Reducing Calgary's flood risk

A guide to The City's Flood Resilience Plan

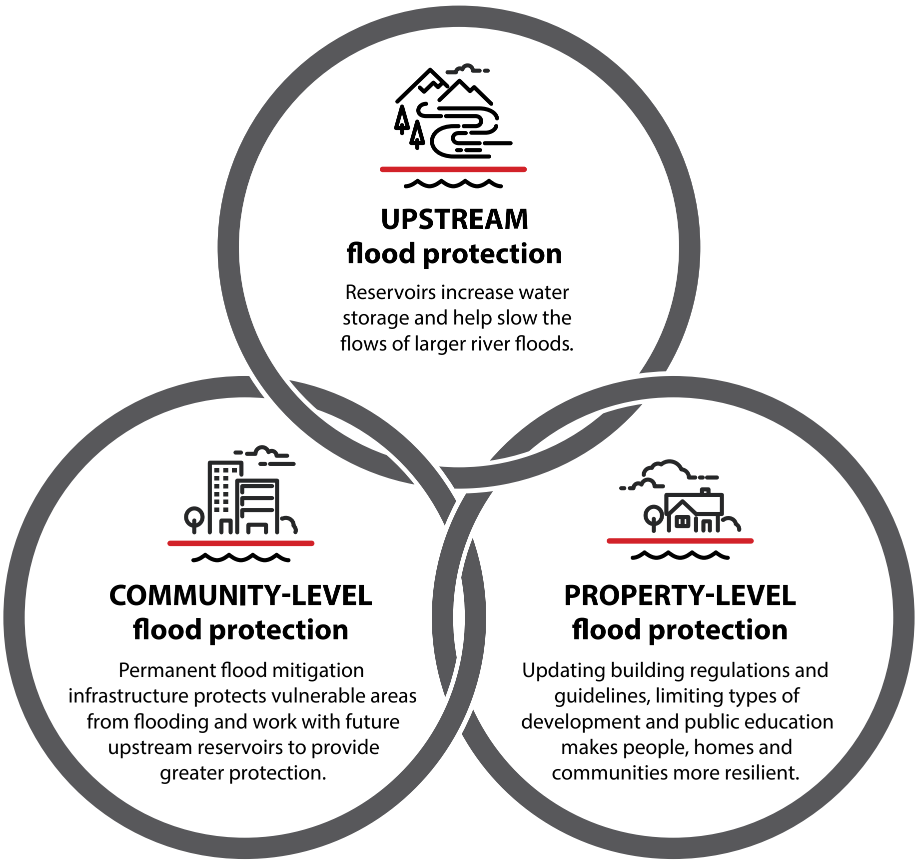
The June 2013 flood experienced in Calgary was catastrophic. Sadly, one Calgarian's life was lost and 80,000 residents were forced to evacuate their homes. Many whose homes were flooded faced trauma as they coped with the challenge of rebuilding or the permanent loss of their home.

> The 2013 flood remains one of Canada's costliest disasters with an estimated $5 billion in damages across Alberta and an estimated $400 million to City of Calgary infrastructure alone.

As a river city, there will always be a need to prepare, respond and adapt to floods. That's why building resilience to flooding is one of our top priorities. And while we can't prevent future floods, we have a plan to reduce their impact.

Elements of the flood resilience plan

The City's Flood Resilience Plan is grounded in the results from several technical studies and public engagement, including the Flood Mitigation Measures Assessment and the recommendations from the 2014 Report from the Expert Management Panel on River Flood Mitigation. It uses a three-layered approach where each element works together to manage our flood risk in Calgary. Together, these measures will make Calgary resilient to at least a future 2013-level flood and significantly reduce our flood risk.



Building flood resiliency on the Elbow River

The Elbow River is a significantly smaller river compared to the Bow River, with lower riverbanks, which makes it more prone to flooding. After exploring multiple options, the best solution for protecting the thousands of residents that live and work along the Elbow River and downtown Calgary is a combination of an upstream reservoir along with new gates on The City's Glenmore Dam. Together, these projects will work together to reduce potential flood damages by over $3 billion through the next century.

UPSTREAM
flood protection

Springbank Reservoir (SR1)

This Government of Alberta project will be located about 18 km upstream of Calgary.

During a flood, some water would be diverted from the Elbow River into the reservoir where it would be temporarily stored and released slowly back into the Elbow River towards Calgary to the Glenmore Reservoir.

> This project will reduce flood risk by 80% on the Elbow River.

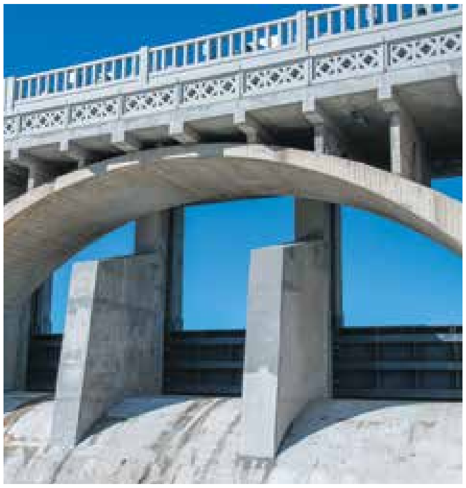
Once all regulatory approvals are in place, the Province will begin construction and the reservoir will be fully operational after the third year of construction.

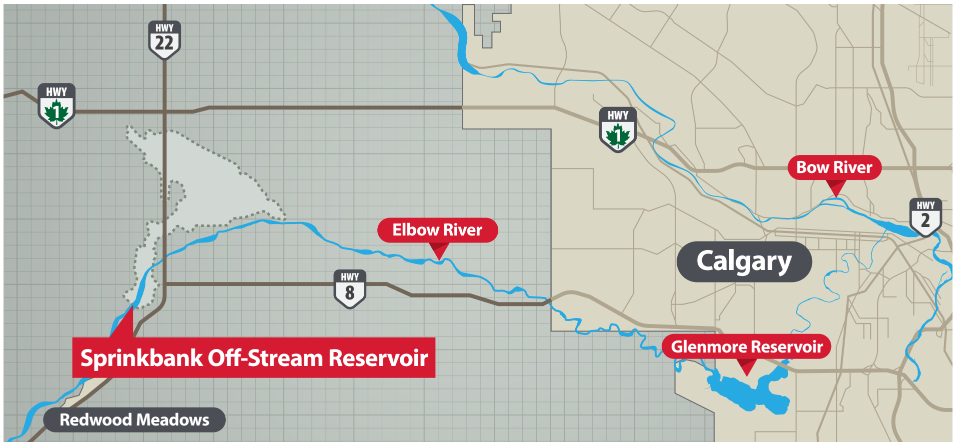
COMMUNITY-LEVEL
flood protection

Glenmore Dam Gates

Completed in summer 2020, the installation of 2.5 metre high steel gates at the Glenmore Dam has doubled the Glenmore Reservoir's water storage capacity and enables us to better control high river flows in the spring on the Elbow River.

Once the Springbank Reservoir is completed upstream, it will work with the Glenmore Dam gates to manage a 2013-size flood.






West Eau Claire Flood Barrier
Photo courtesy of O2 Planning + Design

Building flood resiliency on the Bow River

The Bow River is a large river and most of the existing upstream reservoirs are used for power generation, not flood reduction. Due to the volume of water that would need to be managed on the Bow River in a major flood, upstream reservoirs are critical to slowing down the river. Permanent flood barriers are also still needed to protect low-lying communities closest to the river.

UPSTREAM flood protection

New upstream reservoir on the Bow River

A new upstream reservoir on the Bow River would capture more water from large floods and could provide an additional source of water in the face of climate uncertainty and risk of drought.

The Province is examining three options for a reservoir on the Bow River. If constructed, the reservoir would be a major component in flood mitigation and drought management for Calgary.

For details on the status of this project, visit **alberta.ca/bow-basin-water-management-options**

Modified operations at TransAlta's Ghost Reservoir

Keeping upstream reservoirs like TransAlta's Ghost Reservoir low during flood season also helps control the flow of water and significantly reduces Calgary's risk of flood damage.

An agreement between the Province and TransAlta to modify operations at Ghost Reservoir for flood mitigation purposes runs through 2021 with plans to extend.

> Once these projects are complete, together they will work together to reduce potential flood damages from a 1 in 200-year flood event on the Bow River.

COMMUNITY-LEVEL flood protection

Permanent flood barriers

The foothills west of Calgary make it unlikely that a large enough reservoir could be built to completely slow the river flow of a 2013- level flood without causing overland flooding in some Bow River communities.

Permanent flood barriers in low-lying areas would prevent overland flood water from damaging communities, roads and utilities, including:

- Downtown
- Sunnyside-Hillhurst
- Bowness
- Heritage Drive
- Inglewood
- Bonnybrook Wastewater Treatment Plant

Until a new upstream reservoir is built on the Bow River, community flood barriers would also protect the communities from smaller floods that are more likely to happen.

Work on the individual flood barrier projects are in various stages of design and community engagement. For the status of community flood barrier projects, visit **calgary.ca/floodinfo**

The value of flood protection

With flooding projected to get even worse due to climate change, investing in a suite of flood protection measures is an investment in the safety of our citizens, community resilience, and for future generations of Calgarians.

Achieving flood resilience depends on us working together. It is a responsibility that lies with all orders of government as well as citizens. Flood mitigation infrastructure built within and outside of Calgary, along with individual preparedness, will make Calgary better equipped to face extreme weather events.

SINCE THE 2013 FLOOD

OVER $150 M

HAS BEEN INVESTED IN FLOOD MITIGATION FOR CALGARY.

This has **REDUCED our city's flood risk by about 50 PER CENT** and **our risk of flood damages by $80 M** every year.

20+

PROJECTS

since 2013 have been **completed** or **are underway** to limit the impacts of future flooding.

PROPERTY-LEVEL flood protection

Many of Calgary's older communities were built where flooding is a known risk. Property-level measures, such as updates to building regulations, flood proofing, and limiting types of development in flood prone areas are an important part of making Calgary's communities flood resilient.

When combined with flood mitigation infrastructure like barriers and emergency response plans, these measures can effectively reduce flood risk in existing communities over time and limit new flood risk caused by growth and development.

Since the 2013 flood, changes have been made to the Municipal Development Plan and Land Use Bylaw to provide guidance and better regulate development within the Flood Hazard Area. We're currently exploring potential changes to land use and building regulations to further increase Calgary's flood resilience in all communities with heightened flood risk. Examining restriction of land uses and occupancy types in the floodplain, such as care facilities and schools, are part of this investigation.

Personal flood preparedness

Property owners also have an important role in flood resiliency. We offer several resources, including a Flood Readiness Guide, seasonal newsletter, web resources, and are exploring new programs to support residents in being prepared for potential flooding and flood-proofing their property.

Visit **calgary.ca/floodinfo** for more resources and a list of current and completed flood resilience projects.

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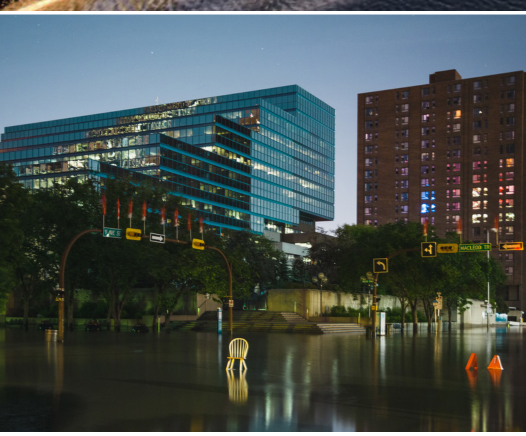

REPORT

Provincial Flood Damage Assessment Study
City of Calgary: Assessment of Flood Damages

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

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February 6, 2015

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

Dear Ms. Ziober:

PROVINCIAL FLOOD DAMAGE ASSESSMENT STUDY
CITY OF CALGARY: ASSESSMENT OF FLOOD DAMAGES

Enclosed please find the draft final report for the aforementioned assignment. The report describes in detail flood damages for the City of Calgary under a range of return frequencies from 1:2 year to 1:1000 year. Damages were calculated employing updated curves and the Rapid Flood Damage Assessment Model developed specifically to assess damages within the Province of Alberta.

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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Alberta Government

Provincial Flood Damage Assessment Study City of Calgary: Assessment of Flood Damages

IBI

Golder Associates

Prepared for Government of Alberta
ESRD - Resilience and Mitigation
by IBI Group and Golder Associates Ltd.
February 2015

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Executive Summary

Introduction

Background

Flood damage estimates are required for evaluating the cost effectiveness of projects designed to alleviate flood impacts. Accordingly, in July of 2014 IBI Group along with Golder Associates Ltd. were retained by the Alberta Government, ESRD Operations, Resilience and Mitigation Branch to undertake the Provincial Flood Damage Assessment Study.

The purpose of the study was threefold:

1. to update/develop flood damage curves in select communities at risk of flooding to 2014 economic values and establish adjustment indices for their use in different flood prone communities across Alberta;
2. to develop a computerized model for estimating flood damages; and
3. to undertake flood damage estimates for select communities throughout Alberta.

The first two components of the Provincial Flood Damage Assessment Study have been completed and are available under separate cover. The City of Calgary was identified as a high priority centre and selected as the pilot municipality for the updating of flood damage curves and development of a Rapid Flood Damage Assessment Model. It is the subject of this study.

