Appendix D

Materials Referenced

D-1 https://floodstory.com

D-2 *A quick history of Calgary floods*

D-3 Bryant and Davies (PDF)

D-4 Flood Mitigation Options Assessment Summary

D-5 Calgary Chamber of Commerce Flood Resiliency Report (PDF)

D-6 *"Unprecedented" flood to blame for Bonnybrook Bridge failure, train derailment in June 2013: report*

D-7 CRCAG May 9, 2016 blog post

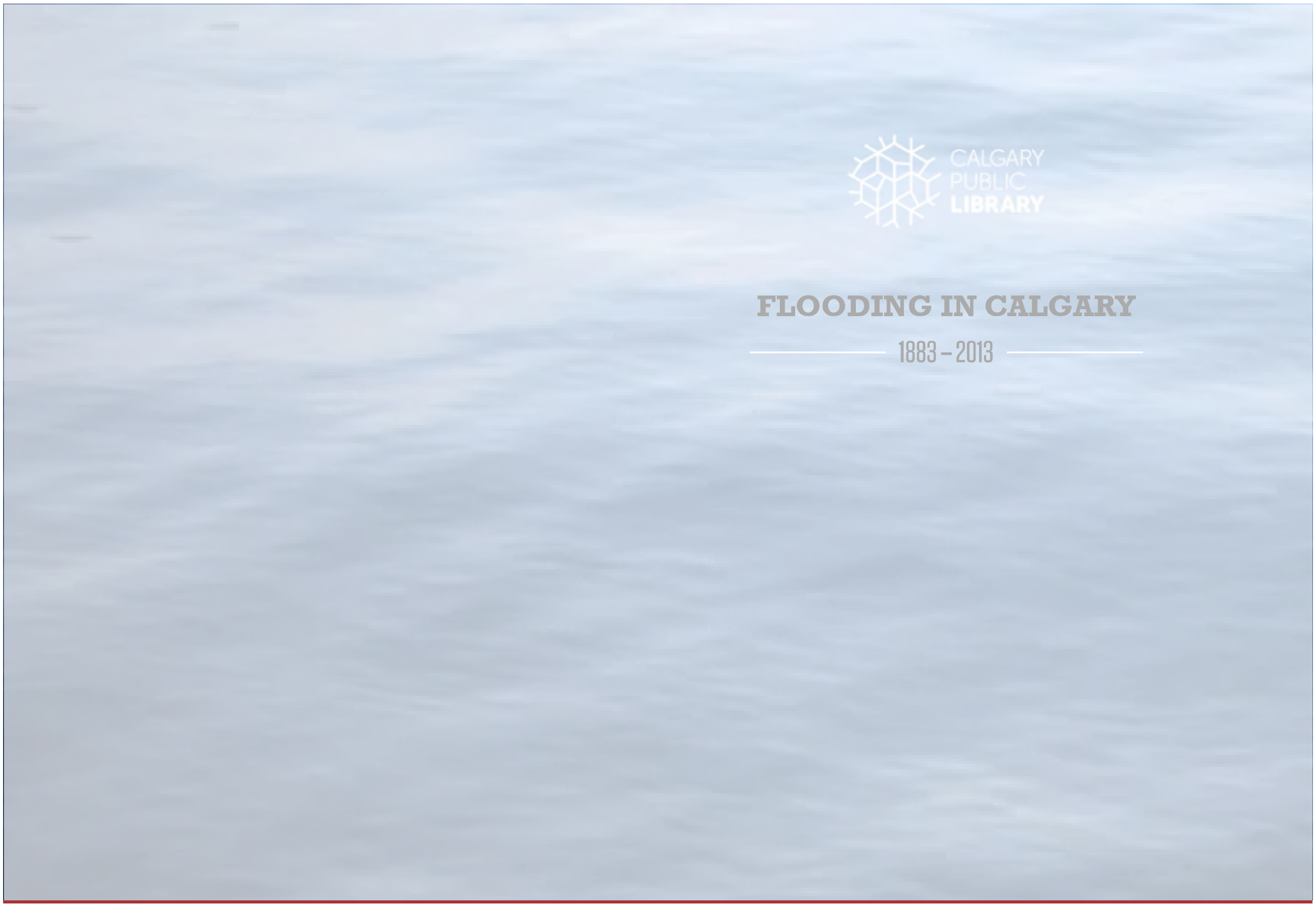
D-8 City of Calgary Infographic

D-9 Southern Alberta FISHES Program

D-10 Calgary Rivers Morphology Study, Summary Report (PDF)

D-11 SR1 Handout dated September 2017 (PDF)

CALGARY FLOOD STORY

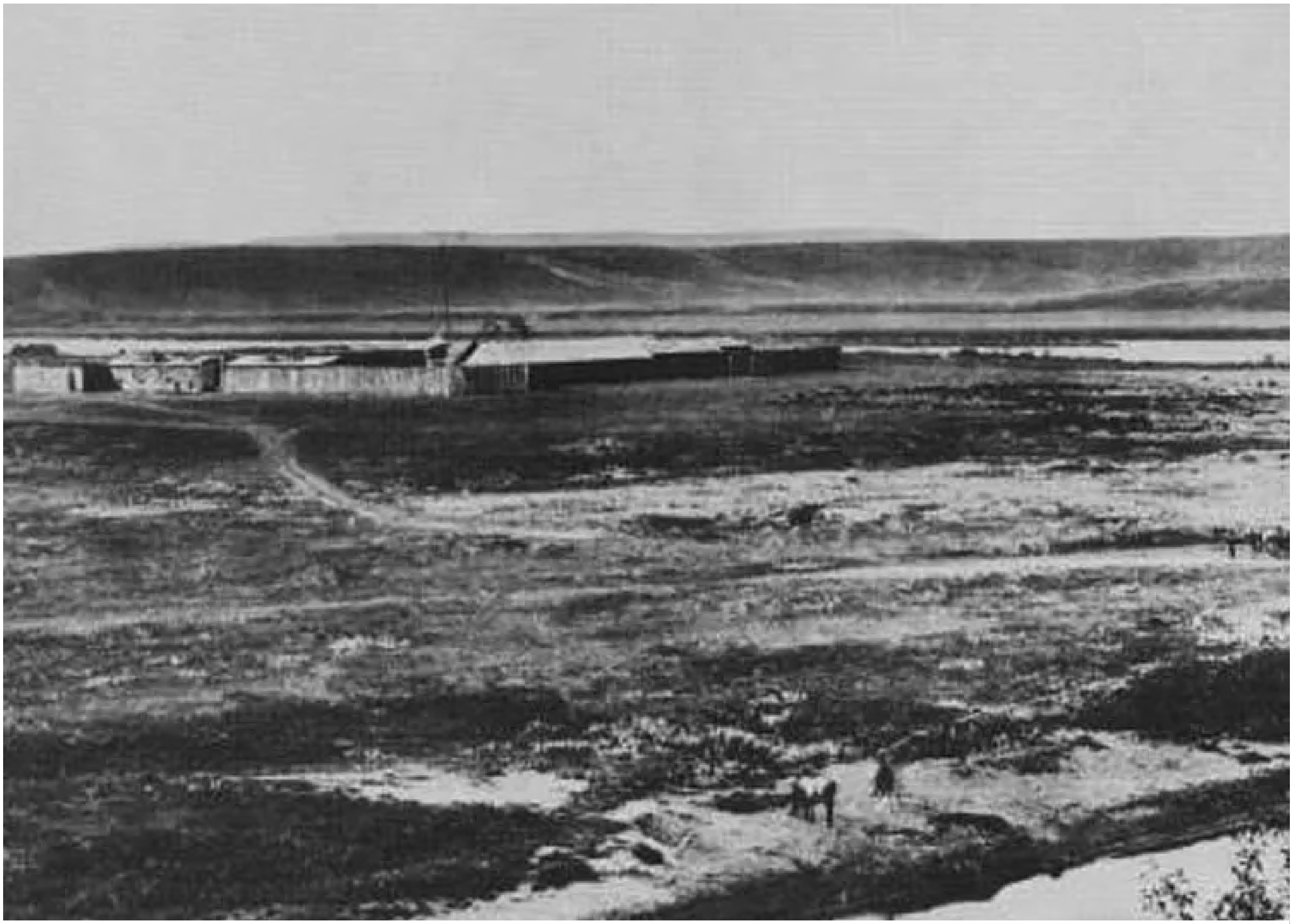


Calgary is a dynamic city built at the confluence of the Bow and Elbow Rivers.

