1.0 INTRODUCTION

The hydrology and the hydraulic models used to develop structural mitigation measures for Whitecourt have been recently updated in Appendices C and D, respectively. This appendix presents the mitigation options as well as their associated costs.

2.0 PROPOSED OPTIONS

2.1 Option 1 – Dykes

2.1.1 Project Description

This option requires constructing dykes along the McLeod and Athabasca Rivers to safely convey flows at the design flood level.

2.1.2 Design Criteria

Whitecourt has a record of two types of flood events: open water and ice jams. Based on an assessment of its flooding history, the design criteria for the McLeod and Athabasca River dykes are as follows:

- McLeod River: Historic ice jam (1943) + 1.0 m freeboard. This is approximately equal to the 1:500 year open water + 1.0 m freeboard.
- Athabasca River between the highway 32 bridge and the confluence with McLeod River: Historic ice jam (1943) + 1.0 m freeboard.
- Athabasca River downstream of confluence with McLeod River: 1:100 year open water + 1.0 m freeboard.

The addition of 1 meter freeboard is consistent with the generally accepted engineering standard for dyke construction, which has been adopted for this assessment.

2.1.3 Conceptual Design

The hydraulic models of the McLeod and Athabasca Rivers indicate that dykes are required to meet the design criteria. However, all of the bridges in the areas of concern provide at least 1.0 m of freeboard for the design events. Therefore, no bridge raises are required.

2.1.3.1 General Arrangement/Alignment Plan

The general arrangement of the Whitecourt dykes is shown on Figure G-1. The dykes are placed to protect the urban centre of Whitecourt and are located a minimum distance of 5.0 m from the channel banks. The dykes are located on both the left and right banks of the McLeod River and only on the right bank of the Athabasca River downstream of the confluence with the McLeod River.

2.1.3.2 Typical Cross-Section

A typical dyke cross-section is shown on Figure G-2. The dykes are designed with uniform clay/alluvium fill and have crest widths of 4.0 m and 3H: 1V side slopes. A toe drain shall be provided if the height is greater than 2.0 m. Based on the floodplain velocities calculated as a part of the hydraulic assessment, no armouring of the dykes is required.

The dyke crest elevation varies along the dyke profile. For the McLeod River, approximately 5,300 m of dyke are required. The crest elevation ranges from 703.0 m at the upstream end to 695.2 m at the downstream end. Based on the available topography, the dyke heights range from 0.5 m to 4.2 m. For the Athabasca River, which requires approximately 3,600 m of dyke (approximately 300 m upstream of the McLeod River and the remaining
downstream of the confluence with the McLeod River), the crest elevation ranges from 697.7 m to 690.0 m. This translates to a dyke height range of 1.1 m to 2.9 m.

2.1.3.3 Capacity of Option 1

The mitigation measures described above provide a minimum freeboard of 1.0 m under the aforementioned design events. The actual capacity of Option 1 to the top of the dyke crests is the 1:680 year flood for the McLeod River, the 1:3,500 year flood for the Athabasca River above McLeod River and the 1:490 year flood for the Athabasca River below McLeod River.

2.1.4 Right of Way / Land Requirements

The right of way (R.O.W) and land requirements for Option 1 – Dykes are as follows:

- Private land affected by dyke construction (golf course) – Approximately 4 ha.
- Public land affected by dyke construction (municipal, parkland, etc.) – Approximately 127 ha.

2.1.5 Cost Estimate

The cost estimate for Option 1 – Dykes is presented in the attached Table G-1. The breakdown includes the following:

- Capital cost.
- 25% contingency on capital cost.
- 10% engineering cost on capital cost plus contingency.
- Right of way (R.O.W)/land cost.
- Annual maintenance cost.

2.1.5.1 Capital Cost

The capital cost associated with the dyke improvements, including the contingency and the engineering cost, is $4,458,000. A report sourced from Alberta Transportation on Provincial weighted unit price averages for 2013 was used to support the selection of unit costs.