Purpose

The primary purpose of the study is to estimate flood damages for a range of flood events such that average annual damages can be computed and employed in a subsequent benefit/cost analysis of potential flood mitigation alternatives.

Scope

The study applies the Rapid Flood Damage Assessment Model to estimate damages using a variety of primary and secondary data sources including tax assessment records and GIS data.

Methodology

To allow for a consistent approach to the evaluation of flood mitigation alternatives, the Province has adopted a standard methodology for flood damage assessment. It employs updated depth-damage curves for various categories of residential and non-residential structures and their contents based on extensive first and second order research including representative sampling of residences and non-residential structures within selected functional groups. The values reflect current residential content and non-residential inventory, display and storage practices. It also employs a Rapid Flood Damage Assessment Model, a computerized relational database for mass assessment of flood damages developed specifically for Alberta using local assessment and GIS data.

City of Calgary

Background

The City of Calgary is the largest city in Alberta and the third largest municipality and fifth largest Census Metropolitan Area (CMA) in Canada. It is situated at the confluence of the Bow River and the Elbow River in the southern part of the Province, in an area of foothills and prairie, approximately 80 km (50 miles) east of the front ranges of the Canadian Rockies.

History of Flooding

Major floods have occurred on the Bow River in 1902, 1915, 1929, 1932 and 2013. Major floods have occurred on the Elbow River in 1915, 1923, 1929, 1932, 2005 and 2013. These are traditionally summer floods caused by a combination of snowmelt and saturated ground conditions, in combination with heavy storms.

There is a continuous record from 1911 of Bow River flows at Calgary; the three largest known floods all occurred before 1911 – in 1879, 1897 and 1902. Reasonably reliable estimates are available for the floods of 1897 and 1902. The fourth-highest known flood at Calgary occurred in 1932. Due to the fortunate coincidence that the just-constructed Glenmore Reservoir, its reservoir still dry, stood in the path of that flood, the damage and disruption caused was much less than might have been expected.

Floodplain Mapping

Nine flood elevations were employed to compute flood damages, including the 1:2, 1:5, 1:10, 1:15, 1:20, 1:50, 1:100, 1:200, 1:500, and 1:1000 year flood events. Flood elevation data was based on the hydraulic output of the HEC-RAS Model provided by the City of Calgary and based on the Bow and Elbow River updated hydraulic model project by Golder Associates dated April 2012.

Inventory of Buildings

Within the identified flood hazard area, which includes the 1:100 year design flood plus a 75 m buffer, the number of buildings totals approximately 7,200 (excluding outbuildings such as garages and storage sheds) and is comprised of 5,620 single-family residential dwellings; 728 semi-detached, triplex and townhouse-style dwelling units; 275 multi-family apartment buildings; and 564 non-residential (commercial/industrial/institutional) buildings.

Damage Estimates

Total damages for the Bow and Elbow Rivers with the sewer backup condition are detailed in Exhibit 3.13 and summarized as follows.

Residential Damages

Direct residential damages equate to $687 million under 1:100 year flood conditions and constitute some 59% of total direct damages.

Commercial Damages

Commercial direct damages equate to $111 million for the 1:100 year flood event or just under 10% of total direct damages.

Infrastructure Damages

Infrastructure damages for the 1:100 year flood are estimated at $299 million or 26% of total direct damages.

Damages to Stampede Park

Direct damages to Stampede Park, including the Saddledome, for the 1:100 year flood equate to $69 million or 6% of total direct damages.

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 Actual damages occur at these flow levels
** Flood Flow primarily contained within the river

Indirect Damages

Indirect damages by themselves constitute some $649 million or 56% under 1:100 year flood conditions. (Indirect damages equate to a higher proportion of direct damages for the lower frequency floods; the unweighted average indirect share is 73% across the range of events.) This is an exceptionally high proportion, driven by commercial indirect damages and Stampede indirect damages in particular.

Total Damages

Total damages including direct and indirect damages for the 1:100 year flood are estimated at $1.815 billion for the Bow and Elbow Rivers combined, with sewer backup damages included.

Average Annual Damages

Average annual damages for the Bow and Elbow combined are $84,431,000 and for the Elbow by itself, $30,111,000.

Alternative Damage Scenario

The previous damage assessment is reflective of worst case conditions, in particular as it relates to commercial indirect damages, Stampede indirect damages and infrastructure damage, especially at the higher flood frequencies. An alternative damage scenario has been developed which reduces damage in these categories.

Exhibit 3.19 describes the reduced total damage estimates. As evidenced, total damages for the Bow and Elbow Rivers for the 1:100 year event have been reduced from $1.815 billion to $1.237 billion with a concomitant reduction in average annual damage from $84,431,000 to $56,342,000. For the Elbow the average annual damage has been reduced from $30,111,000 to $21,729,000.

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

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** Flood Flow primarily contained within the river

1 Introduction

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1.1 Background

Flood damage estimates are required for evaluating the cost effectiveness of projects designed to alleviate flood impacts. Accordingly, in July of 2014 IBI Group along with Golder Associates Ltd. were retained by the Alberta Government, ESRD Operations, Resilience and Mitigation Branch to undertake the Provincial Flood Damage Assessment Study.

The purpose of the study was threefold:

1. to update/develop flood damage curves in select communities at risk of flooding to 2014 economic values and establish adjustment indices for their use in different flood prone communities across Alberta;
2. to develop a computerized model for estimating flood damages; and
3. to undertake flood damage estimates for select communities throughout Alberta.

The first two components of the Provincial Flood Damage Assessment Study have been completed and are available under separate cover. The City of Calgary was identified as a high priority centre and selected as the pilot municipality for the updating of flood damage curves and development of a Rapid Flood Damage Assessment Model. It is the subject of this study.

1.2 Purpose

The primary purpose of the study is to estimate flood damages for a range of flood events such that average annual damages can be computed and employed in a subsequent benefit/cost analysis of potential flood mitigation alternatives.

1.3 Scope

The study applies the Rapid Flood Damage Assessment Model to estimate damages using a variety of primary and secondary data sources including tax assessment records and GIS data.

2 Methodology

2 Methodology

To allow for a consistent approach to the evaluation of flood mitigation alternatives, the Province has adopted a standard methodology for flood damage assessment. It is briefly summarized hereinafter.

For a more detailed description of best practices, principles and guidelines refer to the Alberta Government Bulletin contained in **Appendix A**.

2.1 Preamble

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

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

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

In a first principles approach, damages for residential and commercial/industrial units are estimated employing the updated synthetic depth-damage curves developed for general usage in Alberta. On an ongoing basis, curves are indexed to current values employing Consumer Price, Household Expenditure, and Construction Cost Indices ratios that allow for the conversion of the original base year values to present day values.

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

Finally, and most importantly, flooding may represent a threat to human life and well-being, not only for those residing directly within the floodplain but also for those individuals who may work within the area as well as those volunteers and professionals who are involved in flood fighting activities (see **Exhibit 2.1**).

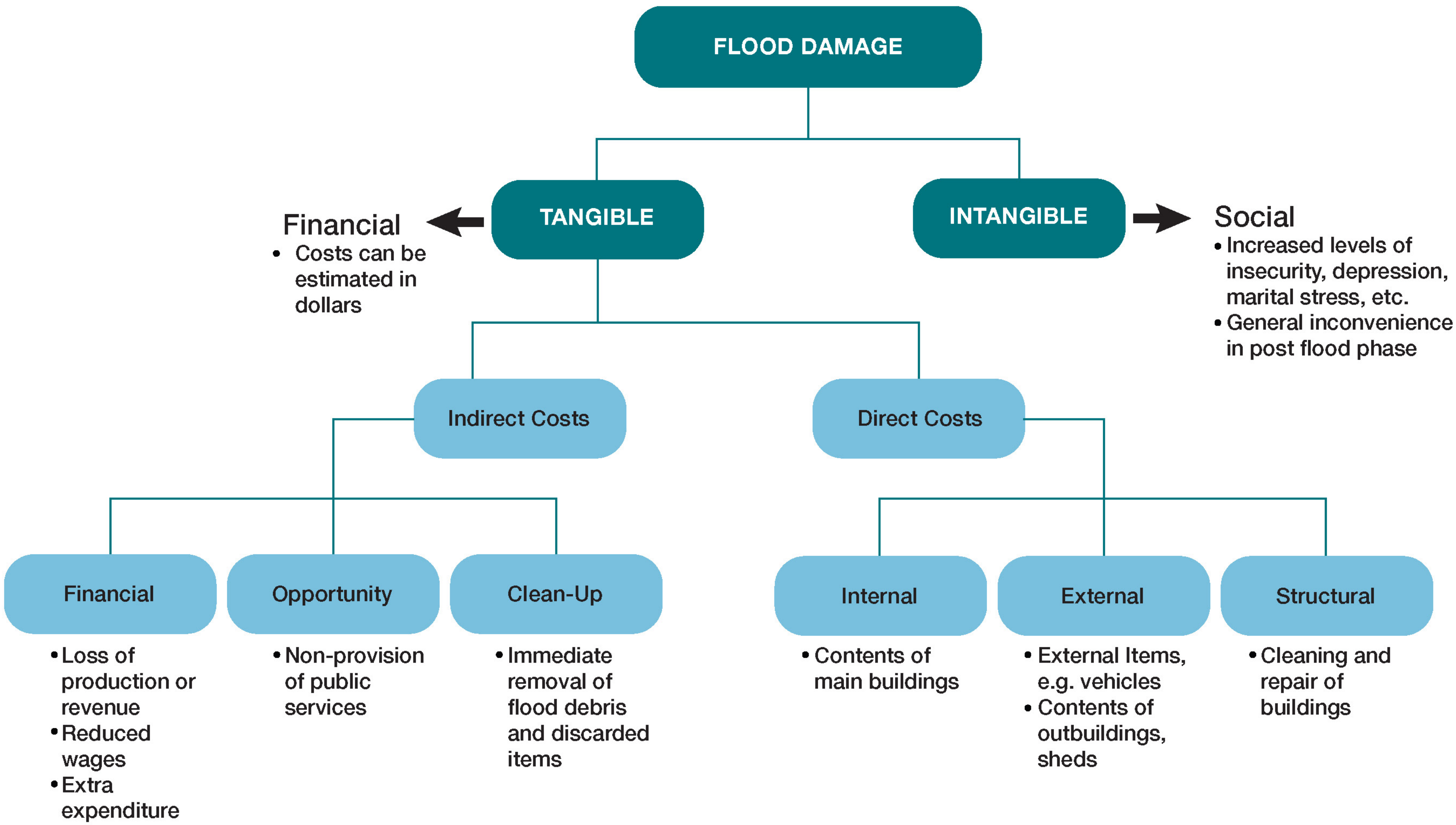
2.2 Flood Elevations

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

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

Unless otherwise specified, the primary source of flood elevation data is the ESRD River Forecast Centre (RFC).

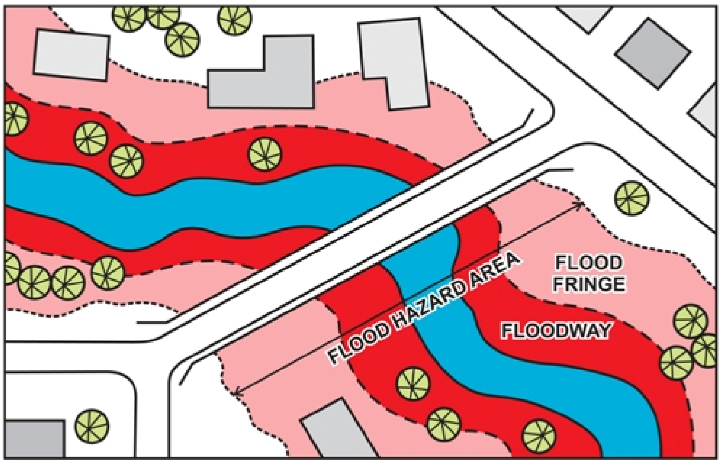
Types of Flood Damage



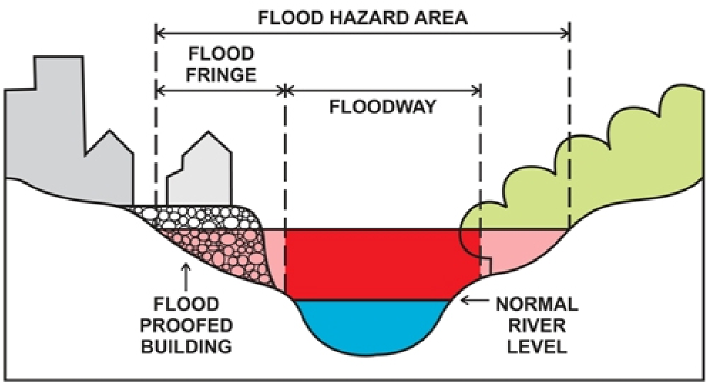
2.3 Floodway/Flood Fringe

The accompanying exhibits (see **Exhibit 2.2** and **2.3**) describe the criteria employed in defining the floodway/flood fringe and adjacent-to area. The floodway is typically defined as the area of deepest and fastest flows, with the flood fringe being that area within the overall floodplain which may suffer only shallow flooding and consequently may accommodate development with the provision that floodproofing measures are implemented.

