent reliable information	Cynthia and Lodgepole are within the Athabasca Basins but are not located on rivers or creeks
Sturgeon County	19,578	No recent reliable information	No recent reliable information	No recent reliable information	No recent reliable information	No recent reliable information	No recent reliable information	No recent reliable information	No recent reliable information	No recent reliable information	No recent reliable information	There are no population centres located within the Athabasca Basins boundary
Parkland County	30,568	None	No	None	Entwistle	No	None	None known	None	No	Very Low	The potential for flooding of the Hamlet of Entwistle is very low as it is setback away from and on an higher elevation than the Pembina River floodplain.
Thorhild County	3,417	1982 or 1978	No	None	None	Yes	None	Unknown	Water management projects such as the widening of ditches, removing debris and constructing drop structures	No	Very low	Between 1980 and 1985 received licences and funding from Province to implement water management projects which significantly reduce potential flooding. Note that only the northern portion of the municipality is within the Athabasca Basins boundary.
ID 12 (Jasper National Park)	34	None in past two years	No	None	None	No	None	None known	None	No	No risk	The CAO did not recall any flooding in the past two years
ID 24 (Wood Buffalo National Park)	590	None in past two years	No	None	None	No	None	None known	None	No	No risk	The CAO did not recall any flooding in the past two years
ID 349 (Cold Lake Air Weapons Range)	0	None in past two years	No	None	None	No	None	None known	None	No	No risk	The CAO did not recall any flooding in the past two years
ID 25 (Willmore Wilderness)	0	None in past two years	No	None	None	No	None	None known	None	No	No risk	The CAO did not recall any flooding in the past two years

Key highlights from the consultations with the 34 municipalities include the following:

- The population of Fort McMurray (61,000) and the surrounding Municipal District of Wood Buffalo (55,000) accounts for one third of the population of the entire Athabasca River Basin geography.
- Eleven (11) municipalities experienced past urban flooding.
- Nine (9) experienced rural land flooding.
- All municipalities have non-structural flood mitigation practices (land use by-law development regulations).
- Historical urban flood areas have some level of mitigation infrastructure in place (dykes, channel improvements, bank stabilization, etc.).
- The most significant recent historical flood damage reported was in Fort McMurray related to 2013 flooding. The municipality is applying for $25 million from the Alberta Disaster Recovery program to repair damaged infrastructure.
- Other flood-related municipal damages typically reported in the survey process ranged from $1 million to $2 million primarily for road and bridge repairs. Very few flood-related damages were reported for municipal facilities.
- Based on the results of the surveys and discussion with the 34 municipalities, the level of risk for future flood damages were evaluated for each municipality. The risk levels are summarized as follows:
  - No Risk: 9 municipalities
  - Very Low Risk: 9 municipalities
  - Low Risk: 10 municipalities
  - Moderate Risk: 2 municipalities (Town of Whitecourt and Town of Slave Lake)
  - High Risk: 1 municipality (Fort McMurray)
  - No recent reliable information: 3 municipalities

Based on the results of the Municipal Stakeholder engagement process, there are only three municipalities with a moderate or high risk for damages arising from flooding across the Athabasca River Basin. These communities are Fort McMurray and the towns of Whitecourt and Slave Lake.

3.1.1.3 External Stakeholders

External stakeholders are considered those groups and organizations that have an interest in flood and water management-related policies and activities within the Athabasca River Basin. These groups include Alberta government ministries such as: Alberta Environment & Sustainable Resources (ESRD); Infrastructure; Alberta Emergency Management Agency; Alberta Transportation; and others. Organizations with a focus on water resources and management of water as a public resource include the Athabasca Watershed Council (AWC), Ducks Unlimited, Trout Unlimited and Alberta Water SMART were also contacted.

The objective of the external stakeholder engagement process was twofold: 1) to obtain additional flood-related historical information and mapping; and 2) to determine any planned or proposed future flood mitigation strategies within the Athabasca River Basin.

The survey for external stakeholders consisted of only four questions designed to determine areas at risk of flooding, known mitigation measures and future high risk areas. The survey was

distributed to external stakeholders twice by email with follow-up phone calls made to encourage completion of the survey. The list of external stakeholders is included in **Appendix B**.

The key results of the survey of external stakeholders include the following observations and results. **Exhibit 3.3** is the summary table of the results of the survey process with the external stakeholder group:

- 12 Stakeholders (excludes the Flood Recovery Task Force itself, First Nations groups and the municipalities contacted individually).
- A total of 8 groups responded to the request for information.
- As expected, the communities of Fort McMurray, Whitecourt and Slave Lake were identified by Infrastructure and ESRD as locations of moderate to high risk of flood damages.
- The ministry of Culture identified Fort McMurray as a flood risk – but not for any government-owned facilities. The 2013 flood damaged a local museum that is run independently of government.
- No significant proposed or future mitigation projects were cited by the stakeholder respondents.
- No infrastructure-owned or operated facilities were determined at risk of flood damages today.
- TransAlta (the major utility company), does not consider any of their infrastructure or facilities located in the Athabasca River Basin to be at risk of flooding.

3.1.1.4 First Nations

Significant effort was applied to provide First Nations and Métis Settlements groups with the opportunity to contribute their knowledge of past flooding events and existing and potential mitigation measures. IBI Group worked collaboratively with Flood Recovery Task Force liaisons and with the ESRD Aboriginal Lead. These individuals assisted with the identification of contacts and a desire to more fully participate in discussions with these groups.

A large number of potential First Nations and Métis Settlements stakeholders were initially identified by Flood Recovery Task Force liaisons and with the ESRD Aboriginal Lead. This large list of possible stakeholders required that a 'filter' process be applied to concentrate engagement efforts on those stakeholders who have experienced flooding in the past and those whom were most at risk of being affected by flood damages to built infrastructure. The filters applied to the stakeholder initial list of contacts for inclusion included the following criteria. That is, those First nations which have not experienced past flooding, and for whom had: 1) less than 50% of land in the basin; 2) no reserves (settlements) in the basin; or, 3) for those with reserves, that these settlements are located more than 1 km from a major river or lake.

A process of emails informing the stakeholders of the process, the survey distribution and telephone interviews was undertaken over a 3 week period.

In total 18 First Nations stakeholders were determined for interviews and survey participation (see **Exhibit 3.4**). Another 16 groups were identified as interested parties and were informed of the process. The collection of information revealed that only four First Nation contacts were affected by past flood events. Additional effort by IBI Group was made in these instances to give these four groups the opportunity to discuss past flooding experiences and resulting damages.

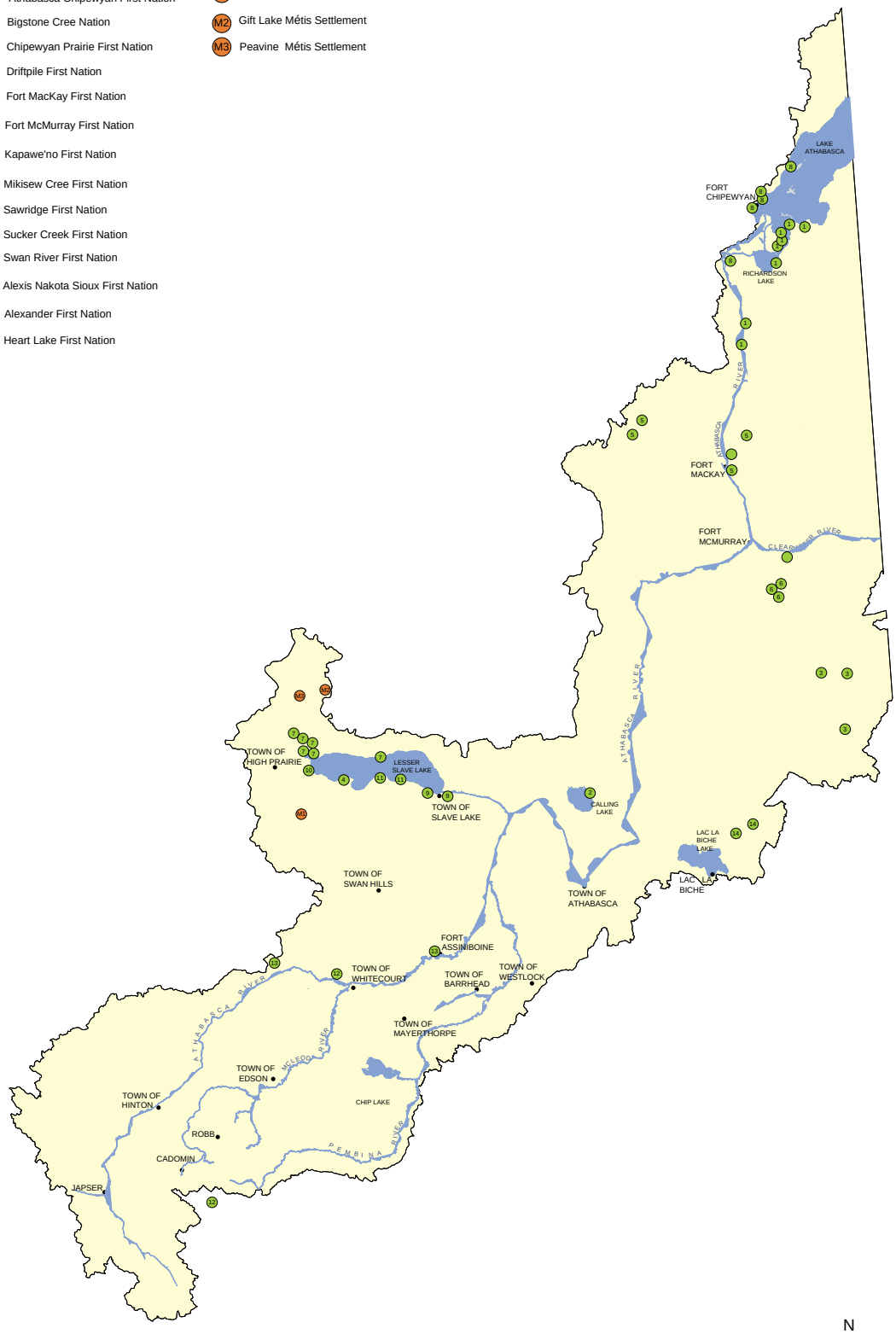
External Stakeholders Survey Results - Athabasca River Basin Feasibility Study

No.	Stakeholder	Contact Information	Rationale for Selection as Stakeholder	Survey Comments
1	**Alberta Environment & Sustainable Resource Development (ESRD)**	**Garry Bucharski** (Joe Prusak, Edmonton - member of AWC) **Rick Friedl - Head of Central Northern Operations Infrastructure (403) 340-7696**	Future responsibility for construction, maintenance, operations of mitigation measures	Key communities of concern for flooding damages are: Whitecourt, Slave Lake and especially Fort McMurray. Do not recommend protection for flooding that results in agricultural damages. No new mitigation projects planned. Focus of upcoming flood mitigation spending is on upgrade and renewal to existing infrastructure.
2	**Athabasca Watershed Council (AWC)**	**Ms. Jen Nicole Landry**, General Manager (780) 865-8223; jnlandry@awc-wpac.ca	Provides info regarding overall understanding of the watershed and concerns & opportunities	Concerned most with Fort McMurray and high flow levels. Concerned that gravel extraction near Fort Assiniboine could increase risk of flooding by damaging local berms. AWC's historically have not taken a position regarding flood prevention.
3	**Alberta Transportation**	**Stephanie Williston**, Manager, Stakeholder Relations, 780-638-1133 stephanie.williston@gov.ab.ca	Responsible party for safe transportation and repair of road damage occurring from flood events	Did not participate
4	**Alberta infrastructure**	**Mr. Mike Ross** (780) 460-4928 Director, Properties Division referred by **Scott Beeby**, Director, Northern Land Development, 780-422-7491 scott.beeby@gov.ab.ca	Source of information regarding flood damages and risk areas	None of Alberta Infrastructure properties have ever experienced damages resulting form flooding of the Athabasca River
5	**Alberta Emergency Management Agency - Municipal Affairs**	**Dave Galea** - Public Safety Initiatives - Municipal Affairs (780) 422-9000 dave.galea@gov.ab.ca	Potential additional source of flood damages information	Fort Chipewyan/Fort McMurray, Edson to Leduc; West Central Northwest and North Central areas received past funding from the Disaster Recovery Program
6	**Alberta Water SMART**	**Ms. Kim Sturgess**, CEO	Consultants for water management initiatives	Did not participate
7	**Ducks Unlimited**	DUC's **Michael Barr** 780-608-8104 m_barr@ducks.ca	Waterfowl habitats and source of local knowledge and their priority areas for future habitats	Did not participate
8	**Trout Unlimited**	**Rick LeBlanc** Northern Lights Fly Tyers 780-637-6706 www.NLFT.org	Waterfowl habitats and source of local knowledge and their priority areas for future habitats	Did not participate
9	**Alberta Culture - Historical Resources Management**	**Catherine Whalley**, Executive Director, Historical Resources, 780-431-2306 catherine.whalley@gov.ab.ca	Potential additional source of flood damages information	No Alberta government-owned or operated facilities at risk. However, local museum in Fort McMurray sustained flood damages in 2013. No other areas or facilities known to Culture identified for this river basin.
10	**Alberta Agriculture Food & Rural Development - Water Division**	**Marshall Eliason**, Manger, Rural Water Program, 780-427-4615 marshall.eliason@gov.ab.ca	Potential concerns expressed regarding water sources; overland drainage or erosion of banks	No information to contribute to study
11	**Alberta Tourism Parks and Recreation**	**Norbert Raffael** Operations Manager (780) 623-5481; **Andy VanImschoot,** Regional Director, West Central 1-780-960-8170 Andy.VanImschoot@gov.ab.ca	Source of information for sites under their management that have experienced flooding.	No knowledge of any Parks or Tourism infrastructure affected by flooding within the Athabasca River Basin.
12	**Utility Companies - TransAlta**	**Mr. Roger Drury** - Hydro Engineering Group; **Laura G. Arnold**, Government Affairs Advisor Ph: 403-267-2584 | Cell: 403-816-0465 | Email: laurag_arnold@transalta.com TransAlta Corporation Calgary, Alberta	Provide future plans for infrastructure in the basin. Provide information on property and infrastructure they own in flood risk areas	No infrastructure concerns in Athabasca River Basin

First Nation and Metis Settlements

LEGEND

- 1 Athabasca Chipewyan First Nation
- 2 Bigstone Cree Nation
- 3 Chipewyan Prairie First Nation
- 4 Driftpile First Nation
- 5 Fort MacKay First Nation
- 6 Fort McMurray First Nation
- 7 Kapawe'no First Nation
- 8 Mikisew Cree First Nation
- 9 Sawridge First Nation
- 10 Sucker Creek First Nation
- 11 Swan River First Nation
- 12 Alexis Nakota Sioux First Nation
- 13 Alexander First Nation
- 14 Heart Lake First Nation
- M1 East Prairie Métis Settlement
- M2 Gift Lake Métis Settlement
- M3 Peavine Métis Settlement



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Feasibility Study - Athabasca River Basins

May 2014

EXHIBIT 3.4

The four affected First Nation groups include:

- Sucker Creek First Nation (residential damages – 3 homes);
- Kapawe'no First Nation (residential damages – 1 home);
- East Prairie Métis Settlement (river erosion damaging roads at three locations); and
- Fort McMurray First Nation (significant flooding in June 2013 in Anzac and Amoco).

In the cases of Sucker Creek First Nation, Kapawe'no First Nation and the East Prairie Métis Settlement the flood damage was constrained to residential properties and road damage. The residences were repaired, moved or some mitigation was undertaken; insurance or the Disaster Recovery Program assisted with this work. The road damage imformation in the East Prairie Métis Settlement has been provided to the Flood Recovery Task Force to identify actions that could be taken to resolve the erosion issues.

In the case of the Fort McMurray First Nation, the information was provided too late in the analysis process to provide recommendations. This information has been provided to the Flood Recovery Task Force to determine what actions could be taken to reduce flood related damages in the future.

