Southern Alberta Flood Recovery Task Force
Flood Mitigation Measures for the Bow River, Elbow River and Oldman River Basins
Volume 1 – Summary Recommendations Report

Submitted to:

Southern Alberta Flood Recovery Task Force
Calgary, Alberta

Submitted by:

AMEC Environment & Infrastructure
Calgary, Alberta

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TABLE OF CONTENTS

1.0 INTRODUCTION

Following the floods of June 2013, the Government of Alberta (GoA) set up the Southern Alberta Flood Recovery Task Force (SAFRTF). In October 2013, AMEC Environment and Infrastructure, a Division of AMEC Americas Limited (AMEC), was contracted to provide a flood mitigation feasibility study for the Bow River, Elbow River, and Oldman River basins.

This study was undertaken under contract to the SAFRTF (CON0015233) and in accordance with the agreed AMEC proposal document submitted to the SAFRTF on 16th September 2013.

2.0 SCOPE OF STUDY

2.1 Geographic Extent

AMEC was contracted to undertake a feasibility study of flood mitigation measures for the Bow River, Elbow River, and Oldman River basins, excluding areas within the City of Calgary. Although mitigation measures within the City of Calgary were not part of the project scope, AMEC was asked to review proposals made by the Flood Advisory Panel (FAP) for dry dams on the Elbow River (at sites EQ1 and EC1) as part of the project scope. It cannot be ignored that proposed dams are primarily for the benefit of Calgary as it would be unfeasible and unnecessary to construct a dam solely for the benefit of properties upstream of Calgary. It is therefore not possible to undertake a flood mitigation study for the Bow River or Elbow River, and to review proposals for dams in those basins, without considering the needs of Calgary to some degree.

The scope of study evolved throughout the contract. Through consultation with the SAFRTF, the project scope can be summarized as:

- Flood mitigation measures for the Elbow River Basin upstream of Calgary city limits;
- Flood mitigation measures for the Bow River basin down to the confluence with the Oldman River, not including Land within Calgary city limits, Highwood River Basin, and Sheep River Basin;
- Flood mitigation measures for the Oldman River Basin;
- Review of proposals by the FAP for dry dams at EQ1 (Quirk Creek) and EC1 (Canyon Creek) on the Elbow River; and
- Review of anticipated flow reductions was made possible with the construction of dry dams on the Ghost River upstream of Waiparous Creek (site BG1) and Waiparous Creek upstream of the Ghost River (BW1).

2.2 Design Standard of Protection

Though the 2013 flood event was the primary driver for these studies, in flood frequency terms, the storm was not uniform across all of the basins within the study area. The flood was much worse in the Elbow River than in the Oldman River Basin. Several estimates have been made of the flood frequency on the Elbow River and though there is variation, all estimates place the

2013 event somewhere between 0.1% annual exceedance probability (AEP) and 1% AEP, and generally in the region of 0.2% AEP.

Part of the problem with estimating the probability of the event is that the established stage discharge relationships for the gauging stations along the Elbow River were based on stream flow measurements that were far less than those experienced in June 2013, and as such, the rating curves could not be relied upon to produce accurate discharge estimates. There was also a large amount of out-of-bank flow and massive changes in channel morphology during the event which makes post event analysis very difficult and highly variable. The destruction of key gauging stations along the Elbow River meant that some of the data had to be "reconstructed" or estimated to produce a volumetric analysis.

Early on in the study, it was agreed with SAFRTF that the design standard of protection would be consistently be the 1% AEP flood and that the 2013 flood event (or other worst event on record) would be used as a check to determine if the proposed mitigation measures, with freeboard allowance, would have protected the infrastructure and people at risk.

The optimal design standard depends on the economic, social and technical feasibility of a scheme. There is a "sweet spot" that must be achieved between standard of protection, damage avoided and cost. The optimum may not necessarily be the worst event on record or even the 1% AEP flood. It may not always be possible to achieve the 1% AEP standard of protection; however, in economic terms, most of the damage avoided (benefit) during the design life of a flood defence is gained from protecting areas that flood with a high frequency.

This balance can only be struck with adequate time to survey past and future (predicted) flood damages and an economic benefit/cost appraisal.

To this end, there are specific recommendations related to the assessment of economic viability for each proposed scheme, as well as for communication of residual flood risk to the public.

3.0 REPORT FORMAT

This suite of reports consists of four volumes as follows:

- Volume 1: Summary Recommendations Report (this report)
- Volume 2: General Information
- Volume 3: Stakeholder Engagement Report
- Volume 4: Flood Mitigation Measures

In recognition of the significance of the major infrastructure projects that are required to protect the City of Calgary to a standard of protection of at least 1% AEP, this report will commence with a description of two dam projects that AMEC has identified which, subject to ongoing geotechnical investigations, may be feasible. The report will also describe ongoing work to assess the flood storage potential in the Bow River basin.

Recommendations are set out in the four volumes of this report in the following format:

Recommendation V#.#:

The V#.# refers to the volume number and sequential recommendation number from that volume. This is to enable the reader of this report to easily cross reference recommendations in later volumes should additional supporting information be desired.

4.0 MAJOR INFRASTRUCTURE

4.1 Elbow River Dams

4.1.1 Dam at McLean Creek

This project concept considers building an earth fill dam across the main stem of the Elbow River. It includes a combined concrete outlet/service spillway structure for discharging normal and flood flows, and includes an auxiliary earth cut spillway channel to protect the dam from extreme floods up to the probable maximum flood (PMF) event.

The proposed earth fill dam (main embankment) traverses a river gorge which is approximately 110 m wide at the base and is steep walled for a height of about 28 m. The river valley itself bends sharply to the north-northeast at the dam site, facilitating the construction of an auxillary spillway on the right bank. Similarly, the topography and river alignment are well suited for construction of a permanent outlet/spillway structure in the left valley abutment.

The project has been designed to contain a minimum 41,200 dam^3 of flood water which, when combined with the 15,400 dam^3 that can be made available with relatively short notice at the Glenmore Reservoir, would provide protection for the 1% AEP flood (41,200 dam^3) to the existing works in the Elbow Valley floodplain downstream of the Glenmore Reservoir. Additional storage is provided above the minimum 41,200 dam^3 value which will provide significant additional protection for larger floods. As currently envisioned in this conceptual design, the maximum flood storage at this site is 58,000 dam^3 prior to auxiliary spillway activation (i.e., reservoir El. 1,426.5 m). Even more storage could be provided at this site with a higher dam; but project costs would be significantly higher.

This conceptual design includes a small permanent pool in the valley bottom extending from the river bottom elevation of 1,379.0 m to outlet structure intake invert elevation of 1,398.0 m, thereby permanently containing approximately 4,000 dam^3 of water as dead storage. This storage would serve to prevent incoming larger bottom sediment from plugging the intake area, and could also replace Allen Bill Pond, which was destroyed by the flood.

With capital and maintenance allowance and an assumed design life of 100 years, the estimated present value of the capital cost (PV$_{cost}$) of construction and the annual or programmed maintenance to keep the structure or scheme operational for this project is $290.7 million with a preliminary benefit cost ratio of 0.6.

The conceptual design (description and drawings) and estimated project costs are provided in **Appendix F** of **Volume 4**.

4.1.2 Offline Storage at Springbank Road

The off-stream dam site at Springbank Road (SR1) is located just west of Calgary, approximately 18.5 km upstream of the Glenmore Reservoir in a relatively undeveloped valley in a ranchland area.

This concept considers diverting extreme flood flow from the Elbow River into an off-stream storage reservoir where it would be temporarily contained and later released back into the Elbow River after the flood peak has passed. Project components include a diversion weir system constructed across the Elbow River, and a diversion channel system excavated through the adjacent uplands to transport flood water into an off-stream reservoir storage site.
The storage site includes a main embankment to contain the diverted flood water and a low level outlet structure incorporated into the embankment to release the water back into the Elbow River after the flood peak has passed.

The offline storage has been designed to contain a minimum 41,200 dam^3 of flood water, which when combined with the 15,400 dam^3 that can be made available with relatively short notice at the Glenmore Reservoir, would provide full protection for the 1% AEP flood to the existing works in the Elbow Valley floodplain downstream of the Glenmore Reservoir. Additional storage is provided above the minimum 41,200 dam^3 value which will provide significant additional protection for larger floods, should they occur. As currently envisioned in this conceptual design, the maximum flood storage at the site is 57,000 dam^3 (i.e., reservoir El. 1,210.5 m). Even more storage could be provided at this site with a higher dam but project costs would be higher.

The project could be designed as a dry pond, or could include a smaller permanent storage pond (live storage). The permanent pond component would serve to dissipate energy when flood water enters the reservoir, and could be used for recreational/environmental purposes and/or an additional water supply source for the City of Calgary. For the purpose of this conceptual assessment a live storage containment of 9,000 dam^3 has been assumed providing a maximum pond depth of 10 m.

With capital and maintenance allowance and an assumed design life of 100 years, the estimated PV_{cost} for this project is $193.8 million with a preliminary benefit cost ratio of 0.9. This PV_{cost} is for construction and maintenance only and does not include an allowance for land acquisition. This scheme does not protect Bragg Creek. Therefore, to achieve the same level of protection for communities along the Elbow River, the SR1 scheme would need to allow for an additional investment of $6.2 million for flood dykes in Bragg Creek.

The conceptual design (description and drawings) and estimated project costs are provided in **Appendix G** of **Volume 4**.

4.1.3 Recommendations for Major Infrastructure

At the time of writing this report, only limited ground investigation data were available at McLean Creek (MC1) and Springbank Road (SR1). The data that is being obtained is vital in determining the viability of either scheme. Though the schemes are radically different in design, based on the information currently available there is little to choose between the two in terms of economics.

Since time is an important factor in this project and a decision cannot be made as to the viability of either scheme, it is recommended that environmental assessments and design for both MC1 and SR1 be taken forward until such time as one becomes the preferred project.

Recommendation V1.1: Environmental assessments and preliminary design for both MC1 and SR1 schemes should be progressed until such time as one becomes the preferred scheme.

4.2 Bow River Dams

The effects of constructing a dam on the Ghost River upstream of Waiparous Creek were assessed as part of this study at the request of the SAFRTF. A flood routing model was prepared using HEC-HMS to assess the regulating effect of Ghost Dam on downstream discharges. Two model scenarios were investigated. The first was storage of the whole hydrograph (i.e., no discharge from the Ghost River), to test the maximum achievable reduction in peak discharge, and 60% storage to simulate a more realistic scenario.

The modelling found that peak discharges would be reduced by 6% to 10% (77 to 129 m^3/s) depending on the design capacity. The flow reductions were then compared with the rating curve at the Water Survey of Canada gauging station (WSC Site 05BH004 Bow River at Calgary) to indicate an expected water level reduction.

Water levels along the Bow River in Calgary would potentially be reduced by a maximum of 0.18 to 0.27 m if 100% of the Ghost River flow is retained. Retaining 60% of the discharge from the Ghost River would result in water level reductions in the range of 0.1 to 0.16 m.

The FAP also recommended the construction of a dam upstream of Benchlands on Waiparous Creek. Due to time constraints on this project, this scenario was not modelled. The basin area of Waiparous Creek is less than that of the Ghost River (upstream of Waiparous Creek) and; therefore, a logical conclusion can be drawn that the benefit of a dam on this creek would be less than that from a dam on the Ghost River.

To provide full protection to the City of Calgary, it is necessary to undertake a full and rigorous review of potential storage sites in the Bow River basin upstream of Calgary. This was not part of the project scope for this study. It is recommended that a detailed review of available storage capacity and operating procedures within existing TransAlta Corporation (TransAlta) facilities be coupled with the identification of new storage sites to determine whether a 1% AEP standard of protection can be offered to the City of Calgary from the Bow River at an economically justifiable cost.

Recommendation V1.2: A detailed review of available storage capacity and operating procedures within existing TransAlta facilities should be coupled with the identification of new storage sites to determine whether a 1% AEP standard of protection can be offered to the City of Calgary using flood storage.

5.0 GENERAL RECOMMENDATIONS

5.1 Residual Flood Risk

Flood mitigation measures cannot guarantee that flooding will never occur in the protected area. In fact, the introduction of some structural mitigation measures merely changes the pathway to flooding or nature of the risk. For example, the construction of a flood control dam or levees may reduce fluvial flooding but a new risk of breach is introduced and must be taken into consideration in the design process. Risks are often highest during the construction of the mitigation measure, as a flood may occur before the structural integrity of the defence is assured by completion. A breach in a half finished flood defence presents a very serious hazard to those who are meant to be protected.

In view of this residual risk, it is recommended that the GoA communicate to the public that flood risk can only be reduced, not eliminated.

Recommendation V2.1: The GoA should make beneficiaries of flood mitigation schemes aware of the nature and extent of residual flood risk after a scheme is complete.

5.2 Flood Forecasting and Warning Improvements

5.2.1 Central Flood Forecasting System

A centralized technical approach to flood warning covering the major urban areas of Alberta is required. The proposed development of a flood warning service aligns with the GoA's seven pillars of mitigation. This would build upon the work currently carried out by Alberta Environment and Sustainable Resource Development River Forecast Centre and would provide residential property owners, business owners and first responders with direct flood warnings via text and email for specific river reaches.

Recommendation V4.1: The GoA should seek to improve the flood forecasting and warning system by developing a Provincial Flood Forecasting Shell and introducing an SMS text messaging or email warning system for all members of the public who sign up to receive direct flood warnings for a given flood risk area.

5.2.2 Replacement and Upgrade of Telemetry Outstations

It is recommended that a major investment be made to replace the stations that were destroyed in June 2013 or in previous floods with a more robust system. This will require a planning study to determine which stations are critical for flood forecasting and for flood frequency analysis across the province and to identify improvements to these stations to ensure continuity and integrity of the gauge record.

Recommendation V4.2: It is recommended that a major investment be made to replace the destroyed telemetry outstations and to upgrade those that were damaged and other vulnerable stations to improve the robustness of the flood forecasting and warning system.

5.2.3 Protection of Downstream Communities and Infrastructure

A fundamental aspect of undertaking to provide flood protection at a location is that the defences must not cause an increase in risk elsewhere. Construction of flood defences in one location can vary significantly, increasing the risk of flooding elsewhere. For example, building dykes or diversions that protect one area from flooding may jeopardize the operation or safety of a downstream asset such as a reservoir (dam) or downstream dykes. It is recommended that any proposals for flood defences be supported with sufficient engineering evidence that the downstream flood risk to communities or infrastructure will not be increased or that it is done so in a planned and manageable way.

Recommendation V4.3: It is recommended that any proposals for flood defences be supported with sufficient engineering evidence that the downstream flood risk to communities or infrastructure will not be increased or that it is done so in a planned and manageable way.

One way of ensuring that flood defence improvements in one area do not adversely affect flood risk in another is to take a basin wide approach to the planning of flood defence infrastructure. It is therefore recommended that the GoA undertake river basin flood management plans as part of the long-term flood management strategy, and that these plans are executed under a single responsible authority. Current studies being undertaken by consultants for the Athabasca River, Red Deer River, Highwood River, Sheep River, Elbow River, Bow River, and Oldman River and South Saskatchewan River basins could form the foundation for these plans.

Recommendation V4.4: It is recommended that the Government of Alberta fund the development of Basin Flood Management Plans for each of the major basins in the province and that these plans are developed and executed by a single responsible authority.

5.2.4 Improvements to Flood Hazard Mapping

There has been considerable improvement in the availability of high quality topographic data on a basin scale since the 1980s. The use of light detection and ranging (LiDAR) to undertake flood mapping is now standard and the accuracy to which floodplain extents can be delineated has improved considerably as a result.

It is recommended that current flood mapping for the province be reviewed and that all flood studies undertaken without benefit of LiDAR or other high quality Digital Terrain Model (DTM), or those where there has been considerable development, be revisited to ensure accuracy.

Recommendation V4.5: It is recommended that current flood mapping for the province be reviewed and that all flood studies undertaken without benefit of LiDAR or other high quality DTM, or those where has been considerable development, be revisited to ensure accuracy.

6.0 RECOMMENDATIONS FOR LOCAL MEASURES IN THE BOW RIVER BASIN

6.1 Emergency Response Plan for Stoney Nakoda First Nation

During engagements with the Stoney Nakoda First Nation, they indicated that there was a need to develop an emergency response plan (ERP) for the community. This ERP would cover more than flooding. Funding should be allocated to the Nation to hire consultants with specialist flooding and emergency response experience to undertake the work on their behalf.

Recommendation V4.6: It is recommended that an ERP be developed for Stoney Nakoda First Nation and for it to include a plan for post disaster recovery.

6.2 Cochrane Flood Study Update

This study has identified deficiencies in the flood mapping at Cochrane. It is recommended that the 1990 flood study be updated with current modelling and mapping techniques. Though a 1-D modelling approach will be adequate, there should be some accounting for the likelihood of ice dams occurring downstream of Cochrane and the associated backwater affects.

Recommendation V4.7: It is recommended that an update of the 1990 flood study for Cochrane be undertaken to reflect new development and land raising. This assessment should include a reassessment of the risk of ice dams or blockages.

6.3 Allen Bill Pond

This study considers the construction of a dam at MC1 downstream of Allen Bill Pond; the pond would be within the impoundment area of this dam. The conceptual dam design includes a permanent pond and this could be an effective replacement for the lost recreation at Allen Bill Pond. If reconstructed, this recreation area will be at risk of flooding in the future.

Recommendation V4.8: It is recommended that the Allen Bill Pond area be returned to nature.

6.4 Highway 40 – Hood Creek Bridge

The Hood Creek crossing on Highway 40 is currently a 2 m diameter corrugated steel pipe (CSP). There is a long history of maintenance issues at this crossing because the watercourse flows through a narrow canyon just before reaching Highway 40. The high velocities through this reach carry debris (trees, boulders, gravel and silt) for deposition at the culvert inlet. In June 2013, the road acted effectively as a dam and a torrent of debris 10 m high built up to block the road.

In a memo provided to Alberta Transportation for another study, AMEC recommended that a bridge would require less maintenance and would provide a larger opening to allow debris flows from the Hood Creek basin to pass beneath the highway.

Recommendation V4.9: The corrugated steel pipe culvert at Hood Creek on Highway 40 is prone to blockages and it is recommended that this culvert be replaced with a new bridge at a capital cost of approximately $2.9M.

6.5 Siksika First Nation

The stakeholder engagement response identified that there were plans to move certain residences and infrastructure from the flood area. There is no detailed flood hazard mapping available for the Siksika reserve. It is therefore recommended that a flood hazard mapping study be undertaken prior to the relocation of this infrastructure to ensure it is moved sufficiently away from floodway and flood fringe areas where possible.

Recommendation V4.10: It is recommended that flood hazard mapping is undertaken and stakeholder engagement is held with the Siksika Nation to determine which properties are candidates for removal from the floodway. Flood defences should also be constructed at locations identified in **Appendix D** of **Volume 4**.

6.6 Raising of Road and Dykes at Priddis

Though there is little infrastructure within the floodway, there is a risk to access and egress during a flood event at Priddis if Range Road 32 becomes impassable. Several properties will be cut off in this case. A simple means of protecting the integrity of this access is to raise the road and to armour the riverside of the road embankment to ensure that erosion does not become problematic.

No specific recommendation was made in the report because it is felt that this upgrade is unlikely to be economically viable. Upon implementing Recommendation V4.19 (below) the viability of the scheme at Priddis should be re-examined.

7.0 RECOMMENDATIONS FOR LOCAL MEASURES IN THE ELBOW RIVER BASIN

7.1 Channel Diversions

Previous studies have suggested that flow could be diverted from the Elbow River near Bragg Creek into Priddis Creek.

At Priddis, downstream of the confluence with Fish Creek, the 1% AEP estimate is 244 m^3/s. There is already a considerable floodway area with infrastructure and properties at risk. Using Priddis Creek to carry Elbow River overflow would significantly extend the floodway and increase flood risk to properties already at risk. The Priddis flood study does not estimate flood frequency beyond the 1% AEP event. However, more than doubling the discharge through Priddis would require substantial buyouts or an engineered channel through the hamlet to ensure those risks are managed effectively. For this reason, AMEC does not feel that this is a feasible option for the protection of the City of Calgary.

Recommendation V4.11: It is recommended that the concept of diverting flow from the Elbow River into the Priddis/Fish Creek basin be abandoned.

7.2 Flood Defences at Bragg Creek

If flood protection infrastructure for the City of Calgary is located downstream of Bragg Creek, there may be a need to protect the hamlet with dykes. Also, the construction schedule for a major infrastructure project may be long. If a decision is made to proceed with SR1 as the preferred flood storage scheme for the Elbow River, then the detailed design and planning for the dykes at Bragg Creek should be initiated as soon as possible.

Recommendation V4.12: It is recommended that once the preferred scheme for Calgary has been identified, flood defences, if necessary, be constructed as soon as possible at Bragg Creek.

7.3 Economic Appraisal for Dams on the Elbow River

A flood mitigation scheme should be underpinned by a robust economic assessment. In order to determine whether it makes economic sense to repair damage or to protect assets at risk, a detailed economic appraisal should asses damages avoided for the lifetime of the proposed scheme. This is important both for major infrastructure projects where the investment is potentially in the hundreds of millions of dollars and local schemes costing much less.
The probability of an event occurring again is a major consideration.

It is recommended a complete economic appraisal be undertaken for all technically feasible projects including the 58th Avenue tunnel (being studied by the City of Calgary) and dams at MC1 and SR1.

Recommendation V4.13: It is recommended a complete economic appraisal of feasible engineering flood mitigation options be undertaken following completion of the conceptual design for the Calgary (58th Ave) tunnel and the dams at MC1 and SR1.

8.0 RECOMMENDATIONS FOR THE OLDMAN RIVER BASIN

8.1 Pincher Creek

There are areas in the floodway and flood fringe which may be viewed as potential development lands. It is recommended that no further development should be allowed in these areas subject to the provision of a site specific flood risk assessment demonstrating that the development lies outside the 1% AEP flood area.

Recommendation V4.14: It is recommended that development be restricted in the floodway and flood fringe areas in Pincher Creek subject to a site specific flood risk assessment demonstrating that the development lies outside the 1% AEP flood area.

Existing flood defences at Pincher Creek may be inadequate to protect to the 1% AEP flood. It is therefore recommended that a thorough condition survey of the existing defences be undertaken. This was not possible during this contract due to time constraints and winter weather. There are also signs of erosion on the left bank of Pincher Creek at the Kettle Creek confluence. This should also be repaired.

Recommendation V4.15: A thorough condition survey should also be undertaken for the existing flood defences in Pincher Creek. The survey should include an assessment of the standard of protection offered by the existing defences and raised where appropriate. The left bank of Pincher Creek should be armoured at the confluence with Kettle Creek.

8.2 Fort MacLeod

There are groynes to prevent the outflanking of the bridge at Highway 811. There is still considerable erosion on the left bank and abutment. This needs to be repaired. It is recommended that the left bank abutment at Highway 811 Oldman River Bridge be armoured as per the drawings in **Appendix J** of **Volume 4**.

Recommendation V4.16: It is recommended that the left bank bridge abutment at Highway 811 Oldman River bridge be armoured.

8.3 Cardston

The channel at Cardston has been dredged in the past. There appears to be some aggradation in the channel; however, the extent of dredging necessary cannot be determined without revisiting the channel hydraulic model. It is recommended that the flood study for Cardston be updated with new modeling and mapping to reflect the current river bathymetry and development in the town.

Recommendation V4.17: The hydraulic model and flood mapping for Cardston should be updated to determine if dredging of the channel is necessary to improve conveyance.

8.4 Piikani First Nation

The Piikani First Nation identified that erosion is problematic along the Oldman River through the reserve lands. Due to the timing of the Piikani engagement meeting and the completion of this study, AMEC cannot follow up this and make specific recommendations for erosion protection for the Oldman River though the Piikani Reserve. It is therefore recommended that further investigations are undertaken with regards to erosion control through the Piikani Reserve and also with regards to the provision of storm water drainage in Brocket.

Recommendation V4.18: It is recommended that further investigations are undertaken with regards to erosion control through the Piikani Reserve and also with regards to the provision of storm water drainage in Brocket.

9.0 GENERAL RECOMMENDATIONS

If the GoA intends to embark on a major investment in flood defence infrastructure, this investment should be underpinned by economic appraisal and to achieve this, flood frequency/damage curves should be developed for all riverside communities where investments are planned. It is recommended that a study be undertaken to estimate flood damages using a common methodology to ensure that comparisons can be made for prioritisation of projects. This project could be undertaken on a province-wide basis.

Recommendation V4.19: It is recommended that a major study be undertaken to estimate flood damages using a methodology or approach similar to the 1986 Elbow River Floodplain Management Study Report.

It is recommended that a robust economic appraisal be undertaken prior to the investment in a flood control dam on the Elbow River. Based on the assumptions and limited data available for this report, it is likely that an economic case can be made to invest upwards of $200 million on flood defence infrastructure in the Elbow River basin.

Recommendation V4.20: It is recommended that a robust economic appraisal be undertaken prior to the investment in major flood control infrastructure in the Bow River, Elbow River or Oldman River basins.

Given that the scope of work assigned to AMEC did not include specific measures for the City of Calgary, this study was limited in terms of investigations into the flood storage potential along the Bow River. It is recommended that a comprehensive investigation into flood storage sites along the Bow River be undertaken.

Recommendation V1.21: It is recommended that further study is undertaken on potential reservoir sites within the Bow River basin and that this study be coordinated with GoA representatives who are negotiating with TransAlta.

10.0 CLOSURE

This report has been prepared for the exclusive use of the Southern Alberta Flood Recovery Task Force. This report is based on, and limited by, the interpretation of data, circumstances, and conditions available at the time of completion of the work as referenced throughout the report. It has been prepared in accordance with generally accepted engineering practices. No other warranty, express or implied, is made.

Yours truly,

AMEC Environment & Infrastructure

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Permit to Practice No. P-4546

Appendix G

Conceptual Design of the Springbank Off-Stream Flood Storage Site

Southern Alberta Flood Recovery Task Force
Volume 4 – Flood Mitigation Measures

Appendix G – Springbank Off-Stream Storage Project

Submitted to:

Southern Alberta Flood Recovery Task Force
Edmonton, Alberta

Submitted by:

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Calgary, Alberta

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TABLE OF CONTENTS

TABLE OF CONTENTS (*cont*)

PAGE

LIST OF TABLES

LIST OF FIGURES

1.0 SPRINGBANK OFF-STREAM STORAGE PROJECT

1.1 Concept Description

The Springbank Off-stream storage (SR1) site was identified as a part of the current flood mitigation study. It is located just west of Calgary approximately 18.5 km upstream of the Glenmore Reservoir in a relatively undeveloped farmland and ranchland area valley.

This SR1 concept considers diverting extreme flood flow from the Elbow River into an off-stream storage reservoir where it would be temporarily contained and later released back into the Elbow River after the flood peak has passed. Project components include a diversion structure constructed across the Elbow River, and a diversion channel excavated through the adjacent uplands to transport flood water into an off-stream storage reservoir. The storage site includes an earthfill dam to temporarily contain the diverted flood water and a low level outlet structure incorporated into the dam to later release the stored water back into the Elbow River after the flood peak has passed. The diversion system, off-stream dam site and reservoir area are illustrated in **Drawing G1**.

The SR1 could be designed as a dry pond (i.e., no storage reservoir except during flood periods) or could include permanent multi-use water storage with much larger flood storage volume above the permanent multi-use storage full supply level (FSL). The multi-use water could be used for recreational/environmental purposes, and/or an additional water supply source for the City of Calgary, and/or for other uses during periods of low river flow or drought. This storage would also serve to dissipate energy when flood water first enters the reservoir. For the purpose of this conceptual assessment a multi-use storage containment of 9,000 dam^3 has been assumed providing a maximum pond depth of 10 m.

The potential use, FSL, volume, and regulation of the permanent multi-use storage component of the reservoir requires further investigation. Future climate change and sediment infilling of Glenmore Reservoir (loss of existing storage due to long-term sedimentation) should be key considerations. Bathymetric surveys indicate that Glenmore Reservoir may have lost 17% of its storage volume since 1933 as a result of river sediment transport.

Some portion of the above-noted multi-use storage could be considered for flood storage (e.g., reservoir lowered in spring in advance of incoming flood, then refilled after flood risk has passed). Multi-use storage has not been included as available flood storage in this conceptual design.

2.0 HYDROLOGICAL OVERVIEW

2.1 Median and Mean Monthly Flows

Median winter and median annual flows for the Elbow River are approximately 4 and 10 m^3/s, respectively, as recorded at ESRD gauging station 05BJ010 (Elbow River at Sarcee Bridge). Mean monthly flows as recorded at station 05BJ010 are provided in **Table G2.1**.

Table G2.1
Elbow River Mean Monthly Flows

Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Mean Flow (m^3/s)	3.5	3.6	4.1	5.3	14.8	27.6	15.2	9.6	8.3	6.6	5.2	4.1

The Springbank Road site is located approximately 16 km upstream of this gauging station, resulting in a 30% reduction in drainage area. The impact of this area's reduction on median and mean monthly flows has not been estimated as a part of this study, but will be much less than 30%.

2.2 Flood Flows

Frequency analysis of flood inflows into Glenmore Reservoir (i.e., 21 km downstream of the Springbank Road diversion site as discussed herein) which was completed for this study resulted in instantaneous flood peak flow and 7-day flood volume estimates as summarized in **Table G2.2**. These estimates are considered to be representative of the upstream Springbank diversion site (i.e., assumes minimal inflow between diversion site and Sarcee Bridge during extreme flood events generated in higher regions of the basin). Background information which provides the basis for these flood estimates is documented separately in **Appendix C** of the main report. Estimates of the June 2013 flood instantaneous peak flow and total flood volume entering Glenmore Reservoir are included for comparison in **Table G2.2**.

Table G2.2
Elbow River Instantaneous Flood Peak and Runoff Volume Estimates

Annual Flood Probability (Return Period)	**Instantaneous Peak Flow (m^3/s)**	**7-day Volume dam^3**
5% Annual Exceedence Probability (AEP; 1:20-year)	440	83,000
1% AEP (1:100-year)	930	130,000
June 2013 Flood	1,260	154,000
0.2% (1:500-year)	1,625	183,000

As indicated by **Table G2.2,** the June 2013 flood instantaneous peak flow and flood volumes were larger than the estimated 1% AEP flood but smaller than the 500-year flood. More detailed frequency analysis should be performed as part of future, more detailed design study.

2.3 Probable Maximum Flood

The Probable Maximum Flood (PMF) is defined as the most severe flood that may be reasonably expected to occur at a particular location. The PMF is normally evaluated by deterministic methods that maximize the various factors contributing to the generation of a flood. The probability of such a flood occurring is very rare (e.g., once in a million years).

A PMF hydrograph at Glenmore Reservoir was previously generated by ESRD and is included in the August 1986 *Elbow River Floodpain Management Study* by WER, IBI and ECOS. The PMF entering Glenmore Reservoir was estimated to have a flood peak value of 3,030 m^3/s and a 7-day volume of approximately 640,000 dam^3, which is approximately 4.2 times the volume of the 2013 flood. ESRD cautions:

> "…that these are preliminary estimates of PMF…subject to considerable error and that a detailed assessment….would be required prior to any detailed design."

3.0 GEOLOGICAL AND GEOTECHNICAL OVERVIEW

A preliminary subsurface field investigation was completed as a part of this study as documented in a separate report entitled *Preliminary Geotechnical Investigation Report, Springbank Off-stream Dam Project* (AMEC, 2014).

The SR1 site is located near the eastern edge of the foothills. The bedrock underlying the area transitions from the Paleocene/Upper Cretaceous Brazeau Formation in the vicinity of the diversion structure, to bedrock of the Paleocene Porcupine Hills Formation farther east and north toward the north end of the off-stream storage dam. Both formations are non-marine deposits generally consisting of cross-bedded and interbedded sandstone, mudstone, and siltstone. A bedrock exposure approximately 12 m high overlain with glacial till is evident in the left valley wall of the Elbow River at the site of the proposed diversion structure.

The findings of the above-noted preliminary geotechnical field investigation program indicate that subsurface soils in the area of the proposed diversion channel, off-stream dam, and reservoir generally consist of medium plastic clay and clay till soil underlain by bedrock consisting of interlayed mudstone, sandstone, and siltstone. Subsurface materials underlying the proposed diversion structure system are expected to consist primarily of fluvial sand and gravel deposits, while the subgrade underlying the dam is expected to consist of a mixture of clay, silt, sand, and gravel soils. The soils encountered during the field investigation are expected to be suitable as foundation materials for the embankments and structures associated with the proposed project development. The clay and clay till soils are also suitable for use in embankment construction for the floodplain berm, diversion channel fills, and the off-stream storage dam embankment.

Granular materials required for structure backfill, dam filters, and drains would need to be brought in from off-site sources. Rock riprap and cobble armour protection would similarly need to be brought in from off-site sources.

4.0 FLOOD STORAGE VOLUME

4.1 Background Considerations

Significant residential development located along the Elbow River floodplain downstream of Glenmore Reservoir is at risk during extreme flood events. Pathway closures are required when Glenmore Reservoir flood discharge reaches 40 m^3/s. Modest overbank flooding of undeveloped areas starts at 120 m^3/s discharge. Widespread basement seepage occurs for discharges of 140 m^3/s. First residents are impacted at discharges of 170 m^3/s. Evacuation of residents is initiated at a discharge of 192 m^3/s.

The most recent Glenmore Reservoir storage capacity and flooded area curves which were produced by Klohn Crippen Berger in 2013 are illustrated on **Figure G4.1**. The existing Glenmore Reservoir storage is used to attenuate flood peaks thereby protecting downstream developments. If an extreme flood is forecast, the City of Calgary opens the Glenmore Reservoir low level DOW valves thereby drawing the reservoir down to provide flood storage for the incoming flood. Maximum permissible drawdown is 5 m below FSL El. 1,076.85 m which equates to a flood storage volume of 15,400 dam^3 (KCB Glenmore Bathymetric Survey, 2013). This drawdown could be accomplished in 25 hours at the maximum discharge rate of 170 m^3/s (maximum discharge before significant downstream flood damages start to occur). In reality a portion of this storage should be drawn down well in advance of an actual flood event forecast (e.g., in the spring when significant snow pack exists in the watershed). The 15,400 dam^3 draw down was successfully achieved in anticipation of the June 2013 flood. The City of Calgary needs to use caution when drawing the reservoir down in that if they draw down the Glenmore Reservoir and the forecast flood does not develop they can be left with insufficient water supply.

Bathymetric surveys by Klohn Crippen Berger for the City of Calgary indicate that Glenmore Reservoir may have lost approximately 17% of its storage volume since 1933 as a result of sediment transport into the reservoir. This process is ongoing.

Table G4.1 provides estimates of the flood volume required to prevent significant damages along the Elbow River downstream of Glenmore Reservoir, considering a continuous discharge of 170 m^3/s from the reservoir for the duration of the flood (i.e., discharge before first downstream residents are impacted by flood water).

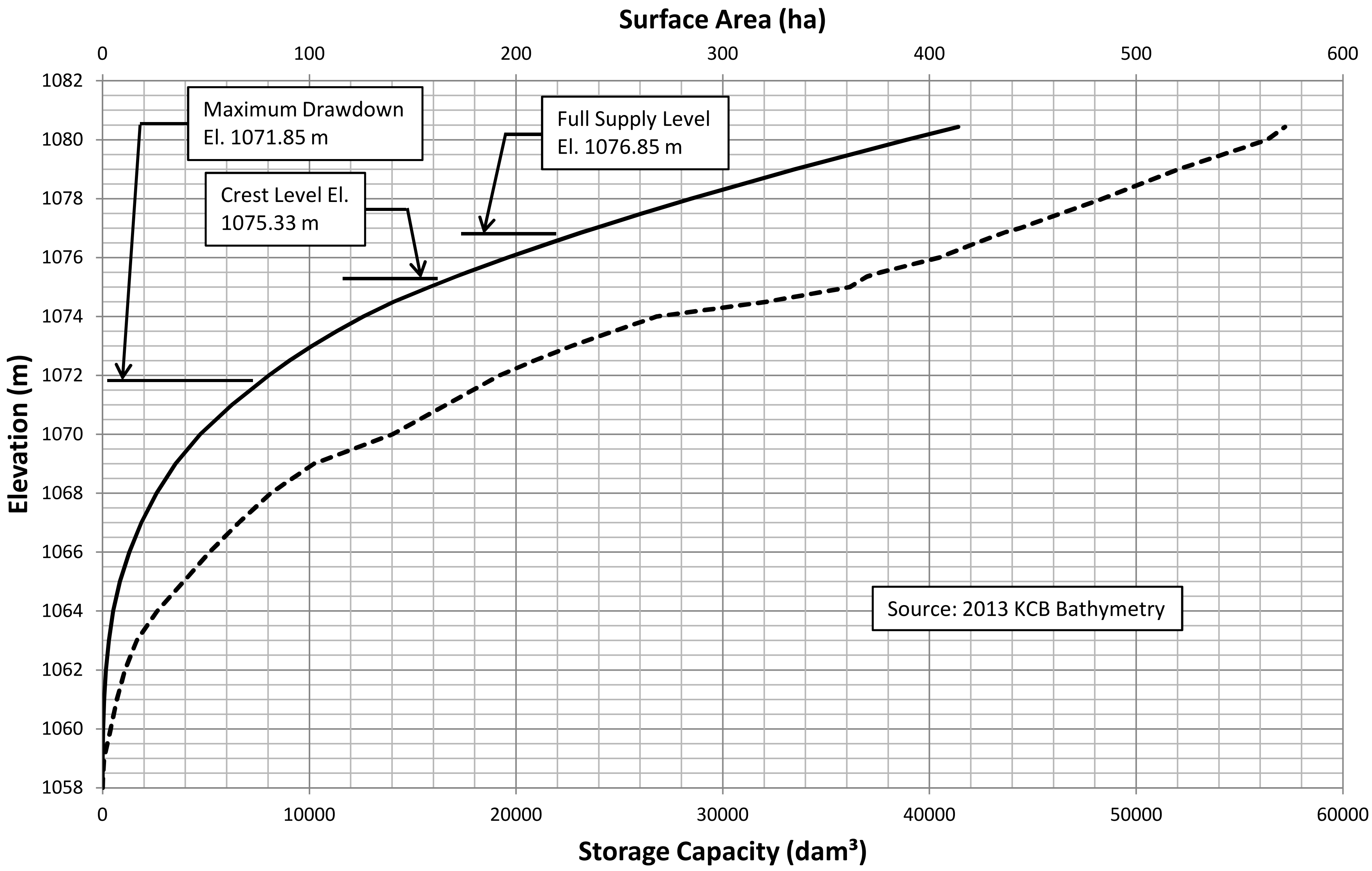
Table G4.1
Required Reservoir Flood Storage Volume to Prevent Damages

Return Period (Years)	Minimum Storage Requirement
5% AEP (1:20-year)	16,800
1% AEP (1:100-year)	56,600
June 2013 Flood	83,000
0.2% (1:500-year)	107,500

Based on the data presented in **Table G4.1,** one can conclude that the Glenmore Reservoir flood storage of 15,400 dam^3 is inadequate to prevent discharge from exceeding the 170 m^3/s value for floods events as small as the 20-year return period flood. The level of protection is even poorer if the City is not successful drawing Glenmore Reservoir down to its minimum El. 1,071.85 m prior to flood impact. It is therefore concluded that the existing level of protection to residences downstream of the Glenmore Reservoir is inadequate. That said, Glenmore Reservoir flood storage does provide significant flood peak attenuation and downstream development protection (e.g., as much as full protection for floods just smaller than 20-year return period, and successfully attenuated June 2013 flood inflow peak of 1,260 m^3/s to discharge of approximately 700 m^3/s).

Figure G4.1

Glenmore Reservoir
Reservoir Storage Capacity and Flooded Area Curves



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4.2 Flood Protection Design Basis

The current Alberta minimum flood protection design standard is the 1% AEP flood, or alternatively can be based on a historical flood event (e.g., June 2013 flood). Increased protection should be considered based on economic assessment and/or when such an event would result in severe societal impact. As an example, the Red River floodway was originally sized to protect Winnipeg from the 0.2% AEP (1:500-year) flood event. It was later enlarged to provide 0.14% AEP (1:700-year) flood protection. Even greater protection was considered but costs were proven to be prohibitive.

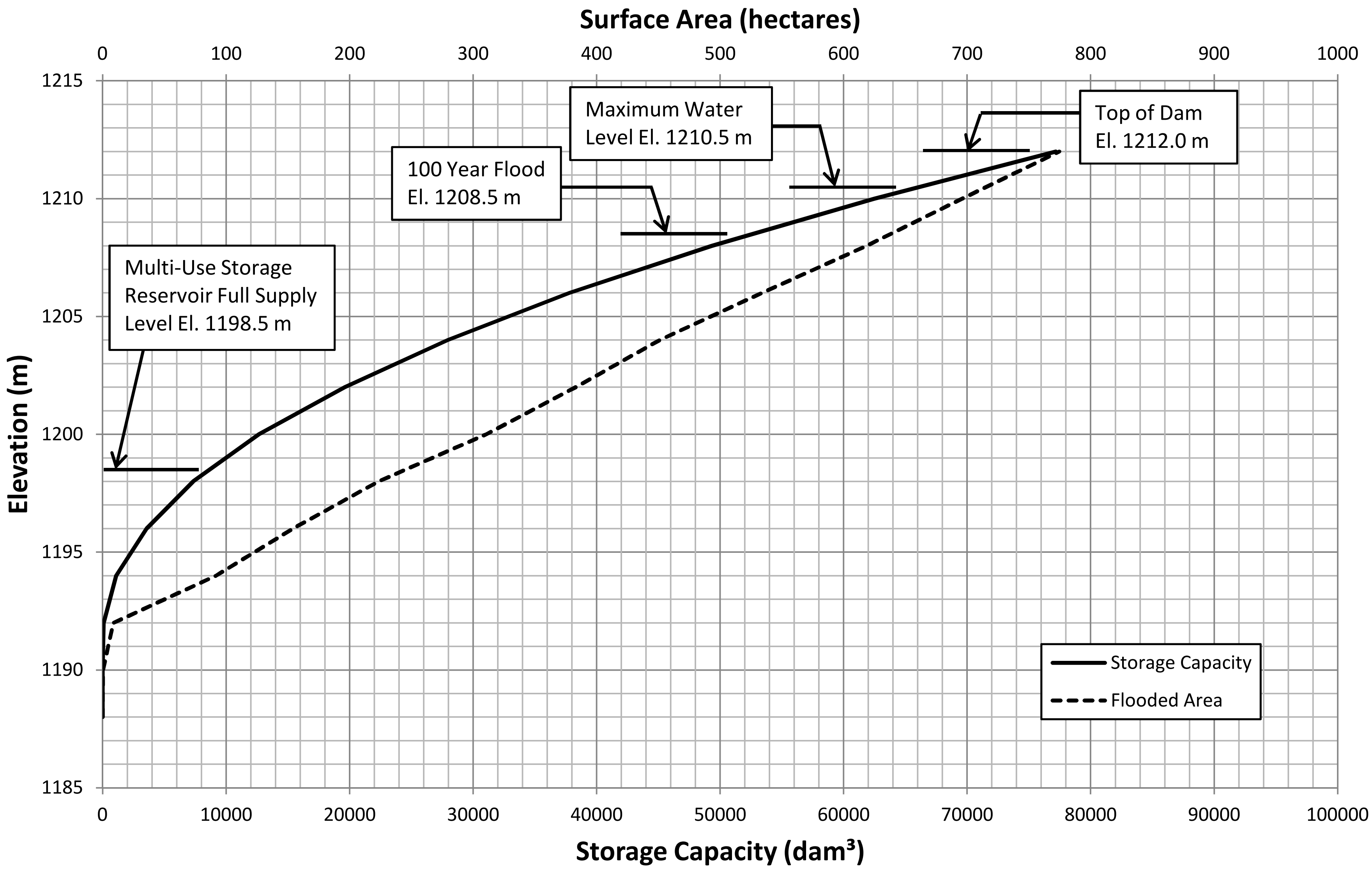
The SR1 concept as presented herein was developed considering the 1% AEP minimum design standard (i.e., total flood storage requirement of 56,600 dam^3). As previously mentioned, Glenmore Reservoir can provide 15,400 dam^3 of that amount. As indicated in **Figure G4.2,** the remaining 41,200 dam^3 flood storage could be provided with a Springbank off-stream storage reservoir water level of approximately El. 1,208.0 m. To account for operational inefficiencies a 1% AEP El. 1,208.5 m has been used. This conservatively assumes that none of the previously mentioned Springbank off-stream reservoir multi-use live storage was pre-released in anticipation of the flood. The conceptual design provides for a nominal 2 m additional storage above the 1% AEP El. 1,208.5 m (i.e., maximum allowable reservoir El. 1,210.5 m) resulting in a combined total flood storage capacity of 72,400 dam^3 (i.e., Glenmore and Springbank combined reservoir storage). Considering the project size presented in this conceptual design, a 2013 magnitude flood would still result in residential damages, but these damage would be greatly reduced as compared to what was experienced in 2013. The Springbank Road project could be built to a higher level than investigated herein to provide enhanced flood protection (e.g., full containment for 2013 magnitude flood or larger). Alternatively, additional projects could be constructed to provide enhanced flood protection above that provided herein.

Figure G4.2 area and capacity curves were developed based on contours developed from 15 m LiDAR, prior to obtaining the 1 m LiDAR illustrated on **Drawings G1** and **G8**. These area and capacity curves should be updated considering the 1 m LiDAR data in future design.

Figure G4.3 illustrates the potential flood flow reduction benefits of the Springbank and Glenmore Reservoir storage when managing the 1% AEP flood. The figure illustrates that a maximum 300 m^3/s flow would be diverted into the off-stream storage site reducing the river flow from 930 to 630 m^3/s at the diversion structure. This resulting 630 m^3/s flow rate is absorbed in Glenmore Reservoir storage. The resulting peak discharge from Glenmore Reservoir is 170 m^3/s; the maximum allowable discharge prior to residential damage. An Elbow River flow of 200 m^3/s has been set as a trigger condition to initiate diverting a portion of the Elbow River flood water into the off-stream storage site. Diversion would only be continued if a major flood develops.

Figure G4.2

Springbank Off-Stream Storage Project (SR1)
Reservoir Storage Capacity and Flooded Area Curves



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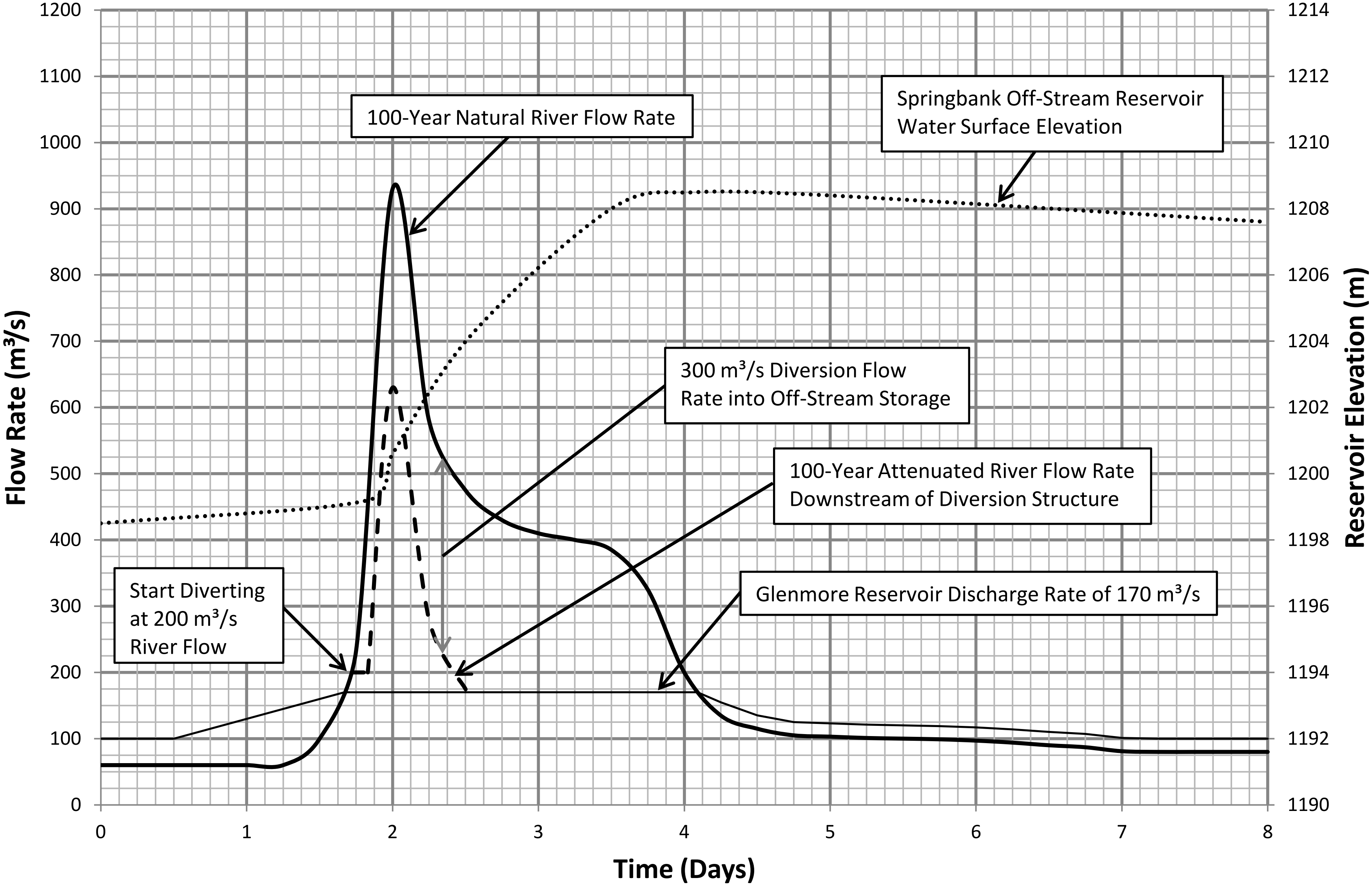
The following additional observations are made with respect to **Figure G4.3**:

- The inflow hydrograph peaks vary rapidly emphasizing the need for improved flood forecasting methods.
- The operators must be quick to open the diversion gates on receipt of a flood warning otherwise the Glenmore Reservoir storage will be filled prematurely, and the Springbank off-stream storage flood protection benefit will be significantly reduced. The gates must be fully opened within the hour of its indicated 200 m^3/s trigger level. This could occur in the middle of the night.
- The Glenmore Reservoir storage component of the design is very important as it attenuates the peak inflow from 630 to 170 m^3/s. This again emphasizes the need for improved forecasting and the importance of drawing Glenmore Reservoir down in advance of the flood. A portion of this storage should be drawn down well in advance of a flood, based on the possibility of a major flood developing (e.g., high snowpack in basin).
- The 1% AEP inflow hydrograph is numerically generated. The benefit would be reduced for an event with a hydrograph having a steeper upstream limb or a flatter downstream limb, but having the same 1% AEP peak flow rate and volume.
- The above-noted operational considerations support building the project to greater than the 1% AEP return period protection level (i.e., increased volume and diversion rate) and/or constructing additional flood protection projects.

Figure G4.3

Springbank Off-Stream Storage Project (SR1)
1% AEP (100 Year) Flood Routing Results



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5.0 PROJECT DESIGN

5.1 General

Pertinent structure data established for conceptual design and described in this report section are provided in **Table G5.1**.

5.2 River Diversion Structure System

A conceptual design layout for the diversion structure system is provided in **Drawing G2**. Additional structure details are provided in **Drawing G3** and **Drawing G4**. The design is similar in concept to the Carseland Weir diversion structure located on the Bow River near the town of Carseland, Alberta, except the diversion capacity for SR1 is significantly greater than at Carseland due to the function as a flood channel. The diversion structure system would consist of a concrete overflow weir section crossing the Elbow River, a gated concrete sluiceway/fishway located adjacent to the left side valley abutment with its invert at the river thalweg level, and a gated diversion outlet structure located in the left valley abutment immediately upstream of the sluiceway. The outlet structure invert level would be located approximately 1.5 m above the river thalweg in order to exclude larger bottom sediment from entering the diversion channel. A robust trash boom has also been considered spanning across the entrance of the diversion outlet structure to manage the risk of floating debris plugging the outlet gate openings.

Detailed hydraulic and sediment transport analysis is required to better establish key structure parameters and to estimate the performance of this structure within the Elbow River flood regime. This analysis should be considered a priority in establishing parameters including weir crest and diversion invert levels, and future operating procedures to ensure that excessive volumes of larger sediment are not diverted out of the river system into the diversion channel during extreme floods. Hydraulic and sediment transport modelling assessment may be required following preliminary office study assessment which would include input from a sediment transport specialist.

Fluvial sand and gravel deposits in the river channel will provide a stable subgrade both to support the diversion structure foundations, and to provide resistance to lateral loads during flood events. Local lacustrine clay and clay till deposits excavated from the adjacent diversion channel are generally of medium plasticity, and are suitable for use in constructing low permeability compacted backfill for headwalls and wing walls that extend into adjacent embankments or native soil abutments.

The diversion weir component of the diversion structure is a relatively massive 100 m long concrete structure with an ogee crest shape and a hydraulic jump stilling basin. This structure serves to reduce approach velocities and increase the river water level to facilitate diversion through the outlet structure into the diversion channel.

Table G5.1
Springbank Road Off-stream Storage Project (SR1) Pertinent Structure Data

Diversion Structure Weir	
River Bed Elevation	1,209.5 m
Weir Crest Elevation	1,213.5 m
Top of Structure Walls Elevation	1,218.0 m
Weir Crest Length	100 m
Basin Elevation	1,208.5 m
Maximum Structure Height	9.5 m
Floodplain Berm	
Top of Containment Embankment Elevation	1,217.9 m
Maximum Height	7 m
Sluiceway/Fishway	
Number and Size of Openings	2 @ 4.0 m high × 8.0 m wide
Type of Control	Radial Gates
Normal Water Level (Non-Flood Condition)	1,210.2 m
Upstream Bottom Invert Elevation	1,209.5 m
Gate Clearance During Normal Flow Condition	3.3 m
Basin Elevation	1,208.5 m
Maximum Structure Height	9.5 m
Diversion Outlet Structure	
Number and Size of Openings	4 @ 3.0 m high × 8.0 m wide
Type of Control	Radial Gates
Gate Invert Elevation	1,211.0 m
Basin Elevation	1,207.5 m
Maximum Structure Height	10.5 m
Diversion Channel	
Upstream Invert Elevation	1,208.5 m
Bottom Width	30 m
Side Slopes (H:V)	3:1
Bed Gradient	0.001
Design Water Velocity	2.5 m/s
Reservoir Inlet Structure	
Crest Elevation	1,205.0 m
Chute Width	24 m
Structure Length	60 m
Off-stream Storage Reservoir	
Multi-use Storage Volume	9,000 dam^3
Multi-use Storage FSL	1,198.5 m
100-year Flood Storage Volume required at SR1	41,200 dam^3
100-year Reservoir Flood Elevation	1,208.5 m
Maximum Flood Storage Volume	57,000 dam^3
Maximum Reservoir Flood Level	1,210.5 m
Off-stream Storage Dam	
Top of Dam Elevation	1,212.0 m
Maximum Dam Height	24 m
Maximum Flood Water Level	1,210.5 m
Freeboard Above Maximum Water Level	1.5 m
Storage Dam Outlet Structure	
Conduit System	1 conduit at 1.5 m wide × 1.8 m high
Gatewell Tower Height	20 m
Size of Gate	1 sluice gate at 1.2 m wide × 1.8 m high
Structure Design Flow	20 m^3/s

The sluiceway/fishway component of the diversion structure is equipped with two 8 m wide radial gates. The sluice gate number and width was selected to provide free passage of fish along the Elbow River without significantly impacting water velocity during normal flow conditions. The sluiceway gates would typically be kept in the wide open position during non-flood conditions allowing free passage of sediment, fish, etc. Partial gate closure would be required as a part of flood operations to provide for adequate flow rate diversion through the outlet structure into the diversion channel, while allowing bottom sediment to pass under the sluiceway structure gates thereby keeping the majority of bottom sediment in the main river system.

The outlet diversion structure is equipped with four 8 m wide radial gates. The outlet structure gates would typically be kept in the full closed position during non-flood conditions. This conceptual design considers opening these gates when extreme flood conditions are anticipated thereby diverting a portion of the flood flow into the off-stream storage site. As previously mentioned, an Elbow River flow of 200 m^3/s has been set as a trigger condition to initiate diverting a portion of the Elbow River flood water into the off-stream storage site. Diversion would only be continued if a major flood develops.

If the flood event is large, the outlet structure gates would be opened to divert a maximum 300 m^3/s out of the Elbow River into the off-stream storage reservoir. In the case of the 1% AEP flood event, the peak flow remaining in the Elbow River would be reduced from approximately 930 to 630 m^3/s, but this flow rate would occur for only a short period of time. Glenmore Reservoir storage would be used to further attenuate this short duration peak flow rate of 630 m^3/s to a maximum reservoir outflow of 170 m^3/s. These operations and flow rates are illustrated graphically on **Figure G4.3**.

Precast concrete access decks, gate system control buildings, instrumentation controls, and automation have been allowed for on both the sluiceway/fishway and diversion outlet structure components of the diversion structure systems illustrated on **Drawing G4,** and allowed for in the cost estimate.

An earthfill floodplain containment berm with crest El. 1,217.9 m will be required across the floodplain connecting the diversion structure system to the south land form to prevent flood water creating a new channel through the floodplain, and thereby prevent flood water from bypassing the diversion area/sluiceway system. This berm would not connect to the existing ground El. 1,217.9 m, but would rather stop short leaving a low gap area for extreme flood passage. The conceptual design considers that the concrete weir and sluiceway system would pass all floods up to the 0.1% AEP flood event, prior to more extreme flood water escaping through this southern gap area. The PMF would be conveyed through the system without overtopping the diversion structure crest. Fuse plugs would not be incorporated into the floodplain berm because of the associated sudden increase in discharge and resulting downstream safety risks in the City of Calgary.

Following stripping of surface organic soils, the exposed subgrade for the floodplain berm is expected to consist of a combination of fluvial sand and gravel deposits and clay/clay till soil. Removal of fine sand or silt overbank materials in the upper portion of the subgrade may be required in some areas prior to placing embankment fill to limit potential for piping below the embankment.

The floodplain berm is a zoned fill with an impervious zone 1A compacted clay core and random compacted 2A fill upstream and downstream shells. Available local medium plastic to low plastic clay and clay till soil will provide suitable borrow material for constructing the impervious 1A compacted core. Local clay soil, as well as reworked bedrock or other excavated materials from the embankment subgrade or diversion channel excavation, will provide suitable material for construction of the upstream and downstream random fill zone 2A shells.

5.3 Diversion Channel and Reservoir Inlet Structure

The proposed diversion channel profile and a typical channel section are illustrated in **Drawing G5**. The diversion channel is designed to convey a peak diversion flow of 300 m^3/s from the Elbow River into the off-stream storage reservoir. The channel has been designed to convey this flow at a relatively high channel velocity of 2.5 m/s in order to transport any sediment which enters from the reservoir and thereby reduce the risk of plugging the diversion channel. The channel is designed with a 24 m bottom width, three horizontal to one vertical side slopes and a 3.6 m water depth. Excavation for the diversion channel will range from approximately 25 m depth near the Elbow River diversion to less than a metre where the channel alignment crosses small creeks. Construction of banks will be required over short stretches of the channel alignment to provide adequate bank height to contain the flood water within the channel. The material excavated from the diversion channel will provide the primary borrow source for construction of the off-stream storage dam and the floodplain berm.

The material excavated from the diversion channel will consist mostly of lacustrine silty clay and clayey silt, silty clay till, and bedrock of the Brazeau and Porcupine Hills Formations. It is anticipated that occasional pockets of sand will also be encountered within the lacustrine and till units. Additional geotechnical drilling during future project phases will serve to better define the relative quantities of clay soil and bedrock that will be excavated from the diversion channel.

The lacustrine and till deposits predominately consist of medium plastic silty clays with occasional instances of either low plastic or high plastic clays. Atterberg limit tests conducted on samples of clay from the area have indicated liquid limits between 34% and 38%, and plastic limits between 18% and 20%. Soil moisture contents measured in the clay have ranged from 11% to 30%. It should be recognized that the number of boreholes drilled to date was limited to five locations due to restricted land access. The laboratory test results are generally consistent with the results of tests obtained on samples of similar clay from other nearby projects.

Bedrock in the project area generally consists of inter-bedded mudstone, siltstone and sandstone. The mudstone is generally extremely weak to weak rock with a consistency similar to very hard soil. The siltstone and sandstone layers are typically discontinuous, and can range from weathered very weak rock to moderately strong rock. Bedrock of the Brazeau and Porcupine Hills formations have been excavated on previous construction projects without use of blasting, by using large hydraulic excavators and large dozers equipped with rippers. Hydraulic breakers can be required to break up stronger siltstone and sandstone layers into pieces suitable for excavation. The weathered sandstone and siltstone, and the mudstone, deteriorates over time with exposure to air and water.

Use of the locally excavated bedrock as engineered fill requires that the blocky broken out pieces of bedrock be thoroughly broken down during compaction to a soil-like consistency. This is accomplished by using thin lifts of material for compaction, moisture conditioning as necessary including turning the soil with a disc or grader and using heavy compaction equipment capable of crushing the individual pieces of material. Large pieces of strong sandstone and siltstone should be stockpiled separately during the excavation process, and not be used for construction of engineered fill.

The clay lacustrine and till deposits are suitable for construction of either impervious zone 1A, or random zone 2 type embankment construction. Soil mixing to distribute pockets of siltier or sandier materials and moisture conditioning will be required during embankment construction. Embankments constructed of the local low to medium plastic clay soil with sideslope angles of 2.5H:1V (horizontal:vertical) or flatter, will provide a factor of safety against slope instability of 1.5 or greater, depending on slope height and with no groundwater present in the slope.

In general, within the lacustrine clay, clay till and bedrock materials expected to be encountered along the diversion channel alignment, slopes excavated to an angle of 3H:1V or flatter will provide a minimum 1.5 factor of safety against slope instability, assuming a 25 m high slope and considering that less than about 40% of slope height is below the groundwater table.

Remoulded bedrock is suitable material for use in constructing random zone 2A fill. Remoulded bedrock or mixtures containing remoulded bedrock may be suitable for use in constructing impervious zone 1A fill provided specific field procedures are implemented to ensure the bedrock is broken down to the consistency of soil during compaction. Sideslope angles of 3H:1V or flatter are recommended for embankments constructed of medium to high plastic remoulded bedrock, and will provide a factor of safety of 1.5 or greater for slope heights of up to 25 m and considering a groundwater level below about 40% of the slope height.

The diversion channel design is presented at a very conceptual level. Future design should consider:

- Sideslope benching to provide improved access for maintenance;
- Further evaluation of required diversion channel velocity to manage diverted sediment;
- Sediment deposition ponds at the existing depressions at stations 3+000 and 4+500;
- Gradient flattening to manage erosion on select reaches;
- Perhaps an intermediary drop structure at approximately station 3+400 to manage erosion at the upstream bridge; and
- Channel erosion protection including topsoiling, grassing, and cobble armour in select reaches.

A concrete reservoir inlet structure will be required at its downstream end where the water is discharged into the reservoir in order to manage the extent of channel erosion. **Drawing G7** illustrates the inlet chute structure concept. The proposed multi-use storage pond allows a reduction in required inlet chute length as compared to if the concept is designed without a pool. Following stripping of organic soil, the subgrade for the inlet structure foundation is expected to consist of clay till. The local clay soil will provide stable subgrade support for the structure foundation, and is suitable for construction of impervious backfill around headwalls, cutoff walls and side walls for the structure.

Ensuring that the larger river bottom sediment is excluded from this channel, and providing high channel velocities to transport any diverted sediment through the channel are extremely important features immediately downstream of the diversion outlet; otherwise, channel plugging could occur during diversion.

5.4 Off-stream Storage Dam and Reservoir

A 3 km long earthfill storage dam having a maximum height of 24 m is required to contain the diverted flood water. The conceptual design considers a zoned earthfill dam with a clay core and random earthfill shells as illustrated in **Drawing G6**. Embankment slopes of 3H:1V are provided, with 6 m wide berms at strategic levels resulting in average dam slopes of between 3H:1V and 4H:1V. The berms are included to provide stability, and to facilitate access for inspection, maintenance, and geotechnical instrument monitoring. The need, width, and spacing of such berms should be further evaluated as part of future design. An interior filter and drainage system and upstream riprap slope protection have been provided. Rock riprap protection has been provided in the active permanent multi-use reservoir zone from reservoir bottom to the lower berm El. 1,202.0 m. It is also provided in the dam crest zone (i.e., El. 1,207.0 to 1,212.0 m) to protect the dam from potential failure in the unlikely event of full flood containment to El. 1,210.5 m combined with a minimum 50% AEP wind event. This upper zone riprap can be covered with topsoil and seeded to provide a more desirable landscape appearance. Consideration should also be given to using a more erosion resistant impervious 1A zone material in the upstream shell/upstream dam surface to reduce the risk of wave damage. The extent of these features will be better established based on more detailed future design work.

Following stripping of surface organic soils, the exposed subgrade for the storage dam embankment is expected to consist of a combination of lacustrine clay and clay till. Previous experience with similar low to medium plastic soil subgrades indicates that subgrade deformations or increase in porewater pressure due to embankment construction are not limiting factors for typical rates of embankment construction.

The main embankment is a zoned fill with an impervious zone 1A compacted clay core and random compacted zone 2A fill upstream and downstream shells. Available local medium plastic to low plastic lacustrine clay and clay till soil will provide suitable borrow material for constructing the impervious zone 1A compacted core. Local clay soil, as well as reworked bedrock or other excavated materials from the embankment subgrade or diversion channel excavation, will provide suitable borrow for construction of the upstream and downstream random zone 2A shells. As discussed previously, it may also be possible to use remoulded bedrock to construct impervious zone 1A embankment subject to demonstration of adequate field procedures.

Embankment slope angles of 3H:1V for slopes formed of random zone 2A fill will provide adequate minimum factor of safety against slope instability for the approximately 24 m height of the main embankment – for an unsaturated slope condition. Assessment of a rapid drawdown condition for the multi-use reservoir full supply water elevation of 1,198.5 m, indicated a factor of safety against slope instability of approximately 1.4 for a 3H:1V upstream embankment angle. A rapid drawdown scenario was not investigated for the 1% AEP condition since even at the maximum 20 m^3/s rate of discharge for the low level outlet, a month or more would be required to lower the stored water level to the permanent pool elevation 1,198.5 m.

The dam system will include a gated low level outlet structure. This structure will include a 1.5 m wide by 1.8 m high concrete conduit through the dam including a gatewell tower located near the dam centerline as illustrated in **Drawing G6**. This structure will be used to release stored water back into the river after the flood has passed. Channel improvements will be required along the creek connecting this outlet to the Elbow River. As previously mentioned, the conceptual design considers a low level outlet system design discharge of 20 m^3/s which could release the contained 1% AEP flood water in a period of approximately 1 month. The design and cost estimate make allowances for a gate system control building, instrumentation controls, and automation.

It is expected that the subgrade soil supporting the low level outlet will consist of either lacustrine clay or clay till soil. Since the location proposed for the low level outlet is an existing natural drainage channel, there may be unconsolidated alluvial soil present along the alignment proposed for the low level outlet. Removal of such soils to a very stiff clay subgrade would be required to provide adequate support for the outlet conduit, otherwise consideration can be given to moving the structure to a location with a better foundation as determined by future drilling. The lacustrine clay soil or glacial clay till soil will provide adequate foundation support for the discharge structure at the end of the conduit.

6.0 EXISTING INFRASTRUCTURE IMPACTS

6.1 General

A number of pipelines, power lines, telephone lines, and road systems will be impacted by the proposed works as schematically illustrated on **Drawing G1**.

6.2 Pipelines, Power Lines and Telephone Lines

Numerous oil and gas pipelines cross the proposed diversion channel route and the off-stream storage dam alignment. These lines will need to be re-routed or lowered. Pipelines identified to date include ATCO Gas distribution lines, a 114 mm Pengrowth Energy Corporation HV line, a 168 mm Alberta Ethane Development Company HV line, a 914 mm Nova Gas Transmission NG line, and a 914 mm Foothills NG line. The Nova and Foothills lines are of particular concern because of their size. Several lines are also located within the proposed reservoir area. Dependent on existing burial depth these lines could be left in-place, or may require lowering, weighting, or rerouting. These include smaller ATCO Gas distribution lines and several Plains Midstream Canada S lines varying in size between 114 and 323 mm.

The extent of necessary oil and gas pipeline relocation has not been finitely established at this level of study. A nominal cost allowance has been included to account for these items.

6.3 Telephone Lines and Power Lines

Telus trench and Fortis power lines are located throughout the project areas. These lines would need to be rerouted or otherwise modified to suit project requirements.

6.4 Road Systems

Existing highways and local roads will be impacted by the proposed project.

A new bridge will be required where the diversion channel crosses Highway 22. The proposed flood storage reservoir would flood over existing Highway 22 at its upstream end, but only during extreme floods. The highway would need to be raised such that it is above the maximum flood level. It is conceivable that Highway 22 may be upgraded to a divided highway in the future; this would need to be considered in the proposed SR1 design.

The existing Springbank road will be submerged by reservoir flood water. Several solutions are feasible including relocation as illustrated on **Drawing G1**, or leaving it at its existing location but constructing a secondary road along the relocation route for use only when the existing road is submerged by flood water. A third option which considers raising the existing road above potential flood water level at its existing location would be a relatively more expensive option. This option may result in increased safety risk so is not recommended at this time.

Several local gravel roads will also be impacted by the proposed project. Rerouting of these roads will be required. Stakeholder engagement input is required as part of the next phase.

7.0 EXISTING LANDOWNERS

The proposed project is located within farmland and ranchland areas. A number of farm and/or ranch yards will be impacted along the diversion channel route and in the area of the off-stream storage dam and reservoir. Camp Kiwanis is located in the floodplain area south of the river and east of the diversion weir. The Tsuu T'ina Nation Indian Reserve, which is located upstream of the diversion structure would not be impacted by the project.

At least one residence located in the southeast quarter of Section 24-24-4 would be submerged by the reservoir and its relocation or purchase would be required. Several residences are located in northeast quarter of Section 24-24-4 as illustrated on **Drawing G8**. Two of the yards are well above the maximum reservoir flood water level and would not be directly impacted by the proposed project. Two of the yards are just above the estimated 1% AEP flood El. 1,208.5 m and could be directly impacted dependent on the maximum flood water level and top of dam levels selected for detailed design and construction (i.e., El. 1,210.5 m considered for conceptual design needs to be investigated further). Berms could be constructed on the west periphery of these yards to protect them from the reservoir flood water. A number of graineries, sheds and other buildings associated with the above four yards exist within the reservoir flood zone and would need to be removed, relocated, or rebuilt at a new location.

8.0 ENVIRONMENTAL AND REGULATORY OVERVIEW

The proposed project is located within the White Zone and is primarily on agricultural land. Project components would directly affect the Elbow River and its associated riparian land. Environmental concerns to be addressed in the project design include:

- Hydrogeology – effects of ponded water on groundwater resources.
- Water quality and quantity – effects of potential changes in stream flows, sediment load, and water quality parameters.

- Fisheries – potential for effects on fish and fish habitat, including possible populations of brook trout, brown trout, bull trout, burbot, longnose dace, longnose sucker, mountain whitefish, and rainbow trout. Bull trout are listed as species of special concern by Alberta's Endangered Species Conservation Committee.
- Soils – effects of changes in flows on soils and potential for soil erosion.
- Wildlife – Provincially designated Key Wildlife and Biodiversity zones are located along the Elbow River, which impose potential timing and construction constraints for the proposed project. Potential effects may occur to species using the zone, including cougar. Wildlife movement patterns may be altered in proximity to the project.
- Vegetation – potential effects on vegetation will be focused on agricultural lands, grazing land. There are no recorded locations for rare plants associated with the project.
- Traditional and non-traditional land use – potential effects include access, changes in traffic patterns and aesthetic concerns. In addition to private landowners, the project site may be located within the Stoney Nakoda and Tsuu T'ina First Nations traditional territories.

The proposed project would require a license to divert water under the *Water Act*, which is administered by ESRD. The project triggers Alberta Regulation 111/93 *Envrionmental Protection and Enhancement Act* (EPEA) Environmental Assessment (Mandatory and Exempted Activities) Regulation, which requires an environmental impact assessment (EIA) be completed for a dam greater than 15 m in height. A water management project that requires an EIA triggers a Natural Resources Conservation Board (NRCB) review. Typically environmental studies to support the EIA would include a minimum of 1- year of site-specific data.

The proponent would submit its project application with its supporting EIA to ESRD, which makes a determination of completeness. Once deemed complete, the NRCB review process would involve a public hearing as part of its review. The NRCB and ESRD have a history of working cooperatively on environmental reviews of this kind. The ESRD/NRCB process could take between 18 and 24 months to complete. At the completion of the process, the NRCB sends its determination to cabinet, who reviews the report and issues the final approval decision.

In addition to the ESRD and NRCB, several other provincial and federal departments will have regulatory roles for the proposed project. These processes can generally occur in parallel with the ESRD/NRCB review, as much of the information required for them supports the environmental review. For example, pre-development and post-development aquatic environmental assessments would be necessary as part of the application for approval under the *Water Act*. Specific authorizations and permits would be obtained subsequent to the ESRD/NRCB decision, if the project was approved.

An overview of the regulatory process is shown in **Table G8.1**.

Table G8.1
Regulatory Process Overview

Regulator	Legislation	Requirements/Process	Schedule
Provincial			
ESRD	EPEA Environmental Assessment Mandatory and Exempted Activities Regulation 111/93	Under EPEA an EIA is required for a dam greater than 15 m in height, as specified in the Mandatory and Exempted Activities Regulation.	18 to 24 months
NRCB	*Natural Resources Conservation Board Act*	The NRCB review process is triggered when a water management project requires an EIA.	
ESRD	*Alberta Water Act*	Authorization	Variable
	Alberta Water Act	Licence and approval	Variable
	Public Lands Act	Dispositions following the Environmental Field Report (EFR) process	5-8 months
Alberta Culture (AC)	*Historical Resources Act*	Application for clearance	Depends on requirements; for historic resources impact assessment, expect 4 to 6 months from initial application for clearance.
Federal			
Fisheries and Oceans Canada (DFO)		Authorization pursuant to the *Fisheries Act* (habitat and fish passage)	90 days post-filing, providing submission is complete.
Miscellaneous Federal Acts		*Migratory Birds Convention Act* (MBCA)	
		Species at Risk Act (SARA)	*n/a*

As currently designed, the proposed project is not listed in the *Regulations Designating Physical Activities*, under the *Canadian Environmental Assessment Act*. It does not result in a reservoir with a surface area that would exceed the annual mean surface area of a water body by 1,500 ha or more and it does not divert 10,000,000 m^3/year or more of water from a natural water body into another natural water body.

9.0 CONSTRUCTION COST ESTIMATE AND PROJECT SCHEDULE

9.1 Project Cost Estimate

A detailed cost estimate is provided in **Table G9.1**. The project cost is estimated to be $158,168,000. This price does not include the cost of land acquisition which will be determined by others. The estimate provided herein is based on 2012 construction price data. Year 2012 prices were used considering that 2013 construction prices are skewed as a result of abnormal activity which resulted from the June 2013 flood event. It is assumed that the construction of SR1 would take place in a more competitive environment for contractors and suppliers, and as such the 2012 prices are considered indicative of realistic project cost. The estimate was produced considering the conceptual designs presented herein. Additional subsurface soils investigations are required to better establish the concept details presented herein. More detailed hydrological assessment and topographic data are required to better establish the size of required works. A contingency allowance of 25% has been included in an effort to account for additional costs which could result from future additional information and the results of more detailed design work. No allowance is included for escalation until the time of construction.

To increase the flood protection above the 1% AEP, to the 2013 flood of record level would require the dam crest level raised by approximately 2.5m to Elevation 1214.5m and would also require a larger diversion outlet structure and channel. These adjustments would result in additional project cost of approximately $55 million. This amount includes contingency and engineering allowances.

Table G9.1
Off-stream Storage Project (SR1) Cost Estimate

Item	Unit	Quantity	Unit Price	Extension
General				
Mob./Demobilization	lump sum	lump sum	7,000,000.00	$7,000,000
Care of Water	lump sum	lump sum	3,000,000.00	$3,000,000
Clearing & Timber Salvage	hectares	10	12,000.00	$120,000
Raise Highway 22	lump sum	lump sum	2,000,000	2,000,000
Local Road Modifications	km	15	250,000.00	$3,750,000
Topsoil/Seeding etc.	m^2	1,200,000	1.50	$1,800,000
	Subtotal General			**$17,670,000**
River Diversion Structure System				
Stripping	m^3	5,000	6.00	$30,000
Common Excavation	m^3	20,000	10.00	$200,000
Structure Fill	m^3	10,000	30.00	$300,000
Diversion Weir Concrete	m^3	4,900	1,000.00	$4,900,000
Sluice/Fishway Concrete	m^3	990	1,000.00	$990,000
Outlet Structure Concrete	m^3	1,900	1,000.00	$1,900,000
Precast Decks	lump sum	lump sum	560,000.00	$560,000
Fine Filter	m^3	1,200	90.00	$108,000
Coarse Filter	m^3	1,200	90.00	$108,000
Piping System	lump sum	lump sum	200,000.00	$200,000
Rock Riprap	m^3	6,400	130.00	$832,000
Bedding Gravel	m^3	2,200	70.00	$154,000
Gate/Hoist Systems	each	6	500,000.00	$3,000,000
Controls/Instrumentation	lump sum	lump sum	300,000.00	$300,000
Electrical/Mechanical	lump sum	lump sum	500,000.00	$500,000
Superstructures	each	2	90,000.00	$180,000
	Subtotal Diversion Structure System			**$14,262,000**
Floodplain Berm				
Stripping	m^3	18,000	6.00	$108,000
Impervious Fill	m^3	90,000	1.50	$135,000
Random Fill	m^3	60,000	1.40	$84,000
Fine Filter	m^3	6,000	90.00	$540,000
Rock Riprap	m^3	8,000	130.00	$1,040,000
Bedding Gravel	m^3	4,000	60.00	$240,000
	Subtotal Floodplain Berm			**$2,147,000**

Item	Unit	Quantity	Unit Price	Extension
Diversion Channel & Reservoir Inlet Structure				
Stripping	m^3	180,000	6.00	$1,080,000
Common Excavation	m^3	1,800,000	5.50	$9,900,000
Rock Excavation	m^3	200,000	10.00	$2,000,000
Impervious Fill	m^3	10,000	20.00	$200,000
Inlet Chute Concrete	m^3	2,000	1,200.00	$2,400,000
Fine Filter	m^3	660	90.00	$59,000
Coarse Filter	m^3	1,760	90.00	$158,000
Piping System	lump sum	lump sum	200,000.00	$200,000
Bridge Crossings	each	1	4,000,000.00	$4,000,000
Pipeline Crossings	lump sum	lump sum	4,000,000.00	$4,000,000
Power Line Relocation	lump sum	lump sum	300,000.00	$300,000
	Subtotal Diversion Channel System			**$24,298,000**
Off-stream Storage Dam				
Stripping	m^3	180,000	6.00	$1,080,000
Borrow Excavation	m^3	1,700,000	5.00	$8,500,000
Overhaul	m^3km	2,500,000	1.50	$3,750,000
Impervious Fill	m^3	1,600,000	1.50	$2,400,000
Random Fill	m^3	1,200,000	1.40	$1,680,000
Fine Filter	m^3	140,000	60.00	$8,400,000
Coarse Filter	m^3	20,000	60.00	$1,200,000
Rock Riprap	m^3	62,000	130.00	$8,060,000
Bedding Gravel	m^3	31,000	60.00	$1,860,000
Geotechnical Instruments	lump sum	lump sum	400,000.00	$400,000
	Subtotal Off-stream Dam			**$37,330,000**
Dam Outlet Structure and Downstream Channel Improvements				
Structure Excavation	m^3	20,000	20.00	$400,000
Structure Fill	m^3	15,000	30.00	$450,000
Reinforced Concrete	m^3	1,600	1,200.00	$1,920,000
Rock Riprap	m^3	600	130.00	$78,000
Bedding Gravel	m^3	300	70.00	$21,000
Gate/Hoist Systems	each	lump sum	160,000.00	$320,000
Controls/Instrumentation	lump sum	lump sum	100,000.00	$100,000
Electrical/Mechanical	lump sum	lump sum	400,000.00	$400,000
Superstructure	lump sum	lump sum	50,000.00	$50,000
	Subtotal Structure & Channel Improvements			**$3,739,000**

Item	Unit	Quantity	Unit Price	Extension
Springbank Road Relocation				
Grading	km	5	550,000.00	$2,750,000
Base/Pavement	km	5	650,000.00	$3,250,000
Creek Crossings	lump sum	lump sum	1,000,000.00	$1,000,000
	Subtotal Springbank Road Relocation			**$7,000,000**
	SUBTOTAL CONSTRUCTION			**$106,446,000**
	Contingencies (25%)			$26,661,000
	Subtotal Construction and Contingencies			**$133,107,000**
	Engineering/Environmental (20%)			$26,661,000
	TOTAL CONSTRUCTION			**$159,768,000**

9.2 Project Schedule and Contracts

Studies to date indicate that the proposed project is feasible. A potential project schedule moving forward would consider both preliminary engineering and environmental impact assessment proceeding on parallel but linked paths, and followed by a detailed design–build or a detailed design-bid-build process.

A number of issues need to be resolved in order to proceed with preliminary design and environmental impact assessment. These include:

- Land access;
- Establishing the level of flood protection to be provided by the project (e.g. 1% AEP flood, 2013 record flood, or larger); and
- Establishing the need for and amount of multi-use storage, if any.

Land access is required in order to proceed with subsurface soil investigations for use in design and cost estimates, and for environmental field investigations. Similarly stakeholder involvement is required to better define project issues and potential solutions. Initiating stakeholder involvement and gaining land access need to be initial priorities.

Key stakeholder input is required to better define the preferred reservoir storage volume which would impact the locations of the diversion structure, diversion channel, off-stream storage dam and associated facilities. As an example a larger reservoir containment would require a larger diversion outlet and channel, a higher dam, the diversion structure to be moved as much as 200 m upstream, could consider the off-stream storage dam moved about 100 m south, and the diversion channel alignment moved up to 100 m north or south of its currently proposed location. Similarly a larger reservoir volume would result in increased impacts to the previously discussed four yard complex located in the northeast of Section 24-24-4. Resolving project size and associated layout needs to be an initial priority.

This conceptual design has provided for a portion of the reservoir to be used for purposes other than, or in addition to, flood storage (i.e. multi-use storage). This concept needs to be endorsed or rejected and the amount of such multi-purpose storage established.

Sediment transport has been identified as a major factor in diversion structure design and should be addressed at the onset of preliminary design, as the results of this assessment could significantly impact the diversion structure configuration. Preliminary design would include hydraulic and sediment transport modelling, if required, to produce detailed structure outline drawings and better establish project cost. Preliminary design should include more detailed subsurface soils investigations and stakeholder involvement. Land access will be required for the preliminary design and environmental field investigations.

Design-build or design-bid-build contracting procedures can be considered for project detailed design and construction. Design-build considers that the work is both designed and built by one project team. Design-bid-build considers that a team is selected to design the project, it then goes to public tender, and is constructed by the successful bidder. Design-build process can result in a reduced time schedule, but the design-bid-build process is considered to be more conventional and appropriate for this project type. The SR1 project could be tendered as one major construction contract, or alternatively divided into two or more contracts. At this time a minimum of three contracts is recommended. One contract would include the diversion structure, floodplain berm, and upstream end of the diversion channel. A second contract would include the remainder of the diversion channel, reservoir inlet chute, off-stream storage dam and associated outlet works. Bridge and road works would be included in the third contract. The contract areas do not overlap and could proceed simultaneously. The multiple contract concept would provide smaller local contractors opportunity to bid this work and could allow earlier initiation of some portions of project construction.

The project schedule is dependent on factors including cash flow, land access/purchase, environmental and regulatory processes, subsurface field investigations (drilling), engineering design and construction. As previously mentioned, engineering design can proceed parallel with environmental studies and regulatory processes which could require 30 to 36 months to complete.

Construction will require a minimum one calendar year, but a 2 or 3-year schedule is preferred considering the size of this project. Of course the government would need to weigh the risk of additional flood damage against the preferred longer construction period. Construction could proceed year-round, taking advantage of both summer and winter seasons. Most of the work would be performed in the spring through fall period; however, significant quantities of work could be completed in the winter. Special measures would be required for winter construction including heating and hoarding for concrete and continuous 24-hour per day earthfill operations. A project schedule can be developed but requires additional owner input.

10.0 CLOSURE

This report is based on, and limited by, the interpretation of data, circumstances, and conditions available at the time of completion of the work as referenced throughout the report. It has been prepared in accordance with generally accepted engineering practices. No other warranty, express or implied, is made.

Yours truly,

AMEC Environment & Infrastructure

Reviewed by:

K.G. KRESS

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2 June 2014
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Geoff Graham, B.Sc. (Hons), MCIWEM C.WEM
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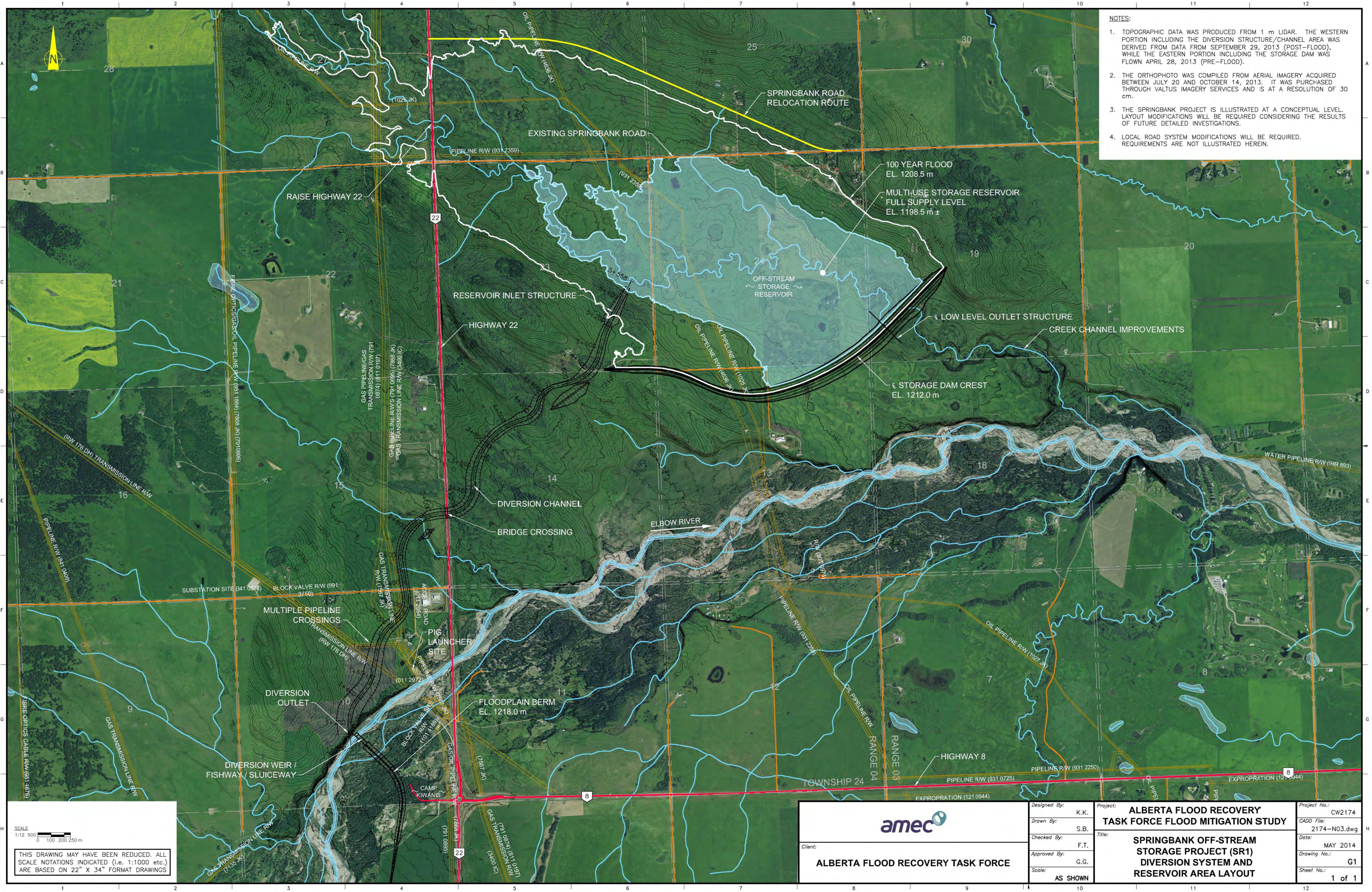
KK/elf

Permit to Practice No. P-4546



NOTES:

1. TOPOGRAPHIC DATA WAS PRODUCED FROM 1 m LIDAR. THE WESTERN PORTION INCLUDING THE DIVERSION STRUCTURE/CHANNEL AREA WAS DERIVED FROM DATA FROM SEPTEMBER 29, 2013 (POST–FLOOD), WHILE THE EASTERN PORTION INCLUDING THE STORAGE DAM WAS FLOWN APRIL 28, 2013 (PRE–FLOOD).
2. THE ORTHOPHOTO WAS COMPILED FROM AERIAL IMAGERY ACQUIRED BETWEEN JULY 20 AND OCTOBER 14, 2013. IT WAS PURCHASED THROUGH VALTUS IMAGERY SERVICES AND IS AT A RESOLUTION OF 30 cm.
3. THE SPRINGBANK PROJECT IS ILLUSTRATED AT A CONCEPTUAL LEVEL. LAYOUT MODIFICATIONS WILL BE REQUIRED CONSIDERING THE RESULTS OF FUTURE DETAILED INVESTIGATIONS.
4. LOCAL ROAD SYSTEM MODIFICATIONS WILL BE REQUIRED. REQUIREMENTS ARE NOT ILLUSTRATED HEREIN.

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THIS DRAWING MAY HAVE BEEN REDUCED. ALL SCALE NOTATIONS INDICATED (i.e. 1:1000 etc.) ARE BASED ON 22" X 34" FORMAT DRAWINGS

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Client:
ALBERTA FLOOD RECOVERY TASK FORCE

Designed By:	K.K.
Drawn By:	S.B.
Checked By:	F.T.
Approved By:	G.G.
Scale:	AS SHOWN

Project:
ALBERTA FLOOD RECOVERY TASK FORCE FLOOD MITIGATION STUDY

Title:
SPRINGBANK OFF-STREAM STORAGE PROJECT (SR1) DIVERSION SYSTEM AND RESERVOIR AREA LAYOUT

Project No.:	CW2174
CADD File:	2174–N03.dwg
Date:	MAY 2014
Drawing No.:	G1
Sheet No.:	1 of 1

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NOTES:

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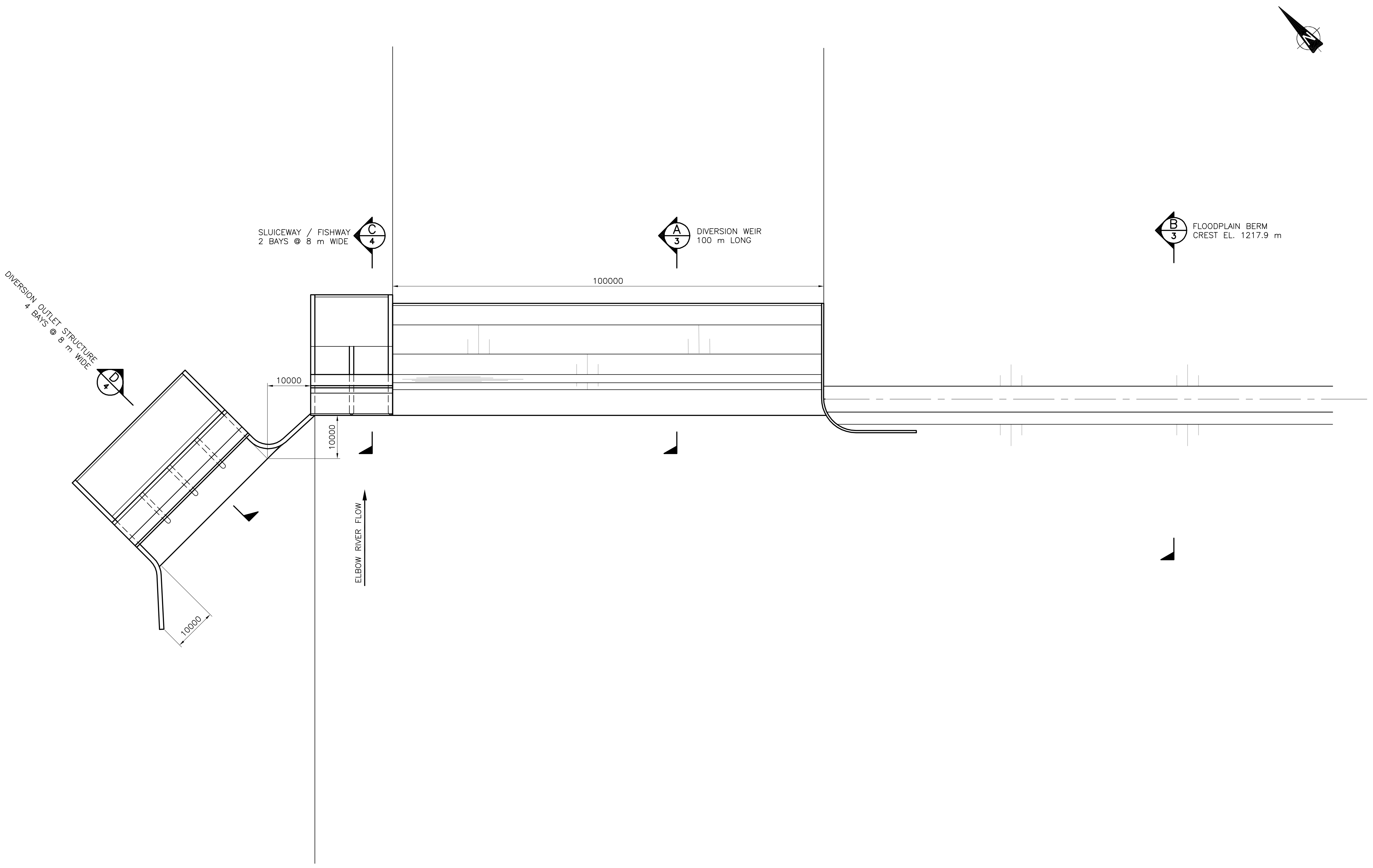

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Designed By: K.K.
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Scale: AS SHOWN

Project:
ALBERTA FLOOD RECOVERY
TASK FORCE FLOOD MITIGATION STUDY

Title:
SPRINGBANK OFF-STREAM
STORAGE PROJECT (SR1)
DIVERSION WEIR / SLUICEWAY / FISHWAY /
OUTLET STRUCTURE SYSTEM

Project No.: CW2174
CADD File: 2174–B08.dwg
Date: MAY 2014
Drawing No.: G2
Sheet No.: 1 of 1

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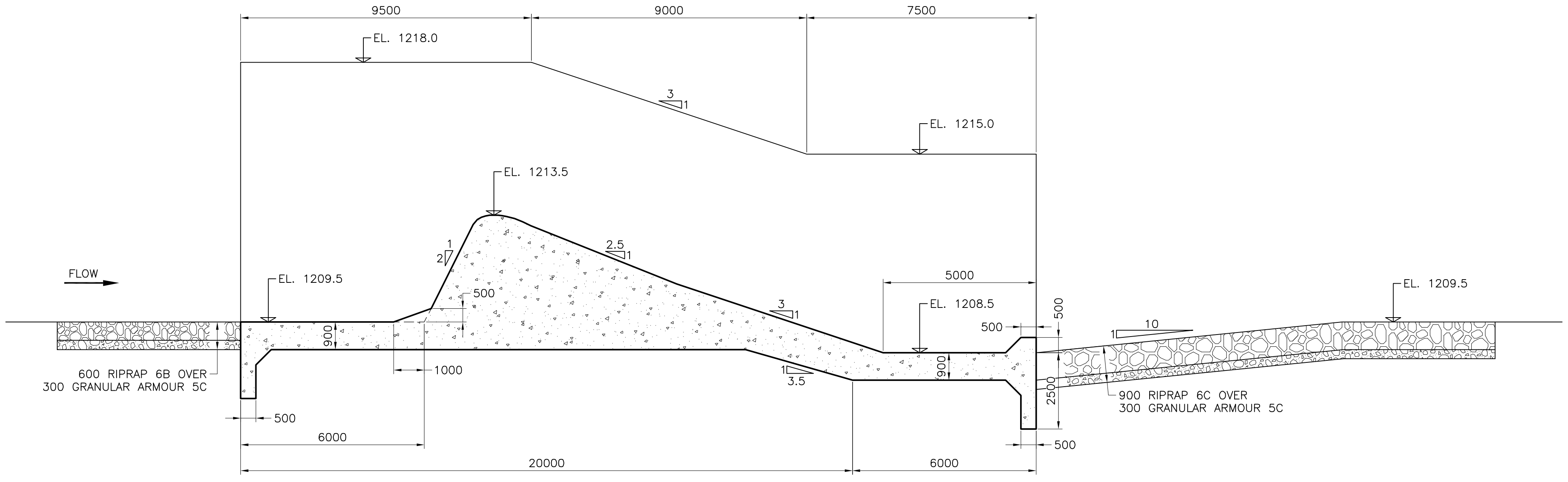

Ⓐ/2 SECTION – DIVERSION WEIR

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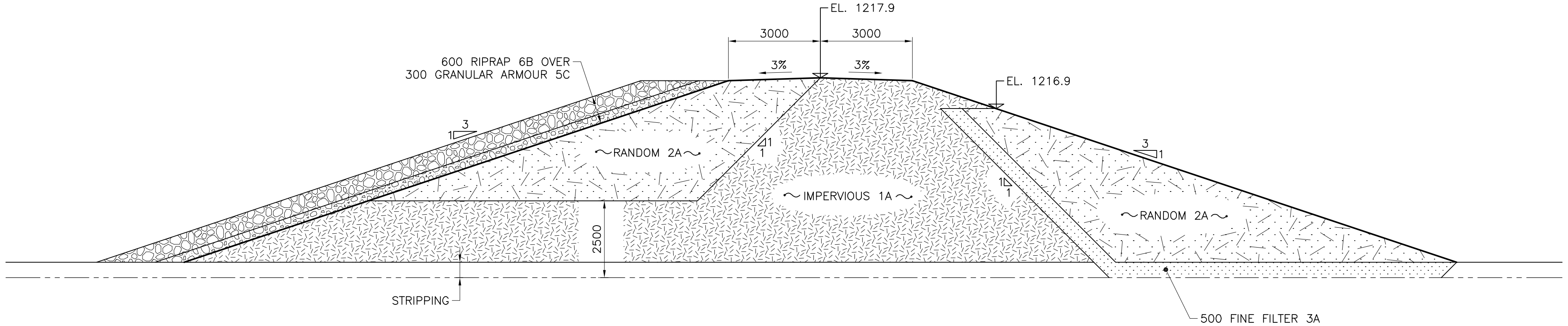

Ⓑ/2 SECTION – FLOODPLAIN BERM

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Client:
ALBERTA FLOOD RECOVERY TASK FORCE

Designed By: K.K.
Drawn By: S.B.
Checked By: F.T.
Approved By: G.G.
Scale: AS SHOWN

Project:
ALBERTA FLOOD RECOVERY TASK FORCE FLOOD MITIGATION STUDY

Title:
SPRINGBANK OFF-STREAM STORAGE PROJECT (SR1) DIVERSION STRUCTURE SYSTEM SECTIONS (SHEET 1 of 2)

Project No.: CW2174
CADD File: 2174–B03.dwg
Date: MAY 2014
Drawing No.: G3
Sheet No.: 1 of 1

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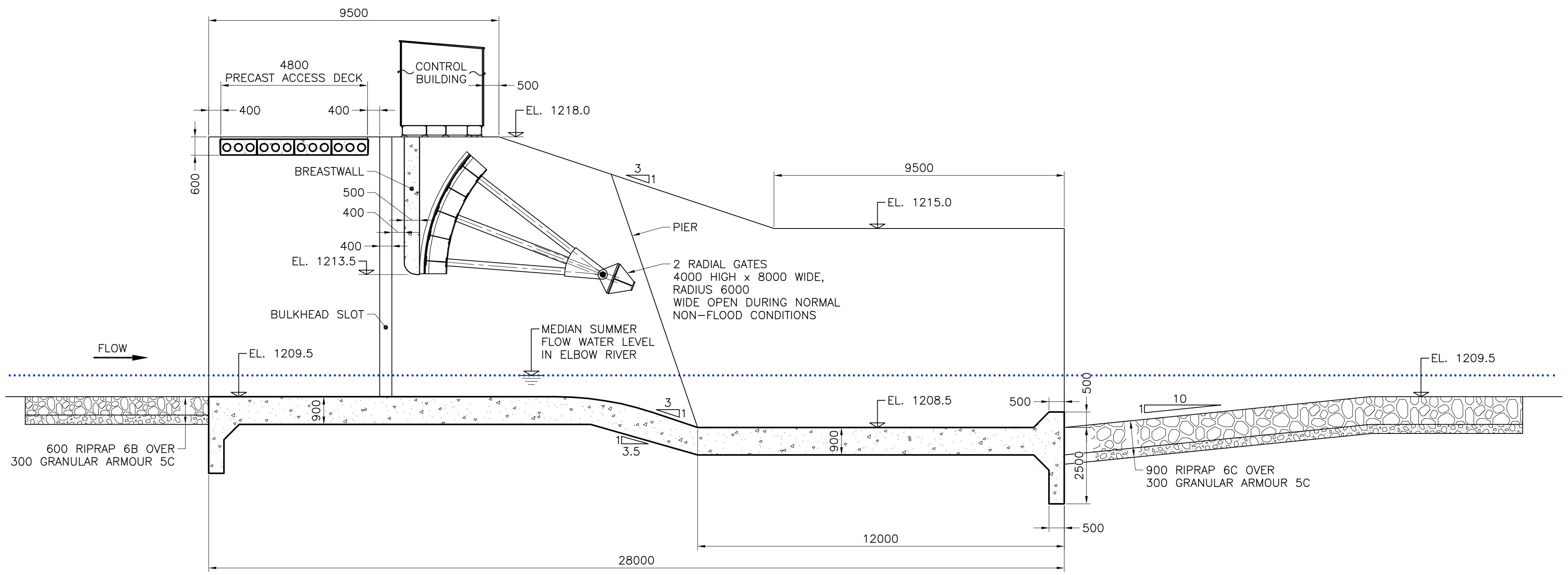

C/2 SECTION – SLUICEWAY / FISHWAY

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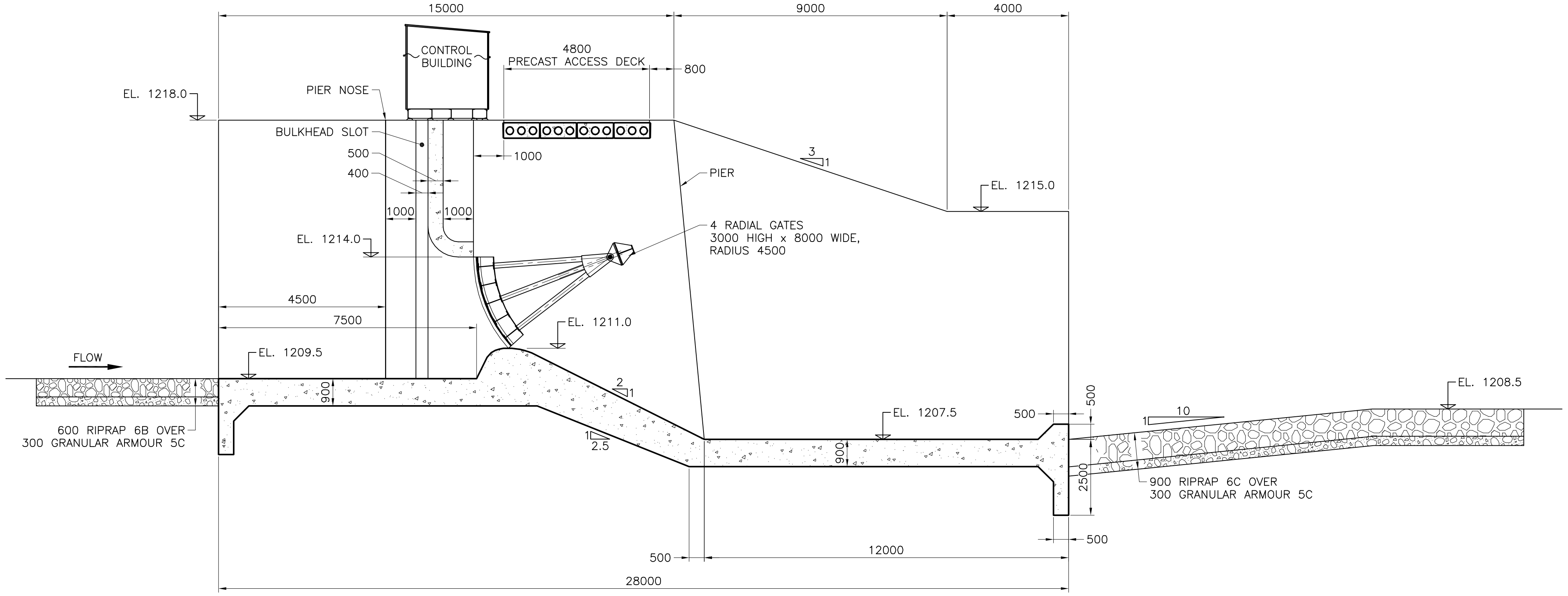

D/2 SECTION – DIVERSION OUTLET STRUCTURE

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amec

Client:
ALBERTA FLOOD RECOVERY TASK FORCE

Designed By: K.K.
Drawn By: S.B.
Checked By: F.T.
Approved By: G.G.
Scale: AS SHOWN

Project:
ALBERTA FLOOD RECOVERY
TASK FORCE FLOOD MITIGATION STUDY

Title:
SPRINGBANK OFF-STREAM
STORAGE PROJECT (SR1)
DIVERSION STRUCTURE SYSTEM
SECTIONS (SHEET 2 of 2)

Project No.: CW2174
CADD File: 2174–B05.dwg
Date: MAY 2014
Drawing No.: G4
Sheet No.: 1 of 1

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NOTES:

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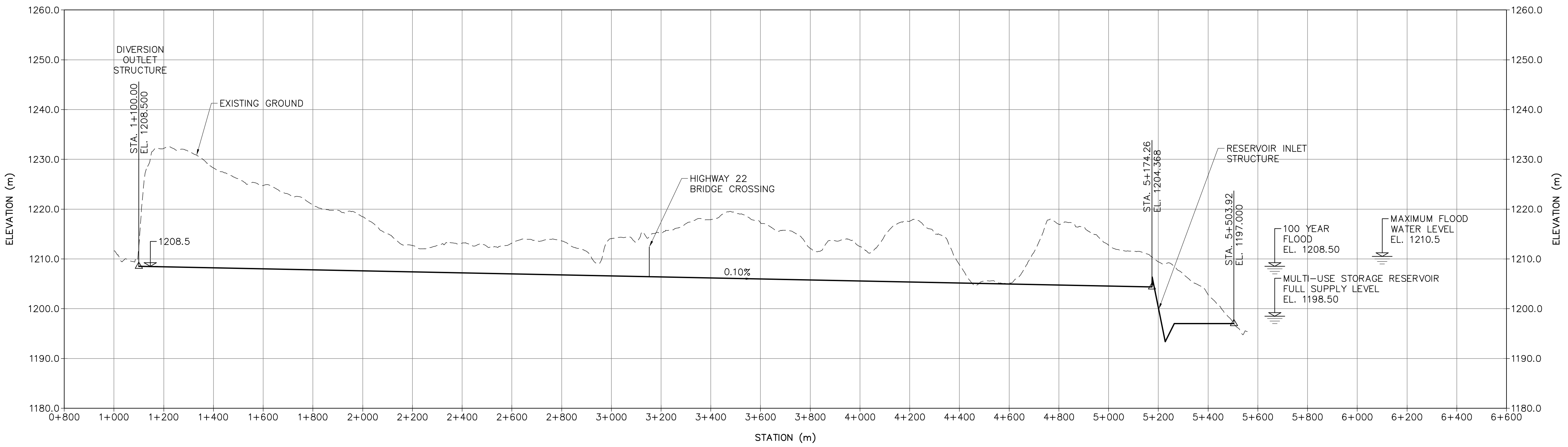

DIVERSION CHANNEL PROFILE

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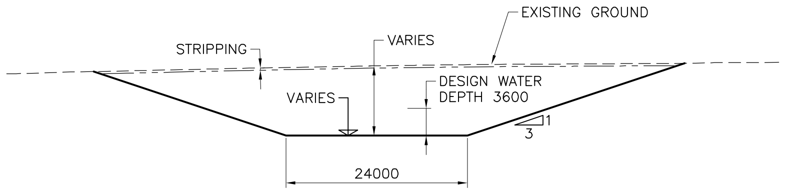

DIVERSION CHANNEL TYPICAL CROSS SECTION

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Client:
ALBERTA FLOOD RECOVERY TASK FORCE

Designed By: K.K.
Drawn By: S.B.
Checked By: F.T.
Approved By: G.G.
Scale: AS SHOWN

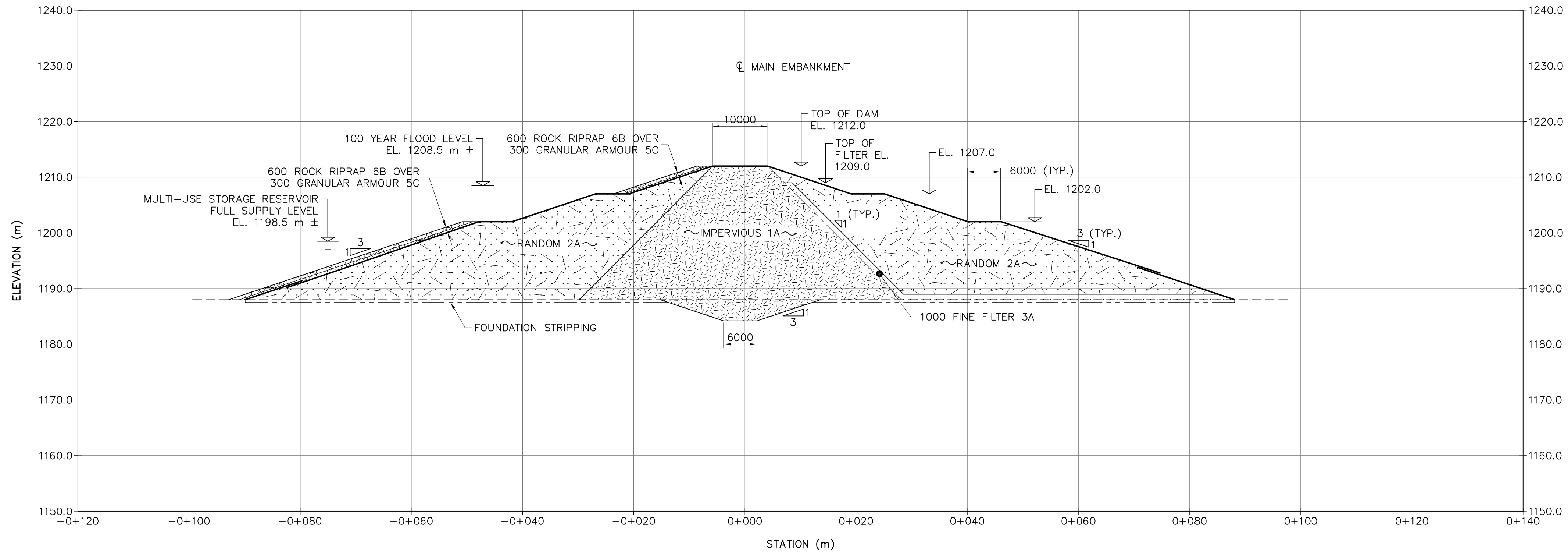
Project:
ALBERTA FLOOD RECOVERY TASK FORCE FLOOD MITIGATION STUDY

Title:
SPRINGBANK OFF-STREAM STORAGE PROJECT (SR1) DIVERSION CHANNEL

Project No.: CW2174
CADD File: 2174–N03.dwg
Date: MAY 2014
Drawing No.: G5
Sheet No.: 1 of 1

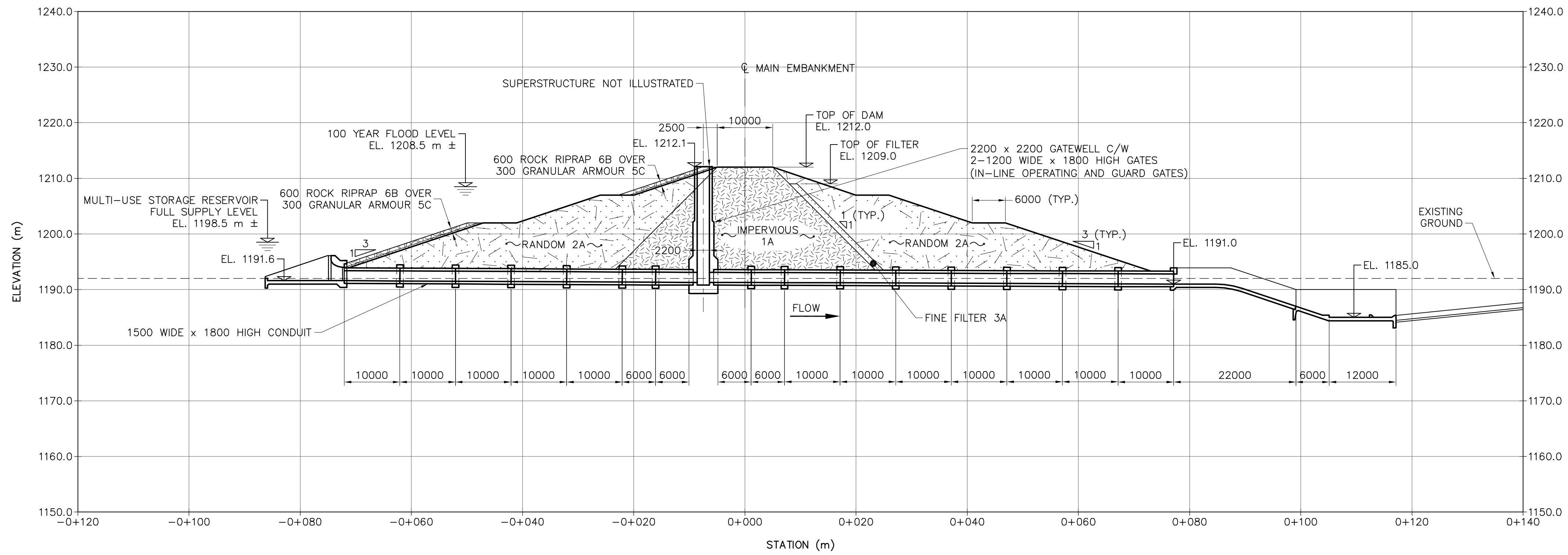
NOTES:

1. ELEVATIONS ARE IN METRES AND DIMENSIONS ARE IN MILLIMETRES UNLESS NOTED OTHERWISE.



OFF-STREAM STORAGE DAM

SCALE 1:500



LOW LEVEL OUTLET STRUCTURE

SCALE 1:500

SCALE
1:500
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Client:
ALBERTA FLOOD RECOVERY TASK FORCE

Designed By: K.K.
Drawn By: S.B.
Checked By: F.T.
Approved By: G.G.
Scale: AS SHOWN

Project:
ALBERTA FLOOD RECOVERY TASK FORCE FLOOD MITIGATION STUDY

Title:
SPRINGBANK OFF-STREAM STORAGE PROJECT (SR1) OFF-STREAM STORAGE DAM & LOW LEVEL OUTLET

Project No.: CW2174
CADD File: 2174−N03.dwg
Date: MAY 2014
Drawing No.: G6
Sheet No.: 1 of 1

*PLOT 1:1=0 (L)

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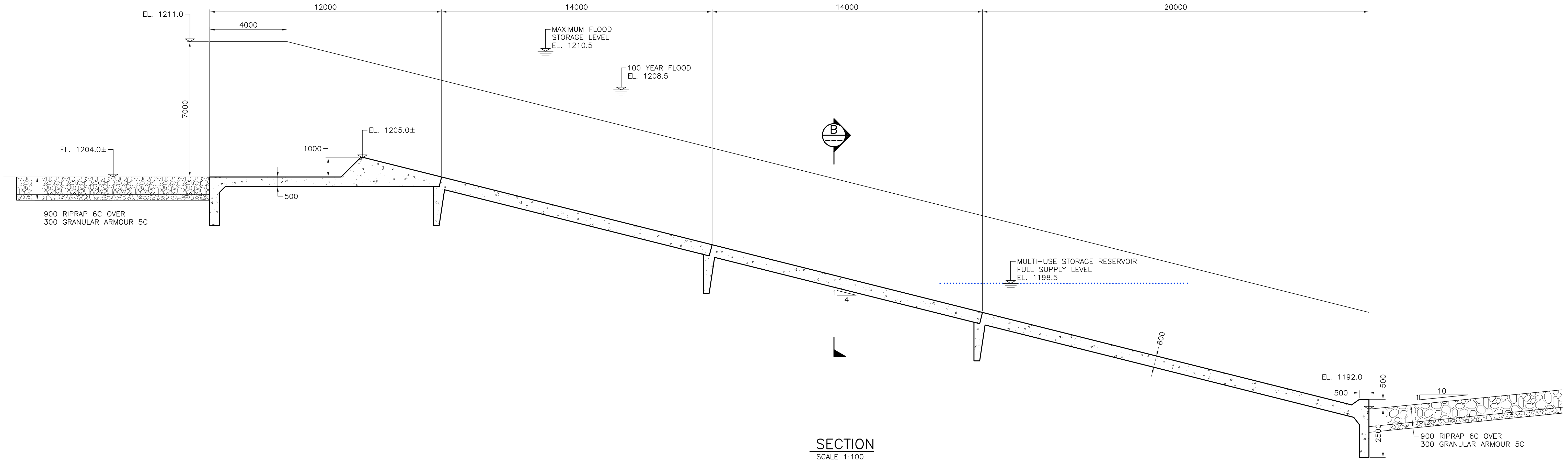
NOTES:

1. ELEVATIONS ARE IN METRES AND DIMENSIONS ARE IN MILLIMETRES UNLESS NOTED OTHERWISE.



SECTION
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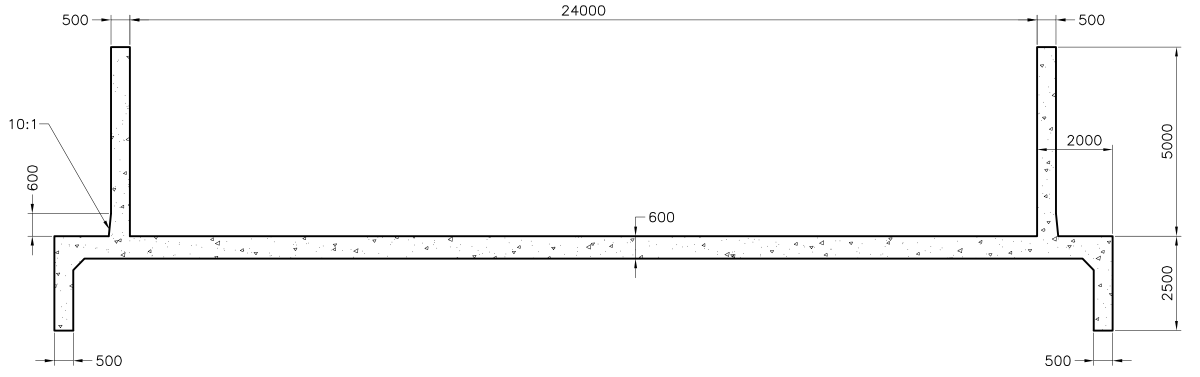

B SECTION
SCALE 1:100

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ALBERTA FLOOD RECOVERY TASK FORCE

Designed By: K.K.
Drawn By: S.B.
Checked By: F.T.
Approved By: G.G.
Scale: AS SHOWN

Project:
ALBERTA FLOOD RECOVERY
TASK FORCE FLOOD MITIGATION STUDY

Title:
SPRINGBANK OFF-STREAM
STORAGE PROJECT (SR1)
RESERVOIR INLET STRUCTURE

Project No.: CW2174
CADD File: 2174–B06.dwg
Date: MAY 2014
Drawing No.: G7
Sheet No.: 1 of 1

*PLOT 1:1=D (L)

NOTES:

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SCALE
1:1000
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Approved By: G.G.
Scale: AS SHOWN

Project:
ALBERTA FLOOD RECOVERY TASK FORCE FLOOD MITIGATION STUDY

Title:
SPRINGBANK OFFSTREAM STORAGE PROJECT (SR1) FLOODED AREA DETAIL IN NE¼-24-24-4

Project No.: CW2174
CADD File: 2174–J03.dwg
Date: MAY 2014
Drawing No.: G8
Sheet No.: 1 of 1

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REPORT

Benefit/Cost Analysis of Flood Mitigation Projects for the City of Calgary: Springbank Off-Stream Flood Storage

Prepared for Government of Alberta
ESRD - Resilience and Mitigation
by IBI Group
February 18, 2015

IBI GROUP
400 – Kensington House, 1167 Kensington Cres NW
Calgary AB T2N 1X7 Canada
tel 403 270 5600 fax 403 270 5610
ibigroup.com

February 18, 2015

Ms. Heather Ziober
Project Manager, Strategic Integration and Projects
Government of Alberta
Environment and Sustainable Resource Development
205 J.G. O'Donoghue Building
7000 - 113 Street
Edmonton, AB T6H 5T6

Dear Ms. Ziober:

BENEFIT/COST ANALYSIS OF FLOOD MITIGATION PROJECTS FOR THE CITY OF CALGARY: SPRINGBANK OFF-STREAM FLOOD STORAGE

Enclosed please find the draft final report for the aforementioned assignment. The report describes the benefit/cost analysis undertaken for the Springbank Off-Stream Flood Storage Mitigation Project in relation to ameliorating the City of Calgary flood damages. This analysis culminates with a comparison of the benefit/cost ratios for the three major mitigation projects under consideration of which the Springbank Off-Stream Flood Storage Project ranks first.

Should you have any questions or require additional information please do not hesitate to contact the undersigned.

Yours truly,

IBI GROUP

Stephen Shawcross
Director

Augusto Ribeiro, P.Eng.

SS/mp

cc: Cathy Maniego, Government of Alberta, Environment and Sustainable Resource Development
Andrew Wilson, Government of Alberta, Environment and Sustainable Resource Development

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Benefit/Cost Analysis for Flood Mitigation Projects for the City of Calgary: Springbank Off-Stream Flood Storage

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Submitted to Government of Alberta
ESRD - Resilience and Mitigation
by IBI Group

February 2015

Study Team Members

IBI Group

Stephen Shawcross

Augusto Ribeiro

Neil MacLean

David Sol

Melinda Tracey

Michele Penn

Valerie Doroshenko

Samantha Huchulak

Garrett Newman

Patrick Wetter

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Jeff Liske

Jonathan Darton

Carla Pereira

Brooke Dillon

Michael Valenzuela

Golder Associates Ltd.

Wolf Ploeger

Carmen Walker

Table of Contents

Executive Summary

Key Metrics

Project Costs

Item	Cost
Project Construction	$159,768,000
Upstream Mitigation	$8,900,000
Land Acquisition	$40,000,000
Total 1:100 Year Protection	**$208,668,000**
Additional Cost for 1:200 Year Protection	$55,000,000
Total 1:200 Year Protection	**$263,668,000**
Annual Operation and Maintenance	$1,800,000

Benefit/Cost Analysis

Indicator	High Damage Scenario		Low Damage Scenario	
	1:100 Year Protection	1:200 Year Protection	1:100 Year Protection	1:200 Year Protection
PV Benefits (average annual damages)	$476,899,000	$639,943,000	$336,847,000	$408,901,000
PV Costs (development & operating total cost)	$255,098,000	$309,607,000	$255,098,000	$309,607,000
Benefit/Cost Ratio	1.87	2.07	1.32	1.32
Net Present Value	$221,801,000	$330,336,000	$81,749,000	$99,294,000
Average Annual Damages	$19,461,291	$26,114,777	$13,746,068	$16,686,439

Benefit/Cost Comparison

Mitigation Project	High Damage Scenario		Low Damage Scenario	
	1:100 Year Protection	1:200 Year Protection	1:100 Year Protection	1:200 Year Protection
SR1	1.87	2.07	1.32	1.32
MC1	1.43	1.65	1.01	1.05
Glenmore	1.21	1.20	0.81	0.83

1 Introduction

1.1 Background

The flood of 2013 was a devastating event for Southern Alberta and the City of Calgary. The flood event had the largest economic impact of any extreme weather event in Canada to date. As part of the response to protect communities from future flood damage, the Province of Alberta commissioned a study through the Flood Mitigation Advisory Panel to provide engineering assessments and practical solutions on possible flood mitigation measures.

In October of 2013, AMEC Environment & Infrastructure (AMEC) was contracted to provide a flood mitigation feasibility study for the Bow River, Elbow River and Oldman River Basins.

A number of mitigation schemes were considered for the Elbow River upstream of the City of Calgary, including an off-stream flood storage project in Springbank.

As part of the subsequent Provincial Flood Damage Assessment Study, IBI Group was commissioned by the Government of Alberta ESRD Operations, Resilience and Mitigation Branch to undertake a benefit/cost analysis of the Springbank Off-Stream Flood Storage project.

1.2 Purpose

The purpose of the benefit/cost analysis is to provide a comparison of project benefits, in terms of damages averted, to project costs including capital and operating costs, to determine if the project under consideration is economically viable.

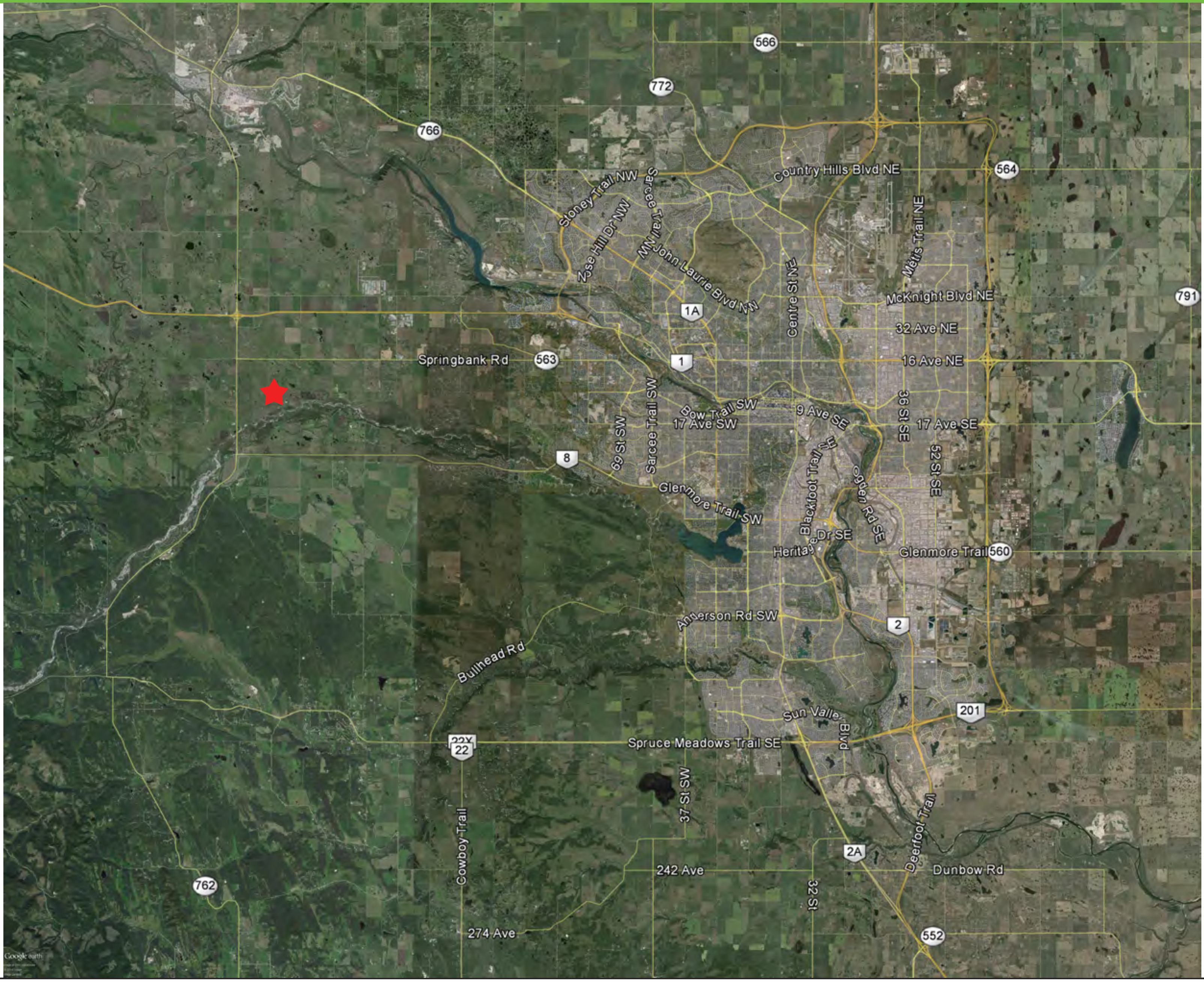
1.3 Scope

For the purposes of this study, benefits are restricted to economic benefits accruing within the study area, which is defined as the flood risk area within the City of Calgary boundaries. The study utilizes current damage estimates based on updated stage-damage curves and the Provincial Rapid Flood Damage Assessment Model. Project costs are based on the estimates prepared as part of the Springbank Off-Stream Storage project submitted to the Southern Alberta Flood Recovery Task Force and dated June 2014.

2 Context

Exhibit 2.1 illustrates the study area, while **Exhibit 2.2** illustrates the location of the off-stream storage project.

Regional Setting



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Alberta Government

Benefit/Cost Analysis for Flood Mitigation Projects for the City of Calgary: Conceptual Design of the Springbank Off-Stream Flood Storage Site

February 2015

EXHIBIT 2.1

Local Setting

IBI

Alberta Government

Benefit/Cost Analysis for Flood Mitigation Projects for the City of Calgary: Conceptual Design of the Springbank Off-Stream Flood Storage Site

February 2015

EXHIBIT 2.2

3 Project Description

The project consists of three basic components:

1. a river diversion structure;
2. a diversion channel and reservoir inlet structure; and
3. an off-stream storage dam and reservoir.

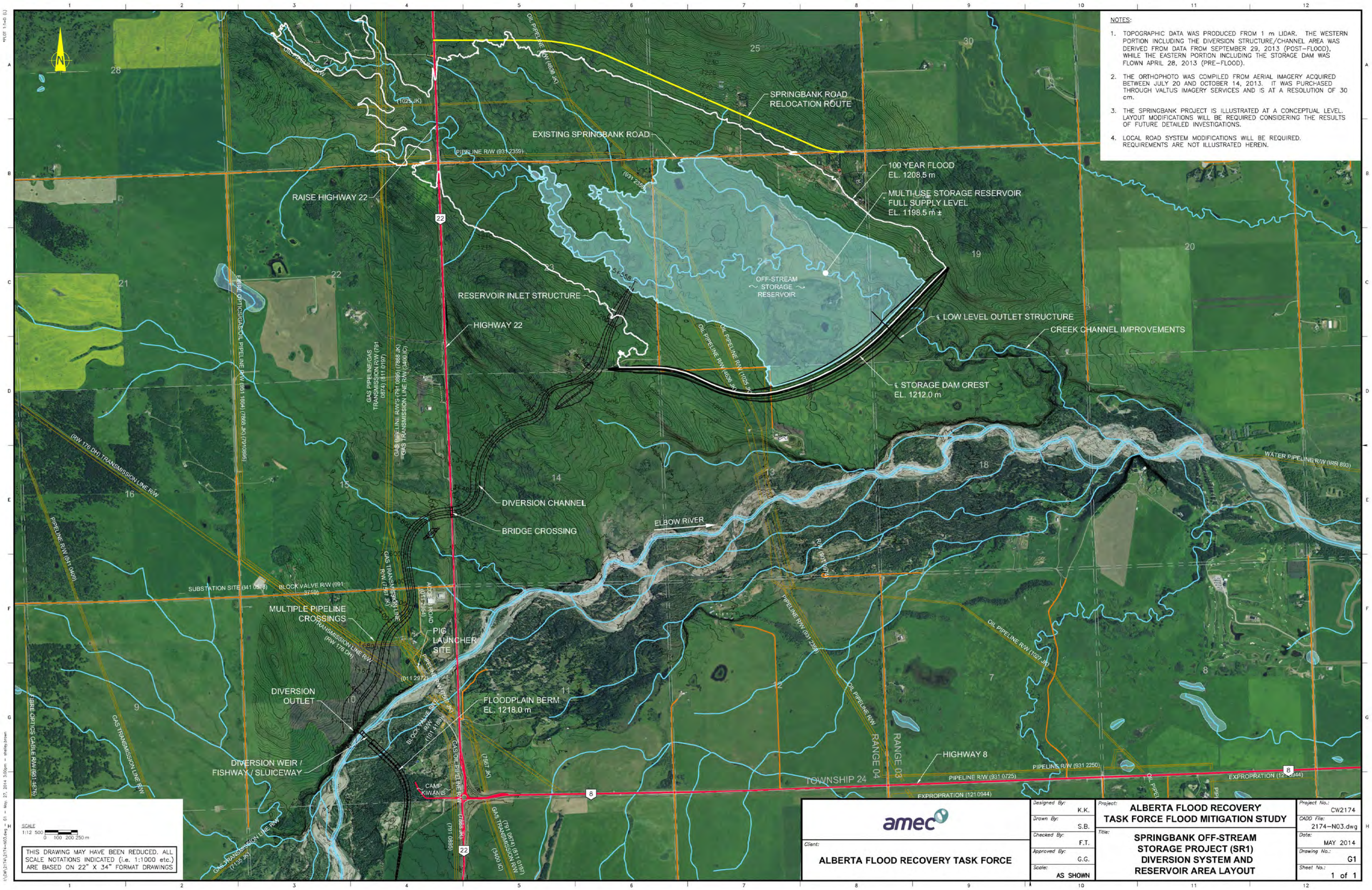
The diversion structure system would consist of a concrete overflow weir section crossing the Elbow River, a gated concrete sluiceway/fishway located adjacent to the left side valley abutment with its invert at the river thalweg level, and a gated diversion outlet structure located in the left valley abutment immediately upstream of the sluiceway. A conceptual design layout for the diversion structure system is provided in **Exhibit 3.1**. Additional structure details are provided in **Exhibit 3.2**, **Exhibit 3.3** and **Exhibit 3.4**.

The proposed diversion channel profile and a typical channel section are illustrated in **Exhibit 3.5**. The diversion channel is designed to convey a peak diversion flow of 300 m^3/s from the Elbow River into the off-stream storage reservoir. The channel is designed with a 24 m bottom width, three horizontal to one vertical side slopes and a 3.6 m water depth.

A 3 km long earthfill storage dam, having a maximum height of 24 m, is required to contain the diverted flood water. The conceptual design considers a zoned earthfill dam with a clay core and random earthfill shells as illustrated in **Exhibit 3.6**. Embankment slopes of 3H:1V are provided with 6 m wide berms at strategic levels resulting in average dam slopes of between 3H:1V and 4H:1V. The berms are included to provide stability, and to facilitate access for inspection, maintenance and geotechnical instrument monitoring.

The dam system will include a gated low-level outlet structure. The structure will include a 1.5 m wide by 1.8 m high concrete conduit through the dam, including a gatewell tower located near the dam centreline as illustrated in **Exhibit 3.7**. This structure will be used to release stored water back into the river after the flood has passed. Channel improvements will be required along the creek, connecting this outlet to the Elbow River.

Springbank Off-Stream Storage Project (SR1) Diversion System and Reservoir Area Layout



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Client:
ALBERTA FLOOD RECOVERY TASK FORCE

Designed By: K.K.
Drawn By: S.B.
Checked By: F.T.
Approved By: G.G.
Scale: AS SHOWN

Project:
ALBERTA FLOOD RECOVERY TASK FORCE FLOOD MITIGATION STUDY

Title:
SPRINGBANK OFF-STREAM STORAGE PROJECT (SR1) DIVERSION SYSTEM AND RESERVOIR AREA LAYOUT

Project No.: CW2174
CADD File: 2174–N03.dwg
Date: MAY 2014
Drawing No.: G1
Sheet No.: 1 of 1

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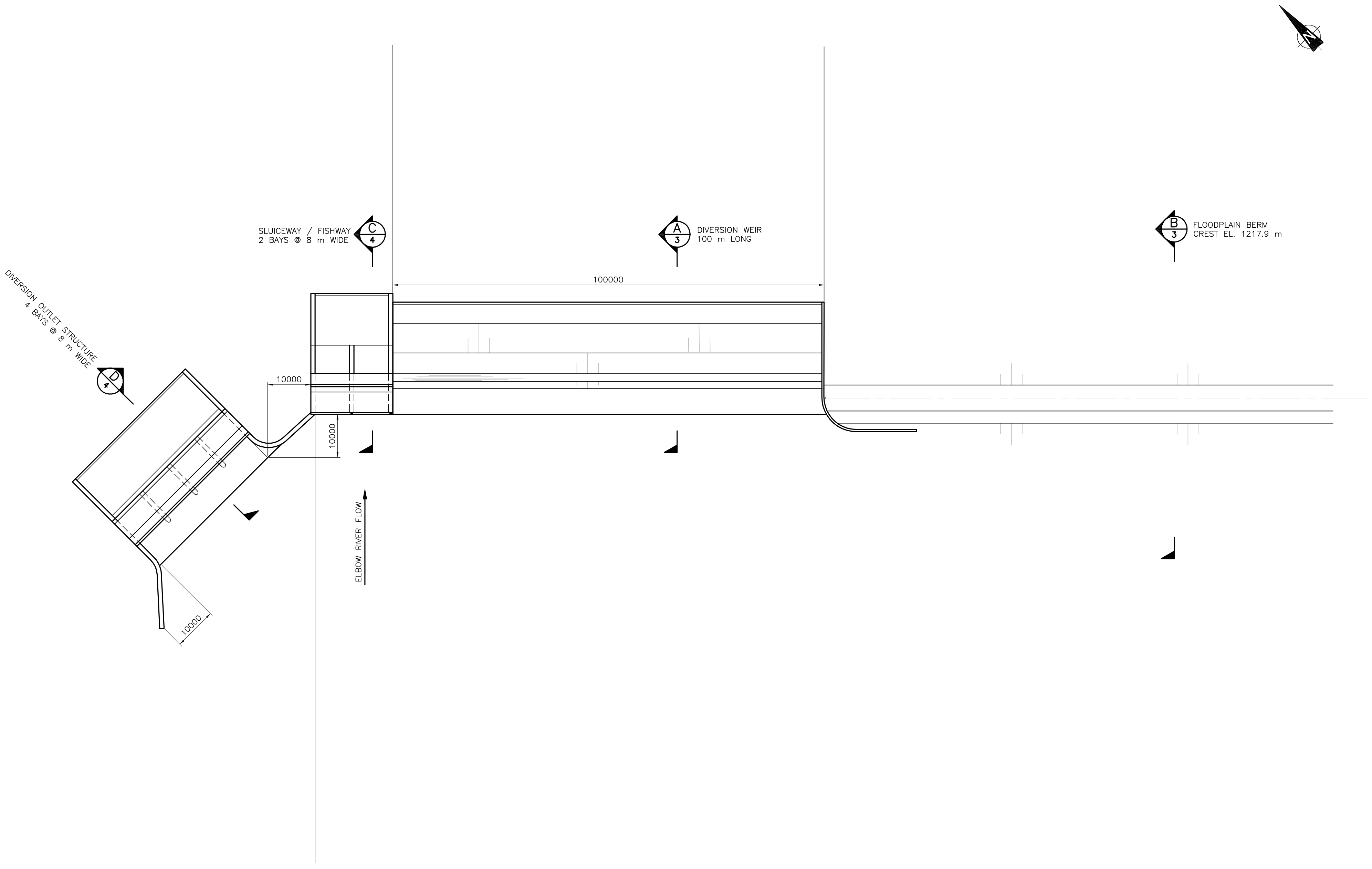
Details - Springbank Off-Stream Storage Project (SR1) Diversion Weir / Sluiceway / Fishway / Outlet Structure System

NOTES:

1. ELEVATIONS ARE IN METRES AND DIMENSIONS ARE IN MILLIMETRES UNLESS NOTED OTHERWISE.



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Checked By:	F.T.
Approved By:	G.G.
Scale:	AS SHOWN

Project:
ALBERTA FLOOD RECOVERY
TASK FORCE FLOOD MITIGATION STUDY

Title:
SPRINGBANK OFF-STREAM
STORAGE PROJECT (SR1)
DIVERSION WEIR / SLUICEWAY / FISHWAY /
OUTLET STRUCTURE SYSTEM

Project No.:	CW2174
CADD File:	2174-B08.dwg
Date:	MAY 2014
Drawing No.:	G2
Sheet No.:	1 of 1

Details - Springbank Off-Stream Storage Project (SR1) Diversion Structure System Sections (Sheet 1 of 2)

*PLOT 1:1=D (L)

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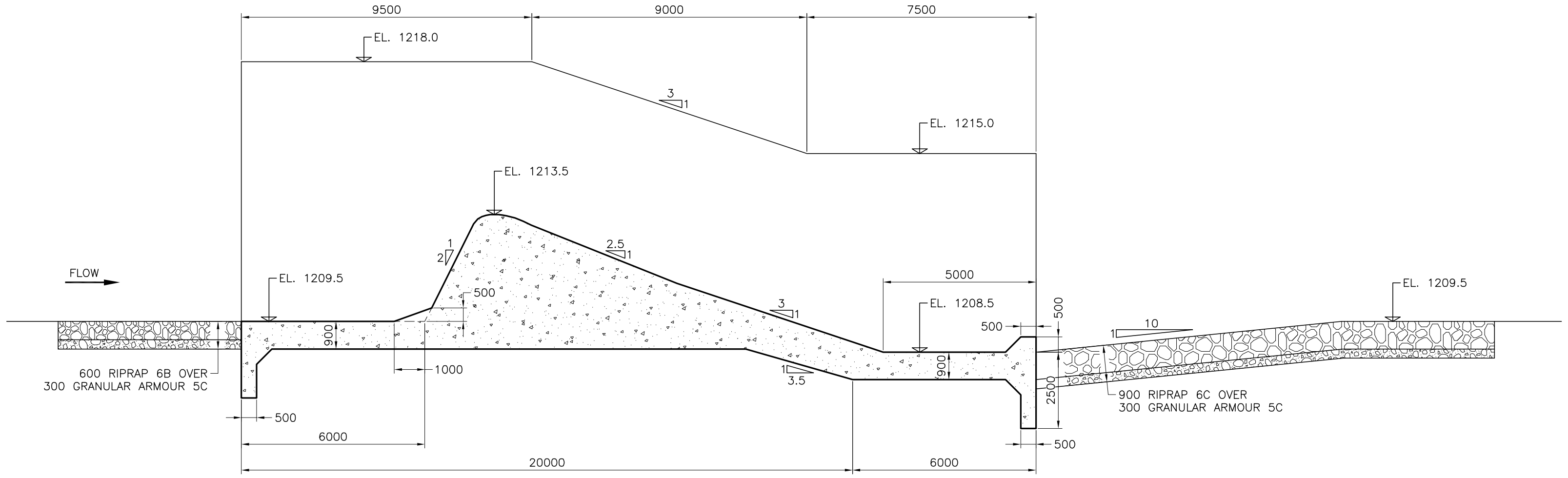

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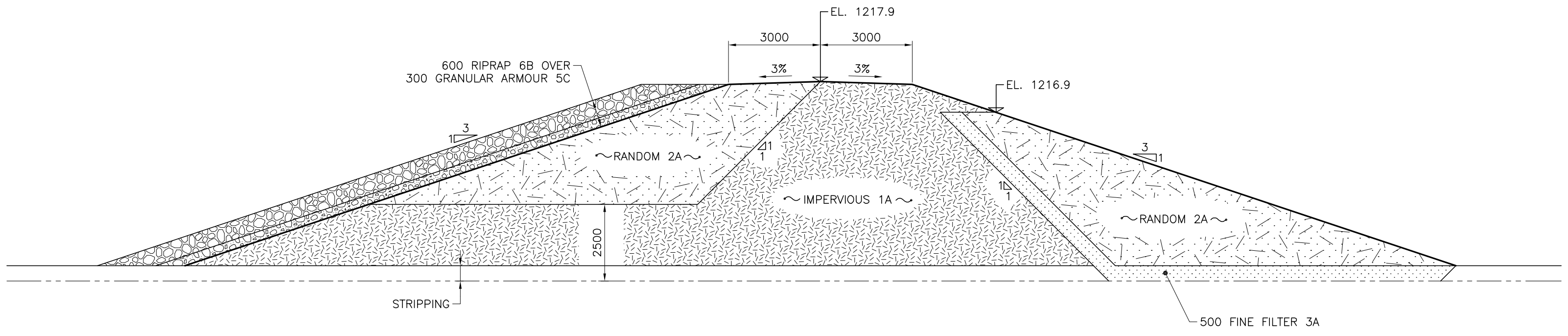

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SCALE 1:100

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Approved By: G.G.
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Project: ALBERTA FLOOD RECOVERY TASK FORCE FLOOD MITIGATION STUDY

Title: SPRINGBANK OFF-STREAM STORAGE PROJECT (SR1) DIVERSION STRUCTURE SYSTEM SECTIONS (SHEET 1 of 2)

Project No.: CW2174
CADD File: 2174–B03.dwg
Date: MAY 2014
Drawing No.: G3
Sheet No.: 1 of 1

Details - Springbank Off-Stream Storage Project (SR1) Diversion Structure System Sections (Sheet 2 of 2)

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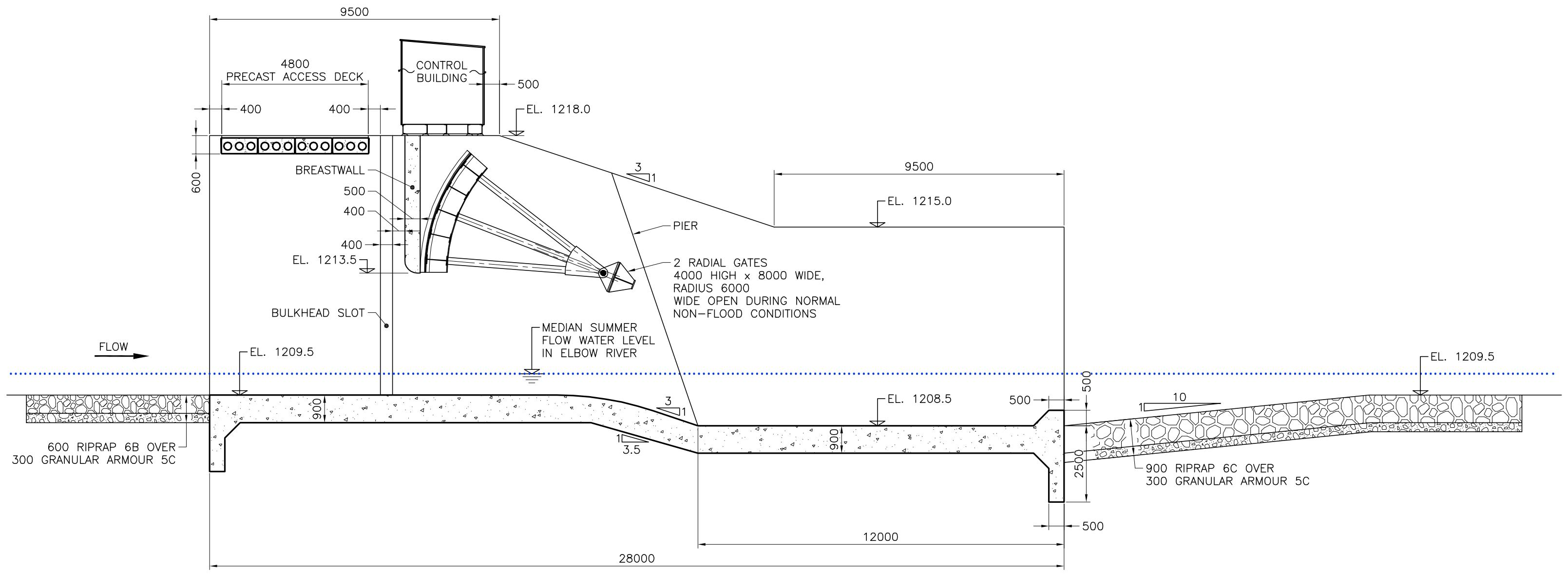

C/2 SECTION – SLUICEWAY / FISHWAY

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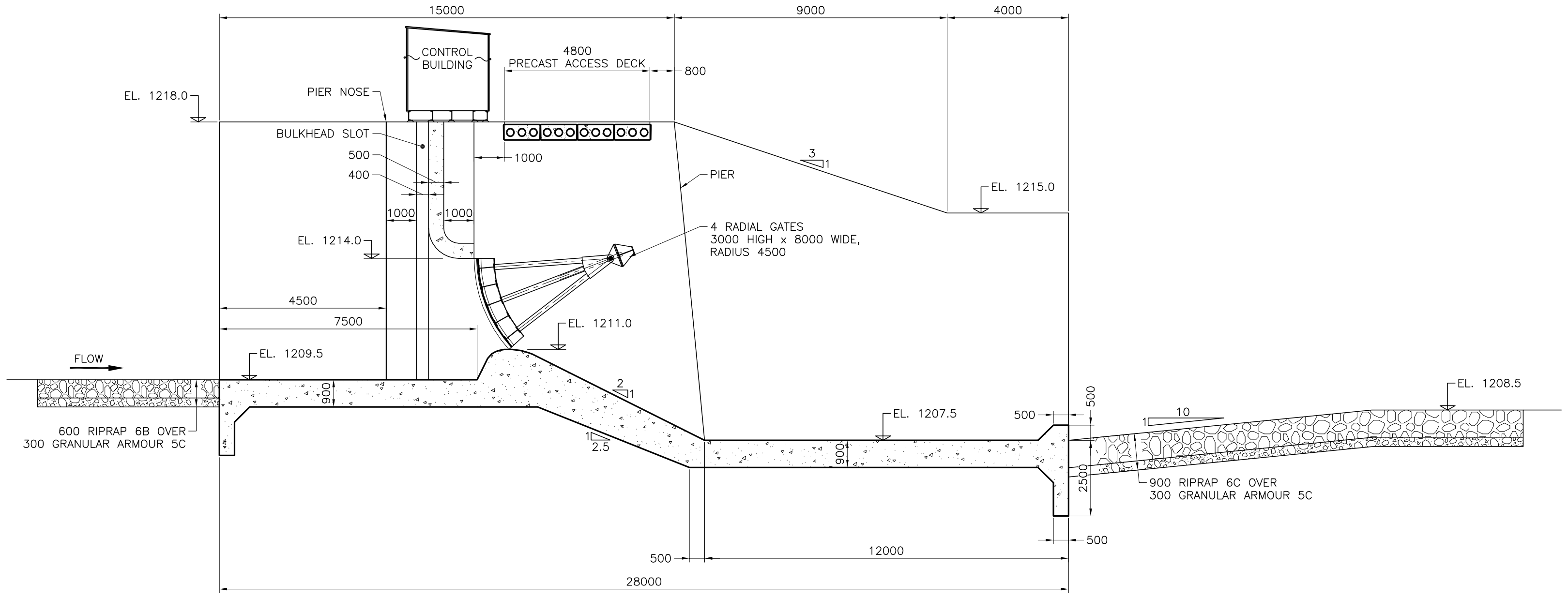

D/2 SECTION – DIVERSION OUTLET STRUCTURE

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Project: ALBERTA FLOOD RECOVERY TASK FORCE FLOOD MITIGATION STUDY

Title: SPRINGBANK OFF-STREAM STORAGE PROJECT (SR1) DIVERSION STRUCTURE SYSTEM SECTIONS (SHEET 2 of 2)

Project No.: CW2174
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Date: MAY 2014
Drawing No.: G4
Sheet No.: 1 of 1

*PLOT 1:1=D (L)

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Details - Springbank Off-Stream Storage Project (SR1) Diversion Channel

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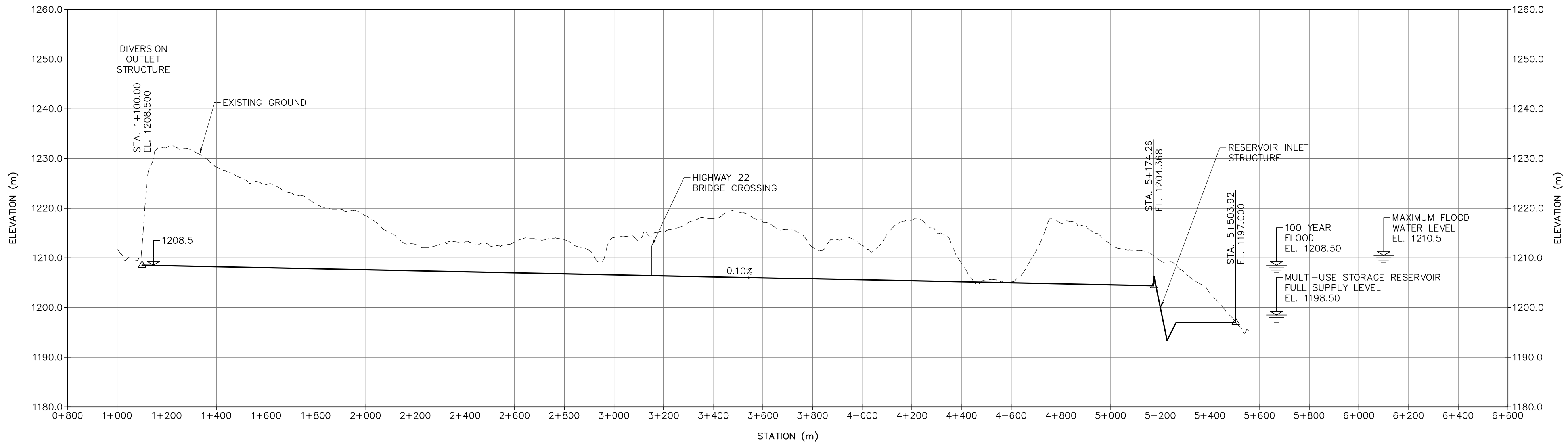

DIVERSION CHANNEL PROFILE

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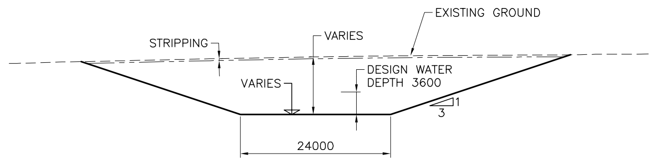

DIVERSION CHANNEL TYPICAL CROSS SECTION

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Title: SPRINGBANK OFF-STREAM STORAGE PROJECT (SR1) DIVERSION CHANNEL

Project No.: CW2174
CADD File: 2174–N03.dwg
Date: MAY 2014
Drawing No.: G5
Sheet No.: 1 of 1

EXHIBIT 3.5

Details - Springbank Off-Stream Storage Project (SR1) Off-Stream Storage Dam & Low Level Outlet

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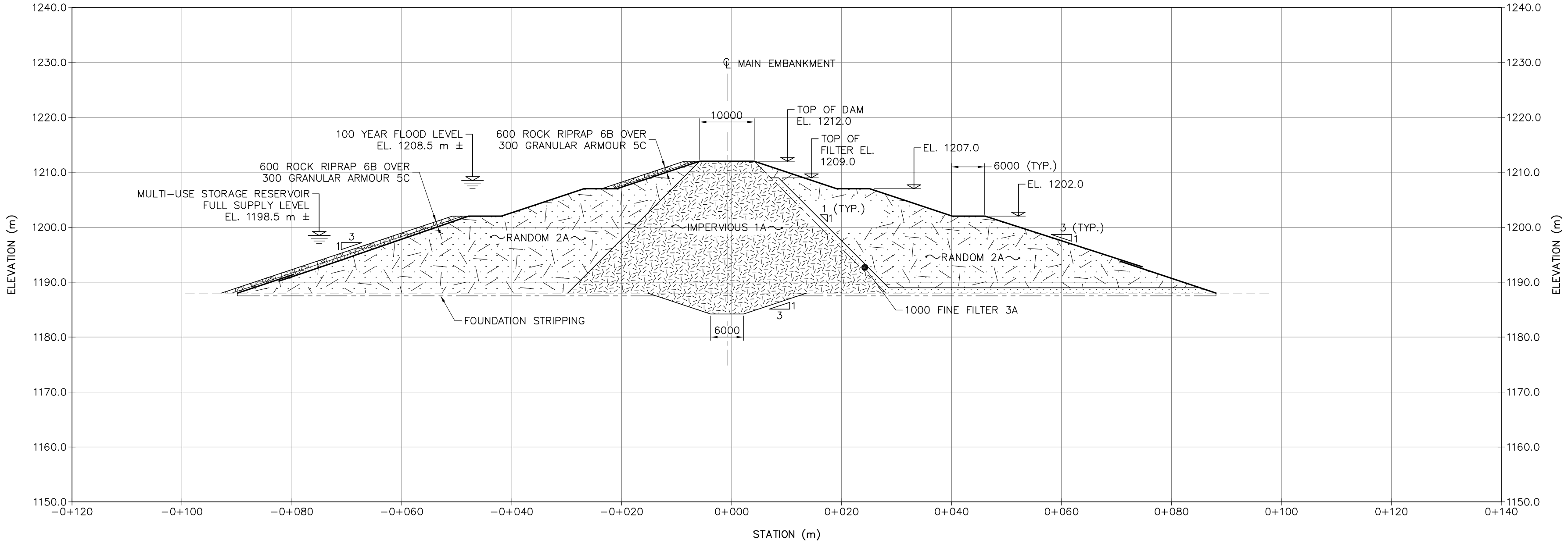
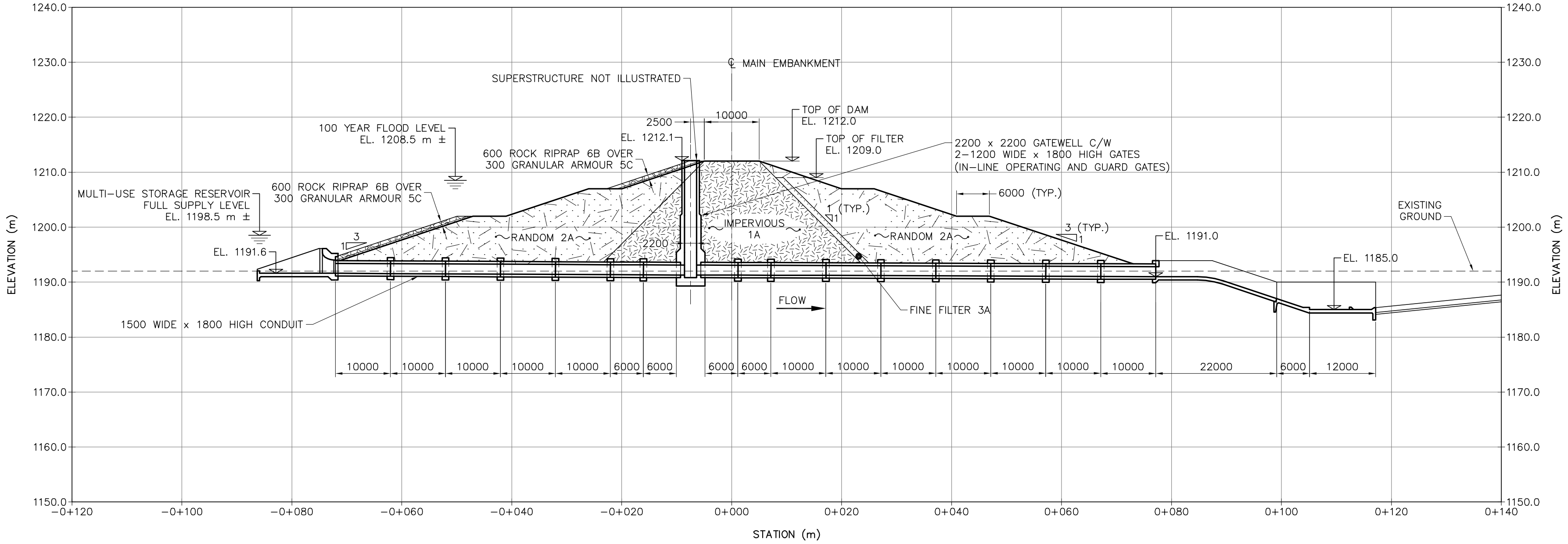


OFF−STREAM STORAGE DAM
SCALE 1:500



LOW LEVEL OUTLET STRUCTURE
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1:500
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Checked By: F.T.
Approved By: G.G.
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Title: SPRINGBANK OFF-STREAM STORAGE PROJECT (SR1) OFF-STREAM STORAGE DAM & LOW LEVEL OUTLET

Project No.: CW2174
CADD File: 2174−N03.dwg
Date: MAY 2014
Drawing No.: G6
Sheet No.: 1 of 1

IBI

Alberta Government

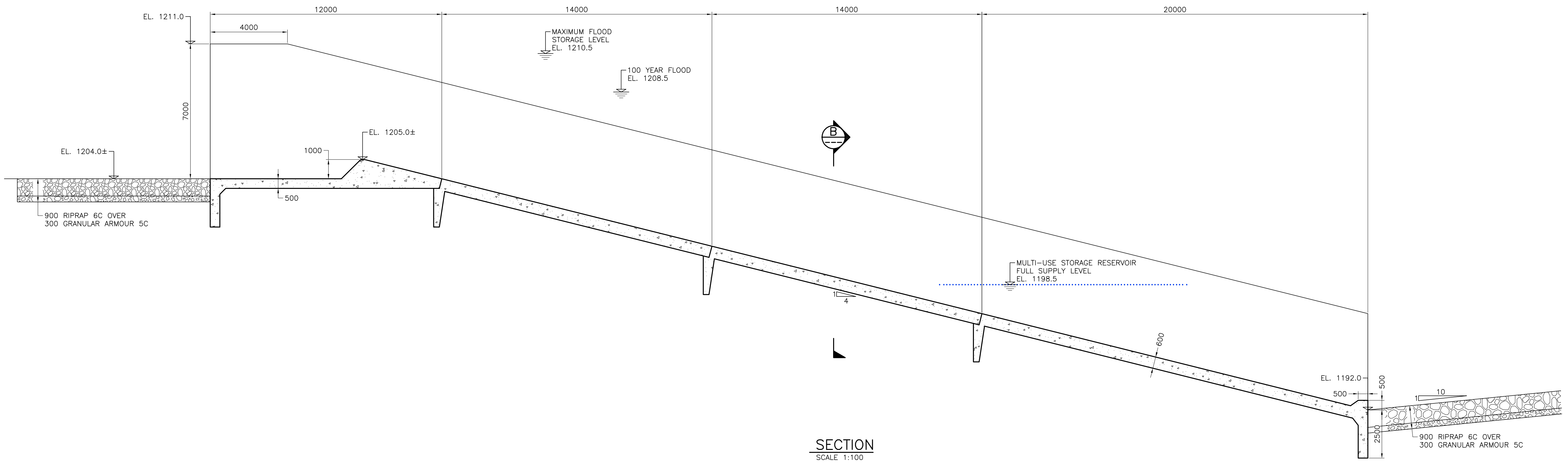
Benefit/Cost Analysis for Flood Mitigation Projects for the City of Calgary:
Conceptual Design of the Springbank Off-Stream Flood Storage Site
February 2015

EXHIBIT 3.6

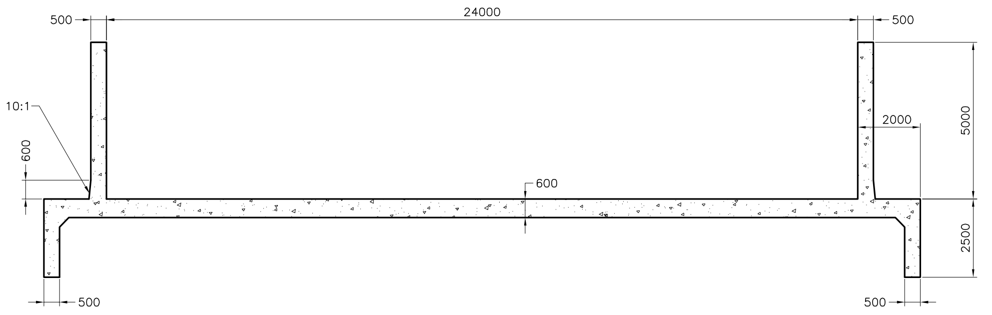
Details - Springbank Off-Stream Storage Project (SR1) Reservoir Inlet Structure

NOTES:

1. ELEVATIONS ARE IN METRES AND DIMENSIONS ARE IN MILLIMETRES UNLESS NOTED OTHERWISE.



SECTION
SCALE 1:100



B SECTION
SCALE 1:100

SCALE 1:100 0 1 2m

THIS DRAWING MAY HAVE BEEN REDUCED. ALL SCALE NOTATIONS INDICATED (i.e. 1:1000 etc.) ARE BASED ON 22" X 34" FORMAT DRAWINGS

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*PLOT 1:1=D (L)

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G						
F						
E						
D						
C						
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A	00	00	00	ISSUED FOR CLIENT REVIEW	X.X.	X.X.

amec

Client: ALBERTA FLOOD RECOVERY TASK FORCE

Designed By: K.K.
Drawn By: S.B.
Checked By: F.T.
Approved By: G.G.
Scale: AS SHOWN

Project: ALBERTA FLOOD RECOVERY TASK FORCE FLOOD MITIGATION STUDY

Title: SPRINGBANK OFF-STREAM STORAGE PROJECT (SR1) RESERVOIR INLET STRUCTURE

Project No.: CW2174
CADD File: 2174–B06.dwg
Date: MAY 2014
Drawing No.: G7
Sheet No.: 1 of 1

4 Cost Estimate

A detailed cost estimate is provided in **Exhibit 4.1A/B**[1]. The project cost is estimated to be $159,768,000. This price does not include the cost of land acquisition. The estimate provided herein is based on 2012 construction price data. Year 2012 prices were used considering that 2013 construction prices are skewed as a result of abnormal activity which resulted from the June 2013 flood event. It is assumed that the construction of SR1 would take place in a more competitive environment for contractors and suppliers, and as such the 2012 prices are considered indicative of realistic project cost. The estimate was produced considering the conceptual designs presented herein. Additional subsurface soils investigations are required to better establish the concept details presented herein. More detailed hydrological assessment and topographic data are required to better establish the size of required works. A contingency allowance of 25% has been included in an effort to account for additional costs which could result from future additional information and the results of more detailed design work. No allowance is included for escalation until the time of construction.

To increase the flood protection above the 1% AEP, to the 2013 flood of record level would require the dam crest level raised by approximately 2.5m to Elevation 1214.5m and would also require a larger diversion outlet structure and channel. These adjustments would result in additional project cost of approximately $55 million. This amount includes contingency and engineering allowances.

4.1 Land Acquisition

Land requirements were based on the conceptual design footprint including the diversion, storage reservoir to contain a 1:100 year event, and dam, and equated to some ±1,760 acres.[2] Currently, this land is under cultivation or pasture. In terms of planning status, the land is currently designated Ranch and Farm District (RF) according to the Rocky View County Land Use Bylaw. The purpose and intent of this land use designation is to “provide for agricultural activities as the primary land use on a quarter section of land or on a large balance of lands from a previous subdivision” (Rocky View County Land Use Bylaw, 1998).

There are no Area Structure Plans in place for the area and according to the County’s Growth Management Strategy, the area has not been recognized as a location for future growth (see **Appendix A**).

To establish potential land acquisition costs, 2014 MLS sales transactions for raw land and country residential style lots within the Springbank area (see **Exhibit 4.2**) were analyzed along with data from country residential developments including Watermark, Silverhorn and Harmony (see **Appendix B**). In addition, real estate brokers were solicited for opinions on potential land values in the general area.

Typical agricultural land values vary considerably depending upon soil quality, crop potential, etc. and vary from $4,000 to $8,000/acre. Larger transactions of farmland (±120 acres) have ranged between $6,000 and $9,000/acre within the general area. Using the upper bound of say $10,000/acre, would equate to a land acquisition cost of $17.6 million.

Developable land values are considerably higher with larger land assemblies (±120 acres) ranging from between $22,000 and $105,000/acre and averaging $50,000/acre.

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[1] AMEC Environmental & Infrastructure, *Southern Alberta Flood Recovery Task Force, Volume 4 – Flood Mitigation Measures, Appendix G – Springbank Off-Stream Storage Project*, May 2014.

[2] Actual land requirements will vary based on the detailed design of the facility which is currently underway.

Off-Stream Storage Project (SR1) Cost Estimate (1 of 2)

Item	Unit	Quantity	Unit Price	Extension
General				
Mob./Demobilization	lump sum	lump sum	7,000,000.00	$7,000,000
Care of Water	lump sum	lump sum	3,000,000.00	$3,000,000
Clearing & Timber Salvage	hectares	10	12,000.00	$120,000
Raise Highway 22	lump sum	lump sum	2,000,000	2,000,000
Local Road Modifications	km	15	250,000.00	$3,750,000
Topsoil/Seeding etc.	m^2	1,200,000	1.50	$1,800,000
	Subtotal General			**$17,670,000**
River Diversion Structure System				
Stripping	m^3	5,000	6.00	$30,000
Common Excavation	m^3	20,000	10.00	$200,000
Structure Fill	m^3	10,000	30.00	$300,000
Diversion Weir Concrete	m^3	4,900	1,000.00	$4,900,000
Sluice/Fishway Concrete	m^3	990	1,000.00	$990,000
Outlet Structure Concrete	m^3	1,900	1,000.00	$1,900,000
Precast Decks	lump sum	lump sum	560,000.00	$560,000
Fine Filter	m^3	1,200	90.00	$108,000
Coarse Filter	m^3	1,200	90.00	$108,000
Piping System	lump sum	lump sum	200,000.00	$200,000
Rock Riprap	m^3	6,400	130.00	$832,000
Bedding Gravel	m^3	2,200	70.00	$154,000
Gate/Hoist Systems	each	6	500,000.00	$3,000,000
Controls/Instrumentation	lump sum	lump sum	300,000.00	$300,000
Electrical/Mechanical	lump sum	lump sum	500,000.00	$500,000
Superstructures	each	2	90,000.00	$180,000
	Subtotal Diversion Structure System			**$14,262,000**
Floodplain Berm				
Stripping	m^3	18,000	6.00	$108,000
Impervious Fill	m^3	90,000	1.50	$135,000
Random Fill	m^3	60,000	1.40	$84,000
Fine Filter	m^3	6,000	90.00	$540,000
Rock Riprap	m^3	8,000	130.00	$1,040,000
Bedding Gravel	m^3	4,000	60.00	$240,000
	Subtotal Floodplain Berm			**$2,147,000**

Item	Unit	Quantity	Unit Price	Extension
Diversion Channel & Reservoir Inlet Structure				
Stripping	m^3	180,000	6.00	$1,080,000
Common Excavation	m^3	1,800,000	5.50	$9,900,000
Rock Excavation	m^3	200,000	10.00	$2,000,000
Impervious Fill	m^3	10,000	20.00	$200,000
Inlet Chute Concrete	m^3	2,000	1,200.00	$2,400,000
Fine Filter	m^3	660	90.00	$59,000
Coarse Filter	m^3	1,760	90.00	$158,000
Piping System	lump sum	lump sum	200,000.00	$200,000
Bridge Crossings	each	1	4,000,000.00	$4,000,000
Pipeline Crossings	lump sum	lump sum	4,000,000.00	$4,000,000
Power Line Relocation	lump sum	lump sum	300,000.00	$300,000
	Subtotal Diversion Channel System			**$24,298,000**

EXHIBIT 4.1A

Off-Stream Storage Project (SR1) Cost Estimate (2 of 2)

Off-stream Storage Dam				
Stripping	m^3	180,000	6.00	$1,080,000
Borrow Excavation	m^3	1,700,000	5.00	$8,500,000
Overhaul	m^3km	2,500,000	1.50	$3,750,000
Impervious Fill	m^3	1,600,000	1.50	$2,400,000
Random Fill	m^3	1,200,000	1.40	$1,680,000
Fine Filter	m^3	140,000	60.00	$8,400,000
Coarse Filter	m^3	20,000	60.00	$1,200,000
Rock Riprap	m^3	62,000	130.00	$8,060,000
Bedding Gravel	m^3	31,000	60.00	$1,860,000
Geotechnical Instruments	lump sum	lump sum	400,000.00	$400,000
	Subtotal Off-stream Dam			**$37,330,000**

Dam Outlet Structure and Downstream Channel Improvements				
Structure Excavation	m^3	20,000	20.00	$400,000
Structure Fill	m^3	15,000	30.00	$450,000
Reinforced Concrete	m^3	1,600	1,200.00	$1,920,000
Rock Riprap	m^3	600	130.00	$78,000
Bedding Gravel	m^3	300	70.00	$21,000
Gate/Hoist Systems	each	lump sum	160,000.00	$320,000
Controls/Instrumentation	lump sum	lump sum	100,000.00	$100,000
Electrical/Mechanical	lump sum	lump sum	400,000.00	$400,000
Superstructure	lump sum	lump sum	50,000.00	$50,000
	Subtotal Structure & Channel Improvements			**$3,739,000**

Item	**Unit**	**Quantity**	**Unit Price**	**Extension**
Springbank Road Relocation				
Grading	km	5	550,000.00	$2,750,000
Base/Pavement	km	5	650,000.00	$3,250,000
Creek Crossings	lump sum	lump sum	1,000,000.00	$1,000,000
	Subtotal Springbank Road Relocation			**$7,000,000**
	SUBTOTAL CONSTRUCTION			**$106,446,000**
	Contingencies (25%)			$26,661,000
	Subtotal Construction and Contingencies			**$133,107,000**
	Engineering/Environmental (20%)			$26,661,000
	TOTAL CONSTRUCTION			**$159,768,000**

EXHIBIT 4.1B

Market Area Considered

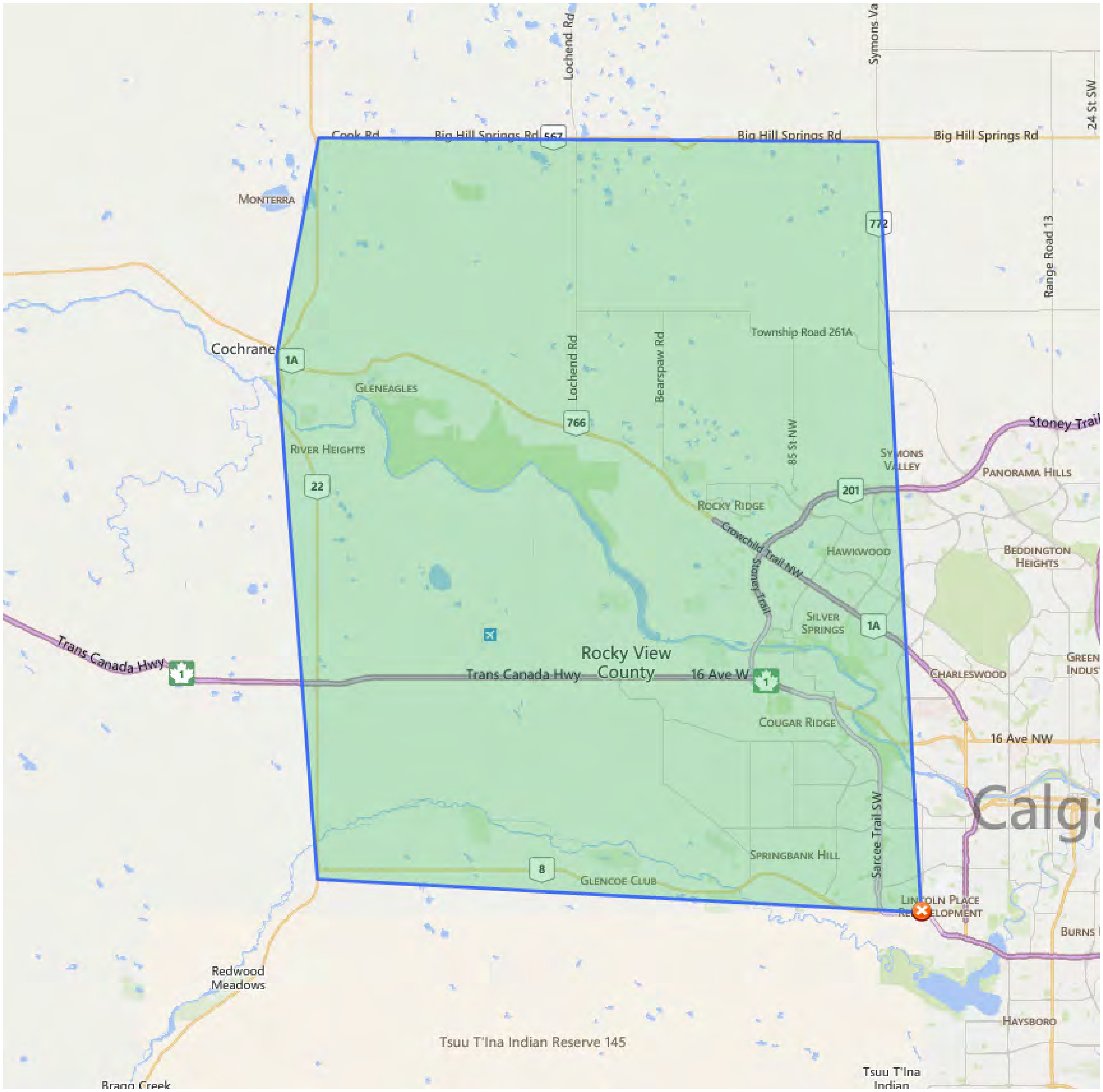

EXHIBIT 4.2

Individual country residential lots sold within the market area range from $107,000 to $378,000/acre and average $193,000/acre. The latter reflects developed land value with the final sales prices reflecting the cost of raw land, servicing (roads, sanitary, storm and water), sales commissions, marketing, legal and developer profit.

The community of Harmony, located within the market area some 2 to 3 km to the north, is a 1,748 acre master-planned community, featuring a 140 acre lake, golf course, village centre and mixed residential community (see **Appendix C**). Assuming approvals were obtained for a similar type of development on the site in question, with an acquisition price of $50,000/acre, total land acquisition under these assumptions would equate to $88 million; however, given the size of the acquisition it is likely that this value would be discounted to reflect the anticipated absorption over a long timeframe. At a discount rate of 4% and a projected 20 year life expectancy for the development, the acquisition cost would be $40.163 million in 2014$.

If the current land owners choose to develop rather than sell the land to a third party developer, then the value of the ultimate project (depending upon a large number of factors) could be worth considerably more than the land value as stated.

In summary, land acquisition costs range from a low of $17.6 million to a high of $40.1 million, depending upon the precise circumstances surrounding the negotiation and ultimate acquisition. For the purposes of this study the higher value, $40 million, is proposed for use in the benefit/cost analysis.

4.2 Flood Defences at Bragg Creek

The flood mitigation measures study for the Bow, Elbow and Old Man River basins recommended flood defences at Bragg Creek if flood protection infrastructure for the City of Calgary was located downstream of Bragg Creek. Protection of the Hamlet via dykes was proposed with a further recommendation that if a decision was made to proceed with SR1 as the preferred flood storage scheme for the Elbow River, then the detailed design and planning for the dykes of Bragg Creek should be initiated as soon as possible.[3] Costs for the dyke system were estimated at $6.2 million (see **Appendix D**).

5 Flood Damages

5.1 Without Mitigation Alternative

5.1.1 City of Calgary

Flood damage estimates were generated for the City of Calgary employing updated stage-damage curves and the Provincial Rapid Flood Damage Assessment Model. Damage assessments were generated for nine return frequencies including: 1:2 year, 1:5 year, 1:10 year, 1:20 year, 1:50 year, 1:100 year, 1:200 year, 1:500 year and 1:1000 year, which allowed for the computation of average annual damages. Damage estimates were also assessed under two cases: a higher or “worst case” condition and a lower or “anticipated case” condition.

The detailed analysis of City of Calgary flood damages is contained under separate cover; however, summary tables are contained in **Appendix E**. For the 1:100 year flood under the higher damage case, total damages on the Elbow are estimated at $741,005,000. Average annual damages for the Elbow River under the higher case equate to $30,110,965.

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[3] AMEC Environmental & Infrastructure, *Southern Alberta Flood Recovery Task Force, Flood Mitigation Measures for the Bow, Elbow and Oldman River Basins, Volume 1 – Summary Recommendations Report – Final,* June 2014.

For the 1:100 year flood under the lower case assumptions, total damages on the Elbow River are estimated at $538,369,000 with average annual damages estimated at $21,728,927.

5.1.2 Other Damages

Flood damage studies, akin to the detailed assessment undertaken for the City of Calgary have not been generated for areas upstream of the Springbank Off-Stream Flood Storage project including Bragg Creek, Redwood Meadows and infrastructure within Rocky View County which would not be protected by the proposed Springbank Off-Stream Flood Storage project. These damages constitute costs over and above those accruing to the City of Calgary and should be taken into consideration as part of the benefit/cost analysis.

A variety of secondary sources were employed to determine damages, including the damage claims submitted under the 2013 Southern Alberta Disaster Recovery Program along with a previous study of Bragg Creek completed for Alberta Environment Planning Division in 1987[4].

In terms of the 2013 Southern Alberta Disaster Recovery Program, the total estimated amount for flood recovery projects between the McLean Creek dam site and the City of Calgary is approximately $5.6 million. This amount is made up of $1.084 million for recovery projects in Rocky View County (including Bragg Creek), $2.657 million for recovery projects in the Townsite of Redwood Meadows, and $1.901 million for recovery projects in the Tsuu T'ina First Nation. Details are contained in **Appendix F**.

5.1.2.1 1987 Bragg Creek Floodplain Management Study

The 1987 Bragg Creek Floodplain Management Study identified 37 residential units and 21 commercial units within the flood hazard area. This has increased to 51 residential units and 29 commercial units, representing an increase of 27% for residential and 28% for commercial. A very cursory assessment of potential damages employing values from the updated stage-damage curves suggests total damages in the order of $12.7 million for the Bragg Creek flood study area for the 1:100 year event.

5.1.2.2 Cost Implications

At this juncture it is not possible to accurately calculate average annual damages for the areas upstream of the Springbank Offstream Flood Storage project. Notwithstanding, in order to account for the other damages, and therefore additional costs that will be incurred by the SR1 project over the MC1 project, an additional $8.9 million in total costs are proposed to be added to the SR1 project.

5.2 With Mitigation Alternative

Implementation of the Springbank Off-Stream Flood Storage project results in a reduction of average annual damages under the four cases as follows:

- 1:100 year level of protection under the higher damage scenario = $19,461,291
- 1:200 year level of protection under the higher damage scenario = $26,114,777
- 1:100 year level of protection under the lower damage scenario = $13,746,068
- 1:200 year level of protection under the lower damage scenario = $16,686,439

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[4] *Bragg Creek Floodplain Management Study – Final Report*, J.N. MacKenzie Engineering Ltd. in association with W-E-R Engineering Ltd., IBI Group and Ecos Engineering Services Ltd., January 1987.

6 Benefit/Cost Analysis

6.1 Benefit/Cost Analysis for Flood Mitigation Projects

For flood mitigation projects, economic evaluation requires a comparison between the events predicted to occur if the project is built and those predicted to occur if the project is not built. This is called the “with and without principle”. For flood control one cannot directly equate an exchange in the market, however flood control benefits can be estimated by assuming they are equivalent to the flood damage prevented.

For flood mitigation projects the probabilistic approach to benefit/cost estimates is used. To reiterate, within the defined flood risk area, flood damages were estimated with the application of depth-damage curves applied to the various return flood events (probability). The flood damage probability distribution was then plotted and the average annual damage (AAD) estimated for project evaluation purposes.

With the updated average annual damages and cost estimates of the diversion alternative, an economic efficiency evaluation was performed. This evaluation is based upon the net present value (NPV) of respective benefits and costs. The net present value of any project is governed by three variables: the average annual cost or benefit, discount rate, and discount period. To provide a consistent economic evaluation of flood mitigation projects across the Province, a common discount rate of 4% was agreed upon and applied. The discount period is the estimate of the alternative’s project life.

The benefit/cost (B/C) ratio of a project is the ratio of net present value of the benefits (average annual damages) over the net present value of the costs. This value is the indicator of economic efficiency. Where the benefits exceed costs, the ratio would be greater than 1.0, and where benefits are less than costs then the ratio would be less than 1.0. An economically-efficient project would have a B/C ratio greater than 1.0. At a B/C ratio of 1.0, the project is at a breakeven point.

6.2 Assumptions/Methodology

The following assumptions were employed in the benefit/cost analysis:

- Costs are based on the estimated capital and operational/maintenance costs presented in Section 4.
- $8.9 million in capital costs was added to the Springbank Off-Stream Flood Storage scenario to account for required mitigation measures upstream.
- Benefits are based on the quantification of flood damages averted as outlined in Section 5.
- The benefit/cost analysis has been carried out using a net present value analysis.
- A 100 year economic analysis.
- Annual operating and maintenance costs of $1.8 million.

6.2.1 MC1 (McLean Creek Flood Storage Project) and SR1 (Springbank Off-Stream Flood Storage Project)

Net benefits for MC1 and SR1 were computed on the basis that the projects will provide protection downstream of Glenmore Dam to the 1:100 and 1:200 year flood events. When these events are exceeded, the damages will start to increase rapidly as the peak discharge passes through the flood hazard area within the City of Calgary. Without additional hydrologic routing, it was assumed that once the design event is exceeded, full damages are incurred. With additional hydrologic routing it is possible that the benefit/cost ratios of these schemes will improve somewhat.

6.2.2 Glenmore Reservoir Diversion

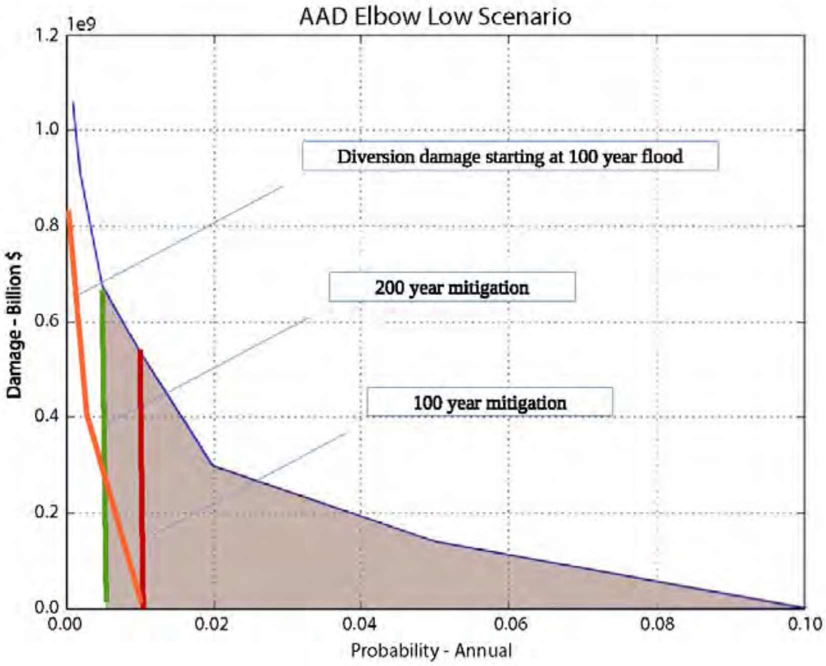
With respect to the Glenmore Reservoir Diversion it was possible to calculate the reduced damages that would be achieved as a result of the 500 and 700 CMS diversion. The incremental flow was passed downstream and damages based on the reduced flood flow were computed to determine the net benefits. Consequently, a higher benefit can be attributed to the diversion scheme based on this higher level of analysis. Notwithstanding the higher overall benefits, the actual benefit/cost ratio as illustrated in the next section is lower than the MC1 and SR1 schemes due to the much higher cost base of the Glenmore Reservoir Diversion.

Exhibit 6.1 illustrates this principle considering the average annual damage on the Elbow under the low damage scenario. If all flood damage can be eliminated then the average annual damage is equal to the area under the curve from the Y to the X axis. This is the total average annual damage.

If a dyke is constructed to a 100 year flood protection, the area right of the red line is subtracted from the total average annual damage. This is the value of the average annual damage averted. However, when the 100 year flood is exceeded then all the properties are flooded instantaneously (area to the left of the red line). Similarly, for a dyke built to the 200 year level of protection.

Conversely, in the case of the diversion tunnel, the mitigation is the area right of the orange line. In this case, when the diverted flow is exceeded, then the damage occurs gradually (slope of the orange curve) rather than vertically, like the dyke situation.

Exhibit 6.1: Affect of Mitigation on Average Annual Damage



6.3 Discussion of Results

Exhibit 6.2 highlights the key results of the benefit/cost analysis of the Springbank Off-Stream Flood Storage project considering the four cases as discussed.

For the 1:100 year level of protection under the high damage scenario the present value of benefits is $477 million versus $255 million in costs, rendering a positive benefit/cost ratio of 1.87.

At the 1:200 year level of protection, the benefit/cost ratio increases to 2.07, an economically viable project with a very attractive benefit/cost ratio.

For the low damage scenario the 1:100 year present value of benefits is $337 million versus costs of $255 million, rendering a benefit/cost ratio of 1.32.

With the 1:200 year level of protection the benefit/cost ratio remains at 1.32, once again an economically viable project with a positive benefit/cost ratio.