Exhibit 2.2: Flood Hazard Area



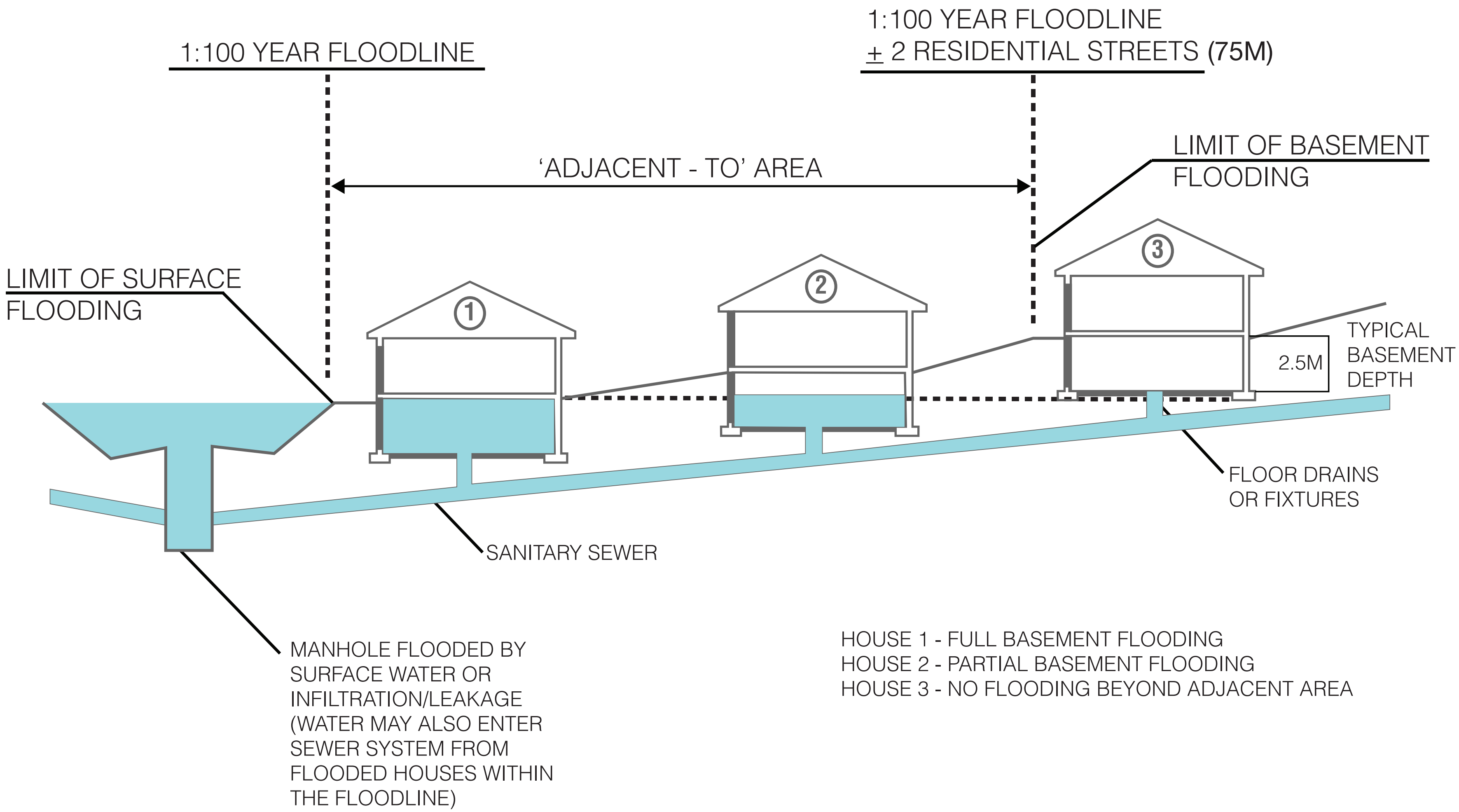
Cross-Section of Flood Hazard Area



2.4 Adjacent-To Areas

Areas outside the floodplain can be subjected to basement sewer backup flooding, primarily through seepage of floodwaters into the sanitary sewer system. To account for this potential flood damage, an adjacent-to area was delineated based on a distance of two dwelling units or ±75 m from the 1:100 year flood line. Essentially, with the sewer backup condition, basements with floor elevations lower than the floodwaters will automatically suffer damages. Exhibit 2.3 depicts this relationship.

Adjacent-To Area Definition Diagram



THE 'ADJACENT - TO' AREA IS THE AREA ADJOINING THE FLOODED SURFACE AREA IN WHICH BASEMENTS MAY BE FLOODED BY BACKED UP SANITARY SEWERS

2.5 Direct Damage Estimates

For the purposes of computing direct damage estimates for the study area all residential and commercial/industrial/institutional structures within the identified flood hazard area are inventoried and damages computed employing the Rapid Flood Damage Assessment Model developed specifically for Alberta.

Infrastructure damages (highways, bridges, railroads, utilities, etc.) are typically determined by the Municipality, or alternatively, a percentage of direct damage is applied to represent potential damages to infrastructure.

2.6 Indirect Damages

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

Indirect damages are best evaluated by developing a checklist of potential effects and methodically assessing each one. The checklist would logically include the amount of use and the duration of interruption of transportation and communication facilities, the number of workers and farmers depending on closed plants and the amount of business lost through a flood emergency. The magnitude of each effect may be estimated by interviewing those affected during recent floods and unit economic values may be assigned by market analysis. Finally, the results may be summed to render a total value for indirect damages.

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

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

The approach employed on the Provincial Flood Damage Assessment Study involved a review of the current situation within the flood study area, i.e., major transportation routes affected by flooding, percentage of industries and businesses affected by flooding, number of residences affected by flooding, and average duration of flooding event, and the application of the appropriate percentage to reflect the relative severity (high, medium or low) of the flood event. In the case of Calgary, for instance, a value of 323% was estimated for commercial indirect damage due to the unusually high concentration of economic activity and hence GDP creation in the flood hazard area.

2.6.1 Residential Indirect Damage

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

2.6.2 Commercial/Industrial Indirect Damage

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

2.6.3 Utilities Indirect Damage

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

2.6.4 Highways Indirect Damage

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

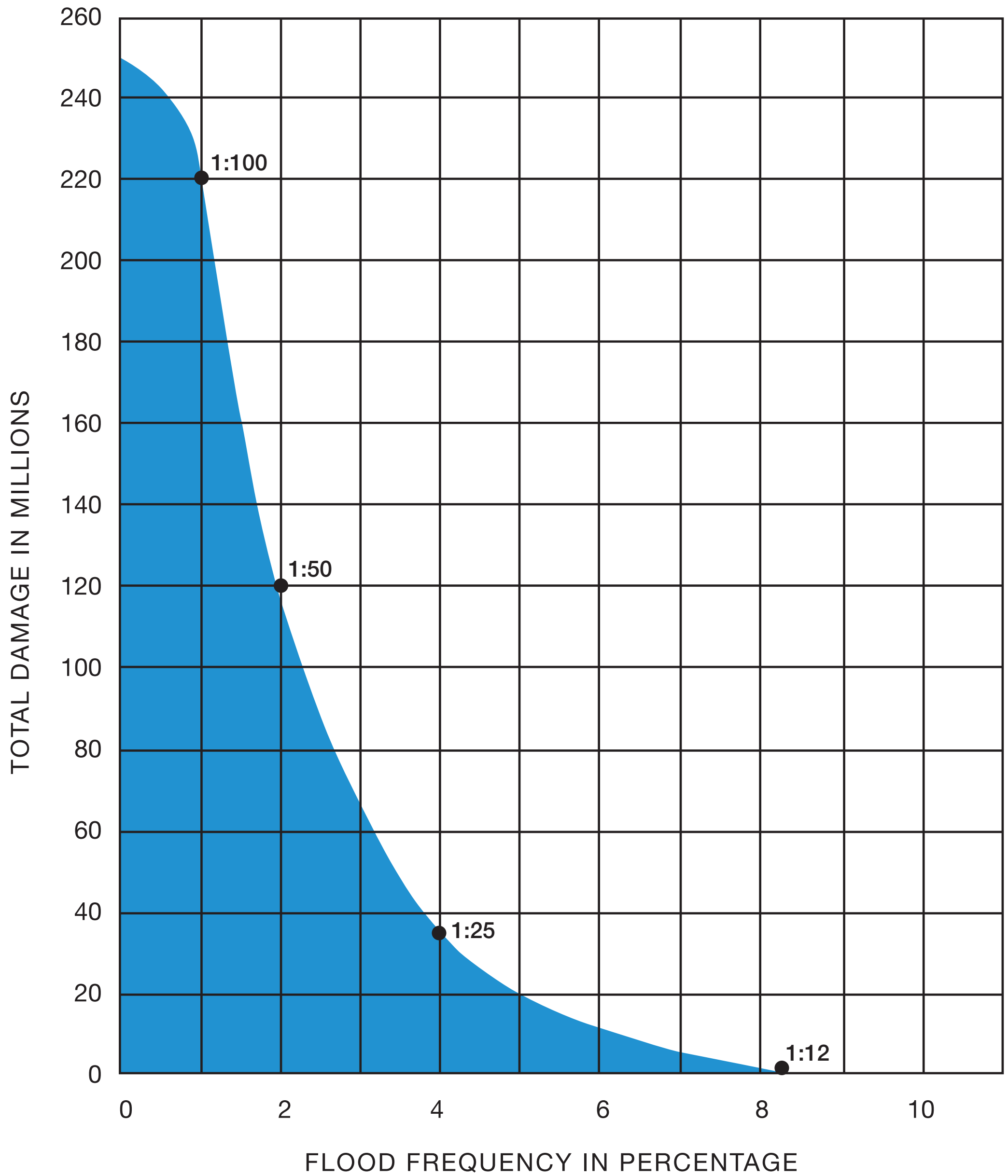
2.7 Total Damage Estimates

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

2.8 Average Annual Damages

Average annual damages are the cumulative damages occurring from various flood events over an extended period of time averaged for the same timeframe. The average annual damage is obtained by integrating the area under the damage-probability curve which depicts total damage versus probability of occurrence (see an example curve in **Exhibit 2.4**).

Example of Damage Probability Curve



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

AVERAGE ANNUAL DAMAGE = $5,750,000

3

Calgary

3 Calgary

3.1 Background

The City of Calgary is the largest city in Alberta and the third largest municipality and fifth largest Census Metropolitan Area (CMA) in Canada. It is situated at the confluence of the Bow River and the Elbow River in the southern part of the Province, in an area of foothills and prairie, approximately 80 km (50 miles) east of the front ranges of the Canadian Rockies.

According to the 2011 Census, the City of Calgary had a population of 1,096,833 residing in 423,417 of its 445,848 total dwellings. According to the City of Calgary 2014 Municipal Census the population was 1,195,194, a 3.3% increase over the 2013 Municipal Census population of 1,156,686.

The economy of Calgary includes activity in the energy, financial services, film and television, transportation and logistics, technology, manufacturing, aerospace, health and wellness, retail and tourism sectors. The Calgary CMA is home to the second-largest concentration of corporate head offices in Canada amongst the country's 800 largest corporations.

The City is large in geographic area, consisting of an inner-city surrounded by communities of various densities. Unlike most cities with a sizable metropolitan area, most of Calgary's suburbs are incorporated into the City proper.

Calgary experiences a dry humid continental climate (Köppen climate classification Dfb). Calgary averages more than 22 days per year with thunderstorms, with most all of them occurring in the summer months.

There are two major rivers that run through the City. The Bow River is the largest and flows from the west to the south. The Elbow River flows northwards from the south until it converges with the Bow River at the historic site of Fort Calgary near downtown.

3.2 Context

Exhibit 3.1 depicts the City in a provincial context and **Exhibit 3.2** in a regional context.