This website tells the story of how flooding has impacted the city and its citizens over the years, and how the community has always come together to rebuild.

Timeline of Major Flood Events

TIMELINE



Calgary Public Library PC_1325

1881 Fort Calgary: Located at the confluence of the Bow and Elbow Rivers, the six-year-old Northwest Mounted Police post was photographed by George Dawson of the Geological Survey of Canada.

ICE JAM DESTROYS BRIDGE

OCTOBER 31, 1883

On the afternoon of October 31, 1883, the pedestrian bridge over the Elbow River was carried away amid icy waters. The debris threatened the Canadian Pacific Railway trestle bridge.

VIEW MORE DETAILS

Glenbow Archives NA-1315-10

Washout on railway bridge on Elbow River, Calgary, Alberta.

NEW BRIDGE DESTROYED

JULY 15, 1884

The rains began on June 22 and by July 15, the flood waters had destroyed the one bridge that survived the 1883 flood and the bridge built to replace the one lost the year before.

VIEW MORE DETAILS

The City of Calgary, Corporate Records, Archives CalA 2013-029-005

Man surveying flood damage on the Bow near 2nd St. East.

COL. WALKER'S HOME FLOATS AWAY

JUNE 17—19, 1897

The flood began on June 17 when the Bow River rose rapidly and overflowed its banks around midnight. The flood surge on the Elbow River hit in the early hours of June 19, 1897.

VIEW MORE DETAILS

City of Calgary, Corporate Records, Archives CalA 2013-029-008

Men in HMS Cupid rowboat on flooded street downstream from the Langevin Bridge.

IN SPLENDID ISOLATION: CALGARY IS CUT OFF FROM NORTH, SOUTH, EAST AND WEST

JULY 2–5, 1902

The Bow's rushing waters – comparable to the rapids and whirlpools of Niagara Falls – washed out bridges and cut off railway access to the city. Calgary was left isolated and without electricity.

VIEW MORE DETAILS

Glenbow Library and Archives NA 4355-17

House in Elbow Park on 40th Ave. SW

CENTRE STREET BRIDGE COLLAPSES

JUNE 28, 1915

Record-breaking rainfall caused the rivers to rise to deadly levels. In addition to wiping out three of Calgary's bridges (including the original Centre Street bridge) the flood of 1915 claimed several lives, including that of one of the city's own workers.

VIEW MORE DETAILS

Glenbow Library and Archives NA 2365-26

Crowds and automobiles on Mission Bridge over Elbow River.

DROUGHT ENDS, FLOODS BEGIN

JUNE 2, 1923

Southern Alberta had faced several years of drought conditions when the rain started falling on June 2.

VIEW MORE DETAILS

Glenbow Library and Archives, NA 1451-39

Calgary Exhibition and Stampede horse barns flooded.

WORST FLOOD SINCE '02

JUNE 3, 1929

From Saturday morning, June 1 to Monday morning, June 2, the Bow River rose from 5.8 feet to over 11 feet. Monday morning the Elbow broke its banks. This would lead to the worst flooding in over 25 years.

VIEW MORE DETAILS

Glenbow Library and Archives NA 2063-3

Glenmore Dam during the flood.

GLENMORE DAM SAVES CITY

JUNE 5, 1932

Thanks to the newly-constructed Glenmore Dam much of the flooding was contained. Still, communities close to the rivers were affected and motorists were left stranded.

VIEW MORE DETAILS

Glenbow Library and Archives NA 2864-1181

Dog pound rescue.

ICE JAM CAUSES FLOODING

DECEMBER 1–6, 1950

The Glenmore Dam could not have prevented the ice jam that started 1950's winter flood. Rescue workers battled below-freezing temperatures to come to the aid of people (and dogs) stranded by the flood.

VIEW MORE DETAILS

City of Calgary Deerfoot4

Deerfoot Trail becomes a lake.

CALGARY GRINDS TO A HALT

JUNE 2005

The rivers, at a record high following three large rainstorms, broke their banks triggering a city-wide state of emergency. 1500 people were forced to evacuate while 40,000 homes and countless pathways and bridges sustained significant damage.

VIEW MORE DETAILS

City of Calgary WC3C9185

Flooded residential street.

CALGARY'S MOST DAMAGING FLOOD

JUNE 20, 2013

The costliest natural disaster in Canadian history, the flood of 2013 damaged or destroyed many homes and businesses as well as vital portions of the city's infrastructure. In the absence of electricity, social media became a powerful tool to disperse information and bring Calgarians together.

VIEW MORE DETAILS

CALGARY FLOOD STORY

Funded by Calgarians through the Flood Recovery Fund

D-2

Calgary

Harry Sanders: A quick history of Calgary floods

Worst flood to hit Calgary was in 1879, according to historian Harry Sanders

CBC News · Posted: Jul 29, 2013 2:06 PM MT | Last Updated: July 29, 2013

This year's flooding isn't the worst that Calgary has seen, says historian Harry Sanders. He lists, in order, the three worst floods to hit the city occured in 1879, 1897 and 1902. (Jonathan Hayward/Canadian Press)

Just in time for Historic Calgary Week, historian Harry Sanders outlines the past 150 years of flooding in Calgary.

- **LISTEN: Historian Harry Sanders talks flooding on the *Calgary Eyeopener*:**

"The very worst one is 1879, so the fort is here, the aboriginal people are here, not much settlement, though, so not a whole lot of impact," says Sanders.

Major historic floods

1879

1897

1902

1915

1929

1932

That flood was not measured, but by all accounts it's the most intense flooding to have hit the city, he says.

"Next comes 1897, which has yet to be exceeded. The second worst flood that we've had," says Sanders.

"Bridges were torn out, buildings flooded and the Walker House at the Inglewood Bird Sanctuary replaced the one that was washed down the river in 1897."

Peak flow of the river and accounts from the time were taken into account when measuring the scale of the flooding, Sanders says.

Around 60 families were relocated after the 1897 flood and more homesteaders started to build on higher ground, says Sanders.

"The third worst flood, still yet to be exceeded, comes in 1902 and that's when the bridge, where the Hillhurst Louise Bridge is now, was damaged."

The Louise Bridge, at 10th Street N.W. in Hillhurst, connects Kensington to Calgary's downtown core. (Joshua Dawn/Flickr)

According to Sanders, there was a whole series of floods after that — including one in 1915 — that washed away the old Centre Street Bridge and one in 1929 that damaged the then-newly opened Calgary Zoo.

Calgary was fortunate in 1932 when flooding was held back by the Glenmore Dam, which had just been built.

"If this flood had occurred in 1931 the dam wouldn't have been ready and if it happened in 1933 the reservoir would have been almost full so it couldn't have held it back," says Sanders.

"The Glenmore Reservoir, when it was new, went from empty to a matter of inches from being crested in two days."

The city has built up so much in the flood plains because we have actually had less flooding than expected, says Sanders.

Harry Sanders lists 1897 as the second worst flood in Calgary's history. This shot was taken looking west from a point on the south bank of the Bow River near Langevin Bridge, which connects Bridgeland to the southeast side of what is now downtown. (Glenbow Museum)

Living with Rivers: Flood Management in Alberta

Technical Report · November 2017

DOI: 10.13140/RG.2.2.18702.87364

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Living with Rivers

Flood Management in Alberta

a report by

Seth Bryant and Evan Davies

for the

Kule Institute for Advanced Studies at the University of Alberta

date

November 1, 2017

UNIVERSITY OF ALBERTA
KULE INSTITUTE FOR ADVANCED STUDY

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Cover photo from National Post. 2013. “Pictures and Videos of Massive Flooding in Canmore and Southern Alberta.” June 20. http://nationalpost.com/news/canada/pictures-and-videos-of-massive-flooding-in-canmore-and-southern-alberta.