Exhibit 6.2: Benefit/Cost Analysis

Indicator	High Damage Scenario		Low Damage Scenario	
	1:100 Year Protection	1:200 Year Protection	1:100 Year Protection	1:200 Year Protection
PV Benefits (average annual damages)	$476,899,000	$639,943,000	$336,847,000	$408,901,000
PV Costs (development & operating total cost)	$255,098,000	$309,607,000	$255,098,000	$309,607,000
Benefit/Cost Ratio	1.87	2.07	1.32	1.32
Net Present Value	$221,801,000	$330,336,000	$81,749,000	$99,294,000
Average Annual Damages	$19,461,291	$26,114,777	$13,746,068	$16,686,439

6.4 Benefits Beyond the Study Area

Of the three mitigation projects under consideration, only one – the McLean Creek Flood Storage project (MC1) – provides benefits beyond the primary study area, the City of Calgary. An analysis of any potential benefits downstream of the City was outside the scope of this analysis. Needless to say, it is anticipated that benefits downstream of the City would be marginal in any event.

6.5 Triple Bottom Line Considerations

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 are the results of outcomes that society desires and have more recently been described as triple bottom line objectives which include, in addition to economic objectives, considerations of environmental and social impacts. In relation to flood mitigation projects, the following criteria are often considered in the evaluation process:

- Disaster prevention:
  - reduces current losses
  - reduces future losses
  - potential residential loss of life
  - potential non-residential loss of life
- Environmental impact:
  - biophysical impacts
  - social impacts
  - aesthetic impacts
- Implementation:
  - complexity
  - flexibility of integration with other measures
- Incidental benefits:
  - recreation
  - drought mitigation
  - other

This study was concerned solely with economic efficiency and consequently does not include analysis of the aforementioned non-commensurable criteria.

6.6 Summary and Conclusions

Exhibit 6.3 below illustrates the relative ranking of the flood mitigation projects.

Exhibit 6.3: Benefit/Cost Ratio

Mitigation Project	High Damage Scenario		Low Damage Scenario	
	1:100 Year Protection	1:200 Year Protection	1:100 Year Protection	1:200 Year Protection
SR1	1.87	2.07	1.32	1.32
MC1	1.43	1.65	1.01	1.05
Glenmore	1.21	1.20	0.81	0.83

The Springbank Off-Stream Flood Storage project achieves a positive benefit/cost ratio under all four scenarios and ranks first ahead of the other two mitigation projects with significantly higher benefit/cost ratios.[5]

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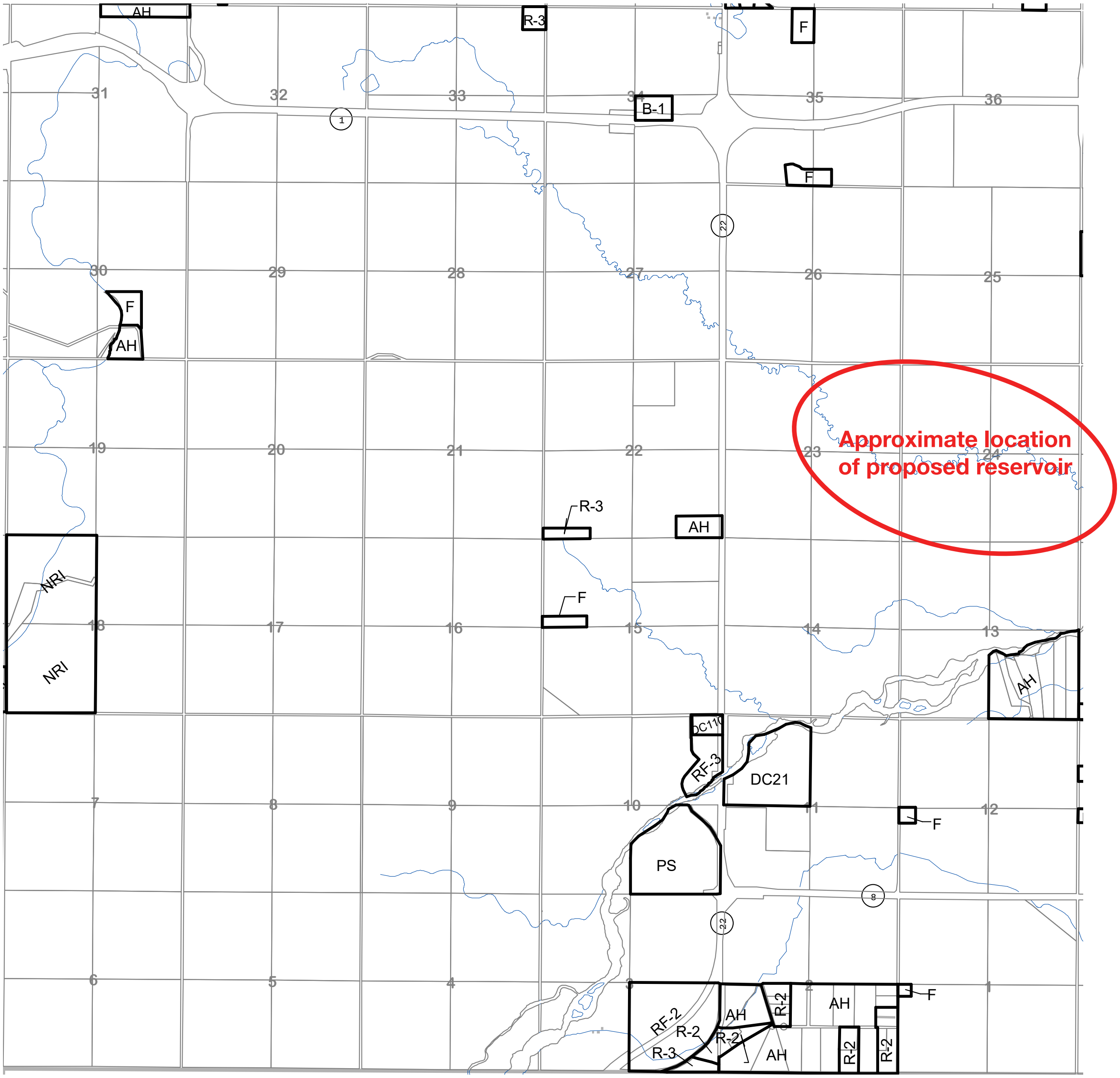
[5] Refer to IBI Group Reports: *Benefit/Cost Analysis of Flood Mitigation Projects for the City of Calgary: McLean Creek Flood Storage (February 2015)* and *Benefit/Cost Analysis of Flood Mitigation Projects for the City of Calgary: Glenmore Reservoir Diversion (February 2015).*

Appendix A – Entitlement Status of Lands for Off-Stream Storage Project

Municipal District of Rocky View #44 - Land Use Map No. 48



ALL LANDS ARE DESIGNATED RF UNLESS NOTED OTHERWISE

RANCH AND FARM DISTRICT	RF
SEE EXCEPTIONS LISTED WITH THIS DISTRICT	RF *
RANCH AND FARM TWO DISTRICT	RF-2
RANCH AND FARM THREE DISTRICT	RF-3
AGRICULTURAL HOLDING DISTRICT	AH
FARMSTEAD DISTRICT	F
RESIDENTIAL ONE DISTRICT	R-1
RESIDENTIAL TWO DISTRICT	R-2
RESIDENTIAL THREE DISTRICT	R-3
HIGHWAY BUSINESS DISTRICT	B-1
GENERAL BUSINESS DISTRICT	B-2
LIMITED BUSINESS DISTRICT	B-3
RECREATION BUSINESS DISTRICT	B-4
AGRICULTURAL BUSINESS DISTRICT	B-5
LOCAL BUSINESS DISTRICT	B-6
HIGHWAY FRONTAGE BUSINESS DISTRICT	B-HF
BUSINESS CAMPUS BUSINESS DISTRICT	B-BC
INDUSTRIAL CAMPUS BUSINESS DISTRICT	B-IC

RECREATION DESTINATION BUSINESS DISTRICT	B-RD
LEISURE AND RECREATION BUSINESS DISTRICT	B-LR
AGRICULTURAL SERVICES BUSINESS DISTRICT	B-AS
POINT COMMERCIAL DISTRICT	C-PT
VILLAGE CENTRE COMMERCIAL DISTRICT	C-VC
LOCAL COMMERCIAL DISTRICT	C-LC
REGIONAL COMMERCIAL DISTRICT	C-RC
INDUSTRIAL ACTIVITY DISTRICT	I-IA
STORAGE AND SALES INDUSTRIAL DISTRICT	I-SS
NATURAL RESOURCE INDUSTRIAL DISTRICT	NRI
HAMLET RESIDENTIAL SINGLE FAMILY DISTRICT	HR-1
HAMLET RESIDENTIAL (2) DISTRICT	HR-2
HAMLET COMMERCIAL DISTRICT	HC
HAMLET INDUSTRIAL DISTRICT	HI
PUBLIC SERVICES DISTRICT	PS
AIRPORT DISTRICT	AP
DIRECT CONTROL DISTRICT	DC

N

MUNICIPAL DISTRICT OF ROCKY VIEW #44

TWP. 24-4-W5M

Part FIVE of the BYLAW No. C-4841-97

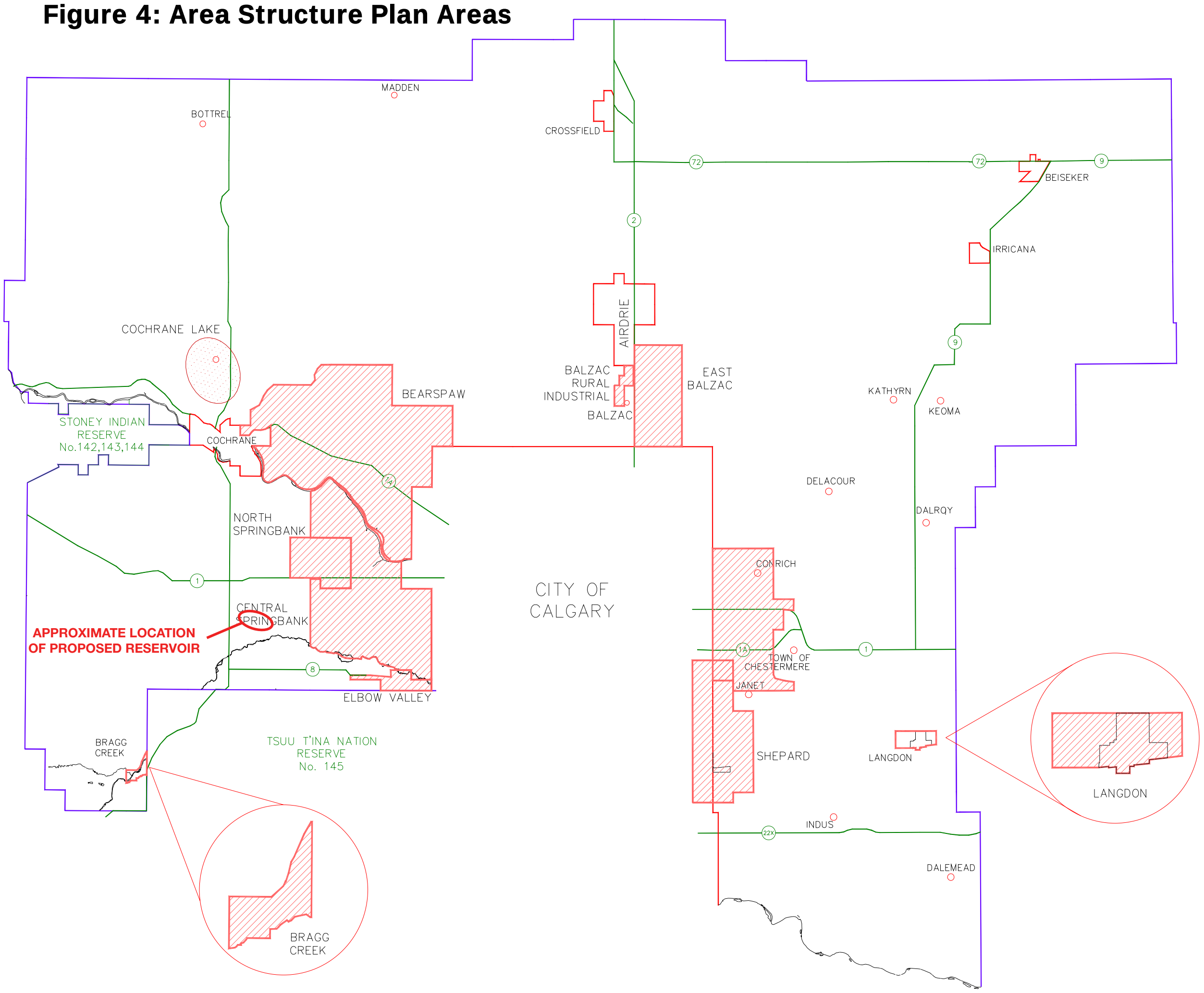
LAND USE MAP No. 48

DATE: Mar 02, 2009

EXHIBIT A-1

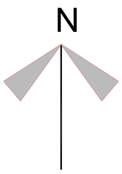
Municipal District of Rocky View #44 - Suggested and Approved Area Structure Plans

Figure 4: Area Structure Plan Areas



MUNICIPAL DISTRICT OF ROCKY VIEW No.44

SUGGESTED AND APPROVED AREA STRUCTURE PLANS

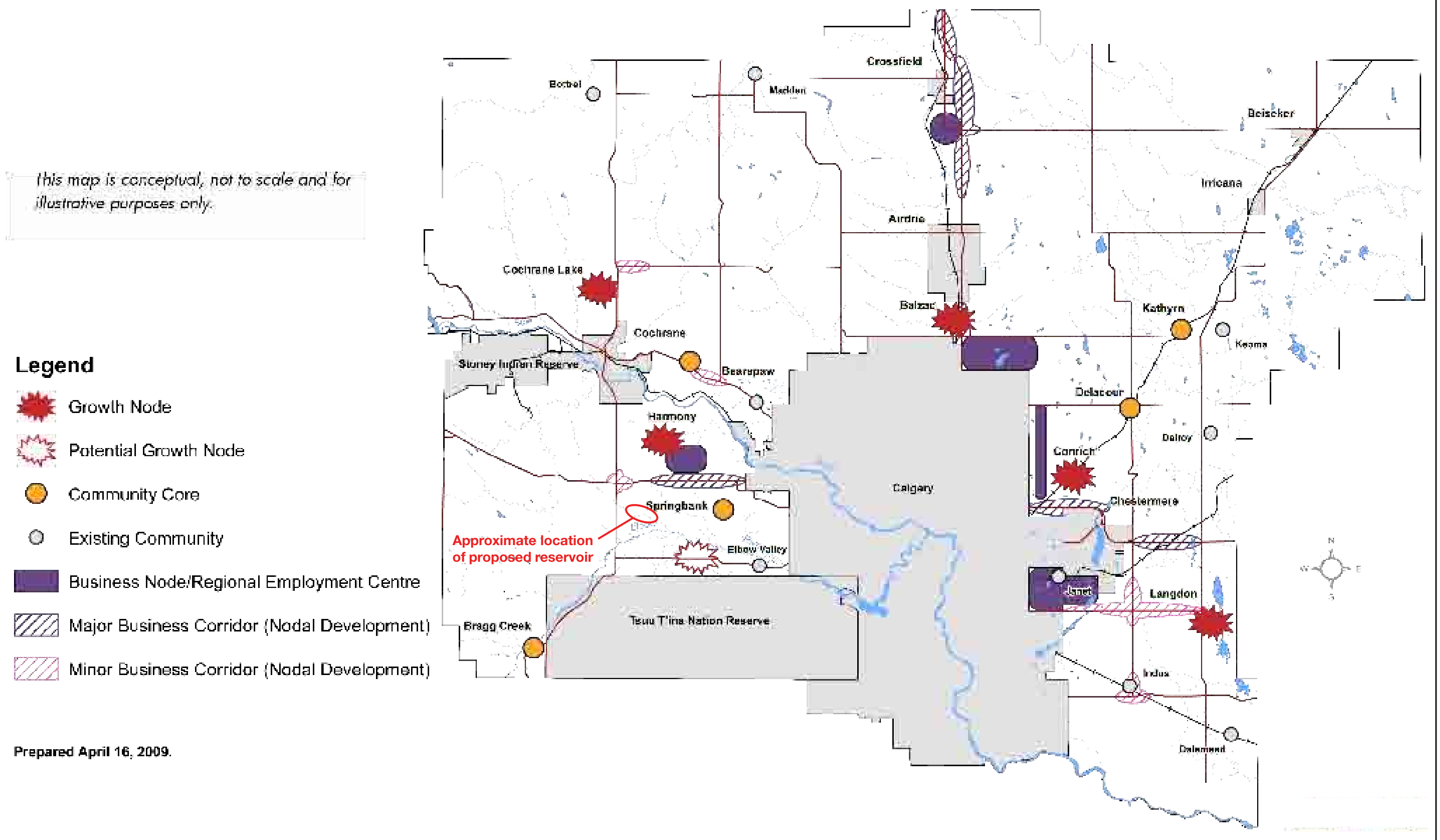


▨ AREA STRUCTURE PLANS
(EXISTING OR BEING PREPARED)

▨ AREAS UNDER DEVELOPMENT PRESSURE

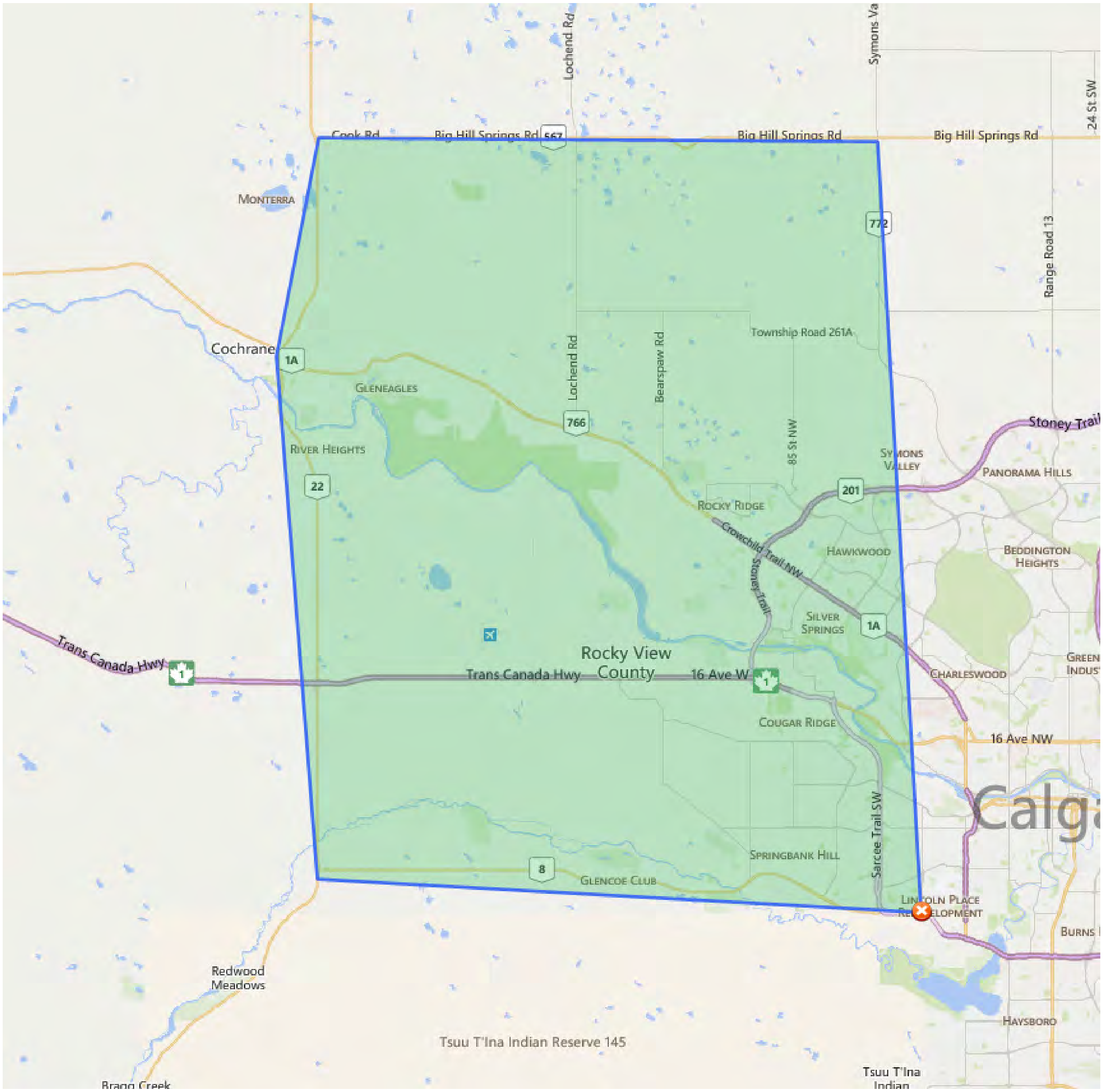
January 2003

Municipal District of Rocky View #44 - Growth Management Strategy Map



Appendix B – Springbank Area MLS Sales and Listing Data for 2014

Market Area Considered



IBI | Alberta Government

Benefit/Cost Analysis for Flood Mitigation Projects for the City of Calgary:

Conceptual Design of the Springbank Off-Stream Flood Storage Site

February 2015

EXHIBIT B-1

Rocky View West Listing

Sta	ML Number	Address	List Price	Sold Price	Community Desc	List Date	Off Market Dat	Total Ac	Days c	Condo Name	Condo Type	Number of Parcels	Cummu	County	List Price / Acre	Sold Price / Acre	Postal Code
A	C3553126	227 CHURCH RANCHES WY NW	$ 719,000.00		Church Ranches	06/02/2013		3.43	650				800	ALBERTA	$ 209,620.99		T3R 1B2
A	C3586217	242258 Windhorse WY	$ 410,000.00		Springbank	19/09/2013		2.05	425				425	ALBERTA	$ 200,000.00		T3Z 0B4
A	C3586227	35 WINDHORSE GR	$ 435,000.00		Springbank	19/09/2013		2.03	425				425	ALBERTA	$ 214,285.71		T3Z 0B4
A	C3599739	Lochend RD NW	$ 8,000,000.00		Bearspaw_Calg	10/02/2014		158.85	281				281	ALBERTA	$ 50,361.98		T3L 2R2
A	C3604034	Highway # 22 North of Cochrane	$ 1,500,000.00		Cochrane Lake	10/03/2014		53.55	253				253	ALBERTA	$ 28,011.20		T4C 1A9
A	C3605546	124 WILLOW CREEK SU	$ 472,500.00		Bearspaw_Calg	21/03/2014		2.02	242				242	ALBERTA	$ 233,910.89		T3R 0K3
A	C3606704	116 GRIZZLY RI	$ 450,000.00		Bearspaw Country Estates	28/03/2014		4.05	235	Z-name Not Listed			235	ALBERTA	$ 111,111.11		T3Z 1H5
A	C3617284	67 CHEYANNE MEADOWS WAY	$ 699,000.00		Church Ranches	23/05/2014		2.34	179				179	ALBERTA	$ 298,717.95		T3R 1B6
A	C3629847	262 Lochend Road	$ 3,969,000.00		None	06/08/2014		157.56	104				104	ALBERTA	$ 25,190.40		T4C 0X0
A	C3631166	251095 WELLAND WY	$ 595,000.00		Bearspaw_Calg	14/08/2014		4.42	96	Z-name Not Listed			277	ALBERTA	$ 134,615.39		T3R 1L3
A	C3631295	41216 Camden Lane	$ 550,000.00		None	12/08/2014		3.95	98				98	ALBERTA	$ 139,240.51		T4C 1B1
A	C3629151	50 BLAZER ESTATES RG	$ 1,100,000.00		Bearspaw_Calg	01/08/2014		8.08	109				109	ALBERTA	$ 136,138.61		T3L 2N7
A	C3641919	116 BEARSPAW MEADOWS	$ 799,999.00		Lynx Ridge	23/10/2014		2.72	26				26	ALBERTA	$ 294,117.28		T3L 2M3
A	C3583465	108 AVENTERRA	$ 359,000.00		Springbank	30/08/2013		2.03	445				445	ALBERTA	$ 176,847.29		T3J 5J4
A	C3640329	31239 TWP RD 252	$ 675,000.00		Springbank	17/10/2014		4	32				32	ALBERTA	$ 168,750.00		T3Z 1E8
A	C3639338	24333 Meadow DR	$ 499,900.00		Bearspaw_Calg	08/10/2014		2	41				41	ALBERTA	$ 249,950.00		T3R 1G3
A	C3621718	10 BEARSPAW VALLEY PLACE	$ 499,900.00		Bearspaw_Calg	16/06/2014		1.96	155				155	ALBERTA	$ 255,051.02		T3G 3G3
A	C3642556	118 WINDHORSE CO	$ 384,900.00		Springbank	03/11/2014		2.05	15				303	ALBERTA	$ 187,756.10		T3Z 0B4
A	C3621729	18 BEARSPAW VALLEY PLACE	$ 499,900.00		Bearspaw_Calg	16/06/2014		1.93	155				155	ALBERTA	$ 259,015.54		T2E 2E2
A	C3575040	242244 WINDHORSE	$ 410,000.00		Springbank	27/06/2013		2.02	509				509	ALBERTA	$ 202,970.30		T3Z 0B4
A	C3637861	6 GLENDALE ESTATES MR	$ 459,000.00		Bearspaw_Calg	29/09/2014		1.98	50				212	ALBERTA	$ 231,818.18		T4C 1A2
A	C3613051	123 BROWN BEAR	$ 399,000.00		Bearspaw Country Estates	02/05/2014		2.08	200				200	ALBERTA	$ 191,826.92		T4C 0B5
A	C3629825	43 Big Hill Springs CV	$ 570,000.00		Bearspaw_Calg	06/08/2014		4.86	104				104	ALBERTA	$ 117,283.95		T4C 1A2
A	C3637529	22 GLENDALE ESTATES MR	$ 389,000.00		Bearspaw_Calg	25/09/2014		2	54	Z-name Not Listed			54	ALBERTA	$ 194,500.00		T3R 1G3
A	C3614265	31060 SWIFT CREEK	$ 494,900.00		Springbank	08/05/2014		2.08	194				194	ALBERTA	$ 237,932.69		T3Z 0B7
A	C3586173	31040 WINDHORSE DR	$ 460,000.00		Springbank	19/09/2013		2.03	425				425	ALBERTA	$ 226,600.99		T3Z 0B4
A	C3586195	12 WINDHORSE BA	$ 460,000.00		Springbank	19/09/2013		2	425				425	ALBERTA	$ 230,000.00		T3Z 0B4
A	C3586198	16 WINDHORSE BA	$ 410,000.00		Springbank	19/09/2013		2	425				425	ALBERTA	$ 205,000.00		T3Z 0B4
A	C3586221	43 WINDHORSE GR	$ 485,000.00		Springbank	19/09/2013		2	425				425	ALBERTA	$ 242,500.00		T3Z 0B4
A	C3586237	242162 WINDHORSE WY	$ 510,000.00		Springbank	19/09/2013		2	425				425	ALBERTA	$ 255,000.00		T3Z 0B4
A	C3586224	39 WINDHORSE GR	$ 485,000.00		Springbank	19/09/2013		2.05	425				425	ALBERTA	$ 236,585.37		T3Z 0B4
A	C3586243	242176 WINDHORSE WY	$ 435,000.00		Springbank	19/09/2013		2.01	425				425	ALBERTA	$ 216,417.91		T3Z 0B4
A	C3586234	242150 WINDHORSE WY	$ 510,000.00		Springbank	19/09/2013		2.02	425				425	ALBERTA	$ 252,475.25		T3Z 0B4
A	C3617248	31156 Township Road 251A	$ 749,800.00		Springbank	23/05/2014		10.63	179	Z-name Not Listed			179	ALBERTA	$ 70,536.22		T3Z 1E6
A	C3602240	21 SWIFT CREEK GR.	$ 588,000.00		Springbank	26/02/2014		2	265				265	ALBERTA	$ 294,000.00		T2Z 0B6
A	C3561891		$ 13,500,000.00		None	05/04/2013		121.37	592				1257	ALBERTA	$ 111,230.12		T3Z 2E4
A	C3633051	37 Westbluff PL	$ 2,450,000.00		Springbank	27/08/2014		10.01	83				83	ALBERTA	$ 244,755.25		T3Z 3P2
A	C3621724	14 BEARSPAW VALLEY PLACE	$ 499,900.00		Bearspaw_Calg	16/06/2014		1.95	155				155	ALBERTA	$ 256,358.97		T2E 2E2
A	C3595058	2 BEARSPAW VALLEY	$ 499,000.00		Bearspaw_Calg	29/12/2013		1.97	324				844	ALBERTA	$ 253,299.49		T3R 1A3
A	C3638507		$ 2,000,000.00		Glendale Meadows	02/10/2014		25.32	47				47	ALBERTA	$ 78,988.94		T4C 2G4
A	C3632325	35195 Springbank RD	$ 8,960,000.00		Springbank	22/08/2014		320	88				436	ALBERTA	$ 28,000.00		T3Z 3H3
A	C3603978	25151 ESCARPMENT RIDGE VW	$ 900,000.00		None	10/03/2014		2.31	253				253	ALBERTA	$ 389,610.39		T3Z 3M7
A	C3618112	Lochend RD	$ 3,080,000.00		Bearspaw_Calg	26/05/2014		138.97	176				176	ALBERTA	$ 22,163.06		T3L 2R2
A	C3593709		$ 3,950,000.00		Springbank	30/11/2013		73.95	353				353	ALBERTA	$ 53,414.47		A0A 0A0
A	C3593826	11 Rolling Range PL	$ 429,000.00		Rolling Range Est	29/11/2013		3.98	354				354	ALBERTA	$ 107,788.95		T4C 1A1
A	C3618530	19 MCKENDRICK PT	$ 684,900.00		Springland Estates	26/05/2014		2.3	176				208	ALBERTA	$ 297,782.61		T3Z 3K1
A	C3639339	24345 Meadow DR	$ 459,000.00		Bearspaw_Calg	08/10/2014		2	41				41	ALBERTA	$ 229,500.00		T3R 1G3
A	C3639342	24349 Meadow DR	$ 449,000.00		Bearspaw_Calg	08/10/2014		2	41				41	ALBERTA	$ 224,500.00		T3R 1G3
A	C3629788	45 BEARSPAW SUMMIT PL	$ 375,000.00		Bearspaw_Calg	06/08/2014		1.98	104				104	ALBERTA	$ 189,393.94		T3A 1G4
A	C3629992	40 Rolling Range DR	$ 3,600,000.00		None	03/08/2014		19.88	107				107	ALBERTA	$ 181,086.52		T4C 2A3
A	C3594983	Bearspaw 160 acres NW of Calgary	$ 1,900,000.00		None	24/12/2013		160	329				601	ALBERTA	$ 11,875.00		T3R 1C4
A	C3629125	251208 RGE RD 32	$ 864,000.00		Springbank	30/07/2014		12.31	111				111	ALBERTA	$ 70,186.84		T3Z 0X0
A	C3586216	31100 WINDHORSE DR	$ 410,000.00		Springbank	19/09/2013		2	425				425	ALBERTA	$ 205,000.00		T3Z 0B4
A	C3586180	4 WINDHORSE BA	$ 435,000.00		Springbank	19/09/2013		2.32	425				425	ALBERTA	$ 187,500.00		T3Z 0B4
A	C3586189	8 WINDHORSE BA	$ 460,000.00		Springbank	19/09/2013		2	425				425	ALBERTA	$ 230,000.00		T3Z 0B4

Rocky View West Listing

Sta	ML Number	Address	List Price	Sold Price	Community Desc	List Date	Off Market Dat	Total Ac	Days c	Condo Name	Condo Type	Number of Parcels	Cummu	County	List Price / Acre	Sold Price / Acre	Postal Code
A	C3586233	114 WINDHORSE CO	$ 460,000.00		Springbank	19/09/2013		2	425				425	ALBERTA	$ 230,000.00		T3Z 0B4
A	C3586239	242168 WINDHORSE WY	$ 460,000.00		Springbank	19/09/2013		2.01	425				425	ALBERTA	$ 228,855.72		T3Z 0B4
A	C3633344	30 GLENDALE ESTATES MR	$ 389,000.00		Bearspaw_Calg	28/08/2014		1.98	82				1015	ALBERTA	$ 196,464.65		T3R 1G3
A	C3629801	35 Big Hill Springs CV	$ 540,000.00		Bearspaw_Calg	06/08/2014		4.6	104				104	ALBERTA	$ 117,391.30		T4C 1A4
A	C3640579	24 GRANDVIEW PL	$ 525,000.00		Springbank	19/10/2014		1.98	30				30	ALBERTA	$ 265,151.52		T3Z 0A7
A	C3616382	24 Villosa Ridge PT	$ 389,000.00		None	20/05/2014		2.04	182				182	ALBERTA	$ 190,686.28		T3Z 1H2
A	C3637865	10 GLENDALE ESTATES MR	$ 499,000.00		Bearspaw_Calg	29/09/2014		2	50				1545	ALBERTA	$ 249,500.00		T3R 1G3
A	C3639734	5 MOUNTAIN GLEN	$ 425,000.00		None	12/10/2014		4	37				37	ALBERTA	$ 106,250.00		T4C 0G6
A	C3621144	34080 GLENDALE Road - TWP RD 260	$ 7,559,000.00		None	07/06/2014		134.5	164				164	ALBERTA	$ 56,200.74		T0L 0W0
A	C3627556	243081 Morning Vista WY	$ 405,000.00		None	21/07/2014		1.98	120				120	ALBERTA	$ 204,545.46		T3Z 0B2
X	C3574569	31119 GRANDARCHES DR	$ 735,000.00		Springbank	22/06/2013	15/11/2014	2.04	511				511	ALBERTA	$ 360,294.12		T3Z 0B6
X	C3627952	Glenbow RD	$ 398,500.00		None	24/07/2014	15/11/2014	3.7	114				114	ALBERTA	$ 107,702.70		T4C 2G4
X	C3626603	260084 GLENBOW	$ 1,498,850.00		None	14/07/2014	15/11/2014	22.6	124				124	ALBERTA	$ 66,320.80		T4C 2G4
X	C3545385		$ 555,450.00		Springbank	06/11/2012	06/11/2014	2.91	730	Z-name Not Listed			730	ALBERTA	$ 190,876.29		T3Z 3K1
X	C3634076		$ 499,900.00		None	02/09/2014	05/11/2014	4.3	64				64	ALBERTA	$ 116,255.81		T1T 1T1
X	C3625542	118 WINDHORSE CO	$ 395,000.00		Springbank	08/07/2014	31/10/2014	2.05	115				290	ALBERTA	$ 192,682.93		T3Z 0B4
X	C3587680	251092 WELLAND	$ 585,000.00		Bearspaw_Calg	27/09/2013	31/10/2014	4.25	399				399	ALBERTA	$ 137,647.06		T3R 1L3
S	C3586252	242230 WINDHORSE WY	$ 435,000.00	$ 388,000.00	Springbank	19/09/2013	28/10/2014	2.03	404				404	ALBERTA	$ 214,285.71	$ 191,133.01	T3Z 0B4
S	C3590964	Springbank Heights DR	$ 545,000.00	$ 535,000.00	Springbank	30/10/2013	27/10/2014	4.1	362				359	ALBERTA	$ 132,926.83	$ 130,487.81	T3Z 1C4
T	C3597033	120 GRANDVIEW WY	$ 499,900.00		Springbank	20/01/2014	07/10/2014	2.04	260				260	ALBERTA	$ 245,049.02		T3Z 0A8
X	C3613618	31038 SWIFT CREEK	$ 455,000.00		Springbank	06/05/2014	06/10/2014	2.04	153				153	ALBERTA	$ 223,039.22		T3Z 0B7
X	C3625066	25 SWIFT CREEK GR	$ 479,000.00		Springbank	05/07/2014	05/10/2014	2.01	92				92	ALBERTA	$ 238,308.46		T3Z 0B6
X	C3618522	24190 MEADOW	$ 529,000.00		Bearspaw Acres	29/05/2014	30/09/2014	2.2	124				124	ALBERTA	$ 240,454.55		T3R 1A8
X	C3588538	30032 LOWER SPRINGBANK RD	$ 539,900.00		Springbank	07/10/2013	30/09/2014	2.08	358				358	ALBERTA	$ 259,567.31		T3Z 3K7
X	C3606041	15 CORRAL VIEW	$ 510,000.00		Springbank	24/03/2014	28/09/2014	2.32	188				188	ALBERTA	$ 219,827.59		T3A 2B7
X	C3595970	10 GLENDALE ESTATES MR	$ 499,000.00		Bearspaw_Calg	10/01/2014	26/09/2014	2	259				1495	ALBERTA	$ 249,500.00		T3R 1G3
S	C3625546	242255 WINDHORSE WY	$ 394,900.00	$ 320,000.00	Springbank	08/07/2014	13/09/2014	2.93	67				242	ALBERTA	$ 134,778.16	$ 109,215.02	T3Z 0B4
S	C3586246	242190 WINDHORSE WY	$ 435,000.00	$ 391,500.00	Springbank	19/09/2013	12/09/2014	2	358				358	ALBERTA	$ 217,500.00	$ 195,750.00	T3Z 0B4
S	C3586248	242208 WINDHORSE WY	$ 410,000.00	$ 369,000.00	Springbank	19/09/2013	12/09/2014	2.02	358				358	ALBERTA	$ 202,970.30	$ 182,673.27	T3Z 0B4
S	E3361283	25006 TWP RD 264A	$ 1,500,000.00	$ 1,375,000.00	None	29/01/2014	09/09/2014	151.5	223				222	ALBERTA	$ 9,900.99	$ 9,075.91	T3R 1J6
S	E3361286	25006 TWP RD 264A	$ 1,300,000.00	$ 1,175,000.00	None	29/01/2014	09/09/2014	137.19	223				222	ALBERTA	$ 9,475.91	$ 8,564.76	T3R 1J6
S	E3361284	25006 TWP RD 264A	$ 1,300,000.00	$ 1,175,000.00	None	29/01/2014	09/09/2014	162.99	223				222	ALBERTA	$ 7,975.95	$ 7,209.03	T3R 1J6
S	E3361285	25006 TWP RD 264A	$ 1,300,000.00	$ 1,175,000.00	None	29/01/2014	09/09/2014	172.75	223				222	ALBERTA	$ 7,525.33	$ 6,801.74	T3R 1J6
X	C3623835	Bearspaw RD	$ 1,400,000.00		Bearspaw_Calg	27/06/2014	08/09/2014	20.02	73				73	ALBERTA	$ 69,930.07		T3R 1C4
X	C3623843	Bearspaw RD	$ 2,000,000.00		Bearspaw_Calg	27/06/2014	08/09/2014	20.02	73				73	ALBERTA	$ 99,900.10		T3R 1C4
X	C3598205	224 BROWN BEAR	$ 409,900.00		Bearspaw Country Estates	29/01/2014	31/08/2014	2.01	214	Z-name Not Listed			214	ALBERTA	$ 203,930.35		T4C 0B5
X	C3605262	Symons Valley Road	$ 2,595,000.00		None	15/03/2014	31/08/2014	103	169			1	169	ALBERTA	$ 25,194.18		T4B 2A3
X	C3613691	29 SWIFT CREEK GR	$ 425,000.00		Springbank	06/05/2014	31/08/2014	2	117	Z-name Not Listed			117	ALBERTA	$ 212,500.00		T3Z 0B7
X	C3617357	244230 OLD BANFF COACH	$ 1,288,888.00		Springbank	24/05/2014	30/08/2014	7.05	98				98	ALBERTA	$ 182,820.99		T2H 0K2
X	C3595707	30 GLENDALE ESTATES MR	$ 388,900.00		Bearspaw_Calg	08/01/2014	26/08/2014	1.98	230				934	ALBERTA	$ 196,414.14		T3R 1G3
X	C3616404	35195 Springbank RD	$ 8,960,000.00		Springbank	20/05/2014	20/08/2014	320	92				348	ALBERTA	$ 28,000.00		T3Z 3H3
S	C3621941	32050 KODIAK SPRINGS RD RD	$ 460,000.00	$ 425,000.00	Bearspaw_Calg	16/06/2014	15/08/2014	2.02	60	Z-name Not Listed			60	ALBERTA	$ 227,722.77	$ 210,396.04	T4C 1X2
X	C3602054	12 Cody Range WY	$ 529,900.00		Bearspaw_Calg	26/02/2014	01/08/2014	2.2	156				338	ALBERTA	$ 240,863.64		T3R 1C1
X	C3608525	31120 GRANDARCHES	$ 469,900.00		Springbank	08/04/2014	31/07/2014	2.03	114				114	ALBERTA	$ 231,477.83		T3Z 0C3
X	C3584175	243020 MORNING VISTA WY	$ 399,000.00		Springbank	05/09/2013	31/07/2014	2	329	Z-name Not Listed			329	ALBERTA	$ 199,500.00		T3Z 0B2
X	C3598421	251095 WELLAND WY	$ 639,000.00		Bearspaw_Calg	31/01/2014	31/07/2014	4.42	181	Z-name Not Listed			181	ALBERTA	$ 144,570.14		T3R 1L3
S	C3586219	242211 WINDHORSE WY	$ 410,000.00	$ 390,500.00	Springbank	19/09/2013	25/07/2014	2.04	309				309	ALBERTA	$ 200,980.39	$ 191,421.57	T3Z 0B4
S	C3597208	63 ROLLING ACRES PL	$ 1,050,000.00	$ 1,000,000.00	Bearspaw Acres	19/01/2014	18/07/2014	19.91	180				209	ALBERTA	$ 52,737.32	$ 50,226.02	T3R 1B8
S	C3623094	214 PARTRIDGE BAY	$ 369,900.00	$ 355,000.00	Partridge Heights	23/06/2014	17/07/2014	2	24	Z-name Not Listed			187	ALBERTA	$ 184,950.00	$ 177,500.00	T3Z 2B9
X	C3596752	232 BROWN BEAR PT	$ 399,500.00		Bearspaw_Calg	17/01/2014	17/07/2014	2.01	181				181	ALBERTA	$ 198,756.22		T3R 1G3
S	C3612237	185 SPRINGBANK HEIGHTS	$ 435,000.00	$ 410,000.00	Springbank	29/04/2014	09/07/2014	2.42	71				71	ALBERTA	$ 179,752.07	$ 169,421.49	T3Z 1C4
X	C3584193	243039 MORNING VISTA WY	$ 349,000.00		Springbank	05/09/2013	06/07/2014	1.98	304				304	ALBERTA	$ 176,262.63		T2Z 0B2
S	C3605365	30 WOODLAND GL	$ 398,700.00	$ 390,000.00	Bearspaw_Calg	20/03/2014	02/07/2014	1.98	102			1	102	ALBERTA	$ 201,363.64	$ 196,969.70	T3R 1G4
X	C3595607	118 WINDHORSE CO	$ 425,000.00		Springbank	07/01/2014	02/07/2014	2.05	176				175	ALBERTA	$ 207,317.07		T3Z 0B4
X	C3595610	242255 WINDHORSE WY	$ 399,900.00		Springbank	07/01/2014	02/07/2014	2.93	176				175	ALBERTA	$ 136,484.64		T3Z 0B4

EXHIBIT B-3

Rocky View West Listing

Sta	ML Number	Address	List Price	Sold Price	Community Desc	List Date	Off Market Dat	Total Ac	Days c	Condo Name	Condo Type	Number of Parcels	Cummu	County	List Price / Acre	Sold Price / Acre	Postal Code
X	C3560024	# Lot 3 25205 Bearspaw PL	$ 474,900.00		Bearspaw_Calg	26/03/2013	01/07/2014	1.98	462				462	ALBERTA	$ 239,848.49		T3R 1H5
X	C3560021	# Lot 1 25205 BEARSPAW	$ 474,900.00		Bearspaw_Calg	26/03/2013	01/07/2014	1.98	462				462	ALBERTA	$ 239,848.49		T3R 1H5
X	C3607552	43 Big Hill Springs CV	$ 535,000.00		Big Hill Springs Est	02/04/2014	30/06/2014	4.86	89				89	ALBERTA	$ 110,082.31		T4C 1A2
X	C3595854	37 EMERALD BAY DR	$ 950,000.00		Springbank Links	09/01/2014	30/06/2014	2.05	172				172	ALBERTA	$ 463,414.63		T3Z 1E3
S	C3608674	31108 SWIFT CREEK TC	$ 499,800.00	$ 470,000.00	Springbank	09/04/2014	25/06/2014	2.06	77	Z-name Not Listed			77	ALBERTA	$ 242,621.36	$ 228,155.34	T3Z 0B7
S	C3620912	206 GRIZZLY	$ 350,000.00	$ 343,000.00	Bearspaw Country Estates	11/06/2014	24/06/2014	2.01	13				13	ALBERTA	$ 174,129.35	$ 170,646.77	T3L 2M7
S	C3585708		$ 319,900.00	$ 305,000.00	Springbank	16/09/2013	24/06/2014	2.84	281				281	ALBERTA	$ 112,640.85	$ 107,394.37	T3Z 2P8
S	C3595505	34 GLENDALE ESTATES MR	$ 399,000.00	$ 380,000.00	Bearspaw_Calg	06/01/2014	19/06/2014	1.98	164				1403	ALBERTA	$ 201,515.15	$ 191,919.19	T3R 1G3
X	C3608310	24039 Burma RD	$ 895,000.00		Bearspaw_Calg	07/04/2014	13/06/2014	15.81	67	Z-name Not Listed			126	ALBERTA	$ 56,609.74		T3R 1E3
S	C3608128	59 Big Hill Spings CV	$ 460,000.00	$ 460,000.00	Big Hill Springs Est	05/04/2014	11/06/2014	4.01	67				67	ALBERTA	$ 114,713.22	$ 114,713.22	T4C 1A2
X	C3595774	244119 PARTRIDGE	$ 470,000.00		Springbank	08/01/2014	08/06/2014	2	151				151	ALBERTA	$ 235,000.00		T3P 0R3
X	C3582915	244119 PARTRIDGE	$ 549,000.00		Springbank	26/08/2013	08/06/2014	2	286				286	ALBERTA	$ 274,500.00		T2P 0R3
X	C3594825	214 PARTRIDGE BA	$ 389,900.00		Partridge Heights	20/12/2013	01/06/2014	2	163	Z-name Not Listed			163	ALBERTA	$ 194,950.00		T3Z 2B9
X	C3584161	213 MORGANS WY	$ 429,000.00		Springbank	05/09/2013	31/05/2014	2	268	Z-name Not Listed			268	ALBERTA	$ 214,500.00		T3Z 0B9
X	C3568110	24 GRANDVIEW PLACE	$ 550,000.00		Springbank	14/05/2013	31/05/2014	1.98	382				382	ALBERTA	$ 277,777.78		T3Z 0A7
X	C3584203	206 MORNING VISTA VW	$ 479,000.00		Springbank	05/09/2013	31/05/2014	2	268				268	ALBERTA	$ 239,500.00		T3Z 0B2
S	C3605791	242091 RGE RD 32	$ 2,195,000.00	$ 2,195,000.00	Springbank	21/03/2014	27/05/2014	20	67				67	ALBERTA	$ 109,750.00	$ 109,750.00	T1X 0K1
S	C3589267	26 ELBOW RIVER RD	$ 549,000.00	$ 500,000.00	Elbow River Estates	15/10/2013	23/05/2014	4.08	220				435	ALBERTA	$ 134,558.82	$ 122,549.02	T3Z 2V2
S	C3575046	3 WINDHORSE	$ 435,000.00	$ 410,000.00	Springbank	27/06/2013	22/05/2014	2	329				329	ALBERTA	$ 217,500.00	$ 205,000.00	T3Z 0B4
X	C3600987	35195 Springbank Road	$ 8,960,000.00		Springbank	15/02/2014	18/05/2014	320	92				256	ALBERTA	$ 28,000.00		T3Z 3H3
S	C3596619	11 KODIAK SPRINGS CV	$ 435,000.00	$ 435,000.00	Bearspaw Country Estates	14/01/2014	17/05/2014	2	123				123	ALBERTA	$ 217,500.00	$ 217,500.00	T4C 0B5
S	C3613969	HAGGARD ROAD	$ 2,299,000.00	$ 2,100,000.00	Springbank	07/05/2014	16/05/2014	34.35	9				9	ALBERTA	$ 66,928.68	$ 61,135.37	T3Z 3P3
X	C3599346	31099 SWIFT CREEK	$ 749,000.00		Springbank	06/02/2014	14/05/2014	2	97				97	ALBERTA	$ 374,500.00		T3A 0J7
S	C3607356	24166 Old Banff Coach RD SW	$ 930,000.00	$ 825,000.00	NONE	01/04/2014	11/05/2014	6.61	39				39	ALBERTA	$ 140,695.92	$ 124,810.89	T3Z 3N4
S	C3586211	24 WINDHORSE BA	$ 410,000.00	$ 370,000.00	Springbank	19/09/2013	09/05/2014	2.06	232				232	ALBERTA	$ 199,029.13	$ 179,611.65	T3Z 0B4
S	C3581797	5 SWIFT CREEK GR	$ 499,800.00	$ 462,000.00	Springbank	15/08/2013	05/05/2014	2.01	263				263	ALBERTA	$ 248,656.72	$ 229,850.75	T3Z 0B6
S	C3607424		$ 1,500,000.00	$ 1,500,000.00	Bearspaw_Calg	01/04/2014	05/05/2014	73.11	34				34	ALBERTA	$ 20,517.03	$ 20,517.03	T4C 1A7
S	C3610858	116 Swift Creek CV SW	$ 459,900.00	$ 430,000.00	Springbank	22/04/2014	02/05/2014	2.07	10				826	ALBERTA	$ 222,173.91	$ 207,729.47	T3Z 0B6
S	C3603531	76 Eagle Butte Ranch	$ 549,000.00	$ 485,000.00	Springbank	06/03/2014	01/05/2014	2.03	56				126	ALBERTA	$ 270,443.35	$ 238,916.26	T3Z 1K3
S	C3541963	13 Country Meadows PL	$ 435,950.00	$ 430,000.00	Springbank	01/10/2012	30/04/2014	1.98	576				576	ALBERTA	$ 220,176.77	$ 217,171.72	T3Z 0C3
S	C3594713	251100 WELLAND WY	$ 680,000.00	$ 635,000.00	Bearspaw_Calg	18/12/2013	30/04/2014	4.84	133				629	ALBERTA	$ 140,495.87	$ 131,198.35	T3R 1L3
X	C3574240	8 Mountain Glen Close	$ 409,000.00		None	20/06/2013	30/04/2014	2	314				314	ALBERTA	$ 204,500.00		T0L 0W0
X	C3578466	21 Silverhorn VA	$ 625,000.00		None	23/07/2013	30/04/2014	1.98	281				281	ALBERTA	$ 315,656.57		T3R 1C8
X	C3598689	Glenbow RD	$ 399,500.00		None	31/01/2014	30/04/2014	3.7	89				89	ALBERTA	$ 107,972.97		T4C 2G4
S	C3485203	39 MORGANS COURT	$ 475,000.00	$ 488,250.00	Morgans Rise	21/07/2011	29/04/2014	2	1013	Z-name Not Listed			1013	ALBERTA	$ 237,500.00	$ 244,125.00	T3Z 0A5
S	C3593855	251225 Range Road 33	$ 279,900.00	$ 275,000.00	Springbank	02/12/2013	28/04/2014	2.13	147	Z-name Not Listed			147	ALBERTA	$ 131,408.45	$ 129,107.98	T3Z 1K7
X	C3589102		$ 469,000.00		None	09/10/2013	09/04/2014	4.05	182				182	ALBERTA	$ 115,802.47		T4B 2B7
X	C3599079	24039 Burma RD	$ 995,000.00		Bearspaw_Calg	05/02/2014	05/04/2014	15.81	59	Z-name Not Listed			59	ALBERTA	$ 62,934.85		T3R 1E3
S	C3541959	9 Country Meadows PL	$ 430,700.00	$ 422,000.00	Springbank	01/10/2012	26/03/2014	1.98	541				541	ALBERTA	$ 217,525.25	$ 213,131.31	T3Z 0C3
S	C3596982	31159 GRANDARCHES	$ 779,000.00	$ 750,000.00	Springbank	17/01/2014	25/03/2014	1.98	67				67	ALBERTA	$ 393,434.34	$ 378,787.88	T3Z 0A7
X	C3586641	116 Swift Creek CV SW	$ 459,900.00		Springbank	22/09/2013	23/03/2014	2.07	182				816	ALBERTA	$ 222,173.91		T3Z 0B6
S	C3601812	244131 PARTRIDGE	$ 549,000.00	$ 500,000.00	Partridge Heights	25/02/2014	17/03/2014	2.01	20				20	ALBERTA	$ 273,134.33	$ 248,756.22	T2P 0R3
T	C3604801	5 MOUNTAIN GLEN CL	$ 399,500.00		None	14/03/2014	17/03/2014	4	32				32	ALBERTA	$ 99,875.00		T4C 0G6
S	C3586229	31 WINDHORSE GR	$ 410,000.00	$ 380,000.00	Springbank	19/09/2013	13/03/2014	2.1	175				175	ALBERTA	$ 195,238.10	$ 180,952.38	T3Z 0B4
S	C3586253	31071 WINDHORSE DR	$ 435,000.00	$ 393,000.00	Springbank	19/09/2013	05/03/2014	2	167				167	ALBERTA	$ 217,500.00	$ 196,500.00	T3Z 0B4
S	C3598161	251116 WELLAND	$ 589,000.00	$ 579,000.00	None	29/01/2014	05/03/2014	4.5	35				35	ALBERTA	$ 130,888.89	$ 128,666.67	T3R 1L3
S	C3563563		$ 579,900.00	$ 549,900.00	None	17/04/2013	03/03/2014	3.98	320				653	ALBERTA	$ 145,703.52	$ 138,165.83	T3Z 2E3
X	C3561483	49 UPLANDS RIDGE	$ 849,900.00		Uplands	03/04/2013	03/03/2014	2	334	Z-name Not Listed			334	ALBERTA	$ 424,950.00		T3Z 3N5
X	C3576960	24166 Old Banff Coach Road RD	$ 1,200,000.00		None	12/07/2013	01/03/2014	6.61	232				232	ALBERTA	$ 181,543.12		T3Z 3N4
X	C3589835	Eagle Butte Ranch	$ 549,000.00		Eagle Butte Ranches	18/10/2013	28/02/2014	2.03	72				72	ALBERTA	$ 270,443.35		T3Z 1K3
X	C3466512	243238 HORIZON VIEW ROAD	$ 995,000.00		Horizon View Estates	18/03/2011	28/02/2014	5.27	1078	Z-name Not Listed			1078	ALBERTA	$ 188,804.55		T3Z 3M3
X	C3590765	164 GRANDVIEW WAY	$ 625,000.00		Springbank	28/10/2013	28/02/2014	1.99	123				123	ALBERTA	$ 314,070.35		T3Z 0A8
X	C3582467	12 Cody Range WY	$ 519,900.00		Church Ranches	22/08/2013	21/02/2014	2.2	183				183	ALBERTA	$ 236,318.18		T3R 1C1
X	C3581383	45 BEARSPAW SUMMIT PL	$ 390,000.00		Bearspaw_Calg	14/08/2013	14/02/2014	1.98	184				275	ALBERTA	$ 196,969.70		T3A 1G4
X	C3592535	35195 Springbank Road	$ 8,960,000.00		Springbank	15/11/2013	14/02/2014	320	91				168	ALBERTA	$ 28,000.00		T3Z 3H3

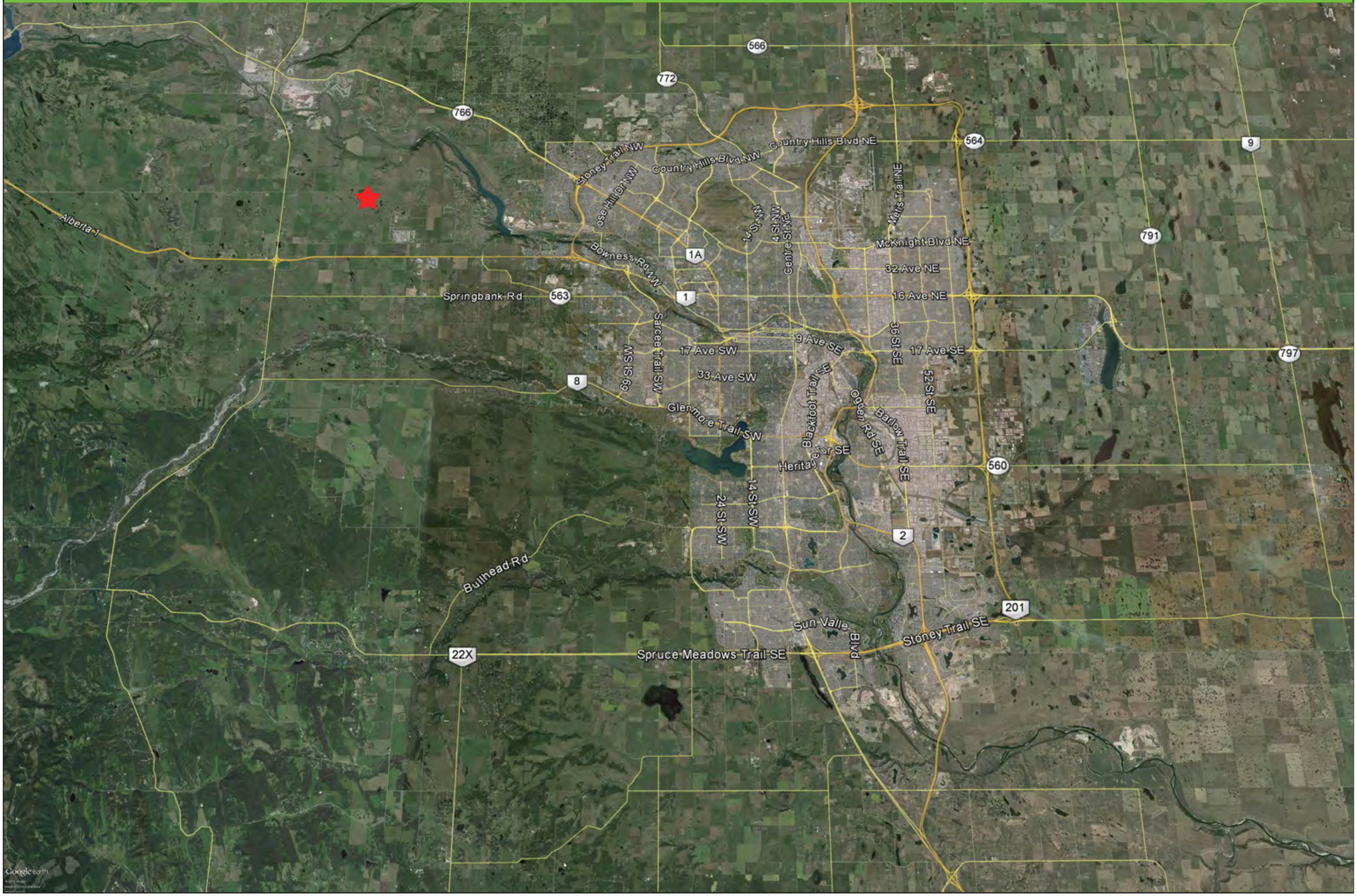
Rocky View West Listing

Sta	ML Number	Address	List Price	Sold Price	Community Desc	List Date	Off Market Dat	Total Ac	Days c	Condo Name	Condo Type	Number of Parcels	Cummu	County	List Price / Acre	Sold Price / Acre	Postal Code
X	C3581253		$ 1,000,000.00		Glenbow	12/08/2013	08/02/2014	4.27	180				180	ALBERTA	$ 234,192.04		T4C 0B7
S	C3592943		$ 2,250,000.00	$ 2,000,000.00	Springbank	20/11/2013	07/02/2014	34.32	79				79	ALBERTA	$ 65,559.44	$ 58,275.06	T3Z 3P3
X	C3580848	3 Cheyanne Meadows GA N	$ 588,000.00		Bearspaw Acres	09/08/2013	06/02/2014	1.98	181	No Name			181	ALBERTA	$ 296,969.70		T3R 1B7
X	C3327199	22 Highway, 4 miles north of Cochrane	$ 1,500,000.00		None	13/05/2008	31/01/2014	53.3	2089				2089	ALBERTA	$ 28,142.59		T4C 1A9
S	C3485205	35 MORGANS COURT	$ 425,000.00	$ 441,000.00	Morgans Rise	21/07/2011	20/01/2014	2	914	Z-name Not Listed			914	ALBERTA	$ 212,500.00	$ 220,500.00	T3Z 0A5
S	C3545360	25198 SPRINGBANK RD.	$ 2,185,000.00	$ 1,800,000.00	Springbank	05/11/2012	20/01/2014	20.29	441	Z-name Not Listed			441	ALBERTA	$ 107,688.52	$ 88,713.65	T3Z 3M8
T	C3594630	63 rolling acres PL NW	$ 1,200,000.00		Bearspaw Acres	16/12/2013	16/01/2014	19.91	31			1	31	ALBERTA	$ 60,271.22		T3R 1B8
S	C3587544	31147 GRANDARCHES DR	$ 799,000.00	$ 750,000.00	Springbank	23/09/2013	14/01/2014	1.98	113				113	ALBERTA	$ 403,535.35	$ 378,787.88	T3Z 0A7
S	C3595608	242163 WINDHORSE WY	$ 450,000.00	$ 417,000.00	Springbank	07/01/2014	14/01/2014	2.02	7				7	ALBERTA	$ 222,772.28	$ 206,435.64	T3Z 0B4
S	C3588038	228 Horizon View GL	$ 595,000.00	$ 550,000.00	Springbank	03/10/2013	13/01/2014	1.98	102				102	ALBERTA	$ 300,505.05	$ 277,777.78	T3Z 3M6
X	C3592381	262 Lochend RD	$ 4,410,000.00		None	08/11/2013	10/01/2014	157.56	63				63	ALBERTA	$ 27,989.34		T4C 2A3
X	C3575097	43 GRANDVIEW PL	$ 595,000.00		Springbank	27/06/2013	06/01/2014	2.03	193				193	ALBERTA	$ 293,103.45		T3Z 0A8
X	E3343728	25006 TWP RD 264A	$ 6,200,000.00		None	02/07/2013	06/01/2014	627.89	188			4	188	ALBERTA	$ 9,874.34		T3R 1J6
S	C3591083	ASPEN DRIVE	$ 500,000.00	$ 500,000.00	Aspen park	30/10/2013	05/01/2014	4	67				67	ALBERTA	$ 125,000.00	$ 125,000.00	T3R 1A5

EXHIBIT B-5

Appendix C – Harmony Mixed-Use Development, Springbank

Regional Setting



IBI

Alberta Government

Benefit/Cost Analysis for Flood Mitigation Projects for the City of Calgary:
Conceptual Design of the Springbank Off-Stream Flood Storage Site
February 2015

EXHIBIT C-1

Local Setting

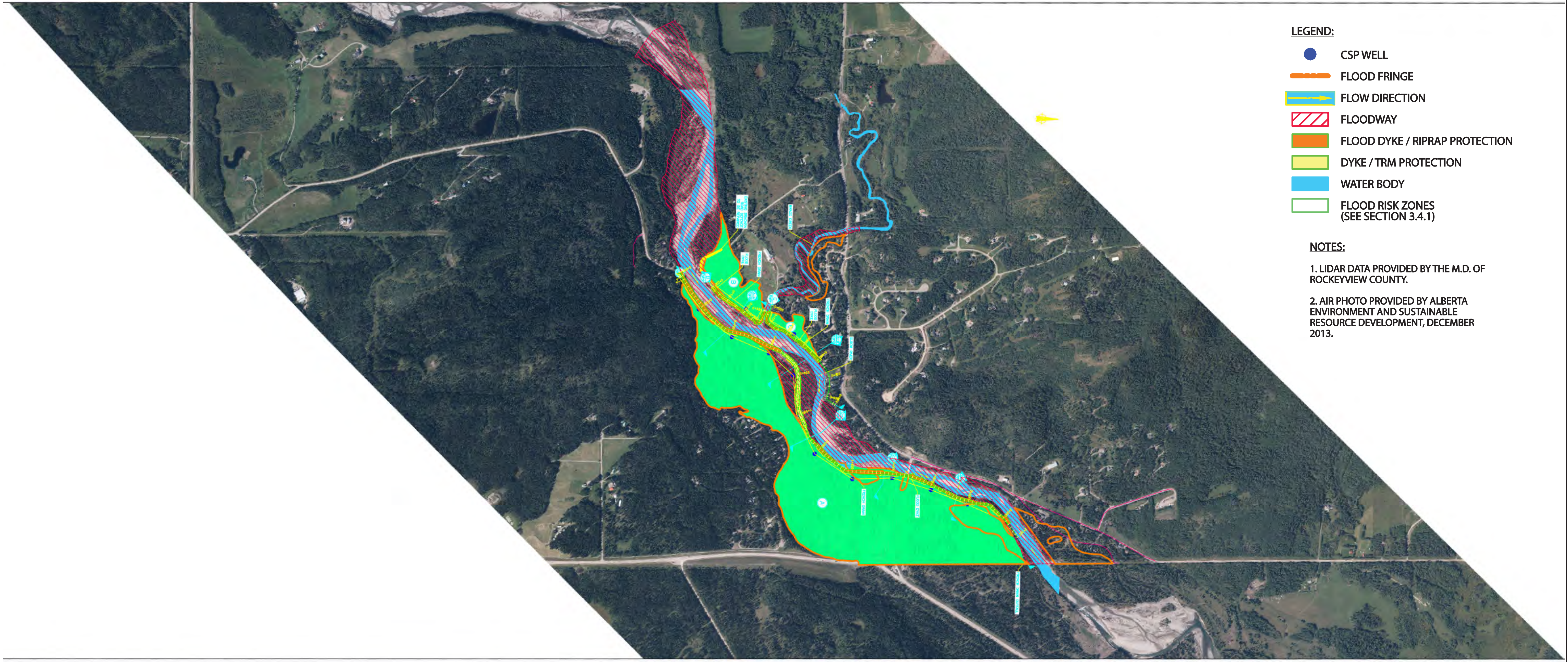
Benefit/Cost Analysis for Flood Mitigation Projects for the City of Calgary: Conceptual Design of the Springbank Off-Stream Flood Storage Site
February 2015

EXHIBIT C-2

Conceptual Master Plan - Harmony

Appendix D – Bragg Creek Proposed Dyke System

Bragg Creek Flood Risk Area and Proposed Dyke System



LEGEND:

●	CSP WELL
━	FLOOD FRINGE
→	FLOW DIRECTION
▨	FLOODWAY
🟧	FLOOD DYKE / RIPRAP PROTECTION
🟨	DYKE / TRM PROTECTION
🟦	WATER BODY
☐	FLOOD RISK ZONES (SEE SECTION 3.4.1)

NOTES:

1. LIDAR DATA PROVIDED BY THE M.D. OF ROCKEYVIEW COUNTY.

2. AIR PHOTO PROVIDED BY ALBERTA ENVIRONMENT AND SUSTAINABLE RESOURCE DEVELOPMENT, DECEMBER 2013.

Source:
amec - Southern Alberta Flood Recovery Task Force
Flood Mitigation Measures for the Bow, Elbow and Oldman River Basins
Volume 4 - Flood Mitigation Measures - Final
June 2014

EXHIBIT D-1

Elbow River at Banff Creek

Source:
amec - Southern Alberta Flood Recovery Task Force
Flood Mitigation Measures for the Bow, Elbow and Oldman River Basins
Volume 4 - Flood Mitigation Measures - Final
June 2014

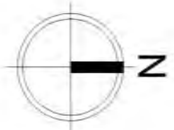
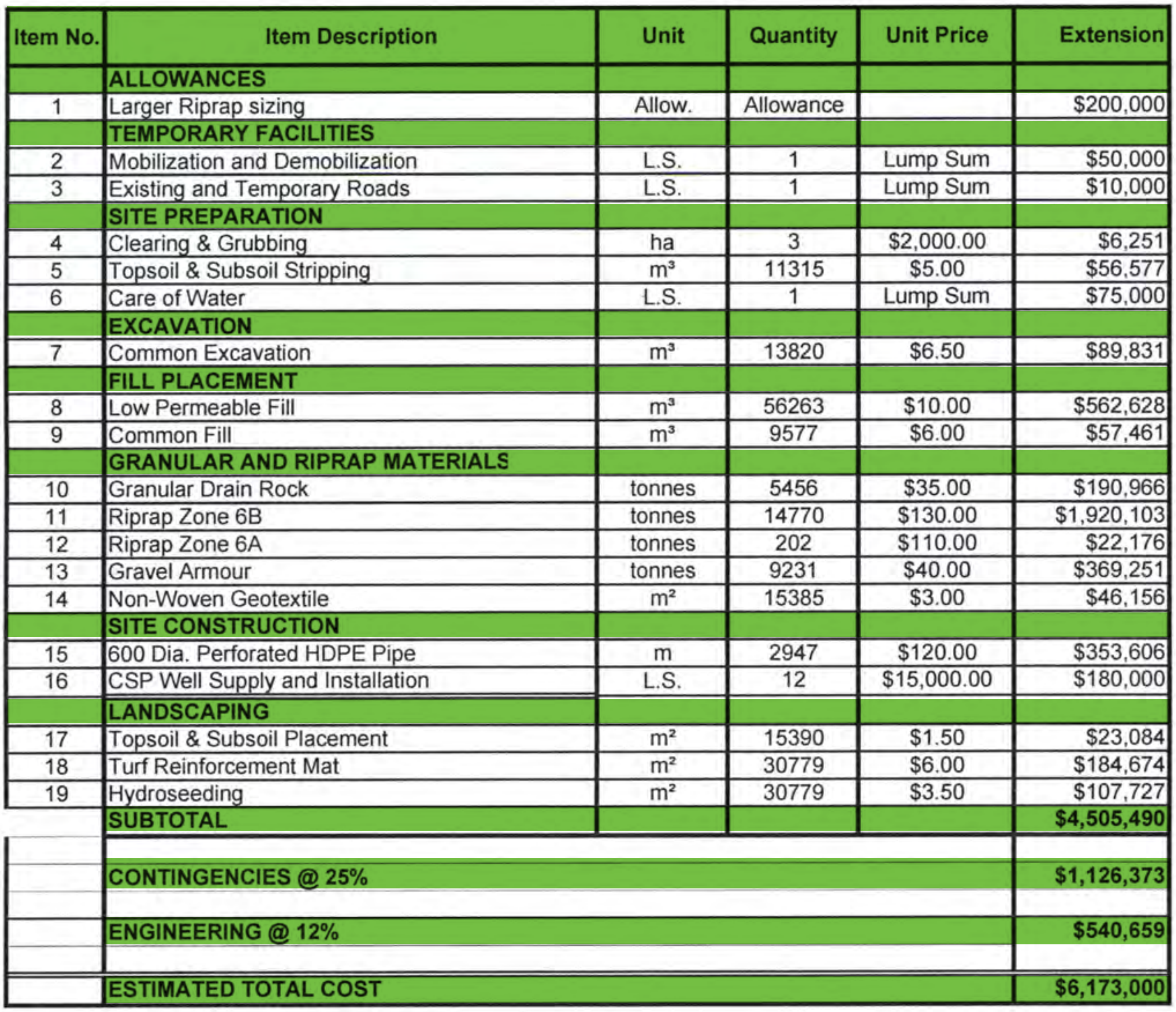


EXHIBIT D-2

Conceptual Cost Estimate - Bragg Creek Flood Defence Dykes & French Drain



Item No.	Item Description	Unit	Quantity	Unit Price	Extension
	ALLOWANCES				
1	Larger Riprap sizing	Allow.	Allowance		$200,000
	TEMPORARY FACILITIES				
2	Mobilization and Demobilization	L.S.	1	Lump Sum	$50,000
3	Existing and Temporary Roads	L.S.	1	Lump Sum	$10,000
	SITE PREPARATION				
4	Clearing & Grubbing	ha	3	$2,000.00	$6,251
5	Topsoil & Subsoil Stripping	m³	11315	$5.00	$56,577
6	Care of Water	L.S.	1	Lump Sum	$75,000
	EXCAVATION				
7	Common Excavation	m³	13820	$6.50	$89,831
	FILL PLACEMENT				
8	Low Permeable Fill	m³	56263	$10.00	$562,628
9	Common Fill	m³	9577	$6.00	$57,461
	GRANULAR AND RIPRAP MATERIALS				
10	Granular Drain Rock	tonnes	5456	$35.00	$190,966
11	Riprap Zone 6B	tonnes	14770	$130.00	$1,920,103
12	Riprap Zone 6A	tonnes	202	$110.00	$22,176
13	Gravel Armour	tonnes	9231	$40.00	$369,251
14	Non-Woven Geotextile	m²	15385	$3.00	$46,156
	SITE CONSTRUCTION				
15	600 Dia. Perforated HDPE Pipe	m	2947	$120.00	$353,606
16	CSP Well Supply and Installation	L.S.	12	$15,000.00	$180,000
	LANDSCAPING				
17	Topsoil & Subsoil Placement	m²	15390	$1.50	$23,084
18	Turf Reinforcement Mat	m²	30779	$6.00	$184,674
19	Hydroseeding	m²	30779	$3.50	$107,727
	SUBTOTAL				**$4,505,490**
	CONTINGENCIES @ 25%				**$1,126,373**
	ENGINEERING @ 12%				**$540,659**
	ESTIMATED TOTAL COST				**$6,173,000**

Source:
amec - Southern Alberta Flood Recovery Task Force
Flood Mitigation Measures for the Bow, Elbow and Oldman River Basins
Volume 4 - Flood Mitigation Measures - Final
June 2014

EXHIBIT D-3

Appendix E – City of Calgary Flood Damage Estimates

Total Damages, Bow and Elbow Rivers, With Sewer Backup

Categories of damage		Return frequency, in years								
		2 *	5 *	10 * *	20	50	100	200	500	1,000
Residential	Direct	$0	$0	$0	$268,753,000	$414,798,000	$686,791,000	$947,786,000	$1,329,201,000	$1,496,364,000
	Indirect 15%	$0	$0	$0	$40,313,000	$62,220,000	$103,019,000	$142,168,000	$199,380,000	$224,455,000
	Total	$0	$0	$0	$309,066,000	$477,018,000	$789,810,000	$1,089,954,000	$1,528,581,000	$1,720,819,000
Commercial	Direct	$0	$0	$0	$15,210,000	$37,446,000	$111,079,000	$271,990,000	$493,824,000	$572,607,000
	Indirect 323%	$0	$0	$0	$49,128,000	$120,951,000	$358,785,000	$878,528,000	$1,595,052,000	$1,849,521,000
	Total	$0	$0	$0	$64,338,000	$158,397,000	$469,864,000	$1,150,518,000	$2,088,876,000	$2,422,128,000
Infrastructure	Direct	$0	$0	$0	$101,508,000	$170,620,000	$299,100,000	$452,626,000	$686,656,000	$780,711,000
	Indirect 20%	$0	$0	$0	$20,302,000	$34,124,000	$59,820,000	$90,525,000	$137,331,000	$156,142,000
	Total	$0	$0	$0	$121,810,000	$204,744,000	$358,920,000	$543,151,000	$823,987,000	$936,853,000
Stampede	Direct	$0	$0	$0	$10,200,000	$42,200,000	$68,900,000	$91,900,000	$166,853,000	$193,472,000
	Indirect 185%	$0	$0	$0	$18,860,000	$78,030,000	$127,400,000	$169,928,000	$308,521,000	$357,741,000
	Total	$0	$0	$0	$29,060,000	$120,230,000	$196,300,000	$261,828,000	$475,374,000	$551,213,000
Total	Direct	$0	$0	$0	$395,671,000	$665,064,000	$1,165,870,000	$1,764,302,000	$2,676,534,000	$3,043,154,000
	Indirect 73%	$0	$0	$0	$128,603,000	$295,325,000	$649,024,000	$1,281,149,000	$2,240,284,000	$2,587,859,000
	Total	$0	$0	$0	$524,274,000	$960,389,000	$1,814,894,000	$3,045,451,000	$4,916,818,000	$5,631,013,000

* No
** Flood Flow primarily contained within the river

EXHIBIT E-1

Total Damages, Bow River, With Sewer Backup

Categories of damage		Return frequency, in years								
		2 *	5 *	10 * *	20	50	100	200	500	1,000
Residential	Direct	$0	$0	$0	$167,738,000	$247,549,000	$387,075,000	$582,482,000	$891,235,000	$991,311,000
	Indirect 15%	$0	$0	$0	$25,161,000	$37,133,000	$58,062,000	$87,372,000	$133,685,000	$148,697,000
	Total	$0	$0	$0	$192,899,000	$284,682,000	$445,137,000	$669,854,000	$1,024,920,000	$1,140,008,000
Commercial	Direct	$0	$0	$0	$15,128,000	$36,965,000	$100,874,000	$256,774,000	$471,284,000	$539,790,000
	Indirect 323%	$0	$0	$0	$48,863,000	$119,397,000	$325,823,000	$829,380,000	$1,522,248,000	$1,743,522,000
	Total	$0	$0	$0	$63,991,000	$156,362,000	$426,697,000	$1,086,154,000	$1,993,532,000	$2,283,312,000
Infrastructure	Direct	$0	$0	$0	$63,102,000	$98,179,000	$168,379,000	$289,606,000	$470,170,000	$528,344,000
	Indirect 20%	$0	$0	$0	$12,621,000	$19,636,000	$33,676,000	$57,921,000	$94,034,000	$105,669,000
	Total	$0	$0	$0	$75,723,000	$117,815,000	$202,055,000	$347,527,000	$564,204,000	$634,013,000
Stampede	Direct	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Indirect 185%	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Total	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total	Direct	$0	$0	$0	$245,968,000	$382,693,000	$656,328,000	$1,128,862,000	$1,832,689,000	$2,059,445,000
	Indirect 84%	$0	$0	$0	$86,645,000	$176,166,000	$417,561,000	$974,673,000	$1,749,967,000	$1,997,888,000
	Total	$0	$0	$0	$332,613,000	$558,859,000	$1,073,889,000	$2,103,535,000	$3,582,656,000	$4,057,333,000

* No

** Flood Flow primarily contained within the river

EXHIBIT E-2

Total Damages, Elbow River, With Sewer Backup

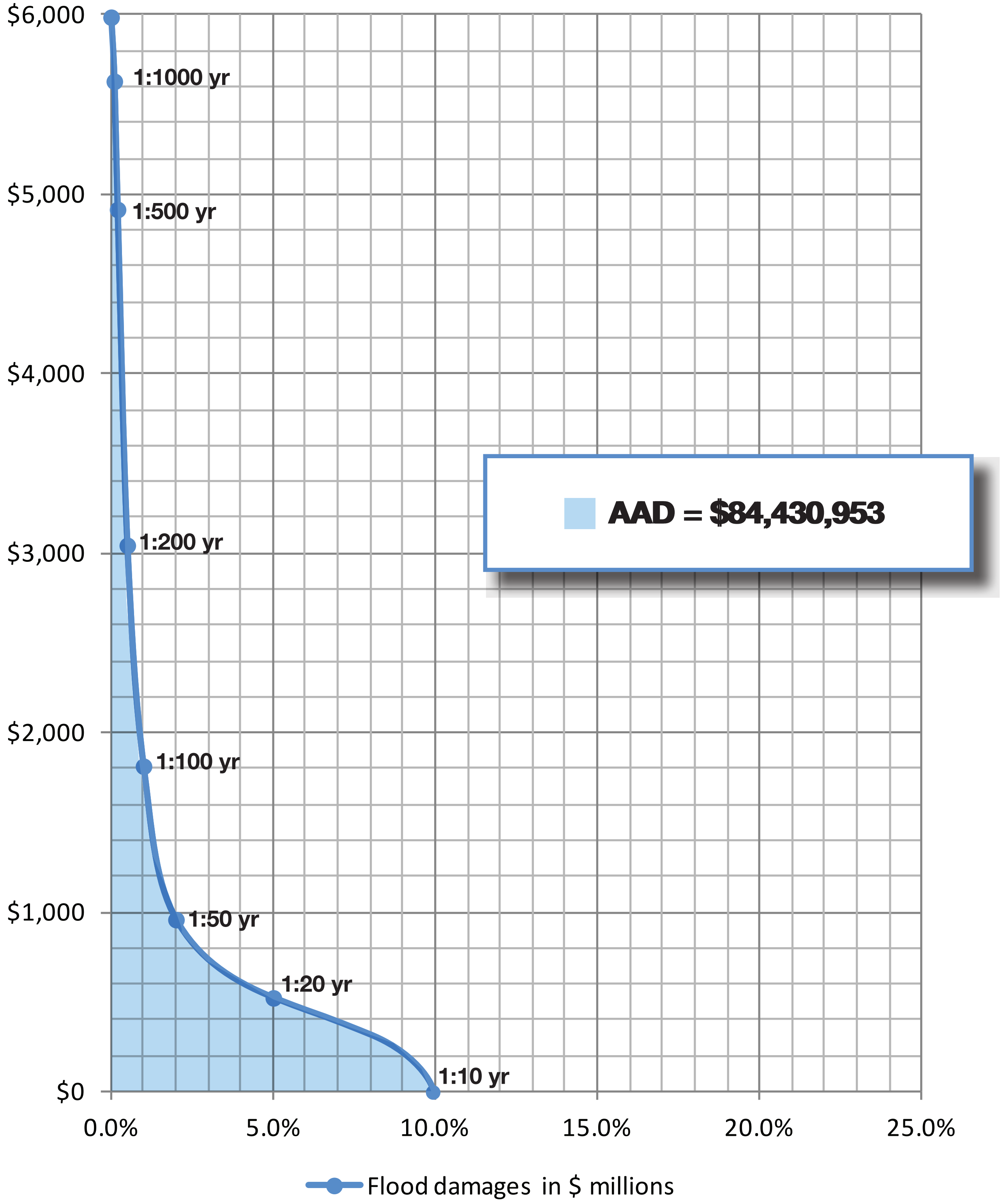
Categories of damage		Return frequency, in years								
		2 *	5 *	10 * *	20	50	100	200	500	1,000
Residential	Direct	$0	$0	$0	$101,015,000	$167,249,000	$299,716,000	$365,304,000	$437,966,000	$505,053,000
	Indirect 15%	$0	$0	$0	$15,152,000	$25,087,000	$44,957,000	$54,796,000	$65,695,000	$75,758,000
	Total	$0	$0	$0	$116,167,000	$192,336,000	$344,673,000	$420,100,000	$503,661,000	$580,811,000
Commercial	Direct	$0	$0	$0	$82,000	$481,000	$10,205,000	$15,216,000	$22,540,000	$32,817,000
	Indirect 323%	$0	$0	$0	$265,000	$1,554,000	$32,962,000	$49,148,000	$72,804,000	$105,999,000
	Total	$0	$0	$0	$347,000	$2,035,000	$43,167,000	$64,364,000	$95,344,000	$138,816,000
Infrastructure	Direct	$0	$0	$0	$38,406,000	$72,441,000	$130,721,000	$163,020,000	$216,486,000	$252,367,000
	Indirect 20%	$0	$0	$0	$7,681,000	$14,488,000	$26,144,000	$32,604,000	$43,297,000	$50,473,000
	Total	$0	$0	$0	$46,087,000	$86,929,000	$156,865,000	$195,624,000	$259,783,000	$302,840,000
Stampede	Direct	$0	$0	$0	$10,200,000	$42,200,000	$68,900,000	$91,900,000	$166,853,000	$193,472,000
	Indirect 185%	$0	$0	$0	$18,860,000	$78,030,000	$127,400,000	$169,928,000	$308,521,000	$357,741,000
	Total	$0	$0	$0	$29,060,000	$120,230,000	$196,300,000	$261,828,000	$475,374,000	$551,213,000
Total	Direct	$0	$0	$0	$149,703,000	$282,371,000	$509,542,000	$635,440,000	$843,845,000	$983,709,000
	Indirect 52%	$0	$0	$0	$41,958,000	$119,159,000	$231,463,000	$306,476,000	$490,317,000	$589,971,000
	Total	$0	$0	$0	$191,661,000	$401,530,000	$741,005,000	$941,916,000	$1,334,162,000	$1,573,680,000

* No

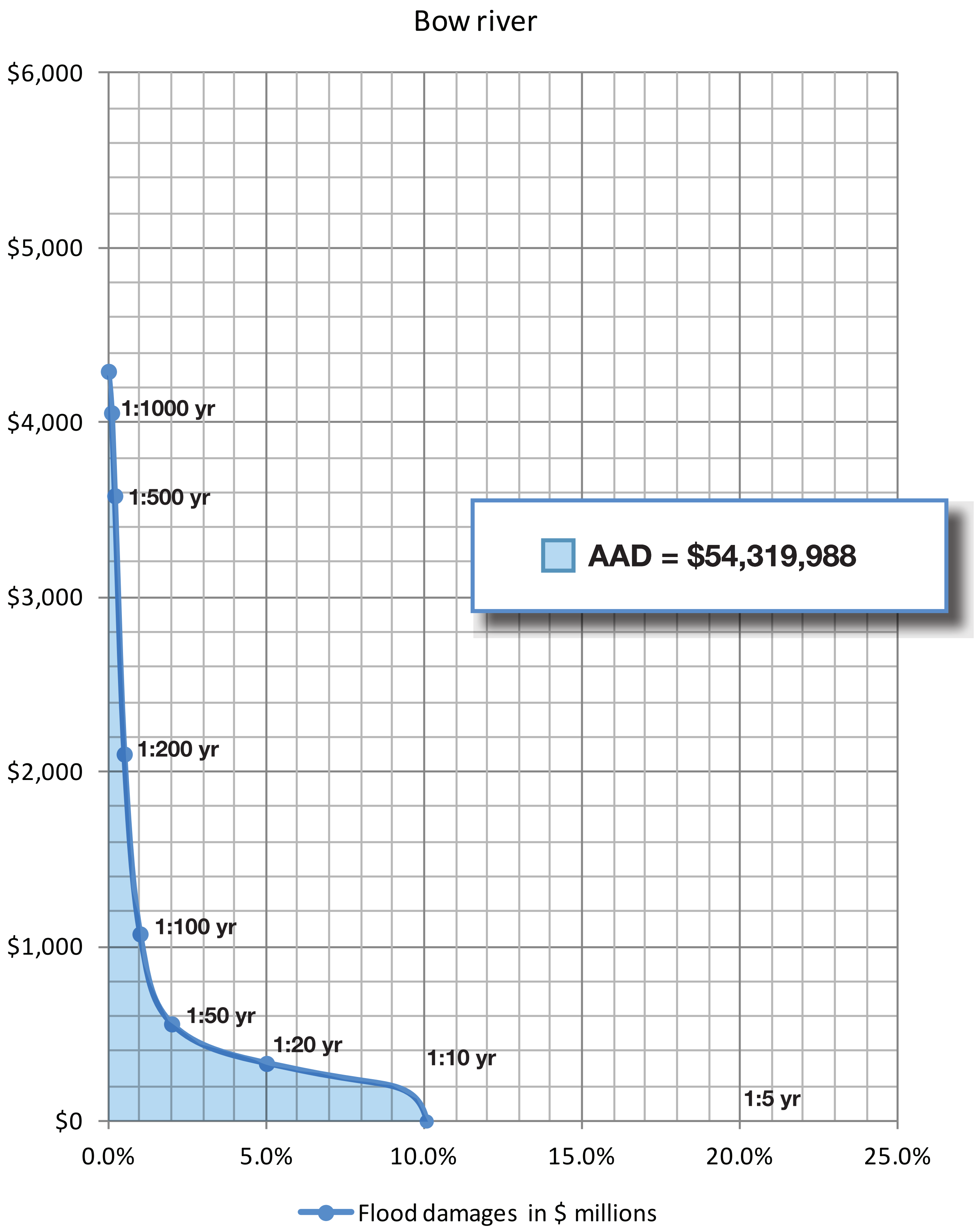
** Flood Flow primarily contained within the river

EXHIBIT E-3

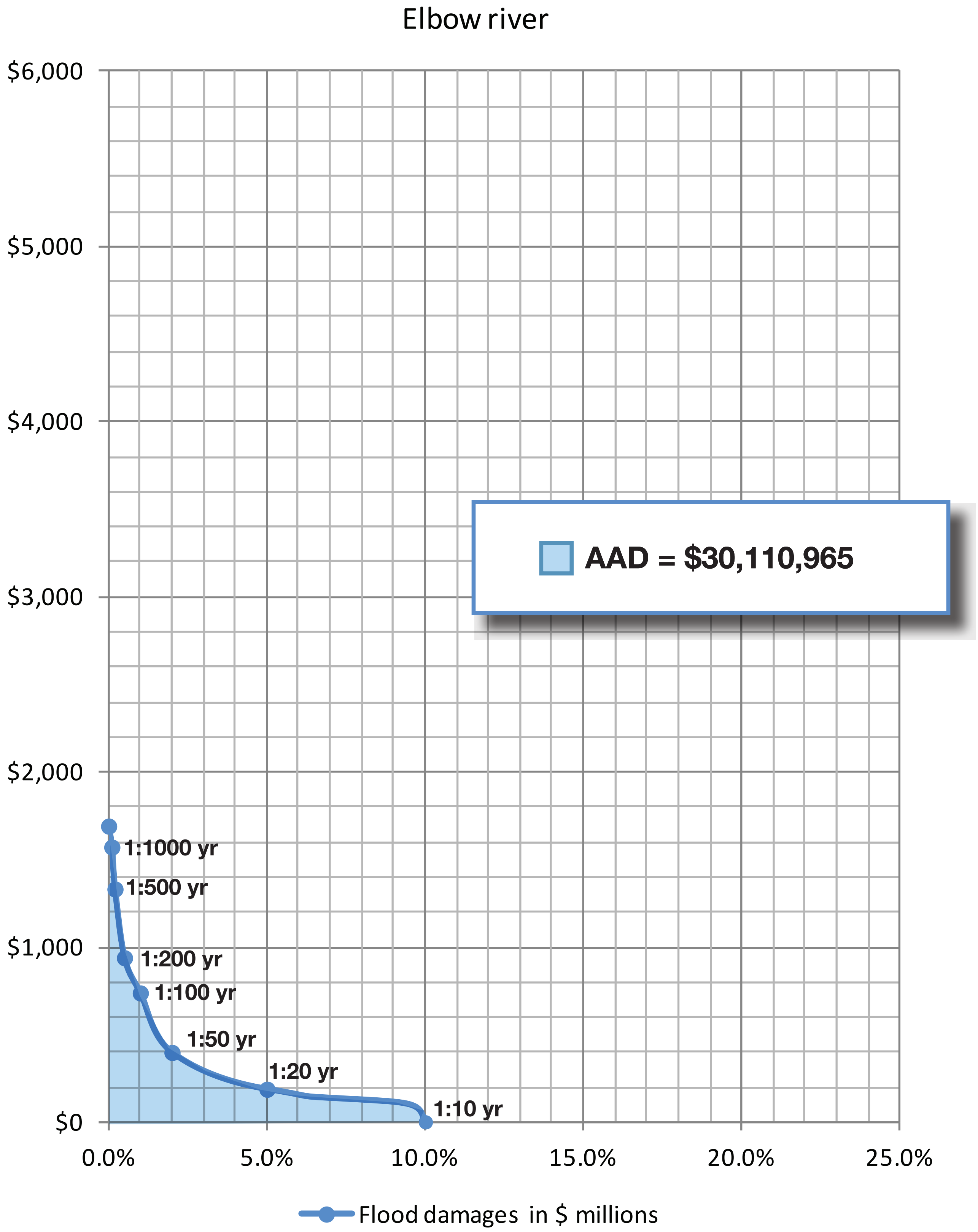
Flood Damages Probability Distribution, Bow and Elbow Rivers



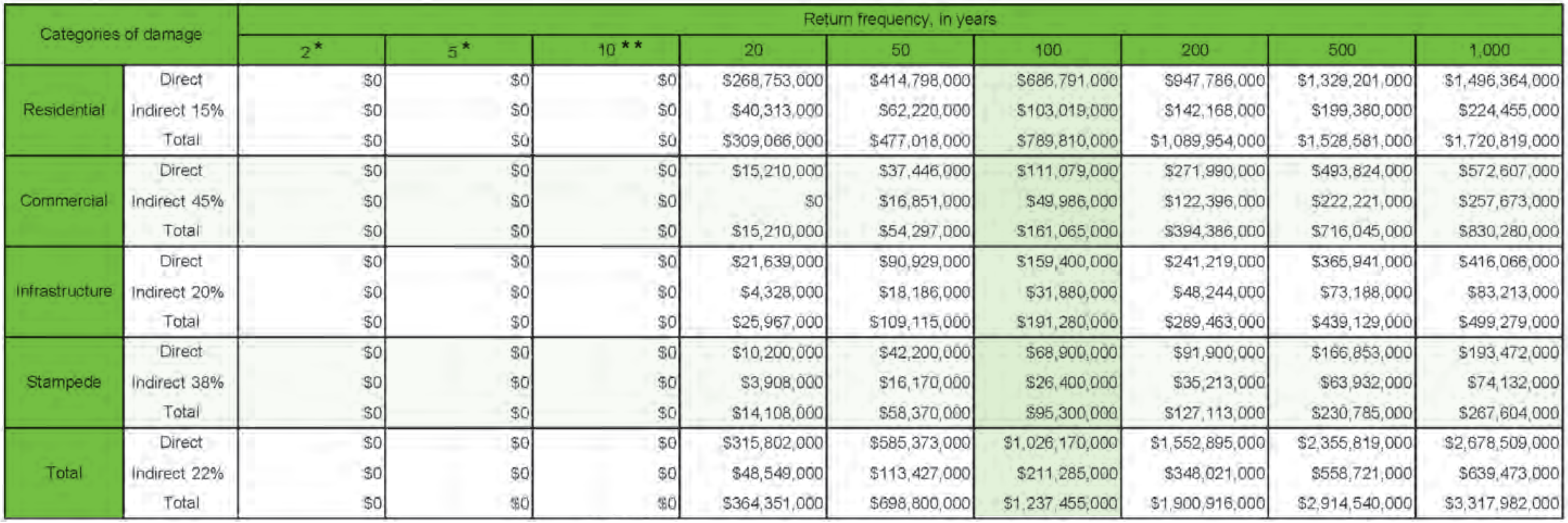
Flood Damages Probability Distribution, Bow River



Flood Damages Probability Distribution, Elbow River



Alternative Damage Scenario - Total Damages, Bow and Elbow Rivers, With Sewer Backup



Categories of damage		Return frequency, in years								
		2*	5*	10 **	20	50	100	200	500	1,000
Residential	Direct	$0	$0	$0	$268,753,000	$414,798,000	$686,791,000	$947,786,000	$1,329,201,000	$1,496,364,000
	Indirect 15%	$0	$0	$0	$40,313,000	$62,220,000	$103,019,000	$142,168,000	$199,380,000	$224,455,000
	Total	$0	$0	$0	$309,066,000	$477,018,000	$789,810,000	$1,089,954,000	$1,528,581,000	$1,720,819,000
Commercial	Direct	$0	$0	$0	$15,210,000	$37,446,000	$111,079,000	$271,990,000	$493,824,000	$572,607,000
	Indirect 45%	$0	$0	$0	$0	$16,851,000	$49,986,000	$122,396,000	$222,221,000	$257,673,000
	Total	$0	$0	$0	$15,210,000	$54,297,000	$161,065,000	$394,386,000	$716,045,000	$830,280,000
Infrastructure	Direct	$0	$0	$0	$21,639,000	$90,929,000	$159,400,000	$241,219,000	$365,941,000	$416,066,000
	Indirect 20%	$0	$0	$0	$4,328,000	$18,186,000	$31,880,000	$48,244,000	$73,188,000	$83,213,000
	Total	$0	$0	$0	$25,967,000	$109,115,000	$191,280,000	$289,463,000	$439,129,000	$499,279,000
Stampede	Direct	$0	$0	$0	$10,200,000	$42,200,000	$68,900,000	$91,900,000	$166,853,000	$193,472,000
	Indirect 38%	$0	$0	$0	$3,908,000	$16,170,000	$26,400,000	$35,213,000	$63,932,000	$74,132,000
	Total	$0	$0	$0	$14,108,000	$58,370,000	$95,300,000	$127,113,000	$230,785,000	$267,604,000
Total	Direct	$0	$0	$0	$315,802,000	$585,373,000	$1,026,170,000	$1,552,895,000	$2,355,819,000	$2,678,509,000
	Indirect 22%	$0	$0	$0	$48,549,000	$113,427,000	$211,285,000	$348,021,000	$558,721,000	$639,473,000
	Total	$0	$0	$0	$364,351,000	$698,800,000	$1,237,455,000	$1,900,916,000	$2,914,540,000	$3,317,982,000

* No

** Flood Flow primarily contained within the river

Alternative Damage Scenario - Total Damages, Bow River, With Sewer Backup

Categories of damage		Return frequency, in years								
		2*	5*	10 **	20	50	100	200	500	1,000
Residential	Direct	$0	$0	$0	$167,738,000	$247,549,000	$387,075,000	$582,482,000	$891,235,000	$991,311,000
	Indirect 15%	$0	$0	$0	$25,161,000	$37,133,000	$58,062,000	$87,372,000	$133,685,000	$148,697,000
	Total	$0	$0	$0	$192,899,000	$284,682,000	$445,137,000	$669,854,000	$1,024,920,000	$1,140,008,000
Commercial	Direct	$0	$0	$0	$15,128,000	$36,965,000	$100,874,000	$256,774,000	$471,284,000	$539,790,000
	Indirect 45%	$0	$0	$0	$0	$16,635,000	$45,394,000	$115,549,000	$212,078,000	$242,905,000
	Total	$0	$0	$0	$15,128,000	$53,600,000	$146,268,000	$372,323,000	$683,362,000	$782,695,000
Infrastructure	Direct	$0	$0	$0	$13,452,000	$52,323,000	$89,734,000	$154,340,000	$250,569,000	$281,571,000
	Indirect 20%	$0	$0	$0	$2,691,000	$10,465,000	$17,947,000	$30,868,000	$50,114,000	$56,314,000
	Total	$0	$0	$0	$16,143,000	$62,788,000	$107,681,000	$185,208,000	$300,683,000	$337,885,000
Stampede	Direct	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Indirect 38%	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Total	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total	Direct	$0	$0	$0	$196,318,000	$336,837,000	$577,683,000	$993,596,000	$1,613,088,000	$1,812,672,000
	Indirect 23%	$0	$0	$0	$27,852,000	$64,233,000	$121,403,000	$233,789,000	$395,877,000	$447,916,000
	Total	$0	$0	$0	$224,170,000	$401,070,000	$699,086,000	$1,227,385,000	$2,008,965,000	$2,260,588,000

* No

** Flood Flow primarily contained within the river

EXHIBIT E-8

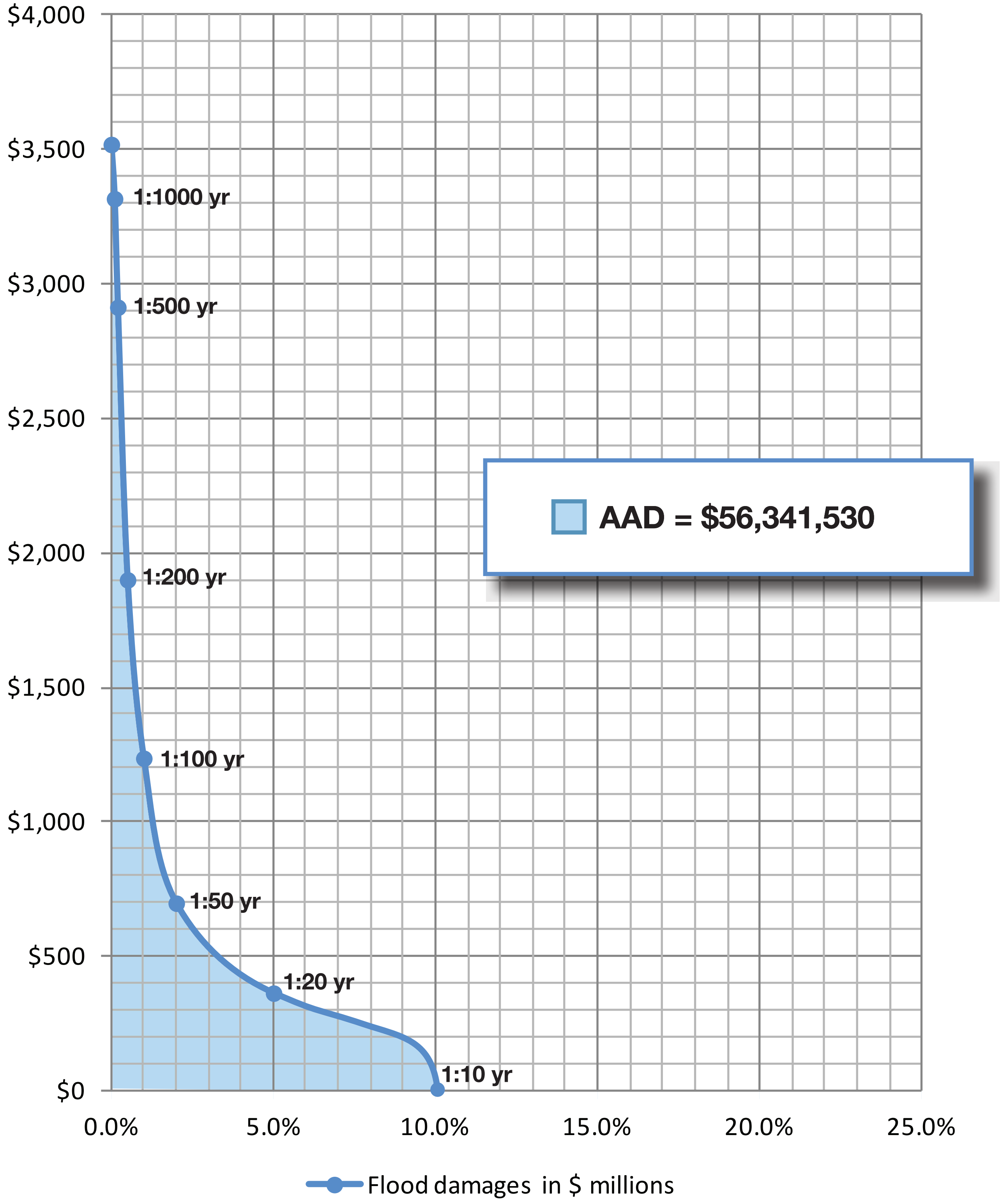
Alternative Damage Scenario - Total Damages, Elbow River, With Sewer Backup

Categories of damage		Return frequency, in years								
		2*	5*	10**	20	50	100	200	500	1,000
Residential	Direct	$0	$0	$0	$101,015,000	$167,249,000	$299,716,000	$365,304,000	$437,966,000	$505,053,000
	Indirect 15%	$0	$0	$0	$15,152,000	$25,087,000	$44,957,000	$54,796,000	$65,695,000	$75,758,000
	Total	$0	$0	$0	$116,167,000	$192,336,000	$344,673,000	$420,100,000	$503,661,000	$580,811,000
Commercial	Direct	$0	$0	$0	$82,000	$481,000	$10,205,000	$15,216,000	$22,540,000	$32,817,000
	Indirect 45%	$0	$0	$0	$0	$216,000	$4,592,000	$6,847,000	$10,143,000	$14,768,000
	Total	$0	$0	$0	$82,000	$697,000	$14,797,000	$22,063,000	$32,683,000	$47,585,000
Infrastructure	Direct	$0	$0	$0	$8,187,000	$38,606,000	$69,666,000	$86,879,000	$115,372,000	$134,495,000
	Indirect 20%	$0	$0	$0	$1,637,000	$7,721,000	$13,933,000	$17,376,000	$23,074,000	$26,899,000
	Total	$0	$0	$0	$9,824,000	$46,327,000	$83,599,000	$104,255,000	$138,446,000	$161,394,000
Stampede	Direct	$0	$0	$0	$10,200,000	$42,200,000	$68,900,000	$91,900,000	$166,853,000	$193,472,000
	Indirect 38%	$0	$0	$0	$3,908,000	$16,170,000	$26,400,000	$35,213,000	$63,932,000	$74,132,000
	Total	$0	$0	$0	$14,108,000	$58,370,000	$95,300,000	$127,113,000	$230,785,000	$267,604,000
Total	Direct	$0	$0	$0	$119,484,000	$248,536,000	$448,487,000	$559,299,000	$742,731,000	$865,837,000
	Indirect 21%	$0	$0	$0	$20,697,000	$49,194,000	$89,882,000	$114,232,000	$162,844,000	$191,557,000
	Total	$0	$0	$0	$140,181,000	$297,730,000	$538,369,000	$673,531,000	$905,575,000	$1,057,394,000

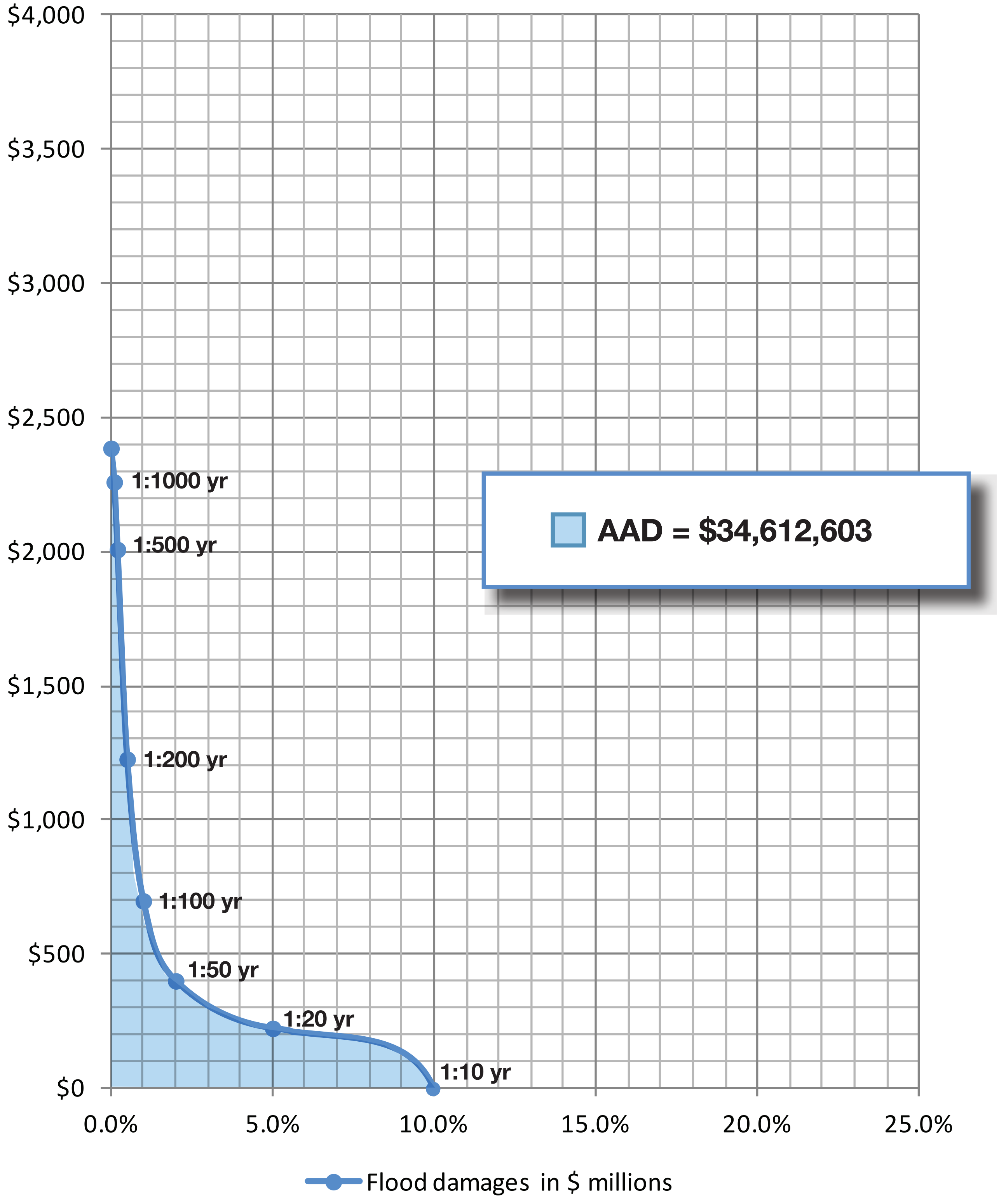
* No

** Flood Flow primarily contained within the river

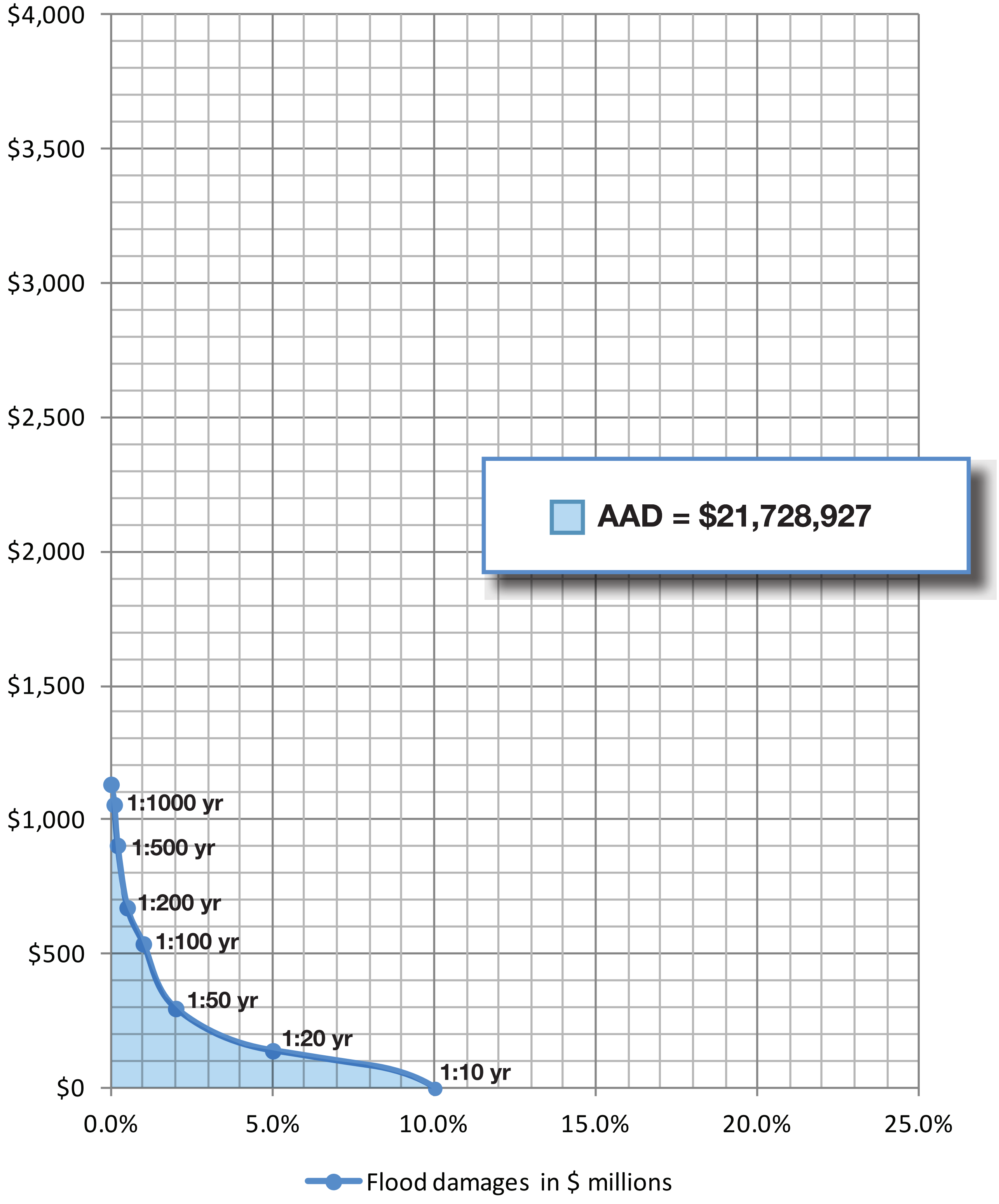
Alternative Damage Scenario - Flood Damages Probability Distribution, Bow and Elbow Rivers



Alternative Damage Scenario - Flood Damages Probability Distribution, Bow River



Alternative Damage Scenario - Flood Damages Probability Distribution, Elbow River



Appendix F – 2013 Southern Alberta Disaster Recovery Program

2013 Southern Alberta Disaster Recovery Program - Ongoing Project Estimate Tracking - As of February 4, 2014

Rocky View County Ongoing Project Estimates

Project Number	Project Name	Status	Approved Estimate (Y/N)	Latest Estimate Date	Estimate ($)	Comments
1	Emergency Operations	Ongoing	Y	Sept. 19, 2013	450000.00	Approved inspection estimate
2	Hamlet of Bragg Creek water intake	Ongoing	Y	Sept. 19, 2013	110000.00	Approved inspection estimate
3	Hamlet of Bragg Creek road damage	Ongoing	Y	Sept. 19, 2013	20000.00	Approved inspection estimate
4	Balsam Ave Erosion	Ongoing	Y	Sept. 19, 2013	25000.00	Approved inspection estimate
5	Access to Hamlet of Bragg Creek Snowbirds Chalet	Ongoing	Y	Sept. 19, 2013	5000.00	Approved inspection estimate
6	Hamlet of Bragg Creek Community Centre	Ongoing	Y	Sept. 19, 2013	35000.00	Approved inspection estimate
7	Wood debris site	Ongoing	Y	Sept. 19, 2013	25000.00	Approved inspection estimate
8	Wintergreen road	Ongoing	Y	Sept. 19, 2013	10000.00	Approved inspection estimate
9	Slapping Tail Pond	Ongoing	Y	Sept. 19, 2013	75000.00	Approved inspection estimate
12	RR 54, S of TWP road 234	Ongoing	Y	Sept. 19, 2013	10000.00	Approved inspection estimate
14	Bracken Road gate and spillway	Ongoing	Y	Sept. 19, 2013	15000.00	Approved inspection estimate
15	Bracken Road	Ongoing	Y	Sept. 19, 2013	25000.00	Approved inspection estimate
16	Bracken Road S TWP Rd 232, Bragg Creek BF72292	Ongoing	Y	Sept. 19, 2013	29000.00	Approved inspection estimate
18	RR 41, S of Springbank Road, Gross Creek BF74057	Ongoing	Y	Sept. 19, 2013	15000.00	Approved inspection estimate
19	Springbank road W of RR 35, Springbank Creek BF9024	Ongoing	Y	Sept. 19, 2013	20770.00	Approved inspection estimate
33	Bragg Creek Municipal Park	Ongoing	Y	Sept. 19, 2013	20000.00	Approved inspection estimate
34	Springbank Park for All Seasons	Ongoing	N	Dec. 9, 2013	194000.00	Applicant initial estimate only
TOTAL BUDGET ESTIMATES FOR ROCKY VIEW COUNTY ONGOING PROJECTS					$1,083,770.00	

2013 Southern Alberta Disaster Recovery Program - Ongoing Project Estimate Tracking - As of February 4, 2014

Townsite of Redwood Meadows Ongoing Project Estimates

Project Number	Project Name	Status	Approved Estimate (Y/N)	Latest Estimate Date	Estimate ($)	Comments
1	Northern berm breach	Ongoing	Y	Sept. 10, 2013	838000.00	Approved inspection estimate
2	Sleigh Drive berm breach	Ongoing	Y	Sept. 10, 2013	75000.00	Approved inspection estimate
3	Use of existing rip rap for flood protection	Ongoing	Y	Sept. 10, 2013	465000.00	Approved inspection estimate
4	Water treatment plant	Ongoing	Y	Sept. 10, 2013	75000.00	Approved inspection estimate
5	Playground berm breach	Ongoing	Y	Sept. 10, 2013	690000.00	Approved inspection estimate
6	Berm breach, #18 Redwood Meadows Drive	Ongoing	Y	Sept. 10, 2013	444000.00	Approved inspection estimate
7	Sanitary sewer pumping station	Ongoing	Y	Sept. 10, 2013	70000.00	Approved inspection estimate
TOTAL BUDGET ESTIMATES FOR TOWNSITE OF REDWOOD MEADOWS ONGOING PROJECTS					$2,657,000.00	

Tsuu T'ina Ongoing Project Estimates

Project Number	Project Name	Status	Approved Estimate (Y/N)	Latest Estimate Date	Estimate ($)	Comments
1	Emergency Operations	Ongoing	N	Sept. 25, 2013	60384.22	Applicant initial estimate only
2	Infrastructure Damage	Ongoing	N	Sept. 25, 2013	211611.26	Applicant initial estimate only
3	Housing	Ongoing	N	Sept. 25, 2013	29914.77	Applicant initial estimate only
4	Band Works	Ongoing	Y	Nov. 11, 2013	800000.00	Approved inspection estimate
5	Redwood Meadows Golf Course	Ongoing	Y	Nov. 11, 2013	800000.00	Approved inspection estimate
TOTAL BUDGET ESTIMATES FOR TSUU T'INA FIRST NATION ONGOING PROJECTS					$1,901,910.25	

TOTAL ESTIMATE OF ONGOING PROJECTS	**$5,642,680.25**

EXHIBIT F-2

Public Information Session | 28 February 2017

Bragg Creek Flood Mitigation Project

Rocky View County
Cultivating Communities

amec foster wheeler

Carson • McCulloch Associates Ltd

evolve
Surface Strategies Inc.

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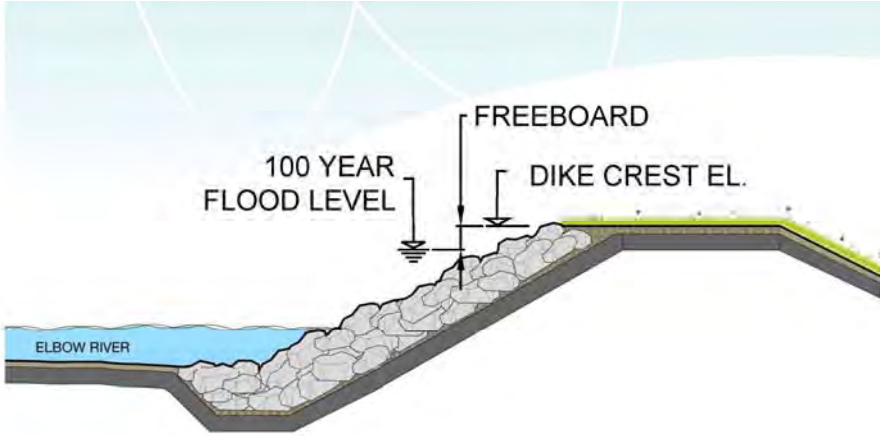
Bragg Creek Flood Mitigation Project
Design Considerations

- Design based on an estimated 100-year flood water level (provincial standard) plus a minimum freeboard of 0.6 m (i.e. 2 ft)



  - Freeboard accounts for items like climate change, riverbed movement effects on flood water level and wave run-up
- Estimates indicate that the 2013 flood was approximately 20% larger than the 100-year event
  - 2013 flood would be contained by the proposed freeboard zone

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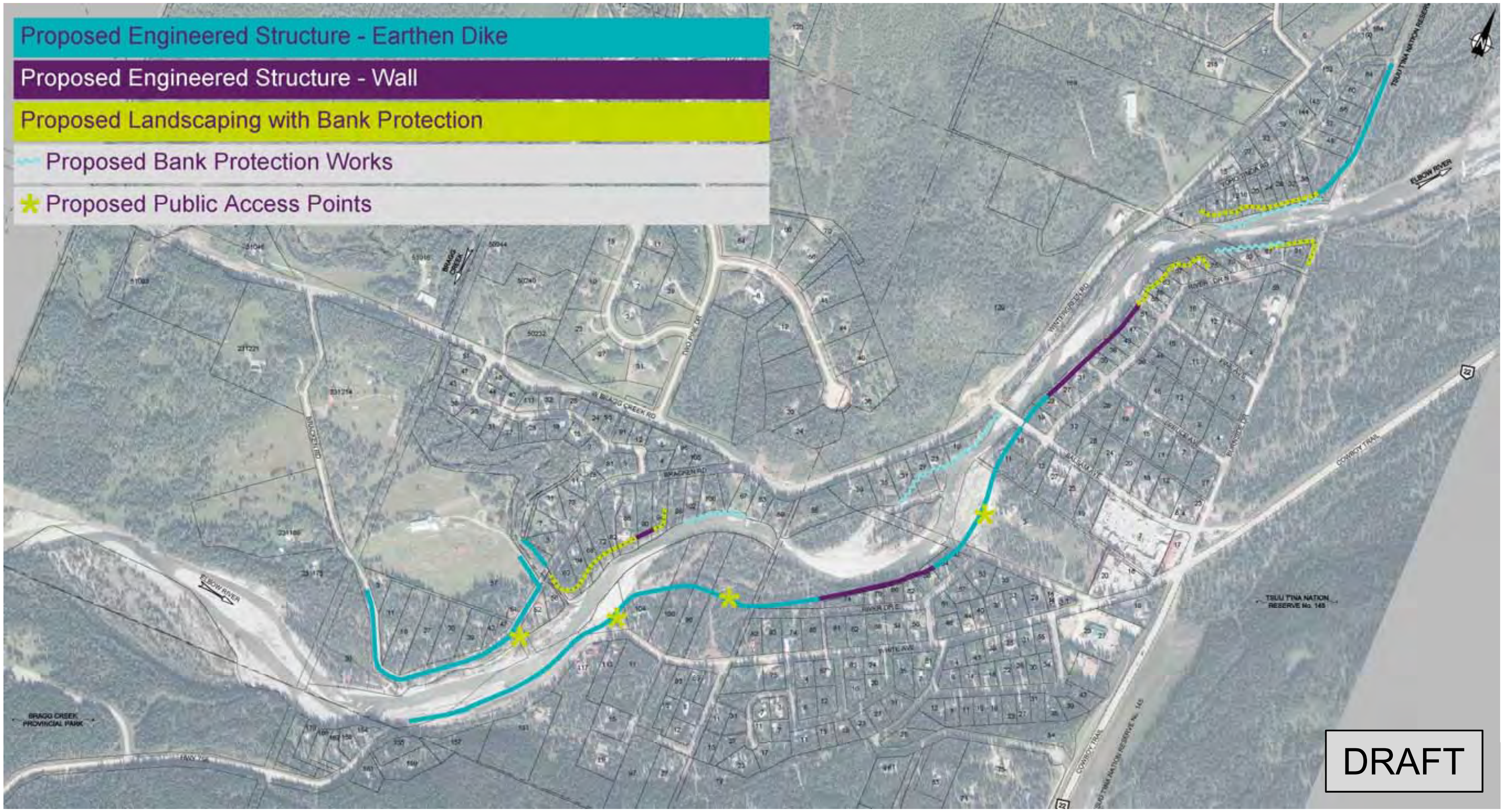
Bragg Creek Flood Mitigation Project
Preliminary Design Overview

ROCKY VIEW COUNTY
Cultivating Communities

amec
foster
wheeler



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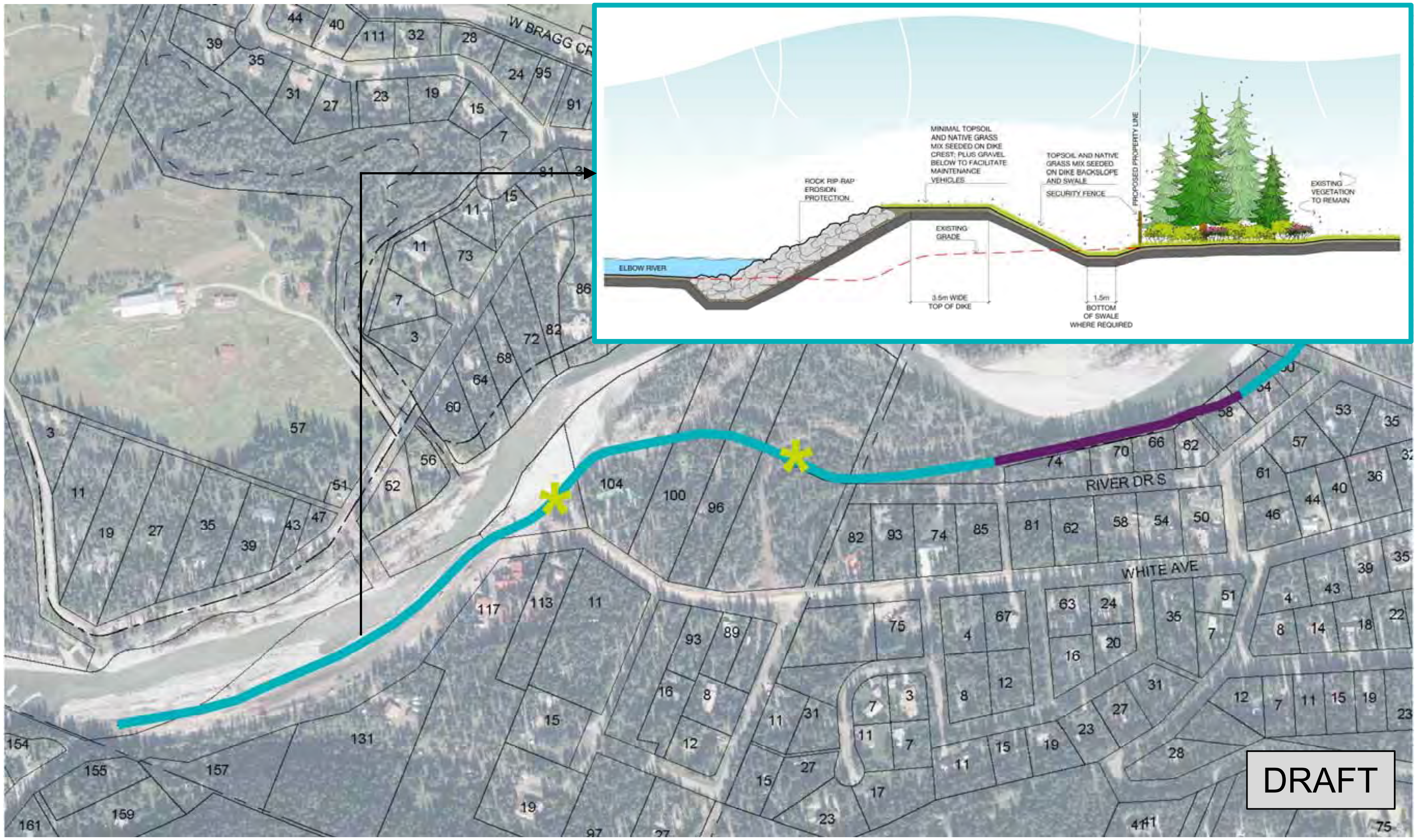
Bragg Creek Flood Mitigation Project
Preliminary Design – East Dike



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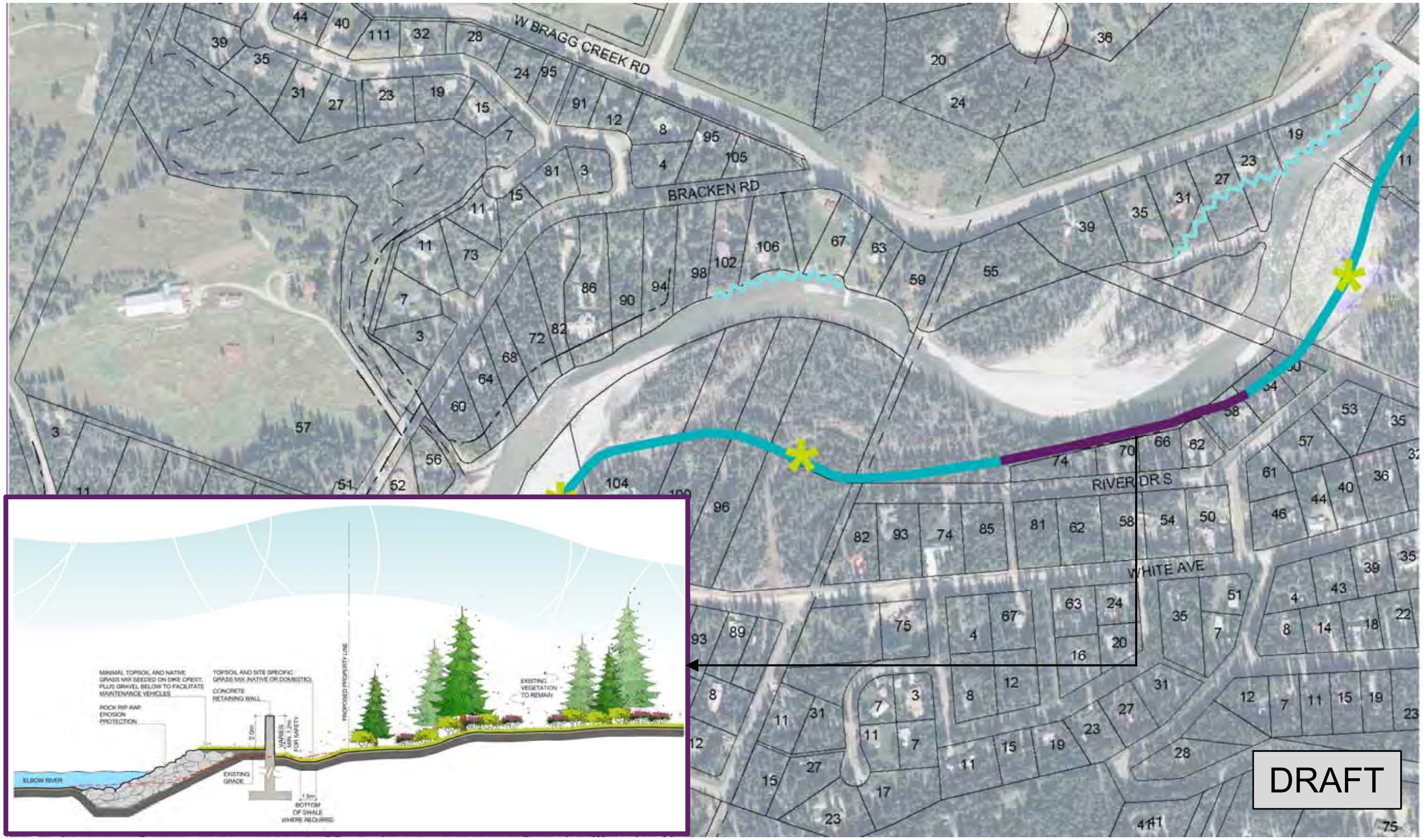
Bragg Creek Flood Mitigation Project
Preliminary Design – East Dike



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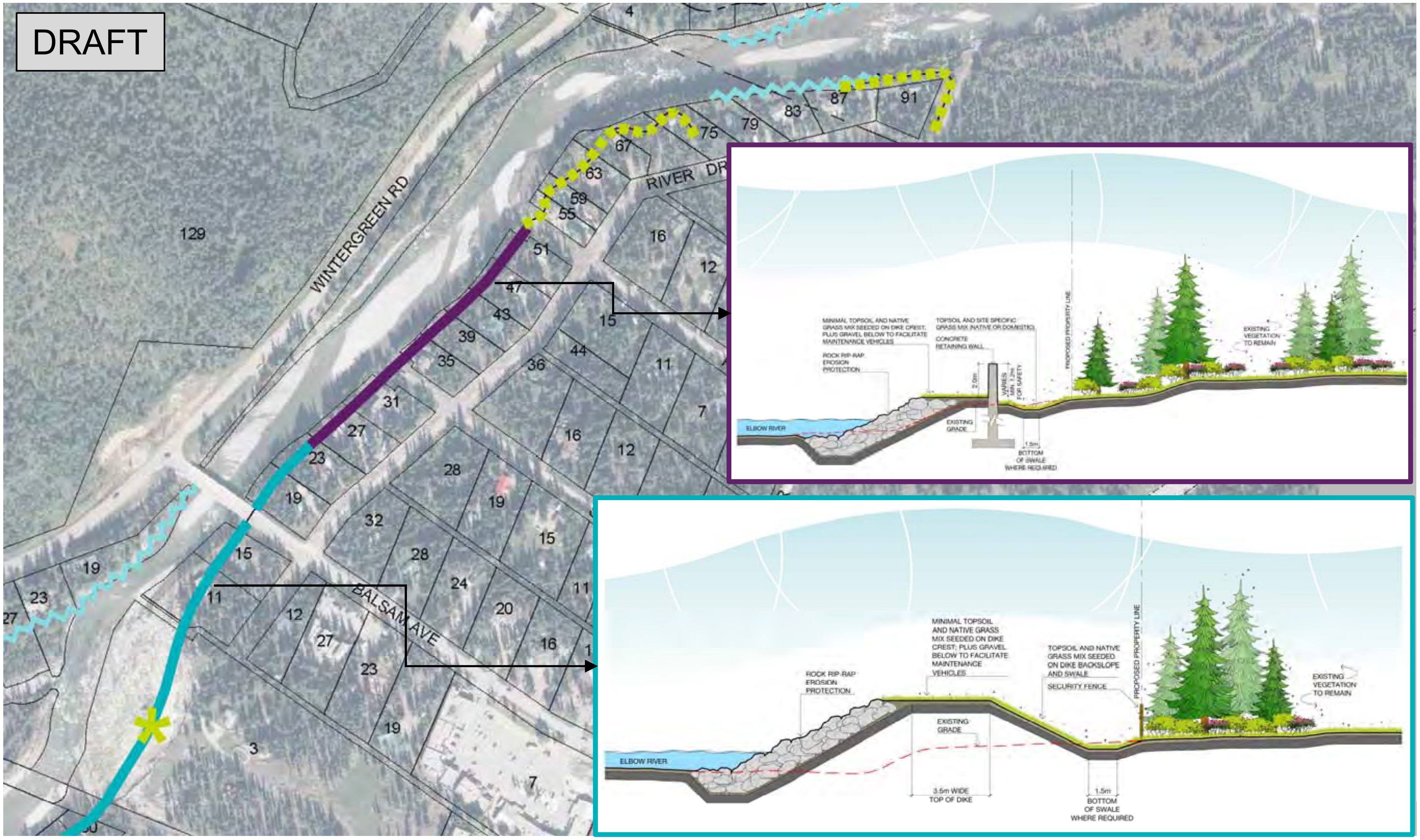
Bragg Creek Flood Mitigation Project
Preliminary Design – East Dike



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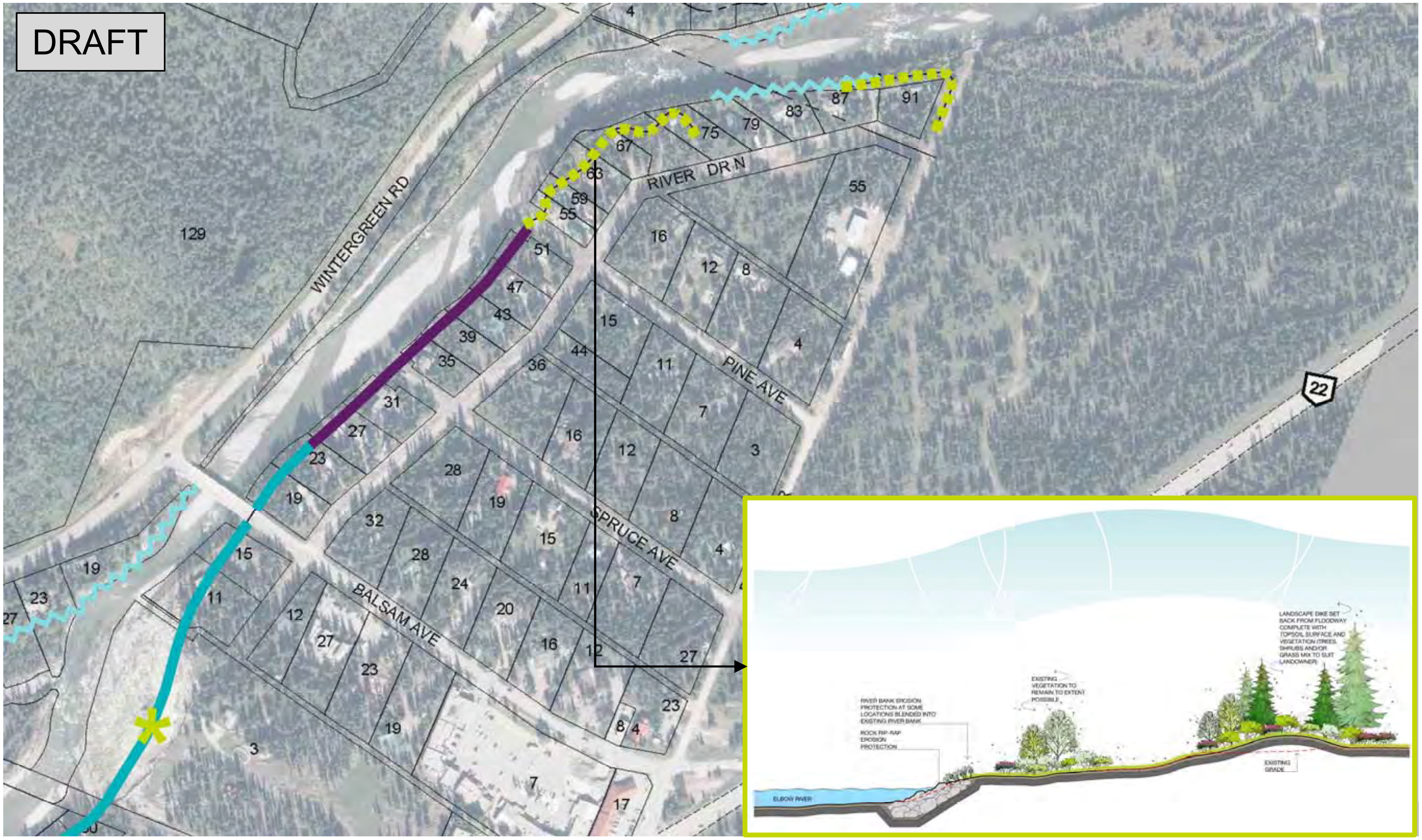
Bragg Creek Flood Mitigation Project
Preliminary Design – East Dike



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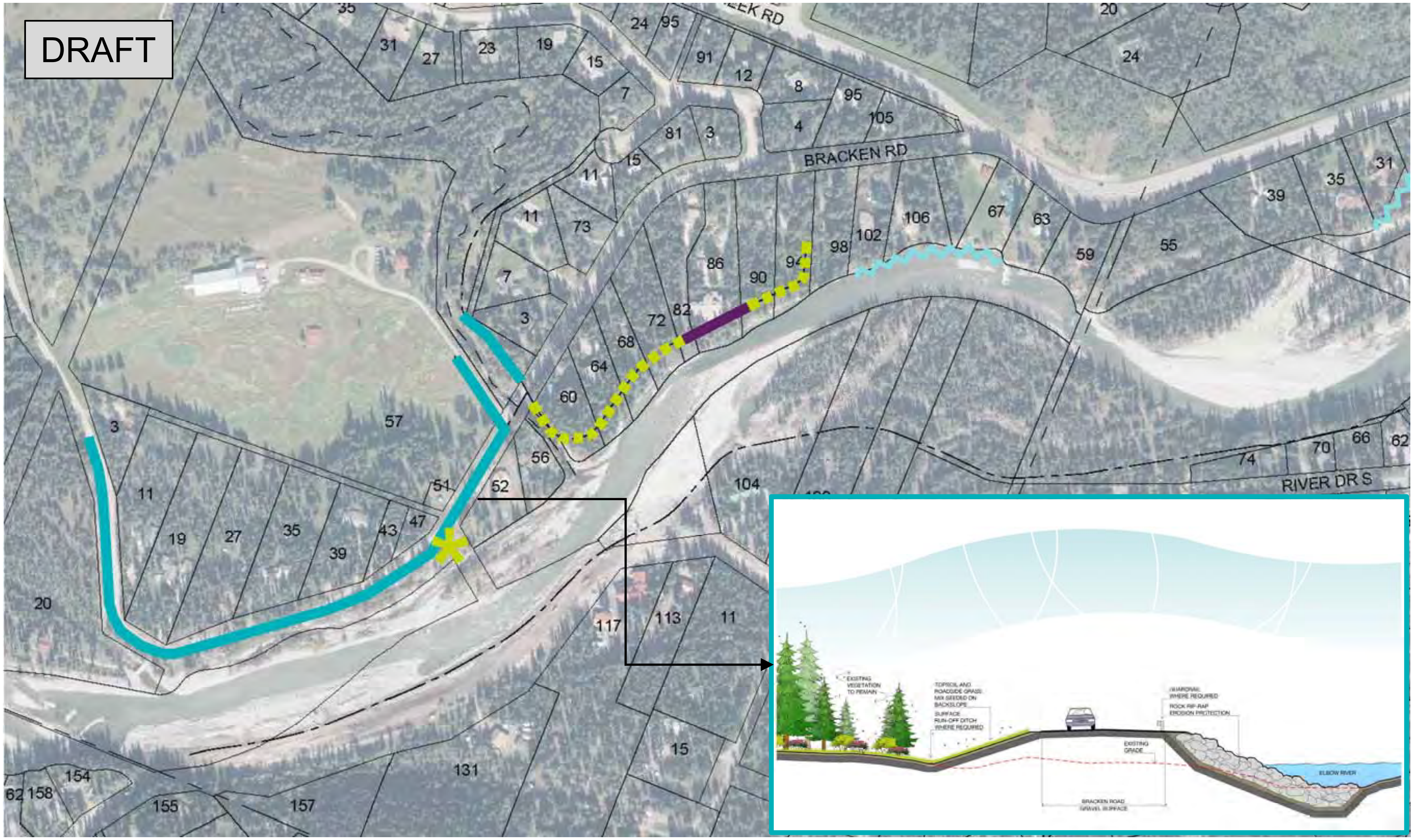
Bragg Creek Flood Mitigation Project
Preliminary Design – West Dike



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Bragg Creek Flood Mitigation Project
Preliminary Design – West Dike

ROCKY VIEW COUNTY
Cultivating Communities

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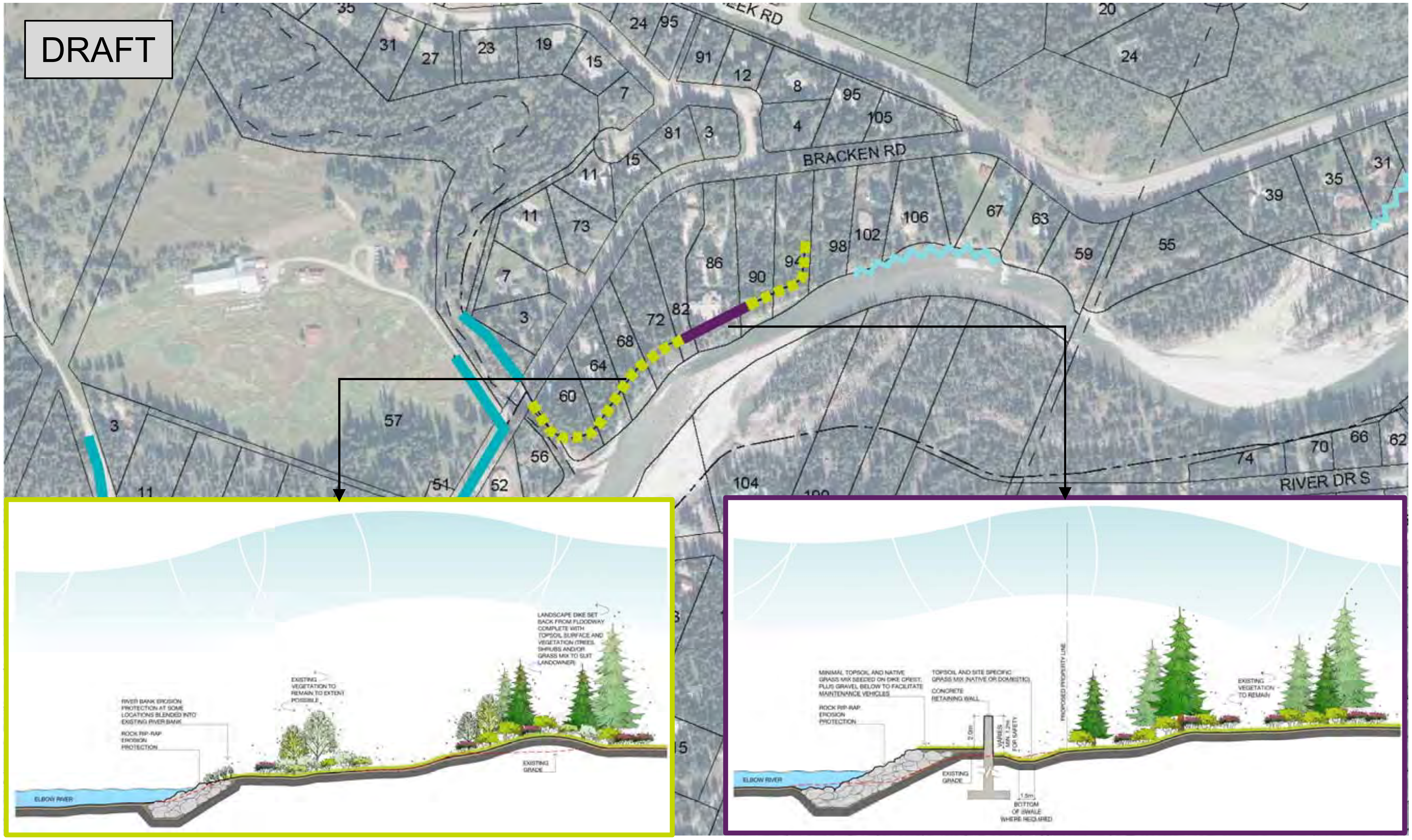

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Bragg Creek Flood Mitigation Project
Preliminary Design – Yoho Tinda Dike

ROCKY VIEW COUNTY
Cultivating Communities

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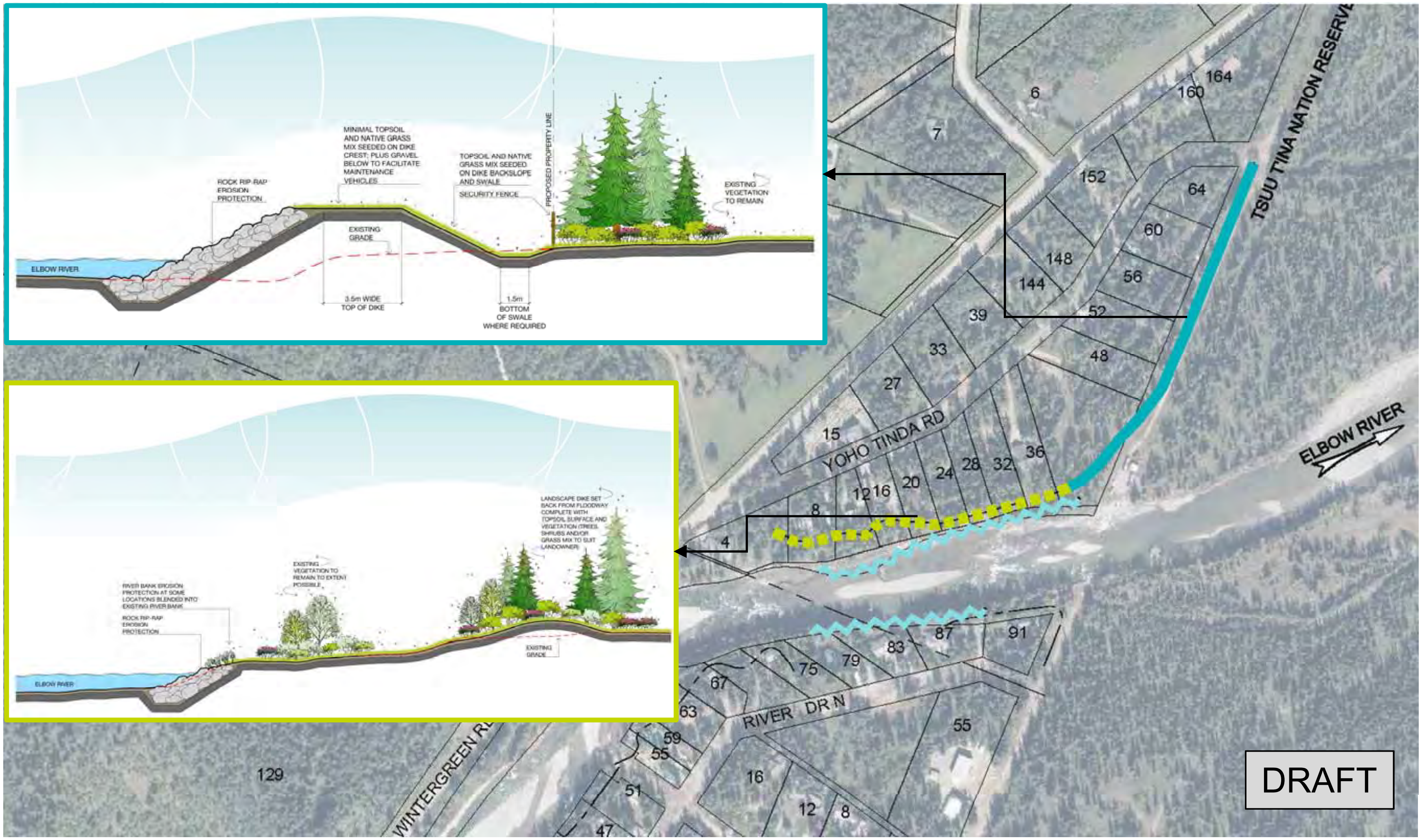

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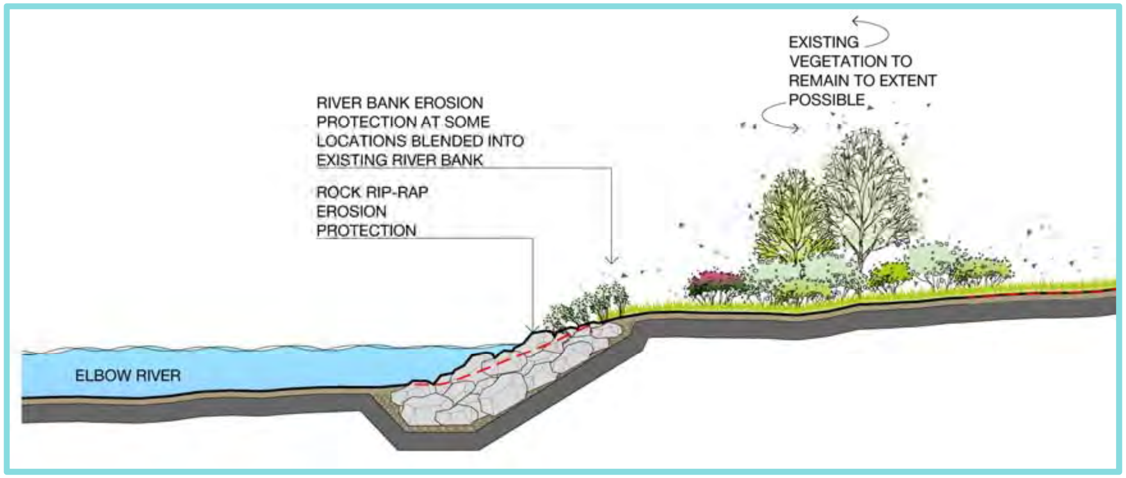
Bragg Creek Flood Mitigation Project

Preliminary Design – Bank Protection



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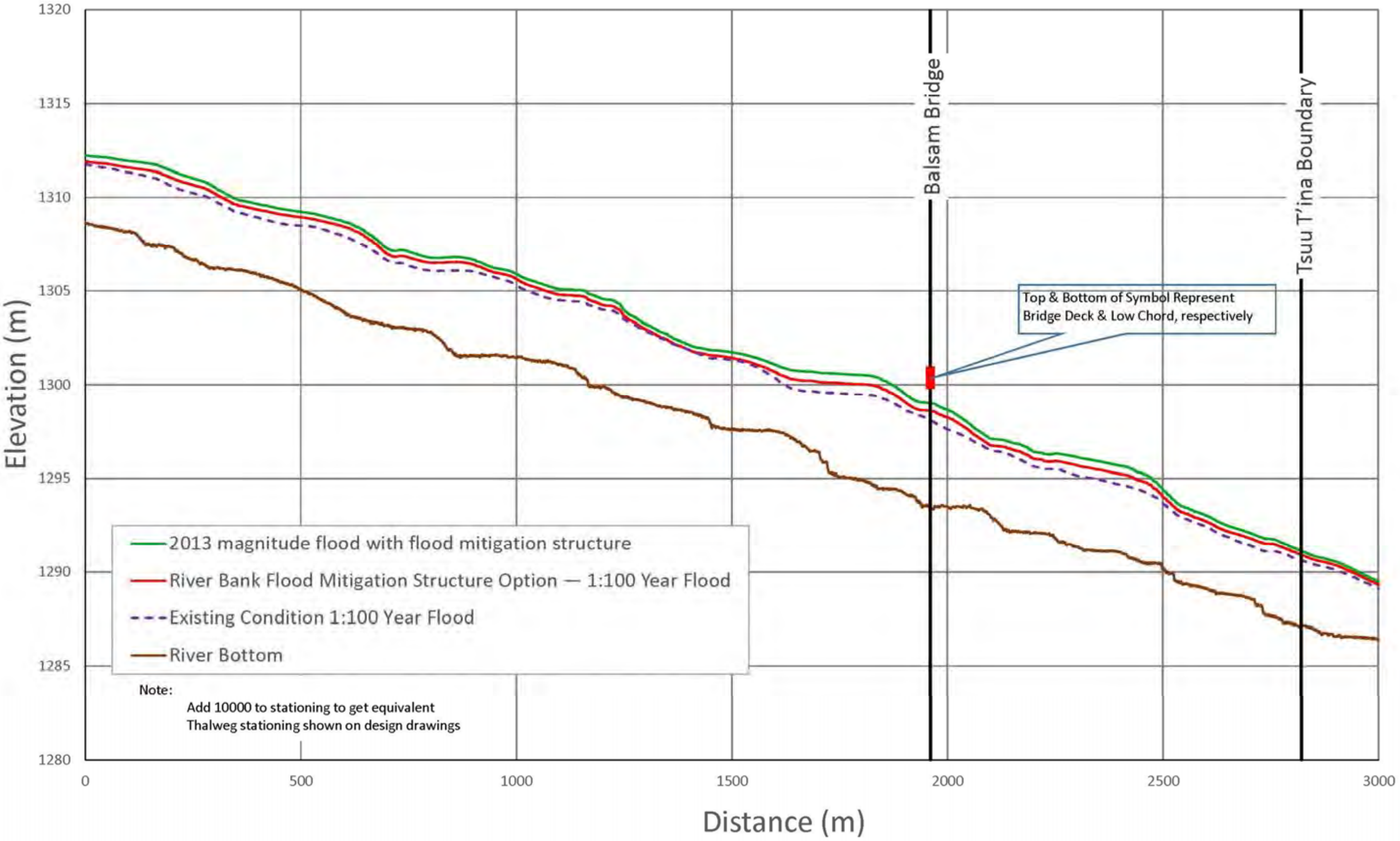
Bragg Creek Flood Mitigation Project
1:100 Year Water Surface Profile

ROCKY VIEW COUNTY
Cultivating Communities

amec foster wheeler

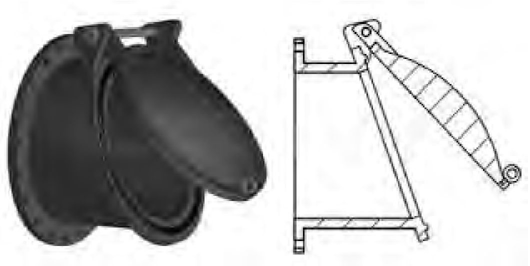
Hydraulic Modeling 1:100-Year and 2013 Flood Water Surface Profiles – Bragg Creek Area



Note:
Add 10000 to stationing to get equivalent Thalweg stationing shown on design drawings

Bragg Creek Flood Mitigation Project
Surface Drainage & Groundwater

- Surface Drainage
  - A swale on the landowner side of the proposed barrier will direct surface drainage to corrugated steel pipes through the barrier
  - An automatic flap gate will be provided at the pipe outlet which will open as a result of water pressure from the landowner side or close as a result of river water pressure during extreme floods



  - A back-up, manually operated sluice gate system will also be provided
- Groundwater Review
  - Flood structures will not impact existing shallow wells or groundwater levels during non-flood conditions
  - Flood structures will reduce but not eliminate the risk of basement flooding as a result of groundwater seepage during extreme floods

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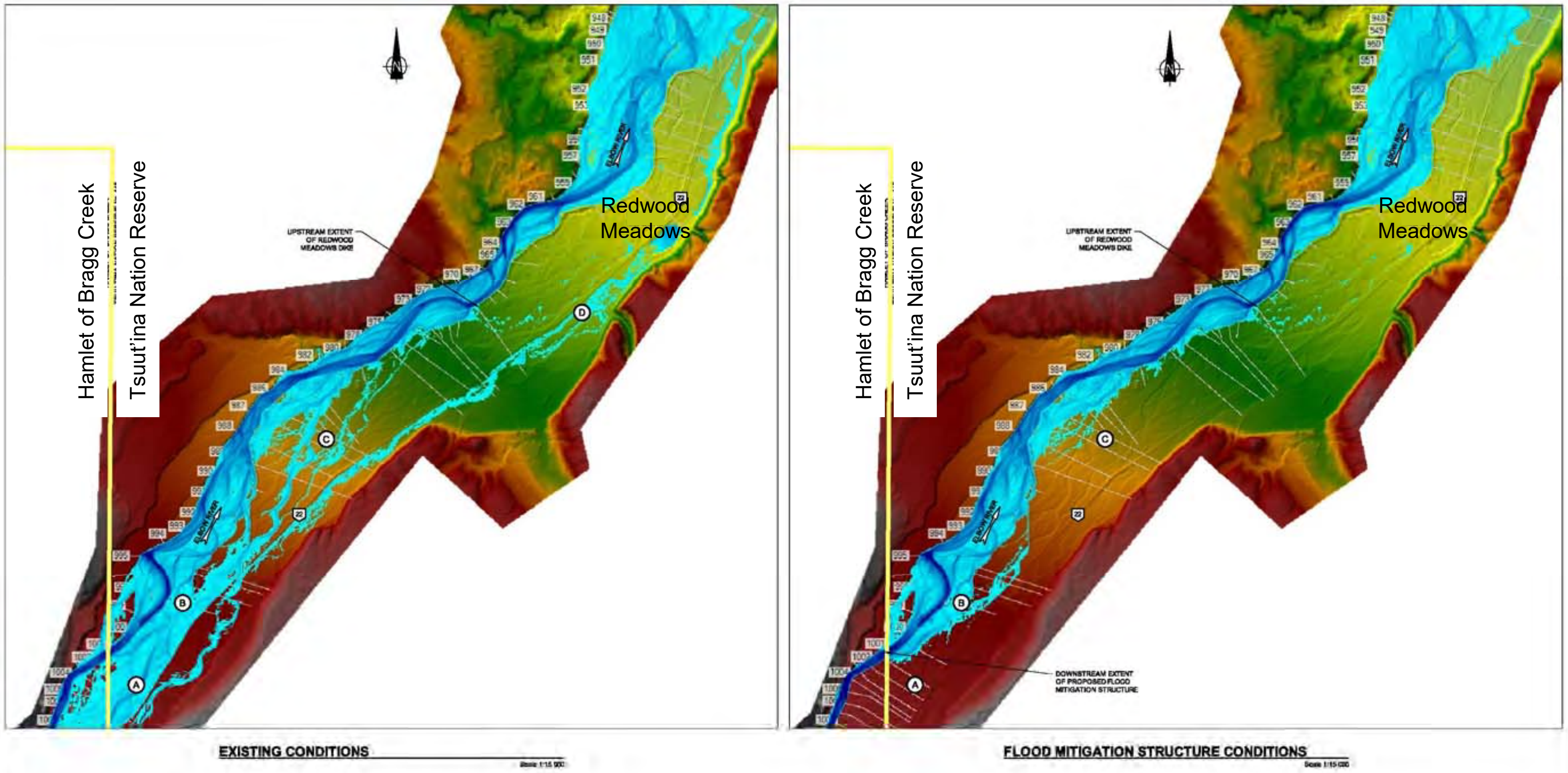
Bragg Creek Flood Mitigation Project
Downstream Impacts



EXISTING CONDITIONS

Scale 1:15 000

FLOOD MITIGATION STRUCTURE CONDITIONS

Scale 1:15 000

FOR DISCUSSION ONLY

0 375 750
1:15000 Metres

Draft

FEATURES IDENTIFIED ON FIGURES

A - AREA ADJACENT TO RESERVE BOUNDARY THAT WOULD NOT BE SUBJECT TO INUNDATION FOR FLOOD MITIGATION STRUCTURE SCENARIOS.

B - HYDRAULIC CONDITIONS AT AND DOWNSTREAM OF THIS POINT ARE GENERALLY SIMILAR FOR EXISTING AND FLOOD MITIGATION STRUCTURE SCENARIOS.

C - FLOOD MITIGATION STRUCTURE RESULTS IN REDUCED FLOODING IN THIS GOLF COURSE AREA.

D - MODEL MAY OVERESTIMATE EXTENT OF FLOODING ON SOUTHEAST SIDE OF HWY 22 AS INFORMATION REGARDING CULVERTS AND DITCH BLOCKS THAT DIRECTS FLOW BACK TO THE RIVER WAS NOT AVAILABLE AND NOT INCLUDED IN MODEL.

NOTES:

1. NUMBERS ON FIGURE IDENTIFY MODEL CROSS SECTION NUMBERS.

DRAFT

amec foster wheeler	PROJECT NAME BRAGG CREEK FLOOD MITIGATION	PROJECT NUMBER CT160213
CLIENT ROCKY VIEW COUNTY Cultivating Communities	SHEET TITLE 1:100 YEAR FLOOD INUNDATION EXTENTS AT TSUU T'INA RESERVE AND REDWOOD MEADOWS	FIGURE NUMBER 6.5
		ISSUE/REVISION A

INTRODUCTION

This report constitutes Martin Ignasiak's review of Alberta Transportation's Springbank Project ("SR1").

Pursuant to the retainer agreement, dated April 30, 2019, Osler, Hoskin & Harcourt LLP is to provide legal advice to Alberta Transportation ("AT") as follows:

(a) Conduct an independent review of SR1's current status in the regulatory process including providing an opinion on the regulatory steps remaining as well as potential timelines for completing the regulatory processes and associated Indigenous and stakeholder consultations, and land acquisition; and

(b) Provide strategic advice to assist AT in advancing the Project on appropriate timelines.

Part I - Regulatory Process Overview and Procedural Steps provides the background of the project as well as a general overview of the provincial and federal regulatory processes including typical timelines. It then provides a history of how SR1 has advanced through each of the provincial and federal regulatory processes until present. My observations and comments on how the processes have unfolded to date are provided. Part I concludes by setting out the remaining regulatory steps as well as an expected time frame for completing the regulatory processes and the land acquisition.

Part II – Strategic Advice for Future Regulatory Steps provides the requested strategic advice to assist AT in advancing SR1 on appropriate timelines.

EXECUTIVE SUMMARY

During the course of preparing this report, I have reviewed numerous documents, including SR1 application materials, thousands of pages of submissions to regulators, hundreds of questions posed by regulators, and AT's responses to those questions. In addition, I have conducted interviews with various employees of AT, consultants working on SR1 and other individuals who have worked on SR1 over the past several years. It is important to stress that while I did receive and consider written submissions from both supporters and opponents of SR1, I did not meet with any of these stakeholders.

SR1 is unique in that:

- SR1 will result in the creation of new Crown lands as opposed to most projects that take up Crown land; and
- SR1 is not being carried out to allow for the recovery of some commodity but instead to manage river flows during rare emergency events.

In addition, it must be pointed out that AT does not typically carry out projects that are subject to the regulatory processes, and associated Indigenous and stakeholder engagement, that apply to SR1. These regulatory processes are today more challenging to navigate than ever before. Despite this, generally AT has developed and executed a well-planned and considered regulatory strategy. For example:

1. The current land acquisition strategy is to pursue negotiated land purchases until the required approvals are issued for SR1. At that time, expropriation proceedings under the *Expropriation Act* will be initiated to ensure that land acquisition does not delay the construction of SR1. The strategy proposed for land acquisition is entirely appropriate.

2. The consultants retained by AT and AT's employees on the SR1 team all possess valuable expertise within their particular areas of responsibility and are well-suited for their roles.

3. AT is well aware of its obligations as they pertain to Indigenous consultation and stakeholder engagement. This is important because carrying out these obligations effectively will be critical if SR1 is to succeed.

4. AT has developed a realistic regulatory plan to obtain the required regulatory approvals.

However, two events have occurred that have resulted in longer regulatory timelines thus far than were originally anticipated:

1. The finding by the Canadian Environmental Assessment Agency that the originally filed Environmental Impact Statement was deficient. This resulted in a delay of approximately 6 months.

2. The issuance of 593 first round information requests, with several sub-questions, by provincial regulators. This number of information requests is unprecedented for a major project.

My advice to AT to minimize the likelihood of any further unanticipated delays is as follows:

1. Maintain a strong Project Lead and a Regulatory Lead, as part of a project leadership team, that is consistent in its composition and committed to SR1 until the requisite approvals are obtained.

2. AT and the Government of Alberta must ensure Indigenous consultation is carried out appropriately. It is evident that AT, its consultants and its internal and external legal counsel are fully aware of these requirements.

3. Recognize that any significant changes to SR1 as currently proposed and assessed will result in significant delay as compared to the timelines set out in Part I of this report.

In my view, continuing to maintain a strong Project Lead and Regulatory Lead, carrying out effective consultation, and recognition of the last recommendation above, as further detailed in this report, will allow AT to advance SR1 on appropriate and achievable timelines. Thank you for the opportunity to provide advice on SR1 and the regulatory processes associated with it.

PART I:
REGULATORY PROCESS OVERVIEW AND PROCEDURAL STEPS

A. Background

As a result of the devastating floods that affected Southern Alberta in 2013, the Government of Alberta established the Southern Alberta Flood Recovery Task Force ("Task Force"). In October 2013, the Task Force contracted with AMEC Environment and Infrastructure to provide a flood mitigation feasibility study for the Bow, Elbow and Oldman river basins ("AMEC Report").[1] On June 1, 2014, the Task Force released the AMEC Report, which recommended various flood mitigation including an earth-fill dam at McLean Creek ("MC1") and SR1. The recommendation in the AMEC Report was to pursue both MC1 and SR1 concurrently until one project became the clear front-runner.

In May of 2015, Deltares, a Dutch environmental company, was contracted by Alberta Environment and Parks ("AEP") to conduct an environmental comparison of SR1 and MC1 ("Deltares Report"). The Deltares Report concluded that SR1 was the superior project because of various costs and environmental measures, as well as the fact that SR1 included flood protection measures to be taken specifically for Bragg Creek and other upstream communities. The Deltares Report ultimately concluded that from an environmental point of view, SR1 leaves the river as a more natural system.[2] Subsequently, SR1 was determined to be the front-runner project.

SR1 is currently undergoing review by both the Government of Alberta, through AEP and the Natural Resources Conservation Board ("NRCB"), and the Government of Canada, through the Canadian Environmental Assessment Agency ("CEAA"). While there have been discussions regarding the complementarity of the two processes, in practice they have been entirely decoupled. As such and in essence, SR1 is undergoing two separate assessments: the provincial assessment under the AEP and NRCB, and the federal assessment under CEAA.

On June 14, 2019, AT filed its responses to numerous information requests posed by both provincial and federal regulators.

B. General Overview of the Regulatory Process

In this section, a high-level overview of the provincial and federal regulatory processes, as they apply to SR1, is provided. Each heading identifies a process step and in brackets provides a general timeline typically associated with that step.

(a) Provincial Process

Terms of Reference (3 months)

If a proponent's proposed project requires an environmental impact assessment ("EIA") under Alberta's *Environmental Protection and Enhancement Act* ("EPEA"), the proponent must submit

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[1] AMEC Environment & Infrastructure, "Southern Alberta Flood Recovery Task Force Flood Mitigation Measures for the Bow River, Elbow River and Oldman River Basins" (June 2014), Volume 2, 1 ("AMEC Report").

[2] Deltares, "Review of two flood mitigation projects: Bragg Creek/Springbank off-stream flood storage and McLean Creek flood storage" (October 7, 2015), 1 ("Deltares Report").

proposed terms of reference for the EIA to AEP. AEP must provide an opportunity for public comment on the proposed terms of reference and consider those comments before issuing the final terms of reference.

The NRCB coordinates with AEP and participates in the process of establishing the final terms of reference.

This step typically takes 3 months but can take longer, depending on the level of public consultation undertaken by the proponent and regulatory agencies.

Supplementary Information Requests (8 to 24 months)

Once the final terms of reference are released, it is up to the proponent to submit an EIA in conformity. Once submitted, provincial regulatory agencies and departments, including AEP and the NRCB, will conduct a technical review of the EIA and may issue supplementary information requests ("SIRs") to the proponent. The purpose of the SIRs is to obtain further information they determine necessary for their review of the project.

SIRs are typically issued in rounds. Almost all projects are subject to at least one round of SIRs and most are subject to two rounds of SIRs. Some projects are subject to three rounds of SIRs. It is rare to exceed three rounds.

This phase introduces significant uncertainty in timelines. Timelines for this phase are influenced by the number of SIRs and the length of time the proponent requires to respond to the SIRs. The full SIR process typically takes anywhere from 8 months to 2 years.

EIA Deemed Complete and Notice of Application (3 to 5 months)

Once the proponent has responded to all of the SIRs, AEP will review the information and will make a determination that the EIA is complete. The NRCB, upon being advised by AEP that the EIA is complete, will issue a Notice of Application.

The Notice of Application will set out a process for persons who may be directly affected by the project, or who, in the NRCB's view, have a *bona fide* interest in the matter, to file objections to the project. If there are objections to the project, the general practice is to proceed directly to a pre-hearing conference to consider preliminary matters prior to publishing a Notice of Hearing. The pre-hearing conference is held to address preliminary and procedural matters.

The NRCB typically requires 3 to 5 months to receive objections, make a determination on who will be participating in a hearing, and to hold a pre-hearing conference.

Hearing (3 to 6 months)

The NRCB will issue a Notice of Hearing setting out the hearing process. The hearing process is a quasi-judicial process meaning that there are substantive and procedural legal requirements to which the process must adhere. This process will allow for those objecting to the project to file submissions regarding the project, including expert reports. The proponent will sit a witness panel that every other party will be entitled to cross-examine under oath. After the proponent's witness panel is cross-examined, it will be questioned by NRCB legal counsel and the NRCB Members. Every party objecting will then have an opportunity to seat its own witness panel. The proponent may then cross-examine each intervener witness panel. Each witness panel may also be questioned by the NRCB's legal counsel and Members. All parties will present final arguments at the conclusion of the hearing.

The hearing phase is almost always the most intense, busy and expensive (on a per-day basis) aspect of the regulatory process. A proponent must dedicate significant resources to hearing preparation if the proponent is to be successful at the hearing. This includes conducting mock-hearing sessions where the proponent's officials and consultants practice responding to cross-examination questions. During this time, the proponent and its consultants are concurrently responding to the written interventions filed by various interveners.

This phase typically takes 3 to 6 months, depending on the length of notice the NRCB gives in advance of the hearing. The hearing itself typically takes from less than a week to a month.

NRCB Report (3 to 4 months)

After the hearing, the NRCB will review all the evidence and argument presented at the hearing and issue a decision report. This report will provide background information on the project, review the positions of the parties, explain the NRCB's conclusions on each of the issues before it, and set out its disposition of the application. If the application is approved, any proposed terms and conditions imposed by the NRCB are stated in the decision report.

The time required for the NRCB to release its report depends on the length and complexity of the hearing. Typically, the NRCB's report is issued within 3 to 4 months from the end of the hearing.

Cabinet Decision (2 weeks to 2 months)

Before the NRCB may grant an approval for the project, the Lieutenant Governor in Council must authorize the NRCB to grant the approval through an Order-in-Council. This step is often referred to as the Government of Alberta's public interest decision. For most projects, this step typically takes several weeks to 2 months.

NRCB and AEP Approval (2 weeks to 3 months)

Once the Order-in-Council has been issued by the Lieutenant Governor in Council, AEP and the NRCB will issue the required regulatory approvals thus allowing the project to proceed. The NRCB approval should be issued within weeks of the Order-in-Council being issued. The required *Water Act* approvals may take up to 3 months.

(b) Federal Process

Project Description Phase (2 months)

Project proponents during this phase submit a Summary of the Project Description. Once a Project Description has been submitted, CEAA will invite public comments on the Summary of the Project Description. This includes comments from interested parties, Indigenous groups and federal departments.

Once CEAA has had an opportunity to consider the submitted public comments, it will make a determination as to whether an Environmental Assessment ("EA") is required. CEAA will also determine at this stage whether the EA will be conducted by the agency or through panel review. EA's conducted by agency review are typically completed in a shorter timeframe as compared to EA's reviewed by a panel.

Submission of Project Description to Determination of EA typically takes roughly 2 months.

EIS Guidelines Phase (1.5 to 2 months)

If CEAA determines that an EA is necessary, it will publish its Draft Environmental Impact Statement ("EIS") Guidelines.[3] The EIS Guidelines determine what the proponent will need to include in their EIS. CEAA will allow public comments on the Draft EIS Guidelines. Once CEAA has considered the comments, it will release its final EIS Guidelines.

Determination of EA to release of the final EIS Guidelines typically takes 1.5 to 2 months.

EIS Conformity Phase (1 to 12 months)

Once the proponent submits its EIS, CEAA will conduct a conformity review in order to determine whether the EIS is in conformity with the EIS Guidelines. It is not uncommon for CEAA to determine that the EIS is not in conformity, in which case CEAA will identify the deficiencies the proponent must address. In some cases, CEAA will reject the EIS and request that a revised EIS be submitted.

If no deficiencies are identified, CEAA typically completes its conformity review in 1 to 2 months. If deficiencies are identified, the timeframe for this step can vary widely depending on how long it takes the proponent to address the deficiencies or re-submit a revised EIS. If a new EIS is required, this step can take up to 12 months or longer.

Information Request Phase (2 to 8 months)

CEAA will typically concurrently announce conformity of the EIS and commencement of the public comment period on the EIS. This will include comments from individuals, interested parties, Indigenous groups and federal departments. This stage constitutes the technical review of the EIS.

CEAA will review the submitted comments and will typically request additional information from the proponent. Similar to the provincial process, additional information requests will be issued in rounds of SIRs. There is almost always one round of SIRs issued by CEAA, often two rounds and in some cases three or more rounds. Each time the proponent submits an answer to the SIRs, a new public comment period is initiated and CEAA will determine if additional SIR are required after taking into account the public comments.

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[3] We refer to environmental impact assessment or EIA and in other cases to an environmental impact statement or EIS. The EIA is the common term used in the provincial regime whereas the EIS is the common term used in the federal regime. In many ways, they are essentially the same thing although the technical information requirements may differ. In joint reviews, a single document is usually filed to meet both the provincial and federal requirements. The terms are used interchangeably herein.

This phase introduces significant uncertainty in timelines. Timelines for this phase are influenced by the number of SIRs and the length of time the proponent requires to respond to the SIRs. From the announcement inviting public comments on the completed EIS to the end of the SIR period for projects undergoing CEAA review (therefore excluding review panel processes) this phase can take from 2 months (if no public comments are received and no SIRs are required) to 8 months. Very few projects reviewed by CEAA have more than 2 rounds of SIRs.

CEAA EA Report (3 to 5 months)

Once CEAA has all the information it requires, it will draft its EA Report. CEAA will then publish the Draft EA Report, along with potential conditions to be recommended to the Minister of Environment and Climate Change Canada ("Federal Minister") for final decision. CEAA will invite public comments on the Draft EA Report and further consult with Indigenous groups on it. The public comment period is typically one month.

After the public comment period closes, CEAA will draft the Final EA Report for submission to the Federal Minister. The amount of time required between the end of the SIR phase and the end of the public comment period on the Draft EA Report to the Federal Minister is typically 3 to 5 months.

Decision Statement by Federal Minister (3 months)

The Final EA Report is typically released along with the Decision Statement by the Federal Minister. The Decision Statement by the Minister will determine whether the project is likely to cause significant adverse effects. The Decision Statement will also include any relevant conditions to be applied and fulfilled by the project. From the end of the public comment period of the Draft EA Report to release of the Decision Statement by the Federal Minister typically requires 3 months.

Federal Authorizations (2 to 3 months)

Federal departments and agencies may issue any required federal authorizations (*Fisheries Act* and *Navigation Protection Act*) required for the project to proceed anytime after the Federal Minister issues a positive Decision Statement. This step typically takes 2 to 3 months.

C. History of the SR1 Regulatory Review

(a) Provincial Process

On July 11, 2014, AT submitted the Project Summary Table to Environment and Sustainable Resource Development ("ESRD"), now AEP. On July 17, 2014, AT submitted its proposed Terms of Reference for the EIA.

On October 1, 2014, ESRD announced that SR1 required an EIA under EPEA and therefore referred the process to the NRCB. On February 5, 2015, the ERSD released its final terms of reference for the EIA.

In October of 2017, AT submitted the SR1 EIA to AEP and the NRCB. On November 16, 2017, AT was informed by AEP that the Human Health Risk Assessment ("HHRA") submitted with the EIA does not conform to the standard guidance and therefore a detailed technical review is not possible until the HHRA is revised and resubmitted. AT filed the revised EIA in March of 2018.

On July 28, 2018, AEP and the NRCB jointly issued the first round of SIRs ("SIR #1"). SIR #1 contained 593 information requests, with several sub-questions. The majority of the questions relate to environmental issues. The remaining topics include: engineering; engagement and consultation; socio-economics; alternative projects; and AT specific questions.

On June 14, 2019, AT responded to SIR #1.

(b) Federal Process

On April 18, 2016, AT submitted the SR1 Project Description to CEAA. On May 9, 2016, CEAA announced a public comment period regarding the Project Description. The original deadline set for public comments was May 30, 2016. During this period, 364 public comments were submitted. It should be noted that of the 364 public comments, roughly 155 public comments followed a template (form letters) and were likely generated as part of an internet campaign. 24 of the public comments were filed after the deadline, including up to June 22, 2016. CEAA did not issue an official extension of the deadline.

On June 23, 2016, CEAA determined that an environmental assessment was necessary and also released and invited public comments on its Draft EIS Guidelines. The deadline for written comments was July 25, 2016. Similar to the Project Description phase however, public comments including from the Department of Fisheries and Oceans Canada ("DFO") were submitted up to and including August 3, 2016. Again, CEAA did not announce an official deadline extension. Unlike in the previous stage, CEAA did not address whether these late comments were taken into consideration. The Final EIS Guidelines were released on August 10, 2016.[4]

On February 24, 2017, CEAA announced that federal funding was available to the public and Indigenous groups to assist in their participation in the EA process.[5] CEAA may decide to provide additional participant funding in the future. CEAA allocated a total of $930,048.05 to a number of Indigenous groups and several individuals.[6] The following Indigenous groups have been awarded federal participant funding:

Indigenous Group	**Amount Allocated**
Blood Tribe First Nation	$79,150
Ermineskin Cree Nation	$79,650
Foothills Ojibway First Nation	$12,100
Ktunaxa Nation Council	$42,068.05
Louis Bull Tribe	$79,650
Metis Nation British Columbia	$12,100
Metis Nation of Alberta – Region 3	$66,140

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[4] CEAA Doc #10.

[5] CEAA Doc #11.

[6] CEAA Doc #27.

Montana First Nation	$79,650
Piikani First Nation	$79,650
Samson Cree Nation	$79,650
Shuswap Indian Band	$12,100
Siksika Nation	$79,650
Stoney Nakoda Nations	$112,150
Tsuut'ina Nation	$79,650

Additionally, the following individuals were awarded participant funding:

Individual	**Amount Allocated**
Brian J. Copithorne	$12,090
John Rodger Robinson	$12,300
Ryan Robinson	$12,300

Separate from the CEAA process, a group of individuals launched a judicial review of CEAA's decision to not refer the environmental assessment to panel review in 2016. The Court found that because it was CEAA that decided not to refer the matter to a review panel, not the Minister, the Minister failed to properly exercise her discretion in deciding not to refer the EA to a review panel. The court remitted the decision back to the Minister for her to personally redetermine whether the assessment should be conducted by a review panel. The Minister ultimately decided (again) not to refer the EA to panel review (August 8, 2017). This introduced uncertainty into the process that took time to address.

On October 17, 2017, AT submitted its EIS to CEAA for compliance review. On November 16, 2017, CEAA notified AT that the EIS was not in conformity with the EIS Guidelines and required a new EIS be submitted. The specific deficiencies found by CEAA were submitted to AT in its Annex 1.

Deficiencies noted by CEAA included that the EIS summary lacked sufficient detail as required by the Final EIA Guidelines and as exemplified in EIS Summaries for past projects; a lack of a well referenced CEAA concordance table which cross references the information provided in the EIS with the information required in the EIS Guidelines;[7] and a lack of discussion on Indigenous traditional territories as specified in the EIS Guidelines.[8]

On December 19, 2017, CEAA further provided its comments on preliminary technical deficiencies that could evolve into SIRs later in the process ("Annex 2"). While Annex 2 deficiencies did not need to be addressed in the re-submitted EIS, CEAA recommended that doing so would expedite the process and preempt the need for potential future SIRs.

On March 29, 2018, AT submitted a revised EIS based on CEAA Annexes 1 and 2. While not all Annex 2 deficiencies were addressed, AT did modify some of its updated EIS based on select points made in Annex 2.

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[7] Annex 1, Deficiency 2.

[8] Annex 1, Deficiency 11.

On April 30, 2018, CEAA announced that the EIS was in conformity with the EIS Guidelines, and welcomed public comments for its first round of SIRs. The official deadline for any such public comments was May 31, 2018. On May 17, 2018 CEAA subsequently extended the deadline for public comments to June 15, 2018 for unstated reasons. While the deadline was extended to June 15, 2018, several groups and individuals submitted comments up to and including June 28, 2018. This includes comments from Natural Resources Canada ("NRCan") and Environment and Climate Change Canada ("ECCC"). It is unclear whether these comments were taken into account.

Several hundred public comments were once again submitted on the updated EIS. This includes comments from federal departments such as DFO, Health Canada, Transport Canada, ECCC, and NRCan. Comments were also received from a number of Indigenous groups.

CEAA took all public comments into account when issuing its SIR #1. CEAA's SIR #1 Part 1 was issued on June 28, 2018. CEAA then issued its SIR #1 Part 2 on August 20, 2018, and SIR #1 Part 3 on August 31, 2018. On June 14, 2019, AT responded to all the federal SIRs.

Independent Reviewer Observations and Comments

In my view, the requirement to resubmit the EIA resulted in a delay of the regulatory process by approximately 6 months. This delay is attributable in large part to the federal process and the CEAA determination of deficiency. However, even absent the federal deficiency determination, AEP's requirement that the HHRA be revised and resubmitted likely would have caused 2 to 3 months of regulatory delay. The original EIS submitted by AT was more focused on the provincial terms of reference than the Final EIS Guidelines. That said, these information requirements could have been addressed through the SIR process. Finally, I note that Stantec advised AT not to file the EIS in October of 2017 on the basis that there was insufficient time to incorporate necessary information in the EIS and it would likely be rejected by CEAA. I understand external legal counsel also expressed concerns that the EIS was not ready to be filed. I am not aware of who made the decision to file the EIS despite these warnings, or why.

As it pertains to the SIR process, the number of information requests in SIR #1 is unprecedented. I have worked on large-scale mining projects (which include processing facilities and engage far more environmental disciplines than SR1) that were subject to less than half this many information requests in the first round. Typical first round SIRs consist of approximately 190 information requests and very often less.

Regulatory agencies often claim that if an application is done properly and meets the information requirements set out in the terms of reference, there will be relatively few information requests. In my experience this is rarely true. Those assigned to review project applications and issue information requests will almost always do so regardless of the quality of the application. That said, there is no doubt that a number of the information requests in SIR #1 are required and appropriate. There are many that attempt to clarify contradictions that exist in the EIA and seek information that ought to have been included in the EIA. This is not unusual. Therefore, while I remain of the opinion that there are a number of information requests that should not have been included in SIR #1, given the content of the EIA, I am of the view that SIR #1 likely would have consisted of approximately 250 questions in any event.

As demonstrated by CEAA's Information Request Package 2 ("CEAA Package 2"), issued in August of 2018, the evolution of Indigenous consultation in regulatory processes presented a challenge for AT. Package 2 was issued by CEAA as part of its mandate to assist the Crown (federal) with fulfilling its duty to consult and inform its assessment of potential impacts on the exercise of Aboriginal or treaty rights. It required that AT engage with each Indigenous group identified in the EIS Guidelines and gather the required information and discuss outstanding concerns. CEAA was directing AT to support and facilitate the participation of Indigenous groups in the review process. This presented a unique challenge because AT has not in recent years been required to engage in the manner of consultation now required in connection with the regulatory review of SR1. There has been considerable evolution in the manner in which Indigenous consultation is undertaken. In addition, SR1 is unique in that unlike most major projects which take up Crown lands, SR1 will result in the creation of new Crown lands. As a result, AT and the Government of Alberta were required to carefully assess how to carry out further consultation with Indigenous groups so that Package 2 could be responded to. The importance and complexity of this issue was further exacerbated by the Federal Court of Appeal's decision on the Trans Mountain Project which was issued on August 30, 2018.[9]

D. Remaining Regulatory Steps and Schedule

Presently, both CEAA and AEP/NRCB are reviewing AT's responses to the SIRs. Taking this into account, my view as to a reasonable schedule for each of the remaining provincial and federal processes is set out in the tables below.

Provincial (AEP & NRCB)			
Step	**Comments**	**Length**	**Estimated Timeline**
Responding to SIRs	Responses to SIR #1 have been submitted in mid-June 2019; and we assume: AEP will take 4 months to review the responses and issue SIR #2 (mid-October); responses to	10 months	April 2020

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[9] *Tsleil-Waututh Nation v. Canada (Attorney General)*, 2018 FCA 153

	SIR #2 will be submitted within 3 months of receipt (mid-February); if there is a third round, they will be issued by AEP and responded to within 3 months.		
EIA Deemed Complete by AEP and NRCB Notice of Application	This includes three weeks for AEP to review the final round of SIRs and to advise the NRCB the EIA is complete. The NRCB will issue a Notice of Application with a 30 day period for filing objections, and will then schedule and hold a pre-hearing meeting. We have added an additional month to take into account this occurs over the summer months thereby creating scheduling issues.	5 months	September 2020
Notice of Hearing	NRCB will issue a Notice of Hearing. We assume a 45 day notice before parties must file hearing submissions and 2.5 months' notice prior to the hearing.	2.5 months	December 2020
Hearing	Assume a 3 week hearing.	3 weeks	early to mid-December 2020
NRCB Report	In my view given the nature of SR1, this step should not take 3 months and should instead take 2 months or less. However, given the Christmas holiday and that NRCB published guidance suggest this can take up to 4 months, I have assumed 3 months.	3 months	March 2021
Order-in-Council	Cabinet formally authorizes NRCB to issue approval.	2 months	May 2021
NRCB and AEP Approvals	AEP will consider and issue any remaining approvals	2 months	July 2021

Federal (CEAA)			
Step	**Comments**	**Length**	**Estimated Timeline**
Responding to SIRs	Responses to SIRs have been submitted in mid-June 2019; and we assume: CEAA will take 3 months to review the responses and issue an additional round of SIRs (mid-September); responses to these SIRs will be submitted 3 months after. We assume a further 4 months to receive and respond to the final round. We note that this would be a significant amount of federal SIRs compared to previous CEAA reviews for other projects. This likely results from the significant number of public comments submitted to CEAA as part of the organized opposition to SR1.	10 months	April 2020
Draft EA Report, Public Comment Period, and Final EA Report	Assumes 2 months to prepare draft EA, 30 day public comment period and another 2 months to finalize and provide to Federal Minister.	5 months	September 2020
Decision Statement by Federal Minister	Usually, additional Indigenous consultation is undertaken as part of this step.	3 months	December 2020
Fisheries Act and *Navigation Protection Act* Authorizations	We have allowed 3 months for finalization of these authorizations.	3 months	March 2021

The timelines are reasonable and achievable, consistent with our review of other comparable regulatory proceedings. Although the above timelines are achievable, I recommend AT exercise caution when publicly discussing its anticipated timelines for regulatory approval. First, opponents of projects understand that creating delay is one of the most effective ways of stopping projects. Announcing definitive milestone dates establishes targets for opponents. Second, in some cases regulators are offended or view it as inappropriate when proponents opine on when a regulator should complete certain processes by.

E. Land Acquisition

The current strategy is to pursue negotiated land purchases until an Order-in-Council and NRCB approval is issued for SR1. At that time, expropriation proceedings under the *Expropriation Act* will be initiated to ensure that land acquisition does not delay the construction of SR1. The strategy proposed for land acquisition is entirely appropriate.

PART II: STRATEGIC ADVICE FOR FUTURE REGULATORY STEPS

This Part II provides strategic advice regarding steps for AT to implement in order to facilitate obtaining the necessary approvals for SR1 on the timelines set out in Part I of this report.

A. Project Management

(a) Introduction

Historically, a project such as SR1 would be developed by engineers and others with the requisite flood-mitigation expertise. This team would then obtain the necessary regulatory approvals required for the project to proceed. However, this approach fails to recognize that regulatory processes have become complex and multifaceted. The traditional approach will not result in success. Major projects, if they are to be successfully navigated through the regulatory process, now require that the project be navigated by a team with an in-depth understanding of not only the engineering and environmental disciplines, but also the regulatory processes themselves, including how to carry out effective Indigenous and non-Indigenous engagement. For example, pipeline companies historically tasked construction experts with identifying potential pipeline routes and once a route was determined, the requisite approvals were sought. Today, many pipeline companies first assign regulatory experts and experts in Indigenous relations to identify potential pipeline routes. Only after they have identified potential routes are the construction experts brought in to assess the feasibility of those routes. Put another way, designing a good project does not guarantee regulatory success.

In addition, while a proponent will typically retain environmental, engineering and legal consultants to assist with obtaining the required regulatory approvals, to be successful it is critical that the proponent continue to actively manage and direct the regulatory strategy and execution. Although AT has for the most part actively managed and directed the regulatory strategy and execution, there have been a number of personnel changes at AT during the regulatory process. Regulatory processes have become much more complicated and in the case of major projects such as SR1, consistent leadership is required. AT recognized this in May of 2018 when a new Assistant Deputy Minister was assigned to SR1 in 2018. This resulted in a warranted shift in strategy that resulted in more effective Indigenous and stakeholder consultation as well as better management of the internal and external members of the SR1 Project team.