3.3 History of Flooding

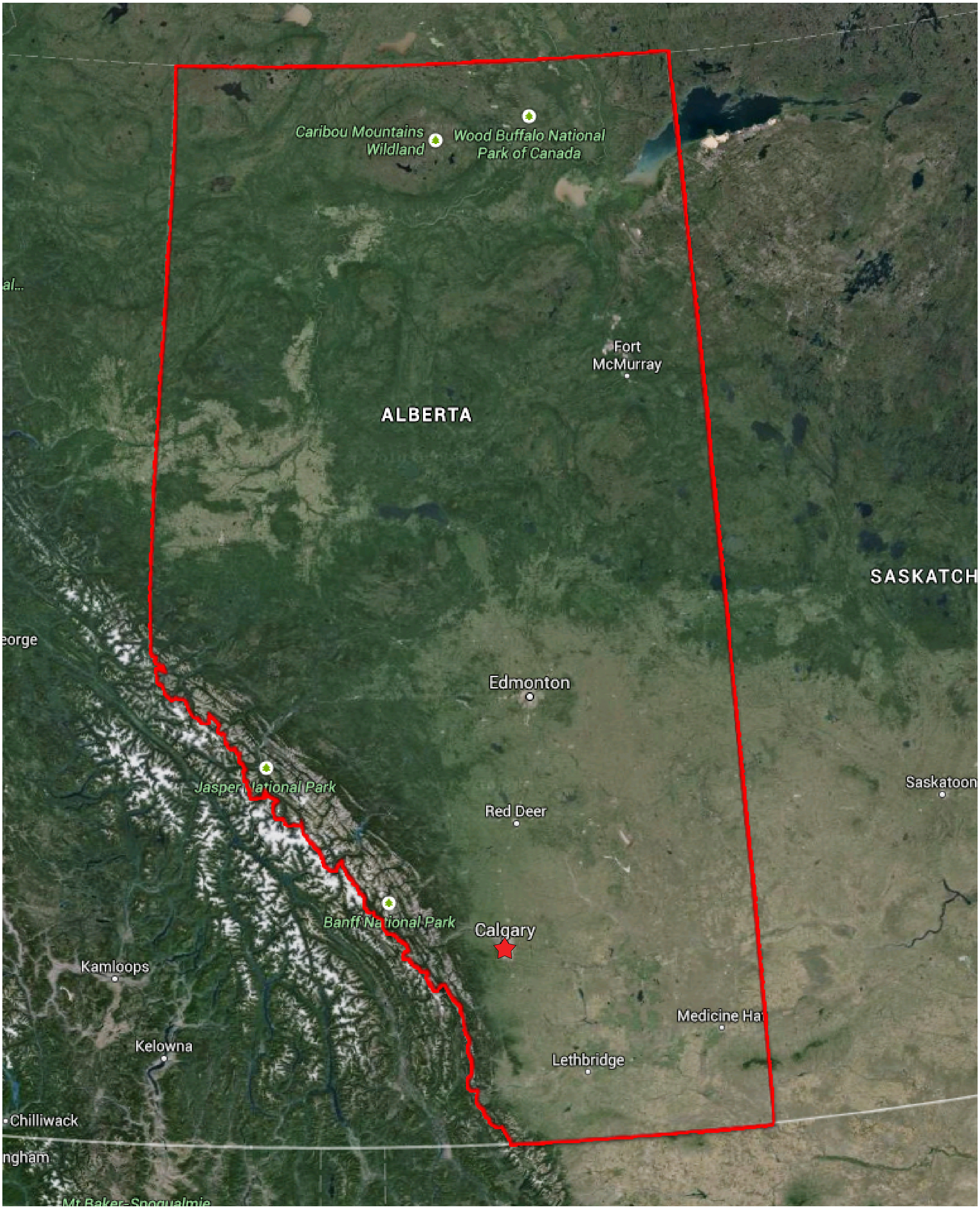
Major floods have occurred on the Bow River in 1902, 1915, 1929, 1932 and 2013. Major floods have occurred on the Elbow River in 1915, 1923, 1929, 1932, 2005 and 2013. These are traditionally summer floods caused by a combination of snowmelt and saturated ground conditions, in combination with heavy storms.

There is a continuous record from 1911 of Bow River flows at Calgary; the three largest known floods all occurred before 1911 – in 1879, 1897 and 1902. Reasonably reliable estimates are available for the floods of 1897 and 1902. The fourth-highest known flood at Calgary occurred in 1932. Due to the fortunate coincidence that the just-constructed Glenmore Reservoir, its reservoir still dry, stood in the path of that flood, the damage and disruption caused was much less than might have been expected.

The 2013 peak flows were recorded as follows:

- Elbow River above Glenmore Dam = 1,200 m^3/s
- Elbow River below Glenmore Dam = 700 m^3/s
- Bow River above the Elbow River confluence = 1,740 m^3/s
- Bow River below the Elbow River confluence = 2,450 m^3/s

Regional Context



Provincial Flood Damage Assessment Study

February 2015

EXHIBIT 3.1

Local Context

IBI | Golder Associates | Alberta Government

Provincial Flood Damage Assessment Study

February 2015

EXHIBIT 3.2

According to the 2014 Hydrology Update Report, the peak flows below the Glenmore Dam on the Elbow River approximate a 1:90 year return, with a similar return period for the Bow River both above and below the Elbow River confluence.

3.4 Floodplain Mapping

Exhibit 3.3 depicts the flood hazard area for the Bow and Elbow Rivers through the City of Calgary. Larger scale flood hazard mapping is contained in **Appendix B**. Nine flood elevations were employed to compute flood damages, including the 1:2, 1:5, 1:10, 1:15, 1:20, 1:50, 1:100, 1:200, 1:500, and 1:1000 year flood events. Flood elevation data was based on the hydraulic output of the HEC-RAS Model provided by the City of Calgary and based on the Bow and Elbow River updated hydraulic model project by Golder Associates dated April 2012.

Return flood elevations by zone and reach are detailed in the damage input/output files enclosed under separate cover.

3.5 Inventory of Buildings

Within the identified flood hazard area, which includes the 1:100 year design flood plus a 75 m buffer, the number of buildings totals approximately 7,200 (excluding outbuildings such as garages and storage sheds) and is comprised of 5,620 single-family residential dwellings; 728 semi-detached, triplex and townhouse-style dwelling units; 275 multi-family apartment buildings; and 564 non-residential (commercial/industrial/institutional) buildings.

3.6 Direct Damage Estimates

The flood damage estimates reflect total potential damages for the various return periods and do not consider any adjustments for structural or non-structural measures currently in place. The unadjusted values allow for the evaluation, including benefit/cost analyses, of both current and proposed mitigation options.

3.6.1 Residential Damages

Residential damages by return period are detailed in **Exhibit 3.4,** which expresses damages to both commercial and residential buildings with no sewer backup for the Elbow and Bow Rivers separately and for the entire flood hazard area.

Exhibit 3.5 expresses the same information but with the sewer backup condition which takes into consideration those units within the adjacent-to area that would suffer basement damage. As evidenced, under the sewer backup condition, 1:100 year damages within the flood study area equate to some $686.7 million. Residential damages along the Elbow River equate to $299.7 million or 44% of the total residential damages.

3.6.2 Commercial Damages

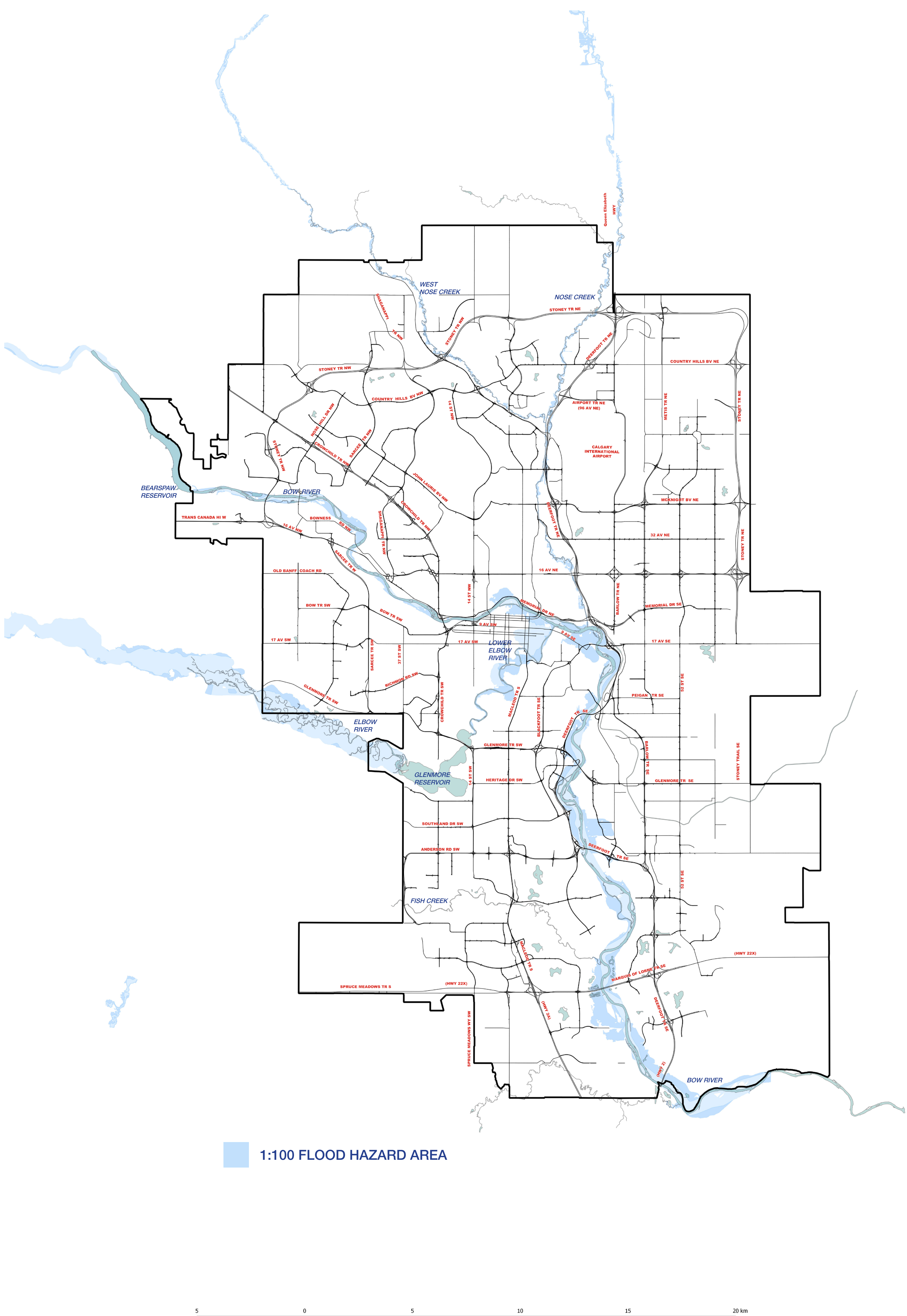
Total direct commercial damages for the entire study area for the 1:100 year flood are estimated at $111.0 million, with some $100.9 million or 91% within the Bow River flood hazard area.

Total commercial and residential building damage for the 1:100 year flood within the Bow and Elbow flood hazard areas equates to some $798 million.

3.6.3 Infrastructure Damages

Flood damages to City infrastructure were estimated by various City Departments based on the 2013 flood and total $372 million. Detailed costs by specific project are contained in **Appendix C** and summarized by category as follows:

Extent of Study Area - Flood Hazard Area



Damages to Commercial and Residential Buildings Without Sewer Backup

River basin	Land use	Return frequency, in years								
		2 *	5 *	10 **	20	50	100	200	500	1,000
Bow River	Low density residential	$0	$0	$0	$9,852,000	$57,562,000	$181,641,000	$353,261,000	$568,375,000	$669,010,000
	High density residential	$0	$0	$0	$25,974,000	$42,993,000	$65,954,000	$123,652,000	$222,294,000	$224,537,000
	Commercial	$0	$0	$0	$15,128,000	$36,965,000	$100,874,000	$256,774,000	$471,284,000	$539,790,000
	Total	$0	$0	$0	$50,955,000	$137,520,000	$348,468,000	$733,685,000	$1,261,953,000	$1,433,338,000
Elbow River	Low density residential	$0	$0	$0	$5,086,000	$43,971,000	$195,729,000	$279,587,000	$338,215,000	$408,261,000
	High density residential	$0	$0	$0	$6,937,000	$16,521,000	$33,440,000	$40,112,000	$48,753,000	$56,590,000
	Commercial	$0	$0	$0	$82,000	$481,000	$10,205,000	$15,216,000	$22,540,000	$32,817,000
	Total	$0	$0	$0	$12,104,000	$60,973,000	$239,375,000	$334,916,000	$409,507,000	$497,667,000
Bow and Elbow	Low density residential	$0	$0	$0	$14,938,000	$101,533,000	$377,370,000	$632,848,000	$906,590,000	$1,077,271,000
	High density residential	$0	$0	$0	$32,911,000	$59,514,000	$99,394,000	$163,764,000	$271,047,000	$281,127,000
	Commercial	$0	$0	$0	$15,210,000	$37,446,000	$111,079,000	$271,990,000	$493,824,000	$572,607,000
	Total	$0	$0	$0	$63,059,000	$198,493,000	$587,843,000	$1,068,601,000	$1,671,460,000	$1,931,005,000

* No actual damages occur at these flow levels
** Flood Flow primarily contained within the river

Damages to Commercial and Residential Buildings With Sewer Backup

River basin	Land use	Return frequency, in years								
		2 *	5 *	10 **	20	50	100	200	500	1,000
Bow River	Low density residential	$0	$0	$0	$141,764,000	$204,556,000	$321,121,000	$458,830,000	$668,941,000	$766,774,000
	High density residential	$0	$0	$0	$25,974,000	$42,993,000	$65,954,000	$123,652,000	$222,294,000	$224,537,000
	Commercial	$0	$0	$0	$15,128,000	$36,965,000	$100,874,000	$256,774,000	$471,284,000	$539,790,000
	Total	$0	$0	$0	$182,867,000	$284,515,000	$487,949,000	$839,255,000	$1,362,518,000	$1,531,101,000
Elbow River	Low density residential	$0	$0	$0	$94,078,000	$150,728,000	$266,276,000	$325,192,000	$389,213,000	$448,463,000
	High density residential	$0	$0	$0	$6,937,000	$16,521,000	$33,440,000	$40,112,000	$48,753,000	$56,590,000
	Commercial	$0	$0	$0	$82,000	$481,000	$10,205,000	$15,216,000	$22,540,000	$32,817,000
	Total	$0	$0	$0	$101,096,000	$167,730,000	$309,921,000	$380,520,000	$460,506,000	$537,870,000
Bow and Elbow	Low density residential	$0	$0	$0	$235,842,000	$355,284,000	$587,397,000	$784,022,000	$1,058,154,000	$1,215,237,000
	High density residential	$0	$0	$0	$32,911,000	$59,514,000	$99,394,000	$163,764,000	$271,047,000	$281,127,000
	Commercial	$0	$0	$0	$15,210,000	$37,446,000	$111,079,000	$271,990,000	$493,824,000	$572,607,000
	Total	$0	$0	$0	$283,963,000	$452,245,000	$797,870,000	$1,219,775,000	$1,823,024,000	$2,068,971,000

* No actual damages occur at these flow levels
** Flood Flow primarily contained within the river

- buildings: $114 million
- roads, bridges, other structures: $164 million
- utilities (sewer, water, stormwater): $48 million
- parks and open space: $46 million
- river clean-up: $1 million

Discounting damages to buildings, which have been estimated under direct commercial damages, these equate to $258 million.