2.1.5.2 R.O.W/Land Cost

Approximately 10 acres (4 ha) of private land are required for the R.O.W of the proposed dyke improvements. Based on a unit price of $1,000,000/acre for private land, the land cost associated to the dyke improvements is $10,000,000.

2.1.5.3 Annual Maintenance Cost

The estimated maintenance costs were assumed to be 0.5% of capital costs for canals. Applying this percentage plus a contingency to the capital costs, the annual maintenance cost is $20,300.

2.2 Option 2 – McLeod River Dam

2.2.1 Project Description

This option is based on information contained in a Provincial Inventory (data base) of Potential Water Storage Sites and Diversion Scenarios managed by Alberta Environment and Sustainable Resource Development
The site was investigated in the late 1960's as part of the work carried out for the Saskatchewan-Nelson Basin Study.

The construction of a dam across the McLeod River upstream of Whitecourt would provide peak flow attenuation during extreme storm events reducing the volume of surface runoff that would reach the town. However, costs for building the dam for flood mitigation are likely to be prohibitive, unless its benefits as a multi-purpose reservoir (i.e., flow regulation and low flow augmentation) are considered.

### 2.2.2 Design Criteria

Very limited information on the McLeod River dam study was available. Based on the capacity of the dam (670 Mm$^3$) and inflow volumes estimated from Whitecourt Intensity-Duration-Frequency (IDF) curves available from Environment Canada, it is assumed that the McLeod Dam could be designed to contain the 1:100 year flood.

Under the 1:500 year flood conditions, the anticipated peak discharge through the emergency spillway was estimated to be 1,300 m$^3$/s. This flow is approximately one third of the peak flow without dam (~4,095 m$^3$/s) and is equivalent to the 1:12 year flood conditions according to the calculations.

It is assumed that the dam would fully attenuate spring runoff flows in the McLeod River and reduce the potential for significant ice jam formation at the confluence of the McLeod and Athabasca Rivers. It is also likely to reduce the potential for ice jam formation along the Athabasca River downstream of the confluence, such that the frequency of occurrence of major ice jam events such as the Historic 1943 jam would be significantly reduced. Thus this option is presented as a "stand alone" alternative to Option 1 –Dykes.

It should be noted that for this feasibility level study, the design as originally proposed was adopted, without modification or further study. Should this project proceed, the dam embankment and spillways would have to be designed to comply with current Canadian Dam Association (CDA) standards and guidelines. As this project would likely be considered to have a High Consequence of Failure, the spillway capacity would need to be designed to safely pass the Probable Maximum Flood (PMF).

### 2.2.3 Conceptual Design

#### 2.2.3.1 McLeod River Dam

The McLeod River Dam would be located approximately 20 km upstream of Whitecourt (Figure G-1). According to the ESRD data base, the original purpose of the dam was flow regulation. The study completed in 1967 proposed the construction of an earth dam across the McLeod River with the following design characteristics:

- Height of earth embankment – 54.9 m.
- Capacity of the emergency spillway – 34,000 m$^3$/s.
- Full supply level (FSL) – 792 m.
- Storage capacity – 670,000,000 m$^3$.

The plan view of the dam and the emergency spillway (original figure from Saskatchewan- Nelson Basin Study) is presented for illustration purposes on Figure G-3.
2.2.3.2 Capacity of Option 2

Assuming that the 1:100 year flood is fully contained and there is no discharge from the dam, the capacity of Option 2 to the top of the river banks through Whitecourt is the 1:600 year flood for McLeod River, the 1:30 year flood for the Athabasca River above McLeod River and the 1:130 year flood for the Athabasca River below McLeod River. Given the low return period of the Athabasca River upstream of the McLeod River, the industrial area in the Athabasca upstream from McLeod are at risk of flooding under the design event.