A project such as SR1 necessitates that a proponent consider a much wider scope of issues. Land use, accommodation of Indigenous concerns, land acquisition and sophisticated opponents to the project mean that the proponent will be pressed to make commitments that are much more complicated and multifaceted than on-site mitigation measures. Before a proponent can commit to these sort of measures, it must carefully assess the precedent that is being created and its ability to deliver on these commitments. Often, these commitments may require approval from other departments and as such, must be carefully considered and approved by the most senior decision makers. In the Government of Alberta, this will include Deputy Ministers and Ministers of AT, AEP and potentially the Alberta Cabinet.[10] The nature of these issues required that they be considered at the highest levels of the organization, just like they would be if the proponent were a private company. These commitments will bind the Government of Alberta, and not just AT, for many years.

(b) Project Lead

During the course of my interviews with those working on SR1, including with the various consultants, AT employees and other Government of Alberta employees, it emerged that there has not been a person who, on a consistent basis, is viewed as the leader of SR1 ultimately responsible for its success. To successfully navigate the regulatory process and to carry out effective Indigenous consultation and stakeholder engagement, there must be continuity within the leadership team responsible for SR1.

To be clear, this is not a reflection on the competence or abilities of any of the individuals working on SR1. To the contrary, all of the consultants and employees appear to possess valuable expertise within their particular areas of responsibility. All of them clearly want to see SR1 succeed. I came across nothing in my review of SR1 that suggested any carelessness on the part of any individual or that any aspect of SR1's design is problematic.

Navigating a major project through today's regulatory processes requires one individual who is responsible for all of the following (the "Project Lead"):[11]

1. Delivering the project approvals on budget and on schedule;
2. Coordinating and managing the engineering lead, Indigenous engagement lead, environmental lead, stakeholder engagement lead, regulatory lead, and land acquisition lead. This includes:
    a. working with the engineering lead and environmental lead to identify potential mitigation measures that are acceptable to the proponent and that can be implemented to help address Indigenous, stakeholder or regulators' concerns;
    b. ensuring that no one is making commitments to Indigenous groups, stakeholders or regulators that will impede or prevent the successful construction or operation of the project on schedule and on budget;
    c. working with legal and the Indigenous engagement team to ensure that the proponent's and Crown's obligations to engage or consult are met; and

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[10] These types of commitments that establish precedent and require coordination among various parties, therefore requiring approval from the highest levels within the organization and sometimes other organizations, are not restricted to projects advanced by government. Industry proponents face the same challenge and have in the past made commitments that must first be approved by the Chief Executive Officer and in some cases the Board of Directors. Sometimes several industry players, such as in the oil sands, work together to make commitments.

[11] In this report I use the term "lead". Often the position is referred to as Project Manager or Director. Different companies use different titles. I've simply used "lead" recognizing that within government some titles such as "lead", "manager", or "director" are perceived very differently than in industry companies.

   d. working with the regulatory lead to ensure that all regulatory requirements necessary to obtain the project approvals are met and that all filings are consistent with the proponent's design, environmental and other commitments.

3. Represent himself or herself as the champion of the project throughout the regulatory processes including during the NRCB hearing. During the NRCB hearing, this individual will be expected to have the authority to make commitments on behalf of the proponent and to be accountable for all aspects of the project. This individual will be the "chair" or "quarterback" of the proponent's witness panel and as such will set the tone of the panel and determine who answers what questions and when.

4. In many cases, this individual is also the public face of the project dealing with media inquiries and also representing the proponent in key stakeholder and Indigenous meetings.

Therefore, the Project Lead must: have senior decision-making power on behalf of the proponent; be an effective speaker in various settings (at a hearing, in meetings with Indigenous groups and potentially in the media); confident; and a strategic thinker. Alberta regulators have previously expressed concern when a proponent fails to put forward an individual with sufficient authority. The then Alberta Energy and Utilities Board stated:[12]

> The Board was pleased to see that the parties were able to establish a cooperative agreement to address the concerns expressed by the interveners. However, the Board was disappointed that the senior Imperial staff referred to in the agreement did not participate in the hearing and provide the Board and the interveners with the opportunity to question them on their commitment to the agreement. The Board was also disappointed to find out that the most senior Imperial official identified in the conflict resolution section may not even be aware of the existence of the agreement or his role in the conflict resolution process.
>
> The Board notes that much of the distrust expressed toward Imperial relates to an apparent breakdown in the fulfillment of commitments when those commitments are taken to Imperial's head office in Calgary for confirmation. The Board believes that a senior staff member should have appeared at the hearing to speak directly to the company's commitment to the agreement and the measures that have been put in place to resolve the operational matters in a timely fashion. In this case the appropriate person may have been the one holding the position identified as the last point of contact in the conflict resolution procedure or another senior executive member. The Board expects senior management (decision makers) to take an active role in the hearing process and believes that especially in this case, it would have resulted in a significant step forward in resolving the trust issues between the parties.

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[12] EUB Decision 2006-037 (May 2, 2006) at page 7.

It should be noted that most major projects successfully advanced through regulatory processes have been championed by very senior individuals within the proponent's organizational structure. This is the case for several reasons. First, the individual must have the authority to direct the day-to-day work of all the employees and consultants working on the project, including Indigenous and non-Indigenous engagement teams, engineering, environmental, land and legal. Second, the person must have direct and quick access to the most senior leadership, which in this case is the Deputy Minister, and when necessary, the Minister. This is because to successfully navigate the regulatory process, a proponent must show that it has taken into account, and has attempted to address, the concerns that have been expressed. This means that the individual must be able to offer commitments that may include, but not be limited to, additional environmental and construction monitoring, notification procedures and on-going consultation through life-of-project, stakeholder access to land and other resources, financial settlements, and contracting and employment opportunities. In the vast majority of cases, this position is a full-time job.

(c) Regulatory Lead

The Regulatory Lead is usually responsible for managing all regulatory filings. This includes ensuring that all regulatory requirements are met and are consistent with the proponent's objectives for the project. The Regulatory Lead manages all of the various environmental consultants to make sure that internal timelines are being met and quality control is achieved. The Regulatory Lead liaises with the Project Lead to make sure that the environmental consultants have all the necessary information required regarding the project to properly carry out their tasks.

(d) Conclusion

The two positions discussed above, Project Lead and Regulatory Lead, are most critical at this stage of the regulatory process if SR1 is to succeed. It is recommended that a Project Team ("PT") be formed to navigate SR1 through the remainder of the regulatory process. The PT usually consists of between 6 and 10 people including the Project Lead, Regulatory Lead, Legal, Environmental (proponent employee who understands the proponent's environmental practices and policies), Engineering, Stakeholder and Indigenous Engagement.[13] In the case of SR1, I recommend land acquisition also be represented. Every proponent organizes itself differently at different stages of the regulatory process. However, a consistent element in almost every successful case is a strong Project Lead and a Regulatory Lead and a leadership team that is consistent in its composition and committed to the project until the requisite approvals are obtained.

---

[13] It should be noted that in some cases Indigenous engagement is conducted by a team different than the one responsible for stakeholder engagement. Often they are combined. It is also common for the Project Lead to undertake the role of Indigenous and stakeholder engagement, with support from others. There are various ways to structure this aspect of the PT, all of which can lead to success. Also, I recommend the PT have dedicated administrative support to take minutes and ensure everyone is aware of their deliverables.

B. Project Updates and Alternatives

MC1 has been advanced by those opposed to the SR1 as a better alternative to SR1. There has been extensive consideration given to the merits of both MC1 and SR1 in the AMEC Report and the Deltares Report. This report does not investigate or assess the merits of MC1. However, it is certain that if AT determines it will now pursue MC1, or if AT makes other significant changes to SR1, the timelines referred to earlier will not be met and the flood mitigation SR1 is intended to provide will be delayed by anywhere from 3 to 8 years or more.

In my experience, and without fail, significant changes to a project during the regulatory process results in years of regulatory delay because new baseline information, new modelling and significant updates are required to all the regulatory filings. In some cases, regulators will consider the scope of changes, terminate the regulatory review and require a new application, thereby restarting the entire process from the beginning.

In addition, the federal government has tabled Bill C-69: *An Act to enact the Impact Assessment Act and the Canadian Energy Regulator Act, to amend the Navigation Protection Act and to make consequential amendments to other Acts*. If SR1 is significantly amended or MC1 is pursued, the federal review process will likely start again and potentially be subject to Bill C-69, if passed.

In my view, even if MC1 were not subject to federal EA review, preparing a new application for MC1, applying for and obtaining the necessary provincial approvals will take at least 3 years and more likely 4 or 5 years. Any significant changes to SR1 as currently proposed and assessed will result in significant delay as compared to the timelines set out in Part I of this report.

C. Indigenous Engagement

From an Indigenous rights perspective, SR1 is a unique project. Unlike almost all other projects I have worked on, SR1 will result in the creation of new Crown lands. Almost every other project I have assisted with results in Crown lands being closed to the public for the purposes of allowing mining activities or other industrial infrastructure. In addition, SR1 is not being carried out to allow for the recovery of some commodity but instead to manage river flows during rare emergency events during which it is dangerous to carry out any traditional activities near the river.

I recommend that AT and the Government of Alberta ensure Indigenous consultation is carried out appropriately. It is evident that AT, its consultants and its internal and external legal counsel are fully aware of these requirements. I have no further recommendations for AT in this regard.

CONCLUSION

Thank you for the opportunity to provide advice on SR1 and the regulatory processes associated with it.

ROCKY VIEW COUNTY

CAPITAL PROJECT MANAGEMENT

TO: Council

DATE: July 28, 2020 **DIVISION:** 1

FILE: 1025-700 **APPLICATION:** N/A

SUBJECT: Provincial Funding Amendment for Bragg Creek Flood Mitigation

EXECUTIVE SUMMARY:

The Province of Alberta has committed $9,425,463 in additional funding to complete the Bragg Creek Flood Mitigation Project.

Under the revised funding agreement, the Province will be providing $358,865 to support 2020 construction, with $9,066,598 being transferred to the County following approval of the 2021 provincial budget. Administration is confident that this amended agreement provides sufficient funding and cash flow to complete the project as intended.

Administration seeks Council's approval to endorse the amended funding agreement and adjust the 2020 budget to make an additional $358,865 available to the project.

ADMINISTRATION RECOMMENDATION:

Administration recommends approval in accordance with Option #1.

BACKGROUND:

The Hamlet of Bragg Creek is subject to regular flooding, with significant events recorded as early as 1915. In 2013, flooding caused widespread damage in the Bragg Creek area to municipal infrastructure, flood protection works, homes, property, and businesses along the Elbow River. The flooding had economic and social impacts in the community long after the waters receded and the physical damage repaired.

In recognition of this long-standing risk, the Federal Government and Government of Alberta has committed funding for the flood mitigation project to protect the community to a design level of 1:100 year event.

In June and July 2019, the County obtained approval for construction from Alberta Environment and Parks under the Water Act and Public Lands Act, and authorization by Fisheries and Oceans Canada under the Fisheries Act.

The tender for construction closed in October 2019. The lowest bid exceeded the initial project estimate of $32.8 million. In April 2020, the Government of Alberta committed additional funds that will allow the project to proceed, with an updated budget of $42.2 million.

The increased provincial contribution totals of $9.4 million, with $358,865 committed to the County in 2020, and the balance of funds being committed for the 2021 budget year. Administration has reviewed the revised cost-contribution agreement (and terms), and believes that the Province's commitment meets the budge and cash flow requirements to complete the project as intended.

Administration recommends that (1) Council authorize Administration to endorse the amending agreement and (2) approve the attached budget adjustment.

Administration Resources
Doug Hafichuk, Capital Projects

BUDGET IMPLICATIONS:

Expenses for budget year 2020 will increase by $358,865 with offsetting revenues coming from the Province of Alberta.

OPTIONS:

Option #1	Motion #1	THAT Administration be directed to endorse the amended funding agreement between Rocky View Count and the Province of Alberta.
	Motion #2	THAT the budget adjustment for the Bragg Creek Flood Mitigation Project be approved as described in Attachment 'A'.
Option #2	THAT alternative direction be provided.	

Respectfully submitted,

"Byron Riemann"

Executive Director of Operations

Concurrence,

"Al Hoggan"

Chief Administrative Officer

DH/bg

ATTACHMENTS:

ATTACHMENT 'A' – Budget Adjustment Form

ATTACHMENT 'B' – Letter from Deputy Minister Yee

Brenda Gellately

From:	Michelle Mitton
Sent:	July 29, 2020 10:54 AM
To:	Brenda Gellately
Subject:	RE: Motions - July 29 Council

Here you go!

2020-07-28-16 (D-7)
Divisions 4 and 5 – Glenmore Trail and Garden Road Intersection Improvement – Budget Adjustment
File: 4055-660

MOVED by Councillor Gautreau that the budget adjustment for intersection improvements at Glenmore Trail and Garden Road be approved as described in Attachment 'A'.

Carried

2020-07-28-17 (D-8)
Division 1 – Provincial Funding Amendment for Bragg Creek Flood Mitigation
File: 1025-700

MOVED by Councillor Kamachi that Administration be directed to endorse the amended funding agreement between Rocky View Count and the Province of Alberta.

Carried

MOVED by Councillor Kamachi that the budget adjustment for the Bragg Creek Flood Mitigation Project be approved as described in Attachment 'A'.

Carried

2020-07-27-34 (K-3)
All Divisions – Confidential Closed Session Item – Blazer Estates – Watermark Water System
File: RVC2020-27

MOVED by Councillor Henn that Administration be directed to negotiate with Blazer Water Systems Ltd. for the acquisition of the water system.

Carried
Absent: Councillor Kamachi
Councillor Kissel

MICHELLE MITTON, M.Sc
Legislative Coordinator | Municipal Clerk's Office

ROCKY VIEW COUNTY
262075 Rocky View Point | Rocky View County | AB | T4A 0X2
Phone: 403-520- 1290 |
MMitton@rockyview.ca | www.rockyview.ca

This e-mail, including any attachments, may contain information that is privileged and confidential. If you are not the intended recipient, any dissemination, distribution or copying of this information is prohibited and unlawful. If you received this communication in error, please reply immediately to let me know and then delete this e-mail. Thank you.

Community Information Session
Springbank Off-Stream Reservoir (SR1)

September/October 2020
Alberta Transportation

Classification: Public

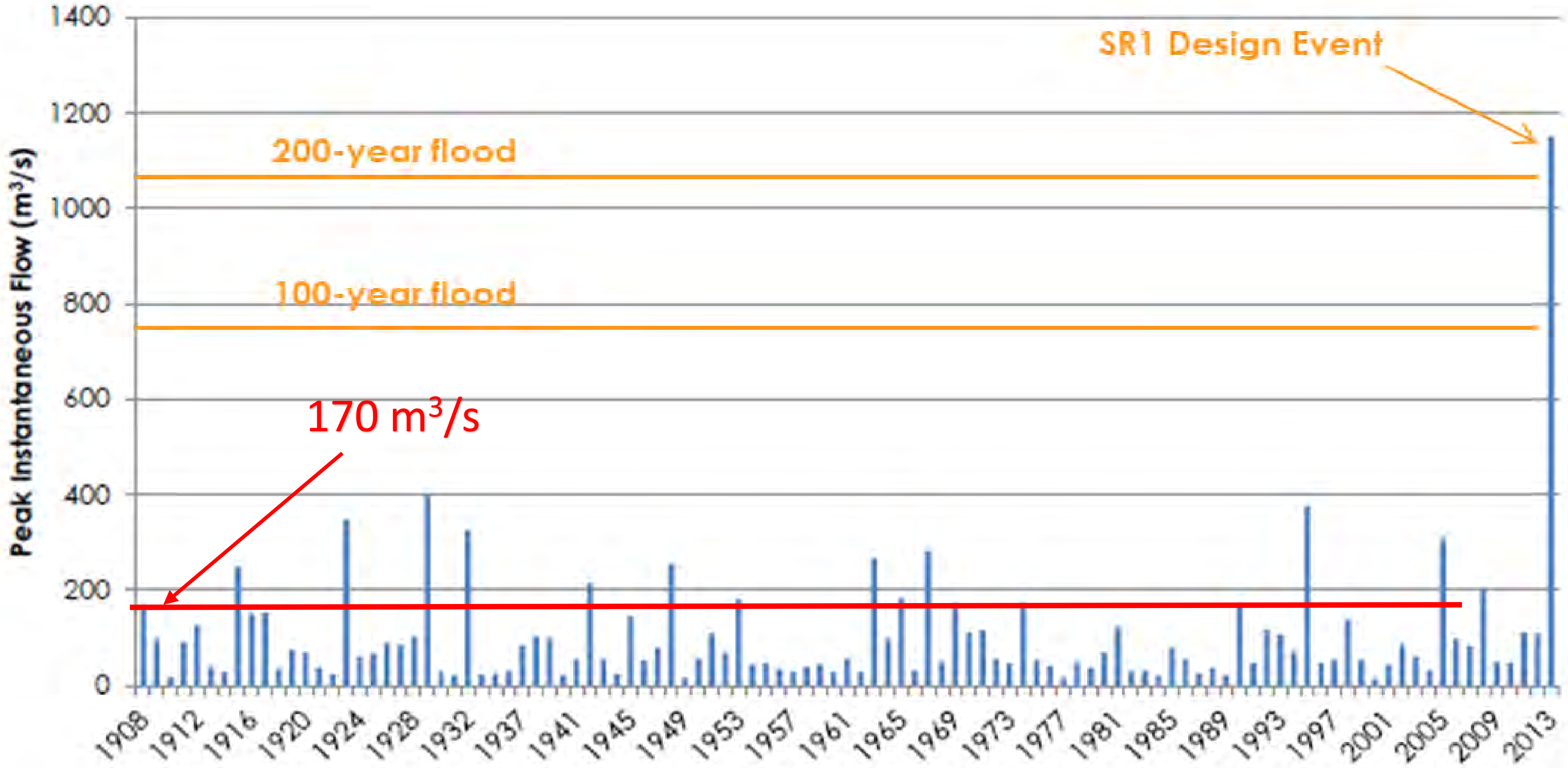
2013 Flood

Massive flooding in southern Alberta and Calgary in 2013 resulted in significant economic and personal costs for the province:

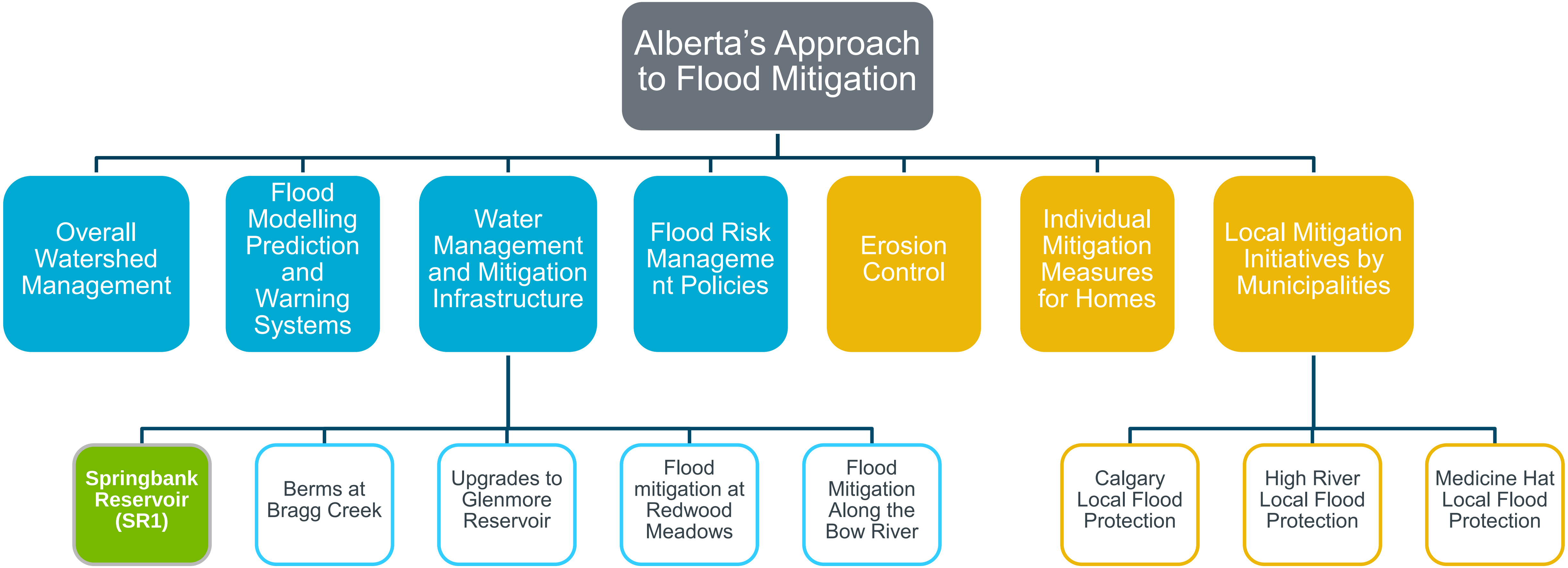
- $5 billion+ in damages and recovery costs
- 5 fatalities
- 4,000 impacted businesses
- Damage to roads, bridges, pathways, parks, and transit systems.
- 80,000 people evacuated
- 3,000 buildings flooded

Historic Floods on Elbow River

Historically, flooding in southern Alberta is a regular and common occurrence.



Provincial System for Flood Mitigation

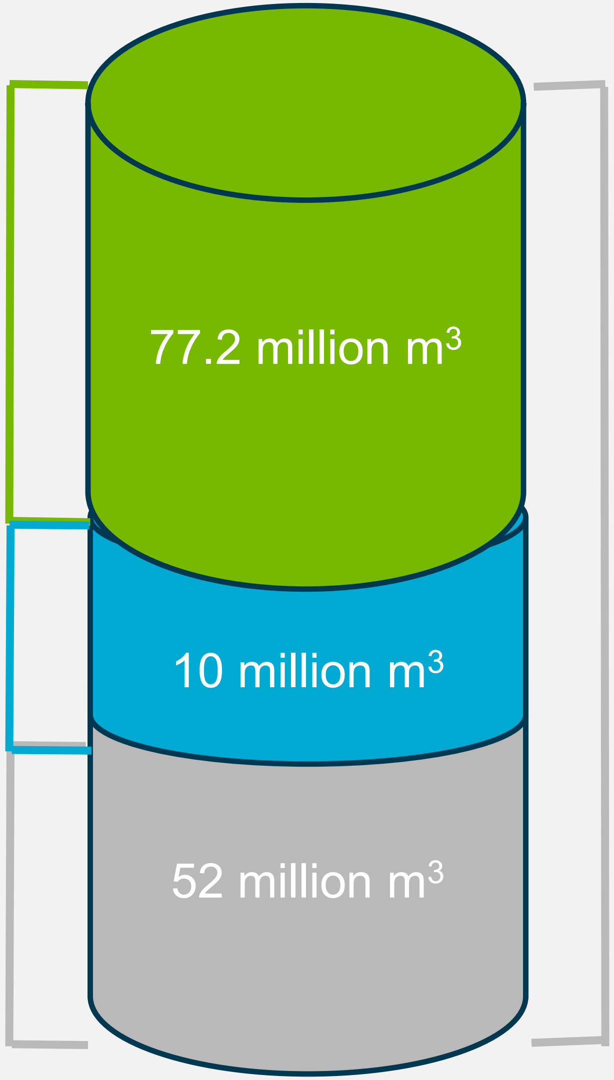


Alberta's Approach to Flood Mitigation

- Overall Watershed Management
- Flood Modelling Prediction and Warning Systems
- Water Management and Mitigation Infrastructure
  - **Springbank Reservoir (SR1)**
  - Berms at Bragg Creek
  - Upgrades to Glenmore Reservoir
  - Flood mitigation at Redwood Meadows
  - Flood Mitigation Along the Bow River
- Flood Risk Management Policies
- Erosion Control
- Individual Mitigation Measures for Homes
- Local Mitigation Initiatives by Municipalities
  - Calgary Local Flood Protection
  - High River Local Flood Protection
  - Medicine Hat Local Flood Protection

Classification: Public

How Does SR1 Work?



SR1 storage

77.2 million m^3

Glenmore storage

10 million m^3

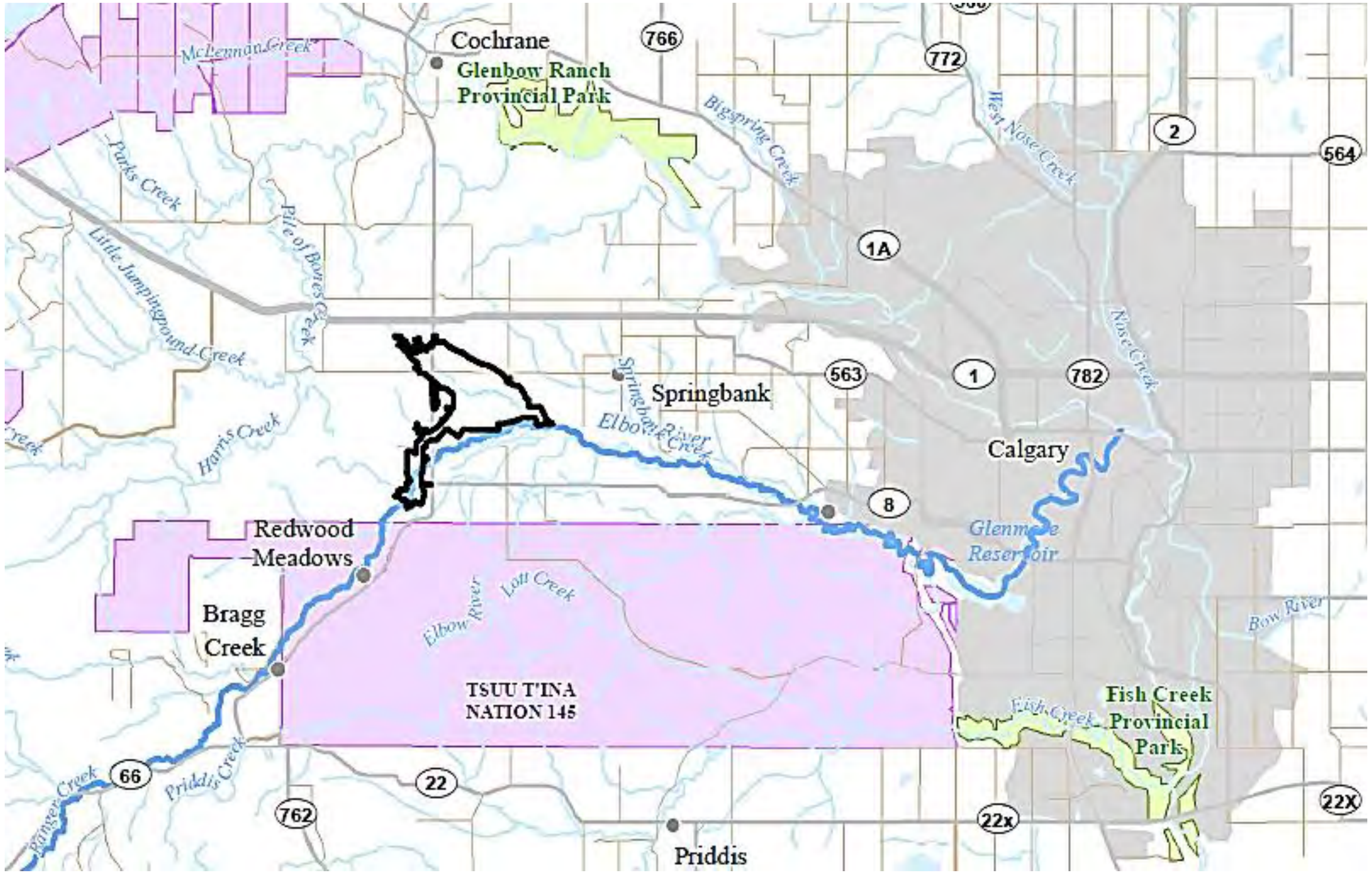
Can Safely Pass Without Damage

52 million m^3

2013 Flood Volume

Classification: Public

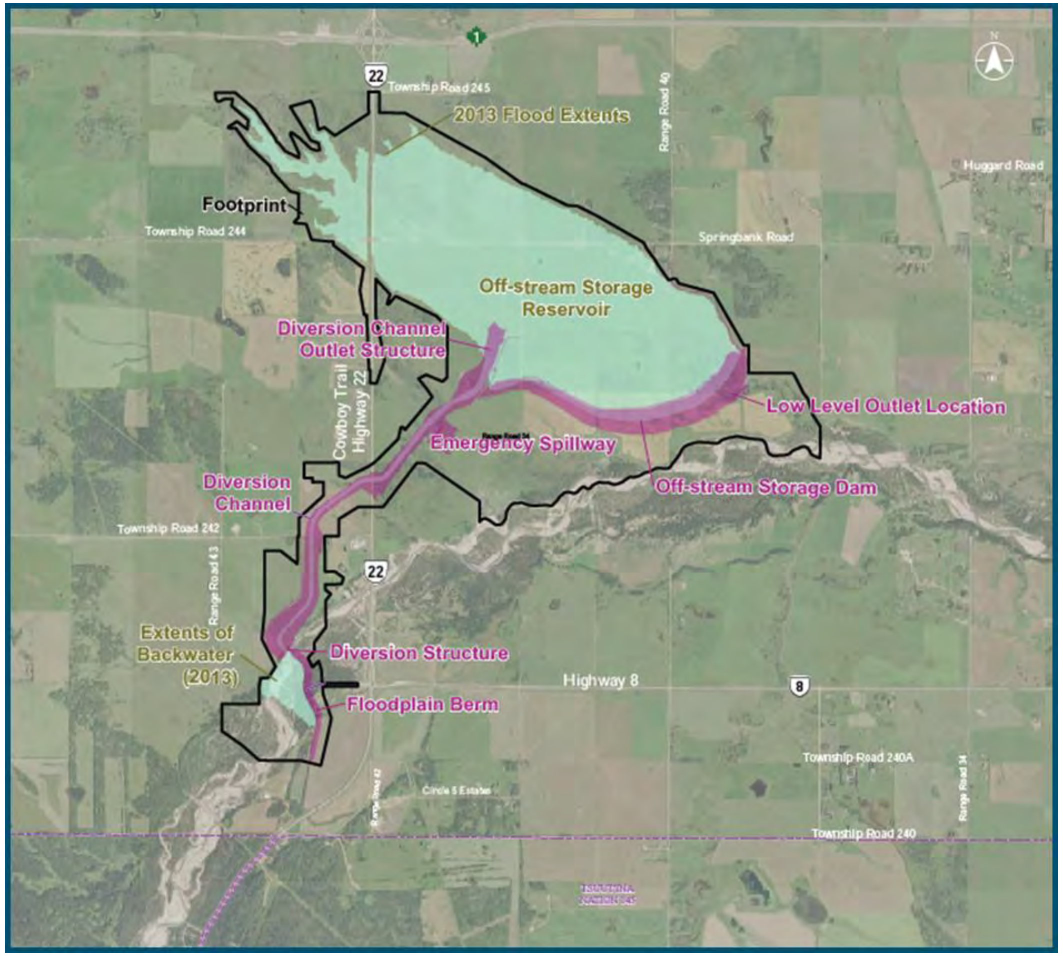
SR1 Location



Location based on:

- Existing topographic conditions.
- Downstream for larger catchment
- Safely pass larger floods
- Minimal impact on environment

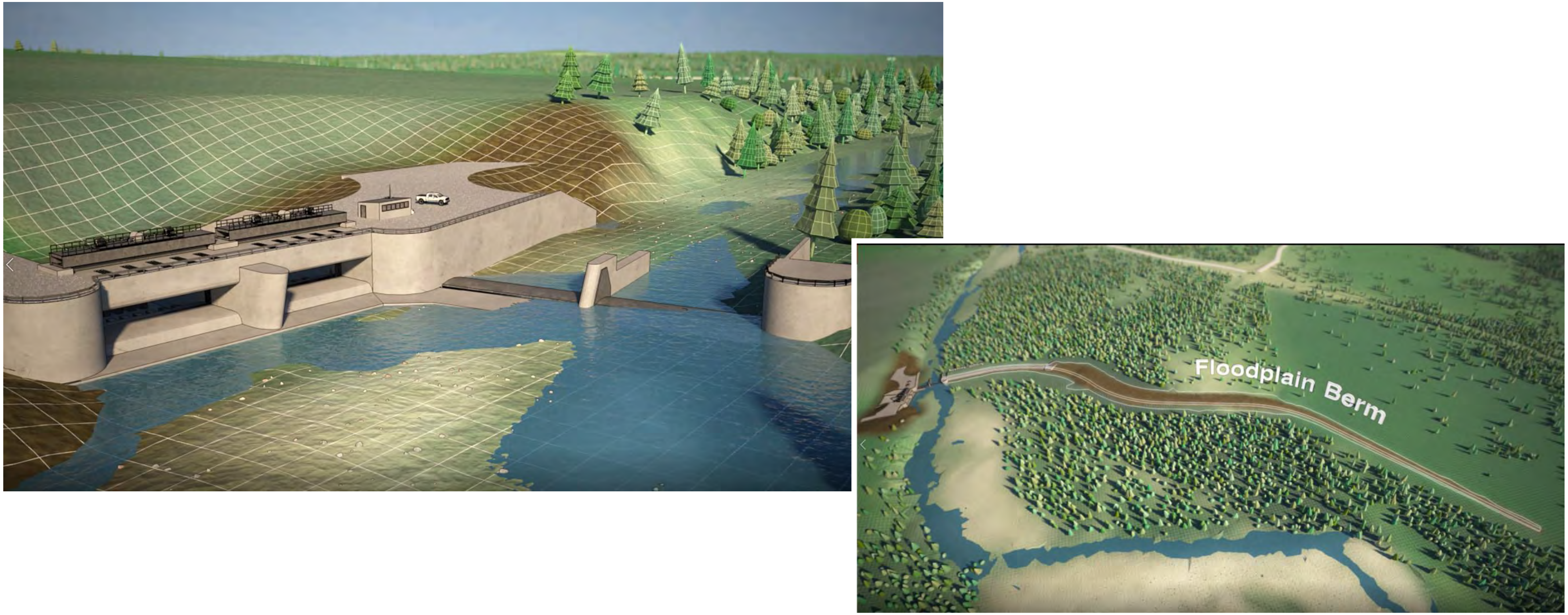
Key Components



- Diversion Structure
  - Debris Barrier
- Floodplain Berm
  - Auxiliary Spillway
- Diversion Channel
  - Emergency Spillway
- Dam
- Low Level Outlet

Classification: Public

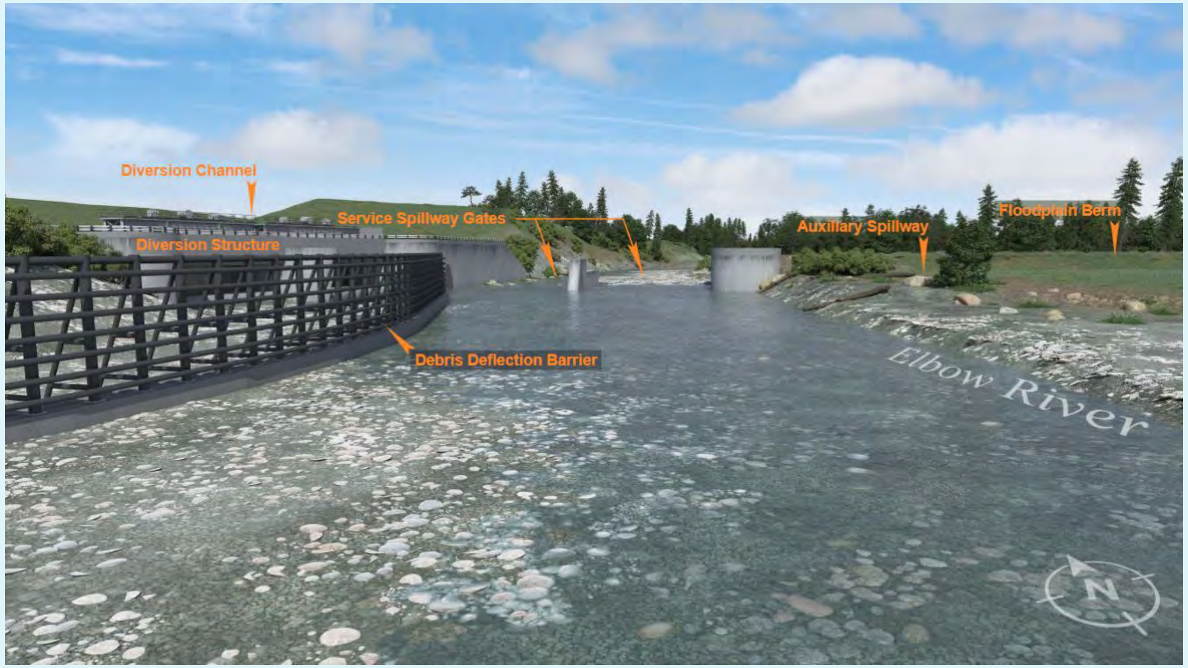
Diversion Structure and Floodplain Berm



Project **Before**

Location: Elbow River at the Diversion Structure

Project **After**



Project **Before**

Location: Highway 22, bridge crossing the Elbow river

Project **After**

Project **Before**

Location: Highway 22, Intersection with Springbank Road

Project **After**

Classification: Public

Project Operations

- Activates at 160m^3/s
- Excess flow diverted to reservoir up to 600 m ^{3}/s
- Up to 77.2 million m^3 in storage

Classification: Public

Emergency Operations Notification

- Alberta Environment and Parks will implement an Emergency Operations Notification system in case of emergencies such as a flood warning:
    - Residents and Indigenous groups will be notified, and public warnings will be issued.
    - Local authorities and emergency services will be contacted.
    - Evacuation zones will be established.
    - Applicable government agencies will be contacted as required.

Classification: Public

Regulatory Process

Provincial Approval

- Environmental Impact Assessment review
- Supplemental Information Requests
- Natural Resources Conservation Board Hearing process

Federal Approval

- Impact Assessment Agency of Canada review
- Supplemental Information Requests
- Construction approvals

Engagement

Stakeholders:

- Landowners
- City of Calgary
- Rocky View County
- Springbank Community Association
- Calgary River Communities Action Group
- Irrigation companies
- Downstream communities
- Bow River Basin Council
- Elbow River Sustainability Alliance

Indigenous Groups:

- Kainai/Blood Tribe
- Piikani Nation
- Siksika Nation
- Stoney Nakoda Nations
- Tsuut'ina Nation
- Ermineskin Nation
- Louis Bull Tribe
- Montana Nation
- Samson Cree Nation
- Metis Nation of Alberta Region 3
- Metis Nation of British Columbia
- Ktunaxa Nation Council
- Foothills Ojibway Society

SR1 Stakeholder Concerns and Mitigations

- Impacts to land, air, water and wildlife.
  - Monitoring plans have been developed to identify and address impacts.

- Land Use
  - Transportation is engaging with First Nations and others to:
    - Determine future land uses.
    - Enable Indigenous participation in construction and operations.

Classification: Public

SR1 Land Use

- Primary use is flood mitigation
- Secondary use principles:
  - Safety overrides all secondary uses
  - Only uses that have a minimal impact on the land will be permitted
  - Indigenous groups' traditional uses and Treaty rights are a priority
  - Non-motorized recreation will be permitted in some areas
  - Grazing may be used to manage ecosystem health
- AEP will develop the final Land Use Plan with stakeholder input

Classification: Public

SR1 Land Acquisition

- Land acquisition
  - Voluntary acquisitions are being pursued.
  - Approximately 25% of land has been acquired.
  - Compensation is based on Expropriation Act principles.

Classification: Public

SR1 Environmental Impacts and Mitigation

- Environmental concerns have been expressed by stakeholders, Indigenous groups, regulators, and the SR1 team.
- Impacts that cannot be mitigated by Project design will be addressed through modeling, monitoring plans, and other restoration measures after construction.

SR1 Mitigation and Monitoring

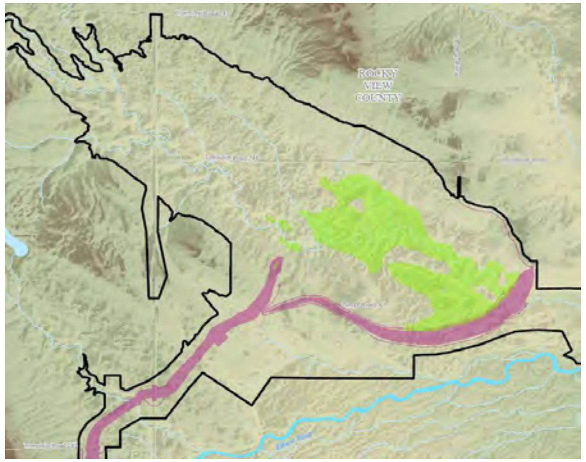
- Mitigation and Monitoring plans are in place to identify when impacts occur and to determine mitigation response.

Fish, Fish Habitat, and Downstream Migration

Sediment and Dust

Surface Water Quality and Contamination

Groundwater and Well Water Impacts



SR1 Mitigation and Monitoring

- Mitigation and Monitoring plans are in place to identify when impacts occur and to determine mitigation response.

Wildlife – Project designed to limit effects on wildlife

Vegetation – Reverts pasture land to more natural state

Air Quality – Dust during construction / operations

Cost and Budget

- Total project budget is $432 million.
- Final project cost will be based on:
  - final land acquisition costs;
  - final design and tendering;
  - cost of conditions from the regulatory process; and
  - project taking longer to complete relative to initial assumptions.

- SR1 is eligible for federal support of $168.5 million under the Government of Canada’s Disaster Mitigation and Adaptation Fund.

Next Steps

- Complete responses to federal and provincial SIRs
- Continue engagement with stakeholders and Indigenous groups
- NRCB issues Notice of Prehearing meeting
- Prehearing meeting (opportunity to ask NRCB to participate in public hearing)
- NRCB Hearing (opportunity for public participation)

Questions or Comments?

To stay up to date about the project please visit our webpage at:
https://www.alberta.ca/springbank-off-stream-reservoir.aspx

For future inquiries please email us at:
Springbank-Project@gov.ab.ca

Classification: Public

Flood Mitigation Measures Elbow River, Sheep River and Highwood River Basins

120990001

Prepared for:
Community Flood Mitigation
Advisory Panel

Prepared by:
Rick Carnduff, M. Eng., P. Eng.

October 25, 2013

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October 25, 2013
File: 1209 90001.100.200

Attention: Mr. Allan Markin, Chair
Community Flood Mitigation Advisory Panel
AMP Financial Inc.
2000 – 444 5th Avenue SW
Calgary, AB, T2P 2T8

Dear Sir,

Reference: Proposed Flood Mitigation Measures
Elbow River, Sheep River and Highwood River Basins

Stantec Consulting Ltd. is pleased to provide you with this draft technical report which describes the proposed flood mitigation measures for the Elbow River, Sheep River and Highwood River basins.

This report presents the design basis, conceptual details and Opinions of Probable Costs for the proposed flood mitigation measures. Recommendations for future action, construction timing and regulatory approval requirements are not included as discussions remain on going with respect to these issues. A CD is inserted on the back cover of the report which contains the PCSWMM model files, video clips of the animated hydraulic gradeline routing through the storage locations and PDF copy of this report.

Should you have any questions or require additional information with respect to this matter, please contact the undersigned.

Sincerely,

STANTEC CONSULTING LTD.

R. D. (Rick) Carnduff, M.Eng., P.Eng.
Principal, Community Development
Phone: (403) 716-8213
Fax: (403) 716-8099
rick.carnduff@stantec.com

c. Mr. A. Corbould, Alberta Transportation
Mr. Mr. T. DiManno, Flood Mitigation Advisory Panel
Mr. R. Lindseth, Flood Mitigation Advisory Panel
Mr. R. Samaska, Pillar Engineering & Inspection Ltd.
Mr. R. Mackenzie, Stantec Consulting Ltd.
Mr. H. Perrin, Stantec Consulting Ltd.

rdc v:\1164\miscellaneous\164-stormwater\swm projects\project files\miscellaneous\flood advisory 2013\report\afap_technical report_transmittal_24oct2013.docx

Sign-off Sheet

This document entitled Flood Mitigation Measures Elbow River, Sheep River and Highwood River Basins was prepared by Stantec Consulting Ltd. for the account of the Community Flood Mitigation Advisory Panel. The material in it reflects Stantec's best judgment in light of the information available to it at the time of preparation. Any use which a third party makes of this report, or any reliance on or decisions made based on it, are the responsibilities of such third parties. Stantec Consulting Ltd. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

Prepared by ____________________
(Rick Carnduff)

Reviewed by ____________________
(Russ Mackenzie)

PERMIT TO PRACTICE
STANTEC CONSULTING LTD.
Signature ____________________
Date Oct. 25/2013
PERMIT NUMBER: P 0258
The Association of Professional Engineers,
Geologists and Geophysicists of Alberta

CORPORATE AUTHORIZATION

R. D. CARNDUFF
Oct. 25/2013

RESPONSIBLE ENGINEER

Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

1.0 Introduction

The Community Flood Mitigation Advisory Panel, hereinafter referred to as the Panel, was created in July 2013 to advise the government of Alberta on possible flood mitigation measures that may be implemented to reduce future flood damages. Stantec Consulting Ltd. was commissioned by the Panel, on behalf of the Government of Alberta, to assist their efforts by providing engineering assessments and practical solutions on possible mitigation measures. To date the Panel has instructed Stantec to address the Elbow River, Sheep River and Highwood River basins with the design objective being mitigation of a flood event identical to that of June 19-21, 2013. As part of the review the Panel advised that any recommendations made should follow a systems approach to the mitigation and it was felt that the best solutions were those that served all Albertans wherever possible.

At the time of this writing, the Panel has requested Stantec to provide investigations for possible mitigation measures within the Bow River basin as well as additional investigations in response to individuals coming forward with local flooding concerns. These additional investigations will be addressed in future writings or updates of this report.

During the course of this assignment the Panel and Stantec collectively met with representatives of the public, the municipalities of Calgary, High River and Bragg Creek, the Provincial government, the Federal government and non-government organizations. Representatives of the three municipalities provided valuable insight on the flood conditions that were experienced this past June and the baseline levels of flow that the three rivers can accommodate without flooding of private properties. A listing of some of the individuals who Stantec contacted on behalf of the Panel is provided in **Appendix C**.

The information presented in this report is limited to the technical aspects of the investigations undertaken by Stantec along with the concepts prepared for the suggested flood mitigation improvements. However the flood mitigation review followed the Province of Alberta's 7 Elements of Mitigation as provided below :

- Overall Watershed Management for floods, drought, water supply, environmental, etc...
- Flood Forecasting, Modelling and Warning Systems
- Flood Risk Management Policies (Mapping, Development Control, Etc...)
- Community Mitigation Panels, Teams and Advisors
- Erosion Control
- Local and Municipal Mitigation Plans and Initiatives
- Individual Mitigation Measures for Homes

2.0 Elbow River Basin

2.1 GENERAL DESCRIPTION

Figure 2.1 illustrates the Elbow River basin at its mouth, which is the confluence at the Bow River. The Panel concentrated its efforts on that portion of the basin upstream of the Glenmore Reservoir as City of Calgary officials indicated that they are undertaking their own review of mitigative measures within the city. Stantec therefore investigated opportunities for new infrastructure within the basin that comprises detention storage, conveyance improvements and diversions.

2.2 RIVER FLOWS

Figure 2.2 shows the June 2013 hydrographs for Elbow River flows entering Glenmore Reservoir and discharging over the reservoir's spillway (Source: City of Calgary). As shown, the peak flow over Glenmore Reservoir was recorded to be about 700 m^3/s. City of Calgary officials indicated that the Elbow River downstream of Glenmore Reservoir can accommodate a flow of about 180 m^3/s before protective measures such as sand bagging are implemented to prevent flooding of private property. From these results it was estimated that a total temporary storage capacity of about 100 million (M) m^3 would be required within the Elbow River basin upstream of Glenmore Reservoir to fully mitigate the 2013 flows to 180 m^3/s.

Flow data was also obtained from Alberta Environment and Sustainable Resource Development (ESRD) for the two active Water Survey of Canada gauging stations on the Elbow River upstream of Glenmore Reservoir. Station 05BJ004 is located at Bragg Creek and station 05BJ010 is located at the Sarcee Bridge. As shown by **Figure 2.3,** there are some gaps in the data for the Sarcee Bridge station, although this is not considered to be crucial for this review. What is more significant is that the flow data provided by ESRD suggest a significantly lower peak than that of the City's data for Glenmore Reservoir inflows; both locations being essentially the same. We discussed this with Ms. Colleen Walford, a River Flow Forecaster with ESRD, who indicated that the City of Calgary data is more reliable because they measure they measure the rise in water level in Glenmore Reservoir and thus translate the stage to volume over time. The June 2013 flow exceeded the established discharge rating of station o5BJ010 so the results are not reliable.

2.3 DETENTION STORAGE SITES

Based on discussions with City officials it was determined that the maximum storage potential of Glenmore Reservoir is in the order of 10 M m^3 should the water level be lowered to its minimum operating level for the Glenmore Water Treatment Plant in advance of a flood event. This comprises only 10% of what is required to mitigate the 2013 flows, so further attention was given to potential storage sites upstream in the basin.

The most common type of storage that has been used for flood control comprises reservoirs that retain a certain amount of permanent water. Glenmore Reservoir is an example, which is typically referred to as retention storage. Retention storage facilities in the form of wet ponds and wetlands are used as stormwater management systems for discharge rate control and treatment of stormwater. Less common, but just as effective, are detention storage facilities that do not retain any permanent water but allow normal flows to pass without hindrance. As large flood control works these are referred to as dry berms or dry dams. In smaller stormwater management systems these comprise multi-purpose dry ponds.

Retention facilities result in the potential for permanent impacts within the permanently wet reservoir. This can result in significant costs to mitigate these impacts and a lengthy period for regulatory approvals. By comparison, detention facilities only cause temporary impacts during construction of the berm/dry dam structure itself which can be mitigated. For this reason dry detention storage facilities were considered for the Elbow River rather than retention facilities.

Existing 1:50,000 scale topographic mapping was initially studied for potential storage sites. Factors that were considered for identifying favourable sites included narrow sections of the river valley to minimize dry dam width, wide upstream valley for enhanced flooded area which translates to storage volume and minimal impacts on farmstead sites, recreation areas or buildings. Sites located on any First Nations land were avoided in this review.

Three potential sites were initially identified for possible consideration. Upon helicopter inspections undertaken on August 6, 2013, two of the sites were chosen as potential favourable storage locations and their locations revised. The proposed detention storage locations are shown on **Figure 2.4**. Both sites are located upstream of Bragg Creek. Site EQ1 is located on the Elbow River at the junction of Quirk Creek. Site EC1 is located on Canyon Creek about 4 km north of secondary Highway 66. .

Orthoshop Geomatics was commissioned to provide LiDAR (Light Detection and Ranging) topographic information for Sites EC1 and EQ1. This work was undertaken in early September 2013. Orthoshop collected point density data at an average of 3 points/m^2 which gave 18 cm resolution, and provided the bare earth DEM (Digital Elevation Model). From this data contours were generated for the two sites.

Conceptual details of the dry dams were prepared and the extents of temporary flooding determined. **Figure 2.5** and **Figure 2.6** show the extents of temporary flooding at the full supply level (FSL) for the two sites while **Table 2.1** and **Table 2.2** list their storage rating relationships. The full supply level is defined as the maximum water level below which discharges are controlled through a low-level conduit. When water levels rise above the FSL emergency discharges occur through an overflow spillway. By comparison, the design operating level (DOL) is the estimated water level based on the 2013 inflows and controlled discharges.

Figure 2.7 and **Figure 2.8** show conceptual details of the dry dams. A low-level conduit is used to convey the controlled discharges through the dam. This conduit is sized based on open channel flow principles to avoid a surcharge condition (i.e. HGL above the crown). An orifice-type control device mounted on the inlet of the conduit controls the discharges based on orifice flow principle. Not shown on the figures, but crucial to the design, is an emergency spillway that is designed to convey flood discharges that result in water levels rising above the FSL (i.e. > 2013 event). The spillway may comprise an open chute over the top of the dry dam or a drop inlet on the upstream slope of the dry dam with closed conduit through the dry dam. This will be addressed further at the time of detailed design. The advantage of the drop-inlet design is that the top of the dry dam is continuous which allows for public use should recreation be incorporated as an amenity.

Table 2.1 - Storage Rating Data for Site EC1

Elevation	Depth (m)	Area (m²)	Volume (m³)
1527.8	0.0	0	0
1530.0	2.2	5,854	6,439
1540.0	12.2	119,797	634,694
1550.0	22.2	223,624	2,351,799
1560.0	32.2	428,842	5,614,129
1566.7 (DOL)	39.3		≈ 9,189,000
1570.0	42.2	630,432	10,910,499
1572.0 (FSL)	44.2	665,556	12,206,487

Table 2.2 – Storage Rating Data for Site EQ1

Elevation	Depth (m)	Area (m²)	Volume (m³)
1532.4	0.0	0	0
1540.0	7.6	229,342	871,500
1550.0	17.6	917,982	6,608,120
1560.0	27.6	1,918,107	20,788,565
1570.0	37.6	2,794,227	44,350,235
1570.1 (DOL)	37.7		≈ 44,628,000
1578.0 (FSL)	45.6	3,688,142	70,279,711

It is anticipated that debris carried by flood waters will collect in front of the conduit inlets. Measures will be incorporated to trap most of this debris so that it does not obstruct flow through the inlet, but there remains the risk of debris partially plugging the inlets. It is therefore recommended that a secondary conduit be installed as a back-up in case the main conduit inlet is partially plugged. This backup conduit would be gated and left in a closed position; being opened only if the main conduit inlet is obstructed.

Other details for the dry dams and structures will be determined at the time of detailed design. As a minimum, these works will need to be designed in accordance with the "Dam Safety Guidelines" (Canadian Dam Association, 2007).

To determine the performance of the two detention sites under the 2013 flood scenario, flow hydrographs were estimated for each site using the flows at Bragg Creek (station 05BJ004) and pro-rating these flows based on contributing area. According to the Water survey of Canada database, the contributing basin area at station 05BJ004 is 790.8 km². Using the available NTS mapping it was estimated that the contributing basin area to site EC1 is 110 km² while the contributing basin area to site EQ1 is 433 km². Thus 13.9% of the Bragg Creek flow was deemed to contribute directly to EC1, 54.8% of the flow contributes directly to EQ1 and the remaining 31.3% of the flow occurs from areas downstream of the two storage sites. **Figure 2.9** shows the estimated flow hydrographs based on these formulae.

The PCSWMM computer model was used to route the flow hydrographs through the EC1 and EQ1 storage sites for the purpose of determining the required sizing of the inlet control orifice and conduit through the dry dam. The PCSWMM model uses the EPA SWMM5 model as the computational engine. The model has the capability to use dynamic flow computations for routing of flows through closed conduits, open channels (including natural river systems) and storage facilities.

The two storage facilities are represented in the model as storage nodes. The storages are represented by a depth-area relationship using the information listed in Tables 2.1 and 2.2. The flow hydrographs that were determined as contributing to each facility (**Figure 2.9**) were input directly into the PCSWMM model as direct inflows to these storage notes.

The existing Canyon Creek and Elbow River water courses were incorporated into the model as far downstream as Bragg Creek for the purpose of comparing the reduction in flows at Bragg Creek as a result of the new storage sites. There was not a deliberate attempt to accurately model the true geometry of the river channels and floodplains since the flow routing is not important for this particular investigation. Rather, a simple trapezoidal geometry was used to convey the flows to Bragg Creek.

Appendix A provides a graphical illustration of the PCSWMM model layout.

Table 2.3 summarizes pertinent details associated with each of the storage locations as well as the peak flows as determined by the PCSWMM model. It is noteworthy that the design FSL for Site EQ1 is much higher than the DOL which can be used as excess capacity to accommodate inflows greater than the estimated 2013 levels. Alternatively the dam height can be reduced for economic reasons.

2.4 FLOW DIVERSION

Additional storage is required to further mitigate the 2013 flood level; preferably downstream of Bragg Creek. However additional suitable sites were not found between Bragg Creek and the City of Calgary. As an alternative, it is proposed to divert flood flows from Glenmore Reservoir to bypass the Elbow River through the City of Calgary.

Three options were considered for this Glenmore Reservoir diversion. Two options involved diverting the flows directly to the Bow River along either 58th Avenue or Heritage Drive, as shown on **Figure 2.10**. Both alignments comprise an underground 8.0 m dia. pipe that would be tunneled under the ground surface to accommodate a peak flow of 500 m^3/s. The third option involved diverting the flows south to Fish Creek, but this was not considered further because of potential impacts to Fish Creek. Upon further review of the other two alignments, the 58th Avenue alignment is preferred.

The concept for the inlet to the diversion tunnel is a vertical drop-shaft inlet that is submerged below the normal operating level of Glenmore Reservoir. The rim elevation is set at the lowest operating level (LOL) for the reservoir which ensures adequate operation of the Glenmore Water Treatment Plant intake. A gate is installed in the tunnel near the inlet. Normally the gate is in a closed position to prevent water from passing through the tunnel when the reservoir water levels are within their normal range of operation. In anticipation of a flood event the water level in the reservoir is drawn down to the LOL. The gate is then opened and water begins to flow over the inlet (weir flow) and down the tunnel to the Bow River. A square inlet with inside dimensions of 10.0 x 10.0 m will pass the design flow of 500 m^3/s assuming an allowable rise in the reservoir level of 2.0 m above the drop-shaft rim elevation.

Table 2.3 – Preliminary Storage Details for the Elbow River

	EC1	EQ1
Top of Dry dam Elevation	1577.0	1583.0
FSL Elevation	1572.0	1578.0
Depth at FSL (m)	44.2 m	45.6 m
Flooded Area at FSL	66.6 ha	368.8 ha
Storage Capacity at FSL	12,206,500 m^3	70,279,700 m^3
Required 2013 Depth, DOL	39.3 m	37.7 m
Required 2013 Storage at DOL	9,189,000 m^3	44,628,000 m^3
Orifice Size	1.2 m dia.	2.0 m dia.
Conduit Size	2.0 H x 3.0 m W	3.0 H x 4.0 m W
2013 Peak Inflow	120.5 m^3/s	474.1 m^3/s
2013 Peak Outflow	18.7 m^3/s	50.3 m^3/s
2013 Peak Flow at Bragg Creek Without Storage	755.7 m^3/s [1]	
2013 Peak Flow at Bragg Creek with Storage	312.2 m^3/s	
2013 Peak Flow Reduction downsteam of Bragg Creek	443.5 m^3/s	

1. The peak flow at Bragg Creek per gauging station 05BJ005 is 866 m^3/s.

Near its outlet at the Bow River the pipe discharges into an underground chamber that is designed to reduce the velocity of the incoming flow. The flow velocities in the tunnel itself will be in the order of 10.0 m/s. Assuming that the inside height of the chamber is 10.0 m, the width of the chamber flares outwards from 10.0 m at the end of the tunnel to 17.0 m at its outlet to reduce the flow velocities to about 3.0 m/s. The chamber discharges into a 20 m wide rock armoured open channel with minimum side slopes of 3H:1V to reduce the flow velocities to about 2.5 m/s, which is roughly the flow velocities in the Bow River itself during flood conditions.

The tunnel outlet chamber will pass under Deerfoot Trail with sufficient clearance to avoid existing utilities. At this time a cover of 3.0 m was assumed. This will result in both the chamber and the rock armoured channel being submerged below the bed level of the Bow River. Thus the flows in the chamber and channel will be fully submerged below the Bow River water levels which will contribute to dissipation of the diversion flow velocities.

Figure 2.11 shows the preliminary design profiles for the two diversion alignments.

McIntosh●Lalani Engineering Ltd. (ML) was commissioned on behalf of the Panel to undertake a preliminary geotechnical investigation of the 58th Avenue tunnel alignment. Their report is provided in **Appendix B.** Generally ML did not identify any unusual or unexpected conditions that may impact the diversion construction. However more detailed investigations are recommended to fully assess the site conditions and determine measures and precautions that will be required for the construction.

3.0 Sheep River Basin

3.1 BACKGROUND INVESTIGATIONS

Figure 3.1 illustrates the Sheep River basin at its mouth, which is its confluence at the Highwood River. The Panel concentrated its efforts on the headwaters area upstream of Black Diamond and Turner Valley. The Panel did not have any opportunities to discuss the flood conditions in the Sheep River with representatives from local municipalities (Black Diamond, Turner Valley, Okotoks, etc.).

3.2 RIVER FLOWS

Flow data was also obtained from Alberta Environment and Sustainable Resource Development (ESRD) for the two active Water Survey of Canada gauging stations on the Sheep River. Referring to **Figure 3.2**, station 05BL012 is located at Okot0ks and station 05BL014 is located at Black Diamond. As shown by the flow hydrographs on **Figure 3.3,** there are significant gaps in the data for both stations which is understood to be caused by the stations being washed out and having to be reinstalled after the main flood flows had passed.. The gauging station at Black Diamond is particularly important because it best reflects the flows within the study area.

3.3 DETENTION STORAGE SITE

As with the Elbow River basin, dry detention storage facilities were considered for the Sheep River upstream of Black Diamond and Turner Valley. Existing 1:50,000 scale topographic mapping was studied for potential storage sites, of which two (2) sites were originally identified.

Upon helicopter inspection of the area, one of the sites was chosen as a potential storage facility and its location was revised slightly. The proposed detention storage location is shown on **Figure 3.4**. Site S2 is located on the Sheep River about 7 km upstream (south-west) of Turner Valley, just below the confluence with Macabee Creek.

Existing LiDAR data was purchased from AltaLIS for Site S2 and adjacent area. The AltaLIS data comprises 15 metre spacing which gives 30 cm accuracy. Using this data contours were generated for the study area.

Conceptual details of the dry dam were prepared and the extents of temporary flooding determined. **Figure 3.5** shows the extents of temporary flooding at the full supply level (FSL) while **Table 3.1** lists the storage rating relationships.

Figure 3.6 shows conceptual details of the dry dam. As with the Elbow River sites, a closed conduit is used to convey the controlled discharges based on open channel flow principles (no surcharging). An orifice-type control device mounted on the inlet of the conduit controls the discharges based on orifice flow principle. Not shown on the figure, but a necessary design element, is an emergency spillway that is designed to convey flood discharges that result in water levels rising above the FSL (i.e. flows > 2013 event). The spillway may comprise an open chute over the top of the dry dam or a drop inlet on the upstream slope of the dry dam with closed conduit through the dry dam. This will be addressed further at the time of detailed design.

Table 3.1 – Storage Rating Data for Site S2

Elevation	Depth (m)	Area (m²)	Volume (m³)
1252.7	0.0	0	0
1254.0	1.3	5,169	3,360
1264.0	11.3	123,591	647,160
1274.0	21.3	402,579	3,278,010
1284.0	31.3	683,426	8,708,035
1294.0	41.3	1,331,981	18,785,070
1297.1 (DOL)	44.4		23,337,000
1298.0 (FSL)	45.3	1,733,524	24,916,080

A secondary conduit would also be installed as a back-up in case the main conduit inlet is partially plugged with debris. This backup conduit would be gated and left in a closed position; being opened only if the main conduit inlet is obstructed.

Other details for the dry dam and structures will be determined at the time of detailed design. As a minimum, these works will need to be designed in accordance with the "Dam Safety Guidelines" (Canadian Dam Association, 2007).

To determine the performance of the detention site under the 2013 flood scenario, a direct-contributing flow hydrograph was estimated for Site S2 using the Black Diamond hydrograph (station 05BL014) and pro-rating the flows based on contributing area. But first the missing flow data for Black Diamond needed to be adjusted to fill in the missing data. The flow hydrograph was compared to other nearby flow hydrographs and it was observed that the shape of the Black Diamond hydrograph most closely resembles the flow hydrograph for station 05BL019 which was used for the Highwood River Basin (see Section 4.0). Thus the missing flow data was estimated assuming that the recession limb follows the same pattern as that of the Highwood River station 05BL019. **Figure 3.7** shows the adjusted flow hydrograph for Black Diamond along with the flow hydrograph for the Highwood River station 05BL019.

According to the Water survey of Canada database, the contributing basin area at station 05BL014 is 592.2 km². Using the available NTS mapping it was estimated that the contributing basin area to site S2 is 500 km². Thus 84.4% of the Black Diamond flow was deemed to contribute directly to S2 while the remaining 15.6% occurs from areas downstream of S2 to Black Diamond. **Figure 3.7** shows the estimated flow hydrographs based on these formulae.

The PCSWMM computer model (see Section 2.3) was used to route the flow hydrographs through the S2 storage site for the purpose of determining the required sizing of the inlet control orifice and conduit through the dry dam. The storage facility is represented in the model as a storage node using the depth-area relationship listed in Tables 3.1. The Town of Black Diamond location was represented as a normal junction node. The flow hydrographs (**Figure 3.7**) were input directly into the PCSWMM model as direct inflows to the storage and junction notes.

The existing Sheep River water course was incorporated into the model as far downstream as Black Diamond for the purpose of comparing the reduction in flows as a result of the new storage site. As with the Elbow River sites, a simple trapezoidal geometry was used to convey the flows to Black Diamond.

Appendix A provides a graphical illustration of the PCSWMM model layout.

Table 3.2 summarizes pertinent details associated with the storage location as well as the peak flows as determined by the PCSWMM model.

Table 3.2 – Preliminary Storage Details for the Sheep River

	S2
Top of Dry dam Elevation	1303.0
FSL Elevation	1298.0
Depth at FSL (m)	45.3 m
Flooded Area at FSL	173.4 ha
Storage Capacity at FSL	24,916,000 m^3
Required 2013 Depth, DOL	44.4 m
Required 2013 Storage at DOL	23,337,000 m^3
Orifice Size	3.8 m dia.
Conduit Size (H x W)	5.0 H x 8.0 m W
2013 Peak Inflow	641.7 m^3/s
2013 Peak Outflow	192.9 m^3/s
2013 Peak Flow at Black Diamond Without Storage	717.8 m^3/s
2013 Peak Flow at Diamond with Storage	280.6 m^3/s
2013 Peak Flow Reduction downstream of Black Diamond	437.2 m^3/s

4.0 Highwood River Basin

4.1 BACKGROUND INVESTIGATIONS

Figure 4.1 illustrates the Highwood River basin at its mouth, which is its confluence at the Bow River. The Panel concentrated its efforts on that portion of the basin upstream of the Town of High River as Town officials indicated that they are undertaking their own review of mitigative measures within the municipality. Stantec therefore investigated opportunities for new infrastructure within the basin that comprises detention storage, conveyance improvements and diversions.

4.2 RIVER FLOWS

Flow data was also obtained from Alberta Environment and Sustainable Resource Development (ESRD) for several active Water Survey of Canada gauging stations in the Highwood River Basin. They are as follows:

05BL004 – Highwood River below Little Bow Canal

05BL007 – Stimson Creek near Pekisko

05BL015 – Little Bow Canal at High River (not used)

05BL019 – Highwood River at Diebel's Ranch

05BL022 – Cataract Creek near Forestry Road

05BL023 – Pekisko Creek near Longview

05BL024 – Highwood River near the Mouth

05BL025 – Highwood Diversion Canal near Headgates (not used)

05BL027 – Trap Creek near Longview

The two stations 05BL015 and 05BL025 were not used for this investigation because they are on man-made water courses that are not part of the natural basin conveyance system. **Figure 4.2** shows the locations of the other gauging stations that were, to some degree, used in support of the investigations while **Figure 4.3** shows the June 2013 flows as provided by ESRD.

As shown by **Figure 4.3,** there are large gaps in the data for most of the gauging stations, which is understood to be caused by the stations being washed out and having to be reinstalled after the main flood flows had passed.

Stantec and the Panel met with Town of High River officials to get an understanding of the magnitude and character of the flood which devastated the Town. The Town had previously engaged Worley Parsons to provide engineering assessments and recommendations for possible flood mitigation measures that the Town might implement within its own municipal boundary. Worley Parsons had prepared a flood river model for planning purposes and in consultation with them and the Town, it was suggested that the peak flow through High River may have been in the order of 1500-1800 m^3/s. Town officials suggested that the Highwood River and proposed dyke upgrades within the town might be able to accommodate peak flows up to about 750 m^3/s before the majority of the town experiences flooding. However, the Hamptons development on the east side of Highway 2 will experience flooding if the flows in the Highwood River exceed about 180 m^3/s

Based on the above information, with emphasis on the suggested flows by the Town of High River and Worley Parsons, it was estimated that a total temporary storage capacity of about 150 million (M) m^3 would be required within the basin to fully mitigate the 2013 flows to 180 m^3/s.

4.3 DETENTION STORAGE SITES

As with the Elbow River basin, dry detention storage facilities were considered for the Highwood River upstream of High River. Existing 1:50,000 scale topographic mapping was studied for potential storage sites, of which five (5) sites were originally identified.

Upon helicopter inspection of the area, three of the sites was chosen as a potential storage facilities, with some revisions to their locations. These proposed detention storage locations are shown on **Figure 4.4**, all of which are located on the Highwood River. Site H2 is located about 7 km upstream (north-west) of Longview, just below the confluence with Ings Creek. Sites H5(1) and H5(2) are located immediately west of the Eden Valley Indian Reserve. Upon further review of the H5 sites it was concluded that the combined benefit of the two sites could be achieved by just Site H5(2) using a higher dry dam to increase the storage capacity. Therefore Site H5(1) was dropped from further consideration.

Existing LiDAR data was purchased from AltaLIS for Site H2 and H5(2) areas. The AltaLIS data comprises 15 metre spacing which gives 30 cm accuracy. Using this data contours were generated for the study area.

Conceptual details of the dry dams were prepared and the extents of temporary flooding determined. **Figure 4.5** and **Figure 4.6** show the extents of temporary flooding at their full supply levels (FSL) while **Table 4.1** and **Table 4.2** list their storage rating relationships.

Figure 4.7 and Figure 4.8 show conceptual details of the dry dams. As with the Elbow River sites, a closed conduit under each dry dam is used to convey the controlled discharges based on open channel flow principles (no surcharging). An orifice-type control device mounted on the inlet of the conduit controls the discharges based on orifice flow principle. Not shown on the figure, but a necessary design element, is an emergency spillway that is designed to convey flood discharges that result in water levels rising above the FSL (i.e. flows > 2013 event). The spillway may comprise an open chute over the top of the dry dam or a drop inlet on the upstream slope of the dry dam with closed conduit through the dry dam. This will be addressed further at the time of detailed design.

Table 4.1 – Storage Rating Data for Site H2

Elevation	Depth (m)	Area (m^2)	Volume (m^3)
1219.25	0.0	0	0
1220.0	0.75	2,485	932
1228.0	8.75	85,737	353,820
1238.0	18.75	236,401	1,964,510
1248.0	28.75	442,753	5,360,280
1258.0	38.75	1,706,348	16,105,785
1260.25 (DOL)	41.0		20,235,000
1268.0 (FSL)	48.75	3,074,902	40,012,035

Table 4.2 – Storage Rating Data for Site H5(2)

Elevation	Depth (m)	Area (m^2)	Volume (m^3)
1432.5	0.0	0	0
1434.0	1.5	20,746	15,560
1438.0	5.5	253,176	563,404
1448.0	15.5	1,183,183	7,745,199
1458.0	25.5	2,142,893	24,375,579
1468.0	35.5	2,972,740	49,953,744
1471.3 (DOL)	38.8		60,245,000
1474.0	41.5	3,460,442	69,253,290
1478.0 (FSL)	45.5	3,844,742	83,863,658

A secondary conduit would also be installed as a back-up in case the main conduit inlet is plugged with debris. This backup conduit would be gated and left in a closed position; being opened only if the main conduit inlet is obstructed.

Other details for the dry dam and structures will be determined at the time of detailed design. As a minimum, these works will need to be designed in accordance with the “Dam Safety Guidelines” (Canadian Dam Association, 2007).

To determine the performance of the detention sites under the 2013 flood scenario, direct-contributing flow hydrographs were estimated for Sites H2 and H5(2). The gauging station 05BL019 is immediately downstream of Site H5(2) so the flows at this station were assumed to reflect the incoming flows at H5(2). The majority of the data for this station is missing, but it appears that the shape of the hydrograph starts out very similar to that of station 05BL022 on Cataract Creek. Also, the contributing watershed to o5BL022 is similar to that of 05BL019. Thus it was assumed that the missing portion of the flow hydrograph for 05BL019 followed the same pattern as 05BL022, so the missing data for 05BL019 was estimated accordingly. **Figure 4.9** shows the adjusted flow hydrograph for 05BL019 along with the hydrograph for 05BL022.

The Trap Creek gauging station 05BL027 is closest to site H2 so this station was utilized to estimate the additional contributing runoff to site H2 from the catchment area downstream of Site H5(2). However the flow hydrograph for 05BL027 is missing the majority of the recession portion of the hydrograph (see Figure 4.3). The missing data was estimated based on the assumption that the recession limb of the hydrograph followed the same pattern as that of the Cataract Creek station 05BL022. The contributing flows to H2 were then estimated using a ratio of contributing drainage areas. According to the Water Survey of Canada database, the total watershed area to station 05BL027 is 165.5 km^2. The estimated contributing area to Site H2, excluding the portion that contributes to Site H5(2), is 416 km^2. Thus the estimated flows at Site H2 are about 2.5 times that of station 05BL027. **Figure 4.9** shows the adjusted flow hydrograph for 05BL027 along with the estimated flow hydrograph at Site H2 from lands downstream of Site H5(2).

An estimate was also made of the additional flows that may have contributed to flooding in the Town of High River from contributing areas downstream of Site H2. The Pekisko Creek gauging station 05BL023 was felt to best represent the flow conditions given proximity to the area and similarity of catchment characteristics. Therefore this station was utilized to estimate the additional contributing runoff to High River from the catchment area downstream of Site H2. However the flow hydrograph for 05BL023 is missing the majority of the recession portion of the hydrograph (see Figure 4.3). The missing data was therefore estimated using the same base assumption as that described above for station 05BL022. The contributing flows to High River were then estimated using a ratio of contributing drainage areas. According to the Water Survey of Canada database, the total watershed area to station 05BL023 is 231.9 km^2. The estimated contributing area to High River, excluding the portion that contributes to Sites H5(2) and H2, is 763.8 km^2. Thus the estimated flows at the Town of High River from lands downstream of Site H2 are about 3.3 times that of station 05BL023. **Figure 4.10** shows the completed flow hydrograph for 05BL023 along with the estimated flow hydrograph at High River from lands downstream of Site H2.

The PCSWMM computer model (see Section 2.3) was used to route the flow hydrographs through the H2 and H5(2) storage sites for the purpose of determining the required sizing of the inlet control orifice and conduit through the dry dam. The storage facilities are represented in the model as storage nodes using the depth-area relationship listed in Tables 2.1. The Town of High River was represented as a normal junction node. The flow hydrographs (**Figures 4.9** and **4.10**) were input directly into the PCSWMM model as direct inflows to the storage and junction notes.

The existing Highwood River water course was incorporated into the model as far downstream as High River for three purposes:

1. To interconnect Sites H2 and H5(2) and simulate the addition of controlled discharges from H5(2) through H2;
2. To compare the reduction in flows as a result of the new storage site; and
3. To simulate the flow diversion described in the next section around High River.

As with the Elbow River basin, a simple trapezoidal geometry was used in the PCSWMM model to approximate the channel routing.

Appendix A provides a graphical illustration of the PCSWMM model layout.

Table 4.3 summarizes pertinent details associated with the storage location as well as the peak flows as determined by the PCSWMM model. The design FSL for both Site H2 and Site H5(2) are much higher than the DOL which can be used as excess capacity to accommodate inflows greater than the estimated 2013 levels. Alternatively the dam height can be reduced for economic reasons.

Table 4.3 – Preliminary Storage Details for the Highwood River

	H2	H5(2)
Top of Dry dam Elevation	1273.0	1483.0
FSL Elevation	1268.0	1478.0
Depth at FSL (m)	48.8 m	45.5 m
Flooded Area at FSL	307.5 ha	384.5 ha
Storage Capacity at FSL	40,012,000 m^3	83,864,000 m^3
Required 2013 Depth, DOL	41.0 m	38.8 m
Required 2013 Storage at DOL	20,235,000 m^3	60,245,000 m^3
Orifice Size	5.0 m dia.	3.7 m dia.
Conduit Size (H x W)	6.0 H x 8.0 m W	6.0 H x 6.0 m W
2013 Peak Inflow	575.1 m^3/s	984.6 m^3/s
2013 Peak Outflow	306.1 m^3/s	168.5 m^3/s
2013 Peak Flow at High River Without Storage	1739.7 m^3/s [1]	
2013 Peak Flow at High River with Storage	717.4 m^3/s	
2013 Peak Flow Reduction at High River	1022.3 m^3/s	

4.4 FLOW DIVERSION

Additional storage is required downstream of Site H2 so as to capture additional contributing flows to further mitigate the 2013 flood level at High River. However additional suitable sites were not deemed suitable because the river bed and valley become wider towards High River and the area is more populated. As an alternative, it is proposed to divert flood flows from Highwood River around High River and reintroduce the water back into the Highwood River downstream of the Town.

Figure 4.11 shows the proposed alignment for the diversion and **Figure 4.12** shows the proposed profile. The diversion is designed for a peak flow of 500 m^3/s. The north-south leg is trapezoidal in shape with a bottom width of 160 m wide so that it may be farmed. The east side slope is 3H:1V while the west side slope is 10H:1V. Its longitudinal gradient is 0.01% to provide non-erosive flow velocities. The east-west leg has a slope of 0.38% which is steep enough to caused erosive flow velocities. Therefore this portion comprises a rock rip-rap trapezoidal channel (or alternative) with a bottom width of 25 m and side slopes of 3H:1V.

There are numerous considerations and alternatives that could be further considered as part of the final design. One such consideration is to incorporate a small ditch in the center of the bottom to accommodate positive drainage of the bottom if it is going to be farmed. The bottom of the channel would thus be sloped towards this ditch (say 1 %) to ensure positive drainage.

Based on the PCSWMM modelling, the peak 2013 flow through the Town of High River with the two storage sites and diversion is 167.4 m^3/s.

5.0 Opinions of Probable Cost

In consultation with contractors who are familiar with this type of work, Stantec prepared Opinions of Probable Cost (OPC) for construction of the proposed mitigation measures as described in Sections 2.0, 3.0 and 4.0. These opinions were prepared in accordance with APEGGA's procedures as described in the presentation made by Dr. Nick J. Lavingia to the APEGGA Annual Conference on June 26-27, 2007. The excerpt from that presentation which was used to guide our estimations is included in **Appendix E**.

Table 5.1 summarizes our OPCs for the mitigation measures. These Opinions exclude professional fees related to designs, construction management, environmental studies or related investigations.

Table 5.1 – Storage Rating Data for Site H5(2)

Mitigation Site	Opinion of Probable Cost (Million Dollars) [1]
Dry Dam Site EQ1	\$75 - \$95
Dry Dam Site EC1	\$30 - \$35
Glenmore Reservoir Diversion	\$200 - \$290
Dry Dam Site S2	\$90 - \$100
Dry Dam Site H2	\$90 - \$100
Dry Dam Site H5(2)	\$85 - \$100
Town of High River Diversion	\$90 - \$100
Totals	**\$660 - \$820**

1. The Opinion of Probable Costs are based on construction of a dry dam to the Design Operating Level (DOL) as described in the Sections 2.0, 3.0 and 4.0.

6.0 Closure

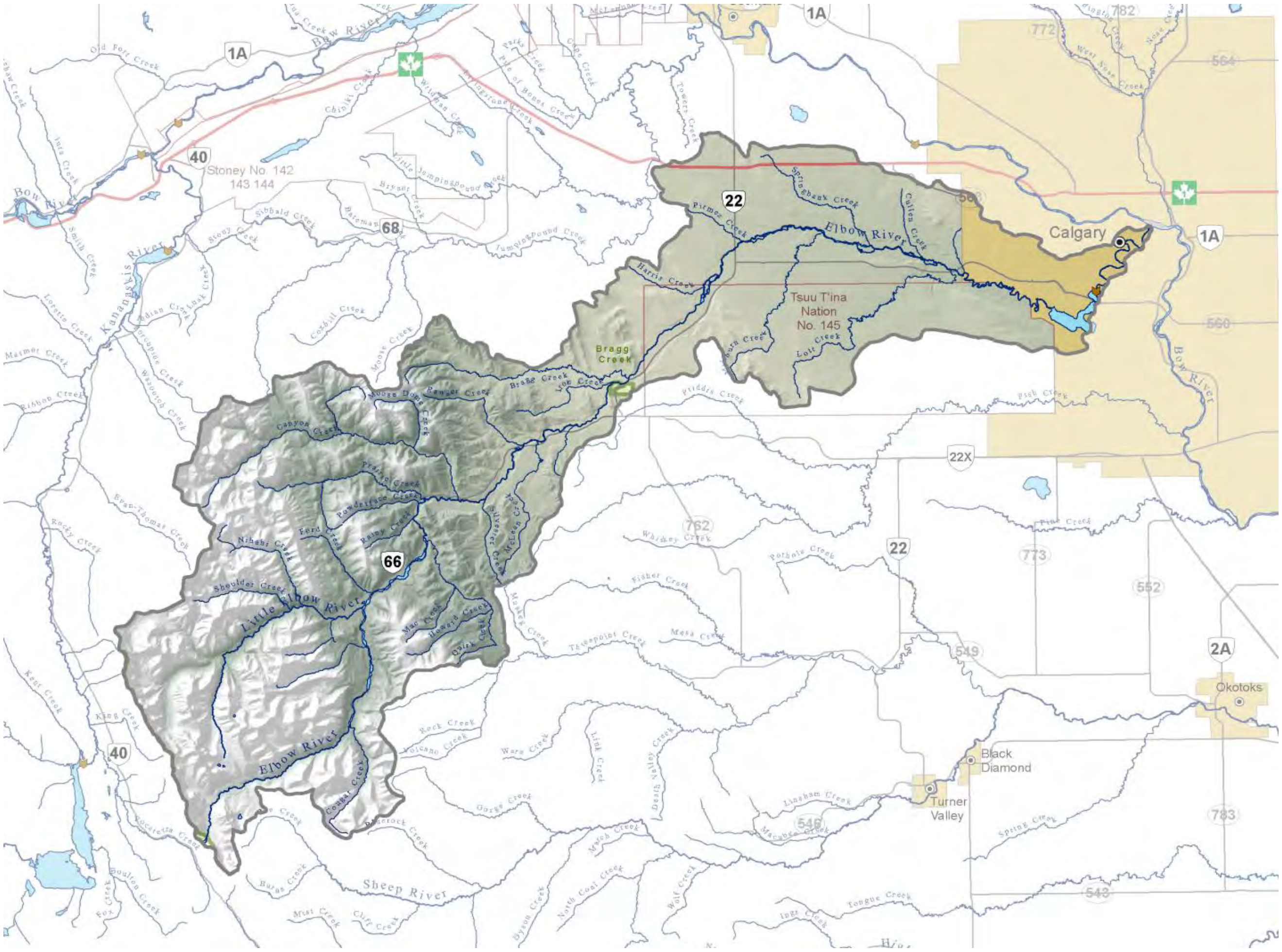
Five (5) dry dam storage sites are proposed for the upper watersheds of the Elbow River, Sheep River and Highwood River basins to mitigate potential future flooding damages to private property and increase public safety. Two sites on the Elbow River will reduce the estimated 2013 flows at Bragg Creek by nearly 60%. One site on the Sheep River will reduce the estimated 2013 flow at Black Diamond by about 60% and two sites on the Highwood River will reduce the estimated 2013 flows at High River by nearly 60%.

These dry dam sites will not result in permanent loss of habitat or impacts to fish and wildlife due to the absence of permanent water behind the dams. Construction of the dry dam structures themselves will temporarily impact only a small percentage of local vegetation which will be mitigated through landscaping of the fill slopes.

Two flow diversions are proposed for the City of Calgary and the Town of High River. An underground pipe diversion will be tunneled from Glenmore Reservoir along 58th Avenue to the Bow River. This diversion will be designed to accommodate a peak flow of 500 m^3/s. Along with the upstream dry dam sites in the Elbow River basin, this diversion will result in downstream flows through The City being in the order of 180 m^3/s (or less) which is low enough that protection measures such as sand bagging will not be required for properties along the Elbow River.

A surface diversion channel will divert flood flows around the Town of High River and reintroduce the water back into the Highwood River downstream of the Town. Designed for a peak flow of 500 m^3/s, this diversion will result in flows through The Town being in the order of 180 m^3/s (or less). This level is low enough to minimize or avoid flooding of the most exposed portion of the Town; that being the Hamptons subdivision.

The total Opinion of Probable cost for construction of all seven (7) mitigation measures is in the order of $660 to $820 million.



Source: Elbow River Watershed Partnership (Website)

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ALBERTA FLOOD ADVISORY PANEL
FLOOD MITIGATION MEASURES

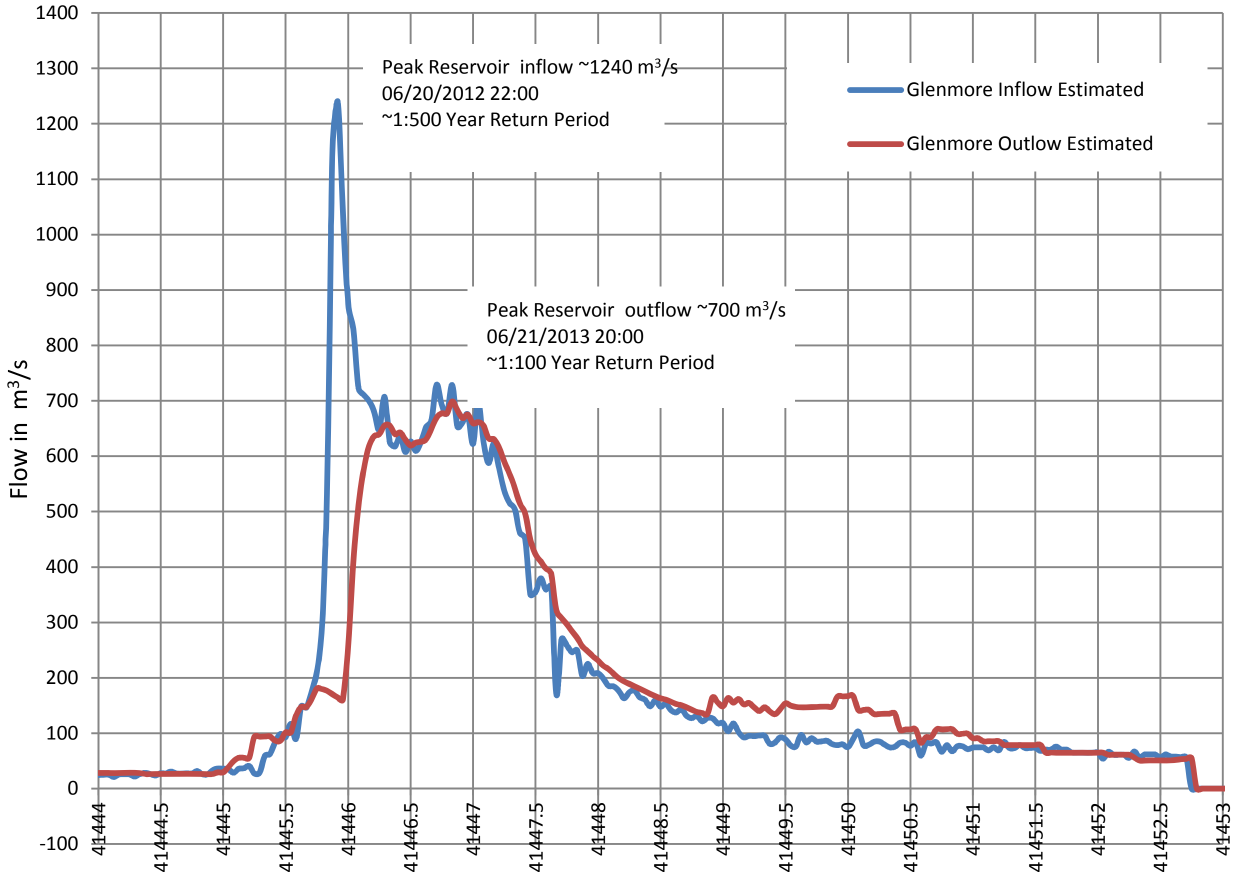
Figure No.

2.1

Title

Elbow River Basin

June 2013 Flood Event Hydrograph - Elbow River at Glenmore Dam



Peak Reservoir inflow ~1240 m³/s
06/20/2012 22:00
~1:500 Year Return Period

Peak Reservoir outflow ~700 m³/s
06/21/2013 20:00
~1:100 Year Return Period

The presented data has yet to be verified by external sources and must therefore be treated as preliminary in nature and subject to change.
This data is being provided for internal use to your agency and your agency alone. It is not to be distributed to others outside of your agency.
Due to the preliminary nature of the data, this information cannot be relied upon and is not being warranted or confirmed by The City of Calgary.

Source: City of Calgary

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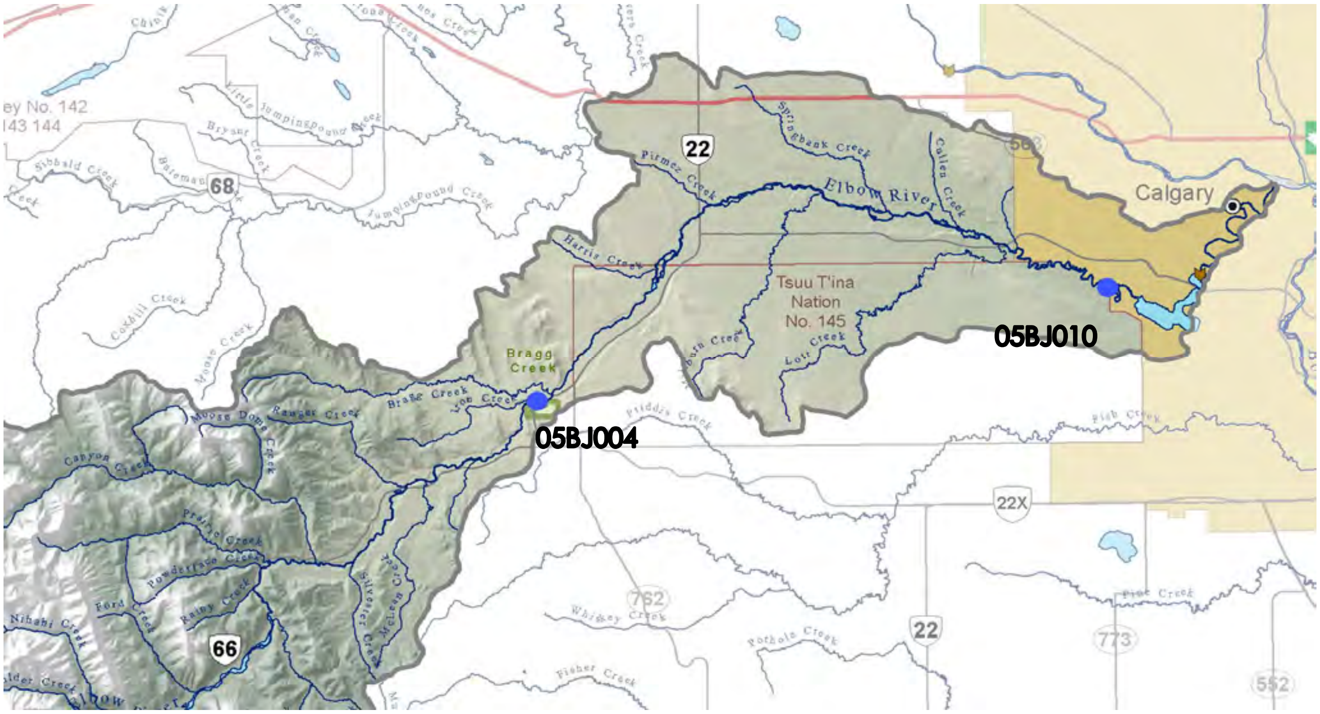
ALBERTA FLOOD ADVISORY PANEL
FLOOD MITIGATION MEASURES

Figure No.
2.2

Title
Elbow River Flows at
Glenmore Reservoir



Source: Alberta Environment and Sustainable Resource Development

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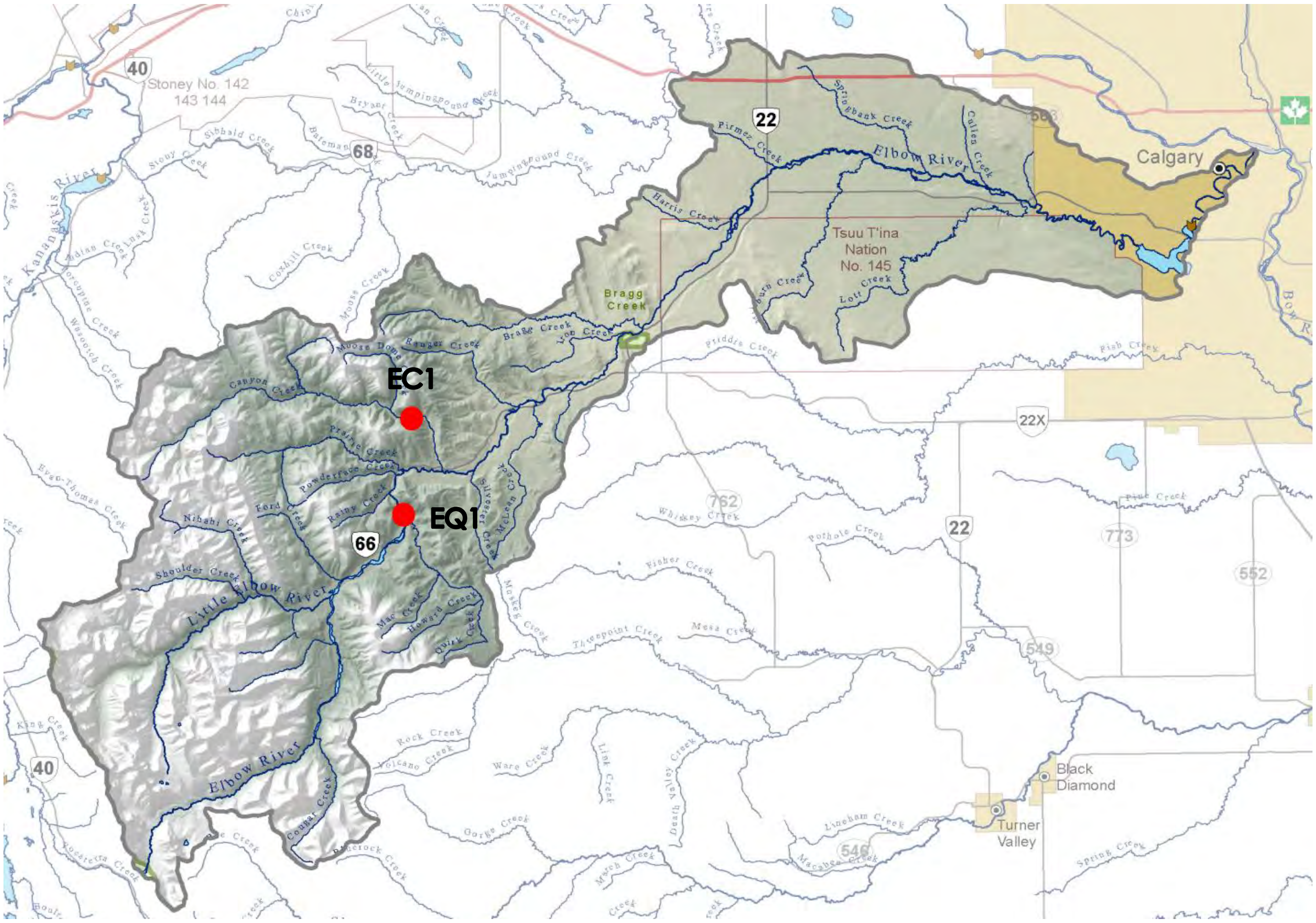
ALBERTA FLOOD ADVISORY PANEL
FLOOD MITIGATION MEASURES

Figure No.
2.3

Title
Elbow River Flows
June 2013



Source: Elbow River Watershed Partnership (Website)

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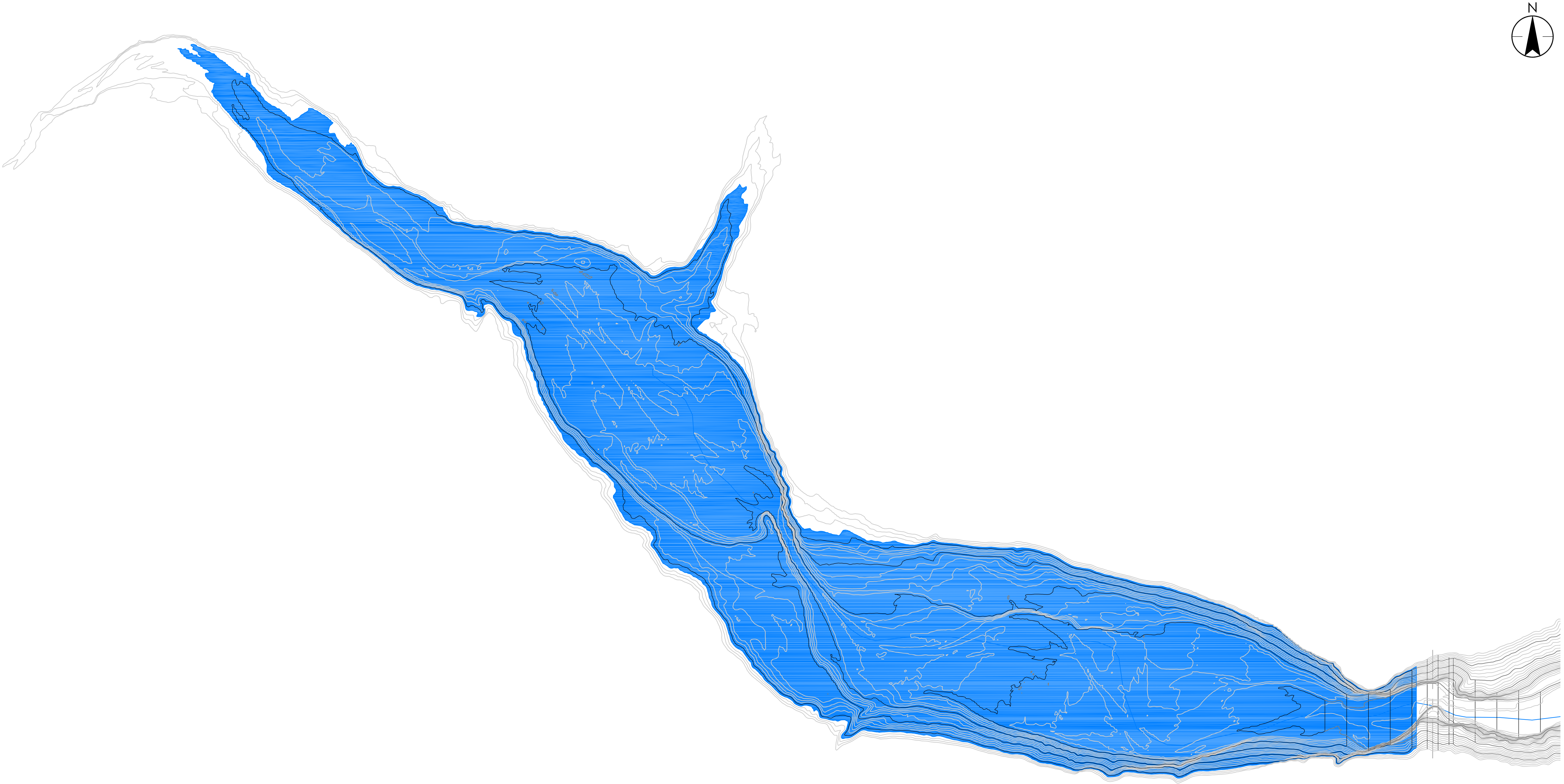
ALBERTA FLOOD ADVISORY PANEL
FLOOD MITIGATION MEASURES

Figure No.
2.4

Title
Elbow River Basin
Storage Sites



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Legend

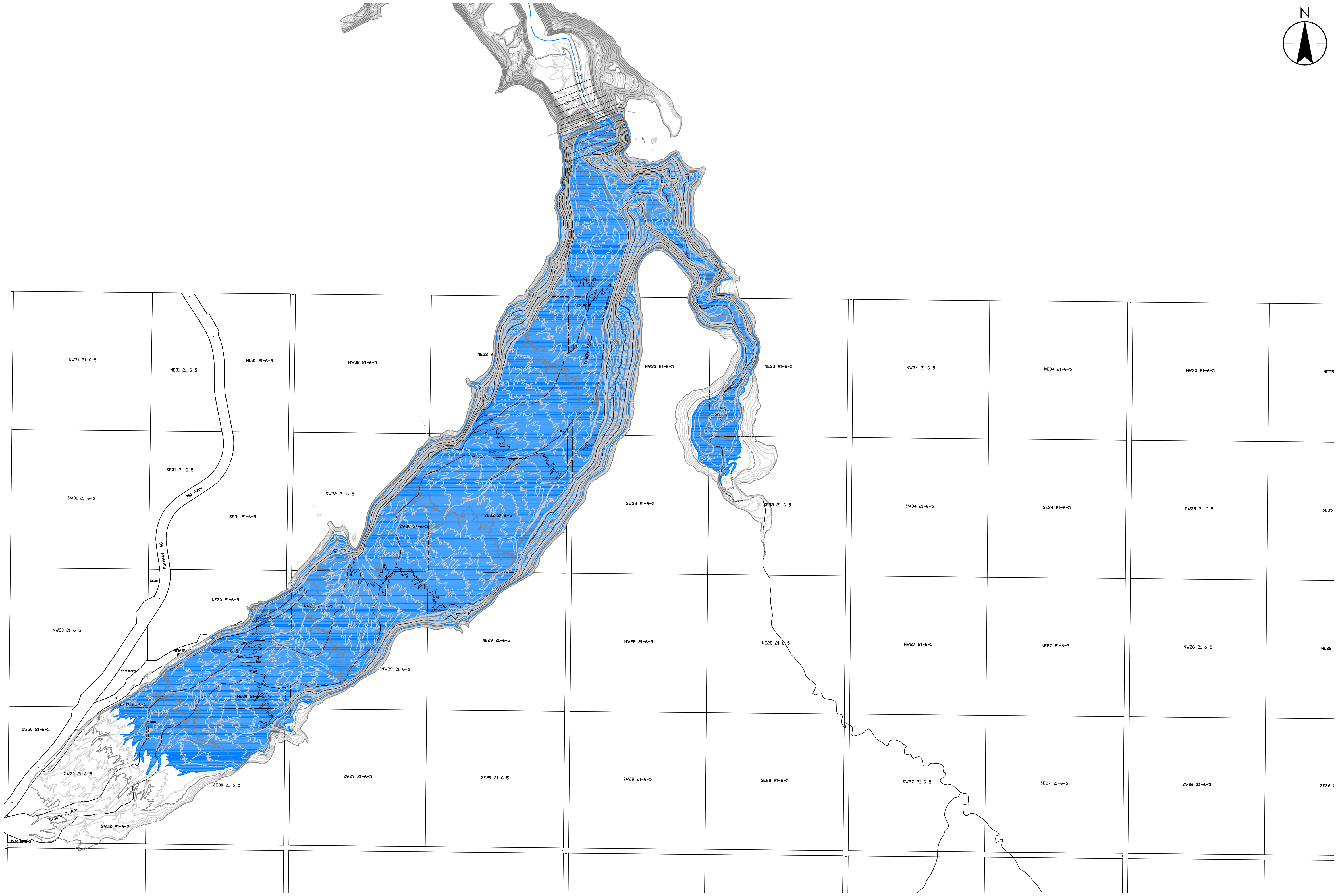
🟦	Ponded Area at FSL (Elev. 1572.0)

Client/Project
ALBERTA FLOOD ADVISORY PANEL
FLOOD MITIGATION MEASURES

Figure No.
2.5

Title
Site EC1 Layout

120990001



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Legend

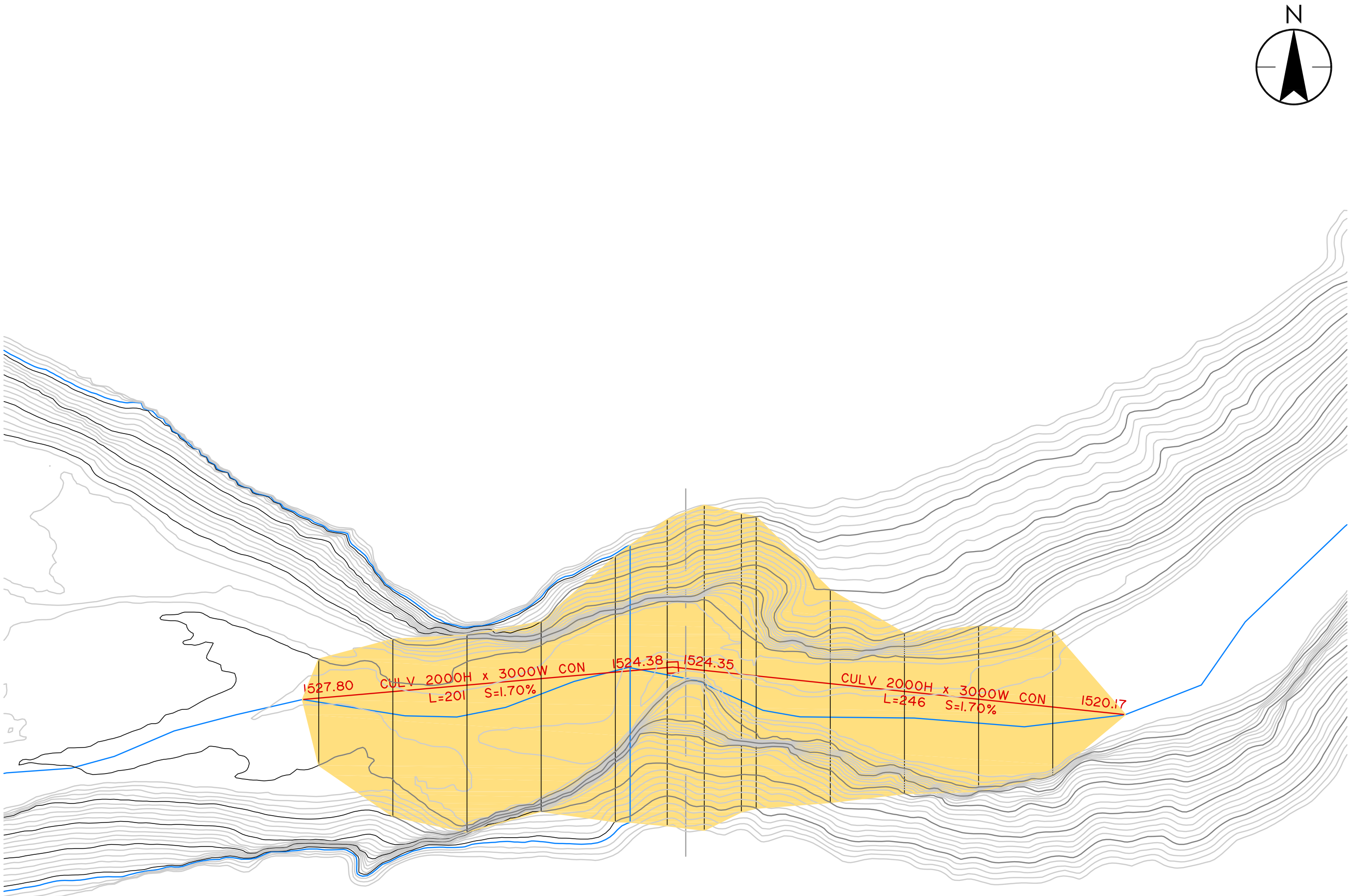
🟦 Ponded Area at FSL (Elev. 1578.0)

Client/Project
ALBERTA FLOOD ADVISORY PANEL
FLOOD MITIGATION MEASURES

Figure No.
2.6

Title
Site EQ1 Layout

120990001



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SCALE: 1:4,000

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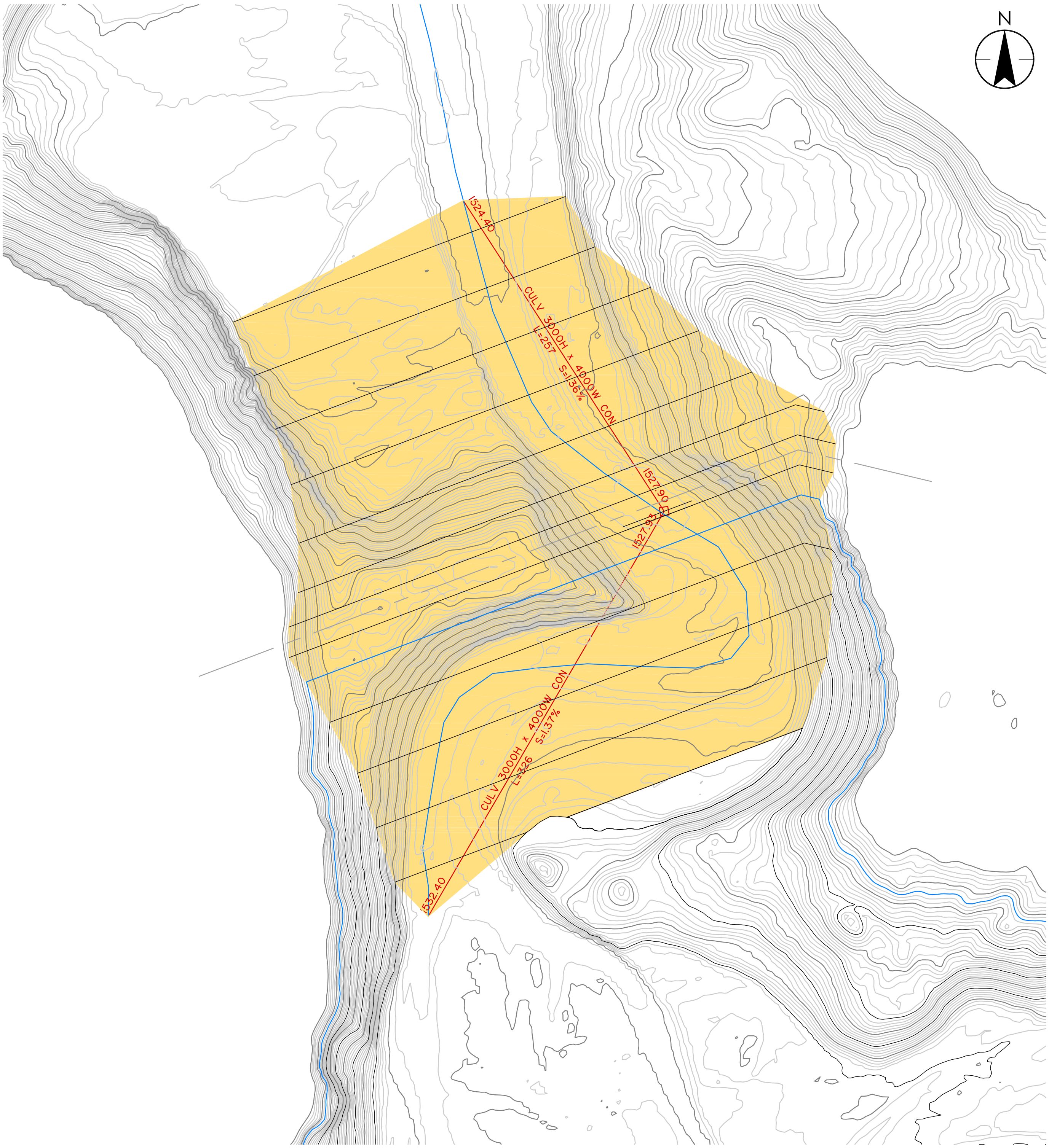
🟨 Berm Footprint
— Flow Passage Conduit

Client/Project
ALBERTA FLOOD ADVISORY PANEL
FLOOD MITIGATION MEASURES

Figure No.
2.7

Title
Site EC1 Dry Dam

120990001



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SCALE: 1:4,000

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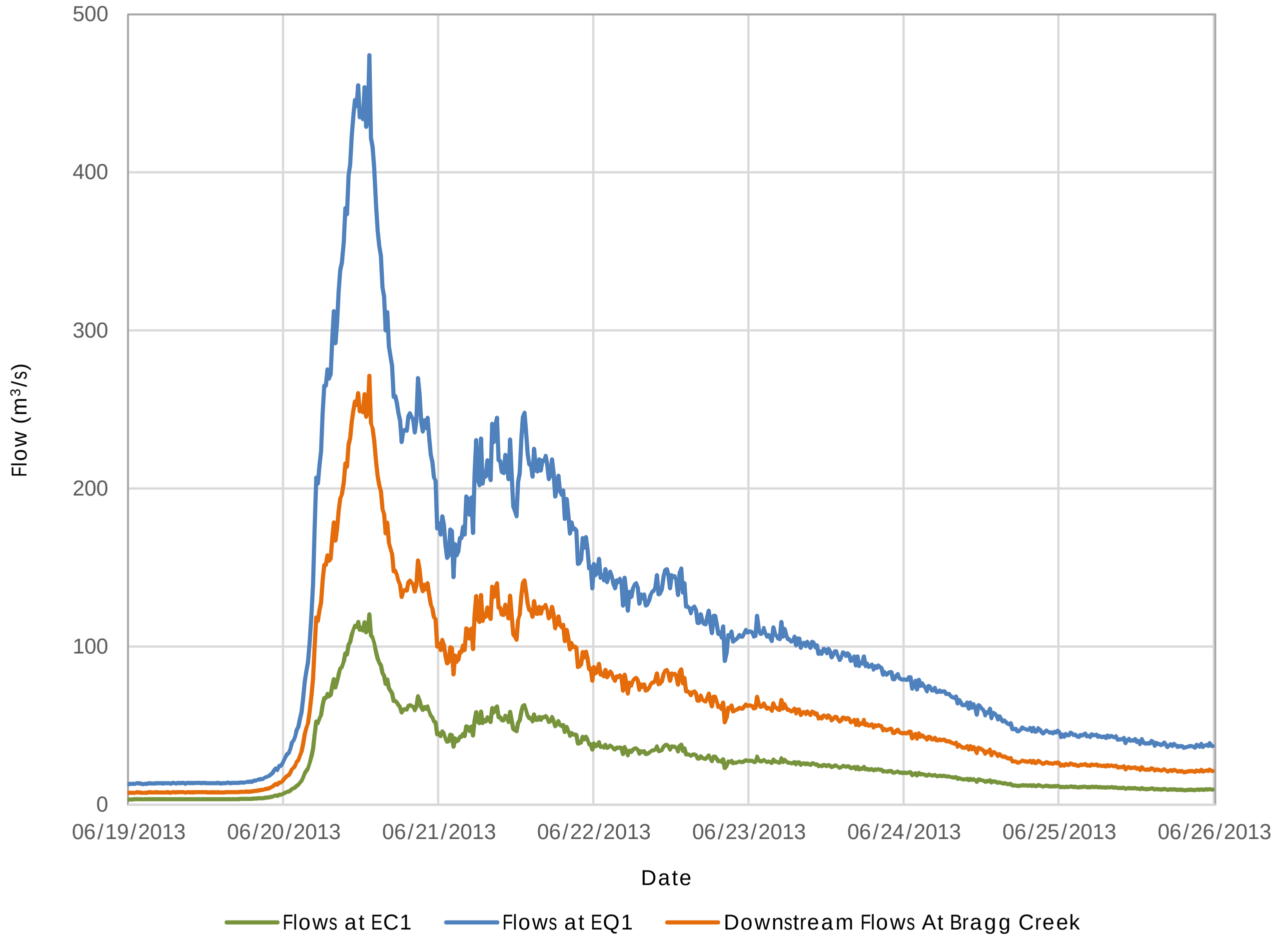
▨ Berm Footprint
— Flow Passage Conduit

Client/Project
ALBERTA FLOOD ADVISORY PANEL
FLOOD MITIGATION MEASURES

Figure No.
2.8

Title
Site EQ1 Dry Dam

120990001



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ALBERTA FLOOD ADVISORY PANEL
FLOOD MITIGATION MEASURES

Figure No.
2.9

Title
Elbow River Flows for
Storage Site Analysis

PLOT DATE: Oct 25, 2013 7:48am
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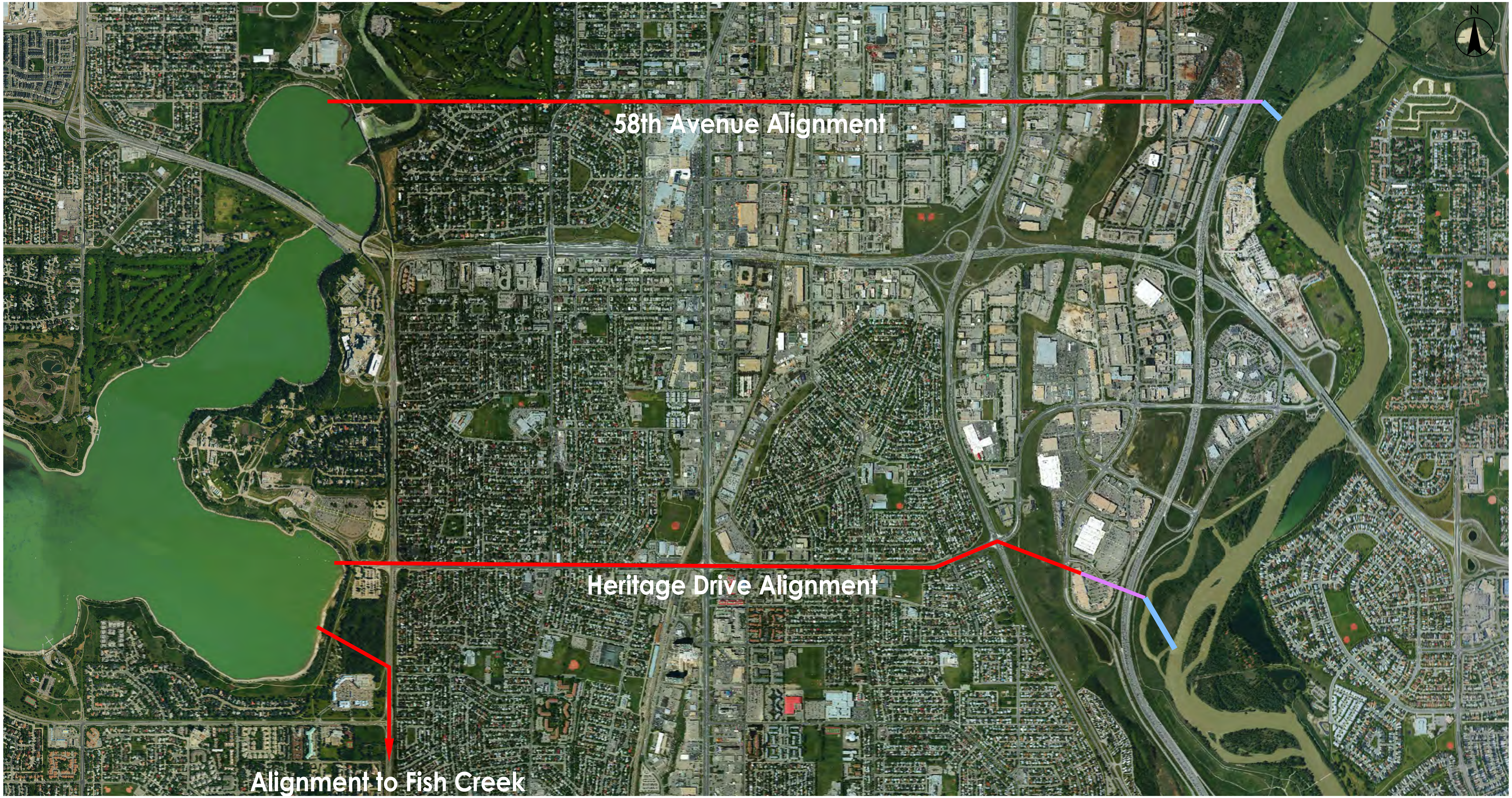

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Legend

🟥 Underground Pipe
🟪 Submerged Duct
🟦 Surface Channel

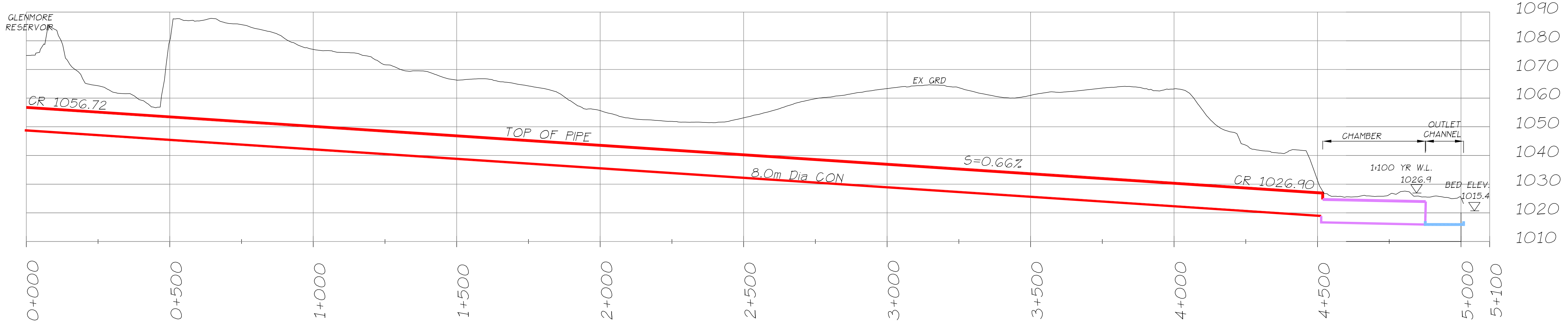
Client/Project
ALBERTA FLOOD ADVISORY PANEL
FLOOD MITIGATION MEASURES

Figure No.
2.10

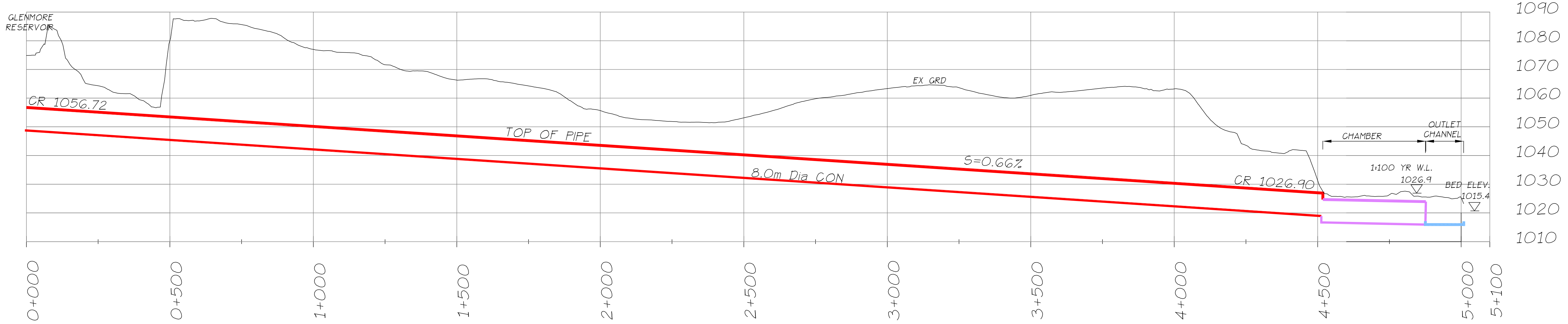
Title
Glenmore Reservoir Diversion

120990001

58th Avenue Alignment



Heritage Drive Alignment



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SCALE 1:15,000

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🟥 Underground Pipe
🟪 Submerged Duct
🟦 Surface Channel

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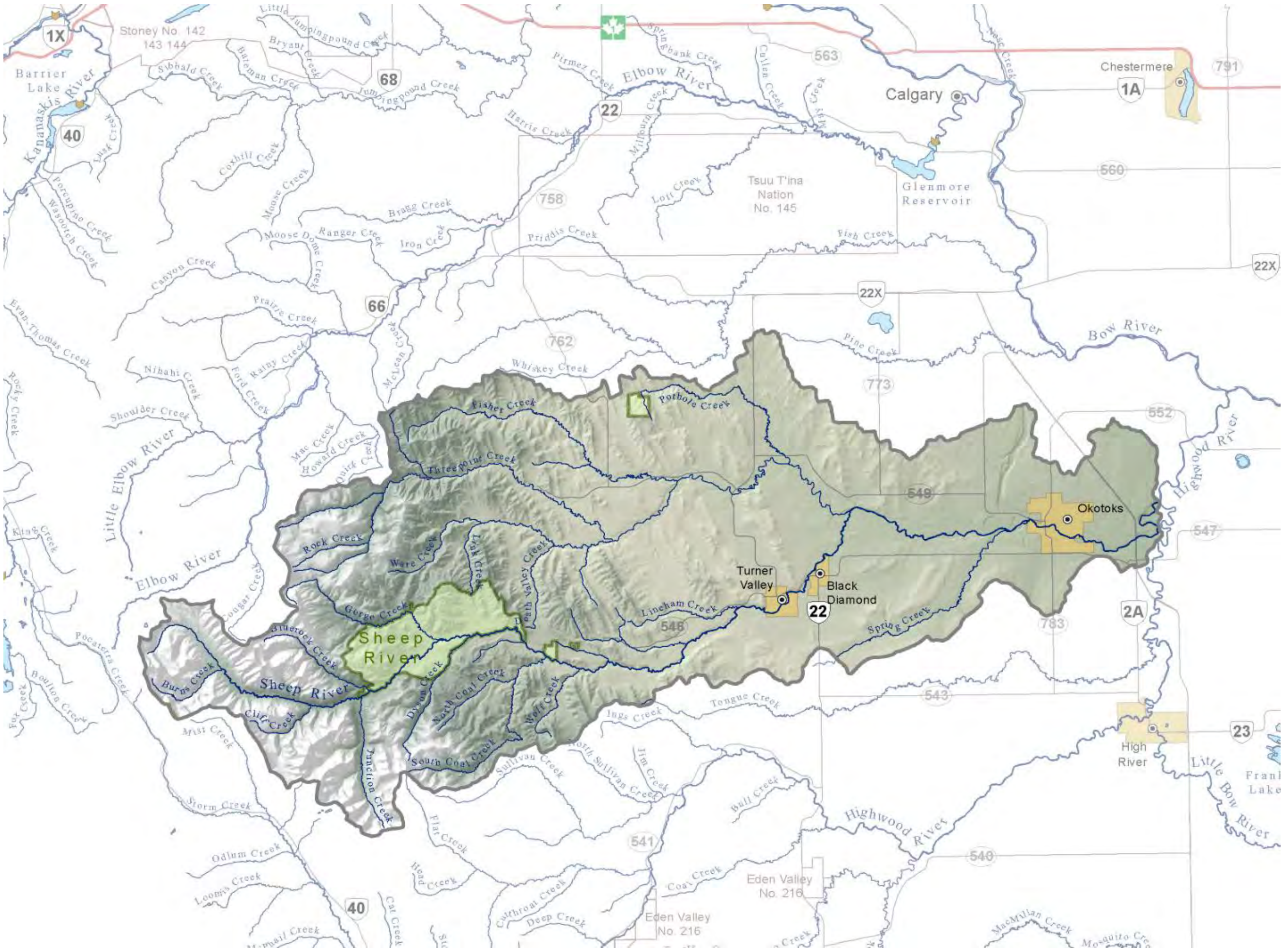
FLOOD MITIGATION MEASURES

Figure No.
2.11

Title
Glenmore Reservoir Diversion Profiles

120990001



Source: Elbow River Watershed Partnership (Website)

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ALBERTA FLOOD ADVISORY PANEL
FLOOD MITIGATION MEASURES

Figure No.

3.1

Title

Sheep River Basin

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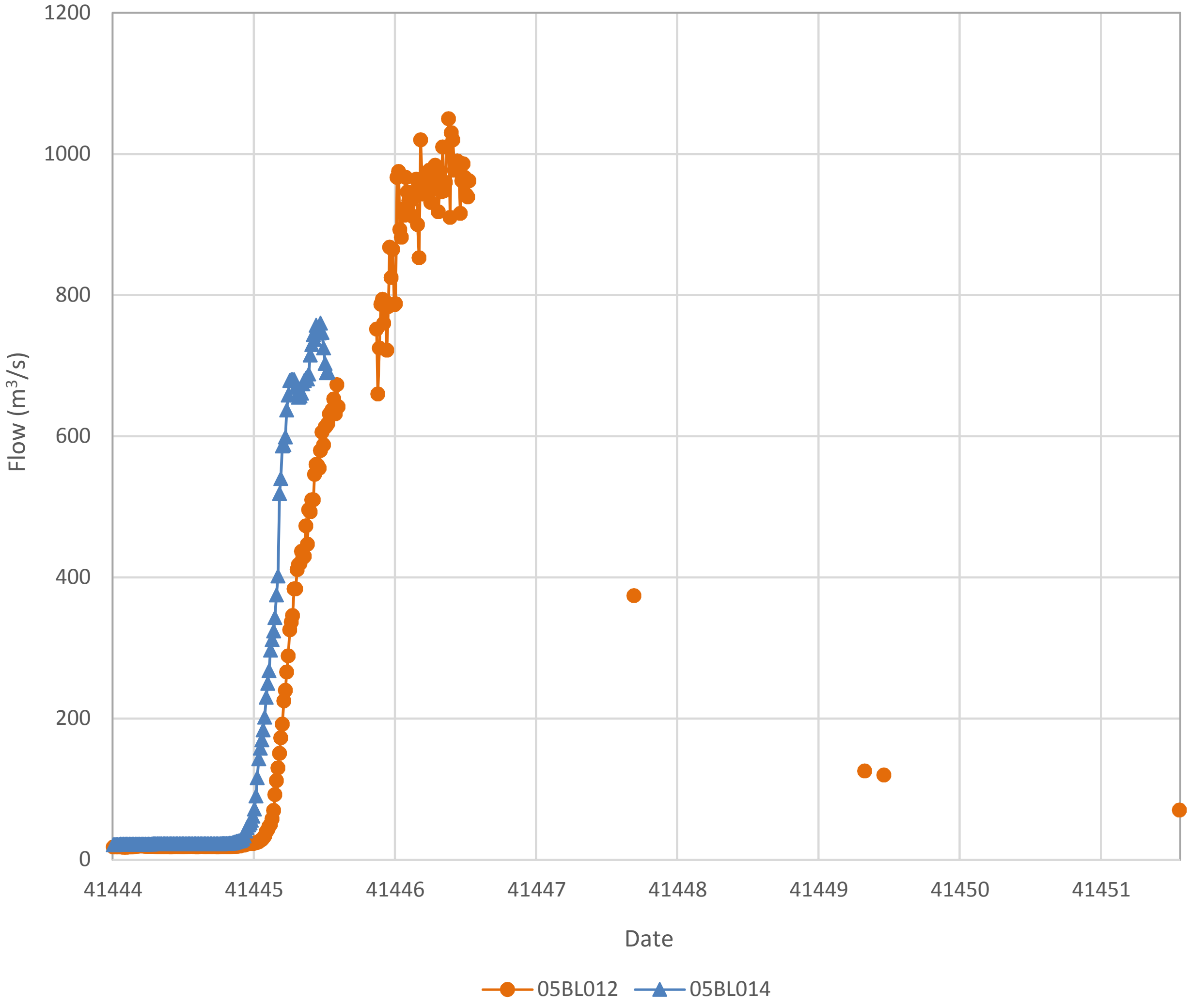
Client/Project
ALBERTA FLOOD ADVISORY PANEL
FLOOD MITIGATION MEASURES

Figure No.
3.2

Title
Sheep River Gauging Stations



Source: Alberta Environment and Sustainable Resource Development

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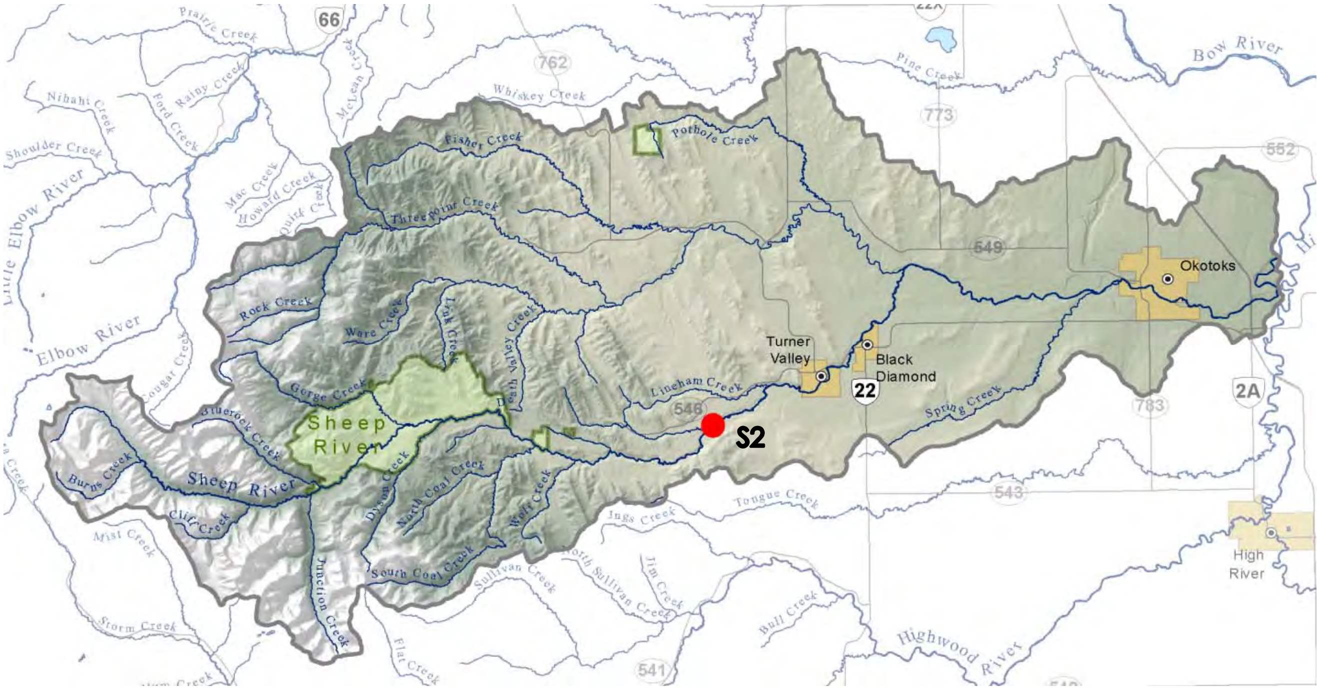
ALBERTA FLOOD ADVISORY PANEL
FLOOD MITIGATION MEASURES

Figure No.
3.3

Title
Sheep River Flows
June 2013



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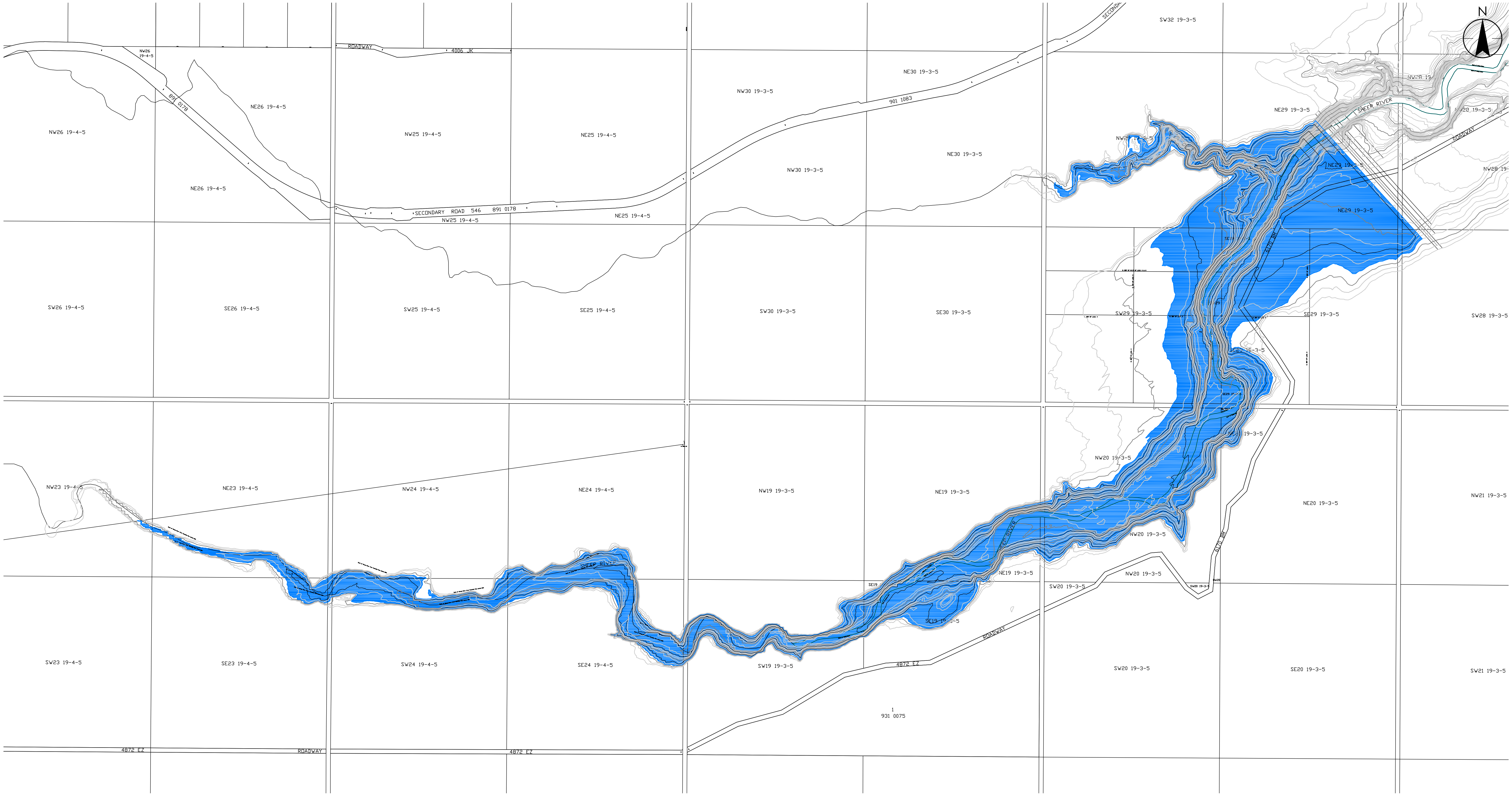
ALBERTA FLOOD ADVISORY PANEL
FLOOD MITIGATION MEASURES

Figure No.
3.4

Title
Sheep River Basin
Storage Site



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Legend

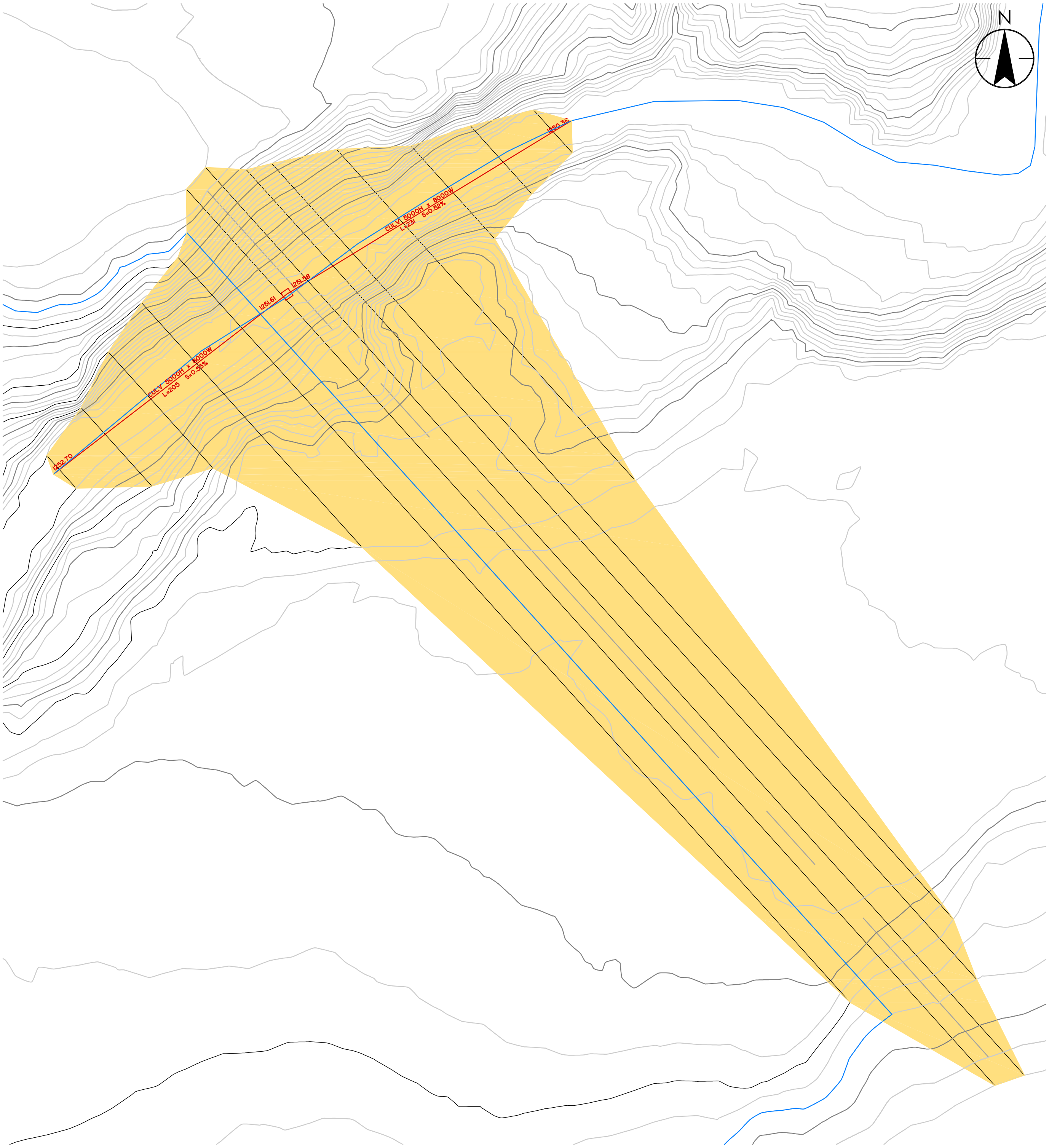
🟦 Ponded Area at FSL (Elev. 1298.0)

Client/Project
ALBERTA FLOOD ADVISORY PANEL
FLOOD MITIGATION MEASURES

Figure No.
3.5

Title
Site S2 Layout

120990001



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SCALE: 1:4,000

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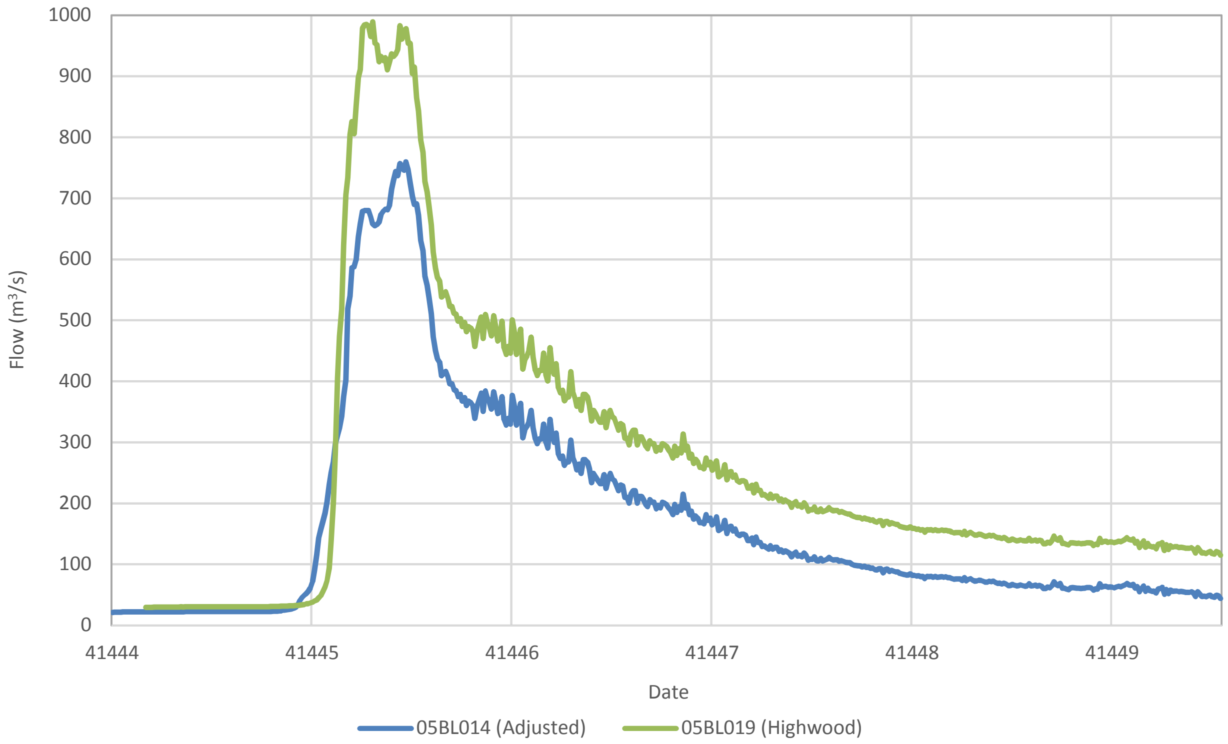
🟨 Berm Footprint
— Flow Passage Conduit

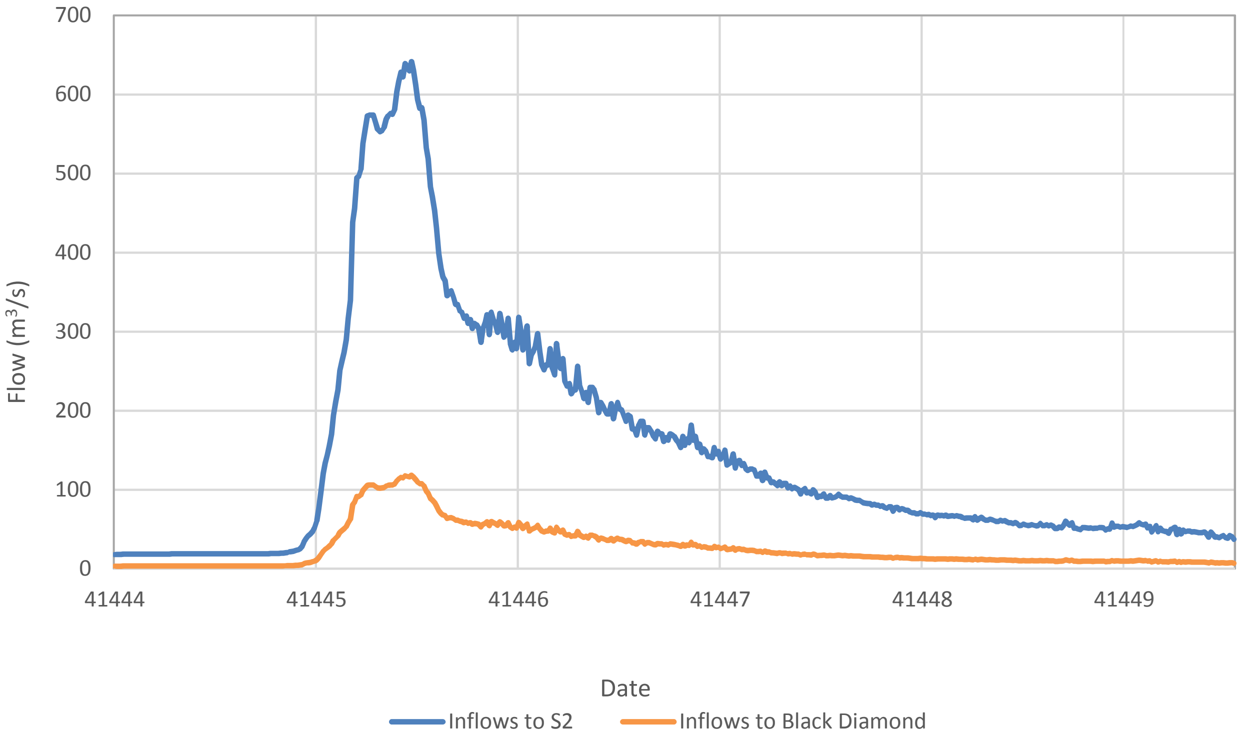
Client/Project
ALBERTA FLOOD ADVISORY PANEL
FLOOD MITIGATION MEASURES

Figure No.
3.6

Title
Site S2 Dry Dam

120990001





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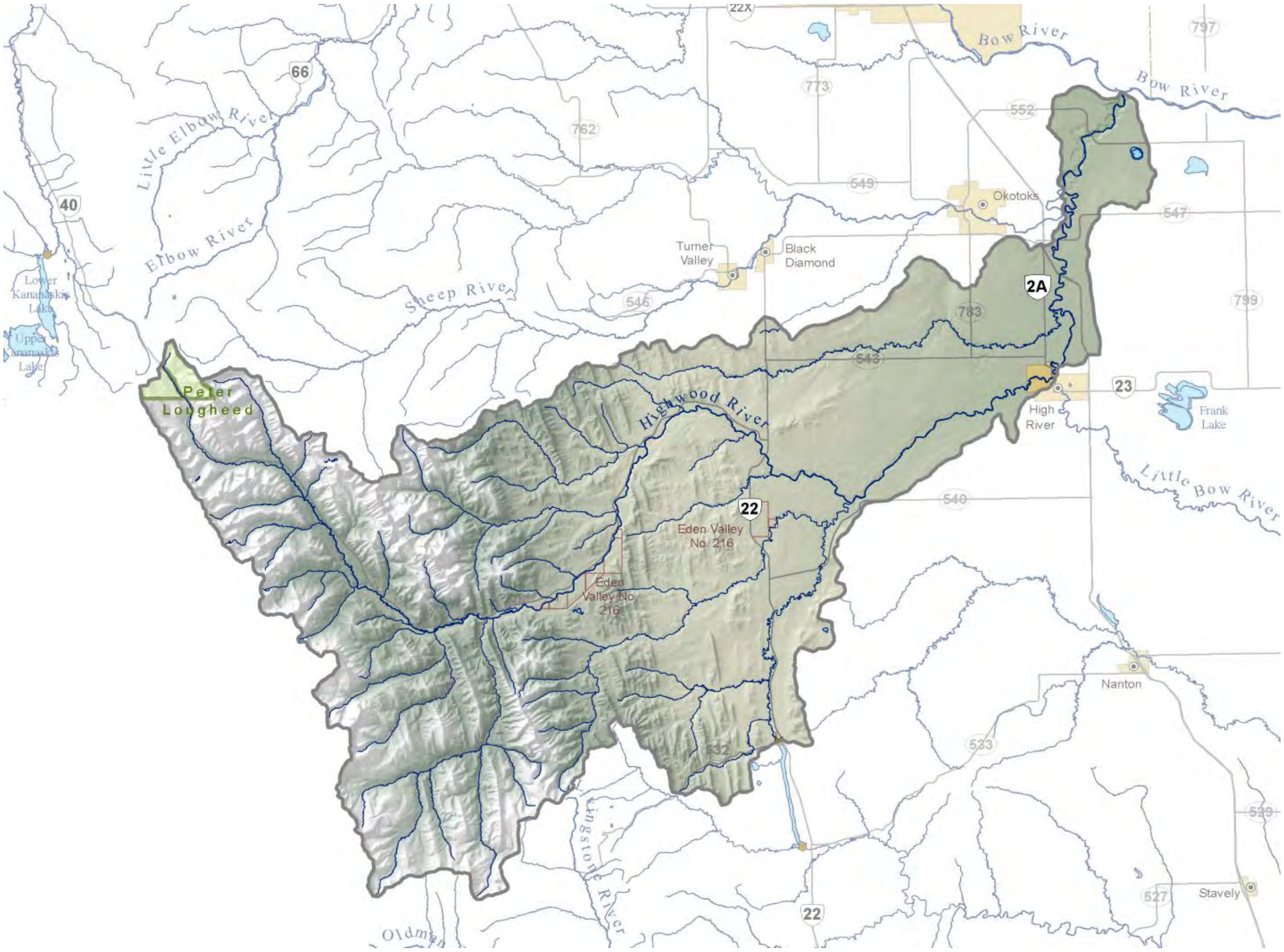
Client/Project
ALBERTA FLOOD ADVISORY PANEL
FLOOD MITIGATION MEASURES

Figure No.
3.7

Title
Sheep River Flows
Storage Site Analysis



Source: Elbow River Watershed Partnership (Website)

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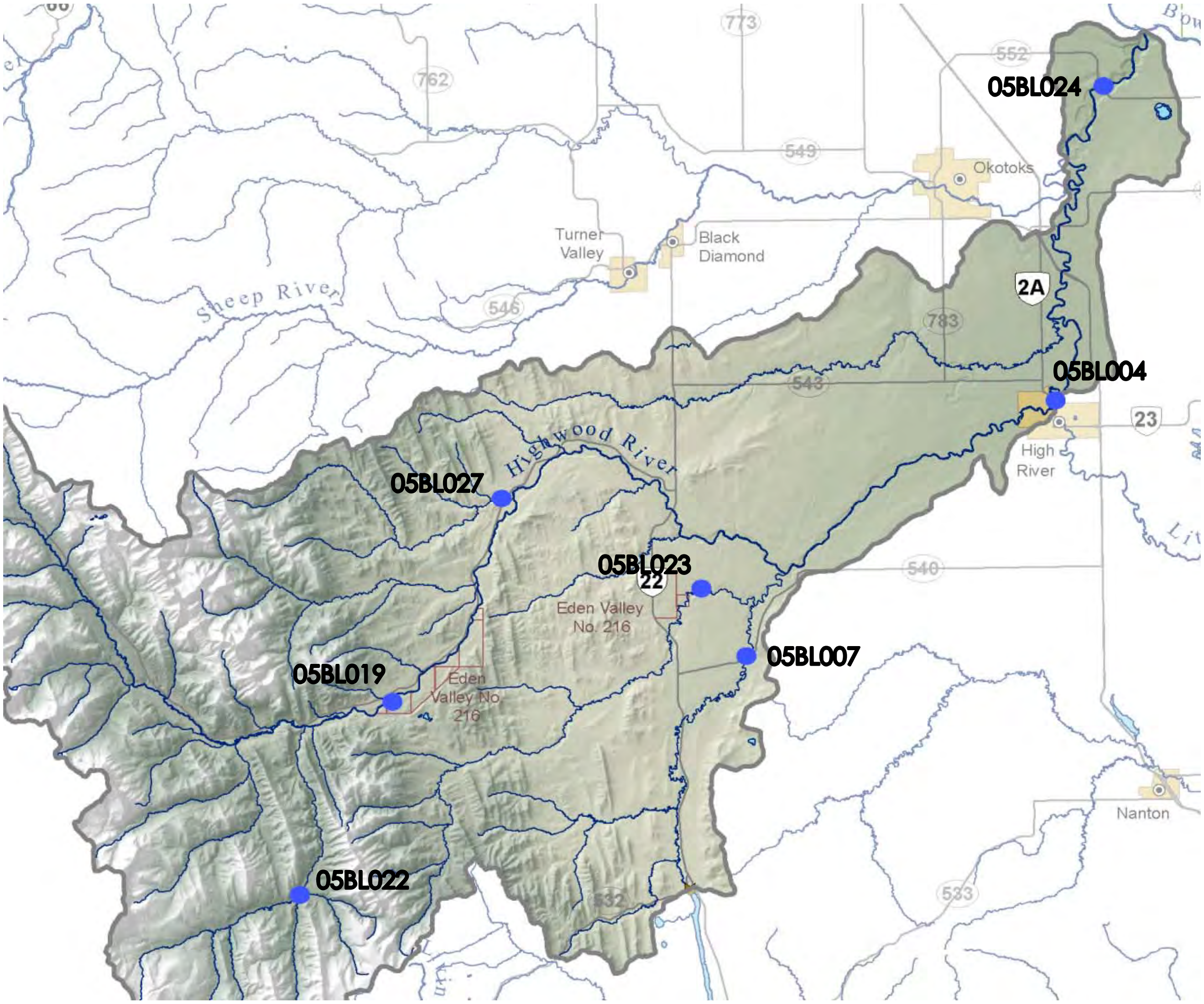
Client/Project
ALBERTA FLOOD ADVISORY PANEL
FLOOD MITIGATION MEASURES

Figure No.
4.1

Title
Highwood River Basin



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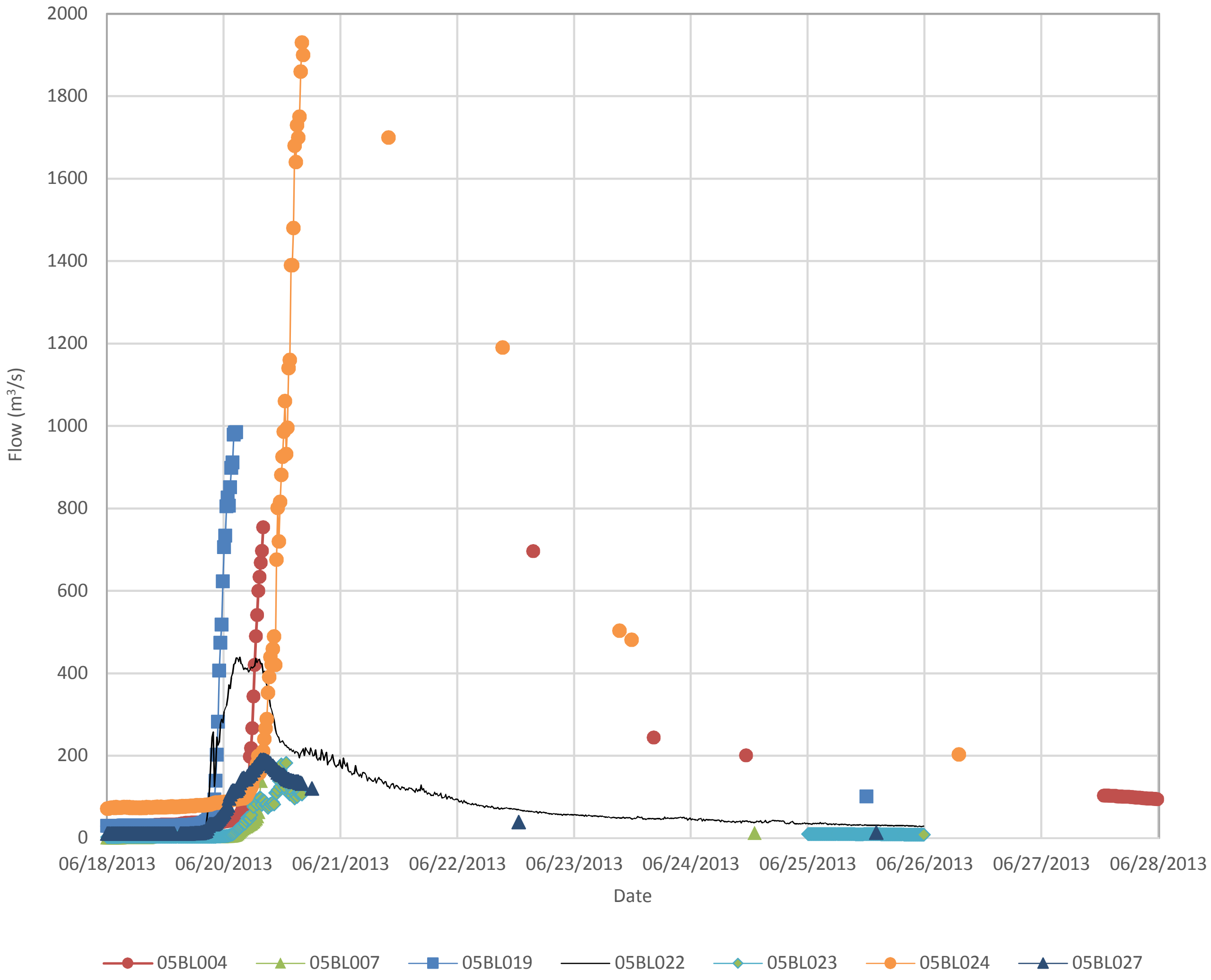
Client/Project
ALBERTA FLOOD ADVISORY PANEL
FLOOD MITIGATION MEASURES

Figure No.
4.2

Title
Highwood River
Gauging Stations



Source: Alberta Environment and Sustainable Resource Development

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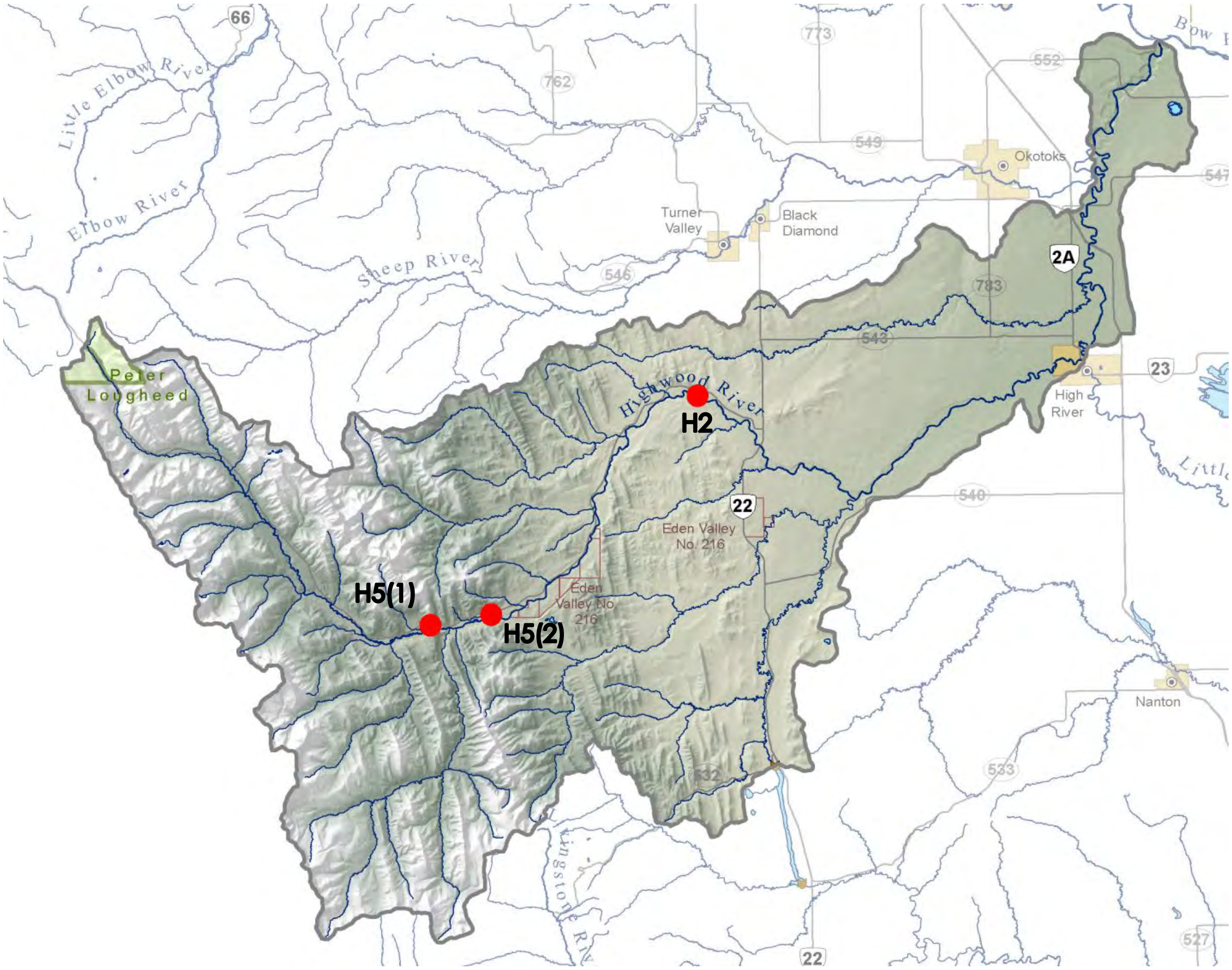
ALBERTA FLOOD ADVISORY PANEL
FLOOD MITIGATION MEASURES

Figure No.
4.3

Title

Highwood River Flows
June 2013



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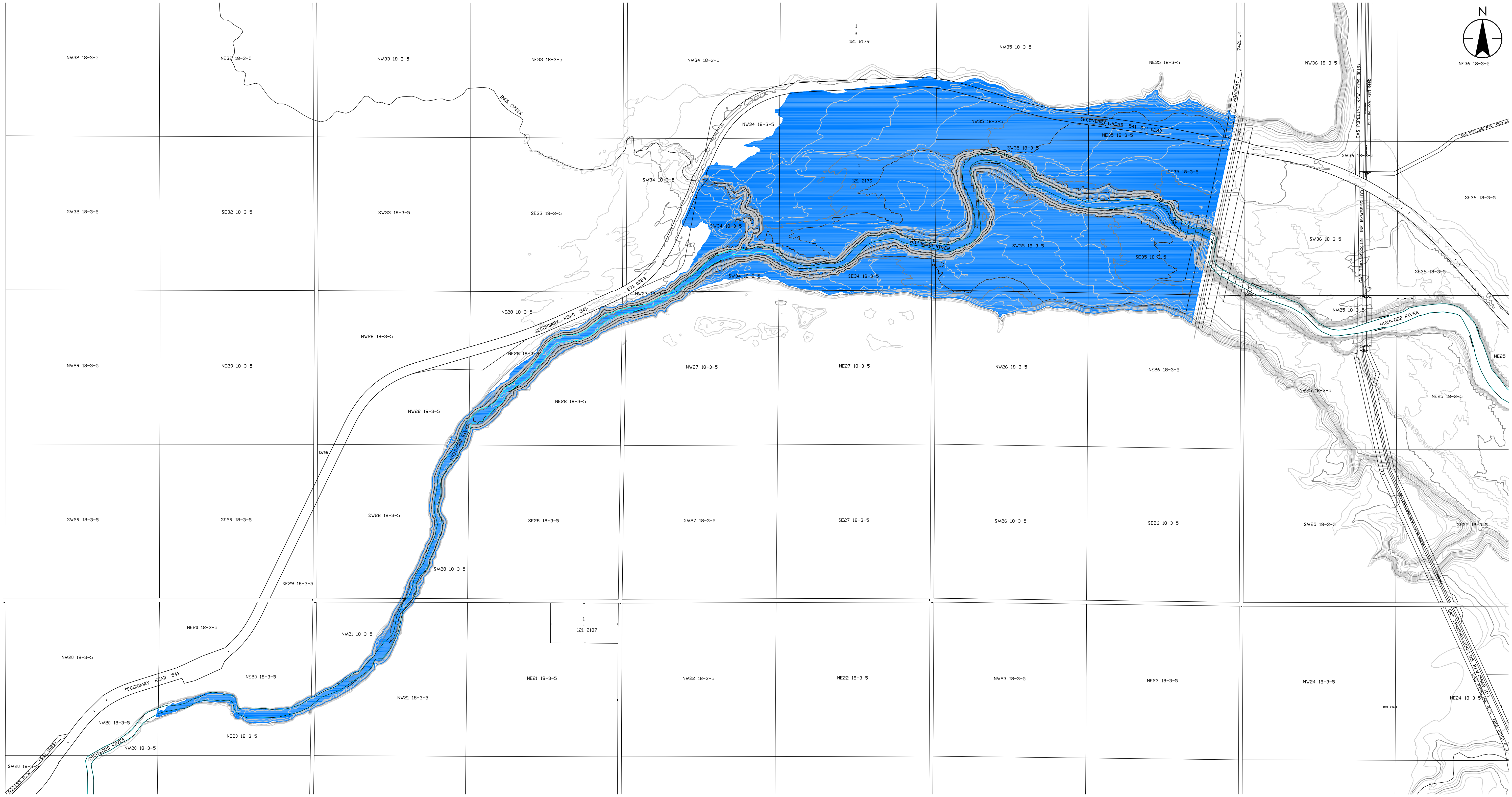
ALBERTA FLOOD ADVISORY PANEL
FLOOD MITIGATION MEASURES

Figure No.

4.4

Title

Highwood River Basin Storage Sites



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Legend

🟦 Ponded Area at FSL (Elev. 1268)

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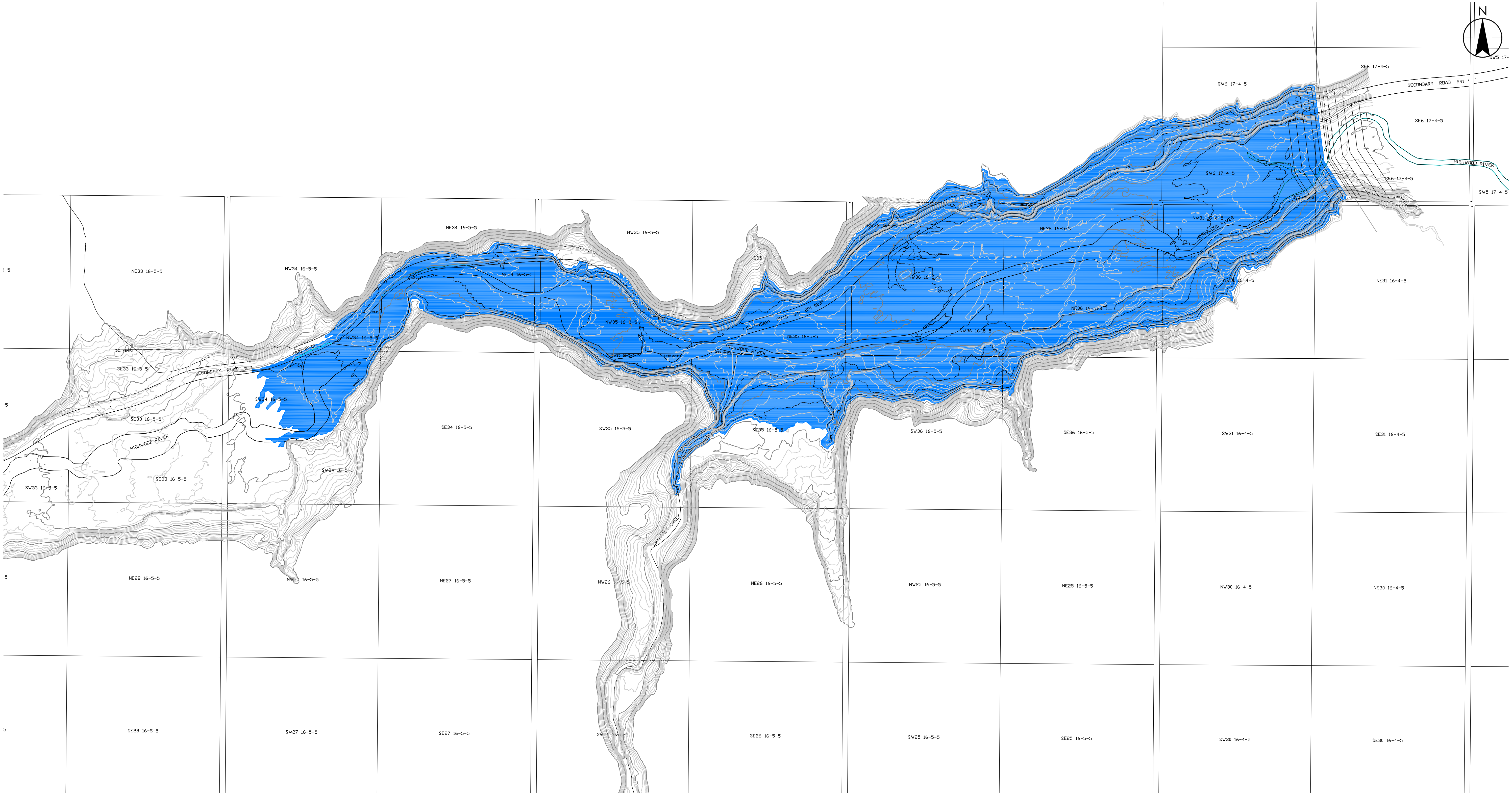
FLOOD MITIGATION MEASURES

Figure No.
4.5

Title
Site H2 Layout

120990001



PLOT DATE: Oct 21, 2013 1:45pm
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SCALE 1:25,000

Stantec

200 - 325 25th Street SE
Calgary, AB T2A 7H8
www.stantec.com

Legend

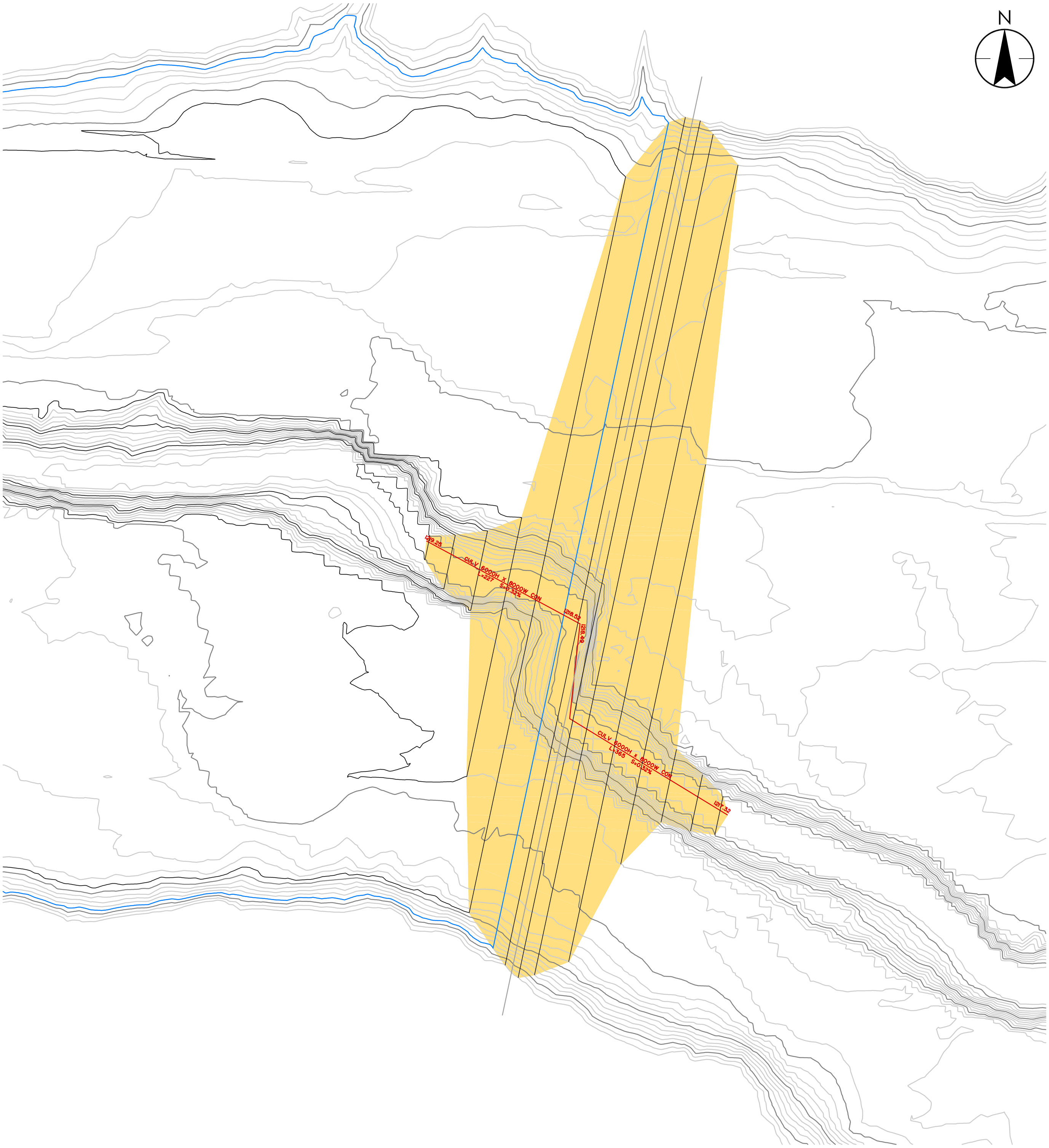
🟦 Ponded Area at FSL (Elev. 1478)

Client/Project
ALBERTA FLOOD ADVISORY PANEL
FLOOD MITIGATION MEASURES

Figure No.
4.6

Title
Site H5(2) Layout

120990001



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FILE NAME: V:\1164\miscellaneous\164-Stormwater\SWM Projects\Project Files\Miscellaneous\Flood Advisory 2013\CAD\AFAP_siteH2_layout.dwg

SCALE: 1:7,500

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Legend

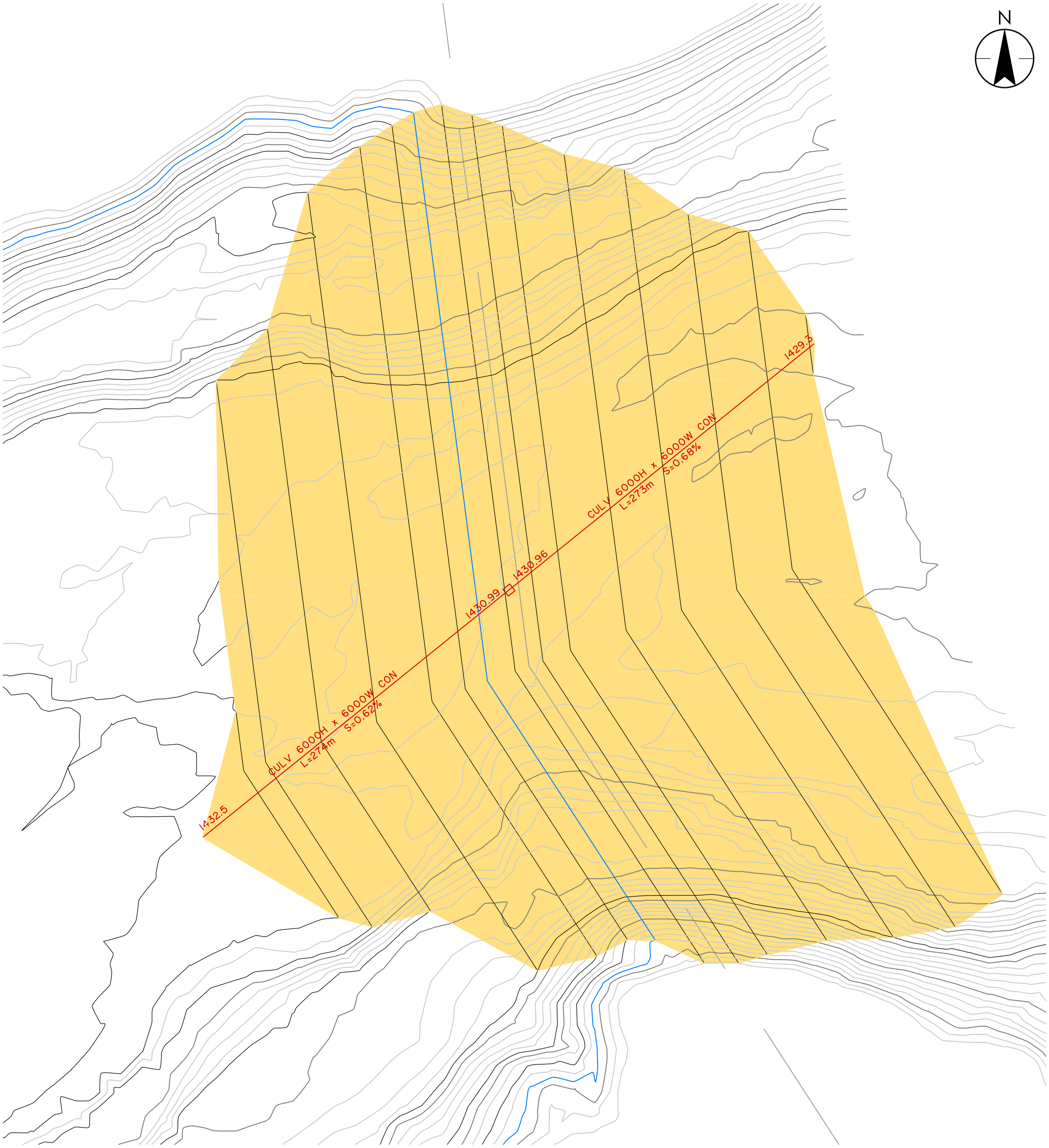
▨	Berm Footprint
—	Flow Passage Conduit

Client/Project
ALBERTA FLOOD ADVISORY PANEL
FLOOD MITIGATION MEASURES

Figure No.
4.7

Title
Site H2 Dry Dam

120990001



PLOT DATE: Oct 23, 2013 7:32am
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SCALE: 1:4,000

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Legend

🟨	Berm Footprint
—	Flow Passage Conduit

Client/Project

ALBERTA FLOOD ADVISORY PANEL
FLOOD MITIGATION MEASURES

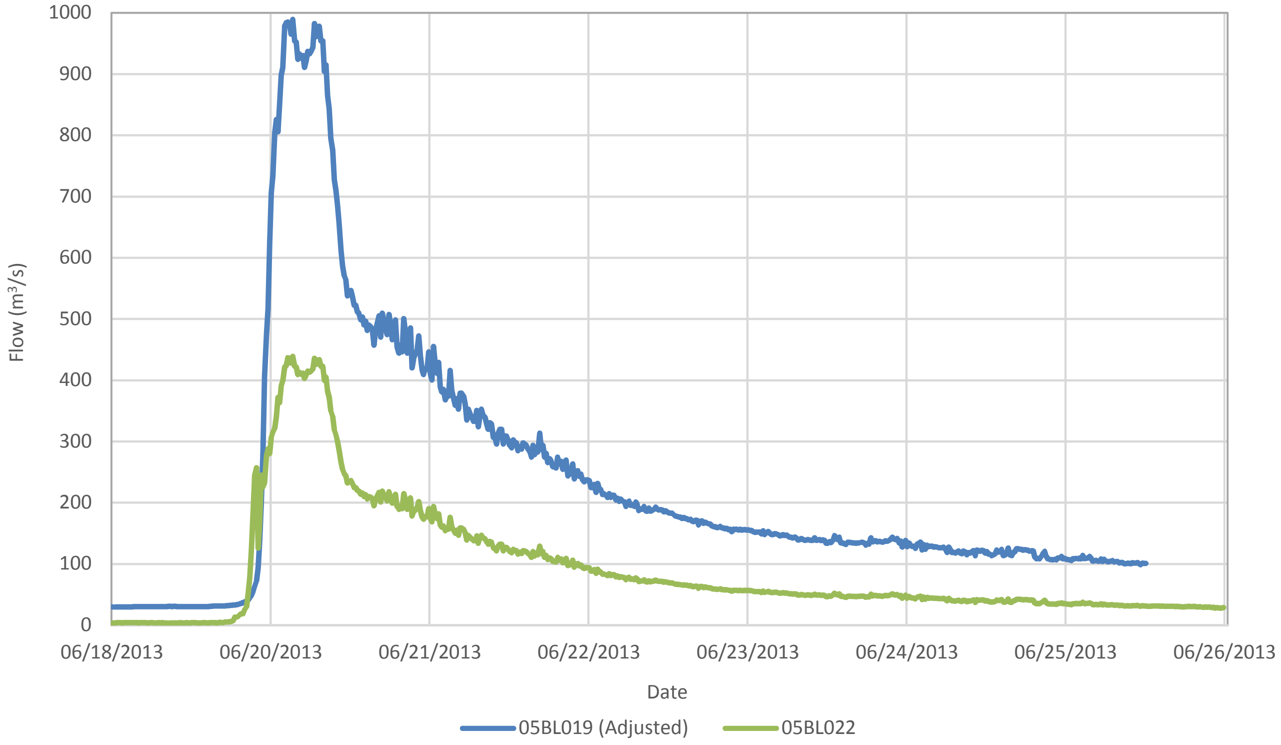
Figure No.

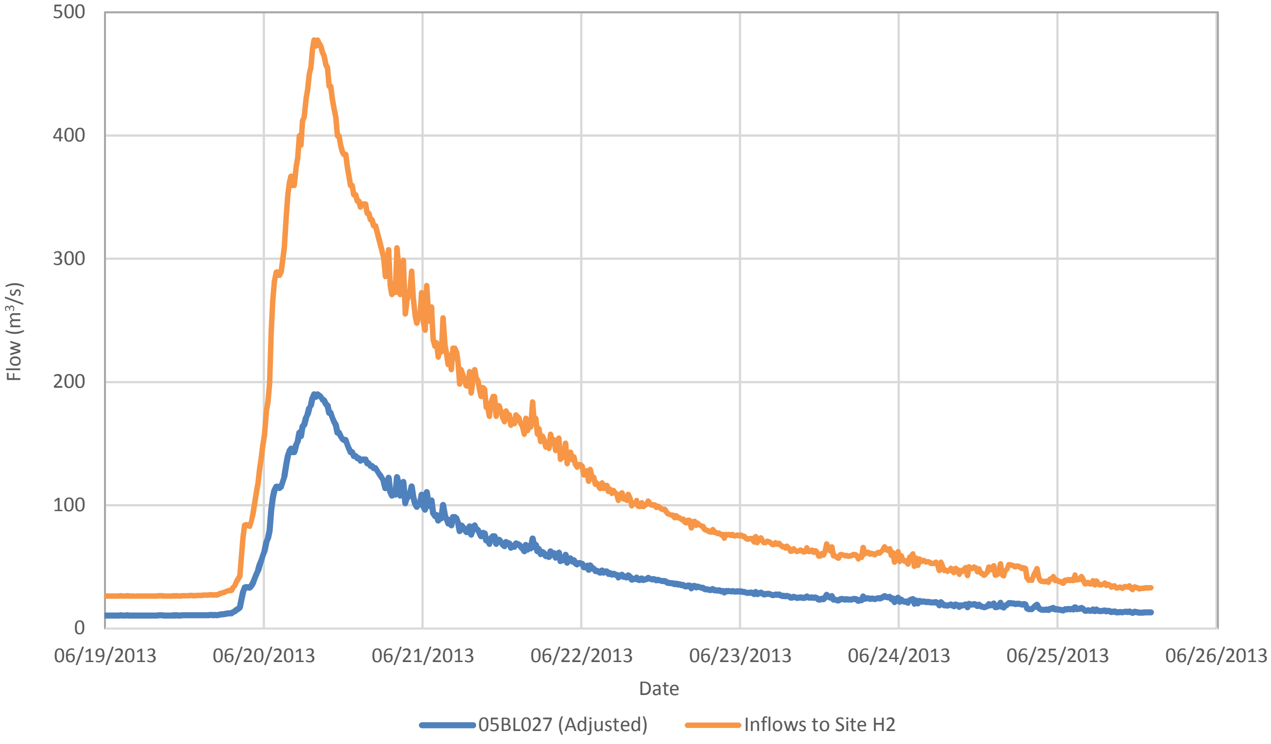
4.8

Title

Site H5(2) Dry Dam

120990001





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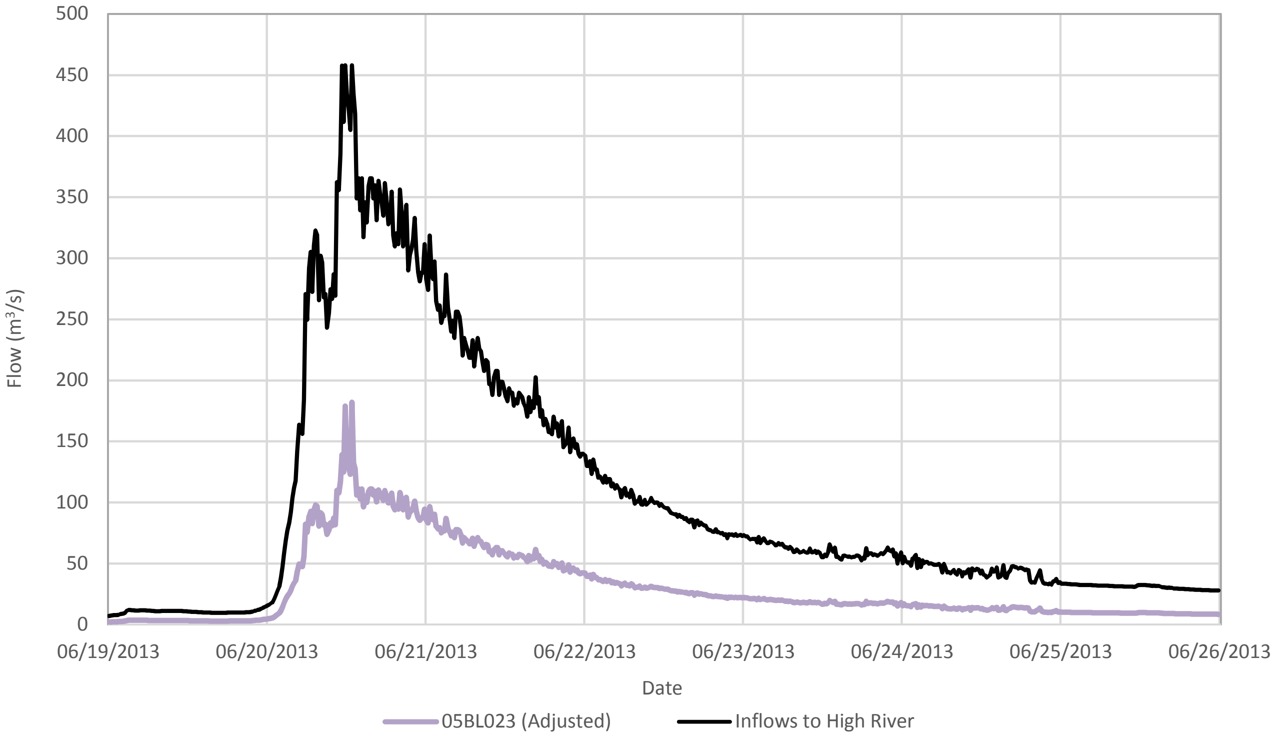
Client/Project
ALBERTA FLOOD ADVISORY PANEL
FLOOD MITIGATION MEASURES

Figure No.
4.9

Title
Highwood River Flows
Storage Site Analysis



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Client/Project

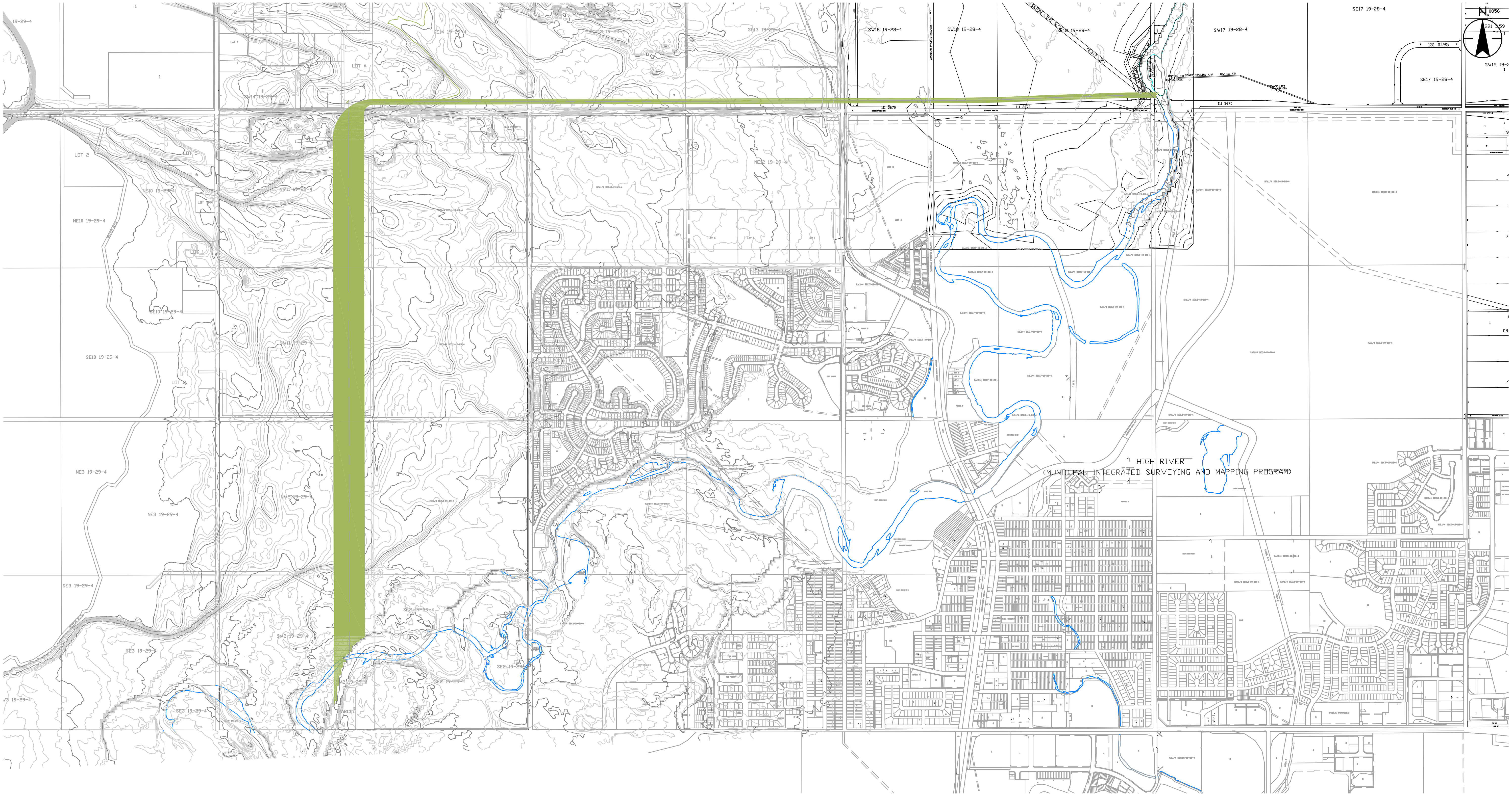
ALBERTA FLOOD ADVISORY PANEL
FLOOD MITIGATION MEASURES

Figure No.