The Calgary Municipal Land Corporation also reported infrastructure damages totalling $2.461 million which have been broken down as follows:

- East Village infrastructure: $227,000
- RiverWalk: $318,000
- 4th Street underpass: $1.916 million

It should be noted that these damages have been included under City infrastructure damages at a slightly higher cost of $2.6 million. For the purposes of this estimate, the higher figure will be retained and is included under the City infrastructure estimate.

See **Appendix D** for damage details relative to the Calgary Municipal Land Corporation assets.

Similarly, the Calgary Stampede reported infrastructure damage of $54 million. Discounting damages to buildings, which have been estimated under damages to Stampede Park, these equate to $24.5 million (see **Appendix E** for damage details). It should be noted that some $11.2 million are related to mitigation costs including the rebuilding of floodwalls, bridges, etc. Business interruption equated to some $785,000 or 1.5% of the total direct damage estimate.

Damages to other franchise utilities have been estimated as follows:

- Enmax $9.6 million
- Telus $7.0 million
- Shaw n/a (requested, but not available at time of writing of report)
- ATCO n/a (requested, but not available at time of writing of report)

Total infrastructure damages for the 2013 flood equate to $299.1 million.

3.6.4 Damages to Stampede Park

3.6.4.1 Introduction

Stampede Park, and in particular the associated annual Calgary Exhibition and Stampede, represents a unique circumstance as it relates to flood damage estimates, so much so that the previous study of the Elbow River treated Stampede Park as a standalone element in the assessment of overall flood damages.

3.6.4.2 Damage Assessment – 1986

The purpose of this component of the 1986 study was to assess the potential economic loss which would be caused by a 1:100 year flood at Stampede Park.

The flood risk period was identified as occurring between May 15 and September 15. As utilization of the park varies widely through the May to September flood hazard interval, three independent flood loss cases were examined:

- The first, or base case identified the potential economic loss suffered through flood damage to permanent structures and facilities, and through the impairment of ongoing operations and activities.
- The second case examined potential economic losses associated with the range of other events typical of the use of Stampede Park on an “average” (i.e., non-Stampede) spring or summer day.
- Finally, the third case specified those additional potential economic losses to facilities, operations and activities which would be associated with a flood during the 11 day period of the annual Calgary Exhibition and Stampede.

Thus, the three cases singly or in combination represented the range of economic losses which could be associated with a 1:100 flood of Stampede Park.

Content Depth-Damage Curves

Potential content damages were assessed by combination of a visual inspection of various premises, and discussions with senior management and day-to-day facilities’ users.

Structural Depth-Damage Curves

In conjunction with the content damage assessment, all available plans, elevations and cross sections of permanent structures and facilities were acquired. Qualified architectural personnel reviewed the various facility plans, and then verified the structural characteristics of the facilities through field inspections. The 44 buildings on site were categorized into five primary construction types based on construction classification, cost and use.

Damage estimates were based on the then-current City of Calgary costs for materials, labour and service. Structural damage and restoration cost estimates were also based on the characteristics of a 1:100 year flood event, assuming a 1.5 day recession period. The estimates also assumed virtually no damage to walls or slabs through hydrostatic pressure, as exterior forces were assumed to be balanced by water backup through drains and leakage through vents, etc.

Annual Stampede Depth-Damage Curves

Flood damage estimates were calculated by interviewing Stampede officials, and exhibitors, operators and owners of the numerous concessions and displays which constitute the exhibition. For selected high value or unique operations, every available operator was interviewed, while a sample of operators of specific types of facilities were interviewed. For example, 16 of 179 food concessionaires were interviewed with respect to flood damages.

Approximately 85 personal and telephone interviews were conducted to assemble the data required to estimate the flood damages associated with the Annual Stampede. A standard interview format was established to direct the data collection efforts.

Essentially, concessionaires were asked questions concerning: the structure that the concession was operated from (e.g., its dimensions, age, construction materials used, value); and the contents of the structure (e.g., equipment, furnishings, merchandise, total value and salvageability of these). In addition, the concessionaires were asked to estimate the extent of the damage that would occur to the structure and contents at incremental flood levels.

The various uses were classified by functional type and location as either inside or outside a permanent structure. Each standard curve was broadly applicable to a functional use, e.g., food services or shows. In total, six functional categories were identified; however, certain of these uses did not occur in both locations, hence 10 standard depth-damage curves were generated (4 common by function to both locations = 8 standard curves; and 1 specialized function to each location = 2 standard curves). Damage curves were also generated for specialized uses, such as mobile television studios, the Indian Village, etc.

Direct Damage Estimates

The accompanying exhibit (**Exhibit 3.6**) describes direct damages to Stampede Park by return flood for the three cases selected for analysis. Case 1, or the base case, identifies the potential economic losses suffered through flood damage to permanent structures and facilities and ongoing operations and activities. Case 2 details potential economic losses associated with a typical day at the Park exclusive of the Annual Exhibition and Stampede. Finally, Case 3 details the potential economic losses to facilities; operations and activities associated with the Annual Exhibition and Stampede. For the 1:100 year event damages range from $4.8 million for Case 1 to $12.6 million for Case 3. For the purposes of estimating direct damages for the overall study area it was decided to employ Case 2 as being most representative given the limited probability of a flood occurring within the eleven day Stampede period and the fact that with sufficient warning time and a well organized evacuation procedure, the Park could be cleared of all temporary uses with damages restricted to permanent structures and contents as per Case 1.

Exhibit 3.6: Stampede Park Potential Direct Damages by Return Flood in 1985 Dollars

	1:17 Year	1:20 Year	1:50 Year	1:100 Year
Case 1	$1,368,000	1,728,000	3,471,000	4,857,000
Case 2	$1,368,000	1,728,000	3,536,000	5,034,000
Case 3	$1,371,000	1,839,000	7,605,000	12,673,000

Indirect Damages

Indirect damages include items such as employment losses, administrative costs, loss of normal revenues, general inconvenience, etc., and are generally calculated as a percentage of direct damages. However, in the 1986 analysis, it was possible to employ centralized accounting records for the Park as a whole in order to more accurately estimate indirect damages.

Financial statements for the years 1983 and 1984 were examined and relevant line items were averaged between the two years in order to reduce the effect of year-to-year fluctuations. Discussions with the Controller indicated that these results were expected to closely parallel the 1985 operating year results. At that time, during the course of the Stampede, the principal source of revenue was gate admissions, followed by midway-generated revenue, grandstand revenue, and rodeo revenue. Horse racing did not take place at the Park during Stampede.

Revenues which accrue to facility users and concessionaires were additional to the gross revenue realized by the Calgary Exhibition and Stampede. The additional revenues were conservatively estimated to be equivalent to 300% of the total revenue generated by the rental of Park facilities. Thus, indirect damages to facility users and concessionaires were accounted for in the 1986 estimates.

In summary, the estimated average daily indirect damages which would have been suffered as a result of the complete closure of the Park during the course of the Stampede were as follows:

Exhibit 3.7: Stampede Park Average Daily Indirect Damages Related to Annual Exhibition and Stampede

Item	Damage Estimate
Gate	$234,100
Midway	903,700
Grandstand	165,000
Rodeo	121,000
Casino	114,600
Lotteries	370,900
Independent Midway	185,600
Saddledome	72,600
Indoor Exhibits	103,800
Food Fair	61,700
Skyride	9,400
Daily Total	**$2,342,400**

As an illustration of the relative scope of indirect damage, a total (10 day) loss of $23,400,000 is equivalent to 185% of the estimated direct damages in the Case 3 1:100 year event.

3.6.4.3 Stampede Park Flood Damages – 2014

The Calgary Stampede and Exhibition reported infrastructure damage of $54 million, with damages to actual infrastructure equating to $24.5 million and the remaining damage to buildings and contents (excluding the Saddledome) constituting $29.5 million. The flood at that location approximated a 1:100 year event.

The Saddledome was flooded to the roof of the event level, corresponding to Row 10 in the arena section. The Calgary Flames Organization reported resulting direct damages to the Saddledome structure of $26.9 million; damages to contents totaled $11.2 million including some $4.0 million in damages to electronic equipment. The salvage value for contents was virtually zero, and it proved necessary to arrange secure disposal of contaminated memorabilia to prevent unauthorized and potentially hazardous re-use of those items. Indirect damages totalled $4.4 million as the Saddledome was closed for 74 otherwise available revenue days while repairs were completed; this was the net indirect loss, as it was possible to reschedule some events.

The reported 2013 damages have been employed to adjust the combined Stampede Park stage-damage curves and indirect damages to 2014$ values. This adjustment was calculated by factoring up the 1985 damage amounts for the other flood return periods in proportion to the observed difference for the 1:100 year event. This adjustment accounts for the changes to the building environment at the park since 1985 (e.g., addition of the Casino and BMO Centre, removal and replacement of barns, etc.). It also accounts for the increased intensity of use – and thus increased indirect damages.

Total Direct Damages

Estimated total direct damages for Stampede Park by return period are detailed in **Exhibit 3.8** with the Case 3 assumptions, assuming the flood event occurs prior to the annual Stampede and Exhibition, causing its cancellation. This worst case indirect damage estimate assumes that the entire 10 day event is lost.

Exhibit 3.8: Stampede Park Potential Direct Damages by Return Flood in 2014 Dollars

	1:17 Year	1:20 Year	1:50 Year	1:100 Year	1:200 Year
Case 3	$7,600,000	$10,200,000	$42,200,000	$68,900,000	$91,900,000

Indirect Damages

Estimated total indirect damages for Stampede Park by return period are detailed in **Exhibit 3.9** for Case 3. The indirect damages are estimated as a percentage of direct damages, reflecting the 2013 event experience.

Exhibit 3.9: Stampede Park Potential Indirect Damages by Return Flood in 2014 Dollars

	1:17 Year	1:20 Year	1:50 Year	1:100 Year	1:200 Year
Case 3	$14,100,000	$18,900,000	$78,000,000	$127,400,000	$169,900,000

Total Damages

Estimated total direct and indirect damages for Stampede Park by return period are detailed in **Exhibit 3.10** for Case 3.

Exhibit 3.10: Stampede Park Potential Total Damages by Return Flood in 2014 Dollars

	1:17 Year	1:20 Year	1:50 Year	1:100 Year	1:200 Year
Case 3	$21,700,000	$29,100,000	$120,200,000	$196,300,000	$261,800,000

3.6.5 Indirect Damage Estimates

3.6.5.1 Commercial Indirect Damages

Lost Hours Worked and GDP

Following the June 2013 flooding in Southern Alberta, Statistics Canada conducted a special Labour Force Survey that included questions about the impact of the flood on hours worked. They found that a total of 5.1 million hours were lost in Alberta. This survey collected data for only the last two weeks of June. Many additional hours were spent as a result of the flood, however all industries except utilities and public administration experienced a net loss during those two weeks.

The Calgary portion of lost hours in June 2013 provides a basis for estimating economic losses that would be experienced (without substitution) in the city at a 1:100 year flood. An estimate of lost GDP can be made using each industry's labour productivity amount multiplied by the industry's lost hours.

Labour productivity data for Alberta in 2013 is the latest available at this time. Real productivity is expressed in chained 2007 dollars. Productivity is not measured for the public sector and no associated losses have been included. To express the total in 2014 dollars, the average of the implicit price deflator for the first three quarters of 2014 is used. The implicit price deflator is equal to current dollar output divided by real output.

Exhibit 3.11: Estimated Lost Work Hours, Labour Productivity, and Real GDP Lost for 1:100 Year Flood in Calgary

Industry	Estimated Hours Lost	2013 Real GDP/Hr	Real GDP Lost
Agriculture	2,900	$44.30	$128,470
Forestry, fishing, mining, quarrying, oil and gas	738,000	$260.30	$192,101,400
Utilities	-18,400	$182.60	-$3,359,840
Construction	263,500	$46.60	$12,279,100
Manufacturing	208,100	$61.70	$12,839,770
Trade	69,700	$42.67	$2,974,099
Transportation and warehousing	86,600	$56.10	$4,858,260
Finance, insurance, real estate and leasing	314,300	$113.75	$35,751,625
Professional, scientific and technical services	758,400	$52.60	$39,891,840
Business, building and other support services	220,900	$32.70	$7,223,430
Information, culture and recreation	129,300	$82.70	$10,693,110
Accommodation and food services	121,300	$23.30	$2,826,290
Other services	78,400	$33.60	$2,634,240
		Total (2007 dollars)	$320,841,794
		Total (2014 dollars)	**$359,070,600**

Commercial Indirect Damages as a Percentage of Commercial Direct Damages

According to this estimate, lost GDP resulting from a 1:100 year flood would total $359 million dollars. Assuming total lost GDP is an appropriate estimate of commercial indirect damages, this equates to 323% of direct damages. This amount of commercial indirect damages in Calgary is exceptionally high in relation to direct damages; the primary reason is the concentration of high production value employment in commercial towers in the downtown core. The direct damage to the main and sub-grade levels of an office building is typically far less than the value of the sum of lost hours on all floors due to the building being closed.