2.2.4 Right of Way / Land Requirements

The right of way (R.O.W) and land requirements for Option 2 – McLeod River Dam are as follows:

- Dam footprint + Flooded reservoir area resulting from dam construction – Approximately 7,300 ha.

2.2.5 Cost Estimate

The cost estimate for Option 2 – McLeod River Dam is presented in the attached Table G-2. The breakdown includes the following:

- Capital cost.
- 25% contingency on capital cost.
- 10% engineering cost on capital cost plus contingency.
- Right of way (R.O.W)/land cost.
- Annual maintenance cost.

2.2.5.1 Capital Cost

According to the information derived from the Alberta government data base, the capital cost of construction of the dam (including the earth embankment and the emergency spillway) was estimated to be $29,000,000 in 1967. Applying an escalation factor of 8.2 for the period 1967 – 2013 and adding a 25% increment as contingency and 10% increment (on capital cost plus contingency) to account for engineering cost, the total capital cost is $326,975,000. The escalation factor was estimated as follows:

- Reports from Alberta Transportation on Provincial weighted unit price averages for 2001, 2007, 2009 and 2013 were available. In addition, average annual provincial unit prices for three classes of construction materials (common excavation, borrow excavation and granular base course) for 1981 and 1991 were provided by Alberta Transportation.
- These sources of unit price data were used to compare the change of unit cost between 1981 and 2013 for the three aforementioned items. The unit price for 1967 was estimated extrapolating from the available data.
- The overall cost escalation factor of 8.2 is the average of the individual escalation factors estimated for the three classes of construction materials considered in the analysis.

Although the information available corresponds to highway works in Alberta, the unit prices compiled from different years provide a reasonable indication of the cost variation over time.
2.2.5.2  **R.O.W/Land Cost**

Approximately 18,000 acres (7,300 ha) would be flooded if the McLeod River dam is built. Based on a unit price of $1,500/acre for bareland, the land cost associated to the reservoir is $27,000,000.

2.2.5.3  **Annual Maintenance Cost**

The estimated maintenance costs were assumed to be 0.15% of capital costs for reservoir/dams. Applying this percentage plus a contingency to the capital costs, the annual maintenance cost associated with the dam is $445,900.

2.3  **Options Comparison Summary**

Table G-3 summarises the capacities and costs of the Whitecourt flood mitigation options.
## Table G-1: Cost Estimate of Structural Mitigation, Whitecourt Option 1

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Description</th>
<th>Unit</th>
<th>Estimated Quantity</th>
<th>Unit price</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Option 1 - Dykes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1</td>
<td>Capital Cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>1.1.1</td>
<td>Earth Embankment</td>
<td>m³</td>
<td>197,000</td>
<td>$15.59</td>
<td>$3,071,230.00</td>
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<td>1.1.3</td>
<td>Granular Filter</td>
<td>m³</td>
<td>4,500</td>
<td>$26.37</td>
<td>$118,665.00</td>
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<tr>
<td>1.1.4</td>
<td>Geotextile</td>
<td>m²</td>
<td>18,600</td>
<td>$2.81</td>
<td>$52,266.00</td>
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<td></td>
<td>Contingency (25% of Capital Cost)</td>
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<td></td>
<td>$810,540.25</td>
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<td></td>
<td>Engineering (10% of Capital Cost plus Contingency)</td>
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<td></td>
<td></td>
<td>$405,270.13</td>
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<tr>
<td>1.2</td>
<td>Right Of Way (R.O.W.) And Land Cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.2.1</td>
<td>Private (open areas/golf courses/commercial/industrial)</td>
<td>acre</td>
<td>10</td>
<td>$1,000,000.00</td>
<td>$10,000,000.00</td>
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<td>1.2.2</td>
<td>Municipal</td>
<td>acre</td>
<td>314</td>
<td>-</td>
<td>-</td>
</tr>
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<td></td>
<td>Total Cost:</td>
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<td>$14,457,971.38</td>
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<tr>
<td>1.3</td>
<td>Annual Maintenance Cost (0.5% Of Capital Cost Plus Contingency)</td>
<td>L.S.</td>
<td>-</td>
<td></td>
<td>$20,263.51</td>
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### Table G-2: Cost Estimate of Structural Mitigation, Whitecourt Option 2