3.1.1.5 Future Flood Damage/Potential Risk

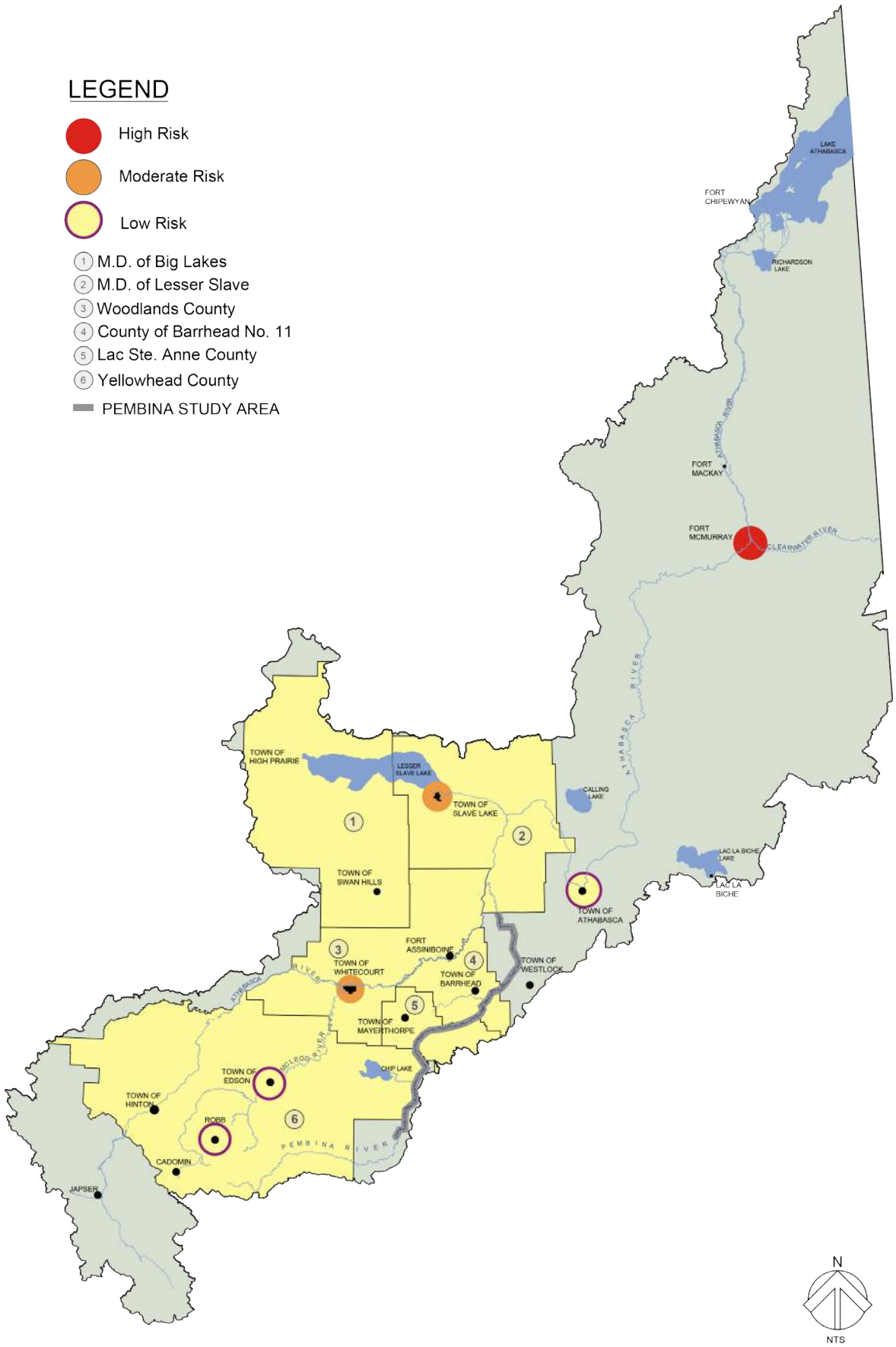
On the basis of the review of background reports and stakeholder interviews the various jurisdictions were assessed with respect to future flood damage potential as high, moderate or low risk (see **Exhibit 3.5**).

- **High Risk**: 1 municipality - Fort McMurray
- **Moderate Risk:** 2 municipalities (Town of Whitecourt and Town of Slave Lake)
- **Low Risk:** 10 municipalities:
  - Town of Edson
  - Town of Barrhead
  - Town of Athabasca
  - Yellowhead County
  - Woodlands County
  - Lac Ste Anne County
  - County of Barrhead
  - M.D. of Big Lakes
  - M.D. of Lesser Slave Lake
  - M.D. of Smoky River

3.1.2 Floodplain Mapping

During the 1990s floodplain mapping was produced for communities throughout Alberta under a federal-provincial initiative known as the Canada-Alberta Flood Damage Reduction Program (CAFDRP). The objective of the program was to identify and map the flood hazard areas in urban communities with a documented history of flooding and to encourage these communities to implement floodplain management practices and policies to regulate future development. The CAFDRP adopted the 1:100 year flood (i.e., a flood event with an average return period of 100 years and a 1% probability of occurrence each year) as the design flood event along with the two zone floodway - flood fringe approach.

Future Flood Damage Potential Risk



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Feasibility Study - Athabasca River Basins

May 2014

EXHIBIT 3.5

The available study reports and hydraulic model files for the following Athabasca River Basin communities included in the CAFDRP were obtained from Alberta Environment and Sustainable Resources (ESRD);Fort McMurray, Slave Lake, Whitecourt, Athabasca, Hinton, Barrhead, Rochester and Sangudo.

3.1.3 Land Use Mapping Within the Flood Hazard Area

Land use data including zoning, ownership and regulations related to development activity within the floodplain were obtained through the appropriate city, town, county or provincial agency jurisdiction.

3.1.4 Historical Flooding

Incidents of historical flooding were noted based on recorded flood events documented in existing floodplain study reports and through the stakeholder interviews.

3.1.5 Disaster Assistance Payments

Records of disaster assistance payments were also obtained for the recorded events where available.

3.1.6 Structural Inventory

Flood affected structures as noted in previous reports were identified and an update of structures undertaken using aerial photography. Determination of class of structure and floor area was detailed separately for each community and varied depending upon the level of information available.

3.1.7 Population “At Risk”

Population “at risk” was determined based on the number of structures and businesses located within the flood hazard area; average household size was determined through municipal census data; and, employment based on standard employee per square foot ratios by business type.

3.1.8 Regulations and Emergency Management Plans

Land use regulations restricting development within the floodplain were noted along with published flood Emergency Management Plans.

3.1.9 Proposed Planning Program/Development and Capital Works

Potential future changes in damages due to increased development within the floodplain were reviewed qualitatively for each community where relevant. In general this analysis refers to zoned vacant land within the floodplain which is available for development.

3.2 Assessment of Flood Damages

3.2.1 Introduction

In a flood event, direct damages can occur both to buildings and infrastructure because of the inundation (hydrostatic effects) and action of the moving water (hydrodynamic effects).

For the Athabasca Basins Study, direct flood damages to residential dwellings includes both content and structural damages as well as the internal clean up costs. Flood damages for commercial properties includes damage to inventory, equipment, and buildings in addition to

clean up costs. As with the residential component, these damages are generally calculated separately for contents and structures.

The commercial structures, due to the nature, range, and diversity of business, do not demonstrate the same uniformity in terms of damage per unit as residential structures. Consequently, categorization is a much more complicated procedure, and the grouping of similar functions for the purposes of estimating flood damages is done in order to maintain study costs within economic reason.

In a first principles approach, damages for residential and commercial/industrial units are estimated employing synthetic depth-damage curves developed for general usage in Alberta. These curves are based on a statistical sampling of structures in Fort McMurray and Calgary. On an ongoing basis, curves are indexed to current values employing Consumer Price and Construction Cost Indices ratios that allow for the conversion of the original values to present values. In the current study, detailed damage estimates previously developed for communities within the Athabasca Basins were updated by prorating the values employing the previously identified indices.

Where available, relevant aerial photography allowed for updating of the structural inventory within the flood risk areas.

Flood events also cause indirect damages. These damages generally include such things as costs of evacuation, alternative accommodation during the flood event, loss of wages and business income due to disruption of business establishments and transportation routes, administrative costs, flood fighting costs, general inconvenience, and general clean up.

Finally, and most importantly, flooding may represent a threat to human life and well-being, not only for those residing directly within the floodplain but also for those individuals who may work within the area as well as those volunteers who are involved in flood fighting activities (see **Exhibit 3.6**).

3.2.2 Flood Elevations

Flood elevations are generally obtained by one of the following methods:

- Direct measurements taken during an actual flood event.
- Highwater mark surveys taken after the flood peak has passed.
- Recorded levels at Water Survey of Canada Hydrometric stations.
- Computed by numerical computer models that have been developed to simulate flows in river and stream channels and across floodplain (overbank) areas.

The primary source of flood elevation data for this study was the ESRD River Forecast Centre (RFC).

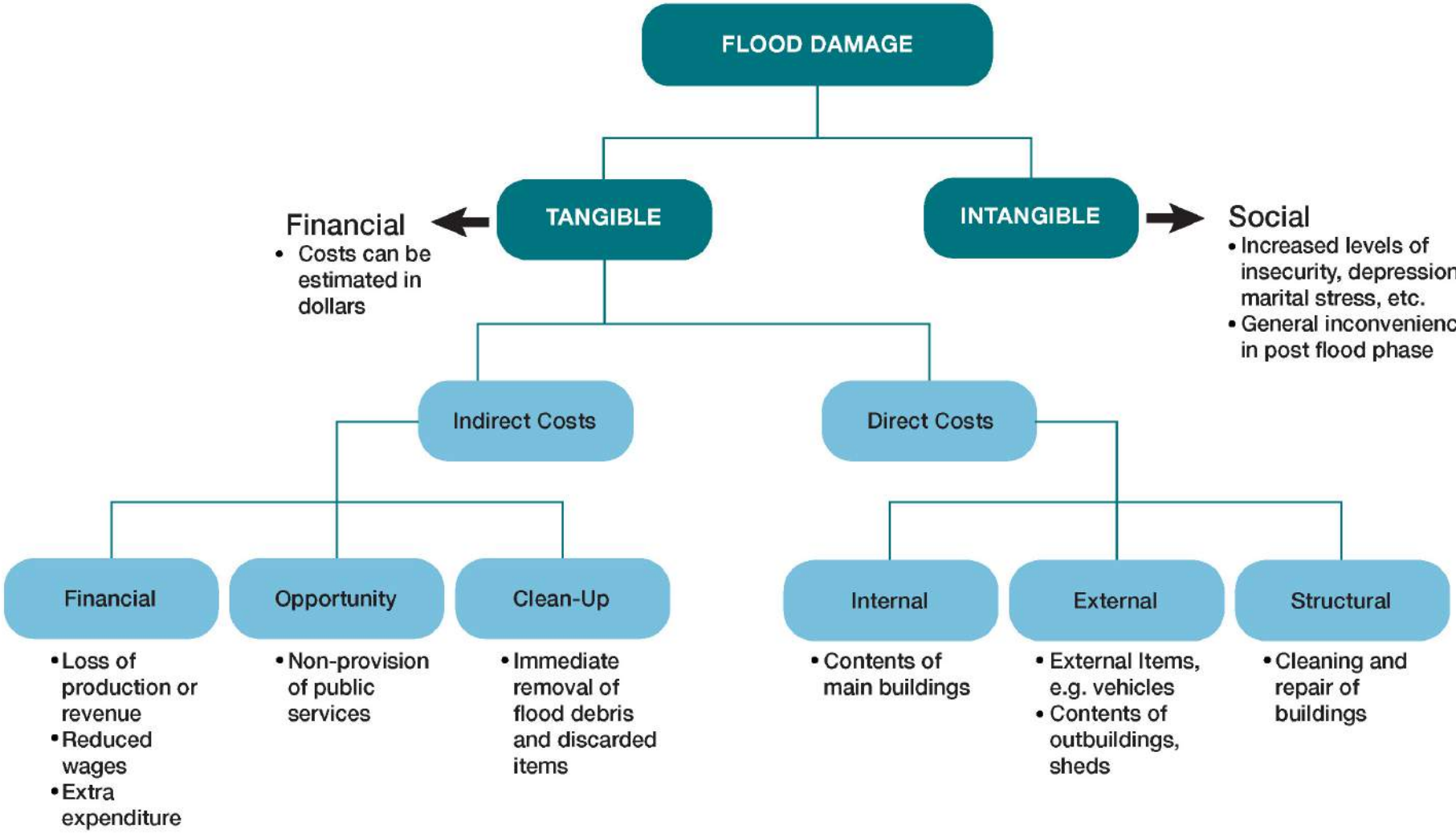
3.2.3 Floodway/Flood Fringe

The accompanying exhibit (see **Exhibit 3.7**) describes the criteria employed in defining the floodway/flood fringe and adjacent-to area. The floodway is typically defined as the area of deepest and fastest flows, with the flood fringe being that area within the overall floodplain which may suffer only shallow flooding and consequently may accommodate development with the provision that there is floodproofing.

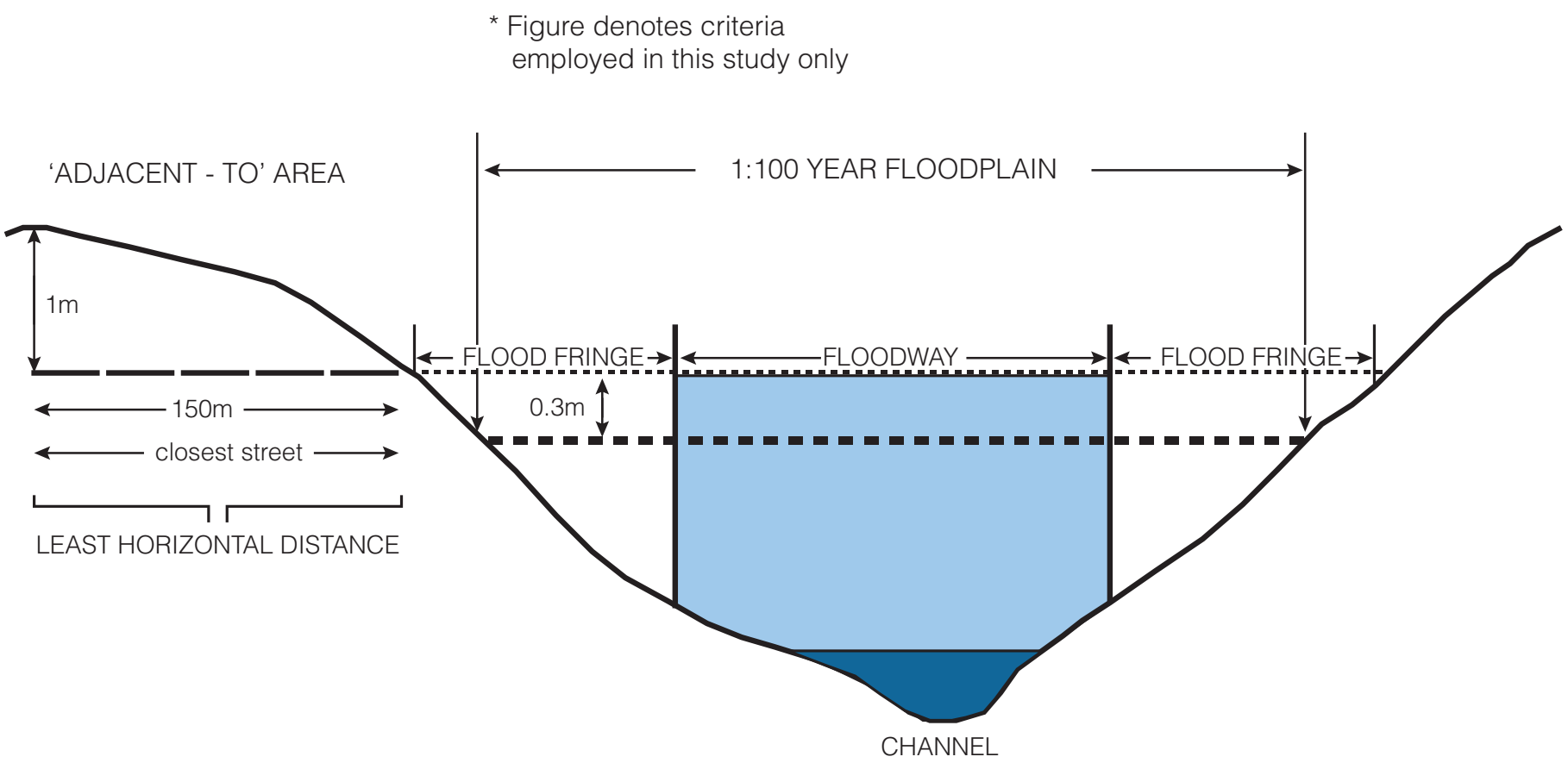
3.2.4 Adjacent-To Areas

Areas outside the floodplain can be subjected to basement sewer backup flooding, primarily through seepage of floodwaters into the sanitary sewer system. To account for this potential flood damage, an adjacent-to area was delineated based on a distance of two dwelling units or

Types of Flood Damage



Floodway - Flood Fringe Delineation



For the purpose of this study, the floodway is defined as:

1) the stream channel and that part of the floodplain required to convey the 1:100 year flood without raising the 1:100 year water surface elevation more than 0.3 m.
2) lies at a depth greater than 0.7 m below the 1:100 year water surface elevation.

±150 m from the 1:100 year flood line. Essentially, with the sewer backup condition, basements which are lower than the floodwaters will automatically suffer damages. **Exhibit 3.8** depicts this relationship.

3.2.5 Direct Damage Estimates

Direct damage estimates are based upon the synthetic depth-damage curves for structure and contents developed as part of the *Fort McMurray, Flood Damage Reduction Program, Phase IIB, Flood Damage Estimates (1982).* Because these curves were also utilized for subsequent studies, including the *Athabasca River Basin Planning Program* (1988), a consistent method for updating damage estimates could be established. Where previous total damage estimates were not available, a similarly updated curve was applied, again providing comparable figures.

The updates to structural damage totals and depth-damage curves were accomplished by employing a multiplier based on relevant indices. The structural indices included Edmonton construction price for structure type and locational factors provided by Alberta Infrastructure. Content damage amounts were updated according to the changes in the consumer price index for Edmonton. Specific details or other variables are indicated where applicable.