Glossary

(Disaster) recovery	Reactions to restore and rebuild from a disaster.
(Disaster) response	Reactions to an active disaster emergency.
Pluvial flood	More localized flooding or drainage failure due to greater rainfall intensity than infiltration capacity in the immediate area of flooding. Sometimes called *urban flooding*.
(Riverine) flood	Traditionally seen as abnormal and detrimental river water inundation of the floodplain. More broadly, (riverine) flooding is the natural process of overbank flow in a river.
2013 Southern Alberta Flood	A series of floods across Southern Alberta which began around June 18, 2013 causing significant damage to Calgary, High River, Canmore, Banff, the Siksika reserve, the Tsuut'ina reserve, and other communities.
Alberta Community Resilience Program (ACRP)	Provincial flood mitigation program. See Appendix A.
Alberta Environment and Parks (AEP)	GOA ministry/department responsible for most provincial programs related to flood mitigation (FHIP, ACRP, WRRP, WMMI, and PFDAT).
Bill 27 — the Flood Recovery and Reconstruction Act	Provides the provincial government greater authority in restricting future development and repeat disaster recovery payments.
Canada Flood Damage Reduction Program (FDRP)	Federal flood mitigation program. See Appendix A.
Cost Benefit Analysis (CBA)	In a flood management context, CBA is a decision-making tool which compares the quantification of costs and benefits to calculate a cost benefit ratio (CBR) to obtain some pre-determined objective. Sometimes referred to as a Benefit Cost Analysis (BCA) depending on how the benefit/cost ratio (CBR vs BCR) is expressed.
Depth-damage curves	Loss function for a single exposure indicator: water depth.
Direct damage	Damage caused by contact with flood waters, debris, or ice.
Disaster Financial Assistance Agreements (DFAA)	Federal flood recovery program. See Appendix A.
Endogenous	In a systems context, these are factors or components inside the system boundary.
Exogenous	Opposite of endogenous.
Exposure indicators	A set of quantified metrics for the intensity of the hazard (e.g. depth) on an element.
Flood control	Those actions that seek to stop or control floods. Typically excludes non-structural solutions such as zoning laws designed to limit/reduce exposure to floods, or actions that promote the benefits of flooding.
Flood damage model	An integrated collection of mathematical functions for estimating the damage of floods. Generally used as part of a flood risk assessment process.
Flood damage model concept: deterministic	A flood damage model whose output provides a single damage value estimate.
Flood damage model concept: probabilistic	A flood damage model that includes a measure of randomness and uncertainty in outputs, manifested as a probability distribution for damage estimates.

Flood damage model philosophy: empirical	A flood damage model developed from historical damage data.
Flood damage model philosophy: synthetic	A flood damage model developed from hypotheses of how flood damage occurs.
Flood Hazard Zone (FHZ) or Area (FHA)	"area of land that will be flooded during the design flood event" (Alberta Environment 2011).
Floodproofing	Small scale, property-level measures to reduce flood vulnerability of structures such as backflow prevention, electrical improvements, penetration improvements, building elevations, foundation drainage systems, and/or flood walls/barriers.
Flood risk cycle	The cyclical and inter-related system of human behavior in relation to floods.
Flood risk reduction	The process or objective of reducing the likelihood and/or magnitude of flood-induced harm to humans and the things they value.
Flood risk reduction measures	Decisions or policy interventions that flood managers and individuals have at their disposal to accomplish flood risk reduction. Also called *flood mitigation measures*.
Government of Alberta (GOA)	The Alberta provincial government and its ministries/departments.
Government of Canada (GOC)	The Canadian federal government and its ministries/departments.
Hazard	A dangerous phenomena which may cause damage to humans and the things they value (UNISDR 2009). In this report, only hazards arising from flooding are discussed.
Indicators	A set of quantifiable metrics which serve as the inputs to a loss function (e.g. exposure indicators or resistance indicators).
Indirect damage	All non-direct damage; those damages resulting from interruptions or recovery from flooding.
Intangible loss	All non-tangible damage; those losses not directly quantifiable monetarily.
Integrated Flood Management (IFM)	Applies systems thinking to achieve a more sustainable use of floodplains by integrating land-use, water, and risk management into one decision-making framework (APFM 2009).
Loss function	Mathematical expression to relate hazard and vulnerability to quantify damage.
Multi-Criteria Analysis (MCA)	Decision process that incorporates multiple criteria (e.g. social, environmental, economic).
Municipal Affairs (MA)	GOA ministry/department responsible for disaster recovery programs (DFA) and provincial land-use zoning laws (e.g. Bill 27 regulations).
Private flood insurance	Overland flood insurance policies for private homeowners in Canada sold by the private insurance industry.
Provincial Flood Damage Assessment Tool (PFDAT) or Rapid Flood Damage Assessment Model (RFDAM)	Flood risk assessment tool developed for Alberta to estimate direct tangible flood damage.
Regulatory event	Flood event used in land-use planning. Often expressed probabilistically as a return period (in Alberta, the regulatory event is typically 100 years).
Reserves	Lands set aside for First Nations (FN) as governed under the Indian Act.

Residual risk	Remaining flood risk after mitigation. Can never be eliminated.
Resilience	"Ability of a system to perform and maintain its functions [under] hostile or unexpected circumstances" (Simonovic 2013, xiv).
Resistance indicators	A set of quantified metrics for how the exposed elements will respond to, or resist, a flood.
Return period	Expression to describe an event based on the number of years which will, on average, pass between it's recurrence.
Risk	In a hazards context, the Knighton definition is most useful: "risk is the combination of the probability of an event and its negative consequences" (UNISDR 2009, 25) or in mathematical terms: risk = hazard probability x consequence. Many more precise definitions have been presented by various authors for more robust quantification and analysis of risk (see "total risk").
(flood) Risk assessment	In a flood management context, the process to quantify the set of potential future flood damages in a probabilistic way. Often risk assessments are performed on numerous flood mitigation options combined with CBA or MCA for use as a decision tool.
Risk-based approach	A more holistic approach to flood management which incorporates risk assessments into decision making.
Standards-based approach	A more traditional approach to flood management generally limited to flood control based on an arbitrary regulatory event.
Tangible damage	Pecuniary/monetary/economic, and therefore easily quantifiable monetary damage.
Total risk	A more complete, holistic measure of risk in a hazards context. Total risk is a function of hazard probability, vulnerability, resilience, and asset quantity (or value) (after Scheuer et al. (2011)).
Vulnerability	"Extent to which changes could harm a system" (Simonovic 2013, xiv).
Watershed Resiliency and Restoration Program (WRRP)	Provincial flood mitigation program. See Appendix A

1 Introduction

Any report on flood management must begin with a definition of *flood*: “unusually high stage or flow over land or coastal area, which results in severe detrimental effects” (Ghosh 2014, 1); or when a “body of water rises to overflow land that is not normally submerged” (Simonovic 2013, 7). The selected author’s word choice reveals some hallmarks of the traditional attitude towards flooding — something both abnormal and detrimental. From the perspective of the landowner whose house is swept downstream, such terms are clearly reasonable.

However, we have always known flooding to be natural (i.e. normal) and modern ecology has identified many aspects of flooding that are necessary for healthy ecosystem function (e.g. nutrient transfer, sediment flush, reproduction cycles) (Peters et al. 2016). Considering this, it would be more appropriate to consider the *absence* of floods as unusual. Unfortunately, society has — for the most part — failed to consider the flood cycle in this way or at this scale. Instead, cities and towns have developed in areas with a probability of flooding. The intersection of this probability and the damage it would cause is the most basic definition of *flood risk*.