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Description</th>
<th>Unit</th>
<th>Estimated Quantity</th>
<th>Unit price</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Option 2 - Mcleod River Dam</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1</td>
<td>Capital Cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1.1</td>
<td><em>Earth Embankment and Emergency Spillway</em></td>
<td>L.S.</td>
<td>-</td>
<td>-</td>
<td>$237,800,000.00</td>
</tr>
<tr>
<td></td>
<td>Contingency (25% of Capital Cost)</td>
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<td>-</td>
<td>-</td>
<td>$59,450,000.00</td>
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<tr>
<td></td>
<td>Engineering (10% of Capital Cost plus Contingency)</td>
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<td>-</td>
<td>-</td>
<td>$29,725,000.00</td>
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<tr>
<td>2.2</td>
<td>Right Of Way (R.O.W.) And Land Cost</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.2.1</td>
<td><em>Bareland (reservoir areas)</em></td>
<td>acre</td>
<td>18,000</td>
<td>$1,500.00</td>
<td>$27,000,000.00</td>
</tr>
<tr>
<td></td>
<td><strong>Total Cost:</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td><strong>$353,975,000.00</strong></td>
</tr>
<tr>
<td>2.3</td>
<td>Annual Maintenance Cost (0.15% Of Capital Cost Plus Contingency)</td>
<td>L.S.</td>
<td>-</td>
<td>-</td>
<td><strong>$445,875.00</strong></td>
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</table>
## Table G-3: Whitecourt Flood Mitigation Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Reach</th>
<th>Design Criteria</th>
<th>Capacity with 1.0m Freeboard</th>
<th>Capacity without Freeboard</th>
<th>Return Period without Freeboard</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Dyke Construction</td>
<td>McLeod River</td>
<td>Historic ice jam + 1.0m freeboard</td>
<td>4,095 m³/s</td>
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<td>1:680</td>
<td>$14,457,971</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Athabasca U/S of McLeod River</td>
<td>Historic ice jam + 1.0m freeboard</td>
<td>4,631 m³/s</td>
<td>6,000 m³/s</td>
<td>1:3,500</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Athabasca D/S of McLeod River</td>
<td>100-yr + 1.0m freeboard</td>
<td>5,250 m³/s</td>
<td>7,800 m³/s</td>
<td>1:490</td>
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<tr>
<td>2</td>
<td>McLeod River Dam</td>
<td>McLeod River</td>
<td>River bank /no freeboard</td>
<td>n/a</td>
<td>1,800 m³/s</td>
<td>1:600</td>
<td>$353,975,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Athabasca U/S of McLeod River</td>
<td>River bank /no freeboard</td>
<td>n/a</td>
<td>2,400 m³/s</td>
<td>1:30</td>
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<td></td>
<td>Athabasca D/S of McLeod River</td>
<td>River bank /no freeboard</td>
<td>n/a</td>
<td>5,500 m³/s</td>
<td>1:130</td>
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</tbody>
</table>

U/S – Upstream, D/S – Downstream
FIGURES
TYPICAL MCLEOD RIVER DYKE SECTION
SCALE 1:200

NOTES
1. DRAINAGE TOES REQUIRED ON DYKES GREATER THAN 2m HEIGHT ONLY.

PROJECT
ATHABASCA RIVER BASINS
FEASIBILITY STUDY

TITLE
WHITECOURT MITIGATION OPTION 1
TYPICAL DYKE SECTION
NOTE
DAM PLAN TAKEN FROM MCLEOD VALLEY DAM SITE PLAN
SASKATCHEWAN-NELSON BASIN BOARD, 1970.