It should be noted that the updated damage estimates using this depth-damage curve may underestimate damages because of changes in household spending and approaches to flood restoration since the original 1982 survey. These changes may have increased the potential damages over this time at a rate greater than the consumer or construction price indices.

There has likely been a significant increase in the number of fully developed basements and household spending on home improvements, electronics, etc. This is evidenced in a 2013 release by insurance provider Aviva Canada stating that the average cost of water damage claims in Alberta rose 109% between 2002 and 2012. The average water damage claim (insurable loss) in 2012 across Canada was $15,500.

The original depth-damage curve also reflected a flood restoration approach that may be less relevant today. A highly detailed and conservative level of repair and restoration was assumed for structure and contents. For example, cleaning and replacing of carpet, repair of drywall to flood line, and reupholstering of furniture were costed. The amount used was the lesser of depreciated cost or restoration. As witnessed in the recent Alberta flooding, current practice would be to remove and replace these goods, only restoring items of particular or unique value.

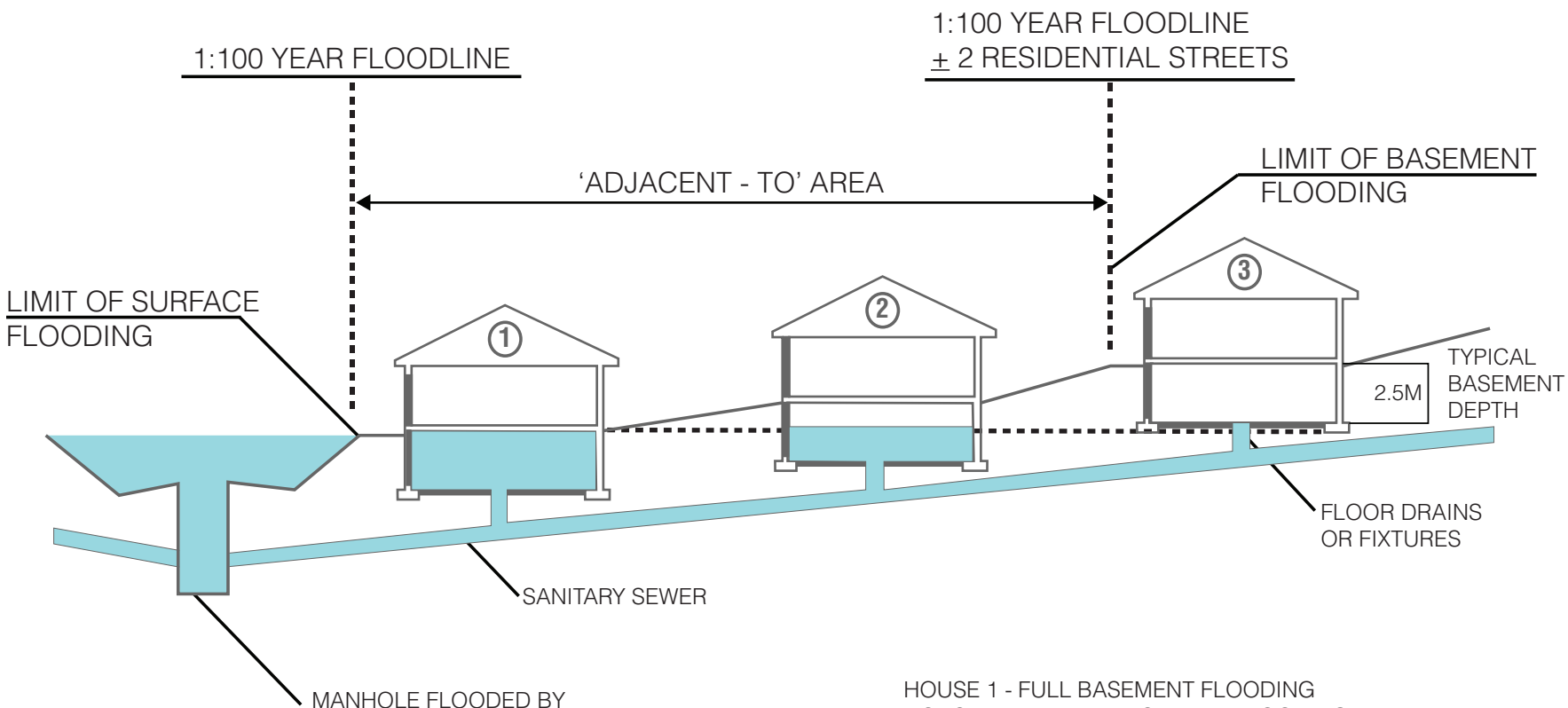
Given the probable significant increase in structure and content values, it would be prudent to conduct an update of the survey. The creation of updated depth-damage curves based on a new survey would be invaluable for estimating future damages in Alberta communities.

3.2.6 Indirect Damages

Indirect damages include such things as costs of evacuation, employment losses, administrative costs, net loss of normal profit and earnings to capital, management and labour, general inconvenience, etc., and are generally calculated as a percentage of direct damages. Values can range from 10% to 45% for specific land use categories but are commonly calculated as being 20% of direct damages. Kates (1965) analyzed a number of studies by the Corps of Engineers to find values of 15% for residential damage, 37% for commercial, 45% for industrial, 10% for utilities, 34% for public property, 10% for agriculture, 25% for highway, and 23% for railroads.

Indirect damages are best evaluated by developing a check list of potential effects and methodically assessing each one. The check list would logically include the amount of use and the duration of interruption of transportation and communication facilities, the number of workers and farmers depending on closed plants and the amount of business lost through a flood emergency. The magnitude of each effect may be estimated by interviewing those affected

Adjacent-To Area Definition Diagram



during recent floods and unit economic values may be assigned by market analysis. Finally, the results may be summed to render a total value for indirect damages.

The complexity of the above evaluation process has led agencies to estimate indirect damages from direct damages based on percentages as discussed previously. The Canada-Saskatchewan Flood Damage Reduction Program uniformly applies an indirect damage calculation of 20% of all categories (combined) of direct damages. This figure is in keeping with guidelines developed by the U.S. Soil Conservation Services who suggest the following ranges for indirect damages:

- Agricultural 5% to 10%
- Residential 10% to 15%
- Commercial/Industrial 15% to 20%
- Highways, Bridges, Railroads 15% to 25%
- Utilities 15% to 20%

The approach employed on the Athabasca Basins Study involved a review of the current situation within the flood study area, i.e., major transportation routes affected by flooding, percentage of industries and businesses affected by flooding, number of residences affected by flooding, and average duration of flooding event and the application of the appropriate percentage.

3.2.6.1 Residential Indirect Damage

The literature surveyed consistently indicates a value of 15% of direct residential damages for computing indirect damages.

3.2.6.2 Commercial/Industrial Indirect Damage

The range in this category is broad and varies from 10% to 45% of direct damages.

3.2.6.3 Utilities Indirect Damage

Values in this category range from 10% to 25% but in general are between 15% and 25%.

3.2.6.4 Highways Indirect Damage

Values in this category range from 10% to 25%.

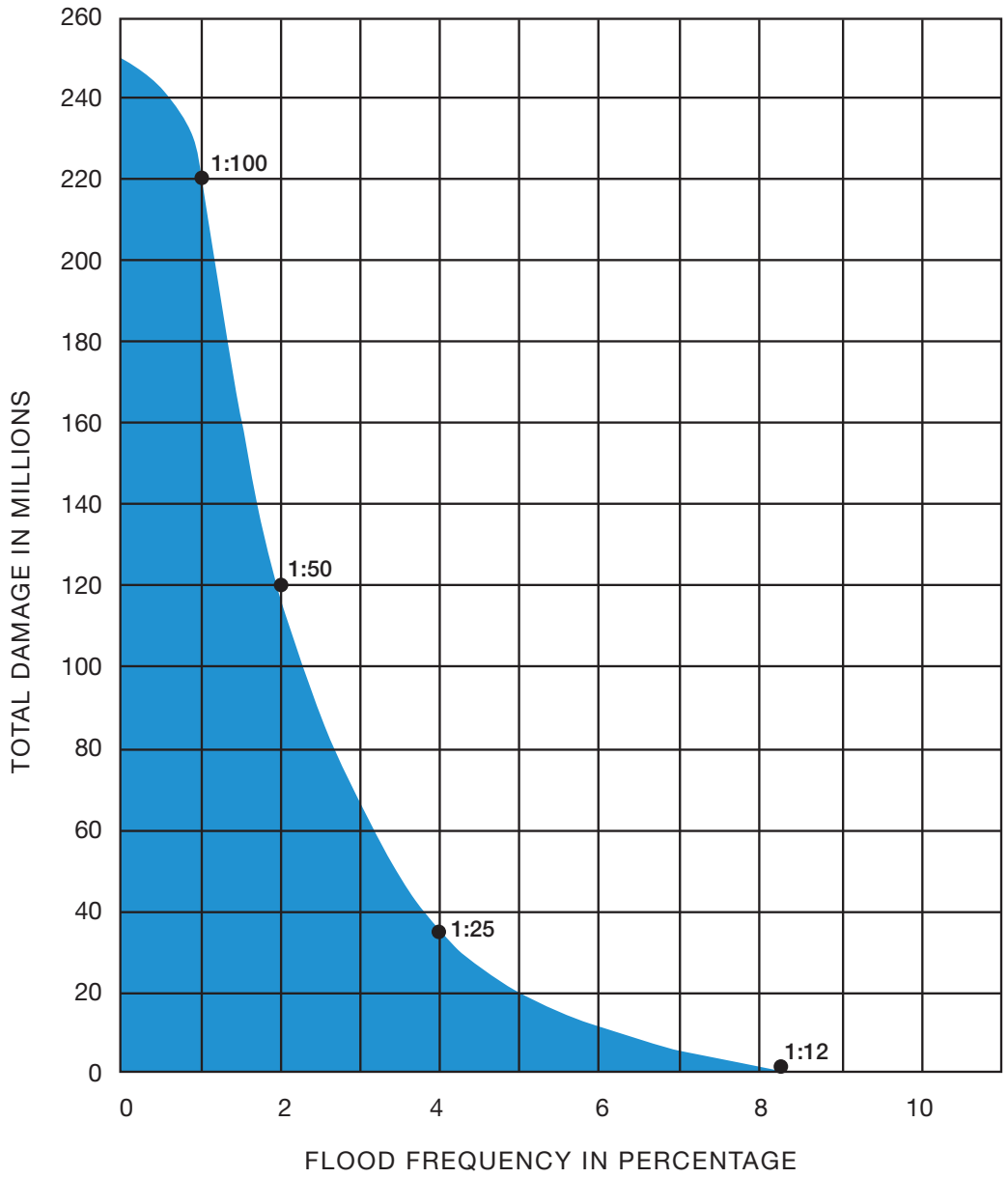
3.2.7 Total Damage Estimates

Total flood damages for each of the return floods (where available) were estimated for each community within the study area employing the methodologies as previously described. These damages include direct damage to residential, commercial/industrial/institutional, utilities/infrastructure and highways, as well as indirect damages.

3.2.7.1 Average Annual Damages

Average annual damages are the cumulative damages occurring from various flood events over an extended period of time averaged for the same timeframe. The average annual damage is obtained by integrating the area under the damage-probability curve which depicts total damage versus probability of occurrence (see **Exhibit 3.9**).

Example of Damage Probability Curve



FLOOD	FLOOD DAMAGE MILLION DOLLARS
1:25	35.0
1:50	118.5
1:100	220.3

AVERAGE ANNUAL DAMAGE
= $5,750,000

3.2.8 Risk Analysis

3.2.8.1 Risk Area

A number of conditions have a direct bearing on the risk factor associated with potential loss of life. These include:

3.2.8.2 Flood Hydrograph

The speed of rise to flood peak is the key consideration. Obviously, the shorter duration, the greater the risk, i.e., summer storm events tend to have a higher peak factor in relation to the duration of the overall flood event whereas snow melt runoff generally has a much slower rise unless occurring in conjunction with an ice jam. A relatively short time from the start of significant flooding to the peak may not allow sufficient time to complete emergency measures activities.

3.2.8.3 Depth of Flooding – 1:100 Year

The deeper the floodwaters, the greater the level of risk posed for both residents and rescue workers alike. Typically, depths between .5 m and greater than 1 m present a higher level of potential risk.

3.2.8.4 Population "At Risk"

The total residential population affected during the 1:100 year event is an important consideration in considering risk. As well, the demographic makeup within the flood hazard area is an additional consideration, particularly if there is a relatively high proportion of elderly people who may require special attention and efforts during the warning and evacuation phases of a flood.

3.2.8.5 Non-Residential Population "At Risk"

Flooding can also potentially expose non-residential populations to risk. In other words, those persons who are employed within the flood risk areas and represent a potentially significant labour force which could be exposed to a potential risk as a result of flooding.

3.2.8.6 Velocity of Floodwaters

The higher the velocity of floodwaters, the greater the level of risk posed for both residents and rescue workers alike. In terms of equating the velocity of floodwaters with risk, a number of agencies including the U.S. Army Corps of Engineers and several states and provinces have adopted, along with depth considerations, a velocity value of greater than 1 m per second, to determine the areas of highest risk within the floodplain.

3.2.8.7 Flood Warning and Emergency Measures

Emergency measures, responsibilities and procedures related to flooding are typically set out in a Municipal Emergency Measures Plan. The plan would outline the primary responsibility of Town crews to protect infrastructure and to evacuate populations "at risk" within the flood hazard area.

3.2.8.8 Transportation Access

Flooding of transportation routes within the flood hazard area is another potential risk to be evaluated as part of a risk analysis. Streets become virtually impassable when inundated with floodwaters between .5 m and 1 m.

3.2.8.9 Nature of Facilities in the Floodplain

Institutional or specialized facilities including hospitals, nursing homes, schools and other public facilities pose an additional level of risk over and above that associated with the flooding event

itself. Typically, very specific procedures are required under the auspices of the Emergency Measures Plan to deal with these situations.

3.3 Preliminary Identification and Assessment of Alternatives

3.3.1 Flood Damage Reduction Alternatives

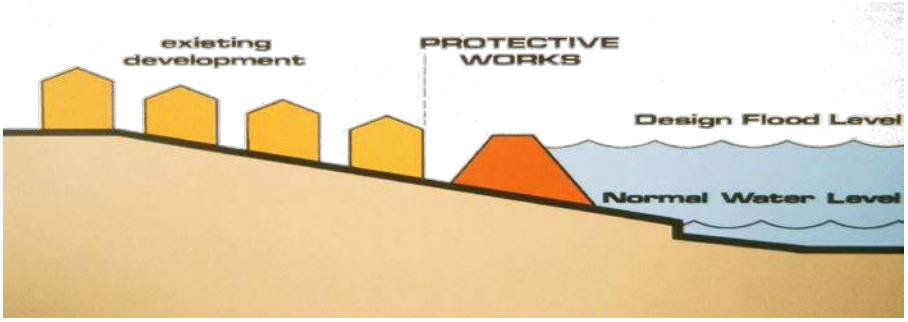
3.3.1.1 General

There are two basic approaches to the problem of reducing flood damages. The first, structural alternatives, consists of methods to control the extent of flooding by construction of dams, reservoirs, dykes or other protective works. The second approach which limits the susceptibility of the developments to flood damages, is effected through a variety of non-structural alternatives, especially land use controls. **Exhibit 3.10** details the various types of flood damage reduction alternatives.

3.3.1.2 Structural Alternatives

Structural alternatives consist of physical works located on or immediately adjacent-to the stream channel for the purpose of confining the floodwaters or reducing the flood stages. Physical structures have been the principal means of flood control in the past. The primary reason for this is that structural solutions can be easily implemented to protect existing development. While these works are effective to the magnitude of the selected design flood, when such floods are exceeded, substantial damages can result. Environmental aspects of structural flood control measures can oftentimes reduce the functional and economic aspects.