3.6.5.2 Residential Indirect Damages

Evacuations

During a flood event, neighbourhoods are evacuated due to the risk of rising floodwater, the loss of essential services, and the loss of safe access. Therefore, evacuation includes homes that are not directly flooded. Between June 20 and 23, 2013, approximately 75,000 Calgarians were evacuated from their homes. Many of these residents would have incurred expenses from being unable to return to their homes during the flood. Assuming an average extra expense of $100 per person over a 48 hour period, this would amount to $7.5 million in indirect damages.

In addition to evacuated homes, the evacuation of institutions will incur expenses for residents within and beyond the flood affected areas. Patients of hospitals and residents of senior citizen homes may require additional and costly support. Children in affected schools and daycare facilities will require alternative care. During the 2013 floods, all Calgary schools were closed and Diploma Examinations were cancelled.

Further evacuations can also be expected due to hazards created during or after a flood. For example, flood evacuations were ordered downstream of the Bonnybrook bridge after a flood-damaged piling collapsed, causing a train carrying hazardous petrochemicals to derail.

Temporary Accommodation Costs for Flooded Buildings

After a flood event, residents of buildings directly impacted will require alternative accommodation for a period dependent on the amount of damage to their homes. At a 1:100 year flood level in Calgary, there is an estimated 6,600 residential dwelling units in affected buildings. The following assumptions have been made to estimate accommodation costs:

- Residents of structures suffering only sewer backup do not require alternative accommodation.
- Residents of single and attached homes with basement flooding will be displaced for an average of one week.
- Residents of single and attached homes with main floor flooding will be displaced for an average of three months.
- All residents of a flooded apartment building will be displaced for an average of one week.
- Residents of an apartment unit directly flooded will be displaced for an average of three months.
- 50% of all displaced households will find accommodation with friends or family.
- All households requiring other accommodation will stay in a hotel for the first week.
- Households requiring accommodation for longer than one week will find rental apartments.
- The average hotel room rate in Calgary is $168 (*Alberta Accommodation Outlook 2014*).
- The average apartment rental rate in Calgary is $1,290 (*CMHC Rental Market Report, Spring 2014*).
- Displaced residents will spend an average of $50 per person per day for meals and incidentals during the week spent at a hotel.
- Single-family houses have an average of 3 occupants and apartments have 1.7 (*The City of Calgary 2014 Census*). The weighted average of flooded units is 2.056 occupants.

Exhibit 3.12 indicates the temporary accommodation costs according to the assumptions listed above.

Exhibit 3.12: Temporary Accommodation Costs

Number of Days Displaced	Number of Households	Daily Accommodation Cost	Daily Incidental Cost	Total Cost
7	3300	$168	$103	$6,255,000
90	929	$43	n/a	$3,595,000
			Total	**$9,850,000**

Loss of Public Services

During and after a flood event, there is significant disruption to public services that adds to the indirect damages incurred by residents.

Damage to or temporary closure of social service facilities such as shelters, food banks, counselling, addiction treatment, etc. has a significant impact on residents who depend on these services.

A large portion of the City's parks, pathways, and other recreation facilities are located adjacent to the rivers. Damage to these amenities during the summer months would result in the cancellation of many community events. During the 2013 floods, 30 Calgary parks were flooded and major events such as Aboriginal Awareness Week, MEC Paddlefest, Park Market, and Sled Island Music Festival were cancelled.

Disruption of transit routes impacts residents throughout the city. A major flood would require cancellation of LRT service in the city centre, severing connections between city quadrants. Alternative transportation expenses could be significant to those who rely on the service. Closure of roadways causes major congestion on alternative routes with traffic delays costing residents significant amounts of time.

Flood Fighting and Clean Up

Neighbours and other volunteers perform a large part of residential flood preparation, fighting, and clean up. After the 2013 floods, thousands of Calgarians assisted homeowners in cleaning up. Some volunteers are organized through agencies such as Samaritans Purse while others were self-organized, bringing their own supplies.

Trauma, Stress, and Anxiety

Research into the effects of severe flooding on residents has shown that the physical and mental health impacts are serious. People who suffered flooding even regard the intangible effects of flooding to be higher than their direct material damage. Intangible effects include loss of memorabilia, psychological stress during the flood and during recovery, where discussions with insurance companies are specifically mentioned.[1]

Residential Indirect Damages as a Percentage of Commercial Direct Damages

Given the aforementioned, a value of 15% was selected for residential indirect damages.

3.6.5.3 Stampede Indirect Damages

Stampede indirect damaged have been calculated at 185% of direct damages.

3.6.5.4 Infrastructure Indirect Damages

Infrastructure indirect damages were estimated at 20% of direct damages.

3.6.6 Total Damages

Total flood damages for each of the return floods have been estimated for the entire study area. These damages include direct damage to residential, commercial/industrial/institutional, infrastructure, Stampede Park, as well as indirect damages. The results are summarized in **Exhibits 3.13 through 3.15.** As evidenced, total damages on the Bow and Elbow Rivers with sewer backup equate to some $1.8 billion for the 1:100 year flood event, increasing to $3 billion for the 1:200 year event and $5.6 billion for the 1:1000 year event.

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[1] Zevenbergen et al., *Urban Flood Management* Leiden: CRC Press, 2011.

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 Actual damages occur at these flow levels
** Flood Flow primarily contained within the river

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 Actual damages occur at these flow levels
** Flood Flow primarily contained within the river

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 Actual damages occur at these flow levels
** Flood Flow primarily contained within the river

The Bow River accounts for approximately 59% of the total damages under a 1:100 year flood. Indirect damages by themselves constitute some $649 million or 56% under 1:100 year flood conditions. (Indirect damages equate to a higher proportion of direct damages for the lower frequency floods; the unweighted average indirect share is 73% across the range of events.)

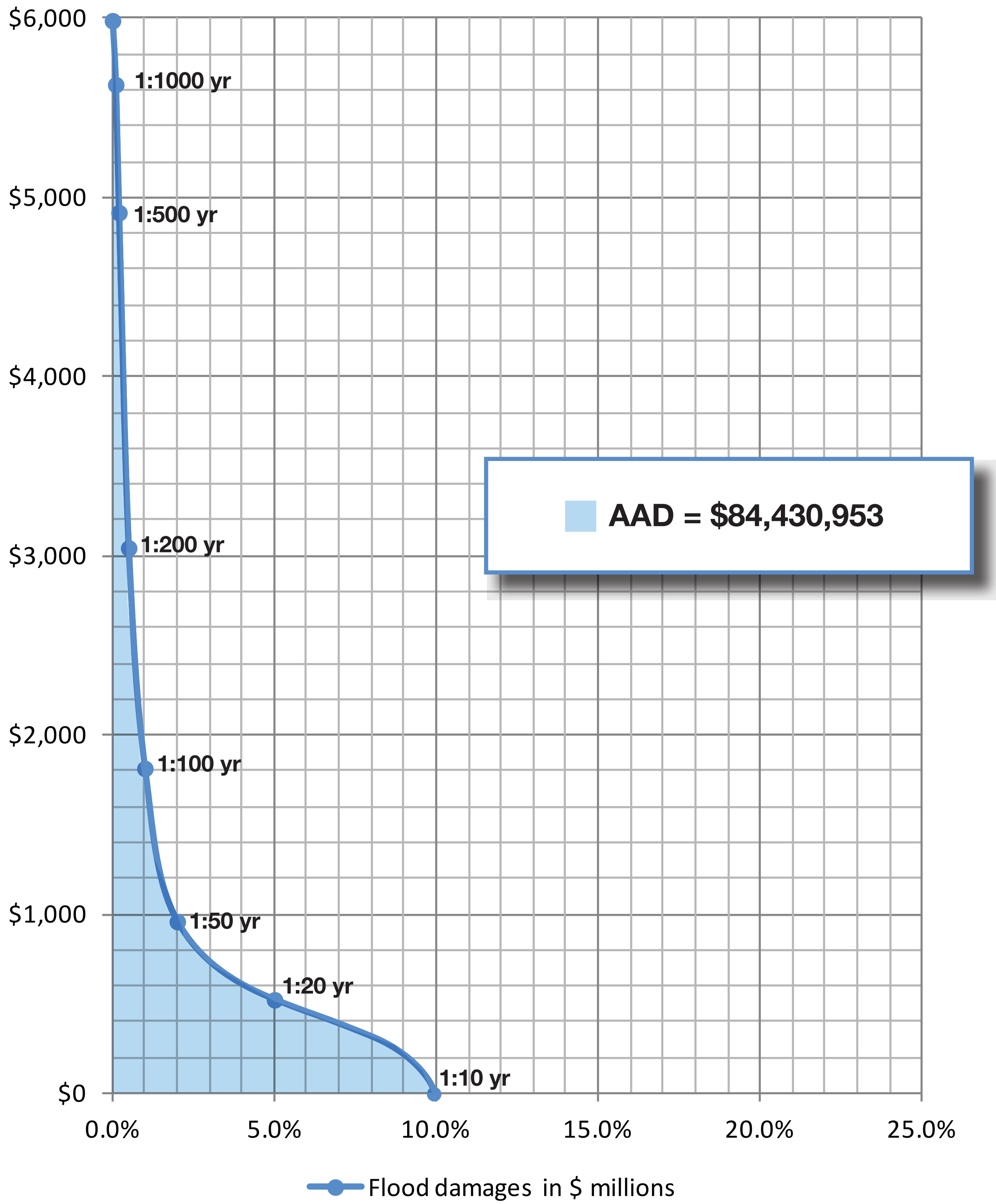
3.6.7 Average Annual Damages

Average annual damages are the cumulative damages occurring from various flood events over an extended period of time averaged for the same timeframe. The average annual damages are obtained by integrating the area under the damage-probability curve which depicts total damage versus probability of occurrence and is illustrated for the entire study area in **Exhibit 3.16**. The average annual damage for the study area is estimated at $84,431,000.

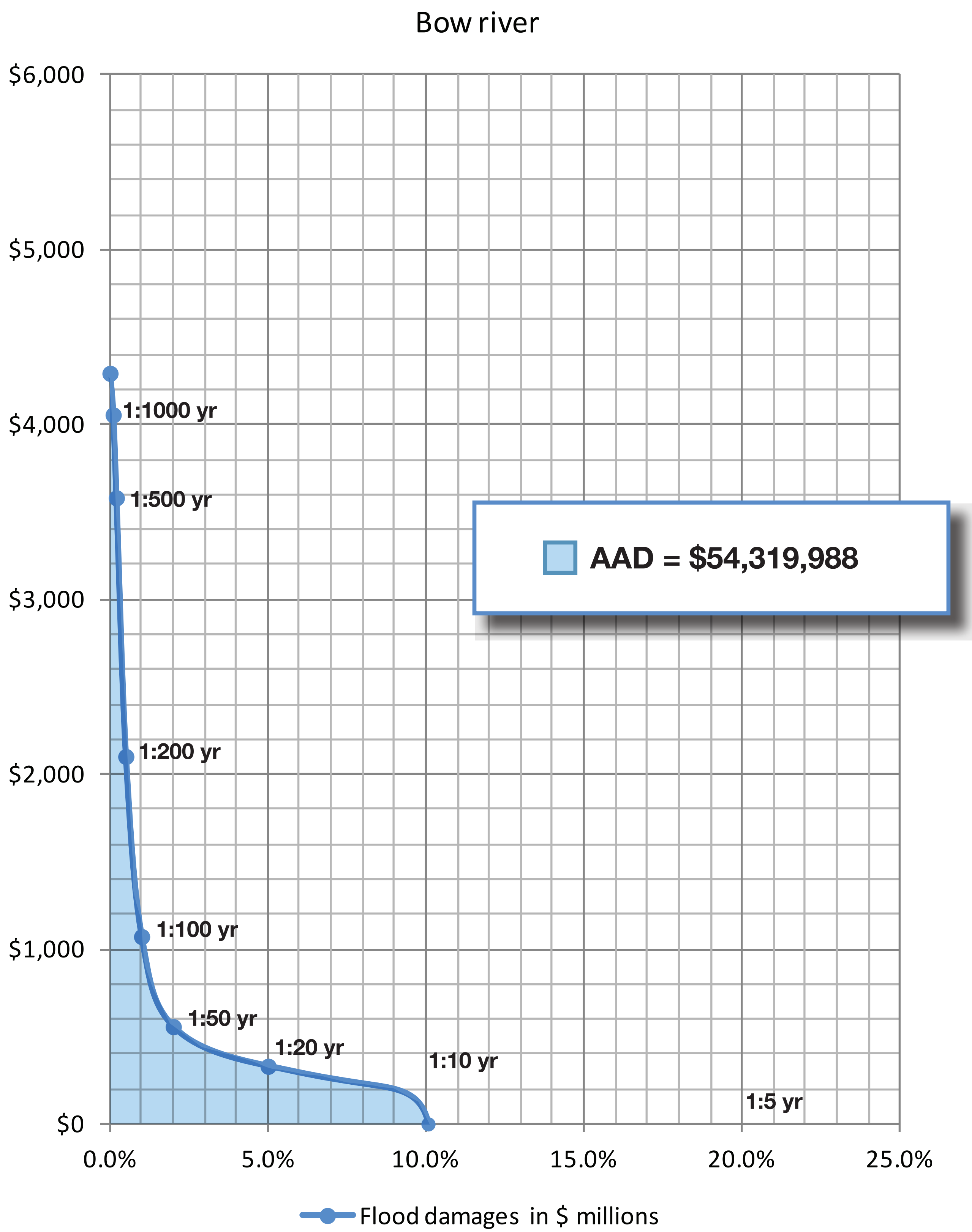
The average annual damage for the Bow River is $54,320,000 (see **Exhibit 3.17**). For the Elbow River flood hazard area the average annual damage is $30,111,000 (see **Exhibit 3.18**).