4.10

Title

Highwood River Flows
High River Analysis



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SCALE 1:20,000

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Legend

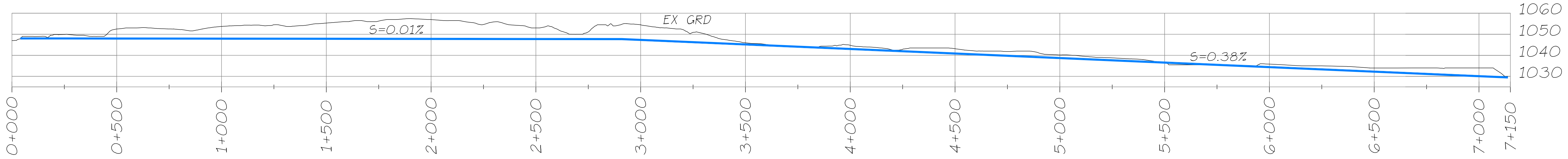
🟩 Diversion Channel

Client/Project
ALBERTA FLOOD ADVISORY PANEL
FLOOD MITIGATION MEASURES

Figure No.
4.11

Title
High River Diversion

120990001



PLOT DATE: Oct 25, 2013 11:54am
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SCALE 1:20,000

Stantec

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Client/Project
ALBERTA FLOOD ADVISORY PANEL
FLOOD MITIGATION MEASURES

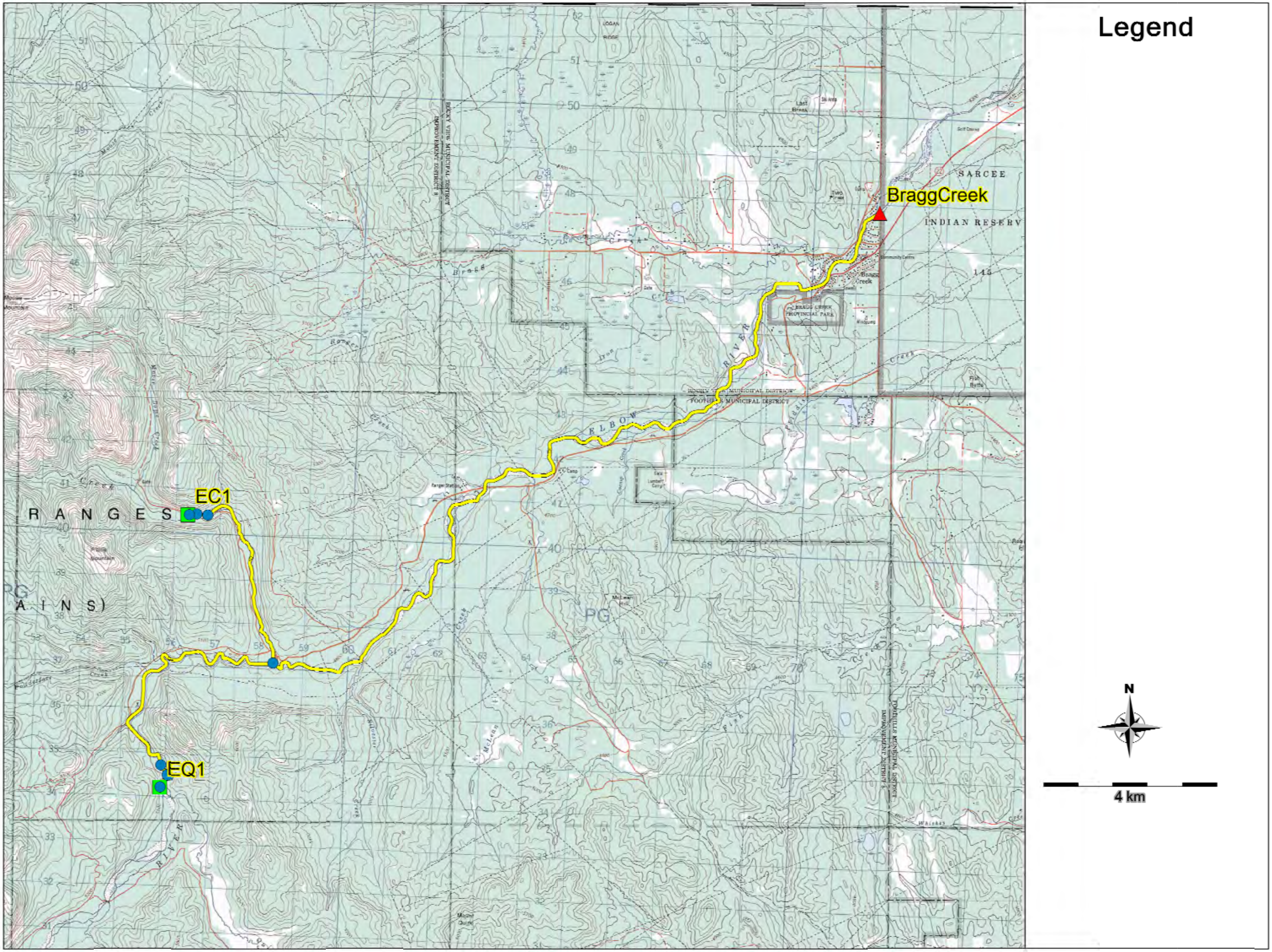
Figure No.
4.12

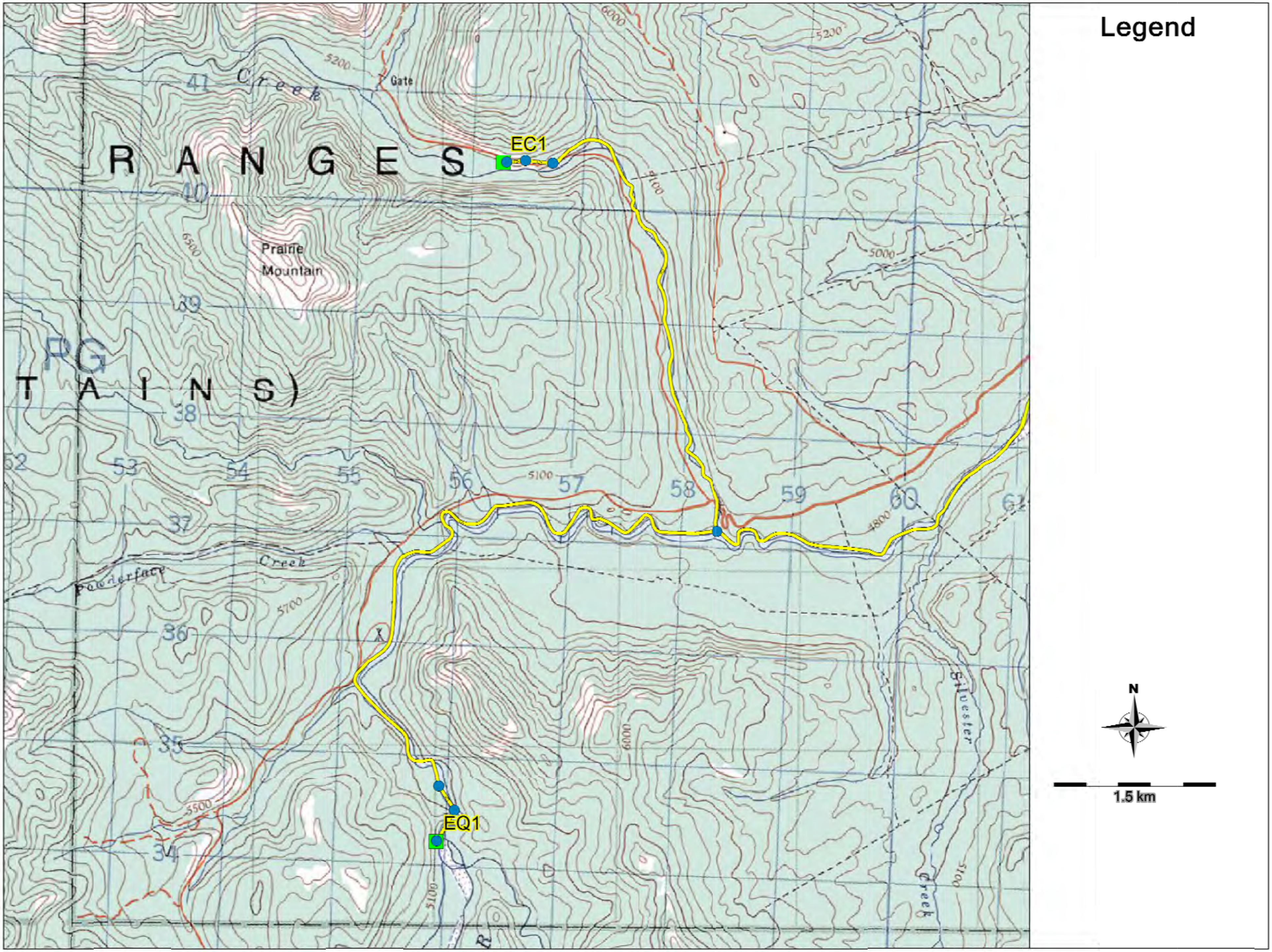
Title
High River Diversion
Profile

120990001

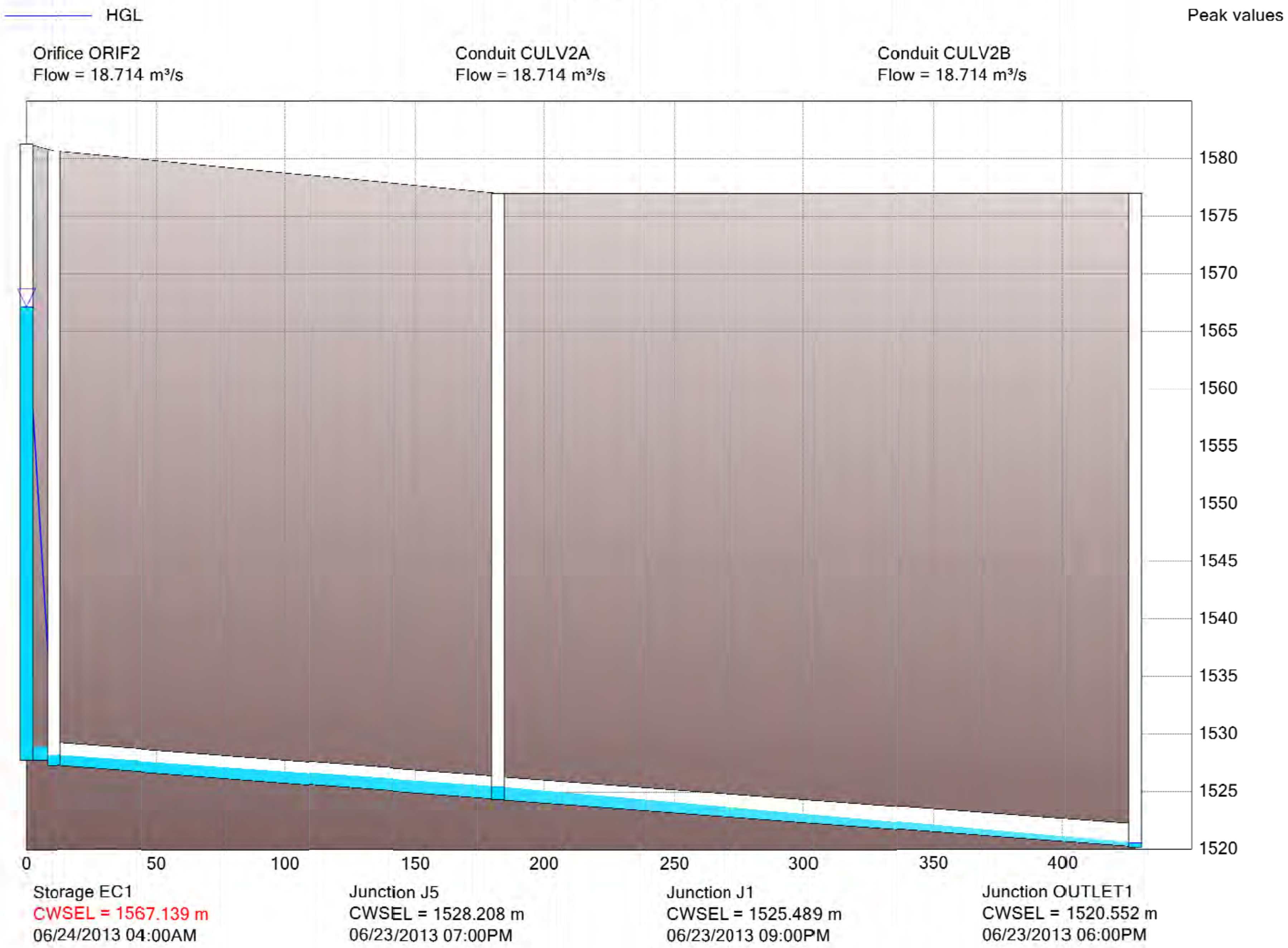
Appendix A

PCSWMM Model Images

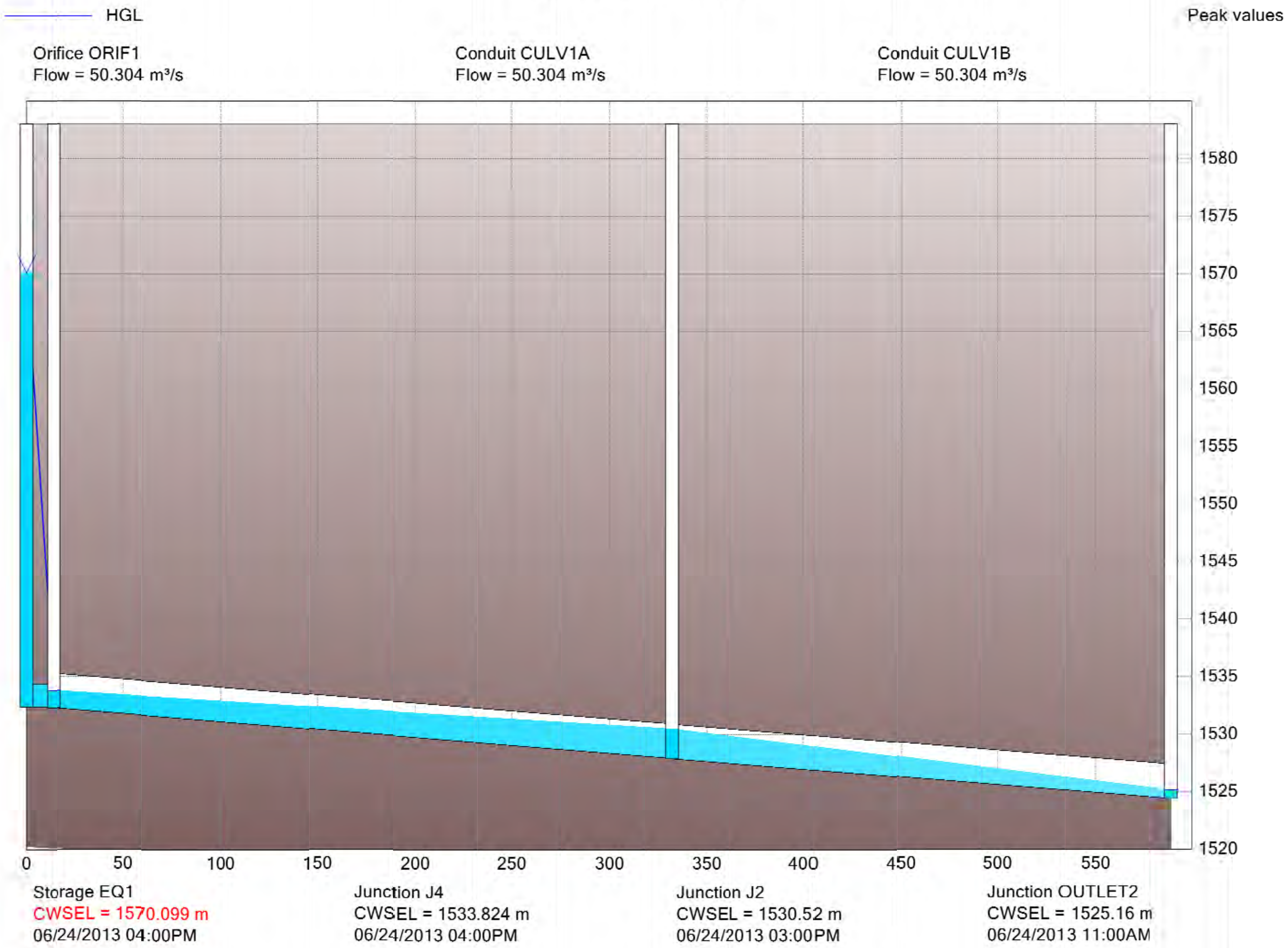

Legend
BraggCreek
EC1
EQ1
N
4 km
SARCEE
INDIAN RESERV
BRAGG CREEK PROVINCIAL PARK
ELBOW
RIVER
R A N G E S
A I N S)
PG

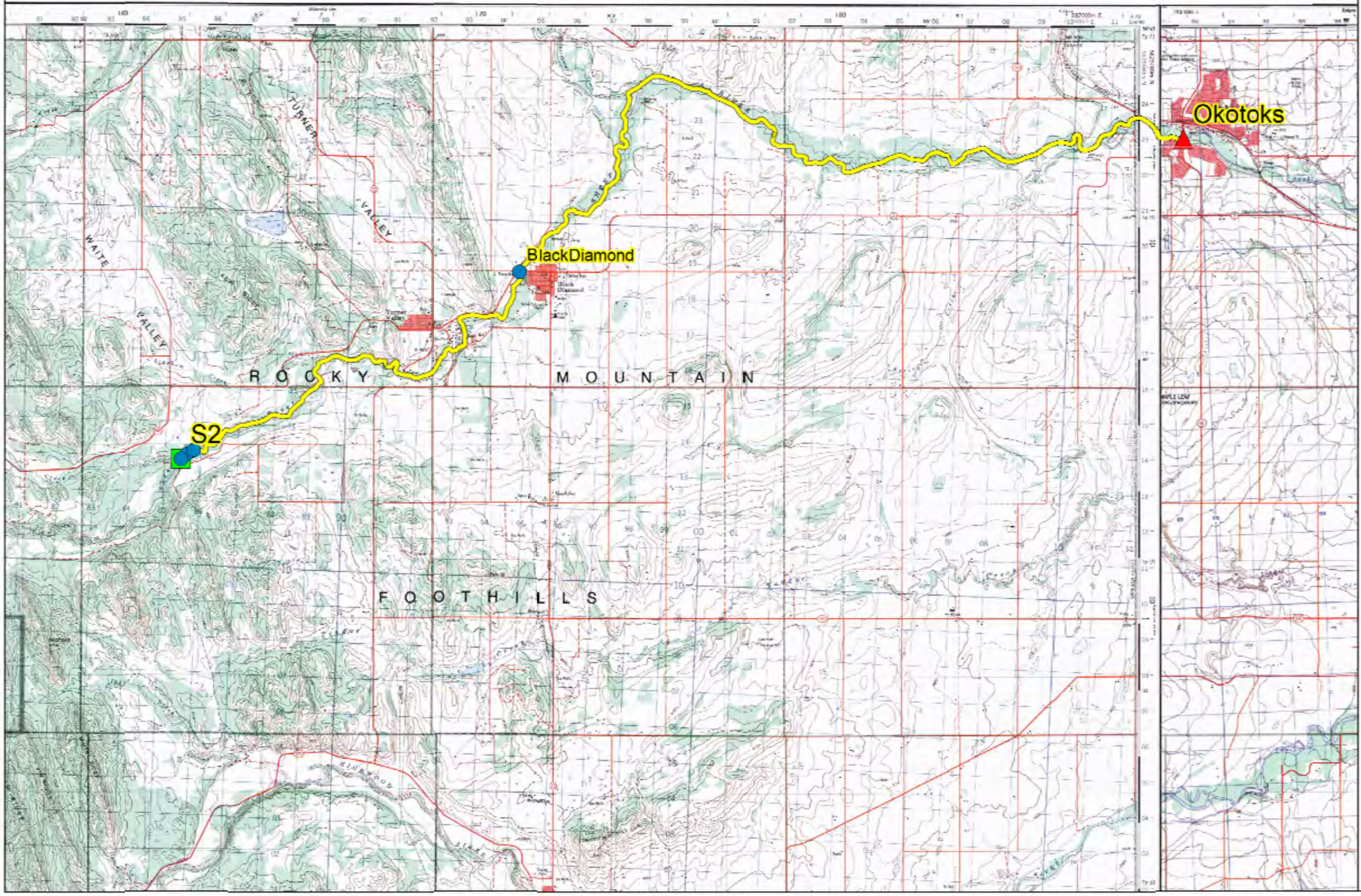

Legend
EC1
EQ1
R A N G E S
T A I N S)
PG
Prairie Mountain
Creek
Gate
Powderface Creek
Silvester Creek
41
40
39
38
37
36
35
34
52
53
54
55
56
57
58
59
60
61
5200
6000
5100
6500
5000
5700
4800
5500
N
1.5 km

Site EC1 Profile

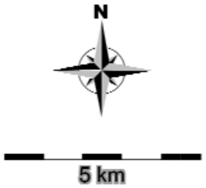


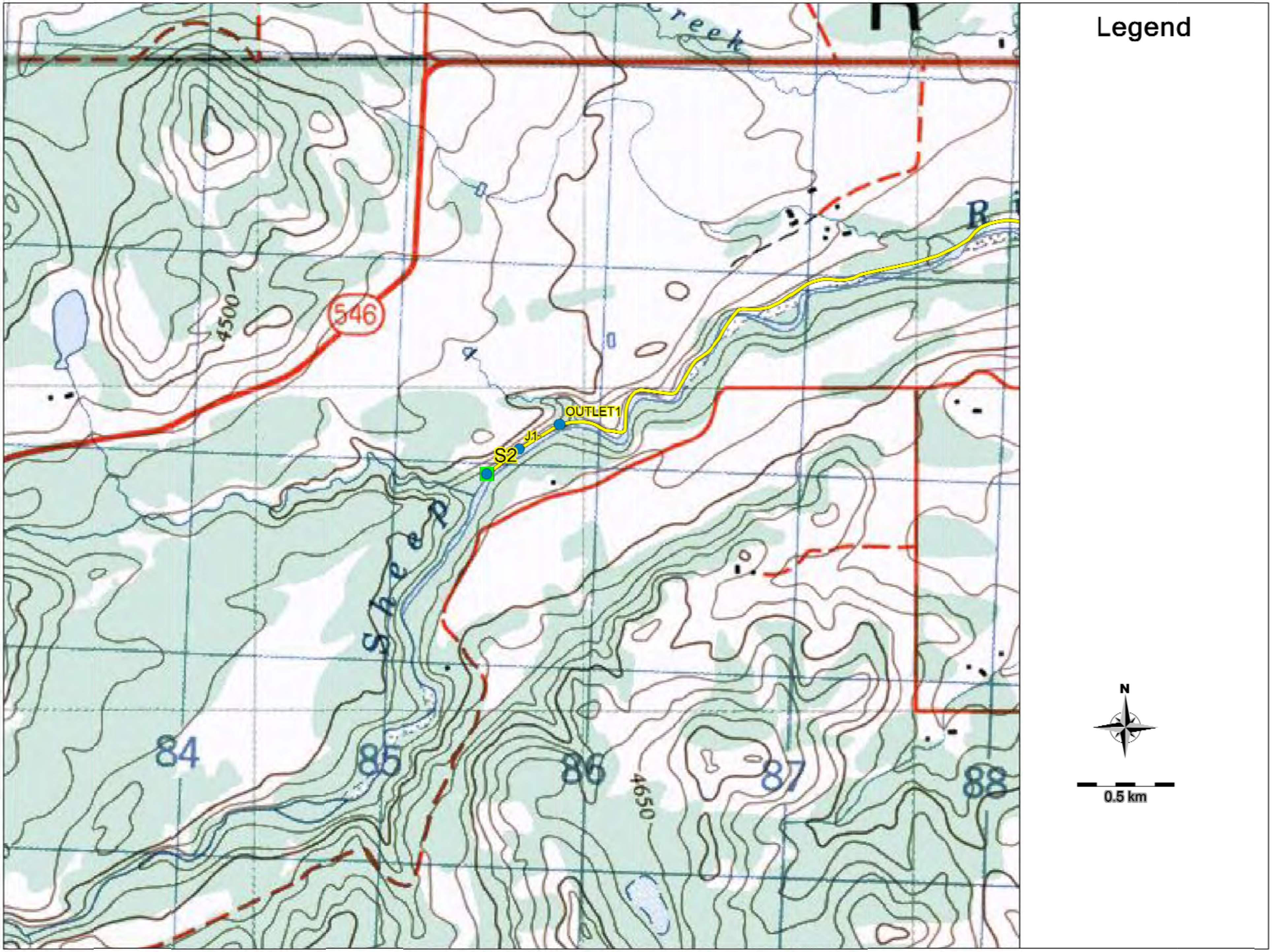
Site EQ1 Profile



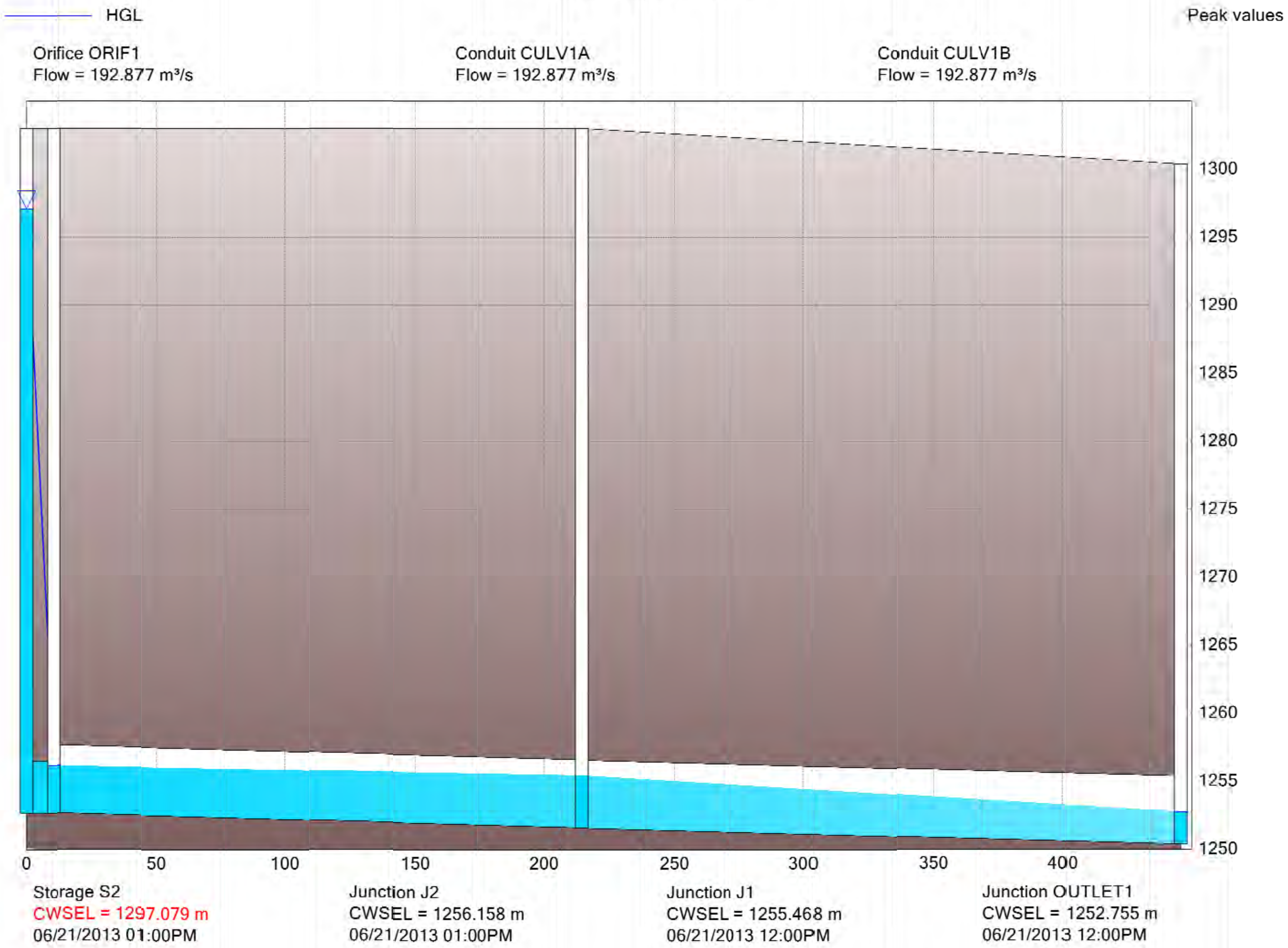

Okotoks
BlackDiamond
S2
ROCKY MOUNTAIN
FOOTHILLS
TURNER VALLEY
WAITE VALLEY

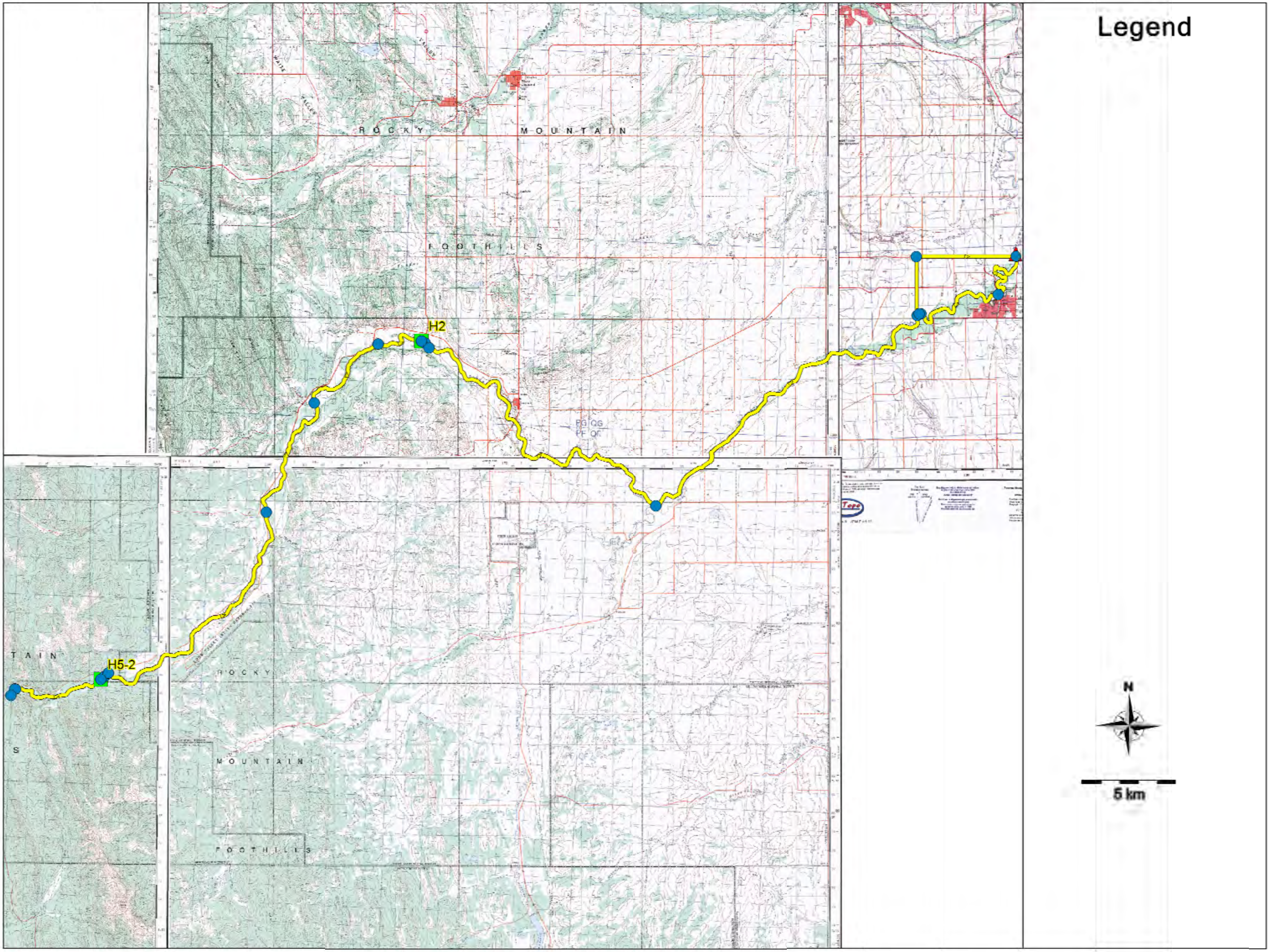
Legend

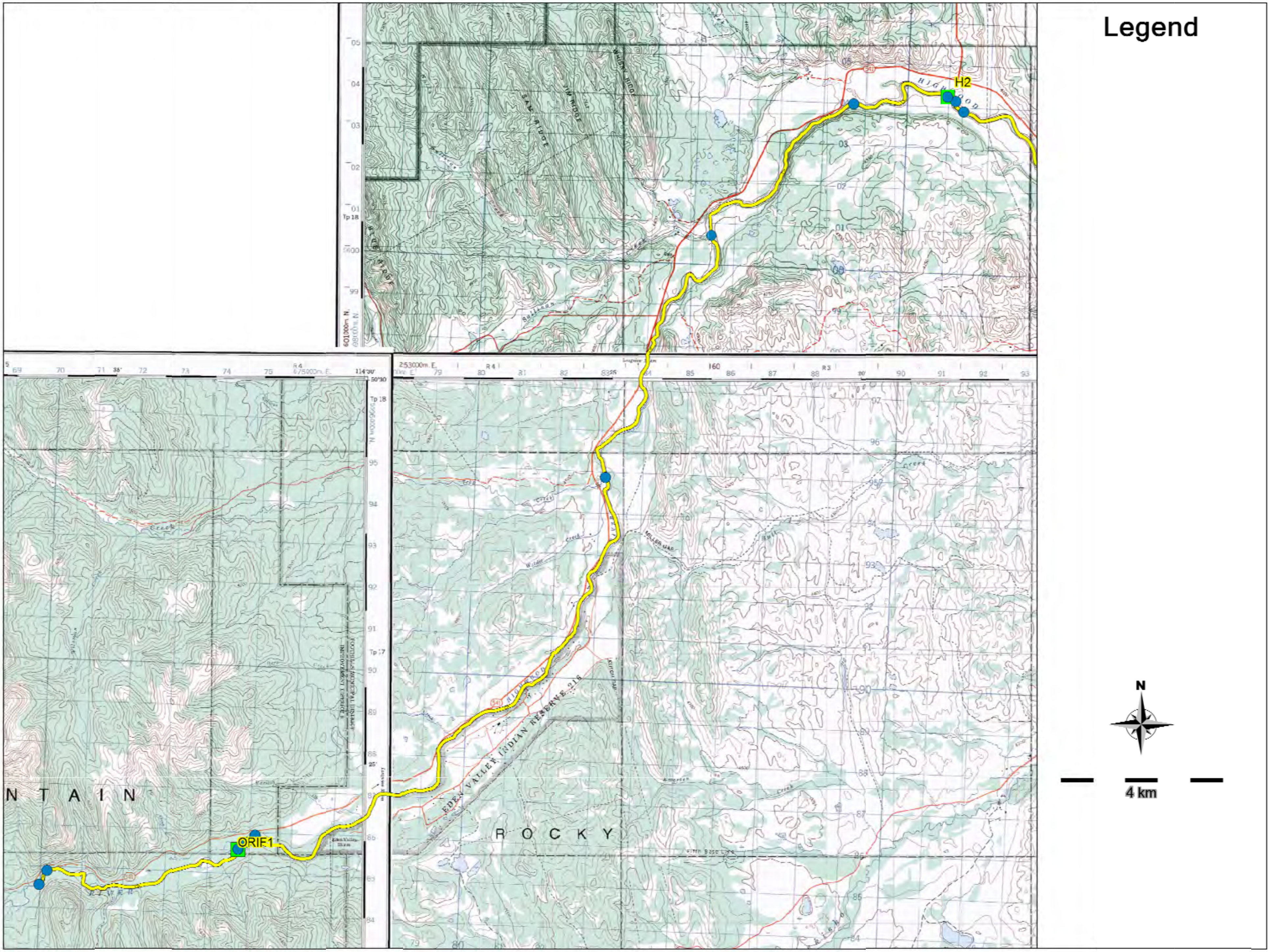

N
5 km

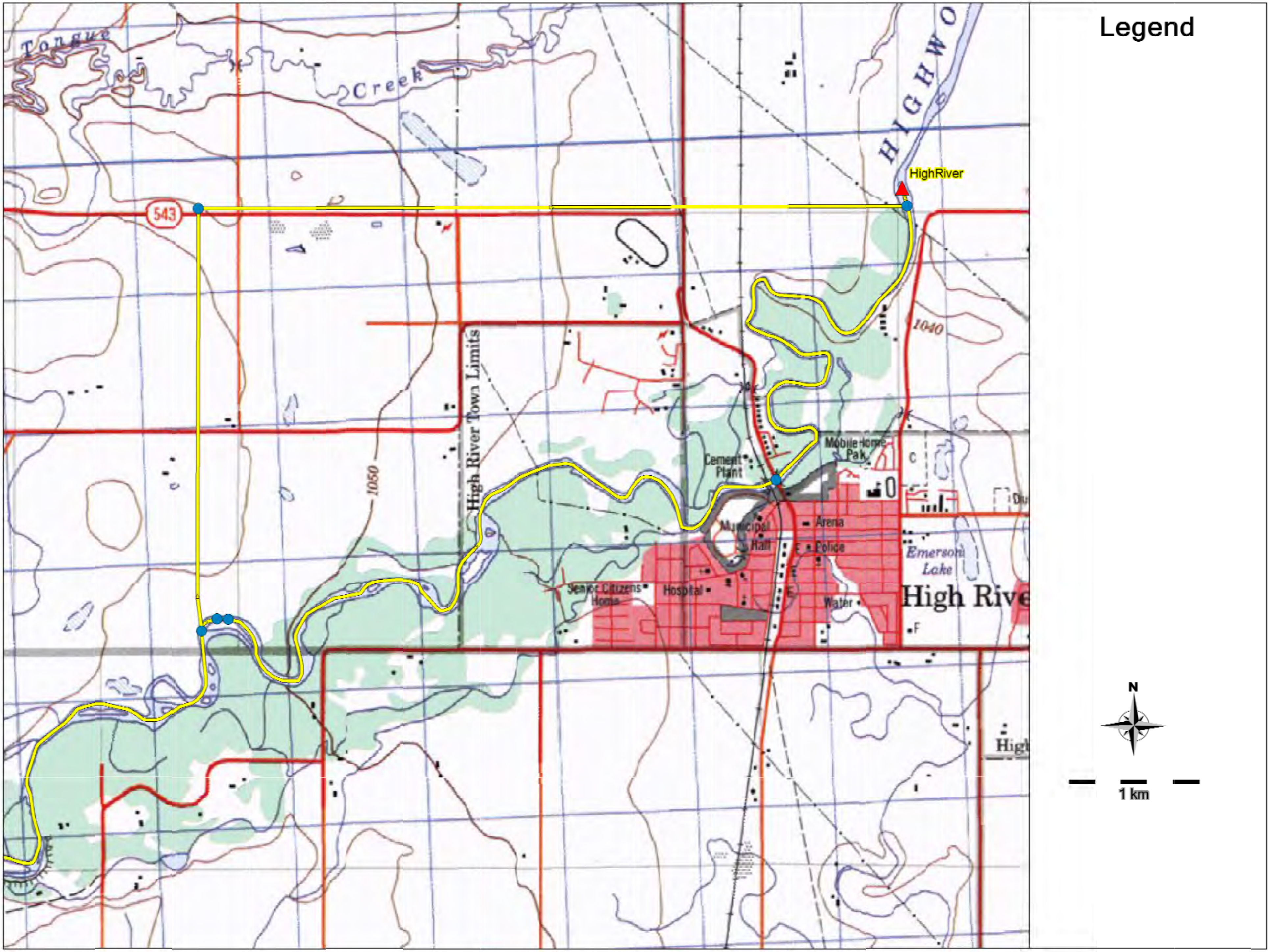

Creek
546
4500
R i
OUTLET1
J1
S2
Sheep
84
85
86
87
88
4650
Legend
N
0.5 km

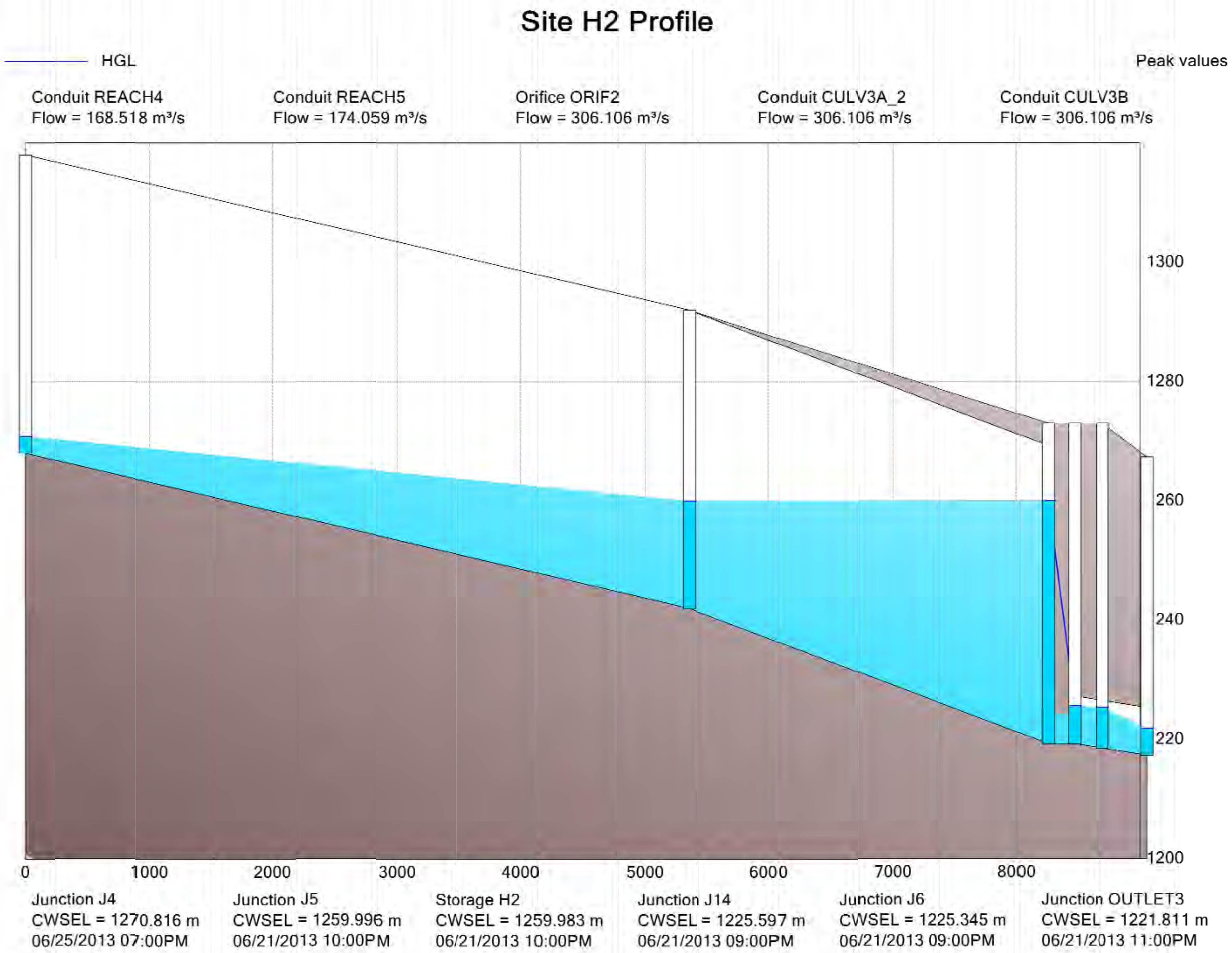
Site S2 Profile



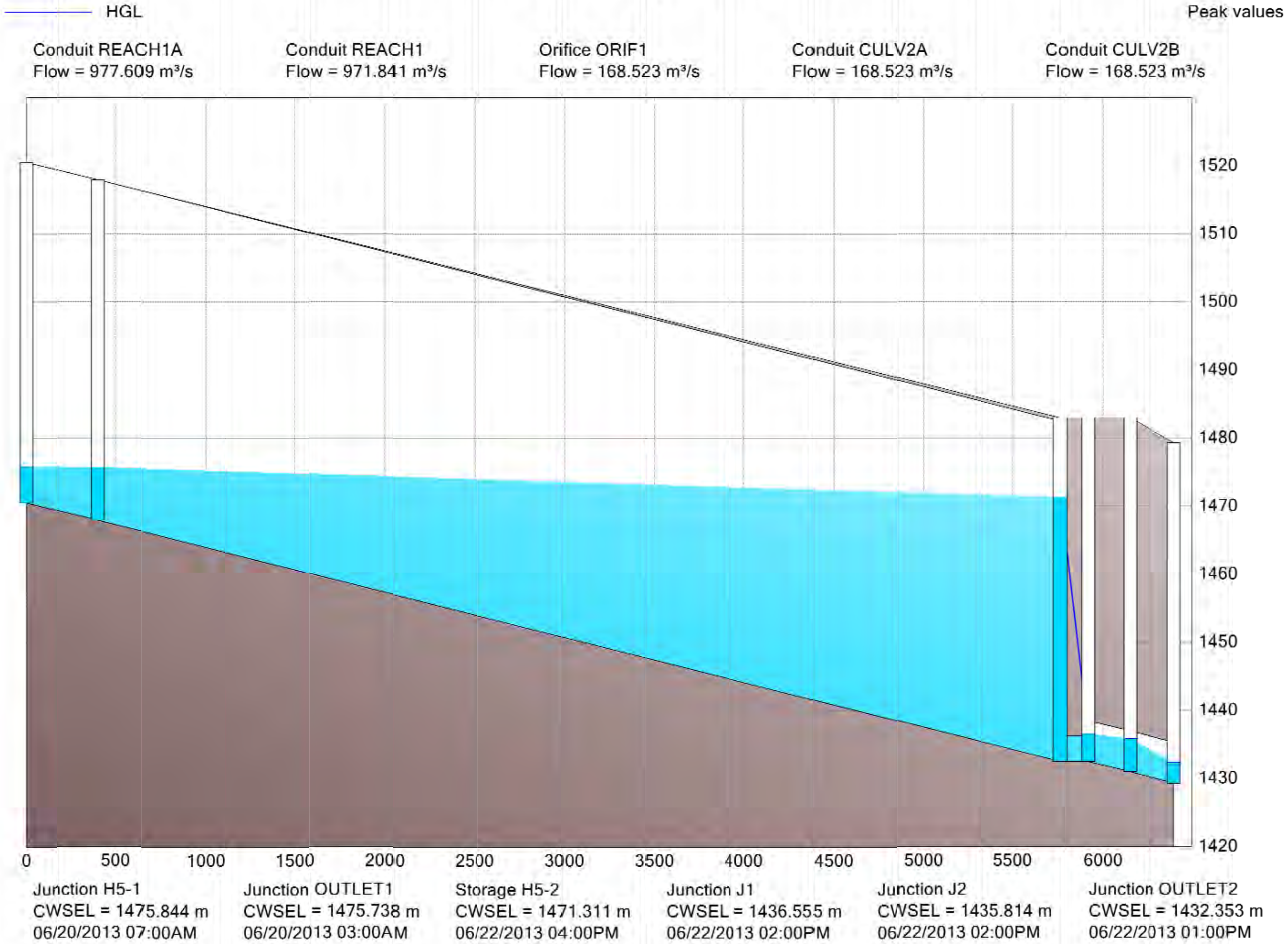

Legend
ROCKY MOUNTAIN
FOOTHILLS
H2
H5-2
TAIN
S
ROCKY
MOUNTAIN
FOOTHILLS
N
5 km


Legend
H2
RIF1
N
4 km
N T A I N
R O C K Y
EDEN VALLEY INDIAN RESERVE 216
HIGHWOOD
Tp 18
Tp 17
R 4
R 3

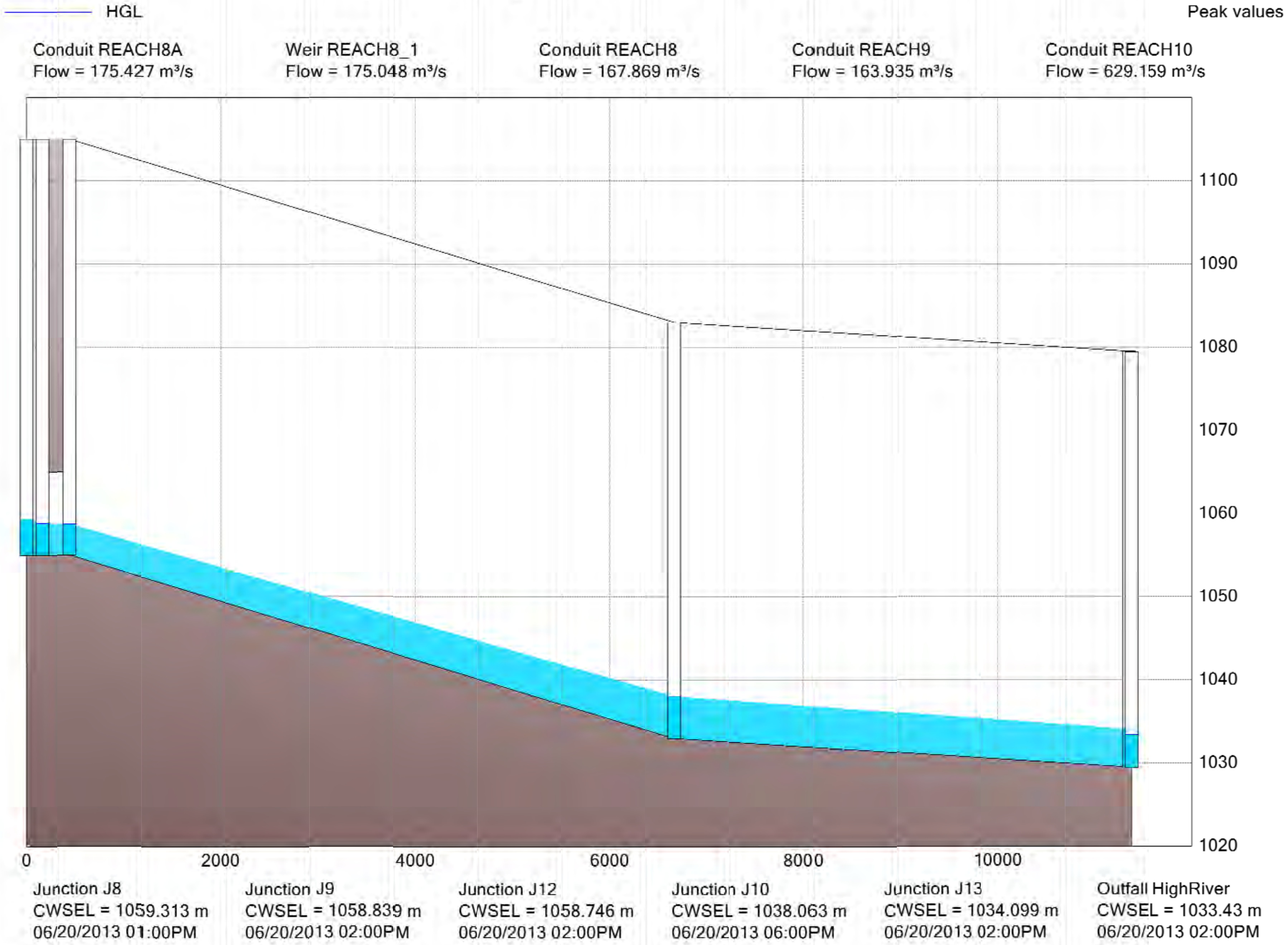

Legend
N
1 km
HighRiver
Tongue Creek
HIGHWO
543
High River Town Limits
1050
1040
Cement Plant
Mobile Home Park
Municipal Hall
Arena
Police
Senior Citizens Home
Hospital
Water
Emerson Lake
High Rive


Site H2 Profile
HGL
Peak values
Conduit REACH4
Flow = 168.518 m³/s
Conduit REACH5
Flow = 174.059 m³/s
Orifice ORIF2
Flow = 306.106 m³/s
Conduit CULV3A_2
Flow = 306.106 m³/s
Conduit CULV3B
Flow = 306.106 m³/s
1300
1280
260
240
220
1200
0
1000
2000
3000
4000
5000
6000
7000
8000
Junction J4
CWSEL = 1270.816 m
06/25/2013 07:00PM
Junction J5
CWSEL = 1259.996 m
06/21/2013 10:00PM
Storage H2
CWSEL = 1259.983 m
06/21/2013 10:00PM
Junction J14
CWSEL = 1225.597 m
06/21/2013 09:00PM
Junction J6
CWSEL = 1225.345 m
06/21/2013 09:00PM
Junction OUTLET3
CWSEL = 1221.811 m
06/21/2013 11:00PM

Site H5(2) Profile



Town of High River Profile with Diversion



Appendix B

McIntosh•Lalani Geotechnical Report

Stantec

McINTOSH • LALANI ENGINEERING LTD.

DRAFT

September 30, 2013

Government of Alberta
c/o Stantec Consulting
200 - 325 - 25th Street SE
Calgary, Alberta
T2A 7H8

ML-6341

Attention: Mr. Harold Perrin

Dear Sir:

Subject: **Preliminary Investigation**
58th Avenue South Aqueduct
Calgary, Alberta

This letter presents the preliminary results of a geotechnical evaluation conducted by McIntosh•Lalani Engineering Ltd. (M•L) for the proposed bored tunnel along 58th Avenue South in Calgary, Alberta. This evaluation was undertaken at the request of Mr. Herold Perrin of Stantec Consulting. The objective of this evaluation was to investigate and log the general subsurface soil and bedrock conditions along the proposed alignment for others to assess the feasibility of the proposed infrastructure works.

This letter presents the results of the drilling program and provides preliminary geotechnical recommendations for design & construction.

1.0 PROJECT DESCRIPTION

It is our understanding that the pipeline will generally follow the 58th Avenue South corridor, extending from Glenmore Reservoir at the west end to the Bow River at the east end, a distance of approximately 4.2 km. The anticipated depths are between 30 and 60 metres below current site grades. It is understood that the incline of the tunnel will range from 0.1% to 0.4%. Based on topography along the alignment, the intake to the tunnel is expected to be via a vertical shaft below the reservoir.

2.0 GEOTECHNICAL INVESTIGATION

2.1 Field Investigation

The fieldwork consisted of advancing five (5) boreholes along the proposed alignment. The boreholes were advanced on September 4-18, 2013 using Beckerhammer and truck-mounted wireline coring drill rigs contracted from Earth Drilling Co. Ltd. of Calgary, Alberta. The Beckerhammer drill rigs were utilized to advance casing to the top of bedrock. Coring was then performed using the truck-mounted coring rig to total depth. The boreholes were positioned to be as evenly distributed along the alignment as possible, subject to traffic accommodation requirements and utility clearance.

The locations of the boreholes, the depths drilled, and the elevations at which bedrock was encountered are summarized in Table 1 below.

Table 1: Summary of Boreholes Advanced

Borehole No.	Location	Total Depth (m)	3TM ref. 114W Coordinates Northing (m)	3TM ref. 114W Coordinates Easting (m)	Ground Elevation (m)	Bedrock Elevation (m)	Termination Elevation (m)
1	Below the Reservoir	60.8	5651666.4	-6689.7	1062.5	1053.9	1001.7
2	58th Ave SW at Elbow Dr SW	60.7	5651670.0	-5557.9	1067.8	1056.8	1007.1
4	58th Ave SE at 4th St SE	60.7	5651652.7	-3684.0	1062.2	1020.2	1001.5
5	58th Ave SE at 11th St SE	30.2	5651704.0	-2739.8	1044.3	1019.7	1014.1
6	Deerfoot Trail	25.6	5651639.2	-2177.2	1025.4	1013.6	999.8

In Borehole #4, the bedrock depth exceeded the readily available length of Beckerhammer casing. Coring was started above the bedrock.

All field work was carried out under the full time inspection of a member of M•L staff. In the field, M•L logged the percentage core recovery and RQD of core samples obtained. The rock descriptions, as well as field estimates of the ISRM grades, are presented in the attached borehole logs. Photographic records of each core are also attached.

Upon completion of the boreholes, PVC standpipe piezometers were installed in each of the boreholes for future groundwater monitoring. Nested piezometers were installed within the deeper wells to identify possible changes in hydrostatic head with depth.

2.2 Laboratory Testing

Compressive strength testing on representative core samples of the bedrock is in progress. The results will be forwarded when available.

3.0 SUBSURFACE CONDITIONS

The general subsurface conditions consisted of 8.6 to 42.0 metres of overburden overlying sedimentary bedrock. The overburden generally consisted of silt and clay tills, some lacustrine silts and clays, and fluvial channel gravels. The sedimentary bedrock was primarily siltstone with some sandstone and mudstone layers.

Overburden

The depths of overburden ranged from 8.6 to 42.0 metres. As the overburden materials encountered were highly variable, the five boreholes will be discussed as three groups:

In Boreholes #1 and #2, the depths of overburden ranged from 8.6 to 11.0 metres and consisted of fluvial channel bottom sandy gravel deposits, overlain by lacustrine silt to silty clay deposits. In Borehole #2, a layer of silty clay till was encountered between the lacustrine and fluvial channel bottom deposits.

In Borehole #4, a layer of fluvial channel bottom gravelly sand was underlain by clayey silt, first till then lacustrine. The bedrock was encountered at a depth of 42.0 m. This location is possibly a trench in the bedrock created by a historical stream.

In Boreholes #5 and #6, the depths of overburden ranged from 11.8 to 24.6 metres. The deposits were generally fluvial channel bottom deposits such as sandy gravel to gravelly sand. Some layers of clayey silt to silty clay were encountered within Borehole #5.

Bedrock

Sedimentary bedrock was encountered within all five boreholes. The upper stratum of the bedrock was weathered, generally transitioning into stronger, intact bedrock with depth. The rock was primarily siltstone with an estimated unconfined uniaxial compressive strength (UCS) of 2 to 25 MPa. The sandstone layers encountered are estimated to have a UCS of 25 to 50 MPa. Thin layers of weaker rock, such as mudstones, coal, and highly weathered siltstone, were encountered and should be expected to be highly fractured and have a UCS of as low as 0.25 MPa. The above given compressive strength estimates will be supplemented with the results of in-progress laboratory testing and the results forwarded when available.

The encountered subsurface conditions are described in detail on the attached borehole logs. Photographic records of each core are also attached.

3.1 Groundwater

Groundwater measurements were last taken on September 20, 2013. Groundwater levels ranged from near surface to 19.82 metres below grade. It is expected that the dissipation of coring water into the bedrock is still in progress, at least for the wells drilled later in the programme. A second set of water level readings will be made in the near future and the results forwarded once available.

The water levels are indicated on the attached borehole logs.

4.0 RECOMMENDATIONS

It is understood that the above described geotechnical investigation was preliminary in nature and the feasibility of tunneling through the bedrock will be assessed by experienced tunneling engineers under separate contract.

M•L makes the following general recommendations:

- The presence of weak layers within the bedrock should be expected. Water seepage may be present in highly weathered layers and coal seams. There can be high water flows in the fractured rock layers. Should high water flows have the potential to affect the tunneling process, the flow potential and pressure should be further evaluated.

- Some layers of the siltstone were weak enough to "gum up" the coring bit and also were prone to washing away. This should be expected during tunneling operations. Many sedimentary bedrock layers are "soil-like", and should be treated as such in tunneling activities.

- Bedrock was encountered in Borehole #4 at 1020.2 m, which is considerably deeper than the 1040 m approximate depth shown on Moran's bedrock topography map (S.R. Moran, "Surficial geology of the Calgary urban area", 1986). Also, based on conversations with the drilling company, who are familiar with the area, bedrock for nearby buildings was encountered at depths of 9-12 metres. As such, this area should be considered highly variable and further investigation must be done for the exact alignment to determine the local topography of bedrock. It is possible that a bedrock trench exists in the area, and the encountered 42 metre depth to bedrock may not even be representative of the deepest location.

5.0 CLOSURE

Recommendations presented herein are based on a geotechnical evaluation of the findings in five (5) boreholes. This represents a preliminary geotechnical investigation only. Construction should only begin after a more thorough investigation is conducted under the direction of an engineer experienced in the chosen method of tunnel construction. This report does not include any recommendations related to contaminants in soil or groundwater.

We trust information presented herein meets with your present requirements. If you have questions or require additional geotechnical services please contact our office.

Respectfully submitted,
McIntosh•Lalani Engineering Ltd.

DRAFT

Alex Taylor-Noonan, E.I.T.
Junior Geotechnial Engineer

Marty Ward, P.Eng.
Senior Project Engineer
APEGA Permit #6482

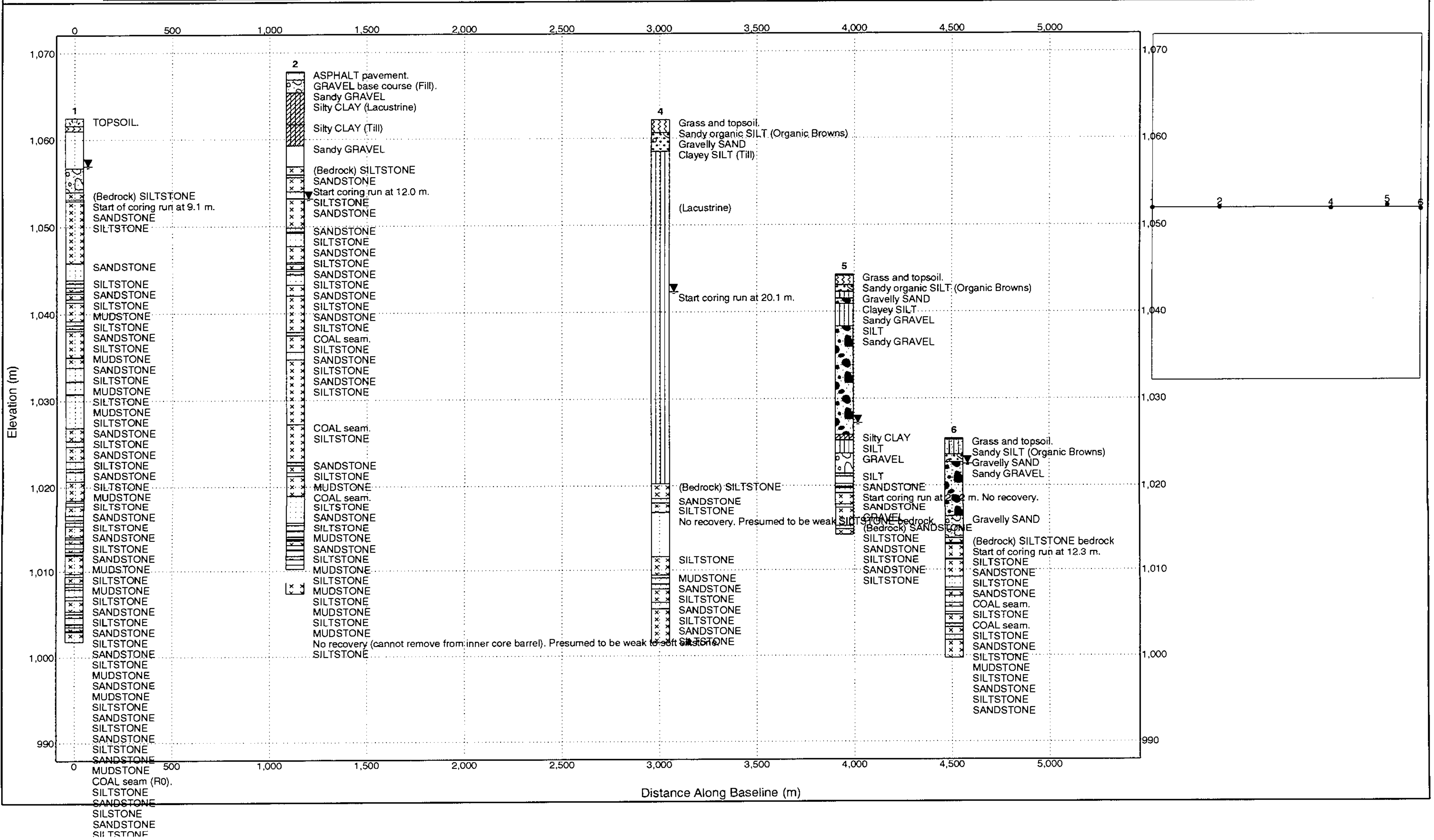
/atn

McIntosh Lalani Engineering

SUBSURFACE DIAGRAM

CLIENT Government of Alberta
PROJECT NUMBER ML-6341

PROJECT NAME c/o Stantec Consulting
PROJECT LOCATION 58th Ave S, Calgary, AB



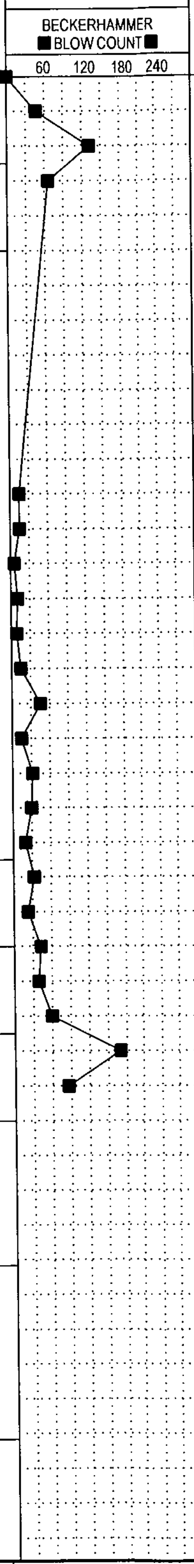
Project: 58th Avenue South Project	Drilling Information:	Borehole No.:1
Client: Government of Alberta	Earth Drilling Co. Ltd.	Project No.:ML-6341
c/o Stantec Consulting	Beckerhammer and Rotary Coring	Elevation:1062.52

SAMPLE TYPE ■ SHELBY TUBE ▮ CORE SAMPLE ☒ SPT SAMPLE ✋ GRAB SAMPLE NO RECOVERY

BACKFILL TYPE ■ BENTONITE ⁚ PEA GRAVEL ▥ SLOUGH ⁘ GROUT ▧ DRILL CUTTINGS ⁙ SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	BLOWS	RECOVERY (%)	RQD (%)	OTHER DATA
0	TOPSOIL.	✋	11-1	0 47 132			
1	SILT (Organic Browns) - trace clay and sand, trace gravel, poor recovery, medium brown. No recovery.	✋	11-2	66			
3.6–5.5				15 15 6 11 9 15 46			
5.7	Sandy GRAVEL - poorly graded, poor recovery.			15 32 30 20			
7		✋	11-3	33 23			
8		✋	11-4	43 39 60			
8.5	(Bedrock) SILTSTONE - highly weathered, close joint spacing, medium grey (R0).	✋	11-5	170 86			
9.1	Start of coring run at 9.1 m. - less weathered, wider joint spacing (R1). SANDSTONE - soft, light grey (R2).	▮	1-1		86	40	
10.5	SILTSTONE - weak to soft, medium grey (R1/R2). - highly weathered (R1). - less weathered (R1).	▮	1-2		100	40	
11.8	- weak (R1). - soft (R2). - weak, dark grey (R1). - medium grey (R1). - soft (R2).	▮	1-3		90	65	Drill string chattering. Quick drilling.

Groundwater ▼ at 5.5 m.



McIntosh Lalani Engineering
Calgary, AB
(403) 291-2345

Logged By: ATN	Completion Depth: 199.33 ft
Reviewed By: Marty Ward	Drilled on: 2013-09-11
Groundwater Depth: 5.59 m	Page 1 of 5

Project: 58th Avenue South Project	Drilling Information:	Borehole No.:1
Client: Government of Alberta	Earth Drilling Co. Ltd.	Project No.:ML-6341
c/o Stantec Consulting	Beckerhammer and Rotary Coring	Elevation:1062.52

SAMPLE TYPE ■ SHELBY TUBE ▯ CORE SAMPLE ☒ SPT SAMPLE GRAB SAMPLE NO RECOVERY

BACKFILL TYPE ■ BENTONITE ⁚ PEA GRAVEL ▥ SLOUGH ⁛ GROUT ▨ DRILL CUTTINGS ⁛ SAND

Depth (m)	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	BLOWS	RECOVERY (%)	RQD (%)	BECKERHAMMER ■ BLOW COUNT ■ 60 120 180 240	PLASTIC M.C. LIQUID 10 20 30 40	OTHER DATA	SLOTTED PIEZOMETER	SLOTTED PIEZOMETER	Elevation (m)
13		- weak seam, dark grey (R1). - medium grey (R2). - weak, dark grey (R1). - soft, medium grey (R2).											1049
14		- highly weathered, dark grey (R0). - soft, light grey (R2).		1-4		100	80						1048
15		- weak (R1). - soft (R2). - moderately wide joint spacing (R2).		1-5		100	80						1047
16		- weak (R1).											1046
17		SANDSTONE - wide joint spacing, light grey (R3).		1-6		100	95			Drill string chattering.			1045
18		SILTSTONE - soft, medium grey (R2).											1044
19		SANDSTONE - light grey (R3). SILTSTONE - soft, medium grey (R2).		1-7		100	100						1043
20		MUDSTONE - weak, dark grey (R1). SILTSTONE - soft, medium grey (R2).		1-8		100	100						1042
21		SANDSTONE - medium grey (R3). SILTSTONE - soft, medium grey (R2).								Slower drilling.			1041
22		MUDSTONE - weak, dark grey (R1).		1-9		100	90						1040
23		- weak, medium grey (R1). - soft (R2). SANDSTONE - light grey (R3). - soft (R2).		1-10		100	100						1039
24		SILTSTONE - weak, dark grey (R1). - soft, medium grey (R2). MUDSTONE - weak, dark grey (R1).								Drill string chattering.			1038
25		SILTSTONE - weak, medium grey (R1).		1-11		100	90						1037
										Very slow drilling, bit plugging up.			

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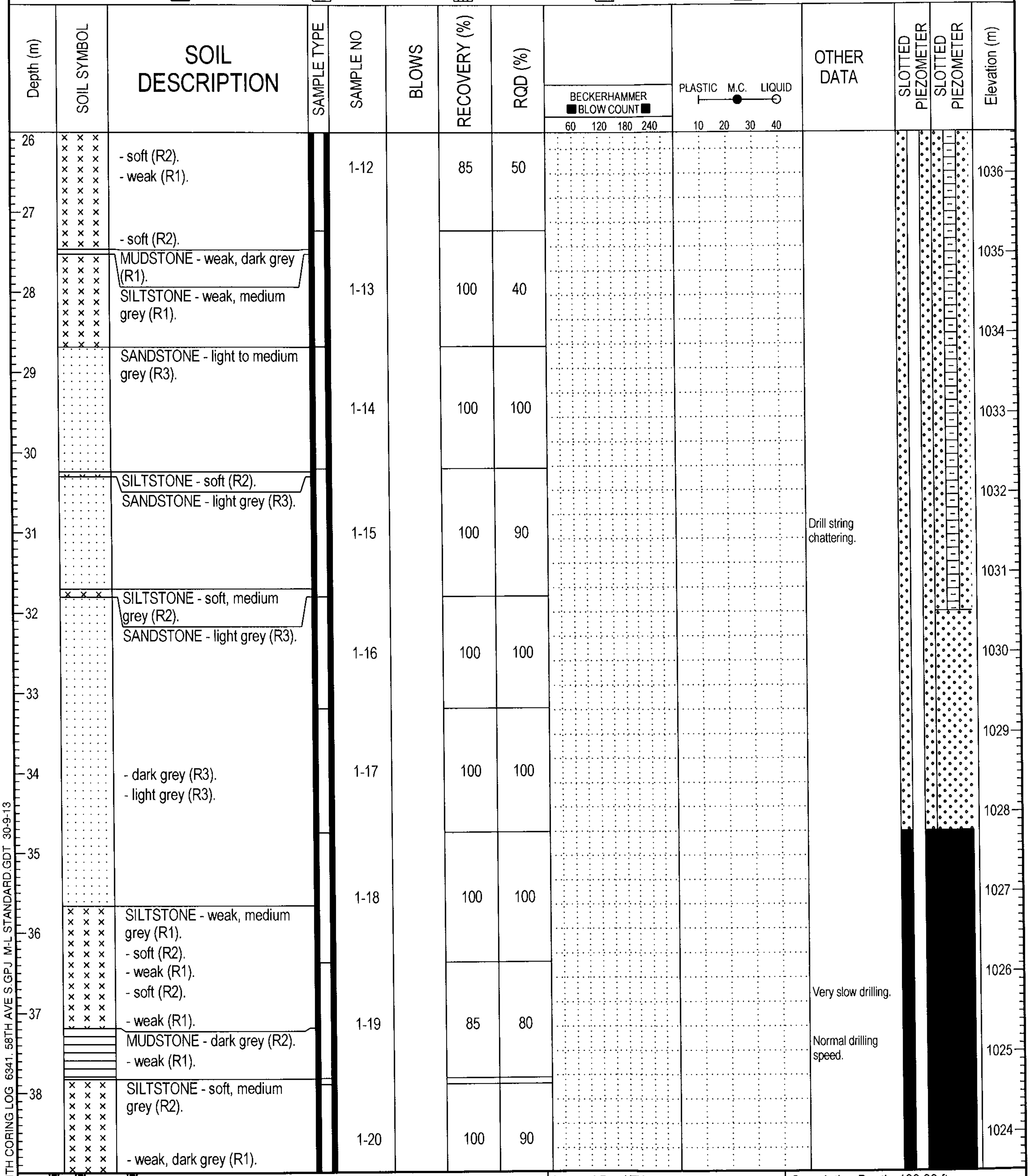
Logged By: ATN	Completion Depth: 199.33 ft
Reviewed By: Marty Ward	Drilled on: 2013-09-11
Groundwater Depth: 5.59 m	

Project: 58th Avenue South Project	Drilling Information:	Borehole No.:1
Client: Government of Alberta	Earth Drilling Co. Ltd.	Project No.:ML-6341
c/o Stantec Consulting	Beckerhammer and Rotary Coring	Elevation:1062.52

SAMPLE TYPE ■ SHELBY TUBE ▯ CORE SAMPLE ☒ SPT SAMPLE GRAB SAMPLE NO RECOVERY

BACKFILL TYPE ■ BENTONITE ⁚ PEA GRAVEL ▥ SLOUGH GROUT ▨ DRILL CUTTINGS ⁙ SAND



SOIL DESCRIPTION	SAMPLE NO	RECOVERY (%)	RQD (%)	OTHER DATA
- soft (R2). - weak (R1).	1-12	85	50	
- soft (R2).				
MUDSTONE - weak, dark grey (R1).				
SILTSTONE - weak, medium grey (R1).	1-13	100	40	
SANDSTONE - light to medium grey (R3).	1-14	100	100	
SILTSTONE - soft (R2).				
SANDSTONE - light grey (R3).	1-15	100	90	Drill string chattering.
SILTSTONE - soft, medium grey (R2).				
SANDSTONE - light grey (R3).	1-16	100	100	
- dark grey (R3). - light grey (R3).	1-17	100	100	
	1-18	100	100	
SILTSTONE - weak, medium grey (R1). - soft (R2). - weak (R1). - soft (R2).				Very slow drilling.
- weak (R1).	1-19	85	80	
MUDSTONE - dark grey (R2). - weak (R1).				Normal drilling speed.
SILTSTONE - soft, medium grey (R2). - weak, dark grey (R1).	1-20	100	90	

McIntosh Lalani Engineering Calgary, AB (403) 291-2345	Logged By: ATN	Completion Depth: 199.33 ft
	Reviewed By: Marty Ward	Drilled on: 2013-09-11
	Groundwater Depth: 5.59 m	

Project: 58th Avenue South Project	Drilling Information:	Borehole No.:1
Client: Government of Alberta	Earth Drilling Co. Ltd.	Project No.:ML-6341
c/o Stantec Consulting	Beckerhammer and Rotary Coring	Elevation:1062.52

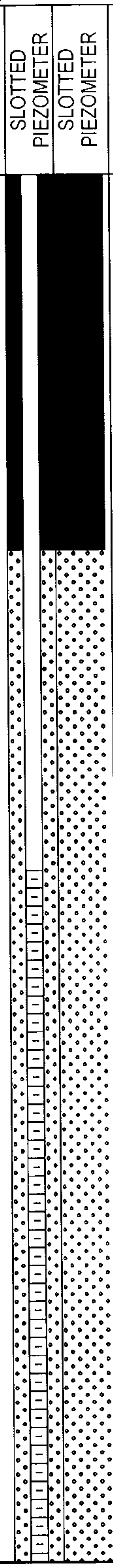
SAMPLE TYPE ■ SHELBY TUBE ▯ CORE SAMPLE ☒ SPT SAMPLE GRAB SAMPLE NO RECOVERY

BACKFILL TYPE ■ BENTONITE ⁙ PEA GRAVEL ▥ SLOUGH GROUT ▨ DRILL CUTTINGS ⁙ SAND

BECKERHAMMER ■ BLOW COUNT ■ 60 120 180 240

PLASTIC M.C. LIQUID 10 20 30 40

Depth (m)	SOIL DESCRIPTION	SAMPLE NO	BLOWS	RECOVERY (%)	RQD (%)	OTHER DATA	Elevation (m)
39	- soft (R2).						
	- weak (R1).						
	- soft, light grey (R2).						1023
	SANDSTONE - light grey (R3).						
40		1-21		100	85		
	SILTSTONE - weak, dark grey (R1).						1022
41	- soft (R2).						
	SANDSTONE - light grey (R3).						1021
		1-22		100	100		
42	SILTSTONE - soft, medium grey (R2).						
	- highly fractured.						1020
43		1-23		100	45		
							1019
44	- dark grey.						
	SANDSTONE - light grey (R3).						
	MUDSTONE - soft, dark grey (R2).						1018
		1-24		100	100		
45	SILTSTONE - soft, dark grey (R2).						
							1017
46	MUDSTONE - weak, dark grey (R1).						
		1-25		100	85		
	SILTSTONE - soft, dark grey (R2).						1016
47	SANDSTONE - light grey (R3).						
	SILTSTONE - soft, medium grey (R3).						1015
		1-26		100	100		
48	- weak to soft (R1/R2).						
							1014
	SANDSTONE - highly fractured (R2/R3).						
49	SILTSTONE - less fractured (R2).						
		1-27		100	60		1013
	SANDSTONE - light grey (R3).						
50	SILTSTONE - soft, dark grey (R2).						
	MUDSTONE - soft, dark grey (R2).						1012
51	SANDSTONE - medium strong, medium grey (R3).	1-28		100	80		
	MUDSTONE - soft, dark grey (R2).						1011
	SILTSTONE - soft, medium						



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Logged By: ATN	Completion Depth: 199.33 ft
Reviewed By: Marty Ward	Drilled on: 2013-09-11
Groundwater Depth: 5.59 m	

Project: 58th Avenue South Project	Drilling Information:	Borehole No.:1
Client: Government of Alberta	Earth Drilling Co. Ltd.	Project No.:ML-6341
c/o Stantec Consulting	Beckerhammer and Rotary Coring	Elevation:1062.52

SAMPLE TYPE ■ SHELBY TUBE ▮ CORE SAMPLE ☒ SPT SAMPLE GRAB SAMPLE NO RECOVERY

BACKFILL TYPE ■ BENTONITE ☐ PEA GRAVEL ▥ SLOUGH GROUT ▨ DRILL CUTTINGS SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE NO	BLOWS	RECOVERY (%)	RQD (%)	BECKERHAMMER ■ BLOW COUNT ■ 60 120 180 240	PLASTIC M.C. LIQUID 10 20 30 40	OTHER DATA	Elevation (m)
52 53	grey (R2). - medium strong (R3). - soft (R2). - medium strong (R3).	1-29		100	80				1010
54	SANDSTONE - medium strong, fractured (R3). SILTSTONE - soft, dark grey (R2). - (R3). - soft (R2). SANDSTONE - light grey (R3).	1-30		100	60				1009 1008
55 56	SILTSTONE - soft, dark grey (R2). SANDSTONE - very close joint spacing, dark grey (R2/R3). MUDSTONE - soft, dark grey (R1).	1-31		100	40				1007
57	COAL seam (R0). SILTSTONE - soft, dark grey (R2). - weak (R1). - soft (R2). SANDSTONE - medium strong, light grey (R3).	1-32		100	85				1006 1005
58 59	SILSTONE - soft, medium grey (R2). SANDSTONE - medium strong, medium grey (R3). SILTSTONE - weak, dark grey (R1).	1-33		100	40				1004
60	SANDSTONE - medium strong, medium grey (R3). SILTSTONE - soft, medium grey (R2). SANDSTONE - medium strong, light grey (R3). SILTSTONE - soft, medium grey (R2).	1-34		100	70				1003 1002
61 62 63 64	END OF HOLE at 60.8 m. 2 standpipes installed, each 25 mm dia PVC: A: to 60.8 m depth with 15.2 m slotted. B: to 32.0 m depth with 15.2 m slotted. Water levels: September 20, 2013 - A: 5.59 m B: 4.07 m								1001 1000 999 998

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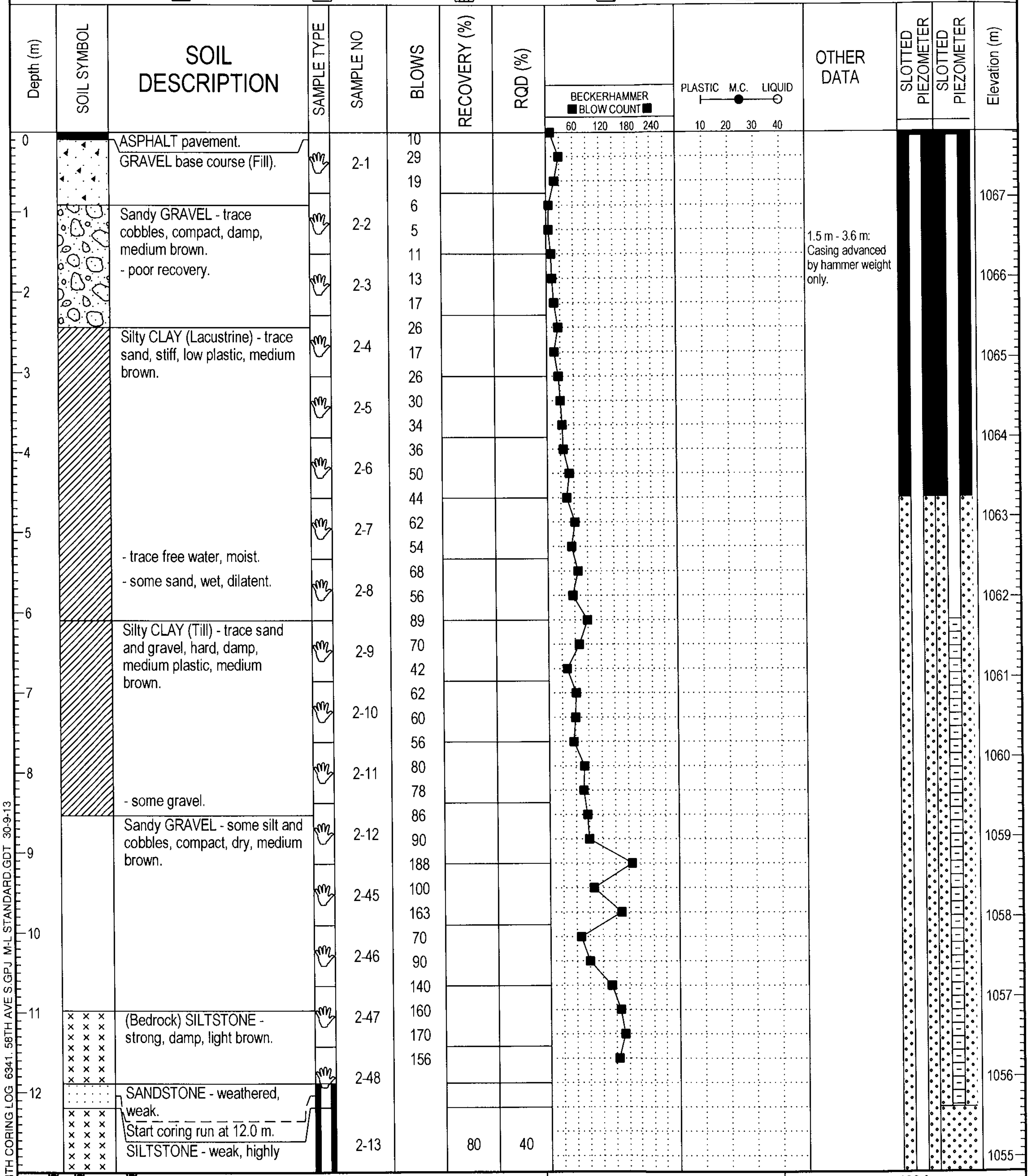
Logged By: ATN	Completion Depth: 199.33 ft
Reviewed By: Marty Ward	Drilled on: 2013-09-11
Groundwater Depth: 5.59 m	Page 5 of 5

Project: 58th Avenue South Project	Drilling Information:	Borehole No.:2
Client: Government of Alberta	Earth Drilling Co. Ltd.	Project No.:ML-6341
c/o Stantec Consulting	Beckerhammer and Rotary Coring	Elevation:1067.82

SAMPLE TYPE ■ SHELBY TUBE ▯ CORE SAMPLE ☒ SPT SAMPLE ✋ GRAB SAMPLE NO RECOVERY

BACKFILL TYPE ■ BENTONITE ⁚ PEA GRAVEL ▥ SLOUGH ⁖ GROUT ▨ DRILL CUTTINGS ⁙ SAND



SOIL DESCRIPTION

ASPHALT pavement.

GRAVEL base course (Fill).

Sandy GRAVEL - trace cobbles, compact, damp, medium brown.
- poor recovery.

Silty CLAY (Lacustrine) - trace sand, stiff, low plastic, medium brown.
- trace free water, moist.
- some sand, wet, dilatent.

Silty CLAY (Till) - trace sand and gravel, hard, damp, medium plastic, medium brown.
- some gravel.

Sandy GRAVEL - some silt and cobbles, compact, dry, medium brown.

(Bedrock) SILTSTONE - strong, damp, light brown.

SANDSTONE - weathered, weak.

Start coring run at 12.0 m.

SILTSTONE - weak, highly

SAMPLE NO	RECOVERY (%)	RQD (%)
2-1		
2-2		
2-3		
2-4		
2-5		
2-6		
2-7		
2-8		
2-9		
2-10		
2-11		
2-12		
2-45		
2-46		
2-47		
2-48		
2-13	80	40

BLOWS: 10, 29, 19, 6, 5, 11, 13, 17, 26, 17, 26, 30, 34, 36, 50, 44, 62, 54, 68, 56, 89, 70, 42, 62, 60, 56, 80, 78, 86, 90, 188, 100, 163, 70, 90, 140, 160, 170, 156

OTHER DATA

1.5 m - 3.6 m: Casing advanced by hammer weight only.

McIntosh Lalani Engineering Calgary, AB (403) 291-2345	Logged By: ATN	Completion Depth: 199 ft
	Reviewed By: Marty Ward	Drilled on: 2013-09-16
	Groundwater Depth: 14.67 m	Page 1 of 5

BECKER WITH CORING LOG 6341, 58TH AVE S.GPJ M-L STANDARD.GDT 30-9-13

Project: 58th Avenue South Project	Drilling Information:	Borehole No.:2
Client: Government of Alberta	Earth Drilling Co. Ltd.	Project No.:ML-6341
c/o Stantec Consulting	Beckerhammer and Rotary Coring	Elevation:1067.82

SAMPLE TYPE ■ SHELBY TUBE ▯ CORE SAMPLE ☒ SPT SAMPLE GRAB SAMPLE NO RECOVERY

BACKFILL TYPE ■ BENTONITE ⁚ PEA GRAVEL ▥ SLOUGH GROUT ▨ DRILL CUTTINGS ⁘ SAND

BECKERHAMMER ■ BLOW COUNT ■ 60 120 180 240

PLASTIC M.C. LIQUID 10 20 30 40

Depth (m)	SOIL DESCRIPTION	SAMPLE NO	BLOWS	RECOVERY (%)	RQD (%)	OTHER DATA	Elevation (m)
13	oxidized and weathered, light brown (R1). - dark grey (R1).						
14	SANDSTONE - soft, highly fractured, light brown (R2).	2-14		100	40		1054
15	SILTSTONE - weak, light grey (R1). - dark grey (R1). - light brown (R1).	2-15		100	40		1053
16	- dark grey (R1). - light grey (R1).						1052
17	- light brown (R1).	2-16		100	50		1051
18	SANDSTONE - moderately strong, oxidized, light brown (R3). SILTSTONE - weak, dark grey (R1).	2-17		100	35		1050
19	SANDSTONE - soft to moderately strong, oxidized, light brown (R2/R3).						1049
20	SILTSTONE - medium grey-brown (R1). - very weak, dark grey (R0). - weak, medium grey-brown (R1).	2-18		100	40		1048
21	- medium grey (R1).					No circulation.	1047
22	SANDSTONE - medium grey (R2/R3). SILTSTONE - medium grey (R1).	2-19		90	40		1046
23	SANDSTONE - soft to moderately strong, light grey (R2/R3). SILTSTONE - weak, medium grey (R1).	2-20		90	80		1045
24	SANDSTONE - soft to moderately strong, light grey (R2/R3). - very close joint spacing.						1044
25	SILTSTONE - weak, dark grey (R1). - moderate joint spacing, medium grey (R1).	2-21		100	60		1043
							1042

BECKER WITH CORING LOG 6341. 58TH AVE S.GPJ M-L STANDARD.GDT 30-9-13

McIntosh Lalani Engineering
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Logged By: ATN	Completion Depth: 199 ft
Reviewed By: Marty Ward	Drilled on: 2013-09-16
Groundwater Depth: 14.67 m	

Project: 58th Avenue South Project	Drilling Information:	Borehole No.:2
Client: Government of Alberta	Earth Drilling Co. Ltd.	Project No.:ML-6341
c/o Stantec Consulting	Beckerhammer and Rotary Coring	Elevation:1067.82

SAMPLE TYPE ■ SHELBY TUBE ▯ CORE SAMPLE ☒ SPT SAMPLE GRAB SAMPLE NO RECOVERY

BACKFILL TYPE ■ BENTONITE PEA GRAVEL ▥ SLOUGH GROUT ▨ DRILL CUTTINGS SAND

SOIL DESCRIPTION	SAMPLE NO	BLOWS	RECOVERY (%)	RQD (%)	OTHER DATA
COAL seam. SILTSTONE - weak (R1). - soft, medium grey (R2).	2-22		100	40	
- weak (R1). - dark grey (R1). - medium grey (R1).	2-23		100	90	
- soft, moderate joint spacing (R2). - weak, close joint spacing (R1).	2-24		100	60	
SANDSTONE - moderately strong, medium grey (R3). SILTSTONE - soft (R2). - very close joint spacing. - moderately wide joint spacing.	2-25		100	80	
- soft to moderately strong (R2/R3). SANDSTONE - medium strong, light grey (R3). - soft (R2).	2-26		100	95	Bentonite slurry used in attempt to regain circulation. Drill string chattering.
SILTSTONE - soft, medium grey (R2). - very close joint spacing, highly fractured (R1). - close joint spacing (R2). - dark grey (R1). - medium grey (R2).	2-27		100	70	
- highly fractured, blocky (R1). - moderate joint spacing, soft (R2).	2-28		100	40	Backcalculation backfill vs depth indicates 'bridge' occured at this depth.
- soft to medium strong (R2/R3). - soft (R2). - highly fractured. - moderate joint spacing. - weak (R1).	2-29		100	80	
- soft (R2). - close joint spacing.	2-30		100	40	

Depth (m): 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38

Elevation (m): 1041, 1040, 1039, 1038, 1037, 1036, 1035, 1034, 1033, 1032, 1031, 1030, 1029

BECKERHAMMER ■ BLOW COUNT ■ 60 120 180 240

PLASTIC M.C. LIQUID 10 20 30 40

SLOTTED PIEZOMETER SLOTTED PIEZOMETER

BECKER WITH CORING LOG 6341. 58TH AVE S.GPJ M-L STANDARD.GDT 30-9-13

McIntosh Lalani Engineering
Calgary, AB
(403) 291-2345

Logged By: ATN	Completion Depth: 199 ft
Reviewed By: Marty Ward	Drilled on: 2013-09-16
Groundwater Depth: 14.67 m	

Project: 58th Avenue South Project	Drilling Information:	Borehole No.:2
Client: Government of Alberta	Earth Drilling Co. Ltd.	Project No.:ML-6341
c/o Stantec Consulting	Beckerhammer and Rotary Coring	Elevation:1067.82

SAMPLE TYPE ■ SHELBY TUBE ▯ CORE SAMPLE ☒ SPT SAMPLE GRAB SAMPLE NO RECOVERY

BACKFILL TYPE ■ BENTONITE ⁚ PEA GRAVEL ▥ SLOUGH GROUT ▨ DRILL CUTTINGS ⁙ SAND

BECKERHAMMER ■ BLOW COUNT ■ 60 120 180 240

PLASTIC M.C. LIQUID 10 20 30 40

Depth (m)	SOIL DESCRIPTION	SAMPLE NO	BLOWS	RECOVERY (%)	RQD (%)	OTHER DATA	Elevation (m)
39	- weak (R1). - moderate joint spacing. - soft (R2).						
40	- medium strong, light grey (R3).	2-31		100	80		1028
	COAL seam.						
41	SILTSTONE - soft, medium grey (R2). - dark grey. - highly fractured.	2-32		100	70		1027
42	- moderate joint spacing. - light grey. - dark grey.						1026
43		2-33		100	95		1025
44		2-34		100	90		1024
45	SANDSTONE - medium strong, medium grey (R3).						1023
	SILTSTONE - soft to medium strong, medium to dark grey (R2/R3).						1022
46	MUDSTONE - soft, dark grey (R2).	2-35		100	85		
	COAL seam.						1021
47	SILTSTONE - soft, medium grey (R2). - soft, light grey (R2). - medium grey.	2-36		100	100	Regained partial circulation.	1020
48							1019
49	SANDSTONE - moderately strong, medium grey (R3). - moderate to wide joint spacing, light grey.	2-37		100	90		1018
50						Drill string chattering.	
51		2-38		100	100	Smooth, quick drilling.	1017
							1016

McIntosh Lalani Engineering
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Logged By: ATN	Completion Depth: 199 ft
Reviewed By: Marty Ward	Drilled on: 2013-09-16
Groundwater Depth: 14.67 m	

Project: 58th Avenue South Project	Drilling Information:	Borehole No.:2
Client: Government of Alberta	Earth Drilling Co. Ltd.	Project No.:ML-6341
c/o Stantec Consulting	Beckerhammer and Rotary Coring	Elevation:1067.82

SAMPLE TYPE ■ SHELBY TUBE ▯ CORE SAMPLE ☒ SPT SAMPLE GRAB SAMPLE NO RECOVERY

BACKFILL TYPE ■ BENTONITE PEA GRAVEL ▥ SLOUGH GROUT ▨ DRILL CUTTINGS SAND

SOIL DESCRIPTION	SAMPLE NO	BLOWS	RECOVERY (%)	RQD (%)
SILTSTONE - soft, dark grey (R2).	2-39		100	85
MUDSTONE - weak, dark grey (R1). - moderate joint spacing.				
SANDSTONE - soft, close jointed, medium grey (R2). - very close jointed.	2-40		100	0
SILTSTONE - soft, dark grey (R2).				
MUDSTONE - weak, dark grey (R1).				
SILTSTONE - soft, moderately wide joint spacing, dark grey (R2).	2-41		100	40
MUDSTONE - extremely weak (R0).				
SILTSTONE - soft, dark grey (R2).				
MUDSTONE - weak, dark grey (R1).	2-42		60	50
SILTSTONE - weak to soft, dark grey (R1/R2).				
MUDSTONE - soft, very close joint spacing (R2).				
No recovery (cannot remove from inner core barrel). Presumed to be weak to soft siltstone.	2-43			
SILTSTONE - weathered, soft, medium grey (R2). - soft to moderately strong (R2/R3).	2-44		100	90

END OF HOLE at 60.5 m.

2 standpipes installed, each 25 mm dia PVC:

A: to 60.5 m depth with 15.2 m slotted.
B: to 12.2 m depth with 6.1 m slotted.

Water levels:

September 19, 2013 - A: 13.55 m
September 20, 2013 - A: 14.67 m
B: 4.84 m

Depth (m): 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64

Elevation (m): 1015, 1014, 1013, 1012, 1011, 1010, 1009, 1008, 1007, 1006, 1005, 1004, 1003

BECKERHAMMER ■ BLOW COUNT ■ 60 120 180 240

PLASTIC M.C. LIQUID 10 20 30 40

OTHER DATA

SLOTTED PIEZOMETER SLOTTED PIEZOMETER

McIntosh Lalani Engineering
Calgary, AB
(403) 291-2345

Logged By: ATN	Completion Depth: 199 ft
Reviewed By: Marty Ward	Drilled on: 2013-09-16
Groundwater Depth: 14.67 m	

Project: 58th Avenue South Project	Drilling Information:	Borehole No.:4
Client: Government of Alberta	Earth Drilling Co. Ltd.	Project No.:ML-6341
c/o Stantec Consulting	Beckerhammer and Rotary Coring	Elevation:1062.15

SAMPLE TYPE ■ SHELBY TUBE ▯ CORE SAMPLE ☒ SPT SAMPLE ✋ GRAB SAMPLE NO RECOVERY

BACKFILL TYPE ■ BENTONITE ⁚ PEA GRAVEL ▥ SLOUGH ▨ GROUT ▧ DRILL CUTTINGS ⁙ SAND

Depth (m): 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12

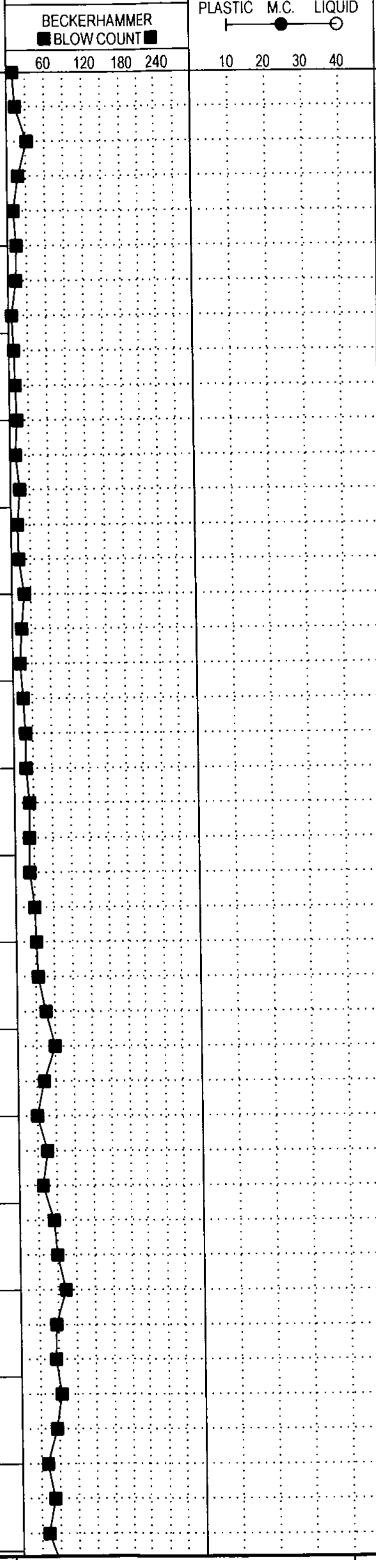
Elevation (m): 1062, 1061, 1060, 1059, 1058, 1057, 1056, 1055, 1054, 1053, 1052, 1051, 1050

SOIL DESCRIPTION
Grass and topsoil.
Sandy organic SILT (Organic Browns) - light brown, dry.
Gravelly SAND - with silt, loose to compact, dry, light grey.
Clayey SILT (Till) - trace sand and gravel, firm, low plastic, trace oxides and precipitates, medium brown.
(Lacustrine) - with sand, no oxides, no precipitates.

SAMPLE TYPE	SAMPLE NO	BLOWS
		10
		14
		32
		18
		10
		14
✋	8-1	13
		5
		8
✋	8-2	10
		12
✋	8-3	9
		15
		11
✋	8-4	12
		20
✋	8-5	15
		12
		16
✋	8-6	19
		19
✋	8-7	24
		23
		23
✋	8-8	30
		32
✋	8-9	34
		46
		60
✋	8-10	42
		30
✋	8-11	46
		38
		55
✋	8-12	60
		73
✋	8-13	57
		56
		64
✋	8-14	56
		41
✋	8-15	52
		42

RECOVERY (%)

RQD (%)



OTHER DATA

Reduced hammer power to prevent plugging.

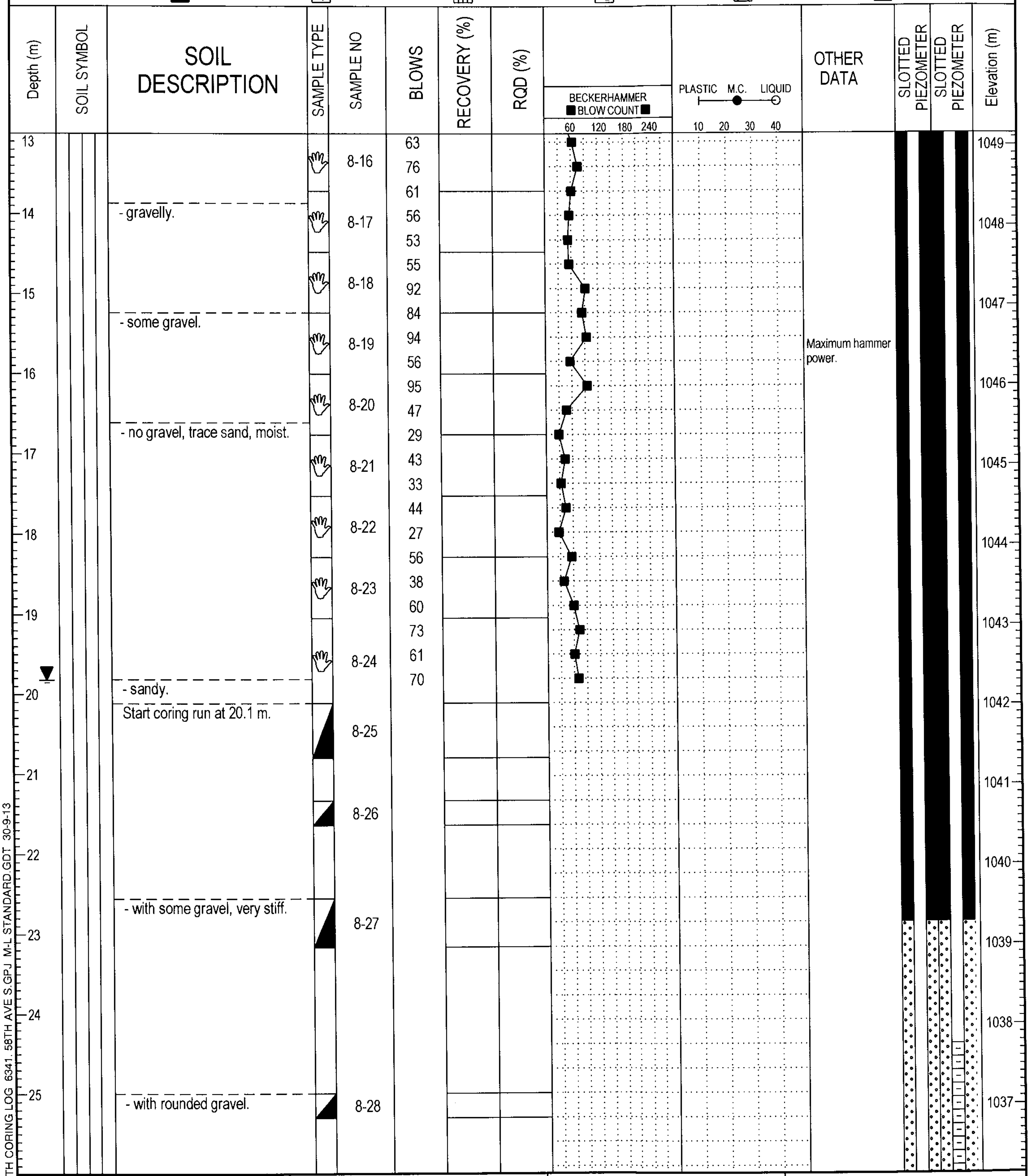
Regular hammer power.

McIntosh Lalani Engineering Calgary, AB (403) 291-2345	Logged By: ATN	Completion Depth: 199 ft
	Reviewed By: Marty Ward	Drilled on: 2013-09-04
	Groundwater Depth: 19.82 m	Page 1 of 5

Project: 58th Avenue South Project	Drilling Information:	Borehole No.:4
Client: Government of Alberta	Earth Drilling Co. Ltd.	Project No.:ML-6341
c/o Stantec Consulting	Beckerhammer and Rotary Coring	Elevation:1062.15

SAMPLE TYPE: SHELBY TUBE, CORE SAMPLE, SPT SAMPLE, GRAB SAMPLE, NO RECOVERY

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND



- gravelly.

- some gravel.

- no gravel, trace sand, moist.

- sandy.

Start coring run at 20.1 m.

- with some gravel, very stiff.

- with rounded gravel.

Sample No: 8-16, 8-17, 8-18, 8-19, 8-20, 8-21, 8-22, 8-23, 8-24, 8-25, 8-26, 8-27, 8-28

Blows: 63, 76, 61, 56, 53, 55, 92, 84, 94, 56, 95, 47, 29, 43, 33, 44, 27, 56, 38, 60, 73, 61, 70

Maximum hammer power.

BECKER WITH CORING LOG 6341. 58TH AVE S.GPJ M-L STANDARD.GDT 30-9-13

McIntosh Lalani Engineering
Calgary, AB
(403) 291-2345

Logged By: ATN	Completion Depth: 199 ft
Reviewed By: Marty Ward	Drilled on: 2013-09-04
Groundwater Depth: 19.82 m	Page 2 of 5

Project: 58th Avenue South Project	Drilling Information:	Borehole No.:4
Client: Government of Alberta	Earth Drilling Co. Ltd.	Project No.:ML-6341
c/o Stantec Consulting	Beckerhammer and Rotary Coring	Elevation:1062.15

SAMPLE TYPE ■ SHELBY TUBE ▯ CORE SAMPLE ☒ SPT SAMPLE GRAB SAMPLE NO RECOVERY

BACKFILL TYPE ■ BENTONITE PEA GRAVEL ▥ SLOUGH GROUT ▨ DRILL CUTTINGS SAND

Depth (m)	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	BLOWS	RECOVERY (%)	RQD (%)	BECKERHAMMER ■ BLOW COUNT ■ 60 120 180 240	PLASTIC M.C. LIQUID 10 20 30 40	OTHER DATA	SLOTTED PIEZOMETER	SLOTTED PIEZOMETER	Elevation (m)
26													1036
		- sandstone boulder for 300 mm.											
27													1035
28				8-29									1034
29													1033
		- trace gravel.											
30				8-30									1032
		- with gravel, some sand.											
31				8-31									1031
32													1030
		- with some cobbles.		8-32									
		- boulder.											
33													1029
34													1028
		- boulder.								Slow drilling.			
		- siltstone boulder.		8-33						Drill string chattering.			
35													1027
				8-34									
36													1026
		- siltstone boulder, strong, medium grey.											
37				8-35									1025
		- with cobbles and boulders.											
38													1024
				8-36									
										Choppy drilling.			

BECKER WITH CORING LOG 6341 58TH AVE S.GPJ M-L STANDARD.GDT 30-9-13

McIntosh Lalani Engineering
Calgary, AB
(403) 291-2345

Logged By: ATN	Completion Depth: 199 ft
Reviewed By: Marty Ward	Drilled on: 2013-09-04
Groundwater Depth: 19.82 m	

Project: 58th Avenue South Project	Drilling Information:	Borehole No.:4
Client: Government of Alberta	Earth Drilling Co. Ltd.	Project No.:ML-6341
c/o Stantec Consulting	Beckerhammer and Rotary Coring	Elevation:1062.15

SAMPLE TYPE ■ SHELBY TUBE ▯ CORE SAMPLE ☒ SPT SAMPLE GRAB SAMPLE NO RECOVERY

BACKFILL TYPE ■ BENTONITE ⁚ PEA GRAVEL ▥ SLOUGH ⁘ GROUT ▨ DRILL CUTTINGS ⁘ SAND

Depth (m): 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51

Elevation (m): 1023, 1022, 1021, 1020, 1019, 1018, 1017, 1016, 1015, 1014, 1013, 1012, 1011

BECKERHAMMER ■ BLOW COUNT ■ 60 120 180 240

PLASTIC M.C. LIQUID 10 20 30 40

SOIL DESCRIPTION	SAMPLE NO	BLOWS	RECOVERY (%)	RQD (%)	OTHER DATA
- some gravel.					
	8-37				
(Bedrock) SILTSTONE - trace gravel and sand, weak, medium grey (R1).	8-38				
SANDSTONE - strong, dry, light grey (R2).					
SILTSTONE - highly weathered, extremely weak, medium grey (R0).	8-39				
- weathered, weak, medium grey (R1).					
No recovery. Presumed to be weak SILTSTONE bedrock.					
SILTSTONE - weak, medium grey (R1).	8-40		60	60	
	8-41		100	100	

SLOTTED PIEZOMETER SLOTTED PIEZOMETER

BECKER WITH CORING LOG 6341. 58TH AVE S.GPJ M-L STANDARD.GDT 30-9-13

McIntosh Lalani Engineering
Calgary, AB
(403) 291-2345

Logged By: ATN	Completion Depth: 199 ft
Reviewed By: Marty Ward	Drilled on: 2013-09-04
Groundwater Depth: 19.82 m	

Project: 58th Avenue South Project	Drilling Information:	Borehole No.:4
Client: Government of Alberta	Earth Drilling Co. Ltd.	Project No.:ML-6341
c/o Stantec Consulting	Beckerhammer and Rotary Coring	Elevation:1062.15

SAMPLE TYPE ■ SHELBY TUBE ▯ CORE SAMPLE ☒ SPT SAMPLE ✋ GRAB SAMPLE NO RECOVERY

BACKFILL TYPE ■ BENTONITE ☐ PEA GRAVEL ▥ SLOUGH ⁙ GROUT ▨ DRILL CUTTINGS ⁙ SAND

Depth (m)	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	BLOWS	RECOVERY (%)	RQD (%)	BECKERHAMMER ■ BLOW COUNT ■ 60 120 180 240	PLASTIC M.C. LIQUID 10 20 30 40	OTHER DATA	SLOTTED PIEZOMETER	SLOTTED PIEZOMETER	Elevation (m)
52		- strong, dark grey (R2).		8-42		100	100						1010
53		MUDSTONE - soft, dark grey (R2).											1009
		SANDSTONE - medium strong, medium grey (R3).											
54		SILTSTONE - soft, dark grey (R2).		8-43		100	80						1008
		SANDSTONE - medium strong, medium grey (R3).											
55		SILTSTONE - soft, dark grey (R2).		8-44		100	80						1007
56		SANDSTONE - medium strong, medium grey (R3).											1006
57		SILTSTONE - medium strong, medium grey (R3).		8-45		100	75						1005
		- coal seams, weak (R1), dark grey.											
58		- soft (R2).		8-46		100	75						1004
59													1003
60				8-47		100	70						1002
		- dark grey.											
61		END OF HOLE at 60.7 m. 2 standpipes installed, each 25 mm dia PVC: A: to 60.7 m depth with 15.2 m screened. B: to 30.5 m depth with 6.1 m screened. Water levels: September 20, 2013 - A: 19.82 m B: 13.33 m											1001
62													1000
63													999
64													998

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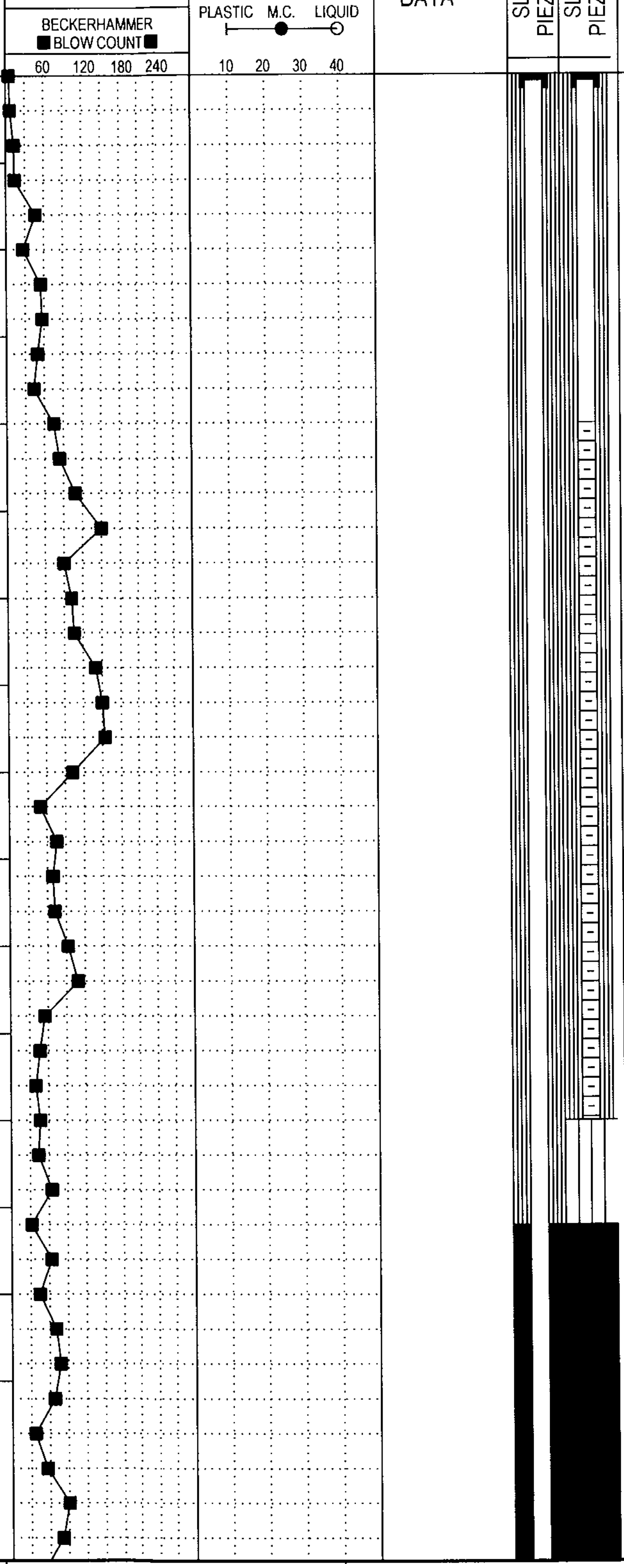
Logged By: ATN	Completion Depth: 199 ft
Reviewed By: Marty Ward	Drilled on: 2013-09-04
Groundwater Depth: 19.82 m	

Project: 58th Avenue South Project	Drilling Information:	Borehole No.:5
Client: Government of Alberta	Earth Drilling Co. Ltd.	Project No.:ML-6341
c/o Stantec Consulting	Beckerhammer and Rotary Coring	Elevation:1044.27

SAMPLE TYPE ■ SHELBY TUBE ▯ CORE SAMPLE ☒ SPT SAMPLE ✋ GRAB SAMPLE NO RECOVERY

BACKFILL TYPE ■ BENTONITE ⁚ PEA GRAVEL ▥ SLOUGH ▨ GROUT ▧ DRILL CUTTINGS ⁘ SAND



Depth (m)	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	BLOWS	RECOVERY (%)	RQD (%)	OTHER DATA	Elevation (m)
0		Grass and topsoil.			5				
		Sandy organic SILT (Organic Browns) - dry, light grey.	✋	7-1	7				1044
					13				
1					14				
		Gravelly SAND - compact, damp, medium brown.	✋	7-2	47				1043
					27				
			✋	7-3	55				
2		Clayey SILT - trace sand and gravel, damp, low plastic, medium brown.			57				1042
					50				
		Sandy GRAVEL - compact, damp, medium grey.	✋	7-4	44				
3					75				
		SILT - with some gravel, stiff, damp.	✋	7-5	84				1041
					109				
4					150				
			✋	7-6	90				1040
					102				
5			✋	7-7	106				
		- some clay.			140				1039
					150				
			✋	7-8	154				
6		Sandy GRAVEL - compact, wet, medium grey.			102				1038
			✋	7-9	50				
					76				
7					69				
			✋	7-11	72				1037
					93				
8			✋	7-10	109				
					55				1036
					47				
			✋	7-12	40				
9					47				1035
			✋	7-13	44				
					65				
10					32				
			✋	7-14	64				1034
					45				
11			✋	7-15	71				
					78				1033
					68				
12					37				
					56				1032
					91				
					81				

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Logged By: ATN	Completion Depth: 99 ft
Reviewed By: Marty Ward	Drilled on: 2013-09-07
Groundwater Depth: 17.07 m	Page 1 of 3

BECKER WITH CORING LOG 6341, 58TH AVE S.GPJ M-L STANDARD.GDT 30-9-13

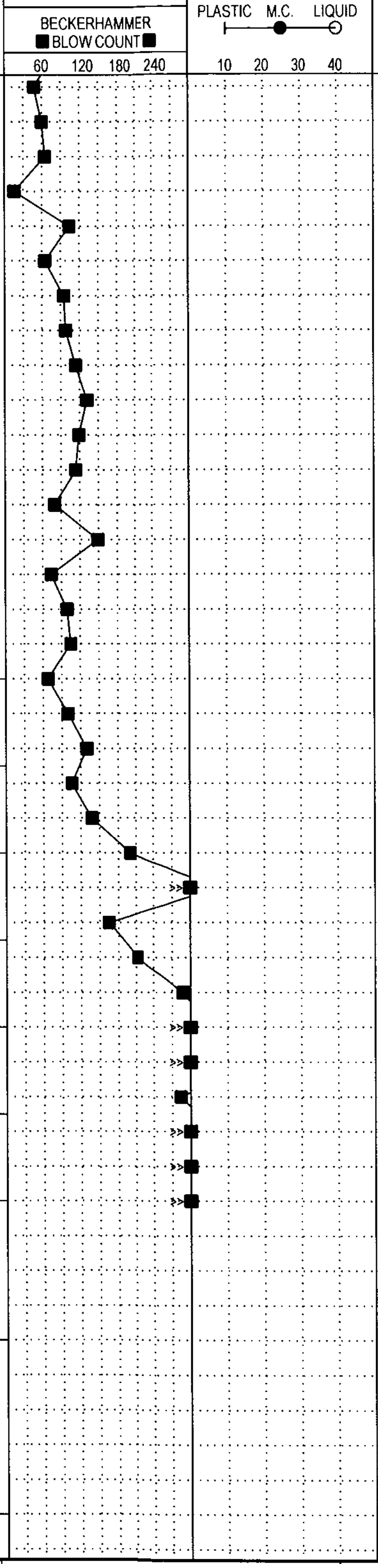
Project: 58th Avenue South Project	Drilling Information:	Borehole No.:5
Client: Government of Alberta	Earth Drilling Co. Ltd.	Project No.:ML-6341
c/o Stantec Consulting	Beckerhammer and Rotary Coring	Elevation:1044.27

SAMPLE TYPE ■ SHELBY TUBE ▮ CORE SAMPLE ☒ SPT SAMPLE ✋ GRAB SAMPLE NO RECOVERY

BACKFILL TYPE ■ BENTONITE ☐ PEA GRAVEL ▥ SLOUGH ⁘ GROUT ▨ DRILL CUTTINGS ⁘ SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	RECOVERY (%)	RQD (%)
13–18.5	- sandstone boulder.				
17 ▼					
	Silty CLAY - stiff, moist, light brown.	✋	7-16		
19	SILT - trace clay and sand, very stiff, moist, light gray.	✋	7-17		
20	- trace gravel.	✋	7-18		
21	GRAVEL - trace cobbles, rounded, light grey.	✋	7-19		
22		✋	7-20		
23	SILT - with some sand and gravel, very stiff.				
	SANDSTONE - damp, medium grey.				
24	Start coring run at 23.2 m. No recovery.				
	SANDSTONE - medium strong, damp, medium grey (R3).	▮			
25	GRAVEL - light yellow-brown.	▮	7-21	75	20
	(Bedrock) SANDSTONE - medium strong, light grey (R3).	▮			
	SILTSTONE - soft, medium grey (R2).	▮			

BLOWS
48
60
65
16
104
65
95
98
114
132
119
114
80
149
74
99
105
68
100
130
106
138
200
346
165
213
288
334
415
284
341
426
400



OTHER DATA

SLOTTED PIEZOMETER

SLOTTED PIEZOMETER

Elevation (m): 1031, 1030, 1029, 1028, 1027, 1026, 1025, 1024, 1023, 1022, 1021, 1020, 1019

BECKER WITH CORING LOG 6341, 58TH AVE S.GPJ M-L STANDARD.GDT 30-9-13

McIntosh Lalani Engineering
Calgary, AB
(403) 291-2345

Logged By: ATN	Completion Depth: 99 ft
Reviewed By: Marty Ward	Drilled on: 2013-09-07
Groundwater Depth: 17.07 m	Page 2 of 3

Project: 58th Avenue South Project	Drilling Information:	Borehole No.:5
Client: Government of Alberta	Earth Drilling Co. Ltd.	Project No.:ML-6341
c/o Stantec Consulting	Beckerhammer and Rotary Coring	Elevation:1044.27

SAMPLE TYPE ■ SHELBY TUBE ▯ CORE SAMPLE ☒ SPT SAMPLE GRAB SAMPLE NO RECOVERY

BACKFILL TYPE ■ BENTONITE ⁚ PEA GRAVEL ▥ SLOUGH GROUT ▨ DRILL CUTTINGS ⁙ SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE NO	BLOWS	RECOVERY (%)	RQD (%)	BECKERHAMMER ■BLOW COUNT■ 60 120 180 240	PLASTIC M.C. LIQUID 10 20 30 40	OTHER DATA	Elevation (m)
26	- weak, highly weathered, dark grey (R0). - soft, medium grey (R2). SANDSTONE - medium strong, light grey (R3).	7-22		100	65				1018
27	SILTSTONE - extremely weak, dark grey (R0). - weak (R1). - soft, medium grey (R2).	7-23		100	60				1017 1016
28	- extremely weak, dark grey (R0). - soft, medium grey (R2).								
29	- dark grey (R2). SANDSTONE - medium strong, medium grey (R3). SILTSTONE - soft, dark grey (R2).	7-24		95	90				1015
30	- weathered, extremely weak to weak, close joint spacing (R0/R1).								1014
31	END OF HOLE at 30.2 m.								1013

2 standpipes installed, each 25 mm dia PVC:

A: to 30.2 m depth with 3.0 m screened.
B: to 9.1 m depth with 6.1 m screened.

Water levels:

September 20, 2013 - A: 17.07 m
B: 3.10 m

Depth (m)	Elevation (m)
32	1012
33	1011
34	1010
35	1009
36	1008
37	1007
38	1006

SLOTTED PIEZOMETER SLOTTED PIEZOMETER

McIntosh Lalani Engineering
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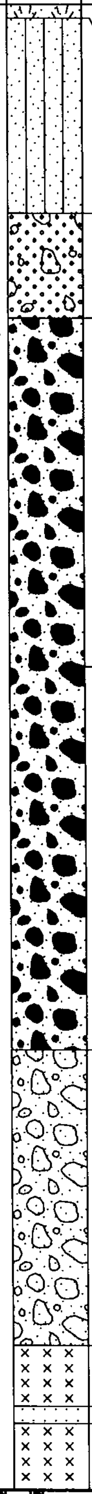
Logged By: ATN	Completion Depth: 99 ft
Reviewed By: Marty Ward	Drilled on: 2013-09-07
Groundwater Depth: 17.07 m	

Project: 58th Avenue South Project	Drilling Information:	Borehole No.:6
Client: Government of Alberta	Earth Drilling Co. Ltd.	Project No.:ML-6341
c/o Stantec Consulting	Beckerhammer and Rotary Coring	Elevation:1025.40

SAMPLE TYPE ■ SHELBY TUBE ▯ CORE SAMPLE ☒ SPT SAMPLE ✋ GRAB SAMPLE NO RECOVERY

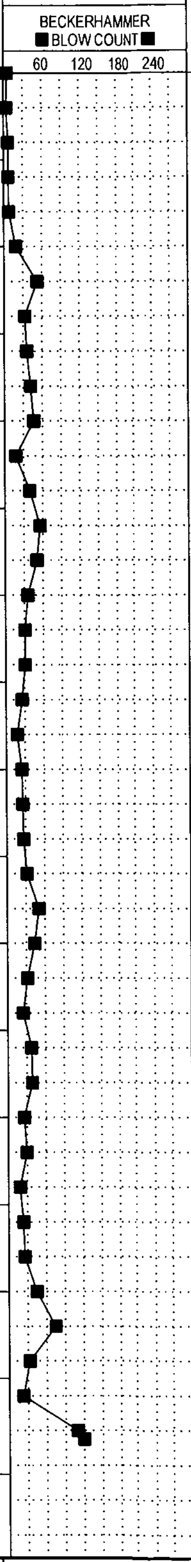
BACKFILL TYPE ■ BENTONITE ⁚ PEA GRAVEL ▥ SLOUGH ⁙ GROUT ▨ DRILL CUTTINGS ⁙ SAND

Depth (m) | SOIL SYMBOL | SOIL DESCRIPTION | SAMPLE TYPE | SAMPLE NO | BLOWS | RECOVERY (%) | RQD (%) | BECKERHAMMER ■ BLOW COUNT ■ | PLASTIC M.C. LIQUID | OTHER DATA | SLOTTED PIEZOMETER | SLOTTED PIEZOMETER | Elevation (m)

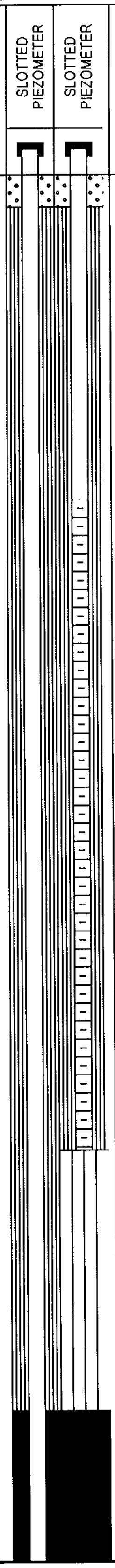


SOIL DESCRIPTION:
- 0 – Grass and topsoil.
- Sandy SILT (Organic Browns) - loose, dry, light brown.
- Gravelly SAND - trace silt, compact, dry, well graded, light brown.
- ▼ Sandy GRAVEL - trace silt, compact, moist, rounded, well graded, medium brown.
- - wet.
- Gravelly SAND - compact, wet, medium grey.
- (Bedrock) SILTSTONE bedrock - weathered, dry, light grey.
- Start of coring run at 12.3 m. SANDSTONE - medium strong,

SAMPLE TYPE	SAMPLE NO	BLOWS	RECOVERY (%)	RQD (%)
		5		
✋	10-1	4		
		7		
		7		
✋	10-2	8		
		19		
✋	10-3	53		
		33		
		36		
✋	10-4	42		
		47		
✋	10-5	18		
		40		
		56		
✋	10-6	51		
		36		
✋	10-7	31		
		31		
		26		
✋	10-8	18		
		25		
✋	10-9	26		
		27		
		32		
✋	10-10	51		
		44		
✋	10-11	32		
		25		
		38		
✋	10-12	39		
		26		
✋	10-13	30		
		19		
		24		
✋	10-14	26		
		45		
✋	10-15	75		
		33		
		23		
✋	10-16	110		
		120		
▯	10-17		100	0



PLASTIC M.C. LIQUID
10 20 30 40



Depth (m)	Elevation (m)
0	
	1025
1	
	1024
2	
	1023
3	
	1022
4	
	1021
5	
	1020
6	
	1019
7	
	1018
8	
	1017
9	
	1016
10	
	1015
11	
	1014
12	
	1013

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Logged By: ATN	Completion Depth: 84 ft
Reviewed By: Marty Ward	Drilled on: 2013-09-10
Groundwater Depth: 2.89 m	Page 1 of 3

Project: 58th Avenue South Project	Drilling Information:	Borehole No.:6
Client: Government of Alberta	Earth Drilling Co. Ltd.	Project No.:ML-6341
c/o Stantec Consulting	Beckerhammer and Rotary Coring	Elevation:1025.40

SAMPLE TYPE ■ SHELBY TUBE ▯ CORE SAMPLE ☒ SPT SAMPLE GRAB SAMPLE NO RECOVERY

BACKFILL TYPE ■ BENTONITE ⁛ PEA GRAVEL ▥ SLOUGH GROUT ▨ DRILL CUTTINGS ⁛ SAND

Depth (m) | SOIL SYMBOL | SOIL DESCRIPTION | SAMPLE TYPE | SAMPLE NO | BLOWS | RECOVERY (%) | RQD (%) | BECKERHAMMER ■ BLOW COUNT ■ 60 120 180 240 | PLASTIC M.C. LIQUID 10 20 30 40 | OTHER DATA | SLOTTED PIEZOMETER | SLOTTED PIEZOMETER | Elevation (m)

SOIL DESCRIPTION

close joint spacing, oxidized, some light brown (R3).

SILTSTONE - weak, very close jointed, dark grey (R1).

SANDSTONE - medium strong, light brown (R3).

SILTSTONE - soft, close joint spacing, light grey (R2).

- weak, very close jointed, dark grey (R1).

- close joint spacing.

- very close joint spacing.

SANDSTONE - medium strong, moderate joint spacing, medium grey (R3).

- close joint spacing.

COAL seam.

SILTSTONE - weak, medium grey (R1).

COAL seam.

SILTSTONE - weak, medium grey (R1).

SANDSTONE - medium strong, medium to dark grey (R3).

SILTSTONE - weak, medium grey (R1).

MUDSTONE - soft, dark grey (R2).

SILTSTONE - extremely weak to weak, dark grey (R0/R1).

SANDSTONE - medium strong, medium grey (R3).

SILTSTONE - weak, medium grey (R1).

SANDSTONE - medium strong, medium grey (R3).

SILTSTONE - soft, dark grey (R2).

END OF HOLE at 25.7 m.

SAMPLE NO	BLOWS	RECOVERY (%)	RQD (%)
10-18		100	40
10-19		100	60
10-20		100	90
10-21		100	75
10-22		85	65
10-23		100	20
10-24		100	90
10-25		100	90

OTHER DATA

0.16 MPa point load index

0.07 MPa point load index

0.10 MPa point load index

0.20 MPa point load index

0.19 MPa point load index

0.05 MPa point load index

Depth (m): 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25

Elevation (m): 1012, 1011, 1010, 1009, 1008, 1007, 1006, 1005, 1004, 1003, 1002, 1001, 1000

BECKER WITH CORING LOG 6341. 58TH AVE S.GPJ M-L STANDARD.GDT 30-9-13

McIntosh Lalani Engineering
Calgary, AB
(403) 291-2345

Logged By: ATN	Completion Depth: 84 ft
Reviewed By: Marty Ward	Drilled on: 2013-09-10
Groundwater Depth: 2.89 m	Page 2 of 3

Project: 58th Avenue South Project	Drilling Information:	Borehole No.:6
Client: Government of Alberta	Earth Drilling Co. Ltd.	Project No.:ML-6341
c/o Stantec Consulting	Beckerhammer and Rotary Coring	Elevation:1025.40

SAMPLE TYPE ■ SHELBY TUBE ▯ CORE SAMPLE ☒ SPT SAMPLE GRAB SAMPLE NO RECOVERY

BACKFILL TYPE ■ BENTONITE ⁝ PEA GRAVEL ▥ SLOUGH ⁙ GROUT ▨ DRILL CUTTINGS ⁙ SAND

Depth (m)	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	BLOWS	RECOVERY (%)	RQD (%)	BECKERHAMMER ■ BLOW COUNT ■ 60 120 180 240	PLASTIC M.C. LIQUID 10 20 30 40	OTHER DATA	SLOTTED PIEZOMETER	SLOTTED PIEZOMETER	Elevation (m)
26		2 standpipes installed, each 25 mm dia PVC: A: to 25.7 m depth with 7.6 m screened. B: to 9.1 m depth with 6.1 m screened. Water levels: September 20, 2013 - A: 2.89 m B: 3.01 m											
													999
27													
													998
28													
													997
29													
													996
30													
													995
31													
													994
32													
													993
33													
													992
34													
													991
35													
													990
36													
													989
37													
													988
38													
													987

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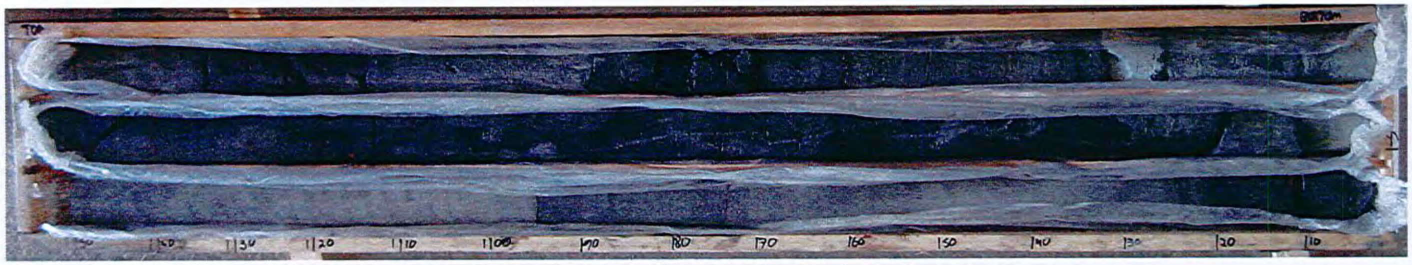
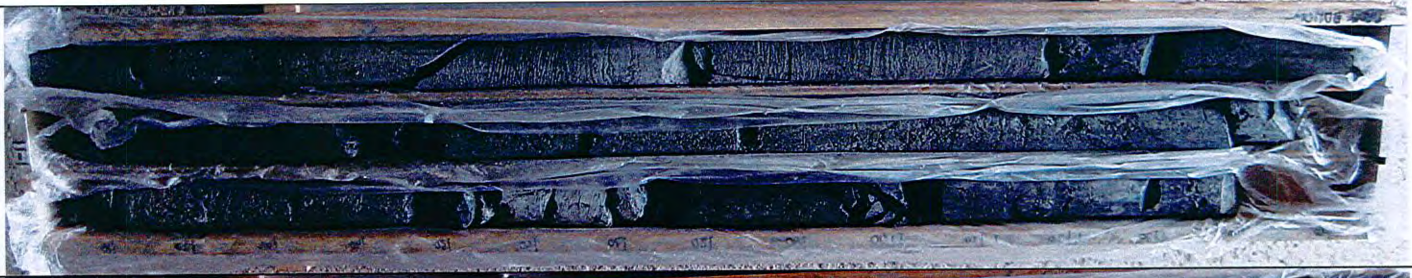
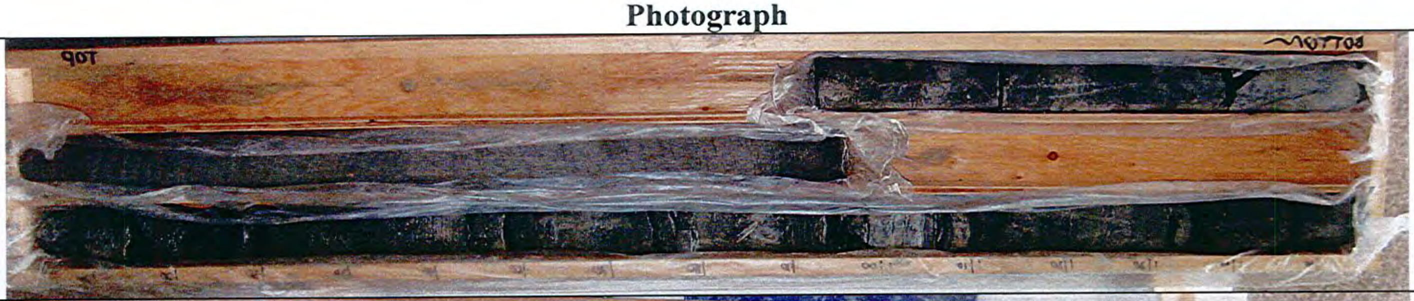
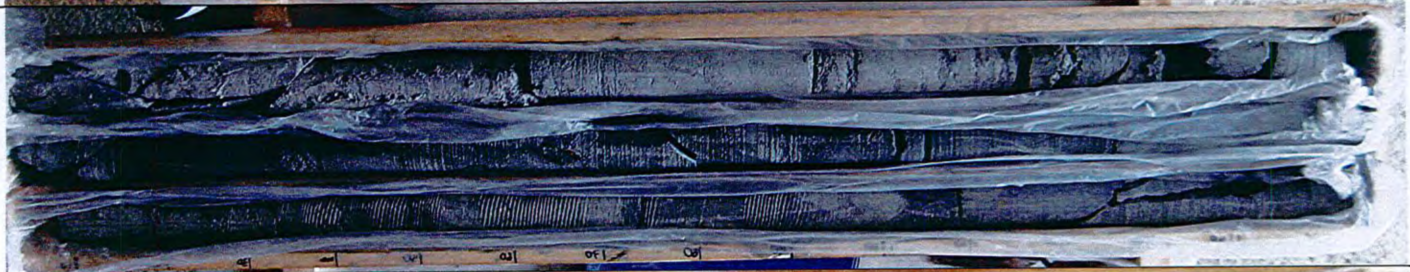
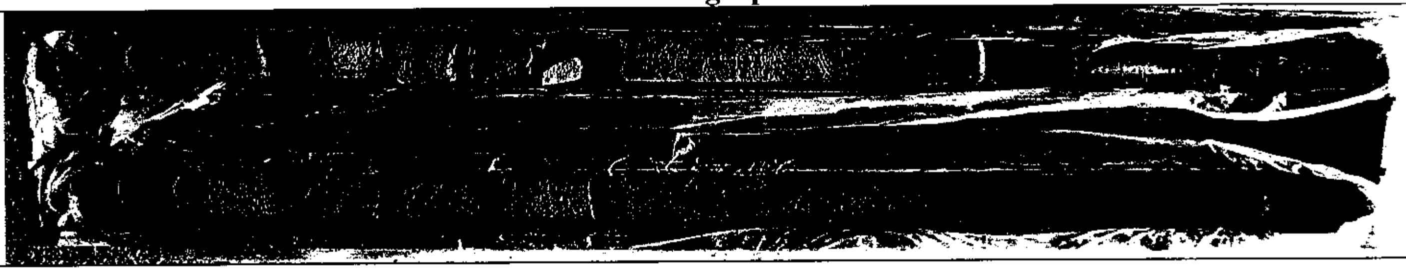
Logged By: ATN	Completion Depth: 84 ft
Reviewed By: Marty Ward	Drilled on: 2013-09-10
Groundwater Depth: 2.89 m	

Borehole #1

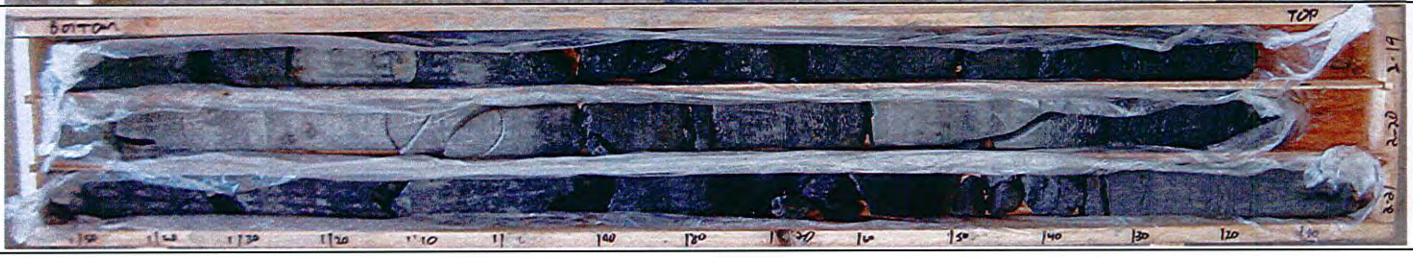
Sample ID	*Top* Depth (m)	Photograph	*Bottom* Depth (m)
1-1	9.1		10.4
1-2	10.4		11.9
1-3	11.9		13.5
1-4	13.5		15.0
1-5	15.0		16.6
1-6	16.6		18.1
1-7	18.1		19.6
1-8	19.6		21.0
1-9	21.0		22.7

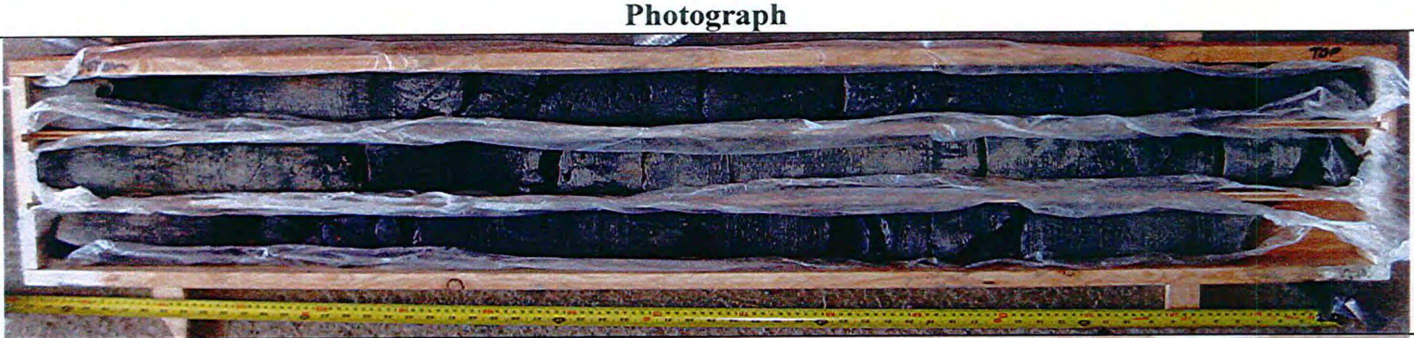
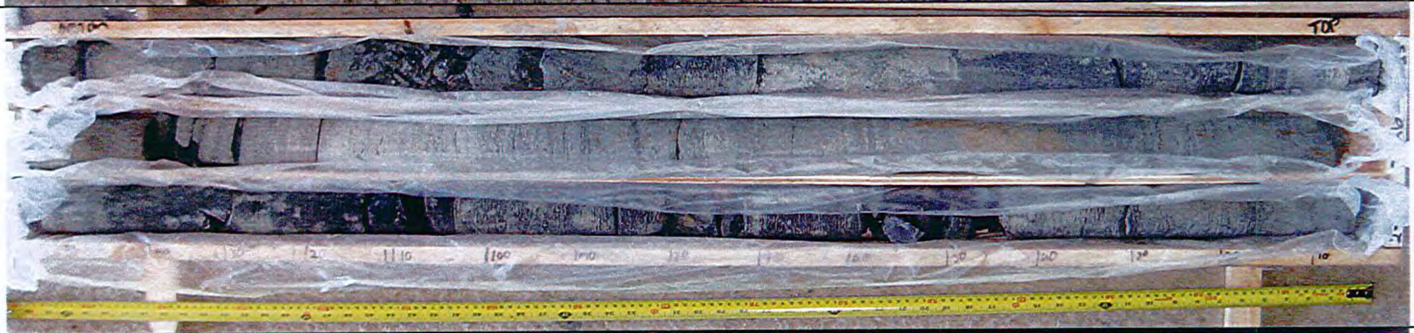
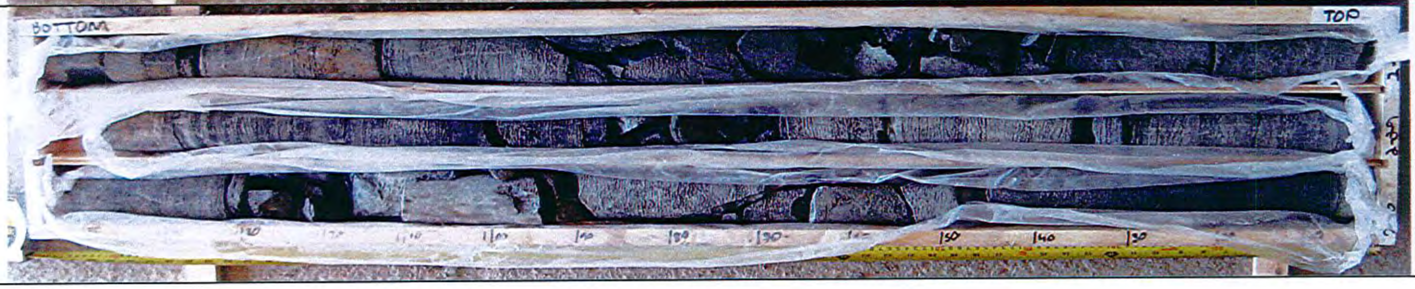
Sample ID	*Top* Depth (m)	Photograph	*Bottom* Depth (m)
1-10	22.7		24.2
1-11	24.2		25.6
1-12	25.6		27.2
1-13	27.2		28.7
1-14	28.7		30.2
1-15	30.2		31.8
1-16	31.8		33.2
1-17	33.2		34.8
1-18	34.8		36.4
1-19	36.4		37.8
1-20	37.8		39.4
1-21	39.4		40.9

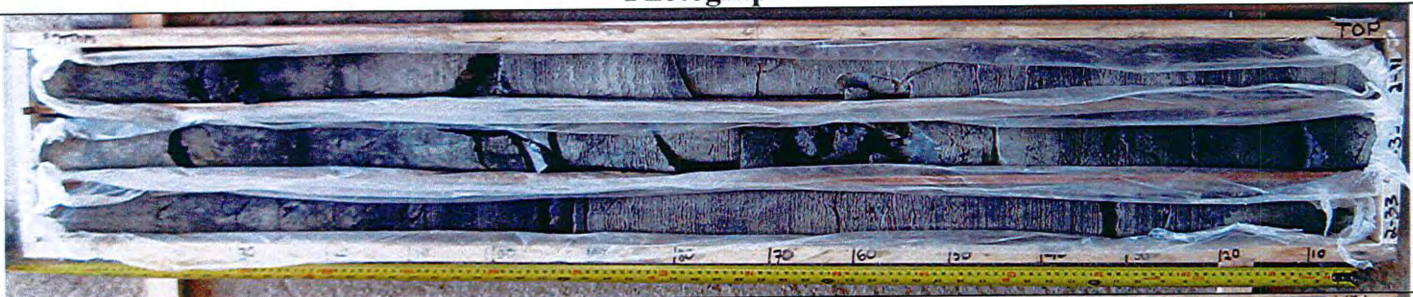
Sample ID	*Top* Depth (m)	Photograph	*Bottom* Depth (m)
1-22			42.4
	40.9		
1-23	42.4		43.9
1-24	43.9		45.4
1-25	45.4		47.0
1-26	47.0		48.6
1-27	48.6		50.1
1-28	50.1		51.6
1-29	51.6		53.1
1-30	53.1		54.7
1-31	54.7		56.1
1-32	56.1		57.7

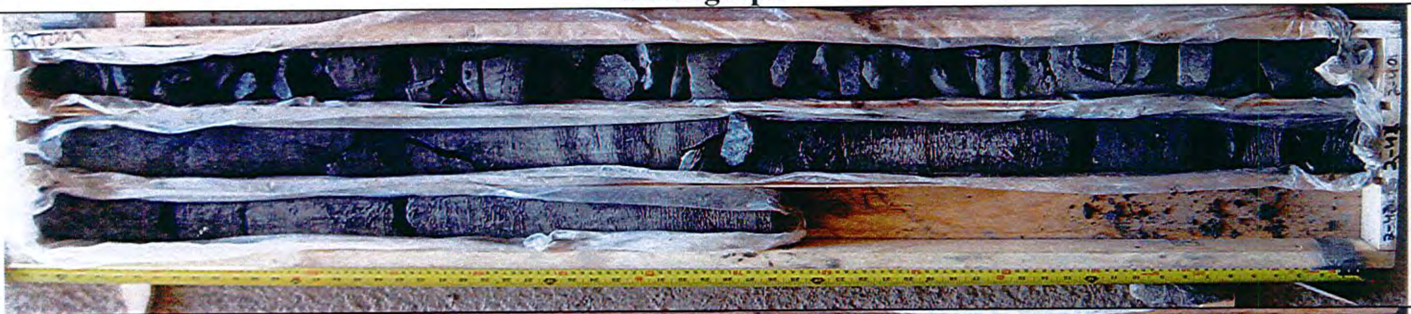
Sample ID	*Top* Depth (m)	Photograph	*Bottom* Depth (m)
1-33	57.7		59.3
empty			
1-34	59.3		60.8

Borehole #2

Sample ID	*Bottom* Depth (m)	Photograph	*Top* Depth (m)
2-13	13.4		11.9
2-14	14.9		13.4
2-15	16.5		14.9
2-16	18.0		16.5
2-17	18.9		18.0
2-18	21.0		19.2
2-19	22.6		21.0
2-20	24.1		22.6
2-21	25.6		24.1

Sample ID	*Bottom* Depth (m)	Photograph	*Top* Depth (m)
2-22	27.1		25.6
2-23	28.7		27.1
2-24	30.0		28.7
2-25	31.7		30.0
2-26	33.2		31.7
2-27	34.7		33.2
2-28	36.3		34.7
2-29	37.8		36.3
2-30	39.3		37.8

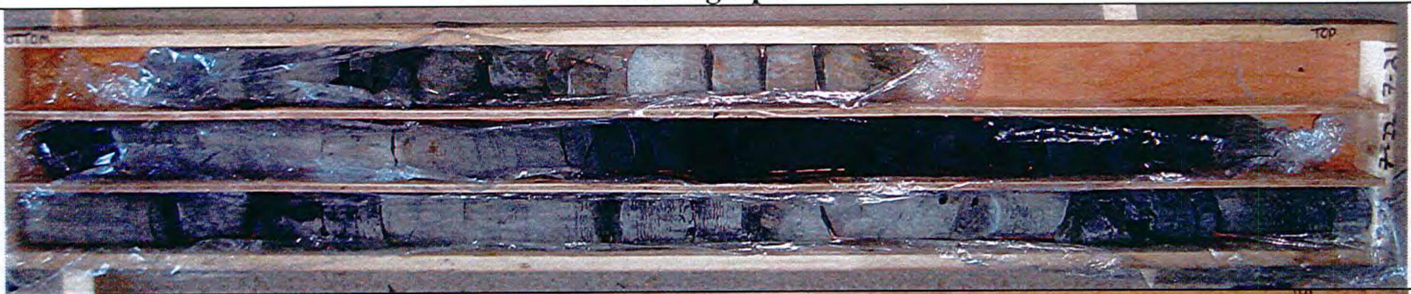
Sample ID	*Bottom* Depth (m)	Photograph	*Top* Depth (m)
2-31	40.9		39.3
2-32	42.4		40.9
2-33	43.9		42.4
2-34	45.4		43.9
2-35	47.0		45.4
2-36	48.5		47.0
2-37	50.0		48.5
2-38	51.5		50.0
2-39	53.1		51.5

Sample ID	*Bottom* Depth (m)	Photograph	*Top* Depth (m)
2-40	54.6		53.1
2-41	56.1		54.6
2-42	57.6		56.1
2-43	58.9		57.6
2-44	60.5		58.9
empty			

Borehole #4

Sample ID	*Top* Depth (m)	Photograph	*Bottom* Depth (m)
8-38	42.4		42.4
8-39	43.9		45.4
8-40	50.6		51.5
8-41	51.5		52.0
8-42	52.0		53.1
8-43	53.1		54.6
8-44	54.6		56.1
8-45	56.1		57.6
8-46	57.6		59.2
8-47	59.2		60.7
empty			
empty			

Borehole #5

Sample ID	*Bottom* Depth (m)	Photograph	*Top* Depth (m)
7-21	25.6		24.1
7-22	27.1		25.6
7-23	28.7		27.1
empty			
empty			
7-24	30.2		28.7

Borehole #6

Sample ID	*Top* Depth (m)	Photograph	*Bottom* Depth (m)
10-17	12.3		13.5
10-18	13.5		15.0
10-19	15.0		16.6
10-20	16.6		18.1
10-21	18.1		19.6
10-22	19.6		21.1
10-23	21.1		22.7
10-24	22.7		24.2
10-25	24.2		25.7

Appendix C

Flood Advisory Individuals and Contacts

Stantec

APPENDIX C

Table C1 – Flood Advisory Panel Contributors and Stantec Expertise

Expert or Organization	Relevance/Background	Recommended Method of Engagement
Allan Markin	FAP Member	Regular Active
Richard Lindseth	FAP Member	Regular Active
Tino DiManno, Stantec Consulting	FAP Member	Regular Active
Robert Samaska, Pillar Engineering pillaring@shaw.ca	Current Advisor to the Flood Panel	Regular Active
Russ Mackenzie, Vice President, Stantec 200 325 25 Street SE Calgary AB T2A 7H8 russ.mackenzie@stantec.com	Current Advisor to the Flood Panel	Regular Active
Harold Perrin, Vice President, Stantec 200 325 25 Street SE Calgary AB T2A 7H8 harold.perrin@stantec.com	Current Advisor to the Flood Panel	Regular Active
Rick Carnduff, Senior Principal, Stantec 200 325 25 Street SE Calgary AB T2A 7H8 rick.carnduff@stantec.com	Current Advisor to the Flood Panel	Regular Active

APPENDIX C

Expert or Organization	Relevance/Background	Recommended Method of Engagement
Vince DiCamillo, Stantec Laurel USE contact through Russ Mackenzie at Stantec 200 325 25 Street SE Calgary AB T2A 7H8 403 716-8212 russ.mackenzie@stantec.com	Vince has spent his entire career consulting for the US Federal Emergency Management Agency (FEMA). His institutional knowledge of their programs and policies make him a unique individual when discussing flood conditions, risk and mitigation of the risk.	Counsel Periodic
John Malueg, Stantec Louisville USE contact through Russ Mackenzie at Stantec 200 325 25 Street SE Calgary AB T2A 7H8 403 716-8212 russ.mackenzie@stantec.com	John is currently leading Stantec overall efforts in disaster recovery and response. John is one of the most forward thinking individuals Stantec has and has single handedly provided Stantec with a unique reputation of addressing the three pillars of disaster management – response, recovery and mitigation	Counsel Periodic
George V. Sabol PhD, PE, Stantec Phoenix contact through Russ Mackenzie at Stantec 200 325 25 Street SE Calgary AB T2A 7H8 403 716-8212 russ.mackenzie@stantec.com	Dr. Sabol's extensive professional experience offers the client a complete suite of solutions complemented by awareness of environmental and budgetary issues. He has 41 years of experience in the US Southwest and internationally in hydrology, hydraulics, and sedimentation of arid and semi-arid lands. He is a Principal in the Water Resources group of Stantec and is responsible for the management of engineering projects involving flood control, sedimentation, dam design and safety, and design of hydraulics structures.	Counsel Periodic

APPENDIX C

Table C2 – Flood Advisory Panel Record of Contacts

Name	Details of Contact	FAP Member Contacted	Response Details
Bryan Walsh | Senior Vice President CBRE Limited Downtown Office Leasing 500 530 8 Avenue SW Calgary, AB T2P 3S8 T 403 750 0524 F 403 269 4202 C 403 620 6136 bryan.walsh@cbre.com	Engineer – Lives on Lansdowne Avenue and has ideas of possible solutions – Professional acquaintance of Tino DiManno	Tino DiManno (via email and voice mail)	Tino DiManno indicated he would call Bryan by mid-August to solicit ideas.
Jim Dewald Dean, Haskayne School of Business University of Calgary jim.dewald@haskayne.ucalgary.ca	Dean of Haskyne School of Business (previous business acquaintance of Tino DiManno). Jim has assembled a group of U of A and U of C academics and has offered to coordinate a flood brain storming session on Sept. 21/13	Tino DiManno (via email)	Tino has reviewed with Allan Markin and will accept the offer on behalf of the FAP. Received email from Jim Dewald that session will be Sept. 21 and they will invite the FAP. Final plans will be arranged by Jim Dewald at the end of August as to who will attend & venue.
Kent Brown	kent@bluearth.ca	Tino DiManno (via email)	Providing the Panel with thoughts on potential future flood mitigation solutions. Tino setup a conference call for August 13 at 2:00 pm. Kent has great ideas on the Peace river basin. Tino will stay in touch.

APPENDIX C

Name	**Details of Contact**	**FAP Member Contacted**	**Response Details**
Ed Davis ehdavis@telus.net 403 243-8634	4320 Britannia Drive SW	Richard Lindseth	Documentation came to Tino by courier and he emailed all materials to the FAP. Richard will review and follow up with Ed Davis.
Alberta WaterSmart (Kim Sturgess) Kim.Sturgess@albertawatersmart.com	Have provided "2013 Great Flood" report to FAP and have contacted us by email.	Tino DiManno	Tino sent e-mail to Kim requesting a follow up meeting. Kim is away until last week of August and she will call then.
Alfred Balm (Chairman of Emergo Canada)	Offered to bring Dutch hydrologist to Calgary on his dime.	Allan Markin and Richard Lindseth	Allan and Richard have been in touch
Charles Hansen (retired Army Corp of Engineers)	Offered some small impoundment solutions	Allan Markin	Allan has been in touch.
Wolf Keller City Flood Task Force 403 268-6752	Ongoing contact	Tino DiManno	Tino is continuing to be in contact with Wolf as required.
Rob Motherwell rmotherwell@spurresources.ca	Infrastructure ideas – optimize and maintain and enhance existing storage capacity.	Tino DiManno	Tino contacted Rob on August 22 to have a preliminary discussion. Russ Mackenzie spoke with him at a public meeting on August 22, 2013.
Malcolm Richardson Retiree 403 601-2708	Retiree living in High River who had some flooding on his land. Asked that the Province formally announce that they are using the 1992 Flood Mapping for their review of homes that will receive flood assistance	Tino DiManno	Russ Mackenzie spoke to Malcolm by phone on August 28, 2013

APPENDIX C

Name	Details of Contact	FAP Member Contacted	Response Details
Henk ten Wolde Trade Commissioner Netherlands Trade Office Suite 257, 8330 – 82 Avenue Edmonton AB T6C 0Y6 h.tenwolde@alberta-holland.com Office – 1-780-490-5004 Fax – 1-780-424-2053			
Robert Samaska Pillar Engineering & Inspection Ltd. 3 Windsor Cr SW Calgary AB T2V 1V4 rsamaska@pillarengineering.ca Office – 403-259-5004 Fax – 403-255-8941 Cell – 403-560-1586			
Dale T. Morris Senior Advisor Embassy of the Kingdom of the Netherlands 4200 Linnean Avenue NW Washington DC 260080 dale.morris@minbuza.nl Office – 1-202-274-2618 Fax – 1-202-966-0737			

Appendix D

Design and Constructability Considerations

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APPENDIX D

Preliminary Considerations

When locating the Dry Dams within the drainage basins of the Sheep River, Elbow River and Highwood River a number of factors were considered as part of the review. In order to understand the level of detail considered and methodology associated with the review we provide the following overview of the site selection process.

Preliminary Site Review

The first step in the selection of suitable sites for the proposed Dry Dams was finding a location that would minimize the material required for the construction of the Dry Dams and would minimize the impact on the natural environment as well as existing facilities such as roads, buildings, pipelines, oil and gas facilities and farm structures. Using the Province of Alberta topographic mapping, possible locations were identified where the Dry Dams could be located, providing the required detention storage volume in the facility. For each river basin, several detention sites were identified and coordinates were established for the sites so that an aerial review could be completed for each of the sites to confirm the suitability of the location for the proposed Dry Dams. Lastly land ownership was considered as it was thought that in order to complete the facilities in a timely manner, it was best if they were located on Public Lands. All but one of the proposed Dry Dams is on Public land.

Secondary Review - Aerial Reconnaissance of the Proposed Sites

Each of the proposed sites was then reviewed from the air using a helicopter to confirm the specific topography, surficial geology if possible, and the facilities and structures in the area. As part of the aerial review several of the proposed sites were eliminated due to facilities observed in the field that would be impacted by the proposed detention reservoir. Several of the proposed Dry Dam locations were moved to ~~a~~ more suitable locations based on what was observed as part of the aerial reconnaissance. As a result of this review the proposed Dry Dam locations along the Highwood (2 locations), the Sheep River (1 location) and the Elbow River (2 locations) were finalized in a conceptual way.

Design and Constructability Considerations – Dry Dams

As part of the overall review, several design and constructability considerations were identified that should be considered as the process moves into detailed design stage. The list is extensive and in order to provide this information in a succinct format we provide the following list of items to be considered as part of the review process for the Dry Dams:

- Safety is of utmost importance and the Dam Safety Guideline should be adhered to as part of the detailed design of the design dams.
- We recommend that the structure (ie pipe or box culvert) that conveys the river flows through the dam should be constructed with an orifice control located at the inlet end of the pipe. This is for public safety and maintenance considerations.
- The inlet side of the pipe should have primary, secondary, and tertiary screening to protect the inlet of the pipe from being blocked by river debris and sedimentation accumulation.

This should include sedimentation traps, river debris fences, settling ponds etc. Also Class II or III armoring should be utilized in the vicinity of the inlet and outlet of the conveyance pipe as the velocities at these locations, especially in flood stage will be severe and the possibility of erosion in these areas would be significant if the area is not protected properly.

- We recommend that a second conveyance pipe be provided as part of the Dry Dam. This pipe would be located well away from the primary pipe and would be used only in the event that the primary pipe became blocked. This would provide a secondary level of safety for maintaining flow through the dam.
- We recommend that a third method of conveyance be provided and that would be established using an overtopping channel or drop structure spillway that could convey the river flows in the event that the primary and secondary conveyance pipes become blocked.
- During the aerial review and onsite inspection surface geology was observed at each of the sites however a more thorough geological investigation of this is required by qualified geologists. It is recommended that a subsurface investigation be completed for each of the dam sites to determine suitability for the proposed structures.
- Sedimentation flows and collection will need to be considered. During the conceptual review, we did speak with geomorpholigists about the sedimentation flows to determine if this consideration would be an issue for the proposed dams. The response was it should be considered in the design and maintenance of the facilities; however it was not a reason to not construct the facilities.
- Slope stability issues within the storage basin and in the vicinity of the Dry Dams were identified as a consideration that should be looked at during detailed design. This was not reviewed as part of the conceptual review.
- For the conceptual review we used 4:1 slope for both the front and back face of the earthen dams similar to slopes on dams used for tailing ponds in the mining and energy business. To protect the face from erosion rock armor should be used and the design of this armor during detailed design should consider wave action, freeze-thaw cycles, durability, availability of material etc.
- The dam will incorporate an impermeable core which should be" keyed" into the non-permeable, suitable material as per conventional dam design engineering.
- The dams are detention facilities. We specifically did not consider them to be retention facilities as this would have a greater impact on the environment and requires larger dams to provide appropriate "freeboard storage". However as part of the review process with the public and stakeholder. It was identified that drought is another major climatic condition that impacts Albertans. This may be an item that could be explored further as part of detailed design as this consideration would necessitate some sort of permanent storage with freeboard.

- Maintenance and Operational Consideration

As part of the detailed design the following should be considered:

- Clearing and “grubbing” of the reservoir area in early spring (before runoff) to prevent dead fall etc. from clogging inlets during May / June / July runoff events.
- Flushing of the inlet and control devices will be required in early spring.
- Safety warning systems should be considered as water levels rise behind the dam.
- Signage along the storage berm will be required to warn of flooding during storm runoff events.
- Appropriate fencing should be considered as required.

Design and Constructability Considerations – High River Overland Diversion

Through discussions with the public, local administration, council member and other professionals the development of the overland drainage proposal was established. As part of this review there were a number of factors that directed the conceptual planning process of the diversion as provided below:

- Officials had indicated that a diversion located south of the town would not be feasible.
- In discussions with hydrologists familiar with the Highwood River we established that backwater effects would not be a concern for the proposed route along the west and north edge of town was followed.
- The alignment of the diversion respected the recently approved land use plan for expansion of the town to the west.
- Cross basin transfer of water was not an option of the proposals review.
- Transferring water from the Highwood River to a smaller tributary was not considered as it was felt that it would cause significant damage to the tributary in a flood event.

Design and Constructability Considerations – Calgary 58th Avenue Tunnel By-pass

A key element to the success of the overall flood mitigation plan is to have a system approach to the plan. The tunnel by-pass offers a key component of the system to the Elbow River flood mitigation. In the review of this option the following were some of the considerations:

- We received advice from tunneling contractor on the installation and preliminary costing for the proposed tunnel.
- The private land ownership at the east end of the tunnel alignment is a consideration and it is recommended that discussions with the landowner should be initiated early in the process to allow for an agreement to be in place in a timely manner.
- The borehole logs indicate that the tunnel is for the most part founded in hard strata.

Closure

This summary of the items considered ~~is~~ above is not exhaustive but has been provided so that the professionals involved with the detailed design are made aware that only a conceptual level of preliminary review that was undertaken in order to identify preliminary solutions ~~to~~ for the 2013 Flood event in a timely manner. During the detailed design and costing of the facilities these assumptions should be re-examined in detail to ensure the suitability of the sites for the proposed dams and to ensure that public safety is maintained.

Appendix E

Cost Estimating & Contingency Determination

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APPENDIX E

Costing of the Dry Dams and By-pass Facilities:

Dry Dams

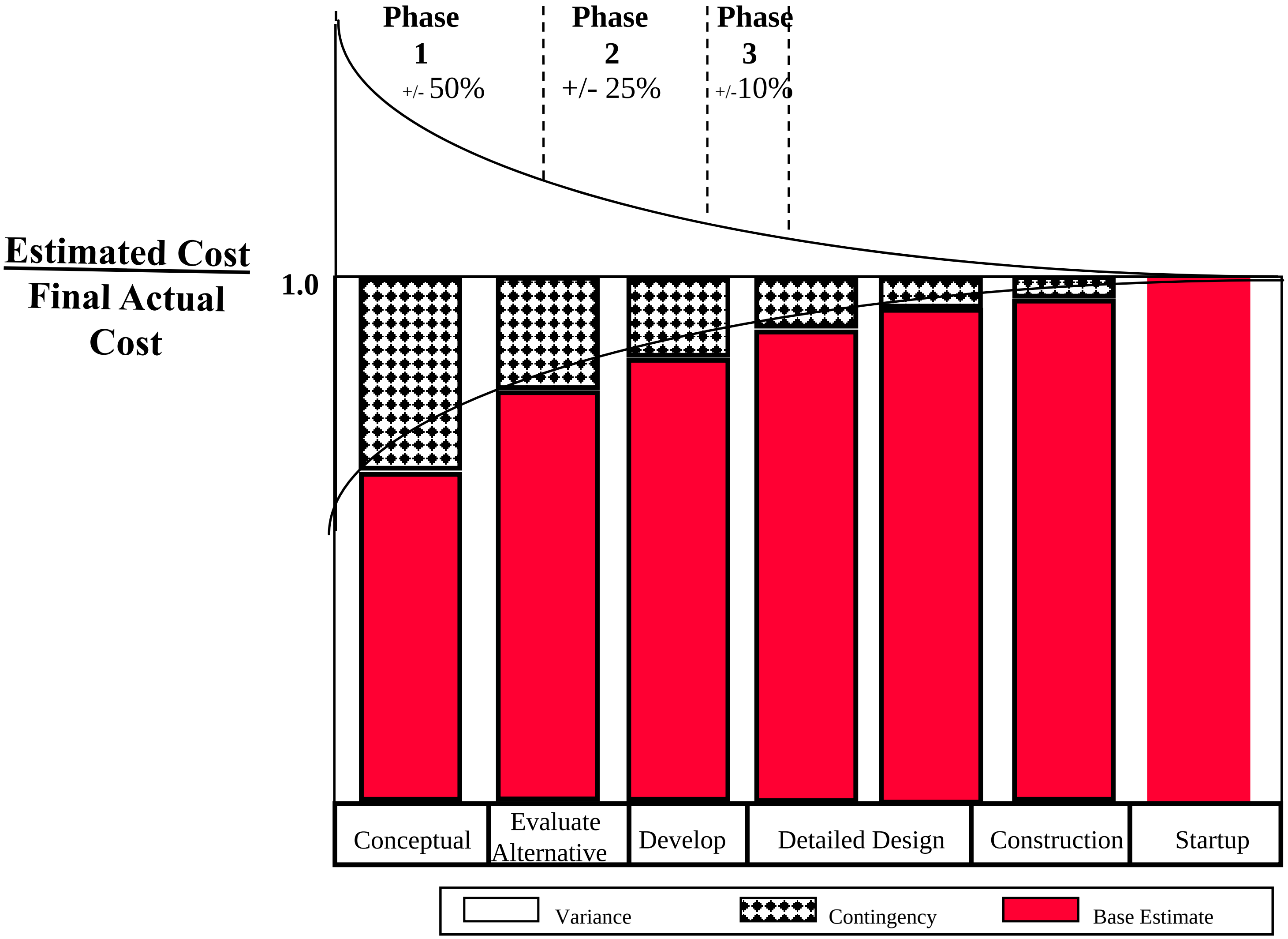
As part of the conceptual review of the facilities, conceptual level costing is provided as attached in Table 5.1. It should be recognized that costing at this conceptual level of detail is within +/- 50%. This is in accordance with the “Estimating and Contingency Determination” guidelines provided as part of the APEGA Project Management Course. A copy of this table is shown in this Appendix. It should be further understood that the costing for the dams is based on the assumptions identified in **Appendix D** as well as the following assumptions used during the conceptual design review, as follows:

- All material required for the construction of the Dry Dams was assumed to be within 1 km of the site. Based on our site review with an earthworks contractor and geotechnical engineer it appeared that this could be achieved however no bore holes were completed to confirm this.
- Slope armor needed to protect the face of the dams would be available through quarry sites in the vicinity of the dam.
- Cost for clearing and grubbing immediately under the dam site was included, however no costs were allowed for the grubbing or clearing of the detention reservoir site as it was felt that this was not required as these areas would be inundated for a short time during any given year. Any costs for annual clearing and grubbing should be considered an operation and maintenance cost.
- The cost to place and compact the earthen material required for the core and over-burden in constructing the dam was included.
- Allowance for a rock armor spillway for overtopping was included.
- An allowance for the conveyance pipe through the dam to maintain year round flows and to restrict flow during flood stage was included.
- An allowance for a second flow through pipe and control valveing to be used for emergency purposes only was included.
- The conceptual costs did not carry a provision for contingency.
- The costs did not include the preliminary reviews (environmental, geological, geomorphology, engineering, geotechnical, biophysical, etc.) required in support of the development permit application.
- The cost did not include any land acquisition costs for coordinating or the purchase of these lands.
- ~~The~~ As previously noted costs do not include and operation or maintenance costs. However in speaking with the delegation from the Netherlands Trade office, they indicated that these costs typically are in the order of 2% of construction cost annually.

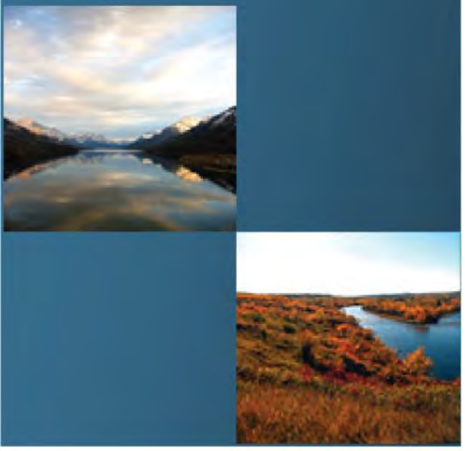
Diversions - City Of Calgary 6-8 m Diameter Tunnel

Preliminary costing for pipe portion of the 58th avenue tunnel was confirmed by a contractor in the Netherlands familiar with this type of work. The order of accuracy of the opinion of probable costs is based on conceptual design which provides for a +/- 50% accuracy.

Estimating & Contingency Determination



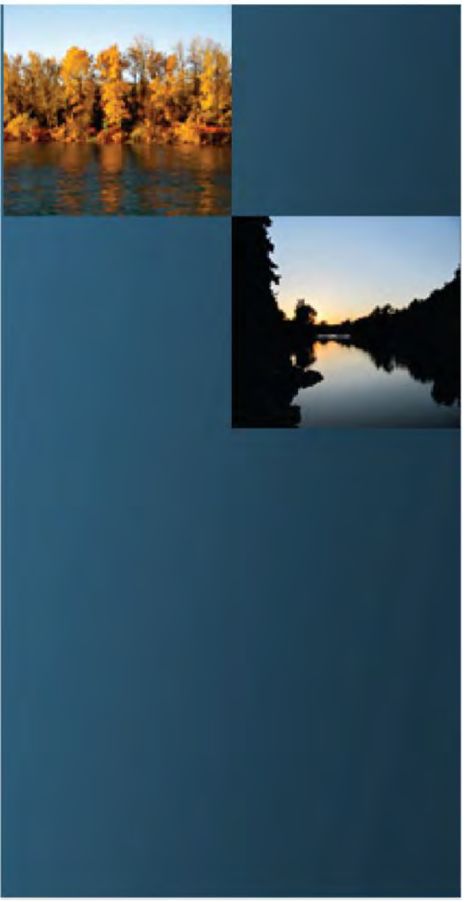
Nick Lavingia



The 2013 Great Alberta Flood: Actions to Mitigate, Manage and Control Future Floods

ALBERTA
waterSMART
Water Management Solutions

Final Version
August 2, 2013



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Executive Summary

June 2013 will be remembered across Alberta as the month of the Great Flood which resulted in the loss of four lives, displaced thousands from their homes, disrupted hundreds of businesses, and caused significant damage to private and public property, land and infrastructure. The immediate responses of municipal, provincial, and federal governments and particularly the people of Alberta to help those impacted by these flood events have been exemplary. However, as the recovery efforts begin to wind-down, the daunting task of rebuilding our communities looms large on the horizon. The rebuilding program must be based on a solid understanding of the confluence of events that caused the flood, the likelihood of recurrence, the efficacy of the proposed mitigation strategies, and the impact of these strategies on the entire South Saskatchewan River Basin.

While we cannot prevent extreme weather, we believe that the weather can be better understood and that actions can be taken to reduce the likelihood of such large-scale destruction resulting from future extreme events. There is a series of logical, science-based, proactive actions that can be taken to strengthen our capacity to respond to these types of natural disasters. The purpose of this paper is to outline these specific actions to inform the policy discussions currently underway in committee rooms across the province.

A broad group of water practitioners from across Alberta, Canada and the world have participated in developing this paper. Collectively they have identified specific actions that can be taken to mitigate, manage, and control the impacts of extreme weather events resulting in floods and the inevitable opposite condition of severe drought. These are summarized into six recommendations:

1. Anticipate and plan for more extreme weather events, including both flood and drought.
2. Improve our operational capacity to deal with potential extreme weather scenarios through better modelling and data management.
3. Investigate the cost/benefit balance of investing in physical infrastructure such as on and off-stream storage, diversions, and natural infrastructure such as wetlands.
4. Consider flood risks in municipal planning and strengthen building codes for new developments in flood plains.
5. Evaluate options for overland flood insurance.
6. Manage our water resources collaboratively, following the examples of the Bow River Consortium and the Cooperative Stormwater Management Initiative, and ensure Watershed Planning and Advisory Councils (WPACs) across the province have proper authority and funding.

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Contents

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Introduction

June 2013 will be remembered across Alberta as the month of the Great Flood. In late June a major rain event caused massive flooding in the South Saskatchewan River Basin (SSRB), affecting tens of thousands of families throughout the region, resulting in the loss of four lives, displacing thousands from their homes, disrupting hundreds of businesses, and causing significant damage to private and public property, land and infrastructure.

The immediate responses of the municipal, provincial and federal governments and particularly the people of Alberta to help those impacted by these flood events have been exemplary. In particular in Calgary, where 26 communities were affected, the excellent cooperation and collaboration between City officials, businesses, emergency response services, and the public prevented many possible deaths (only one person died in Calgary) and ensured minimal disruption in services. The Government of Alberta (GOA) responded to the flood by pledging $1 billion in disaster recovery assistance, and the Government of Canada promised full support for flood relief. The stories of heroism and sacrifice from ordinary Albertans are abundant.

However, as the immediate response and recovery efforts begin to wind down, the daunting task of rebuilding our communities looms large on the horizon. Decisions on priorities for investment must be made by individual home and business owners, the councils of the affected municipalities and counties, and the provincial and federal governments. The preliminary estimates of the total cost of Alberta's recovery efforts range from three to five billion dollars.

The rebuilding program must be based on a solid understanding of the confluence of events that caused the flood, the likelihood of recurrence, the efficacy of the proposed mitigation strategies, and the impact of these strategies on the entire river basin. Our analysis shows that Albertans from all parts of the province should be prepared to experience more frequent and severe weather events, including floods and droughts. Due to the urgent need for action our recommendations focus on the South Saskatchewan and Bow River basins. However the conclusions from our work have implications for the rest of Alberta and Canada.

While we cannot prevent extreme weather, we believe that the weather can be better understood and that actions can be taken to reduce the likelihood of such large-scale destruction resulting from future extreme events. There is a series of logical, science-based, proactive actions that can be taken to strengthen our capacity to respond to these types of natural disasters. The purpose of this paper is to outline these specific actions to inform the policy discussions currently underway in committee rooms across the province. As this paper was written, the goal was to engage as many thought leaders as possible in this important discussion. The contributors to this paper (listed in Appendix A) ensured that the recommendations herein represent clear, consistent, implementable, and fundable solutions.

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Background

The idea for this White Paper arose from a discussion group at the Canadian Water Summit, which was held in Calgary on June 27, 2013. The discussion was hosted by IBM, and was designed and conducted by Alberta WaterSMART. Thirty water experts from across Canada and around the world participated in the discussion group.

The first draft of the White Paper was distributed to the discussion group participants, the Western Irrigation District (WID) executive, the Bow River Basin Council (BRBC) executive, the South East Alberta Watershed Alliance (SEAWA) Director, the Scientific Director of Alberta Innovates – Energy and Environment Solutions (AIEES), a small number of GOA staff members, the Chief Executive Officer of the Association of Professional Engineers and Geoscientists of Alberta (APEGA), members of the Canadian Academy of Engineering (CAE), the Hydrologics modelling team, and the Alberta WaterSMART team and board. In addition, a summary of the recommendations was posted on the Alberta WaterPortal for input and comments from the public.

This final version of the White Paper represents the contributions of several dozen water practitioners and interested members of the environment community and the public. Every effort was made by the authors to include the comments received. The contributors to this paper are listed in Appendix A. Any errors or omissions in this document are the responsibility of the authors and not the contributors.

Summary of Recommendations

There are actions that can be taken to mitigate, manage, and control the impacts of extreme weather events resulting in floods and the inevitable opposite condition of severe drought. These are summarized into six recommendations:

1. Anticipate and plan for more extreme weather events, including both flood and drought.
2. Improve our operational capacity to deal with potential extreme weather scenarios through better modelling and data management.
3. Investigate the cost/benefit balance of investing in physical infrastructure such as on and off-stream storage, diversions, and natural infrastructure such as wetlands.
4. Consider flood risks in municipal planning and strengthen building codes for new developments in flood plains.
5. Evaluate options for overland flood insurance.
6. Manage our water resources collaboratively, following the examples of the Bow River Consortium and the Cooperative Stormwater Management Initiative, and ensure Watershed Planning and Advisory Councils (WPACs) across the province have proper authority and funding.

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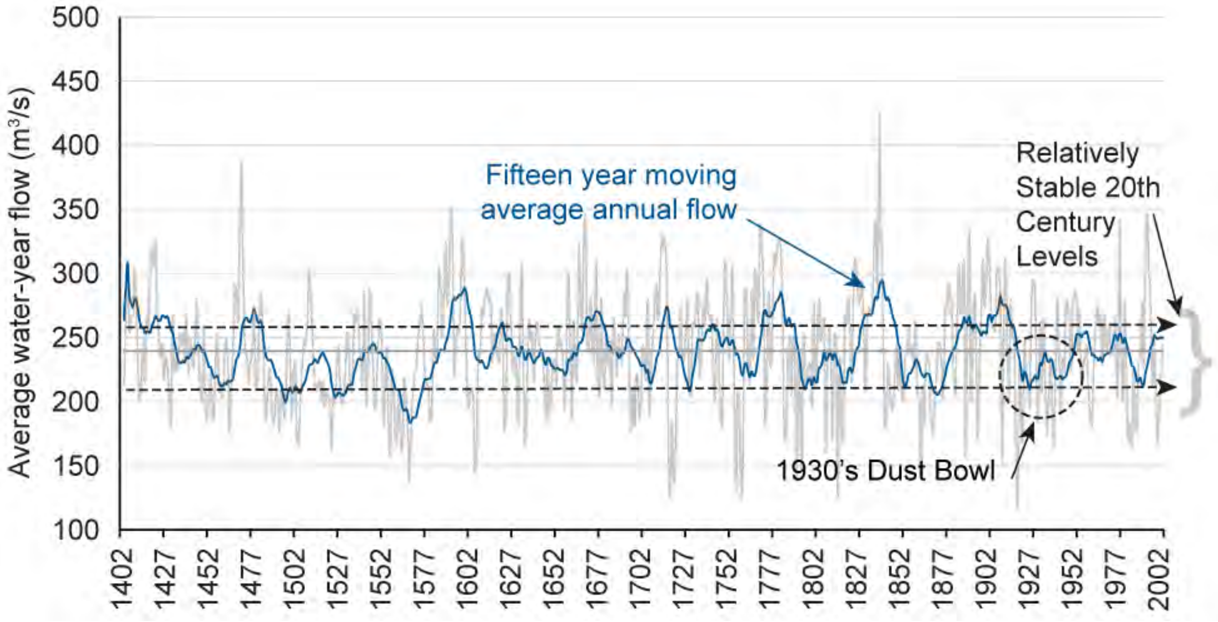
This White Paper expands on these recommendations and provides a summary of short-term actions that can be taken immediately to begin implementing these recommendations. It is hoped that all of these recommendations will help to inform the policy discussions currently underway in committee rooms across the province, as well as to educate those impacted by the flood event and anyone involved in water management activities.

1. Anticipate and plan for more extreme weather events.

Alberta, and specifically southern Alberta, should be prepared to experience larger and more frequent extreme weather events in the future, including both floods and droughts. This is important because these events have huge impacts on people and on our economy. These impacts are costly and are likely to become more costly as Alberta's population grows.

Detailed studies of historical tree ring data in southern Alberta show a remarkably consistent trend in the SSRB flows over the last 600 years. This data indicates that flood and drought events in the past were far more severe than we have experienced during the mid to late 20th century. The pre-historic record (Figure 1) suggests that we should be prepared for extreme weather events that are worse in terms of severity and frequency than the ones we have experienced in recent history. For example, the 2013 flood was one of five similar sized flood events on the Bow River in 130 years (Figure 2).

Figure 1: SSRB Flows (Bow River + Oldman River)



Source: David Sauchyn, PARC, University of Regina

History would suggest that we should consider the recorded maximum and minimum flow levels in our infrastructure and response planning. As a further complication, this planning must take drought into

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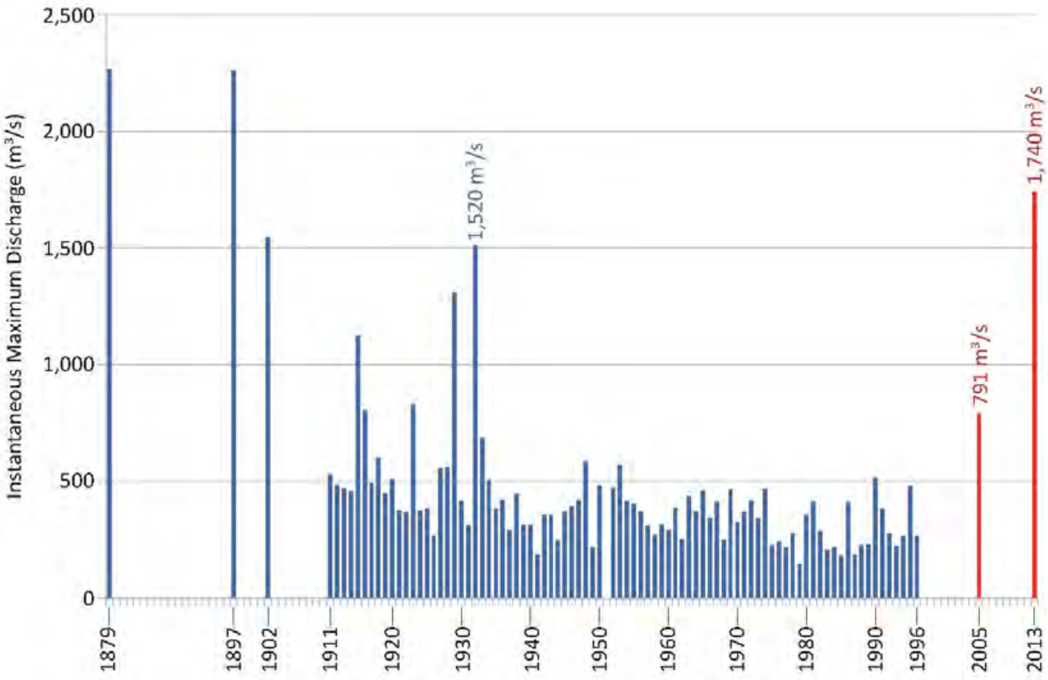
account, as flooding and drought can occur right after one another (e.g. 2001 and 2002 were major drought years, while 1995, 2005, 2011 and 2013 were major flood years) or even in the same year.

Figure 2: Maximum Water Discharge in the Bow River at Calgary between 1879 – 2013



Source: Modified from Neill, C.R. and Watt, W.E., 2001. Report on Six Case Studies of Flood Frequency Analysis. Prepared for Alberta Transportation and Civil Engineering Division Civil Projects. April 2001. Figure 5.1 p44

Although the Great Flood of 2013 did not have the highest flow rate in the history of the SSRB, it very likely has caused the most damage and had the largest economic impact of any extreme weather event in Canada to date. The costs of this flood will surpass the ice storm of January 1998 in Ontario and Quebec, which totalled $1.9 billion according to the Insurance Bureau of Canada (IBC).

The population of southern Alberta is currently projected to grow by sixty percent over the next thirty years (Alberta Treasury Board & Finance 2012). If development continues according to the same patterns as has occurred over the last thirty years, it is likely that damage from another major flood incident would be even more significant in terms of financial costs and physical impact than in 2013. Anticipating and planning for more extreme weather events is an important factor to consider in planning at all levels of government, as these events have a significant impact on the economy.

Before the flooding had subsided discussion had already entered the media around whether or not man made climate change contributed to the severity of the flood. Climate change is a contentious issue in Alberta that will continue to generate heated debate. However, based on the historical record as noted above, there is clearly a natural variance of the climate which requires adaptation in the short term. This paper focusses on adaptive actions to be made around water management in response to

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extreme events, providing space for ongoing conversations, actions, and policies regarding climate change.

Understanding the relationships between weather, river flows, population growth, and potential economic impacts is essential to planning for the future. Therefore, we make the following recommendations to better understand and plan for more extreme weather events.