Exhibit 3.11 – Structural Alternatives



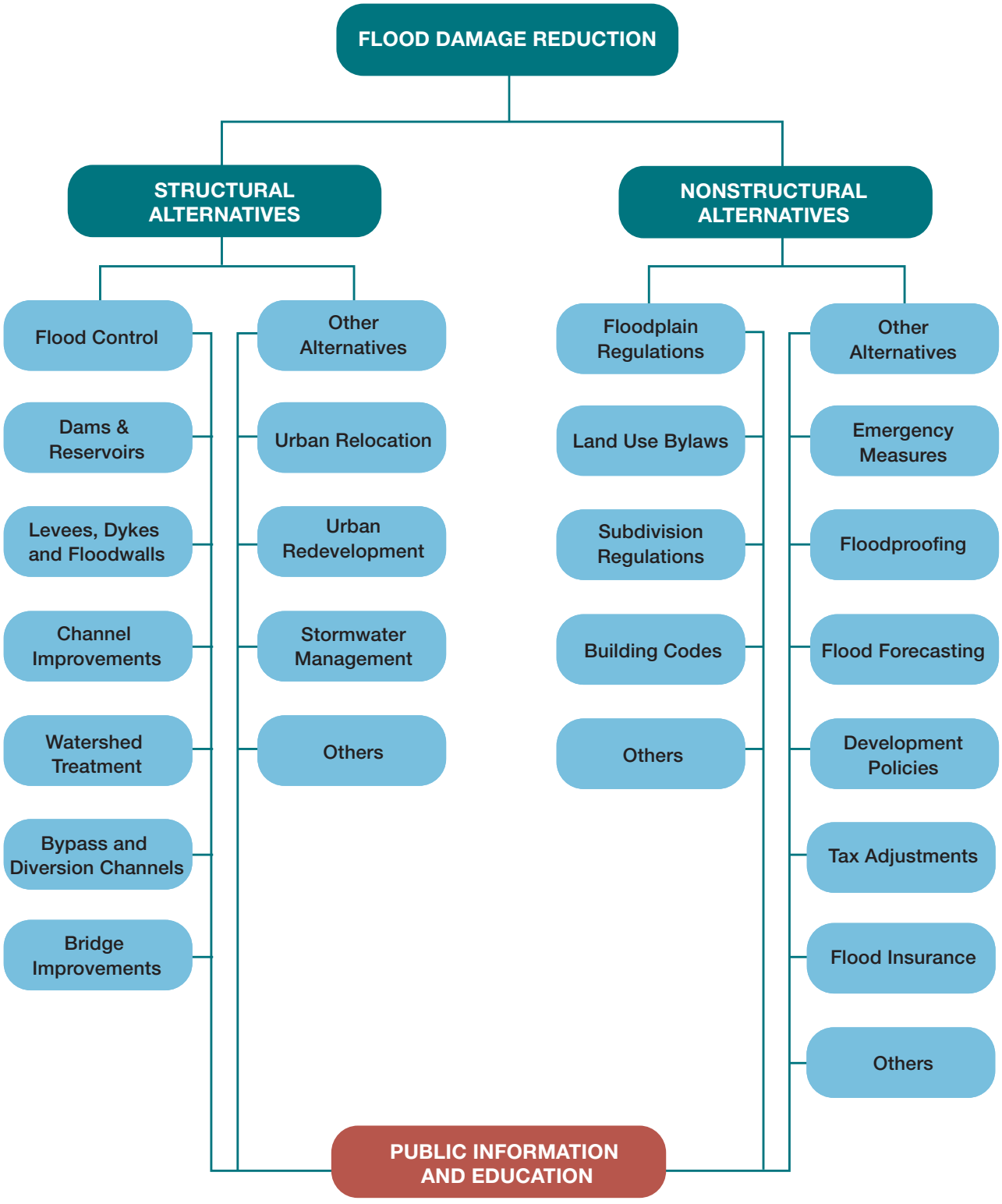
3.3.1.3 Non-Structural Alternatives

Non-structural alternatives to reduce the damages from floods include: floodplain regulations in the form of land use bylaws, subdivision regulations and building codes, floodproofing, flood forecasting, development policies, evacuation and contingency measures, tax adjustments and flood insurance. For the most part, non-structural alternatives are classified as preventive rather than corrective, in that they seek to reduce flood damage by restricting via some form of land use control, development in the floodplain rather than providing protection for existing development.

Exhibit 3.12 – Non-Structural Alternatives



Flood Damage Reduction Alternatives



3.3.2 Development of Selected Mitigation Alternatives

Structural mitigation alternatives were developed where the potential for significant damages was expected to be high and in cases where non-structural measures were likely to be ineffective. Considerations included both the aerial extent of flooding as well as depth-velocity. In some communities, mitigation alternatives had been proposed in the past and where information was available from old study reports, previous designs were revisited and costs updated. In cases where mitigation alternatives had not been previously investigated, various options were considered and conceptual level designs were prepared for those deemed to be best suited to the magnitude of the problem and the specific site conditions.

3.3.3 Evaluation Criteria

Traditional economic analyses of flood mitigation alternatives have generally assumed a straightforward objective of maximizing the net benefits (total benefits minus total costs) that accrue to a project. Society however, has other goals besides economic efficiency. These goals or objectives area the results of outcomes that society desires and have more recently been described as triple bottom line objectives which include considerations of economic, environmental and social impacts. The purpose of multi-objective evaluation is to account for these various goals in the evaluation process. For the purposes of this study, criteria have been subdivided into four basic categories as follows:

- Economic Efficiency
  - project costs
  - net benefits
  - project benefits
  - benefit cost ratio
- Disaster Prevention
  - reduces current losses
  - reduces future losses
  - potential residential loss of life
  - potential non-residential loss of life
- Environment Impact
  - biophysical, social, aesthetic
- Implementation
  - complexity
  - flexibility of integration with other measures
- Incidental Benefits with an Emphasis on Drought Mitigation

3.3.3.1 Economic Efficiency

3.3.3.1.1 Project Costs

Economic costs are simply the estimated direct capital costs required to implement the various alternatives being compared. A common base was employed for the evaluation of economic costs, particularly as it related to structural alternatives. All structural alternatives were designed to provide a 1:100 year flood protection level and a common discount rate of 4% was used. The

discount period was varied in accordance with the anticipated project life of these various alternatives.

3.3.3.1.2 Project Benefits

This evaluation incorporates a comparison of the costs and benefits which are measured in current dollar values. The present value of both benefits and costs was calculated on the basis of the real discount rate for provincial projects (4%) and the anticipated project life. Project cost estimates include the initial or capital cost plus the annual costs for operation and maintenance during the life of the project expressed in present value terms.

Project benefits were measured in terms of the reduction in flood damages to the existing development within the flood study area. Net benefits or present worth was also determined and represents the difference between project benefits and project costs expressed in January 2014 dollars. Project benefits are based on the present worth of total damages averted and include direct, indirect, and highways/utilities damage.

3.3.3.2 Disaster Prevention

3.3.3.2.1 Reduces Present Losses

This equates to an immediate economic benefit in terms of floodplain damage reduction. For example, immediate relocation of dwellings within the flood study area would result in a significant reduction of potential existing damages. Conversely, flood zoning has no immediate effect on the reduction of potential damages in flood prone areas.

3.3.3.2.2 Reduces Future Losses

This criteria evaluates both structural and non-structural alternatives in terms of their ability to prevent future losses. The primary emphasis is on the provision of protection for those areas not yet developed. The greater the potential for preventing future losses, the higher the ranking in the scoring process.

3.3.3.2.3 Potential Residential Loss of Life

When flooding occurs in populated areas, there exists a possibility that human life could be lost, especially if people reside within the floodplain. This possibility was recognized and the potential estimated for consideration in the evaluation process. For any particular alternative, an absolute measure of risk can be estimated as 1% of the average annual number of floodplain residents exposed to flooding. However, for the purposes of this exercise, a qualitative approach was used to compare structural and non-structural alternatives. Alternatives were rated as high, medium or low with respect to potential for loss of life.

3.3.3.2.4 Potential Non-Residential Loss of Life

It is recognized that flooding may result in the loss of lives of those who are accessory to the event. Although it is not possible to describe this potential in quantifiable terms, the evaluation process did provide for a relative rating of the objective from high risk to low risk. This is directly related to the characteristics of the alternatives proposed; i.e., no adjustment and flood regulations are perceived as representing high risk, whereas those measures which contain or divert the flood, i.e., dams and storage structures, would be rated as low risk. Alternatives such as dykes constitute the middle ground in that, although the design flood is contained, there is potential for failure and exceedence of the design flood and hence a medium level of risk.

3.3.3.3 Environmental Impact

3.3.3.3.1 Bio-Physical

In the 1983 study (ECOS 1983), the evaluation of alternatives related the potential direct and indirect biophysical impacts associated with a particular alternative to such things as loss of recreational land, loss of outdoor education potential, and short and long-term disturbances (e.g., erosion, impact on aquatic biota, disruption of fish habitat, removal of vegetation). Regulatory and mitigation requirements were also considered.

For this current feasibility study, the environmental (biophysical) evaluation criteria consider the potential direct and indirect adverse impacts of a project on the existing biophysical conditions, and consider the following parameters:

- environmental sensitivities, including:
    - areas of natural vegetation;
    - fish and fish habitat;
    - species at risk or species of conservation concern and their habitat;
    - soil sensitivities and erosion potential;
    - historic resources and potential for discovery of unknown historic resources; and
    - designated areas (e.g., Parks and Natural Areas, Key wildlife and biodiversity Zones, Environmentally Significant Areas);
- restricted activity periods (i.e., time periods when construction activities are not permitted);
- required mitigation activities (i.e., standard practice, technically and economically feasible); and
- Municipal, Provincial and Federal regulatory requirements (i.e., approvals, authorizations, and compliance requirements).

Details of the approach and project alternative evaluations are provided in **Appendix H** in the draft technical memorandum titled 'Athabasca River Basin Feasibility Study – Description of Environmental (Biophysical) Evaluation Criteria and Environmental Consequence Rankings for Three Proposed Flood Prevention and Mitigation Projects' (Golder 2014c).

Preliminary environmental reviews and environmental consequence evaluations were conducted for projects in municipalities determined to have high (Fort McMurray) or moderate (Town of Slave Lake and Town of Whitecourt) risk for future flood damage potential (see Section 3.1.1.5). Projects in municipalities with low risk for future flood damage potential were not evaluated from an environmental perspective.

3.3.3.3.2 Social

This entails social impact or social disruption other than that created by a flooding event and relates more directly to community disruption and distress brought about by such alternatives as relocation which may sever or significantly alter small insular communities, older established neighbourhoods and long standing residences, etc. An interesting sociological study of the removal of a town from a flood area was done in Shawnee Town in 1942 by Janes who lived there for several months during the project study. A remark from one of his interviews sums up the attitude to moving after the initial emotional response to the flood had subsided; "I am not

going to move ... if you left most of the people around here to themselves, they would not think of moving."[7]

This parameter is expressed in relation to the number of homes (or businesses) dislocated or adversely affected by a particular alternative. As well, it considers temporary disruption during construction activities.

3.3.3.3.3 Aesthetics

Aesthetics, although somewhat subjective, may be analyzed (and quantified) with respect to certain visual experiences, common to high scenic quality in the landscape. Contributing visual experiences stem from interesting viewing opportunities and vistas, significant sight lines and spatial relationships which reflect the salient features (scenic attributes) of a given area.

This parameter involves a relative measure of the impact of a particular alternative on aesthetic quality including potentially improved aesthetics.

3.3.3.4 Implementation

The complexity or ease of implementation category entails a non-quantitative assessment of the relative difficulty of facilitating the various measures. Emphasis is placed on institutional implications and considers among other things:

- mechanisms already in place including existing statutory controls and processes;
- level of awareness;
- jurisdictional problems; and
- additional manpower and facilities required to implement.

3.3.3.5 Incidental Benefits

Certain alternatives may result in benefits non-related to flood damage reduction such as improved aesthetics and environmental quality, the provision or expansion of recreation opportunities, opportunities for local employment, etc. Again this is a relative measurement amongst the various alternatives.

3.3.4 Evaluation Procedure

Alternatives were ranked according to their economic efficiency which was broken down into four basic components: costs, benefits, net benefits, and B/C ratio (see **Exhibit 3.13A** and **Exhibit 3.13B**).

Techniques for the evaluation of social/environmental objectives fall into three categories:

1. monetary evaluation procedures;
2. non-monetary evaluation procedures; and
3. future options approaches.

For the purposes of this study, a non-monetary evaluation technique was employed in which non-commensurables were quantified but not in dollar values. Essentially this method illustrates the relative effects of alternative management strategies on various social/aesthetic/ environmental objectives through the use of a scoring/ranking matrix. The procedure required that qualitative values (ranging from very high to very low) were established for each specific objective to enable a measure of achievement for each alternative in relation to these objectives. Individual objectives are unweighted (each receives equal weighting in the evaluation).

[7] Janes, R.W., *The Collective Action Involved in the Removal and Relocation of Shawnee Town, Illinois*, (Unpublished Ph.D. Dissertation, Department of Sociology, University of Illinois, 1942).

Evaluation Matrix: Commensurable Objectives

ALTERNATIVES	ECONOMIC EFFICIENCY				
	PROJECT COSTS $1,000	PROJECT BENEFITS $1,000	NET BENEFITS $1,000	B/C	RANK
1. Ice Control Structure	81,700	52,802	-28,898	0.65	4
2. Dyking Inside River	28,500	46,112	17,612	1. 62	2
3. Dyking Outside River	20,000	46,112	26,112	2.30	1
4. Channel Improvements	N/A	N/A	N/A	N/A	N/A
5. Storage Crooked Rapids*	710,000	N/A	N/A	N/A	N/A
6. Storage Clearwater	87,300	52,802	-34,398	0.61	5
7. Ring Road and Dyke**	52,200	46,112	-6,088	0.88	3
8. Flood Zoning	N/A	N/A	N/A	N/A	N/A
9. Relocation	365,577	55,833	-309,743	0.15	10
10. Flood Proofing-Fill	332,581	63,048	-269,533	0.19	9
11. Flood Proofing-Foundation	309,487	63,048	-246,439	0.20	8
12. Flood Proofing-Seals & Cls.	137,392	31,681	-105,711	0.23	7
13. Flood Proofing-Seals & Cls.	112,419	31,618	-80,738	0.28	6
14. Downstream Blasting	N/A	N/A	N/A	N/A	N/A
15. Contingency Measures	N/A	N/A	N/A	N/A	N/A

* Medium Head

** Low Growth Scenario

Evaluation Matrix: Non-Commensurable Objectives

ALTERNATIVES	DISASTER PREVENTION				ENVIRONMENTAL IMPACT					
	REDUCES CURRENT LOSSES	REDUCES FUTURE LOSSES	POTENTIAL RESIDENTIAL L.-0.-L.*	POTENTIAL NON-RESIDENTIAL L.-0.-L.*	BIO-PHYSICAL	SOCIAL	AESTHETIC	IMPLEMENTATION	INCIDENTAL BENEFITS	RANK
1. Ice Control Structure	H	H	L	L	H	VL	M	M	M	3
2. Dyking Inside River	H	H	M	M	M	L	VL	L	M	2
3. Dyking Outside River	H	H	M	M	VL	L	VL	L	M	1
4. Channel Improvements	L	L	H	H	H	VL	M	L	L	8
5. Storage Crooked Rapids*	VH	VH	L	L	VH	VL	M	VH	H	4
6. Storage Clearwater	H	H	L	L	H	VL	H	H	M	5
7. Ring Road and Dyke**	L	M	M	M	L	L	M	M	M	6
8. Flood Zoning	VL	M	VH	VH	VL	M	VL	M	VL	9
9. Relocation	VH	VH	VL	VL	VL	VH	L	VH	H	1
10. Flood Proofing-Fill	H	H	L	L	L	H	H	VH	H	6
11. Flood Proofing-Foundation	H	H	L	L	L	H	H	VH	H	6
12. Flood Proofing-Seals & Cls.	M	M	L	L	L	H	H	VH	H	7
13. Flood Proofing-Seals & Cls.	M	M	L	L	L	H	H	VH	H	7
14. Downstream Blasting	VL	VL	VH	VH	L	VL	VL	VL	VL	8
15. Contingency Measures	L	L	L	L	VL	L	VL	M	VL	5

*L.-0.-L.: Loss-of-Life



APPENDIX E

1.0 INTRODUCTION

The primary flood risk in Fort McMurray is associated with ice jam events on the Athabasca River that occur at the confluence with the Clearwater River. Damage caused by ice jam flooding has been recorded as far back as the 1800's. Previous evaluation of flood risk and consideration of flood mitigation measures in Fort McMurray has been focused solely on ice jam flooding.

The recent open water flood on the Hangingstone River, which caused damage in June of 2013, has brought to attention to the open water flood risk that exists along this river in addition to the ice jam inundation risk.

This study re-evaluates the conceptual structural mitigation options available for providing protection from both ice jam and open water floods in Fort McMurray, taking into consideration the additional hydrologic data that has been collected over the years since the previous studies (IBI, 1983 and Trillium, 2000) were conducted and utilizing the latest topographic information to plot flood lines with greater accuracy than was done in the past.

2.0 EXISTING STRUCTURAL MEASURES

Existing structural flood mitigation measures for Fort McMurray are mainly limited to the Snye Dyke, which was constructed in 1966 to shift the ice jam control point on the Athabasca River from "the Snye" approximately 1.5 kilometers downstream to the confluence with the Clearwater River, effectively lowering the ice jam inundation levels along the Clearwater River by one meter.

The City of Fort McMurray is in the process of designing and building 1:100 Year dyke protection for the lower town site. Some stages of construction for this project are underway while engineering studies continue.

3.0 PREVIOUSLY PROPOSED STRUCTURAL MITIGATION MEASURES

Conceptual designs for structural mitigation options have been developed in previous studies. A flood damage assessment and mitigation study was undertaken in the early 1980's IBI (1983). This study looked at structural mitigation options ranging from dyking (most economical) to upstream dams and ice control structures on the Athabasca River. A report by Trillium (2000), focused on a ring road dyke in combination with secondary earth dykes to protect the Lower Town Site and the community of Waterways along the Clearwater River.

4.0 METHODOLOGY

This study made use of previously proposed conceptual designs that are still applicable to flood damage prevention in Fort McMurray after considering any changes in hydrology, hydraulics or development that have occurred since they were first proposed. Modifications or enhancements were made to previously proposed designs as appropriate. The cost estimates from previous studies were adjusted to 2013 prices using cost escalation factors. Cost escalation factors were estimated using available unit cost information provided in previous studies as well as current and historical unit cost information provided by Alberta Transportation.