Pluvial flooding[a] is increasingly identified as a source of harm, especially in heavily urbanized areas (Simonovic 2014). While many of the issues, solutions, and themes discussed overlap with pluvial flood risk, this report is focused on riverine flooding. Unlike pluvial flooding, which is inherently local in both risk and policy intervention, riverine flooding is generated at a larger spatial and temporal scale — and therefore intertwined with the broader political levels that hold jurisdiction over the watershed (i.e. provincial and federal). For clarity, we therefore drop the suffix “riverine” and henceforth simply refer to “flooding”.

We further narrow our focus and limit the discussion to flood risk and its management in Alberta, Canada. Key issues for understanding the context of flood risk in Alberta are: 1) recent population growth and development patterns (Figure 1 and Figure 2); 2) relatively low population density; and 3) the scale of surface waters. Alberta has eight major river basins (Figure 1 and Table 1) with a combined annual discharge of 131 billion cubic meters draining to the Arctic Ocean, Hudson’s Bay, or the Gulf of Mexico (Statistics Canada 2011). These basins are made of 66.2 million ha of farmland, urban development, mountains, prairies, and northern boreal forest. Management of flood risk on such a massive scale in Alberta is therefore intertwined with: 1) water use — for farms, cities, and industry; 2) land-use — from forestry, agriculture, and resource extraction; and 3) environmental preservation — for recreation and habitat. Furthermore, the political climate in Alberta has become very disaster-sensitive after the triple pain of $1.0, $5.1, and $8.8 billion (CAD2016[b]) disasters over five years — or roughly 6% of the total annual provincial budget[c]. Most notably, on June 18, 2013, a low-pressure system stalled in the headwaters above Southern Alberta, triggering widespread flooding and devastating much of the province, including the largest city: Calgary. The significance of this event on flood management in Alberta, and across Canada, cannot be understated.

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[a] See glossary.

[b] Dollar amounts in this report are in 2016 CAD, unless otherwise stated.

[c] Estimates for the 2011 Slave Lake Fire (KPMG 2012), the 2013 Southern Alberta Flood (section 4.4.1), and a preliminary estimate for the 2016 Fort McMurray Fire (Alam and Islam 2017) adjusted to 2016 CAD with Consumer Price Index (Statistics Canada 2017c). These damage estimates are combined and compared with the 2016 provincial budget of 51$BN (Alberta Government 2016d) .

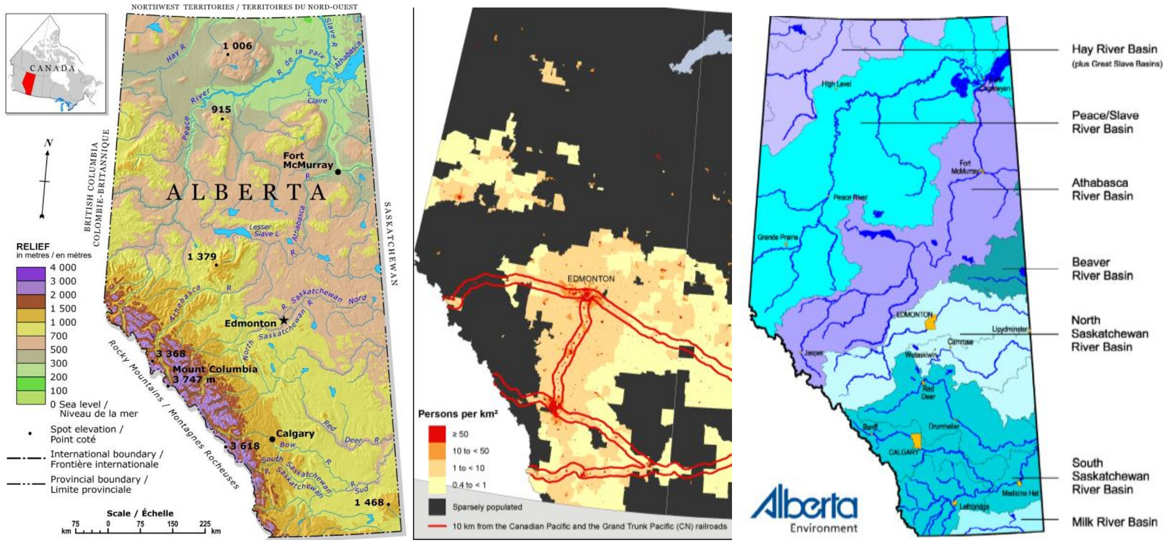


Figure 1 – Maps of Alberta:

a) Topography showing Rocky Mountains (>3000m) in the SW and Lake Athabasca in the NW (~120m) (YellowMaps 2003);

b) Population density showing the major cities in red (>50 persons/km2), the sparsely populated census blocks in grey and a 20km buffer along the major rail lines (red lines) (Statistics Canada 2006);

c) Major river basins in Alberta (see Table 1) (Alberta Government 2005).

Table 1 - Summary of basin statistics organized by Watershed Planning and Advisory Councils (WPAC).

River Basin	Sub-Basin	WPAC	DRPs[1]
Hay			0
Peace/Slave		Mighty Peace Watershed Alliance	9
Athabasca	Athabasca	Athabasca Watershed Council	2
	Lesser Slave	Lesser Slave Watershed Council	4
Beaver		Beaver River Watershed Alliance	0
North Sask.	North Sask.	North Sask. Watershed Alliance	10
	Battle River	Battle River Watershed Alliance	1
South Sask.	Bow River	Bow River Council	6
		Oldman Watershed Council	11
	Red Deer	Red Deer River Watershed Alliance	6
	South Sask.	South East Alberta Watershed Alliance	4
Milk		Milk River Watershed Council	2
Total			**55**

[1]Disaster Recovery Program count as reported by the CDD (2017).

High hazard areas (i.e. floodplains) often present attractive development opportunities — at least on a short time-scale — as they are adjacent to waterways (water supply and transportation benefits), flat, and fertile. For these reasons, the floodplains in many regions are now densely populated, leading to destruction and human suffering during floods. To manage and reduce this suffering, society has historically intervened (after the fact) and invested considerable resources in flood management, response, and recovery — what we call *flood risk reduction.* How those resources have been invested in Alberta and their efficacy are the focus of this report.

1.1 The Back Story

The motivation for this report lies in three observations in Alberta: 1) floods continue to damage society and property; 2) government resources are focused on recovery rather than prevention; and 3) annual flood damage is rising and will continue to do so without additional policy intervention.

Flood loss trends

Frechette (2016) documents the rise in flood recovery costs for the Government of Canada (GOC) since the mid-1960's. However, flood damage data are inconsistent and unclear across events and sources because of: 1) a lack of standards for measuring damage; 2) composite natural disasters (i.e. hurricanes with flooding); and 3) a lack of clear jurisdictional responsibilities (National Weather Service 2015; Guha-Sapir et al. 2015). While these challenges make any temporal or spatial comparisons difficult, the available data shows that tangible flood damage is climbing (Figure 2).