- **Analyze the confluence of events that resulted in the 2013 flood.** This flood event closely resembled pre-1933 flood events. There are several theories why the maximum water discharge in the Bow River remained so low from 1933 until 2005. One theory is that there were severe forest fires in the foothills and mountains in the late 1800s and early 1900s, which could have resulted in more rapid runoff, ultimately resulting in high peak water flows. Another theory is that as the TransAlta hydro reservoirs came on-stream, they increasingly blunted the flood flows. However, neither of these theories explains the 2005 and 2013 rain events. Some work has already been done to explain changes in southern Alberta river flows based on climate variations, including the Pacific Decadal Oscillation (Alberta Innovates – Energy and Environment Solutions and WaterSMART Solutions Ltd. 2013). However more work needs to be done to understand other factors that are influencing the weather. The key meteorological, landscape, land use, and urban design factors that caused or contributed to this event in conjunction with the likely changes in frequency and magnitude of these events in future decades must be studied and debated. This analysis can then be used to signal how frequently we can expect these events in the future and their potential magnitude, allowing for better planning. The modelling work done as part of the Bow River Project and SSRB Adaptation Project is an excellent starting point and can be used to assess the impacts of flood flows, land cover, and changing weather patterns as well as the effects of various mitigation options.

- **Overlay potential development scenarios on the weather scenarios**. Land use in the South Saskatchewan watershed will change over the next thirty years as the population increases. Models such as the ALCES tool run by the ALCES Group can be used to understand how development will alter the landscape, which has a major impact on stormwater management, flood mitigation, and watershed saturation. This type of analysis is being incorporated in the current Alberta Innovates – Energy and Environment Solutions (AI-EES)-funded studies on river management in the SSRB.

- **Determine the magnitude of potential economic loss from another flood event.** As the 2013 flood has demonstrated, floods are extremely costly. An analysis of the physical and economic losses incurred in this flood, as well as other recent floods, would provide a baseline for assessing the magnitude of losses from potential future events. This type of analysis is being considered by the IBC, and they would be an excellent resource for this work. The results of this analysis would support and justify the necessary investments in planning and infrastructure that are needed to reduce the impacts of another flood.

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- **Take a holistic approach when analyzing storm, flood, and drought data.** When analyzing storm, flood, and drought data, a holistic approach to hydrology assessment is required that includes data from watersheds outside of the watershed where the weather event occurred. In the case of southern Alberta, the flood history for all of the river basins with headwaters along the east slope of the Rockies needs to be examined to get a complete view of the frequency and magnitude of potential floods resulting from severe storm events along the eastern slopes. These storms are regional, not basin specific, as was shown in the 2005 event where the final rain dropped in the Red Deer basin, not the Bow basin. In addition, it would be extremely beneficial if meteorological data from across the North American continent could be shared between experts to improve monitoring capabilities. The Delft Flood Early Warning System (FEWS) program has been used in other parts of the world to assemble and analyze this type of data and could provide some guidance for Alberta.

2. Improve our operational capacity to deal with potential extreme weather scenarios through better modelling and data management.

Improving our operational capacity is integral to ensuring that the most appropriate mitigation strategies have been analyzed, developed and implemented before the next flood or drought occurs. This includes increasing modelling efforts and ensuring that drought and flood planning receive equal attention from policy-makers. Modelling should be based on the best data available. Efforts to collect more water-related data such as snowpack, precipitation, evapotranspiration, and sublimation and their effects on streamflow should be a high priority. Where possible, it is important to include the quantitative evaluation of natural ecosystem functions and services in the form of flood mitigation from forests and other natural land cover in the headwaters, wetlands and healthy riparian areas.

Considerable work is already underway in this area, but can be accelerated and improved through the following actions.

- **Ensure that data is available and easily accessible so that it can be used in modelling and planning by researchers, municipalities, provincial officials, and private property owners.** Historical and current data should be used to better understand and model the long-term trends referenced above. Researchers and planners should utilize the data from the new provincial monitoring agency to ensure consistency. The GOA has data that should be made available either through the monitoring agency or through public websites. In particular, increased data on groundwater is required for flood potential forecasts. Monitoring and research that is funded by the GOA (e.g. snowpack monitoring) should continue. When known, flood and drought risk and vulnerability should be clearly communicated to researchers and accurately portrayed. Impacts of a changing climate should be accounted for, including changing precipitation patterns, drought and heat waves.

- **Investigate back-up systems for Water Survey of Canada gauging systems to maintain data continuity during large events.** During the 2013 flood, every Water Survey of Canada gauge

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between Banff and Calgary went out of service prior to the peak flows occurring. TransAlta, the City of Calgary, the irrigation districts and the GOA need real-time data to operate their water retention systems. Currently a standard stream gauging system is built on the bank of the stream and is prone to being damaged or flooded. A realistic short-term action is to ensure that real-time data stations maintain integrity during the flood event. This could involve adding more gauges in more secure locations, and researching alternate systems that could initiate operation when the existing gauges are overwhelmed.

- **Improve predictive capacity through increased modelling and data management.** Models that run a variety of scenarios, using in some cases well over 80 years of gauge data, can help decision-makers understand the possible outcomes and impacts of a flood or drought event. Decision-makers should increase their use of modelling capacity to ensure that a variety of extreme weather scenarios have been taken into account in policy planning, and so that specific mitigation measures and plans can be identified, properly analyzed and implemented. Publicly available models have already been developed for some parts of Alberta (e.g. the OASIS model has been developed by the University of Lethbridge and Hydrologics, and is being applied by Alberta WaterSMART in the SSRB). Improved operational capacity can be achieved by:

    - Developing flood potential forecasts. Hydrometeorlogic data can be used to investigate the nature and extent of flood risk. The magnitude and frequency of major floods can be estimated in order to identify where funding should be allocated to support adaptation measures. As an example, Red River basin managers have developed these kinds of tools (see Warkentin1999) and some of their work should be adopted in Alberta.
    - Increasing flood risk mapping. Flood mapping for 1:200 year, 1:500 year, 1:1000 year or possibly Probable Maximum Flood events should be considered and vulnerable areas should be identified. This needs to be kept up to date, as mapping precision can decrease with time resulting in increasingly less reliable statistics.
    - Utilizing the best available technologies. Remote sensing tools should be developed and incorporated into Alberta's flood planning and response. Alberta has some of the best LIDAR inventories (remote sensing technology that uses lasers to measure distance) in the world, but there is a need for new digital elevation models to be built. Options like the American GRACE satellite and the new Canadian RADARSAT constellation satellite can be used for better surface groundwater mapping. GRACE could play a big role in understanding flooding and groundwater relationships.
    - Developing communication tools. Publicly available and user friendly tools can be developed to help engage and educate the public with respect to high flood risk areas. These tools could show the high water level mark associated with a given flooding event and outline which communities would be affected by flooding at different flow rates. Mitigation and damage reduction options can then be designed to meet each specific risk profile.
    - Increasing basin-specific modelling. Current models such as the Bow River Operational Model (BROM) should continue to be upgraded to incorporate new data and inputs such

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as groundwater and smaller streams. Land cover and use, water quality, wetland, and riparian habitat data should be incorporated into the BROM.

  - Using BROM as an operational support tool. BROM should be used by water managers and reservoir operators in training exercises to help them prepare for a variety of flood and drought scenarios. This was demonstrated as part of the Bow River Project (see www.albertawater.com/Bow River Project).

- **Recognize that flood and drought planning are interconnected, and that both should receive an equal amount of attention.** Over the last decade in the SSRB the majority of water management strategies have been drought-related. Flood-related water management strategies should receive an equal amount of attention. Drought and flood mitigation strategies can be used to benefit each other; for example implementing the Bow River Project recommendations, including flexible and collaborative management, can improve environmental conditions under normal circumstances and ensure adaptive responses to either drought or flood conditions.

- **Develop a better understanding of the relationship between flooding and groundwater.** Alluvial aquifers (shallow groundwater-bearing channels connected to surface water bodies such as rivers) are vital natural infrastructure. Further investigations should be conducted in order to understand the effects of flooding on groundwater, and vice versa. Some work has been done in this area specifically by Alberta Environment and Sustainable Resource Development (ESRD), and this work should be leveraged and the data made available publicly. More specifically:

  - In the City of Calgary, there should be a detailed review of the alluvial aquifer around the Bow and Elbow Rivers to map the groundwater levels and the sensitivity to rises in river levels. This work is essential to understanding the risks to office buildings, residential homes, businesses and condominiums close to the rivers, and to determine appropriate building standards. Work that has been done to date should be made publicly available and easily accessible.
  - The hydrological cycle should be better understood in its entirety on a regional scale with respect to the SSRB. This includes a detailed understanding of the interactions and relationships between groundwater, surface water, precipitation, snow pack and related factors such as sublimation and evapotranspiration, snowmelt, aquifer recharge/discharge and variations in climate. There are academic studies of many of these elements that could support a larger integrated study. The current AIEES-funded study of The Future of Water in Alberta could perhaps use the Bow River Basin as a case study for its integrative work on water issues in Alberta.

- **Re-evaluate the potential for slumps and mudslides during flooding events.** Numerous communities in the municipalities affected by the 2013 flood are situated near the edge of steep slopes that were formed by river erosion. Steep slopes that consist of large quantities of glacial and lake sediments become unstable and may fail when materials are removed from the base of these slopes or when the ground becomes saturated. Although major slumping and mudslides did

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not occur in Calgary, they occurred in Canmore and other areas. The potential for these to occur in the future throughout the region should be assessed and preventive measures implemented.

- **Build upon work that has already been done.** Current and future policy should build upon work that has already been done, such as the 2006 Groeneveld Provincial Flood Mitigation Report. Unfortunately that report was not released until 2012 and is now somewhat out of date. However the basic tenets and recommendations still apply and the report should be updated and analyzed for effectiveness using the latest data and modelling techniques and then implemented where needed most. In addition, during the past decade the ALCES Group has completed several projects along the east slope drainage basins from the U.S. border, through the Oldman Basin, to the Bow River Basin upstream of Calgary. All of these projects have examined elements of water flow and water quality, among a broader suite of indicators. Other work currently underway has been identified elsewhere in this paper, including the IBC reports, the SSRB projects, and projects underway at the Universities of Alberta (Goss *et al*), Regina (Sauchyn *et al*) and Saskatchewan (Pomeroy *et al*).

- **Engage public health professionals in assessing mitigation measures.** Floods create immediate public health risks to drinking water supplies, a risk that has been mainly dealt with by means of precautionary boil water advisories. Given the experience of the 2005 and 2013 floods, additional risk management measures for protecting drinking water and assessment of the effectiveness of boil water advisories, particularly when power outages and/or natural gas shut-offs also exist, should be pursued. There are also public health concerns with remediation efforts from flooding, including exposure to sewage contamination, growth of toxic molds and dealing with food spoilage. Public health professionals should be engaged in assessing mitigation measures to determine if better health practises and/or advice is needed for future events.

3. Investigate the cost/benefit balance of investing in physical and natural infrastructure.

Extreme weather events often catalyze discussion on the resiliency and adequacy of water infrastructure such as dams, canals, diversions, reservoirs, and natural features such as wetlands. A conversation about water infrastructure opportunities in Alberta is needed now. Billions of dollars will be spent on flood recovery and rebuilding efforts and some of this money should be invested in infrastructure to mitigate the impacts of future extreme weather events. It is important to remember that there is no one single infrastructure solution that will resolve all issues in the SSRB. The recommendations included here should be viewed as tools in a toolkit rather than either/or options. Even with properly planned and implemented infrastructure, the risks of building in flood-prone areas and the cost of recovering from a flood need to be carefully balanced.

- **Conduct cost-benefit and risk analyses to assess the best use of capital funds to support infrastructure spending decisions.** Obviously public funds are scarce and must be directed to the use which maximizes the benefits to society. After recovery from the current flood event,

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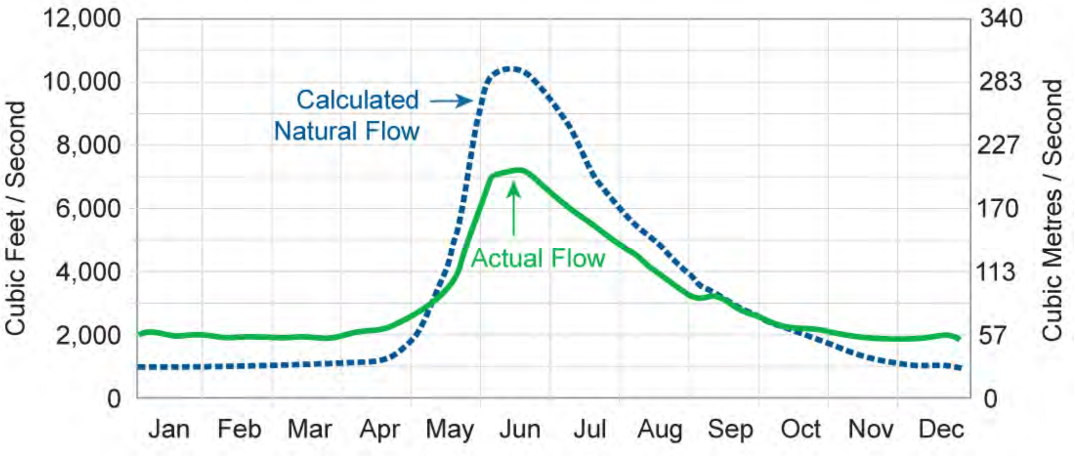
preventative physical and natural infrastructure initiatives should be identified, evaluated, and where justified, planned and implemented. An excellent example of how infrastructure is already being utilized to manage water flows is the management of the Bow River through the City of Calgary by the TransAlta hydro dam infrastructure during normal times (Figure 3). The benefit of this infrastructure is that it ensures a stable and steady flow of water in the Bow River; the managed flow is double the natural flow in the winter months, which ensures that the City of Calgary can operate its water treatment plants within the legislative parameters set out by the GOA. A stable flow in the winter also helps prevent ice jams and floods, and the lower than natural flow in the summer months can mitigate minor to moderate flooding. Other examples include the Glenmore Dam on the Elbow River, operated by the City of Calgary, and the Oldman Dam on the Oldman River, operated by ESRD. Other opportunities have been explored, and some new ideas are noted in this section.

Figure 3: Bow River at Calgary - Natural vs. Managed Flows
(38 years data)



Source: BRBC State of Watershed Plan 2010

- **Consider all available infrastructure options**. Unnecessary impacts to natural infrastructure should be avoided wherever and whenever possible. Where pipes, intakes and outfalls are needed for municipal water, wastewater, and stormwater infrastructure, the value of natural resources that may be affected by their implementation should be considered. Decision-makers should take advantage of opportunities to retrofit river shorelines using soft engineering practises; that is the use of ecological principles and practises to reduce erosion and achieve stability of shorelines, while enhancing habitat and improving aesthetics. The redevelopment of the Detroit River shoreline is often cited as an example of successful soft engineering practise. In addition, other low-impact developments, such as porous/pervious pavement, should be considered.

- **Use the best available risk assessment tools.** Over recent years new tools have been developed to assess risk more broadly for public infrastructure. Groups such as the Public Infrastructure Engineering Vulnerability Committee (PIEVC) of the World Engineering Council look broadly and

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systematically at infrastructure vulnerability to climate change from an engineering perspective. Tools like the PIEVC infrastructure vulnerability protocol, developed by Engineers Canada and Natural Resources Canada and used across Canada and internationally, provide a proven approach to understanding the risks and vulnerabilities of existing infrastructures to the threats of extreme climatic events. The standards and practices developed by the PIEVC have already been tested in Alberta and could inform investment decisions as the GOA and municipal governments consider new infrastructure investments.

- **Implement the recommendations of the Bow River Project.** Over the last four years, the major water license holders on the Bow River have collaborated on developing water management protocols for the Bow River that incorporate many of the recommendations included in this White Paper. The GOA should work together with the Bow River Consortium and TransAlta to flexibly implement these recommendations. This agreement on future water management is an essential first step toward on-going, systematic improvement to the Bow River watershed, and will facilitate planning and implementation of damage reduction strategies for both future floods and droughts.

- **Utilize on-stream storage for flood control.** The Bow, the Elbow and the Oldman Rivers all have existing on-stream storage behind dams built primarily for power generation for the Bow, and water supply management for the Elbow and Oldman. Better integration of this storage capacity to embrace broader objectives of flood and drought management could significantly increase the capacity to manage extreme weather events and improve environmental conditions under normal circumstances. Current SSRB modelling can provide the structure for assessing these options. Some specific recommendations include:

    - Investigating opportunities and costs of using TransAlta storage for flood control and drought mitigation. The BROM model should be used to evaluate the extent to which reservoir capacity can be used to manage extreme weather events. The model provides for the assessment of the opportunity costs of lost power generation compared to the capacity to reduce peak flood flow. The velocity in the level of peak flood flow and elevation and the period of time in which flows are reduced can then be translated into flood flow maps to show areas where action can be taken to reduce flooding. This modelling exercise must include the downside risk of lowering reservoir levels if the expected rain/flood event does not occur or occurs at a lower than forecast amount. The key to improved risk management for flood and drought is an agreement on risk sharing and risk management among water users, taking into account maintaining appropriate environmental base flows.
    - Developing a flow/flood damage relationship for Banff, Canmore, Morley, Cochrane, Calgary, Carseland, Siksika, Medicine Hat and other significant communities and infrastructure. This information would be based on water flow rates and would demonstrate the amount of land that could be covered by water and the resulting potential economic damage at various peak flow rates. A hydrodynamic flood model should be developed and used to test flood operating strategies and trade-offs between location of available storage and potential damage.

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  - Evaluating multi-purpose storage and operations on the Highwood and Sheep Rivers. Some work has already been done to model the Highwood/Sheep system, and this could be the basis for assessing storage and operating options.
  - Evaluating increased storage for flood control at the Glenmore Reservoir and upstream of the Elbow River for storage and power generation.
  - Evaluating the potential impact of gradual accumulation of sediment in reservoirs and implementing an active reservoir sediment management plan.

- **Utilize off-stream storage more effectively for flood mitigation.** The irrigation districts have made use of man-made lakes for water storage for decades. Watershed management can be made more resilient by diversifying off-stream storage options, including increasing storage volumes or altering operating conditions. The Western, Bow River and Eastern Irrigation Districts should be engaged in a discussion as to how they can further utilize their infrastructure to help mitigate flood risks, while ensuring a robust response to drought conditions.

- **Improve management of headwater areas so that natural wetlands and riparian zones continue to act as a buffer for heavy rainfall.** The ability of the headwaters to capture and retain snowmelt and spring run-off should be optimized. The current development of the South Saskatchewan Regional Plan (SSRP) presents an opportunity to enhance flood avoidance and mitigation in southern Alberta. Headwater management should be addressed in the SSRP and could include, for example:

  - Making headwater landscape health a management priority for prairie rivers to naturally optimize water production and water quality, and to moderate the release of water throughout the spring and summer seasons.
  - Shifting from clear-cut logging to canopy-retention logging. This will help to reduce canopy snow loss while spreading out the snow melt over a longer period, and retaining the ability of the forest canopy and groundcover to intercept and retain rain.
  - Supporting high population densities of beavers in some headwaters to maximize their free ecosystem services.
  - Limiting off-road vehicles and industrial vehicles to trails and roads designed to minimize gullying and sedimentation and to avoid water source areas such as fen meadows and wetlands.
  - Investing public funds in the purchase of ecosystem services such as small check dams in coulees, wetland restoration, and/or revegetation of exposed or eroded soil from landowners in source water areas.

- **Incorporate natural infrastructure such as wetlands, riparian areas, natural storage conditions and land cover into flood and drought mitigation planning.** Utilized properly, natural infrastructure can be used as an effective long-term solution to ensure that people, infrastructure and natural systems are less vulnerable to flooding. In addition to flood control, ecosystems provide many economically beneficial services that support and protect humans and nature such as filtering pollutants, controlling erosion, producing fish and providing clean drinking water.

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Moreover, natural infrastructure can have lower long-term maintenance costs than physical infrastructure. However the functions of the natural infrastructure such as wetlands must be understood to avoid unintended consequences elsewhere in the basin. The provincial wetlands strategy is needed to help guide the effective use of wetlands. In addition, the BRBC recently published the Bow Basin Management Plan (2012) which addresses wetlands, riparian areas, land use and headwaters protection. This document is in the process of being endorsed by a large number of Bow Basin stakeholders. The other WPACs in the SSRB, including the Oldman Watershed Council (OWC) and the South East Alberta Watershed Alliance (SEAWA), are also exploring natural infrastructure opportunities. Non-traditional opportunities such as gravel bed storage and aquifer storage and recovery should also be examined.

- **Investigate and identify sparsely habited or uninhabited areas that could be potentially flooded with minimal economic and environmental impact.** This measure applies to rural areas where there are large, unoccupied pieces of land. Areas where floodwaters can be diverted using an engineered system should be identified, and a system should be put in place to compensate any land or property owners for lost revenue and inconvenience. Intentional flooding did occur in some areas during the 2013 flood (e.g. in the Bow River Irrigation District) and has occurred in other jurisdictions. While flood impacts still occur, they are often not as large as they would have been if the flood waters reached more populated areas. A specific example is the Portage Diversion where channel banks (dikes) were intentionally breached in the 2011 Manitoba flood event. The dikes were breached in order to increase the capacity of the diversion channel, protecting the weir (see Manitoba 2011 Flood Review Task Force Report). This protected the urban areas by sacrificing two farms, whose owners were compensated for their losses and inconvenience. This option must be modelled and understood thoroughly to avoid unintended consequences, and requires the agreement and participation of those impacted. Intentional flooding should be more broadly considered by all parties in flood management.

4. Consider flood risks in municipal planning and strengthen building codes for new developments in flood plains.

The recent flood event revealed several weaknesses in current development practises in the urban areas in southern Alberta. Some of these practises can be addressed reasonably quickly, while others will take more time. However, all are possible within the current municipal planning structure.

- **Conduct cost-benefit and risk analyses to assess the best use of capital funds to support municipal planning and land use decisions.** As decisions are made on rebuilding existing and building new developments in flood-risk areas, it would be prudent to conduct cost-benefit and risk analyses on the costs of changing building and/or zoning codes. These costs would likely be borne by governments, as well as developers, owners and tenants. There should be some basis for evaluating the benefits of enhanced building codes and zoning plans against the costs of their implementation.

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- **New municipal development in potentially flood-prone areas must be reconsidered.** Increased flood plain mapping is needed to better inform decision-makers at all levels on whether building should go ahead in flood plain areas. This mapping should include groundwater mapping as well as surface water. Much of this mapping has been done, but its existence is not widely known and not all is publicly available. In addition, as noted previously, maps must be kept current by incorporating new experience. If new development is to be discouraged in flood-prone areas, then incentives and disincentives will need to be provided in order to change the land use habits of urban developers. Examples of disincentives are higher property taxes for new developments or a requirement to have overland flood insurance for those choosing to build in a flood-prone area. Examples of incentives include provision of costs of relocation outside the flood zone. This appears to be the policy direction of the GOA in response to the 2013 event. Purchasing back lands in flood-prone areas and establishing parks and other public use spaces could provide a societal benefit for the larger community.

- **Land use planning should be connected to watershed planning.** Flood plain development is primarily an urban issue. The broader issue of land use must also be considered, particularly in rural municipalities and farming and public lands, including the effect this land has on flooding in the urban centres. It is important to model potential land cover changes that could result from threats of pine bark beetle or forest fires reducing water retention, and what improvements to water retention might result from enhanced riparian or wetlands functions. Models such as the BROM and ALCES could be used here. Some specific areas that should be considered in land use planning include:

    - Headwater basins. Headwater basins are incrementally (slowly in some, faster in others) losing their water-holding and aquifer-recharging capacity because of overlapping land uses that encourage faster overland flow of precipitation or snowmelt. Key land uses reducing groundwater infiltration and increasing overland flow are forestry, agriculture, residential construction, and the transportation network associated with forestry and energy.
    - Construction of built capital close to surface water. High levels of built capital (roads, residences, utilities, tourism, oil and gas, agriculture) have been and are being constructed close to all levels of surface water. As noted above, municipal development, as well as the construction of other capital, in potentially flood-prone areas should be reconsidered.

- **Refine our zoning and building codes.** A review of world class zoning and building code practises for office towers, condominiums, residential homes, and businesses should be undertaken. In many new office towers and condominiums in Calgary, electrical and mechanical systems are located in the lowest parking or basement levels along with the back-up generators. In this major flood, many of the parking structures and basements were flooded after the power was cut, which disabled the sump pumps. The flooding damaged or destroyed electrical and mechanical systems located at the lowest levels. Some basic redesign and relocation of these systems and addition of back-up generators above the flood line should result in less damage and faster recovery. The

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location of critical information infrastructure should also be based on a clear understanding of possible water penetration during a major flood event. One specific recommendation is that multi-story buildings (commercial and residential) impacted by the flood should be required to test their sump pumps to ensure that these pumps are adequately sized to remove the water that penetrated their parking structures. These sump pumps should also be placed on a separate circuit from the electrical system of the remainder of the building and linked to a backup generator that will allow the sump pumps to keep working in the event of a power shut-down. Another recommendation is that building codes should be changed to allow flood-prone residences to relocate basement density to a third floor (i.e. current codes allow for two storeys to be built, so moving the home up one storey is a possibility). Homes in flood-prone areas could be designed without basements and possibly on static or adjustable stiles (e.g. hydraulic jacks or manually operated systems). Flood-prone subdivisions could be designed with engineered walls that could be raised or lowered to desired heights around the community.

- **Recognize the importance of urban stormwater run-off management.** Flooding can have an impact on municipal stormwater and sanitary sewer systems. For example, in the community of Sunnyside in Calgary the flood protection levee largely prevented overland flooding from the Bow River, yet many houses suffered damage due to storm and/or sanitary sewer back-up. The management of urban run-off is as important as rural run-off, and the system must be designed to cope with simultaneous high rainfall and high river conditions.

- **Encourage APEGA to revise and update their practice standards to include assessment of risks due to natural disasters.** Engineers and geoscientists practice their profession under a provincial act that is administered by the Association of Professional Engineers and Geoscientists (APEGA). Many of the recommendations made above involve engineering and geology practice. A tangible action item for APEGA would be to ask its Practice Standards Committee to include an assessment of risk due to natural disasters in their risk management practice standard. This can be done either by updating the 2006 Risk Management document to include substantially greater emphasis on risk management for natural disasters, or to develop an additional document that focuses on risk management for natural disasters. This involves identifying hazards, applying risk assessment to analyze the evidence about the magnitude and probability of risks, and then developing viable alternatives to prevent or mitigate damages arising from risks. As a participant in this White Paper, the CEO of APEGA would welcome constructive suggestions about how best to harness the large volunteer professional capacity and experience that APEGA can access to make a meaningful contribution towards improved flood risk management in Alberta. This same request should be made of the other professional associations that oversee architecture, planning and installation practices in Alberta.

- **Make a variety of tools widely available to all Albertans to inform them about a future flood.** The majority of communication on the 2013 flood was carried out through social media. Many Albertans received information from Twitter, as Premier Redford, City of Calgary, Calgary Police, Mayor Nenshi, ESRD, and many others, provided constant updates. It would be worthwhile for the

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GOA to consider how it could use social media as well as traditional avenues of communication as effective public communications tools both leading up to and during natural disasters.

5. Evaluate our insurance options.

Currently, overland flood insurance is not available in Canada. Historically, the provincial government, backstopped by the federal government, stepped in to provide assistance for rebuilding when overland flood damage occurred during a flood event. For a variety of valid reasons including the magnitude of the damage, the GOA appears to be reconsidering this past practice for those wanting to rebuild the same home in the same location. There is some public support for putting conditions on payouts to reduce future tax burden to the general public from another flood. It is clear that many in the most affected areas are experiencing uncertainty and very likely significant financial hardship, especially if they are retired and were depending on their home value to support their income.

The issue is whether the affected homeowners have an option to rebuild. One idea that has been noted repeatedly since the flood occurred is offering overland flood insurance for the areas in the flood plain. Overland flood insurance potentially provides an option for homeowners who can afford it to rebuild their homes along the river's edge, ensuring that these homeowners continue to pay municipal taxes. In 2010, a study (see Sandink et al 2010) was conducted by the Institute for Catastrophic Loss Reduction and Swiss Re which concluded that overland flood is insurable for Canadian homeowners. They provided a proposal to put this insurance into place. The GOA should consider whether overland flood insurance should be brought into the province. Flood insurance programs provide important economic signals about the use and management of flood plains. At a minimum, rates for flood insurance in repetitive loss areas should be actuarially sound and reflect the true risk of flooding. Higher rates could help to guide development out of some of these high value, high repetitive loss areas. This is an area that is outside our area of expertise, and more investigation needs to be done to determine if this is a concept worth pursuing.

6. Manage our water resources collaboratively.

There are a variety of players involved in water management in Alberta, including the federal, provincial and municipal governments, as well as local watershed groups, irrigation districts, hydro power companies, non-government organizations, and others. Each has a valuable role to play in water management. Improved collaboration and information sharing between these groups is required to improve flood mitigation measures, and the following recommendations support these points. It should be noted that in the aftermath of the 2013 floods there has been great cooperation between emergency organizations at all levels of government. From local volunteer fire services to regional departments responsible for roads or electrical infrastructure to the RCMP and military, all were pitching in and cooperating with acknowledged on-scene commanders. Similarly, the transportation agencies and organizations responsible for pipeline security were cooperating to manage specific crisis situations. Politicians appeared to support each other without shifting blame or

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raising questions of jurisdiction. These positive demonstrations of cooperation should continue through the following recommendations.

- **Support WPACs to work with their memberships to assess flood risk, consequences, and mitigation strategies, and to provide advice to GOA.** Under the *Water for Life* strategy, the WPACs have been given a specific role to play in managing water in the watershed. WPACs including the BRBC, the OWC, and SEAWA can and should take a leadership role in analyzing, evaluating, and advising on adaptation strategies to address future flood and drought circumstances. These organizations have the balanced membership and the neutral forum to convene and enable collaborative assessment of the data, to identify an array of mitigation options, and to provide leadership and advice on future water management in the Bow, Oldman and South Saskatchewan River systems. They are ready, willing and able to perform this vital function.

- **Consider creating a Provincial Water Authority.** In 2011, the Premier's Council for Economic Strategy recommended that an Alberta Water Authority be created. The driver behind this recommendation was the acknowledged risk that "within our thirty-year horizon, Alberta's current water management structure will be unable to effectively manage our water resources …" If an Authority was created as originally planned, it would be responsible for:

    - Water Information. The Authority would create and maintain a fully integrated and accessible water information system to support planning and decision-making. The need for more easily accessible data for modelling and planning purposes could be met through this central entity.
    - Water Infrastructure. The Authority would develop a long-term infrastructure plan to support effective water management, which would include on and off-stream storage facilities and natural infrastructure. The need for a review of infrastructure requirements that are appropriate for both flood and drought management could be met through the Authority.

- **Support and provide increased capacity to smaller municipalities to respond to natural disasters.** The cities of Calgary, Lethbridge and Medicine Hat were all well-equipped and ready to respond to the flood. However, smaller municipalities have less capacity to respond to natural disasters. The GOA should work with these small communities to coordinate emergency response plans and to determine where capacity gaps exist prior to the next natural disaster.

    Federal and provincial agencies should provide local governments with training, up-to-date science and data, and decision support tools to properly guide decision-making. In particular, local communities need to be informed about the full range of solutions to protect their communities, including the benefits of using natural infrastructure. This information should inform hazard mitigation, land use plans and local ordinances.

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The Short-Term Response to the 2013 Great Alberta Flood

Over the next six months significant progress can be made on several of the recommendations noted above. These actions can provide evidence of tangible progress toward mitigating, managing, and controlling future floods.

1. **Anticipate and plan for more extreme weather events**

- Engage one of the research teams currently working on understanding weather impacts on stream flows to analyze weather patterns and trends to propose a workable theory for the occurrence of the flood. Translate this work into specific guidance that can inform weather warning systems.
- Engage existing models such as BROM to understand the specific impacts and streamflow rates generated by specific flood events.

2. **Improve our operational capacity to deal with a variety of potential extreme weather scenarios through better modelling and data management.**

- Open the doors to the data rooms so that all relevant data is easily accessible for modelling and planning throughout the SSRB.
- Implement the recommendations of the Bow River Project, including engaging TransAlta in the project through an economic arrangement with GOA.
- Engage one of the research teams currently working on groundwater mapping to map the alluvial aquifers around the Bow and Elbow Rivers to provide information on the interaction between the rivers and the aquifers. This will provide some guidance on the extent of the flood plain for various flood levels.
- Investigate the use of risk management tools such as PIEVC to incorporate flood risks into investment decisions on infrastructure.
- Research specific hydrometeorlogic indicators used by other jurisdictions that are used to understand the nature and extent of flood risk. Identify five indicators that Alberta should be monitoring now and in the future.

3. **Investigate the cost/benefit balance of investing in physical and natural infrastructure.**

- Use existing models to begin assessing engineered and natural infrastructure options for flood management and mitigation.

4. **Consider flood risks in municipal planning and strengthen building codes for new development in flood plains.**

- Fund a project to review and summarize best zoning and building code practises in North America, Europe and Australia related to flooding and how those can be applied to Alberta.
- Place a moratorium on new development in potentially flood-prone areas until the analyses outlined above are completed.
- Encourage APEGA to revise and update their practice standards to include consideration of risks in a flood event. Encourage other professional associations (e.g. architects, planners) to do the same.

5. **Evaluate our insurance options.**

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- Investigate the potential for overland insurance to deal with those property owners who wish to build or rebuild in the flood plain.

6. Manage our water resources collaboratively.

- Incorporate the recommendations contained in this report into the South Saskatchewan Regional Plan.
- Support WPACs to assess flood and drought risk, consequences, and mitigation strategies.
- Consider the consolidation of water-related functions (e.g. fish, energy, irrigation) into Watershed-based Authorities to support implementation of the various Regional Land Use Plans.
- Provide increased capacity and support to smaller municipalities to deal with natural disasters.

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APPENDIX A

WHITE PAPER CONTRIBUTORS

The following is a list of individuals from Alberta, Canada and the world who engaged in consultation with Alberta WaterSMART on this White Paper. Contributors were not asked to provide an endorsement of the White Paper, or of the recommended flood mitigation actions outlined within. Rather, respondents were asked to share their insights and feedback to ensure that our work adequately captured and reflected elements of the current conversation about flood mitigation and adaptation measures in the water policy community. Every effort was made to ensure that this White Paper reflected the comments received from the contributors. However, any errors and omissions in this paper are the responsibility of the authors and not the contributors.

A Compendium document has been prepared that includes the comments and discussion as received from the contributors to the extent possible and as agreed to by the contributors. Some of these contributions have already been featured on the Alberta WaterPortal to generate more conversations on the flood event and possible actions. Hopefully the excellent suggestions contained in the Compendium will be of value to the policy and decision makers in committee rooms across the province. While there are well-regarded experts that we have no doubt missed in our consultation, such exclusion was not intentional.

Expert Group	Last Name	First Name	Position	Institution or Organization
Canadian Water Summit Discussion Group	Braun	Erwin	General Manager	Western Irrigation District
	Brawn	Bob	Board Member	Alberta Water Foundation
	Cramwinckel	Joppe	Director, Water	World Business Council on Sustainable Development
	Doucette	Brian	Director of Sustainable Innovation	Suncor Energy
	Freek	Kerry	Editor	Water Canada
	Kelly	Mike	Chair; Special Advisor	Bow River Basin Council (BRBC); Alberta WaterSMART
	Kun	Karen	Executive Director	Waterlution
	Maas	Tony	Director, Freshwater Program	World Wildlife Fund (WWF)
	Olver	Tom	Marketing Manager, Natural Resources	IBM
	Piñero	Edwin	Executive Vice President and Chief Sustainability Officer	Veolia Water North America
	Renzetti	Steven	Professor of Economics	Brock University
	Riggs	Geoff	Global Business Services - Smarter Planet Project Manager, Business Development	IBM

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	Sommerfeld	Larissa	Policy Specialist	Alberta WaterSMART
	Sturgess	Kim	CEO	Alberta WaterSMART
	Sweetman	Jon	Manager, Water Resources	Alberta Innovates – Energy and Environment Solutions (AI-EES)
	Taylor	Lorne	Special Advisor	Alberta WaterSMART
	Tenney	Doug	Vice President, Hydro Development	ATCO Power
	Van Ham	John	Manager, Environmental Stewardship	ConocoPhillips Canada
	Veljkovic	Maja	Natural Resources Executive and Research Liaison	IBM
	Watanabe	Anthony	President & CEO	Innovolve
	Wojnarowski Downes	Lisa	North America Regional Coordinator	Alliance for Water Stewardship; The Nature Conservancy
Calgary Working Group	Bennett	Mark	Executive Director	Bow River Basin Council (BRBC)
	Bjornsen	Ryan	Hydrogeologist	Alberta WaterSMART
	Eden	Lauren	Researcher	Alberta WaterSMART
	Kelly	Mike	Chair; Special Advisor	Bow River Basin Council (BRBC); Alberta WaterSMART
	Minnich	Keith	Special Advisor	Alberta WaterSMART
	Phillips	Bob	Executive Director	South East Alberta Watershed Alliance
	Sheer	A. Michael S.	Environmental Policy Analyst	HydroLogics
	Sheer	Daniel P.	Founder and President	HydroLogics
	Sommerfeld	Larissa	Policy Specialist	Alberta WaterSMART
	Zehnder	Alexander	Scientific Director, Water Resources	Alberta Innovates – Energy and Environment Solutions (AI-EES)
Engineering Working Group	Chalcroft	David B.	P.Eng., FEC, FCAE, Past President; Consulting Engineer	APEGA
	Danyluk	Darrel	P.Eng., FCAE, Vice President; Chair; Past President	World Federation of Engineering Organizations (WFEO); WFEO Committee on Engineering and Environment; APEGA
	Flint	Mark	P.Eng., CEO	APEGA
	Hrudey	Steve E.	FRSC, FSRA, IWAF, PhD, DSc(Eng), PEng Professor Emeritus at the Analytical and Environmental Toxicology Division; Councillor	Faculty of Medicine and Dentistry, University of Alberta; APEGA

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	Sturgess	Kim	P.Eng., FCAE, Past President; Past Councillor	Canadian Academy of Engineering; APEGA
Additional Contributors	Brawn	Bob	Board Member	Alberta Water Foundation
	Campbell	Carolyn	Conservation Specialist	Alberta Wilderness Association; including comments from some Alberta Environment Network members
	Drury	Roger	Hydro Project Developer	TransAlta Generation Partnership
	Fennell	Jon	Principal Hydrogeologist and VP, Geosciences & Water Security	Integrated Sustainability Consultants Ltd.
	Francis	Wendy L.	Program Director	Yellowstone to Yukon Conservation Initiative
	Goheen	Kevin	Executive Director	The Canadian Academy of Engineering
	Gill	Vijay	Principal Research Associate, Transportation and Infrastructure	Conference Board of Canada
	Kern	Marshall	Associate	Bowman Centre for Technology Commercialization
	Lund	Charlie	Professional Engineer; Sunnyside Resident	Calgary, Alberta
	MacRae	Andy	Board Member; Executive Director	Alberta WaterSMART; Russell Reynolds Associates
	Meller	Brian	Hydrologist	Lethbridge, Alberta
	Raymond	Greta	Chair, Board Member	CAWST, Alberta Water Foundation
	Rood	Stewart	Professor and Board of Governors Research Chair in Environmental Science Dept. Biological Sciences	University of Lethbridge
	Sauchyn	Dave	Senior Research Scientist; Professor of Geography	Prairie Adaptation Research Collaborative (PARC); University of Regina
	Stelfox	Brad	Landscape Ecologist	ALCES Landscape and Land UseLtd.
	Thompson	Stella	Board Chair	Alberta WaterSMART
	Van Ham	Megan	Program Manager	Alberta WaterSMART
	Van Tighem	Kevin	Fourth-Generation Albertan, Professional Ecologist	Retired
	Walsh	Bryan	P.Eng. Senior Vice President	CBRE Limited

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Project Summary Table

Proponent Name:	Alberta Transportation	Date:	July 11, 2014
Project Name:	Springbank Off-stream Storage Project	Company Contact Name and Information:	Syed Abbas, Director Water Management Section Transportation 3rd fl Twin Atria Building 4999 - 98 Avenue Edmonton, AB T6B 2X3 Phone: 780 644-7022 Fax: 780 415-0475 E-mail: syed.abbas@gov.ab.ca
Name of Company that will hold Approval:	Alberta Transportation until project completion then transfer to Alberta Environment and Sustainable Resource Development for Operation	Company Website:	www.transportation.alberta.ca
Type of Project (e.g., in-situ, mine, quarry, upgrader, etc.):	Off-stream water storage (flood control) reservoir	New Project, Expansion, Additional Phase or Modification:	New
Projected Construction Start (Month/Year):	08/2016	Projected Operation Start (Month/Year):	10/2017
Life of Project (# years, YYYY - YYYY):	2017-indefinite Permanent installation	Project Location (Legal Land Description) and Municipality:	Project centered on Section 24-Township 24 –Range 4, West of the Fifth Meridian in Rocky View County
Total Project Area (ha):	Approximately 600 ha (full extent to be determined in final design)	Private, Federal, or Provincial Land:	Private (to be purchases by Crown)
Nearest Residence(s) (km):	One residence within flooded area.	Nearest First Nation Reserve(s) (name and km):	Tsuu T'ina Nation 145 (3 kilometres from diversion structure)
Types of Activity (major project processes, components including capacity/size, if availalble):	Capture and storage of flood water for later release (maximum 57,000 dam^3).	Power Source (If on site power generation describe quantity (MW) and facilities):	Minor requirements for controls from local grid.

Project Products:	N/A	Average Production Capacity per Year (specify units):	N/A
Method of Product Transport (e.g., pipeline, rail, truck):	N/A	Location of End Market:	N/A
Infrastructure Requirements (roads, pipelines, water intake, storage, tankage):	Diversion works(embankment and gates), canal, dam	Project By-Products:	N/A
Expected Types of Air Emissions (e.g., SO_2, NO_x, CO_2):	Minor dust during construction (approximately 18 months). None during operation	Expected Types of Effluent Releases (note the water bodies the effluent will be released to):	None
Types of Wastes Generated:	Minor construction waste during construction. None during operation. May be some accumulation of sediment and debris following flood.	Waste Management Facilities (i.e., Disposal Well, Salt Caverns, Landfill, or Third-Party):	None construction waste to be removed from site and disposed of at appropriate disposal facility.
Nearest Waterway/Waterbody (name and km):	An unnamed creek runs through the proposed reservoir. The creek empties into the Elbow River approximately 3 km downstream of the proposed dam.	Watercourse Crossings (type of crossing, any Class A to C waterbodies):	N/A
EPEA Approval Required (Y/N/Unknown):	Y	Regulatory Board(s) (ERCB/NRCB/AUC):	NRCB
Water Act Licence Required (Y/N/Unknown. If yes: purpose, source and estimated volumes):	Y	*Water Act* Approval Required (Y/N/Unknown. If yes, purpose):	Y, flood control structures on bed and shore of natural water body
Will any of the components or activities associated with the project affect fish and/or fish habitat?	Y	*Are any works or undertakings proposed to take place in, on, over, under, through or across a navigable water?*	There are no waterways on the Navigation Projection Act List of Scheduled Waters affected by the project. Alberta Transportation recognizes use of the Elbow River for recreational boating.

Identify applicable sections in the Schedule to the Federal *Comprehensive Study List Regulations*: (Y/N/Unknown):	No	Identify applicable federal legislative or regulatory requirements referred to in the *Law List Regulations* (i.e., permits, licenses, authorizations):	Possible authorization under the Fisheries Act
Waterbodies Required (Y/N/Unknown/NA. If yes, # and ha):	Y., 500 ha at 100 year flood elevation.	Nearest Water Well (km) (Domestic and Commercial):	Water well in farmstead within pool area.
Nearest Provincial Highway (# and distance):	Hwy 22 within project area.	Access Improvements to Provincial Highway:	Possible construction access.
Traffic Impact Assessment Required (Yes/No/Unknown):	No	Total Area to be Disturbed (ha):	Not yet determined
Identify Existing Land and Water Use(s), Resource Management, or Conservation Plans within or near the project site:	Residential, agriculture, recreation land uses.	Post-reclamation Land Use(s):	The installation is permanent so only construction disturbance is to be reclaimed. Lands will be reclaimed to agricultural and recreation use as appropriate.
Decommissioning Start and End (YYYY-YYYY)	N/A	Reclamation Start and End (YYYY - YYYY):	2016-2017 (construction disturbances only)
Unique Environmental or Social Considerations (Describe or None):	None	Historic Resources Impact Assessment Required (Y/N/Unknown):	Y
Estimated Construction Person-Years of Employment:	50 people for 18 months	Estimated Operation Persons-Years of Employment:	1 person, continuous
Construction or Operation Camp Required (Y/N/Unknown. If yes, on-site or off-site):	N	Method of Transport of Employees to Site (Construction and Operation):	Individual vehicle or bus during construction. Individual vehicle during operation.
Date Stakeholder Engagement Started (Public/Aboriginal):	Sept 9, 2014.	Aboriginal Groups Involved in Stakeholder Engagement:	Treaty 7
Public Groups involved in Stakeholder Engagement:	Yet to be identified		

Bow Basin Flood Mitigation and Watershed Management Project

March 31, 2014

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Innovates
Energy and
Environment Solutions

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Further, the list of individuals and the organization they represented, which appears in Appendix A, reflects those who participated in some or all of the working group meetings for this project. Their inclusion on this list does not suggest advocacy for any particular strategy discussed, but rather provides a sense to the reader of the range of perspectives involved in the working group discussions.

Contents

Abbreviations, Acronyms, and Definitions

(A)ESRD	(Alberta) Environment and Sustainable Resource Development
BRBC	Bow River Basin Council
BRID	Bow River Irrigation District
BROM	Bow River Operational Model
CBRH	Carseland-Bow River Headworks
cdm	cubic decametre (1 cdm = 1,000 cubic metres)
cms	cubic metres per second
DUC	Ducks Unlimited Canada
EID	Eastern Irrigation District
GIS	Geographic Information System(s)
GoA	Government of Alberta
NHN	National Hydrography Network
SSRB	South Saskatchewan River Basin. The South Saskatchewan River Basin includes the sub-basins of the Bow River, Red Deer River, and South Saskatchewan River (including the Oldman and other tributaries)
SSRP	South Saskatchewan Regional Plan
SWCRR	South West Calgary Ring Road
WRMM	Water Resources Management Model
Flood fringe*	The portion of the flood hazard area outside the floodway. Water in the flood fringe is generally shallower and flows more slowly than in the floodway. New development in the flood fringe may be permitted in some communities and should be flood-proofed.
Flood plain	The active river valley that can be occupied by streamflow. Typically relatively flat areas of varying width constructed by alluvial processes and over bank deposition from previous flood events. Hydrologically, a flood occurs when streamflow exceeds channel capacity, and water enters the flood plain.
Floodway*	The portion of the flood hazard area where flows are deepest, fastest and most destructive. The floodway typically includes the main channel of a stream and a portion of the adjacent overbank area. The floodway is required to convey the design flood. New development is discouraged in the floodway and may not be permitted in some communities.

* Definitions from Government of Alberta.

1 Executive Summary

Severe flood and drought conditions have occurred in Alberta throughout living memory, history and prehistory. Although droughts have been more common, floods are not rare. The events in June 2013 caused loss of life and devastated homes, businesses, property, infrastructure, and landscapes. Following emergency responses by various authorities and volunteer agencies, the Government of Alberta established the Flood Recovery Task Force to explore and recommend options for responding to future such events. This project was designed to identify, examine and assess the intended and unintended consequences and trade-offs of potential flood mitigation options for the Bow River Basin from a "headwaters to confluence" river system perspective, and to make flood mitigation and resiliency recommendations to the Task Force.

The enormous scale, scope, and impact of the 2013 flood were such that many of the mitigation alternatives proposed so far are similarly large and impactful. Most of the options presented in this report have significant costs and carry environmental, social, or economic consequences. No one option is able to meet all needs. The choice of levels of protection in each affected area is a matter of social policy to be decided by elected officials. Once targets are set, the necessary suite of flood mitigation options can be identified and implemented to achieve the target, given the broad range of potential future flood events. Chapter 8 of this report describes three hypothetical target flow rates set by the participants as potential starting points for mitigation. The targets were applied to specific locations on four river systems, the Highwood, Sheep and Elbow tributaries, and the Bow main stem. These targets were set as starting points and may need to be revised as the costs and impacts of mitigation are better understood.

Choices among where to invest in mitigation options, where to redirect flood flows, where to reinforce banks, where to put in new infrastructure, and where to accept impacts on homes, businesses, fisheries, ecosystems, park lands, roads, bridges, and other factors are complex, difficult, and highly charged with uncertainties of many kinds. Nonetheless choices will be made among many diverse trade-offs, as repeating an estimated $6-billion in damages is presently deemed unacceptable.

A wide variety of experienced water managers, experts, and decision makers from across the Basin actively participated in this collaborative project, freely sharing their knowledge, expertise and perspectives. The purpose was to identify and examine as many alternative flood mitigation concepts as reasonably possible, to raise the many negative and positive factors to be considered for each, to model and compare the effectiveness of each option and combinations of options, and to report our findings and conclusions to the Provincial Flood Recovery Task Force.

This project clearly showed that a systemic, watershed-based approach is essential. Mitigation options implemented in one part of the complex and interrelated Bow River and tributary system can have major, even catastrophic, consequences in other parts of the system. Mitigation activities in the upstream reaches will have a cumulative effect on downstream communities and infrastructure. Diverting flow away from one community may transfer an unacceptable risk to another. All mitigation options will affect the watershed; they must function to build the natural resiliency of the watershed and allow for sound water management under flood, drought, and normal conditions. These interconnections have been known for decades and modelled for years by many of the participants in this project.

It is understandable and natural for flood impacts to be mitigated locally or regionally, but management of a basin-wide system is the responsibility of the Province. A prudent approach requires comparative assessments of every option, and an evaluation of the effects of options in combination prior to committing significant resources to something that could prove counterproductive and perhaps more damaging than doing nothing in some cases. This project is intended to inform a small part of the larger systemic approach as described in the Government of Alberta's publication, *Respecting Our Rivers: Alberta's Approach to Flood Mitigation*.

Specific mitigation options examined in this project were compiled from various sources, and many were modelled individually and in combination for the Bow, Elbow, Highwood, and Sheep river systems. A number of the flood mitigation concepts showed promise on their own while others were generally not supported. The group's identification and assessment of these mitigation targets and the infrastructure and other mechanisms to reach them in no way implies endorsement of these options. The objective was to provide the factual data needed for decision makers to be fully informed of what is possible, not necessarily what is advisable.

Participants identified mitigation options that could be combined to achieve a range of mitigation targets. Recognizing the quickly approaching flood season, two combinations were developed to identify achievable mitigation options for spring 2014 and 2015.

The most promising near-term options for flood mitigation throughout the Bow River Basin that were identified through this project are:

1. Operate TransAlta facilities for flood control when needed. This should be implemented immediately for relatively low cost and maintained over the long term to achieve overall water management improvements as described in the Bow River Project results.
2. Construct a channel for the Highwood River through the Town of High River capable of handling 1300 cms or more. If needed, construct a channel north around High River to mitigate flood impacts on the town without increasing flood flows down the Little Bow system south of the town.
3. Operate Glenmore Reservoir in the same manner as in 2013. It was acknowledged that Glenmore Reservoir was operated optimally for flood peak attenuation during the 2013 flood event.
4. Apply existing wetland, riparian, and land management policies and plans to stop further loss and achieve a level of wetland and riparian restoration throughout the headwaters, foothills, and prairie reaches of the Bow System. This includes implementing the new Wetland Policy, making all wetland impacts subject to the mitigation process, implementing watershed and land management plans, and enforcing existing legislation.
5. Reinforce existing downstream infrastructure as soon as possible with spillways conforming to full safety standards, given potentially higher future flows; in particular, Bassano Dam and Travers Dam.
6. Improve resourcing for forecasting systems and better integration of communications to the first responders and the public if and as severe flood risk potential increases and becomes imminent.

Options to achieve medium and longer term flood flow targets

A system-wide approach to watershed management with a focus on flood mitigation options will remain an ongoing challenge for the next several years. To determine what the options might be, hypothetical flood flow targets were set by the participants using estimates from many official and unofficial sources. Alternatives to meet each of the targets were tested in the model. Both infrastructure and natural functions were included in the dozens of model runs conducted by the participants during interactive modelling sessions. The table below shows the hourly peak flow mitigation targets and locations. These targets were set in categories with increasingly rigorous objectives. The targets are for medium- or long-term mitigation purposes, can be mixed and matched as needed across categories, and assume the short-term actions will be taken immediately.

Many of these targets are already being revised upward by local actions such as the channelling of the Highwood River through High River, buyouts of homes in the floodway in High River and Calgary, protective actions for the water treatment plant in Okotoks, planned berming in Medicine Hat, and many other local and regional flood damage-reduction activities.

Bow Basin mitigation targets

Location	Hourly Mitigation Target 1 (cms)	Hourly Mitigation Target 2 (cms)	Hourly Mitigation Target 3 (cms)	1:100 Event (cms)
Bow River upstream of the confluence with the Elbow	~1050	~825	~540	1970
Elbow River downstream of Glenmore Reservoir	~450	~300	~180	758
Highwood River at High River	~1500	~1300	~1100	750
Sheep River at Okotoks	~850	~750	~650	954

Recognizing that the entire system has to be taken into account in any substantial mitigation infrastructure, Tables 7 and 9 in the text provide some preliminary downstream flow rates where major infrastructure may be in jeopardy.

By applying many of the mitigation options presented in Tables 3, 4, and 5, almost all of the targets in the table above could be achieved. However, there were clearly diminishing returns as one progresses to increasingly aggressive hourly mitigation targets. For example, on the Bow and Elbow rivers, achieving Target 1 reduced the flooded area in Calgary by 11 km^2, from approximately 40 kms^2 to 29 km^2. This area includes the stream channel, so the area of flood reduction consists almost entirely of areas that are outside the river banks. Target 2 reduced the approximate area flooded by an additional 3 km^2 and Target 3 by a further 1 km^2. See the GIS representations in Figures 62, 65, and 68.

Achieving the more aggressive mitigation target scenarios would require a considerable array of expensive and environmentally impactful new infrastructure. For many participants this raised the issue of too much control. Flood flows up to the point of serious safety threats or severe negative economic consequences are necessary as are healthy functioning river ecosystems. Further discussion centred on how much ordinary citizens are willing to pay in terms of pure financial costs as well as environmental and recreational costs to protect a relatively small number of homes, businesses, and infrastructure. The all-in costs including environmental and social issues versus the benefits of flood protection against relatively low probability flooding would have to be carefully considered by decision makers before proceeding down the path to some of the more aggressive mitigation targets.

In some cases, such as the Highwood River at High River, little in addition to the channelization infrastructure that is underway and planned may be needed at this location, recognizing upstream communities may still face flood mitigation challenges. The Elbow River presents the greatest challenge with a net reduction from inflow to Glenmore Reservoir of approximately 1200 cms to meet the most stringent target of 180 cms in the modelled 2013 event. In this event, Glenmore was able to reduce the peak flow downstream to 700 cms but had the peak runoff continued for several more hours it would have had to release the full inflow. This is where social policy decisions are likely to be the most difficult.

Next steps in flood mitigation decision making, including implementation of the short term options described above, should include:

1. Social policy decisions on what flow rate and elevation level we want to target mitigation to in each basin.
2. Comparative cost-benefit analyses of what it would take to achieve the desired mitigation targets, including consideration of these measures in terms of their ecological, social, recreational, downstream, and upstream impacts.
3. Analysis of the level and location of risk associated with these mitigation measures including upstream and downstream consequences, transfer of risk, and the cost of mitigating the negative impacts of the mitigation.
4. Setting aside some percentage of the costs of the infrastructure being engineered and built, proposed to be approximately 5-10% of the total, which would be used exclusively to retain and improve healthy functioning ecosystems and to establish and operate a collaborative governance function to administer and support watershed management.
5. Broad and full communication of the flood mitigation information, analyses and decisions to all communities and residents in the Bow River Basin.

A flexible, adaptive, and resilient approach to flood mitigation is needed since the next flood will no doubt have different characteristics than previous flood events. Planning to fight and win the last battle is rarely a successful strategy particularly with infinitely variable climate and weather patterns. Protecting against such a severe and massive flood will require some potentially severe and massive trade-offs among a variety of mitigation options, none of which are pleasant to contemplate nor beneficial to everyone. This report has laid out some of the options available to us, on the assumption that we as a society must not allow a recurrence of the human and economic damages suffered in the flood of 2013.

2 Introduction

Albertans value and respect the role that water plays in their day-to-day lives. Access to water is fundamental to human settlements and is the basis for economic activity and quality of life throughout Alberta. In the South Saskatchewan River Basin (SSRB), severe flood and drought conditions have occurred throughout living memory, history, and prehistory. Although droughts have been more common, floods are not rare. With the 1995 and 2005 flood events still in recent memory, the June 2013 floods were devastating, affecting families, homes, businesses, property, infrastructure, and landscapes.

Following emergency responses by various authorities and volunteer agencies, the Government of Alberta (GoA) established the Flood Recovery Task Force[1] to explore and recommend options for responding to future such events. The Task Force's scope includes all flood-prone basins in the province, but much of the initial attention has been on the Bow River system. Figure 1 shows the area covered by the Bow River Basin.[2]

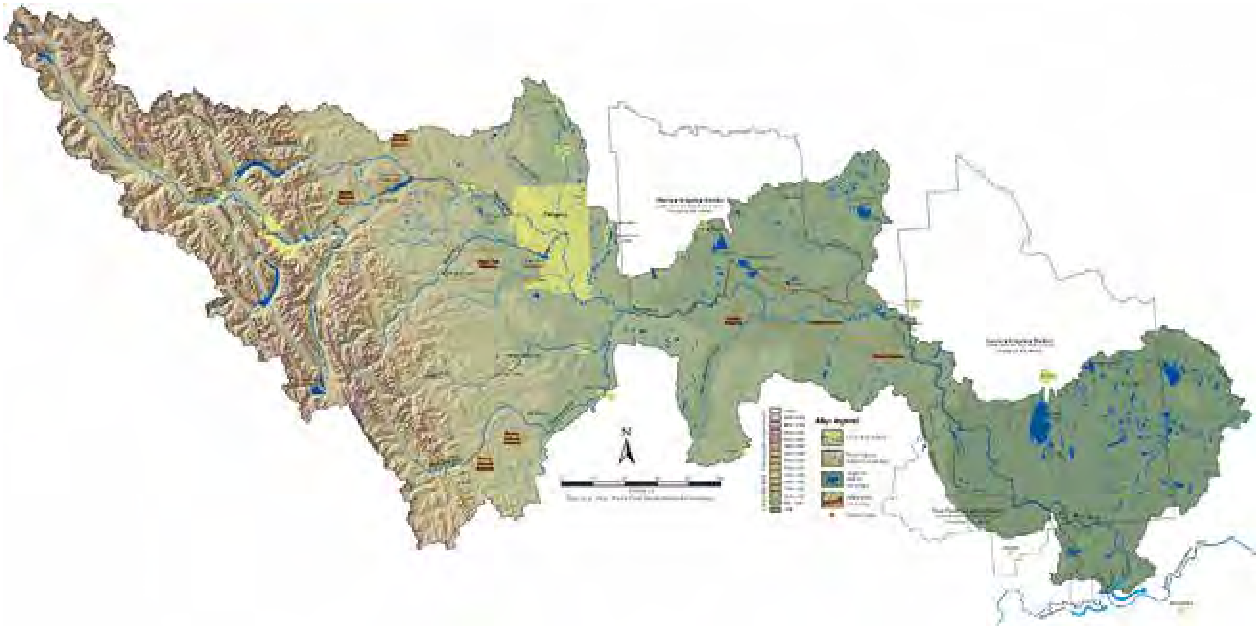

Figure 1: The Bow River Basin

The Bow River Basin is a highly responsive hydrological system with a disproportionate amount of mountain catchment characterized by steep slopes, high terrain, and late snowmelt. Precipitation is concentrated in May, June, and July and shifts quickly between catchment areas with limited warning. The historic record shows the basin to be prone to large flood events as well as periods of drought and periods of relatively "normal" conditions, as illustrated for the Bow River (Figure 2) and for the Elbow River below Glenmore Reservoir (Figure 3).

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[1] See http://www.alberta.ca/Flood-Recovery.cfm

[2] The map in Figure 1 is provided courtesy of the Bow River Basin Council (www.brbc.ab.ca).

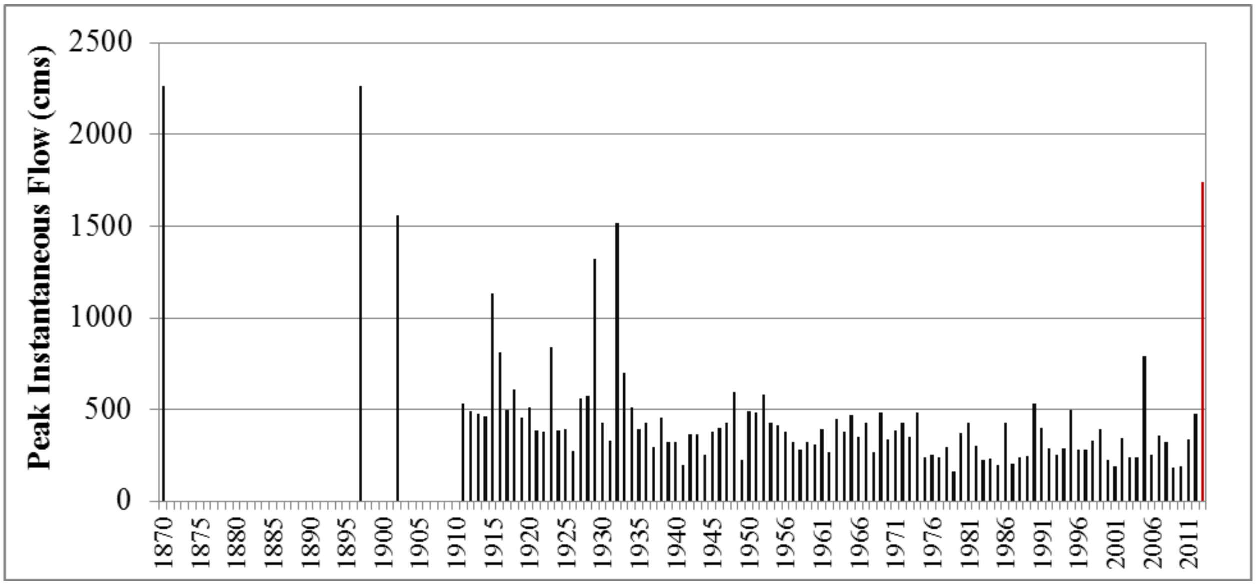

Figure 2: Peak instantaneous flow for the Bow River (1870 to 2013). The red bar indicates preliminary estimates of peak instantaneous flow in 2013.

Data sources: Water Survey Canada Archived Hydrometric Data and the City of Calgary

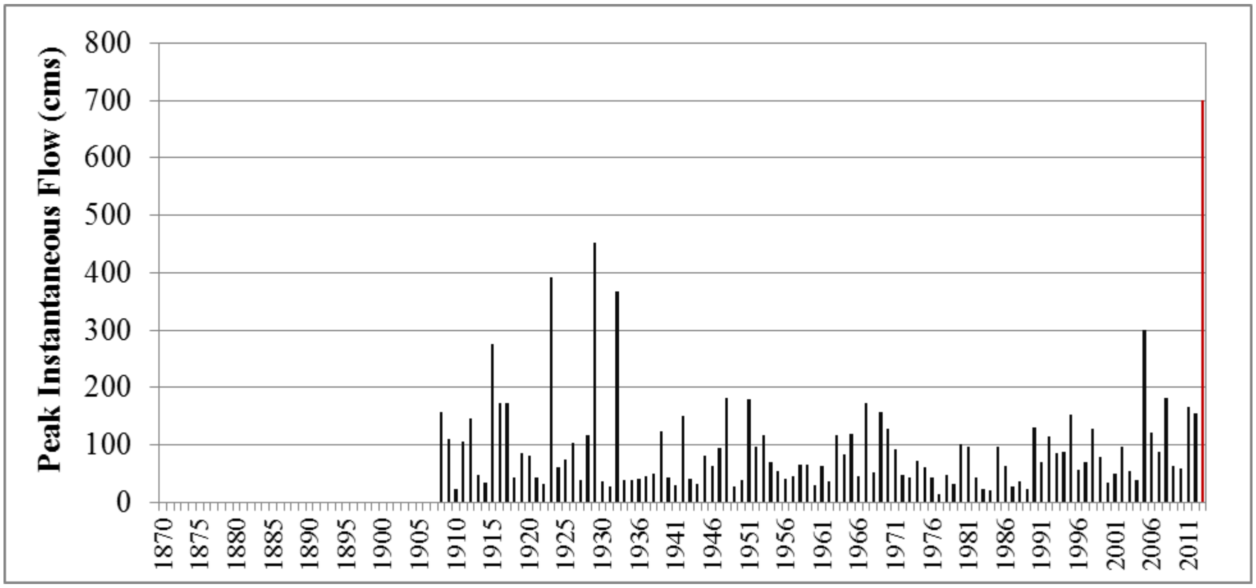

Figure 3: Peak instantaneous flow for the Elbow River below Glenmore Reservoir (1870 to 2013). The red bar indicates preliminary estimates of peak instantaneous flow in 2013.

Data sources: Water Survey Canada Archived Hydrometric Data and the City of Calgary

Both droughts and floods test water management infrastructure and operations as well as human ingenuity and creativity. Existing approaches are proving inadequate to mitigate the risks and damages from these socially and economically stressful events. With the magnitude and impact of the 2013 floods, recent focus has naturally been on flood mitigation. But given Alberta's long experience with drought and the reality of increasing climate variability and change, it is vital that we manage the province's water resources and watersheds with flexibility and adaptability to ensure resilience and sound watershed management, no matter what future conditions might be. Comprehensive water management frameworks are already in place in the Bow Basin or are being developed; examples of these are the 2006 *Water Management Plan for the South Saskatchewan River Basin (Alberta)*[3] and the 2008 *Water Management Plan for the Watersheds of the Upper Highwood and Upper Little Bow Rivers* (including the Sheep River).[4]

This project was designed to recognize and capitalize on the extensive body of work done to date on river management in the SSRB to identify, explore, and assess potential flood mitigation options in the Bow Basin. It applied proven methods, analytical tools, data, and information that support the development of adaptation strategies and opportunities in response to climatic and hydrologic conditions throughout southern Alberta. The experience, knowledge, and expertise of a wide range of stakeholders from throughout the Basin were essential to the success and credibility of the work.

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[3] Available online at http://www.environment.alberta.ca/documents/SSRB_Plan_Phase2.pdf

[4] Available online at http://environment.gov.ab.ca/info/library/7977.pdf.

3 Project Objectives and Scope

This project was undertaken to:

- Enhance understanding of the immediate causes and consequences of the 2013 flooding in the Bow River system, including the Elbow, Sheep, and Highwood tributaries, by filling gaps related to data, interpretation, quantification, and application of flood flow levels. When the origins, locations, and rates of flood flow are understood, it becomes possible to determine more effective means to mitigate and reduce damages from future floods.
- Develop a consistent mechanism to evaluate the effectiveness of alternative flood mitigation strategies, relocation, infrastructure, and other ideas to reduce flood damage. The approach taken with this project was to combine data assembly, reviews, testing, and application of the Bow River Operational Model (BROM) with a flood inundation visualization tool to assess the relative effects of mitigation techniques, both individually and in combination.
- Facilitate the collaborative identification and development of practical and resilient adaptation strategies by individuals and organizations with extensive experience and knowledge related to the Bow River system.
- Enable the collaborative testing of new and adaptive operating strategies, infrastructure, and natural systems using the comprehensive and interactive mass balance streamflow model (BROM) of the entire Bow River Basin.
- Identify the intended and unintended consequences of potential flood mitigation options, including trade-offs, from a “headwaters to confluence” watershed perspective.
- Put forward flood mitigation and resiliency recommendations to the Government of Alberta’s Flood Recovery Task Force.

The project focused on the Bow River Basin including the Bow, Elbow, Highwood, and Sheep rivers. While the flood mitigation options were specific to this Basin, they aligned with the objectives and frameworks established by the province-wide Flood Recovery Task Force. The project did not examine the economic and social impacts of flood flows, nor did it undertake detailed engineering or feasibility analysis, but it does offer informed opinion on advisability. Participants noted the potential value of local mitigation options but the overall project looked more broadly at flood mitigation options from a basin-wide perspective.

As participants moved through this work, they identified uncertainties and unknowns that should be recognized:

- The role and significance of groundwater in flooding remains uncertain. Groundwater and green water[5] are both forms of natural storage and contribute greatly to streamflow. The complexity of these issues needs to be communicated to and understood by decision makers.

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[5] Green water is the precipitation on land that does not run off or recharge the groundwater but is stored in the soil or temporarily stays on top of the soil or vegetation. Eventually, this part of precipitation evaporates or transpires through plants. Green water can be made productive for crop growth (although not all green water can be taken up by crops, because there will always be evaporation from the soil and because not all periods of the year or areas are suitable for crop growth). Source: Hoekstra, A.Y., Chapagain, A.K., Aldaya, M.M. and Mekonnen, M.M. (2011) *The water footprint assessment manual: Setting the global standard*, Earthscan, London, UK.

- Flood flow levels are still in a draft stage and are being debated. What level are we mitigating to? This is a social policy question that needs to be addressed.
- River hydraulics in many areas of the Bow Basin continue to be poorly understood, for example, around High River where tributaries, ground water and bank interactions add to the complexity of the river dynamic.
- Models are useful tools, but they do have limits. They cannot reflect all aspects of water movement through systems and across the landscape in real time, nor can they capture the temporary barriers and emergency response measures put in place during a particular event. It is very difficult for large-scale watershed models like the BROM to capture changes in local barriers and fortifications that affect streamflow. The model cannot take into account any channel morphology or bathymetry effects occurring as a result of the 2013 flood, which occurred after the modelling data set was collected.
- The BROM is a large-scale screening level model that does not explicitly account for streamflow routing and changes in the speed of flow. Participants raised a number of important issues to be addressed, many of which are not part of this modelling process, but rather are for consideration by decision makers who must take into account the screening of more detailed local-scale hydraulic modelling, engineering, economic, and environmental factors, risk assessments, and systemic issues.
- Return frequencies (e.g., 1 in 100) are a statistical estimate. More relevant to humans is actual water levels, and Winnipeg provides an example. All programming and mitigation structures in Winnipeg are established by water level, not flow rate return period. Primary datum is the James Avenue Pumping Station. Datum 0 is the normal winter ice level. That becomes the reference point for everything in the city, including mitigation. In Winnipeg the Primary Dikes are built to a standard of 26.5 feet above datum (river gradients are taken into account).

4 Methodology

4.1 A Collaborative Approach

The collaborative nature of this project was designed to identify and use the most accurate and comprehensive data and facts and, thereby, build understanding, confidence, and trust among participants. It provided an opportunity for government agencies at the provincial, regional, and local levels to work closely with most of the major stakeholders in the Bow River Basin in a neutral setting. The starting point was a common set of objectives and agreed-upon data that could be applied and tested using transparent and proven modelling tools. Among others, one outcome was an integrated suite of analytical tools, specific to the Bow Basin, that are open, accessible, and usable by anyone.

A wide variety of experienced water managers, experts, and decision makers from across the Basin actively participated in the project, freely sharing their knowledge, expertise, and perspectives. The work was co-funded by Alberta Innovates – Energy and Environment Solutions and by the Government of Alberta Flood Recovery Task Force. Tremendous in-kind support was provided by project participants. Representatives of the Task Force attended project meetings and indicated a strong interest in receiving the results. The Bow River Basin Council (BRBC) partnered with the project by opening up four forums to obtain broader input on potential flood mitigation options and by ensuring the outcomes align with watershed management plans.

Participants gathered for three full-day meetings in November 2013, and in January and February 2014, spending time at two of these meetings in live modelling sessions to examine potential flood mitigation options and combinations of options.

4.2 Project Tools and Technologies

The project applied proven methods, analytical tools, data, and information to support the assessment of flood mitigation options. Specific components included OASIS modelling technology, XA Solver technology, and Geographic Information System (GIS). The OASIS and XA Solver patents are held by HydroLogics Inc. and Sunset Software, respectively. These technologies were made available via HydroLogics Inc. Upon completion of this initiative, the tools and access to them and the supporting data and knowledge will continue to be publicly accessible without additional licensing. Tools and data were combined and applied collaboratively by project participants to identify, quantify, and test specific practical solutions to mitigate future flood risk and damage. Project tools and technologies were designed to look at many possible flood scenarios, not just those observed in 2013.

4.2.1 The Bow River Operational Model (BROM)

An interactive mass balance water model – the BROM – was developed and refined through the 2010 Bow River Project and the 2013 SSRB Adaptation to Climate Variability Project,[6] and has been tested for accuracy and credibility by senior water managers from governments, irrigation districts, and other water interests over the past several years. The BROM has been used in

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[6] Reports from these projects are available by searching on the Alberta WaterPortal at http://www.albertawater.com/.

previous projects to a) evaluate and recommend changes to existing infrastructure and operations on the Bow River system to improve environmental, social, and economic conditions under current climate patterns, and b) assess strategies to manage and mitigate conditions that may arise due to future climate variability and change. Data used in the BROM were obtained from Alberta Environment and Sustainable Resource Development's (ESRD) Water Resources Management Model (WRMM), Alberta Agriculture and Rural Development, the Irrigation Demand Model, Water Survey Canada, TransAlta, and various municipalities in the Bow Basin, including the City of Calgary.

The BROM can address multiple objectives and evaluate many performance measures besides flood flows, including water shortages, power, and environmental indices. It is a daily time step model for the available historic flow record (1928-2009), and was converted to an hourly time step model for this project for the 2005 and 2013 floods.

This modification allowed flood peaks to be captured as well as hourly operations that were or could be implemented during flood situations. Hourly streamflow data were not available for all naturalized flow locations represented in BROM; therefore, peak flows were iteratively calibrated to known upstream and downstream locations for the 2005 and 2013 flood events. The calibration involved scaling existing daily inflows by observed hourly flows at nearby stations in 2005. Synthetic hydrographs were derived for 2013 at locations without observations. The synthetic hydrographs were based on hourly preliminary Water Survey Canada data from nearby stations, then scaled appropriately based on preliminary peak flow estimates.

Hourly streamflow simulations compared well with observations in 2005 and preliminary observations in 2013 at the Water Survey Canada station 05BH004 (Figure 4). While the flow levels and rates in specific locations may not match the actual event precisely, the simulated flows were considered to be a good representation of the events and useful for understanding the direction and magnitude of flood mitigation options. Participants worked with the model to test and validate various flow levels for mitigation purposes during live modelling sessions.

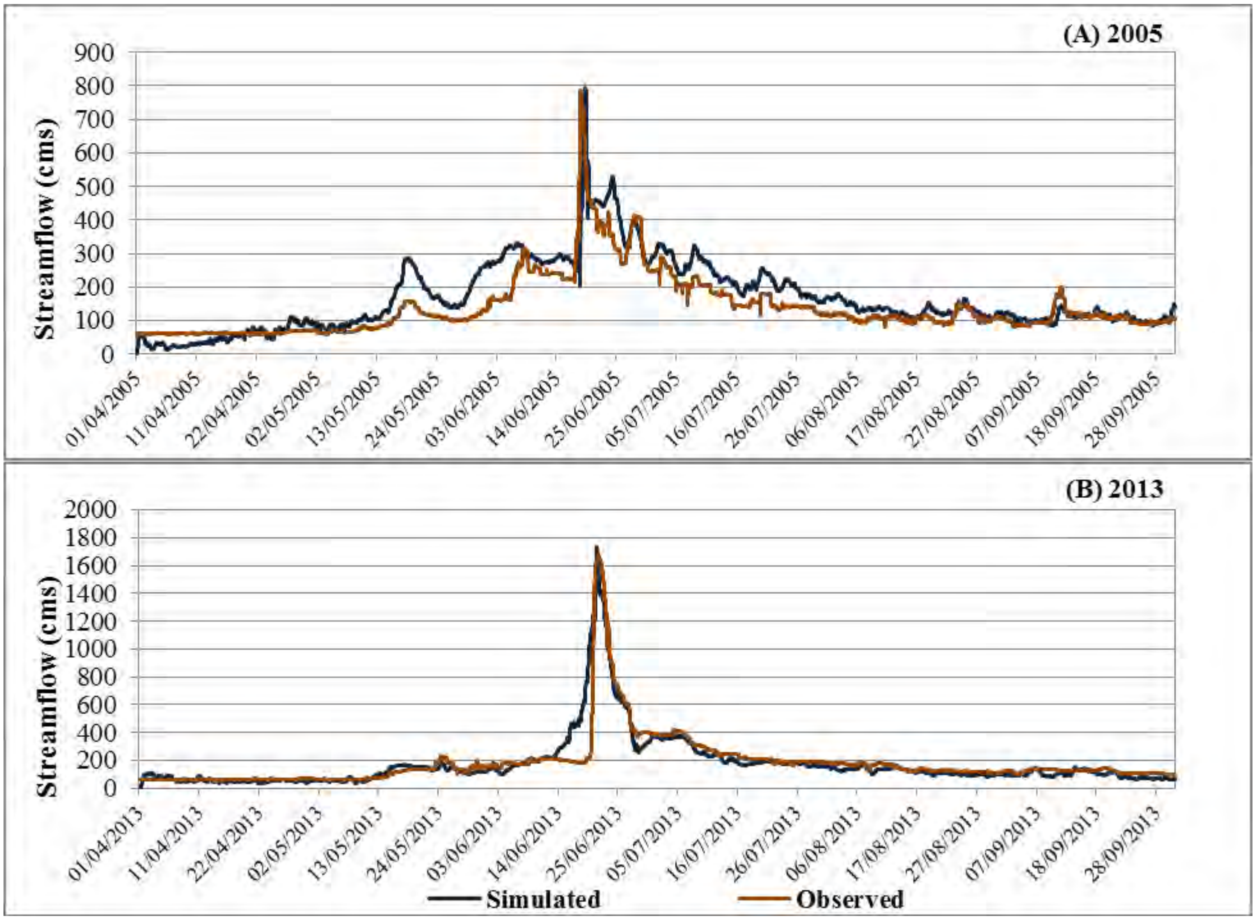

Figure 4: Comparison of observed and simulated hourly streamflow in the Bow River upstream of the confluence with the Elbow River in (A) 2005 and (B) 2013

The BROM is a mass-balance hydrology model and not a hydrodynamic model, flood inundation model, or precipitation runoff model. As such, it cannot be used directly to model flood flows resulting from changes to upland land cover, flood plain connectivity, channelization, or precipitation patterns. However, these effects can be modelled in BROM if estimates of their impact on storage and travel time are known.

Figure 5 illustrates the breadth and complexity of the area modelled in the BROM for this project.

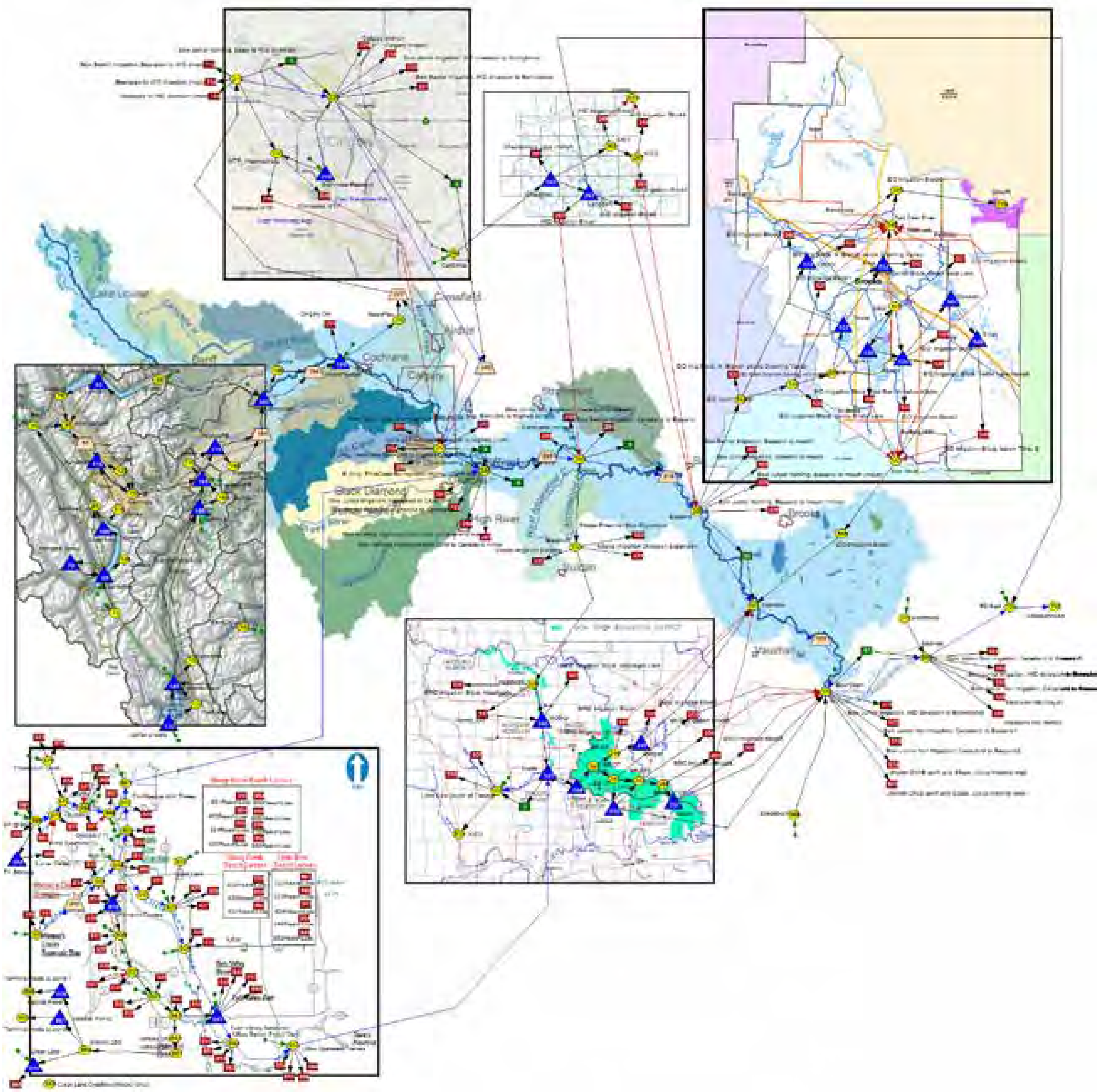

Figure 5: Schematic showing the area modelled in the BROM

4.2.2 Flood Visualization Engine

A new flood visualization engine covering the City of Calgary was developed by GranDuke Geomatics Ltd. for this project to make the flood flow performance measures meaningful and understandable.The goals were to:

- See where flood flows would spill over river banks
- Estimate how much spillover would occur
- Approximate where water would go
- See how the flooding relates to existing floodway mapping
- Assess relative differences in flooding as a result of mitigation options.

Flood extent estimates were based on the 2005 and 2013 flood events that were simulated using BROM.

The visualization tool is very data intensive and uses data from both ESRD and the City of Calgary. Two key data sets were required for this modelling and were provided by the City of Calgary:

- transects with associated rating curves exported from a hydraulic model (HEC-RAS), and
- raster digital surface models showing "bare earth" elevations.

Six hundred and fifty transects along the Bow and Elbow rivers were acquired as ESRI Shapefiles. Rating curve (stage vs. discharge) data generated using HEC-RAS were provided for each transect. The data were delivered as a MS Excel™ file that included a linear interpolator to compute water surface elevation for each transect at a given discharge.

Two additional datasets were also acquired to facilitate the modelling process:

- side-channel flow proportions as a function of streamflow, and
- stream main channel and island hydrography GIS data.

Golder Associates Ltd. (2012)[7] provided key information regarding streamflow partitioning between main and secondary channels. GIS features representing the Bow and Elbow rivers were acquired from the National Hydrography Network (NHN) via GEOBASE (www.geobase.ca).

Flood inundation maps were developed by interpolating water surface elevations between the 650 cross sections. The difference between the water surface elevation and "bare earth" elevations was generated through overlay analysis in a GIS. Areas of inundation were deemed valid if a) the inundated area was spatially connected to the river mainstem, or b) the inundated area was within 250 metres of the spatially connected flood extent. The extents of flood inundation were then compared and verified using previously published flood maps and airborne imagery acquired during the June 2013 flood.

The 1:100 flood values from the City of Calgary that were used in the flood visualization tool are based on the following reference: Golder Associates Ltd. 2010. *Hydrology Study, Bow and Elbow River Updated Hydraulic Model Project, Revision A.* Prepared for Alberta Environment. Report No. 09-1326-1040.

Following the verification of preliminary results, several model improvements were identified and implemented. The modifications were implemented to address a) depth of water discrepancies between the Bow and Elbow rivers that were forecast following mitigation strategies, and b) extreme events where flooding was observed well beyond transect extents near a sharp meander along the Elbow River. Following the model modifications, three comparison datasets were used to assess model accuracy:

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[7] Golder Associates Ltd. 2012. *Hydraulic Modelling and Inundation Mapping, Bow and Elbow River Updated Hydraulic Model Project.* Report Number 09-1326-1026.7000. Prepared for The City of Calgary and Alberta Environment and Water.

1. Simulated results for the 1:100 year event were compared to the Flood Hazard Mapping datasets published by GoA.
2. Simulated results for the 1:100 year event were compared to the flood mapping conducted by the City of Calgary.
3. Aerial imagery flown shortly after the 2013 flood were accessed through a GIS image service hosted by the GoA, and airborne imagery was provided by the City of Calgary. These datasets were used to check for obvious discrepancies.

The flood visualization tool was delivered as a web application powered by GranDuke servers and accessible through any browser that supports the Google Earth plug-in. Google Earth provides free access to relatively up-to-date imagery as well as three-dimensional buildings, neighbourhood labels, and labelled roads. Figure 6 shows an example of a flood inundation extent. The visualization engine also includes a graphing component that enables users to compare inundation extents.

The flood visualization graphic component includes the river channels in its statistics, so a calculation of total area flooded will include not only the over-bank flooding, but also the normal river channels. Thus when mitigation options are modelled and the area flooded is shown to be reduced, nearly all of that calculated reduction will consist of locations not normally under water. For example, the base case shows about 40 km^2 in total was covered by water, but this includes the stream channels. If a mitigation strategy reduces the flooded area by 10 km^2, the stream channels are still covered in water, so virtually all of the reduction in flooded area comprises normally dry land.

Figure 6: An example of the flood visualization engine. The pale blue polygon is an example of a flood inundation extent shown in the tool.

4.3 Assessing Potential Flood Mitigation Options: What Are We Mitigating To?

As potential flood mitigation options were identified and the data required were made available, each option was modelled using the BROM and presented to participants at the working sessions. Participants examined and refined these options and their potential mitigation impacts, and had opportunities to suggest new approaches or combinations. These general approaches, the more specific mitigation options, and the results of the modelled runs are described in the following sections.

The performance measures used for assessing flood mitigation results are flow values compared against the 2005 and 2013 hourly base case runs at four locations. Flow comparisons are made at: 1) the Bow River upstream of the Elbow Confluence; 2) the Elbow River downstream of the Glenmore Reservoir; 3) the Sheep River at the Town of Okotoks; and 4) the Highwood River at the Town of High River.

Table 1 presents the suite of mitigation targets discussed and used in this project for key locations in the Bow Basin. Numbers in the column labelled “initial mitigation targets” were identified initially and, as participants worked with them and as municipalities and others gathered more information, the targets were revised to be more realistic and achievable (the column labelled “revised mitigation targets”).

Table 1: Potential Bow Basin mitigation targets

Location	Initial Mitigation Target (cms)	Revised Mitigation Target (cms)
Bow River upstream of the confluence with Elbow	~825	~1050
Elbow River downstream of Glenmore Reservoir	~180	~450
Highwood River at High River	~180	~1500
Sheep at Okotoks	~750	~750

Mitigation targets were developed from discussions with municipal officials, water managers, project participants, and from results of the flood flow visualizations. Mitigation targets are required for decision making on mitigation infrastructure, pre-flood planning, estimations of cost for mitigation options, and cost of previous and forecast flood inundation. They are intended to be flexible in the sense that reaching slightly higher or lower flow rate targets with one or another mitigation option should be part of the costs and benefits evaluation. For example, if raising the Ghost Reservoir dam and dike system by 3 metres as modelled impinges on the railway or First Nations reserve, but 2.5 metres would not, then a model run with a 2.5 metre raise as opposed to 3 metres could be provided, or any other level; the peak flow reduction could then be approximated, which may become the new mitigation target for practical purposes.

Both the initial and revised targets, and others, are shown in the modelling results in Section 7. They continue to evolve and ultimately the GoA will decide what the targets should be. This is a fundamental social policy decision that will be influenced by many factors. To inform this important discussion and decision, three different flow target scenarios were developed as mitigation options were combined, and this work is described in Section 8.

5 Flood Mitigation Approaches

Seven broad flood mitigation approaches were identified in this project and discussed by participants. These approaches align with many of the principles and key elements identified in *Respecting Our Rivers*, the pamphlet published by the GoA that described the Province's approach to flood mitigation.[8]

The approaches are summarized in Table 2; further commentary and feedback received from participants during meetings and at the BRBC forums is noted below the table for each approach. This commentary is presented in two categories: comments pertaining to the operations and approach, and comments on potential impacts on the river system or watershed.

Table 2: Flood mitigation approaches

Approach	Brief description
Relocation	Reduce risk to people and property by removing infrastructure from the flood plain and restricting future development
Dry dams	Build detention facilities that temporarily detain high flows but allow normal flows to pass without hindrance and do not permanently retain water
Diversions[9]	Divert high flows around high risk areas; diversion channels could include new overland routes; existing overland routes, and subsurface tunnels
Wetland storage	Use natural storage function of wetlands to temporarily detain high flows
Natural river functions	Restore natural river functions to slow and detain high river flows; this includes wetlands, healthy riparian areas, bio-engineered bank protection, re-widening the floodway, natural channel design, meander belts, active flood plains
Change existing operations	Draw down spring reservoir levels and/or raise full supply level capacities of existing reservoirs to capture high flows
Land management	Implement best land management practices in upstream areas (headwaters) to slow the water from reaching infrastructure; this includes wetland restoration, timber harvesting, wildfire management, timber disease and pest management, off highway vehicle trail management, reducing fragmentation and linear disturbances

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[8] This document is available online at https://pabappsuat.alberta.ca/albertacode/images/respecting-our-rivers.pdf.

[9] This report uses the common definition of diversion as "altered stream flow" rather than a diversion of water for a licensed offstream use.

Relocation

This approach reduces risk to people and property by removing infrastructure from the flood plain and restricting future development. Potential relocation sites include floodways and flood fringes throughout the Bow Basin.

Operational comments:

- Relocation after the 2013 flood event includes floodway buyouts and future development restrictions. The best approach is not to develop in a susceptible flood plain, and to enforce development restrictions. Relocation is the only way to be certain of avoiding infrastructure flooding.
- Moving infrastructure and homes where appropriate and functional is a more effective and may be a less costly solution than flood mitigation structures that simply address the symptoms and spread the risk to others. Mitigation approaches are trade-offs in an attempt to protect people so they can continue to live and work in active flood plains, and the costs are borne by all Canadians as well as by the affected aquatic communities.
- The assumption is that it is often cheaper to mitigate than to move existing development. "Givens" may be, for example, that downtown Calgary and large infrastructure such as dams will not be moved.
- Flood plains are mobile and flood maps should be kept up to date to improve cost-effectiveness of potential relocations. If mitigation funds are repeatedly requested, costs should be borne by those who want to develop and live in these areas.
- It can be challenging to make individual relocation choices in the context of a basin's decisions on mitigation options.

Impact on river system or watershed:

- Relocation enables restoration of natural river functions, such as more space for rivers to run, additional buffering, more green space, and improved water quality.
- If Albertans truly want their rivers to look as natural as possible in the future, and to provide good habitat for fish and wildlife, the best way to achieve this is to prohibit further development within the entire floodway and, where feasible, the whole flood plain. If this is done, and those who now have houses located in the flood plain are provided with assistance to relocate, then the amount of money that would need to be spent on erosion control and the Disaster Recovery Program would be greatly reduced in the future, although short-term costs may be quite high.

Dry dams

Dry dams, or detention facilities (barrier with culvert or concrete reinforced opening, whether gated or not), would be built to temporarily detain high flows but allow normal flows to pass without hindrance; such structures do not permanently retain water. Representatives of the Flood Recovery Task Force and the Expert Panel on Flood Mitigation visited the operators and facilities of Miami Conservancy District dry dams in Dayton, Ohio in January 2014. This interaction was valuable in pointing out the differences between dry and wet dams in terms of their construction, operations and maintenance, financing, the mitigation the structures can offer, and the impact they have on the river system.

In preliminary assessments, potential sites for dry dams were identified in all four river systems in the Bow Basin:

- Bow: Waiparous Creek, Ghost River, West of Bearspaw Reservoir
- Elbow: Quirk Creek, Canyon Creek, McLean Creek
- Highwood: West of Eden Valley, Ings Creek
- Sheep: Macabee Creek, Three Point Creek

Operational comments:

- Dry dams must be built to full dam safety standards, including a spillway, as the consequences of failure could be extreme.
- Ongoing operation and maintenance costs as well as initial costs are significant.
- Dry dams would need to be managed for public safety at all times.
- Dry dams would require extensive and ongoing debris and silt management.
- Sizing the outlet design will be critical to prevent significant inundation for extended periods during normal high runoff. Gates may be required, which could enable better overall management of dry dam operations, but entail additional maintenance and cost.
- Water velocity could be substantial at the outlet, and energy dissipation would require a concrete stilling basin or other such energy dissipation measure. An arch-pipe culvert would likely require a concrete floor to mitigate scour and undermining. An impressive vortex is likely to form, which would have potential to draw floating debris down. There are likely a few ways this could be minimized, but it will be a challenge and there may be no way to guarantee that debris will not be a problem.
- These openings may be too big rather than too small unless they have gates. Bigger is better for fisheries and for allowing natural flooding and debris movement up to a highly unusual flow rate. The smaller size would be subject to tremendous pressure with a large magnitude flood; many large culverts were crushed and dislocated from their bedding material in the 2013 flood, which would be very harmful to an earth fill dam.
- Post-flood event releases need to be understood and information shared appropriately, as these releases would create temporary high flows through the river system.
- Structures should be built and operated to help mitigate future droughts as well as floods, thus making them no longer dry dams, which raises a number of other issues to be addressed.
- Dry dams require a clear governance and decision-making process in all aspects of structure management.
- The further upstream that structures are placed, the greater the chance that a flood will miss the structure.
- There is potential to create a false sense of security downstream; for example, a dry dam could be built with the intent of protecting downstream residents, but if a flood occurs outside the dam’s catchment area, downstream residents who thought they were protected by the structure could still be in jeopardy.
- Land ownership could be an important issue and potential barrier in siting new infrastructure.
- Dry dams have been used elsewhere but typically in streams that go dry and have much lower gradients.

- Compared to the Elbow River system, the dry dams of the Miami Conservancy District in Ohio are in a radically different ecosystem and climate and have a much different elevation drop in their rivers, as well as differing riparian ecology and species. To expect the same results of a dry dam in each system may be misleading. The highest rainfall event in the Miami River occurred in 1925 at 121 mm in one day. Over three days, 170 mm was recorded in Bragg Creek in 2013. Considering the length and drop of each river, the average drop of the Miami River is 0.64 m/km, whereas the average drop of the Elbow River is 8.83 m/km. The run off coefficient in the Alberta East Slopes would be much higher than in the Eastern Corn Belt Plains Ecoregion, with a dramatic difference in soils and slope. Additionally the saturation rates would play a significant role in timing of flows. This presumably led to issues in Ohio with siltation and some woody debris entering the system, but in our East Slopes we would face a very different issue of introducing shallow-rooted large woody debris and large boulders with significant gradient and bed load movement. This will make flows, timing, and debris very different, as well as the associated ongoing maintenance costs. The aquatic community in the Miami River is also different, with slow moving waters and poor-swimming fish species. As long as there is active flood plain for the fish to escape the flows, they likely are not often washed downstream. Another significant difference is seen in the case of the Taylorsville Dam (built in 1914), on the Miami River located 10 miles north of Dayton, Ohio. A view on Google Earth shows that the community has taken a major step away from the active river channel. There has been little or no development in the active flood plain through Dayton proper. Instead there is functional flood plain and active forests upstream of the dry dam and, in the flood plain, only parks and golf courses with minimal infrastructure.
- When considering the financing for building and operating such a structure, it was noted that in Ohio the facilities are paid for by homeowners who benefit from the dam through a special levy on property tax.

Impact on system or watershed:

- Dry dams would likely impede fish passage and destroy spawning sites.
- Potential locations are in valued ecosystems and wildlife corridors as well as popular recreation areas. The overall landscape and use of the area would be changed, including substantial loss of vegetation, creating more potential for erosion.
- Habitat for both flora and fauna would be lost, potentially affecting some species at risk.
- The implication of limiting, un-gated culverts is that entire flood peaks would be cut off, which means loss of the beneficial flood pulses that are important for rivers, riparian areas, and flood-dependent species such as willow, poplar, and cottonwoods.
- The temporarily flooded area behind a dry dam prevents opportunity for new development and infrastructure. Such flooding could also be stressful for trees that do not tolerate periodic sustained submergence.
- Dry dams would be most useful if they were built lower on the main stem rather than high in a tributary to offer a greater catchment area for the structure.
- Dry dam failure could lead to cascading failures of downstream dams in the system. Should such a failure occur, it would carry a greatly increased risk of loss of life.

Diversions and channelization

This approach involves diversion of high flows around or through high risk areas via constructed channels. Diversion channels could include new overland routes, existing overland routes, and subsurface tunnels. A number of potential diversion sites in the Bow Basin have been identified and are at varying levels of consideration and study. The list of potential diversion options includes:

- Calgary conduit under 58th Avenue
- Calgary open channel or conduit diversion along 14th Street to Fish Creek
- Calgary open channel diversion along South West Calgary Ring Road (SWCRR) to Fish Creek
- Elbow River open channel diversions through Priddis Creek and/or old irrigation channels
- High River enhanced channelization of the Highwood River through the town
- High River overland diversion north of the Town of High River
- Highwood open channel diversion to the Little Bow River.

Operational comments:

- Challenges from overland and underground diversions include diffusion of high velocity outflow, debris, backwater risk, possibility of increased erosion and sedimentation, and relocated flood risk.
- Debris and sediment management and the difficulty of access to maintain the system in an extreme event must be considered.
- Diversion management would require clear governance and decision-making process.
- If diversion channels are cost-effective, they are potentially a good solution.
- If there is a diversion channel and offstream storage, storage is limited by the capacity of the channel.

Impact on system or watershed:

- Water quality could be a concern at the outflow of an underground diversion or open channel due to potential leaching of contaminated areas that are not normally flooded.
- A diversion channel would restrict access to slower water flow by fish and wildlife. In the 2013 event, fish moved into sheltered (low flow depth and velocity) inundated areas for protection and may not have this opportunity with an above-ground diversion, and certainly not with a tunnel.
- Diversions could negatively affect recharge of alluvial aquifers.
- Diversions may increase the need for flood mitigation in areas downstream and may create ethical and legal issues if risks are transferred from one area to another.
- Potential increase and/or acceleration of time to peak flow in downstream areas may require additional safety measures at downstream infrastructure including bridges, highways, and communities. Furthermore, impacts on downstream dams (Bassano, Twin Valley, Travers) would need to be clearly understood and the appropriate upgrades made.

Wetland storage

The natural storage function of wetlands could be used to temporarily detain or slow high flows. Specific sites with high potential in the Bow Basin include Jumpingpound Creek and Ghost River, with others to be identified. Wetland conservation and restoration would likely play a more important role in communities lower in the watershed than in headwaters areas, underscoring the value of wetlands when the watershed is considered as a whole. Project participants stressed repeatedly the value of wetlands in mitigating floods, as well as providing many other benefits to the ecosystem and watershed. In addition to looking at wetland detention on specific sites, there was strong support for efforts to re-establish wetland and riparian areas more broadly in the basin.

Operational comments:

- The success of this approach would depend on availability of storage capacity in a flood event, influenced by wetland type, its saturation going into a high-flow event, and its location relative to streams and rivers.
- Many wetland areas have been lost and are unlikely to be recovered, so the potential value of this approach is much reduced from what it once was, and this degradation has already reduced watershed resiliency. Remaining wetlands should be protected from development, harmful logging practices, destructive recreational activity, and other improper land uses, especially in the headwaters.
- A significant area of wetland would be required to detain large flow volumes such as those experienced in 2013. Potential mitigation value is likely higher in less extreme flood events and for overall watershed diversity and health.
- Wetland restoration done in partnership with landowners is an opportunity during implementation of the new provincial Wetland Policy. A current and appropriate wetland inventory is a key first step.
- Infrastructure may be required to divert flow to wetland areas. This type of infrastructure has been successful in many urban environments.
- Wetlands offer a range of mitigation functions throughout the basin including resisting and slowing flows in the steep slope headwaters, absorbing and detaining flows in the Prairie pothole region, and maintaining the effectiveness of other control structures and mitigation measures throughout the basin by moderating inflows.
- Much of the science, knowledge, and policy already exist for the effective conservation and restoration of wetlands; the next step is recognizing and pursuing wetland opportunities.

Impact on system or watershed:

- Wetlands are an integral component of a healthy functioning watershed, increasing the resilience needed to achieve many watershed objectives in addition to flood mitigation. Among these are removal of phosphorus, nitrogen, sediment, and heavy metals – additional benefits that are not necessarily provided by other mitigation options. Maintaining wetland integrity fits well with overall watershed management.

- A recent report by Ducks Unlimited Canada (DUC)[10] describes the flood mitigation role that wetlands can play, and shows that investing in wetland restoration and conservation is a cost-effective means of helping to mitigate flooding.
- The text box summarizes the important role that wetlands can play in mitigating floods and maintaining a healthy watershed. As an example, the constructed wetlands at Fish Creek appear to have made a meaningful difference in retention and flow of water through that area in the 2013 flood.

> "Wetlands are known to be an effective flood control measure. The ability of wetlands to act as storage basins on the landscape, allows for increased water storage, slowing the release of water from extreme rainfall events into surrounding streams and rivers, thereby decreasing flood heights and volumes (Ramsar 2011). Areas that are rich in wetlands, particularly in headwater regions, have shown to be less at risk for flooding, whereas regions that have seen large amounts of wetland loss have been shown to experience a greater degree of flooding (Ramsar 2011). Flood attenuation is only one of many ecosystem services that wetlands provide, and these rich ecosystems, also provide a variety of critical ecosystem services, i.e. drought prevention, biodiversity, habitat, increase water quality (nutrient and pollutant filtering), groundwater recharge, carbon sequestration, etc., that are valuable and support other societal objectives (GoA 2011)."
>
> Source: Ducks Unlimited Canada. 2014. *Wetland Conservation and Restoration as Flood Mitigation Tools in the Bow River Basin*, p. 3.

- A follow-up report coming soon from DUC will identify opportunities for short-term actions and high potential locations for conservation and restoration.

Natural river functions

With this approach, natural river functions would be restored as a means to slow and detain high flows. Natural river functions include healthy riparian areas, bio-engineered bank protection, restoring the natural flood plain, natural channel design, and others. High potential sites for such restoration are the Elbow River upstream of and through Calgary, upstream and downstream Highwood River sites, and conservation sites in the Town of High River.

Operational comments:

- All the damage in 2013 was to infrastructure; natural areas either depend on or are resilient to flood events. Healthy functioning ecosystems depend on the natural cycle of flooding and the disruption and benefits that floods bring. Thus, the only damage caused by floods is going to be to people and their property. Many areas of deeply rooted trees and intact riparian vegetation and understory throughout the Bow River system held up very well during the 2013 flood, showing little if any erosion. The protected Inglewood Park region is one example of this. As well as showing the resiliency of the riparian zone, it is an example of where the river has the ability to fully spread the flows across the river bed and dissipate energy.
- In the past, we have allowed intensive development and infrastructure investments in some flood plains. Thus it should not be surprising that damage to these developments from the 2013 floods resulted in the most expensive disaster in Canadian history.

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[10] Ducks Unlimited Canada. 2014. *Wetland Conservation and Restoration as Flood Mitigation Tools in the Bow River Basin*. Available by searching on the WaterPortal at http://www.albertawater.com/.

- Part of this approach should include taking an integrated look at geomorphology and channel migration zones, and not allowing development where fill is used to build up banks. That sort of development can put people at risk when channels migrate.
- Meander belts and alluvial flood plains and aquifers should be identified and respected.
- In some places, erosion due to improper recreational access along a river bank can compromise natural integrity.
- It is important to allow the stream room to move throughout its flood plain.
- Voluntary rehabilitation and/or conservation by landowners could be encouraged in support of this approach. Organizations such as Cows and Fish, Watershed Stewardship Groups, land trusts, and some rural municipalities are already working with landowners to undertake such initiatives and these efforts are encouraged.

Impact on system or watershed:

- Provided that erosion is not accelerated as a result of human activities (e.g., removal of riparian vegetation, overgrazing, off-highway vehicles), natural processes create some of the best fish habitat in rivers and streams. Armouring river banks to prevent erosion adversely affects not only fish and wildlife habitat, but also the aesthetics, the function of the river, and the transfer of energy.
- We need to consider what we want our rivers to look like in the future. Perhaps it is time that question was asked of all Albertans, since the bed and shore of rivers belongs to them. Otherwise, the decision as to what our rivers look like in the future will be made by the adjacent landowners, who have built houses, golf courses, etc., in the flood plain or on top of erodible river banks.
- If Albertans truly want their rivers to look as natural as possible in the future, and to provide good habitat for fish and wildlife, the best way to achieve this is to prohibit further development within the entire floodway and, where feasible, the whole flood plain. If this is done, and those who now have houses located in the flood plain are provided with assistance to relocate, the amount of money that would need to be spent on erosion control and the Disaster Recovery Program would be greatly reduced in the future, although short-term costs may be quite high.
- ESRD's *Stepping Back from the Water* report[11] highlighted the role riparian areas play in reducing peak flows and downstream flooding. Plants resist the flow and dissipate the energy, allowing increased time for infiltration into the soil and for sediment to settle out. The report's beneficial management practices guidelines are a starting point for the easiest and least expensive form of natural mitigation, which is to stop land use practices that degrade the natural function of riparian areas.
- Since "erosion control" through developed areas typically means bank armouring, the statement on page 5 of the GoA's pamphlet *Respecting Our Rivers*, is something that some people would not agree with: "Investing in erosion control today..." ensures that water "...flows within natural channels in the future..." Armoured banks are not what many would call "natural channels" and will require ongoing investment for maintenance.

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[11] Government of Alberta. 2012. *Stepping Back from the Water: A Beneficial Management Practices Guide for New Development near Water Bodies in Alberta's Settled Region*. Available online at http://environment.alberta.ca/04100.html

- The relative contribution of individual natural river function measures to mitigate large floods may be small but locally significant. However, the cumulative impact could be valuable and can achieve many watershed objectives through the river's entire flow regime (e.g., droughts and floods).

Change existing reservoir operations

Existing operations could be changed to draw down spring reservoir levels and/or increase capacity of full supply levels of existing reservoirs to attenuate high flows. Potential sites for this approach include all the existing reservoirs, in particular the Ghost, Barrier, and Glenmore reservoirs.

Operational comments:

- Changing reservoir operations requires clear governance and a decision-making process.
- Sediment should be actively monitored to avoid storage loss, whether the reservoir is used for its designed purpose or for flood mitigation.
- Managing for floods, including releasing water in advance of a possible flood, needs to be carefully monitored and balanced with managing for drought. Reservoirs can be made to serve multiple purposes but only with a sound basis for forecasting inflows as well as outflows.
- Operations for flood mitigation should be designed to minimize the risk to fill reservoirs in mid to late July when river flow typically drops. The flood mitigation operations must be balanced with other water management considerations since water storage often provides essential services later in the year.
- Changing reservoir operations in isolation can result in considerable peak flow reduction, but works best with other options in combination. A key factor is linking many data sources to improve forecasting to understand the probability of refilling and spur a continuum of action as a particular storm risk increases.
- The best approach is to optimize what is already in place before building new mitigation infrastructure; this is also one of the mitigation options that can be implemented most quickly and flexibly.

Impact on system or watershed:

- Pre-releases would need to remain below specified flood thresholds to mitigate damage from a flood that may or may not occur.
- As with any structures, operational errors can lead to cascading system failures.
- Drawing down or raising water levels may have temporary and only periodic negative recreational, environmental, and aesthetic impacts (e.g., on property owners, boaters, nesting birds, shoreline erosion).
- Temporary and occasional local flooding could become a risk for infrastructure along the reservoir shoreline.
- If lowered reservoirs are unable to refill due to extremely dry conditions after the flood, and thus cannot supplement low flows through the winter, these reduced winter flows could affect environmental conditions and ice dam flooding.

Land management

Implementing best land management practices in upland areas could slow the water and potentially prevent it from reaching infrastructure. Practices affected include wetland restoration, timber harvesting, timber disease and pest management, off highway vehicle management, urbanization (i.e., reducing impervious surfaces), and reducing fragmentation and linear disturbances. Priority areas where land management may be effective are found throughout the Bow watershed including headwater and upland areas, for example the Ghost-Waiparous watershed and the Elbow headwaters.

Operational comments:

- Protecting the headwaters involves difficult political trade-offs, but has been done and other jurisdictions provide good examples.
- The Eastern Slopes have been affected by intensive linear disturbances, timber harvesting, other resource development, urbanization, and recreational activity. Best management practices should be applied where possible to mitigate the impacts of these disturbances on sediment loading and runoff generation.
- A systems approach to protecting ecosystems and watersheds is needed. However, in mountainous areas such as Banff National Park where development restrictions are in place, floods still occur with heavy rains, suggesting land management is part of overall watershed health but will play a limited role in mitigating large flood events.
- Much would be learned from studying the overall impacts of the 2013 flood in Banff National Park. While the Park did suffer infrastructure damage and emergency conditions, the proportional damage was probably lower than in Canmore or Calgary. If so, there might be two complementary hypotheses for the effect: a) infrastructure, or at least newer infrastructure, tends to be built with greater consideration to working within the natural ecosystem; and, b) pristine watersheds, while not eliminating floods, resulted in flows being attenuated by the upland landscape and flood plain storage.
- The current draft of the South Saskatchewan Regional Plan (SSRP) is designed to address many land management concerns and opportunities. Additional timber harvesting and managed off-highway vehicle access to some areas and not others can be used to mitigate and manage rapid runoff in the headwaters.

Impact on system or watershed:

- While the relative contribution of individual land management measures to flood mitigation may be locally significant but small, especially in very high-flow flood events, the cumulative impact could be sizeable and may achieve many other watershed objectives in addition to flood mitigation.
- Improved land management achieves many watershed objectives during the periods of time when rivers are not in flood condition, in addition to flood mitigation.

6 Flood Mitigation Options for the Bow Basin

Specific mitigation options for each river system were compiled from various sources, including suggestions from project participants and work done previously for the Flood Recovery Task Force. These options were modelled by the project team prior to live meetings, and were reviewed and refined, individually and in combination, during two of the project meetings. The full list of individual mitigation options is shown in the tables below, by river system; the underlined options were modelled, but data were not available to model those not underlined. In some cases, options were identified but not explored by the participants and therefore are not discussed further in this report. Each modelled option is briefly described in Section 7 along with a summary of the modelling results.

6.1 Bow River System

Project participants discussed at length potential mitigation targets for each river system and options that might achieve them. For the Bow River main stem at Calgary, the mitigation target discussion ranged from approximately 800 cms to approximately 1150 cms. It was noted that different targets may be needed upstream (e.g., for Banff, Canmore, and Cochrane). The first and most logical place to look for mitigation is at existing infrastructure: TransAlta facilities. The group considered a broad range of mitigation options, as reflected in Table 3; among these were:

- Flood control operations on TransAlta reservoirs when needed
- Expanding existing infrastructure owned by TransAlta (raising reservoirs and diversion)
- Construction of new dry dams (at Ghost, Waiparous, Bearspaw, and Barrier).

These discussions reinforced the need for the best possible streamflow and snowpack data, soil moisture content, and meteorological forecasts to inform operational decisions. As well, flexibility in the system is critical so that reservoir levels can be flexibly and adaptively adjusted as approaching storms are monitored.

Table 3: Flood mitigation options: Bow River

Concept Category	Short Term (Quick Wins by 2014)	Medium Term (2-5 years - by 2018)	Long Term (> 5 years)
Natural Mitigation	· Initiate bio-engineered bank protection where appropriate	· Wetland detention on Jumping Pound Creek · Wetland detention on Ghost River · Wetland detention capacity of the whole Bow Basin · Enforce Ghost-Waiparous Access Management plan and others · Acknowledge and avoid the river's meander belts · Change location of Johnson's Island dike to allow natural flooding	· Full wetland and riparian system assessment and re-establishment program · Mitigation through land management and use practices that reduce runoff throughout the Bow Basin
Operational Mitigation	· Operate Ghost for flood control · Operate all tributary control structures for flood control · Monitor ice dam formation and manage as needed	· Assess value of dredging Ghost reservoir · Auxiliary spillway at Johnson's Island to avoid dike surge	
New Infrastructure Mitigation	· Armour river banks in key spots · Divert high water into suitable low lying areas	· Expand capacity of Ghost Reservoir · Low level outlet in Ghost to expand capacity · Rebuild/expand Ghost diversion · Expand Barrier Reservoir · Municipal storm water projects (on- and off-steam storage into tributaries) · Debris protection to keep Carseland-Bow River Headworks canal intake open	· Dry dam west of Bearspaw Dam (BR1) · Dry dam on Ghost River (BG1) · Full service dam on Ghost River · Dry dam on Waiparous Creek (BW1) · Dry dam between Lower Kananaskis Lake and Barrier · Full service dam downstream of Bassano Dam ("Eyremore Reservoir")

6.2 Elbow River System

Discussion on mitigation targets for the Elbow began with 180 cms, then evolved to approximately 450 cms, recognizing the need for local protection and relocation. The City of Calgary noted that this flow of 450 cms would require approximately 5,500 residences to be evacuated. Looking to existing infrastructure as a way to meet the targets, Glenmore Reservoir operations was a first step. The group looked at a broad range of mitigation options, as reflected in Table 4, including:

- Flood control operations on Glenmore Reservoir (current and expanded)
- Various diversions: overland or tunnel, upstream and in Calgary
- Potential dry dams (Quirk Creek above Elbow Falls; Canyon Creek, and McLean Creek)
- Sum of small solutions including wetlands and land management.

Table 4: Flood mitigation options: Elbow River

Concept Category	**Short Term** (Quick Wins by 2014)	**Medium Term** (2-5 years - by 2018)	**Long Term** (> 5 years)
Natural Mitigation	· Initiate bio-engineered bank protection where appropriate	· Increase the capacity of the Elbow River through Calgary · Natural channel design through developed areas · Engineered wetlands in Fish Creek · Wetland detention capacity of the whole Bow Basin	· Mitigation through land management and use practices that reduce runoff throughout the Bow Basin
Operational Mitigation	· Operate Glenmore for flood control · Dredging in reservoir and/or river reaches	· Low impact development to manage storm water	
New Infrastructure Mitigation	· Armour river banks in key spots · Divert high flow into suitable low-lying areas	· Diversion from Glenmore to Bow River under 58th Ave. · Priddis Creek area diversion upstream of Bragg Creek to Fish Creek, with detention · Glenmore to Fish Creek diversion (SWCRR or other path), with detention · Multiple historically identified detention sites · Dikes protecting downtown Calgary infrastructure	· Dry dam at Quirk Creek (EQ1) · Dry dam on Canyon Creek (EC1) · Detention on Prairie Creek · Multiple small detentions instead of one · Expand capacity of Glenmore reservoir

6.3 Highwood and Sheep River Systems

Discussion on mitigation targets for the Highwood-Sheep system started at 180 cms through High River, and evolved to approximately 1500 cms, recognizing the berming planned for the town. It was recognized that this option in the town of High River may not fully reflect the concerns of upstream and downstream rural homeowners. At present, the Sheep and Highwood rivers have few existing control structures, so opportunities for mitigation using existing structures are limited. The next promising option was to look at diversions around municipal and other infrastructure. Two high potential diversions were considered: a new north diversion and/or augmenting natural flow south into the Little Bow system. Both would be significant investments and it is uncertain at this time which, if either, of these might proceed. Other options, including dry dams, were also explored (Table 5), but dry dams continued to receive very little support. It was noted repeatedly that full cost-benefit analysis is needed before any major infrastructure investments proceed.

It was also noted that the Highwood Water Management Plan Phase 1 included a WRMM Modelling Review of Additional Storage. This study found that there were no useful full service storage sites available in the Highwood system because of the unreliability of water supply in that area to fill them.

Table 5: Flood mitigation options: Highwood and Sheep Rivers

Concept Category	**Short Term** (Quick Wins by 2014)	**Medium Term** (2-5 years - by 2018)	**Long Term** (> 5 years)
Natural Mitigation	· Initiate bio-engineered bank protection where appropriate	· Re-naturalize the flood plain · Reconnect dried oxbow lakes · Riparian and wetland inventory assessment (expand on previous 2000-2002 health assessments) · Wetland detention capacity of the whole Bow Basin	· Wetland and riparian restoration program · Mitigation through land management and use practices that reduce runoff throughout the Bow Basin
Operational Mitigation	· Temporary diversion into natural depressions		
New Infrastructure Mitigation	· Armour river banks in key spots · Channelization of the Highwood through High River combined with existing natural diversion south into the Little Bow · Divert high water into suitable low-lying areas	· Diversion of Highwood North around High River with Bassano reinforcement · Diversion of Highwood south into Little Bow system with Travers build and expanded capacity at Twin Valley Reservoir	· Dry Dam west of Eden Valley Reserve (H52) · Dry dam upstream of Longview (H2) · Full service dam upstream of Longview · Dry dam upstream of Turner Valley (S2) · Detention at Three Point Creek confluence · Detention above Three Point Creek

6.4 Combinations

Flood mitigation solutions for the Bow Basin will almost certainly be a combination of options – operational changes, infrastructure, and natural measures; several combinations were modelled and explored, and these are presented in Table 6. Modelling results for these combinations are described in Section 8. All combinations should be evaluated for their full system effects, especially the potential for downstream flooding or damage created by passing the flow faster and more efficiently into downstream municipal developments or infrastructure that may not have been affected otherwise.

Table 6: Potential combinations of flood mitigation options

River System	Potential Combination
Bow	· Operate TransAlta facilities (Ghost, Barrier, Minnewanka, Spray, Kananaskis Lakes) for floods · Operate and expand TransAlta facilities (Ghost and Barrier) · Dry dam upstream of Bearspaw, Operating TransAlta facilities (Ghost, Barrier, Minnewanka, Spray, Kananaskis Lakes) · Three dry dams: west of Bearspaw (BR1), on Ghost River (BG1), and on Waiparous Creek (BW1) + Operating TransAlta facilities (Ghost, Barrier, Minnewanka, Spray, Kananaskis Lakes) for floods · BR1, BG1, and BW1 dry dams + Operate and expand TransAlta facilities
Elbow	· Aggressive Glenmore operations and Quirk Creek (EQ1) dry dam · Glenmore operations + Priddis region diversions · Glenmore operations, Priddis region diversions, wetlands, land management · Calgary bypass + Quirk Creek (EQ1) dry dam · Calgary bypass + Glenmore operations (smaller tunnel?)
Highwood/Sheep	· North diversion around High River and augmented south diversion into Little Bow · Two dry dams: west of Eden Valley Reserve (H52) and upstream of Longview (H2) + North diversion · Sheep River dry dam (S2) and Threepoint Creek dry dam on switches
Whole Bow Basin	· 'Quick Win' – Operate TransAlta and Glenmore for floods · 'Optimize the current system' – Wetlands + land management + Glenmore operations + TransAlta operations + augmenting the south diversion · 'Infrastructure' – All dry dams and diversions · 'Flow target' – whatever it takes to get to target flows at Calgary, High River, Okotoks, Bassano Dam, Medicine Hat, etc. · 'Local benefit/downstream impact' or 'need to manage as a basin' – e.g., Calgary tunnel + north diversion = impact to Bassano or diversion to Little Bow = impacts to Travers.

6.5 Other Options

Some of the options discussed could not be modelled in the BROM because sufficient data do not exist or because the options were outside the scope of a mass balance model. Examples include fully quantifying land management and wetland effects, and local mitigation like flow rate changes due to barriers and berming.

7 Modelling Results

This chapter presents the modelling results for the underlined mitigation options shown in Tables 3, 4, and 5 in Section 6. The results for each option are organized by river system, starting with the Bow, then the Elbow, and finally the Highwood-Sheep. Operational and infrastructure results are presented first for each river system, and results for the natural mitigation options appear at the end, since they apply generally to all systems. To guide readers in interpreting the charts, the following information is provided:

- Dates shown in the charts that accompany each option are formatted by day/month; for example, 17/6 is the 17th of June.
- Two mitigation targets are shown in each chart. The red line is the target that was initially proposed and the green line is the target that evolved as the work on this project progressed.
- The dashed black line represents the GoA 1:100 event.

7.1 Bow River System

Operate Ghost Reservoir for flood control

This option involved lowering the upper storage level rule curve for Ghost Reservoir by about 5 metres in advance of an expected flood. A probabilistic forecast-based system would be used to determine if and when the reservoir is lowered and by how much; in other words, it would be triggered by a forecast event and not held low every year. Additional storage of about 31,000 cdm would enable the reservoir to attenuate high flows on the Bow main stem and leverage its position as having the greatest catchment area in the basin (other than Bearspaw which has a larger catchment area but currently far less storage capacity). Figure 7 shows the location of Ghost Reservoir (node 185) relative to other infrastructure on the Bow River system upstream of Calgary.

It is important to recognize that the TransAlta operations during the 2013 event certainly helped to reduce the flood peak seen through Calgary and the rest of the downstream Bow River Basin. That impact is already reflected in the simulated flood shown as the Base Case in BROM and in the charts below. The participants worked to identify what further mitigation might be achieved with the existing reservoirs, over and above what was accomplished in 2013.

This run lowered the Ghost Reservoir upper storage level rule by ~ 5 m down to 1186 m from 17/6 – 21/6 (with a three day lowering/filling period). The run added a flow target downstream of Ghost that will force the reservoir to store water (up to 1191.78 m) when flood waters are peaking (that is, greater than 1050 cms).

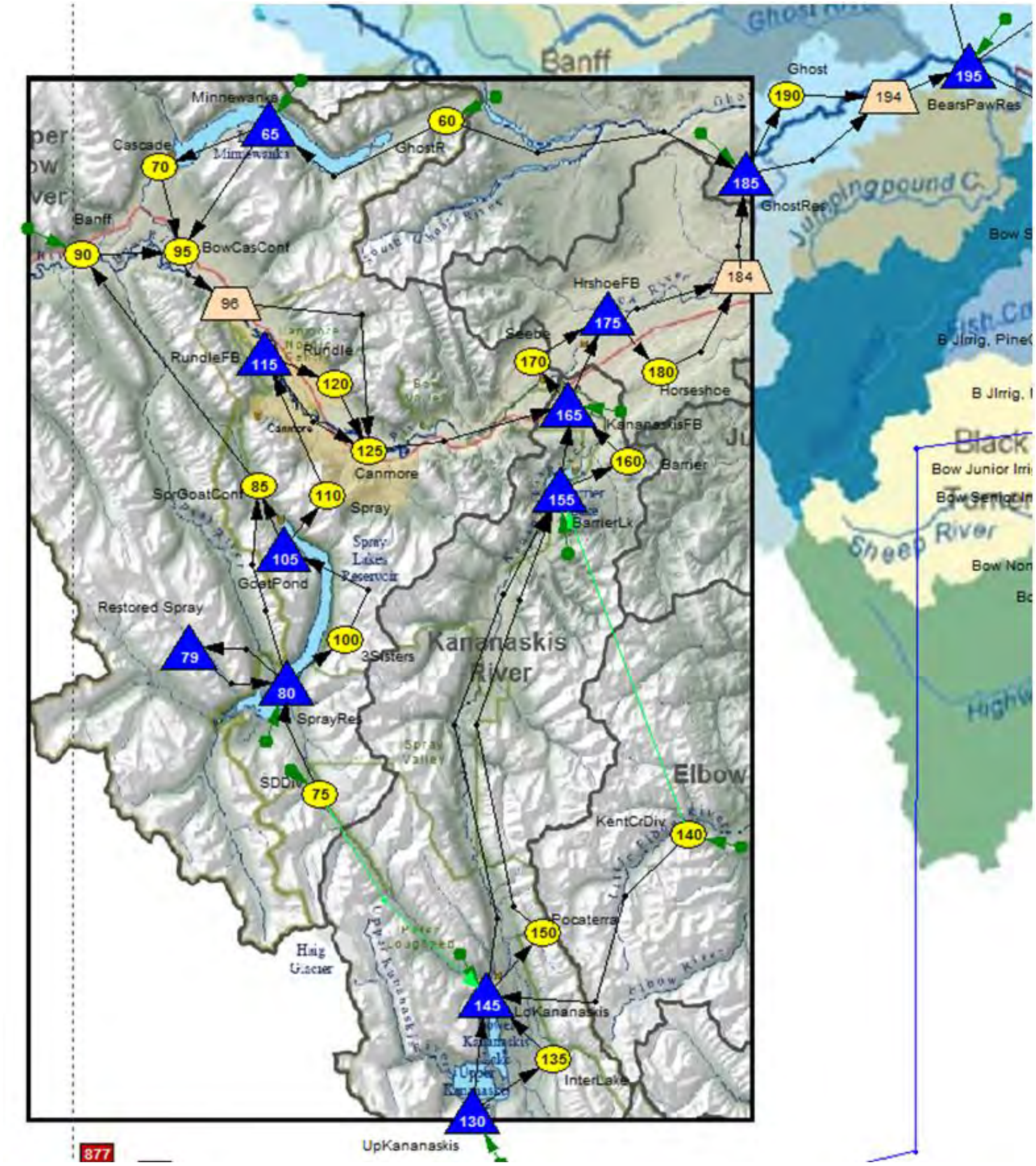

Figure 7: The Upper Bow region with general locations of existing structures

Operation of Ghost Reservoir for flood control reduced flows in the Bow River upstream of the Elbow confluence by 34 cms in the 2005 modelled scenario, and by 550 cms in the 2013 modelled scenario (Figure 8). The reason flood flows were not reduced by a significant amount in the 2005 flood relative to the 2013 flood was the much higher flow objective set as a flood flow target. The 2005 flood barely exceeded this flow target, but the 2013 flood exceeded it by nearly 70%.

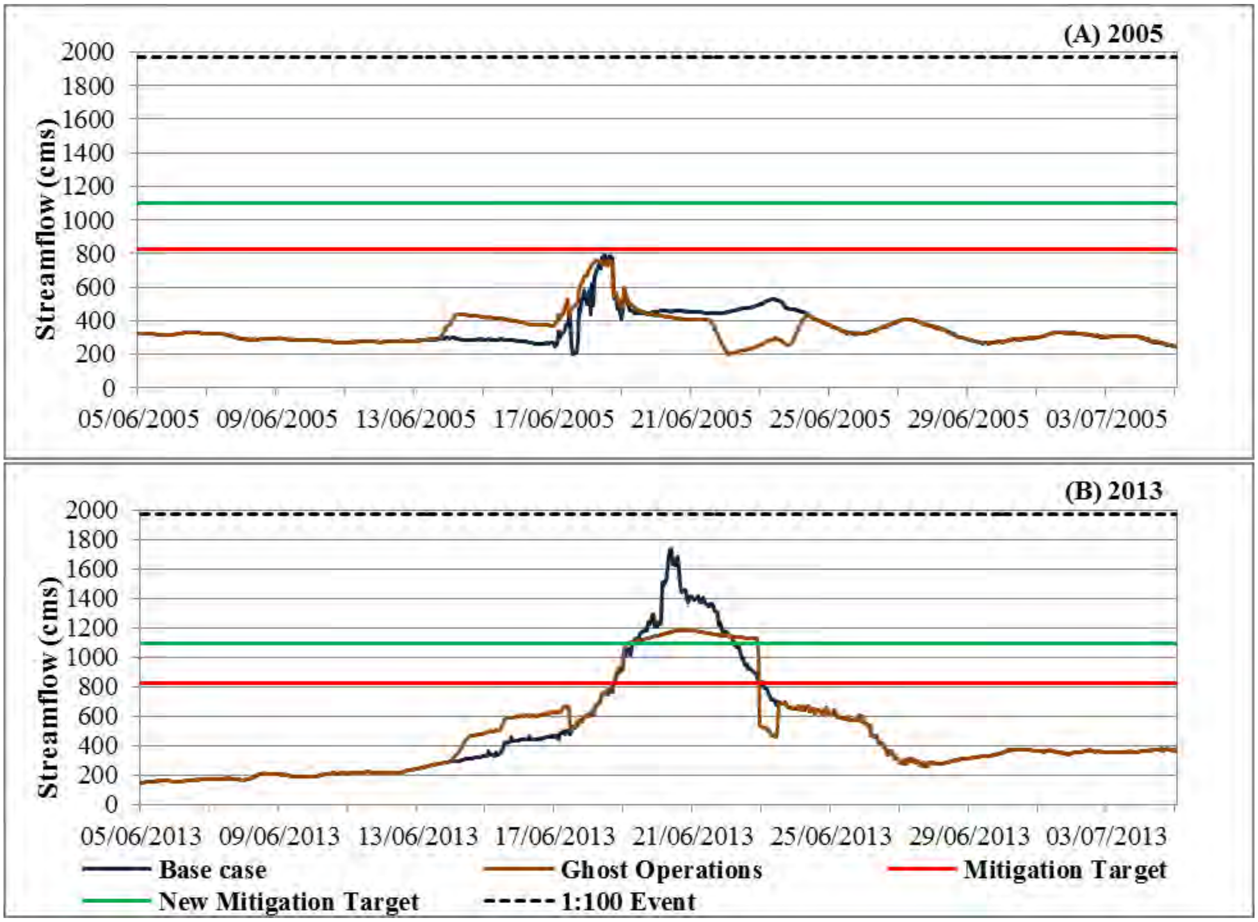

Figure 8: Comparison of streamflow in the Bow River upstream of the Bow-Elbow confluence between base case and operating Ghost Reservoir for flood control in (A) 2005 and (B) 2013

In discussing this mitigation option, participants noted that recreational and aesthetic concerns could arise for users of Ghost Reservoir if water is pre-released, and the release rate would need to consider the risk of proactively-induced damage. As a flood event develops, outflow must match or exceed inflow to keep the freeboard space in the reservoir to be able to attenuate the peak flow during the coming big event. Pre-releases need to take into account the need to refill after the middle of July when flow normally starts to drop rapidly. Once the reservoir is full, outflow must again match inflow to mitigate overtopping the dam. Overall operations for flood mitigation would include filling some of the larger upstream reservoirs to full supply level (FSL) if necessary, based on improved and reliable forecasts so as not to contribute to the peak flood flows. This additional storage may offset a dry period starting immediately after the flood. As well, an integrated systemic approach would ensure irrigation district reservoirs are able to fill as the upstream flood tapers off but they still have strong flow downstream.

The question arises whether operations designed to mitigate smaller floods can mitigate larger floods. Further work should be done to determine if targets should be set for upstream (e.g., Cochrane and Canmore) in light of effects in Calgary. The initial target of 825 cms would result in manageable damage to Calgary and would rely on measures implemented within the city such as temporary and permanent barriers. Finally, this option would likely have an impact on power generation for the reservoir operator, TransAlta. Although the Bow hydro system provides a minimal portion of daily or annual electricity to the grid, impact on power generation and potential compensation would need to be considered. These matters can be resolved, and although this option by itself does not achieve the lower range of the mitigation targets, it does reduce peak flows substantially and could be implemented quickly and cost-effectively with appropriate agreements with TransAlta. This option, like others involving releases ahead of possible flood events, relies on the best possible forecasts of preceding conditions and the location and duration of heavy precipitation as individual storms approach.

Operate all tributary control structures for flood control

This mitigation option expands on the previous option by also lowering Barrier Reservoir by about three metres prior to a forecasted flood event, and allowing it to fill up to FSL to attenuate flood peaks. Furthermore, Minnewanka and Spray reservoirs, and the Kananaskis Lakes were operated to hold back flood inflows, as they were during previous flood events, 2013 in particular. Ghost Reservoir is operated in the same manner as in the previous run – "Operate Ghost Reservoir for flood control."

Operation of all upstream tributary control structures for flood control reduced flows in the Bow River upstream of the Elbow confluence by 10 cms in the 2005 modelled scenario, and by 590 cms in the 2013 modelled scenario (Figure 9).

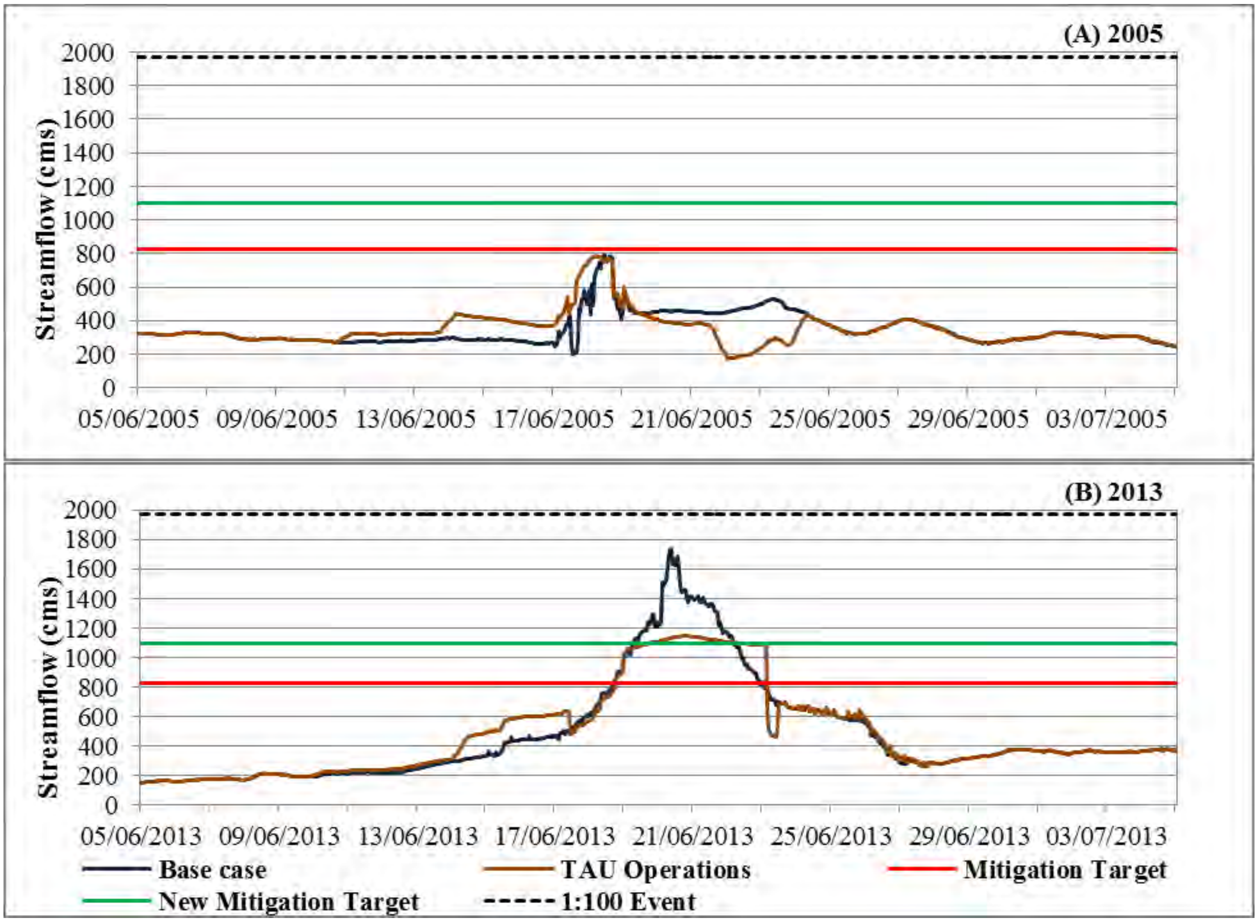

Figure 9: Comparison of streamflow in the Bow River upstream of the Bow-Elbow confluence between base case and operating all tributary control structures for flood control in (A) 2005 and (B) 2013

This option is an operational extension of operating Ghost Reservoir for flood mitigation. To use Ghost Reservoir and reduce risk of inadequate storage for offsetting low flows later in the year, allowing the large upstream reservoirs of Minnewanka, Spray, and Upper and Lower Kananaskis to fill, depending on conditions and forecasts, is logical and potentially necessary to enable

Ghost Reservoir to release no more than a set flow rate to mitigate a major flood. Ghost is the receiver of all the flow from all the upstream reservoirs and natural flow in the main stem, as well as the Waiparous and Ghost rivers that flow directly into Ghost Reservoir. Although this combination achieves an additional 40 cms reduction from the peak flow, it provides some risk protection in the event of a dry period following a rapid flood event.

Rebuild a larger Ghost Diversion into Lake Minnewanka

This model run assumed the diversion from Ghost River into Lake Minnewanka, which was destroyed in 2013, would be rebuilt to convey a flow of up to 100 cms. It was assumed that the diversion (Figure 10) would only be used when Ghost River flows were greater than 200 cms.

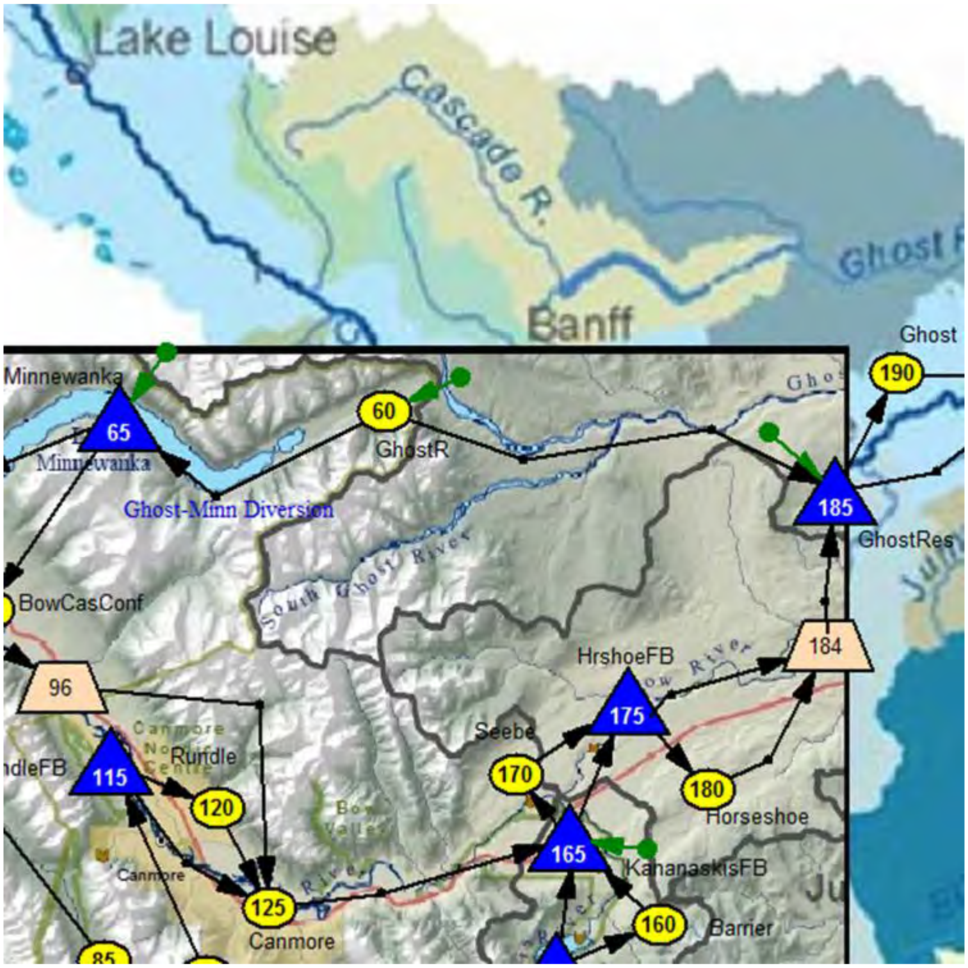

Figure 10: General location of the Ghost Diversion, represented by the arrow from node 60 to 65

The diversion was not used in the 2005 run because the diversion was only used when flows were greater than 200 cms, which was higher than the Ghost River estimated hourly peak flow in 2005. However, there was a reduction of 100 cms from the simulated peak flow in 2013 in the Bow River upstream of the Elbow confluence (Figure 11). It is estimated that the 2013 inflow to Minnewanka after the diversion was destroyed was zero, but that a slightly downstream berm caused flows into Minnewanka between 10 and 50 cms. This would reduce the net benefit by approximately that amount, but only if Minnewanka was full at that time and had to spill whatever inflows it received.

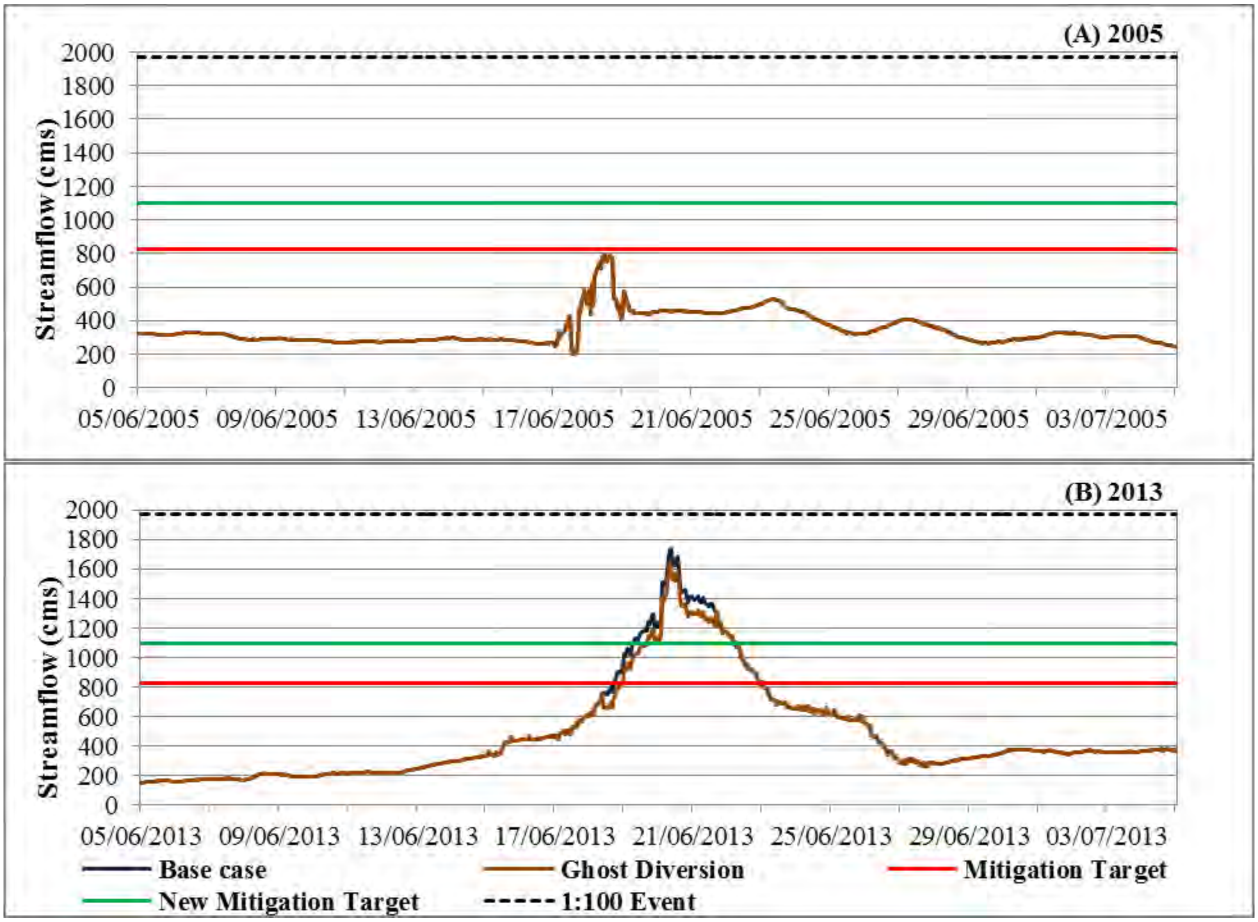

Figure 11: Comparison of streamflow in the Bow River upstream of the Bow-Elbow confluence between base case and operating all tributary control structures for flood control in (A) 2005 and (B) 2013

The TransAlta-owned and operated diversion was blown out in 2013 and would need to be rebuilt with increased capacity to handle higher flows. Depending on conditions at Minnewanka, the reservoir may need to be lowered slightly to contain the extra inflow long enough to not increase net flow through Canmore during the peak flow period.

It is very likely that TransAlta will rebuild the Ghost diversion in some form. There may be opportunity for cost sharing given that the new diversion may offer a basin-wide flood mitigation service. Permitting on the rebuild could begin soon, underscoring the need for discussion on this option to begin quickly. Since the reservoir itself is within Banff National Park, federal-provincial negotiations may be needed to modify operations on the reservoir during the infrequent but nearly certain to occur 1:50 to 1:100 year return flood.

Expand the capacity of Ghost Reservoir

This option would raise the dam and dike system of Ghost Reservoir by 3 m but would keep the existing FSL so that the additional storage is only used for emergency purposes. This model run lowered the Ghost Reservoir upper storage level rule by about 5 m, down to 1186 m from 17/6 – 21/6 (with a three day lowering/filling period). The run added a flow target downstream of the reservoir that will force it to store water 3 m higher than current FSL, to 1194.78 m when flood waters are peaking (more than 875 cms), creating additional storage of about 52,000 cdm to attenuate high flows on the Bow main stem.

Expanding Ghost Reservoir and operating it for flood control reduced flows in the Bow River upstream of the Elbow confluence by 34 cms in the 2005 modelled scenario, and by 725 cms in the 2013 modelled scenario (Figure 12).

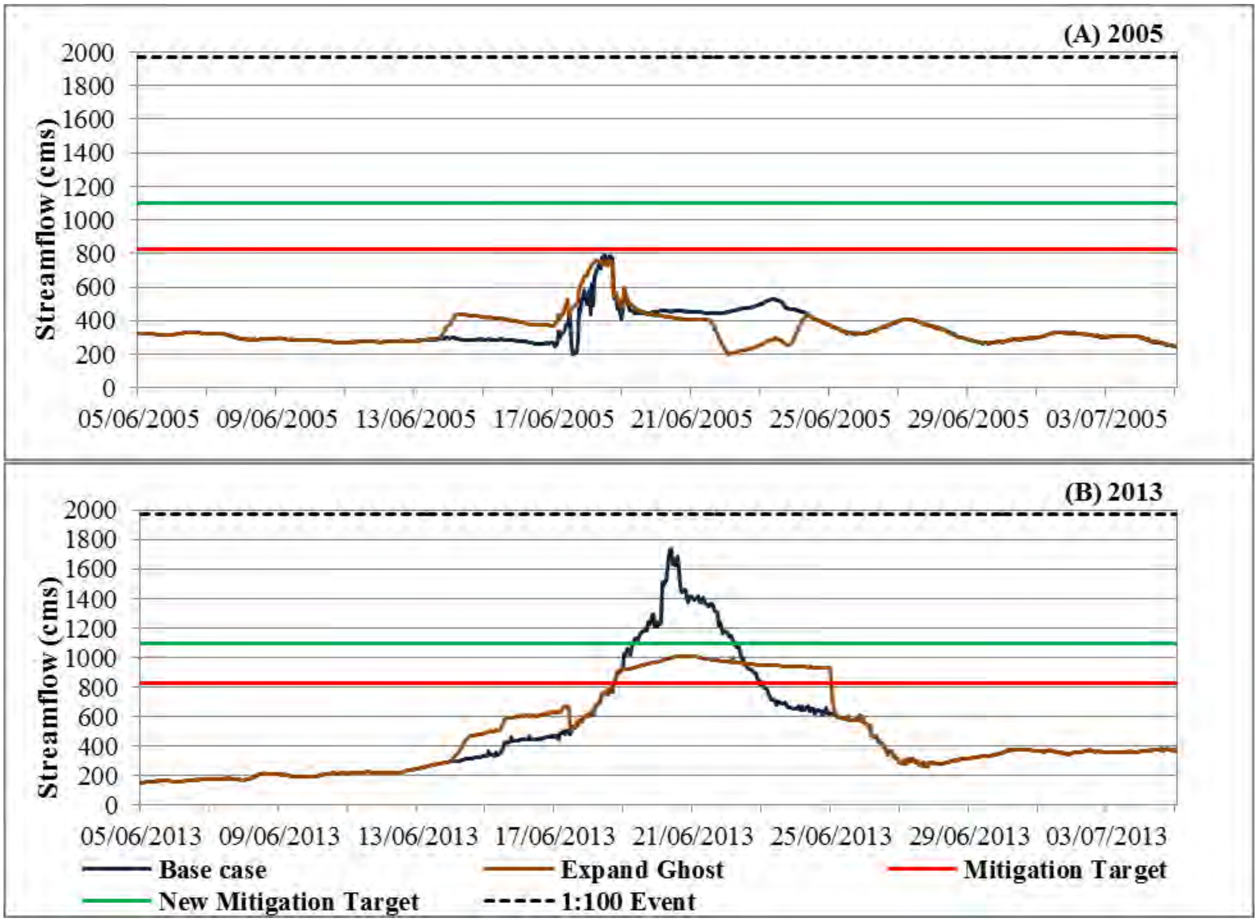

Figure 12: Comparison of streamflow in the Bow River upstream of the Bow-Elbow confluence between base case and expanding Ghost Reservoir for flood control in (A) 2005 and (B) 2013

This option would pose occasional temporary local flooding risk along the reservoir shoreline, which may affect a summer village, railway, and possibly First Nations land. A survey of the region would quickly determine the extent of this flooding and if and to what extent any actual impacts would be felt at 3 m or whether more or less storage volume would be available.

Expand Barrier Reservoir

This run lowered the Barrier Reservoir upper storage level rule by about 3 m prior to the flood (with a three day lowering/filling period). The run added a flow target downstream of Barrier that will force the reservoir to store water 3 m higher than current FSL, to 1378.56 m when flood waters are peaking (more than 205 cms).This option would be triggered by a forecast event so the reservoir would not be held low every year.

Expanding Barrier Reservoir and operating for flood control reduced peak flows in the Bow River upstream of the Elbow confluence by 106 cms in the 2013 modelled scenario, while extending the duration of the high flows. In Calgary it did not affect peak flows in the 2005 modelled scenario (Figure 13).

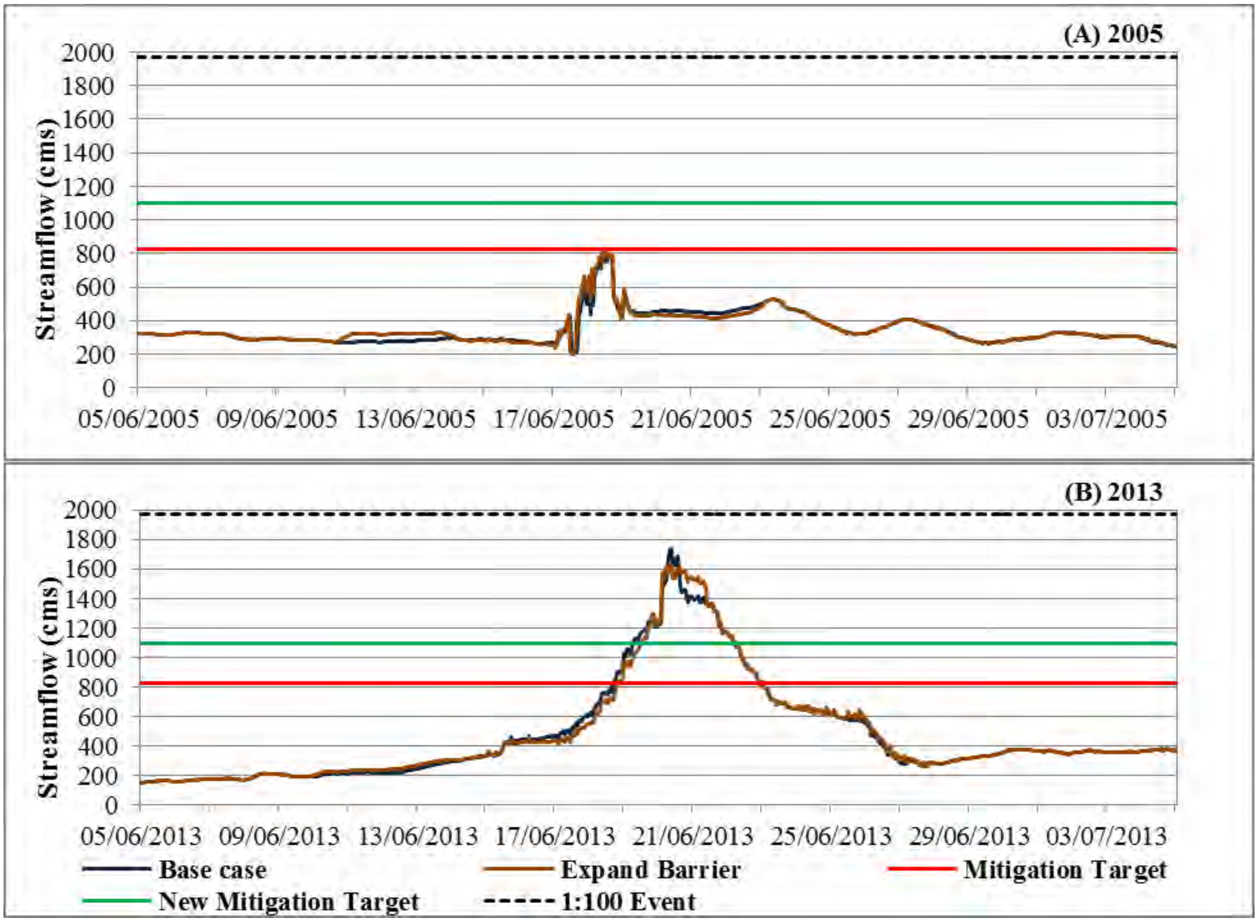

Figure 13: Comparison of streamflow in the Bow River upstream of the Bow-Elbow confluence between base case and expanding Barrier Lake for flood control in (A) 2005 and (B) 2013

Like all the options, raising the Barrier structure is problematic due to the benchland geomorphology. The existing dam fills up the first valley already and raising it would extend that flooding into the next larger area on an occasional and temporary basis. It could add a substantial volume of storage but the cost should be evaluated relative to other alternatives for the Bow system. The Kananaskis system, to which Barrier belongs, may not receive the same amount of rainfall as seen in 2013 in future floods, but there are data that could assess the risk-reward potential.

Debris protection to keep Carseland-Bow River Headworks canal intake open

This option simulates the deflection of debris away from the Carseland-Bow River Headworks (CBRH) canal intake by installing rock spurs, thus allowing diversions from the Bow River to continue during high flows. The diversion would be maximized at 51 cms when Bow River flows at Carseland exceed 1000 cms. In practice, the Bow River Irrigation District (BRID) demands and reservoir storage levels would also need to be considered before allowing the maximum diversion.

The rationale for this option is that during floods the intake to the canal that supplies water to the BRID plugs with debris, making it impossible to divert any water until the river recedes and the debris can be cleared away. If debris could be deflected away from the canal intake, up to 51 cms could continue to be diverted. Depending on conditions further downstream in McGregor and Travers reservoirs, as well as in the BRID’s internal system, it may not be possible to always divert this full amount, but it would usually be possible to do it for the duration of a typical flood.

Allowing CBRH diversions to continue at the maximum during high flows reduced flows in the Bow River at Bassano Dam by 51 cms in the 2005 modelled scenario and in the 2013 modelled scenario (Figure 14). This is a small change that could be done quickly and contribute to successful flood mitigation efforts until a larger spillway is constructed at Bassano.

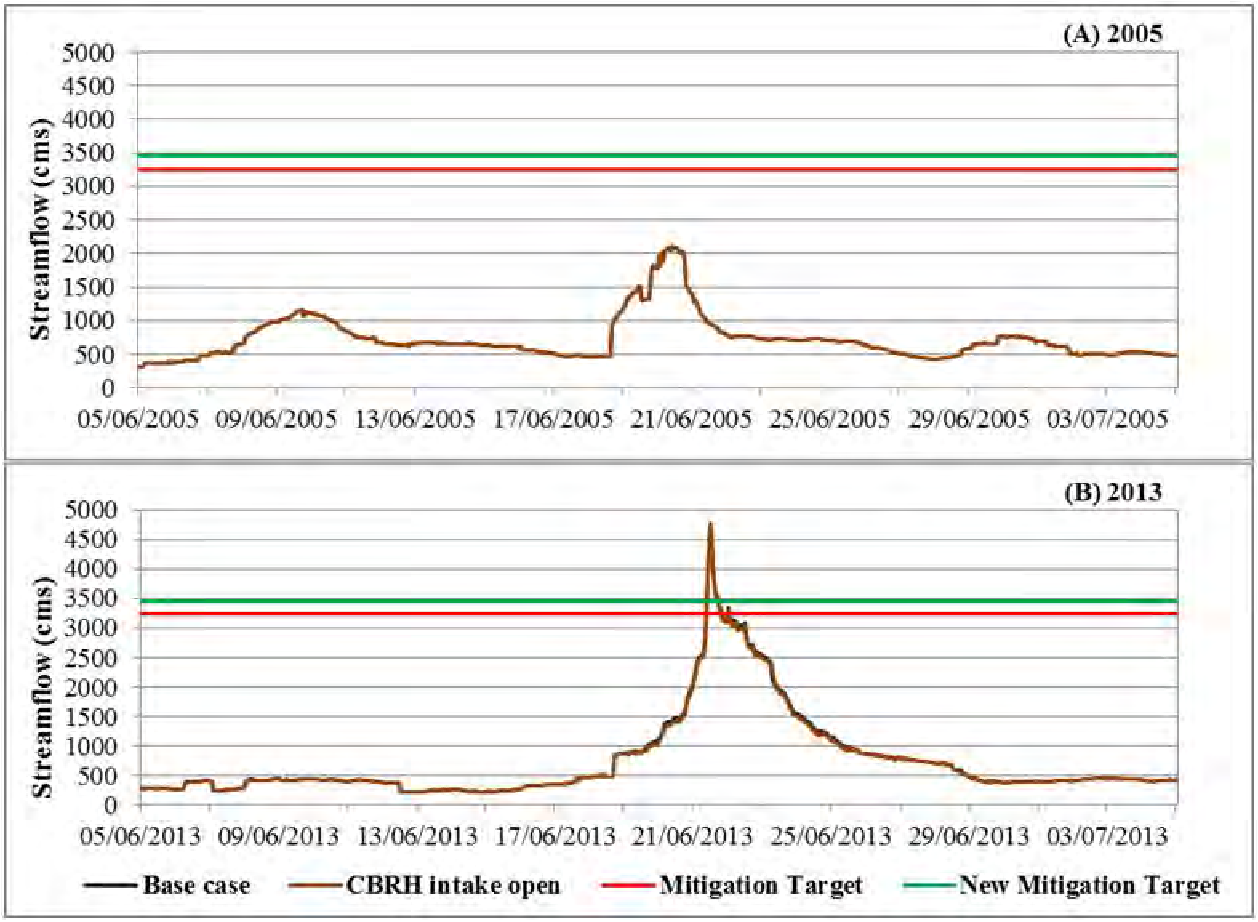

Figure 14: Comparison of streamflow in the Bow River at Bassano between base case and keeping the CBRH intake open through debris control in (A) 2005 and (B) 2013. Note: the lines are over-plotted.

The extreme turbidity of flood water makes it undesirable to take this water into the canal, but on the other hand the current situation is also hard on the canal, because the rapid drop in the canal water level when the intake becomes clogged causes slope failures. It would be up to ESRD, who owns the canal, to decide if this were acceptable relative to other risks of damage downstream.

The best way to divert debris away from the intake would probably be to construct one or two rock spurs just upstream of the intake, to direct the debris toward the middle of the channel, where it would be carried over the weir. This may also be beneficial to the fishery, under a wide range of flow conditions; one fisheries biologist has suggested that many of the small fish that are entrained in the canal are probably newly hatched fry drifting with the flow. Such fish might be diverted away from the canal intake by spurs. The cost of one or two spurs should be relatively small, so even though the benefit will be limited, this may be cost-effective. This could be modelled in the BROM by eliminating the current restriction on the Carseland diversion at high flows. The biggest potential benefit would likely be seen at Bassano Dam and Medicine Hat, so the model of the entire SSRB would be required to demonstrate the latter benefit; the full model will not be available until the fall of 2014.

Change location of Johnson’s Island dike

One specific suggestion arose that illustrates the need to explore alternative solutions. This was the option related to changing the location of Johnson’s Island dike to allow a more natural flood flow.

At the Carseland diversion, there is a concrete weir across the south channel of the river, a large dike across Johnson’s Island, and a fuse plug (a section of dike made primarily of gravel, designed to wash out rapidly once it is overtopped) across the north channel (Figure 15).

Figure 15: Aerial photograph of Carseland diversion showing dike across Johnson’s Island

The fuse plug had a crest elevation a bit lower than the top of the dike so that a large flood would wash out the fuse plug to allow flow in the north channel without damaging the dike. This is what happened in 2013, and once the fuse plug was gone, all of the flow was going down the north channel, with no water over the weir. It was extremely challenging to block the north channel with a cofferdam, restoring flow over the weir and into the canal after the flood. A new fuse plug is now being built behind the cofferdam, which will essentially restore the pre-flood condition.

The only apparent value in the large dike across the island is that it prevents flood damage to the north abutment of the weir by preventing flow adjacent to it, which is critical. It might be better to remove this dike and instead build a dike that would wrap around the end of the weir to protect the abutment, as well as blocking the north channel with a berm that would be more solid than the fuse plug. This would allow the river to flow over the island during floods, as it would have prior to development, rather than building up to an extreme depth and then washing out the fuse plug. This is an example of where a more natural solution may be better.

Assess value of dredging Ghost Reservoir

Also related to the operation of TransAlta reservoirs for flood control was the question of whether lost storage capacity could be regained by dredging the reservoirs to remove the sediment and aggregate that have accumulated over many years. Dredging was put forward as perhaps a more cost-effective means of gaining storage in the headwaters when compared to raising existing structures or building new structures.

Ghost Reservoir was presented as a specific example where this opportunity should be investigated. While this was not discussed in detail, TransAlta did indicate its position that dredging Ghost Reservoir would regain little capacity in the live storage. The City of Calgary recently shared the results of a study it commissioned to determine if dredging Glenmore Reservoir would significantly improve downstream flood mitigation. Its conclusion was that dredging would have negligible flood mitigation benefits.

Dry dam west of Bearspaw Dam (BR1)

This option is a 25.4 m high dry dam with a capacity of 48,500 cdm on the Bow River upstream of the existing Bearspaw Dam (blue triangle 196 in Figure 16). It is quite far downstream in the Bow system and thus could potentially mitigate high rainfall events in various headwater catchments. The dry dam would be used to attenuate flows greater than 1225 cms in the Bow River.

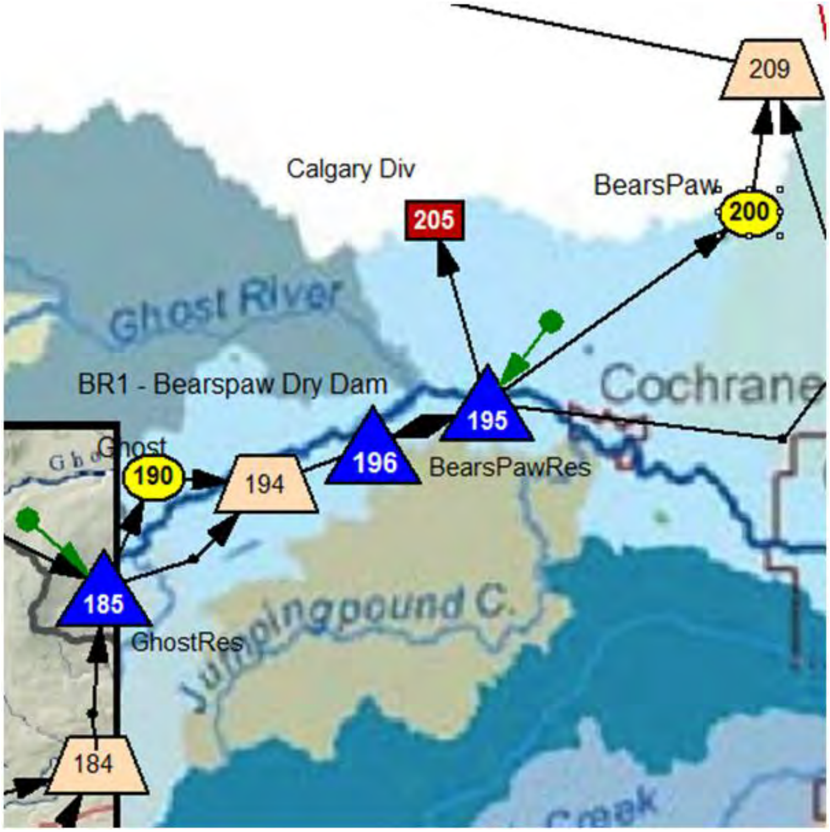

Figure 16: General location for possible Bearspaw dry dam (node 196) ***(not to scale and not intended to suggest specific sites)***

Use of the dry dam BR1 reduced flows in the Bow River upstream of the Elbow confluence by 510 cms in the 2013 modelled scenario, and did not affect peak flows in the 2005 modelled scenario (Figure 17). However, it is very unlikely that new infrastructure of this magnitude would be built before optimizing the mitigation potential of existing infrastructure, in particular the Ghost Reservoir just upstream of this identified dry dam site. The mitigation value and impact on flow through Calgary of this option would be reduced if Ghost Reservoir were first operated for flood control.

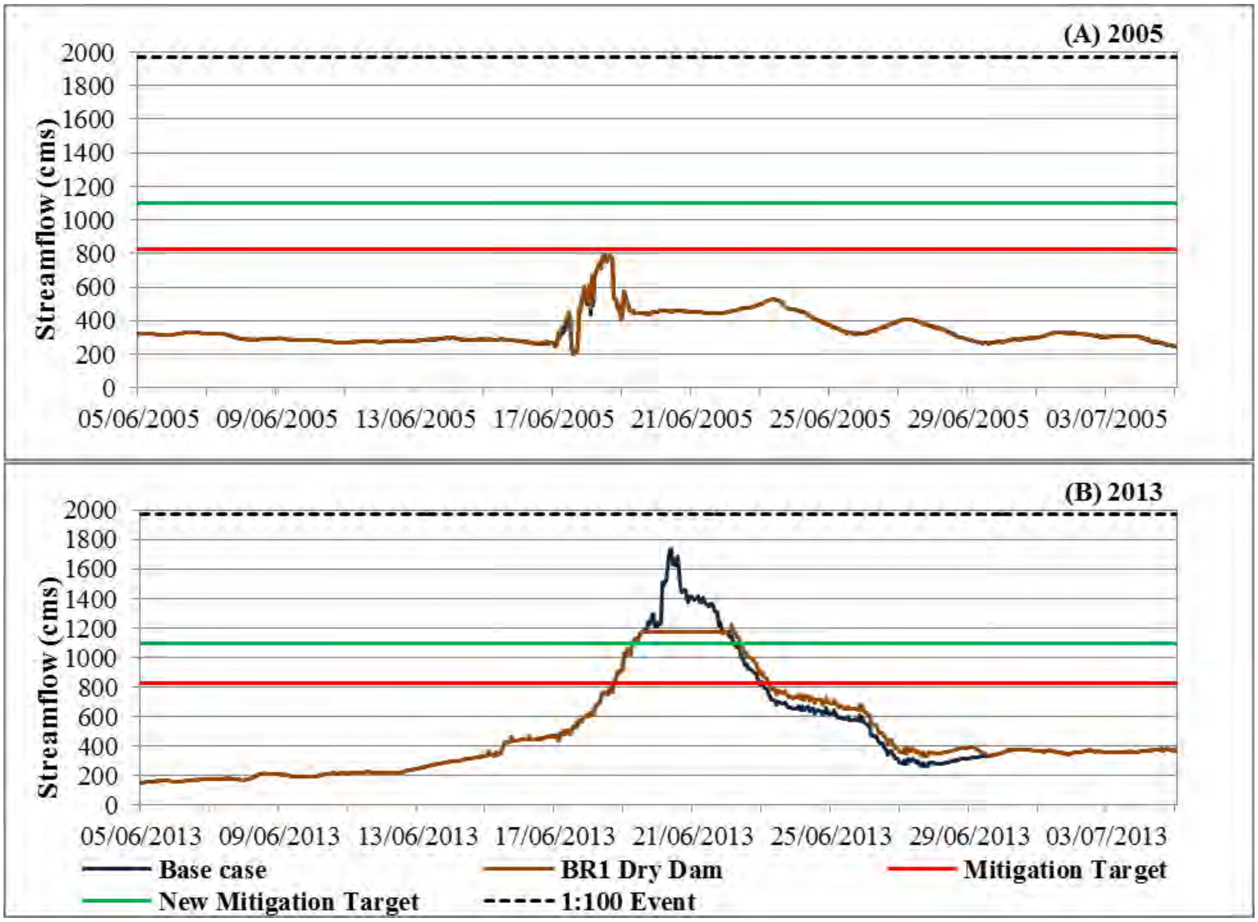

Figure 17: Comparison of streamflow in the Bow River upstream of the Bow-Elbow confluence between base case and a dry dam west of Bearspaw Dam (BR1) for flood control in (A) 2005 and (B) 2013

This option is located in or near Glenbow Provincial Park and if it proceeded, it would affect wildlife and recreational corridors, riparian areas, and the CPR rail line. There is a lot of development pressure in this area, both upstream in Cochrane and downstream on the western edge of Calgary which could also pose a conflict.

As with any dry dam, there are issues related to public safety, debris management, and ecological impacts. Participants stressed the need to fully understand post-flood event releases, especially if multiple dry dams are releasing water at the same time. Again the participants emphasized that new infrastructure of this magnitude should not be built before optimizing the mitigation potential of existing infrastructure.

Dry dam on Ghost River (BG1)

This option is a 39.6 m high dry dam with capacity of 62,800 cdm, located on the Ghost River upstream of the Benchlands and Waiparous communities (blue triangle 182 in Figure 18). The intended function is to attenuate flows greater than 205 cms in the Ghost River. The Ghost River has a relatively small catchment area and in the upper reaches, the river disappears under a huge boulder field, so a dry dam could be circumvented by underground streaming depending on its depth, its location, and its construction method.

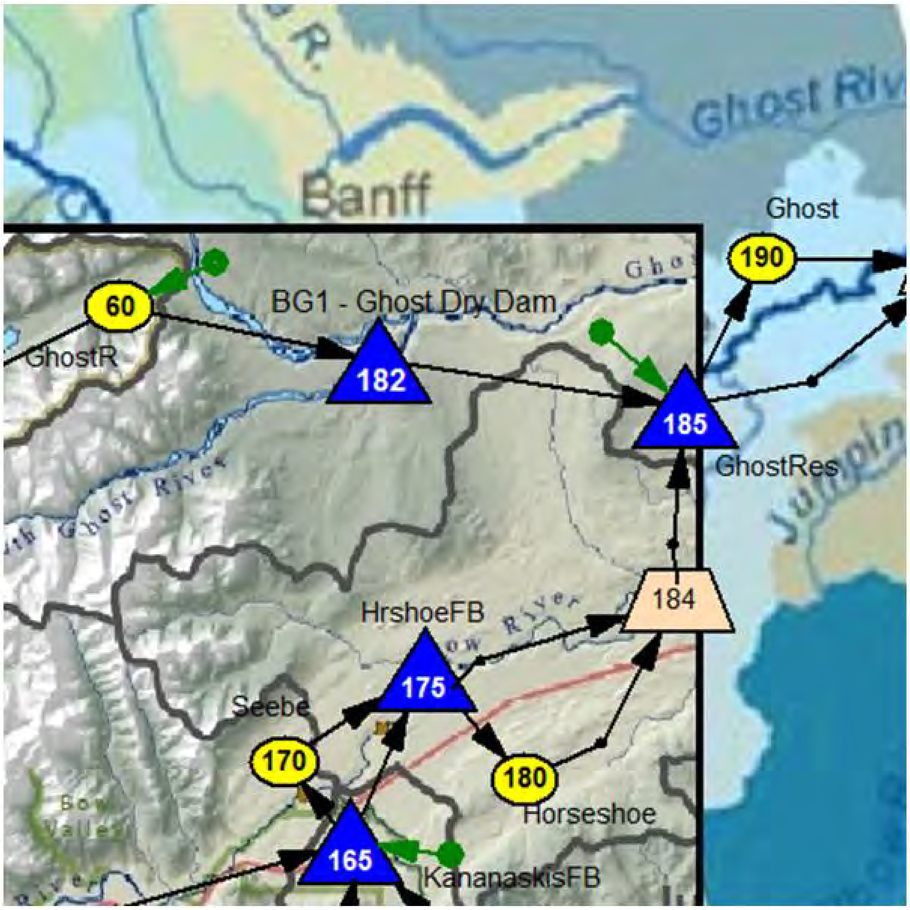

Figure 18: General location for possible Ghost River dry dam (node 182) ***(not to scale and not intended to suggest specific sites)***

Use of the dry dam BG1 reduced flows in the Bow River upstream of the Elbow confluence by 375 cms in the 2013 modelled scenario, and did not affect peak flows in the 2005 modelled scenario (Figure 19).

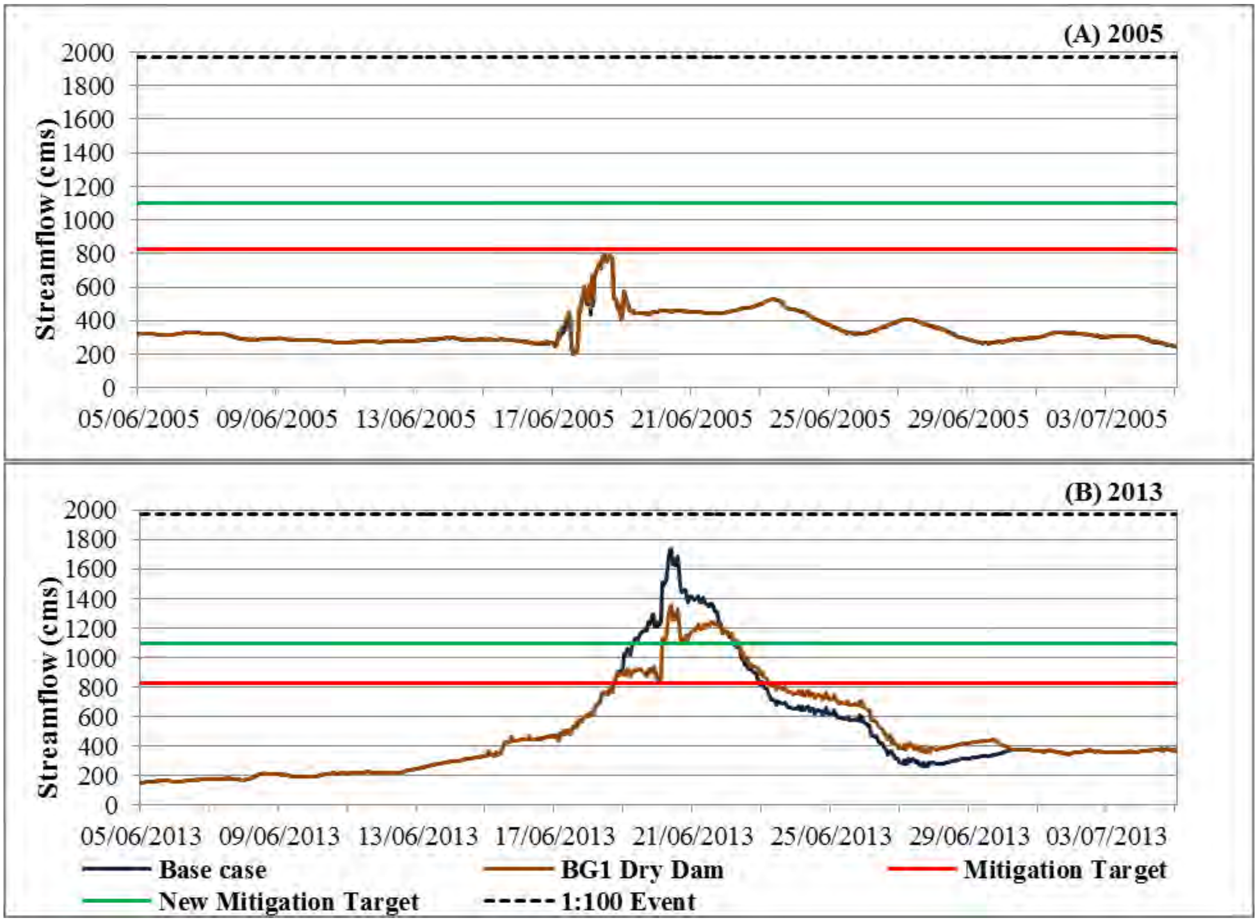

Figure 19: Comparison of streamflow in the Bow River upstream of the Bow-Elbow confluence between base case and a dry dam on the Ghost River (BG1) for flood control in (A) 2005 and (B) 2013

In the 2013 event, rains fell heavily in this area, which increases the appeal of this option for capturing water. However, in other events, rain may fall in different parts of the catchment, reducing the flood mitigation value of infrastructure in this location. Placing such options lower in the system increases the catchment area. If dry dams are to be built and used intermittently, public safety for campers and hikers could become an issue if the dams fill quickly. Other issues relate to debris management and ecological impacts, all of which should be carefully considered in a cost-benefit analysis.

Dry dam on Waiparous Creek (BW1)

This option is a 38,000 cdm, 40 m high dry dam on Waiparous Creek upstream of the Hamlet of Waiparous (blue triangle 183 in Figure 20). It would be used to attenuate flows greater than 40 cms in Waiparous Creek.

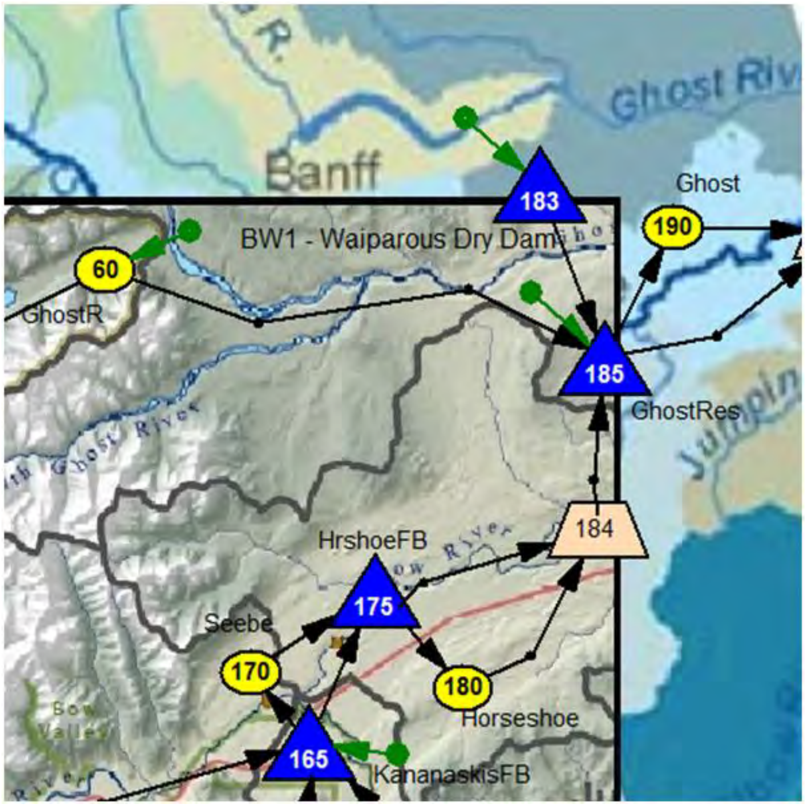

Figure 20: General location for possible Waiparous Creek dry dam (node 183) ***(not to scale and not intended to suggest specific sites)***

Use of the dry dam BW1 reduced flows in the Bow River upstream of the Elbow confluence by 78 cms in the 2013 modelled scenario, and did not affect peak flows in the 2005 modelled scenario (Figure 21).

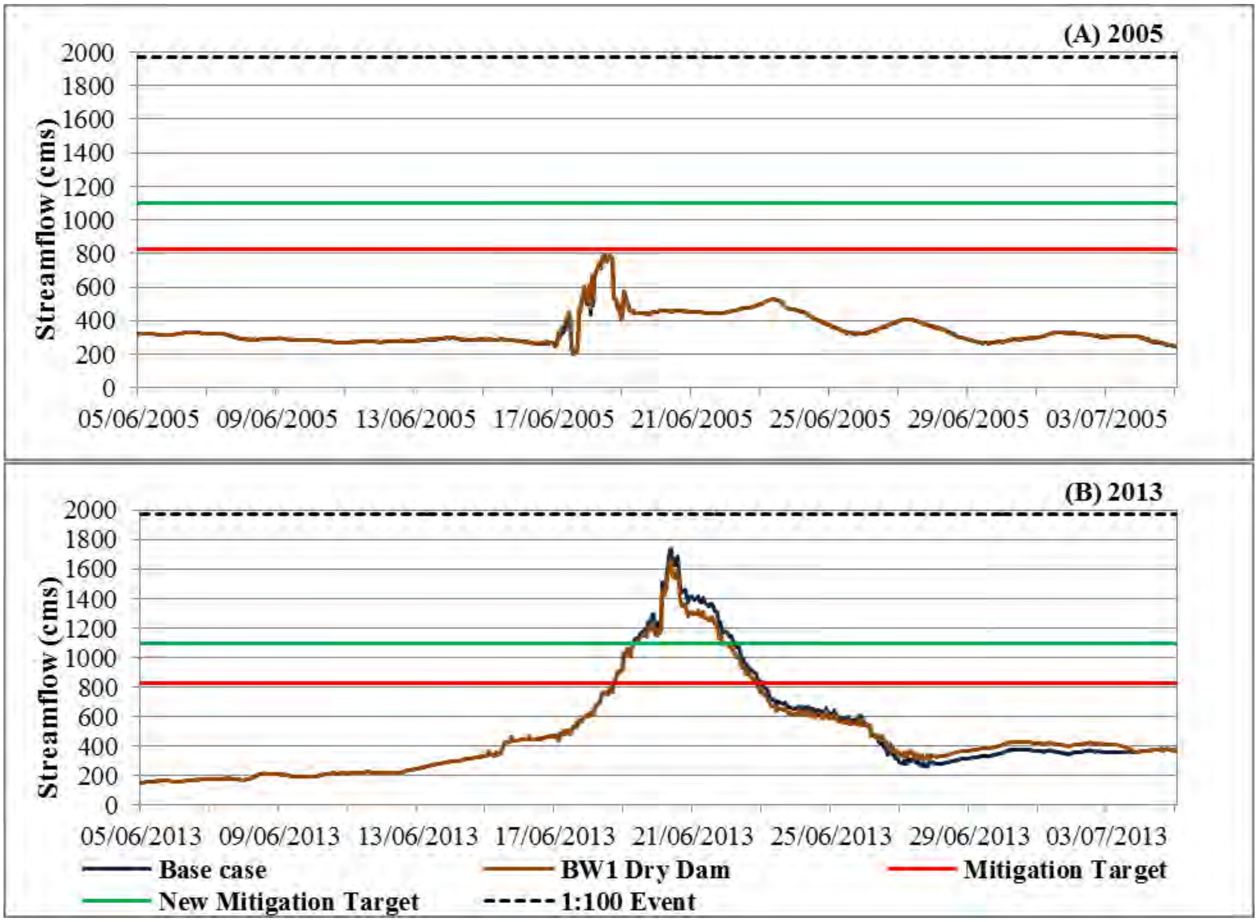

Figure 21: Comparison of streamflow in the Bow River upstream of the Bow-Elbow confluence between base case and a dry dam on Waiparous Creek (BW1) for flood control in (A) 2005 and (B) 2013

The proposed location for this structure is in a popular recreation area with valued ecosystems. A dry dam here would have major ecological and recreational impacts, which raise important but different questions. Clarification would be needed as to what recreational activities would be allowed around such structures, which would also change access to the area. Any time a permanent structure is put on a water body, it affects fisheries, mostly negatively. In the Waiparous area, westslope cutthroat trout is a species at risk that could be affected by this particular structure. Compensatory mechanisms add cost, permitting delays and operational challenges to any dam.

Dry dam between lower Kananaskis Lake and Barrier Reservoir

This option is a 50,000 cdm capacity dry dam upstream of Barrier Reservoir on the Kananaskis River (blue triangle 151 in Figure 22). Specific dimensions or locations for this facility were not provided. The dry dam would attenuate flows greater than 160 cms in the Kananaskis River.

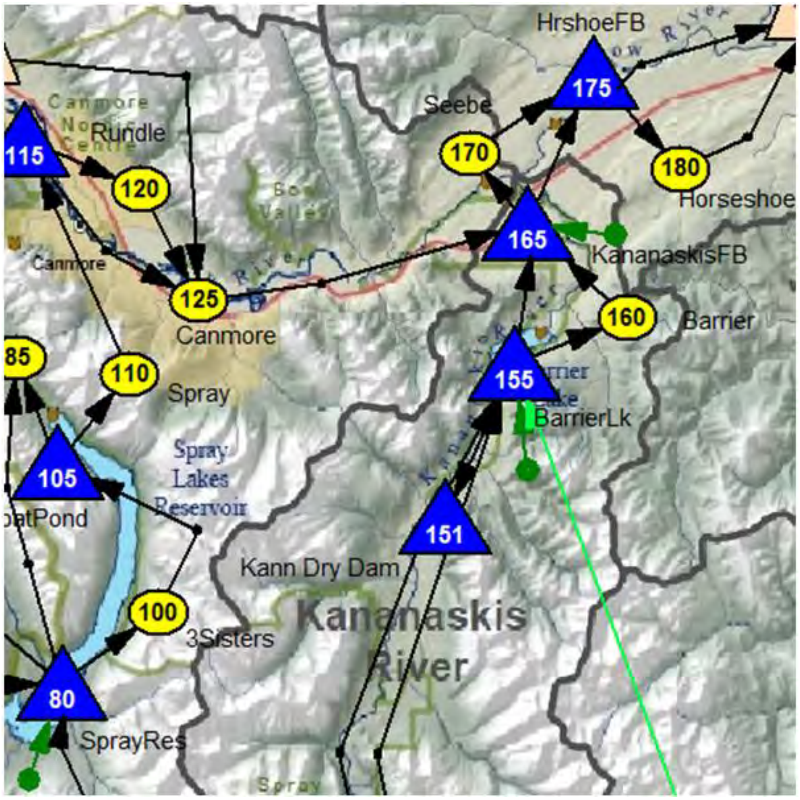

Figure 22: General location for possible Kananaskis dry dam (node 151) ***(not to scale and not intended to suggest specific sites)***

Use of the Kananaskis dry dam reduced flows in the Bow River upstream of the Elbow confluence by 143 cms in the 2013 modelled scenario, and did not affect peak flows in the 2005 modelled scenario (Figure 23).

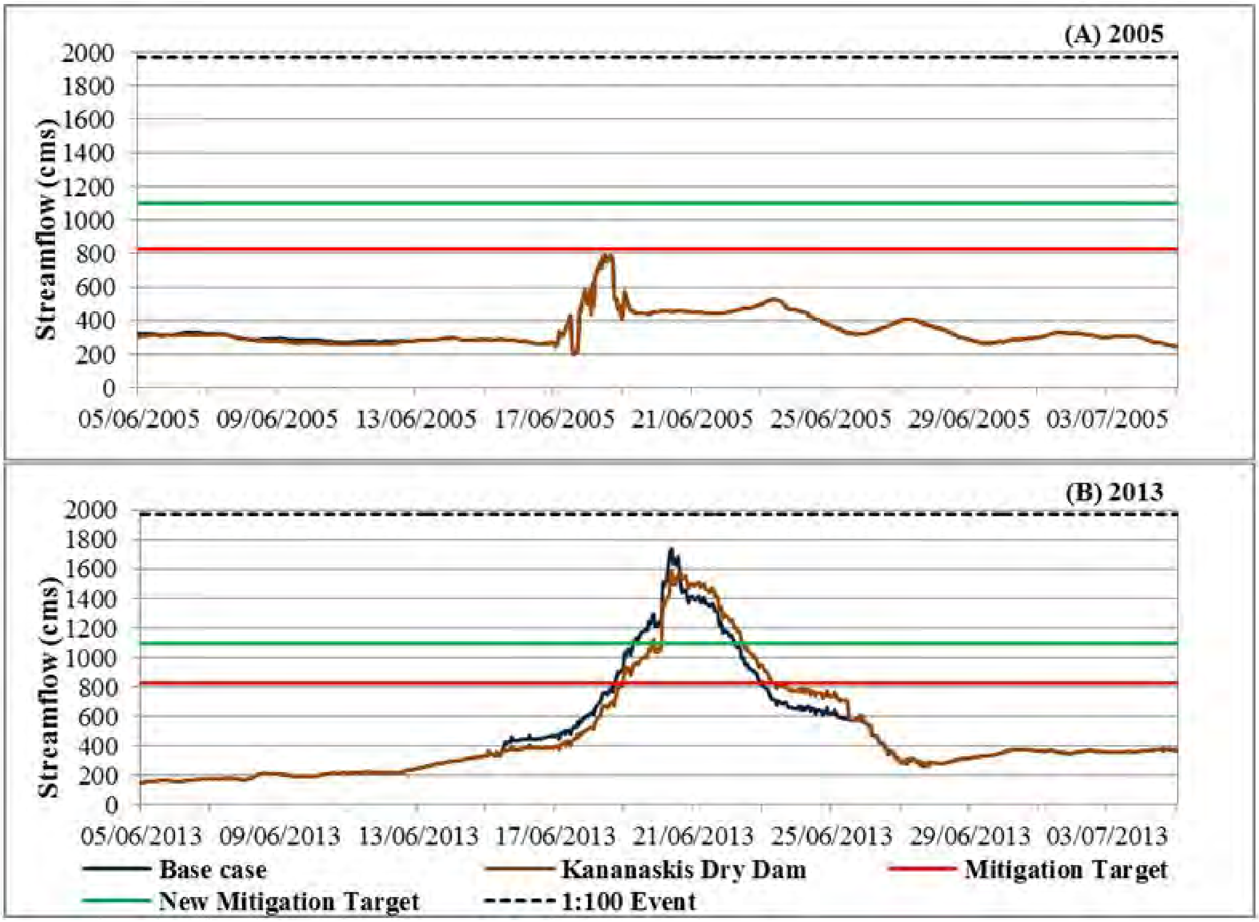

Figure 23: Comparison of streamflow in the Bow River upstream of the Bow-Elbow confluence between base case and a dry dam between lower Kananaskis Lake and Barrier for flood control in (A) 2005 and (B) 2013

As with any dry dam, there are issues related to public safety, debris management, and ecological impacts. Participants stressed the need to fully understand post-flood event releases, especially if multiple dry dams are releasing water at the same time. This option would need to be compared with potentially raising Barrier Reservoir and dike system to whatever elevation would equal this amount of temporary storage or more with potentially fewer environmental and other impacts.