Cost estimates for previously proposed mitigation structural mitigation measures fall into two categories: lump sum costed options; and options with a more detailed construction cost breakdown.

4.1 Lump Sum Cost Options

Construction cost estimates for previously developed options that do not require any design modifications were considered as lump sum costs and adjusted to 2013 prices using a cost escalation factor. All options that were included in this study without design modifications were reported in 1983 prices in the 1983 IBI flood damages

assessment report. The construction costs for these options were adjusted to 2013 prices using a 1983 to 2013 average cost escalation factor.

4.2 Construction Cost Breakdown

The structural mitigation options related to adding value (increased protection provided by adding freeboard) to proposed dyke projects required modification and cost adjustment.. Many of the added value dyke options considered in this study are modified from designs developed in Trillium (2000). The costs for these options were estimated by applying a 2000 to 2013 cost escalation factor to the unit rates used in Trillium (2000) and applying those escalated unit rates to the modified quantity estimates.

4.3 Cost Escalation Factors

Based on a review of historical unit pricing in Alberta between 1980 and 2013 (provided by Alberta Transportation), average construction cost escalation factors were estimated for converting 1983 costs and 2000 costs to 2013 prices. The 1983 and 2000 cost escalation factors are 3.8 and 2.0 respectively.

4.4 Unit Rates

The 2000 cost escalation factor was used to adjust unit rates used in Trillium (2000) to 2013 prices. A summary of the unit rate adjustment is provided in Table E-1.

Table E-1: Unit Rate Adjustments for Options with Modified Quantity Estimates

Cost Item	Unit	Unit Rate	
		Trillium 2000	Adjusted to 2013
Embankment Fill	m^3	$15	$30*
Land Acquisition	m^2	$35	$70
Landscaping	m^2	$5	$10
Grade Preparation	m^2	$2	$4

*Note: This price includes borrow excavation, hauling, and placement of embankment fill.

5.0 STRUCTURAL MITIGATION OPTIONS

The structural mitigation options considered in this assessment include:

1) Dyke options for added value beyond the current ring road dyke design in development by the City:
   a) Add freeboard to Prairie Loop Boulevard Ring Road Dyke design.
   b) Waterways Dyke; Waterways Dyke and Ptarmigan Trailer Park Dyke.
   c) MacDonald Island Dyke.
   d) Hangingstone Dyke.
2) Ice Control Structure on the Athabasca River.
3) Medium Head Dam on the Athabasca River.
4) High Head Dam on the Athabasca River.

5) Clearwater Dam and Gates.

5.1 Option 1 – Dyke Options for Added Value

The Regional Municipality of Wood Buffalo (the City) is currently in the process of designing and implementing a comprehensive flood protection program for the Lower Town Site and Waterways. Specific information from on-going studies was not available for inclusion in this report, however, a general description of the current plans for dyke construction was obtained through discussions with City engineering staff (informal meeting on March 24, 2014). Based on these discussions, it is understand that the City's long term plan (5 years or longer) is to provide flood protection to the 100-year ice jam level (250.0 m) for the Lower Town Site and Waterways by constructing a series of elevated roadways and earth embankment dykes, the major components of which include:

1. Prairie Loop Boulevard Ring Road (between Hardin Street and Franklin Avenue)
2. Raised roadway between Hardin Street and Main Street
3. Secondary earth embankment dykes west from Main Street to existing Snye Dyke along the Athabasca River, and east from Longboat Landing (at Franklin Avenue) to Highway 63 along the Hangingstone River
4. Saline Creek Parkway from Hangingstone River east past Waterways
5. Ptarmigan Trailer Park Dyke (under consideration – not confirmed by City engineering staff)

The approximate alignments for these planned flood protection measures are shown in Attachment 1, which is a draft figure dated February 28, 2014 from a yet to be finalized report by Northwest Hydraulics Ltd. (NHC). The alignments shown in Attachment 1 are substantially, but not entirely consistent with the description of proposed construction staging provided by City engineering staff. The dyke alignments used for this assessment (shown in Figure E-1) are based on Attachment 1 and the following description of construction staging provided at the March 24, 2014 meeting with City engineering staff:

1. Eastern leg of Prairie Loop Blvd (PLB) between Hwy 63 and Riedel Street is complete as a two lane roadway to an elevation of 248.5 m
2. PLB between Riedel Street and Hardin Street and Saline Creek Parkway from the Hangingstone River east past Waterways are currently being constructed to an elevation of 250.0 m, (planned to be completed within the next two years
3. Planned construction over a two year timeframe includes roadway improvements from Hardin Street west to Main Street (at 250.0m) and Secondary diking from Main Street west to the Snye Dyke (at 250.0m),
4. Planned construction over a five year (possibly longer) timeframe includes rebuilding PLB from Reidel Sreet east to Franklin Ave (at 250.0m) with an option to construct a river pathway dyke along PLB from Reidel Street east to Qween Street. In the river pathway dyke option, PLB would remain at 248.5m as far as Qween Street.

The planned dyke alignments are not entirely continuous because in some cases, such as the section of PLB south of Franklin Ave, new development is to be flood-proofed (landfilled) to 250.0m to be in compliance with the residential flood proofing By-Law in effect since the mid 1990's. This by-law prohibits construction of habitable

space below elevation 250.0 m.. Examples of newer developments built or under construction with main floor at or above 250.0 include:

- River Walk Villa's (Reidel Street at Clearwater R.)
- Longboat Landing and Winchester Landing (east of PLB, north of Hangingstone River and adjacent to Clearwater River)

For the purposes of this assessment, it was assumed that all flood protection measures currently being planned by the City will be completed and only dyke options that would add value to the City's current plans were considered. These options are described in the following sections. Their alignments are shown in Figure E-1.

5.1.1 Option 1a - Add Freeboard to Proposed Dyke System for Lower Town Site

The current dyke system proposed by the City, including the Prairie Loop Boulevard ring road has a top of berm elevation at the 100-year ice jam level (250 m). Option 1a would be to increase the height of the ring road and associated secondary embankment dykes by 1 meter to provide freeboard above the design elevation. The addition of 1 meter freeboard is consistent with the generally accepted engineering standard for dyke construction, which has been adopted for this assessment. The typical cross sections used for the quantity calculations are shown in Figure E-2. The typical cross section for the 4-lane Prairie Loop Boulevard Ring Road Dyke is based on a roadway section provided by the City.

5.1.2 Option 1b – Add Freeboard to Proposed Saline Creek Parkway (Waterways)

The City has initiated construction of an elevated 2-lane roadway dyke (Saline Creek Parkway) along existing Saline Creek Drive (with a top of berm elevation at the 100-year ice jam level (250 m) to protect the Waterways community east of the Lower Town Site along the Clearwater River, where a number of residential properties would be inundated during a 100-year ice jam event. The City is also considering construction an earth embankment dyke with a top of berm elevation at the 100-year ice jam level (250 m) to protect Ptarmigan Trailer Park which is located to the west of Waterways adjacent to the Hanginstone River..

Option 1b includes two sub-options:

- Option 1b-1 would be to add 1 meter of freeboard to the proposed Saline Creek Parkway Dyke only.
- Option 1b-2 would be to add 1 meter of freeboard to the proposed Ptarmigan Trailer Park Dyke as well as Saline Creek Parkway Dyke.

The dyke alignments and typical sections for Options 1b-1 and 1b-2 are shown in Figures E-1 and E-2.

5.1.3 Option 1c – MacDonald Island Dyke

Trillium (2000) developed a cost estimate for building a dyke to protect the recreation center on MacDonald Island with a dyke constructed to a top elevation at the 100-year ice jam water surface elevation (250 m). The quantity estimate for this option was scaled up to account for the additional material and area requirements associated with providing an additional 1 m of freeboard above the 100-year ice jam elevation.

The dyke alignments and typical sections for Option 1c are shown in Figures E-1 and E-2.

5.1.4 Option 1d – Hangingstone Dyke (Greyling Subdivision)

Previous studies focused on ice jam flooding only and did not identify a need for structural mitigation on the Hangingstone River upstream from Highway 63 associated with open water flooding. An open water flood in June 2013, which was estimated to be approximately a 50-year event (see Appendix C), caused flooding along the Hangingstone River. Much of the open water flood risk along the Hangingstone River would be mitigated by construction of the Prairie Loop Boulevard Ring Road Dyke. However, a review of the high water marks measured following the June 2013 event in conjunction with the rating curve for the Hangingstone River and the results of the open water flow frequency analysis, suggest that the neighborhood of single family homes along the Hangingstone River upstream from Highway 63 would potentially be inundated by a 100-year open water flood on the Hangingstone River. The City has indicated they have no current plans for flood protection measures in this neighborhood.

Option 1d would be to construct a dyke with a top elevation of 254 m to provide protection to the 100-year open water event (plus 1.0 m freeboard) on the Hangingstone River. The alignment and typical section for this option are shown in Figures E-1 and E-2.

5.1.5 Quantity Estimate for Added Value Dyke Options

The material and area requirements associated with the added value dyke options are summarized in Table E-2.

Table E- 2: Quantity Estimates for Added Value Dyke Options

Option	Embankment Fill Volume (m^3)	Footprint Area (m^2)
1a	222,005	40,952
1b-1	92,134	20,472
1b-2	98,966	24,672
1c	24,191	10,200
1d	7,000	4,550

5.2 Option 2 – Ice Control Structure on the Athabasca River

It has been proposed that ice jamming potential at Fort McMurray could be controlled by constructing an overflow weir with auxiliary gates to retain ice upstream of Fort McMurray on the Athabasca River. This option has been evaluated by a number of previous studies funded by Alberta Environment in the late 1970's and early 1980's the results of which are summarized in IBI (1983). The conceptual drawings for this option that were included in IBI (1983) are shown in Figure E-3. Reductions of ice jam levels of 1.6 to 4.2 m at the Fort McMurray town site have been estimated for this option though the effectiveness of such a structure is difficult to predict. These reductions in ice jam levels may not be enough to totally eliminate the possibility of 100-year flooding at the lower town site without the addition of dykes.

Thurber (1983) performed a geotechnical investigation and concluded no major geotechnical difficulties are anticipated for the construction of the proposed ice control structure.

Lump sum construction cost estimates for an Athabasca River ice control structure, originally developed by Acres Consulting Services for Alberta Environment in 1980, were escalated to 1983 prices in IBI (1983). A cost escalation factor of 3.8 was applied to the 1983 cost estimate reported by IBI to convert the lump sum cost to 2013 prices.

5.3 Options 3 and 4 – Dams on the Athabasca River at Crooked Rapids

Structural Mitigation Options 3 and 4 are variations of a similar concept: construction of a dam and multi-use reservoir on the Athabasca River about 42 km upstream of Fort McMurray at Crooked Rapids. The primary function of the dam would be to generate hydropower with the secondary objective of flood attenuation and ice retention. Two locations in the vicinity of Crooked Rapids were identified as potential dam sites; one suitable for a medium-head dam (78 m high) and the other for a high-head dam (165 m high). Option 3 would be to construct the Medium Head Dam and Option 4 would be to construct the High Head Dam. The conceptual design drawings for the Medium Head Dam option, developed by Crippen Engineering Ltd and presented in IBI (1983), are shown in Figures E-4, E-5, and E-6.

A Feasibility study for these projects that was completed in 1975 on behalf of Alberta Environment is summarized in IBI (1983). It was noted that both sites have “severe” technical challenges including poor abutment foundation conditions. The technical challenges associated with the Medium Head Dam proposal were believed to be manageable, but the High Head Dam proposal has greater uncertainties associated with its technical feasibility.

As with the Ice Control structure (Option 3), the effectiveness of these dam projects at mitigating Fort McMurray ice jam flooding is somewhat uncertain. The reservoir would certainly provide ice retention and could be used to retain water and reduce flows during the spring breakup period.

Lump sum construction cost estimates for the Medium Head and High Head Dam options at Crooked Rapids, originally developed for the 1974 Alberta Environment study, were escalated to 1983 prices in IBI (1983). A cost escalation factor of 3.8 was applied to the 1983 cost estimates reported by IBI to convert the lump sum cost to 2013 prices.

5.4 Option 5 – Dam and Gates on the Clearwater River

This option, proposed by IBI (1983) involves construction of a dam on the Clearwater River upstream from Fort McMurray to impound the entire flow of the Clearwater River during the spring breakup period. It is estimated that the impounded required to store this amount of water during a 100-year spring runoff period would extend approximately 50 km up the Clearwater River valley. An additional gate structure would be required at the confluence of the Clearwater River and the Athabasca River to prevent ice jam produced floodwaters on the Athabasca River from flowing up the Clearwater River and flooding the lower town site.

The conceptual designs for this option presented by IBI (1983), shown in Figures E-7 and E-8, was based on an estimated 100-year ice jam elevation of 252 m and did not include any freeboard. The 100-year ice jam water surface elevation is now considered to be 250 m. It was decided that proceeding with cost estimates based on a gate structure designed to ice jam elevation of 252 m would provide appropriate freeboard above the 100-year ice jam elevation. This is considered to good engineering practice, especially due to the structures location at the mouth of the Clearwater River, where it may be subjected to dynamic ice forces and local fluctuations in water levels potentially exceeding the 100 year level.

A cost escalation factor of 3.8 was applied to the 1983 cost estimates developed by IBI to convert the lump sum cost to 2013 prices.

6.0 COST ESTIMATE

The cost estimates for the structural mitigation measures in terms of 2013 prices are provided in the attached Table E-3. Contingency and engineering costs were assumed to be 25 percent and 10 percent of construction costs, respectively. Land acquisition costs were estimated for the Added Value Dyke options based on an escalated land acquisition cost of $70 per square meter. Annual operation and maintenance costs were assumed to be 0.5 percent for dyke options and 1 percent for large in-channel structural options.

REFERENCES

ABENV (1993). Review of Flood Stage Frequency Estimates for the City of Fort McMurray Final Report. Technical Services and Monitoring Division. Water Resources Services. Alberta Environmental Protection. November 1993.

IBI (1983). Fort McMurray Flood Damage Reduction Program Phase III-B Preliminary Appraisal of Alternatives.Technical Report and Appendices. Ecos Engineering Services and IBI Group. March 1983.

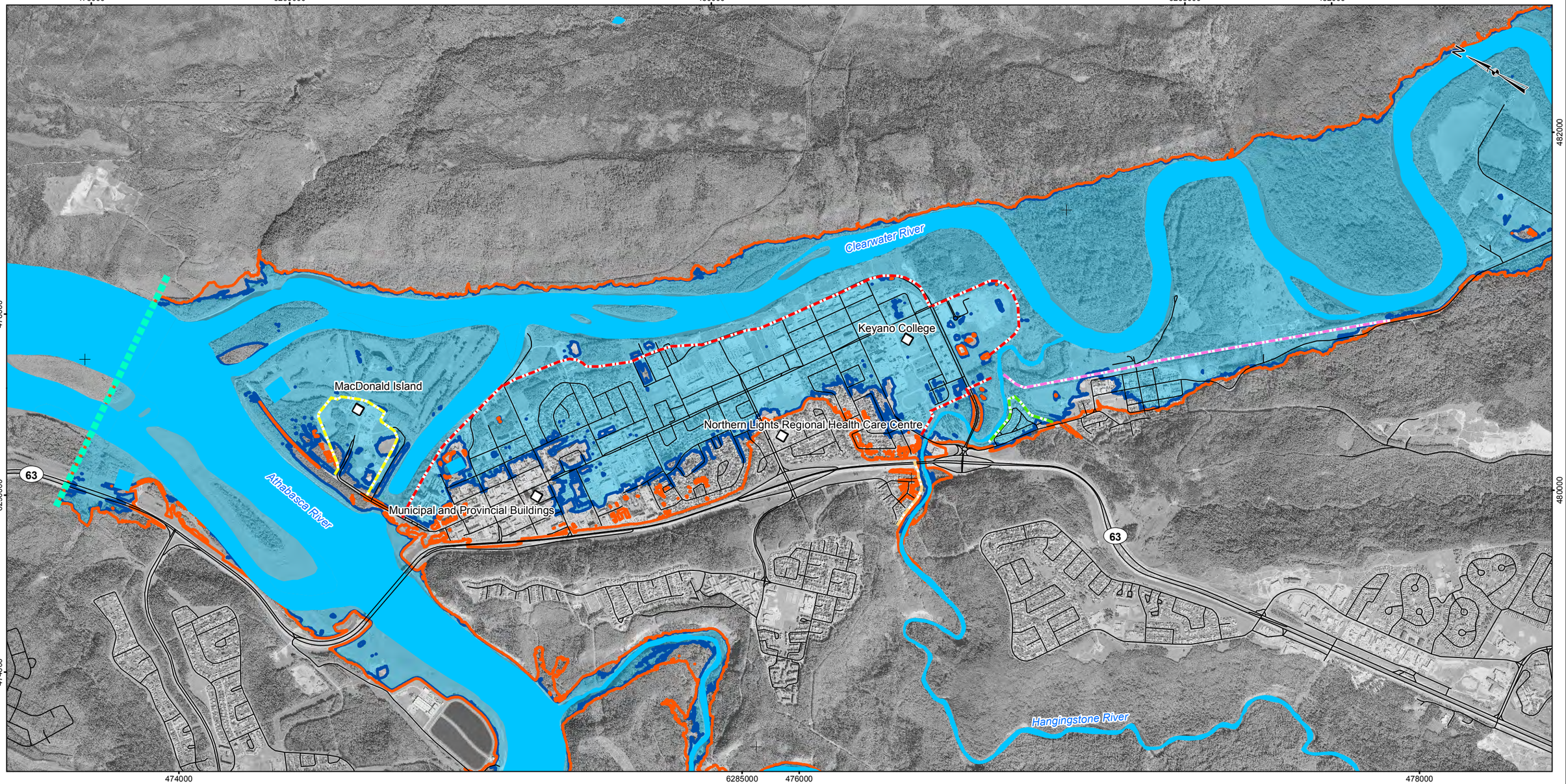
Trillium (2000). An Evaluation of Providing Flood Control at Fort McMurray By A Staged Diking Approach. Trillium Engineering and Hydrographics Inc. Edmonton, Alberta. July 2000.