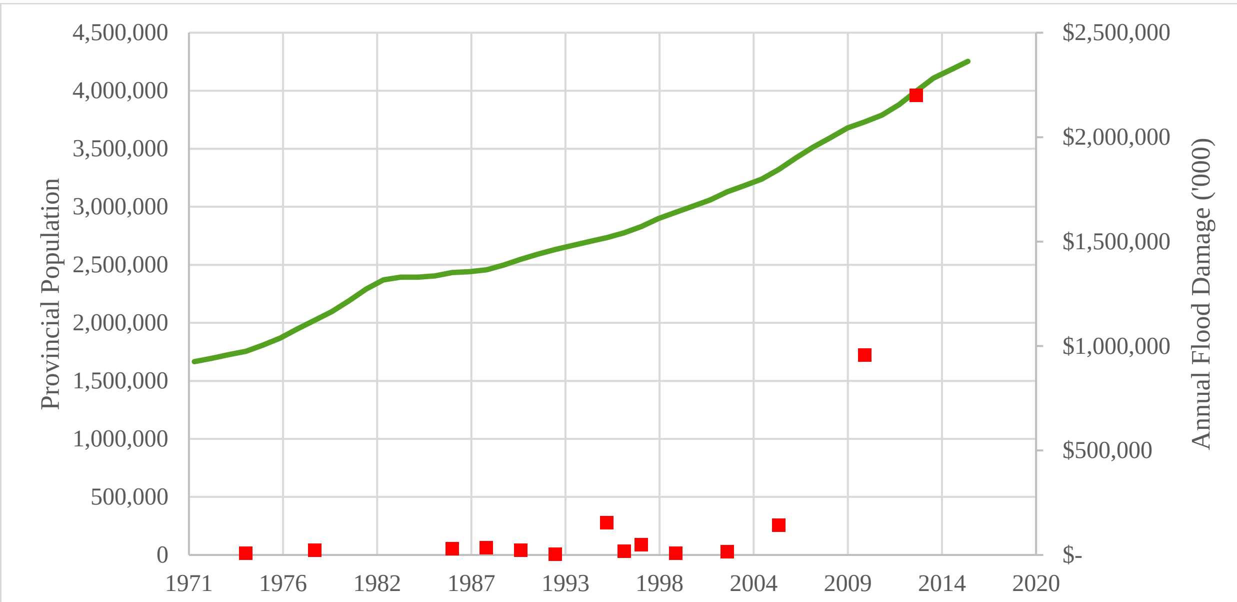


Figure 2 - Flood damage trends in Alberta. Red squares are annualized damage estimates in thousands for flood events from the Canadian Disaster Database (CDD)(17 of 37 events have no available damage estimate) (Public Safety Canada 2017). The green line is the population estimate for Alberta (Statistics Canada 2017b).

Government Spending

Analyzing government spending on flood management, response, and recovery over time is complicated by: 1) obscurity and coarseness in financial reporting; 2) frequent restructuring of ministries[d]; and 3) payment transfers. Furthermore, separating mitigation from recovery spending is subjective even with the most transparent accounting. Despite these challenges, it appears that provincial recovery spending in Alberta has been much greater than mitigation spending, with substantial mitigation spending coming only after the 2013 Southern Alberta Flood. Additionally, federal disaster recovery spending, of which flooding in Alberta is the largest recipient, is projected to rise 18-fold from 1970 levels (Frechette 2016). There is consensus in the literature that mitigation is a necessary pursuit for meaningful flood risk reduction (Simonovic 2013; Zevenbergen et al. 2010; Wong 2011). Considering this, we argue that the GoA needs additional and continued encouragement to prioritize mitigation over recovery. An ounce of prevention is worth a pound of flood debris cleanup.

[d] The Ministry of Environment and Parks (AEP) has been restructured twice since 2012 (Alberta Government 2016i)

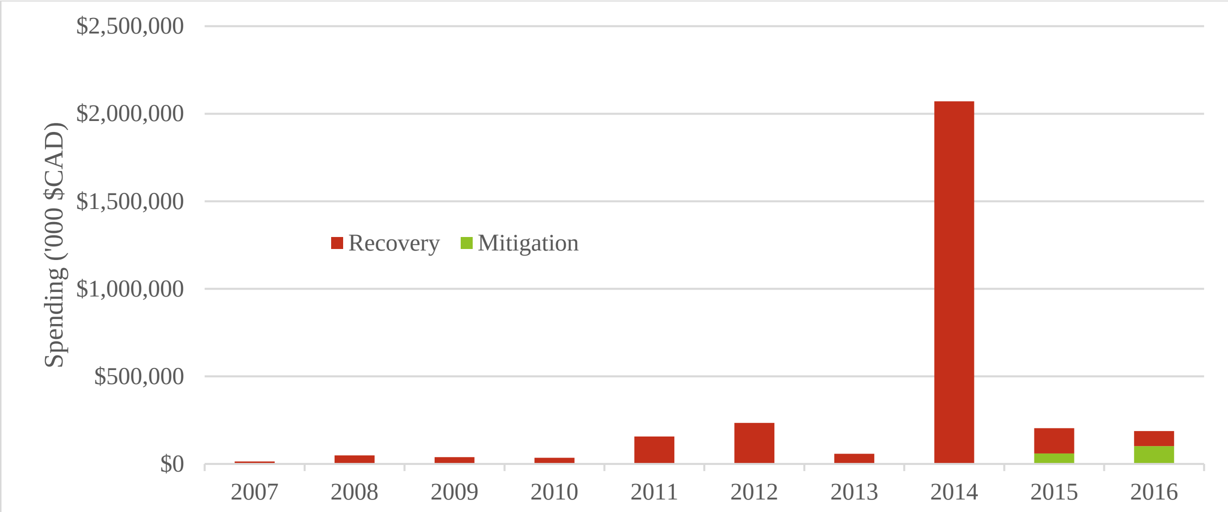


Figure 3 - Alberta Government 10 years of spending on flood mitigation and recovery. Compiled from annual financial reports for Alberta Environment and Parks (AEP) (Alberta Government 2016f), Municipal Affairs (MA) (Alberta Government 2016g) and Indigenous Relations (IR) (Alberta Government 2016a). Recovery costs include spending on all disaster types and emergency response. All MA and IR spending tabulated as recovery. All AEP spending with the heading 'recovery' tabulated as recovery. Recovery amount reflects the latest 2013 DRP estimate (recorded in fiscal year 2014).

The Changing Floodscape

Trends in both human development and the environmental response will continue to drive up flood risk: climate change is projected to increase rainfall intensity (Burn and Whitfield 2016), population is expected to rise and continue urbanizing in Canada (UNDESA 2015), and the subsequent land development may continue to affect catchment and channel properties. All these factors contribute to creating a moving target for flood managers. Because of this uncertainty, society will need to implement flexible, resilient, and comprehensive strategies to achieve sustained flood risk reduction.

1.2 Objective

In short, we aim to reduce flood risk in Alberta. We believe that improvements to the way society plans for and manages floods are the most effective way to accomplish this reduction. However, before building towards a more floodproofed society, we must first understand where we are. Thus, the goal of this report is to explore and explain how floods are currently managed in Alberta. To accomplish this, we provide the major context shaping flood management practices into what they are today — including an overview of general flood management concepts from the academic literature, the history of flood management in Canada prior to 2013, and a summary of the 2013 Southern Alberta Flood. Building on this context, we then review the policies and trends shaping flood management decisions in the post-2013 Alberta, significantly including a section dedicated to First Nations. To ground this insight to the reality of flood management in Alberta, we present the opinions and observations of 15 municipal flood managers. Finally, we close by analyzing past recommendations and the current challenges facing Alberta's flood managers. In this way, we address gaps in the literature by: 1) providing an overview of flood management specific to Alberta; 2) explaining how those efforts are applied to FN; and 3) presenting the opinions and observations from the end users of flood policy in Alberta. We hope this report is useful both to researchers, through identifying areas in need of further study, and Alberta's flood managers, by placing their efforts into a broader context and drawing attention to their accomplishments and areas of potential improvement.

In preparing this report we: reviewed academic and grey literature; held conversations with federal, provincial, and municipal flood managers; and surveyed 14 municipal flood managers. In this way, we hope to provide a balance of quantitative and qualitative perspectives on the fast-evolving landscape of flood risk reduction in Alberta. However, this treatment is far from comprehensive; instead our goal was to provide limited and useful information on those topics where information was readily available and uncontroversial. While every effort was made to provide an accurate, unbiased account, we have certainly committed errors and omissions. We hope you can overlook such sins and find value in this work.