Full service dam downstream of Bassano Dam ("Eyremore Reservoir")

The concept of storage on the lower part of the Bow main stem has been explored in prior work. It was identified as a potential flood mitigation option should some of the potential new storage be held as freeboard to capture high flows. In effect, part of the dam would function as a dry dam to reduce flows through Medicine Hat. A summary of the prior work is presented below. It was not explored in the working sessions of this project.

In 1977, the former Prairie Farm Rehabilitation Administration, a federal government agency, examined the option of onstream storage at the Eyremore dam site about 10.5 km north of secondary highway 539.[12] Storage capacities considered at the time (from 627,000 acre-feet to 1.6 million acre-feet) would have made this reservoir far larger than any existing reservoirs in the Bow Basin.

In the SSRB Adaptation to Climate Variability Project, Phase II,[13] Eyremore Reservoir was raised as a potential strategy to capture flows at the lower end of the Bow River system which could then be released to meet the environmental needs of the lower river as well offer potential flow augmentation and flood mitigation benefits to downstream users. For the purpose of the project, the model assigned to Eyremore was:

- Maximum live storage of 250,000 acre-feet (308,300 cdm)[14],
- A minimum flow of 1000 cfs (28.3 cms) leaving the reservoir when storage is available (400 cfs if Eyremore emptied), and
- A 100 cfs requirement that must be passed to Eyremore from Bassano dam.

Eyremore had a number of benefits to the river system and to water users. It reduced the number of days of shortage for all irrigation districts across the 30-year period of record and substantially improved the flows below Bassano Dam and downstream, by the release from Eyremore of 1,000 cfs flows. With Eyremore positioned below Bassano, it eliminates the Eastern Irrigation District's (EID) responsibility for ensuring the 400 cfs flows below Bassano are met. The flow below Bassano can now be met with stored water. Eyremore also affects BRID, which no longer needs to pass as much water through to EID. This strategy also reduces the number of river calls, which increases the amount of time TransAlta can store water, and similarly reduces the number of low flow days for Calgary.

Eyremore Reservoir would capture water further downstream, levelling out peaks and eliminating the need to calculate time of travel from Bearspaw in keeping downstream flows healthy. It would catch any additional releases by TransAlta, thus creating opportunities and flexibility to use this water below the reservoir, for example, to pulse flows in support of riparian health. Eyremore could potentially assist with flood control at Medicine Hat and could benefit the Oldman system by a) relieving pressure to supply minimum flows through Medicine Hat, and b) helping to meet the 50% apportionment requirement in dry years.

Potential disadvantages to this strategy include that it represents additional onstream storage which, among other environmental impacts, disrupts aquatic ecosystem function, and that the capital costs and time required for construction would be significant.

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[12] The exact location considered by PFRA was Section 14, Twp 18, Range 18, W4M, at 50 deg, 31 min Lat, 112 deg, 23 min Long.

[13] The report from this project is available by searching on the Alberta WaterPortal at http://www.albertawater.com/.

[14] 1 acre-foot (AF) = 1.233 cdm; 1 cubic foot/second (cfs) = 0.0283 cms.

7.2 Elbow River System

Approximately two-thirds of Calgary's flood damage risk is on the Elbow River because it has more encroachment in the flood plain, while the Bow is largely set back. This raises discussion of the importance and relative cost-effectiveness of planning and relocation to reduce encroachment in the flood plain. A number of the mitigation options considered for the Elbow River focused on mitigating peak flows through Calgary during flood events, but also considered what mitigation the options might offer to upstream communities.

Operate Glenmore for flood control

In the 2013 event, Glenmore Reservoir (Figure 24) was lowered by about 3.7 m below the crest prior to the flood, and then filled up to 1077.54 m. This attenuated the approximately 1200 cms inflow down to an outflow of 700 cms. The modelling scenario allowed Glenmore Reservoir to be lowered 4.0 m below crest and to fill to 1077.54 m.

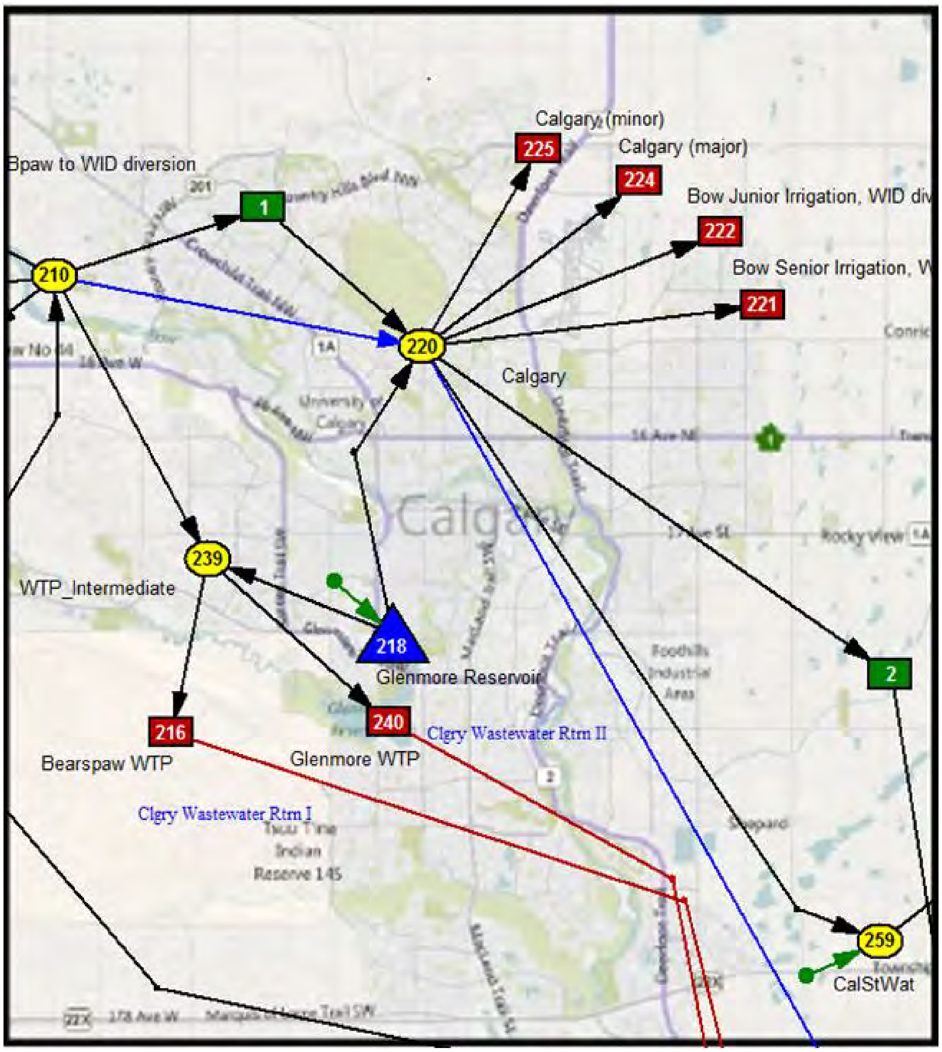

Figure 24: Modelled location of Glenmore Reservoir (node 218) *(not to scale)*

Operating Glenmore Reservoir for flood control reduced flows in the Elbow River by 199 cms in the 2005 modelled scenario and by an additional 20 cms relative to the ~500 cms reduction already achieved in 2013 (Figure 25). This demonstrates that operators did an outstanding job of managing Glenmore Reservoir for flood control in 2013. However, it was noted that the Reservoir reached full capacity so for the last half of the flood event, outflows nearly equalled inflows. Had the storm event lasted longer, Glenmore would have been able to offer very little to attenuate the flood flows as the outflows would have had to equal the inflows.

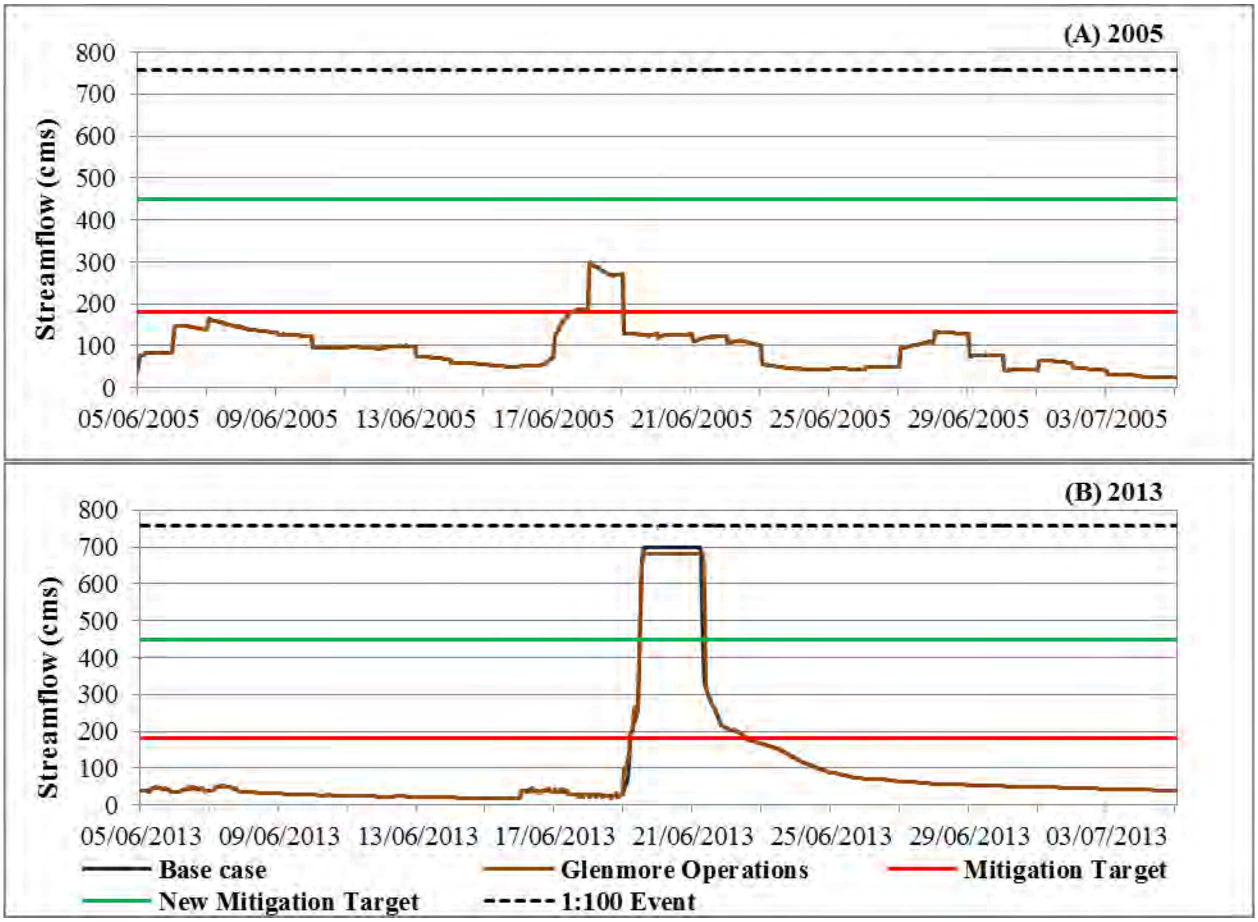

Figure 25: Comparison of streamflow in the Elbow River downstream of the Glenmore Reservoir between base case and operating Glenmore for flood control in (A) 2005 and (B) 2013

Glenmore Reservoir was built to supply water, not to attenuate floods, but proactive management in the 2013 event was nevertheless very effective. Levels cannot currently go below 4 m as this would compromise the causeway and jeopardize drinking water supply intake. In the longer term, infrastructure changes might be considered to raise Glenmore dam crest elevation or lower the intakes; but this could lead to safety concerns, and the cost of a major rebuild would need to be compared to other mitigation alternatives. Changing stop logs might allow reservoir capacity to go up by about six million cubic metres (1.5 m elevation), but their function is unclear in flood conditions with concern about the potential for overtopping and safety issues. A major capital project would be required to replace the existing stop logs with operable gates. The gates could allow for additional storage in the reservoir, which would add to the reservoir attenuation capacity for flood events.

If Glenmore Reservoir had not been aggressively lowered in 2013, and only filled to the natural crest before passing inflows, flows downstream would have been much higher, as seen in Figure 26.

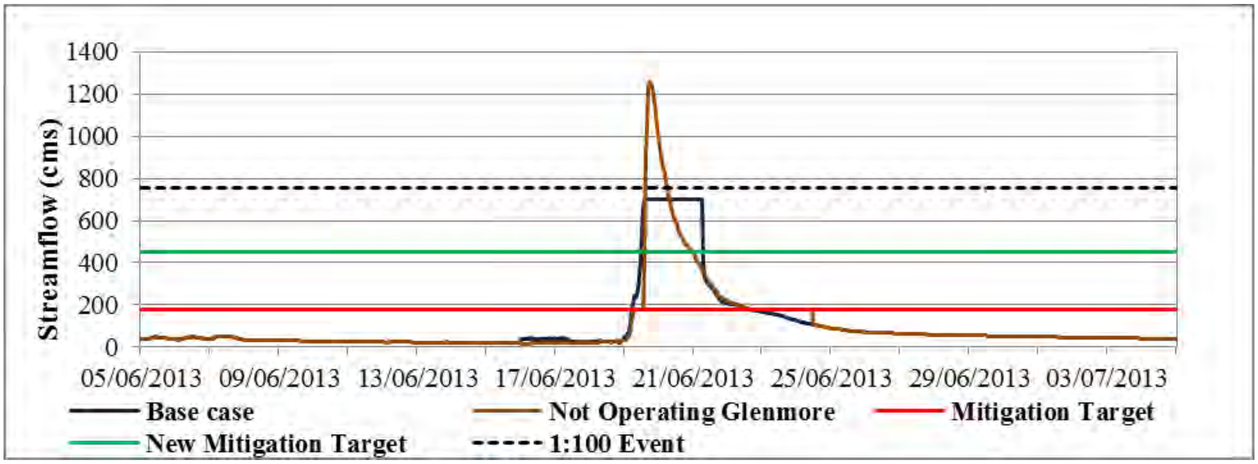

Figure 26: A comparison between the 2013 base case and not operating Glenmore Reservoir as it was done in 2013

Diversion from Glenmore to Bow River under 58th Avenue

This diversion – a long, mostly bedrock tunnel – would bypass the Elbow River through downtown Calgary, diverting flows directly from Glenmore Reservoir to the Bow River. It is conceived as an underground tunnel 8 to 10 metres in diameter with a vertical drop shaft inlet submerged below the normal operating level of Glenmore Reservoir. In this model run, the bypass had a 500 cms capacity to reduce the outflows from Glenmore into the Elbow River (Figure 27).

Figure 27: Proposed location for 58th Avenue diversion in Calgary

Use of the bypass reduced flows in the Elbow River by 120 cms in the 2005 modelled scenario, and by 500 cms in the 2013 modelled scenario (Figure 28).

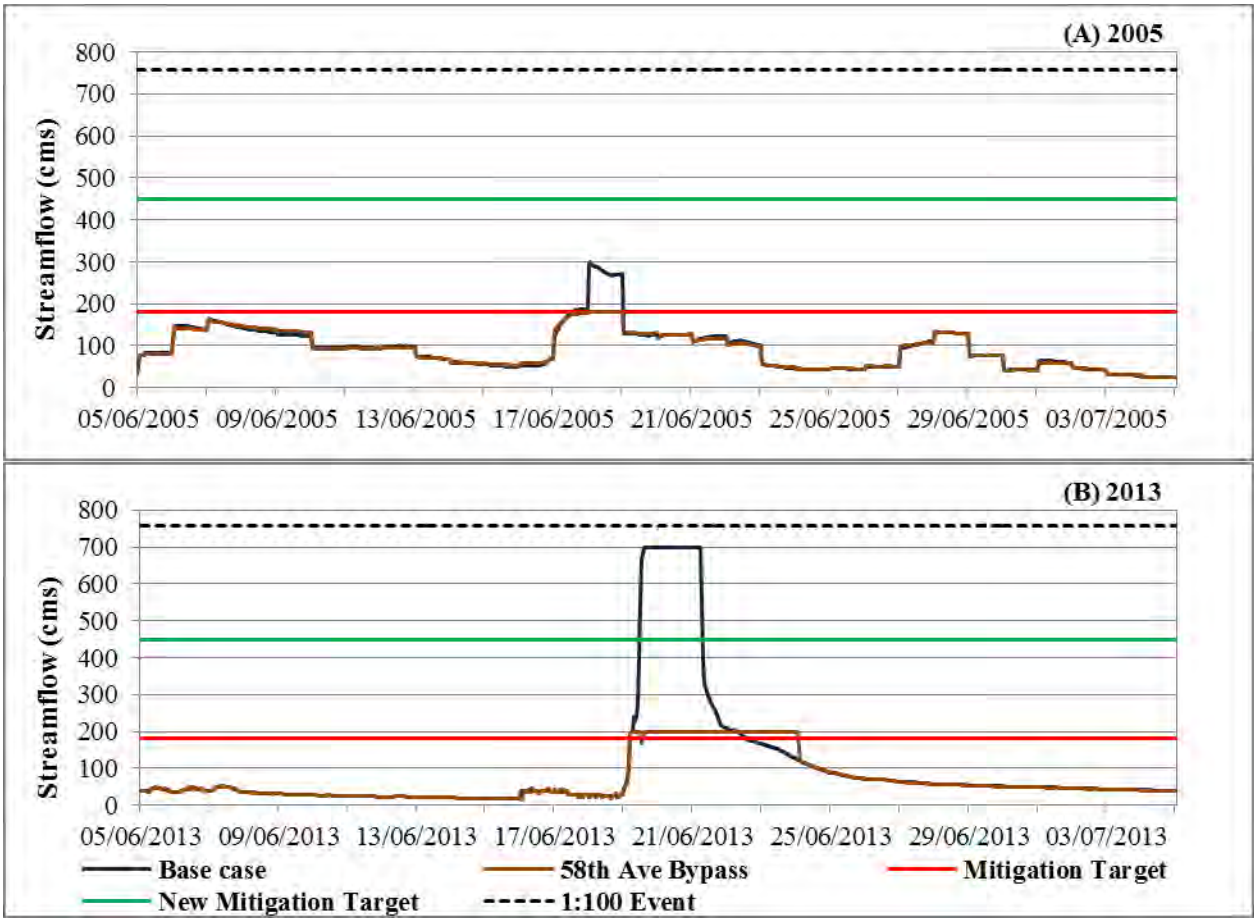

Figure 28: Comparison of streamflow in the Elbow River downstream of the Glenmore Reservoir between base case and a 500 cms diversion in (A) 2005 and (B) 2013

In addition to the cost and the extended period of disruption in a very busy part of Calgary for several years of construction, participants expressed a number of concerns about this proposed diversion. Water quality, local habitat impacts, and erosion concerns on the Bow at the outlet, even with dissipation measures are of concern. The part of Calgary that could be at risk from flooding (that is, the areas downstream of the tunnel outlet into the Bow River) has a number of sites that are likely contaminated from former uses and could be exposed and leached in a flood (e.g., former munitions plant, creosote factory, refinery, battery dump, auto wreckers, landfill). This option could affect subdivisions downstream in south Calgary (Deer Run, Riverbend, and others), potentially increasing their risk of flooding (depending on the timing of the peaks on the Bow and Elbow Rivers), making this option a solution for “part of Calgary,” not a full “Calgary” solution.

This tunnel would go under Deerfoot Trail and could affect the railway from a safety and construction standpoint. If installed at a relatively shallow depth, there could be underground fracturing, and many other detailed engineering issues would have to be safely resolved. A primary issue would be how to dissipate the flow’s energy before it gets to the Bow River. The energy dissipation requirements to slow the water in the tunnel before the outflow to the Bow are possible from an engineering perspective, but likely very expensive. Backwater effects would need to be well understood and managed to avoid the tunnel outlet creating a “wall” for the Bow River and backing flows coming down the Bow into flood-prone areas.

Downstream impacts could be significant. This diversion would not detain any flows; rather, it would pass flow that otherwise would have been slowed and detained as it flooded the local areas. If this option had been used in the 2013 event, some strongly believe that it could have bypassed enough additional flow through Calgary at the peak that would have destroyed Bassano Dam and increased flooding in Siksika and Medicine Hat. While many variables influence the timing and size of peak flows downstream, it was generally recognized that the impact of a diversion of this size would raise safety concerns for downstream infrastructure. Thus, if it were to be implemented, the spillway at Bassano would need to be increased and upgraded, and further mitigation added at Medicine Hat to address the increased downstream risks. These downstream options should be taken before the upstream diversion tunnel is constructed.

A positive aspect is that it would not likely affect Glenmore Reservoir operations beyond the normal flood flow operations. This tunnel option would likely be considered a measure of last resort for Glenmore. Perhaps it could be operated with a low level valve for use at lower stages although vortices and other issues may require a control mechanism at the downstream end of the tunnel. Water quality dependencies for the outlet on the Bow River are unclear. This is also known to be a rather expensive option and provides no benefits upstream of the Glenmore Reservoir, which may be a concern for locations upstream on the Elbow River. A more detailed engineering study of the feasibility and cost of the tunnel is underway.

Priddis Creek area diversion(s) upstream of Bragg Creek to Fish Creek with small reservoirs

This option includes a number of measures that build on the natural topography of the Elbow River before it reaches Calgary. It includes a bypass through Priddis Creek to Fish Creek with a capacity of 345 cms (see Figure 29). Very preliminary estimates suggest that a 345 cms diversion would require a channel about 50 m wide and 3 m deep, to accommodate flow depth of ~1.7 m plus an additional ~1 m of freeboard in case of blockages. It would likely have a riprap armour lining with an average diameter of about 500 mm. In the modelling, it was assumed that 35% of total streamflow to Glenmore Reservoir would be available at the intake. In addition to the diversion, a small (~250 cdm capacity) new reservoir upstream of the diversion (node 213; Figure 29), and two dry dam storage sites of ~275 cdm capacity each on Priddis Creek (nodes 219 and 226; Figure 29) were included in the model run, as well as utilizing wetland storage on both the Elbow River and on Priddis Creek.

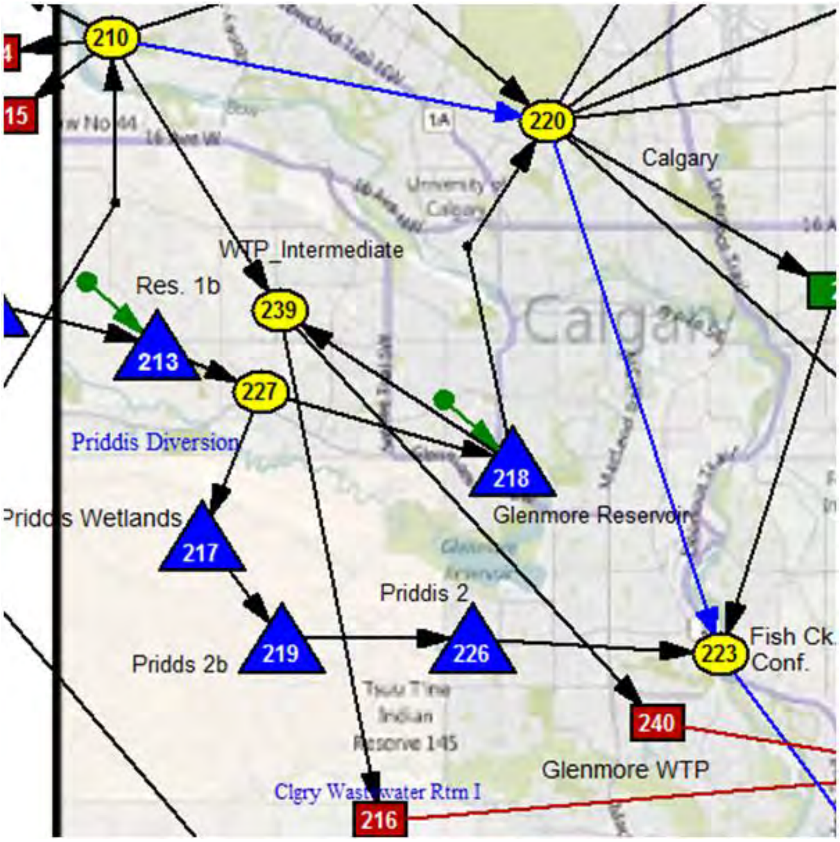

Figure 29: General location for possible Priddis Creek diversion and associated storage sites *(not to scale and not intended to suggest specific sites)*

Use of the Priddis Diversion and associated storage sites reduced flows in the Elbow River by 107 cms in the 2005 modelled scenario, and by 325 cms in the 2013 modelled scenario (Figure 30).

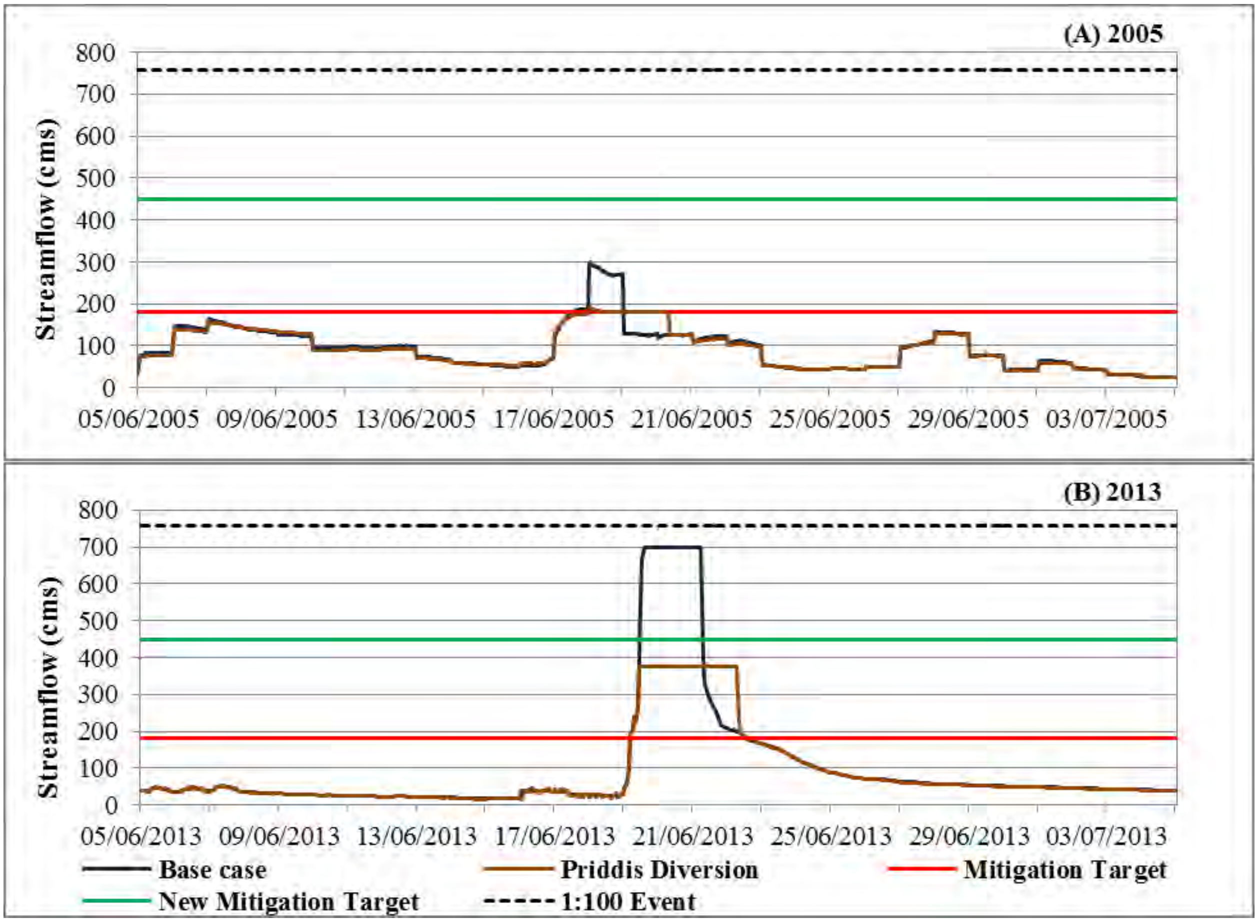

Figure 30: Comparison of streamflow in the Elbow River downstream of the Glenmore Reservoir between base case and including a Priddis Creek diversion run in (A) 2005 and (B) 2013

This option would take flows from the Elbow River and divert to the Fish Creek system. Under 2013 modelled conditions, the diversion would reduce Glenmore inflow by about 345 cms. There are advantages and disadvantages to this option. One negative is that a lot of water would be unnaturally added to this system. In 2013, flows peaked from 2 cms to 220 cms at Priddis. In a real event like 2013, high flows (probably about 200 cms) were already occurring and with additional diverted flow it could further overwhelm the natural capacity and ecosystem as a new oversized channel would be created. This diversion would raise significant concerns about effects on the area around the diversion, including the direct effect on nearly 500 landowners in the region, water supply for local communities, infrastructure impacts (roads, culverts, homes, recreation facilities, etc.), drainage, and groundwater impacts. Backwater impacts could include amplified erosion, and residence protection requirements would be costly. The Priddis Creek system already has drainage challenges as well as water quality and quantity issues. Any flood mitigation or storage options would need to consider the impact on area drainage, and how natural drainage may change as channels erode and move. These and other concerns are well understood and identified by the MD of Foothills.

Areas in this region (north of Bragg Creek) contribute to the main stem Bow and Elbow rivers and have experienced high wetland drainage and loss, which means faster runoff to both rivers, adding to peak flows. Wetland restoration done in partnership with landowners represents an opportunity during the implementation phase of Alberta's new Wetland Policy. Perhaps it could be plausible for municipalities that would benefit from such action to direct their wetland funds to this area and others to obtain more restoration and possibly more valuable locations for the same expenditure. Technical discussions leading to an appropriate wetland inventory are needed to properly see the degree of wetland loss and opportunity.

Participants raised many challenging issues in considering the Priddis Creek option on the Elbow, including:

- Operating goals, mitigation targets, and design elements should be considered early to inform the processes to develop and approve local mitigation activities.
- Land acquisition costs for any infrastructure will be a key factor.
- There will be trade-offs among stakeholders and infrastructure all along the system, including First Nations. Decision makers need to consider the matters of fairness, compensation, and relocation when it comes to transferring impacts from Calgary to others who might otherwise have been less or not at all affected. For example, the homes along the north side of the Elbow River will potentially be protected with a temporary barrier to avoid conveyance of large flows to the downtown Calgary core. This leaves the homes on the south side of the Elbow exposed to flooding, so the trade-off may be to protect Elbow south side homes or Priddis homes.
- A big concern is that Fish Creek Park suffered a great deal of infrastructure damage in 2005 and 2013 at 200 cms, so mitigation options need to consider the impacts of forcing a significantly higher flow through this system.

A positive for this option is that it would benefit Bragg Creek and other upstream communities, but as with other options the costs, benefits, risks, and trade-offs need to be examined. Abandoned irrigation canals and potential storage sites could possibly be used to disperse and get water from the Elbow to the Fish Creek system at lower flow rates to mitigate damages to Fish Creek but more detailed on-site evaluation is necessary to assess overall mitigation value.

Multiple historically identified detention sites

The model run that examined this option included three reservoirs, which were identified in previous flood mitigation studies (Figure 31):

- Reservoir Site D - Same location as EC1
  - 2097/4935/9870 cdm capacity at 21/30/45 m dam heights
  - Assume 10% of total inflow to Glenmore Reservoir would be available at the dam site
- Reservoir Site F – Unsure of exact location, assume upstream of McLean site (Figure 31)
  - 1629/4380 cdm capacity at 18/30 m dam heights
  - Assume 10% of total inflow to Glenmore Reservoir would be available at the dam site
- McLean / Priddis Site 1 – Upstream of Bragg Creek
  - 831/2024 cdm capacity at 25/46 m dam heights
  - Assume 65% of total inflow to Glenmore Reservoir would be available at the dam site

The reservoirs were operated to keep at an assumed normal pool elevation (i.e., operated as reservoirs to normally hold water), unless flows downstream of Glenmore would exceed the flood threshold, then water was allowed to be stored up to the maximum storage of each reservoir to attenuate flows downstream.

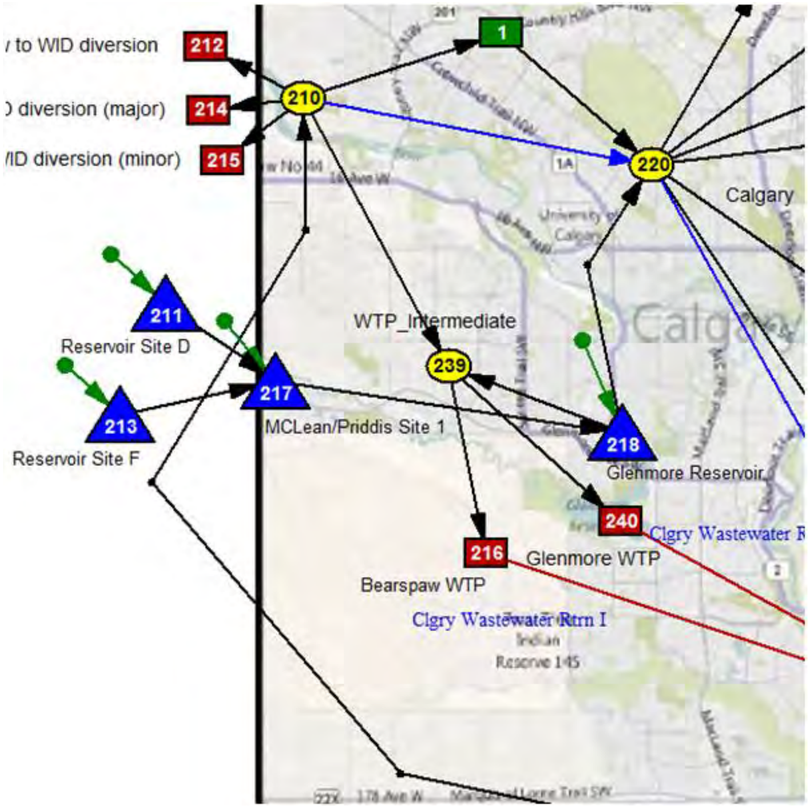

Figure 31: General location of historically identified detention sites (nodes 211, 213, and 217) ***(not to scale and not intended to suggest specific sites)***

Use of the historically identified detention sites for flood mitigation reduced flows in the Elbow River by 89 cms in the 2005 modelled scenario, and by 150 cms in the 2013 modelled scenario (Figure 32).

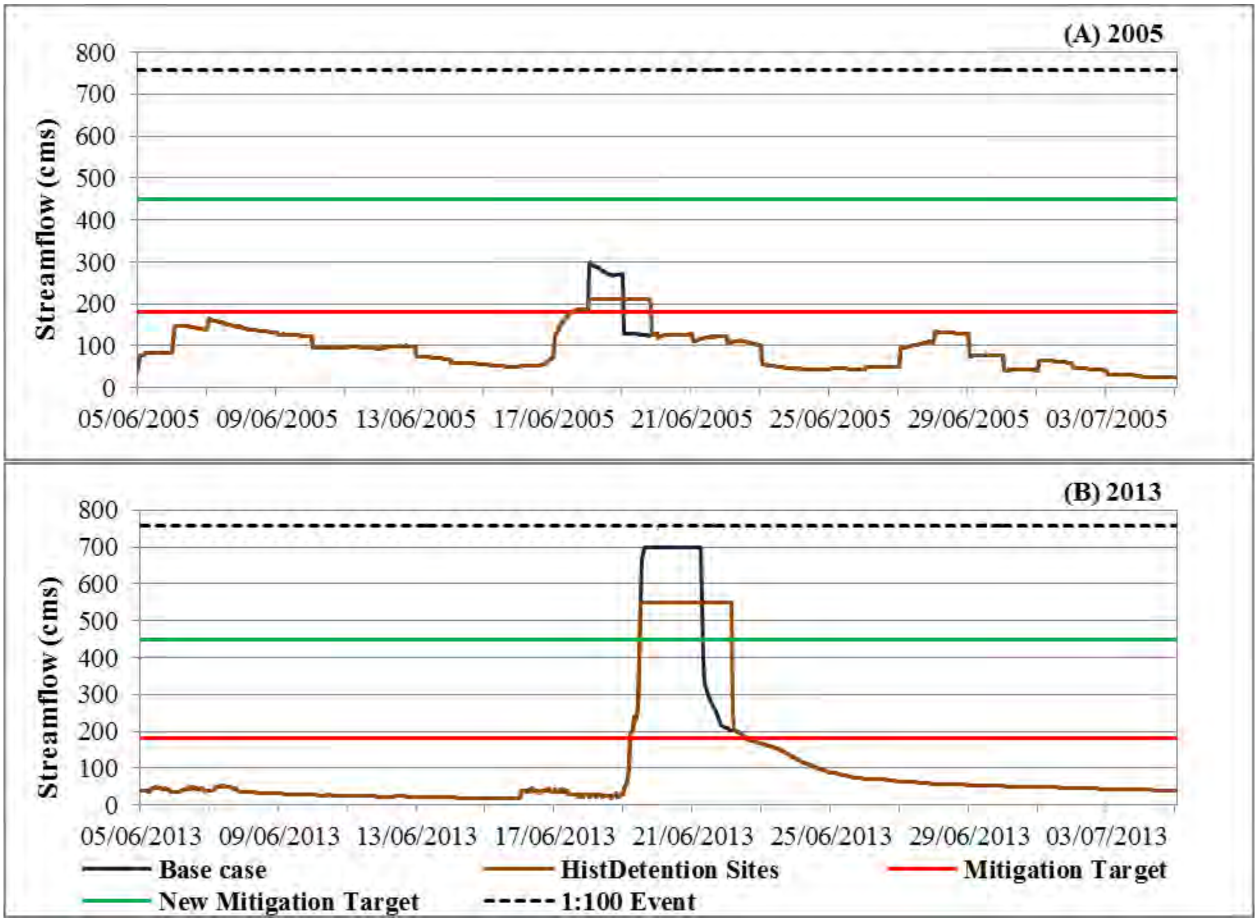

Figure 32: Comparison of streamflow in the Elbow River downstream of the Glenmore Reservoir between base case and including historically identified detention sites in (A) 2005 and (B) 2013

These locations are distributed throughout the watershed and are considered feasible for water detention. In the 2013 flood, they would have filled naturally to some extent and a closer look would be required to determine if any additional storage would have been available. In the 2013 modelled situation, Glenmore outflows would have dropped over 100 cms from 780 to 654 cms. In 2005, outflows went from 300 cms to about 230. This option has less effect on peak flows than some other options but may be less costly to build. It does not rely on a single large piece of infrastructure, but it does potentially transfer risk from urban landowners to rural landowners. They would likely be compensated but this adds a different aspect of cost and complexity compared with the risk and cost of alternatives. Disadvantages from an operations perspective are that more isolated sites will have higher operating costs; there will also be issues of access and safety. These sites would still be dammed and, like other options, need a full risk assessment and appropriate level of design and oversight.

Dry dam on Elbow River Main Stem at Quirk Creek (EQ1)

This option is a 45.6 m high dry dam facility on the Elbow River main stem at the junction with Quirk Creek, with a storage capacity of 70,279 cdm (blue triangle 213 in Figure 33). It would reduce the flow along the Elbow River upstream of Bragg Creek and, given its location, would capture inflow from 35% of the total catchment of Glenmore Reservoir. The dry dam was modelled to attenuate flows greater than 50 cms.

This proposed site appears to have been assessed in the 2008 report, *Assessment of Potential Water Storage Sites and Diversion Scenarios* prepared by MPE Engineering for Alberta Environment, which looked at potential water storage and diversion sites. EQ1 appears to match site 76 Ford Damsite Elbow River Project. While that study was considering sites for full service dams with some different requirements and purposes to a dry dam, it was ranked low (C out of A, B, C), scoring low on supply/demand, dam safety consequence, and geotechnical criteria. The considerations noted were: near provincial protected area, difficult cutoff, and upstream of Bragg Creek and the City of Calgary. Current work by the Task Force’s engineering consultants appears to be assessing other potential sites including just upstream of the confluence of the Elbow River and McLean Creek, in the McLean Creek Recreational Area of Kananaskis Country.

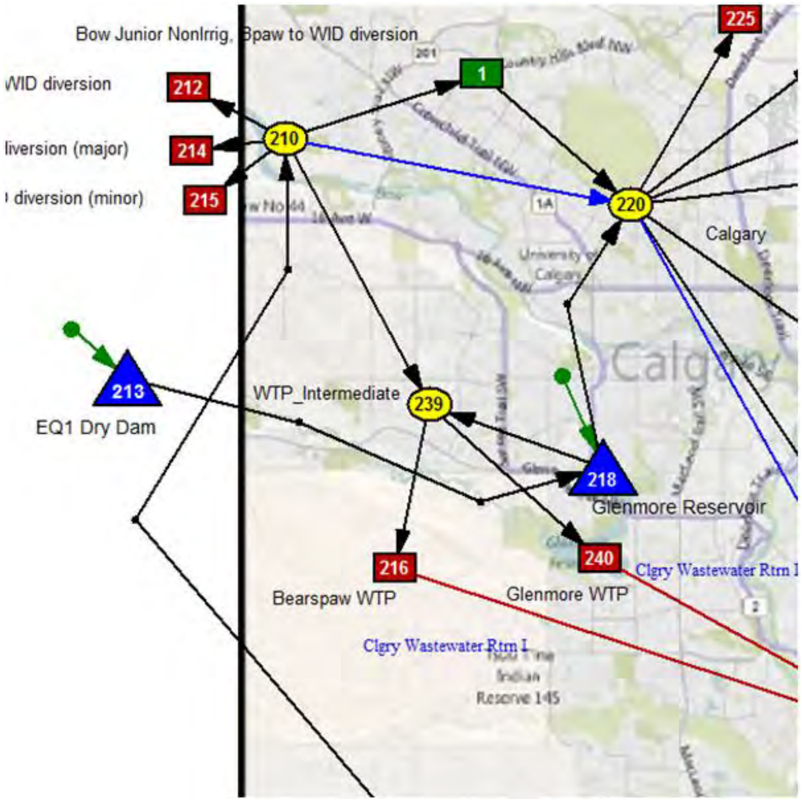

Figure 33: General location for the EQ1 dry dam on the Elbow River Main Stem at Quirk Creek (node 213) ***(not to scale and not intended to suggest specific sites)***

Use of the dry dam EQ1 reduced flows in the Elbow River by 55 cms in the 2005 modelled scenario, and by 280 cms in the 2013 modelled scenario (Figure 34).

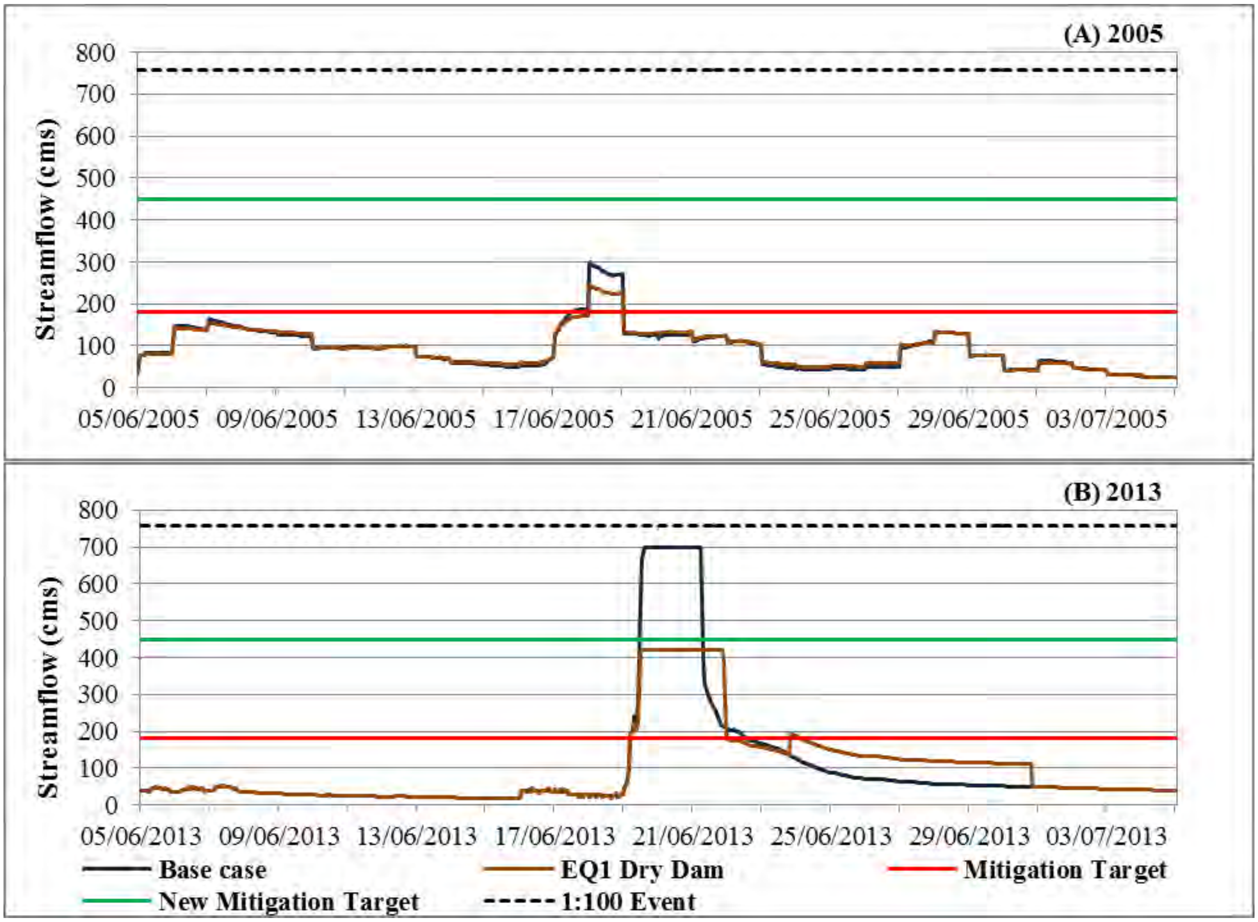

Figure 34: Comparison of streamflow in the Elbow River downstream of the Glenmore Reservoir between base case and a dry dam on Quirk Creek in (A) 2005 and (B) 2013

Like dry dams generally, this proposed option would affect fisheries and fish movement. If this dry dam backs water up to Quirk Creek and the Little Elbow, which seems likely, it may have a substantial impact on spring spawning fish, although large gates might help fish movement. It was noted that this stretch of the Elbow River accumulates massive amounts of gravel, sand, silt, and dead trees particularly during floods, which could quickly block the flow passage and impound water behind the dam. Subsequent slumping and logjams could then clog the spillway, potentially causing overtopping of the dam.

This dry dam would also have an impact on Cobble Flats day use area and any access from there when flooded. Some participants wondered if such a structure were to be built, whether it might be better as a “full service” dam to supply water for Calgary, Bragg Creek, Rocky View County, and the MD of Foothills. Storage high in the system increases the ability to address stress points through the whole system. At the same time, there is the question of whether EQ1 is too high in the system and if it would ever fill, thus limiting its flood mitigation potential. This site contains alluvial sediments, and a detailed geotechnical study would be essential to understand the groundwater dynamics of the area.

Dry dam on Canyon Creek (EC1)

This option is a 44.2m high dry dam detention facility with 12,206 cdm capacity, located on Canyon Creek about 4 km north of secondary Highway 66 (blue triangle 217 in Figure 35). It would attenuate flows greater than 20 cms in Canyon Creek upstream of Bragg Creek and capture 10% of the total streamflow to Glenmore Reservoir.

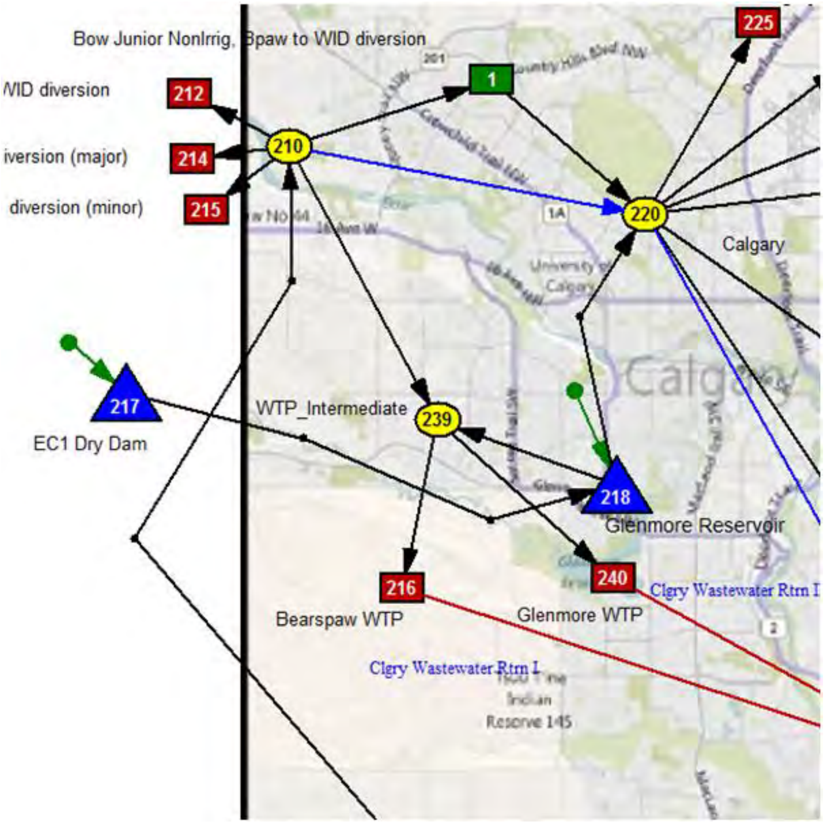

Figure 35: General location for possible dry dam on Canyon Creek (node 217) ***(not to scale and not intended to suggest specific sites)***

Use of the dry dam EC1 reduced flows in the Elbow River by 10 cms in the 2005 modelled scenario, and by 80 cms in the 2013 modelled scenario (Figure 36).

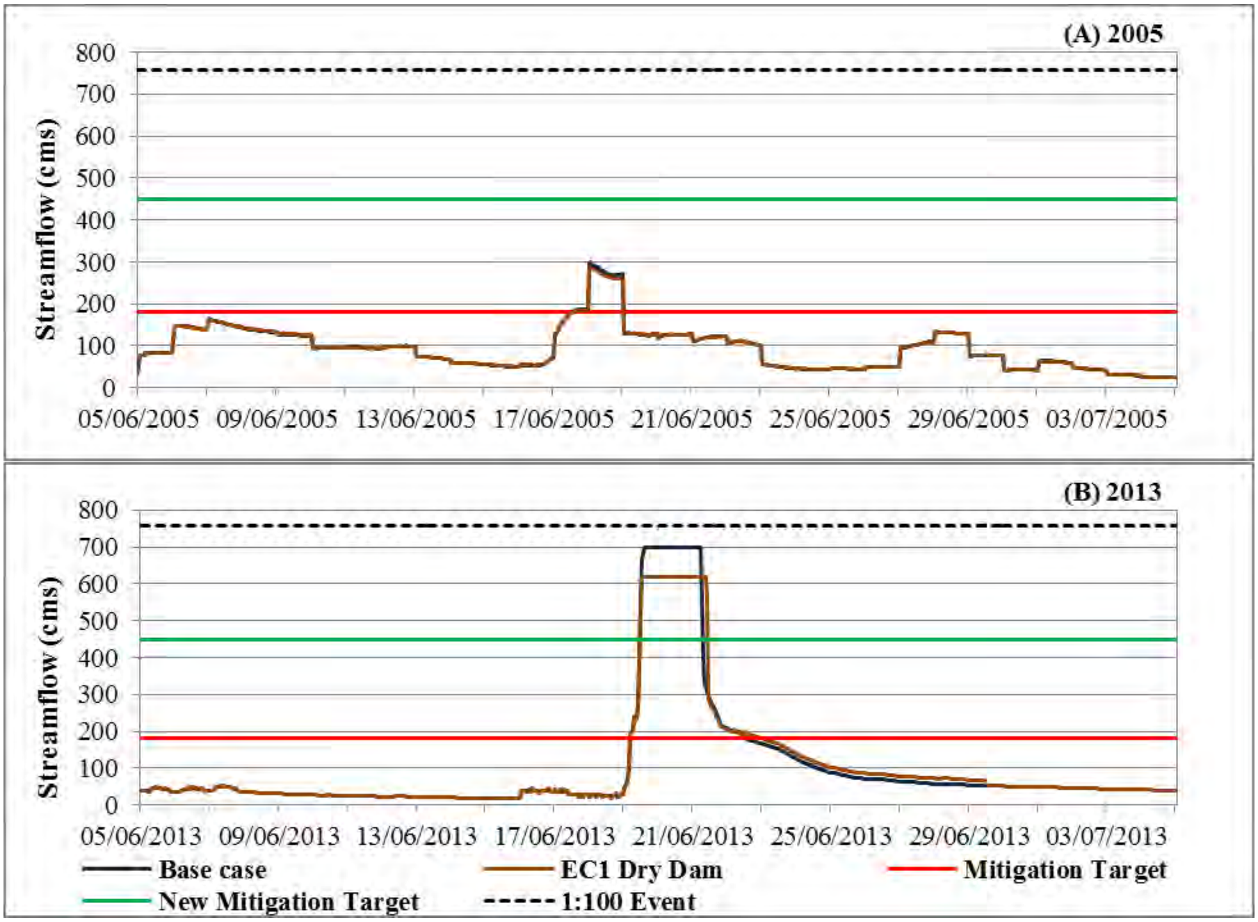

Figure 36: Comparison of streamflow in the Elbow River downstream of the Glenmore Reservoir between base case and a dry dam on Canyon Creek in (A) 2005 and (B) 2013

EC1 has a relatively small catchment area and therefore limited value. The proposed location is in a popular recreation area with valued ecosystems. There was discussion on whether Prairie Creek would perhaps be a more suitable site. As with any dry dam, there are issues related to public safety, debris management, and ecological impacts. Participants stressed the need to fully understand post-flood event releases, especially if multiple dry dams are releasing water at the same time.

Multiple small detentions instead of one

Possible small detention sites in the Elbow system are shown in Figure 37 as blue triangles labelled Dry Dams 1-5. There was no information given on specifications of this option, so the run used the following hypothetical assumptions:

- Five dry dams in series, totalling 100,000 cdm storage, with the storage capacity of each increasing as they progress downstream
- Where possible, operate to fill the upstream dams first, and then progress downstream
- Dam 1 = 10,000 cdm, captures inflow from 5% of the total catchment of Glenmore Reservoir
- Dam 2 = 15,000 cdm, captures inflow from additional 5% of the total catchment of Glenmore Reservoir (10% in total)
- Dam 3 = 20,000 cdm, captures inflow from additional 10% of the total catchment of Glenmore Reservoir (20% in total)
- Dam 4 = 25,000 cdm, captures inflow from additional 10% of the total catchment of Glenmore Reservoir (30% in total)
- Dam 5 = 30,000 cdm, captures inflow from additional 20% of the total catchment of Glenmore Reservoir (50% in total)

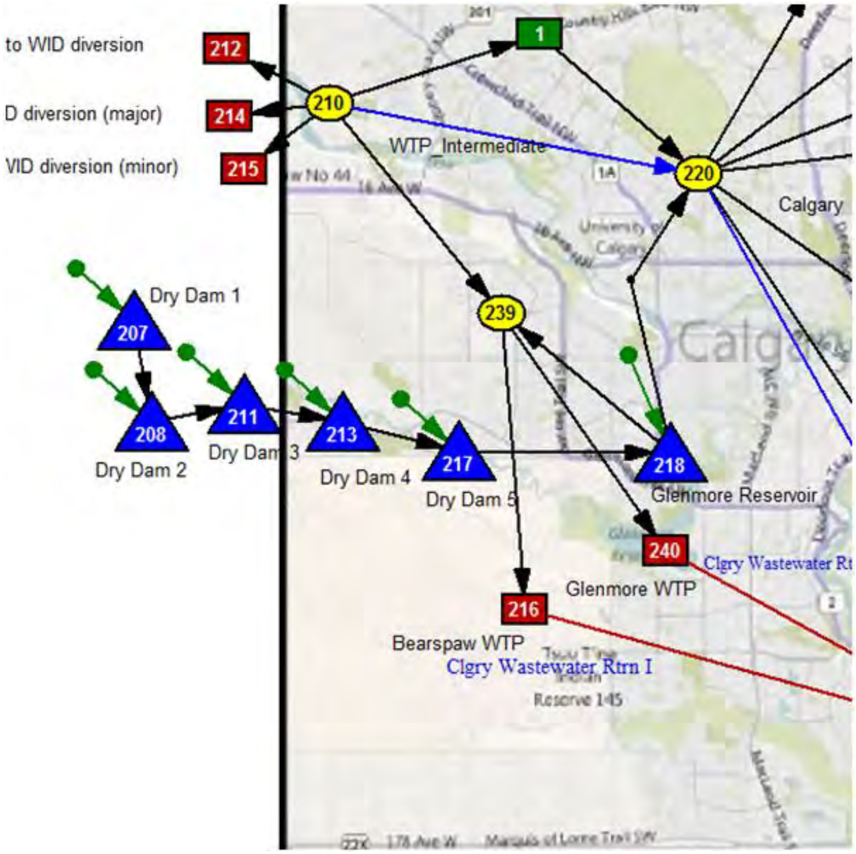

Figure 37: General locations for multiple small detentions on the Elbow River system (nodes 207, 208, 211, 213, and 217) ***(not to scale and not intended to suggest specific sites)***

Use of the multiple dry dams reduced peak flows in the Elbow River by 119 cms in the 2005 modelled scenario, and by 465 cms in the 2013 modelled scenario (Figure 38).

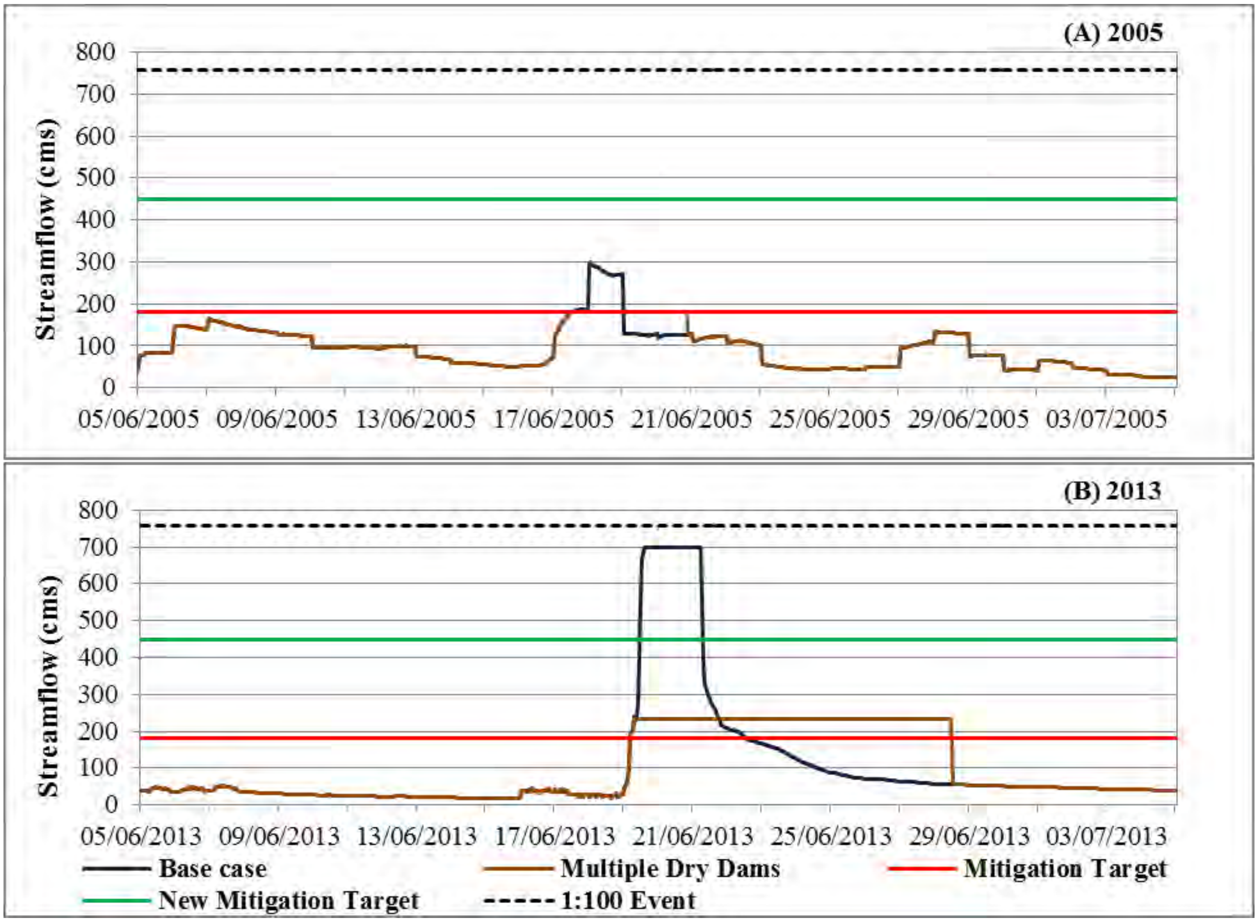

Figure 38: Comparison of streamflow in the Elbow River downstream of the Glenmore Reservoir between base case and multiple small detention sites in (A) 2005 and (B) 2013

The concept behind this option of multiple small dry dams or off stream detention sites was to improve resilience against varying sources of rainfall and runoff during future floods. Operating them in sequence can reduce the size of any single detention site and may reduce the environmental footprint of mitigation compared to a single large dry dam. As with other options, additional review and detailed evaluation would be needed prior to any decision to proceed with any or all of the conceptualized sites and sizes of each.

Expand the capacity of Glenmore Reservoir by raising FSL

This option increased the maximum elevation without uncontrolled release for Glenmore Reservoir by approximately 2.5 m to 1080 m. The reservoir was also lowered prior to a flood by 4.0 m below the crest, similar to the "Operate Glenmore Reservoir for flood mitigation" run.

Raising the maximum elevation of Glenmore Reservoir reduced flows in the Elbow River by 120 cms in the 2005 modelled scenario, and by 175 cms in the 2013 modelled scenario in addition to the mitigation provided by Glenmore operations in 2013 (Figure 39).

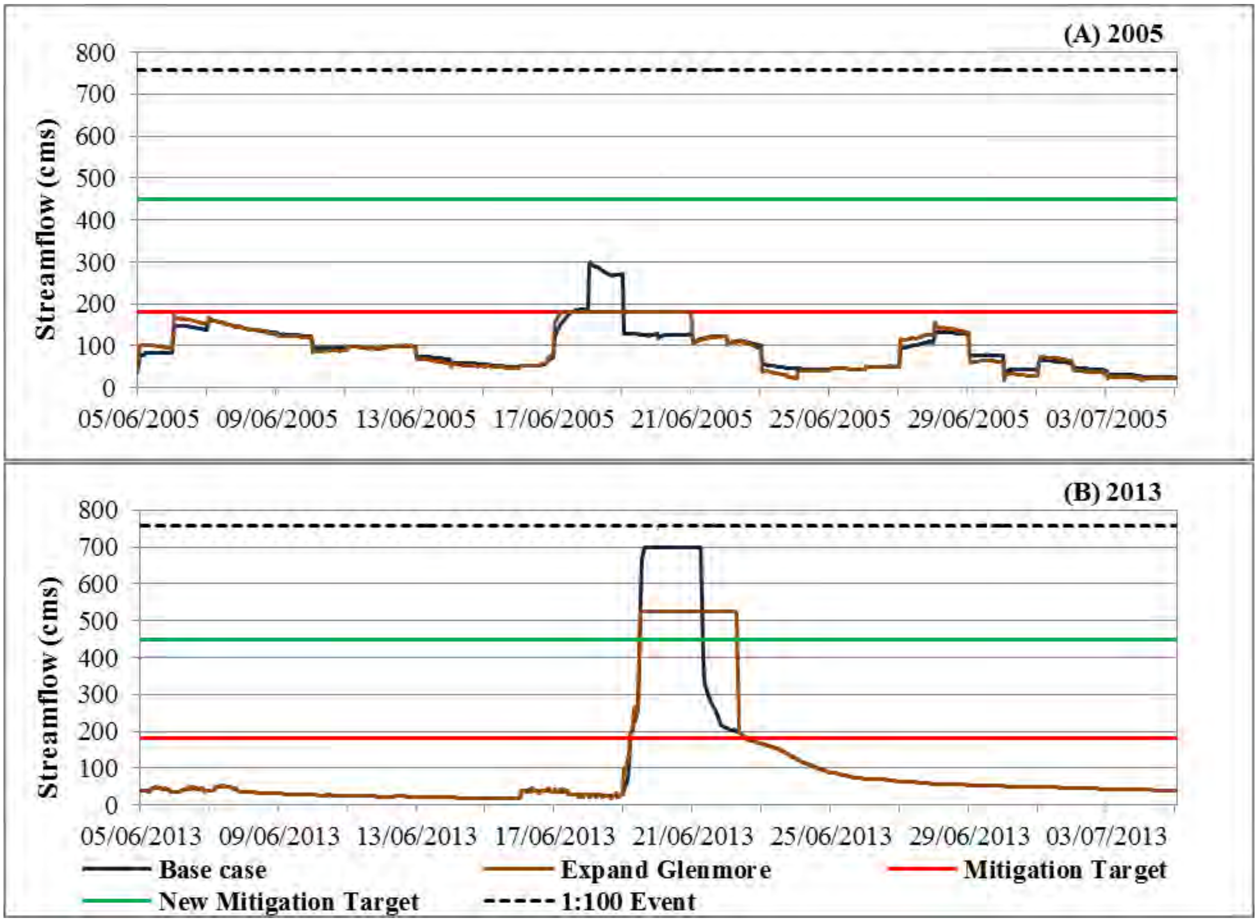

Figure 39: Comparison of streamflow in the Elbow River downstream of the Glenmore Reservoir between base case and expanding Glenmore for flood control in (A) 2005 and (B) 2013

Expanding Glenmore Reservoir by increasing FSL by 2.5 m was intended to allow for this extra drawdown and freeboard, enabling additional mitigation of outflows from the reservoir. In addition to providing some further short-term reduction in flood flows, this option should allow Glenmore to store more water prior to and during a drought for municipal purposes for Calgary and the several municipalities relying on Calgary for regional water supplies. A detailed survey of the area would be required before further consideration to evaluate any requirements for relocation or other costly effects that may make this option less attractive.

7.3 Highwood and Sheep River Systems

North Diversion

This option would divert flood flows from the Highwood River around the Town of High River, reintroducing flow back into the Highwood River downstream of the town. The bypass would be designed to divert up to 500 cms around the town, as shown in Figure 40.

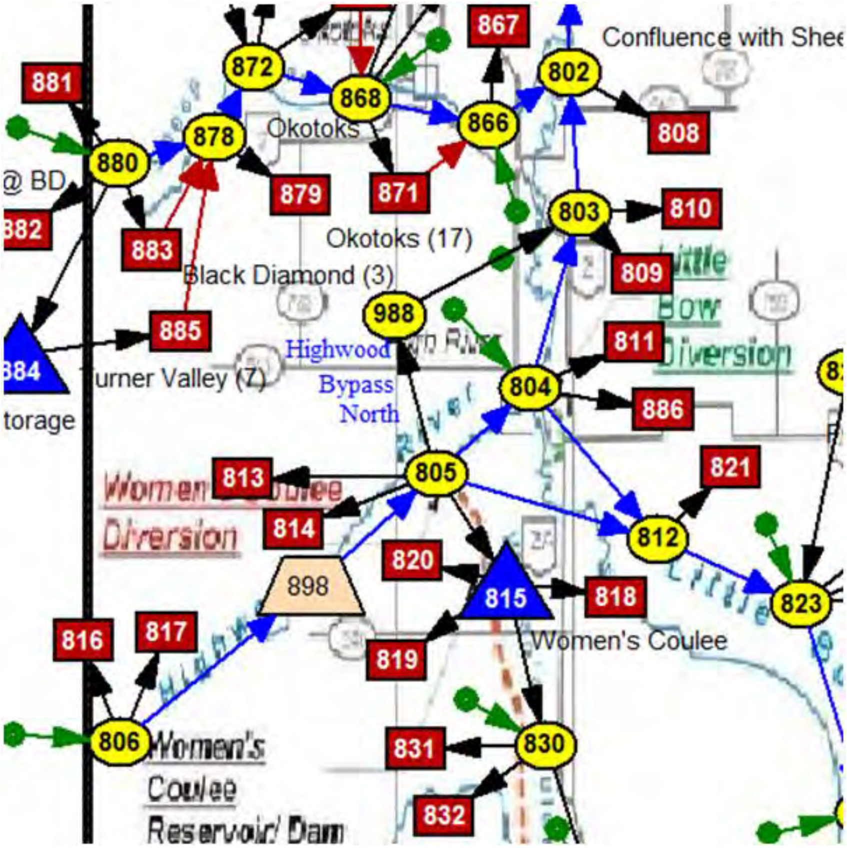

Figure 40: General location for possible Highwood North diversion. The diversion is represented by an arrow going to node 988, then returning at node 803 *(not to scale and not intended to suggest specific sites)*

Use of the North bypass reduced flows in the Highwood River through High River by 311 cms in the 2013 modelled scenario, and did not affect peak flows in the 2005 modelled scenario (Figure 41).

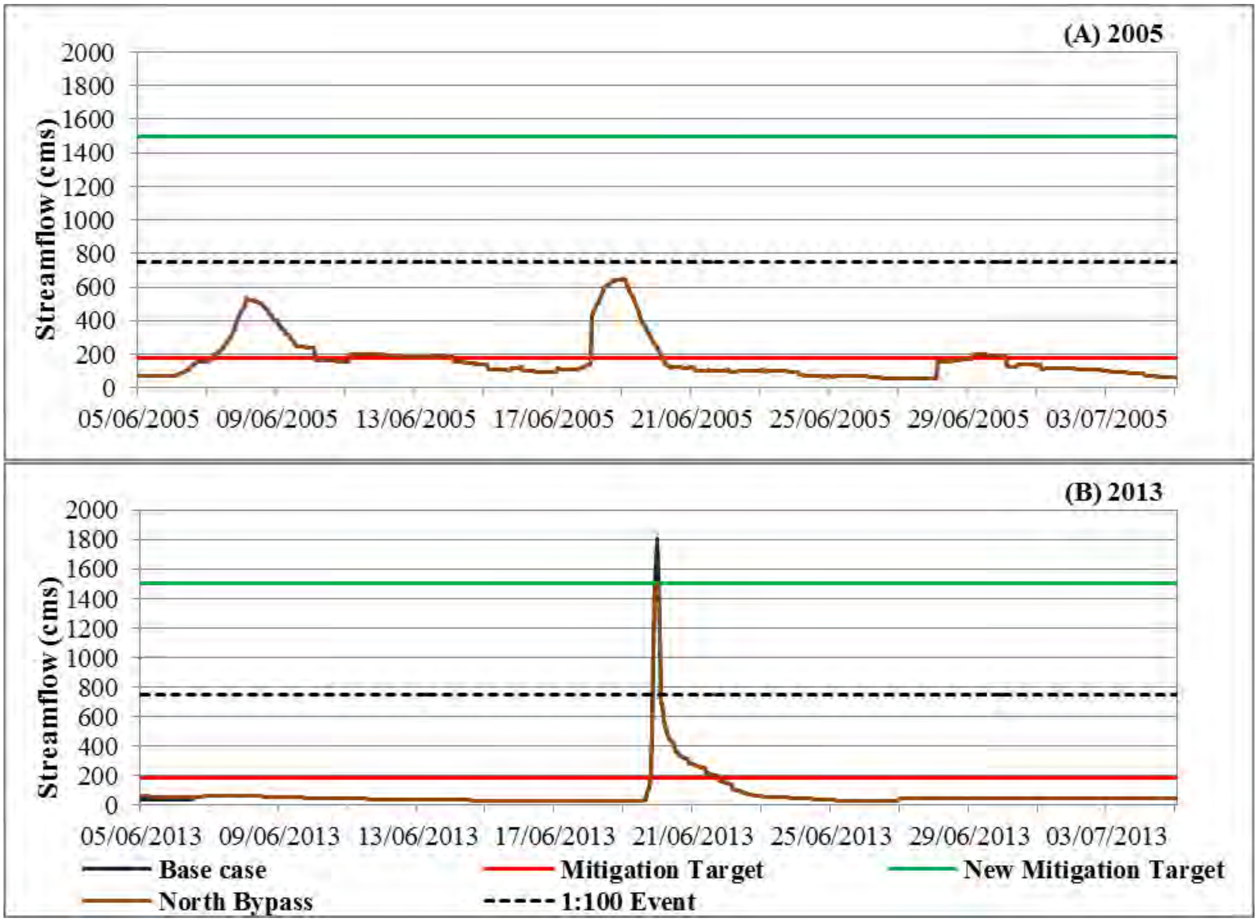

Figure 41: Comparison of streamflow in the Highwood River near High River between base case and a north bypass for flood control in (A) 2005 and (B) 2013

A very low preliminary mitigation target of 180 cms for High River was quickly revised to be higher, recognizing the Town's efforts already underway with local berming and reinforcement, which will allow the town to withstand flows of ~1500 cms or less. A North diversion was considered first to minimize the risk of increased flooding on the Little Bow River with potentially disastrous consequences for some rural landowners, Travers Dam, and downstream at Medicine Hat, which may occur with a South diversion. Subsequently, a South diversion was also proposed, and is analyzed separately, but interaction between the two diversions is complex. It was noted that it may be easier to divert into the Little Bow from an engineering perspective, but there are two dams on the Little Bow already and a dam failure on top of a flood would be the worst case.

It is understood that the proposed current northern diversion return flow locations are entering a low gradient reach of the Highwood River that is documented in the Highwood Management Plan as the most sensitive fish habitat for water management operations during open water season. Instream flow, water quality, and water temperature performance objectives are set to protect this reach and, when these objectives are triggered, first in time, first in right (FITFIR) water policy operations are activated for the water licence users in the area. Currently, activating this trigger results in reduced flow diversions to the Little Bow Basin and a potential call for reduced licensed water withdrawal from the upstream Highwood and trigger reach, depending on water licensing priorities. In drought years this can result in significant licensed water deficits, particularly to irrigation licensed use. In making the decision on this North diversion consideration has to be given to how the flow returned to the Highwood River will affect the health and performance of this sensitive reach under normal flow conditions, particularly during low summer flows. From a fisheries perspective, a North diversion that routes flow from and back into the Highwood River system would be preferable to a South diversion that routes more Highwood River flow into the Little Bow River.

If there is a commitment to build a diversion around High River, then the North diversion is shorter, less contentious, and would affect fewer people. It is “easier,” likely medium term in terms of timing, and may be the safer option in many ways. Nevertheless, moving water intentionally from one place to another with artificial diversion is contentious, value-laden, and brings legal implications for people and infrastructure that natural flooding would not. The preference is to minimize impacts and damages, but this is not just a cost-benefit argument, it is also an ethical and political decision when transfer of risk is considered. Cost-benefit analysis is needed that considers local and regional impacts on the receiving water bodies, as well as impacts to new areas inundated by the diversion that are not naturally affected by Highwood historical flood flows. Cumulative effects flood modelling scenarios should be done as part of the cost-benefit assessment, recognizing that High River’s flood infrastructure changes at different flood levels. Risks of doing nothing beyond the existing and planned changes in channel capacity through the town should also be assessed, as should the option of overland flooding outside the town.

Receiving water bodies affected by the diversion will require follow-up riparian monitoring and designation of compatible flood plain land management use to enable natural or assisted riparian habitat development and recovery. The benefits of flood flows in sustaining natural groundwater recharge in the High River and Okotoks areas were not discussed, but maintenance of groundwater recharge through the respective river reaches is important to municipal supply and groundwater discharge back to the river during low summer and winter flow periods.

South Diversion

This second option to bypass the Town of High River would be used to augment the natural overland flows (of approximately 400 cms in 2013) from the Highwood River to the Little Bow River by an extra 300 cms (Figure 42). This model run also assumed Twin Valley Reservoir would surcharge above FSL to prevent flows downstream from going above 250 cms, as flow above this level would severely damage the spillway at Travers Reservoir and present significant risk to the downstream system.

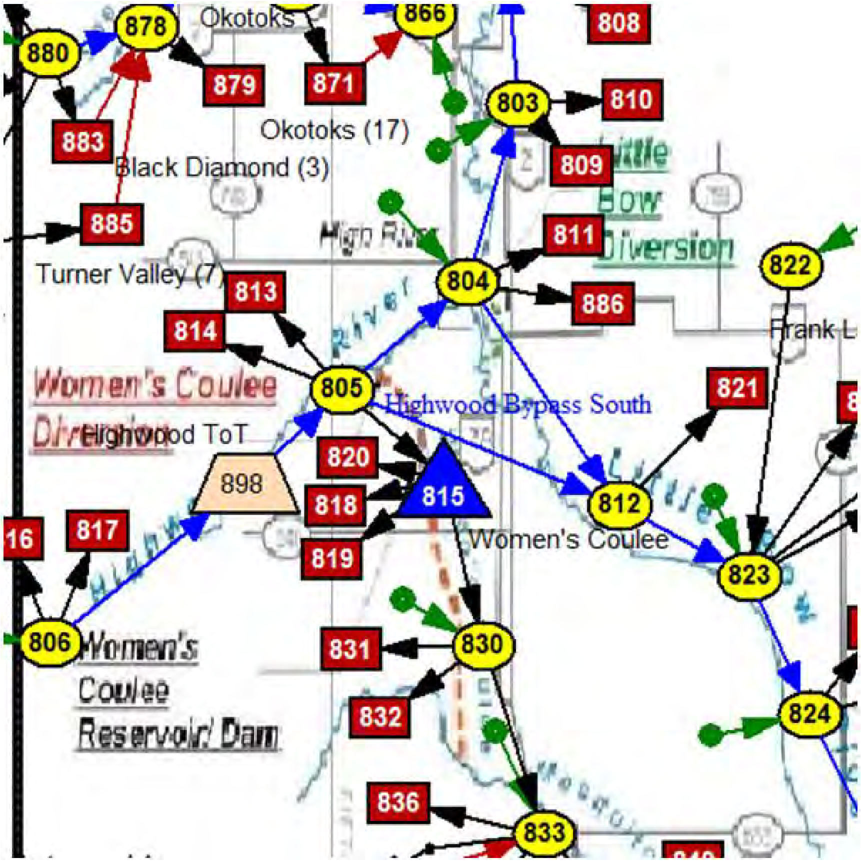

Figure 42: General location for possible Highwood South diversion. The diversion is represented by the arrow from node 805 to 812 *(not to scale and not intended to suggest specific sites)*

Use of the South bypass reduced peak flow rates in the Highwood River through High River by 273 cms in the 2013 modelled scenario, and did not affect peak flows in 2005 (Figure 43).

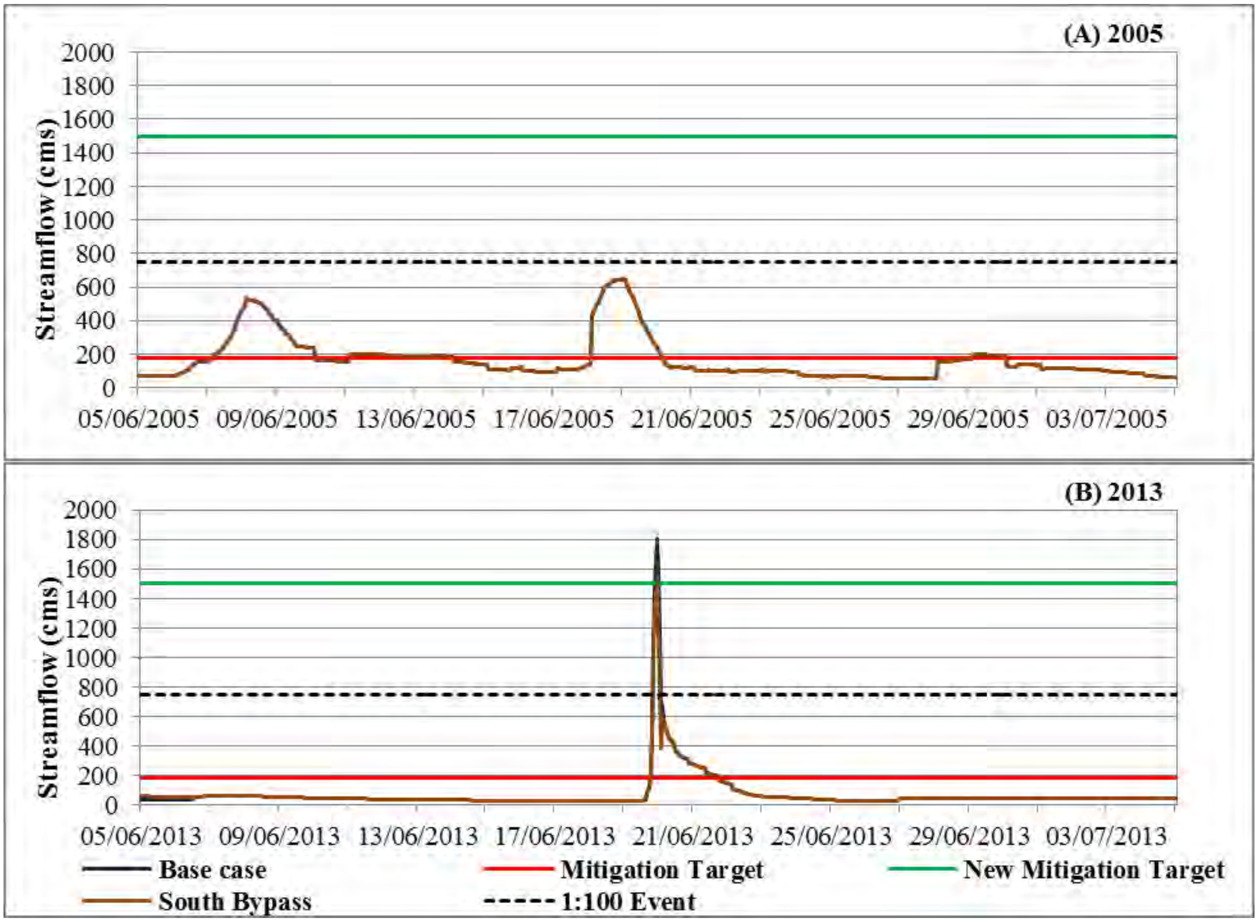

Figure 43: Comparison of streamflow in the Highwood River near High River between base case and a south bypass into the Little Bow for flood control in (A) 2005 and (B) 2013

The potential diversions for mitigating peak flows at High River raised a number of challenging questions, but participants generally thought the South diversion would be more complex and take longer to implement. In 2013, modelling done by High River suggested that 400 cms went naturally to the Little Bow via overland flow. The enhancement assessed with the model added a further 300 cms. The 400 cms flow was manageable only because it could be stored in the Twin Valley Reservoir. The Travers Reservoir spillway can only pass a flow of 250 cms and would need to be upgraded to release more. However, development has encroached on the river valley downstream of the dam possibly because of a false sense of security due to the fact that Travers has surcharged and controlled downstream peak flow rates in the past. This should not be relied upon; the Travers Reservoir spillway should be upgraded to safely accommodate higher potential flows in the future. Costly infrastructure upgrades would also be needed to storage, roads, bridges, and other infrastructure to make the southern diversion viable if the peak diverted flow rate to the Little Bow has a total flow of 700 cms. And it must be recognized that most private valley properties and other infrastructure would be damaged or lost. Costs may dictate where mitigation occurs (e.g., rural vs. Town of High River), but it is necessary to look at the region as a whole and the downstream consequences of each option.

Any decision about enhancing natural overland flow to the Little Bow as a flood mitigation option has to consider the complexity and compatibility of current land and water use in the valley and adjacent to the valley where there are agriculture and acreage homestead developments, irrigation, livestock operations, and petroleum production operations. Infrastructure associated with numerous domestic groundwater wells and municipal licensed diversion off-takes supports valley and upslope residential and agriculture developments and these must be examined as well as the large instream reservoir operations (which were done in the modelling). If enhancing and channeling the natural overland flow to the Little Bow is going to be used as a flood mitigation option, it needs to be properly managed; that is, the land must be appropriately farmed to avoid nutrient runoff and erosion.

Many of the same concerns noted for the North diversion with respect to intentional re-direction of water, cost-benefit analysis, and others apply to the South diversion too. The future growth of High River and impacts on the Little Bow need to be evaluated from both a flood and drought perspective. Part of the risk assessment would be to estimate how often either of the proposed diversions may be used. The Town of High River is working to confirm its berming plans, which are expected to accommodate a flow of ~1500 cms through the town presumably making this the new target flow at which to evaluate mitigation options. As of March 2104, the Town’s plans are to install infrastructure to avoid any additional flood flow down the Little Bow beyond what was experienced in 2013 and not to build the North diversion at this time. Plans may change as new modelling and flow data are derived from the Worley Parson model and more detailed engineering studies are completed. At this time it does not appear that any dry dams on the Highwood would be necessary for High River to manage a flood similar to 2013. However, there are other upstream communities that may have an interest in control structures further upstream.

Dry dam west of Eden Valley Reserve (H5(2))

This option is a 45.5m high dry dam with capacity of 83,864 cdm, located on the Highwood River immediately west of the Eden Valley Indian Reserve (blue triangle 997 in Figure 44). It was assumed that 56% of total streamflow to High River would be available at the dry dam site. The dry dam would attenuate flows greater than 100 cms in the river.

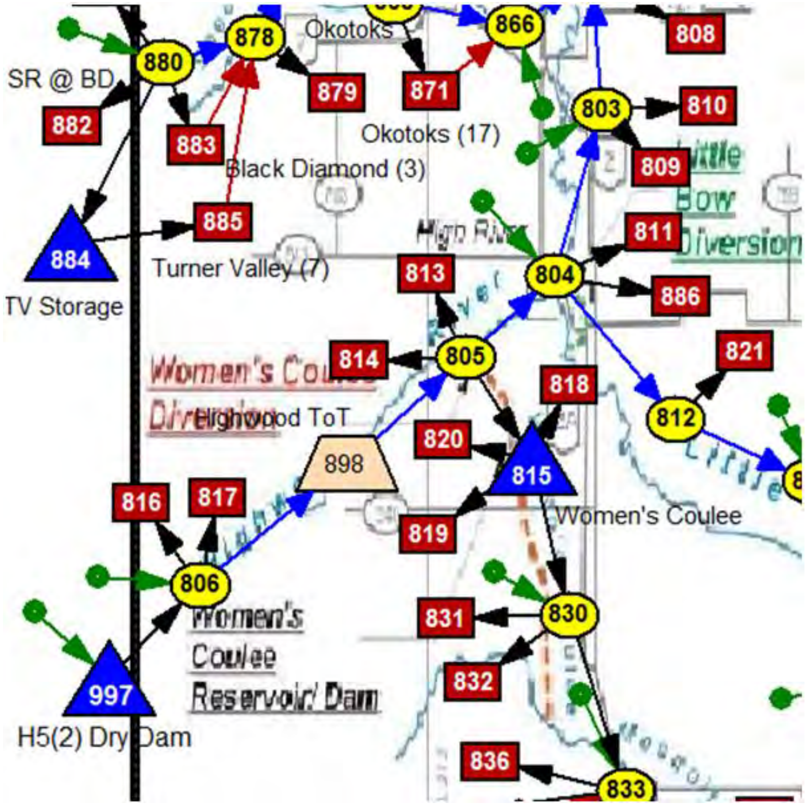

Figure 44: General location for possible dry dam west of Eden Valley Reserve (node 997) ***(not to scale and not intended to suggest specific sites)***

Use of the dry dam H5(2) reduced peak flow rates in the Highwood River by 260 cms in the 2005 modelled scenario, and by 800 cms in the 2013 modelled scenario (Figure 45).

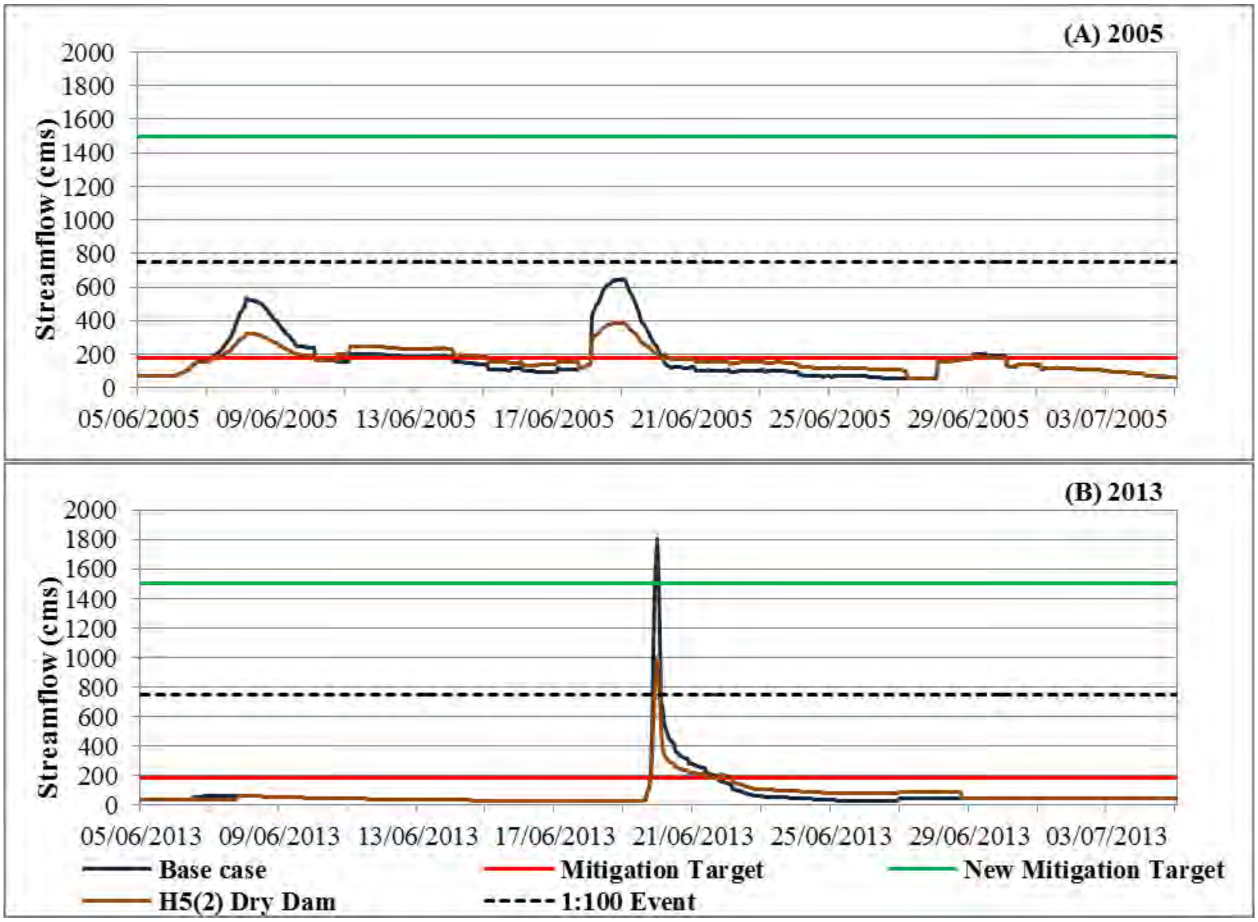

Figure 45: Comparison of streamflow in the Highwood River near High River between base case and a dry dam west of Eden Valley (H5(2)) for flood control in (A) 2005 and (B) 2013

This dry dam would affect Highway 541 which is the primary south access to Kananaskis Country. It would also have a significant effect on the character of the area, which is now relatively pristine with few management controls on it. As with other options considered for the Highwood River system, any interference with the Highwood River upstream will have significant consequences for fish habitat. This is important because the Highwood River is the compensating fishery for the Lower Bow due to dams on the Upper Bow and Elbow, providing key spawning and rearing habitat for sport fish. The current Water Management Plan is geared to protecting this fishery, but flood mitigation could change that focus. Participants also stressed that the Eden Valley Reserve should be part of this discussion.

As with any dry dam, there are issues related to public safety, debris management, and ecological impacts. Participants stressed the need to fully understand post-flood event releases, especially if multiple dry dams are releasing water at the same time.

Dry dam upstream of Longview (H2)

This option is a 48.75 m high dry dam with 40,012 cdm capacity, located on the Highwood River about 7 km upstream (northwest) of Longview, just below the confluence with Ings Creek (blue triangle 988 in Figure 46). For the modelling, it was assumed that 79% of total inflow to High River would be available in the catchment for the dry dam site. The dry dam was used to attenuate flows above 200 cms in the river.

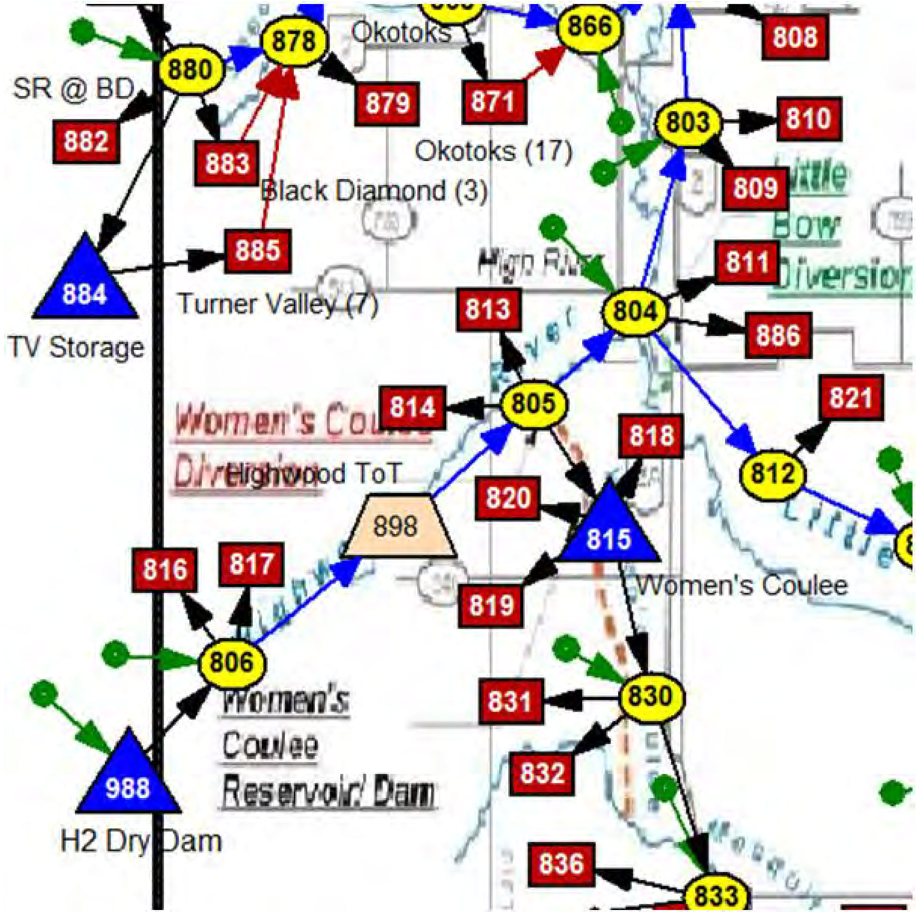

Figure 46: General location for possible dry dam upstream of Longview (node 988) ***(not to scale and not intended to suggest specific sites)***

Use of the dry dam H2 reduced peak flow rates in the Highwood River by 312 cms in the 2005 modelled scenario, and by 1183 cms in the 2013 modelled scenario (Figure 47).

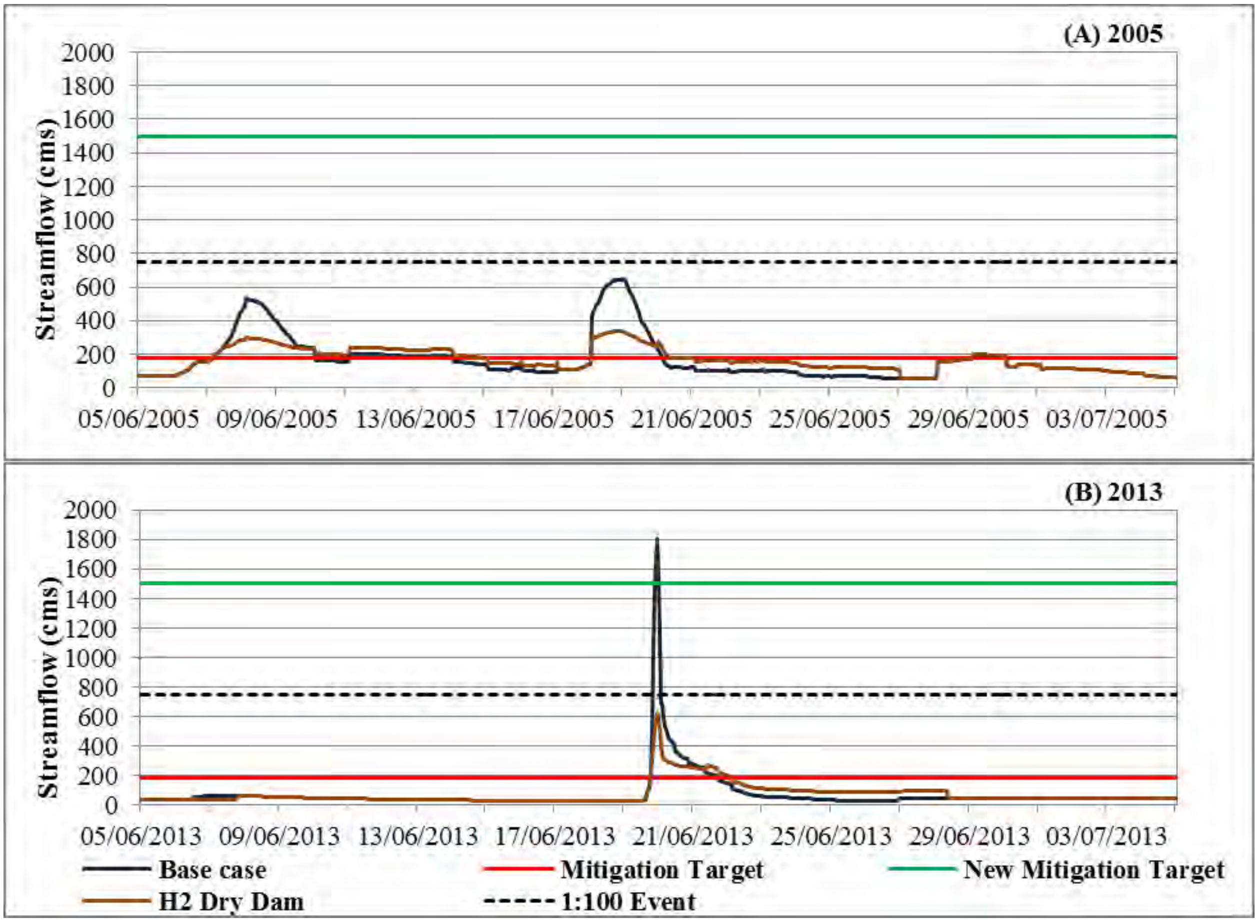

Figure 47: Comparison of streamflow in the Highwood River near High River between base case and a dry dam upstream of Longview (H2) for flood control in (A) 2005 and (B) 2013

The flow reductions achieved with this dry dam were far in excess of what would be required to mitigate flooding for the Town of High River, but the appropriate mitigation target would need to consider the other communities in the area and their current rebuilding and fortification targets. Like the dry dam west of Eden Valley Reserve, a dry dam upstream of Longview would affect Highway 541 and would have significant impacts on several Alberta Parks public recreation areas. The Highwood and Sheep are essential to the trout fishery along the Bow River, and dry dams on these river systems would have a huge impact on the sport fishing community in Calgary and beyond. Options for overland flooding of cultivated fields or rangeland in this area might also be considered.

As with any dry dam, there are issues related to public safety, debris management, and ecological impacts. Participants stressed the need to fully understand post-flood event releases, especially if multiple dry dams are releasing water at the same time.

Dry dam upstream of Turner Valley (S2)

This 45.3 m high dry dam with a capacity of 24,916 cdm capacity is located on the Sheep River about 7 km upstream (southwest) of Turner Valley, just below the confluence with Macabee Creek (blue triangle 989 in Figure 48). In the model run, it was assumed that 89% of total streamflow to Black Diamond would be available at the dry dam site, based on the catchment area to this point. The dry dam was used to attenuate flows greater than 425 cms in the river.

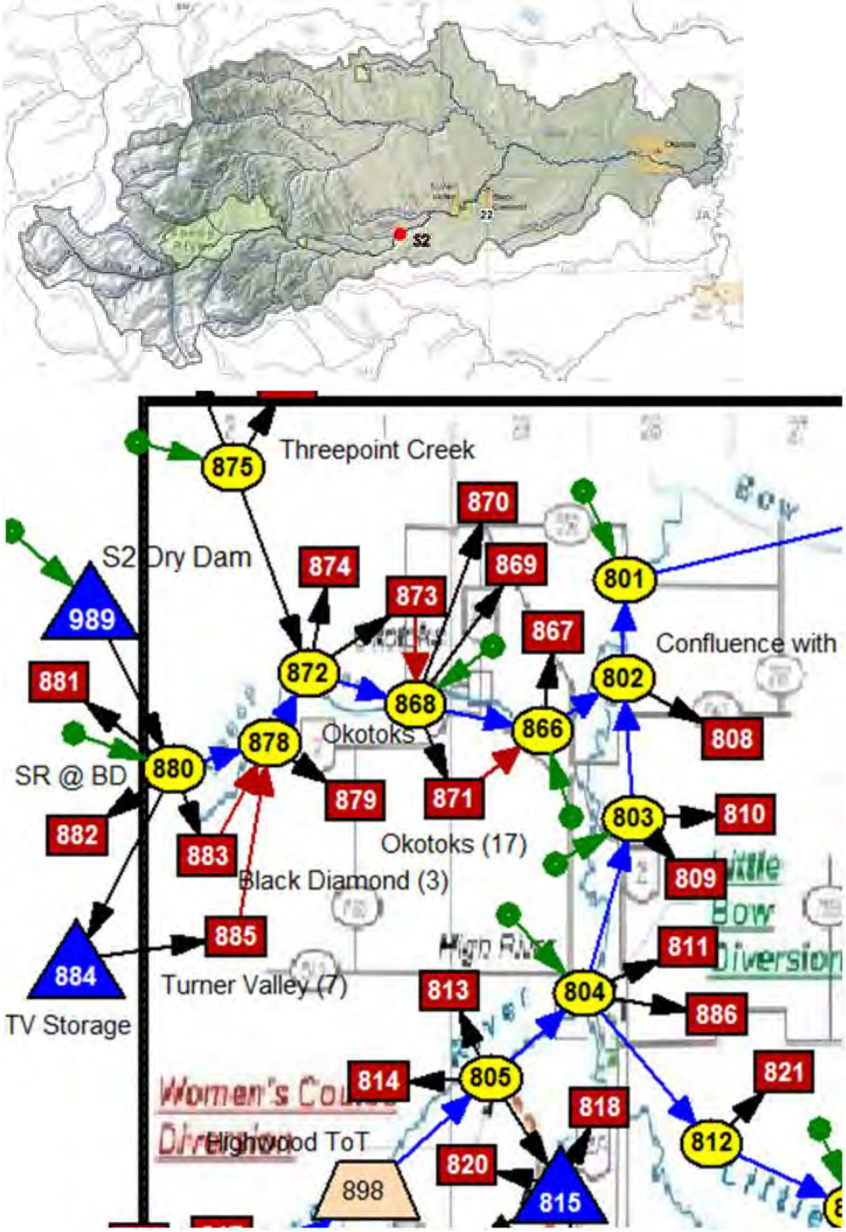

Figure 48: General location of possible S2 dry dam upstream of Turner Valley (node 989) ***(not to scale and not intended to suggest specific sites)***

Use of the dry dam S2 reduced peak flow rates in the Sheep River by 256 cms in the modelled 2013 scenario, and did not affect peak flows in the 2005 modelled scenario (Figure 49).

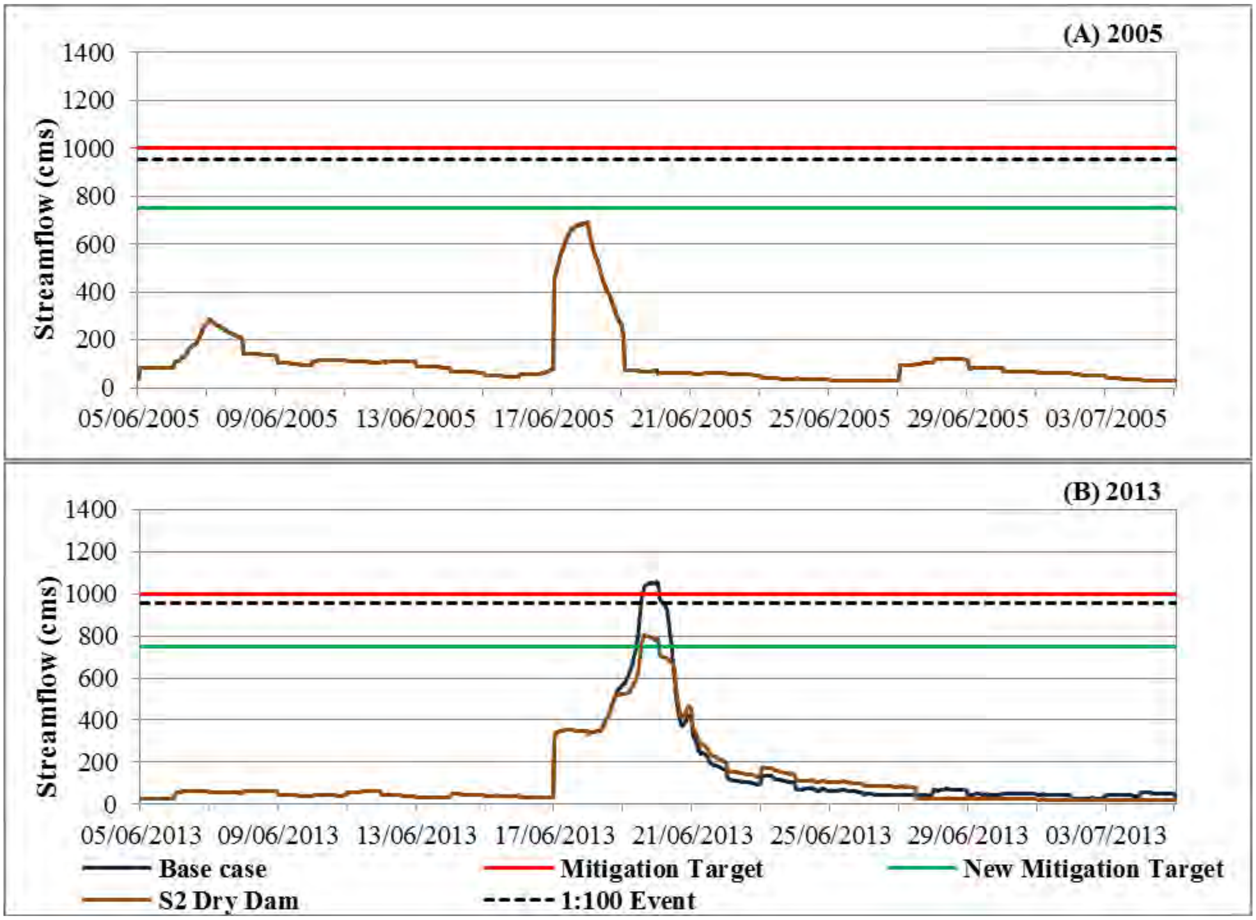

Figure 49: Comparison of streamflow in the Sheep River near Okotoks between base case and a dry dam upstream of Turner Valley (S2) for flood control in (A) 2005 and (B) 2013

In the 2005 and 2013 flood events, Okotoks received peak flow rates of 1000 cms, but the Sheep River at Black Diamond is only part of the challenge, as Threepoint Creek contributes a significant part of the flow through Okotoks. Potential offstream storage is being explored using gravel pit operations. Detention upstream of Turner Valley and at Threepoint Creek could help with a variety of floods. It was noted that a dry dam in the S2 location would help Turner Valley (600 cms is design level at Turner Valley to protect the water treatment plant), but it would affect Sheep Road.

No flood mapping exists between Black Diamond and Okotoks and this should be done with a focus on urban areas to understand the extent of floods, not just the impacts of flows. The MD of Foothills is looking at rip rap and erosion control mitigation options in eight places between Turner Valley and Okotoks.

It was noted that the Sheep River system is recognized as a highly sensitive ecosystem and also supplies water to a large area of irrigated land. If storage infrastructure is considered for this river, its potential for drought mitigation should also be assessed. As with any dry dam, there are issues related to public safety, debris management, and ecological impacts. Participants stressed the need to fully understand post-flood event releases, especially if multiple dry dams are releasing water at the same time.

Detention at Threepoint Creek Confluence

This option involves a dry dam with 50,000 cdm capacity located just upstream of the confluence of the Sheep River and Threepoint Creek (blue triangle 990 in Figure 50). The specific location or viability of proposed locations for such a structure was not part of the working group discussion or assessment. The dry dam was used to attenuate flows greater than 50 cms in Threepoint Creek.

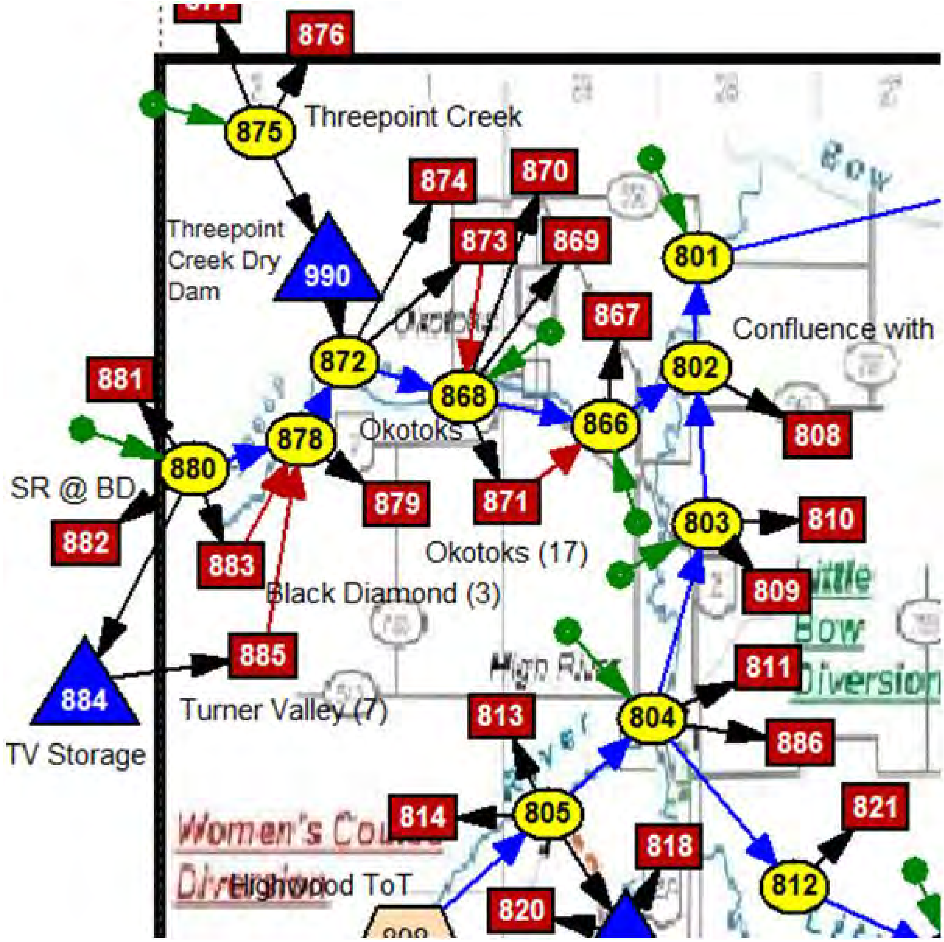

Figure 50: General location for possible dry dam at Threepoint Creek confluence (node 990) ***(not to scale and not intended to suggest specific sites)***

Use of the Threepoint Creek dry dam reduced flows in the Sheep River by 149 cms in the 2005 modelled scenario, and by 168 cms in the 2013 modelled scenario (Figure 51).

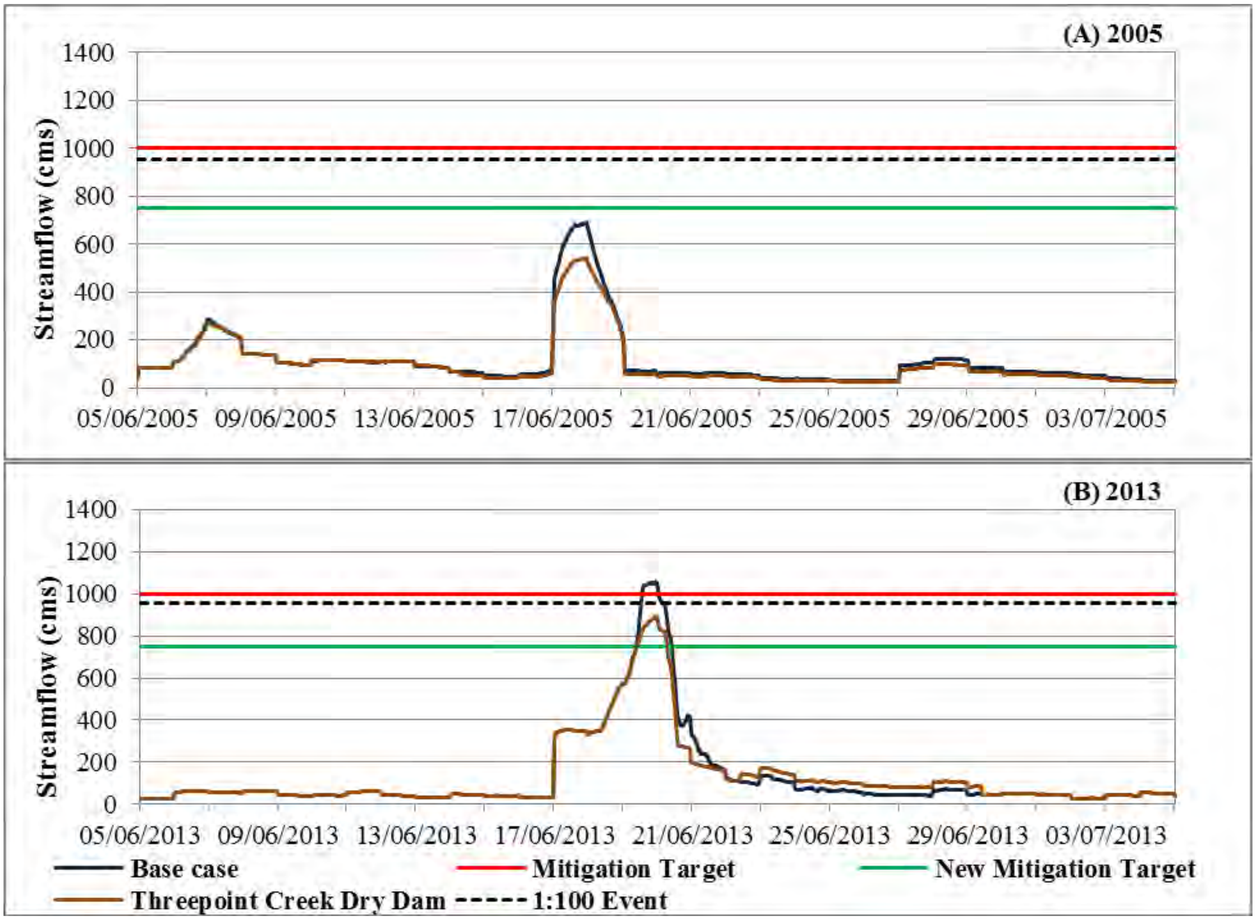

Figure 51: Comparison of streamflow in the Sheep River near Okotoks between base case and a dry dam on Threepoint Creek for flood control in (A) 2005 and (B) 2013

In 2005, most of the flow came from Threepoint Creek, not the mainstem of the Sheep River, so a dam on both would reduce flow for a variety of floods. Rural homeowners in the Threepoint Creek area and the communities around Millarville were severely affected by the 2013 flood and regularly experience flash flooding. No flood mapping exists between Black Diamond and Okotoks and this should be done, likely with a focus on urban areas and infrastructure, to understand and visualize the flood inundations associated with a range of high flows. Both Threepoint Creek and Sheep River have important fisheries so the impact of dry dams on fish habitat in the highly-valued Sheep-Highwood fishery must be considered. If a dry dam has to be considered, participants' preference was for detention at Threepoint Creek rather than upstream of Turner Valley. That said, this location would offer no benefit to homeowners upstream on the Creek. Landscape changes due to development may be a contributing factor to increased runoff, and opportunities for improved landscape management should be assessed before considering these options.

As with any dry dam, there are issues related to public safety, debris management, and ecological impacts. Participants stressed the need to fully understand post-flood event releases, especially if multiple dry dams are releasing water at the same time.

7.4 Natural Mitigation Options for the Bow Basin

Throughout this project, participants stressed the need to integrate natural landscape approaches into any solutions to deal with flood mitigation in the Bow Basin. Working with natural systems can reduce flood risk, and this sometimes means simply respecting the river and staying out of its path. Many of the comments on natural mitigation options are reflected in the discussion of three flood mitigation approaches in Section 5: Wetland Storage, Natural River Functions, and Land Management. All three approaches must be part of the flood mitigation portfolio. Natural mitigation options that were suggested and modelled for this project focused on:

- Improving wetland detention capacity of the whole Bow Basin, and
- Mitigation through land management and use throughout the Bow Basin.

As a basin, we have made decisions about development and watershed functions over a long period, which have put us in the position we are today. Restoring and enhancing wetland function to improve storage, and better land use and management practices throughout the watershed can address a variety of existing problems, not only flood mitigation. Some infrastructure solutions will likely proceed, but if we don't improve watershed functions, infrastructure will not work as well as it should and the net return on that investment will deteriorate. Improving riparian and wetland health and function and land management are crucial components of any successful, long-term flood mitigation strategy. Participants recognized that these approaches by themselves may have a limited impact on the whole system in any given year, but can have important local effects. Improving these functions provides many significant benefits that are also valuable in times of drought and under normal climate conditions.

Wetland Storage

Project participants repeatedly stressed the value and importance of wetlands in helping to mitigate floods and provide a range of environmental goods and services. A wetland inventory for Alberta is needed to document existing wetlands, loss of wetlands, the state of wetland health, and the state of riparian health for river corridors, including tributaries. Runoff vulnerability studies are also needed to identify and prioritize projects for protecting and improving watershed capacity to reduce landscape runoff and improve natural storage. Pothole wetlands were identified as being advantageous in flood mitigation because they are not connected.

Preliminary modelling was done to compare streamflow in the Bow and Elbow Rivers in 2013 with a scenario of implementing a wetland restoration program. A similar run was done for the Highwood and Sheep Rivers. Approximately 23,500 cdm of wetland storage across the entire system was assumed to be restored and function like a series of reservoirs. It is difficult to estimate wetland storage. In nature, wetlands support groundwater recharge and plant growth simultaneously, both of which are continuously adding capacity and neither of which occurs on a barren landscape. For the modelling, very basic assumptions were made about how wetlands would behave for flood mitigation. Inflow to and outflow from wetlands were determined based on the time of year (during and post-freshet), and outflow was determined using a negative exponential decay as a function of storage.

The runs show no difference in peak flows with or without wetland restoration (Figure 52 and Figure 53), but it was suggested that any impact would be more effective for low to medium flows and less for higher flows. It is unlikely that the modelling is exactly correct for this option, as it does not reflect smaller scale aspects, such as damping the timing of runoff and local effects on surface water-groundwater interactions. There are many watershed benefits of wetland retention, whether they reduce major flood peaks or not.

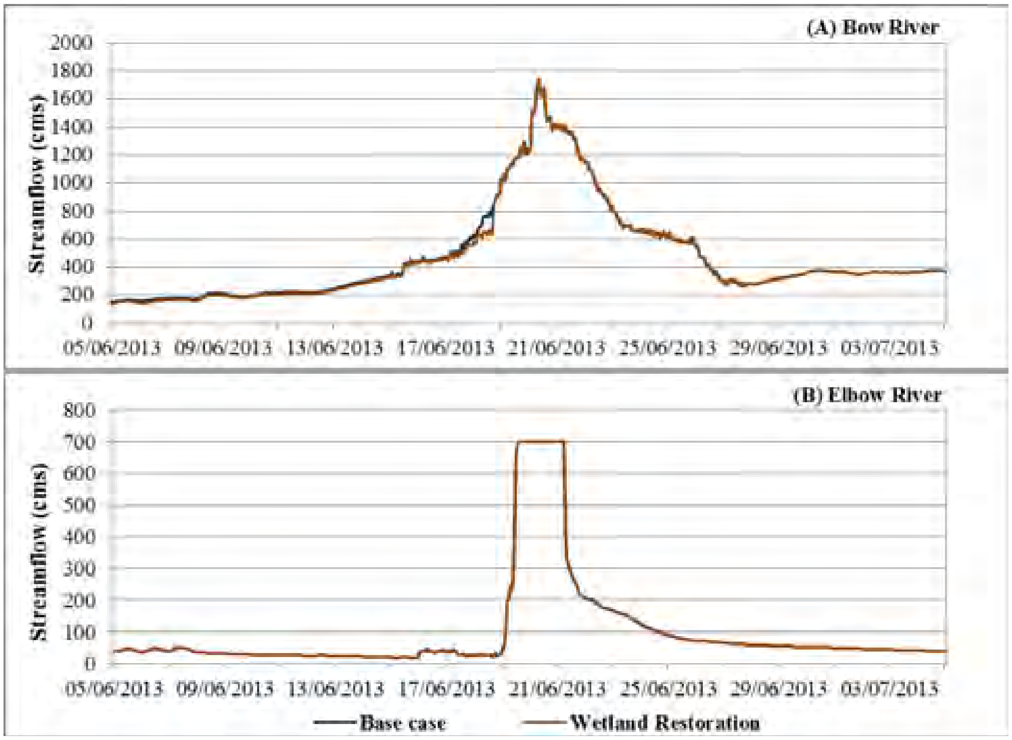

Figure 52: Comparison of streamflow in the (A) Bow and (B) Elbow Rivers in 2013 and a scenario of implementing a wetland restoration program

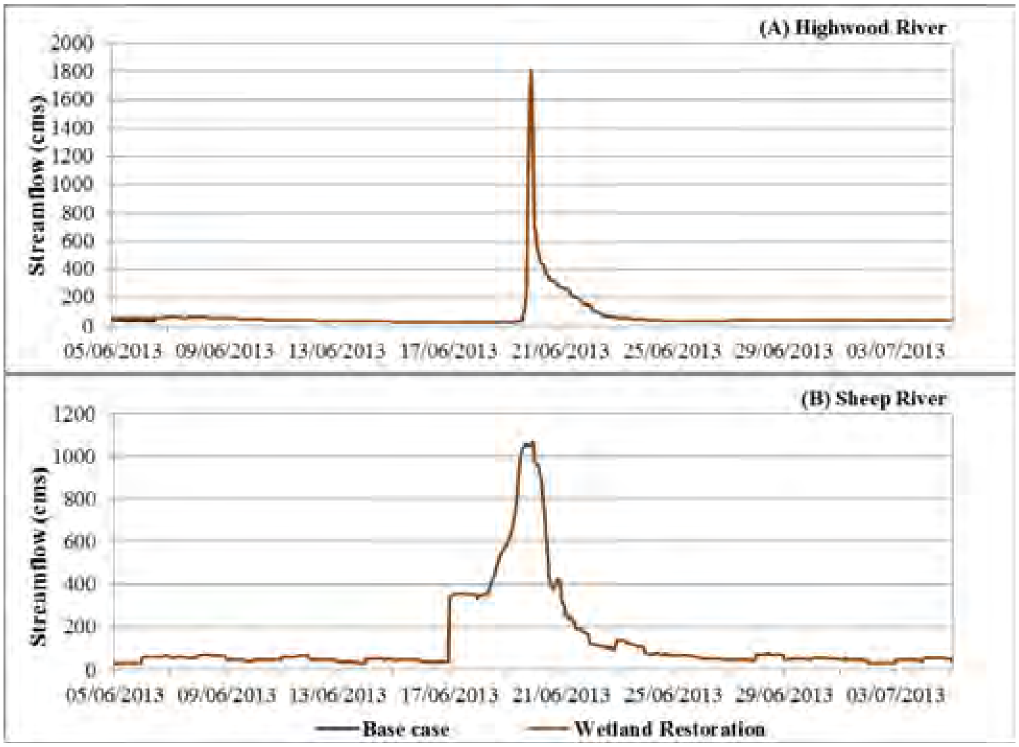

Figure 53: Comparison of streamflow in the (A) Highwood and (B) Sheep Rivers in 2013 and a scenario of implementing a wetland restoration program. Note: the lines are over-plotted.

Land Management

A key component of land management that was stressed repeatedly was “avoid flood plains.” Mitigation options can help protect existing flood plain developments, but these structures can also create a false sense of security. Land use managers and planners should take seriously the need to put new development elsewhere. As was said many times, “Getting out of the way is the only certain way to avoid flood damage.”

Lack of appropriate land management can lead to many activities that could convey flows downstream (e.g., timber harvesting practices, linear access such as roads and cutlines, off-road vehicle erosion channels). Changing land management practices could also help remove debris from the system and could have bigger impacts in smaller and/or sustained flood events. Improving land management practices would engage a number of industry sectors, recreation organizations, and communities and could have positive economic impacts depending on how it was done. It could also offer some benefits for drought mitigation (e.g., improving groundwater recharge, retaining snow pack, slowing melting).

Some modelling was done to compare streamflow in the Bow and Elbow river systems in 2013 with a scenario of implementing best land management practices (Figure 54). A similar run was done for the Highwood and Sheep systems (Figure 55). The runs show no visible impact from this option due to the fact that these runs simply applied a 1% reduction to inflows in 2013. The 1% reduction in 2013 was based on the assumption that the flood was the result of a large rain-on-snow event falling mostly in steep mountain terrain. Land management strategies are assumed to have less impact on peak flows driven by this type of extreme event. However, empirical field studies and process-based hydrological modelling studies are required to fully understand land management implications on flood mitigation. There is an opportunity to use topography to identify areas to work on first, such as reconnecting wetlands and flood plains, or reconnecting flood plains such as at the confluence of the Bow and Highwood for storage.

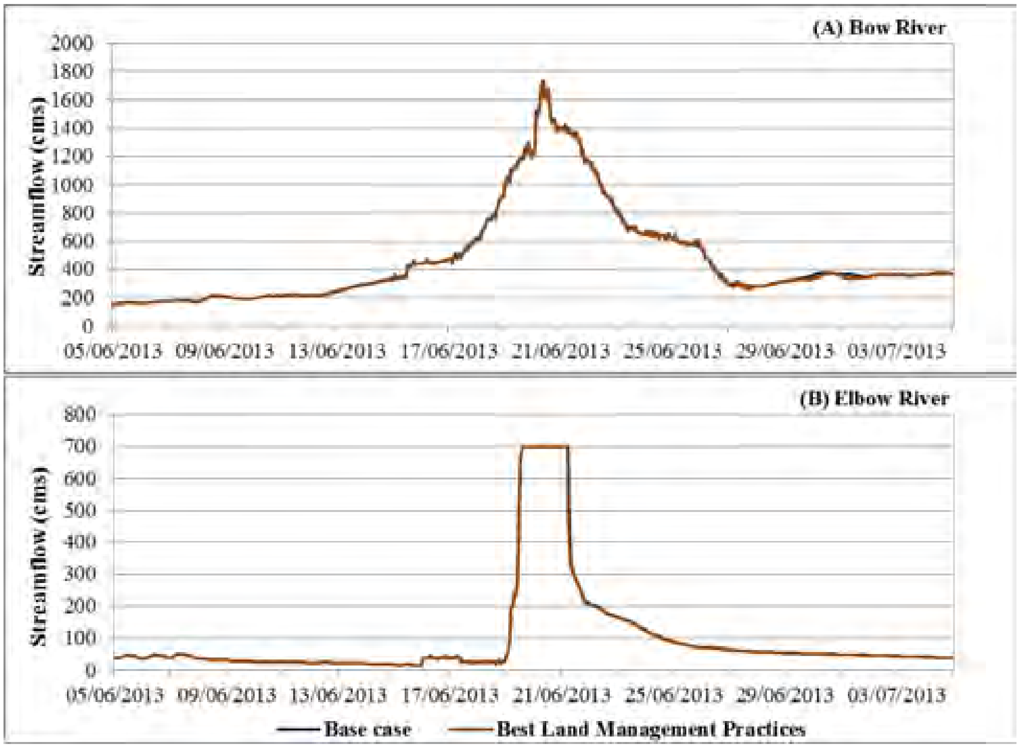

Figure 54: Comparison of streamflow in the (A) Bow and (B) Elbow Rivers in 2013 and a scenario of implementing best land management practices

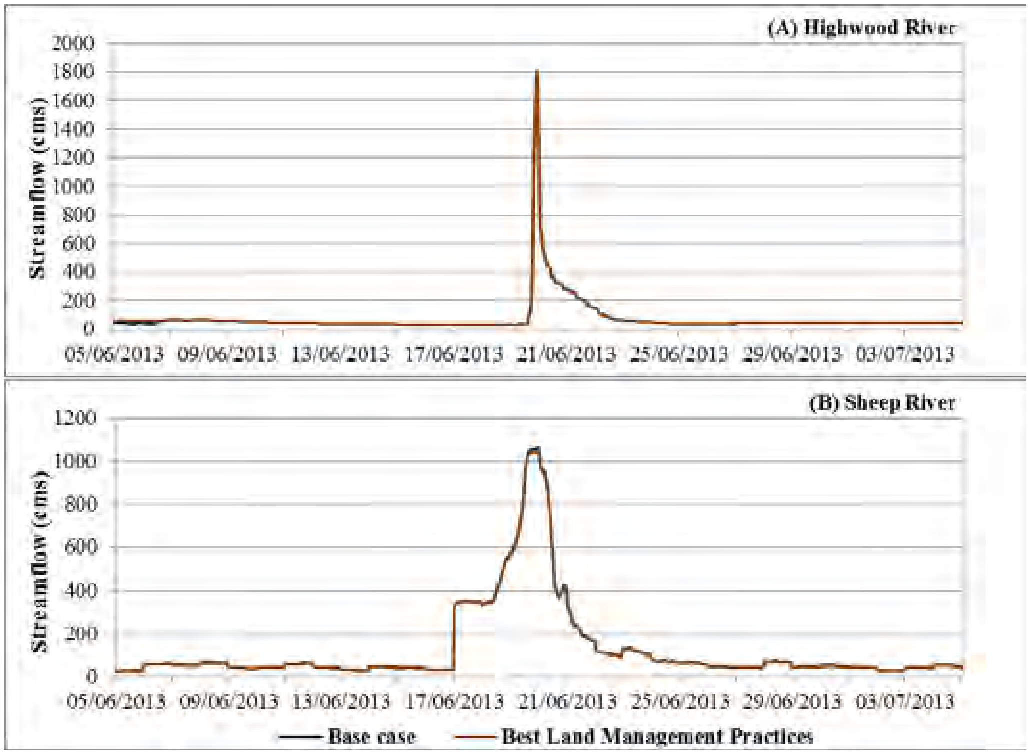

Figure 55: Comparison of streamflow in the (A) Highwood and (B) Sheep Rivers in 2013 and a scenario of implementing best land management practices. Note: the lines are over-plotted.

8 Reaching Mitigation Targets: Mitigation Combinations

A number of individual flood mitigation options showed promise on their own, and participants identified those that could be combined to achieve various mitigation targets. These combinations were developed based on several important considerations:

- Existing infrastructure should be used first and leveraged and used as effectively as possible.
- New infrastructure, particularly dry dams, is very costly and comes with a wide range of potential environmental, safety, and social consequences.
- All mitigation should be based on principles of sound watershed management.
- Resilience, flexibility, and adaptability are essential components of water management.
- A collaborative governance and decision-making process is needed to manage the system of interdependent water infrastructure. Moving water intentionally from one place to another is contentious and becomes an ethical, financial, and political decision when transfer of risk is considered.
- As described in the introduction, human safety is the first priority followed by protecting the economic core of Alberta represented by downtown Calgary, and then reducing damage to homes and other infrastructure at least cost and minimizing negative environmental and other consequences.

This section describes five mitigation combinations. The first two combinations are designed to achieve results for spring 2014 and spring 2015. The other, longer-term, combinations were developed by looking at three scenarios based on three hourly peak flow mitigation targets.

8.1 What can be done for 2014?

Much has already been done or has at least been started since June 2013. These ongoing efforts were recognized by participants as the first line of defence should flooding occur this coming spring of 2014:

- Local protection in municipalities including local berming and diking, as is being done in High River, and river bank armouring, as is being done by Okotoks to protect its water treatment plant;
- Ongoing flood preparedness efforts: emergency planning, supply replenishment, communications improvements, buyouts, and others;
- Property buyouts through the Disaster Recovery Program; and
- Continued public education and awareness around water management.

These measures are expected to continue, were assumed to be part of the combination of mitigation activities for 2014, and are in addition to the concepts that were modelled. The participants identified mitigation options that could be implemented in the Bow Basin to ensure quick action in the spring of 2014:

- Implement agreement to modify TransAlta’s facility operations to provide some level of flood control
    - Based on forecasts, lower Barrier Reservoir’s upper storage level rule by about 3 m (down to 1368.33 m) from 14/6 – 20/6. These dates were selected for modelling purposes to show the potential of this option; in effect, the model assumes perfect forecasting. Real activities would be based on real conditions and the best available forecasts and risk factors at the time.
    - Based on forecasts, lower Ghost Reservoir’s upper storage level rule by about 5 m (down to 1186 m) from 17/6 – 21/6. These dates were selected for modelling purposes to show the potential of this option; in effect, it assumes perfect forecasting. Real activities would be based on real conditions and the best available forecasts and risk factors at the time.
    - Match 2013 flood operations for Minnewanka, Spray and Upper and Lower Kananaskis reservoirs (maintain at slightly below rule curve to enable rapid filling without major releases during a flood period).
- Operate Glenmore Reservoir for flood control
    - Lower Glenmore 4 m prior to forecast flood, and allow it to rise to attenuate flood peak.
- Put in place an integrated forecasting system to facilitate decision making on infrastructure management (releasing or holding water in reservoirs).
- Enforce wetland and land management plans and policies to stop further degradation in the headwaters; initiation of activities to build the flood mitigation potential of these natural services.
    - This could not be specifically modelled in BROM.

The BROM was applied to simulate TransAlta and Glenmore Reservoir operations for flood control. As Figure 56 shows, using TransAlta and Glenmore Reservoir operations for flood control resulted in a modelled peak flow that was reduced to 1145 cms and 680 cms in the Bow and Elbow rivers, respectively for the modelled 2013 event. The spatial flooding extent was reduced substantially along the Bow River. However, flood extent was not reduced substantially along the Elbow River. The overall flood inundation extent throughout Calgary was reduced from ~40 km^2 in the 2013 base case to ~34 km^2 in the 2014 run (Figure 57).[15] Recall that the total area covered in water includes the river channels, so the reduction in flooded area is 6 km^2 out of 40 km^2 but that all 6 km^2 are lands not normally under water. Although the percent reduction may appear small, that is not an accurate statistic because stream channels are included in both calculations – that is, stream channels are included in both the 40 km^2 in the 2013 base case and the 34 km^2 in the 2014 run. This statement also applies to similar calculations of area flooded described later in this report for other scenarios.

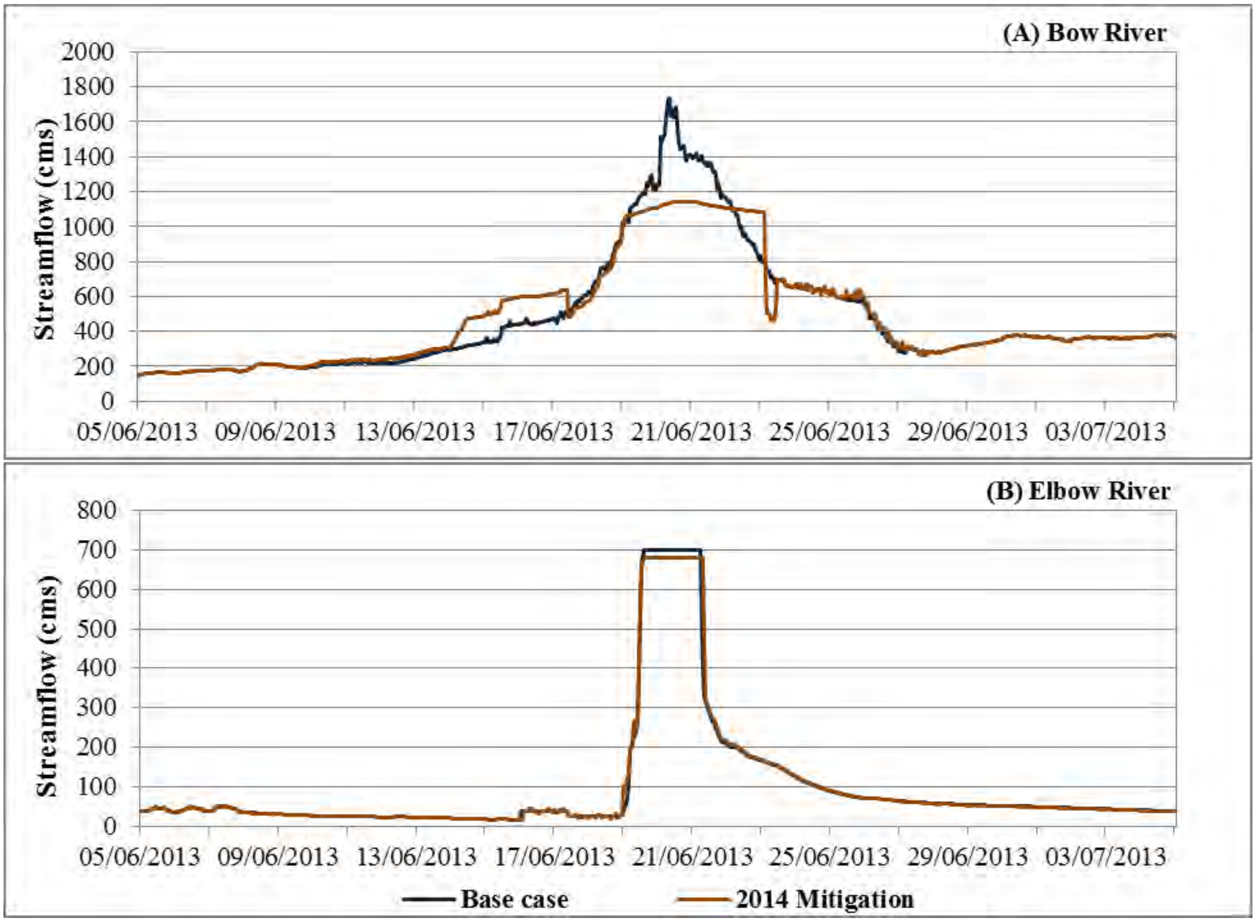

Figure 56: Comparison of streamflow in the (A) Bow and (B) Elbow Rivers assuming the 2013 flood reoccurred in 2014 and was mitigated as described above

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[15] The 1:100 values from the City of Calgary that were used in the flood visualization tool are based on the following reference and differ from values shown in this report: Golder Associates Ltd. 2010. *Hydrology Study, Bow and Elbow River Updated Hydraulic Model Project, Revision A.* Prepared for Alberta Environment. Report No. 09-1326-1040.

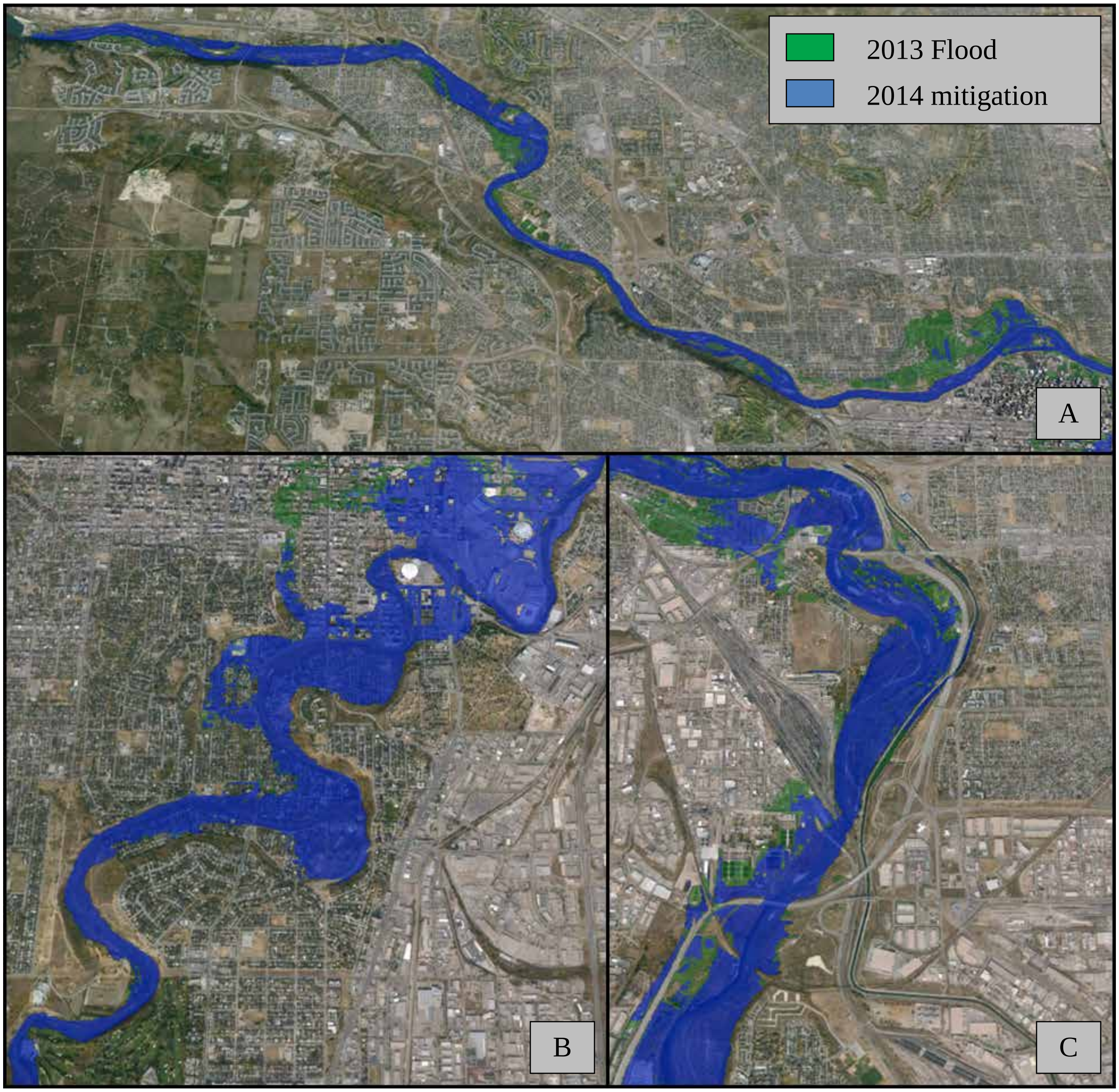


Figure 57: Visualization of the estimated 2013 flood extent and mitigation in 2014 for the Bow River upstream in Calgary (A), the Elbow River downstream of Glenmore Reservoir (B), and the Bow River downstream in Calgary (C)

The benefits and any concerns related to potential changes in operation of TransAlta reservoirs were described in Section 7.1. As noted in Section 7.2, Glenmore Reservoir was operated very well in 2013 for flood mitigation. Additional benefits might be secured by operating TransAlta facilities even more aggressively for flood control but would require a management agreement with the company or some form of government or collaborative operational control under flood forecast conditions, with appropriate compensation.

Flood mitigation actions upstream have implications for downstream users. In the Bow River Basin, downstream users include municipalities (e.g., Medicine Hat), First Nations (e.g., Siksika

First Nation), irrigation districts (EID, BRID), and other users into Saskatchewan. These downstream users need to understand the impacts of upstream mitigation activities on the speed and timing of future flood flows and take appropriate mitigation action themselves. And those putting the upstream measures in place must identify and address the downstream impacts.

A primary example of this is downstream irrigation infrastructure: Carseland diversion, Bassano Dam, and Travers Dam. The consequence of dam failure in any of these cases would be catastrophic. Berming and diking upstream to prevent municipal flooding means less upstream detention therefore more flow downstream during the peak event. Diversions, overland or underground, to reroute flows away from infrastructure reduces local flooding but gives higher peak flow downstream. Dry dams that detain high flows during the peak events should mean reduced peak flow downstream. Changing operations to detain high flows should mean reduced peak flow downstream. The effects of any of these activities upstream is additive.

Table 7 shows how upstream mitigation activities might accumulate to create significantly higher peak flows at Bassano Dam. The starting point is the ~4300 cms flow that was estimated at Bassano Dam in the 2013 flood event. The flow impacts of upstream mitigation actions are then added or subtracted to see the accumulating effect on the flow at Bassano Dam. As an example, berms through High River will send an additional 300 cms downstream in Spring 2014, increasing the flow at Bassano to 4600 cms. Protection along the Elbow could add another 100 cms for a cumulative total of 4700 cms at Bassano. The rest of the table can be interpreted similarly for each of the four scenarios across the top and the variety of mitigation options down the side. The bottom line of revised flow at Bassano can then be compared to the 2013 estimated peak flow to see the accumulated effect of the mitigation options.

Table 7: Examples of the additive downstream impacts of upstream mitigation activities

	Spring 2014		**With High River Channelization**		**With Additional Diversions**		**With a Dry Dam on the Elbow**	
2013 Peak Flow at Bassano Dam *(EID estimate)*	**~4300 cms**		**~4300 cms**		**~4300 cms**		**~4300 cms**	
Upstream Mitigation	***Impact (cms)***	***Flow (cms)***	***Impact (cms)***	***Flow (cms)***	***Impact (cms)***	***Flow (cms)***	***Impact (cms)***	***Flow (cms)***
Repeat 2013 Glenmore flood operations	0	4300	0	4300	0	4300	0	4300
Build berms through/ around High River	+ 300	4600	+ 750	5050	+ 300	4600	+ 300	4600
Build protection along Elbow *(illustrative estimate)*	+ 100	4700	+ 150	5200	+ 150	4750	+ 150	4750
Build protection along Bow *(illustrative estimate)*	+ 50	4750	+ 100	5300	+ 100	4850	+ 100	4850
Repeat 2014 TransAlta flood operations	0	4750	0	5300	0	4850	0	4850
Further operate TransAlta for flood control *(modelled ~ 600cms)*	- 300	4450	0	5300	0	4850	0	4850
Calgary tunnel *(500cms)*	n/a	n/a	n/a	n/a	+ 150	5000	n/a	n/a
Dry dam on Elbow *(modelled)*	n/a	n/a	n/a	n/a	n/a	n/a	- 300	4550
Revised Flow at Bassano	**4450**		**5300**		**5000**		**4550**	

This accumulative effect reinforces the need to implement and manage flood mitigation as a system and to find and take advantage of opportunities to offset negative impacts downstream. Downstream municipal and infrastructure planners need to prepare for the full range of future flood events as well as whether upstream flood mitigation measures will operate successfully. It is critical that existing downstream infrastructure be reinforced to comply with full safety standards, given potentially higher future flows.

8.2 What can be done for 2015?

This combination focuses on mitigation options that could be applied for spring 2015 in the Bow, Elbow, Highwood, and Sheep river watersheds. It includes:

- Building on 2014 activities described in Section 8.1
    - Implement agreement to operate TransAlta facilities for water management improvements including flood control
    - Operate Glenmore for flood control.
- Adding some new infrastructure
    - Rebuild and increase diversion from Ghost River to Minnewanka to 100 cms during flood
    - Divert 300 cms from the Highwood River north around High River or south into Little Bow
    - Divert 20 cms from the Elbow River into Priddis Creek or alternative route (20 cms, or 10% of the 2013 flow, was estimated by participants as a manageable addition to what would naturally spill into Priddis Creek from the Elbow River).
- Continuing to develop additional components:
    - Ongoing flood preparedness efforts
    - Continued local berming and diking, informed by impacts assessment
    - Improved emergency communications and scalable alert systems, backcountry advisories, and others, as well as continued public education and awareness around water management
    - Wetland and riparian restoration, land management enforcement and activities
    - Established and tested ensemble and integrated weather risk forecasting system in place
    - Collaborative governance watershed advisory board in place and operational.

The BROM was applied to simulate TransAlta and Glenmore Reservoir operations, a reconstructed 100 cms diversion into Lake Minnewanka, a 20 cms Priddis Region diversion, and augmenting flow into the Little Bow by 300 cms. Local diking and berming are also assumed to be implemented, but these were not captured in the BROM.

The peak hourly streamflow was reduced to 1060 cms and 660 cms in the Bow and Elbow rivers, respectively for the 2013 modelled event (Figure 58). Implementing a 100 cms diversion into Lake Minnewanka further reduced the flood extent along the Bow River relative to 2013. The Priddis diversion only resulted in a small flow reduction and did not substantially decrease the extent of flooding relative to 2013. The overall flood inundation extent throughout Calgary was reduced from ~40 km^2 in the 2013 base case to ~32 km^2 in the 2015 run (Figure 59).

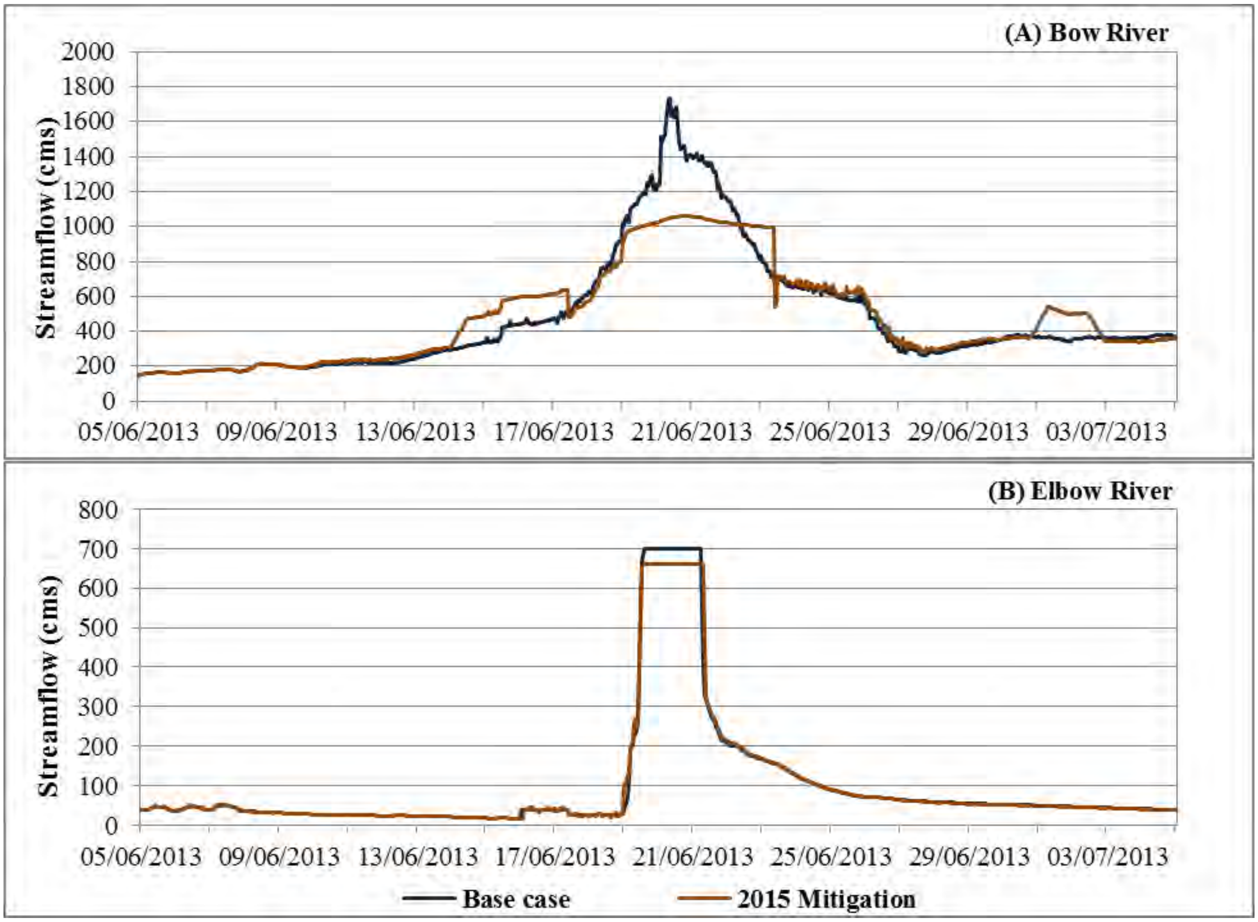


Figure 58: Comparison of streamflow in the (A) Bow and (B) Elbow Rivers assuming the 2013 flood occurred in 2015 and could be mitigated

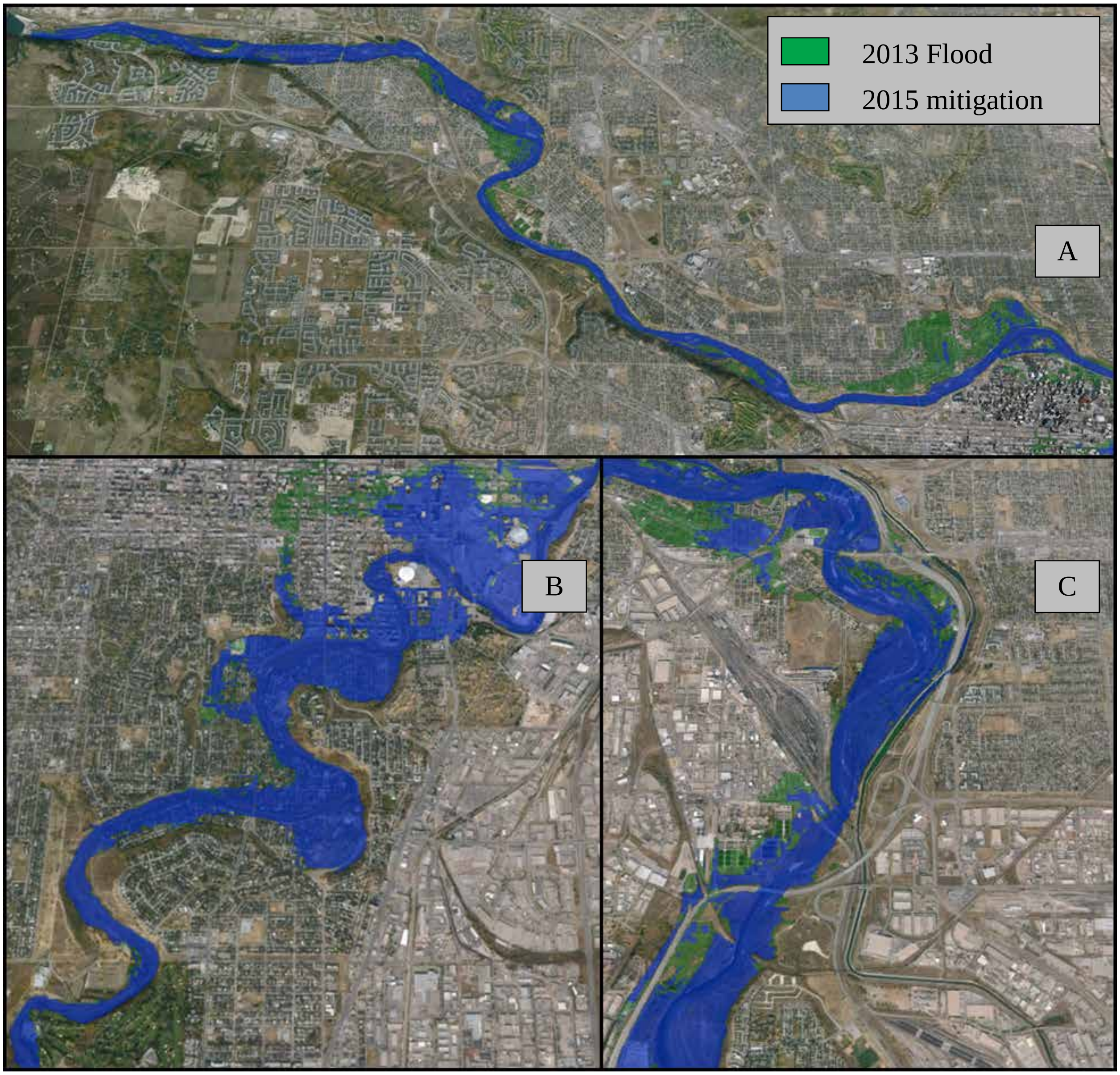


Figure 59: Visualization of the estimated 2013 flood extent and mitigation in 2015 for the Bow River upstream in Calgary (A), the Elbow River downstream of Glenmore Reservoir (B), and the Bow River downstream in Calgary (C)

Augmenting natural overland flow into the Little Bow resulted in a peak hourly flow reduction to 1538 cms in the Highwood River at High River for the modelled 2013 event (Figure 60). There was no flow reduction in the Sheep River.

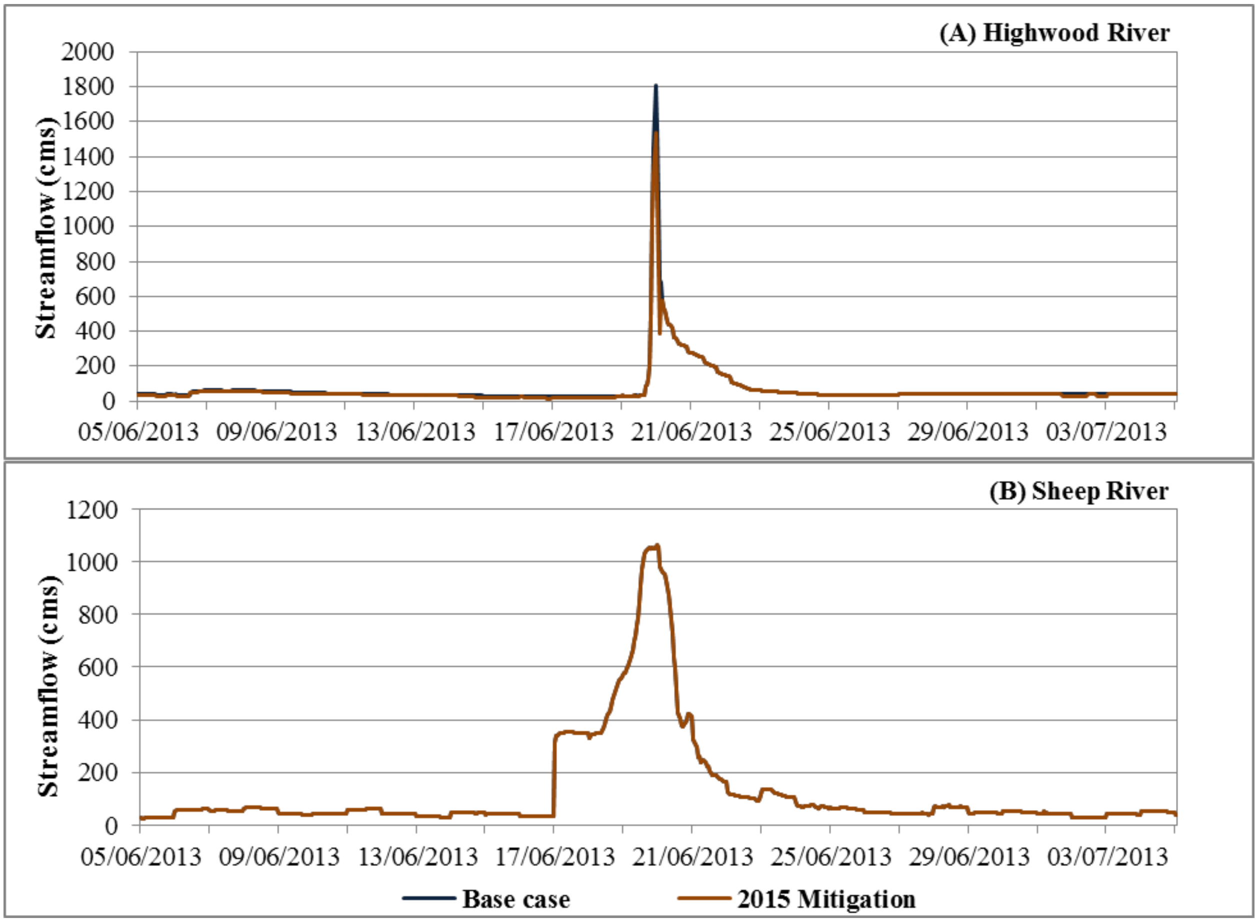


Figure 60: Comparison of streamflow in the (A) Highwood and (B) Sheep Rivers assuming the 2013 flood occurred in 2015 and could be mitigated. Note: Local mitigation (berming, diking) were not accounted for in these model runs; black line is largely hidden behind brown line on these charts.

Questions and issues related to implementation and risks of the North and South diversions around High River, particularly with respect to the South diversion into the Little Bow, were discussed in Section 7.3.

8.3 Mitigation Target Scenarios

A broader range of mitigation options could be implemented and made operational in the longer term beyond 2015. The decision as to which options to implement should be driven by the social policy question of what we are trying to mitigate to. The three mitigation target scenarios described in Sections 8.4, 8.5, and 8.6 were done to determine what infrastructure and other mitigation actions would be necessary to meet the three hourly mitigation targets shown in Table 8.

Table 8: Bow Basin mitigation targets

Location	Peak Hourly Mitigation Target 1 (cms)	Peak Hourly Mitigation Target 2 (cms)	Peak Hourly Mitigation Target 3 (cms)	1:100 Event (cms)
Bow River upstream of the confluence with the Elbow	~1050	~825	~540	1970
Elbow River downstream of Glenmore Reservoir	~450	~300	~180	758
Highwood River at High River	~1500	~1300	~1100	750
Sheep River at Okotoks	~850	~750	~650	954

Source: 1:100 Event values provided by the Government of Alberta Flood Recovery Task Force, November 2013

The 1:100 event values used as a reference in the figures in this report are based on flood frequency analyses conducted prior to the 2013 event. They are the currently-official design discharges used in the provincial flood hazard mapping. The values were provided by the Government of Alberta Flood Recovery Task Force. More recent studies are updating the 1:100 event values but these are in preliminary stages and not yet published. These design discharge values differ from the 1:100 event values provided by the City of Calgary and used in the flood visualization tool.

These mitigation targets are not set in stone and in some instances are already being increased by local actions such as the floodway through High River, relocation of infrastructure, protective actions for the water treatment plant in Okotoks, temporary and permanent berming in Medicine Hat and other locations, and many other local and regional flood damage reduction activities. The target scenarios are intended to inform the nature and extent of infrastructure changes needed to attain reduced peak flow levels through varying degrees of mitigation targets. In addition to mitigation targets, the threshold flows for downstream structures must be considered (Table 9).

Table 9: Flow thresholds for downstream structures

Location	Flow above which safety of structure is of concern
Bow River flow at Carseland Dam	3200
Bow River flow at Bassano Dam	3450
Little Bow flow into Travers Reservoir	250

8.4 Mitigation Target Scenario 1

Mitigation Target Scenario 1 was designed to achieve the Target 1 hourly mitigation target (MT1), as shown in Table 8 in the Bow, Elbow, Highwood, and Sheep river watersheds.

Operational, infrastructure, and natural mitigation options were used in combination to achieve this target and a functional governance decision-making process is assumed to be in place:

- Implement agreement to operate TransAlta facilities for flood control
- Operate Glenmore Reservoir for flood control
- Increase diversion from Ghost River to Minnewanka to 100 cms during flood
- Divert 300 cms from Highwood River north around High River (or south into Little Bow)
- Divert 345 cms from the Elbow River into Priddis Creek (or alternative options, as previously described)
- Build a dry dam on Threepoint Creek
- Basin-wide land management
- Basin-wide wetlands storage
- Improved probability forecasts for floods and reservoir management
- System in place for collaborative management of entire watershed

The BROM was applied to simulate TransAlta and Glenmore Reservoir operations, a reconstructed 100 cms diversion into Lake Minnewanka, a 300 cms diversion north of High River, a 345 cms Priddis region diversion, the Threepoint Creek dry dam, a 1% reduction in streamflow as a function of land management practices, and wetland restoration. Local diking and berming were also assumed to be implemented.

Implementing these options reduced peak hourly streamflow in the Bow and Elbow rivers at Calgary to 1059 cms and 375 cms, respectively for the modelled 2013 event (Figure 61). The flood inundation extent was reduced throughout Calgary along the Bow and Elbow rivers from ~40 km^2 in the 2013 base case to ~29 km^2. The greatest change relative to 2013 was along the Elbow River, due largely to the Priddis regional diversion being substantially increased (Figure 62).

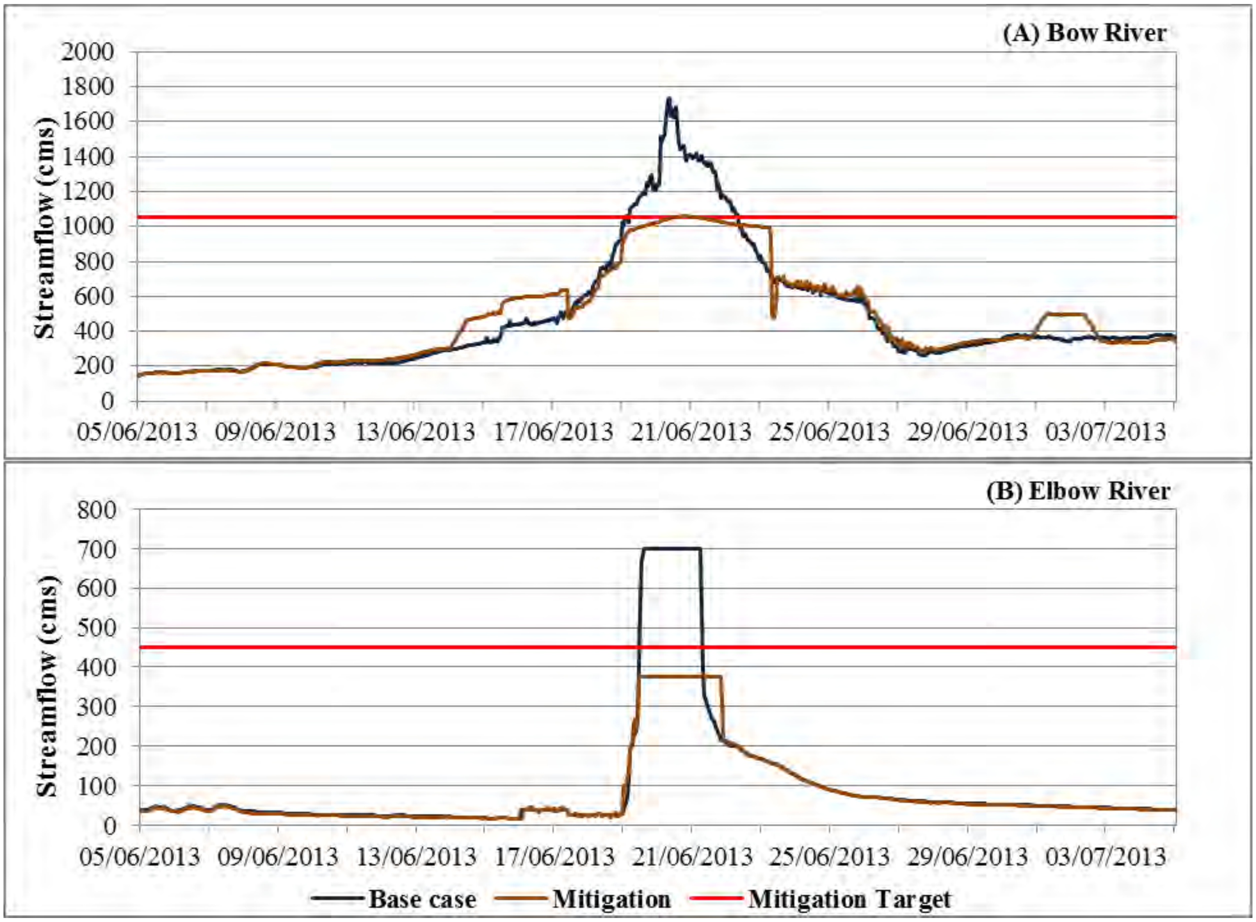


Figure 61: Comparison of streamflow in the (A) Bow and (B) Elbow Rivers in 2013 and applying infrastructural and natural mitigation to attempt to reach the mitigation target (MT1)

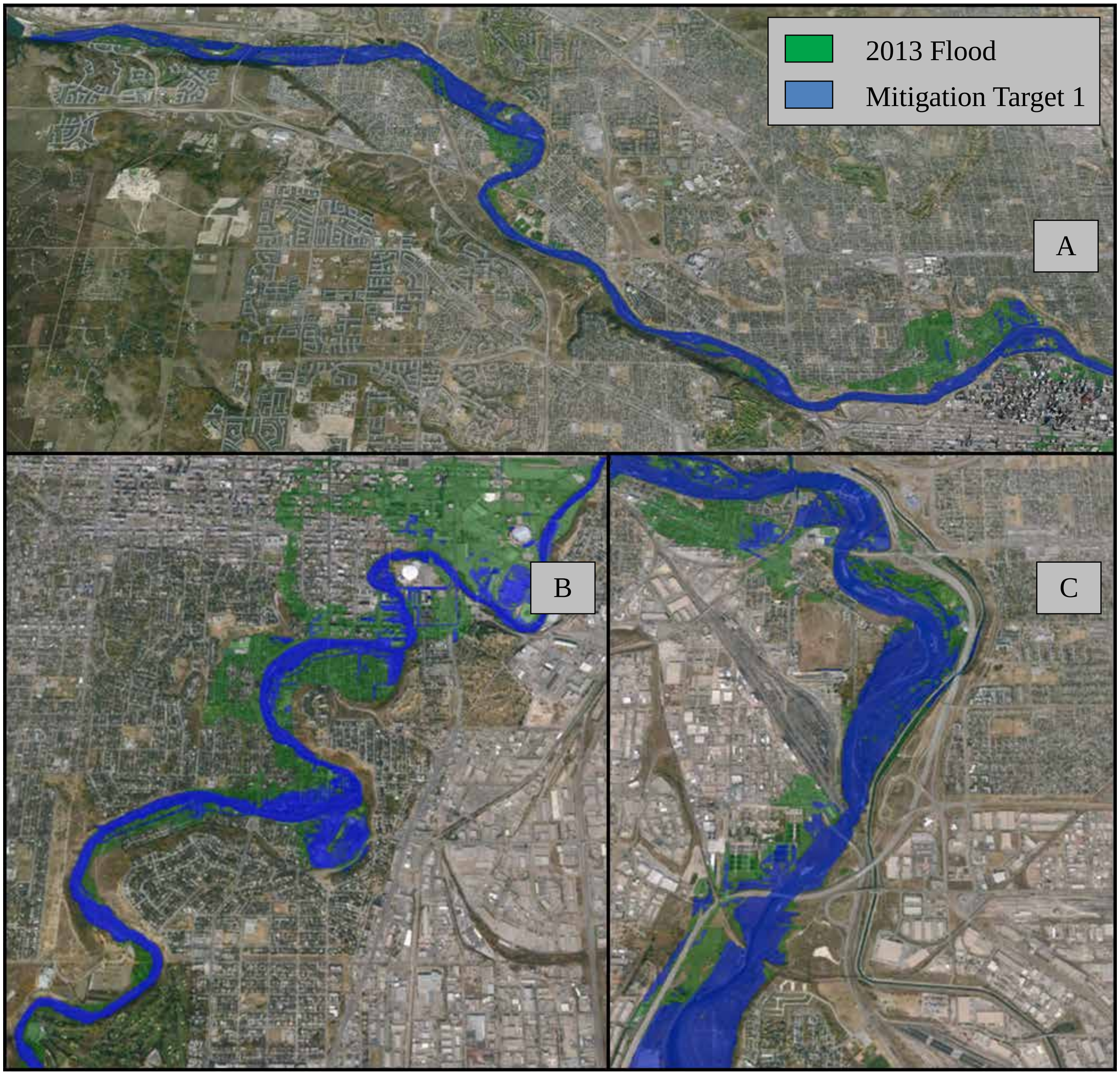


Figure 62: Visualization of the estimated 2013 flood extent and Mitigation Target 1 for the Bow River upstream in Calgary (A), the Elbow River downstream of Glenmore Reservoir (B), and the Bow River downstream in Calgary (C)

Peak hourly flow in the Highwood River was reduced to the 1500 cms mitigation target by implementing a 300 cms North diversion in the modelled 2013 event. The peak hourly flow in the Sheep River was reduced to 836 cms as a result of the Threepoint Creek dry dam (Figure 63).

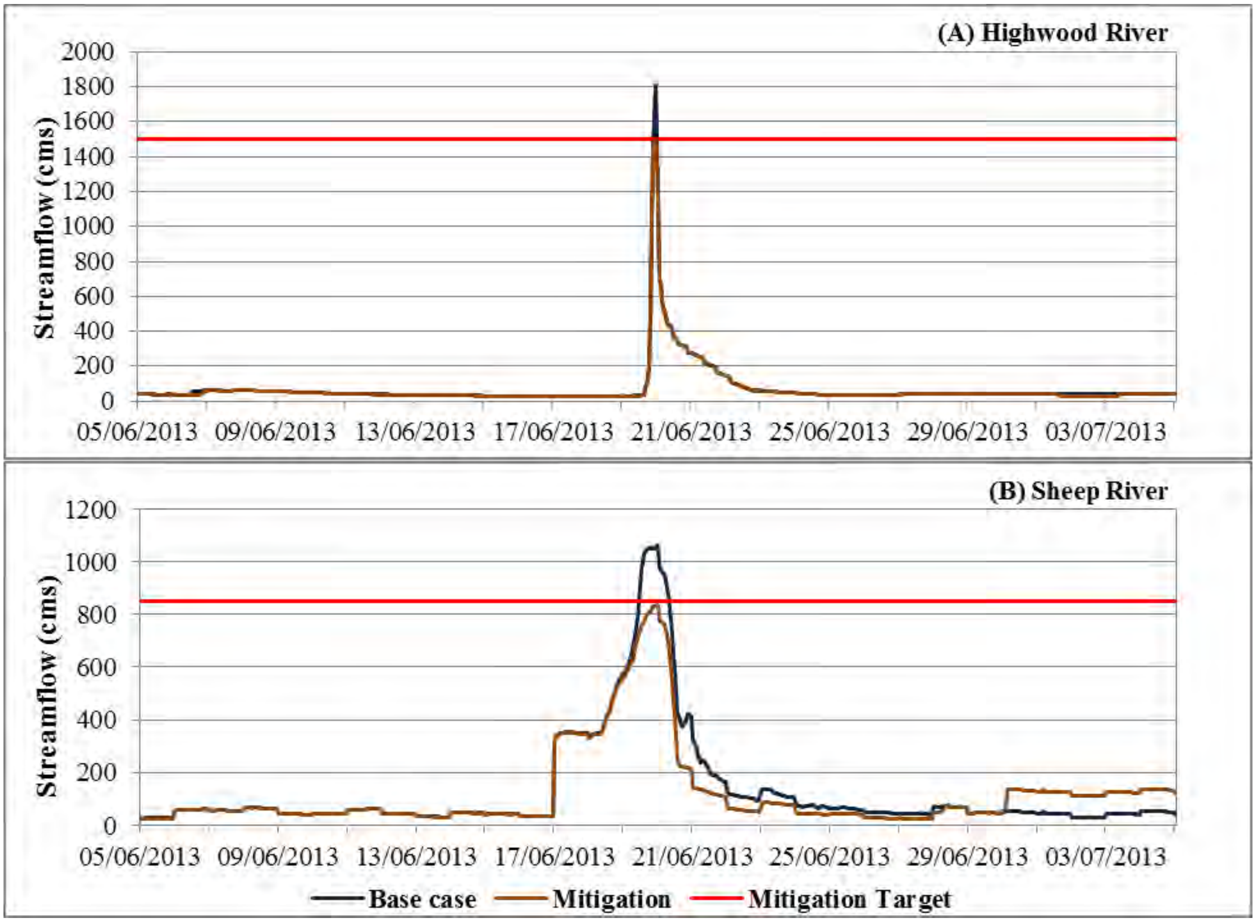


Figure 63: Comparison of streamflow in the (A) Highwood and (B) Sheep Rivers in 2013 and applying infrastructural and natural mitigation to attempt to reach the mitigation target (MT1)

The results show that the Threepoint Creek dry dam alone can reduce the peak flow through Okotoks to the MT1 target. Additional berming or other protection in the townsite may achieve the flood mitigation goal without the need for additional control structures upstream.

8.5 Mitigation Target Scenario 2

This combination was designed to achieve the second hourly mitigation target (MT2), excerpted from Table 8; these targets are:

Bow River upstream of Elbow = 825 cms
Elbow River downstream of Glenmore = 300 cms
Highwood River at High River = 1300 cms
Sheep River at Okotoks = 750 cms

Operational, infrastructure, and natural mitigation options were applied in combination to achieve this target, specifically:

- All of Scenario 1 (TransAlta flood control; Glenmore flood control; Minnewanka 100cms diversion; Highwood 300cms diversion; 345 cms Elbow diversion; dry dam on Threepoint Creek; land management; wetland storage)
- Improved probability forecasts for floods and reservoir management
- System in place for collaborative management of entire watershed

PLUS

- More Elbow diversion OR EQ1 dry dam on Quirk Creek above Elbow Falls
- Expanded Highwood diversion of 500 cms instead of 300 cms
- Two upstream dry dams on the Bow (BG1-Ghost River and BW1-Waiparous Creek)
- The S2 dry dam on the Sheep River

To meet these targets in the Bow, Elbow, Highwood, and Sheep rivers a series of natural, operational, and infrastructure mitigation measures were required. The BROM was applied to simulate TransAlta and Glenmore Reservoir operations, wetland restoration, an inflow reduction of 1% as a result of best land management practices, the BG1 and BW1 dry dams, a 100 cms Minnewanka diversion, a 345 cms Priddis diversion plus another diversion with ~80 cms capacity to handle the remaining flow to reach the mitigation target, S2 and Threepoint Creek dry dams, and a 500 cms North diversion around High River. Local diking and berming were also assumed to be implemented for the 2013 modelled event.

The addition of large dry dam infrastructures resulted in peak hourly streamflow in the Bow and Elbow rivers being reduced to 804 cms and 300 cms, respectively (Figure 64). The flood inundation extent was substantially reduced along the Bow and Elbow rivers. The overall change in flood extent throughout Calgary was a reduction from ~40 km^2 in the 2013 base case to ~26 km^2 (Figure 65).

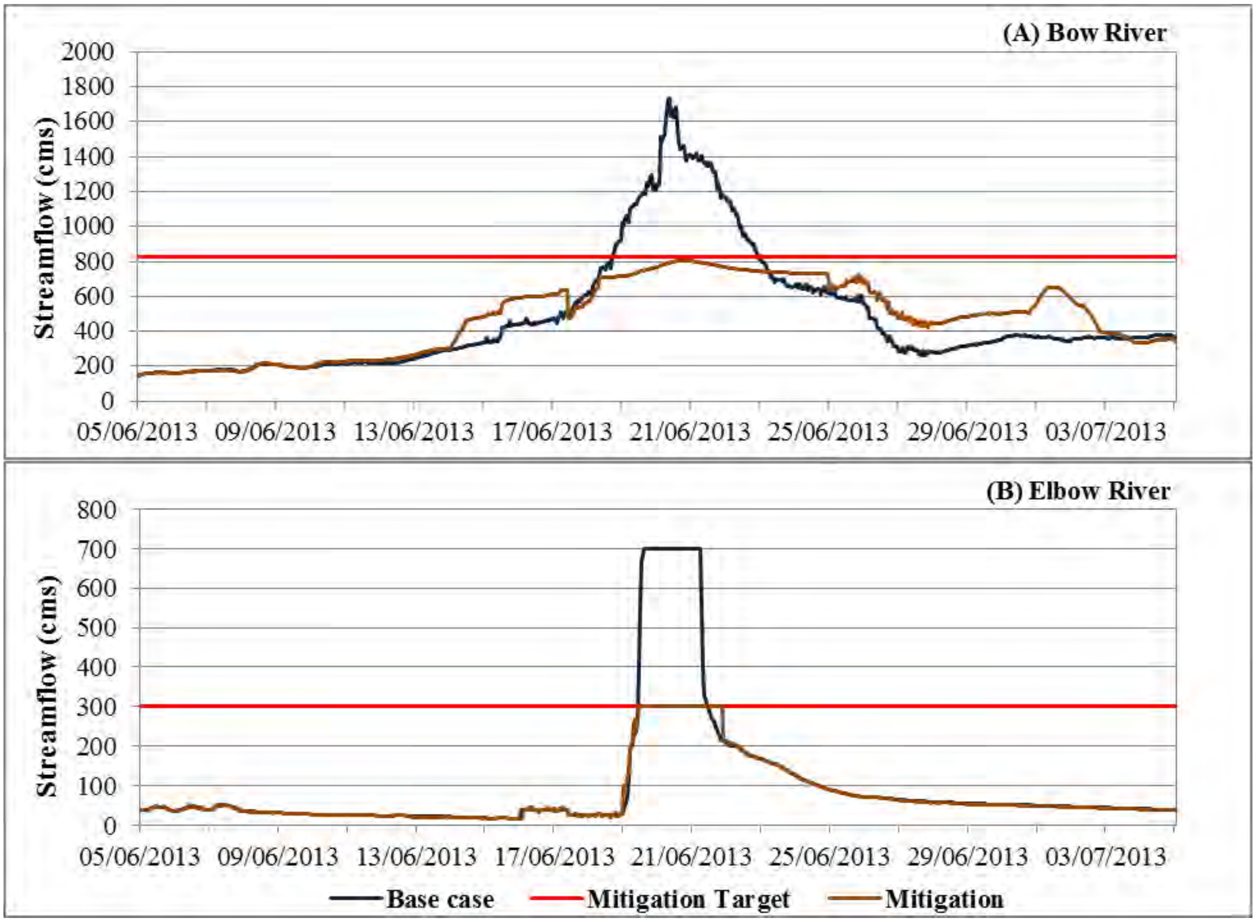


Figure 64: Comparison of streamflow in the (A) Bow and (B) Elbow Rivers in 2013 and applying infrastructural and natural mitigation to attempt to reach the mitigation target (MT2)

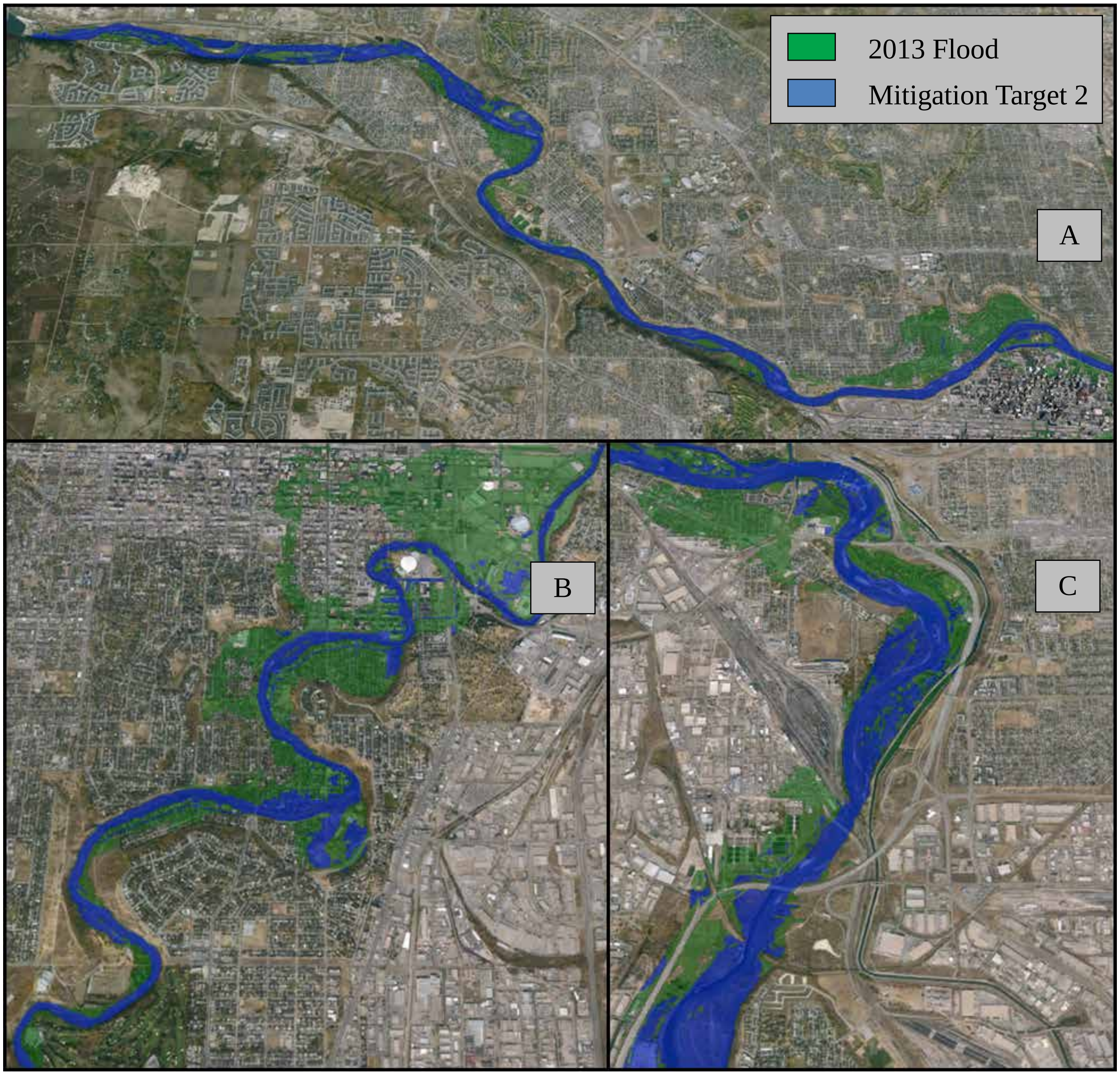


Figure 65: Visualization of the estimated 2013 flood extent and Mitigation Target 2 for the Bow River upstream in Calgary (A), the Elbow River downstream of Glenmore Reservoir (B), and the Bow River downstream in Calgary (C)

Increasing the North diversion around High River to 500 cms resulted in a peak hourly flow of 1300 cms for the 2013 modelled event. The peak hourly flow in the Sheep River was reduced to 748 cms as a result of the S2 and Threepoint Creek dry dams (Figure 66).