TABLE

Table E-3: Cost Estimate of Structural Mitigation, Fort Murray

Option No.	Description	Land Acquisition	Construction Cost	Contingency	Engineering	Total	Project Life (Years)	Annual O & M as % of Capital Cost	Operation and Maintenance (Annual Cost 2014)
1	**Dyke Options for Added Value**								
	1a – Add 1.0 m Freeboard to Dyke System for Lower Town Site (above 100 year Ice Jam Level)	$ 2,866,645	$ 7,233,471	$ 1,808,368	$ 723,347	$ 12,631,831	50	0.005	$ 45,209
	1b-1 - Add 1.0 m Freeboard to Saline Creek Parkway (Protect Waterways only)	$ 1,433,039	$ 3,050,614	$ 762,654	$ 305,061	$ 5,551,369	50	0.005	$19,066
	1b-2 - Add 1.0 m Freeboard to Saline Creek Parkway and Ptarmigan Trailer Park Dyke (Protect Waterways and Trailer Park)	$ 1,433,039	$ 6,828,374	$ 1,707,094	$ 682,837	$ 10,651,345	50	0.005	$42,677
	1c - McDonald Island Dyke (Protect new Recreational Complex)	$2,000,000	$3,192,530	$798,133	$319,253	$6,309,916	50	0.005	$19,953
	1d - Hangingstone Dyke (upstream of Memorial Drive)	$500,000	$273,700	$68,425	$27,370	$869,495	50	0.005	$1,711
2	**Ice Control Structure On The Athabasca River**	-	$230,280,000	$57,570,000	$23,028,000	$310,878,000	75	0.01	$2,878,500
3	**Medium Head Crooked Rapids Dam On The Athabasca River**	-	$2,086,200,000	$521,550,000	$208,620,000	$2,816,370,000	75	0.01	$26,077,500
4	**High Head Crooked Rapids Dam On The Athabasca River**	-	$6,764,000,000	$1,691,000,000	$676,400,000	$9,131,400,000	75	0.01	$84,550,000
5	**Clearwater Dam And Gates**	TBD	$310,840,000	$77,710,000	$31,084,000	$419,634,000	75	0.01	$3,885,500

FIGURES



LEGEND

- *OPTION 1a – ADD 1 m FREEBOARD TO PROPOSED DYKE PROTECTION FOR LOWER TOWN SITE*
- *OPTION 1b-1 – ADD 1m FREEBOARD TO PROPOSED SALINE CREEK PARKWAY DYKE*
- *OPTION 1b-2 – ADD 1 m FREEBOARD TO PROPOSED PTARMIGAN TRAILER PARK DYKE*
- *OPTION 1c – MACDONALD ISLAND DYKE TO PROTECT RECREATIONAL COMPLEX*
- *OPTION 1d – HANGINGSTONE DYKE TO PROTECT GREYLING SUBDIVISION*
- ROAD
- ICE JAM AT CLEARWATER RIVER CONFLUENCE
- 1:100 INUNDATION EXTENT-ELEVATION 250.0 m
- HISTORIC MAXIMUM INUNDATION EXTENT - ELEVATION 252.0 m
- OPEN WATER

REFERENCE

HYDROLOGY AND ROAD DATA OBTAINED FROM CANVEC © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED. IMAGERY© GOVERNMENT OF ALBERTA, FISH AND WILDLIFE DIVISION 2005
DATUM: NAD83 PROJECTION: UTM ZONE 12N

500 0 500
SCALE 1:25,000 METRES

PROJECT
Alberta
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ATHABASCA RIVER BASINS FEASIBILITY STUDY

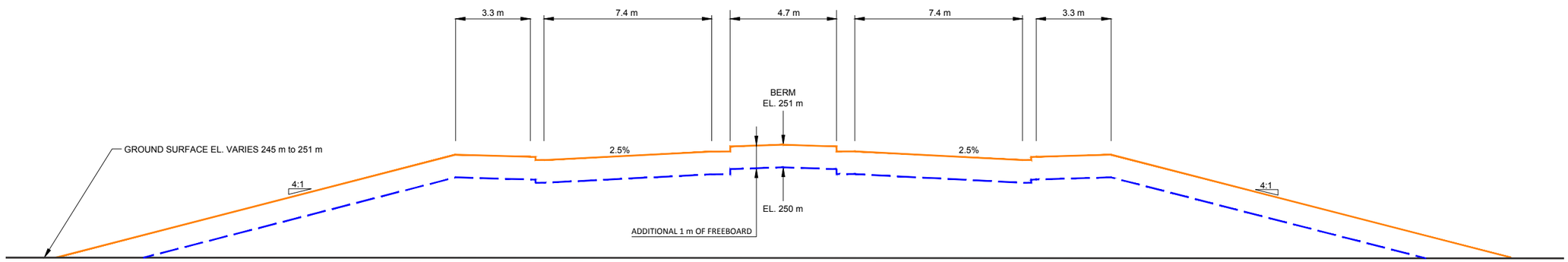
TITLE
FORT MCMURRAY STRUCTURAL MITIGATION OPTION 1 – ADDED VALUE DYKING OPTIONS

Golder Associates
IBI GROUP

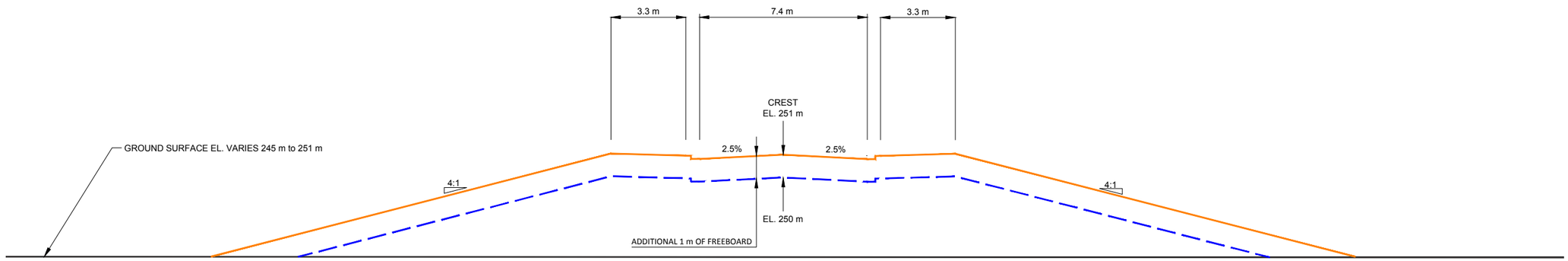
PROJECT	14-1351-0001
SCALE AS SHOWN	REV. 0

FIGURE: E-1

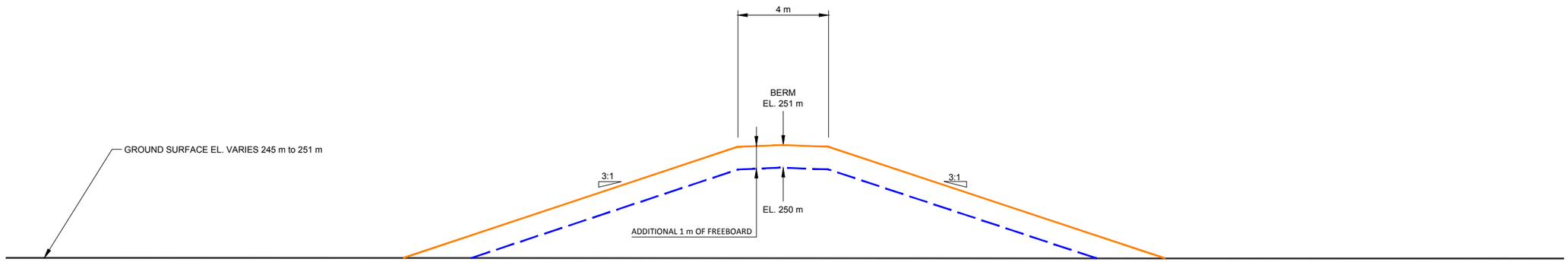
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TYPICAL SECTION FOR PRAIRIE LOOP BOULEVARD RING ROAD DYKE – 4 LANE ROAD



TYPICAL SECTION FOR SALINE CREEK PARKWAY ROAD / DYKE – 2 LANE ROAD



TYPICAL SECTION FOR EARTH EMBANKMENT DYKES

0 5 10
SCALE METRES

LEGEND

- EXISTING GROUND
- PROPOSED DESIGN
- PROPOSED DESIGN WITH ADDITIONAL 1 m FREEBOARD

NOTES

FEATURES WITHOUT DIMENSIONS SHOWN ARE SCHEMATIC ONLY, NOT TO SCALE.

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ATHABASCA RIVER BASINS
FEASABILITY STUDY

TITLE

FORT McMURRAY STRUCTURAL MITIGATION OPTION 1 - ADDED VALUE DYKE OPTIONS TYPICAL SECTIONS

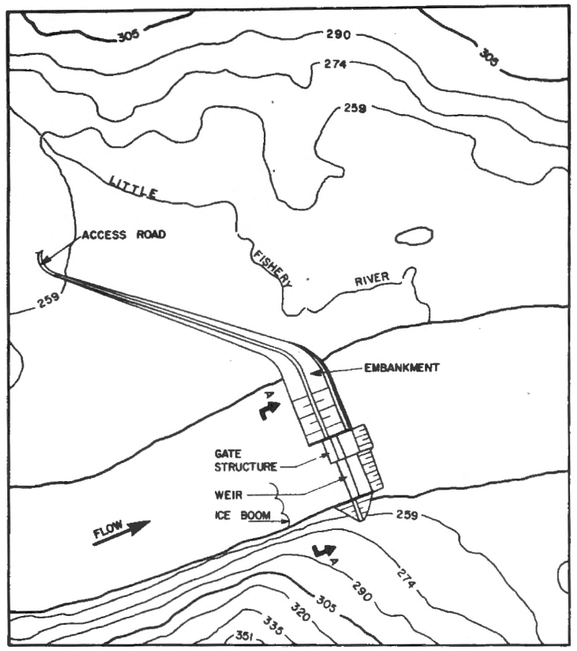
Golder Associates

IBI GROUP

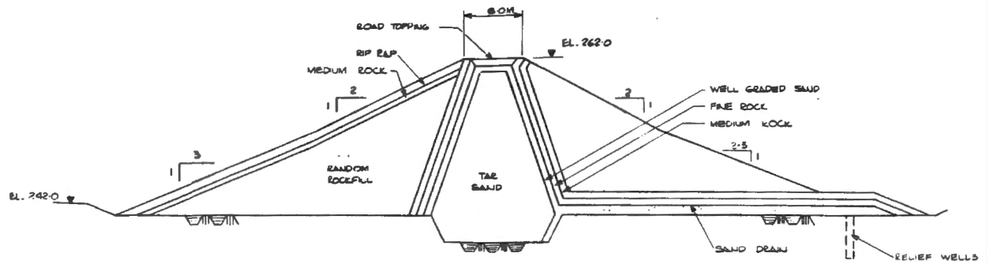
PROJECT	14.1351.1000
SCALE AS SHOWN	REV. 0

FIGURE: E-2

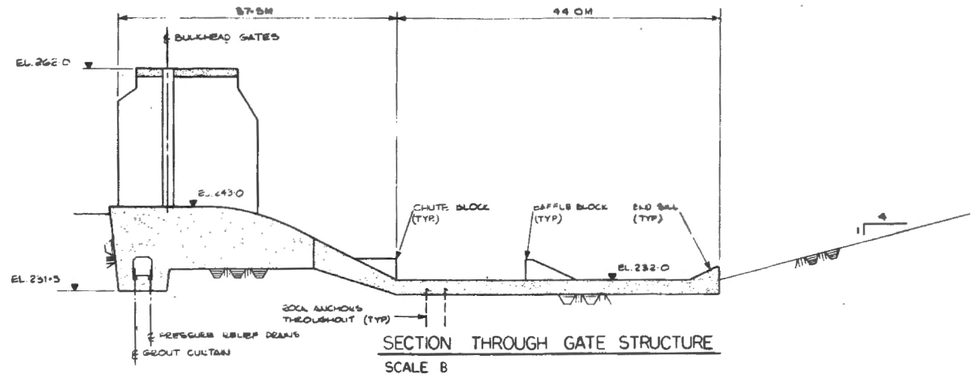
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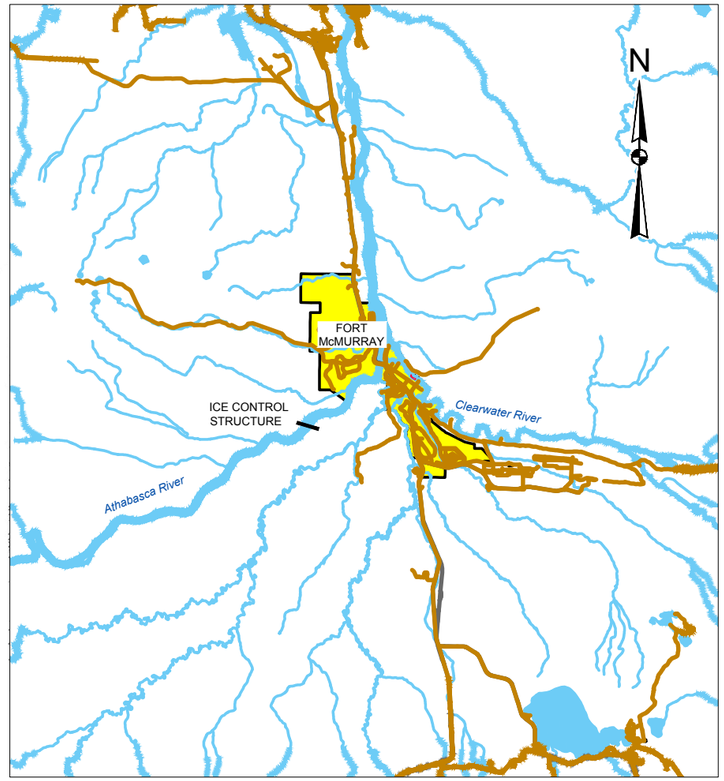
ICE CONTROL STRUCTURE LAYOUT
SCALE A



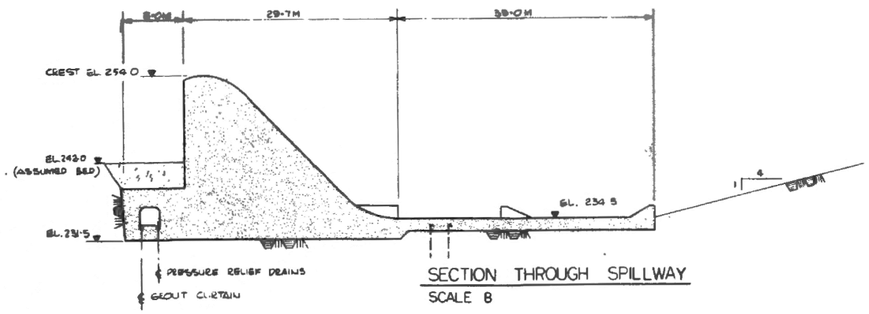
DYKE CROSS-SECTION
SCALE B



SECTION THROUGH GATE STRUCTURE
SCALE B



LOCATION MAP



SECTION THROUGH SPILLWAY
SCALE B

0 10 20 30

SCALE

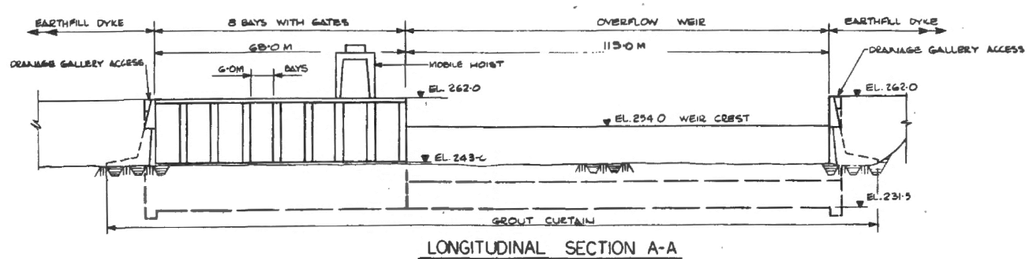
KILOMETRES

SCALE C 0 10 20 30 40 50

SCALE B 0 10 20 30

SCALE A 0 100 200 300 400 500

SCALE IN METRES



LONGITUDINAL SECTION A-A
SCALE C

LOCATION MAP LEGEND

- ICE CONTROL STRUCTURE
- ROADWAY
- WATERCOURSE
- CITY BOUNDARY
- WATERBODY

REFERENCE

SOURCE: DRAWINGS BY ACRES CONSULTING SERVICES LTD. PRESENTED IN IBI GROUP AND ECOS ENGINEERING SERVICES (1983).
DATUM: NAD83, PROJECTION: UTM ZONE 12.