2 Flood Management: Concepts in Literature

Before wading through the nuances of flood management in Alberta, we must first equip ourselves with some basic concepts and terms. This background allows us to place the current Alberta practices into context with emerging global practice. We start by defining a term for the shared objective of flood management in Alberta and this report:

Flood Risk Reduction

The theme of this report is *flood risk reduction*. The use of such a broad term is necessary to encapsulate the diverse stakeholder interests and subsequent management paradigms commonly used to further these interests (Figure 4). Historically, the phrase *flood control* was used, but this limits the discussion to those actions that seek to stop or control floods, and excludes non-structural solutions such as zoning laws designed to limit exposure to floods, or actions that promote the benefits of flooding. The term *flood management* is also too specific, because it implies a top-down command-and-control approach to flood risk mitigation, or the planning phase (see below). Instead, we consider flood risk reduction to be a discipline: a branch of knowledge with diverse stakeholders, methods, applications, and views. Finally, *flood damage reduction* is also incomplete as it implies that management decisions are made according to a single criterion: reducing damage to human systems. This approach ignores the broad range of criteria that are important to society and removes emphasis on the probabilistic nature of the flood cycle. For example, cost is generally a criterion, but increasingly environmental and aesthetic criteria are also considered. Therefore, we consider "flood control", "flood management", and "flood damage reduction" to be integral components or considerations of flood risk reduction.

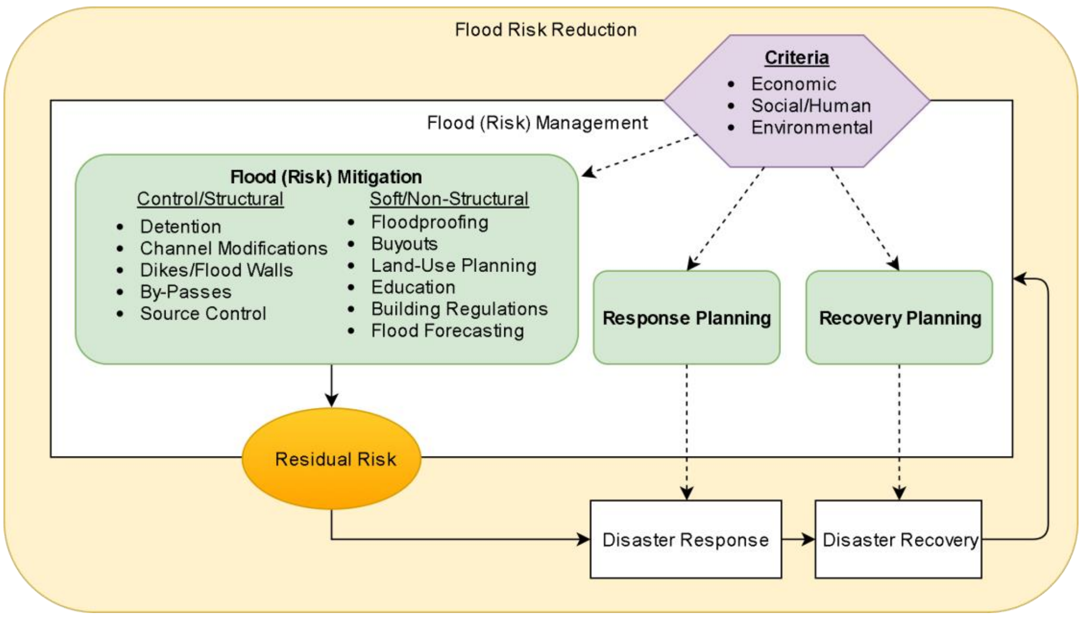


Figure 4 - Flood Risk Reduction Framework. Dashed lines indicate 'influences' while solid lines indicate that one step 'leads to' the next. White boxes represent different classes of flood risk reduction over the flood risk cycle while green boxes represent specific activities.

Flood Management

Canadian lexicon treats *flood management* as the pro-active planning, mitigation, or preparation phase of flood risk reduction; it is in contrast to the phases of *response* (reactions to an active disaster emergency) and *recovery* (reactions to restore and rebuild from a disaster) (Shrubsole 2013). However, actions taken during and after a flood are dependent on the planning that occurred before the flood. For example, the systems for disaster response and recovery are generally established pre-event. Whether those systems are triggered depends on how effective the flood management policies have been at protecting assets from harm – i.e. the *residual risk*. Therefore, flood management is the most influential component in long-term flood risk reduction, and the focus of this report.

2.1 Standards-Based Approach

The traditional or *standards-based approach* to flood management is to design flood protection, or limit development, based on some predetermined standard or *regulatory event* (Messner 2007). This arbitrary regulatory event is often expressed as a *return period*, and serves as a quantification of the level of flood risk deemed acceptable by the community (see Table 2 for some examples). In other words, the regulatory event establishes a flood hazard zone (FHZ) where outside assets are "safe" for development without flood-based restrictions, and inside development is restricted or protected. Additionally, this return period may be applied to the design of flood control structures: implemented to bring a community's hazard down to an acceptable level.

Table 2- Select regulatory event return periods for standards-based flood control approach.

Location	Regulatory Event Return Period (yrs)	Probability of Exceedance[8]	Reference
British Columbia	200	22%	(Burrell et al. 2015)
Alberta	100	39%	(Alberta Environment 2011)
Alberta - Hospitals	1,000	5%	(Alberta Government 2013a)
Saskatchewan	500	10%	(Burrell et al. 2015)
Manitoba[1]	100	39%	(Burrell et al. 2015)
Ontario[2]	100	39%	(Burrell et al. 2015)
Quebec	100	39%	(Burrell et al. 2015)
New Brunswick[3]	100	39%	(Burrell et al. 2015)
Nova Scotia	100	39%	(Burrell et al. 2015)
Prince Edward Island	100	39%	(Burrell et al. 2015)
Newfoundland/ Labrador[4]	100	39%	(Burrell et al. 2015)
Yukon[5]	N/A		(Burrell et al. 2015)
Northwest Territories	100	39%	(Burrell et al. 2015)
Nunavut[6]	N/A		(Burrell et al. 2015)
UK	1,000	4.88%	(MMM Group 2014)
National Floodplain Management Framework	350	13.31%	(MMM Group 2014)
Holland (Netherlands)[7]	10,000	0.50%	(Hoeksema 2006)

1. *or flood of record if greater;*
2. *or Hurricane Hazel (1954) or Timmins rain (1961) transposed over a specific watershed if greater;*
3. *or 1973 flood if greater;*
4. *Flows are often adjusted to 2020, 2050 and 2080 based on climate-change projections.*
5. *No standards as of 2017.*
6. *No flood hazard mapping program.*
7. *Level of protection for dike design. Following the 1995 floods the Netherlands have adopted a risk based approach.*
8. *Calculated over an assumed lifetime of 50yrs assuming a Poisson distribution.*

While the standards-based approach is simple and widely accepted, there are a few noteworthy concerns:

- the public perceives return periods incorrectly (i.e. a 1:100 year flood as one that will only occur once every 100 years);
- the approach does not account for floods greater than the return period (i.e. risk outside the FHZ);
- there is no quantification of risk.

The last point is especially problematic in regions with significant development prior to flood hazard mapping and well-enforced land-use policies. In such cases, significant assets are likely within the FHZ. These assets are generally in need of additional flood control or protection to match the community's level of acceptable risk. This (all-too-frequent) scenario raises several practical questions: how much are we willing to pay for said protection?, and what protection option achieves the optimal balance of our communal values (e.g. cost vs. damage vs. environment vs. recreation)? To answer these, a risk-based approach is required.

2.2 Risk-Based Approach

The biggest difference between a standards-based approach (described above) and a *risk-based approach* is the inclusion of potential future flood damage in decision making. To accomplish this, some sort of quantification, or estimate, of the expected future damage is required. When these so called damage assessments are combined in a probabilistic way to account for all the potential future scenarios, the process is called a *risk assessment* (Plate 2002). However, before we can dive into the relevant details, we need to arm ourselves with some terminology.

2.2.1 Risk, Vulnerability, and Resilience

The simplest definition of risk (as related to hazard science) is the Knighton definition: "risk is the combination of the probability of an event and its negative consequences" (UNISDR 2009, 25); or in mathematical terms: *risk = hazard probability x consequence.* As an example, a riverside park may have a very high flood probability if it floods every year, but very low consequence and therefore risk because few things would be damaged were that flood to occur.