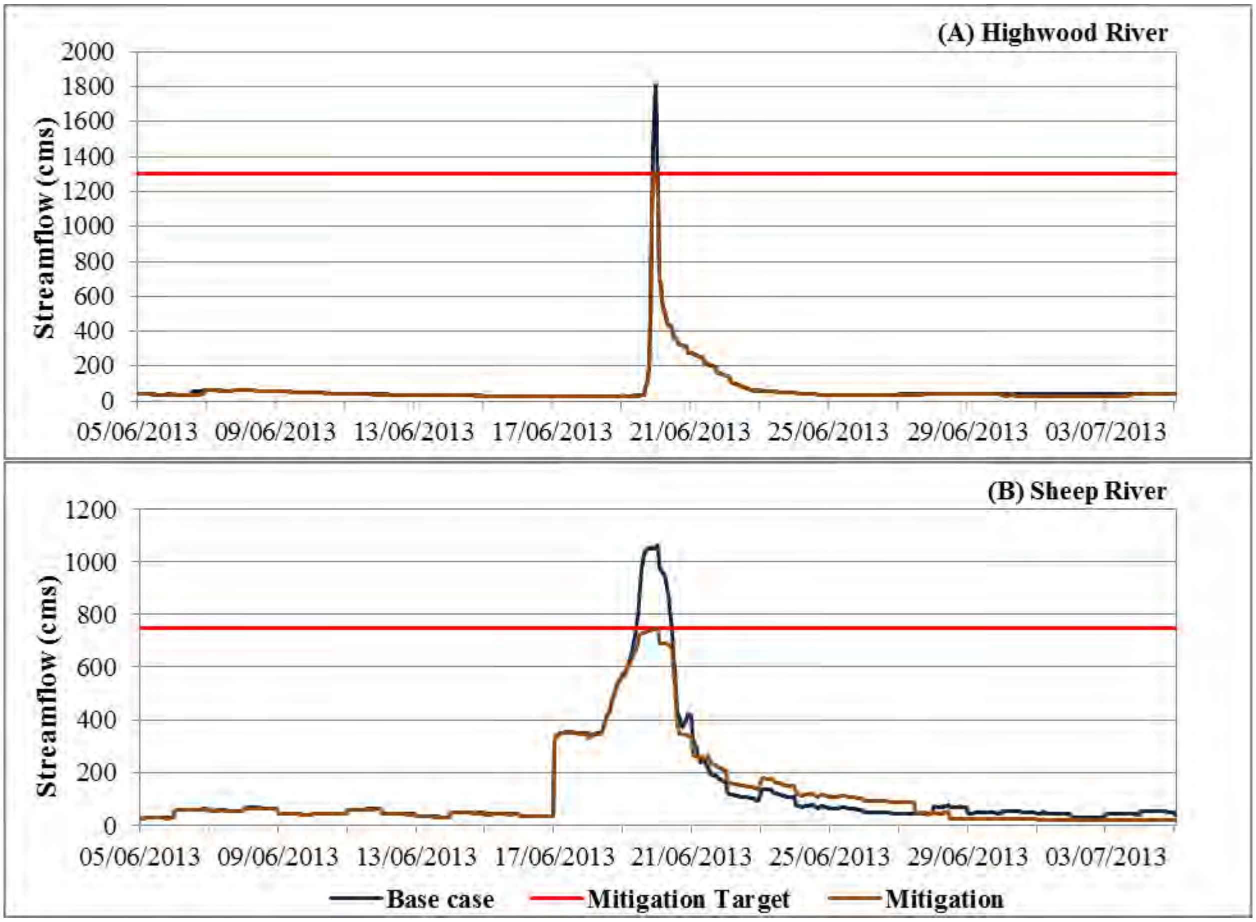


Figure 66: Comparison of streamflow in the (A) Highwood and (B) Sheep Rivers in 2013 and applying infrastructural and natural mitigation to attempt to reach the mitigation target (MT2)

Achieving the targets set in MT2 would require a considerable array of expensive and environmentally impactful new infrastructure. The targets for the Bow River through Calgary, and the Highwood and Sheep rivers through High River and Okotoks respectively are probably at or beyond what is required to protect life and most property and ensure safety under conditions of lesser flood flows than were experienced in 2013. It is more of a challenge to mitigate damages to existing homes and infrastructure along the Elbow River; that said, this run showed a substantial reduction in flooded area (~26 km^2 instead of ~40 km^2 in the 2013 base case) as visible in Figure 65.

The Elbow River has the greatest percent reduction targets of all the river systems and is shown to reach the 300 cms MT2 target in this run, down about 60% from the 700 cms which was already reduced by 40% by applying proactive flood management tactics on Glenmore Reservoir operations. The total percentage reduction in peak flow on the Elbow from inflow to Glenmore to below Glenmore Reservoir would have to reach 75% to achieve the MT2 scenario.

Some of the targeted peak flows reductions in MT2 may already have been raised due to regional and local actions to reduce flood damage. High River may need to reach only 1500 cms as a maximum flow target and Okotoks may be able to withstand a higher peak flow than 573 cms (approximately 750 cms). The actual mitigation targets will vary according to local initiatives such as relocation, permanent and temporary berming, armouring, raising essential infrastructure, pumping, and other less expensive and less environmentally disruptive actions. All of these local and regional activities can substantially reduce the overall costs (social, economic, and environmental) of mitigating flood damage given the relatively low annual probability of another flood of the size and extent of the 2013 event. As described in the introduction, human safety is the first priority followed by protecting the economic core of Alberta represented by downtown Calgary, and then reducing damage to homes and other infrastructure at least cost while minimizing negative environmental and other unintended consequences.

8.6 Mitigation Target Scenario 3

This combination was designed to achieve the third hourly mitigation target (MT3), excerpted from Table 7; these targets are:

Bow River upstream of Elbow = 540 cms
Elbow River downstream of Glenmore = 180 cms
Highwood River at High River = 1100 cms
Sheep River at Okotoks = 650 cms

Operational, infrastructure, and natural mitigation options were used in combination to achieve this target, specifically:

- All of Scenario 2 (TransAlta flood control; Glenmore flood control; Minnewanka 100cms diversion; Highwood 500cms diversion; 345 cms Elbow diversion; additional Elbow diversion or EQ1 dry dam; dry dams on S2 and Threepoint Creek; dry dams on Ghost River-BG1 and Waiparous Creek-BW1; land management; wetland storage)
- Improved probability forecasts for floods and reservoir management
- System in place for collaborative management of entire watershed.

PLUS

- Dry dam on Bow main stem above Bearspaw (BR1)
- The 500 cms 58th Ave tunnel OR more overland diversion OR dry dam EQ1
- Expanded Highwood diversion of 700 cms instead of 500 cms
- Increased flood flow retention by the S2 and Threepoint Creek dry dams

The BROM was used to simulate TransAlta and Glenmore Reservoir operations, wetland restoration, an inflow reduction of 1% as a result of best land management practices, the BG1, BR1, and BW1 dry dams, a 100 cms Minnewanka diversion, a 345 cms Priddis diversion plus another diversion (Fish Creek or ring road) with the capacity to handle the remaining flow to get down to target, S2 and Threepoint Creek dry dams, and a 700 cms North diversion around High River for the 2013 model event.

The addition of another dry dam (BR1) resulted in peak hourly streamflow in the Bow River being reduced to 674 cms, still short of the 540 cms target. Larger diversions (specific locations not identified) in the Elbow watershed resulted in a peak hourly streamflow of the targeted 180 cms (Figure 67). The flooded extent was further reduced along the Bow and Elbow rivers, with a very small amount of flooding. The overall change in flood extent was from ~40 km^2 in the 2013 base case to ~25 km^2 (Figure 68).

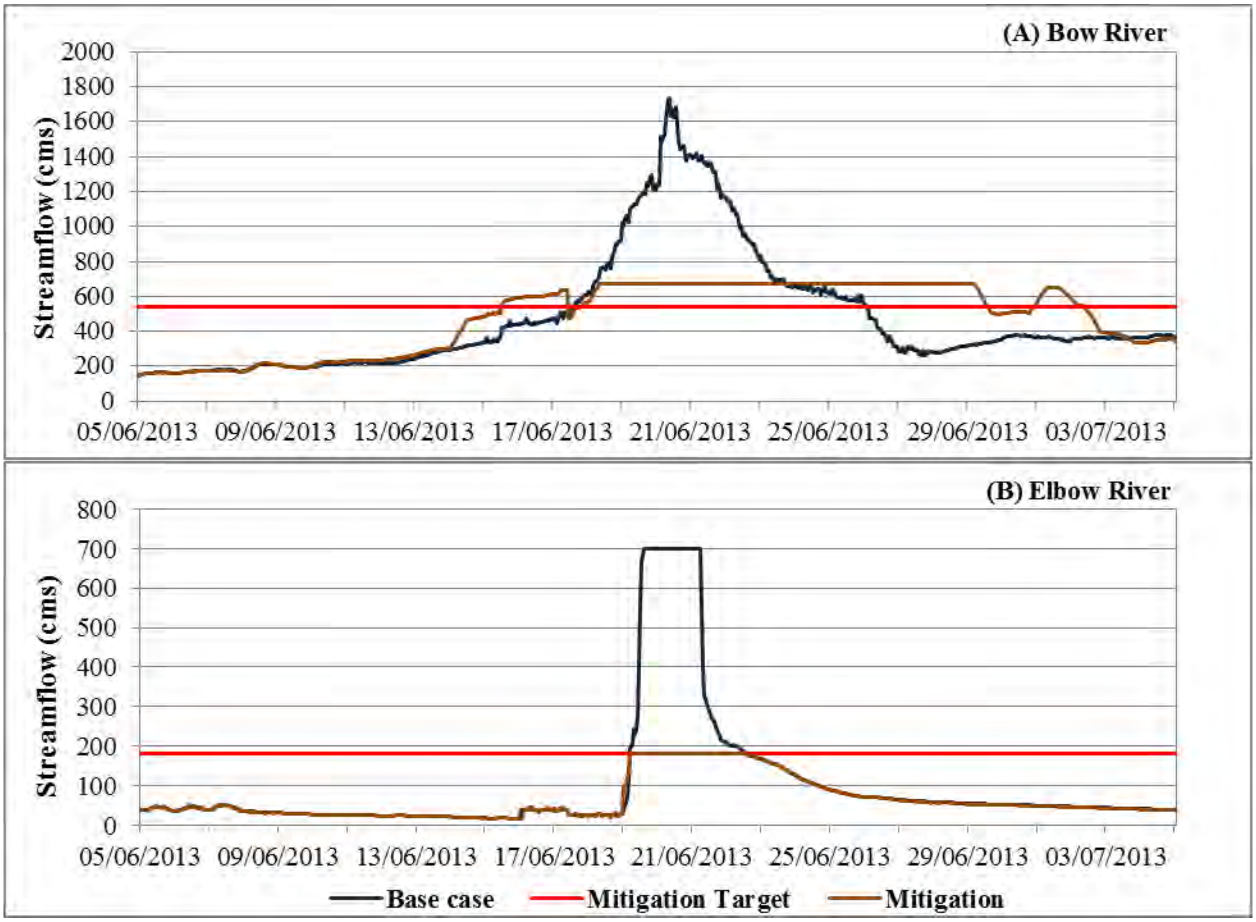


Figure 67: Comparison of streamflow in the (A) Bow and (B) Elbow Rivers in 2013 and applying infrastructural and natural mitigation to attempt to reach the mitigation target (MT3)

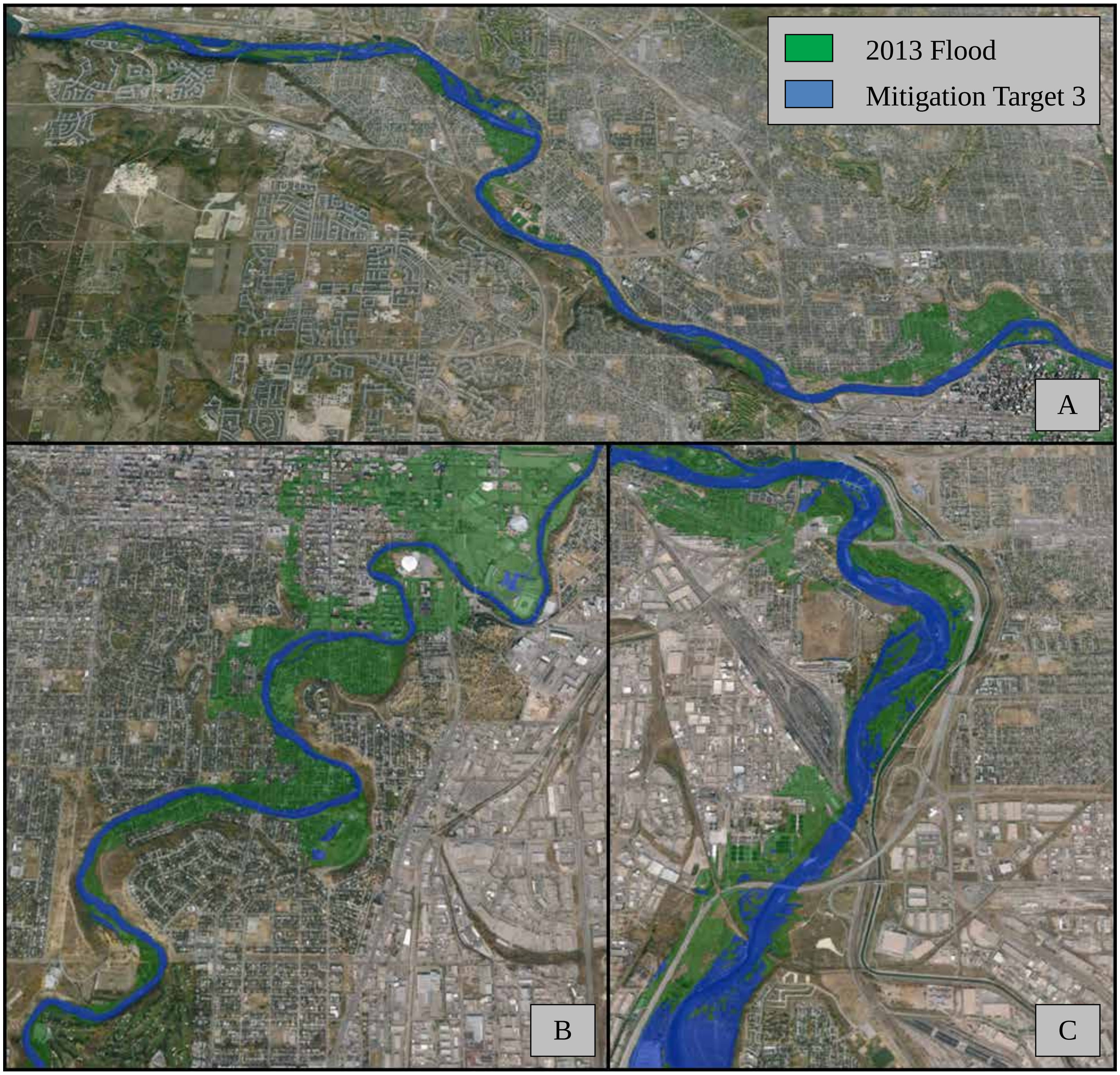


Figure 68: Visualization of the estimated 2013 flood extent and Mitigation Target 3 for the Bow River upstream in Calgary (A), the Elbow River downstream of Glenmore Reservoir (B), and the Bow River downstream in Calgary (C)

Increasing the North diversion around High River to 700 cms resulted in a peak hourly flow of 1100 cms for the modelled 2013 event. The peak hourly flow in the Sheep River was reduced to 573 cms as a result of the S2 and Threepoint Creek dry dams (Figure 69).

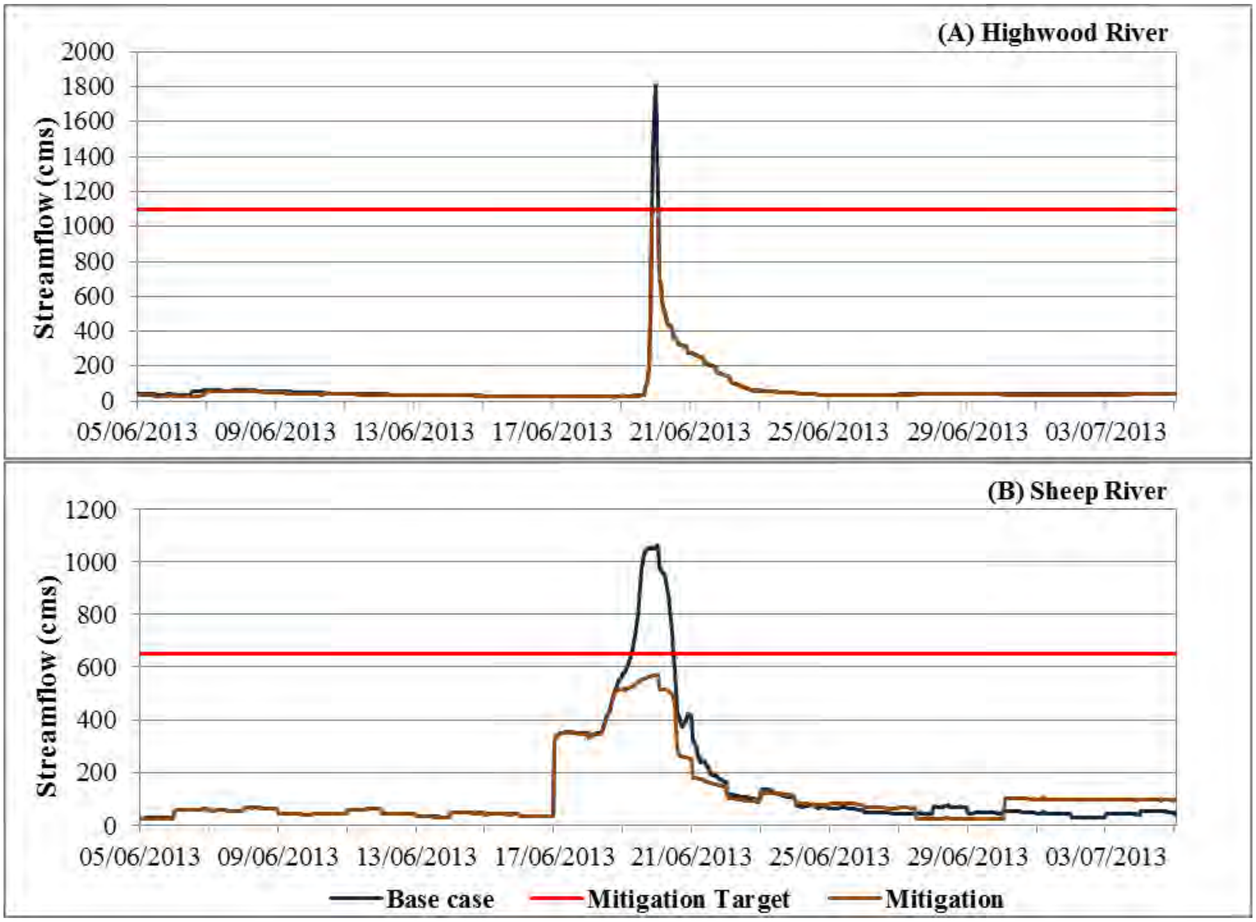


Figure 69: Comparison of streamflow in the (A) Highwood and (B) Sheep Rivers in 2013 and applying infrastructural and natural mitigation to attempt to reach the flow target (MT3)

This run illustrates that herculean efforts may achieve the minimization of flood flow on each of the river systems. But for many participants this raised the issue of too much control. Flood flows up to the point of serious safety threats or severe negative economic consequences are necessary for healthy functioning river ecosystems. This scenario also triggered a good deal of discussion about how much ordinary citizens are willing to pay in terms of pure financial costs as well as environmental and recreational costs needed to protect a relatively small number of homes, businesses, and infrastructure. The additional infrastructure for this third scenario only reduced flooding by another 1 km^2 compared with 11 km^2 for Mitigation Target 1, and 3 km^2 for Mitigation Target 2. Clearly there are diminishing returns as current proposals for additional infrastructure are added in. The all-in costs including environmental and social issues versus the benefits of flood protection against relatively low probability flooding would have to be carefully considered by decision makers before proceeding down the path to these particular mitigation targets.

The three Mitigation Target categories can be mixed and matched and do not have to proceed together for each river system. For example, if one doesn’t have to mitigate to such rigorous targets on the Bow, Highwood, and Sheep rivers, perhaps an alternative is to spend more resources examining and implementing a variety of damage reduction options for the Elbow system.

9 Key Messages

A flexible, adaptive, and resilient approach to flood mitigation is needed since the next flood will no doubt have different characteristics than previous flood events. Planning to fight and win the last battle is rarely a successful strategy particularly with infinitely variable climate and weather patterns. Protecting against such a severe and massive flood will require some potentially severe and massive trade-offs among a variety of mitigation options, none of which are pleasant to contemplate nor beneficial to everyone. This report has laid out some of the options available to us, on the assumption that we as a society must not allow a recurrence of the human and economic damages suffered in the flood of 2013.

We cannot prevent floods or droughts. However, we can achieve some level of flood mitigation through a coordinated combination of operational, infrastructure, and natural options. These must be operated in an integrated manner with appropriate governance, involving water managers and applying other expertise throughout the system. All of these elements must be carefully considered in thorough and comparative cost-benefit analyses and in light of sound water management.

Effective watershed management cannot respond only to specific flood events such as 2013, but must build the resiliency of the watershed to adapt to the full potential range of hydrological and climatic conditions. Understanding how flood mitigation measures affect low flows, water supply, and ecosystem conditions is of paramount importance to ensuring long-lasting watershed health. Despite the risks and damage of large floods, flooding is a natural occurrence and has beneficial impacts for humans and the environment that should not be completely lost.

Moving people and infrastructure out of the flood plain is the only sure way to avoid flood damage. Even with the buyouts already underway, it is recognized that much of the existing infrastructure will remain in the flood plain. To prepare for the spring of 2014, municipalities are already implementing local flood mitigation measures, and these measures need to be considered within basin-scale mitigation plans. Longer term development restrictions throughout the flood plain, possibly as a prerequisite for provincial mitigation investments, are only prudent as a part of the government’s approach to flood mitigation for the basin.

Some degree of long-term cost-effective flood and drought mitigation is available by ensuring a basin-scale perspective on existing reservoir operations. An agreement should be implemented prior to this flood season between the Province of Alberta and TransAlta that supports and governs TransAlta in operating its reservoirs for flood control when needed; this is essential in implementing some of the quick and effective measures for the 2014 flood season. In parallel, effort must be put into compiling the best meteorological and hydrological forecasting possible to inform operational decision making and enable a collaboration-based integrated management system for both flood and drought in the best interest of the whole basin.

Diversions on different scales and using different methods offer the opportunity to route flows away from infrastructure and, in some cases, these diversions build on natural flow pathways. How the diverted flow rejoins the river system needs to be carefully managed. It is critical that these diversions do not simply transfer flood risk from one community to another without fairly derived and complete compensation. All the trade-offs involved in this type of mitigation, social, economic, environmental and psychological need to be carefully assessed, but difficult decisions do need to be made.

Dry dams are a massive and expensive undertaking with many complexities: full safety standards, possibly gated spillways and culvert operations, debris management, ongoing maintenance and management, and river function impacts. There was little support among participants for dry dams, even in the Elbow River system where this type of infrastructure may play the greatest role in reducing flood flows for Calgary. The many environmental, social, and economic factors and risks associated with dry dams need to be understood and assessed in a detailed and comparative cost-benefit analysis.

Maximizing natural resiliency by improving wetland management, implementing best management practices on the landscape, and restoring natural river function are crucial to any flood mitigation solution. There are a number of practical and reliable means of doing this, including:

- Set aside some percentage of the costs of the engineered infrastructure developments being proposed and built. This percentage, proposed by many participants to be approximately 10% of the total, would be used exclusively to retain and improve healthy functioning ecosystems and for a collaborative governance function to make decisions in support of overall watershed management.
- Identify high priority locations for the establishment of wetland conservation or restoration programs.
- In combination with the GoA’s purchase of flood-prone properties, provide support and incentives (cash or enhanced tax treatment) for voluntary conservation of riparian areas and flood hazard areas within both urban and rural reaches.
- As an extension to the above, engage landowners in the river valleys in voluntary land conservation, leading to perpetual and term agreements that would set aside natural areas and allow riparian enhancement activities to occur.

The most promising near-term options for flood mitigation throughout the Bow River Basin that were identified through this project are:

1. Operate TransAlta facilities for flood control when needed. This should be implemented immediately for relatively low cost and maintained over the long term to achieve overall water management improvements as described in the Bow River Project results.
2. Construct a channel for the Highwood River through the Town of High River capable of handling 1300 cms or more. If needed, construct a channel north around High River to mitigate flood impacts on the town without increasing flood flows down the Little Bow system south of the town.
3. Operate Glenmore Reservoir in the same manner as in 2013. It was acknowledged that Glenmore Reservoir was operated optimally for flood peak attenuation during the 2013 flood event.
4. Apply existing wetland, riparian, and land management policies and plans to stop further loss and achieve a level of wetland and riparian restoration throughout the headwaters, foothills, and prairie reaches of the Bow System. This includes implementing the new Wetland Policy, making all wetland impacts subject to the mitigation process, implementing watershed and land management plans, and enforcing existing legislation.

5. Reinforce existing downstream infrastructure as soon as possible with spillways conforming to full safety standards, given potentially higher future flows; in particular, Bassano Dam and Travers Dam.
6. Improve resourcing for forecasting systems and better integration of communications to the first responders and the public if and as severe flood risk potential increases and becomes imminent.

Next steps in flood mitigation decision making, including implementation of the short term options described above, should include:

1. Social policy decisions on what flow rate and elevation level we want to target mitigation to in each basin.
2. Comparative cost-benefit analyses of what it would take to achieve the desired mitigation targets, including consideration of these measures in terms of their ecological, social, recreational, downstream, and upstream impacts.
3. Analysis of the level and location of risk associated with these mitigation measures including upstream and downstream consequences, transfer of risk, and the cost of mitigating the negative impacts of the mitigation.
4. Setting aside some percentage of the costs of the infrastructure being engineered and built, proposed to be approximately 5-10% of the total, which would be used exclusively to retain and improve healthy functioning ecosystems and to establish and operate a collaborative governance function to administer and support watershed management.
5. Broad and full communication of the flood mitigation information, analyses and decisions to all communities and residents in the Bow River Basin.

Any mitigation involves trade-offs. The hope is that a balanced suite of mitigation options will be pursued to increase safety and reduce risk of damage while enhancing the long term health and resiliency of our watershed.

Appendix A: Project Participants

Organization	**Representative(s)**
Alberta Agriculture and Rural Development	Andrea Gonzalez Roger Hohm
Alberta Environment and Sustainable Resource Development	Andrew Paul David DePape Derek Lovlin Jenny Earle Jon Jorgenson Paul Christensen Peter Onyshko Satvinder Mangat Werner Herrera
Alberta Innovates – Energy and Environment Solutions	Jon Sweetman
Alberta Tourism, Parks and Recreation	Joey Young Melanie Percy Scott Jevons
Bow River Basin Council	Mark Bennett Mike Murray
Bow River Irrigation District	Richard Phillips
City of Calgary	Deighen Blakely Edith Philips Frank Frigo Harpreet Sandhu Rick Valdarchi Wolf Keller
Ducks Unlimited Canada	Tracy Scott
Eastern Irrigation District	Earl Wilson
Fisheries and Oceans Canada	Marek Janowicz
Highwood Management Plan – Public Advisory Committee	Shirley Pickering
Kananaskis Improvement District	Arnold Hoffman
MD of Bighorn	Erik Butters
MD of Foothills	Hugh Pettigrew Julie McLean Suzanne Oel
Rocky View County	Jorie McKenzie
Spray Lakes Sawmills	Gord Lehn
Town of High River	Douglas Holmes Reiley McKerracher
Town of Okotoks	Rick Quail
TransAlta	Don Thomas Roger Drury Scott Taylor
Trout Unlimited Canada	Brian Meagher
Western Irrigation District	Erwin Braun
Western Sky Land Trust	Jerry Brunen
Flood Recovery Task Force (as observers)	Andre Corbould Andrew Wilson Cathy Maniego

Organization	Representative(s)
Alberta WaterSMART	Colin Savoy Kim Sturgess Megan Van Ham Mike Kelly Mike Nemeth Ryan MacDonald
GranDuke Geomatics Ltd.	Guy Duke Kevin Grant
HydroLogics Inc.	Casey Caldwell Dan Sheer A. Mike Sheer

Alberta Flood Mitigation: Proposed Springbank Off-Stream Storage Project

Government of Alberta-Landowner Meeting
July 18, 2015
Ranchehouse, Cochrane

Welcome & Meeting Overview

Susan Davis Schuetz
Facilitator
Alberta WaterSMART

Welcome

- **Introductions**
- **Purpose of meeting**
  - Share information on the proposed Springbank Off-stream Storage Site (SR1) project.
  - Listen and gather landowner perspectives, including questions, concerns, interests and requests.
  - Acknowledging the Government of Alberta's limited communication to date, develop a mutually meaningful engagement process by gathering landowner perspectives on preferred engagement activities / next steps.
- **Desired outcomes**
  - Shared understanding of the proposed SR1 project.
  - Shared understanding of landowner perspectives.
  - Everyone leaves here today feeling the meeting was a "good use of their time".
  - Today's meeting was the first step in a meaningful engagement process.

Meeting Process

- **Principles to guide discussions**
  - Listen actively – seek first to understand and then to be understood.
  - Be respectful of the potential diversity of experiences and views in the room.
  - Today is not about agreement – it is about getting the perspectives out on the table.
  - Endeavour to speak from your own experience.
  - Participate to the fullest extent possible.
  - Discussions are without attribution (taping, media, notes) to create an environment where everyone is comfortable to speak freely.

Meeting Process

- **Roles**
  - WaterSMART: manage the process to preserve its integrity and to obtain objectives and desired outcomes.
  - GoA, AMEC: to provide information, respond to questions and listen carefully to and gather landowner feedback.
  - Landowners: to listen, ask questions and share concerns, interests and/or requests.
- **Small group breakout sessions**
  - Provide an opportunity for everyone to share.
- **Documentation**
  - Use of flip charts to capture perspectives in the moment to ensure captured correctly.
  - Draft meeting notes for attendee review and comment.
  - Feedback forms.

Agenda

- **Welcome & Introductions**
- **Presentation**
  - Past communication and engagement moving forward
  - Alberta's Approach to Flood Mitigation
  - Proposed Action: Elbow River Flood Mitigation
  - Springbank Off-Stream Storage Site
  - Questions and Discussion
- ***Break***
- **Breakout group sessions**
  - Additional SR1 questions and comments, and discussion.
  - How do you wish to be engaged going forward?
- **Next Steps**
- **Closing Comments**

Presentation on Proposed SR1

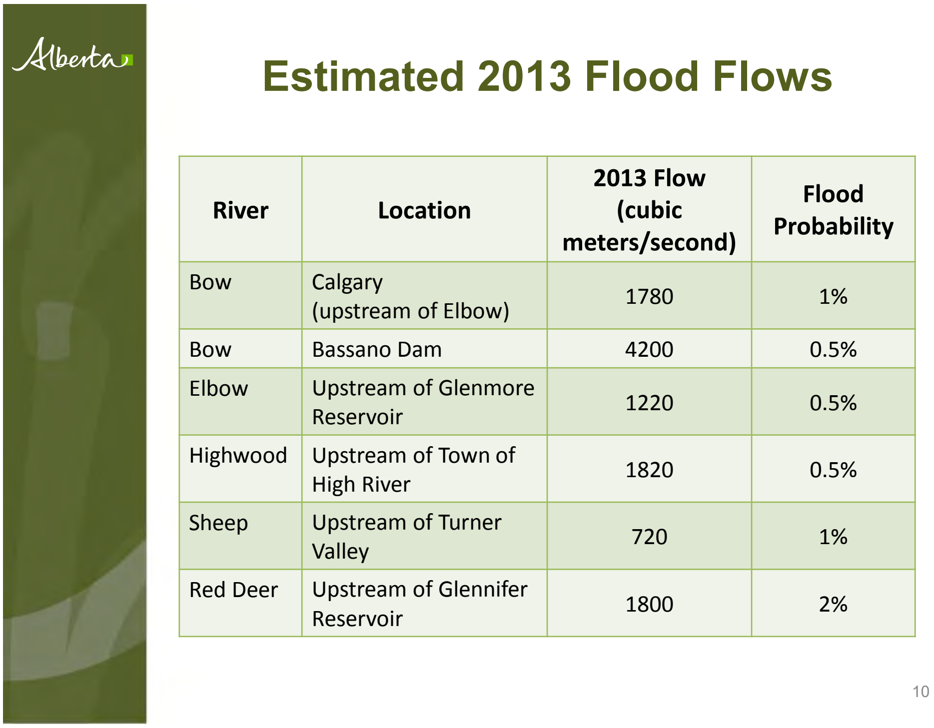
- **Participant questions**
  - Questions pertaining to a particular slide? Ask away.
  - Consider holding broader type questions until the end of the presentation as an answer to your question may be forthcoming.

Alberta's Approach to Flood Mitigation

Matt Machielse
Assistant Deputy Minister
Alberta Environment and Sustainable Resource Development

Stakeholder Engagement

- Stakeholder engagement is important throughout the mitigation process.
- We acknowledge the lack of communication with potentially impacted landowners during feasibility studies, and that we need to do better.
- It is our goal to make communication and engagement a focus as we move forward.



Estimated 2013 Flood Flows

River	Location	2013 Flow (cubic meters/second)	Flood Probability
Bow	Calgary (upstream of Elbow)	1780	1%
Bow	Bassano Dam	4200	0.5%
Elbow	Upstream of Glenmore Reservoir	1220	0.5%
Highwood	Upstream of Town of High River	1820	0.5%
Sheep	Upstream of Turner Valley	720	1%
Red Deer	Upstream of Glennifer Reservoir	1800	2%

2013 Southern Alberta Flood Impacts

- **The June 2013 flooding was the largest and most expensive natural disaster in Alberta's history.**
- **The flood impacted Alberta's people, economy, infrastructure, and environment.**
- **The provincial and federal governments are estimated to spend nearly $5 billion to recover and rebuild.**
- **Flood events are natural occurrences and cannot be prevented. We can, however, mitigate against the impacts of future floods.**

A Layered Approach to Mitigation

Alberta's approach to flood mitigation involves several layers, and includes:

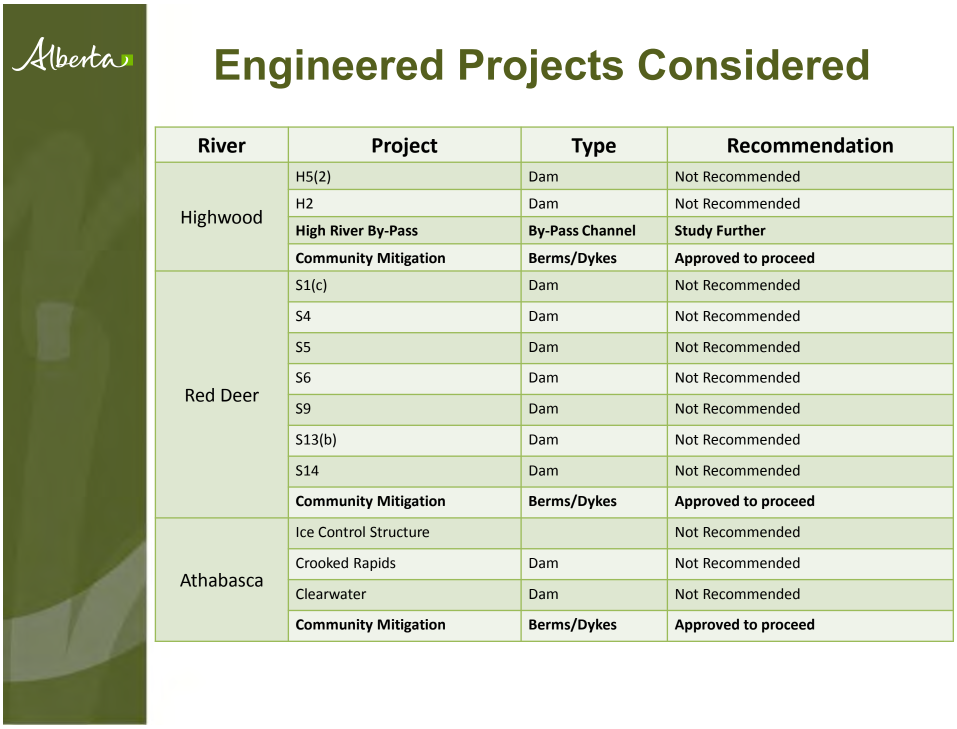
- Non-structural Mitigation: wetland restoration and enhancing riparian areas
- Local community mitigation
- Erosion control: repair and reinforce susceptible riverbanks
- Flood modelling prediction and warning systems
- Mitigation measures for homes
- Water management and mitigation infrastructure

Flood Mitigation Studies

- Following the 2013 flooding in Southern Alberta, studies were undertaken to review and assess mitigation options throughout Alberta
- The Government of Alberta received draft mitigation study reports in March 2014
- Through the completion of studies, consultant engineering firms were able to provide recommendations on various mitigation options that should be explored further

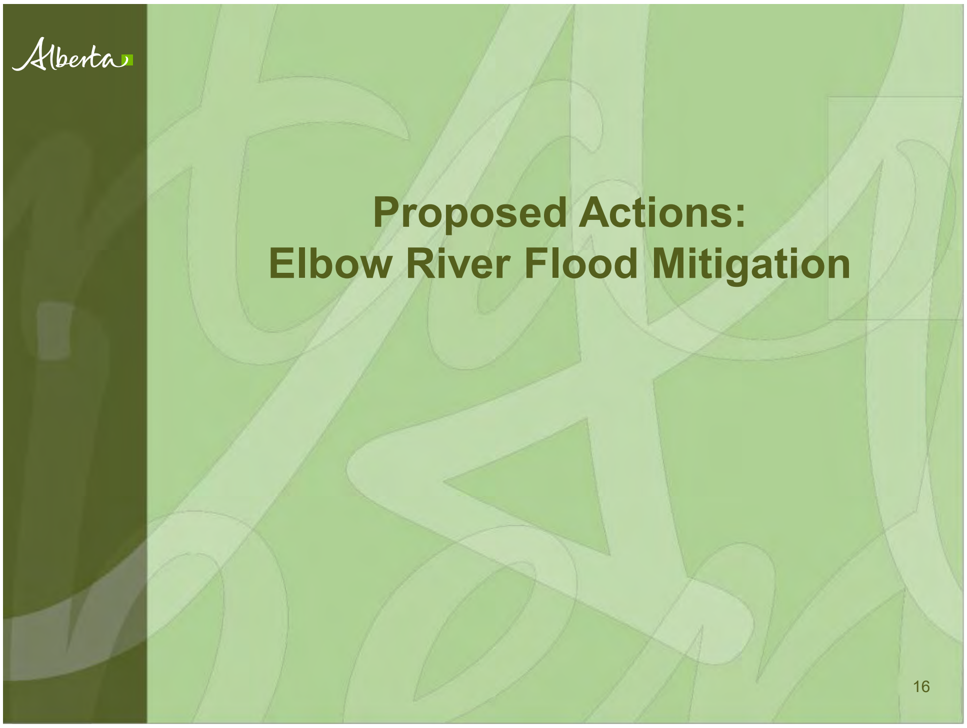
Engineered Projects Considered

River	Project	Type	Recommendation
Bow	BG1	Dam	Not Recommended
	BW1	Dam	Not Recommended
	BR1	Dam	Not Recommended
	Community Mitigation	**Berms/Dykes**	**Approved to proceed**
Elbow	FC1	Dam	Not Recommended
	EQ1	Dam	Not Viable
	EC1	Dam	Not Viable
	MC1	**Dam**	**Decision required after Calgary tunnel study**
	SR1	**Off-Stream**	**Approved for engineering design**
	Priddis	By-Pass	Not Recommended
	Calgary	**Tunnel**	**Study Further**
	Community Mitigation	**Berms/Dykes**	**Approved to proceed**
Sheep	S2	Dam	Not Recommended
	Community Mitigation	**Berms/Dykes**	**Approved to proceed**



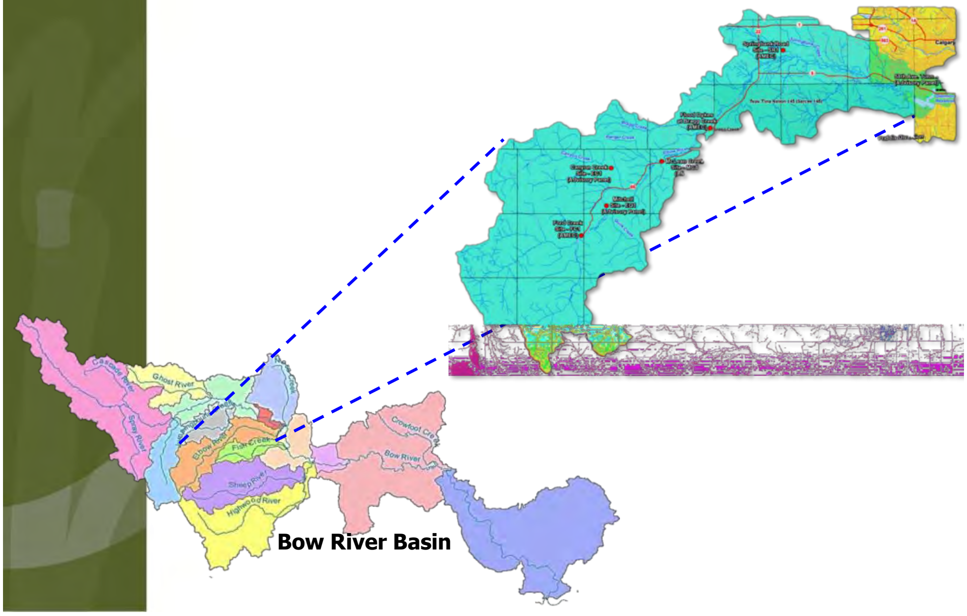
Engineered Projects Considered

River	Project	Type	Recommendation
Highwood	H5(2)	Dam	Not Recommended
	H2	Dam	Not Recommended
	High River By-Pass	**By-Pass Channel**	**Study Further**
	Community Mitigation	**Berms/Dykes**	**Approved to proceed**
Red Deer	S1(c)	Dam	Not Recommended
	S4	Dam	Not Recommended
	S5	Dam	Not Recommended
	S6	Dam	Not Recommended
	S9	Dam	Not Recommended
	S13(b)	Dam	Not Recommended
	S14	Dam	Not Recommended
	Community Mitigation	**Berms/Dykes**	**Approved to proceed**
Athabasca	Ice Control Structure		Not Recommended
	Crooked Rapids	Dam	Not Recommended
	Clearwater	Dam	Not Recommended
	Community Mitigation	**Berms/Dykes**	**Approved to proceed**



Proposed Actions: Elbow River Flood Mitigation

Elbow River Watershed



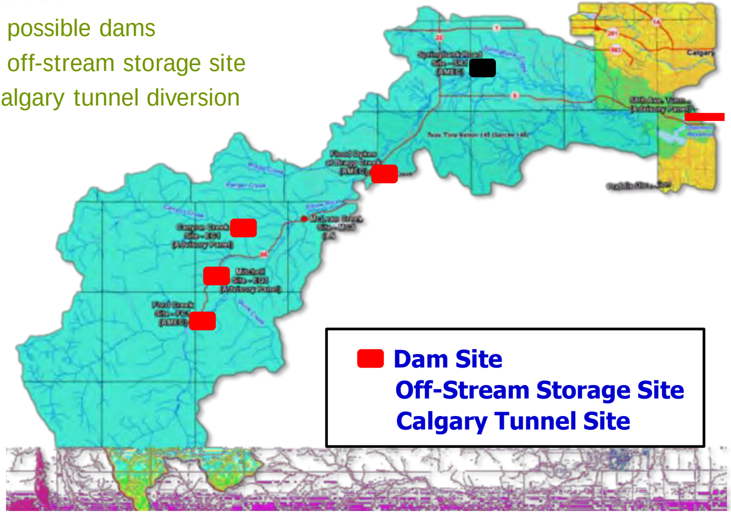
Elbow River Basin
Flood Mitigation Study Criteria

- **Identify and assess potential storage sites that would provide flood protection to the City of Calgary.**
- **Criteria Considered:**
  - Potential storage volume, environment and social impacts.
  - At minimum, sites must provide storage volume of 41,200 dam³ to protect against a 1% (1:100 year) flood event, and up to 2013 flood requirements of 67,600 dam³
- **Specific design standards would be developed later.**

Elbow River - structural mitigation options

Included:

- 4 possible dams
- 1 off-stream storage site
- Calgary tunnel diversion



Initiatives going forward

River	Project	Type	Recommendation
Elbow	FC1	Dam	Not Recommended
	EQ1	Dam	Not Viable
	EC1	Dam	Not Viable
	MC1	**Dam**	**Study Further**
	SR1	**Off-Stream**	**Study Further: approved for detailed engineering and design studies**
	Priddis	By-Pass	Not Recommended
	Calgary	**Tunnel**	**Study Further**
	Community Mitigation	**Berms/Dykes**	**Approved to proceed**

Options Assessed and Removed from Further Consideration

- **EQ1 – Quirk Creek Site**
  - Intolerable risk due to soil and rock conditions
- **Elbow River Dam Site FC1**
  - No advantage compared to MC1, and less effective protection than MC1 unless flood occurs in a particular part of the basin
- **Priddis Creek By-Pass**
  - Would result in harm to Priddis Creek and Fish Creek due to the movement of sediment, and risk to aquatic species.
- **EC1 Concept**
  - Potential storage volume too small relative to flood mitigation requirements

Elbow River Mitigation Options Being Considered Further

- **Elbow River Dam Site MC1**

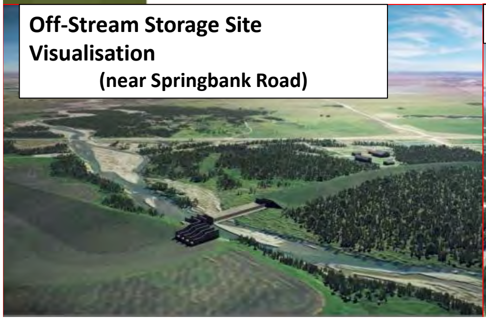
- **Calgary Tunnel**
  - Diverts water from the Glenmore Reservoir on the Elbow River to the Bow River
  - Feasibility study undertaken by the City of Calgary (engineering firm Hatch Mott MacDonald)
  - Estimated cost of $457 million

- **Springbank Off-Stream Storage Site**

Elbow River - structural mitigation options

Future Focus:

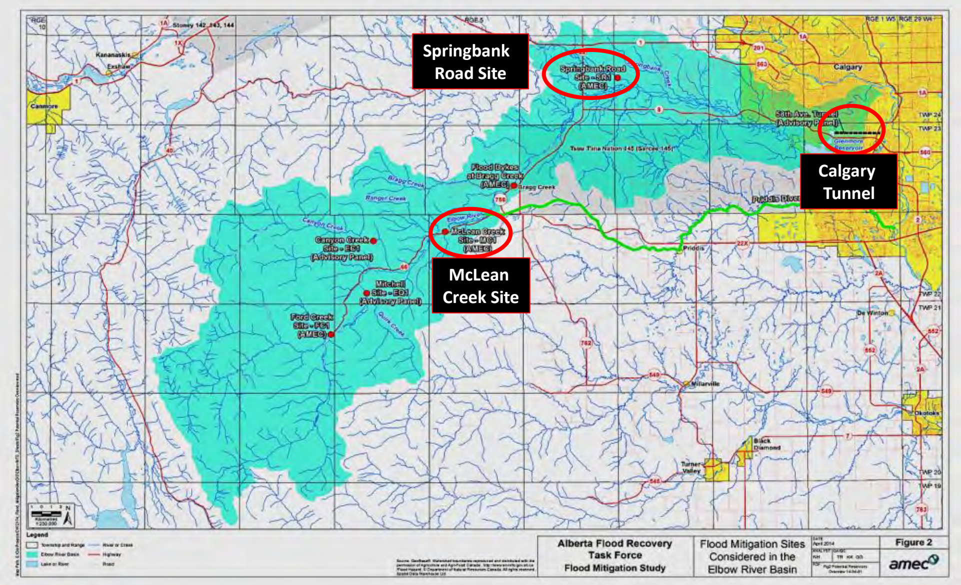
- 1 proposed dam;
- 1 off-stream storage site; and
- Calgary tunnel diversion.
  - The City of Calgary has conducted a feasibility study on the tunnel.



Off-Stream Storage Site Visualisation
(near Springbank Road)

McLean Creek On-Stream Dam Site Visualisatio

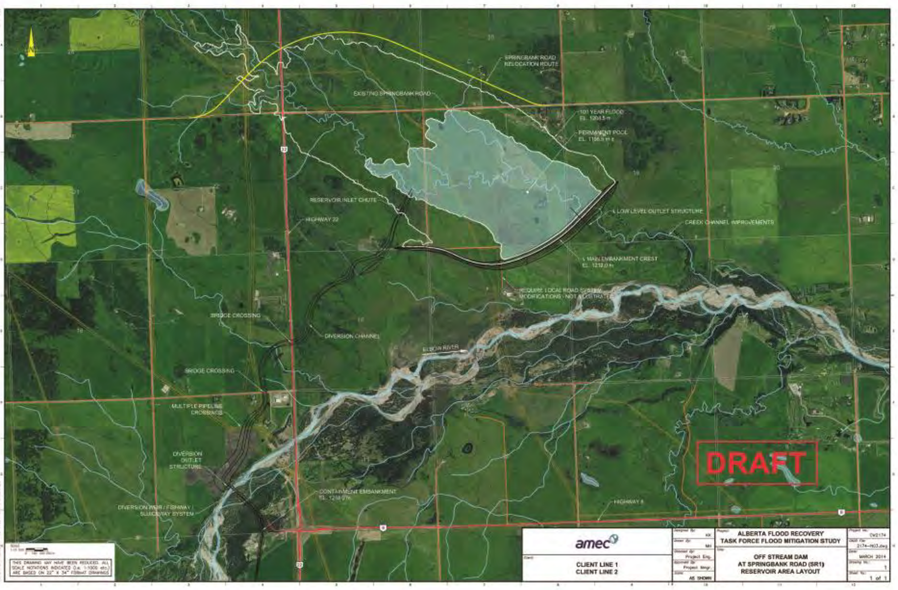
Proposed Structural Mitigation Options



Off-Stream vs On-Stream Storage

- **Drought Protection: live storage can be added to either option**
- **On-stream (MC1): $189 Million**
  - Protects Bragg Creek and Calgary
  - Store 58,000 dam³ of water
- **Off-stream (SR1): $193 Million**
  - Protects Calgary
  - Store 57,000 dam³ of water
  - Less physical disturbance to the stream
  - Less construction window restrictions
  - Fish passage on the Elbow River can be implemented

Springbank Off-Stream Storage Site



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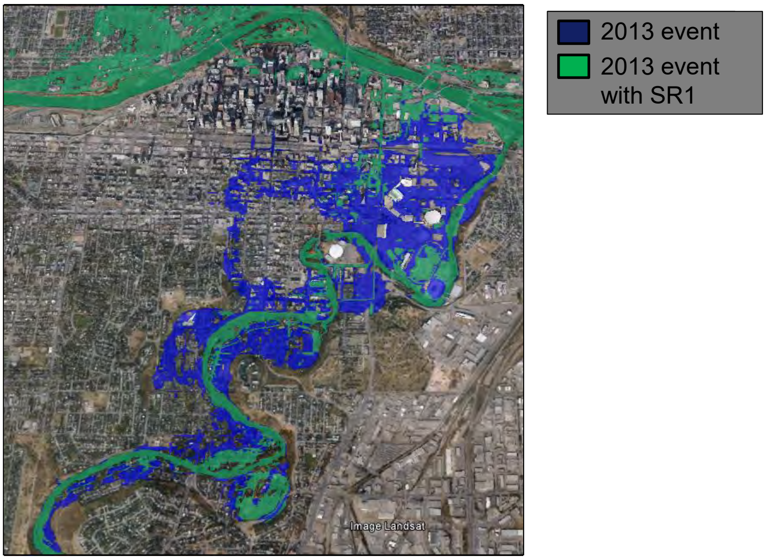
Why this Location?

- **Meets storage volume criteria**
- **Natural topography**
- **Fewer impacts to infrastructure and environment, relative to other options**
  - Off-stream storage also results in fewer environmental impacts compared to on-stream options
- **Provides an effective level of mitigation based on location**
- **Based on preliminary review, soils appear suitable**

Effects of Springbank (SR1)

Off-stream storage



🟦 2013 event
🟩 2013 event with SR1

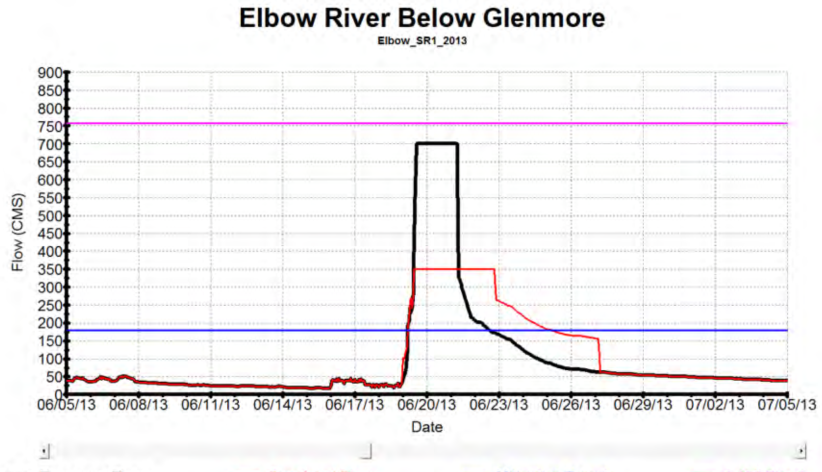
SR1 Concept: An Overview

- Canal carries water from the Elbow River into an off-stream storage reservoir.
- Reservoir temporarily contains flood waters.
- Waters are later released back into the Elbow River after the flood peak has passed.

SR1 Concept: An Overview

- **Diversion of flood waters triggers at a flow rate of 200 cubic metres per second (cms).**
  - This is approximately equivalent to a 10% flood event
- **Diversion capacity is 300 cms.**
- **During a 1:100 flood event, peak flows would be reduced from 930 to 630 cms flowing into the Glenmore.**

Example of SR1 Performance



Modelling provided by Alberta WaterSMART, www.albertawatersmart.com
***Results include mitigation from 2013 Glenmore Dam operations**

Why Does SR1 Require Detailed Engineering?

- **Conceptual studies did not offer the level of detail required to recommend the preferred major project for protecting major infrastructure along the Elbow River.**
  - Geotechnical and environmental studies are necessary.
- **Conceptual studies did not develop design standards, or assess design and operation options.**
- **All mitigation options have both positive and negative consequences. We intend to pursue options with the most benefit and least negative impact.**

Questions?

Breakout Group Sessions

Susan Davis Schuetz
Facilitator
Alberta WaterSMART

Breakout Group Discussion Questions

- **Please provide us with additional feedback and comments regarding the SR1 concept.**
- **How would you like to be engaged as detailed engineering and design of the SR1 concept moves forward?**

Alberta

Break

15 Minutes

Alberta

Breakout Group Discussion Questions

- **Please provide us with additional feedback and comments regarding the SR1 concept.**
- **How would you like to be engaged as detailed engineering and design of the SR1 concept moves forward?**

Alberta

Next Steps

Matt Machielse
Assistant Deputy Minister
Alberta Environment and Sustainable Resource Development

Alberta

Moving Forward: Next Steps for SR1

- **Select a firm to complete detailed engineering and design**
  - RFP closes on August 6, 2014
- **Undertake detailed engineering and design**
  - Beginning September 2014 (12-14 months)
- **Regulatory review process**
- **Land conversations**

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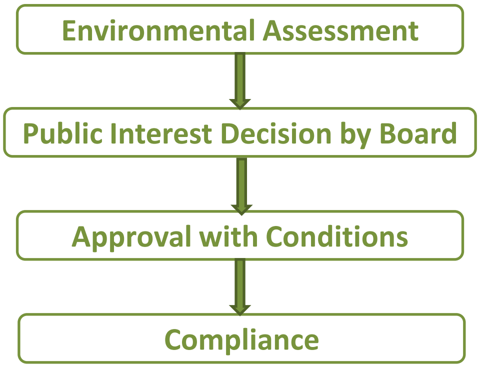
The Regulatory Process

Alberta

Regulatory Process

The Environmental Assessment Process is the first of four regulatory steps



Environmental Assessment

Public Interest Decision by Board

Approval with Conditions

Compliance

Regulatory Process Cont.

- **Environmental Assessment**
  - Determines what the environmental, social, economic and health implications of a project may be.
- **Public Interest Decision**
  - The NRCB (National Resource Conservation Board) reviews the project (and EIA) and decides if it is in the public interest to let the project go ahead.
- **Approval with Conditions**
  - Multiple regulators give formal approval (with conditions) to the project under various pieces of legislation. (e.g. *Fisheries Act, Water Act, Historical Resources Act*)
- **Compliance**
  - Ensure the project is operating within the specified approval conditions.

Canadian Environmental Assessment Act (CEAA)

- **Canadian Environmental Assessment Agency to make a determination on whether or on the project requires assessment and approval under the CEAA**

- **Federal process would likely occur concurrently.**

Land Conversations

Milo Steele
Manager
Alberta Infrastructure

SR1 Land Conversations

- **Conversations between Alberta Infrastructure and landowners in the proposed SR1 design area will begin shortly.**
- **Agents will contact landowners regarding land access required for testing as part of the detailed engineering phase.**
- **Our goal is to work with land owners to minimize potential disruption.**

SR1 Land Conversations

- For properties to be acquired, agents will work with owners on compensation amounts.
- Will use independent appraisers and industry professionals to assist discussions.
- Land agents are available to answer questions today.

Engagement Going Forward

Matt Machielse
Assistant Deputy Minister
Alberta Environment and Sustainable Resource Development

Alberta

Engagement Going Forward

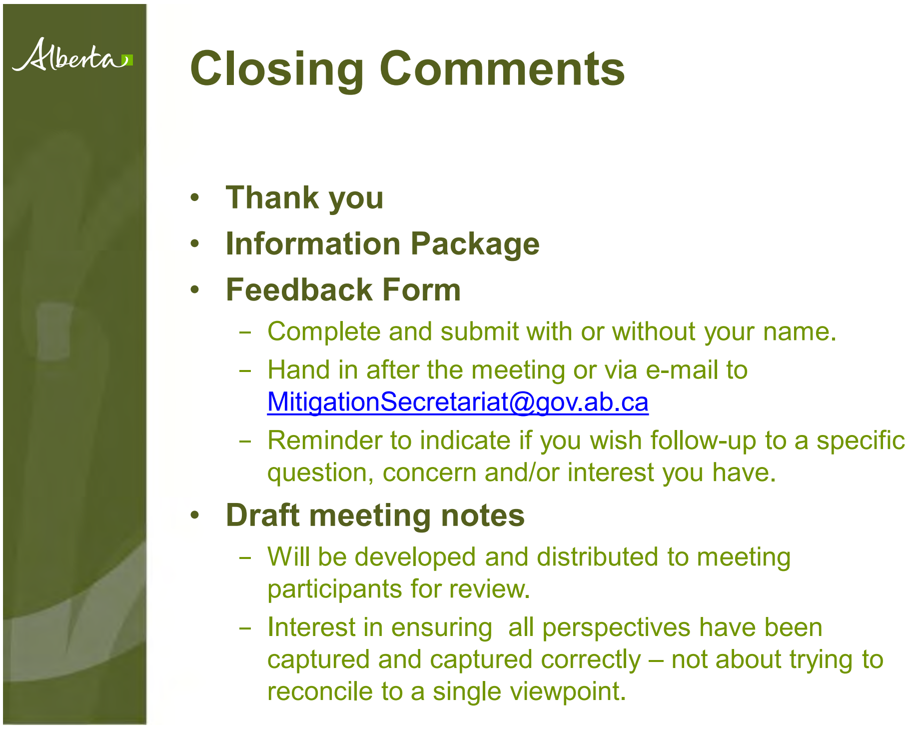
- **Thank you for sharing all of your ideas, comments, and feedback.**
  - All comments and feedback we have received today will be summarized and sent out via email.
- **The engagement process will be ongoing.**
  - EIA process beginning next week.
  - Opportunities for further engagement based on feedback today.
- **Email us at MitigationSecretariat@gov.ab.ca**

Alberta

Closing Comments

Susan Davis Schuetz

Facilitator
Alberta WaterSMART



Closing Comments

- Thank you
- Information Package
- Feedback Form
  - Complete and submit with or without your name.
  - Hand in after the meeting or via e-mail to MitigationSecretariat@gov.ab.ca
  - Reminder to indicate if you wish follow-up to a specific question, concern and/or interest you have.
- Draft meeting notes
  - Will be developed and distributed to meeting participants for review.
  - Interest in ensuring all perspectives have been captured and captured correctly – not about trying to reconcile to a single viewpoint.

The 2013 Great Alberta Flood: Progress Report on Actions to Mitigate, Manage and Control Flooding

Final version
April 24th, 2014

ALBERTA
waterSMART
Water Management Solutions

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Contents

Introduction

Spring run-off and flooding have occurred frequently in southern Alberta over the last 140 years of recorded river flows. However, the June 2013 flood event proved to be the most devastating and damaging in our Province's recorded history. Tens of thousands of families and individuals were displaced from their homes, four lives were lost, businesses were greatly disrupted, and estimated property damage exceeded $6 billion.

In the days and weeks following the flood, efforts focused on returning communities to business as usual. To do this, municipalities worked around the clock to get essential services such as water treatment and transportation operational again. The provincial government offered emergency funding to families impacted by the flood and volunteer workers helped with clean-up efforts. While the immediate needs of southern Albertans were met with enthusiasm and exceptional cooperation, a larger framework for recovery was being set in motion.

The Alberta government's creation of the Assistant Deputy Minister (ADM) Flood Recovery Task Force was initiated in the immediate aftermath of the June 2013 floods to support the Ministerial Flood Recovery Task Force. The ADM Flood Recovery Task Force is mandated with coordinating and supporting recovery efforts in communities impacted by the flood. In addition to the ADM Flood Recovery Task Force, a variety of activities have been undertaken by municipal governments, businesses, individuals and communities to rebuild areas impacted by the flood which have helped southern Albertans overcome the devastating impacts of this natural disaster.

Recommendations outlined in the original Flood White Paper, *The 2013 Great Alberta Flood: Actions to Mitigate, Manage and Control Future Floods*, were intended to provide logical, science-based, proactive actions that could be used to strengthen Alberta's ability to respond to natural disasters. While the majority of recommended actions have been addressed, gaps remain that will require attention to further achieve well-rounded and comprehensive decision-making in the area of flood mitigation. The purpose of this progress report was to engage as many water experts and members of the public as possible to capture all flood recovery and mitigation projects to date and address areas that requiring further action.

Background

This Progress Report is a follow-up document to the original Flood White Paper entitled, *The 2013 Great Alberta Flood: Actions to Mitigate, Manage and Control Future Floods* released by Alberta WaterSMART on August 2, 2013. Specifically, the following six recommendations provided the focal point for the analysis of actions and next steps to be determined:

1. Anticipate and plan for more extreme weather events, including both flood and drought;
2. Improve our operational capacity to deal with potential extreme weather scenarios through better modeling and data management;
3. Investigate the cost-benefit balance of investing in physical infrastructure such as on and off-stream storage, diversions, and natural infrastructure such as wetlands;
4. Consider flood risks in municipal planning and strengthen building codes for new developments in floodplains;
5. Evaluate options for overland flood insurance, and;
6. Manage our water resources collaboratively, following examples of the Bow River Consortium and the Cooperative Stormwater Management Initiative, and ensure Watershed Planning and Advisory Councils (WPACs) across the province have proper authority and funding.

Purpose and Process

The purpose of this progress report was to engage members of the public and water experts to capture flood recovery and mitigation projects to date and address areas that require further action. The analysis was structured around actions outlined in the *Great Flood White Paper*, matching actions currently underway or taken to date with the recommendations. This allowed the research team to identify gaps. These gaps were subsequently sorted into three stages depending on the length of time needed to resolve: short-term (in 2014), medium-term (into 2015) and long-term (2015 and after).

The first draft of the *Progress Report* was distributed to the original contributors of the *Flood White Paper* to provide feedback. Comments provided by contributors have been included in the final version of the *Progress Report*. Additionally, a version of the *Progress Report* was posted here on the Alberta WaterPortal for input and comments from the public. For the final version, every effort was made by the authors to include comments received. Any errors or omissions in this document are the responsibility of the authors and not the contributors.

Summary of Gaps

Overall, significant progress has been made on many of the action items recommended in the *Great Flood White Paper*. While many action items are currently underway or have been addressed, there remain a number of options that have not yet been pursued. Each open action item has been summarized within a timeline of short term gaps that should be addressed within 2014, medium-term gaps that can occur by 2015, and long-term gaps that should be considered for broader water management after 2015. Open action items are summarized within these three timelines:

1. **Short-term gaps**
    - Conduct cost-benefit and risk analyses to assess the best use of capital funds to support infrastructure spending decisions – Underway but not yet completed.
    - Conduct cost-benefit and risk analyses to assess the best use of capital funds to support municipal planning and land-use decisions – Underway but not completed.
    - Use the best available risk assessment tools – This is a focus of the City of Calgary's Expert Panel, but we are unclear on specific progress on this action.
2. **Medium-term gaps**
    - Improve predictive capacity through increased modeling and data management – Well underway but not yet completed.
    - Develop a better understanding of the relationship between flooding and groundwater – Just now receiving increased attention.
    - Re-evaluate the potential for slumps and mudslides during flood events – Just now receiving increased attention.
    - Engage public health professionals in assessing flood mitigation measures – Not done to date to the best of our knowledge.
    - Improve watershed management, especially headwater areas so that natural wetlands and riparian zones continue to act as a buffer for heavy rainfall – Identified as a key issue but not yet underway.
3. **Long-term gaps**
    - Refine our zoning and building codes – Underway but not yet completed.
    - Consider creating a Headwaters Management Authority – No action to date.
    - Implement a Water Literacy Campaign – Underway but more to do.

This *Progress Report* expands on these three gap areas in an effort to inform current policy discussions and encourage public awareness of recovery and flood mitigation actions done to date. The observations provided indicate areas where there is still room for improvement.

1. Short-Term Gaps

Short-term gaps refer to recommendations that have not been fully addressed or observed in the original *Great Flood White Paper*, but should be considered in 2014. Additionally, these gaps have been identified in our analysis as the most-pressing and important areas to fulfill before a decision is made on flood mitigation methods.

- **Conduct an open and transparent cost-benefit and risk analyses to assess the best use of capital funds to support infrastructure and spending decisions.** While a cost-benefit analysis was conducted for the Flood Recovery Erosion Control (FREC) program, no specific announcements have been made on cost-benefit analyses for other infrastructure projects. This is an important area to pursue before a final decision on large flood mitigation infrastructure is made. Understanding the costs, benefits and risks of specific projects is integral to present and future uses of flood mitigation developments. A cost-benefit analysis should also include an understanding of the benefits and risks of specific projects occurring in different watersheds as well as upstream and downstream risks of proposed projects. For example, contributors expressed concern with inadequate cost-benefit analyses of dry dam infrastructure that could easily become clogged with debris in the event of a flood, further requiring high maintenance costs. A cost-benefit analysis should also account for fairness by not passing costs and/or impacts from those who have chosen to own or develop property in at-risk floodplain areas to citizens that have not made the same choices.

- **Conduct cost-benefit analyses to assess best use of capital funds to support municipal planning and land-use decisions** in municipalities that have not already done so**.** In pursing cost-benefit analyses, municipalities can create a foundation for evaluating the potential for new building codes and zoning plans against the cost of their implementation. Using this approach to understand the costs, benefits and risks associated with specific projects aids in municipal planning. This includes understanding the upstream and downstream impacts of specific projects.
- **Use the best available risk assessment tools** to determine the costs, benefits and risks of specific flood mitigation projects. For example, the PIEVC infrastructure vulnerability protocol, developed by Engineers Canada, has been proven to address and understand the risks and vulnerabilities of existing infrastructure to the threat of extreme climactic weather events. Using this tool would help the provincial and municipal governments consider and assess new investments in flood mitigation infrastructure.

2. Medium-Term Gaps

Medium-term gaps refer to those recommendations that have received a considerable amount of work but remain unfinished. While work has been done to address these specific areas, gaps do remain that prevent full recovery efforts from being realized. Efforts to fully address these gaps can be achieved in 2015 with coordinated efforts of all stakeholders involved.

- **Improve predictive capacity through increased modelling and data management.** Projects including the Flood Forecasting Workshop, Flood Indicators Project led by Alberta WaterSMART and Alberta Innovates – Energy and Environment Solutions (AI-EES), and work done by Alberta's River Forecast Centre have addressed flood forecasting, modelling and data management. Gaps remain, however, in provincial government flood risk mapping that can be used in conjunction with visualization tools such as the Bow River Operational Model (BROM). Also, the availability of technology such as GRACE satellite and RADARSTAT for groundwater is limited for government employees and academics to access. To improve Alberta's predictive capacity for flooding, flood risk mapping and the availability of new technologies should be improved to ensure reliable modelling and data management systems are being used.

It is important to note that significant work is underway in this area that ensures good solutions will be implemented as quickly as possible.

- **Develop a better understanding of the relationship between flooding and groundwater.** This is a vitally important area for understanding the sources of flooding that has yet to be explored in Alberta. While surface water flooding has been addressed as the cause for major flooding across southern Alberta in 2013, little attention has been paid to the state of groundwater and its relationship with surface water. This is of particular importance in the western half of Alberta where most river flows are on and through highly porous alluvial aquifers. Any municipality where there is a significant alluvial aquifer, such as in High River, should address groundwater. Recently, significant attention has shifted to groundwater as a source of flooding which bodes well for an increased focus on groundwater issues in the next year.
- **Re-evaluate the potential for slumps and mudslides during flood events** to determine their impact on communities downstream. This area has received little attention yet has significant implications if not fully understood. Studies should be conducted that evaluate the entire watershed and how instability upstream can heighten risks and flood impacts downstream. This includes sediment loading that can severely harm flood mitigation infrastructure. This work is linked to the groundwater work noted above.
- **Engage public health professionals in assessing mitigation measures.** Collaboration between provincial and municipal governments with public health officials is important to the response and recovery processes after a flood occurs. An assessment of the effectiveness of boil water advisories and water restrictions placed on communities during the 2013 flood could provide lessons-learned that apply to future floods or droughts. Furthermore, issues of mental health recovery and resiliency are important and should be addressed.
- **Improve watershed management, especially headwater areas so that natural wetlands and riparian zones continue to act as a buffer for heavy rainfall.** Efforts in this area have been addressed by the Alberta WaterSMART and AI-EES *Bow River Basin Flood Mitigation and Watershed Management Project;* however, more analysis is needed to fully understand options for natural flood mitigation. Both public and water expert feedback to this *Progress Report* amplified the need for more natural flood mitigation options to be studied rather than focusing solely on hard infrastructure. For example, the Alberta Wilderness Association recommended that an environmental cost-benefit analysis be conducted for possible flood mitigation solutions to ensure actions do not have costly impacts on headwaters and downstream communities, water supply, as well as fish and wildlife habitats. Additionally, it will be critical to ensure that the South Saskatchewan and North Saskatchewan Regional Plans include substantive measures to restore and maintain landscape conditions that support snow retention, promote groundwater recharge and that slow the release of water from headwater regions through improved land management.

3. Long-Term Gaps

In our analysis, long-term gaps emerged as areas that remain predominant goals for water management in Alberta. These actions require more study and entail more time to implement given the need to address short term actions first. For this reason, the gaps identified below can be addressed post-2015.

- **Refine our zoning and building codes** to restrict developments on floodplains. Shortly after the June 2013 flooding in southern Alberta, the provincial government released *the Flood Recovery and Reconstruction Act, Bill 27* that restricts new construction and development projects on floodplains. Additionally, the City of Calgary recently proposed changes to the City's *Municipal Development Plan* and *Land Use Bylaw 1P2007* to address flood areas throughout the city. Further actions could be undertaken to address this gap, including a review of world-class zoning and building code practices as well as how economic levers can be used to discourage floodplain developments.
- **Relocation should be explored further as a form of flood-risk reduction.** Contributors to this *Progress Report* suggested that relocation strategies remain the most cost effective means of flood risk reduction. In any discussion of new or existing developments in the floodplain there should be further promotion of relocation. Contributors also advocated that if new developments are being kept out of the floodway then it is equally important to relocate developments at risk of being flooded again.
- **Consider creating a Headwaters Management Authority** that can manage and address watershed conditions within the provincial government. Implementing a management agency with the ability to oversee land-use decisions is important to regulating future developments throughout Alberta. Additionally, given the prevalence of flooding and drought conditions experienced in Alberta, a Headwaters Management Authority would help to address these extreme circumstances. This concept is consistent with the idea of a Provincial Water Authority as outlined in the Premier's Council for Economic Strategy (May 5, 2011), but is targeted towards land-use regulation on public land in source water areas.
- **Implement a water literacy campaign** to educate Albertans about the hydrological cycle, landscape, and climactic factors affecting water supply and flooding throughout the province and the impact of private decisions have on riparian function, flood risk, water recharge and water quality. Considerable information has been made available through the Alberta WaterPortal, the GoA Flood Mitigation website, WPAC's and watershed management groups, universities, the Telus Spark Science Centre, Telus World of Science and many other water organizations. The need for a proactive water literacy campaign was specifically identified by members of the public who provided feedback to this *Progress Report*.

Summary

Much progress has been made since the June 2013 floods. Specifically, action items recommended in the original Flood White Paper, *The 2013 Great Alberta Flood: Actions to Mitigate, Manage and Control Future Floods* have received attention with some areas requiring further action. The key short term gap to be addressed over the next few weeks as investment decisions are contemplated is the need to complete a thorough cost-benefit analysis of the various options for flood mitigation. This analysis should be comprehensive and inclusive of environmental and life-cycle costs, as well as open and transparent to the public. Furthermore, there should be a separate and specific discussion about risk and how it is reduced, transferred or transformed. This gap was clearly identified by those contributing to the *Progress Report*.

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Elbow River Historical Detention and Diversion Sites

January 2014

ALBERTA
waterSMART
Water Management Solutions

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Contents

Figures

Tables

Executive Summary

The purpose of this study is to review historical records to identify previously proposed detention and diversion sites on the Elbow River, and determine if these historical sites have any merit for further investigation and consideration by the Government of Alberta (GoA) as an alternative to the mitigation options currently being reviewed by the Flood Recovery Task Force.

An initial historical review of potential detention and diversion sites on the Elbow River provided twelve possible options that could be implemented to mitigate for both flood and drought.

Of the twelve identified historical detention and diversion sites it is recommended that the Priddis Creek diversion be seriously considered as an option for flood and drought mitigation. The Priddis Creek diversion is designed to mitigate for flooding upstream of Bragg Creek and the City of Calgary using the natural creek bed and low lying topographical areas for channeling the water flows. By using natural topography the Priddis Creek diversion has a greater potential to slow down the water; subsequently reducing peak flows. It is also recommended that the historical resevoir sites identifed by the Department of Interior in the 1890s, along with the McLean Site, should be further investigated for feasibility. These storage sites are recommended due to their use of natural topography and their ability to mitigate for flooding upstream of Bragg Creek and the City of Calgary.

In order to ensure that all the flood mitigation options are considered for all watersheds throughout Alberta, Alberta WaterSMART recommends further investigation into all mitigation options by continuing to undertake this type of historical analysis for all watersheds throughout Alberta.

Introduction

Alberta was devastated by the Great Flood of June 2013. Countless families, homes, businesses, properties, infrastructures and shared lands were affected. Following the immediate and necessary response and recovery efforts undertaken, the GoA is carefully identifying, considering and assessing the appropriate actions to mitigate, manage and help control future flooding events. Numerous ideas, proposals, and mitigation strategies are currently being assessed for feasibility and will be subject to final approval by the GoA.

Within the Elbow River watershed, there are historical maps, reports and investigations that contain information with respect to detention and diversion sites that were proposed for use in flood and drought mitigation strategies. Some of these sites were studied to the point where engineering schematics were completed. For a variety of reasons, these proposed mitigation strategies were never carried through to implementation.

The purpose of this study is to review historical records to identify previously proposed detention and diversion sites, and determine if these historical sites have any merit for further investigation and consideration by the GoA as an alternative and or complement to other mitigation options currently being reviewed. Note that detailed historical records exist for all of Alberta, but for the purposes of this study, the historical review will be limited to the Elbow River watershed upstream of the City of Calgary and Bragg Creek.

Upon reviewing the past 100 to 110 years of historical documentation WaterSMART Solutions Ltd. (WaterSMART) uncovered a number of possible options that could be implemented as a part of a comprehensive plan for both flood and drought mitigation.

In 2008, the GoA conducted a study on potential diversion and detention sites throughout all watersheds within Alberta. This study was entitled the *2008 Water for Life Assessment of Potential Water Storage and Diversion Scenarios* (GoA, 2008). In this report all historical diversion and detention sites identified on the Elbow River during this review were compared to the 2008 Report to determine if they have previously been considered for feasibility.

1. Historical Review

The chronological timeline of proposed historical detention and diversion sites located on the Elbow River is described below. It should be noted that while some concepts were originally identified for drought mitigation, and others were identified for flood mitigation, the various proposals offer the potential to address both drought and flood mitigation when considered as part of a comprehensive plan.

The Department of the Interior reservoir sites and the Calgary Irrigation Company canal/Pirmez diversion were originally developed for drought mitigation during the late 1890s. Over the past 50 years, these ideas have continued to be mentioned in flood mitigation reports developed on the Elbow.

The Priddis Creek diversion, along with the Ford, Mitchell, Sarcee and McLean detention sites were all projects put forward over the last 100 to 110 years for flood mitigation on the Elbow River.

1.1 Calgary Irrigation Company

The Calgary Irrigation Company was established by William Pearce who was a strong advocate of irrigation as a solution to the periodic droughts that affected the prairie west. The Company intended to provide water to the Town of Calgary and irrigation water to its immediate surroundings (Gilpin, 2010) (see Figure 1).

1.1.1 Pirmez Diversion

This diversion was first conceptualized by the Calgary Irrigation Company in the 1890s (Figure 1). It was subsequently constructed before the turn of the century and is still operable today. The beginning of the Pirmez diversion is located on the Elbow River approximately two kilometres (kms) upstream of the Highway 22 and Highway 8 intersection (Map 1, attached). The diversion flows east approximately 21 kms, intersects and joins Six Mile Coulee, and then divides into two separate legs; one leg flows northeast for approximately 27 km where it terminates in the Bow River, and the other legs flows approximately 42 km southeast terminating in the Highwood River. The total route, including both legs, is approximately 90 kms (Map 1 attached). It is important to note that a substantial portion of the Pirmez Diversion resides within the Tsuu T'ina Reservation.

In a 1986 Elbow River Flood Management Study (WER et al. 1986) published by WER, IBI and ECOs Engineering for Alberta Environment and the City of Calgary, this canal, referred to as the Pirmez diversion, was proposed as a part of a series of flood mitigation concepts. The 1986 Report articulated the key impacts of the Pirmez diversion including:

- the river would be totally altered by substantial channelization and increased flood flows;
- the use of Tsuu T'ina Reservation lands are required and would be affected by channel alignment; and
- recreational facilities in Fish Creek would be impacted by flooding and channelization.

No numbers were reported on the potential storage or diversion flows for the Pirmez concept (WER et al. 1986).

This diversion site was not assessed in the 2008 Water for Life Assessment of Potential Water Storage and Diversion Scenarios (GoA, 2008).

Figure 1: The Pirmez Canal

Figure 1 above is a clipping from the Calgary Herald dated February 20, 1896 showing the completed length of the canal along with the proposed extension.

1.2 Department of Interior

The Department of the Interior was established in 1873 by Sir John A. MacDonald to administer the settlement of the western territory recently acquired from the Hudson's Bay Company. As part of this responsibility, the Department conducted topographic and hydrographic surveys beginning in the 1890s in the foothills of Alberta to identify the locations of detention sites, canals, diversion points and the potential water supply available for use in the future development of irrigation systems. The annual reports of the Department of the Interior for the 1890s contain detailed outlines of the results obtained.

The detention sites identified in the 1897 Department of Interior Annual Report are presented in section 1.2.1 and 1.2.2 and shown on Map 1

1.2.1 Department of Interior Storage Sites on the Elbow River

All storage sites identified by the Department of Interior were never constructed only planned.

Reservoir Site D: situated on Canyon Creek, a tributary of the Elbow River, within Sections 28 and 29, Township 22, Range 6, west of the 5th Meridian (28/29-022-06W5M) (Map 1). The proposed location for a dam is presented at the mouth of the canyon within the southwest quarter of Section 28 (SW-28). This site was also identified by the Allan Markin Flood Advisory Panel for a dry detention site referred to as EC1.

<u>Rough capacity estimates are:</u>

With a 21 metre dam	2,097,440 m^3
With a 30 metre dam	4,935,152 m^3
With a 145 metre dam	9,870,305 m^3

Reservoir Site E (including Mitchell Dam Site): situated on the Elbow River within 04/05-022-06W5M and 29/32/33-021-06W5M (Map 1). The proposed location for a dam is presented within the NW-04.

Reservoir Site E was subsequently proposed as a detention site in the 1979 Elbow River Flood Study (Monenco, 1979) by Monenco Consultants prepared for Alberta Environment. This report identified Reservoir Site E and the Mitchell Dam Site for additional upstream storage.

The Mitchell Dam Site, which has also been identified by the Markin Panel as dry detention site EQ1, was reviewed in the 2008 Water for Life Assessment of Potential Water Storage and Diversion Scenarios and was determined to be a geologically unsuitable location for a permanent dam based on a review undertaken by the Prairie Farm Rehabilitation Association (PFRA) in 1969 in which the site was identified to be on highly permeable rockslide debris (GoA, 2008).

Reservoir Site F: situated on Elbow River within 17/20/21-021-07W5M (Map 1). The proposed location for a dam is found within SW-21, where the stream flows between limestone rock walls.

<u>Rough capacity estimates are:</u>

With an 18 metre dam	1,628,600 m^3
With a 30 metre dam	4,379,948 m^3

1.2.2 Department of Interior Storage Sites on Fish Creek

Reservoir Site G: situated on Fish Creek within 11/12/13/14-022-04W5M (Map 1 and Figure 2). The proposed location for a dam is the NE-12.

<u>Rough capacity estimate is:</u>
With a 10 metre dam 7,526,107 m^3

Reservoir Site H: situated on Fish Creek within 10/11/14-022-05W5M (Map 1 and Figure 2). The proposed location for a dam is within SE-14.

<u>Rough Capacity estimate is:</u>
With a 24 metre dam 9,475,493 m^3

Figure 2 below is a photograph taken in the 1890s depicting the topography of the area that was chosen for Reservoir Site H.

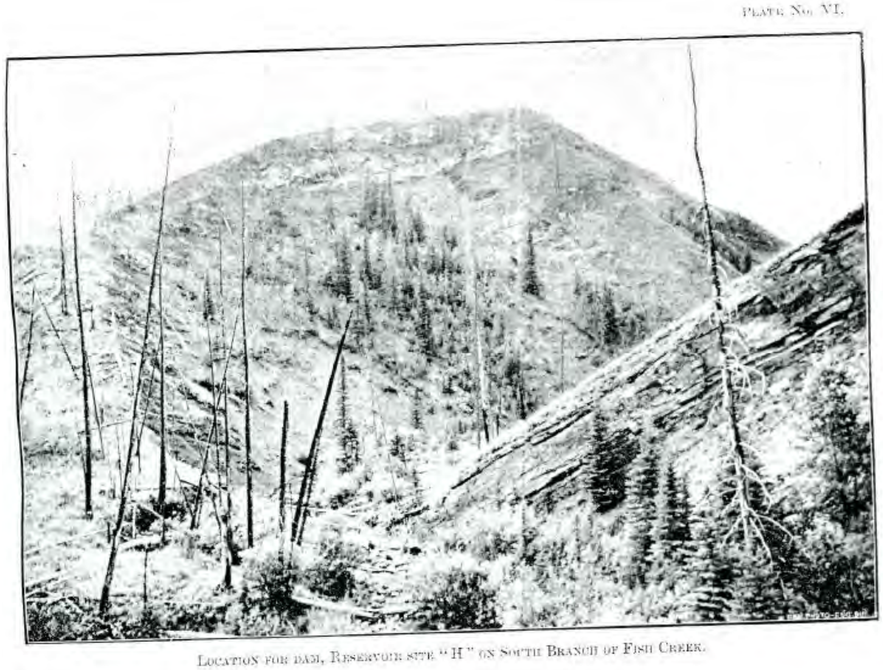


Figure 2: Reservoir Site H South Branch of Fish Creek (Department of Interior, 1897 pVI).

With the exception of Reservoir Site E, the detention sites identified above were not reviewed in the 2008 Water for Life Assessment of Potential Water Storage and Diversion Scenarios.

1.2.3 Priddis Creek Diversion

The Priddis Creek diversion was first conceptualized in 1900 by the Department of Interior with two on-stream detention sites identified as part of the diversion structure (Department of Interior, 1900) (see Figure 3). Figure 3 presents a map created in 1900 by the Department of Interior, which depicts the historical Priddis Diversion concept of diverting water upstream of Bragg Creek from the Elbow River through the Priddis Creek valley, flowing down into Fish Creek, and ultimately into the Bow River.

No written account of volume estimations for the two proposed detention sites identified on the 1900 Map was discovered during this historical review.

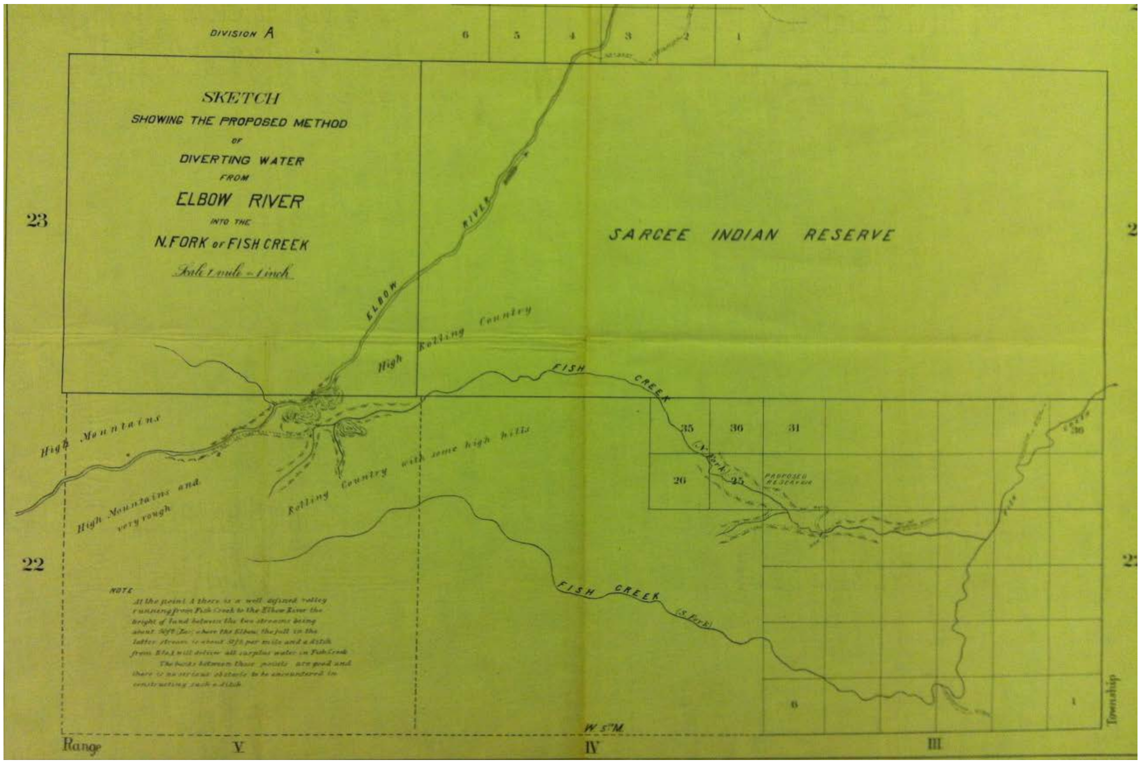


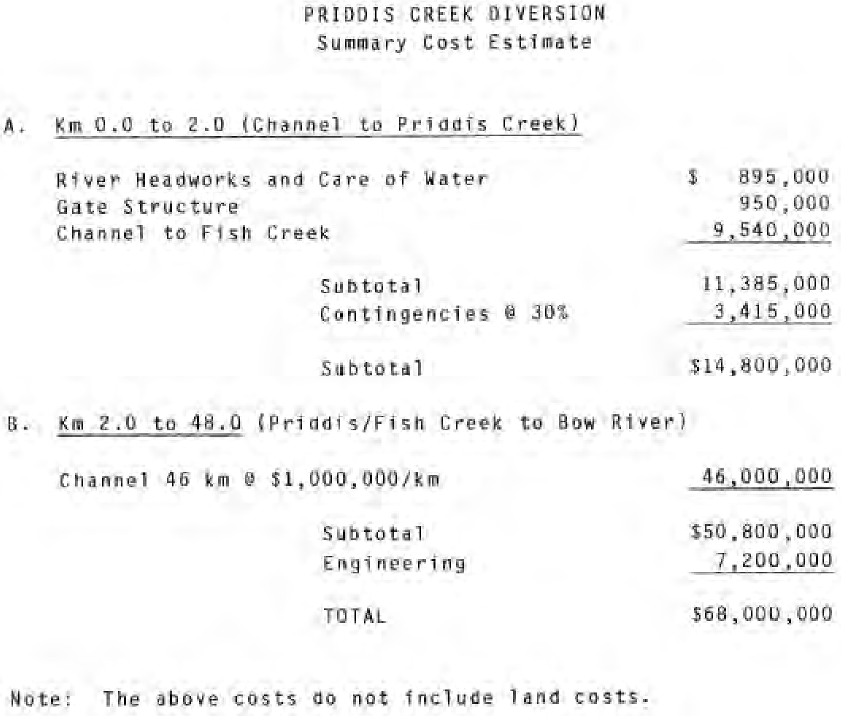
Figure 3: Proposed Method of Diverting Water from the Elbow River to North Fish Creek (Department of Interior, 1900).

The Priddis Creek diversion was revisited in the 1986 Elbow River Flood Management Study published for the Alberta Environment and the City of Calgary. In this report it was referred to as the Priddis diversion. The diversion was to be located approximately one km upstream of Bragg Creek, in the form of an un-gated constructed weir and a gated diversion network (see Map 1). The diversion would be designed for the gate to be opened during significant flood events, allowing Elbow River water to flow down the channel to the receiving stream. The diverted water would flow along the Priddis Creek valley for 21km to Fish Creek. It would then flow another 26km through the Tsuu T'ina Reserve and Fish Creek Park and ultimately into the Bow River.

The 1986 Elbow River Floodplain Management Study estimated that the Priddis diversion would divert approximately an additional 345 cubic metres per second (m^3/s) of water, assuming that the Glenmore Reservoir pre-releases are 283 m^3/s. If Glenmore outflow is limited to 170 m^3/s then the diversion channels and structures would have to be increased to upwards of 530 m^3/s. Figure 4 presents a table taken from the 1986 report outlining the cost of the Priddis Creek Diversion, assumed to cost $68,000,000 (WER et al. 1986).

The 1986 Report articulated the possible key impacts of the Priddis Creek Diversion including:

- the river would be totally altered by substantial channelization and increased flood flows;
- the use of Tsuu T'ina Reservation lands are required and would be affected by channel alignment; and
- recreational facilities in Fish Creek would be impacted by flooding and channelization (WER et al. 1986).



PRIDDIS CREEK DIVERSION
Summary Cost Estimate

A. Km 0.0 to 2.0 (Channel to Priddis Creek)	
River Headworks and Care of Water	$ 895,000
Gate Structure	950,000
Channel to Fish Creek	9,540,000
Subtotal	11,385,000
Contingencies @ 30%	3,415,000
Subtotal	$14,800,000
B. Km 2.0 to 48.0 (Priddis/Fish Creek to Bow River)	
Channel 46 km @ $1,000,000/km	46,000,000
Subtotal	$50,800,000
Engineering	7,200,000
TOTAL	$68,000,000

Note: The above costs do not include land costs.

Figure 4: 1986 Cost Estimate of the Priddis Creek Diversion (WER et al. 1986p5-17)

This diversion site was not assessed in the 2008 Water for Life Assessment of Potential Water Storage and Diversion Scenarios (GoA, 2008).

1.3 The 1979 Elbow River Flood Study

In 1979, Alberta Environment Planning Division contracted Monenco Consultants Ltd. to do a flood mitigation study on the Elbow River. Their findings included the development of two on-stream storage sites on the Elbow and the expansion of the capacity of the Glenmore Reservoir.

The two on-stream storage sites are shown on Map 1 and are described below.

Mitchell Site: originally selected in 1914 and located within 4/5/8-022-06W5M (Map 1). The location of this site overlaps with Reservoir Site E as described in Section 1.2.1 of this Report. In 1969 the PFRA determined this site geologically unsuitable and proposed a new site just downstream of the confluence of Ford Creek and Elbow River. This site is referred to as the Ford Site (Monenco, 1979) (Map 1).

Ford Site: originally selected by the PFRA in 1969 located in 24/25-021-07W5M.

Rough capacity estimate is:

40,715,008 m^3 (Monenco, 1979)

Both sites were reviewed in the 2008 Water for Life Assessment of Potential Water Storage and Diversion Scenarios. As described above the Mitchell Site was determined to be geologically unsuitable by the PFRA study of 1969 in which the site was identified to be on highly permeable rockslide debris. The Ford Site was problematic due to its location in a naturally protected area (GoA, 2008). It is important to note that the dry detention site proposed by the Markin Panel (referred to as EQ1, Map 1) is located at the proposed Mitchell site and therefore has been predetermined to be geologically unsuitable.

1.4 The 1986 Elbow River Floodplain Management Study

In 1986, WER Engineering, IBI Group and ECOs Engineering published the Elbow River Floodplain Management Study for Alberta Environment and the City of Calgary. The study determined the potential of additional upstream storage in the form of the Sarcee and McLean Reservoir sites along with two diversions through Fish Creek Park: the Priddis and the Pirmez diversions (see Map 1).

The additional detention on the Elbow River was proposed as follows:

Sarcee Reservoir/Dam Site: Located approximately 1.5 km upstream of the Glenmore Reservoir immediately west of the "Weaselhead".

Rough Capacity estimate is:

With a 22 metre dam	42 000 000 m^3
With a 26 metre dam	64 900 000 m^3

Key Impacts of the proposed Sarcee Site include:

- part of the military reserve would be subject to flooding;
- very few residencies or agricultural land would be directly impacted;
- habitat for wildlife affected;
- fish spawning impacted;
- Weaslehead area encroached upon;
- Sacree Trail affected;
- Tsuu T'ina Reservation lands required; and
- siltation rate in Glenmore reduced (WER et al. 1986).

McLean Reservoir/ Dam Site: Located upstream of Bragg Creek.

<u>Rough Capacity estimate is:</u>

With a 25 metre dam	24 600 000 m^3
With a 46 metre dam	49 200 000 m^3

Key impacts of the proposed McLean Site include:

- parts of Kananaskis Country impacted;
- highway 66 relocated;
- wildlife habitat affected; and
- some degree of flood protection afforded to Bragg Creek (WER et al. 1986).

Neither of these detention sites were reviewed in the 2008 Water for Life Assessment of Potential Water Storage and Diversion Scenarios (GoA, 2008).

2. Potential Detention and Diversion Volume

Based on the Allan Markin Flood Advisory Panel's review of the 2013 flood event it is estimated that there would have to be a total temporary storage capacity of 100,000,000 m^3 upstream of the Glenmore Reservoir in order to fully mitigate the 2013 flows to 180 m^3/s downstream of the Glenmore Reservoir. Flows above 180 m^3/s, downstream of the Glenmore Reservoir, would require the implementation of protective measures such as sand-bagging to prevent flooding of private property (Carnduff, R., 2013).

The potential detention and diversion volumes for the various historical proposals are shown in Table 1.

Table 1: Historical Detention and Diversion Volume

Historical Concept	Storage Capacity (m^3)	Estimated Flow Diversion (m^3/s)	Comments
Reservoir Site D	2,097,440 / 4,935,152 / 9,870,305	-	21 / 30/ 45 metre dams
Reservoir Site E/Mitchel Site	31,461,597	-	35 metre dam, geologically unsuitable for a permanent dam
Reservoir Site F	1,628,600 / 4,379,948	-	18 / 30 metre dams
Reservoir Site G	7,526,107	-	10 metre dam
Reservoir Site H	9,475,493	-	24 metre dam
Ford Site	40,715,008	-	-
McLean Site	24 600 000/ 49 200 000	-	25/46 metre dams
Sarcee Site	42 000 000 / 64 900 000	-	22/26 metre dams
Priddis Reservoir Site 1	-	-	-
Priddis Reservoir Site 2	-	-	-
Priddis Diversion	-	345	Assuming Glenmore pre-releases of 283 m3/s; If pre-releases of Glenmore is 170m3/s then the diversion channels and structures would have to be increased to upwards of 530m3/s
Pirmez Diversion	-	-	-
Total	**137,364,245**	**345**	

Implementing a series of detention and diversions on the Elbow River, as outlined in this historical review and shown in Table 1 above, has the potential to mitigate for future floods and store water for future droughts. Furthermore, there is the potential to detain more water on the Priddis Creek Diversion along with the potential to divert more water via the Pirmez Irrigation Canal.

Table 2 : Allan Markin Flood Advisory Panel Proposed Projects on the Elbow Detention and Diversion Volumes

Markin Panel Elbow River Concept	Storage Capacity (m^3)	Estimated Flow Diversion (m^3/s)	Comments
EC1	12,000,000	-	
EQ1	70, 000,000	-	Geologically unsuitable location for a permanent dam based on the PFRA 1969 Study
CB1	-	500	-
Total	**82,000,000**	**500**	

(Source: Carnduff, R. 2013)

3. Summary of Findings

In review of the potential detention and diversion sites located on the Elbow River watershed some concepts have a greater potential for flood and drought mitigation based on differing factors including:

- Flood mitigation potential upstream of both Bragg Creek and the City of Calgary;
- Drought mitigation potential;
- Topographical design of the detention site;
- Engineer work already completed on concept;
- Whether or not the project is located on the Tsuu T'ina Reservation due to complications around developing on First Nations Land;
- Whether the project was discouraged in the 2008 Water for Life Assessment of Potential Water Storage and Diversion Scenarios; and
- If the project has potential to slow down water and reduce peak flows.

Table 3 below shows the concepts that have the greatest potential for flood mitigation. These concepts are identified in green on Map 1.

Table 3: Concepts with the Greatest Potential for Flood Mitigation

Concept	Comments
Priddis Diversion	• Mitigates for flood upstream of Bragg Creek and City of Calgary; • Uses natural creek bed and low lying areas for channeling water; • Potential to slow down water and reduce peak flows; • Engineering work already completed; and • Could be implemented to mitigate for drought.
Priddis Reservoir Site 2	• Natural topography of the area suits the construction of a reservoir; • Mitigates for flood upstream of Calgary; and • Mitigates for drought.
McLean Site/Priddis Reservoir Site 1	• Mitigates for flood upstream of Bragg Creek and City of Calgary; • Engineering work has been completed for this site; and • Mitigates for drought.
Reservoir Site D/EC1	• Mitigates for flood upstream of Bragg Creek and City of Calgary; • Natural topography of the area suits the construction of a reservoir; and • Reservoir Site D mitigates for drought.
Reservoir Site F	• Mitigates for flood upstream of Bragg Creek and City of Calgary; • Natural topography of the area suits the construction of a reservoir; and • Mitigates for drought.
Reservoir Site G	• Mitigates for flood upstream of the City of Calgary; • Natural topography of the area suits the construction of a reservoir; and • Mitigates for drought.
Reservoir Site H	• Mitigates for flood upstream of the City of Calgary; • Natural topography of the area suits the construction of a reservoir; and • Mitigates for drought.

Table 4 below outlines concepts that have a lesser potential for mitigation. These concepts are identified in purple on Map 1.

Table 4: **Concepts with Limited Potential for Flood Mitigation**

Concept	Comments
Pirmez Diversion	• Substantial portions are located on the Tsuu T'ina Reservation
Sarcee Site	• Located on the Tsuu T'ina Reservation
Reservoir Site E/ Mitchel Site/ EQ1	• Area is geologically unsuitable for a permanent dam • Discouraged in the 2008 Water for Life Assessment of Potential Water Storage and Diversion Scenarios
CB1	• Does not mitigate for Bragg Creek • Does not mitigate for upstream of diversion within the City of Calgary • Does not mitigate for drought • Speeds up water downstream
Ford Site	• Scale of dam is problematic for healthy aquatic ecosystems within the Elbow River headwaters • Discouraged in the 2008 Water for Life Assessment of Potential Water Storage and Diversion Scenarios

4. Recommendations

WaterSMART recommends further investigation into the Priddis Diversion concept. Based on review of the 1986 Elbow River Floodplain Mangement Study and the potential to divert 345 m^3/s, this diversion makes it a ideal choice as it bypasses both Bragg Creek and the City of Calgary. Furthermore after a brief review of the topography surrounding the Priddis Valley, further storage on this diversion is practical, making it cost effective. Flooding of Fish Creek and other low lying areas along the diversion would be ideal to off-set property damage within the City of Calgary. Moreover, due to the location of the Priddis Deversion concept it would be an ideal project to couple with natural mitigation solutions like wetland development. Addtionally, the diversion has the potential to be channeled to meet up with Pine Creek, subsequently splitting river flows in order to reducing flow volumes. It is recommended that this concept be modeled in the Bow River Operational Model (BROM) and considered as an alternative to the proposed Calgary ByPass (BCP1, Map 1).

WaterSMART also recommends that the historical resevoir sites identifed by the Department of Interior in the 1890s, along with the McLean Site should be further investigated for fesiability.

Based on the success of this historical review of proposed detention and diversion sites on the Elbow River, WaterSMART recommends further investigation into all mitigation options by continuing to undertake this type of historical analysis for all watersheds throughout Alberta.

5. Conclusion

The historical review of potential detention and diversion sites on the Elbow River provided a number of possible options that could be implemented to mitigate for both flood and drought. It is recommended that the Priddis Diversion be seriously considered as an option for flood and drought mitigation. Lastly it is important to continue to conduct this type of historical review for all watersheds throughout Alberta in order to ensure all flood mitigation options are considered.

6. References

Calgary Herald. February 20 1886. Calgary Irrigation Company Advert

Carnduff, R. 2013. Flood Mitigation Measures Elbow River, Sheep River and Highwood River Basins. Prepared for the Community Flood Mitigation Advisory Panel. Prepared by Stantec.

Department of Interior. 1900. Proposal Method of Diverting Water from the Elbow River to Fish Creek

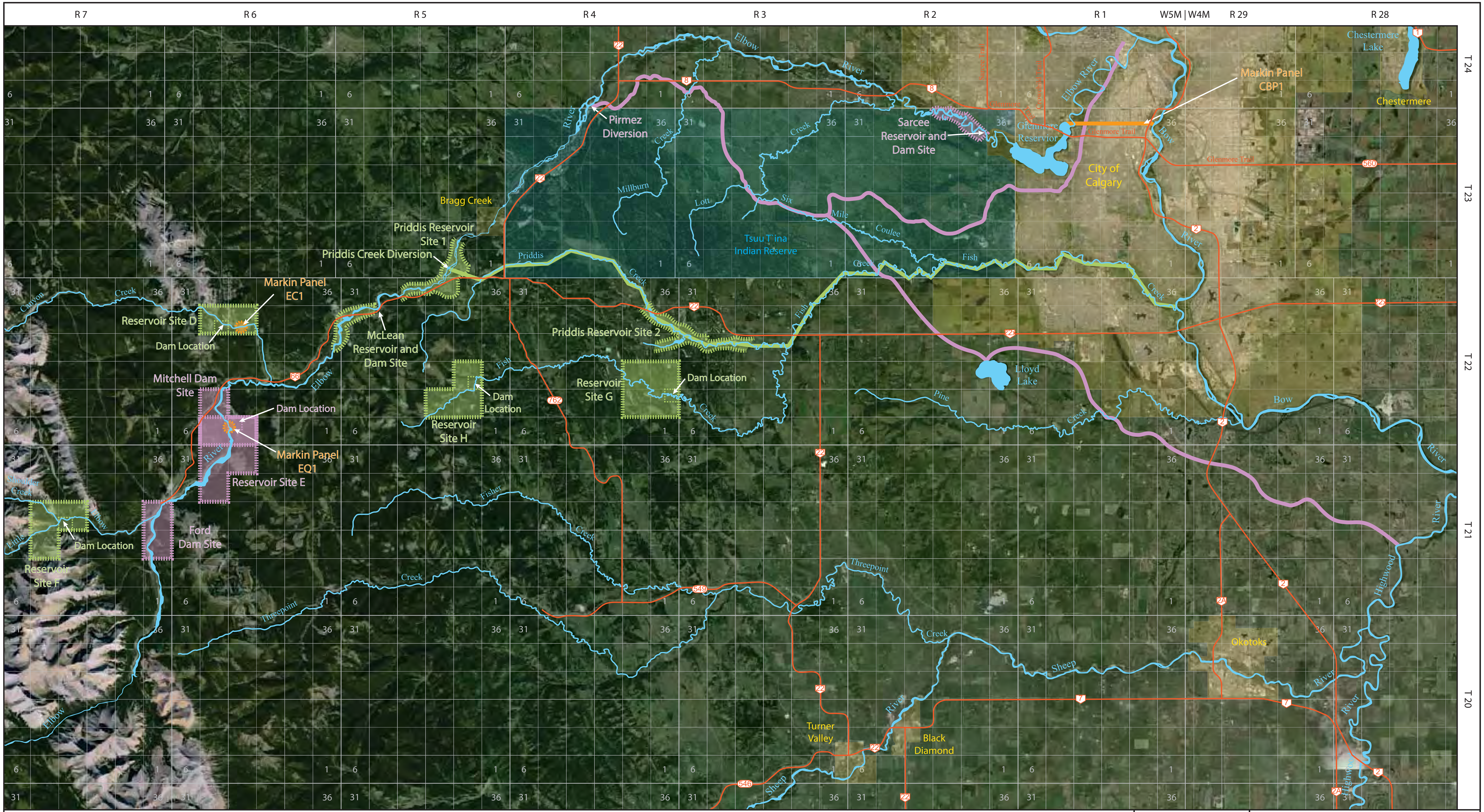
Department of Interior. 1897. Sessional Papers (No.13)

Gilpin, J. 2010. The Elbow River in the Life of a City

Government of Alberta. 2008. Water for Life: reliable, quality water supplies for a sustainable economy, Assessment of Potential water Storage Sites and Diversion Scenarios

Monenco. 1979. Interim Report Elbow River Flood Study

WER, IBI & ECOs. 1986. Elbow River Floodplain Management Study



Legend:

- 🟨 Municipality
- Major Highways
- Hydrography
- Tsuu T`ina Reserve

Diversion and Reservoir Concepts:

- Historical diversion/reservoir with greater potential for mitigation
- Historical diversions/reservoir with limited potential for mitigation
- Markin Panel diversion/reservoir concepts

Map References:

1. Calgary Herald, 1886. Calgary Irrigation Company Advert. Februray 20, 1886.
2. Carnduff, R. 2013. Flood Mitigation Measures Elbow River, Sheep River and Highwood River Basins. Prepared for the Community Flood Mitigation Advisory Panel. Prepared by Stantec.
3. Department of Interior. 1897. Sessional Papers (No.13).
4. Department of Interior. 1900. Proposal Method of Diverting Water from the Elbow River to Fish Creek.
5. Google Inc., 2013. *Google Earth Software.* Version 7.1.2.2041
6. Government of Alberta, 2013. *Alberta Environement and Sustainable Energy Development-Water Well Database* <accessed on-line November 2013, http://groundwater.alberta.ca/WaterWells/>
7. Monenco. 1979. Interim Report Elbow River Flood Study.
8. WER, IBI & ECOs. 1986. Elbow River Floodplain Management Study

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Scale: 0 2 4km

ALBERTA watersMART Water Management Solutions

Alberta Government

PROJECT

Elbow River Historical Diversions and Detention Sites

TITLE

LOCATION OF HISTORICAL DIVERSIONS, DENTENTION SITES AND PROPOSED MARKIN PANEL STRUCTURES

PREPARED BY: Alberta WaterSMART
PROJECT NUMBER: -
CREATED BY: RB
DATE ISSUED: November 29, 2013
DATE REVISED: December 13, 2013
VERSION NUMBER: 3.0

MAP: 1

Elbow River Flood Mitigation Project Decisions Fact Sheet

Benefit-cost analysis studies show the Springbank Off-stream Reservoir offers a higher benefit-cost ratio than the McLean Creek Dry Dam or Glenmore Reservoir Diversion (also known as the Calgary Tunnel).

Benefit-Cost Ratios for Proposed Projects

	Worst-Case Damage Scenario		Anticipated Damage Scenario	
	1:100 Protection	1:200 Protection	1:100 Protection	1:200 Protection
Springbank Off-stream Reservoir	1.87	2.07	1.32	1.32
McLean Creek Dry Dam	1.43	1.65	1.01	1.05
Glenmore Reservoir Diversion	1.21	1.20	0.81	0.83

Assumptions and Methodology

Assumptions and methodology used in **all three** benefit-cost analyses:

- Damage assessments were generated for nine return frequencies to calculate average annual damages, including: 1:2 year, 1:5 year, 1:10 year, 1:20 year, 1:50 year, 1:100 year, 1:200 year, 1:500 year and 1:1000 year.
- Damage estimates were also assessed under two cases:
  - a higher, or “worst case”, condition, and
  - a lower, or “anticipated case”, condition.
- Costs are based on the estimated capital and operational/maintenance costs presented in Section 4 of each report.
- Benefits are based on the quantification of flood damages averted as outlined in Section 5 of each report.
- The benefit/cost analysis has been carried out using a net present value analysis.
- A 100-year economic analysis was used.
- Annual operating and maintenance costs are assessed at $1.8 million.

For both the **Springbank Off-stream Reservoir** and **Glenmore Reservoir Diversion**, $8.9 million in capital costs were added to each project to account for required mitigation measures upstream in Bragg Creek and Redwood Meadows.

For the **Springbank Off-stream Reservoir**, an additional $40 million in capital costs were added to account for land acquisition.

For the **McLean Creek Dry Dam**, an additional $45 million in capital costs were added to account for the replacement or relocation of impacted Parks infrastructure.

For both the **Springbank Off-Stream Reservoir** and **McLean Creek Dry Dam**, it was assumed that once the design event is exceeded, full damages are incurred. This is due to the absence of additional hydrologic routing.

For the **Glenmore Reservoir Diversion**, it was possible to calculate the reduced damages that would be achieved as a result of the 500 and 700 cubic metres per second diversion (1:100 year and 1:200 year protection, respectively). The incremental flow was passed downstream and damages based on the reduced flood flow were computed to determine the net benefits. Consequently, a higher benefit can be attributed to the diversion scheme based on this higher level of analysis.

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Total Estimated Costs for Proposed Projects

Below is a breakdown of the estimated costs for 2013-level protection used in the benefit-cost analysis for each project. Annual operating and maintenance costs of $1.8 million were added to each project.

	Springbank Off-stream Reservoir	McLean Creek Dry Dam	Glenmore Reservoir Diversion (700 m^3/s)
Estimated construction costs for 2013-level protection	$214,768,000	$294,581,000	$498,200,000
Land acquisition	$40,000,000		
Park/Infrastructure replacement		$45,000,000	
Bragg Creek protection	$8,900,000		$8,900,000
Environmental Impact Studies		$4,000,000	
TOTAL	**$263,668,000**	**$343,581,000**	**$507,100,000**

Provincial Flood Damage Assessment Study

The Alberta government initiated the Provincial Flood Damage Assessment Study (PFDAS) in July 2014 to:

- Update/develop flood damage curves in select communities at risk of flood to 2014 economic values and establish adjustment indices for their use in 60 different flood-prone communities across Alberta;
- Develop a computerized model for estimating flood damages; and
- Undertake flood damage estimates for select communities in Alberta.

Key points regarding content and structural stage-damage curves include:

- Direct flood damages were estimated separately for residential and non-residential structures, and also for losses to structures versus contents;
- Potential losses vary significantly by the type of use, reflecting differences in construction materials, techniques and quality, and also in the amount and type of contents located in those structures;
- The analysis resulted in updated depth-damage curves for various categories of residential and non-residential structures and contents based on extensive first- and second-order research including representative sampling of residences and non-residential structures within selected functional groups.

Calgary, High River, Fort McMurray and Drumheller were identified as high priority communities and will be the subject of flood damage assessments undertaken as part of the PFDAS. Flood damage assessments for High River, Fort McMurray and Drumheller will be complete at the end of March.

The City of Calgary was selected for the pilot study due to recent flood damage experience, large inventory of residential and commercial structural types and categories, recent update of hydraulic modelling in 2012 and analysis of 2013 flood flows, and availability of accurate rehabilitation costs.

Total damage along the Elbow River (within Calgary) for a 1:100 year flood
Anticipated Damage Scenario

Categories of Damage	Direct	Indirect	Total
Residential	$299,716,000	$44,957,000	$344,673,000
Commercial	$10,205,000	$4,592,000	$14,797,000
Infrastructure	$69,666,000	$13,933,000	$83,599,000
Stampede	$68,900,000	$26,400,000	$95,300,000
Total	$448,487,000	$89,882,000	**$538,369,000**

The full versions of all reports are available at http://www.alberta.ca/flood-mitigation-studies.cfm.

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Room for the River Pilot in the Bow River Basin

Advice to the Government of Alberta
With Addendum

February 27, 2015

ALBERTA
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Please Note:

The *Room for the River* pilot process applied in the Bow Basin and the subsequent *Room for the River* report are not government policy. This is a pilot project. The advice in this report will be taken under consideration by the Government of Alberta to help inform sound water management and policy decisions.

This is not a public consultation process. This is a pilot project carried out with a technical working group and the WPAC to provide advice to the Government of Alberta. It is a first step to gaining a comprehensive inventory of flood mitigation projects.

Executive Summary

In the 18 months since the 2013 floods occurred in Alberta, a wide range of mitigation options for the Bow River Basin has been identified, studied, and implemented by the Government of Alberta (GoA), municipalities, non-government organizations, and others. With a number of options still under consideration, the GoA announced in the fall of 2014 that it wanted to look more closely at the approach taken by the Netherlands to manage flooding in the Rhine River branches, called the *Room for the River* program. A pilot project was undertaken in the Bow River Basin to consider the Dutch program and measures and the extent to which they could be adapted and applied here to reduce vulnerability of people and infrastructure and improve the overall environmental quality of the Bow and Elbow rivers. A secondary objective was to develop and pilot a systematic *Room for the River* framework and process that, if valuable, could be replicated in other basins throughout the province. Contributors to the pilot reflected the many interests in the basin including water managers, watershed groups, municipalities, environmental groups, domain experts, and the interested public.

The pilot study area included the Bow and Elbow main stems, broken down into eight river segments – four in the Bow and four in the Elbow. Using a simple, systematic framework, an initial scan was done for each river segment, identifying examples of and opportunities for mitigation using *Room for the River* measures. Potential "no regrets" opportunities were identified as well as observations on how a broader *Room for the River*-type program might be effectively applied in Alberta.

Through previous experience and its *Room for the River* program, the Netherlands has learned that:

- Clear, specific objectives are essential, and they must be well defined and communicated.
- The assessment and selection process should rely on undisputed hydraulic modelling and cost-benefit analysis for every flood mitigation option being considered.
- Rivers are powerful; it is best to rely as little as possible on infrastructure that can fail, and berming is a last resort.
- It takes a lot of time to inform and engage citizens and to build the necessary social and political capital, but this time is earned back during implementation.

Maintaining or creating room for the river in Alberta would involve using both the natural landscape and built infrastructure to channel high flows around infrastructure (diversion), create a larger river cross section to allow high flows to pass (conveyance), detain high flows temporarily (storage), and offer local protection where needed. Contributors to the pilot strongly urged that: Alberta protect the health of the province's watersheds, remembering that "the protection of the aquatic environment is an underlying principle for managing natural resources in Alberta";[1] mitigation activities be grounded in respecting our rivers and their many values; and the environmental, social, and economic trade-offs for mitigation options be thoroughly understood.

For a program like this to be successful, the GoA and those in the basin must first define what flood levels they are mitigating to and at what costs, and what risks (frequencies and consequences) they are willing to accept.

Calgary was the largest municipality hit by the 2013 flood. Since then, the City has moved forward with numerous studies, policy initiatives, and new mitigation activity along both the Bow and Elbow rivers.

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[1] Alberta Environment. 1999. *Framework for Water Management Planning*, p. 19.

Other opportunities were identified in this pilot, some of which can be acted on relatively quickly while others will take time to implement. Larger mitigation options on the Elbow are being further studied, including SR1 (off-stream storage in Springbank), MC1 (dry dam on the Elbow River near McLean Creek), and the Calgary tunnel (diversion from the Elbow River to the Bow River). At the same time, work needs to continue on smaller projects and possible relocation opportunities, while ensuring efforts are made to protect riparian areas, fish habitat, and other natural features that are important to aquatic ecosystem health. Likewise, for the Bow River, while many mitigation options have been identified and implemented, renewed effort is needed to ensure that key initiatives do not flag. These include stronger impetus for relocation, prevention of future floodplain development, and negotiation of a long-term watershed agreement between the GoA and TransAlta regarding the management of upstream reservoirs.

Twenty possible “no regrets” opportunities across the Bow Basin were identified in two main categories: policies and decisions, and projects or actions. Opportunities related to policies and decision making are broader in scope and could take longer to implement; e.g., strengthening and enforcing policy and regulation to minimize new development in the floodplain. Potential “no regrets” projects or actions are specific and could be advanced in the near term, such as revising the Southwest Calgary Ring Road Bridge design to leave room for the Elbow River and Fish Creek.

Contributors to the pilot project felt there was value in adapting and applying the *Room for the River* concept to flood mitigation efforts in Alberta. They stressed, however, that these efforts should build on work and study already done to date, be applied through an integrated watershed management approach, including the headwaters and tributaries, and should integrate drought, water quality, and ecosystem and flood risk concerns. An Alberta *Room for the River*-type program could define specific objectives against the following key elements:

- Safety and Security = managing flood risk
- Water Supply = managing drought risk
- Water Quality = managing minimum flows for healthy aquatic ecosystems, biodiversity, drinking water, and recreation.

Raising individual and community awareness and understanding about watershed functions and the effects of flooding will be a crucial part of any program. The various jurisdictions with responsibilities for flood mitigation need to effectively share and communicate knowledge, data, and other scientific findings. Sharing of such information will help improve cross-jurisdictional coordination and collaboration on watershed planning and emergency planning. And, perhaps most importantly, a successful program of this nature would need long-term political, local, and financial support and accountability.

This pilot garnered great interest in the water community in the Bow River Basin. Since the flooding in 2013, there has been an elevated level of awareness and discussion about water management in many parts of the province. This has been particularly noticeable in the Bow River Basin, due in part to the excellent work of the Bow River Basin Council. The approach and purpose tested in this pilot offer a way to harness public momentum and interest in water management, build on the deep expertise and experience of those in the water community, and provide a long-term program for thoughtful and effective water management and flood mitigation throughout Alberta.

Contents

List of Tables

List of Figures

1. Introduction

Albertans value and respect the role that water plays in their day-to-day lives. Access to water is fundamental to human settlements and is the basis for our economic activity and quality of life. Although droughts have been more common in Alberta's recent history, floods are not rare. With the 1995 and 2005 flood events still memorable, the June 2013 floods were devastating, affecting families, homes, businesses, property, infrastructure, and landscapes. Following emergency responses by various authorities and volunteer agencies, the Government of Alberta (GoA) established the Flood Recovery Task Force and, subsequently, the Resilience and Mitigation (RAM) Branch in Alberta Environment and Sustainable Resource Development (ESRD).

All flood-prone basins in the province are being examined for mitigation opportunities, with much of the initial attention on the Bow River Basin (the Bow, Elbow, Highwood and Sheep river systems). Diverse options have been examined at the municipal and provincial levels through basin modelling and the development of engineering concepts. This resulted in three large infrastructure measures being selected for further study: the Springbank off-stream storage reservoir, a diversion tunnel from the Elbow to the Bow River, and the McLean Creek dry dam. As well, berming and other local protection measures have been built or are planned in many locations, and flood policy and regulatory options are being reviewed in a number of jurisdictions. This pilot does not replicate the extensive work done to date; rather it is intended to build on existing work by continuing the flood mitigation discussion and highlighting the complexity of a system that requires layers of mitigation.

A project completed in early 2014 for the Task Force[2] focused on the Bow River Basin by identifying seven broad flood mitigation approaches and assessing many specific flood mitigation options for the basin. The project aligned with many of the principles and key elements contained in *Respecting Our Rivers*, the pamphlet published by the GoA that described the Province's approach to flood mitigation.[3] The mitigation approaches are summarized in Table 1.

Table 1: Flood Mitigation Approaches

Approach	Brief description
Relocation	Reduce risk to people and property by removing infrastructure from the flood plain and restricting future development
Dry dams	Build detention facilities that temporarily detain high flows but allow normal flows to pass without hindrance and do not permanently retain water
Diversions*	Divert high flows around high risk areas; diversion channels could include new overland routes, existing overland routes, and subsurface tunnels
Wetland storage	Use natural storage function of wetlands to temporarily detain high flows
Natural river functions	Restore natural river functions to slow and attenuate high river flows; this includes wetlands, healthy riparian areas, bio-engineered bank protection, re-widening the floodway, natural channel design, meander belts, and maintaining active flood plains
Change existing operations	Draw down spring reservoir levels, delay filling, and/or raise full supply level capacities of existing reservoirs to capture high flows
Land management	Implement best land management practices in upstream areas (headwaters) to

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[2] See http://albertawater.com/work/research-projects/resilience-and-mitigation-branch for more information.

[3] Online at https://pabappsuat.alberta.ca/albertacode/images/respecting-our-rivers.pdf.

Approach	Brief description
	slow the water from reaching infrastructure; this includes wetland restoration, timber harvest best management practices, wildfire management, timber disease and pest management, off highway vehicle trail management, reducing fragmentation and linear disturbances

* This term refers to the common definition of diversion as "relocated stream flow" rather than a diversion of water for a licensed off-stream use.

Both this project and the *Respecting Our Rivers* document reaffirm that a systemic, watershed-based approach to flood mitigation is essential. Mitigation options implemented in one part of the complex and interrelated Bow River and tributary system can have major, even catastrophic, consequences in other parts of the system. Mitigation activities in the upstream reaches may have a cumulative effect on downstream communities and infrastructure. Diverting flow away from one community may transfer unacceptable risk to another. All mitigation options will affect the watershed; the options chosen must function to build the health and natural resiliency of the watershed and allow for sound water management under flood, drought, and normal conditions.

In the 18 months since the 2013 floods, various mitigation options for the Bow River Basin have been identified, studied, and implemented by the GoA, municipalities, non-government organizations, and others. With a number of options still under consideration, the GoA announced in the fall of 2014 that it wanted to look more closely at the approach taken by the Netherlands to manage flooding in the Rhine River branches, called the *Room for the River* program. The advice drawn from that discussion and analysis is documented in this report.

1.1 Purpose and Context

In response to serious flood threat and severe impacts on people and property, the Netherlands initiated its *Room for the River* program in the later 1990s (see Section 2.1 for more details). Their experience offers a chance for Alberta to learn from others when it comes to identifying, choosing, and implementing suitable flood mitigation measures.

The objective of this pilot project was to build on what has already been identified, studied, and implemented in the Bow River Basin, to ensure that the Dutch *Room for the River* approach and measures have been considered and applied as appropriate in the basin to reduce flood hazard and improve the overall environmental quality of the rivers.

A secondary objective was to develop and pilot a systematic framework and process for identifying specific *Room for the River* options. If valuable, the framework and process could be replicated in other basins throughout the province. A key to success was working with water managers, watershed managers, and experts who know the rivers best (see Appendix A for a list of contributors to this pilot). Many of these organizations and individuals have not only been directly involved in managing water in the Bow River Basin, they also actively participated in previous collaborations to model and identify Bow River water management opportunities for both drought and flood mitigation.[4]

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[4] For more information on these projects, visit the Water Portal at http://albertawater.com/work/research-projects/ssrb-adaption.

The pilot project targeted three outcomes:

1. Provide specific advice to the GoA, including:
    - A scan of specific, actionable opportunities to further implement *Room for the River* measures along the Bow and Elbow main stems above and within Calgary.
    - Recognition of what has already been done along the Bow and Elbow rivers to create room for the river.
    - Identification of possible practical and implementable "no regrets" opportunities.[5]
    - Suggestions on a potential broader program, process and engagement.
2. Elevate understanding among the water community in the Bow River Basin of the *Room for the River* program, measures, and associated opportunities in Alberta.
3. Produce a tested framework and process for applying *Room for the River* measures to all watersheds in Alberta.

1.2 Scope of the Pilot Project

To ensure appropriate focus and timely completion, careful consideration was given to what was in scope and out of scope for this initial pilot. As mentioned earlier, the pilot was intended to build on prior work and decisions, not replicate them, and the scope of the project was set accordingly. The scope parameters are shown in Table 2.

Table 2: Scope of the Bow *Room for the River* Pilot Project

	In Scope	Out of Scope
Geography	• Main stems of the Bow and Elbow rivers from above Ghost Dam and the confluence with Quirk Creek to the southern boundary of the city of Calgary	• Tributaries to the Bow or Elbow • The Bow below Calgary • The Highwood and Sheep rivers
Options and Opportunities	• Infrastructure options, operational changes, and natural functions for flood mitigation • Basin scale and local scale options • Primarily surface water quantity, but water quality and groundwater comments will be captured	• Specific Disaster Recovery Program and individual landowner-related decisions • Comprehensive water and risk management discussion
Impacts	• Upstream, downstream, and system-wide impacts • High-flow, low-flow, and "normal-flow" impacts (watershed management) • Identification of potential complexities and dependencies	• Detailed engineering or feasibility and constructability analysis • Detailed environmental, social, or economic impacts
Findings	• Advice on where *Room for the River* measures have already been applied and a scan of further opportunities • Specific, actionable quick wins	• Comprehensive, triple bottom line evaluation of options • A detailed prioritization study

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[5] "No regrets" opportunities are those mitigation measures that should be beneficial under any and all river conditions; i.e., they have a net positive effect for flood mitigation, with little to no negative consequence.

1.3 Process and Approach

A simple, systematic framework was developed for applying *Room for the River* measures to the Bow River Basin. For each segment of the basin and for each measure (described in more detail in Section 3.1), four questions were asked:

1. Is the measure applicable and relevant for this river segment and, if so, how?
2. Where has this measure already been applied and has it been effective?
3. What options are still being implemented, are planned, or have been proposed?
4. How could this measure be implemented?

If the answer to the first question was "no," subsequent questions were not pursued.

The pilot study area was divided into eight river segments – four in the Bow and four in the Elbow – to enable manageable discussion of the examples and opportunities. These river systems are complex with many interdependencies; breaking them into segments does not imply that any one segment is independent of or more important than any other. The segments were delineated primarily by looking for common river morphology and considering the location of infrastructure. The intent was to reflect the diversity of the systems while maintaining a reasonable number of segments to enable productive discussion. Figure 1 illustrates the geographic scope of the entire project; maps of each river segment appear in Section 3.1.

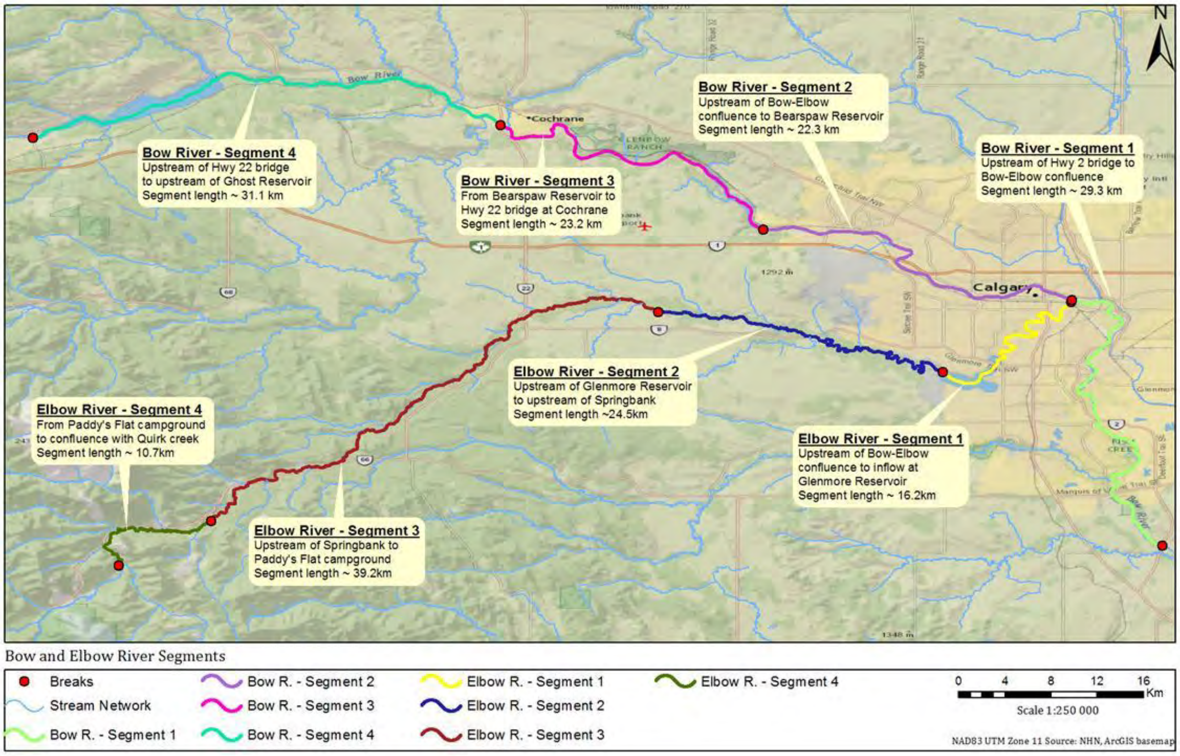

Figure 1: Geographic Scope of the Pilot Project in the Bow River Basin

To complete the initial scan for each river segment, project staff first researched and reviewed existing materials (recent flood and engineering studies from municipalities, the Province, and groups involved in the watershed) and interviewed knowledgeable and experienced representatives from select municipalities, non-government organizations (including Watershed Planning and Advisory Councils and Watershed Stewardship Groups), and others. Once this information was compiled and details added to the framework for each segment, the project team held a one-day multi-stakeholder technical session in Calgary in November 2014 to engage water managers, watershed managers, and experts. Representatives from the Dutch *Room for the River* program participated in the session to share their experience and bring additional expertise to the discussion. The compiled findings from the research, interviews, and working session were presented to the Bow River Basin Council in early December to obtain broader input. This document – the pilot project's final report – with advice on *Room for the River* implementation and further options in the Bow River Basin was prepared and submitted to the GoA in mid-December. The entire process was facilitated by Alberta WaterSMART with Deltares as expert advisors on the *Room for the River* program.

2. *Room for the River* Management Approach

2.1 The Dutch Approach

Room for the River is a program designed and implemented by the Government of the Netherlands. It followed a transition in river management policy away from the historic approach of managing flood risk by raising embankments and toward a new approach of creating room for conveyance throughout the river system.

In 1996, the Flood Protection Law (now Water Law) was introduced. It set specific protection levels and required five-year reviews and reports to Parliament on the Rhine design parameters and flood infrastructure. In 2001, the levels from two recent flood events resulted in the design discharge for the Rhine branches being increased from 15,000 m^3/s to 16,000 m^3/s. At the same time, a new policy was introduced, adding two key components: the preference for no further dike heightening (i.e., that dike heightening be considered only as a last resort), and a secondary program objective of enhancing natural and cultural landscape values (i.e., "spatial quality"). Thus the specific goals of the current Dutch program are to:

1. Safely cope with a 1:1,250 year discharge of 16,000 m^3/s without flooding, and
2. Enhance the overall spatial quality of the river landscape.

The Dutch process followed five main steps:

1. Define the problem with specific objectives and clear constraints, considering the geo-ecological functioning of the system and the long-term consequences of current policy.
2. Develop an inventory of potential projects that could be considered to help achieve the specific program objectives.
3. Determine the expected hydraulic impact, cost-effectiveness, and attractiveness of all potential projects and build the Planning Kit (see below), communicating all this data.
4. Working collaboratively with many participants and using the Planning Kit, select the suitable ideas against the objectives for the region; that is, which projects together can achieve the pre-defined goal within the budget constraints?
5. Implement the selected projects locally under national supervision with transparency and extensive engagement throughout.

Sharing knowledge with stakeholders has been a fundamental part of the program in the Netherlands. All results from the early research that went into the problem definition were captured in an understandable way in a single volume that was very explicit about the uncertainties.

The Planning Kit tool ("Blokkendoos") is a simple, interactive, visual tool showing the hydraulic effect and cost data needed for any user to examine and select sets of individual mitigation measures. This tool allows the user to select various measures throughout the Rhine branches to try to collectively meet the safety objective within a pre-set budget. The tool created a common base of knowledge, allowed users to test their own ideas, and provided a sense of empowerment to affected communities.

The second objective – spatial quality – reflected a balance of functionality (for everyday use), sustainability (geo-ecologically robust), and attractiveness (culturally meaningful and aesthetic). An independent Spatial Quality team (the Q team) was struck to provide advice and to peer review spatial quality for all projects that went ahead.

Nine broad mitigation measures were identified under the *Room for the River* program (Table 3).

Table 3: *Room for the River* Measures: Dutch Definitions

***Room for the River* Measures** (as described by the Dutch program*)
1. Dike relocation: Relocating a dike inland widens the floodplain and increases room for the river.
2. Depoldering: The dike on the river-side of a polder[6] is lowered and relocated inland. This creates space for excess flows in extreme high water situations.
3. High-water channel: A high-water channel is a diked area branching off from the main river to discharge some of the water via a separate route.
4. Lowering floodplains: Lowering or excavating part of the floodplain increases the room for the river in high water situations.
5. Lowering groynes[7]: At high water levels, groynes may obstruct the flow in the river. Lowering groynes speeds up the rate of flow.
6. Removing obstacles: If possible, removing or modifying obstacles in the river bed will increase the rate of flow.
7. Water storage: Provide temporary water storage in extreme situations where the storm surge barrier is closed and there are high river discharges to the sea.
8. Deepening summer bed: Excavating or deepening the surface of the river bed creates more room for the river.
9. Dike reinforcement: Dikes are reinforced at given locations where river widening is not feasible.

* Source: Room for the River Summary Brochure; March 2012.

Measure 8, essentially dredging, was commonly used in the past in the Netherlands to reduce sediment build-up in navigation channels. Their experience has shown that it has limited effect as the river typically quickly re-deposits sediment in dredged areas, which reduces the benefit or necessitates repeated dredging. Measure 7, water storage, is recognized as having very limited opportunities in the Netherlands. Some opportunities may exist upstream in Germany but those options have not advanced to date. A further limiting factor on potential storage infrastructure is the consequence of infrastructure failure; in the Netherlands, infrastructure failure would be catastrophic given the population density and location. In addition to the risk of catastrophic failure, large infrastructure also means that the burden of a reservoir is borne in a different area from the area that receives the benefits. For these reasons, water storage that uses natural low-lying areas such as polders is much preferred over storage that requires dam infrastructure.

Land required for any of the *Room for the River* measures has usually been handled in one of three ways:

- It was bought by the Government then resold with different conditions on use,
- It was bought by the Government and converted to public land, or
- A compensation arrangement was made with the current landowner for intermittent flooding.

Fisheries and habitat values are important throughout the floodplain area, the main channels, and side channels. Through the spatial planning team, the program has tried to restore aquatic and semi-aquatic spaces, although this is a particular challenge during low-flow periods.

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[6] A polder is a low-lying tract of land enclosed by dikes that forms an artificial hydrological entity that has no connection with outside water other than through manually operated devices. (adapted from Wikipedia, http://en.wikipedia.org/wiki/Polder)

[7] A groyne is a rigid hydraulic structure built from a river bank. It directs high velocity flows away from the banks, mitigates erosion, and keeps navigation channels open. Groynes are generally placed in groups.

A critical point when considering which measures are most appropriate is the nature of the hydraulic effect of managed water. Simply, water storage should reduce the water level downstream; creating a larger cross section (that is, making room for the river) should reduce the water level locally and upstream. These concepts are often poorly understood.

Rijkswaterstaat, the National Water Authority in the Netherlands, has administered the *Room for the River* program for about 14 years. Of the 700 projects identified in that time, 39 are expected to be implemented by 2015 within a budget of €2.3 billion (about Cdn$3.3 billion). The expected effect is that 4400 hectares of surface area (about 10% of the system) will be "returned" to the river floodplain. In so doing, the peak flow levels will be reduced so that water level is lowered by 30 cm on average along all three river branches, creating the conveyance capacity for the specified target of 16,000 m^3/s. Additional information on the *Room for the River* program is available online in English at http://www.ruimtevoorderivier.nl/english/.

2.2 The Southern Alberta Context

Numerous differences in geography and hydrology exist between the Netherlands and Southern Alberta (Table 4) that must be recognized when potential *Room for the River* measures are being contemplated in this province. Furthermore, the Dutch measures are essentially engineered structural changes, whereas Alberta has indicated the importance of capitalizing on natural river and watershed functions for flood mitigation, as highlighted in the *Respecting Our Rivers* document. These differences do not negate the opportunity to learn from the Dutch program and measures, rather they were recognized as important context throughout the pilot discussions.

Table 4: Differences between River Systems in the Netherlands and Alberta

Hydrology of the Netherlands	Hydrology of Southern Alberta
The Netherlands is in the coastal region, partly below sea level	Southern Alberta comprises mountains, foothills, and prairies
The Netherlands has a temperate humid, maritime climate	Alberta has a relatively cold, dry, continental climate
The Netherlands' rivers branch through static channels through flat terrain with a leveed floodplain	Southern Alberta's rivers course down steep slopes and move and converge through foothills and onto the prairie
The Rhine flood events see gradual peaks of up to ~16,000 m^3/s over more than a week	The Elbow and Bow see flashy peaks of ~1,300 m^3/s and ~2,000 m^3/s, respectively, in two to three days
The Netherlands has issues with sedimentation of fine material (siltation) but few other water quality concerns	Southern Alberta has issues with transport of fine and coarse material and debris, and complex water quality concerns
Development has encroached on the river throughout the country; *Room for the River* is lowering the flood level by removing the "straitjacket"	Southern Alberta has a mix of development near and on the river and stretches that are free of development; Alberta is about mitigating flood while respecting our rivers' natural characteristics
One of the primary purposes of the Rhine River is navigation for transport vessels upstream into Germany; water supply is not a limiting factor	The rivers are managed for water supply in a closed basin; all rivers have multiple functions and uses, including a healthy and thriving recreational cold water fishery
Salt water is a concern	Groundwater plays a key role
The Netherlands is dealing with increasing river discharge where timing is less of an issue and trans-boundary upstream retention is difficult	Southern Alberta is dealing with natural variability where timing is crucial and upstream retention within the same jurisdiction may be possible

With these differences in mind, *Room for the River* measures can be adapted to fit the Alberta context and perhaps categorized to reflect how mitigation is often discussed in Alberta: diversion, conveyance, detention, other, and last resort. Examples in place or being considered on the Bow and Elbow main stems are included with the adapted measures in Table 5.

Table 5: *Room for the River* Measures in the Alberta Context

Measure	How it might be defined in the Alberta context	Examples on the Bow and Elbow main stems
DIVERSION		
1. High-water channels	• Create flood bypasses through the floodplain	• Building a Calgary tunnel diversion • Designated overland flooding route through Erlton • Gravel removal in side channels
CONVEYANCE		
2. Dike relocation	• Relocate permanent or temporary barriers, possibly in combination with relocation	• Revisiting Bragg Creek buyouts
3. Lowering floodplains	• Remove material from floodplain • Change policy on allowing fill in floodplains	
4. Removing obstacles	• Set development back from the river (flood way, fringe, plain) • Reduce the size and location of infrastructure in the floodplain; e.g., roads, bridge abutments • Minimize obstacles in the riverbed	• Conservation easements on the Bow and Elbow • Relocation of floodplain development • Revision to SWCRR Elbow overpass plan • Design of bridges e.g., the Peace Bridge • Removal or lowering of gravel/cobble bars
DETENTION		
5. Water storage	• Adjust operations of existing infrastructure • Dredge reservoirs • Construct detention sites (on-stream, off-stream, wetlands, ponds) • Prevent destruction of naturally occurring detention sites • Designate agricultural and park lands in the floodplain as flood zones • Restore riparian zones for absorption	• Upgrading Glenmore Reservoir infrastructure • Contouring upstream end of Ghost Reservoir • Building off-stream storage in Springbank (SR1) • Design light infrastructure spaces (e.g., golf courses) to temporarily flood • Restoring riparian banks near Cochrane • Retaining wetlands, log jams in the headwaters • Possibly, already identified WRRP projects
OTHER MEASURES		
	• Flood proof infrastructure in floodplains • Restore riparian zones for bank stabilization • Enforce land use controls in upper watershed	• Building flood proofing in Erlton • Design and location of ATV facilities in the headwaters
LAST RESORT MEASURES		
	• Reinforce barriers (permanent or temporary) at given locations where river widening is not feasible • Dredge river beds	• Strengthening Sunnyside berm • Armouring Stampede banks • Raising berm at Redwood Meadows

As potential mitigation measures are examined, an important consideration is the relative scale of mitigation options compared to each other and to the mitigation objectives set for a particular river. In Figure 2, for example, the two columns on the right show the approximate storage volumes that would have needed to be held back in the 2013 flood on the Bow and Elbow rivers to mitigate flows to illustrative targets. The remaining four columns show the approximate volumes of various storage options in the watershed. The chart demonstrates the relative contribution each option might make toward achieving the most stringent overall mitigation targets. This chart should not be read as dismissing the role that storage can play in mitigation, but instead highlights the need to look to a series of mitigation measures working together toward a reasonable mitigation target.

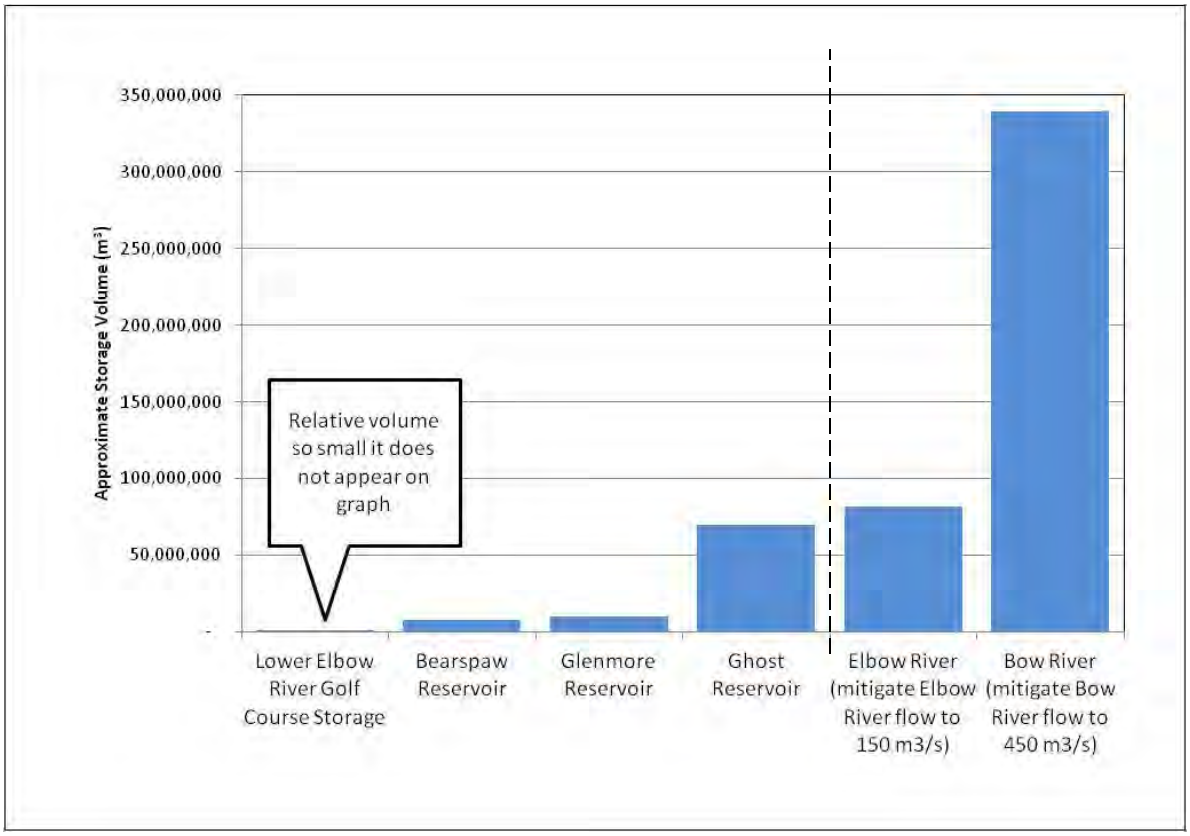


Figure 2: **Illustrative Relative Volumes - Bow River Basin Reservoirs and 2013 Flood Event**

Source: City of Calgary, 2014. Values provided by City of Calgary and TransAlta; volumes are approximate for comparison purposes.

In Figure 2 the flood volumes are calculated as volumes above "normal" flows for the Bow and Elbow rivers over the flood duration. Glenmore Reservoir storage volume is from the recent City of Calgary bathymetry survey. The "storage area" available at the Calgary Golf and Country Club along the Elbow River assumes a two-metre deep retention facility on the floodplain portion of the golf course.

3. Advice to Government of Alberta from the *Room for the River* Pilot in the Bow River Basin

3.1 Initial Scan of the Bow and Elbow River Pilot Study Area

When the initial scan was begun in late 2014, various flood mitigation options continued to be under consideration by the GoA whereas others had already been assessed as not warranting further study at this time. This report is not suggesting that options previously not recommended for further study be re-opened. Where relevant, references to these decisions are shown in the tables for each river segment in the column "What options remain?"

3.1.1 Bow River Segment 1

This segment of the Bow River (Figure 3) extends from upstream of the Highway 2 Bridge to the confluence with the Elbow, a distance of approximately 29 km. This segment did not experience as much damage in the 2013 flood as other areas. A number of broad policy instruments are already in place or are being developed for this segment, primarily through the City of Calgary. Discussion focused on looking at opportunities to attenuate the flow upstream as well as minimizing future encroachment in the segment's floodplain.

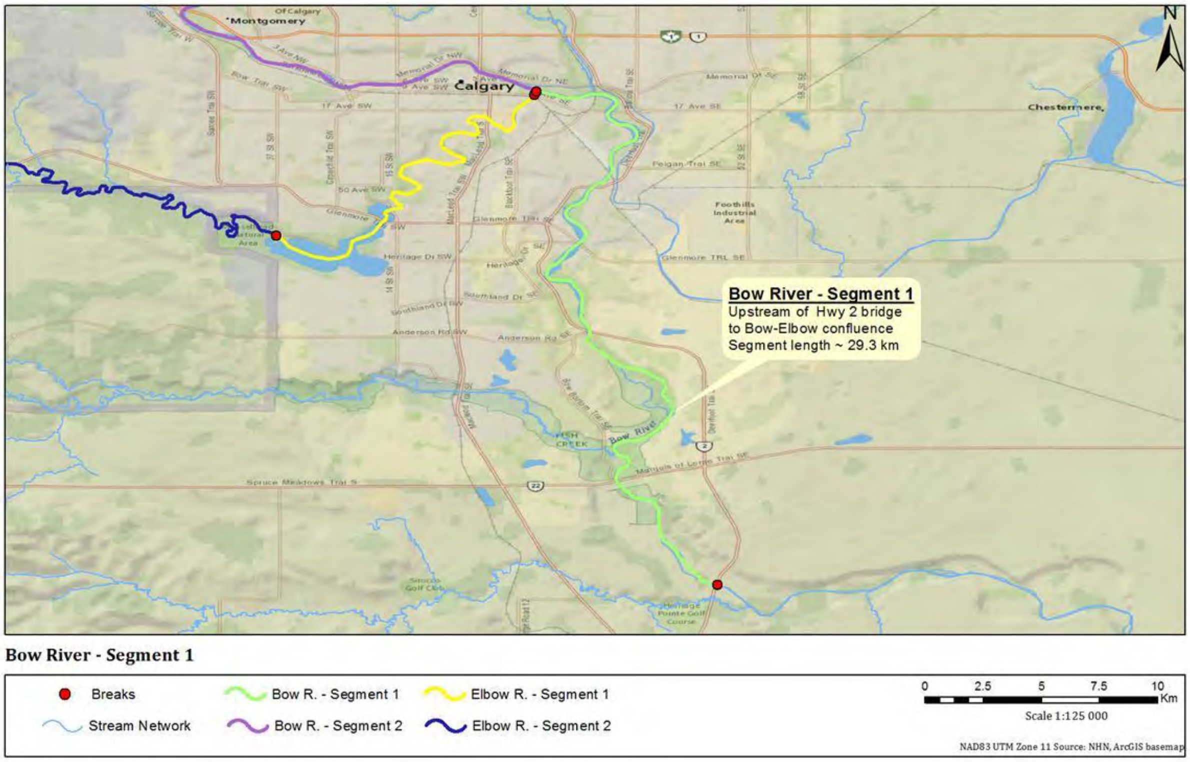


Figure 3: Bow River – Segment 1

Table 6 shows the initial scan of specific opportunities to further implement *Room for the River* measures along this river segment, as well as actions that have already been taken.

Table 6: **Initial Scan of *Room for the River* Opportunities for Bow River – Segment 1**

Measure	Apply?	What has already been done?	What options remain?
DIVERSION			
1. High-water channel	Maybe		• Use Western Headworks Canal as diversion channel (not recommended by City Expert Panel) • Create a small bypass channel through the Inglewood golf course
CONVEYANCE			
2. Dike relocation	Yes		• Buyouts in targeted locations to enable relocation of current or planned barriers
3. Lowering floodplains	Maybe		
4. Removing obstacles	Yes	• Many setbacks already in effect along the river from Harvie Passage down • The wide-span bridge on 37th Street SW over Fish Creek is an example of a bridge designed to allow room for the river • Reduced floodplain development through the City of Calgary's Environmental Reserve Setback Policy; e.g., Quarry Park development has a 60m setback • Removed grandfathering of flood fringe development requirements through Phase 1 review of the City of Calgary's Land Use Bylaw and Municipal Development Plan (MDP)	• Where appropriate, as identified by the City of Calgary's morphology study, remove or lower select gravel/cobble bars in the Bow main stem to remove resistance • Continue to reduce floodplain development through the City of Calgary's Environmental Reserve Setback Policy. The City of Calgary and the GoA could explore a more flexible approach in how much setback is taken, accounting for topography. • Reduce floodplain development through the City of Calgary's Riparian Strategy and associated education, mapping, and designation • Encourage the "right kind" of development in the floodplain and flood fringe (e.g., parks) • Minimize development in the floodplain through the Land Use Bylaw/MDP Phase 1 and 2 update • Prohibit new development in the flood fringe, and existing development to be flood proofed • Minimize stormwater infrastructure (i.e., ponds) in the floodplain • Should it be closed, return Fish Creek Wastewater Treatment Plant (WWTP) location to the river • Identify aging infrastructure along the river in areas that could be returned to the river when the infrastructure is removed; e.g., Highway 22X gravel pit; Remington LaFarge site • Look for more flood mitigation opportunities in new developments; e.g., Quarry Park • Redesign Harvie Passage to fail in high-flow event thus removing any incremental flooding it may cause upstream, e.g., in Inglewood • Modify Cushing Bridge (17th Ave.) abutment to

Measure	Apply?	What has already been done?	What options remain?
			allow higher conveyance • Review grandfathered development along the lower Bow in Calgary
DETENTION			
5. Water storage	Yes	• Wetland conservation through the City of Calgary's Wetlands Conservation Policy; e.g., wetland area in Quarry Park • Cranston stormwater detention	• Urban stormwater ponds through the City of Calgary's Stormwater Management Strategy • Promote wetland preservation and enhancement through the City of Calgary's Wetlands Conservation Policy • Improve riparian health and absorption using the City of Calgary's Bioengineering Design Guidelines
OTHER MEASURES			
	Yes	• Riparian maintenance through the City of Calgary's Riparian Strategy	• Graduated flood protection level requirements • Improve riparian health and bank stabilization using the City of Calgary's Bioengineering Design Guidelines
LAST RESORT MEASURES			
	Maybe	• Raise the ground under riverside redevelopments; e.g.; Quarry Park	• City of Calgary River Flood Protection Conceptual Design Study currently studying flood barriers in key locations; e.g., Heritage Drive , Glenmore Trail, Bonnybrook WWTP • Update temporary flood barrier plans to protect against higher flood levels

Additional commentary:

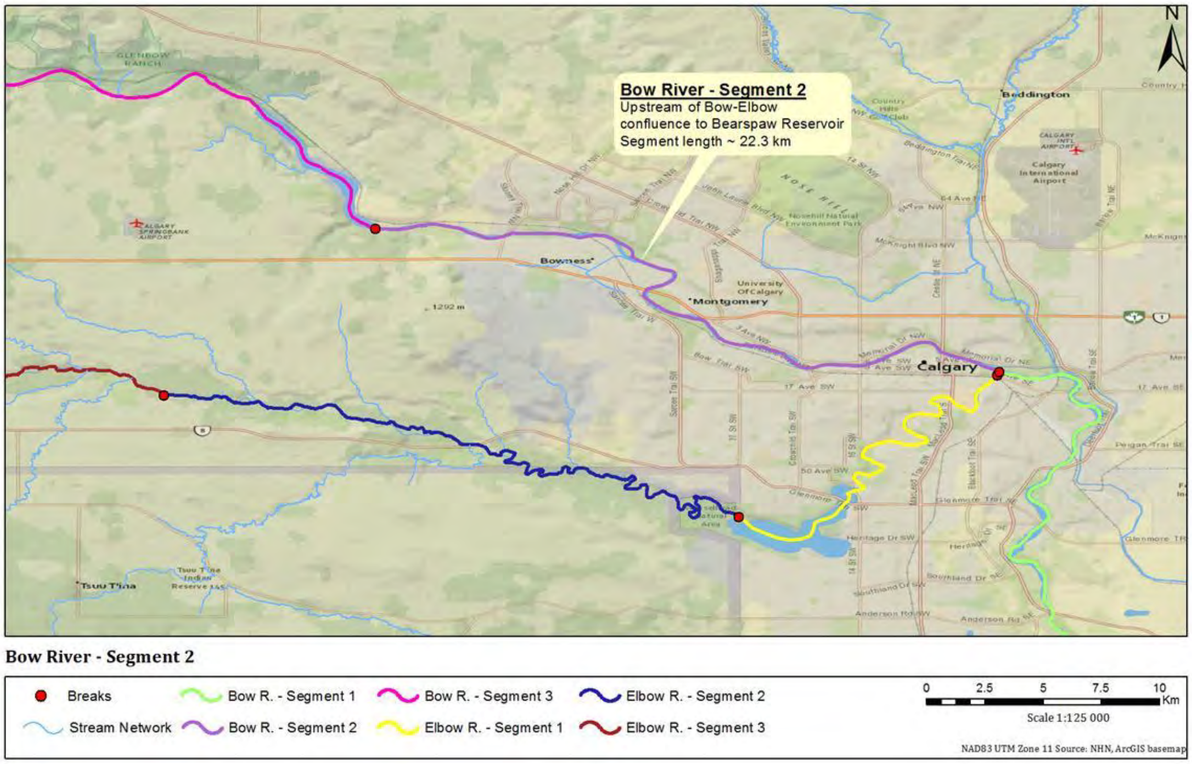
- Many riparian setbacks already exist in this lower segment of the Bow and infrastructure is generally less dense in the floodplain. Nevertheless, flood mitigation considerations should be incorporated into any new developments. Buyouts and relocation incentives offer some potential for making room for the river. In addition, perhaps a more flexible approach to setbacks can be taken that accounts more for topography. Currently only specific and limited setbacks are taken.
- The City of Calgary will be launching a riparian program in early 2015 to begin integrating the bylaw with mapping and to designate different riparian management zones.
- The City's river morphology study, expected to be complete by the end of 2015, will recommend if any gravel or cobble bars should be lowered or removed to reduce flood-related risk along the Bow and Elbow rivers (i.e., to lower flood water levels). Such removal can carry temporary risk to riverine ecology.
- Areas below dams tend to be gravel-starved, so if gravel is removed from one section of a river, consideration should be given to putting it back in the river at a place where it would be

useful. Roosting areas for ducks and geese can also be disrupted by the removal or lowering of gravel bars. This comment applies to many segments of the pilot study.

- Potential remains for future development in some low-lying areas, and consideration should be given to not grandfather developments that that are currently in the process of permitting or construction.
- The City’s River Flood Protection Conceptual Design Study will include permanent and temporary barrier options throughout the Bow and Elbow floodplains; the results of this study will help determine if and where to create new flood barriers or raise existing flood barriers in key city locations.
- The concept of using the Western Headworks Canal as a diversion channel was not recommended by the City Expert Panel. This was in part due to the capacity of this canal being ~30m^3/s, about 1.2% of the 2013 flood peak flow (2,400m^3/s); therefore it would not convey a great deal of flow from the Bow, and it would cause a lot of damage to the channel itself as well as to downstream infrastructure including Chestermere Lake and the Western Irrigation District canals. In addition, the canals would still be managing considerable urban and agricultural stormwater flow in the region.
- Outreach and information to clarify, for example, what a 1:100 return period event is, would help people better understand flood risks (i.e., what is the chance of a 1:100 year return period event occurring during the 40 years that someone owns a specific home).
- Public education on personal flood preparedness can help to reduce the impacts of flood events, improve emergency response times, and improve recovery.

3.1.2 Bow River Segment 2

This segment of the Bow River (Figure 4) extends from upstream of the Bow-Elbow confluence to the Bearspaw Reservoir, and is approximately 22 km long. This stretch of river passes through the heart of the city of Calgary. It encompasses several city parks, the Bearspaw Water Treatment Plant, and large sections of residential properties, curves around the downtown area and runs adjacent to the Calgary Zoo. Several islands are found in this segment, including three with significant development on them – Prince's Island Park, St. Patrick's Island, and St. George's Island. Discussion focused on opportunities to remove obstacles in the floodplain, which may cause local and upstream flooding.



Bow River - Segment 2
Upstream of Bow-Elbow confluence to Bearspaw Reservoir
Segment length ~ 22.3 km

Figure 4: Bow River – Segment 2

Table 7 shows the initial scan of specific opportunities to further implement *Room for the River* measures along this river segment, as well as actions that have already been taken.

Table 7: Initial Scan of *Room for the River* Opportunities for Bow River – Segment 2

Measure	Apply?	What has already been done?	What options remain?
DIVERSION			
1. High-water channel	Maybe		
CONVEYANCE			
2. Dike relocation	Yes		• Buyouts in targeted locations to enable relocation of current or planned barriers
3. Lowering floodplains	Maybe		• Where appropriate, as identified by the City of Calgary's morphology study, complete targeted removal or lowering of gravel/cobble bars in the Bow main stem to remove resistance (e.g., above the 10th Street Bridge) for larger return period events (possibly 1:5 year event and greater) • If appropriate, remove islands to increase flow capacity in the river; e.g., Prince's Island Park, St. Patrick's Island, St. George's Island (Calgary Zoo Island)
4. Removing obstacles	Yes	• Peace Bridge designed to let pass 1:100 year return period flood • The new St. Patrick's Island Bridge designed to be a free-span structure across the river channel • The wide-span Stoney Trail Northwest Bridge is an example of a bridge designed to allow room for the river • Removed grandfathering of flood fringe development requirements through Phase 1 review of the City of Calgary's Land Use Bylaw and MDP	• Minimize development in the floodplain through Phase 2 review of the City of Calgary's Land Use Bylaw and MDP • Reduce floodplain development through the City of Calgary's Environmental Reserve Setback Policy • Reduce floodplain development through the City of Calgary's Riparian Strategy • Minimize stormwater infrastructure in the floodplain • Develop common goals with landowners in the river valley to promote land use that aligns with *Room for the River*; e.g., Western Sky Land Trust Project • Modify Bowness Road Bridge (and possible TransCanada Bridge below) to remove constriction
DETENTION			
5. Water Storage	Maybe	• Riparian maintenance through the City of Calgary's Riparian Strategy	• Improve riparian health and absorption through the City of Calgary's Riparian Strategy • Design light infrastructure spaces (e.g., parks, pathways, golf courses) to carry or temporarily store floodwater • Urban stormwater ponds through the City of

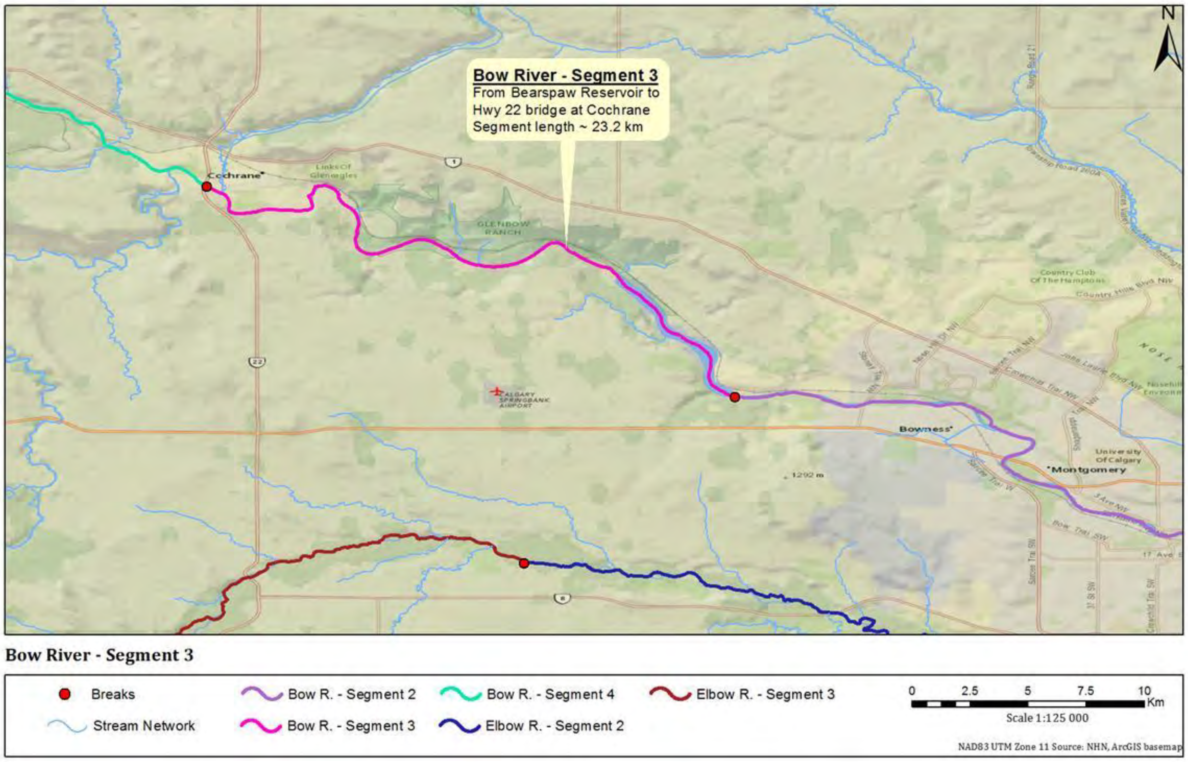
Measure	Apply?	What has already been done?	What options remain?
			Calgary's Stormwater Management Strategy • Promote wetland preservation and enhancement through City of Calgary's Wetlands Conservation Policy
OTHER MEASURES			
	Yes		• Graduated flood protection level requirements • Self-insuring new homes in the floodplain • Improve riparian health and bank stabilization using the City of Calgary's Bioengineering Design Guidelines • Dredge the main stem river bed in selected locations to increase flow capacity
LAST RESORT MEASURES			
	Yes	• Raising the ground under riverside redevelopments (e.g. East Village) to reduce need for river flood barriers	• City of Calgary River Flood Protection Conceptual Design Study currently studying flood barriers in key locations; e.g., Sunnyside berm, Bowness berm, automated barrier at Centre St. Bridge • Update temporary flood barrier plans to protect against higher flood levels

Additional commentary:

- Permanent barriers along this segment are more feasible than along the Elbow but still present a challenge because they would need to be about two metres high.
- Constructing dikes (berms) may be the most cost-effective approach to mitigating flood damages for some communities (e.g., Bowness).
- There are stormwater and groundwater issues in this area.
- Gravel/cobble bars can impede water flow, so their strategic removal or relocation within the riverbed might be a "no regrets" measure that could be quickly implemented. This should be very selective and possibly limited to areas that resulted from artificial encroachments.
- Buyouts were supported as a means for creating more room for the river in this segment. To avoid engineered infrastructure, much larger scale buyouts and removing large numbers of the structures would be required in this segment (e.g., Bowness). Conservation easements could be used in conjunction with buyouts to prevent future development in the floodplain. Likely the only feasible alternative to buyouts in this area is upstream infrastructure that carries risk of failure.
- Light infrastructure areas, such as golf courses and some parkland, could be deliberately allowed to flood under certain circumstances, but appropriate and equitable guidelines and agreements would need to be in place.
- Removing islands (e.g., Prince's Island Park, St. Patrick's Island, St. George's Island) would have considerable ecological and economic consequences, including reductions in riparian and fish habitat and loss of recreational areas and attractions.
- Public education on personal flood preparedness can help to reduce the impacts of flood events, improve emergency response times and improve recovery.

3.1.3 Bow River Segment 3

Segment 3 of the Bow River is shown in Figure 5. It extends for approximately 23 km between Bearspaw Reservoir at the western edge of the city of Calgary and the Highway 22 Bridge in Cochrane. This area currently has little development except in the town of Cochrane although there are some residences along the banks of Bearspaw Reservoir. Discussion focused on maintaining the room the river now has in this segment by minimizing future obstacles in the floodplain.



NAD83 UTM Zone 11 Source: NHN, ArcGIS basemap

Figure 5: Bow River – Segment 3

Table 8 shows the initial scan of specific opportunities to further implement *Room for the River* measures along this river segment, as well as actions that have already been taken.

Table 8: Initial Scan of *Room for the River* Opportunities for Bow River – Segment 3

Measure	Apply?	What has already been done?	What options remain?
DIVERSION			
1. High-water channel	No		
CONVEYANCE			
2. Dike relocation	Maybe		• Relocate the berms near the CP railway
3. Lowering floodplains	No		
4. Removing obstacles	Yes		• Minimize development in the floodplain; develop away from the river • Limit development in the floodplain in the Cochrane area • Minimize stormwater and water treatment infrastructure in the floodplain; if needed, build to minimize impact on river conveyance • Design multi-use facilities throughout the watershed (e.g., bike paths in Glenbow Ranch park) to minimize impact on flow • Assess the need to remove or lower select grave/cobble bars in the Bow main stem to remove resistance. • Develop common goals with the landowners in the river valley to promote land use that aligns with *Room for the River*; e.g. Western Sky Land Trust Project
DETENTION			
5. Water storage	Maybe	• Riparian health initiative to improve riparian absorption along the Glenbow Ranch	• Enforce no net change in discharge on new developments above the floodplain; e.g. on the plateau above Glenbow Ranch • Preserve Glenbow Lake wetland complex • Dredge Bearspaw Reservoir to maximize freeboard for flood mitigation (limited benefit due to small size of reservoir) • Allow low-lying open areas to temporarily flood (e.g., Glenbow Ranch Park or further west); may require diversion infrastructure for off-stream storage (dry dams on Bow not recommended for further study by GoA)
OTHER MEASURES			
	Maybe	• Riparian bank restoration projects near Cochrane	• Improve riparian health and function for bank stabilization • Do not allow gravel mining in riparian areas
LAST RESORT MEASURES			
	No		

Additional commentary:

- Much of the north side of the river in this segment is established as a provincial park but it is under growth pressure, particularly on the higher plateau above Glenbow Ranch Provincial Park and on the south side of the river, from both population and industrial activity. Of particular note is the important wetland complex that is under immediate threat in the Glenbow Lake area. As development occurs, there is a risk of losing absorptive capacity as areas are paved or otherwise made impermeable causing additional and more rapid runoff to the river system. The existing room for the river should be maintained to provide future flood mitigation.
- We need to better understand the role of groundwater in flooding and how development affects infiltration.
- It was suggested that there should be no armouring, dikes, or on-stream storage along the natural river portions of this segment. There may be some small opportunities for off-stream storage. The new Wetland Policy could offer some synergies with respect to storage and these can be explored.
- It was noted that removing gravel from the riverbed and floodplain probably should not, in general, be encouraged. However, some cobble/gravel bars may form in response to the choking caused by the bridge abutments in Cochrane that impede the natural river flow.
- The current gravel pits around Cochrane are high and set relatively far back from the river. Future gravel pit operations could perhaps be built in a manner to temporarily store some flood water, recognizing that the storage volumes of these gravel pits would be very limited. That said, the general sense is that gravel pits should not be operated close to the river.

3.1.4 Bow River Segment 4

Segment 4 of the Bow River (Figure 6) extends for approximately 31 km from upstream of the Highway 22 Bridge in Cochrane to upstream of Ghost Reservoir. From the Ghost Reservoir downstream to Cochrane, the river banks are sparsely settled although there is a gas processing plant adjacent to the river. The town of Cochrane did not suffer serious damage in the 2013 flood, but if the heaviest rainfall had been only 50 kilometres north, there could have been some risk to the town infrastructure from the Bow River. Discussion focused on maintaining the room the river currently has in this segment and advancing water storage opportunities using existing infrastructure.

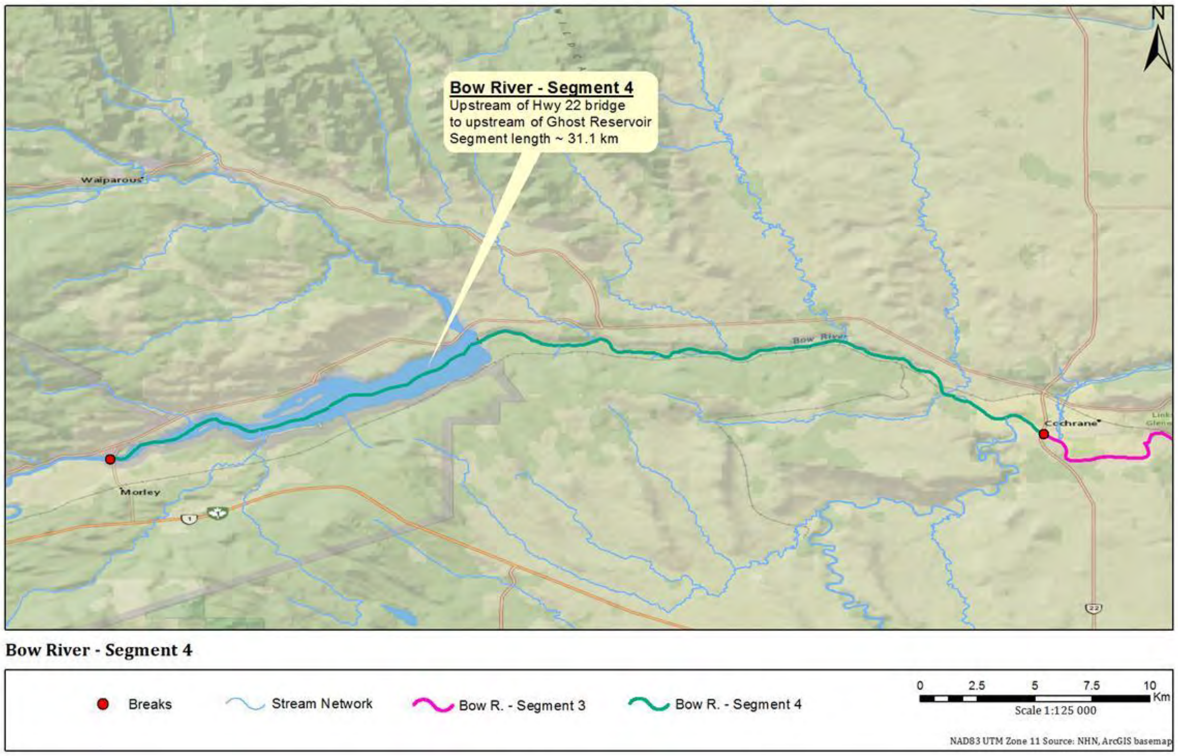


Figure 6: Bow River – Segment 4

Table 9 shows the initial scan of specific opportunities to further implement *Room for the River* measures along this river segment, as well as actions that have already been taken.

Table 9: Initial Scan of *Room for the River* Opportunities for Bow River – Segment 4

Measure	Apply?	What has already been done?	What options remain?
DIVERSION			
1. High-water channel	Maybe		• Potentially broaden the river channel (natural channel design should be considered)
CONVEYANCE			
2. Dike relocation	Maybe		• Relocate the berms near the CP railway
3. Lowering flood plains	Maybe		
4. Removing obstacles	Yes		• Limit any further development in the floodplain; e.g., development on or near Ghost Reservoir • Minimize new berms and hard bank armouring • Implement and enforce wetland policy and riparian policy (for County) to reduce development in the floodplain and promote wetland maintenance • Locate new energy industry infrastructure outside the floodplain and/or design it to have minimal impact on flow regulation functions • Develop common goals with landowners in the river valley to promote land use that aligns with *Room for the River*; e.g. Western Sky Land Trust Project
DETENTION			
5. Water storage	Yes		• Increase flood mitigation through operational changes to Ghost Reservoir, perhaps coupled with new off-stream storage to address drought risk • Expand flood mitigation capacity of Ghost Reservoir through sediment removal (study underway) • Expand flood mitigation capacity of Ghost Reservoir through upper reservoir bottom contouring to resolve fish stranding limitations • Improve riparian health and absorption through Rocky View County's Riparian Protection Land Use Bylaws • Implement and enforce wetland policy and riparian policy (for County) to reduce development in the floodplain and promote wetland maintenance • Increase emphasis on avoidance of wetland loss under the Alberta Wetland Policy in targeted areas; e.g., south of Bow River below Ghost Dam • Do not remove beaver dams and log jams unless they increase flood risk • Build weir infrastructure to temporarily flood open spaces; e.g., east of Wildcat Hills gas plant (on-stream

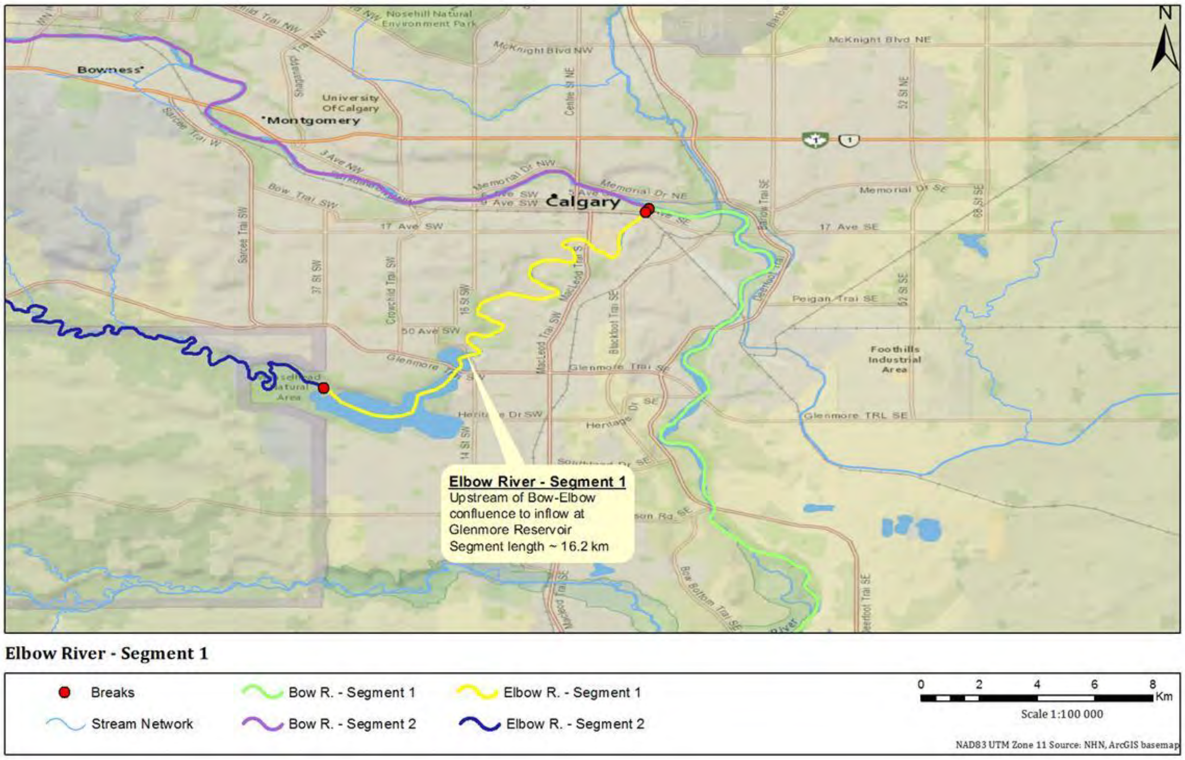
Measure	Apply?	What has already been done?	What options remain?
			dry dams on Bow not recommended for further study by GoA) • Assess the feasibility of temporary off-stream flooding upstream of Cochrane (dry dams on Bow not recommended for further study by GoA)
OTHER MEASURES			
	Maybe		• Improve riparian health and function for bank stabilization through Rocky View County's Riparian Protection Land Use Bylaws • Ensure Crown land areas continue to be protected and retained
LAST RESORT MEASURES			
	No		

Additional commentary:

- Discussion of this segment looked at avoiding the need for berms and other flood mitigation infrastructure, and preventing development in the floodplain and near Ghost Reservoir.
- Other industrial development could also be located away from the river.
- Ghost Reservoir could be given a stronger mandate for flood prevention (with appropriate compensation).
- Ghost Reservoir mitigation should be coupled with enhanced riparian and land cover upstream of the reservoir to decrease sediment loading into the water body.

3.1.5 Elbow River Segment 1

This segment of the Elbow River (Figure 7) flows for about 16 km through Calgary, upstream of the Bow-Elbow confluence to the Glenmore Reservoir inflow. This segment is a naturally meandering portion of the river with several subsurface ancient riverbeds now buried under the city. It has been heavily developed with residential and commercial infrastructure all along its length through the city. The area around this segment of the river was heavily damaged in the 2013 flood event, due in part to obstacles that created severe local flooding in the relatively heavily developed areas encroaching on the flood way and flood fringe. It is believed that flood flows from the Elbow were involved in much of the flooding of the downtown areas, well away from this river. Residences and businesses near this stretch of the Elbow were evacuated and some areas are not yet back to normal operations. Discussion focused on opportunities to remove obstacles in the floodplain.



Elbow River - Segment 1
Upstream of Bow-Elbow confluence to inflow at Glenmore Reservoir
Segment length ~ 16.2 km

Figure 7: Elbow River – Segment 1

Table 10 shows the initial scan of specific opportunities to further implement *Room for the River* measures along this river segment, as well as actions that have already been taken.

Table 10: Initial Scan of *Room for the River* Opportunities for Elbow River – Segment 1

Measure	Apply?	What has already been done?	What options remain?
DIVERSION			
1. High-water channel	Yes	• Designated overland flooding route through Erlton	• Elbow to Bow diversion tunnel (Calgary Glenmore Reservoir Diversion Tunnel is being further studied) • Build a conveyance channel through Mission and the Beltline
CONVEYANCE			
2. Dike relocation	Maybe		• Buyouts in targeted locations to enable relocation of current or planned barriers
3. Lowering flood plains	Maybe		• Possibly lowering parkland already located in the floodplain
4. Removing obstacles	Yes	• The Sandy Beach Bridge, Rideau Park Bridge and Riverdale Avenue Bridges have been redesigned to allow larger river flows • Redevelopment restrictions are in place for the floodway and fringe (Land Use Bylaw/MDP Phase 1 update) • Residential buyouts in the floodplain - 16 properties have been bought out by the Province • Reducing floodplain development through the City of Calgary's Riparian Strategy • The Calgary Golf and Country Club has remained set back from the river with the Audubon Certification	• Look for opportunities to modify bridges to remove restrictions on the river (many utility tie-ins); e.g. 9th Ave. Bridge and rail bridge into Inglewood • Remove or modify obstacles; e.g., the Stampede horse barns located in the floodway are designed to flood • Apply mandatory riparian setbacks to all new development following the City of Calgary's Riparian Strategy • Reduce floodplain development through the City of Calgary's Environmental Reserve Setback Policy • Where appropriate, as identified by the City of Calgary's morphology study, remove or lower gravel/cobble bars in the river to increase channel conveyance capacity for specific flood events (i.e., for 1:5 year return period event and above); possible example is gravel bars at the second pier of the Mission Bridge • Continue with appropriately designed residential buyouts
DETENTION			
5. Water storage	Yes	• Urban stormwater ponds through the City of Calgary's Stormwater Management Strategy • Preservation and promotion for wetlands through the City of Calgary's Wetlands Conservation	• Increase storage in Glenmore Reservoir through infrastructure changes; e.g., gates to replace stop logs • Increase storage in Glenmore Reservoir through a large scale infrastructure project (not recommended as the area does not allow for large increases in storage even if

Measure	Apply?	What has already been done?	What options remain?
		Policy • Sandy Beach Community Association riparian re-establishment	surrounding communities were to be relocated) • Dredge the Glenmore Reservoir to increase live storage for flood mitigation (not recommended by the City of Calgary as it would provide very little storage at great expense and create environmental problems) • Design light infrastructure spaces (e.g., parks, pathways, golf courses) to carry or temporarily store floodwater
OTHER MEASURES			
	Yes	• Allowing building in the floodplain areas but requiring buildings to be resistant to flooding; e.g., community of Erlton • Riparian maintenance through the City of Calgary's Riparian Strategy	• Graduated flood protection level requirements • Self-insuring new homes at flood risk • Limit development in areas identified to be alluvial floodplain • Improve riparian health and bank stabilization using the City of Calgary's Bioengineering Design Guidelines • Raising the ground level at Stampede Park
LAST RESORT MEASURES			
	Yes	• Bank armouring through riprap, modified riprap or enhanced riparian zones; e.g.; bio-engineering banks of riprap with vegetation (willows, cottonwoods, etc.) near the Talisman Centre	• Barrier at 4th Street to protect downtown core • City of Calgary River Flood Protection Conceptual Design Study currently studying permanent and temporary flood barrier options in key locations throughout the city • Update temporary flood barrier plans to protect against higher flood levels

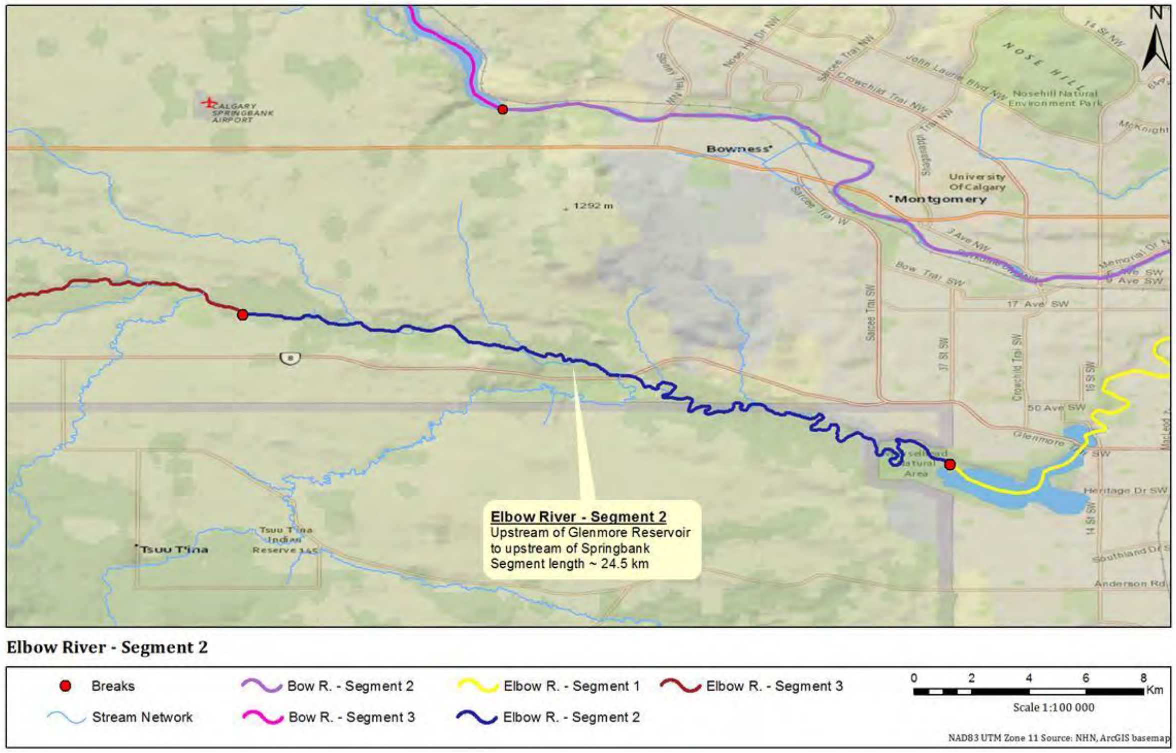
Additional commentary:

- Considerable development in this segment is near the river and there is little room for mitigation. The question was asked whether there is sufficient room left for the river in this segment. Relocations and buyouts in key locations continue to be raised as important. It was suggested that when a property goes on the market in a flood-risk area, the GoA could buy it at fair market value, remove the buildings, and use those properties as flood inundation areas. Furthermore, the buyout program could be extended from the flood way only to also include flood fringe properties.
- In addition to looking ahead at ways to mitigate impacts through flood-resistant construction, new infrastructure and buildings must be maintained to reduce damage from future flood events. Proper design targets and consistent standards need to be in place through building codes and other regulatory mechanisms. Assuming increased climate variability, current standards may well be out of date.

- There could be opportunities to work with partners such as golf courses, which might play a more significant role during flooding to hold back water then be repaired after an event with some compensation; however the storage volumes would be quite limited.
- It is worth exploring how flood mitigation measures could be made to have multiple uses and be aesthetically pleasing.

3.1.6 Elbow River Segment 2

This segment of the Elbow River (Figure 8) extends for approximately 24 km from upstream of Glenmore Reservoir to upstream of the Springbank community. This segment includes a meandering and braided river system as it approaches the lower end of the river before entering Glenmore Reservoir. Several golf courses, rural subdivisions, acreages, and expanding development from Calgary are located along this segment. The region is subject to considerable development pressure as an attractive, scenic, and close-in option for high end homes. Discussion focused on removing obstacles in the floodplain and looking for opportunities to create local, temporary storage or side channels.



Elbow River - Segment 2
Upstream of Glenmore Reservoir
to upstream of Springbank
Segment length ~ 24.5 km

Elbow River - Segment 2

NAD83 UTM Zone 11 Source: NHN, ArcGIS basemap

Figure 8: Elbow River – Segment 2

Table 11 shows the initial scan of specific opportunities to further implement *Room for the River* measures along this river segment, as well as actions that have already been taken.

Table 11: Initial Scan of *Room for the River* Opportunities for Elbow River – Segment 2

Measure	Apply?	What has already been done?	What options remain?
DIVERSION			
1. High-water channel	Maybe		• Create or expand secondary channels in natural drainage locations; e.g. a diversion from the Elbow into Fish Creek (not recommended for further study by GoA)
CONVEYANCE			
2. Dike relocation	Yes		• Move berms protecting golf courses back from the river and allow golf courses to flood
3. Lowering flood plains	Maybe		• Work with the extraction industry to target gravel mining in beneficial areas
4. Removing obstacles	Yes	• Continued enforcement of Rocky View County building codes to minimize obstacles and damage in the floodplain • Reducing floodplain development through City of Calgary's Environmental Reserve Setback Policy • Reducing floodplain development through the City of Calgary's Riparian Strategy • Setting back the new Gardner development south of the Elbow	• Modify the twin bridges on Highway 8 to make them wider span • Re-evaluate the SW Calgary Ring Road plan to include wide-span bridges over the Elbow that will maintain the river's current room • Apply mandatory riparian setbacks to all new development through the City of Calgary's Riparian Strategy • Where appropriate remove or lower gravel/cobble bars and impediments to increase conveyance capacity of river for specific return period flood events; i.e., > 1:5 year return period • Develop common goals with landowners in the river valley to promote land use that aligns with *Room for the River*; e.g., Western Sky Land Trust Project • Allow golf courses to flood when needed by removing berms and being compensated for damages caused by the occasional flood; e.g., Elbow Springs Golf Course • Review and remedy poorly done bank protection or reclamation
DETENTION			
5. Water storage	Yes	• Mitigation using urban stormwater ponds through the City of Calgary's Stormwater Management Strategy • Preserving and enhancing	• Identify areas that would be used for passive or active storage; e.g., parks • Promote further wetlands retention opportunities through the City of Calgary's Wetlands Conservation Policy • Use root wads and log jams to slow water

Measure	Apply?	What has already been done?	What options remain?
		wetlands through the City of Calgary's Wetlands Conservation Policy • Riparian zone maintenance through the City of Calgary's Riparian Strategy • Preserving riparian absorption by restricting cattle in the riparian area; e.g., Alberta Agriculture Growing Forward program	• Potential local high flow retention on Millbrook Creek in new Gardner development south of the Elbow • Improve riparian health and absorption through the Rocky View County Riparian Protection Land Use Bylaws • Improve wetland retention using Rocky View County's Wetland Conservation policies • Evaluate the SW Calgary Ring Road plan as dry dam to co-function as in-stream storage in case of imminent flooding
OTHER MEASURES			
	Yes		• Improve riparian health and bank stabilization; e.g., softening the area that was channelized around Highway 8
LAST RESORT MEASURES			
	Maybe	• Raise the ground under riverside redevelopments; e.g., Discovery Ridge	• City of Calgary River Flood Protection Conceptual Design Study currently studying flood barriers to protect communities upstream of Glenmore Reservoir • Update temporary flood barrier plans to protect against higher flood levels

Additional commentary:

- Using aquifers for natural underground water storage would likely have limited benefit as the rates of injection would only be a very small percentage of the flood flow rate.
- Root wads, log jams, and riparian absorption would have limited impact on slowing water, especially in very high-flow events.
- The break between river segments 2 and 3 should perhaps be revised as it currently divides the Springbank community.
- There are many examples of bank protection or enhancements that have resulted in the river being narrowed and having steeper sides. This channelizing could be softened by revisiting and restoring poorly-done bank projects, including the unregistered ones that have not been listed.

3.1.7 Elbow River Segment 3

Segment 3 of the Elbow River (Figure 9) runs for approximately 39 km from upstream of Springbank to Paddy's Flat campground. It passes through Bragg Creek and Redwood Meadows, both of which were damaged in the 2013 flood. The river system is largely natural apart from some acreages, rural residences, and small businesses until the river nears Bragg Creek and Redwood Meadows. Upstream of Bragg Creek the river is a focal point for year-round recreational activity for many Southern Alberta residents due to its proximity and relatively wild beauty and natural setting. Several campgrounds and recreational sites exist in or near the floodplain. Discussion focused on mitigating local risk by removing obstacles in the floodplain and creating upstream storage to mitigate flood damage in Calgary.