PROJECT

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ATHABASCA RIVER BASINS
FEASABILITY STUDY

TITLE

FORT McMURRAY
STRUCTURAL MITIGATION OPTION 2
ICE CONTROL STRUCTURE

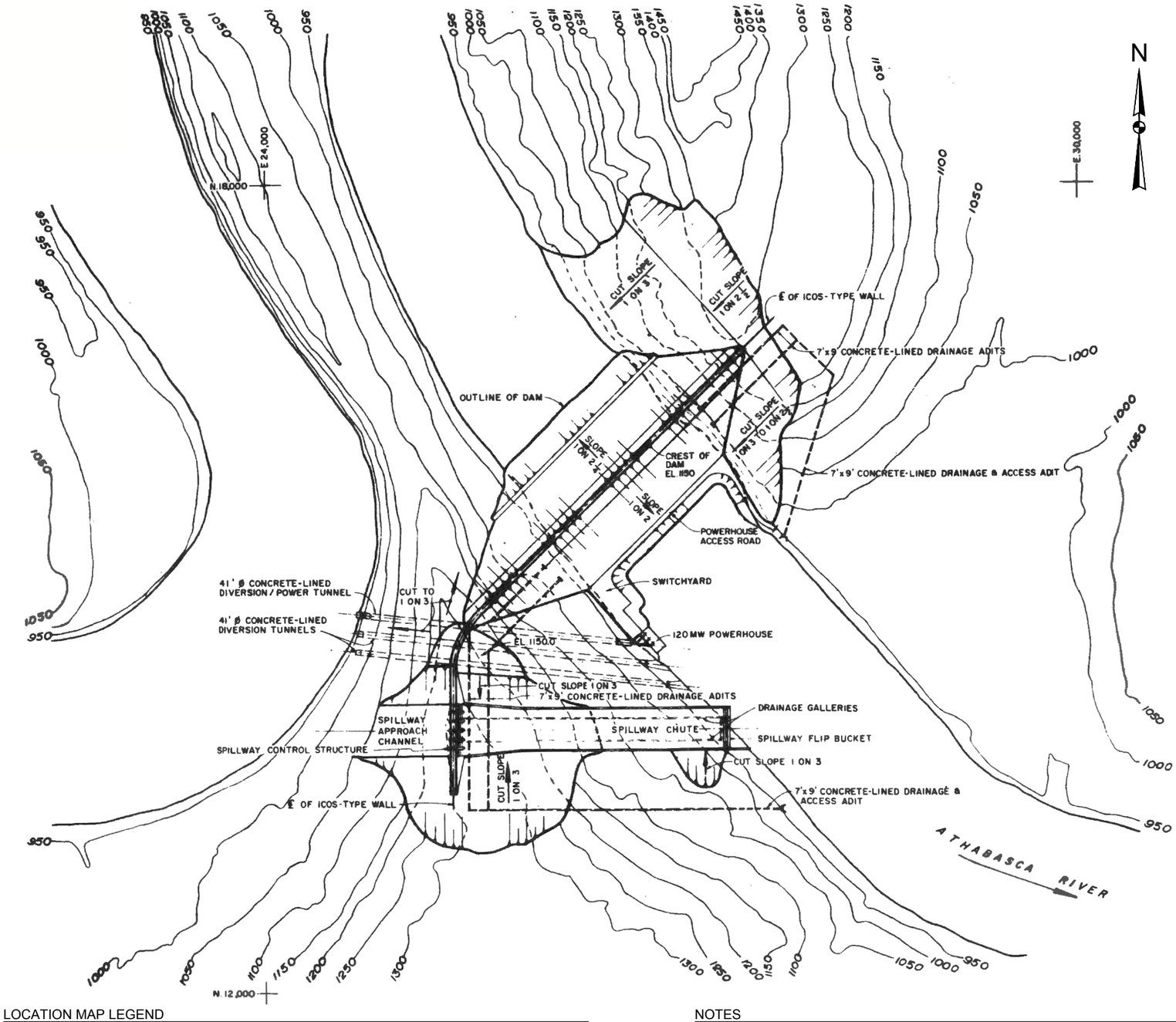
Golder Associates

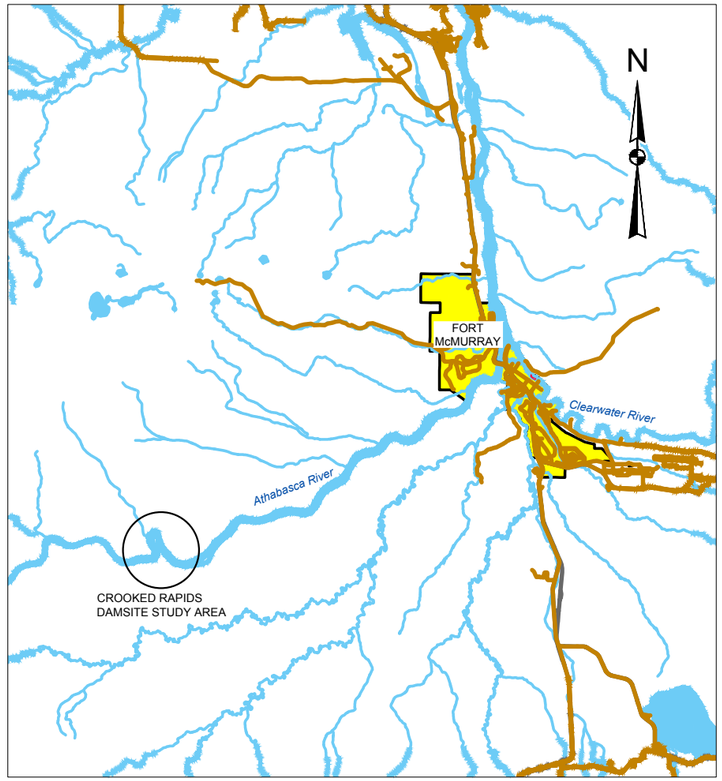
IBI GROUP

PROJECT	14.1351.0001
SCALE AS SHOWN	REV. 0

FIGURE: E-3

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LOCATION MAP

0 10 20 30
SCALE KILOMETRES

400 0 400 800 1200
SCALE IN FEET

LOCATION MAP LEGEND

- STUDY AREA
- ROADWAY
- WATERCOURSE
- CITY BOUNDARY
- WATERBODY

REFERENCE

SOURCE: DRAWINGS BY ALBERTA DEPARTMENT OF ENVIRONMENT BASED ON WORK CARRIED OUT BY CRIPPEN ENGINEERING LTD. PRESENTED IN IBI GROUP AND ECOS ENGINEERING SERVICES (1983).
DATUM: NAD83, PROJECTION: UTM ZONE 12.

NOTES

1. FOR SECTIONS OF DAM SEE FIGURE 3.
2. FOR SECTIONS ALONG SPILLWAY AND TUNNELS, AND THROUGH POWERHOUSE SEE FIGURE 4.
3. SLOPES ABOVE UPSTREAM PORTALS OF TUNNELS AND ABOVE UPSTREAM SLOPE OF DAM ON RIGHT BANK TO BE CUT TO 1 ON 3. FOR CLARITY CUT LINES NOT SHOWN ON PLAN. SEE SECTIONS FIGURES 3 AND 4.
4. FOR SLOPE OF FILL OVER CUT AND COVER SECTIONS OF TUNNELS SEE FIGURE 4.
5. CONTOURS OBTAINED FROM AIR PHOTO MAPPING BY NORTHWEST SURVEY CORPORATION LIMITED, JUNE 1974. ELEVATIONS ARE ABOVE G.S.C. DATUM.
6. RESERVOIR VOLUME CURVES OBTAINED FROM ROUGH CONTOUR MAPS SUPPLIED BY CALGARY POWER LTD.
7. SPILLWAY APPROACH CHANNEL AND CHUTE TO BE LINED.
8. SITE ROADS NOT SHOWN.

PROJECT

ATHABASCA RIVER BASINS FEASABILITY STUDY

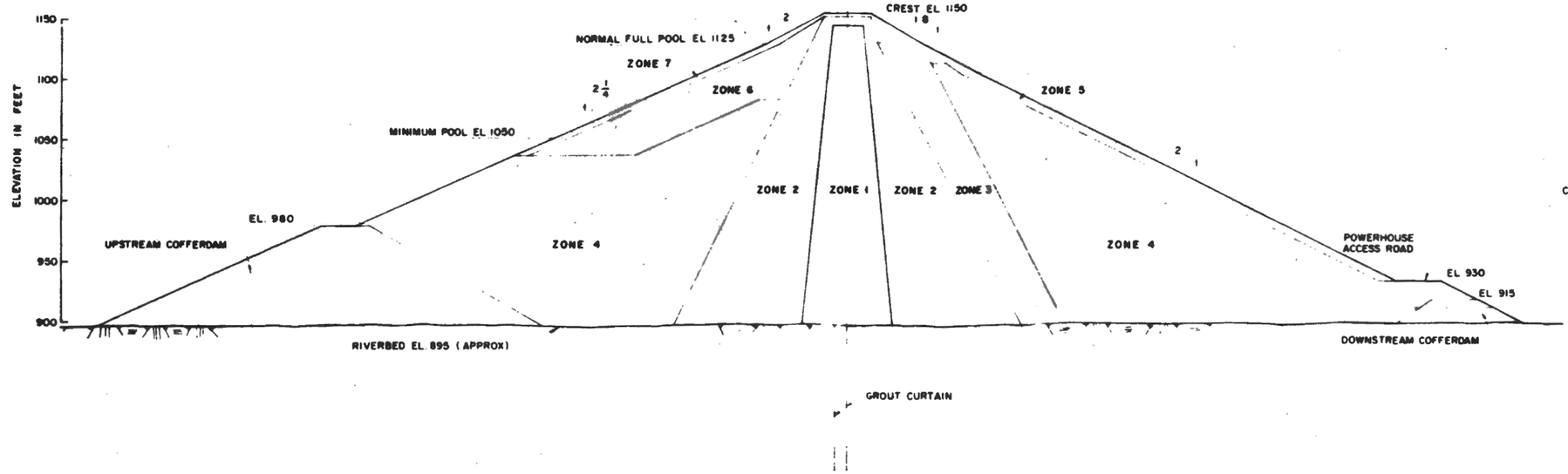
TITLE

FORT McMURRAY STRUCTURAL MITIGATION OPTION3 CROOKED RAPIDS DAM PLAN

PROJECT	14.1351.1000
SCALE AS SHOWN	REV. 0

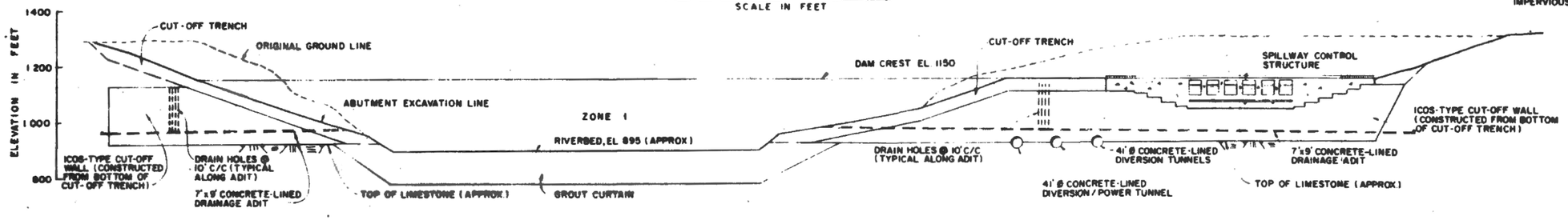
FIGURE: E-4

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DAM CROSS-SECTION AT MAXIMUM HEIGHT

50 0 50 100 150
SCALE IN FEET



SECTION ALONG DAM AXIS

200 0 200 400 600
SCALE IN FEET

ZONE	MATERIAL
1	RICH TAR SANDS
2	QUARRIED LIMESTONE FINES, OR SANDY MATERIAL FROM REQUIRED EXCAVATIONS
3	CLEAN FILTER AND DRAIN GRAVEL
4	QUARRY-RUN LIMESTONE (COARSER MATERIAL TOWARDS OUTSIDE SLOPES)
5	CLEAN QUARRIED LARGE-SIZED LIMESTONE
6	CLEAN QUARRIED MEDIUM-SIZED LIMESTONE
7	RIPRAP
COFFERDAMS	MAINLY ROCK-ZONING TO BE DECIDED ON BASIS OF DIVERSION SCHEME

NOTES

1. FOR LOCATION OF SECTIONS SEE FIGURE 6
2. FOR SECTIONS ALONG TUNNELS AND SPILLWAY SEE FIGURE 8
3. SLOPES AND DIMENSIONS OF FILL ZONES MAY VARY SOMEWHAT FROM THOSE SHOWN. QUANTITIES BASED ON SLOPES & DIMENSIONS SHOWN
4. ZONE 3 TO BE CARRIED UP ABUTMENT UNDER DOWNSTREAM SHELL
5. ALL FILL MATERIALS, EXCEPT RIPRAP & OTHER LARGE ROCK NEAR EXTERIOR SLOPES, AND PARTS OF COFFERDAMS, TO BE PLACED IN LIFTS AND COMPACTED
6. DRAINAGE ADITS AND DRAIN HOLES PROJECTED ON TO SECTION
7. CUT-OFF TRENCH TO BE BACKFILLED WITH IMPERVIOUS MATERIAL

REFERENCE

SOURCE: DRAWINGS BY ALBERTA DEPARTMENT OF ENVIRONMENT BASED ON WORK CARRIED OUT BY CRIPPEN ENGINEERING LTD. PRESENTED IN IBI GROUP AND ECOS ENGINEERING SERVICES (1983).

PROJECT

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ATHABASCA RIVER BASINS FEASABILITY STUDY

TITLE

FORT McMURRAY
STRUCTURAL MITIGATION OPTION 3
CROOKED RAPIDS DAM SECTION

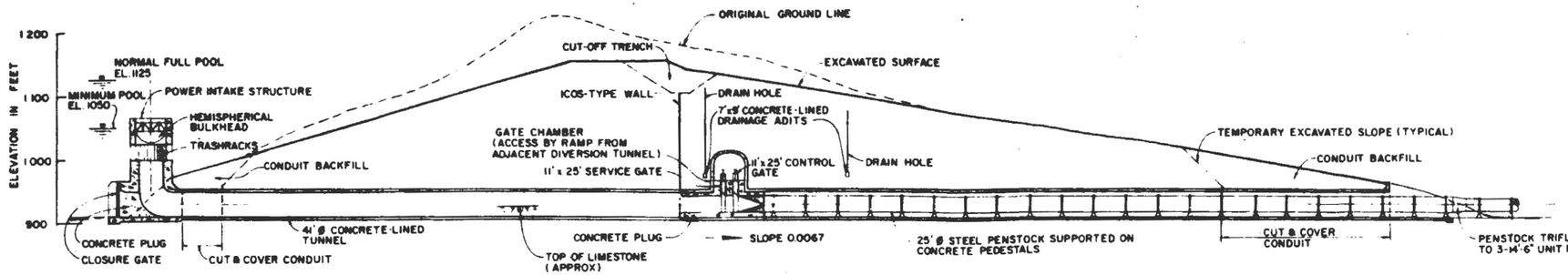
Golder Associates

IBI GROUP

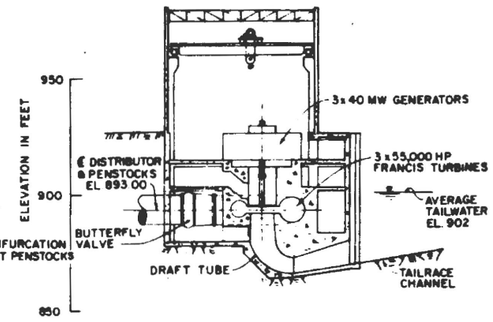
PROJECT	14.1351.1000
SCALE AS SHOWN	REV. 0