When considering a complex system in the context of hazards, it becomes important to include additional factors to understand the behavior of the flood risk cycle: *vulnerability* and *resilience.* Many definitions and frameworks have been presented to define vulnerability and resilience (and risk) precisely (Birkmann 2013; Wong 2011; and Cutter et al. 2008 provide overviews). Here we use the systems-oriented definitions laid out by Simonovic (2013, xiv), where vulnerability describes the "extent to which changes could harm a system" and resilience describes the "ability of a system to perform and maintain its functions [under] hostile or unexpected circumstances". From these definitions, it is clear that there is considerable overlap between vulnerability and resilience – as explained by Cutter (2008) – both affecting the consequences of a hazard. This is similar to the framework of Scheuer et al. (2011), which presents the *total risk* as a function of hazard probability, vulnerability, resilience, and asset quantity (or value).

To illustrate the practical meaning of these terms, let us return to our park metaphor — with the added complexity of a campground. Both tent campers and RV campers experience the same flood hazard probability (as they occupy the same campground) but have different vulnerabilities (RVs are higher off the ground), resilience (tents can be dried more quickly and easily), and asset values. When taken together, these flood risk cycle components lead to different total risk for the tents and RVs. In this example, the park flood risk manager could better reduce flood risk for the whole community were they to recognize this differential, and adopt different risk mitigation strategies for the tent (e.g. sandbags) than for the RV campers (e.g. water proofed electrical hook ups). In contrast, the ducks in the park have almost no vulnerability and very high resilience: flood hazard barely ruffles their feathers. Equipped with these terms, we can now quantify the total flood risk of complex systems to better inform our management decisions.

2.2.2 Decision Making

Uncertainty

Flooding is a highly-uncertain natural phenomenon: one can never be sure when or where a flood will occur; or predict the magnitude of the event, or the vulnerability/resilience of the assets. However, flood management decisions must be made —and choosing to do nothing is also a choice. To classify such decision making under uncertainty, Tannert et al. (2007) presents their igloo framework (Figure 5), which separates decisions based on the level of knowledge available:

- *Closed knowledge*: full certainty in the decision (e.g. will buildings next to the river be flooded eventually? Answer: certainly);
- *Open knowledge*: enough knowledge available to quantify the risk (e.g. what is the probability of flood damage to some building in the floodplain this year? Answer: 10%);
- *Open ignorance:* lack of knowledge can be reduced (e.g. exactly which buildings are at risk of flooding? Answer: as we are not sure yet, we will protect them all just to be safe while we collect more data);
- *Closed ignorance:* lack of knowledge cannot be reduced (e.g. what will the funding be for flood management in ten years? Answer: I cannot know).

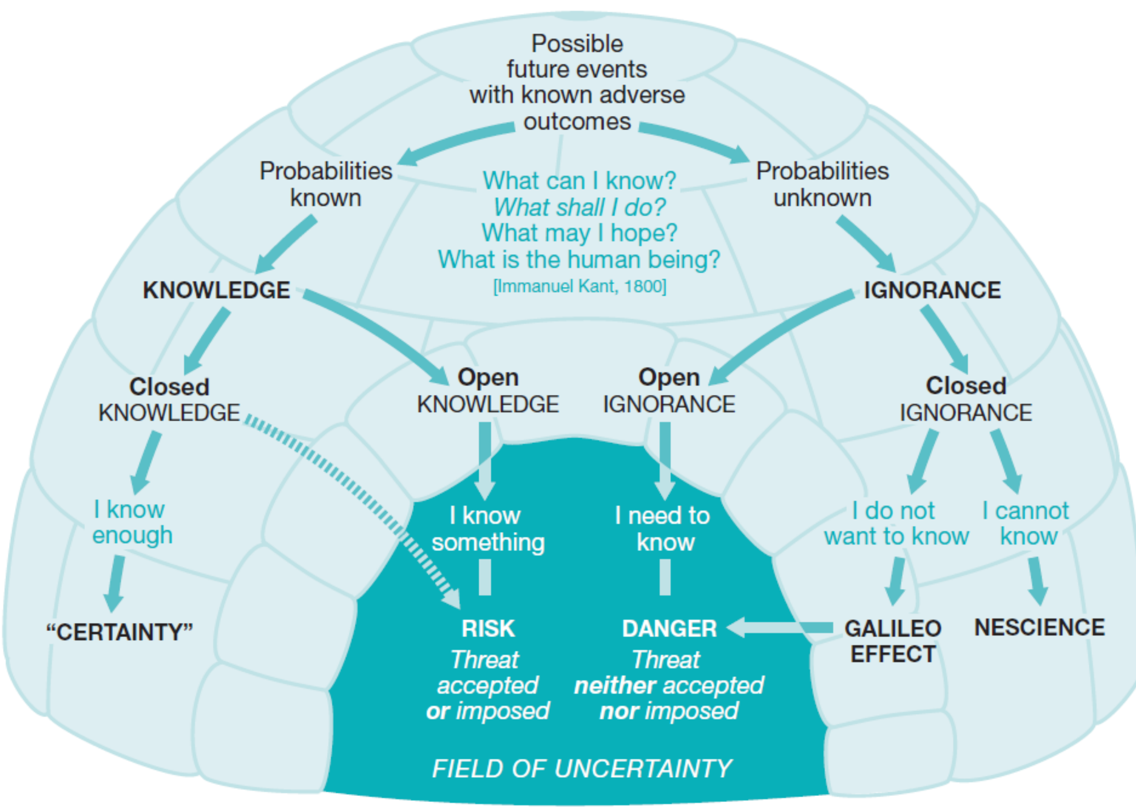


Figure 5 - The igloo of uncertainty from Tannert et al. (2007).

Flood management decisions are primarily concerned with converting *open ignorance* scenarios to *open knowledge* scenarios through study (modelling and data collection). Decision makers are ethically motivated to quantify the risk and seek out additional knowledge to reduce decision uncertainty (Tannert et al. 2007). Keeping these guidelines in mind, we now explore some of the decision-making tools available to flood managers.

Risk-based decision methods

Flood managers are tasked with selecting the appropriate measures to optimize, or balance, a community's values in the pursuit of flood risk reduction. In the simplest case, a manager must balance the cost of construction and maintenance of the measure (e.g. a dike) against the perceived benefit (e.g. future loss reduction). For this single criteria approach (economic efficiency), a *Cost Benefit Analysis* (CBA) is typically applied (Merz et al. 2010). Such an approach ignores factors not easily quantified with a monetary value, such as ecological health, cultural landmarks, or differential vulnerability (discussed below). Decisions made with a CBA are likely to leave many stakeholders unsatisfied.

In more complex scenarios — where either the number or the influence of stakeholders is greater — a manager must consider additional environmental, aesthetic, cultural, and other criteria. To do so, a *Multi-Criteria Analysis* (MCA) can be applied (N. Smith, Brown, and Saunders 2016). While MCA is a more robust tool, it introduces more subjectivity in the selection and weighting of criteria. No standardized or universally accepted approach exists to establish and identify the appropriate criteria (Dodgson et al. 2009). The process is further complicated by the changes in community values over time, perhaps related to a flood event, which may cause the criteria set or weighting to change over time as well (Figure 6). For example, following the 2013 flood, community action groups pressed for additional and immediate flood control, likely reducing the relative weight of environmental and aesthetic criteria vs expediency (CRCAG 2016). While both CBA and MCA have limitations, they are accepted methods for arriving at a rational decision and communicating the process.