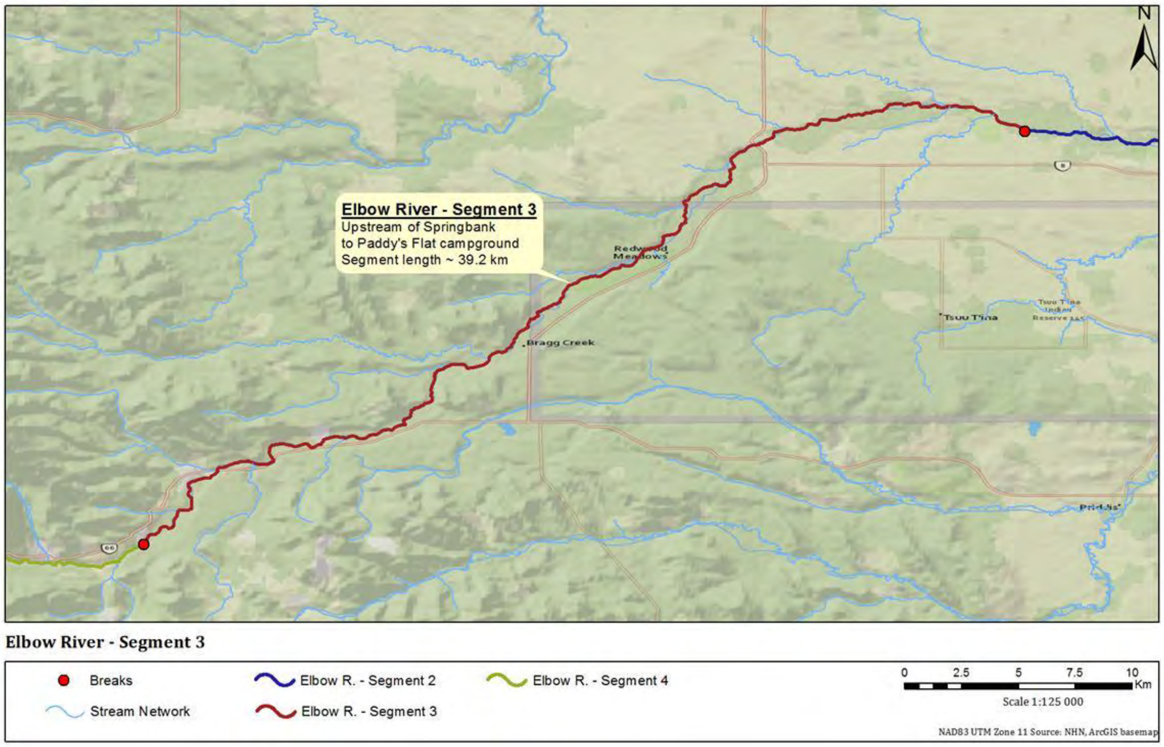


Figure 9: **Elbow River – Segment 3**

Table 12 shows the initial scan of specific opportunities to further implement *Room for the River* measures along this river segment, as well as actions that have already been taken.

Table 12: Initial Scan of *Room for the River* Opportunities for Elbow River – Segment 3

Measure	Apply?	What has already been done?	What options remain?
DIVERSION			
1. High-water channel	Maybe		• Create or expand secondary channels in natural drainage locations; e.g., a diversion from the Elbow into Priddis Creek (not recommended for further study by GoA)
CONVEYANCE			
2. Dike relocation	Yes	• Modifications to Redwood Meadows berm	• Low density areas are heavily bermed; relocating berms in conjunction with buyouts should be examined • Relocate Redwood Meadows berm, recognizing land ownership implications
3. Lowering flood plains	Maybe		• Redesign or removal of the bedrock in the Elbow River around and/or through the town of Bragg Creek
4. Removing obstacles	Yes	• Continued enforcement of Rocky View County building codes to minimize obstacles and damage in the floodplain • Centennial Trail was moved up and out of the floodplain • Allen Bill pond is not being rebuilt	• Strictly implement the Rocky View County Plan which identifies growth and no-growth areas • Strictly apply riparian setbacks to all new development, no exceptions • Consider buyouts in the flood fringe in Bragg Creek (low density) • Use Bragg Creek as a pilot for implementing *Room for the River* in mitigation planning • Where appropriate, remove or lower the gravel/cobble bars in the Elbow above Bragg Creek (benefits need to be studied as this may only lower flood water levels a short distance upstream) • If appropriate, remove the groynes just upstream of Highway 22 Bridge to increase channel conveyance capacity (these groynes may protect the bridge abutments or a buried pipeline) • Widen the span of the Highway 22 Bridge north of Highway 8 • Encourage the removal of Redwood Meadows and the berm instead of a lease renewal (very preliminary concept) • Develop common goals with landowners in the river valley to promote land use that aligns with *Room for the River*; e.g. Western Sky Land Trust Project

Measure	Apply?	What has already been done?	What options remain?
DETENTION			
5. Water storage	Yes		• Construct a dry dam above Bragg Creek (MC1 – currently being further studied) • Construct an off-stream reservoir for high flow storage in Springbank (SR1 – currently being further studied) • Improve riparian health and absorption through the Rocky View County Riparian Protection Land Use Bylaws • Improve wetland retention using Rocky View County's Wetland Conservation policies
OTHER MEASURES			
	Yes	• The water treatment plant in Bragg Creek is located to withstand 1:100 predicted flood flows but is not designed to withstand high level floods at or within its walls	• Retrofit basements behind the dike to protect from seepage and groundwater flooding • Do not allow basements in new developments • Look for opportunities to widen the river course by removing obstacles in the Elbow upstream of Bragg Creek • Improve riparian health downstream of Bragg Creek before Calgary, east of Highway 22 before 101st Street
LAST RESORT MEASURES			
	Maybe	• Existing dike upstream of Bragg Creek was built to 1:20 year flood • Mountain River Estates has armoured banks and reconstructed intake • Riprap at Highway 22 Bridge north of Highway 8	• Berm and armour banks along the Elbow by Bragg Creek as suggested by the AMEC report (this was considered to address only parts of the flood mitigation solution)

Additional commentary:

- Post-2000 buildings in Bragg Creek were largely undamaged by the 2013 flood, demonstrating the effectiveness of the County's municipal development initiatives and permitting requirements.
- Relocating the Redwood Meadows berm would likely require a separate process as it is located on First Nations land.
- A groyne is a type of river training structure that is used to force local river flow in a specific direction. In the Alberta context, groynes are used primarily for erosion protection along a river bank; they modify the local direction of flow and local flow velocity but generally have minimal, if any, impact on flow rate. Any groyne structure creates an obstruction, or obstacle, in the river channel and tends to increase local upstream water levels. That is why the Dutch

are trying to remove and/or lower groynes along their river channels. Groynes would rarely be used in an engineered application to try and reduce water levels during a flood and they would have little value in terms of mitigating downstream flood impacts on the Bow River.

- Groynes can be designed to be more “fish friendly.” When banks are heavily armoured, groynes are often put in because fish do not like channelization and groynes act to reduce velocity directly downstream of the structure (similar to a large boulder) and thus may benefit fish in homogeneous stream channels. Generally, when considering impacts on fish, the best option is to leave natural stretches of the river alone.
- With respect to the groynes just upstream of the Highway 22 Bridge, it was noted that these groynes are protecting an exposed gas pipeline until it can be reburied and were meant as a temporary solution.
- The larger infrastructure measures being studied in this segment (SR1 and MC1) place the burden on this segment (primarily ranchers’ homes and their land) while the benefits are realized downstream (largely in Calgary). This imbalance is not typically favoured under the program in the Netherlands. In addition, the program in the Netherlands prefers to avoid large mitigation infrastructure because of its associated risk of catastrophic failure.
- Compensation for land required for larger mitigation measures has been approached in three different ways in the Netherlands: bought by the Government then resold with different conditions on use; bought by the Government and converted to public land; or a compensation arrangement was made with the current landowner. Compensation for SR1 may need to address many affected parties, not only the directly affected landowners.
- A diversion from the Elbow River into Priddis Creek was discussed in 2013 and not recommended for further study by the GoA. Concerns raised in that discussion included that the area already took large flows in 2013; additional diverted flow could further overwhelm the natural capacity and ecosystem as a new oversized channel would likely be created; there would be direct effects on nearly 500 landowners, water supply for local communities, infrastructure (roads, culverts, homes, recreation facilities, etc.), drainage, and groundwater; and the question of whether this option was simply transferring flood risk from one community to another.
- More science and data are needed to better understand the hydraulics of these river segments and the full impact any one of these mitigation measures may have – locally, upstream, and downstream. Specific examples suggested as needing additional science include the SR1 project and opportunities for secondary channels in natural drainage locations.
- From a broader watershed management perspective, it is important to consider the relative value of single purpose infrastructure; for example, the dry reservoir at SR1 might provide room for the river, but may not satisfy the broader needs of watershed management in times of drought as well as flood.
- Although several Flood Recovery Erosion Control projects were applied for and received preliminary approval, such as mitigation on the northwestern bank of the Elbow as well as through the extensive breakthroughs on the Herron property, these projects have not yet been granted the go-ahead from ESRD and hence, have not yet been addressed.

3.1.8 Elbow River Segment 4

Segment 4 of the Elbow River (Figure 10) extends from Paddy's Flat campground up to the confluence with Quirk Creek, a distance of about 11 km. This segment is primarily natural with a naturally functioning river. Discussion focused on maintaining the room the river currently has in this segment and exploring opportunities for upstream retention, both small and potentially larger scale.

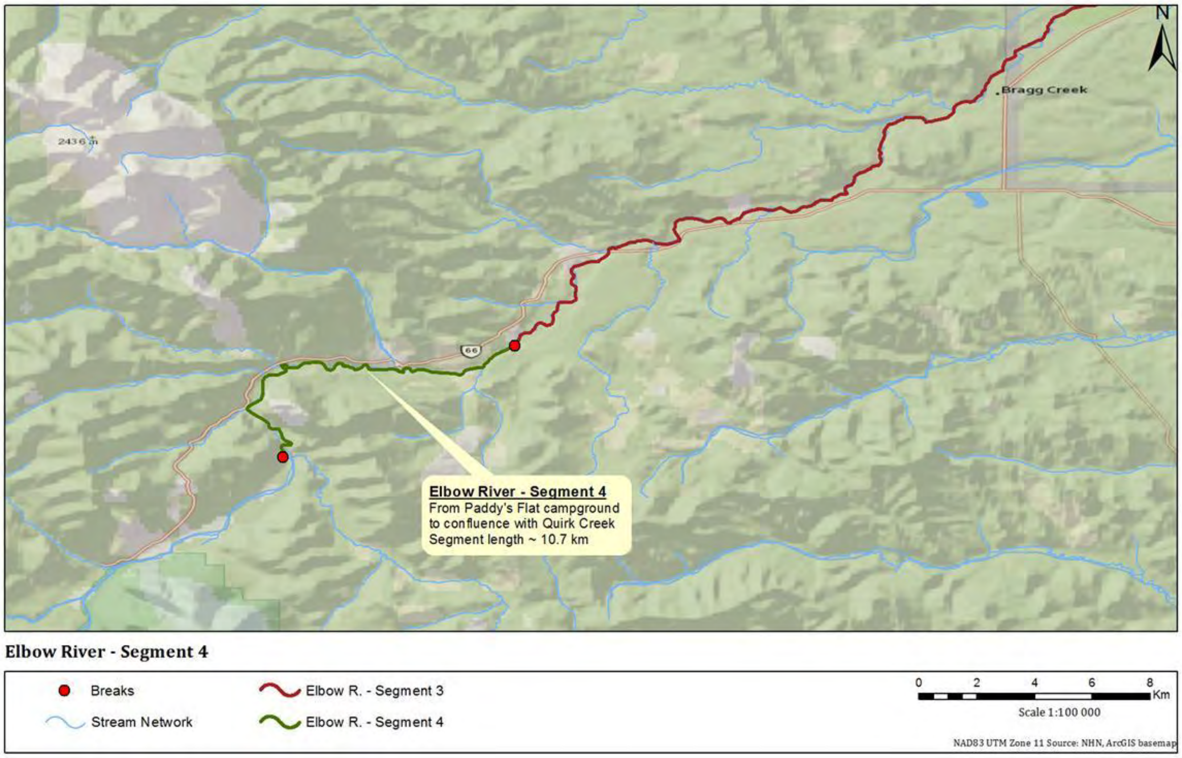


Figure 10: **Elbow River – Segment 4**

Table 13 shows the initial scan of specific opportunities to further implement *Room for the River* measures along this river segment, as well as actions that have already been taken.

Table 13: **Initial Scan of *Room for the River* Opportunities for Elbow River – Segment 4**

Measure	Apply?	What has already been done?	What options remain?
DIVERSION			
1. High-water channel	No		
CONVEYANCE			
2. Dike relocation	No		

Measure	Apply?	What has already been done?	What options remain?
3. Lowering flood plains	No		
4. Removing obstacles	Yes		• Revisit building of campgrounds, boat launches, and access in the floodplain; either relocate amenities or build to have least impact on natural stream functions • Implement and enforce wetland policy and riparian policy to avoid development in the floodplain and promote wetland maintenance • Modify or remove structures that constrain flow during flood events, such as buildings, pathways, and bridges; e.g., review past and present infrastructure, and plan how to improve future design • Apply mandatory riparian setbacks to all new development following Rocky View County's Riparian setback policy, to potentially achieve a consistent approach throughout the watershed regardless of jurisdiction • Develop common goals with landowners in the river valley to promote land use that aligns with *Room for the River*; e.g. Western Sky Land Trust Project
DETENTION			
5. Water storage	Yes		• Identify areas that could be used for storage, following the example of the dry dam structures and removal of floodplain infrastructure in Ohio (not recommended for further study by GoA in this reach; MC1, which is still under consideration, is located in Elbow Segment 3) • Reduce and optimize location and design of multi-use facilities throughout the watershed (e.g., ATV trails) to minimize impact on flow regulation functions • Improve and retain wetlands by following Rocky View County's Wetland Conservation policies • Improve riparian health and absorption by following the Rocky View County Riparian setback policy
OTHER MEASURES			
	Maybe		• Improve riparian health and bank stabilization through Rocky View County's Riparian Protection Land Use Bylaws • Ensure Crown land continues to be protected and retained • Improve riparian health and bank stabilization; e.g., woody vegetation at stream crossings • Do not remove beaver dams and log jams unless they increase flood risk and/or engineer or promote log jams to provide upstream retention of water
LAST RESORT MEASURES			
	No		

Additional commentary:

- This river segment is recognized as being quite dynamic as seen by its movement after the 2013 floods. Maintaining room for it to move was stressed as a priority for local benefit as well as for its role in attenuating flood flows as they move downstream.
- Engineering log jams to provide upstream retention of water can lead to downstream problems in the event of failures and can pose a barrier to fish movement.
- Land use controls in the headwaters, such as protecting and enhancing wetlands, improving logging practices, and better managing ATV routes can provide flood mitigation benefits as well as improve water quality and riparian health.
- Dry dam structures and removal of floodplain infrastructure are paired techniques in Ohio's flood mitigation. Dry dams have been discussed extensively in Alberta since June 2013 highlighting: the differences between the Ohio and Alberta locations; the burden of new dam infrastructure from an operations, maintenance and reliability perspective; and the impact of a dry dam on sensitive headwaters with vital fisheries, ecosystems and habitat values and where unimpeded material transport is important.
- One area for consideration is the need for a consistent approach for river mitigation in jurisdictions throughout the watershed for land uses, setbacks, or barrier removal, rather than identifying opportunities for one municipality only. The GoA would need to be involved in this work and the approach would apply irrespective of jurisdiction.

3.2 "No regrets" Opportunities

Having considered examples and opportunities within each river segment in the pilot study area, it was then possible to look across the system for potential "no regrets" opportunities, recognizing that it is difficult to achieve truly no regrets because there are trade-offs with every action. With input from the expert contributors, some practical and implementable "no regrets" opportunities were identified in two main categories: policies and decisions, and projects or actions. All these potential opportunities are consistent with the principle that the "straitjacket" for the rivers should not be tightened; that is, at a minimum these opportunities should not further constrain the Bow and Elbow rivers and where room for the river now exists, it should be maintained. Furthermore, to the extent possible, "no regrets" opportunities should not preclude future options for flood mitigation.

Some of these "no regrets" opportunities are basin-wide, others are common to several segments in the pilot, and others are specific to one river segment. Opportunities in the first category typically relate to policies, regulations and decision making, are broader in scope, and could take longer to implement. Opportunities in the second category are typically more specific projects or actions that could be advanced in the near term.

3.2.1 Possible "No regrets" Opportunities: Policies and Decisions

No priority is assigned to the possible "no regrets" opportunities shown in Table 14.

Table 14: Possible "No regrets" Opportunities: Policies and Decisions

Opportunity	Segment	Implementing the Opportunity
Map inundation and/or hazard across the whole basin to provide a base of knowledge for development, mitigation and recovery decisions, and enforcement	Basin-wide	Continue to fully fund the ESRD hydrology studies and flood hazard mapping projects currently underway, with the Bow River watershed as a first priority. Integrate all government efforts and funding for mapping to benefit all and to be accessible by all, and include both rural and urban areas.
Document damage to infrastructure to retain institutional memory on flood impacts to inform future building and mitigation	Basin-wide	Document the cost of damages and lost business production caused by the 2013 flood, including insurance claims, provincial compensation, buyouts and other costs to repair damages to all infrastructure, berms, bridges, roads, etc. throughout the region. Collect digital pictures and footage from media and others and compile into an online database for long-term public access.
Strengthen and enforce policy and regulation to halt or minimize new development in floodplains	Basin-wide	Have Alberta Municipal Affairs put in place clear province-wide guidance to more rigorously limit inappropriate new developments in the floodplain in all municipalities. As new mapping changes the floodplain parameters, areas may require more specific policy.
Ensure projects are rebuilding more robustly than before; e.g., new Glenmore Dam gates higher than original stop logs	Basin-wide	Research and apply best management practices (BMP) and/or best available technology (BAT) criteria to flood-related project applications for provincial funding or shared funding.
Revisit standards and incentives to promote building roads and bridges to leave more room for the river	Basin-wide	Consider a higher provincial standard for new infrastructure construction in the floodplain. All projects applying for provincial funds or shared funding for transportation infrastructure should be assessed against stringent floodplain standards and criteria in order to receive funding and to proceed.
Establish more stringent guidelines for new pipeline and utility construction in or across floodplains	Basin-wide	The Alberta Energy Regulator and other responsible agencies (e.g., the National Energy Board) consult with private sector pipeline and construction companies to establish world class standards for all pipeline crossings of rivers and other water bodies.
Establish basin wide guidelines for "as needed" flooding of light infrastructure areas	Basin-wide	In collaboration with affected municipalities and parties, develop and apply guidelines for agreements related to use of such lands for periodic flooding, including compensation or restoration costs.
Stop the removal of log jams in the headwaters (where it is not close to flood risk) to maintain natural retention	Bow 4 Elbow 4	In collaboration with local municipalities, forest products companies, and other commercial and recreational users of the headwaters, establish clear

Opportunity	Segment	Implementing the Opportunity
		guidelines for dealing with log jams, beaver dams, and other natural flow blockages throughout the Bow watershed (with consideration given to potential flood or erosion risks) and apply through the South Saskatchewan Regional Plan (SSRP).
Strengthen and enforce land use BMPs to maintain the flow regulation and retention in the catchment	Basin-wide	Refine and establish BMPs for recreational and commercial/industrial land use and, as above, apply clear guidelines for treatment of natural streamflow impediments using the SSRP.
Improve monitoring of precipitation and river flow measurements as well as the methods and timeliness of public communications related to possible flood warnings	Basin-wide	Monitoring of precipitation and river flow is improving but information on appropriate emergency response needs to be shared by the data collectors with the public in an effective and timely manner. Timely communications among the US National Weather Service, Environment Canada, and provincial forecasting services as well as data from standardized and trained local citizenry measurements (such as is well-established throughout the US) can enhance early warning systems and provide real-time information during an emergency event.

3.2.2 Possible "No regrets" Opportunities: Specific Projects and Actions

No priority is assigned to the "no regrets" opportunities shown in Table 15.

Table 15: Possible "No regrets" Opportunities: Specific Projects and Actions

Opportunity	Segment	Implementing the Opportunity
Revise SWCRR plans to include a wide span bridge, preserving the room for the Elbow River	Elbow 2	As a first step, evaluate what changes can be made under the current agreement to widen the spans of the SWCRR Elbow River Bridge and the Fish Creek Bridge, and ensure that triple bottom line accounting is incorporated in any plan revisions. Consider alternatives to optimize room for the river considerations at this location.
Secure long-term watershed agreement with TransAlta revising Ghost Dam operations for flood and drought mitigation and other basin interests	Bow 4	Such an agreement has the support of many key stakeholders in the Bow River Basin. That said, there are trade-offs between the local impacts on land owners and business operators and flood protection in Calgary. A memorandum of understanding or preliminary agreement subject to further modelling, review, and consultation with stakeholders can and should be developed and in place prior to April 2015. This should be done in parallel with the broader public discussion already announced by the GoA.
Remove gravel above the 10th Street Bridge as an example of targeted, science-based removal of flow obstacles	Bow 2	This measure is based on unnatural obstructions that cannot be removed and which then create unnatural obstacles to flood flow in certain instances. Provincial

Opportunity	Segment	Implementing the Opportunity
		approvals and support should be put in place to assure rapid approvals from the federal Department of Fisheries and Oceans and other agencies. Because areas below dams tend to be gravel-starved, consideration could be given to putting any gravel removed through this measure back in the river at a place where it would be useful. Other similar obstacles throughout the basin should be evaluated and prioritized for removal in other river segments.
Increase emphasis on avoidance of wetland loss and encourage wetland restoration in targeted areas; e.g., south of Bow River below Ghost Dam	Bow 3 Bow 4	The Alberta Wetlands Policy establishes a clear priority for avoiding wetlands. This priority can be strongly favoured by ESRD in areas where flood and drought issues may be affected by wetland loss. Engage Ducks Unlimited Canada to investigate wetland restoration opportunities in targeted areas in collaboration with local Watershed Stewardship Groups. Preserve Glenbow Lake wetland complex that is under immediate threat from development
Revisit buyouts to secure properties that could make room for the river: past applications (e.g., Bragg Creek) and future market purchases (e.g., like Calgary Stampede did)	Bow 1 Bow 2 Elbow 1 Elbow 3	Initiate a review of unsuccessful buyout applications from 2013/2014. Extend buyout offer to selected floodplain residents, not just those in the flood way. Develop a long-term purchase program budget and process that enables buyouts whenever flood zone residential properties come on the market to gradually make more room for the river in high hazard areas.
Pilot a community (e.g., Bragg Creek) through RftR planning process to identify effective mitigation measures	Elbow 3	Apply a local version of the Dutch five-step process for flood mitigation selection to a flood-affected community; e.g., Bragg Creek. A somewhat larger region may need to be involved to enable RftR measures to be effective rather than focusing on a single small stretch of river. In either case, it is important to discuss with upstream and downstream stakeholders rather than in isolation.
Run a community through an education and mini RftR process (Dutch tool and communication techniques with tangible outcomes)	Elbow 3	Apply a local version of the Dutch communication and education techniques to raise the understanding of flood mitigation to a flood-affected community, e.g. Bowness.
Build the critical barriers already identified; e.g., Bonnybrook WWTP, automated gates at Centre Street Bridge	Bow 2	Protect high value areas in the flood way and flood fringe that cannot feasibly be removed should be a high priority. Work with municipalities to identify and categorize vulnerability and risk, then prioritize. Establish multi-year budgets and design, build, and operate the required infrastructure.

Opportunity	Segment	Implementing the Opportunity
Fund the already identified Watershed Resiliency and Restoration Program projects to achieve the RftR objectives and measures	Basin-wide	Focus funds within the ESRD program to strengthen all flood- and forecast-related areas and focus on flood hazard regions and locations as a first priority.
Engage recreational users and all landowners, both urban and rural, in the Bow and Elbow river valleys regarding land characteristics, land use, and potential opportunities for restoration, enhancement and preservation.	Basin-wide	Support the conservation approaches already underway. GIS mapping of all land parcels, tenureship and prioritized conservation has been completed for the Bow and Elbow rivers. Western Sky, based on previous success of this program along the lower Bow River, is now undertaking two-year outreach with roughly 250 landowners along these rivers. Support the education and awareness building efforts already underway, many through the resident Watershed Stewardship Groups. Outreach to urban dwellers should include information on low impact development and permeability, the importance of flood preparedness, and the need for everyone to be informed and take responsibility for their own decisions and actions.

3.3 Suggestions on a Potential Broader Program, Process, and Engagement

3.3.1 How a *Room for the River*-type Program Might Look in Alberta

The initial research on the Dutch experience and input from contributors led to the identification of several key features that should be part of a *Room for the River*-type program in Alberta. These are described below and all components are viewed as important.

An integrated watershed and river management approach should be the basis of a program for Alberta.

> The program in the Netherlands offers a good example from which to learn, bearing in mind that important climatic, geographic, hydrologic, physiographic, and demographic differences exist between Alberta and the Netherlands. The Dutch experience relies heavily on engineered structural changes, while Alberta has committed, as reflected in the GoA's document *Respecting our Rivers*, to a broader approach that includes promoting natural river functions for flood mitigation wherever possible. Contributors to this pilot project stressed there is no single solution. An integrated watershed management approach, including the headwaters, the tributaries, and all downstream reaches, should be the path forward for Alberta, using all available tools (useful and accurate data and models, municipal and provincial regulations and guidelines, conservation easements, best management practices, triple bottom line analysis, and others). This includes determining the potential effects that actions in one area might have upstream, downstream, and across the entire watershed.

An Alberta program must have a clearly stated purpose and objectives and well-defined design parameters.

Are we trying to reduce the probability of a flood occurring? Reduce the risk to people when a flood does occur? Improve watershed health so flood hazards are better absorbed?

In defining the program objectives, it is critical to distinguish between flood hazard and flood risk: hazard refers to the potential of floods to cause harm, while risk reflects the probability that actual harm occurs to people, their property, and infrastructure. As long as people stay out of the way of a hazard, there is no risk.

This stems directly from the Dutch program where the first thing they did was define and then communicate what level of flood protection they wanted to achieve and how they planned to work with stakeholders to achieve it. For Alberta, the starting point should be GoA leading work to define clear objectives for both flood and drought mitigation so that potential actions can be evaluated in a systematic way against those objectives. Without such objectives, piecemeal actions will be taken, designed to different levels of flood protection, with no indication of how they might complement each other. The Bow River Basin Flood Mitigation and Watershed Management Project[8] took a step toward this when it collaboratively modelled and assessed a long list of mitigation options, both individually and in combination, against a suite of target flow rates for the Bow and Elbow rivers.

The objectives for a program of this nature need to be organized and defined in a manner that is tangible and understandable to the basin residents.

Two potential frameworks were suggested through the course of this pilot:

Potential Framework 1 is simple and easy to communicate:

1. Diversion – channel high flows around infrastructure
2. Conveyance – create a larger river cross section to allow high flows to pass
3. Storage – detain high flows temporarily
4. Other
5. Last Resort Measures – protect infrastructure from high flows

Potential Framework 2 is slightly more technical, highlighting the hydraulic aspects of the measures:

1. Increase natural retention in the headwaters to reduce flood peaks.
2. Maintain breadth in the upstream floodplain to attenuate flood peaks by lowering and widening the flow distribution curve, and thus lowering the downstream risk.
3. Create conveyance capacity through the floodplain to minimize risk.
4. Create upstream storage to reduce flood peaks and lower the downstream risk.

With integrated water management as the premise, this type of program should consider all concerns and issues of water management, while remaining focused on flood mitigation.

Given the complex dynamics of the basins, a flood mitigation program should not be pursued in isolation from other water management considerations in the basin. To that end, integrated water management would include:

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[8] See http://albertawater.com/work/research-projects/resilience-and-mitigation-branch for more information.

- Safety and Security = managing flood risk
- Water Supply = managing drought risk
- Water Quality = managing minimum flows for healthy aquatic ecosystems, biodiversity, drinking water, and recreation

Each of these could be established as parallel but interdependent efforts, each with specific objectives and a manageable scope. An effective and resilient flood mitigation program must always be considered in the larger context, seeking as much synergy with the other objectives as possible. Most importantly, there must be a line of sight across the objectives for each effort to ensure a comprehensive, integrated set of water management goal for the basin.

The name of an Alberta program would likely differ from the program in the Netherlands given the different context and expected objectives.

With the Netherlands' primary focus on increasing conveyance capacity, using the word "room" is highly appropriate. The purpose, objectives, and goals should inform the program name in Alberta; the name might include the words "respect", "retain", or "make room for" the rivers, for example.

Sufficient science, data, modelling, study and open communication are required to enable informed and timely flood mitigation decisions.

Science-based tools including wetland and groundwater inventories, cumulative effects studies, mapping, and associated engineering and ecological studies should be part of the program planning and design phase. Data are needed in specific areas to determine solutions that make sense locally. In the headwaters, for example, data are not available to show the extent to which land use and land management changes might mitigate a flood event.

Flood maps need to be updated and better flood modelling, monitoring, forecasting, and improved communication and warning systems are also needed. Evaluation of costs and benefits, along with social implications of proposed measures, need to be completed prior to moving forward. Economic analysis of potential engineered solutions should cover the full length of time that infrastructure or management practices might have an impact. Long term operating and maintenance costs can have considerable financial implications over a 50- to 100-year time span. As important is a thorough evaluation of the potential "side-effects" or unintended consequences over such long planning horizons.

Such information is the basis for determining risk, developing policy, and designing mitigation projects. Outside of the City of Calgary, there is limited hydraulic data. This makes it very difficult to specifically and locally assess the potential benefits (in terms of water level reduction) that might be realized by implementing the potential *Room for the River* measures identified in the individual river reaches.

This element will take some time to complete, but first requires a commitment to do it. Backed by sound science, the need for policy or legislation that, for example, stops or minimizes development in the floodplain, becomes clear and convincing, and policy development itself becomes more straightforward. Alberta-focused work would also enable the GoA to apply what has been learned elsewhere to our own unique circumstances.

The planning timeline should be extended, while recognizing that some actions can and should be implemented quickly.

The Dutch experience demonstrates how long it takes to raise awareness and change mindsets about flooding and mitigation, build social and political capital, and work through a thorough assessment of the hydraulic impact and true costs and benefits of potential mitigation options. As part of a solid and ongoing process, long-term (perhaps 25-50 years) watershed management plans should be developed that provide for periodic progress reports on mitigation activity. Progress reports could be done every five years perhaps with Watershed Planning and Advisory Councils (WPACs) and Watershed Stewardship Groups providing an appropriate venue for this type of engagement and activity.

Clearly it takes time to do the planning and analysis needed to establish a solid scientific and economic foundation for decisions that are likely to involve significant public funds over the long term. In the Netherlands, the program has been running for 14 years and began with a firm policy direction and budget commitment. This important work should not be rushed. Alberta cannot reasonably expect to distill three decades of Dutch experience, including redefining their risk levels, to “no regrets” or “quick wins.” It is reasonable and often necessary to develop long-term plans with many short-term objectives and actions built in. There is some urgency to act so that people do not become complacent and forget the importance of being prepared for the next flood event. Many effective mitigation options are known and can be implemented quickly (such as an agreement to modify upstream reservoir operations on the Bow River), while others, such as moving people and infrastructure out of the floodplain, will take longer.

It behooves Alberta to put appropriate policies and plans in place in a timely manner so when the next flood comes, a rapid and effective response will be possible. Contributors to the pilot were keen to see action on options that could be implemented in the next year.

An Alberta program needs to take into account land tenureship.

The suite of potential mitigation activities will vary dramatically across a basin, and land tenure may well influence what options are feasible and what can be implemented. Land tenure in the Bow River Basin includes Crown land, large tracts of First Nations land, private rural landholdings, provincial grazing leases, and urban centres. Other basins are likely to have a similar diversity of tenure and different approaches will be needed for each, ranging from voluntary incentive-based tools to mandatory government-led mitigation projects.

3.3.2 How the Process Might Move from Scan to Prioritize to Implement

Contributors were enthusiastic and offered many useful insights and comments about a potential process. They recognized that substantial effort has been exerted since the 2013 flood and that the evaluations and comments collected during consultations since the flood should inform any potential *Room for the River*-type program and process. The next steps will be critical to maintain momentum and advance the work.

An important aspect to long-term success of such a program in Alberta will be changing the way people think about living beside a river, both in terms of risk and responsibility**. Raising awareness and**

understanding about watershed functions and how flooding affects a community and individuals would be a good place to start, using materials developed specifically for the watershed.

Connection to other activities needs to be well navigated; for example, Bill 27 only deals with development in the floodway. The GoA needs to quickly provide guidance to municipalities to address continuing development and construction in the flood fringe so that municipalities can shift away from business-as-usual. It is relatively straightforward to impose land use controls in greenfield development but very complex in redevelopment where social, economic, and other functions are already in place. If further room is given to a river, what is flood fringe today can be floodway tomorrow. Our rivers are migratory. That is one of the essential elements that nature demands and an important characteristic that makes our rivers beautiful. Further, developing a consistent approach to setbacks throughout the watershed, regardless of jurisdiction, should perhaps be contemplated. A consistent approach for flood mitigation across jurisdictions throughout the watershed would need to work in concert with municipal programs and standards. More broadly, alignment between a *Room for the River*-type program and the flood mitigation objectives that exist in documents such as *Respecting Our Rivers* would need to be clearly established and communicated. Finally, Alberta is already committed to meeting other water management objectives that differ from the Dutch situation. The Bow River Basin is closed to new water licences, it supports an extensive irrigated food production industry, it contains many valued environmental and recreational resources including a world renowned sport fishery, and is not used for any appreciable commercial navigation. Any flood mitigation efforts should ensure that existing objectives continue to be met.

More broadly, **communication of knowledge, data, and other scientific findings between jurisdictions needs to improve**. These same jurisdictions also need to communicate and collaborate on watershed planning and emergency planning, which could be facilitated through an initial desk-top modelling simulation exercise and regular sessions every few years to ensure progress is made on weaknesses or failure points.

It was recognized that **selecting the scale of the study area is a challenge**. While there is a desire to have manageable river segments to consider measures for each reach, it is important to remember that the river is an integrated holistic system. This issue can be addressed by applying an integrated and open model to assess interdependencies within the entire river system from headwaters to confluence and beyond.

It was noted that evaluation of options must be comprehensive and take a triple bottom line approach that considers environmental, social, and economic impacts. The next phase – **prioritization of opportunities – must be systematic, based on facts and data, objective-driven, and transparent**.

Well defined and managed collaborative governance would be fundamental to the success of such a prioritization exercise. Given the many complexities and interdependencies within the water management system, **the roles, responsibilities, and decision-making authority of all involved parties** would need to be clearly defined and communicated. This would be especially important to the many municipalities whose residents are directly affected by the resulting decisions, as well as irrigation districts, livestock operations, and other water users.

Having been through a thorough prioritization process, the Dutch are now in a position of having **well-studied options available to them for implementation if and when the need arises**. This body of knowledge and options allows them to plan well ahead into the future as well as leverage windows of opportunity for implementation when the public will, political will, and budgets are available.

The program in the Netherlands has been and continues to be **supported by long-term funding and national level policy.** This has been fundamental to the program's ability to invest in the necessary research, education, and broad engagement, as well as take a leadership role in driving challenging social change. In Alberta, a continuing dialogue involving public, technical, and policy experts will be needed to further develop this approach, and financial implications should be clearly defined.

3.3.3 What Engagement Might be Appropriate

Many individuals and organizations should be engaged in any new Alberta program and its corresponding discussion. Municipalities and the GoA in particular need to work very closely together to identify and decide on appropriate mitigation strategies.

The importance of communication and raising awareness with the general public and flood-affected communities is recognized as a key driver in the success of the program in the Netherlands. Significant effort was put into creating their Volume 1 document that summarized the research and debate that went into the development of the very specific objectives for the program. This **early communication elevated the common understanding of flood dynamics**, creating the necessary platform for an informed and productive selection of specific mitigation measures.

Further public engagement, building on that done in 2013-14 in Alberta, could occur that lays out options with the latest engineering and cost-benefit analyses, then people could work through an **exercise to examine trade-offs within a specified budget**. This is similar to the Dutch process and could give people a better understanding of the trade-offs involved in flood mitigation and broader water management decisions. An Alberta tool similar to the Dutch Planning Kit is already partially developed: an interactive river balance model has been completed with several dozen mitigation options available for testing against flow rate, interdependencies of alternatives and, in some cases, estimated flood inundation extents. What remains to be completed is a more refined interface for the public along with more specific costs, operating parameters and hydraulic impacts for some of the options.

3.4 Lessons from the Pilot Project

This initial pilot was an excellent learning experience from both a planning and delivery perspective. If such a process were to be extended to other basins and over time, these lessons can provide valuable guidance.

Take the time to get the right people in the room for the technical working session.

Interest in this pilot project was high throughout the water community. The technical working group that provided input on November 14 already functioned very well at a high level. Representatives came from a diversity of organizations, bringing solid technical expertise and experience in water management issues. The facilitators spent considerable time in the initial stages meeting individually with key participants and influencers to explain the approach, expected outcomes, and scope of the pilot. This early communication effort was invaluable in securing the engagement of critical participants and in gathering material and insight to bring to the full working group for discussion.

Because many of the working group members already knew and had worked with each other, they had a high degree of trust and cooperation. This collaboration was critical to the pilot's success and the same core group should be used again for any further work on the Bow River Basin. Although there was comfort within the group, application of the Chatham House Rule[9] was a valuable addition to the process.

Early presentations to key municipal groups are vital.

Presentations in advance of the working session to key municipal groups such as the City of Calgary and the MD of Rocky View gave participants more detailed information and enabled them to come better prepared to the working group session. By also giving them a chance to ask questions and provide comments, the facilitators could clarify aspects of the pilot and refine materials if needed.

Establish different forums through which different participant types can provide input.

Beyond the technical working session, the project team worked with the WPAC – the Bow River Basin Council – to facilitate a separate opportunity to share the work to date and gather input from a broader, public group.

Invest in doing the preliminary work (interviews, literature searches, and other methods) to collect and circulate information prior to the technical working session to help contributors prepare.

This advance work creates a draft scan of what is already being done in the basin and where future options exist. With this provided in advance, contributors could focus at the working session and drill down into details and specifics as appropriate. It made more efficient use of time and enabled a much more productive discussion.

Clearly reference the relevant studies and decisions already made.

Extensive flood mitigation studies, workshops, and decisions have occurred since the June 2013 floods. The project team was diligent in bringing this foundational material into the pilot to ensure the project and the associated discussion built on and did not replicate previous work or revisit prior decisions. Communicating and managing this element took considerable effort, required constant attention, and will need careful management if this pilot is expanded to other river basins in the province.

Be consistent and clear on the scope of the work.

Such a project could potentially become very large and unwieldy. Deciding early on what is in and out of scope is essential to keep the work manageable and prevent discussions from getting off topic. Once those parameters are set, they should be consistently and clearly communicated in written work, presentations, and discussions with participants.

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[9] When a meeting, or part thereof, is held under the Chatham House Rule, participants are free to use the information received, but neither the identity nor the affiliation of the speaker(s), nor that of any other participant, may be revealed.

Provide a relevant and reasonable set of maps and data and ensure they are presented at a scale that is useful.

For a project like this, the volume of maps and data can be substantial and potentially overwhelming. It is important to take time in advance to select materials that are most useful and relevant. Slides should also be shown with appropriate audiovisual equipment to ensure they are legible.

Allow the program measures and approach to be flexible to the needs of each basin.

It was important to adapt the measures and language used in the Netherlands to reflect the nature and opportunities of the pilot study area. Interestingly, the measures that generated greatest discussion in this pilot (including retaining existing room for the river, building new upstream detention, removing obstacles, and local flood protection) were applied differently from those being implemented in the Netherlands (including relocation of dikes, depoldering, removing obstacles, and lowering the floodplain).

Make sure participants and others understand this was a *pilot* project. Much more work remains to be done within a much larger and more complex discussion.

This project was valuable and helped advance the thinking about flood mitigation on the main stems in the Bow River Basin, and it provides a sound basis for further actions, perhaps for more comparative analyses and longer term prioritization within these river segments. The pilot has also provided some good lessons for expanding the program to other river systems in Alberta. If further work is intended, a plan should be developed for how the program will be rolled out across the province and what resources will be dedicated.

The pilot provided a basis for decision making that has gone beyond mere consultation with potentially affected parties, into the realm of involvement and enabling water managers, participants, municipalities, and the water community to help set the agenda and develop practical mitigation actions, while understanding the implications that may flow from these actions.

Overall, contributors expressed strong support for the pilot and appreciated that it was tapping into the knowledge base resident in the basin. Input from the Dutch experts was appreciated and valued – both the experience they brought and as a challenging voice asking tough questions in the Bow River Basin. The GoA was urged to consider creating appropriate communications to share information with municipalities to let them know what is happening and how to provide input.

4. Closing Comments

Contributors to the pilot strongly urged that Alberta protect its wild rivers and the health of the province’s watersheds, that mitigation activities be grounded in respecting our rivers and their many values, and that the environmental, social, and economic trade-offs of the larger mitigation options be thoroughly understood. Adapting the *Room for the River* program and measures for Alberta offers a well-tested approach for driving productive, watershed-based assessment of mitigation, recognizing the differences in geography, hydrology, climate, geomorphology, and demographics between Alberta and the Netherlands. Any program that is developed and implemented here should take an integrated watershed management approach, dealing with flood and drought conditions, and using all available tools.

The initial scan of options was a useful starting point for the pilot and any subsequent program as it enabled a broad, systematic discussion of the pilot study area. It captured many different types of possible mitigation opportunities, emphasizing the importance of a system approach to flood mitigation as well as the need for thorough and data driven assessment to support prioritization. It helped the discussion move to identifying potential “no regrets” opportunities that could be advanced in the short term. Many lessons can be drawn from the program in the Netherlands on the nature of information, tools, engagement, and support needed to move successfully through this process.

Many mitigation options for the Bow River Basin main stems have been identified and are being implemented, but momentum needs to be maintained to advance work in other areas, particularly on specific projects and actions that are already known to be useful mitigation options. At the same time, work needs to continue on smaller projects and possible relocation opportunities, while ensuring efforts are made to protect riparian areas, fish habitat, and other natural features that are important to aquatic ecosystem health.

If a *Room for the River*-type program were to be developed in Alberta, the objectives, scope, and governance must be clearly defined and communicated. The program should have a name appropriate for the Alberta context. Objectives should be defined for safety and security, water supply, and water quality. It will be essential to raise individual and community awareness and understanding about watershed functions and the effects of flooding. And, perhaps most importantly, the program would need long term political, local, and financial support and accountability.

As noted earlier, this pilot garnered great interest from the water community in the Bow River Basin. Since the flooding in 2013, there has been an elevated level of awareness and discussion about water management in many parts of the province. The approach and purpose tested in this pilot offer a way to harness the public momentum and interest in water management, to build on the deep expertise and experience of those in the water community, and provide a long-term program for thoughtful and effective water management and flood mitigation throughout Alberta.

Acronyms

ATV	All-terrain vehicle
BAT	Best Available Technology
BMPs	Best Management Practices
ESRD	(Alberta) Environment and Sustainable Resources Development
GoA	Government of Alberta
MDP	Municipal Development Plan
RAM	Resilience and Mitigation (Branch, of ESRD)
RftR	Room for the River
SSRP	South Saskatchewan Regional Plan
SWCRR	Southwest Calgary Ring Road
WPAC	Watershed Planning and Advisory Council
WWTP	Wastewater Treatment Plant

Appendix A: Contributors to the *Room for the River* Pilot in the Bow River Basin

Many thanks to the following organizations who contributed their knowledge, time and expertise to the *Room for the River* Pilot in the Bow River Basin. In some cases, more than one representative from the organization was involved.

Alberta Agriculture and Rural Development
Alberta Environment and Sustainable Resource Development
    (Fisheries, Forecasting, Bow River Operations, Resilience and Mitigation, and Parks Branches)
Alberta Wilderness Association
Bow River Basin Council
Bow River Irrigation District
Calgary River Valleys
City of Calgary
Cochrane Environmental Action Committee
Cows and Fish: The Alberta Riparian Habitat Management Society
Ducks Unlimited Canada
Elbow Public Advisory Committee
Elbow River Watershed Partnership
Fisheries and Oceans Canada
Highwood Management Plan – Public Advisory Committee
Kananaskis Improvement District
Municipal District of Bighorn
Municipal District of Foothills
Rocky View County
Spray Lakes Sawmills
Town of High River
TransAlta
Trout Unlimited Canada
Western Irrigation District
Western Sky Land Trust

Alberta WaterSMART and Deltares contributed through their contracted roles as project facilitators and content experts.

Addendum

This addendum reflects the feedback received in response to the *Room for the River Pilot in the Bow River Basin – Advice to the Government of Alberta* report issued December 19, 2014. The *Room for the River* Pilot report was distributed online through the Alberta WaterPortal and the BRBC website and received further public attention from presentations, newspaper articles and radio interviews.

Public feedback on the report was welcomed until January 31, 2015. Feedback was received in writing through the Alberta WaterPortal, direct emails, verbally through one on one discussions and public meetings, and through publicity sources such as newspapers. This addendum summarizes the feedback received, without attribution, in bullet point form. The content found in this addendum does not necessarily reflect the views of other participants or the project team.

This addendum will be forwarded to the Government of Alberta (GoA) as advice as per the original *Room for the River Pilot in the Bow River Basin* objective. Furthermore, all feedback has been captured in its raw form and will also be submitted to the GoA. Content in this addendum has been ordered to reflect the organization of the original *Room for the River* report. Words in quotations reflect the language used by the responder. Feedback in its raw form will only be viewed by the authors of this report and the GoA.

1. Introduction

- In Table 1 “Flood Mitigation Approaches” it was suggested that the traditional wet reservoir approach should be added. It was suggested that because water supply and flows are seasonal the utility of storage to balance flows, maintain environmental objectives and prevent flooding make it a potential alternative. The water supply environmental aspects of the Bow system make wet storage more valuable than in the Dutch context.

1.2 Scope of the Pilot Project

- It was suggested that tributaries and headwaters should be included in the scope as this is where natural detention can be increased.
- It was noted that climate adaptability should have featured more prominently in the report.

1.3 Process and Approach

- It was recommended that the author look at communities in the Western United States and Canada with similar topography, climate, and regional economics as a basis for this study.
- It was suggested that it will likely be a combination of both structural and non-structural solutions that would lead to optimum flood protection with minimal costs.
- It was suggested that solutions that have a far reaching impact and that take years or decades to fully realize, refine and operate should be emphasized.
- It was noted that the report appears to be a collection of thoughts – not analyzed, prioritized nor summarized. Additionally, the report does not link well to some intercity issues on both Bow and Elbow rivers.
- It was suggested that it would be beneficial to have cost benefit analysis as well as hydraulic modelling done for all of the proposed Room for the River measures before the initial scan is issued to the public.
- It was noted that an overall analysis of the river should be conducted and that the river should not only be analysed in separate segments; analyzing segments is fine for local solutions but the effect of the overall situation should be considered. For example, raising the dikes in Redwood Meadows will help protect the community but will likely cause more erosion downstream. The degree to which upstream river segments affect downstream segments should be quantified.
- It was suggested that clear, specific objectives should be agreed on and communicated.
- It was recommended that any reference to First Nations lands or waters should be prefaced by direct consultation and meaningful discussion with the impacted populations.

2. *Room for the River* Management Approach

2.1 The Dutch Approach

- It was noted that in the Dutch context, even with more than a decade of program development, the program continues to re-assess and refined design targets – this indicated the importance of consultation, process, documentation, and decision making structures (governance) from the start.
- It was noted that there is potentially a need to elucidate the role of private, government required, or voluntary insurance in the Dutch context since insurance can significantly affect the cost-benefit profile of various mitigation options.

2.2 The Southern Alberta Context

- It was recommended that the report consider the multiple jurisdictions in Alberta who have decision making power over the river systems as compared to the Netherlands. In Alberta there are federal, provincial and municipal jurisdictions which overlap. Due to this jurisdictional overlap it was suggested that single family housing, which may fall within multiple jurisdictions, can be negatively impacted in favour of other infrastructure. It was suggested that too much emphasis is placed on the protection of areas such as the Stampede grounds, city owned revenue properties and critical infrastructure and new developments in relation to protection of single family housing.
- It was noted that the report refers to several City of Calgary documents such as guidelines, strategies, conceptual design studies, etc. These should be enforced consistently and should not act as a "distraction" from the significant steps necessary to mitigate, protect and make room for the river.
- It was suggested that the list of differences between the river systems in the Netherlands and Alberta, as seen in Table 4, indicates that using the proposed measures from the Netherlands would probably not apply to Alberta.
- A number of changes were suggested to Table 5 "Room for the River Measures in the Alberta Context":
    - Add the McLean Creek Dry Dam (MC1).
    - Move dredging from "last resort measures" into "conveyance".
    - The original wording of "detention and other measures" is too weak and that ATVs and associated facilities are not the only problem. It was suggested that more discussion is required regarding clearcut logging in the upper watershed, especially around the wetlands; it was noted that this should be stopped it in favour of more selective parch-cut approach.
- It was suggested that reinforcement of dikes and berms should not be characterized as "last resort". Dikes and berms should be built and / or reinforced wherever doing so is the best option. The term "last resort" has a pejorative connotation that is not appropriate for Alberta.
- It was noted that there is support surrounding the idea that a number of steps can be taken that together achieve the level of protection and risk tolerance appropriate for areas to be defended. Where possible, upstream steps should be preferred to downstream steps. The cumulative impact of these steps must be considered when assessing residual flood risk. Land protected by upstream dams and other watershed management techniques might not require a berm. Houses behind an adequate berm might not need any additional protection. Additionally, it must be noted that if the river overtops a berm designed for a 1:100 return period then houses with their own 1:100 protection will not be protected.
- It was suggested that it should be plainly indicated that storage of around 100 M cubic metres is needed on Elbow to attenuate a 1:100 flood to a 1:10 flood. About 6 times this volume is needed on the Bow. These are very large volumes and exceed the practical amounts of storage available from ad hoc log jams, wetlands, or floodplain lowering schemes.
- It was suggested that land use should be considered in the project scope and that more emphasis could have been placed on maintaining the pristine upper catchments and limiting land use changes that could increase risk. We should be looking at the whole landscape for flood mitigation, not just the river that receives its water from the landscape. For example:

  - If all motorized traffic was confined to trails designed to divert overland flow into vegetated areas rather than funnel it downstream;
  - If logging ground rules required much more canopy retention to shade the spring snowpack and prescribed lower re-stocking densities so that regrowth is spaced, rather than closed-canopy;
  - If beavers were protected from trapping or even supplemented by releasing problematic beavers from elsewhere;
  - If permanent roads were built with bridges designed to function as small "dry dams" rather than with culverts that blow out in high water – then water would drain much more slowly to the larger rivers.

3. Advice to Government of Alberta from the *Room for the River* Pilot in the Bow River Basin

3.1 Initial Scan of the Bow and Elbow River Pilot Study Areas

3.1.1 Bow River Segment 1

Suggestions regarding Table 6 "Initial Scan of *Room for the River* Opportunities for Bow River – Segment 1":

- It was suggested that Cranston should not be referenced as a good example for water storage (stormwater detention). Many people associate it with development that is too close to the river.
- There were many suggestions that development in the East Village and construction of the new Calgary Public Library should be stopped.
- It was questioned why the East Village and other downtown infrastructure was not listed as potential obstacles to be moved.
- There was concern expressed regarding references in the Room for the River report related to raising floodplain lands before redevelopment in the East Village and Inglewood. It was noted that this appears to be inconsistent with the Room for the River approach.
- Additional points were suggested under "other measures":
  - Flood awareness campaigns / public education.
  - Expanded or enhanced emergency response capacity.
  - Flood proofing and hardening of critical infrastructure.
  - Groundwater protection policy, mapping and / or infrastructure.

3.1.2 Bow River Segment 2

Suggestions regarding Table 7 "Initial Scan of *Room for the River* Opportunities for Bow River – Segment 2":

- It was suggested that the statement "Minimize stormwater infrastructure in the floodplain" that appeared in the original Room for the River Pilot report is inappropriate for Sunnyside, where a significant cause of the flooding was due to inadequate stormwater infrastructure.
- It was recommended that engineering and feasibility studies should be conducted to determine whether certain components of existing storm sewer systems can be re-routed to non-flood plain areas.
- There was some support for buyouts in Bowness.

- It was suggested that other measures should include groundwater protection policy, mapping and / or infrastructure.

3.1.3 Bow River Segment 3

Suggestions regarding Table 8 “Initial Scan of *Room for the River* Opportunities for Bow River – Segment 3”:

- It was suggested that other measures should include groundwater protection policy, mapping and / or infrastructure.

3.1.4 Bow River Segment 4

Suggestions regarding Table 9 “Initial Scan of *Room for the River* Opportunities for Bow River – Segment 4”:

- It was proposed that in order to ensure the long-term sustainability of reservoirs along the Bow River system, sedimentation must be measured and addressed in a transparent and accountable manner. Data, results and the interpretation from the bathymetric study on the Ghost Reservoir must be publicly available. The operations of not only the Ghost reservoir, but all TransAlta reservoirs, must be re-considered in a different light. TransAlta should be required to submit bathymetric studies and maps to the Alberta Government on a regular basis and such information should be made publicly available.
- It was suggested that a natural way by which sediment infilling in the Ghost Reservoir can be reduced is to ensure that land-use in the Ghost River Watershed does not exacerbate soil erosion and run-off. A balance must be found between resource extraction, land-use, and protection of forest ecosystems not only in the Ghost River watershed, but all the upper watersheds of the Eastern Slopes.
- It was noted that if the Provincial government intends to take steps towards enhancing natural river and watershed functions for flood mitigation then the recommendations in the Room for the River Report for the Bow River Segment 4 should be followed. These recommendations outline long-term sustainable measures to enhance resiliency during flood and drought periods.
- It was suggested that other measures should include groundwater protection policy, mapping and / or infrastructure.

3.1.5 Elbow River Segment 1

Suggestions regarding Table 10 “Initial Scan of *Room for the River* Opportunities for Elbow River – Segment 1”:

- It was suggested that a moratorium be implemented on all development on the river banks that will reduce the room for the river until a master plan for flood protection is in place and the potential impact of additional development is understood.
- It was suggested that the river should be channelled in areas such as 4th Street and downtown instead of berming.
- There were many concerns expressed regarding the suggestion of further buyouts.
- Strategic buyouts were recommended in order to make room for the river in an effective manner following a transparent strategy. There should be a restriction on future development if the purchase is consistent with a plan to make the remaining community safer.

- There was support for buyouts in Roxboro and Elbow Park.
- It was recommended to stop berming the Stampede grounds and to not raise these lands.
- It was suggested that the river should be dredged to increase conveyance.
- A respondent noted that in the Room for the River report deepening river channels did not get much comment. It was suggested that in the Elbow Segment 1, it would seem that deepening the river channel combined with berming could have a material impact on flood mitigation in Calgary communities.
- It was noted that "Relocation of current or planned barriers" should only be done only if the new barriers are a viable option considering all affected parties.
- Clarification was requested regarding "Self-insuring new homes at flood risk".
- It was noted that in the Room for the River report dredging the Glenmore Reservoir is referenced as having "great expense" and was dismissed. Regarding this concept, questions were raised about the expense and how it compares to other alternatives. Respondents felt that more definition of the cost and impact should be available before dismissing dredging the Glenmore Reservoir.
- It is recommended that dredging the Glenmore Reservoir should be considered and studied further by an independent firm.
- It was noted that in other jurisdictions the reservoir intake has been lowered, albeit due to drought, this could be a future consideration by the City of Calgary. Further study on this option, together with the changes at the top of the dam, should be considered to determine the maximum protection the Glenmore reservoir can offer in the event of a flood.
- It was noted that other measures should include groundwater protection policy, mapping and / or infrastructure.
- It was questioned why the community of Mission was not listed as potential obstacles to be moved.

3.1.6 Elbow River Segment 2

Suggestions regarding Table 11 "Initial Scan of *Room for the River* Opportunities for Elbow River – Segment 2":

- It was noted that Table 11 addresses some low volume storage options, such as Millbrook Creek and wetlands, however Figure 2 "Illustrative Relative Volumes – Bow River Basin Reservoirs and 2013 Flood Event" suggests these are unlikely to have appreciable impact. These projects are still likely to have habitat and water supply benefits however flood benefits may be insignificant.

3.1.7 Elbow River Segment 3

Suggestions regarding Table 12 "Initial Scan of *Room for the River* Opportunities for Elbow River – Segment 3":

- There were many concerns regarding the option to "Encourage the removal of Redwood Meadows and the berm instead of lease renewal (very preliminary concept)" on page 31 in the Room for the River report. It was noted that the Redwood berm protects not only the community but also highway 22 and the high-pressure gas pipeline that runs along the right-of-way on the west side of the highway. It was also noted that if the option to remove

Redwood Meadows is to remain on the list other communities along the river should also be suggested for removal.

- It was proposed that a sensible and cost-effective mitigation measure is to invest in additional improvements to the berm along the Redwood Meadows community as well as to the north and south of the existing infrastructure. To do so, the province also needs to coordinate with the federal government to remove some of the roadblocks encountered during the planning for the north berm re-construction in the spring of 2014.
- A responder noted the original report incorrectly stated that the community of Redwood Meadows suffered from flood damage in 2013. In fact, the damage to Redwood Meadows was limited to severe erosion of the flood containment berm while the community itself only suffered from rising groundwater levels. Recent upgrades to the berm were designed to protect the community from the river flow rates experienced in 2013.
- It was suggested that there are two potential options in Bragg Creek in the flood plain:
    - One is to do nothing and have people flood proof their homes and businesses and help them pay for it. In essence this will make the entire flood plan available for the river.
    - A second choice is to channelize the river between dykes on either side of the river. Some properties would still have to be expropriated to provide the land for the dykes. Although this seems like a clear choice the design of this dyke system must force all the water in the river at peak flows into a very narrow space. The water will be moving at high velocity and it will not have the room it had in 2013. However, channelizing the river between two dykes presents a number of challenges including catastrophic breach of the dyke and non-river water trapped behind the dykes. There seems to be political and popular support for damming the Elbow River at McLean Creek. The respondent was not confident that such a dam can be 100% guaranteed to not unleash a flood through the Hamlet.

  The respondent did not feel that the Room for the River approach offered a solution for Bragg Creek and felt the time used to study the issue could be used to move forward with solutions, mainly dyking.
- There was support for buyouts in Bragg Creek.

Comments referring to multiple segments

McLean Dam (MC1) and Springbank Diversion (SR1)

- It was noted by many respondents that the Dutch Room for the River the approach makes reference to the consequence of infrastructure failure and thus does not recommend large infrastructure solutions.
- Respondents commented that both MC1 and SR1 are large infrastructure solutions and that smaller more ecological based solutions may be favourable wherever possible.
- Many respondents noted that engineered structures such as dams and dykes should be considered temporary and potentially dangerous measures of flood defence.
- There were many requests for immediate release of the cost-benefit analyses for large flood projects as well as preliminary environmental analyses for MC1 and SR1 before final decisions are made regarding whether to proceed with these projects.

- There was agreement expressed with the statement “Compensation for SR1 may need to address many affected parties, not only the directly affected landowners” on page 33 in the Room for the River report.
- There was a perception among some respondents that the current approach of comparing large infrastructures costs of SR1 versus MC1 is misleading. Full cost comparison (financial, environmental, social and community) should be a core principle of a Room for the River approach in Alberta.
- One respondent perceived that the following costs are missing from the SR1 costs:
    - The money already spent for flood protection upgrades to Redwood Meadows;
    - The money already spent for flood repair to Bragg Creek, and for resident compensation;
    - The upcoming, approved , money to be spent for berm construction at the Tsuu Tina golf course adjacent to Redwood Meadows, and
    - The cost of private land acquisition.
- It was noted that the Room for the River report does not explore the risk and consequences of catastrophic failure of infrastructure for projects such as SR1 and MC1. It is recommended that significant infrastructure projects should be required to outline the catastrophic failure scenario and the available mitigation possibilities.
- It is recommended that infrastructure should be designed, built and operated to be reliable.
- It was recommended that those who benefit directly from the SR1 should pay an annual premium for the protection provided to them by SR1.
- Respondents opposed to SR1 stated the following concerns:
    - Risk of catastrophic failure;
    - Ecological damage;
    - Cost;
    - Negative impact to the community of Springbank due to degradation of ranch and farm land;
    - Flood concerns to upstream communities of Redwood Meadows and Bragg Creek are not addressed, and
    - Risk to drinking water quality degradation and well contamination.
- Respondents in favour of SR1 offered the following reasons:
    - Passes though already disturbed areas, and
    - Grazing could still occur in most years in the diversion area.
- Respondents opposed to MC1 stated the following concerns:
    - Risk of catastrophic failure;
    - Ecological damage – both upstream and downstream, and
    - Cost.
- Respondents in favour of MC1 offered the following reasons:
    - No land costs, therefore it should be less costly than the Springbank diversion;
    - Protection will be offered to Redwood Meadows and Bragg Creek as well as the City of Calgary;
    - Potential for recreation, and
    - It is situated up in the foothills area and there is room to install measures to safeguard against failure.

- One respondent noted that the Province of Alberta needs to explore alternatives which use natural ecological functions and create more biodiversity and habitat rather than destroy it as the Elbow McLean Creek Dam proposal would.
- It was suggested that consideration should be given to constructing smaller versions of both SR1 and MC1; a respondent felt there is an advantage in having two water control projects as a way of mitigating the effects of "catastrophic failure" at one of these sites.

Buyouts

- It was noted that the incorporation of cost benefit analysis in determining buyout versus mitigation was always intended to be part of a rational risk management approach on floodplains but does not seem to have been implemented.
- It was suggested that commercial buyouts as well as residential buyouts should be considered in Calgary.
- Successful buyouts were cited as being a very important step moving forward. It was noted that the most important part of the report is the discussion / mention of a continuing relocation and buyout program. Not only should this be left in the report, but it needs to be emphasized.
- Some successful buyout programs were mentioned including: Mississippi in 1993, Grand Forks, North Dakota in 1997, Baker County, Georgia in 1994, Iowa, Charlotte Mecklenburg, Shepherdsville, Kentucky in 1998, and the US Federal Emergency Management Agency (FEMA). It was noted that the analysis of Shepherdsville's buyout project shows an average return on investment to be 245 percent; meaning that an estimated savings of $2.45 in property damages for each dollar invested has been realized since the project's implementation.
- Many respondents opposed the suggestion in the Room for the River report that future buyouts of properties in the flood way or flood plain merit further consideration. Respondents noted that the flood of 2013 damaged most of the homes in Rideau, Roxboro, Erlton, East Elbow Park, Riverdale and many homes in Elbow Park proper. The flood did not stop at the edge of the flood fringe. So a buyout plan limited to the flood way or flood fringe would still leave huge sections of these communities under water.
- It was suggested that what would be fair to homeowners in the case of buyouts would be to include grandfathering and / or exemption clauses for properties that were developed prior to the 2013 flood; while regulating that future development is approached with flood mitigation in mind should approval be given.
- Many respondents expressed dissatisfaction with the 2013/14 buyout program and unease that future buyout programs will follow the same trend.

Other

- It was recommended that if the revision of flood danger mapping for the worst case scenario has not been properly completed it should be completed immediately.
- It was recommended that consideration should be given to restrictions on municipalities to ensure they do not reduce the room for the river, increasing risk, liability and cost to both the government and individuals in existing developments. Areas that were specifically noted to restrict or stop development:
    - The East Village which will narrow the channel for the Bow;

    - Major development and roads in the West Village narrowing the channel and directing water elsewhere;
    - High rise developments downtown; and
    - Development aimed to harden the north river bank of the Elbow.
- It was suggested that the present negotiations with respect to monitoring, operation and control of the Ghost Reservoir should be expanded to all reservoirs and river basins in Alberta.
- It was recommended that engineering studies should be conducted to improve reservoir and river capacities to prevent undesirable flooding.
- It was noted, with gratitude, that the report and the Netherlands did not adopt rescue as an option for managing flood risk. If a strategy fails people certainly need to be rescued but rescue cannot be the primary plan.
- It was noted that if berming is the only protection available in the short term and if the City berms to protect its interests we must have a corresponding right to berm and the support of municipal, provincial and federal resources to do so. To date, the City of Calgary has prevented communities from collaborating to construct effective protective berms.
- It was noted that Room for the River will require changes to the Municipal Government Act (MGA) and the functioning of the Municipal Government Board (MGB). At this time, municipal governments do not have the final authority to prohibit not only riparian development, which they consider unsafe or inappropriate, but also developments affecting wetlands and other key environmental attributes.
- It was suggested that by managing stormwater, protecting wetlands and healthy forests in the headwaters, and maximizing the width and effectiveness of the floodplain, the need for major infrastructure projects can be evaluated as one of the many tools outlined in Room for the River to mitigate flood, not as the only solution.
- There was support for the idea that riparian and wetland areas must be central to the strategy while working towards removing vulnerable infrastructure from flood prone areas.
- It was suggested that special policy areas should be considered in the policy discussion surrounding floodway development regulations. Special policy areas would exist within flood hazard areas, however regulation would take into account upstream and / or local mitigation. As such, regulations may be favourable to homeowners within the area. Such an approach would demonstrate to homeowners that the Provincial Government puts the priority of sustainable communities through the protection of people and property at the forefront, versus an approach that stifles community growth.
- It was suggested that timber harvesting should be decreased. The Room for the River report does not specifically discuss the risks currently posed by the presence of industrialized logging in our upper watersheds. A healthy forest ecosystem — which includes wetlands — provides a natural defense against flood and drought periods. Yet timber harvest in our Eastern slopes is allowed to proceed at rapid pace, even though the clearcut methods used can result in compromised wetlands, increased stream flows and peak instantaneous discharge, exacerbated soil erosion, and enhanced sediment loading of our rivers and reservoirs.

3.2 “No regrets” Opportunities

- It was noted that a comprehensive review of the watershed is welcome as long as it proceeds in a way that does not unduly delay the implementation of truly “no regrets” projects.
- It was suggested that the term “no regrets” be replaced by more suitable language. All the flood mitigation options involve making investments and tradeoffs. There are few that can be truly characterized as “no regrets”.

3.2.1 Possible “No regrets” Opportunities: Policies and Decisions

Suggestions regarding Table 14 “Possible “No regrets” Opportunities: Policies and Decisions”:

- There was support for statement 2 “Document damage to infrastructure to retain institutional memory on flood impacts to inform future building and mitigation” – it was suggested that the passage of time or the current financial pressures on all levels of government elevate the risk of ignoring upstream mitigation.
- The wording of statement 3 “Strengthen and enforce policy and regulation to halt or minimize new development in floodplains” was perceived to be much too weak, it was suggested that it should be replaced with “…to rigorously limit inappropriate…”.
- It was suggested that statement 3 makes sense if applied only to land that will not be defended, but it should not be used to prevent the renewal of existing communities that will be defended.
- It was suggested that statement 9 “Strengthen and enforce land use BMPs to maintain the flow regulation and retention in the catchment” should have a specific action and language that is more precise.

3.2.2 Possible “No regrets” Opportunities: Specific Projects and Actions

Suggestions regarding Table 15 “Possible “No regrets” Opportunities: Specific Projects and Actions”:

- Regarding statement 5 on page 39 of the Room for the River Report “Revisit buyouts to secure properties that could make room for the river: past applications (e.g., Bragg Creek) and future market purchases (e.g., like Calgary Stampede did)” it was suggested that clarification is needed regarding what is meant by “Develop a long-range purchase program budget and process that enables buyouts whenever flood zone residential properties come on the market to gradually make more room for the river in high hazard areas.”
- In relation to statement 4 – “Increase emphasis on avoidance of wetland loss and encourage wetland restoration in targeted areas” – it was suggested that any land use which puts existing wetlands in jeopardy must be reconsidered in light of the 2013 flood. At present, Alberta protects wetlands in the White Zone, but no mechanism exists to protect wetlands in the Green Zone. Wetlands in the Green Zone are “in trouble” due to unregulated recreation and industrialized forestry.

3.3 Suggestions on a Potential Broader Program, Process, and Engagement

3.3.1 How a *Room for the River*-type Program Might Look in Alberta

- It was suggested that a Root Cause Analysis (RCA) should be conducted into the June 2013 flooding in Alberta.

- It was recommended that the June 19 to 22, 2013 rain storm should be clearly defined as a “cold low” long intensity rainstorm and not a flash flood.
- It was recommended that a proper design criteria review should be conducted to determine the appropriate return rate and risk tolerance – the current 1:100 level of protection is too low. The following additional comments regarding return period were noted:
    - The Dutch service level of 1:1250 year return is very high – it is unlikely to be economically achievable in the Bow Basin.
    - In the Alberta or Bow contexts it may not be possible to achieve uniform service level at reasonable costs, based on the configuration of the catchments and existing systems within them.
    - A 1 in 250 return period is appropriate to determine flood hazard areas and account for some of the uncertainties, and that the use of 1 in 500 is appropriate for evaluating risk to critical infrastructure like water and wastewater plants with associated intakes and outfall.
- It was recommended that the Dutch model, which favours a multi-layered approach to flood mitigation as opposed to a single large scale solution, should be followed.
- It was noted that the report discusses long-term political financial support as well as accountability. Perhaps it could suggest a governance structure, or at least identify the governance structure utilized in the Dutch context to ensure delivery of the room for the river program.
- It was suggested that an in-depth study of the Sheep River, Three Point Creek and Okotoks river system should be conducted to understand why Okotoks did not flood.
- On page 43 the report indicates that an Alberta program needs to take into account land tenureship; some reviewers were in agreement with this.

3.3.2 How the Process Might Move from Scan to Prioritize to Implement

- It was noted that there is support for a continued process of engagement in a longer process of planning and educating to favour a Room for the River approach.
- It was noted that there are multiple references to environmental impacts, but social or community impacts do not seem receive the same attention. It was suggested that the Room for the River approach should have some basic tenet that pushes the consideration of social and community impacts as critical components of the approach. Projects that benefit more citizens should get preference over ones where fewer citizens benefit.
- It was suggested that methodology to evaluate riparian ecosystem function is required in order to be able to compare these functions with flood mitigation objectives and benefits.
- It was suggested that land should be identified as “to be defended” versus “may be flooded”.
- It was suggested that a study of groundwater impacts should be carried out, especially in complex areas like Sunnyside, where hill runoff, high river levels, rainfall and sewer back-up all interact.
- It was recommended that a hydraulic flood model should be developed; most effective strategies can only be identified after hydrological modelling has identified specific choke points.
- It was suggested that cost benefit analysis should be incorporated in determining what properties are bought out versus which properties are mitigated.

- It was asked that the GoA recognizes that engineering structures such as dams and dykes are, at best, temporary and potentially very dangerous measures to deal with floods.

3.3.3 What Engagement Might be Appropriate

- It was demanded that the community and stakeholders should be involved in projects such as the Room for the River program. This should include landowners, ranchers, and First Nations who have lived on this land for centuries and have a wealth of knowledge of the river.
- It was noted that the report could more strongly stress the need for excellent technical resources, hydraulic models, maps, scientific studies, risk evaluation tools and state of the art translation of these into visual and teaching tools to engage meaningful public and stakeholder engagement.
- It was noted that the Dutch had the advantage of an already somewhat confined river and social licence to improve the situation through working along and in the river / flood plain somewhat in a "no matter what the costs" (social, environmental and economical) manner, notwithstanding their significant efforts in education and consultation. No matter what the government position in Alberta, there will be no agreement among the many stakeholders, that our government should tackle the issue in same fashion as the Dutch. There are groups who will oppose any efforts to confine or direct river flow given their understanding of the river and its "value"; a contrast to other groups who represent and fear the economic impacts of urban river flooding. These agendas and opinions will not, and have not, changed quickly. The best option is to slowly move people out of the flood plains through provincial and municipal legislation.

4. Closing Comments

- It was recommended that the conclusion should emphasize that a long, thorough, engagement-rich process and governance or decision making structure will be critical to ensuring the social and political capital to realize a program.
- Disappointment was expressed regarding the report to the extent that it gives credence to old behaviours that will continue to contribute to flooding, the cost of which is borne by individuals. We recommend significant changes to the Municipal Government Act to require Environmental Impact Assessments and accountability for increasing the risk to existing communities.
- It was noted that more policy without recognition that mitigation needs to be implemented (Springbank off-stream reservoir) does not make any logical sense and "screams" of lack of forethought.
- It was recommended that the government should proceed with the ecologically-based ideas in the Room for the River Bow-Elbow program. These recommendations emphasize restoring natural flood and drought buffering wetlands and river-side vegetation, strategically moving back vulnerable buildings and other infrastructure from rivers, and avoiding reliance on berming river edges and on costly dams subject to catastrophic failure.
- It was noted that the GoA is encouraged to continue with this process for the entire watershed; undertake advice from the Room for the River Pilot project; and to develop a funding mechanism that provides steady and adequate resources for those organisations with mandates that align with and support the report's advice.

- It was recommended that the Room for the River Bow-Elbow Pilot project idea should be supported, including expanded buyouts of properties in high hazard areas. The pilot will help make more room in the flood plain to disperse flood waters in lower density areas, restore flood and drought resilient wetlands and river-side vegetation, and minimize reliance on ecologically harmful river berms and dams.
- It was noted that some respondents do not support the Room for the River model.
- It was noted that this pilot will help make more room in the flood plain to disperse flood waters in lower density areas, restore flood and drought resilient wetlands and river-side vegetation, and minimize reliance on ecologically harmful river berms and dams.
- It was noted that in the Netherlands they have been working on Room for the River for many years, and on flood mitigation in general for hundreds of years before that. As Albertans we should take the time to study all the options before us and consider the impacts on people and the environment before going ahead with huge projects that may or may not prove to be suitable in Alberta.

Flood Mitigation Options Assessment Summary

A City of Calgary Summary

Full report prepared by IBI Group and Golder Associates

December 15, 2017

Introduction

Calgary was built at the confluence of two mountain rivers, making it vulnerable to river flooding. The downtown economic core, the beltline areas and other communities are at risk of being flooded by the Bow and Elbow rivers every year. These vital areas include government buildings, social and health services, historic communities, commercial and industrial areas, major tourist attractions and recreation facilities (Figure 1).

The 2013 floods in Southern Alberta were one of Canada's most costly natural disasters, resulting in loss of life as well as significant property damage, personal impact and social and economic disruption. The 2013 flood event emphasized the need to address flood risk in Calgary, protect public safety and reduce future social, environmental, and economic flood damages to our city. This imperative drove the recommendation for The City to gain a better understanding of Calgary's flood risk and the changing dynamics of the floodplain, and develop evidence-based strategies to reduce flood risk.

The Flood Mitigations Options Assessment, completed for The City by IBI Group and Golder Associates Ltd. in 2017, is an important step towards achieving these goals. The study undertook four key steps:

1. Develop a detailed computer model to calculate the risk of flood damages within the city (Damage Model).
2. Assess the risk of flood damages under a number of scenarios with potential mitigation options in place (Scenario Analysis).
3. Compare mitigation scenarios using a framework that considers cost, benefit and social-environmental sustainability (Sustainability Assessment).
4. Provide recommendations for reducing potential river flood damages though structural and non-structural measures (Recommendations).

The purpose of this document is to provide an overview of key findings from the study.

"Flood Mitigation remains a top priority for The City of Calgary."
(Utilities and Corporate ServicesCommittee, April 2017)

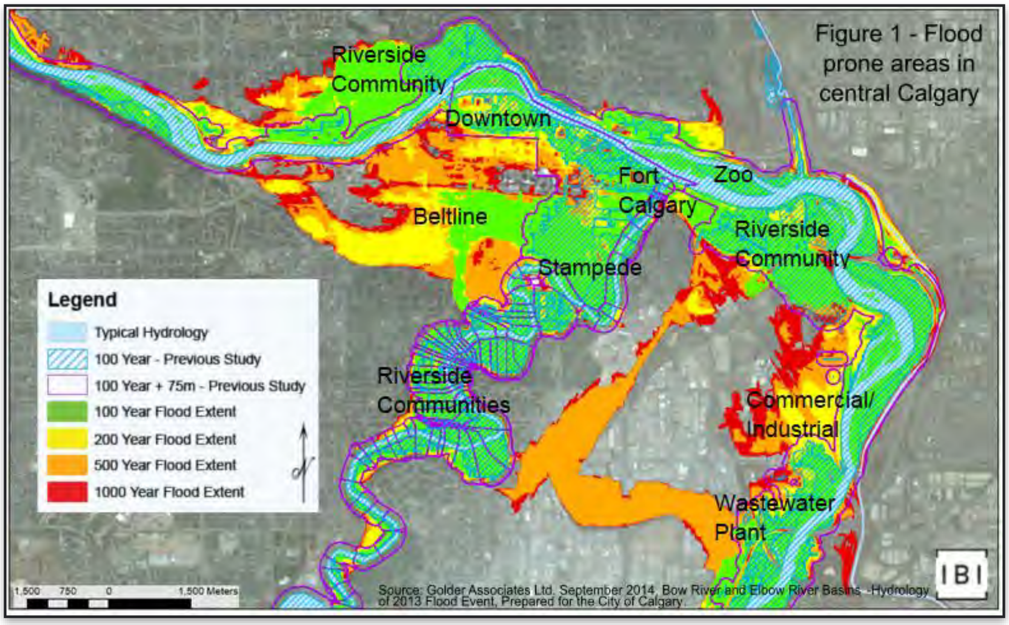


Figure 1 - Flood prone areas in central Calgary

Source: Golder Associates Ltd. September 2014. Bow River and Elbow River Basins -Hydrology of 2013 Flood Event, Prepared for the City of Calgary.

The Flood Damage Model

Understanding the impacts of flooding is a crucial part of mitigating against the hazard. One way to understand the impacts is to create a flood damage model. In general, a flood damage model calculates the depth of flood water at every property for various sized flood events. It then calculates the estimated damage based on the flood depth, current land use and infrastructure on that property. Where possible, The City's model also calculates a financial value for environmental and social impacts of flooding, which provides a more holistic evaluation of flood impacts.

The City's flood damage model is an updated version of a model previously created by IBI Group and Golder Associates for the Province of Alberta (AEP, 2014). The area considered in this study (Figure 2) encompasses all of the flood prone areas within the city limits on the Bow and Elbow Rivers, up to a 1:1000 year flood.

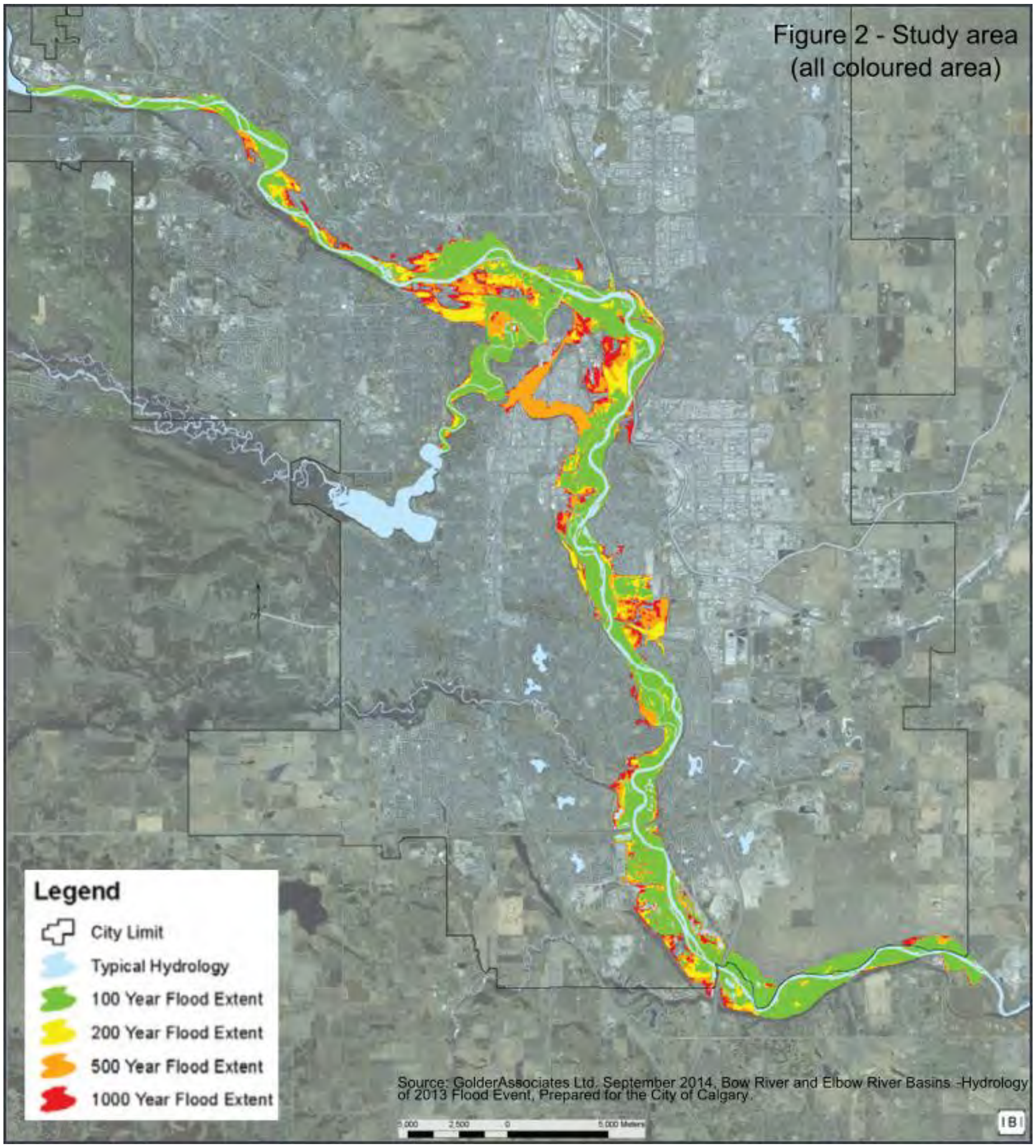


Figure 2 - Study area (all coloured area)

Source: GolderAssociates Ltd. September 2014, Bow River and Elbow River Basins -Hydrology of 2013 Flood Event, Prepared for the City of Calgary.

A 1:100 year flood has a 1% chance of occurring in a given year, and a flow rate of 2820 m^3/s on the Bow River downstream of the Elbow confluence.

A 1:200 year flood has a 0.5% chance of occurring in a given year, and a flow rate of 3520 m^3/s on the Bow River downstream of the Elbow confluence.

A 1:500 year flood has a 0.25% chance of occurring in a given year, and a flow rate of 4600 m^3/s on the Bow River downstream of the Elbow confluence.

A 1:1000 year flood has a 0.1% chance of occurring in a given year, and a flow rate of 5600 m^3/s on the Bow River downstream of the Elbow confluence.

Scenario Analysis

The study used the flood damage model to assess the flood risk in Calgary with and without mitigation. Without mitigation measures, such as those put in place since 2013, the average cost of flooding in Calgary would be nearly $170 Million per year. This value is the cost of damages from all floods that could happen (large and small), averaged out as annual payments. This amount is called the “average annual damages” (AAD).

With the existing mitigation in Calgary, including the projects currently under construction in 2017 (e.g., the flood barrier in West Eau Claire/downtown and upgraded gates on Glenmore Dam), the average annual damages have been reduced by 30% to $115 Million per year. This significant reduction in flood risk has been a notable achievement for our city, with support from citizens and The Province.

The remaining risk of $115 Million per year is still high. The study also explored a number of mitigation scenarios to further reduce potential flood damages. Each scenario is a plausible combination of options that can prevent flooding in communities, or remove buildings and people from harm’s way. The process for selecting mitigation scenarios for consideration involved an initial screening of options, taking into account local feasibility, functional reliability, financial efficiency, and environmental and social impact.

The resulting options considered for mitigation scenarios included:

- Watershed-level structural flood mitigation measures – new reservoirs and refined operations of existing reservoirs upstream of Calgary on the Bow and Elbow Rivers.
- Community-level structural mitigation – new flood barriers within Calgary, and
- Property-level and land use policy-based mitigation measures.

The results of this analysis include calculation of a cost-benefit ratio for each scenario, and the “residual” average annual damages that large floods could still cause, even with the proposed mitigation measures in place. The following table shows the results of the analysis. A full description of each of scenario is provided in the full report.

The technical information used for each measure, such as size, location and conceptual cost, was based on other technical studies, such as The City’s Permanent Flood Barrier Protection Assessment (2017), and The Province’s Bow River Working Group (report submitted in 2017), of which The City has been an active member. A protection level to the 1:200 year flood (which has a 0.5% chance of occuring in any year) was selected for the assessment, to evaluate the feasibility of protecting beyond the current provincial standard and to address future climate uncertainty.

The City’s ongoing improvements to forecasting and emergency response were included in all scenarios.

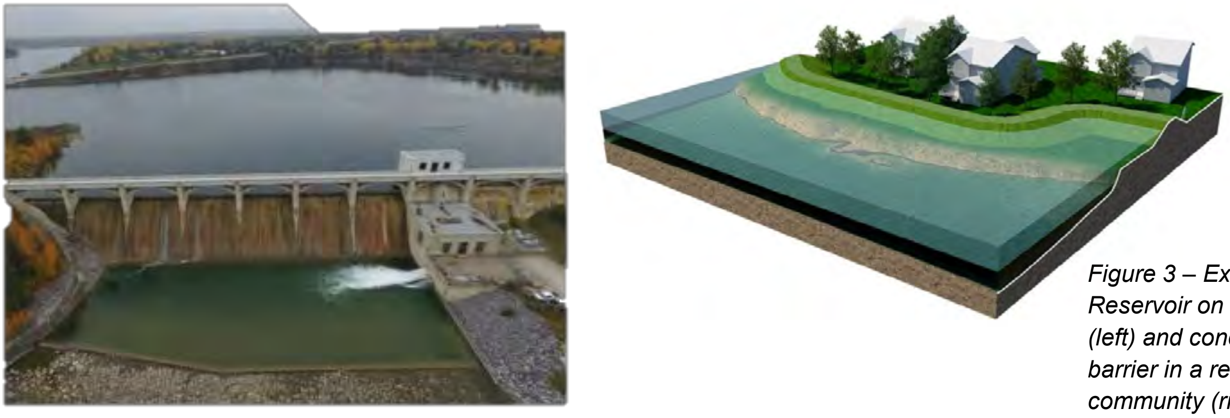


Figure 3 – Existing Glenmore Reservoir on the Elbow River (left) and conceptual flood barrier in a residential community (right).

Summary of Scenario Analysis

All scenarios include the flood protection provided by:

- Glenmore Dam, including the upgraded gates.
- TransAlta agreement with The Province to operate reservoirs in the Bow River system for flood mitigation.
- Existing and under-design barriers as of 2016 (e.g., Stampede, Zoo, West Eau Claire, Heritage Drive & Glendeer Circle, Centre Street Bridge, Bonnybrook, Deane House).
- Existing stormwater outfall gates and stormwater management plans.
- Existing flood forecasting and emergency response plans (including temporary flood barriers).

Scenario	**Capital Cost**	**Benefit-Cost Ratio***	**Residual Average Annual Damages (AAD) – per year**
Existing (Baseline) – does not include the TransAlta operational agreement	N/A	N/A	$115 million
1**) Springbank Off-Stream Reservoir** (SR1) on the Elbow River	$510 million	3.22	$45.2 million
2) **Springbank Off-Stream Reservoir** (SR1) on the Elbow River and a new **reservoir on the Bow River**	$1.41 billion	1.35	$31.8 million
3) **Elbow River barriers** below the Glenmore Dam and a **Bow River reservoir**. Total length of the barriers is estimated at 14.6 km.	$1.80 billion	1.06	$44.7 million
3a) **Scenario 3 plus groundwater controls** included with the barriers.	$1.96 billion	1.08	$38.2 million
4) **Springbank Off-Stream Reservoir** (SR1) **and Bow River barriers** (no upstream reservoir on the Bow). Total length of the barriers is estimated at 30 km.	$900 million	2.53	$34.6 million
4a) **Scenario 4 plus groundwater controls** included with the barriers.	$1.13 billion	2.09	$28.8 million
5) **Elbow River barriers** below the Glenmore Dam and **Bow River barriers** (no upstream reservoirs). Total length of barriers is estimated at 44 km.	$1.32 billion	1.69	$45.6 million
5a) **Scenario 5 plus groundwater controls** for barriers.	$1.75 billion	1.55	$31.9 million
6) **Buyouts** of all residential properties in the 1:200 year floodway (980 properties)	$1.81 billion	0.47	$88.8 million
7) **Upstream reservoirs on the Bow and Elbow Rivers with 1:25 barriers** for Downtown, Sunnyside and Bowness on the Bow River. Total length of the barriers is estimated at 4.5 km.	$1.45 billion	1.33	$31.5 million
7a) **Scenario 7 without reservoir on the Bow.**	$547 million	3.07	$43 million

Scenario	**Capital Cost**	**Benefit-Cost Ratio***	**Residual Average Annual Damages (AAD) – per year**
8) **Scenario 7 plus groundwater control** for Sunnyside and a 1:200 level barrier for the downtown core.	$1.47 billion	1.32	$31 million
8a) **Scenario 8 without upstream reservoir on the Bow.**	$569 million	3.02	$43 million
9) **Scenario 8a with higher barriers** (1:100 for Bowness/Sunnyside and 1:200 for Inglewood/Downtown).	$658 million	2.84	$38.6 million

**Note: The benefit-cost ratio does not reflect the benefit/cost of individual measures, but of all the measures included in the scenario working together. The benefit-cost ratio is all benefits over the life of the project (100 years was used in the analysis) divided by all costs over the life of the project (100 years).*

Benefit-cost ration (B/C Ratio) = Benefits / Costs. If the B/C Ratio is greater than 1, the scenario is cost-beneficial. If benefits equal costs, the B/C Ratio = 1, and the project will “break even”. If benefits are less than the costs, the B/C Ratio is less than 1.

Sustainability Assessment

In addition to technical analysis using the flood damage model, a sustainability assessment was conducted for each mitigation scenario.

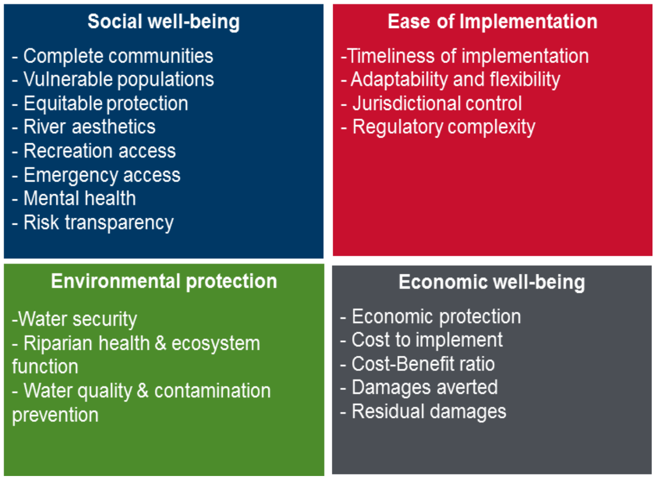
Mitigation scenarios were evaluated through technical analysis, sustainability assessment and public engagement.

Each flood mitigation scenario was evaluated in the areas of social well-being, environmental protection, economic well-being and ease of implementation (Figure 4). Each theme area was equally weighted. The criteria within each area, their assigned individual weightings, and the scores for each mitigation scenario were determined based on:

- Feedback from public engagement.
- Subject matter expertise from across *several City departments.*
- *IBI Group and Golder's expertise.*
- *The City's Triple Bottom Line Policy, Sustainability Direction, Sustainability Appraisal Tool* and watershed goals, and
- Best practices in sustainability analyses.

Significant community and stakeholder engagement work was undertaken to inform the study (e.g. development of the sustainability criteria, scenario evaluation) and the direction of The City's future mitigation work. Public engagement activites included:

- Community Advisory Group (flood-affected and non-flood-affected citizens who met throughout the duration of the project).
- Telephone survey (randomized third-party) on values around the river, flooding, mitigation and development, and
- Public booths, workshops and open houses (11 events city-wide).



Social well-being

- Complete communities
- Vulnerable populations
- Equitable protection
- River aesthetics
- Recreation access
- Emergency access
- Mental health
- Risk transparency

Ease of Implementation

-Timeliness of implementation
- Adaptability and flexibility
- Jurisdictional control
- Regulatory complexity

Environmental protection

-Water security
- Riparian health & ecosystem function
- Water quality & contamination prevention

Economic well-being

- Economic protection
- Cost to implement
- Cost-Benefit ratio
- Damages averted
- Residual damages

Figure 4 – Flood mitigation scenario sustainability assessment criteria

At the end of the study, The City also reconvened with the Expert Management Panel on River Flood Mitigation, established after the 2013 flood, to gather their perspectives on how the assessment's recommended approach aligned with the Panel's original vision and recommendations.

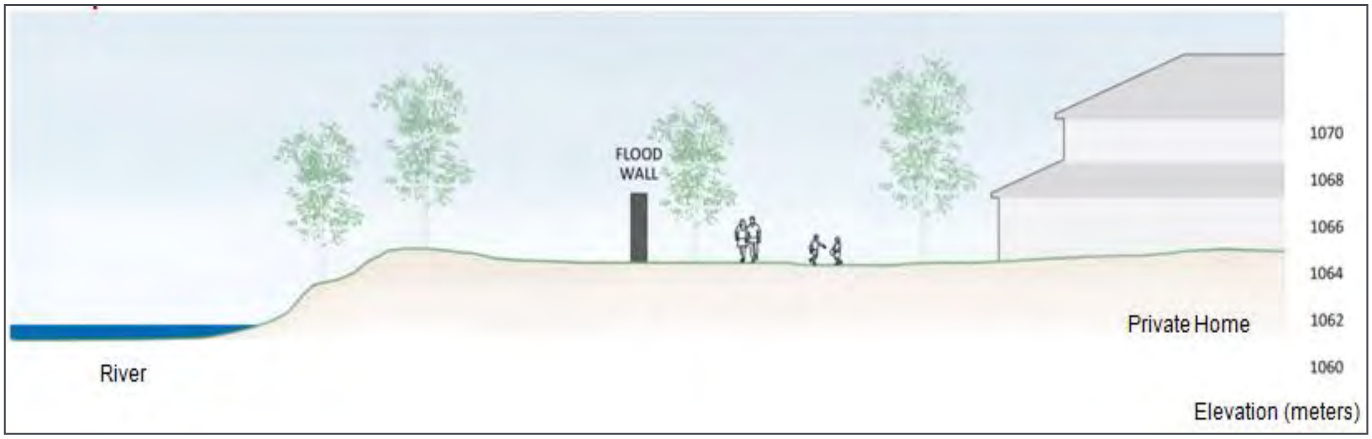


Figure 5 – Social and environmental impacts of 1:200 year flood barriers (illustrated here) were evaluated.

Results and Recommendations

The assessment provided a multi-faceted and robust evaluation of the opportunities and challenges associated with each potential mitigation scenario. Under the Sustainability Assessment, upstream mitigation (reservoirs) scored highest due to:

- Potential climate adaptability and water security benefits.
- Geographical extent and equitability of protection along the entire river downstream of the reservoir, and
- Lower level of community disruptions compared to large barriers.

The study identified that because community-level flood barrier projects are within The City's jurisdiction, they can be constructed more quickly than watershed-scale projects such as reservoirs, which is a benefit.

The study also highlighted the drawbacks of each mitigation measure. Every mitigation measure is designed to protect against a certain sized flood, and can be overtopped by rare larger events. Dams and reservoirs cause significant environmental impacts, take years to plan and construct, and have a small chance of catastrophic dam failure, although this is mitigated through rigourous dam safety legislation in Alberta. Barriers (such as illustrated in Figure 5) lack any protection benefits for events larger than the design flood, are aestheticly and environmentally intrusive; may not protect against groundwater flooding, and cannot provide opportunities for drought management, energy generation, or recreation.

To address the deficiencies of each individual measure, and to provide adaptability for future climate uncertainty, multiple or redundant defences can be used to create a layered approach for increased resiliency. Scenarios that included upstream reservoirs and complementary low-height barriers scored higher than fortification of the rivers by barriers alone or upstream reservoirs alone. This aligns with concepts of integrated watershed management and integrated flood risk management, which aim to manage the watershed as a holistic system and create climate adaptable resilience.

The mitigation scenario including upstream reservoirs on the Bow and the Elbow, small barriers at specific locations along the Bow (to achieve equivalent level of protection) and complementary non-structural measures had among the lowest residual average annual damages, and a robust #1 ranking for sustainability.

Scenario 1
The study results showed that the Springbank Reservoir (SR1) on the Elbow River removes a significant portion of flood risk, as does the current 5-year agreement between the Government of Alberta and TransAlta to operate the Ghost Reservoir on the Bow River for flood mitigation. Together, these measures reduce the city-wide flood risk by another 30%. This scenario has a very high benefit-cost ratio of 3.2. It does, however, leave a high residual risk ($45.2 Million per year), largely on the Bow River, as the level of protection provided in this scenario is not as high on the Bow as the Elbow.

Scenario 2
To further reduce risk on the Bow, the potential mitigation benefits from an additional (new) reservoir on the Bow River was modelled upstream of Calgary. This change increases the capital cost significantly, but lowers the residual annual average flood damages to $31.8 Million per year.

Scenarios 3, 3a, 4, 4a, 5 and 5a
These scenarios investigated mitigating flooding using barriers on each river without having an upstream reservoir to provide additional mitigation. Residual average annual flood damages were between $28.8 and 45.6 Million per year. The costs, however, were similar or higher than building reservoirs. This is due to the amount of private land that would have to be aquired along the river to accommodate barriers large enough to mitigate against flooding because upstream reservoirs are not in place. Scenarios involving large flood barriers scored low on the sustainability analysis, however, largely due to the social and environmental impacts of constructing large permanent barriers, in a few cases up to 6m high, along the rivers.

Scenario 6
Buyouts of properties in a hypothetical floodway based on a 200-year flood were assessed as a mitigation solution. The results showed this measure is one of the most costly, even though it did not provided mitigation to all properties at risk of flood damage. While the study acknowledged flood damages would be completely eliminated for the bought-out properties, the high cost of purchasing the properties made it the only scenario that was not cost-beneficial. Further discussion on property buy-out is included in the following section.

Scenarios 7, 7a, 8, 8a and 9
After reviewing public input and the results of the first six scenarios, Scenarios 7, 7a, 8, 8a and 9 were developed to assess combinations of reservoirs and barriers on the Bow River. Because a new reservoir on the Bow River would likely still not provide enough flood water storage to mitigate a 2013-sized flood event, and because of the long timeframe to explore and build such a reservoir, complementary barriers were modelled along the Bow. These barriers were modelled in locations where extra measures are required in addition to a reservoir, to achieve equivalent levels of protection to that committed to on the Elbow River.

While the addition of these barriers increase the cost of these scenarios, it also increases benefits correspondingly, and increases the equitability of protection for all at-risk Calgary communities. These scenarios were ranked the highest out of all of the options.

Non-Structural Options

In addition to structural mitigation measures such as reservoirs and flood barriers, the study also evaluated potential non-structural measures that can reduce future flood damages in Calgary. It identified feasible measures and generalized costs and benefits. The measures identified form a basis for The City's ongoing work exploring policy and land use based flood resiliency measures.

Contingency Measures

These measures include forecasting and warning systems, keeping citizens educated and updated, emergency response planning and enhanced connections and partnerships. These methods are highlighted as being essential, flexible and low-cost.

Land Use Regulations

The study acknowledges that while not developing in a floodplain eliminates flood damages, historic development patterns have led to a complex relationship between cities and floodplains, and the social and economic value of development in floodplains is significant.

The study identified basement damages as a significant risk, even with current or stricter building flood proofing regulations. Over time, basement damages could be reduced by implementing regulations that eliminate development of below grade space, prohibiting habitable space (such as bedrooms or suites) in basements, and requiring sump pumps and sewer backflow preventers in all flood prone areas.

Further investigation of the costs and benefits associated with specific potential land use regulation changes is recommended.

Property Level Mitigation/Floodproofing

Property level mitigation is described by the researchers as being cost-effective and keeps flood readiness front of mind for citizens. The emphasized options include incentives for sump pumps and backflow preventer valves. Other options include higher elevation of main floors, basement removal or finishing basements with materials that are easy to clean after floods, and property-level flood protection such as berms and flood gates for commercial and larger buildings.

Exploration of property level mitigation is recommended in combination with structural measures, and can significantly reduce private property damage from groundwater, sewer back-up and overland flooding. Public engagement demonstrated an interest from Calgarians for more public education on reducing flood risk and financial incentives for private property owners to flood proof homes and other buildings. The Assessment recommended that The City explore the development of an incentive program for property level measures with a supporting education program.

Flood Insurance

The study suggests that flood insurance should not be relied on to achieve acceptable levels of protection. The costs and levels of risk involved suggest that premiums for unmitigated homes are not viable for most property owners. Insurance is a tool to redistribute the financial risk of flooding, not prevent flood damages.

What about buying out properties at risk?

Property ownership and development within Calgary's floodplain is diverse, spanning many land uses and demographics. The cost of buying out all properties at flood risk in Calgary and converting them to parkland is extrodinarily high (over $2 Billion) – far more costly than any other mitigation option assessed.

Not all properties have to be bought out to reduce future flood damages. Buying out select properties, however, leaves many other properties still in need of protection. The fincanical and social implications of buying properties must be considered very carefully.

There are also ways to alter how Calgary develops that can decrease flood risk – for example, restricting land uses that would be at most risk during a flood, and protecting high-value riparian areas. The City is exploring or already implementing such options.

Currently in Calgary, no new development is allowed in the floodway, and development in the flood fringe must be flood-proofed. The City continues to investigate the costs and benefits of removing or further restricting development in Calgary's floodplain.

What's Next:
The City's River Flood Mitigation Strategy

Based on the results of this study and other work undertaken since 2013, The City recommended an informed flood resiliency and mitigation strategy, which was approved by Council in April 2017. Subsequently, an implementation plan was approved by Council in June 2017 that outlined a combination of watershed and community level mitigation that allows flexibility and adaptability in managing flood risk.

The recommended scenario is Scenario 8, which has the lowest residual average annual flood damages, and provides the most timely and equitable protection to communities at risk of flooding from the Bow and Elbow Rivers.

Recommended Scenario: #8

- Upstream reservoirs on the Bow River (upstream of Calgary) and Elbow River (SR1).
- Low-height barriers for Sunnyside, Bowness and Pearce Estates on the Bow River.
- 1:200 barrier for the downtown core.

While The City of Calgary can implement some mitigation measures within its jurisdiction, it is essential that upstream mitigation is built to provide the level of protection needed for Calgary. The City will continue to support and advocate for upstream mitigation on both the Elbow and Bow Rivers.

As approved by Council, work is already underway to fund, design and construct barriers to complement a potential new reservoir on the Bow River that would achieve equitable protection for all at-risk communities across the city.

The City has implemented several lessons-learned from the 2013 flood, and continues to improve forecasting, emergency response, citizen education and communication, and preparedness for citizens, businesses and city departments.

Other non-structural solutions, such as policy, regulations, education, incentives and selective property buyouts are being explored to complement structural measures and provide further flood resiliency for Calgary.

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Government of Alberta. Springbank Off-stream Reservoir. http://www.transportation.alberta.ca/sr1.htm

The full Flood Mitigation Options Assessment report can be requested by contacting 311.

For more information on flooding in Calgary, resiliency and mitigation,
please visit www.calgary.ca/floodinfo or contact 311.

PROJECT UPDATE

BRAGG CREEK FLOOD MITIGATION PROJECT
UPDATE 1 –APRIL 2018

BACKGROUND

The 2013 southern Alberta floods were the most costly disaster in Canadian history. In the Bragg Creek area, the flooding caused widespread damage to municipal infrastructure, flood protection works, homes, property, and businesses along the Elbow River. The flooding had economic and social impacts in the community long after the waters receded and the physical damage was repaired.

PROJECT OVERVIEW

The hamlet of Bragg Creek is subject to regular flooding, with significant events being recorded as early as 1915. In recognition of this long-standing risk, the Government of Alberta agreed to fund a flood mitigation project for the community.

MILESTONE ACCOMPLISHMENTS TO DATE

November, 2014: The Government of Alberta provides funding to Rocky View County to conduct preliminary studies, develop designs, and prepare estimates for the construction of flood mitigation structures.

December, 2015: Based on the studies and designs prepared by Rocky View County, the Government of Alberta commits to providing $32.8 million to the Bragg Creek Flood Mitigation Project. The project is designed for a one-in-a-hundred-year flooding event.

June, 2016: Rocky View County posts a Request for Proposals for professional services and awarded the project to AMEC Foster Wheeler.

July 2016: AMEC Foster Wheeler commences gathering project information through land and river surveys and physical assessments. These include geotechnical, aquatic habitat, biophysical, and historical and archaeologic resource surveys, as well as structural assessments of the Balsam and Bracken Road bridges. The information created and gathered was used to support the hydraulic model and flood barrier designs.

Milestone Accomplishments To Date -- Continued

November 2016: One-on-one meetings were held with landowners who will be directly affected by the project. These meetings addressed project impacts and landowner concerns.

February and May 2017: Formal grant contribution agreements were signed with the Government of Alberta and the Federal Government for a total project budget of $32.8 million.

March 2017: The County began acquiring the land necessary to implement the project. Approximately 30% of required lands have been obtained to date.

July 2017: The County applies for the necessary approvals (Water Act Application) from Alberta Environment and Parks.

NEXT STEPS

1. Public Notice Advertisement of Water Act Application
    - In keeping with regulations, the County publically advertised the Alberta Environment & Parks approved Water Act Application in the Rocky View Weekly on March 27, 2018.
    - Stakeholders will have an opportunity to submit a Statement of Concern within 30 days of the advertisement.
    - Rocky View County will address any stakeholder concerns to the satisfaction of Alberta Environment & Parks.
    - If and when Step 1 and Step 2 are complete, approval will be granted (expected in September 2018).

2. First Nation Consultation – Treaty 7 Nations
    - Alberta Environment & Parks requires a "Level One" consultation with First Nations.
    - Project Introductory Letters were mailed out in late March of 2018.
    - Rocky View County will consult First Nations. The County will address impacts to historical and traditional uses to the satisfaction of Alberta Environment & Parks.
    - If and when Step 1 and Step 2 are complete, approval will be granted (expected in September 2018).

3. Land Acquisition – Privately Owned Lands
    - Affected landowners have been provided with a detailed compensation package.
    - Discussions are on-going.
    - Expected completion is May 2018.

Next Steps -- Continued

4. Department of Fisheries & Oceans – Fisheries Act Authorization

   - Due to proposed construction activities, the County will be required to provide offsetting measures to counterbalance unavoidable impact on fish habitat. This will include reviewing areas within the Elbow River watershed previously damaged during the 2013 floods.
   - An offsetting plan will be prepared when a suitable area has been identified and approved by the Department of Fisheries & Oceans.
   - Expected completion is September 2018.

5. Possible Expropriation
   - If the expropriation of land it required, it would take approximately one year from the start of process. All subsequent steps listed below would be delayed accordingly.

6. Tendering Construction
   - The tender engineering drawings are 80 percent complete. The design will be completed in parallel with the Water Act process, and the completion of land acquisition to address any final design changes.
   - The County will post a Request for Prequalification for construction services in August 2018.
   - Upon approval of the Water Act Application, a tender document will be sent to the prequalified contractors for bid submissions.
   - Expected award of the tender is October 2018.

7. Construction Commencement
   - Depending on timing of regulatory approvals and the acquisition of project lands, the County anticipates construction commencing as early as the late fall of 2018. Flood mitigation construction will also depend on winter conditions and therefore could extend into the spring of 2019.

MORE INFORMATION

Specific details, drawings, and reports are available by searching “Bragg Creek Flood Mitigation” at www.rockyview.ca.

QUESTIONS

Any questions or comments regarding this project can be directed to Rafeal Odie, Senior Project Manager, Capital Projects, at 403-520-7292 or rodie@rockyview.ca.

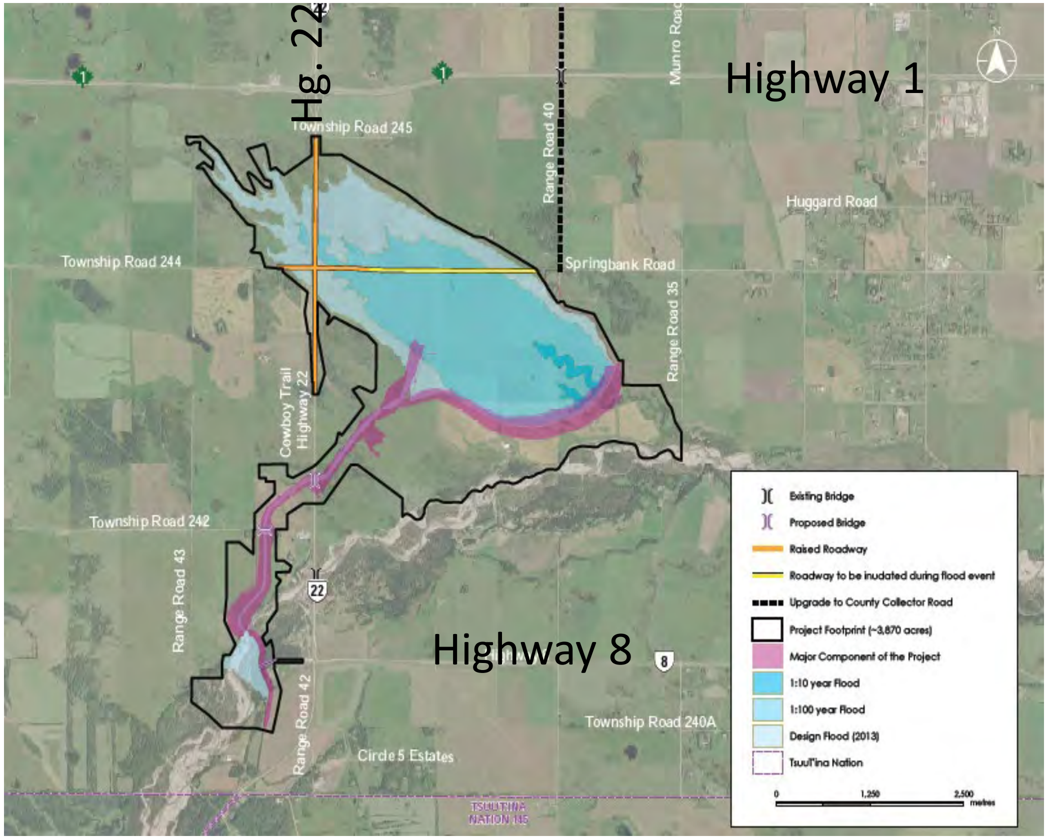
Elbow River - Flood Protection

- Rocky View County recognizes and accepts the need for flood protection on the Elbow River

- Damages from a **new** event on the Elbow River are estimated at nearly $942 million dollars

- GOA has chosen Springbank Dry Reservoir (SR1) as the primary means to mitigate flood protection

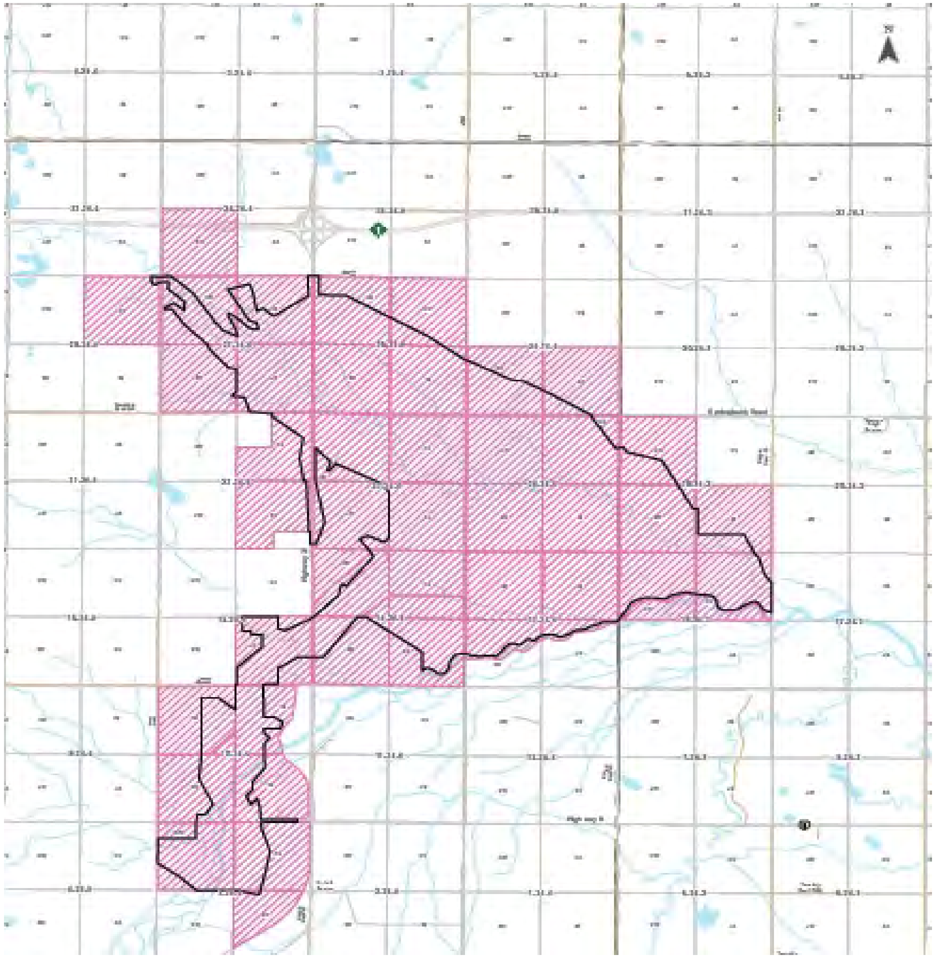
Springbank Dry Dam



Elbow River Diversion

- Store water for up to a 1:200 flood event
- Will divert water at flows of 160 M³/d - 17% chance of operating every year
- Costs
    - $432 million – gross cost
    - $372 million - Net cost assumes the resale of purchased land that is not needed for operation.

SR1 - Land Acquisition



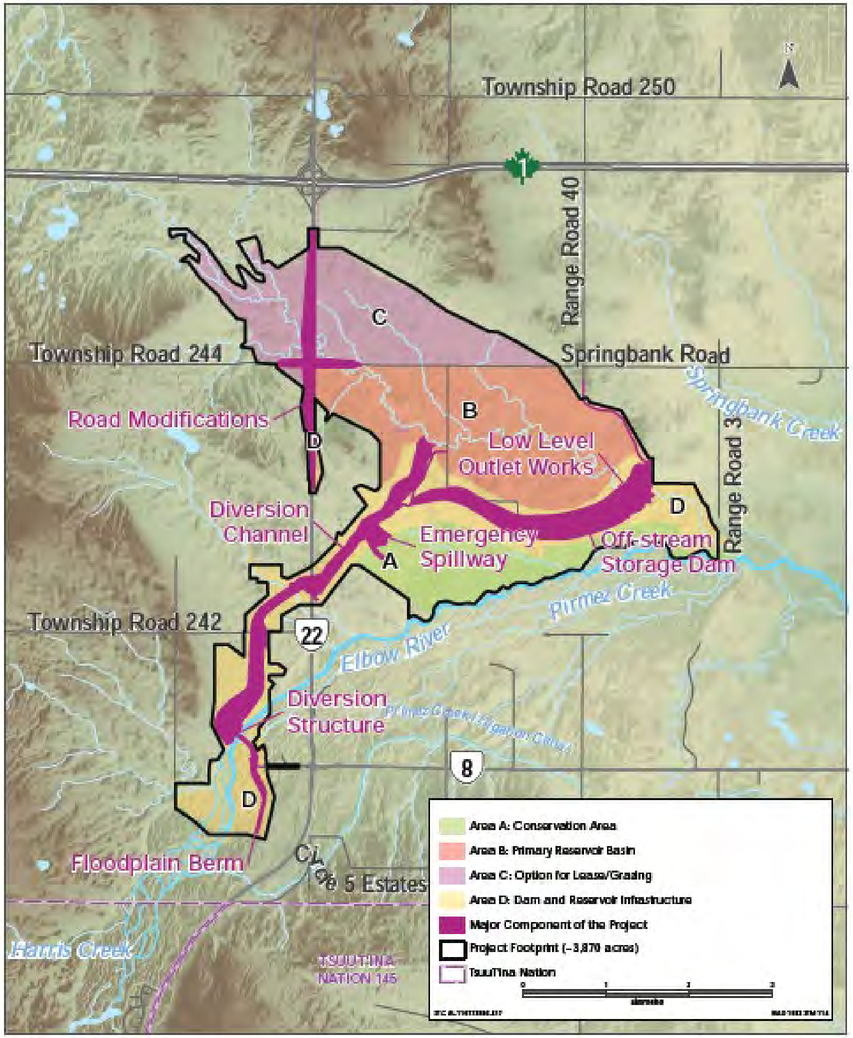
Acquisition

- Footprint is approximately 3,870 ac
- Total land acquisition 6,800 ac
- Cost $432 million (net $372 million assuming the resale of purchased land)

Land

- High quality ranch land
- 51.5% - undisturbed water courses, wetlands, shrub lands, forestland and grassland
- 28% - improved pastureland
- 20.5% - hay or is cropped

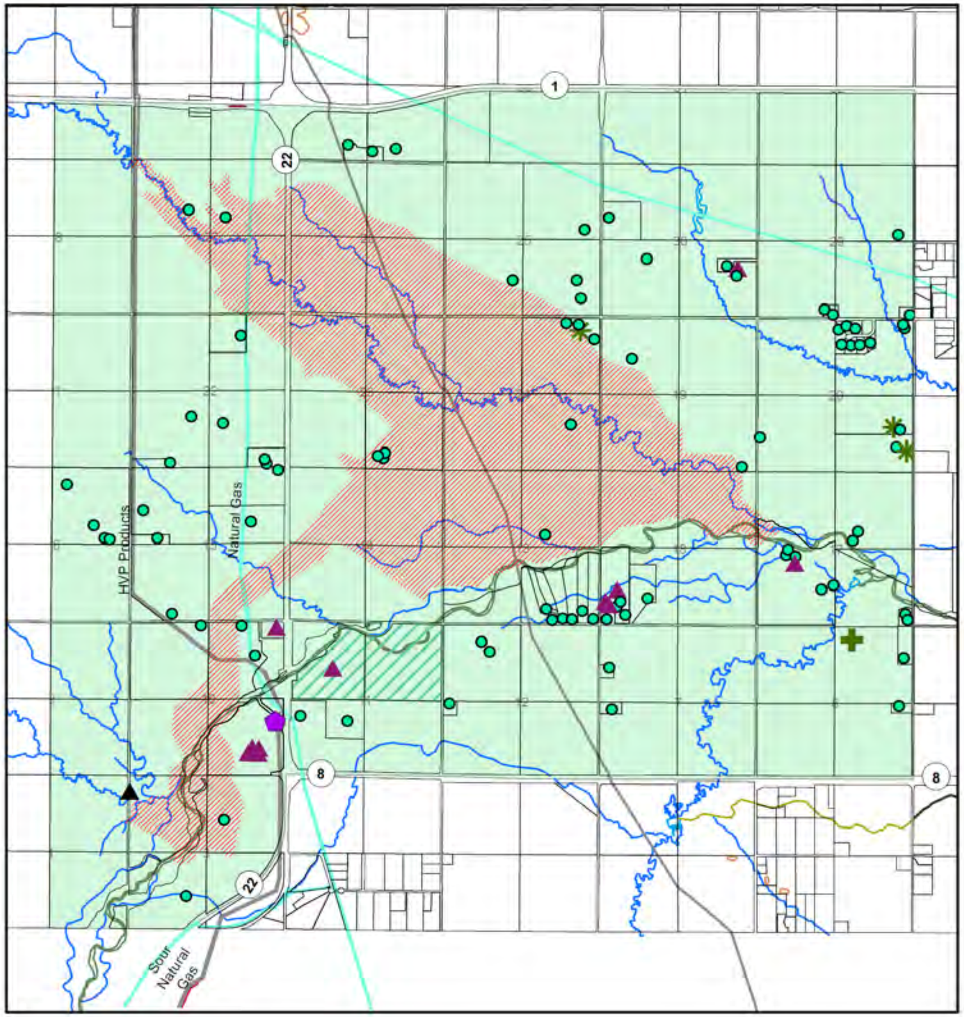
SR1 – Post Flood



Post Flood Event

- Maximum flood event will take 2 to 3 months to drain
- Isolated pockets of dead water after an event (approx. 300 acres)
- Silt - 1 to 400 cm thick over 700 acres of land
- Area B – No public access, may be used for research
- Area C – May be used for grazing

SR1- Impacts / Benefits



Impacts

- Loss of agriculture ranch land
- 87 residents on or near reservoir are impacted
- Loss of Camp Kiwanis
- Silt and dust
- Damage to County Roads

Benefits

- No local benefits
- Minor down stream benefit to County Residents
- Important regional benefit

Options

- Report makes no recommendation of one option over another
- Report concludes that other options were prematurely dismissed

Mclean Creek

Priddis Diversion

Tsuut’ina Storage

Room for the River

Mclean Creek (MC1) vs SR1

Cost / Benefit – No difference

- Official costs have narrowed - SR1 $372 million vs MC1 $406 million
    - Assumptions – resale of land?, MC1 has a higher contingency fee, no value assigned to enhance protection of Bragg Creek

Value based reasons

SR1 over MC1	Alternative Value-Based decisions
SR1 affects grazing areas and a small number of Albertans	No Albertans live near MC1
MC1 is more ecologically sensitive to disturbance	Native grasslands and shrub lands are equally sensitive and more imperiled
Choosing SR1 protects the commercial and tourism uses of MC1	Long-term sustainable agriculture has equal value for society
MC1 would have a direct negative impact on the recreational values of the region	Benefitting communities should share some of the costs of flood mitigation

Technical Reasons

Selection Rationale	Observation
SR1 is more effective than MC1 because it is further downstream and has a larger catchment area.	SR1 catchment is 25% larger than that of the. However, the upper part of the Elbow River basin generally has higher runoff potential
MC1 is on-stream, more likely to trap rocks and trees, putting the structure at risk	MC1 is designed to manage debris with a relatively deep dead storage in the reservoir
The Project is closer to Calgary and is more operationally accessible.	It takes about 15 minutes to drive from SR1 to MC1.
SR1 is less subject to catastrophic failure during construction	All dams on the Bow and Elbow were built with the MC1 risk potential

Options

Priddis Diversion

- Divert water from the Elbow River through Priddis Creek to Fish Creek and then to the Bow River.
- Concerns over buyouts or the need for an engineered channel to protect the hamlet
- Government of Alberta directed no further study for this option.

➢ Insufficient technical analysis to assess whether this would provide flood mitigation without transferring risk to the Priddis community.

Tsuut'ina Nation – Water Storage

Raised the possibility of water storage on Treaty lands, which could reduce peak flows to the Priddis diversion

'Room for the River' Report

- Shifts the focus from 'fighting the water' to 'living with water'
- Create "room for the river" through improved conveyance, storage, diversion, and retaining water on the landscape

➢ Identified options in the Room for the River have been forgotten and the impacts of flood mitigation are not shared

First Nations Consultation

- First Nations do not believe they have been appropriately consulted
- Potential for significant delays if there are legal challenges

Other Considerations

- Drought Protection
  - 40 droughts last 200 years on avg. one every 5 years
- Water Deliverability
  - City of Calgary instantaneous diversion rate for water withdrawals will be met by the year 2036
- Recreation

Summary

Observations

- Flood protection for the City of Calgary is needed
- SR1 impacts were placed solely on the County and Tsuut’ina
- Other options were not given the same level of technical evaluation as SR1
- Downstream and other mitigation measures to share the impacts have been neglected
- The need for regional drought protection, water delivery, and recreation was not fully considered
- The Tsuut’ina Nation does not believe it was appropriately consulted, which could result in significant delays

Recommendation to the Province

- Step back, evaluate, and reconsider all options on an equal technical basis
- Engage the public on value-based decisions within the context of sharing the impact of flood mitigation
- Implement other flood control measures as identified in the Room for the River report, such as improving conveyance, purchasing flood-prone properties, and establishing new wetland and flooding areas
- Appropriately consult with the Tsuut’ina Nation and engage them as partners who may bring a new solution to the table.

Questions & Comments

Elbow River Watershed & SR1: The lost opportunity for comprehensive water management

Elbow River Sustainability Alliance (ERSA)

January 27, 2020

ERSA Attendees

- Bragg Creek:
    - Dave Klepacki, B.Sc, MS, PhD, extensive experience in geological and earth sciences, earth mapping
    - Dave Rupert, Lead, Miranda Rosin Campaign, Community outreach
- Springbank:
    - Karin Hunter, B.Comm., CFA, President of the Springbank Community Association and the Elbow River Sustainability Alliance (ERSA)
- Redwood Meadows:
    - Dr. Karen Massey, PhD, Psychology
- Landowners:
    - Mary Robinson: RN, Pioneer Ranching Family (1888), owner of Moose Hill Ranch, rancher
    - Brian Copithorne, Pioneer Ranching Family (1800s); wildlife enthusiast
    - Lee Drewry, HR Director who spent 35 years in the oil and gas industry

Who we are: Advocates for lasting and positive change in the Elbow River Valley

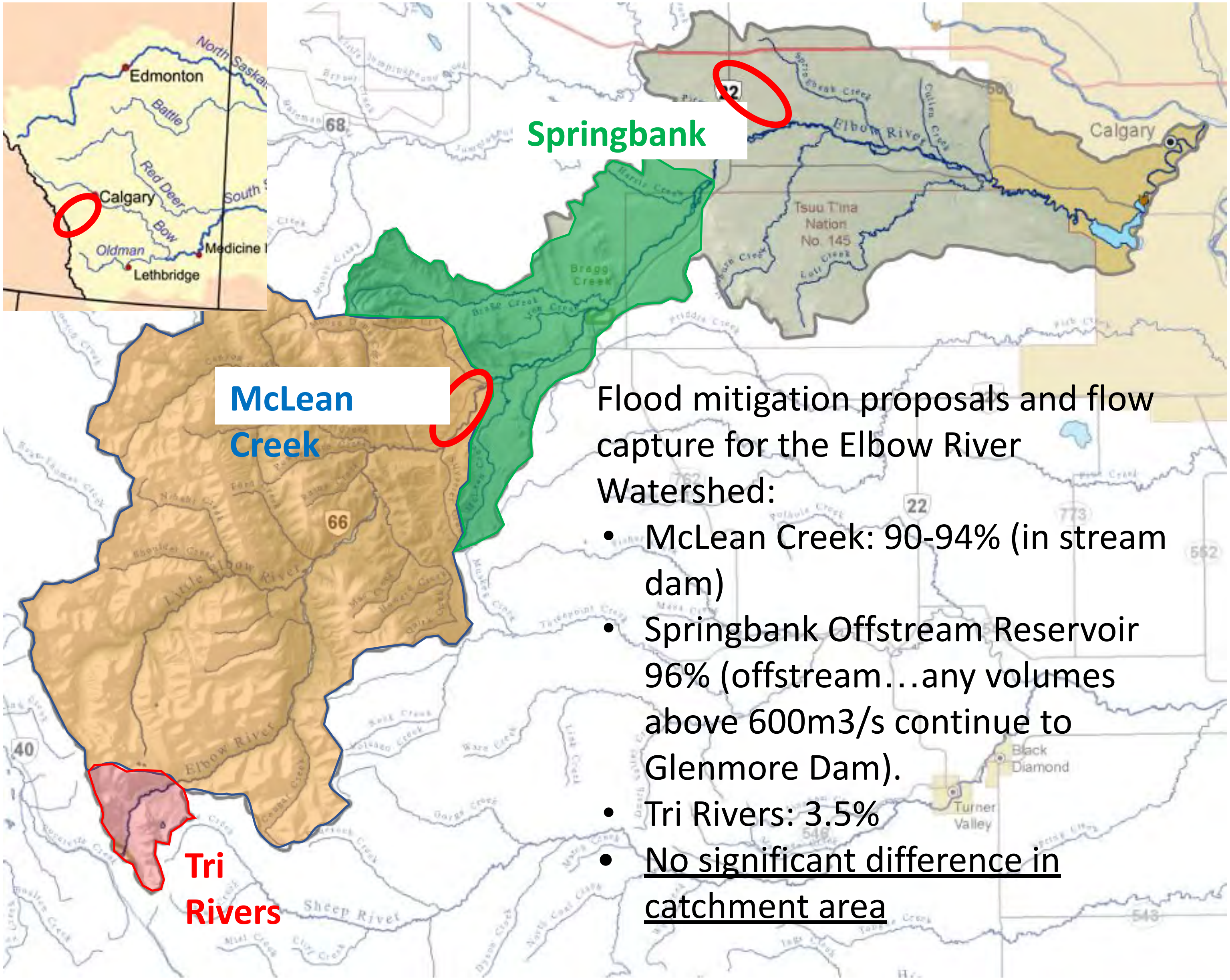
- Elbow River Sustainability Alliance:
    - Concerned, volunteer Alberta residents of communities west of Calgary who are either negatively impacted by SR1 or provided with inferior flood mitigation in Bragg Creek and Redwood Meadows
    - We are united, knowledgeable and committed
- We are concerned with broader water management on the Elbow River, not just flood mitigation
- We advocate for a legacy water management project that will create value for all Albertans
- We believe that SR1 is <u>not</u> in the public interest

Our voices count.

SR1 is mired in challenges; MC1 opportunity should be explored

- Water Management: Reality Check! Flood is just one risk facing Albertans
    - 500,000 people use Elbow River water for drinking
    - Elbow River flows are declining; drought is a pressing issue
    - Wildfire risk is growing and wildfire can negatively impact water quality
- SR1 was chosen quickly and in a flawed process:
    - The 2013-2019 consultation, decision making, and engineering studies for flood mitigation were limited, secretive, rushed and inadequate
    - The scope of regulatory concerns are a direct result of a rushed and inadequate process
    - SR1 is a useless tool for drought, fire or recreation
- Springbank Offstream Reservoir: Untested and single-minded
    - Temporary reservoir that will severely degrade local and downstream ecosystems
    - Threatens Calgary's drinking water when drained after flood events
    - Eliminates Rocky View County revenue streams without compensation
    - Flawed flood mitigation tool
- McLean Creek reservoir: Conventional engineering and predictable outcomes
    - Permanent reservoir that will provide drinking water security, flood protection for all communities, wildfire suppression and tourism revenues for local communities
    - Protects more Albertans from more threats, for less money!
    - A bottom release dam would protect and enhance ecosystems for downstream fisheries and wildlife and change, but not degrade, local ecosystems

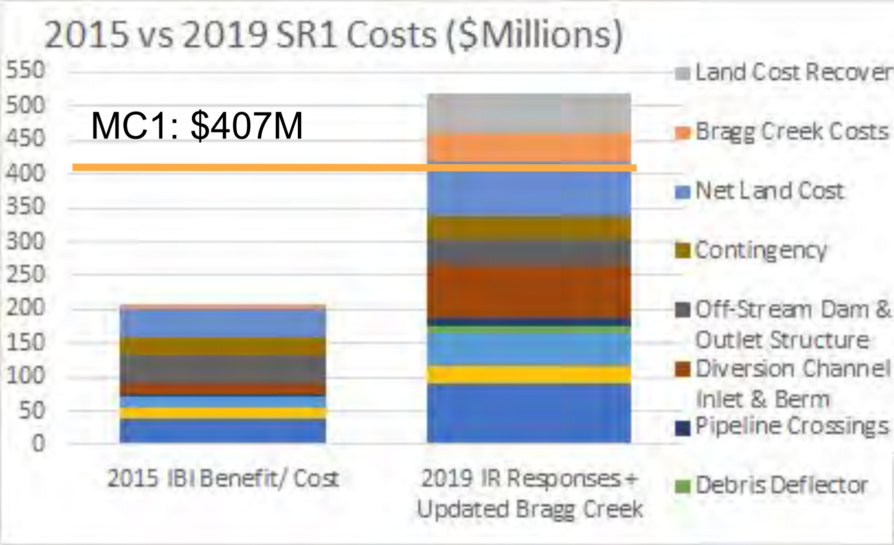
MC1 and SR1 both protect Calgary



Flood mitigation proposals and flow capture for the Elbow River Watershed:

- McLean Creek: 90-94% (in stream dam)
- Springbank Offstream Reservoir 96% (offstream…any volumes above 600m3/s continue to Glenmore Dam).
- Tri Rivers: 3.5%
- <u>No significant difference in catchment area</u>

SR1 project has changed materially over time

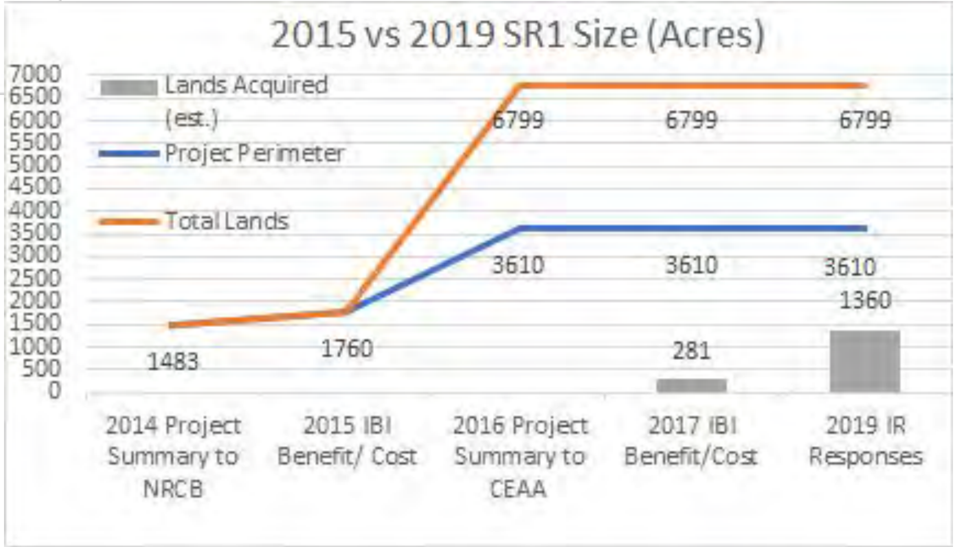


SR1 Costs more than McLean Creek by more $100M

AND...SR1 erodes value from West Rocky View in perpetuity; MC1 creates value!

SR1 land needs have grown from 1400 acres in 2014 to nearly 7000 acres

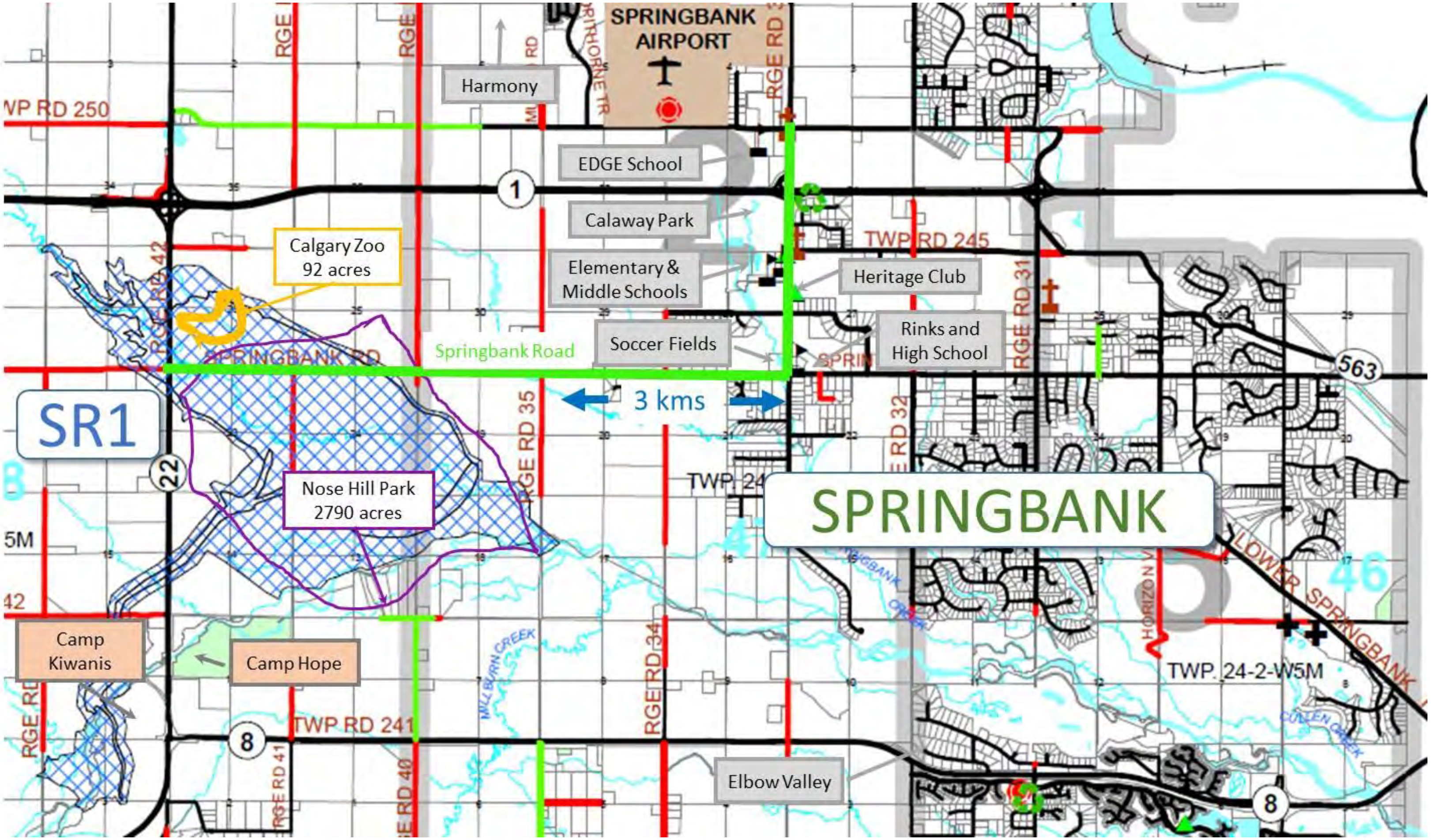
The project has grown unchecked.



SR1 costs: https://www.nrcb.ca/download_document/2/83/9104/20190614-at-eia-to-nrcb-re-ceaa-ir-response-package-3-appendix-ir45-2

MC1 Costs: sir1-response-appendix-ir6-1

What we know now: Lasting and ongoing negative outcomes as a direct result of SR1



What we know now: hundreds of acres covered in silt

Negative outcomes to both air and water quality

Result is a massive wasteland in a growing community

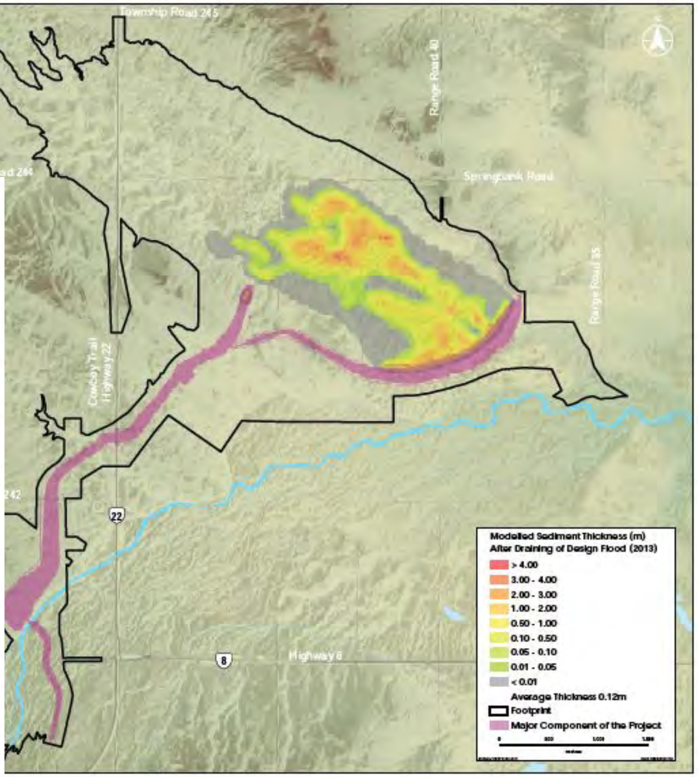
Impact on both plants and animals is negative and ongoing

Permanent silt accumulation from reservoir use

Source: Mary Robinson, following 2013 flood

What we know now: Post-flood mud & silt create health concerns

Modelled Sediment Thickness (m) After Draining of Design Flood (2013)



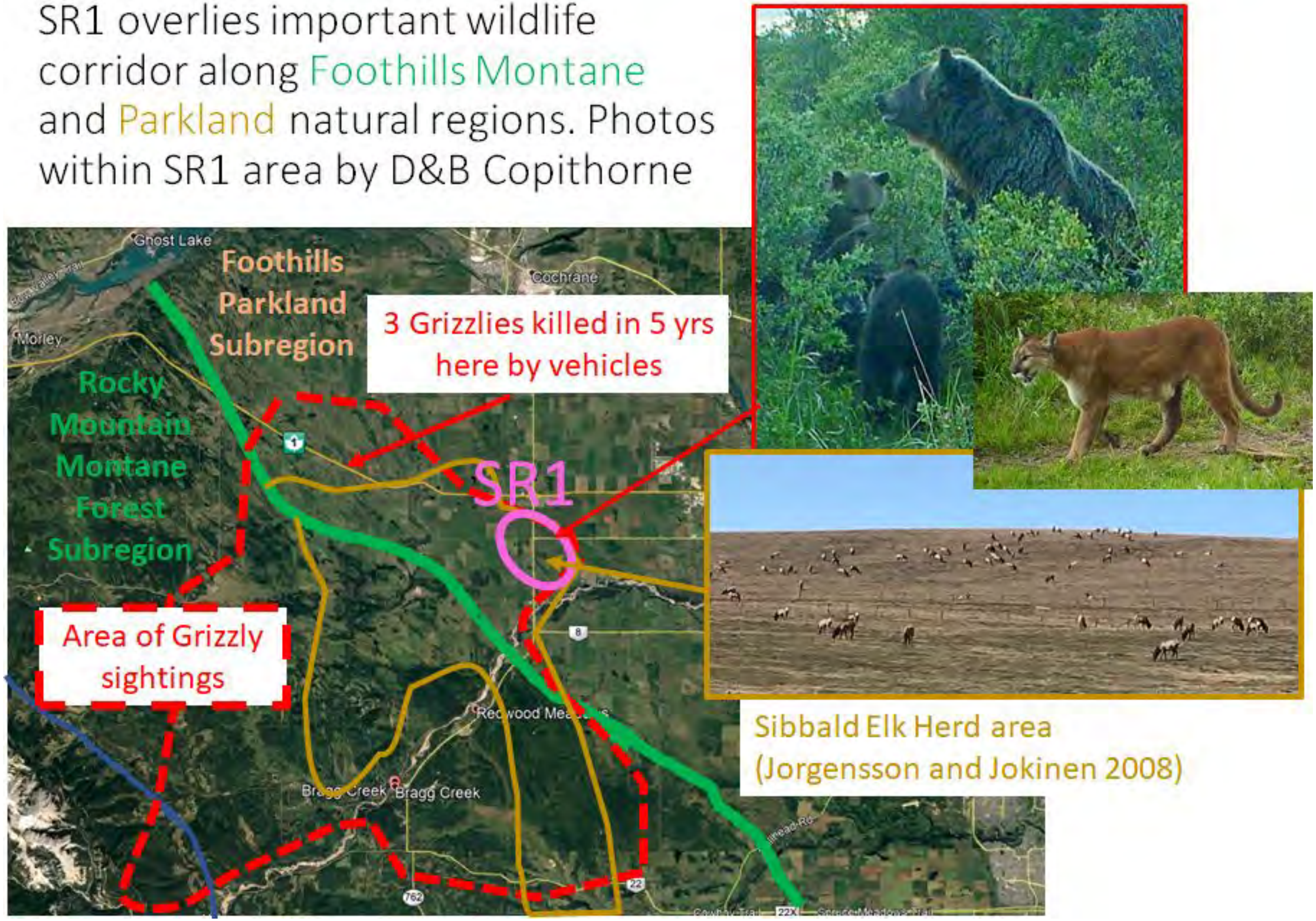
A drained pond near the Alberta Birds of Prey Centre, which staff believe was the source of a West Nile Virus outbreak which killed 15 of the centre's birds in the Summer of 2018. The centre is located in the municipality of Coaldale, Alta., and town has launched and investigation into the source of the outbreak. CALGARY

Death of 15 rescued birds prompts investigation into source of West Nile Virus in southern Alberta

RYAN RUMBOLT Updated: December 22, 2018

What we know now: Lasting wildlife impacts

SR1 overlies important wildlife corridor along Foothills Montane and Parkland natural regions. Photos within SR1 area by D&B Copithorne



3 Grizzlies killed in 5 yrs here by vehicles

Area of Grizzly sightings

Sibbald Elk Herd area (Jorgensson and Jokinen 2008)

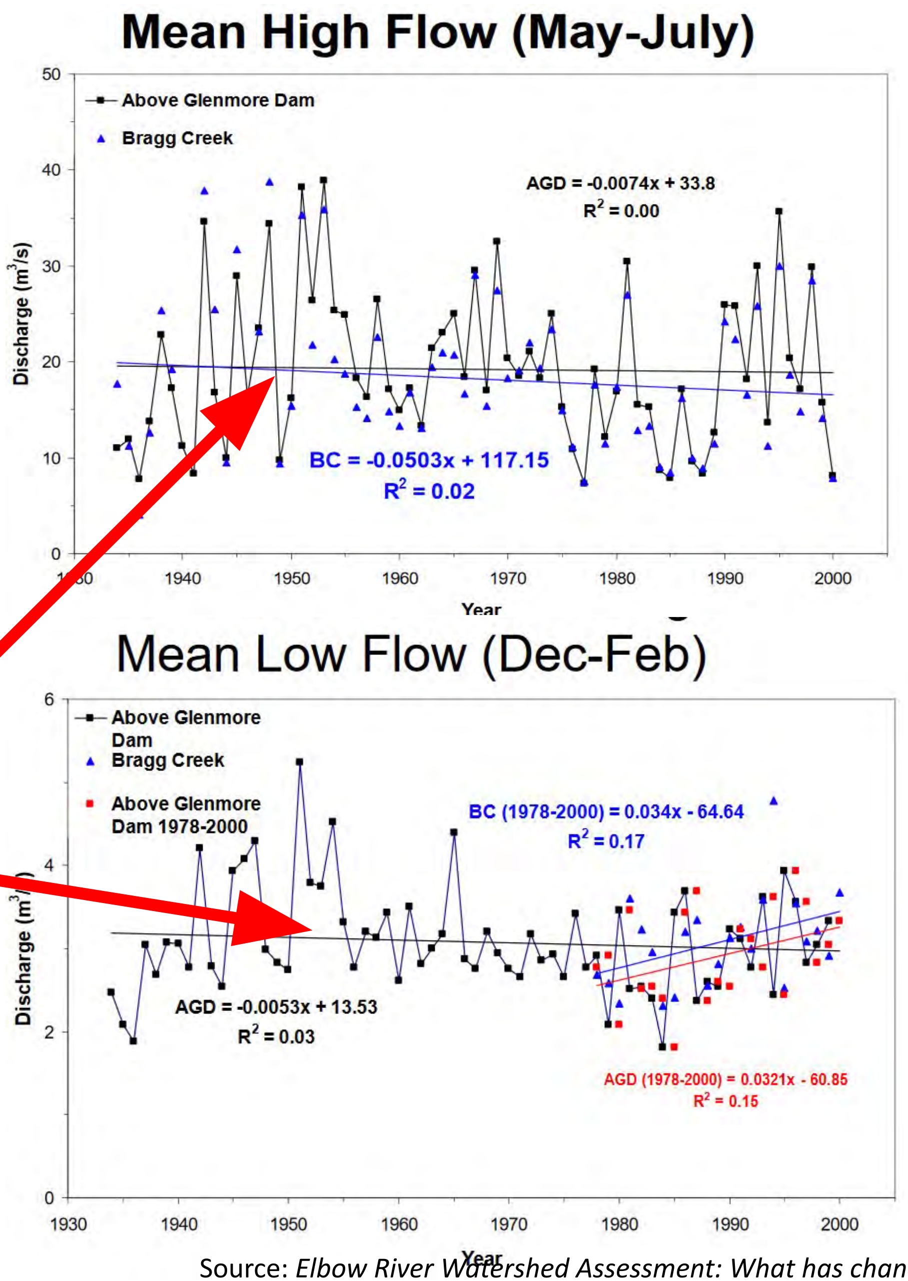
Drought & water security: Lost opportunity with SR1

Big Elbow River at Forget-me-not pond, August 2017

What we know now: Elbow River flows are decreasing

How can SR1 help? It can't.
Only MC1 can store water for the future.

-20%/100 years



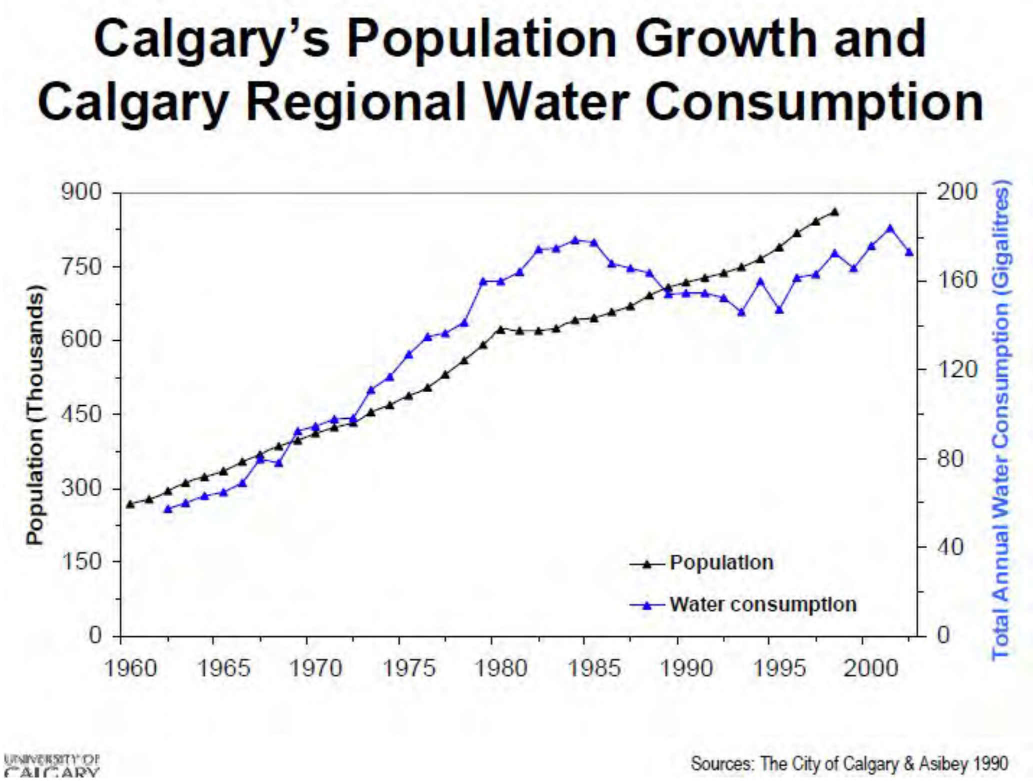
Mean High Flow (May-July)

Mean Low Flow (Dec-Feb)

Source: *Elbow River Watershed Assessment: What has changed in the past 14 years: Univ of Calgary Env. Sci. 502 Sept 2015*.

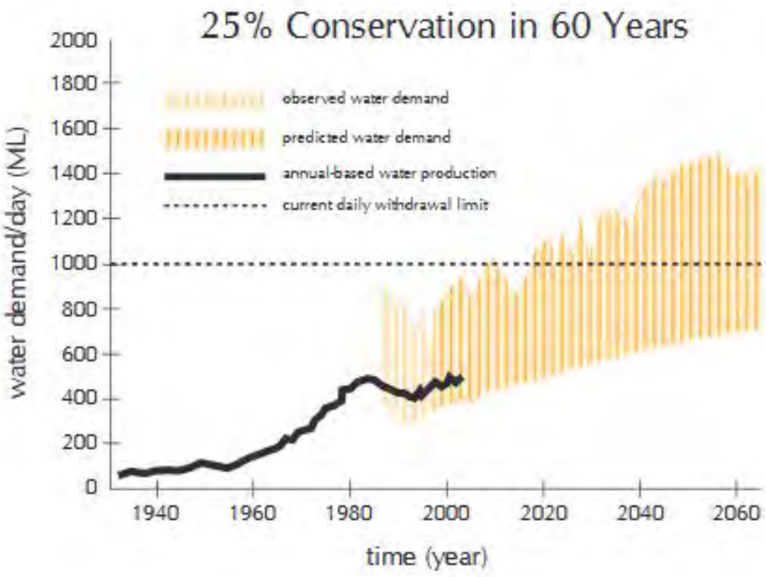
(U of C EnSc502 2012)

What we know now: Calgary has a water security problem



Calgary's Population Growth and Calgary Regional Water Consumption

Sources: The City of Calgary & Asibey 1990

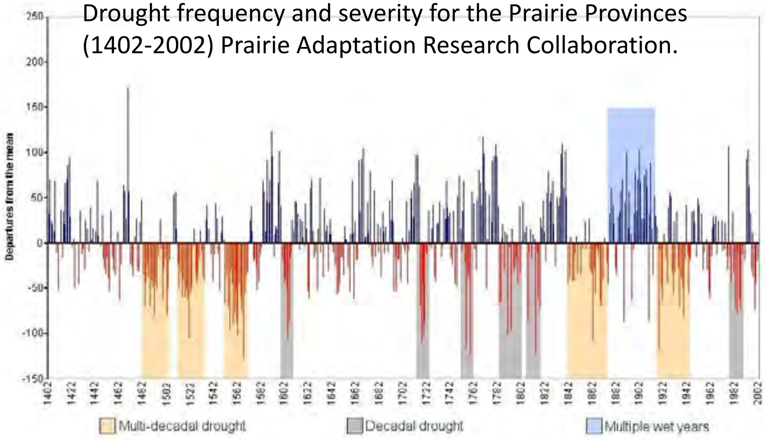


25% Conservation in 60 Years

The Elbow River supplies approximately 40% of Calgary's water needs. May 14 2019 Calgary City Special Meeting on water security predicts water licenses exceeded 2036.

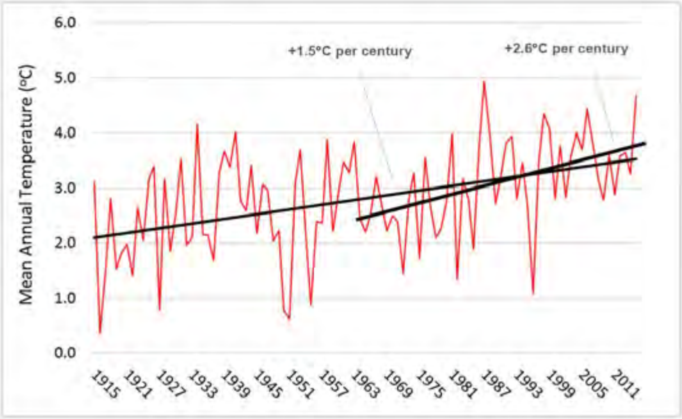
What we know now: Rising temperatures and increasing drought

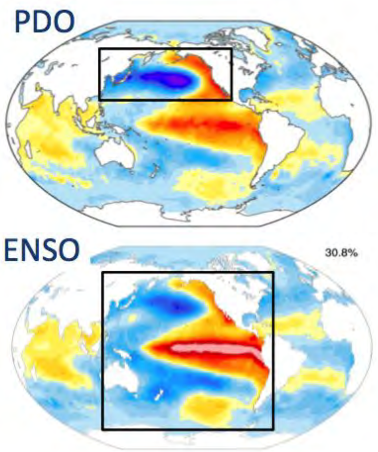
"It isn't going to be 50 years between droughts. We're going to be moving into a more constant state of dry." Dr. Mary-Ellen Tyler, U of C Drought Adaptation professor.

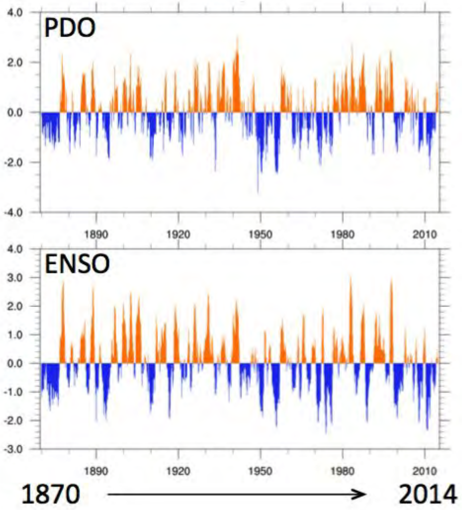


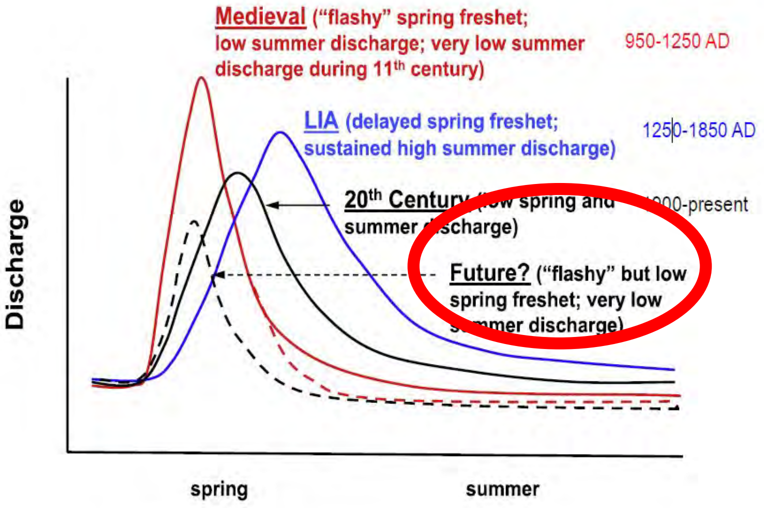
Drought frequency and severity for the Prairie Provinces (1402-2002) Prairie Adaptation Research Collaboration.

Figure 2: Mean Annual Temperature in the Bow Valley Corridor (1915-2015)





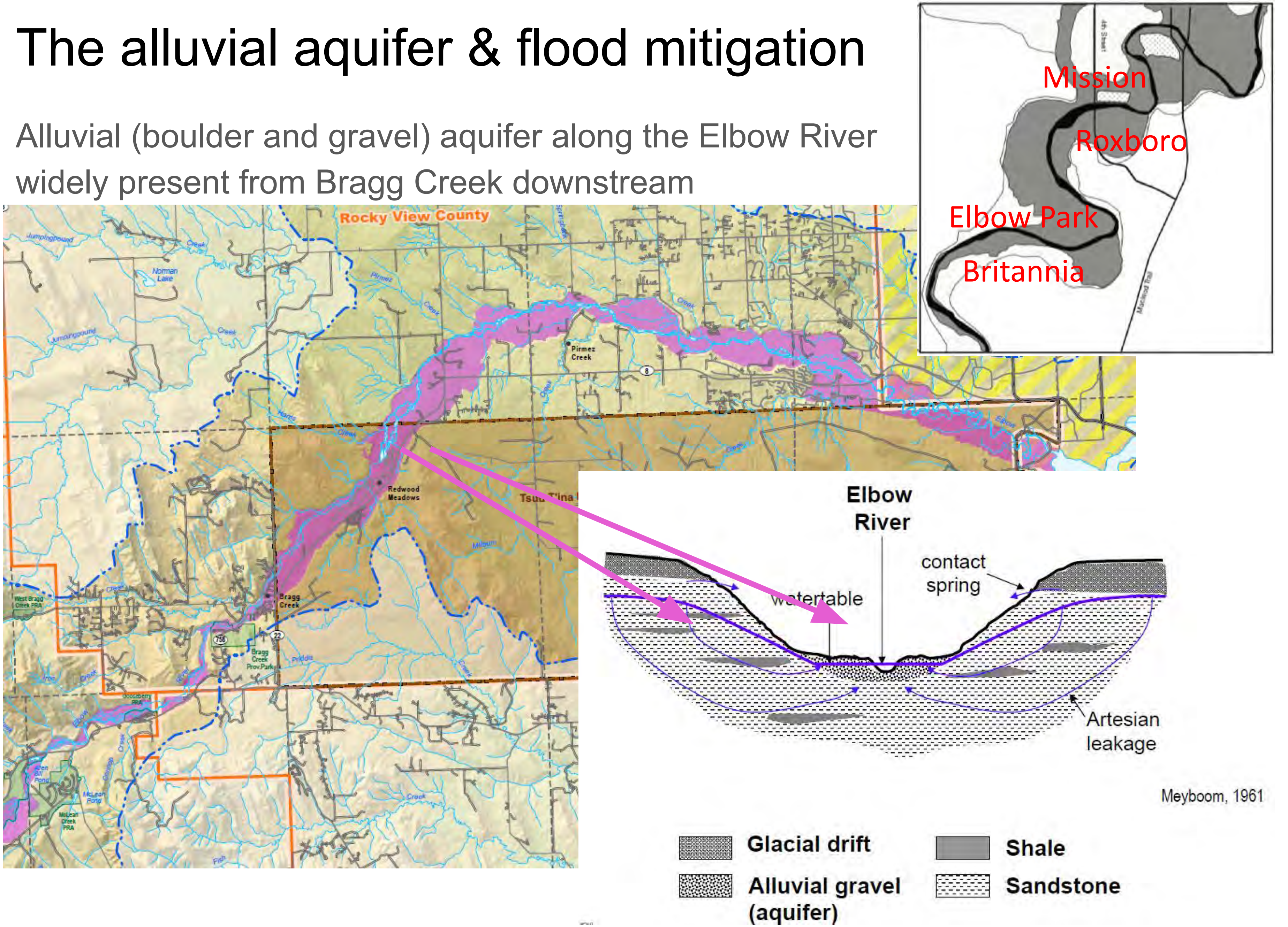




Source: Wolfe et al., 2008

The alluvial aquifer & flood mitigation

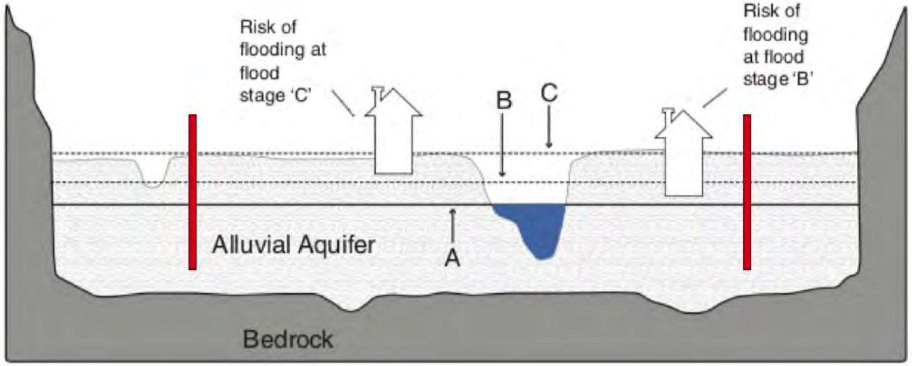
Alluvial (boulder and gravel) aquifer along the Elbow River widely present from Bragg Creek downstream

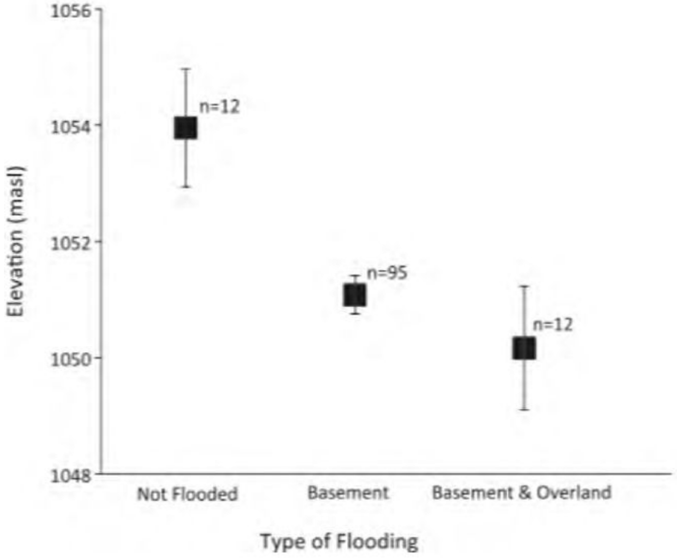


Meyboom, 1961

What we know now: Berms will not protect against groundwater flooding! Controlling river height essential.

Basement flooding at Redwood Meadows, June 2013.
Note 60-80cm basement flooding 200-300m from the river…behind the berms!
The alluvial aquifer delivered the water despite berms.





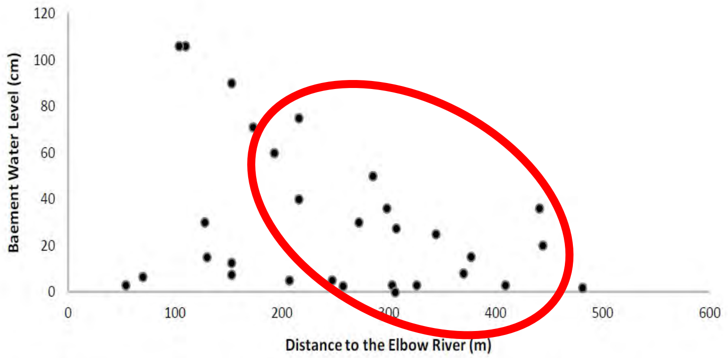


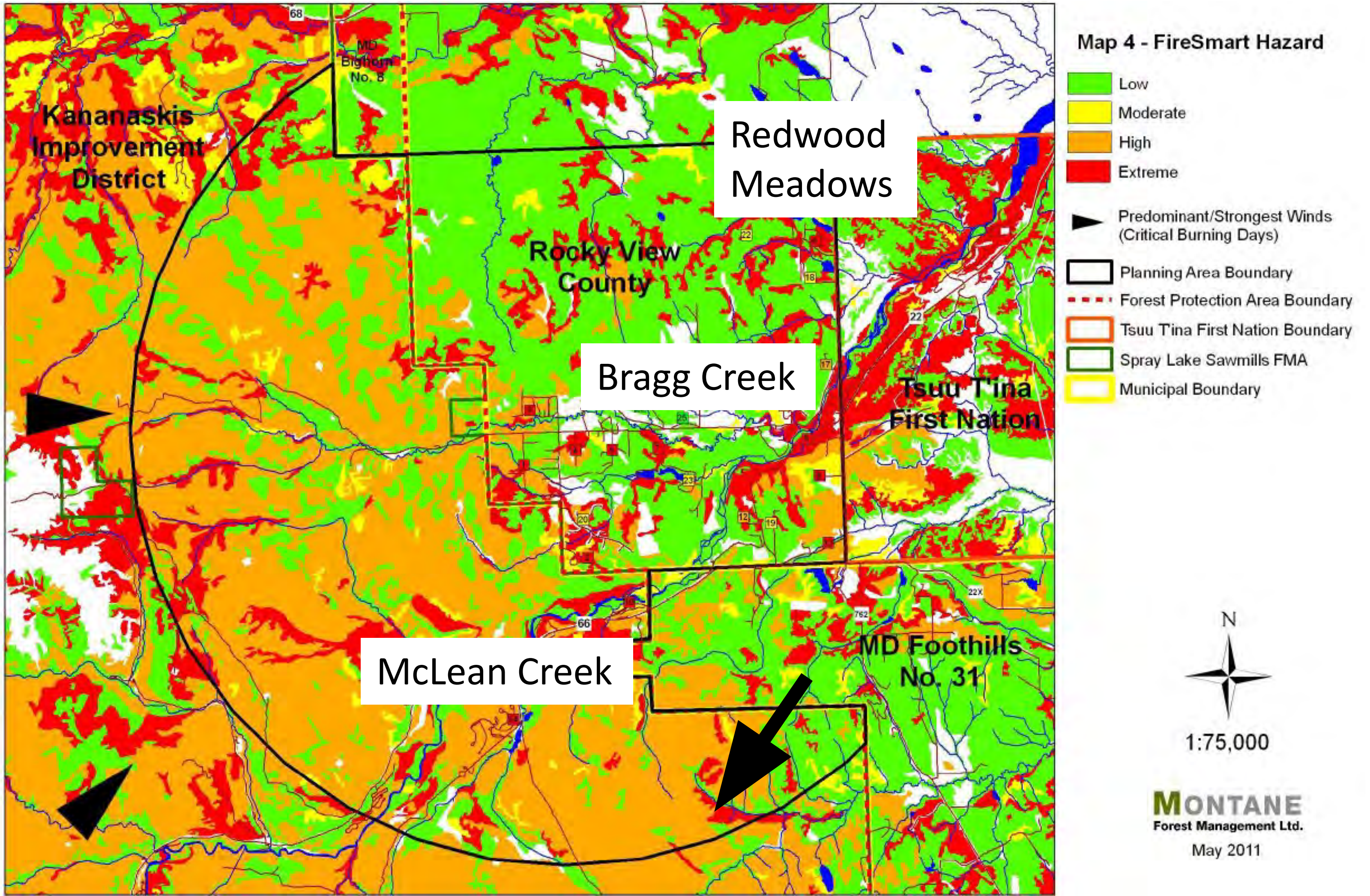
Figure 1. Flood water height above basement floor (cm) with distance of the home to the Elbow River (m).

"Basement flooding, not sewer backup, blamed for damaging homes along Elbow River in 2013." Aboud,Ryan and Osborn, (U of C) Utoday June 19, 2018.

University of Calgary ENSC501: Jabush, Grant and Ryan
Sept 2014

What we know now: Elbow River Valley is at risk of wildfire

Jasper and Bragg Creek are Alberta's highest risk communities for wildfire. SR1 does not store water and cannot help manage this risk; only MC1 can.



Wildfire in the Kananaskis region jeopardizes Calgary’s drinking water

Wildfires in the Elbow River watershed could also impact the potable drinking water of over 500,000 Albertans.

“A large fire could have a profound effect on raw water quality (especially in the small Elbow River watershed) and the effect could last for years.”

Champion Lakes/McLean Creek Wildfire May 27-31 2018, 16 kms South-West of Bragg Creek

City of Calgary Water Supply Infrastructure - Climate Change Vulnerability Risk Assessment, Prepared by Associated Engineering Ltd. for the City of Calgary - May 2011)

McLean Creek Dam: the best long-term outcome for all communities

A permanent in-stream, bottom release reservoir with 80-100 M m3 capacity, storing ~20 M m3 (Barrier Lake sized)

MC1 can help with flood, drought, fire and provide recreation capacity

MC1 is a win/win outcome and creates value for Albertans

The proposed McLean Creek dry dam on the Elbow River. *GOVERNMENT OF ALBERTA RENDERING / CALGARY HERALD*

WIKIPEDIA

Coordinates: 36.4332°N 117.9509°W

Owens Lake

Owens Lake is a mostly dry lake in the Owens Valley on the eastern side of the Sierra Nevada in Inyo County, California. It is about 5 miles (8.0 km) south of Lone Pine, California. Unlike most dry lakes in the Basin and Range Province that have been dry for thousands of years, Owens held significant water until 1913, when much of the Owens River was diverted into the Los Angeles Aqueduct, causing Owens Lake to desiccate by 1926.[2] Today, some of the flow of the river has been restored, and the lake now contains some water. Nevertheless, as of 2013, it is the largest single source of dust pollution in the United States.[3] The lake was the epicenter of a magnitude 5.8 earthquake that occurred on June 24, 2020.

Contents

History

Owens Lake was given its present name by the explorer John C. Frémont, in honor of one of his guides, Richard Owens.[4] Richard Owens however never stepped foot in the valley. The lake's original name, given by the *Nüümü* (Owens Valley Paiute), is *Patsiata*.[5]

Owens Lake

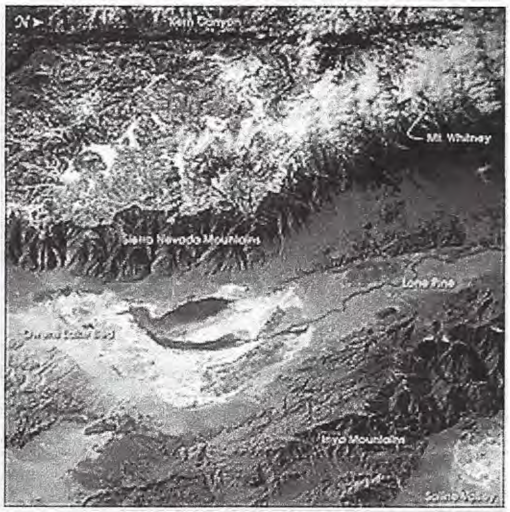
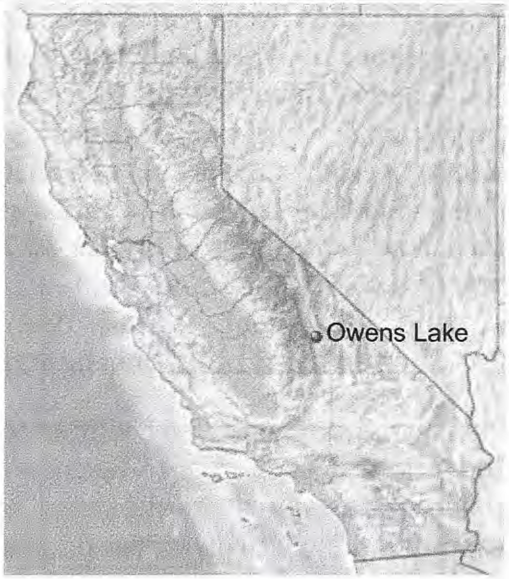


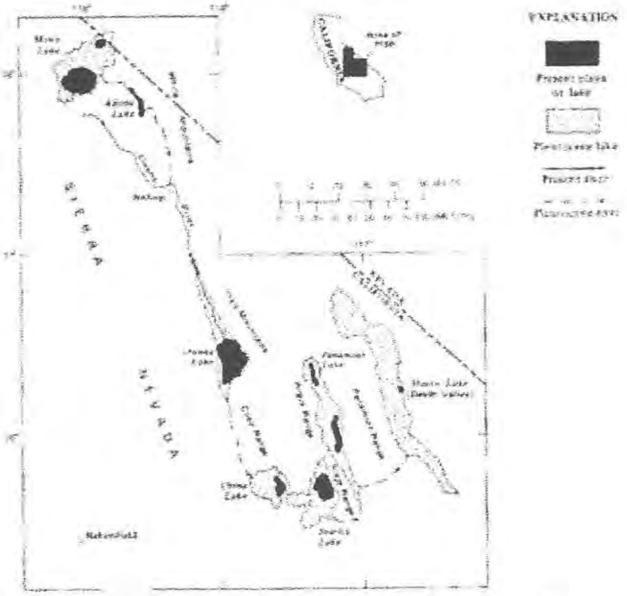
Image of the Owens Valley from the International Space Station – oriented top = true west.



Location	Sierra Nevada Inyo County, California, United States
Coordinates	36.4332°N 117.9509°W
Type	Flat
Primary inflows	Owens River Natural springs and wells

Basin countries	United States
Max. length	17.5 mi (28.2 km)
Max. width	10 mi (16 km)
Max. depth	3 ft (0.91 m)
Surface elevation	3,556 ft (1,084 m)[1]
References	GNIS feature ID 272820[1]

Before the diversion of the Owens River, Owens Lake was up to 12 miles (19 km) long and 8 miles (13 km) wide, covering an area of up to 108 square miles (280 km²). In the last few hundred years the lake had an average depth of 23 to 50 feet (7.0 to 15.2 m), and sometimes overflowed to the south, after which the water would flow into the Mojave Desert.[2] In 1905, the lake's water was thought to be "excessively saline."[6] It is thought that in the late Pleistocene about 11–12,000 years ago Owens Lake was even larger, covering nearly 200 square miles (520 km²) and reaching a depth of 200 feet (61 m). The increased inflow from the Owens River, from melting glaciers of the post-Ice Age Sierra Nevada, caused Owens Lake to overflow south through Rose Valley into another now-dry lakebed China Lake, in the Indian Wells Valley near Ridgecrest, California. After the glaciers melted, the lake waters receded. This accelerated with human exploitation of the lake, even before the Los Angeles Aqueduct was built, because Owens Valley farmers had already diverted most of the Owens River's tributaries' flow, causing the lake level to drop slightly each year.



Map showing the system of once-interconnected Pleistocene lakes in eastern California (USGS)

Starting in 1913, the river and streams that fed Owens Lake were diverted by Los Angeles Department of Water and Power (LADWP) into the Los Angeles Aqueduct, and the lake level started to drop quickly.[7] As the lake dried, soda processing at nearby Keeler, California, switched from relatively cheap chemical methods to more expensive physical ones. The Natural Soda Products Company sued the city of Los Angeles and built a new plant with a $15,000 settlement. A fire destroyed this plant shortly after it was built, but the company rebuilt it on the dry lakebed in the 1920s.

During the unusually wet winter of 1937, LADWP diverted water from the aqueduct into the lakebed, flooding the soda plant. Because of this, the courts ordered the city to pay $154,000. After an unsuccessful appeal to the state supreme court in 1941, LADWP built the Long Valley Dam, which impounded Lake Crowley for flood control.[7]

Conditions

The lake is currently a large salt flat whose surface is made of a mixture of clay, sand, and a variety of minerals including halite, burkeite, mirabilite, thenardite, and trona. In wet years, these minerals form a chemical soup in the form of a small brine pond within the dry lake. When conditions are right, bright pink halophilic (salt-loving) archaea spread across the salty lakebed. Also, on especially hot summer days when ground temperatures exceed 150° F (66 °C), water is driven out of the hydrates on the lakebed creating a muddy brine. More commonly, periodic winds stir up noxious alkali dust storms that carry away as much as four million tons (3.6 million metric tons) of dust from the lakebed each year, causing respiratory problems in nearby residents.[7][8] The dust includes carcinogens, such as cadmium, nickel and arsenic.[9]

Management

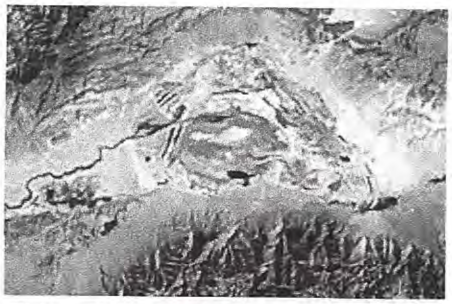
Owens Lake from the Horseshoe Meadows Road

The LADWP and the California State Lands Commission own most of the Owens Lake bed, though a few small parcels along the historic western shoreline are privately owned.[10] In 2004, the California Department of Fish and Wildlife (CDFW) acquired a 218-acre (88 ha) parcel at the foot of Owens Lake. Designated the Cartago Wildlife Area in 2007, it is one of the few remaining spring and wetland areas on the shore of Owens Lake.[11] CDFW is using mitigation funds from CalTrans to enhance habitat.

As part of an air quality mitigation settlement, LADWP is currently shallow flooding 27 square miles (69.9 km²) of the salt pan to try to help minimize alkali dust storms and further adverse health effects. There is also about 3.5 square miles (9.1 km²) of managed vegetation being used as a dust control measure. The vegetation consists of saltgrass, which is a native perennial grass highly tolerant of the salt and boron levels in the lake sediments.[12] Gravel covers are also used.[13]

Alkali dust storm at Owens Lake

Ecology



This astronaut photograph highlights the mostly dry bed of Owens Lake.

This once-blue saline lake was an important feeding and resting stop for millions of waterfowl each year. During a visit to Owens Lake in 1917 Joseph Grinnell from the Museum of Vertebrate Zoology in Berkeley reported "Great numbers of water birds are in sight along the lake shore--avocets, phalaropes, ducks. Large flocks of shorebirds in flight over the water in the distance, wheeling about show in mass, now silvery now dark, against the gray-blue of the water. There must be literally thousands of birds within sight of this one spot."

Owens Lake is still recognized as an Important Bird Area in California by the National Audubon Society.[10] At the shore, a chain of wetlands, fed by springs and artesian wells, keep part of the former Owens Lake ecosystem alive. Snowy plovers nest at Owens along with several thousand snow geese and ducks. As a result of current dust mitigation efforts, shallow flooding of the lakebed has created both shallow and deeper (about 3 feet (0.9 m) deep) habitats on the lakebed.[14] This water, although seasonally applied, is helping to buoy the lake's ecosystem causing hope in conservationists that an expanded shallow flooding program could do even more. There are no serious plans, however, to restore Owens to anything resembling a conventional lake.[7]

On April 19, 2008, the Eastern Sierra Audubon Society, Audubon California, and the Owens Valley Committee held the first lake-wide survey of the bird populations of Owens Lake. Volunteers recorded a total of 112 avian species and 45,650 individual birds — the highest total number of birds ever officially recorded at Owens Lake. Volunteers identified 15 species of waterfowl (ducks and geese) and 22 species of shorebirds. The highest totals for individuals of a species included 13,873 California gulls (an inland nester at Mono Lake and elsewhere); 9,218 American avocets; 1,767 eared grebes; 13,826 *peeps* or small sandpipers such as dunlin, western and least sandpipers; and 2,882 individual ducks.[12]

Local industry

Cerro Gordo Mines

The remains of the Cottonwood Charcoal Kilns.

The town of Cartago, below the Sierra Nevada near present-day Olancha, California, was the western shipping port for the Cerro Gordo Mines production and transported goods across Owens Lake with the northern ports of Swansea and Keeler directly below the mines. From Cartago a barge-like vessel, the *Bessie Brady,* was launched in 1872, which cut the three-day freight journey around the lake down to three hours.[15]

Much of the freight it carried was silver and lead bullion from the Cerro Gordo mines, which at their height were so productive that the bars of the refined metals waited in large stacks before twenty-mule team teamsters could haul it to Los Angeles. The trying three-week (one way) journey improved after the formation of the Cerro Gordo Freighting Company, run by ancestors of regional historian Remi Nadeau who has written of this period.

The town of Keeler, below the Inyo Mountains on the former north shore, replaced Swansea as the shipping port for the mines after the 1872 Lone Pine earthquake. In the 1870s it had a population of 5,000 people as the center of trade for the Cerro Gordo mines.

The Cottonwood Charcoal Kilns, traditional stone masonry 'beehive' charcoal kilns, were built to transform wood from trees in Cottonwood Canyon above the lake into charcoal, to feed the Cerro Gordo mines' silver and lead smelters across the lake at Swansea. The ruins are located on the southern side of the lakebed near Cartago. They were similar to the nearby Panamint Charcoal Kilns near Death Valley. The kilns are identified as California Historical Landmark #537.[16]

Other enterprises

In 1879 silver mining ended, but Keeler was saved when the Carson and Colorado Railroad built narrow-gauge rail tracks to the town. It then became a soda, salt, and marble shipping center until 1960. The rail line had been sold to Southern Pacific Railroad in 1900. Keeler's current population is around 50 people and continues in decline.

In the 20th century the Clark Chemical Company operated on the northwestern shore at Bartlett, with evaporation ponds for lake brine and a plant to extract its chemicals.

Mineral extraction plants around the lake:[17]

- Inyo Development Company, 1887-1920
- Natural Soda Products Company/Michigan Alkali Company/Wyandotte Chemical Corporation, 1912-1953
- California Alkali Company/Inyo Chemical Company, 1917-1932
- Pacific Alkali/Columbia-Southern Chemical Corp./Pittsburgh Plate Glass, 1928-1968
- Permanente Metals Corporation, 1947-1950

- Morrison and Weatherly Chemical Corporation (M&W)/Lake Minerals Corporation (LMC)/Cominco American Inc./Owens Lake Soda Ash Company (OLSAC)/U.S. Borax/Rio Tinto Minerals, 1962–present. Rio Tinto Minerals has mineral lease renewals through 2048.[18]

Filmography

Numerous Western films have been shot by Owens Lake, including *Westward Ho* (1935), *Maverick* (1994), *Riders of the Dawn* (1937), *Across the Plains* (1939), *Stage to Tucson* (1951), *From Hell to Texas* (1958) and *Nevada Smith* (1966).[19]

Other films that had scenes shot at Owens Lake or the nearby Alabama Hills where Owens Lake is visible includes *Top Gun* (1986), and *Tremors* (1990).[20]

Public access

The Cartago Wildlife Area continues to develop as a wildlife-viewing area for the public. The site is open year-round for viewing numerous bird species attracted to the ponds and wetlands as well as the ruins of a historic soda ash plant from the World War I era and the 1920s.[12]

See also

- Owens River course
- List of lakes in California
- Los Angeles Aqueduct
- California Water Wars
- List of drying lakes
- California Historical Landmarks in Inyo County

A view of the Sierra Nevada mountains and surroundings from Earth orbit, taken on the STS-51-F mission in 1985. Owens Lake is in the lower right, with a reddish tint.

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Sprinklers are used to control dust in Keeler, a tiny town on the eastern shore of Owens Lake.
Frank Foster

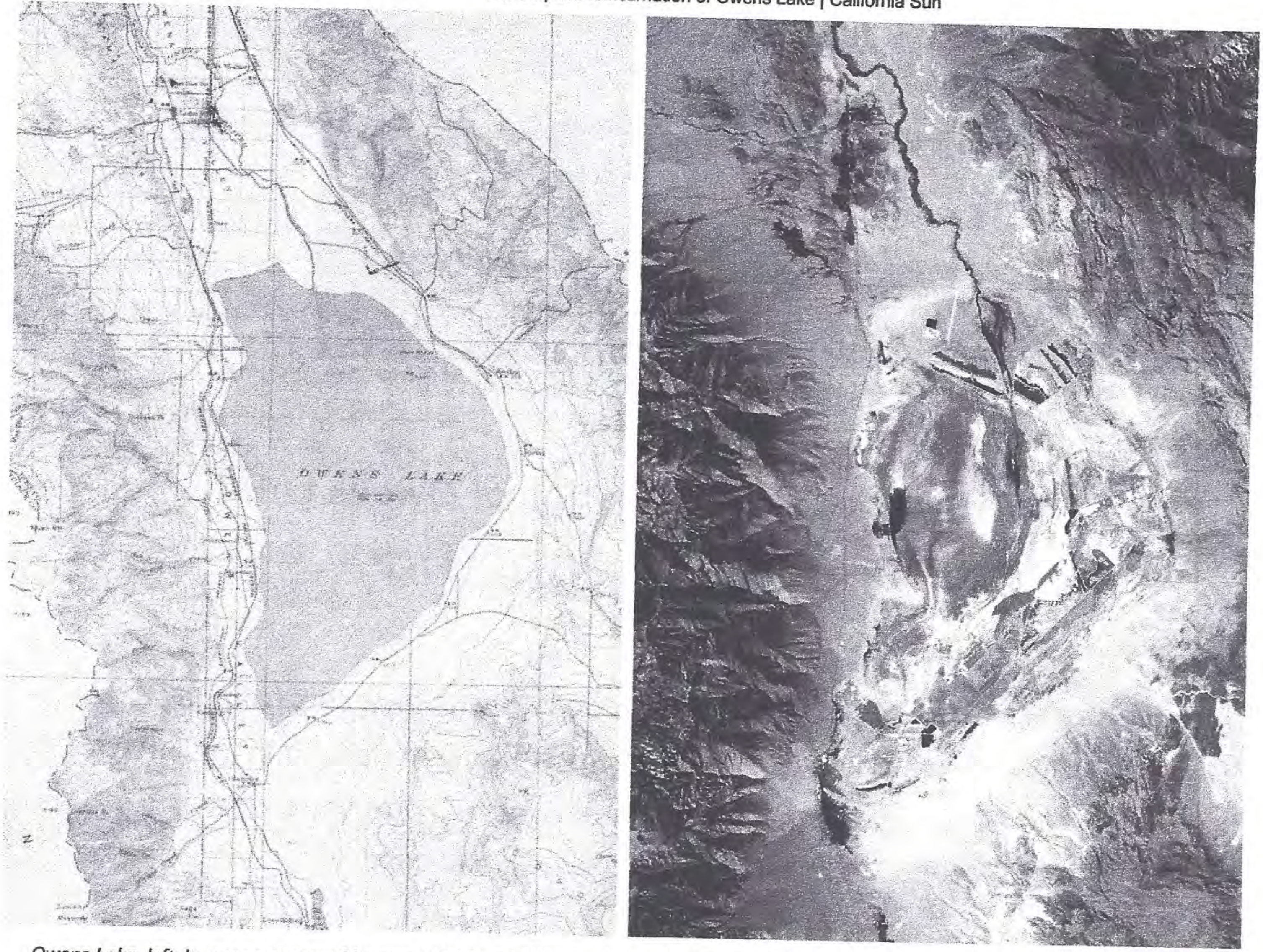
The surprise reincarnation of Owens Lake

by Mike McPhate
Dec 06, 2018

A century ago, Los Angeles pulled a sensational swindle. Agents from the city posed as farmers and ranchers and strategically bought up land in the lush Owens Valley, 200 miles to the north. Water rights in hand, the thirsty metropolis proceeded to drain the region via a great canal.

If the deception weren't bad enough, the result was one of the nation's worst ecological disasters. The 100-square-mile Owens Lake was emptied, creating a salt flat the size of San Francisco that unleashed enormous amounts of hazardous dust.

As recently as 2013, it remained the largest single source of dust pollution in the United States.



Owens Lake, left, in a map surveyed between 1905 and 1911, and seen from space in 2011.

U.S. Geological Survey; NASA

Even so, the lakebed has been experiencing a turnaround. Under court order, Los Angeles has spent about $2 billion over the last two decades to introduce vegetation and shallow flooding.

That's led to a dramatic reduction in the dust blowing off the desiccated ground as well as another outcome that took many by surprise: the almost overnight return of tens of thousands of birds on the Pacific Flyway — grebes, dowitchers, whimbrels, sandpipers, sparrows, and others. Last April, Owens Lake was designated as a shorebird reserve of international importance.

Berms and shallow flooding have been used to control dust and create habitat in the Owens lakebed.

Los Angeles Department of Water and Power

"It's certainly not what the department of water and power thought they were doing," said Alexander Robinson, a landscape architect at U.S.C. and author of the new book "The Spoils of Dust." Now that the habitat has been created, he added, "They've basically gotten locked into maintaining it in perpetuity."

Owens Lake will likely always remain robbed of its former glory thanks to Los Angeles's water dependance. But it's begun to transition into a natural jewel of different sort, a stark and sweeping landscape ringed by majestic mountains and attracting new life.

"It's a success story," Robinson said. "But it's also a surprise and accident and it's a testament to the power of "just add water' in an arid climate. Everything changes."

Photographer Frank Foster has been shooting images in the Owens Valley. He shared a selection with the California Sun.

A view across the dry lakebed toward the White Mountains.

Frank Foster

The dry soil of Keeler, on the remote eastern edge of the dry lake.

Frank Foster

An abandoned mine on the northwestern shore of Owens Lake.

Frank Foster

The exposed lakebed has been an environmental crisis.

Frank Foster

While desolate, the strange beauty of Owens Lake has slowly lured back visitors.

Frank Foster

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