FIGURE: E-5

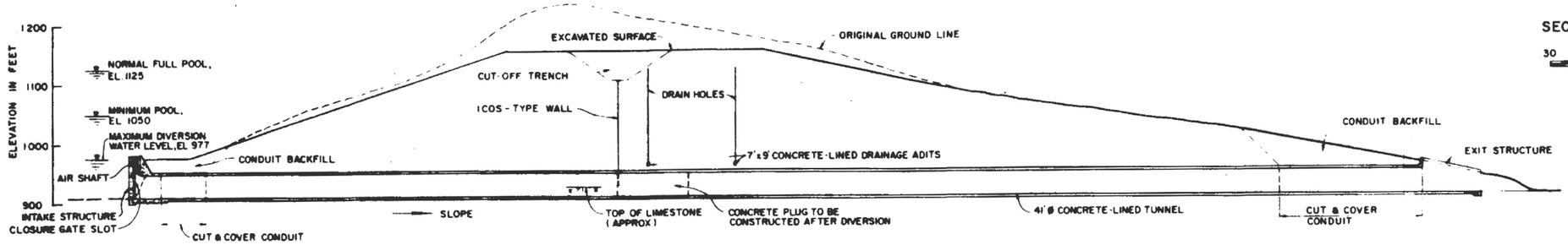
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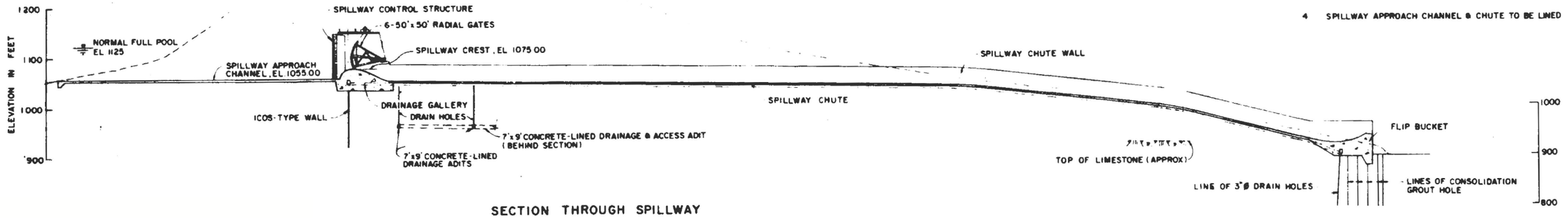
SECTION THROUGH DIVERSION / POWER TUNNEL



SECTION THROUGH POWERHOUSE



SECTION THROUGH DIVERSION TUNNELS
(TYPICAL FOR TWO TUNNELS)



SECTION THROUGH SPILLWAY

100 0 100 200 300 400
SCALE IN FEET

NOTES

1. FOR LOCATION OF SECTIONS SEE FIGURE 6
2. FOR CLARITY, ACCESS RAMP AND AIR VENT SYSTEM TO GATE CHAMBER NOT SHOWN
3. CUT-OFF TRENCH TO BE BACKFILLED WITH IMPERVIOUS MATERIAL
4. SPILLWAY APPROACH CHANNEL & CHUTE TO BE LINED

REFERENCE

SOURCE: DRAWINGS BY ALBERTA DEPARTMENT OF ENVIRONMENT BASED ON WORK CARRIED OUT BY CRIPPEN ENGINEERING LTD. PRESENTED IN IBI GROUP AND ECOS ENGINEERING SERVICES (1983).

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ATHABASCA RIVER BASINS FEASABILITY STUDY

TITLE

FORT McMURRAY STRUCTURAL MITIGATION OPTION 3 CROOKED RAPIDS TUNNEL SECTION

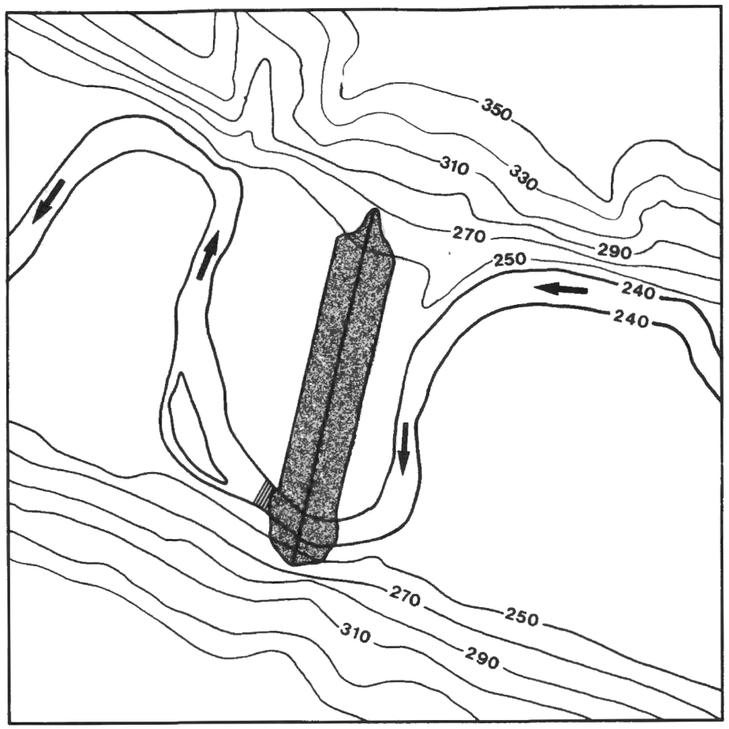
Golder Associates

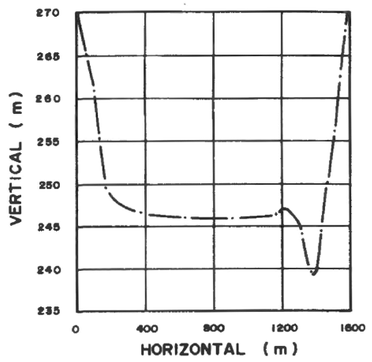
IBI GROUP

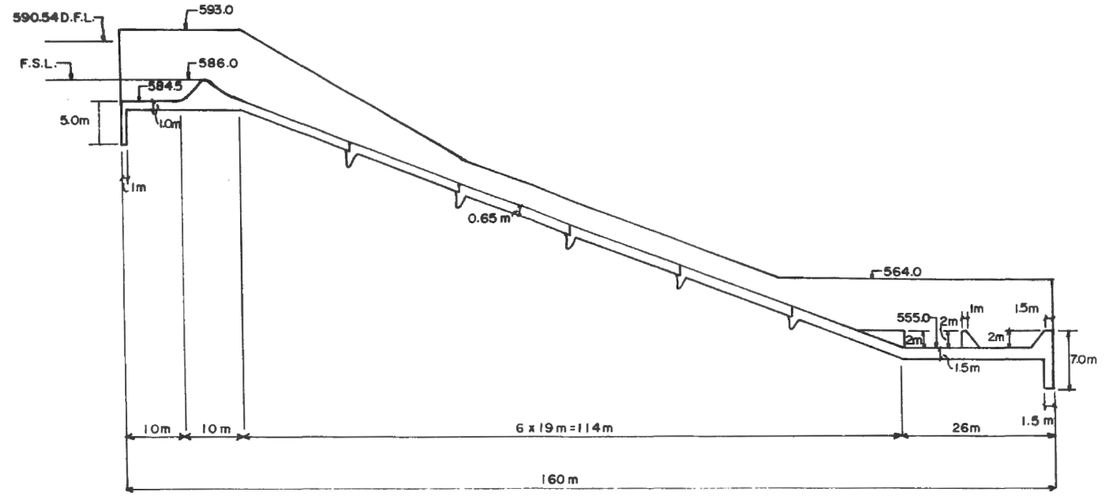
PROJECT	14.1351.1000
SCALE AS SHOWN	REV. 0

FIGURE: E-6

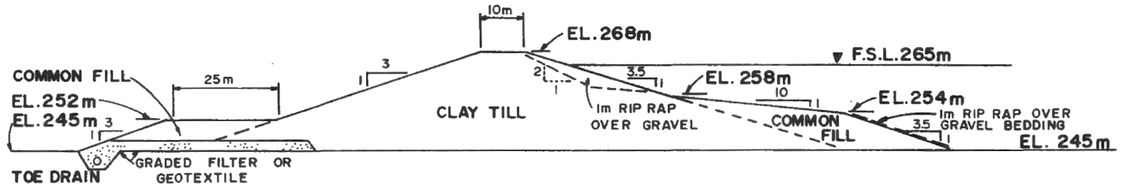
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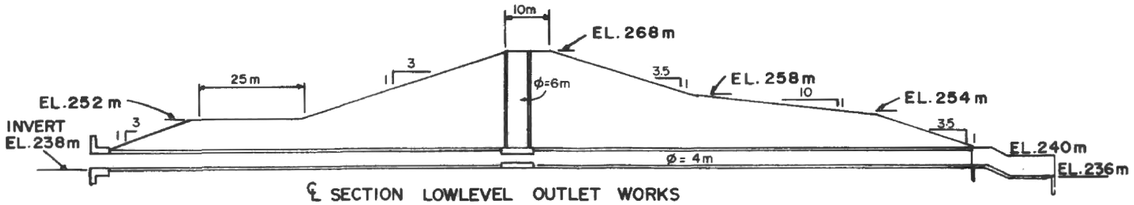




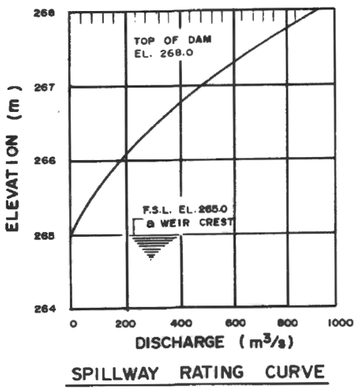
℄ SECTION SPILLWAY



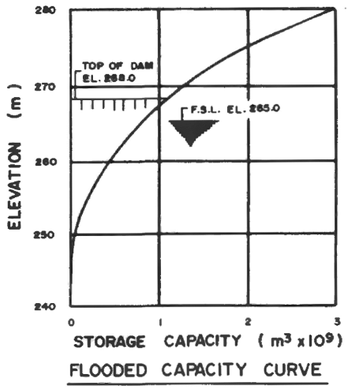
TYPICAL EMBANKMENT SECTION



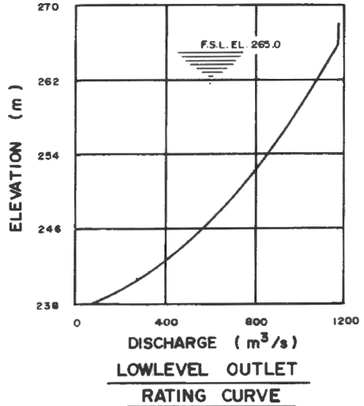
℄ SECTION LOWLEVEL OUTLET WORKS



SPILLWAY RATING CURVE



FLOODED CAPACITY CURVE



LOWLEVEL OUTLET RATING CURVE

REFERENCE

SOURCE: DRAWINGS BY ACRES CONSULTING SERVICES LTD. PRESENTED IN IBI GROUP AND ECOS ENGINEERING SERVICES (1983).

PROJECT

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ATHABASCA RIVER BASINS FEASABILITY STUDY

TITLE

FORT McMURRAY STRUCTURAL MITIGATION OPTION 5 CLEARWATER DAM

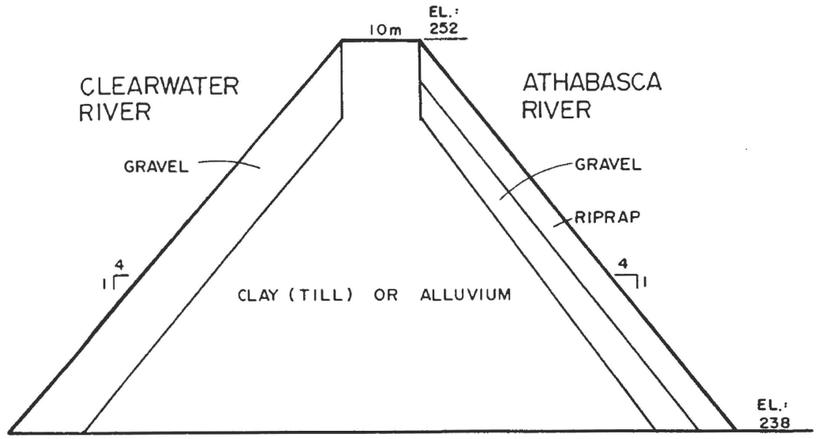
Golder Associates

IBI GROUP

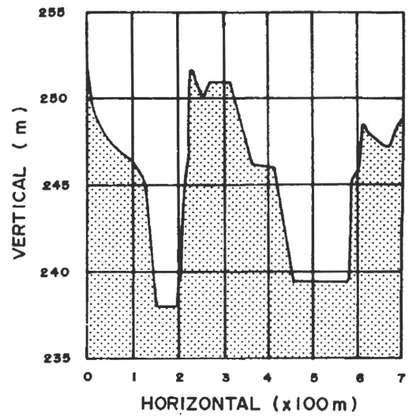
PROJECT	14.1351.1000
SCALE AS SHOWN	REV. 0

FIGURE: E-7

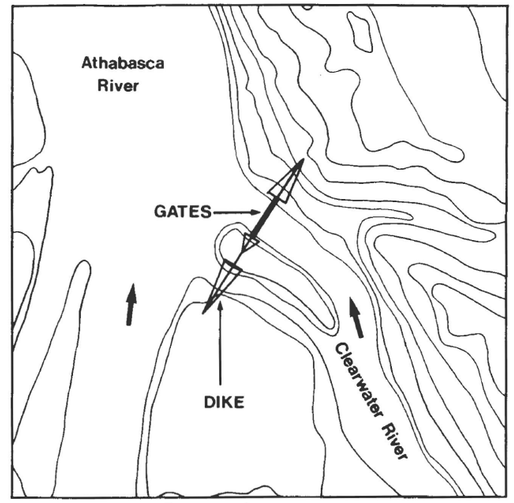
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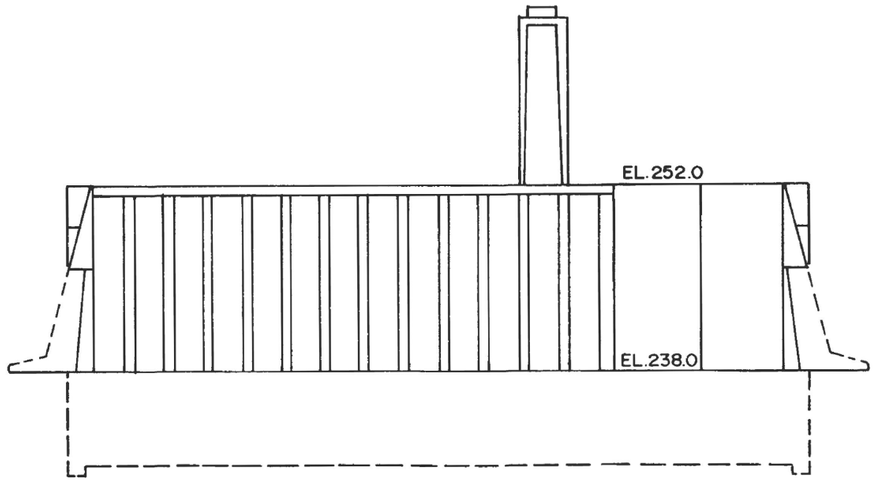
Proposed Dyke - Cross Section



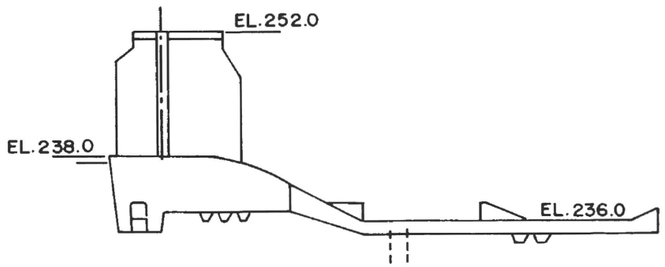
Clearwater Mouth Channel Cross Section



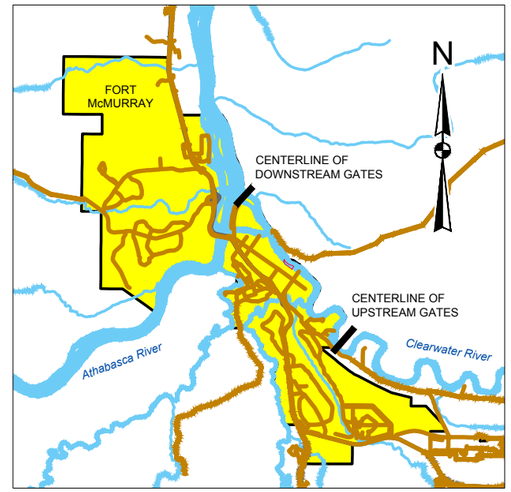
Clearwater Gates Layout



Gate Structure - Longitudinal Section NTS



Gate Structure - Cross Section NTS



LOCATION MAP

0 10 20 30
SCALE KILOMETRES

LOCATION MAP LEGEND

- DAM CENTERLINE
- ROADWAY
- WATERCOURSE
- CITY BOUNDARY
- WATERBODY

REFERENCE

SOURCE: DRAWINGS BY ACRES CONSULTING SERVICES LTD. PRESENTED IN IBI GROUP AND ECOS ENGINEERING SERVICES (1983).
DATUM: NAD83, PROJECTION: UTM ZONE 12.

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ATHABASCA RIVER BASINS FEASABILITY STUDY

TITLE

FORT McMURRAY STRUCTURAL MITIGATION OPTION 5 CLEARWATER GATES

Golder Associates

IBI GROUP

PROJECT	14.1351.1000
SCALE AS SHOWN	REV. 0

FIGURE: E-8

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