In terms of average annual damage, two damage scenarios were computed: (1) basement flooding only occurs when flood elevation exceeds grade elevation; and (2) basement flooding occurs when flood elevation exceeds basement floor elevation referred to as "sewer backup" condition. The average annual damage estimation is extremely sensitive to damages occurring at the frequent flood events. Assuming that all basements are flooded from sewer backup for the 1:10 year flood would skew the ADD results by a third. Since basement flooding has been historically minor at that flow event, basement flood damages below the 1:10 year event were not used to calculate average annual damage. By selecting the sewer backup condition for the other return periods, the results are quite conservative and erring on the high side of damages.

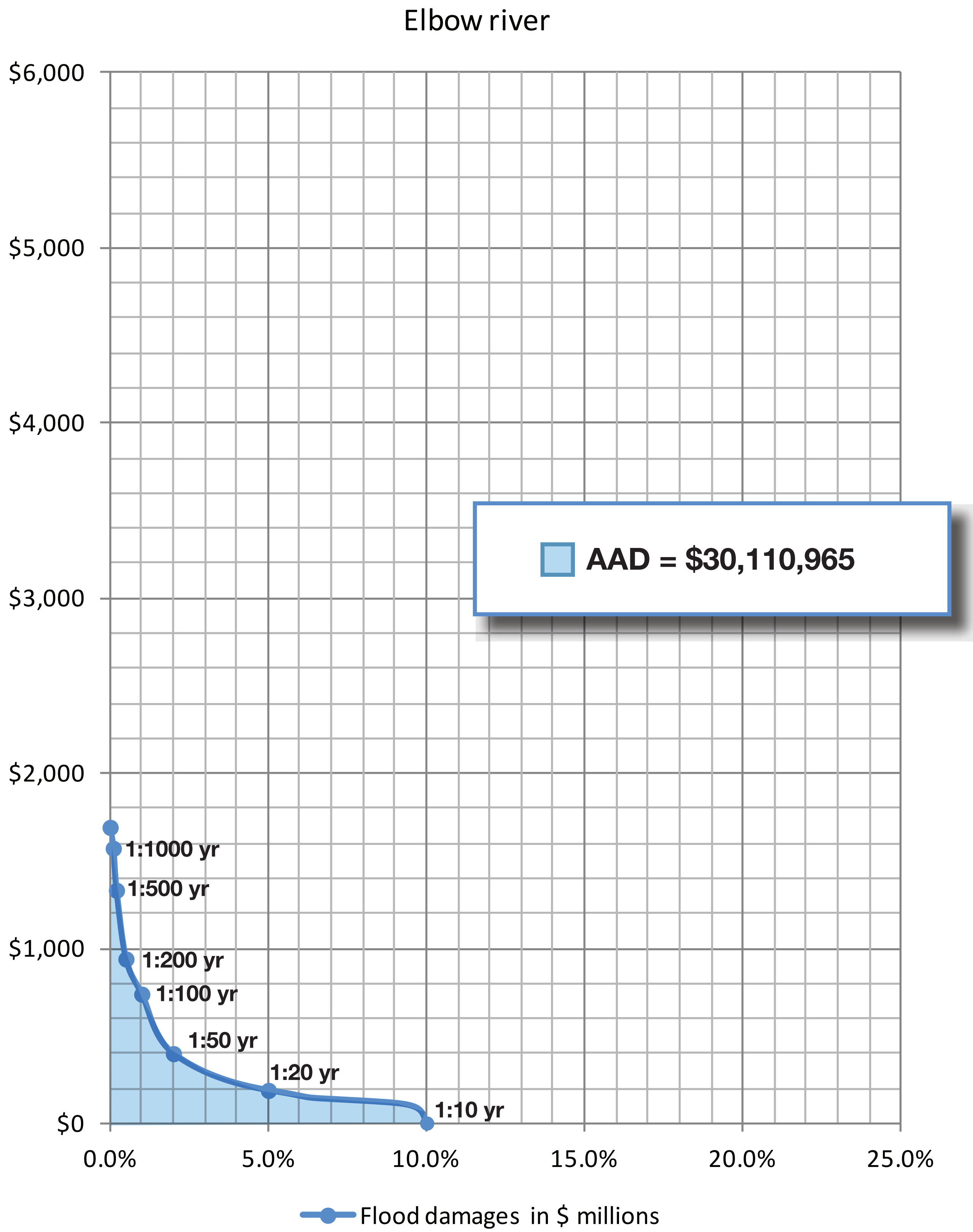
Flood Damages Probability Distribution, Bow and Elbow Rivers



Flood Damages Probability Distribution, Bow River



Flood Damages Probability Distribution, Elbow River



3.6.8 Alternative Damage Scenario

The previous damage assessment is reflective of worst case conditions, in particular as it relates to commercial indirect damages, Stampede indirect damages, and infrastructure damage, especially at the higher flood frequencies. An alternative damage scenario has been developed which reduces damage in these categories:

1. Commercial Indirect Damages – These costs were provided by the Conference Board of Canada and were based on a survey of productivity loss for a two week period immediately following the 2013 flood. This estimate of GDP loss did not account for post-flood economic recovery (substitution over time) nor geographic substitution of economic activity. For these reasons, the alternative damage scenario employed the more typical commercial indirect damage factor, in this case in the higher end of the range (45% versus 323%). Damages were also adjusted for the higher frequency events to reflect a greatly reduced impact on commercial operations, especially in the downtown.
2. Stampede Indirect Damages – These damages were based on the complete loss of the 10 day annual Calgary Exhibition and Stampede revenues, and while this loss could be experienced, depending upon the timing of the flood, the alternative scenario considers a more typical potential revenue loss during the non-Stampede timeframe. Accordingly, the indirect damage factor was reduced from 185% to 38%.
3. Infrastructure Damage – These damages were based on the City of Calgary's municipal infrastructure recovery list, but also include costs for mitigation projects that were implemented to prevent or ameliorate future damages. Infrastructure damage was adjusted to reflect a more typical percentage of other direct damages (residential and commercial). In addition, damages at higher frequencies were reduced to characterize anticipated losses at lower flow rates.

Exhibits 3.19 through **3.24** describe the reduced total damage and average annual damage estimates. Total damages for the Bow and Elbow Rivers for the 1:100 year event have been reduced from $1.815 billion to $1.237 billion with a concomitant reduction in average annual damage from $84,431,000 to $56,342,000. The average annual damage for the Elbow River is reduced from $30,111,000 to $21,729,000.

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 Actual damages occur at these flow levels
** 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

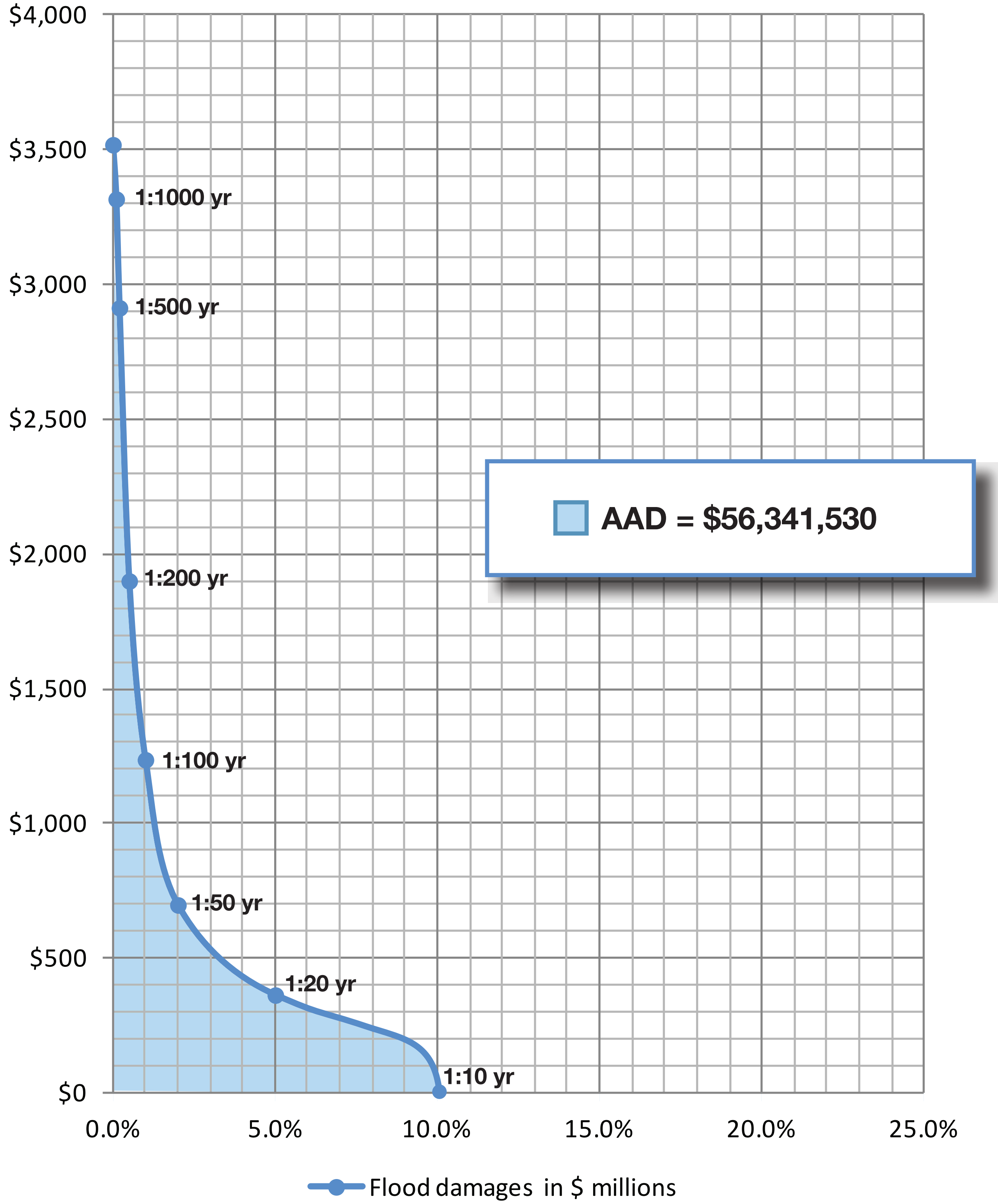
* No Actual damages occur at these flow levels
** Flood Flow primarily contained within the river

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

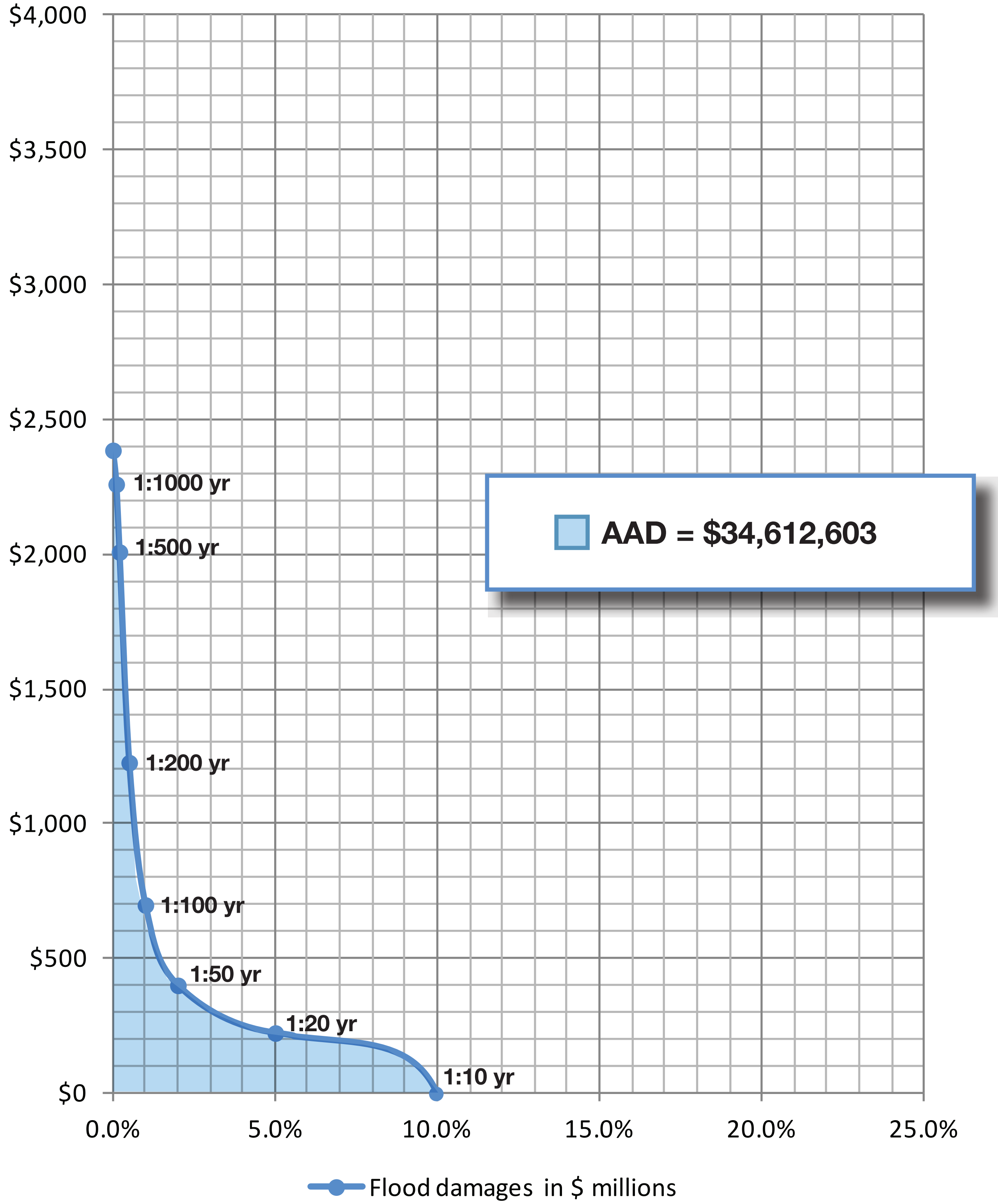
Categories of damage		Return frequency, in years								
		2 *	5 *	10 **	20	50	100	200	500	1,000
Residential	Direct	$0	$0	$0	$101,015,000	$167,249,000	$299,716,000	$365,304,000	$437,966,000	$505,053,000
	Indirect 15%	$0	$0	$0	$15,152,000	$25,087,000	$44,957,000	$54,796,000	$65,695,000	$75,758,000
	Total	$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 Actual damages occur at these flow levels
** Flood Flow primarily contained within the river

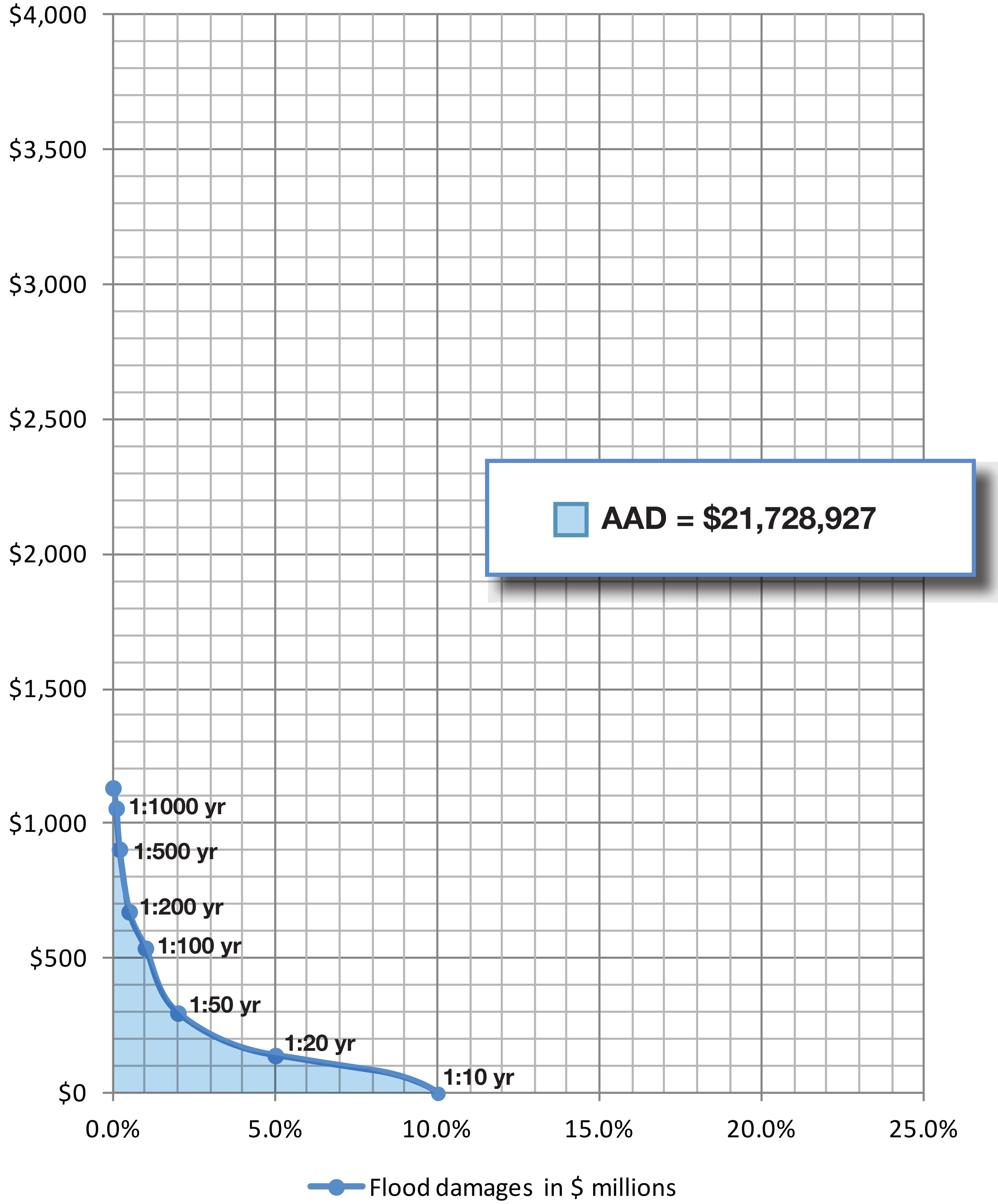
Alternative Damage Scenario - Flood Damages Probability Distribution, Bow and Elbow Rivers



Alternative Damage Scenario - Flood Damages Probability Distribution, Bow River



Alternative Damage Scenario - Flood Damages Probability Distribution, Elbow River



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Memorandum

To/Attention	Sandra Davis	**Date**	September 29, 2020
From	David Sol	**Project No**	119424
cc			
Subject	City of Calgary - Flood Scenarios 2 (Baseline, Full, SR1)		

Introduction

Background

In February 2017, IBI Group and Golder Associates completed the Flood Mitigation Options Assessment study for the City of Calgary (the 2017 study)[1]. The 2017 study included an update to the Government of Alberta's 2014 Provincial Flood Damage Assessment Tool[2] to incorporate the most up-to-date hydrology as well as social and environmental costs of flooding into the damage model. A groundwater model was also created to account for damages that occur due to groundwater infiltration or sewer backup that can occur in areas adjacent to surface flooding.

The 2017 study used the updated flood damage model to assess the flood risk in Calgary with and without mitigation. The mitigation options considered included watershed-level structural measures (such as reservoirs), community-level structural mitigation (such as flood barriers), and non-structural property-level measures (such as land use policy and flood-proofing buildings). These measures were combined into 13 flood mitigation scenarios. A protection level to the 1:200 flood was selected for the scenarios.

The flood damage model produced damage estimates for each of the 12 modeled flood events (1:5 to 1:1000 floods) for each scenario. Using the event probabilities corresponding damage estimates, the cost can be expressed as Average Annual Damages (AAD). The difference between the AAD with and without the mitigation is the annual damages averted for the scenario. This constitutes the benefit side of a benefit/cost analysis. In addition to the damages averted and benefit cost results, each of the mitigation scenarios were also scored for other factors including social, environmental, implementation, and economic objectives.

Purpose

After completion of the 2017 study, The City continued to develop and revise mitigation scenarios including new permanent and temporary barrier heights and alignments, and operations of existing reservoirs. IBI Group and Golder Associates were requested to assess a

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1 For more information on the Flood Mitigation Measures Assessment, visit http://www.calgary.ca/UEP/Water/Pages/Flood-Info/Stay-informed/Flood-Mitigation-Measures-Assessment.aspx A copy of the full report is available at https://cityonline.calgary.ca/Pages/Product.aspx?category=&cat=&id=8092-12527-14294-00002-P

2 Provincial Flood Damage Assessment: https://open.alberta.ca/publications/7032365

set of new or updated scenarios using the modeling and damage estimation method employed for the 2017 study.

Scope

The scope of this assessment is as follows:

- Create flood inundation surfaces, including groundwater, for each of the scenarios using the same modeling methods as the 2017 study;
- Calculate estimated damages for each scenario, including AAD; and
- Provide damage result data for each scenario and a summary memo.

Scenario Definitions

This memo contains the results from three scenarios as outlined below.

2019-03: Updated Baseline

This scenario is intended to provide the baseline damages from the current status with no upstream storage, existing barriers, and current flow operations. It includes:

- downtown barrier with a 2,390 cms level of protection;
- Glenmore Dam gates; and
- current operating agreement with TransAlta.
- Temporary barriers are not included.

2019-01: Full flood resilience plan

This scenario is intended to illustrate the benefits and residual damages with the current plan fully implemented. It includes:

- new reservoir on the Bow River with optimized peak reduction, keeping flows through Calgary as low as possible;
- Springbank off-stream reservoir on the Elbow River;
- Bowness barrier with a 1,230 cms level of protection;
- Sunnyside barrier with a 1,230 cms level of protection;
- downtown barrier with a 2,390 cms level of protection; and
- Glenmore Dam gates.
- Temporary barriers are not included.

2019-02: SR1

The scenario is intended to illustrate the benefits of the Springbank off-stream reservoir alone. To do so, the scenario includes all the mitigation in the full flood resilience plan (2019-01) except for SR1. The difference between the two is assumed to represent the benefits of SR1.

Damage Calculations

As completed for the scenarios included in the 2017 study, damages were calculated using the updated Provincial Flood Damage Assessment Tool for the following categories:

- Direct damage to buildings, including contents and structures,
- Residential displacement
- Business Interruption

Additionally, other indirect damages were previously calculated as a percentage of direct damages, extrapolated from past events. This includes:

- Infrastructure damages
- Habitat restoration (based on federal offsetting costs)
- Emergency operations
- Waste disposal
- Traffic disruption

Finally, the intangible impact to households was based on health impact and willingness to pay research, primarily from the UK, and adjusted for demographics, as detailed in the 2017 study.

As with the 2017 study, there are several areas of greater uncertainty. Groundwater surfaces were generated with data from limited cross sections and all buildings exposed to the modeled groundwater were assumed to be flooded. This results in very high groundwater damage amounts for the more frequent floods (1:5 to 1:10 floods). These amounts were adjusted in the same manner as the 2017 study to account for adaptations (waterproofing, sump pumps, etc.) that frequently flooded properties would make. Further study on groundwater flooding in Calgary is required.

The flood modelling results in overland inundation caused directly by the river overtopping its banks as well as isolated areas that are disconnected but at a lower elevation that the adjacent river surface. These isolated areas are potentially flooded due to connection to the river by storm sewer systems or because they cannot drain stormwater. The "Isolated" flood areas were identified as being gated, gated and pumped, or having no protection. The surface flooding model was applied as follows: 100% for no protection, 50% for gates, and 0% for gates and pumps. The groundwater model was applied to all the remaining structures.

The indirect damage categories that are estimated as a percentage of direct overland damages are applied consistently across all scenarios. With the exception of waste disposal, which is directly related to building damage, there is uncertainty in how much these damages would vary between scenarios. For example, emergency operations may be a much higher percentage of direct damages during an extreme event when barriers are protecting buildings but the City is still in a state of emergency due to high waters.

Results

The output of the damage model for each scenario is detailed in the table below. There is greater uncertainty in using some of the damage types (such as groundwater and isolated flooding), or the categories (such as emergency response) for comparing these scenarios. Therefore, the total for overland inundation is provided along with the total damage estimate.

Scenario	Area	Remaining AAD - Overland Inundation - Buildings	Remaining AAD - Total	Overland Inundation Benefit (vs 2019_03)	Total Benefit (vs 2019_03)
2019_01 full plan	Citywide	$2,910,662	$16,238,241	$35,505,112	$59,107,341
	Bow	$1,444,473	$9,171,389	$18,636,042	$34,551,452
	Elbow	$1,466,189	$7,066,852	$16,869,070	$24,555,889
2019_02 full plan without SR1	Citywide	$20,706,584	$43,369,085	$17,709,190	$31,976,498
	Bow	$3,192,893	$13,817,051	$16,887,621	$29,905,790
	Elbow	$17,513,690	$29,552,034	$821,569	$2,070,708
2019_03 updated baseline	Citywide	$38,415,774	$75,345,583	$0	$0
	Bow	$20,080,515	$43,722,841	$0	$0
	Elbow	$18,335,259	$31,622,742	$0	$0

For all scenarios, significant benefit is estimated from the proposed overland flood mitigation measures, and these measures also help reduce basement damages from groundwater. However, groundwater remains the most significant source of damage for frequent flooding after these measures are in place. This is especially true of the scenarios with upstream mitigation which is modelled with an extended release of stored floodwaters. In the model, this results in propagation of groundwater further from the surface flooding than in the other scenarios. The groundwater modelling was based on limited data and thus has a high level of uncertainty. Further study into groundwater conditions through the river valleys would be required to more accurately estimate the impact of groundwater on basements during a flood. The conservative approach to groundwater damages used in this study may overstate the residual damages, which are largely from groundwater, and thus underestimate the benefit of these scenarios, i.e., a building protected from overland flooding may still be returning significant groundwater damages in the model. Full aversion of damages from basement flooding due to high groundwater during a river flood may not be feasible using structural measures; to further reduce basement damages, alternate measures, such as regulation of basement elevations, may be considered.

We trust that the above summary of additional mitigation scenarios is in line with our discussions and satisfies your requirements. Please contact the undersigned if you have any questions.

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