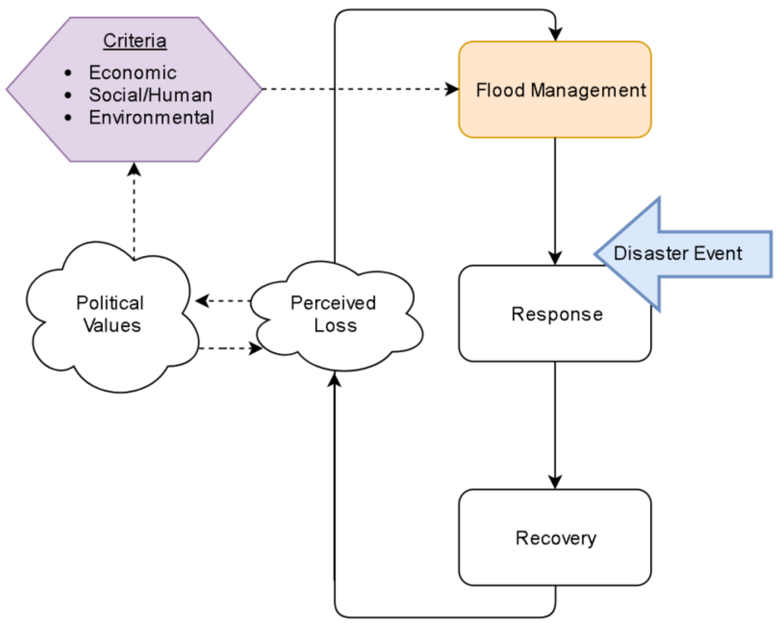


Figure 6 - Framework for the influence of values on the flood risk cycle. Solid arrows signify the temporal process. Dashed arrows signify influences.

2.2.3 Risk Assessment

The foundation of any risk-based decision method (i.e. CBA or MCA) is a *risk assessment* performed for each mitigation scenario or option deemed worthy of consideration (Figure 7). As mentioned above, a flood risk assessment probabilistically combines flood hazards with the potentially flooded element's (e.g. houses, roads, farms, people, economies, and so on) vulnerability to calculate a damage estimate. The core of a flood risk assessment is the *loss function* which provides the mathematical component to relate hazard and vulnerability to damage. To feed this loss function, the hazard and vulnerability must first be quantified into *indicators*. The full risk assessment process provides a tool to quantify the total expected loss of a mitigation option over its lifetime.

2.2.3.1 Indicator Development

Risk assessments rely on large synthetic datasets (flood variables) to quantify the physical hazard spatially and probabilistically with *exposure indicators* (Figure 7). Exposure indicators describe the intensity of the hazard (e.g. depth, velocity, duration, etc.) on an element (e.g. house, road, etc.) (Messner 2007). The most basic risk assessments use only one exposure indicator: water depth, leading to the so-called *depth-damage curves* (D. Smith 1994). However, intuition suggests that the damage to an element during a flood depends on more than just depth. For example, the flood damage resulting from a house flooded for 30 minutes should differ significantly from a house flooded for 30 days. A series of analyses on three floods in Germany has confirmed this, and revealed that along with depth and duration, contamination also has a significant effect on flood damage (Merz, Kreibich, and Lall 2013).

However, knowing the physical flood properties (exposure indicators) is only one piece of the puzzle. To estimate the damage of a potential flood, it is necessary to understand how the exposed elements will respond to, or resist, the flood. These metrics are called *resistance indicators* (Messner 2007). To understand the need for such metrics, consider two neighbours who experience the same flood (equal exposure) and have equivalent property values. However, one neighbor has floodproofed her home, and therefore increased her resistance to flood damage, while the other neighbor has not. These differences would be reflected in the exposure indicators and therefore the result of the loss function (flood damage). Incorporating such nuances is important to estimate the damage of a future flood accurately, and to quantify the benefit of flood mitigation efforts.

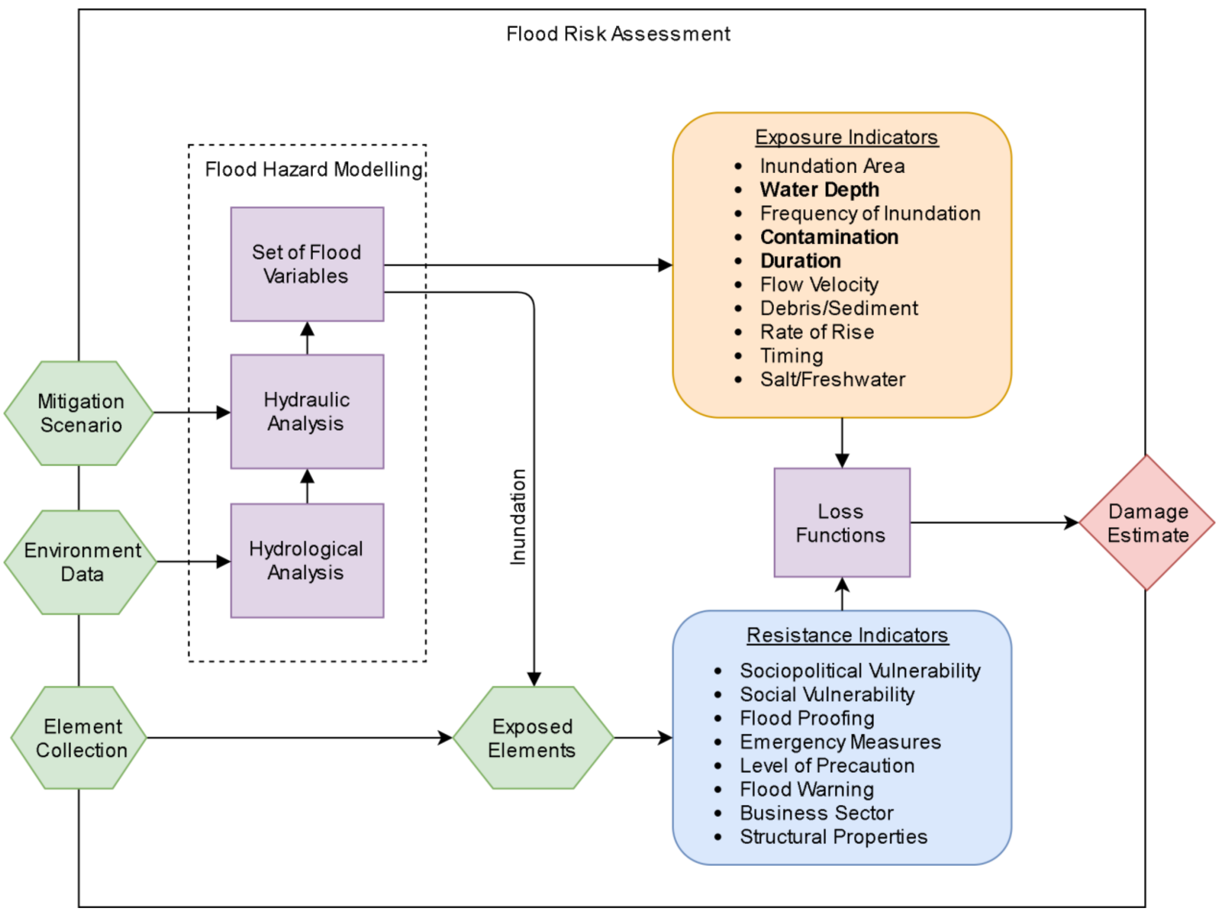


Figure 7 - Flood risk assessment process diagram. Generally, decision makers repeat this process for each mitigation scenario under consideration and compare the results through CBA to determine the optimal mitigation choice. Exposure indicator lists adopted from (Merz et al. 2010). Indicators in bold were identified as "significant" by Merz, Kreibich, and Lall (2013). Element collection is the spatial data set of potential exposed elements — from which the exposed elements subset is determined based on the inundation area.

2.2.3.2 Damage Types

To estimate potential flood damage, a *loss function* is used to mathematically relate exposure and resistance (see above). However, before selecting and calibrating a loss function, it is useful to classify flood damage into four groups based on metric (tangible/intangible) and mechanism (direct/indirect) (Jonkman et al. 2008):

- *Tangible:* pecuniary/monetary/economic damage easily quantifiable monetarily;
- *Intangible:* all non-tangible damage; losses not directly quantifiable monetarily;
- *Direct*: damage caused by contact with flood waters, debris, or ice;
- *Indirect*: all non-direct damage; those damages resulting from interruptions or recovery from flooding.

Considering the broad range of damages fitting under this classification scheme, different loss functions should be developed for the different loss categories. For example, it would be inappropriate to use the same loss function to estimate the damage to a house (direct-tangible loss) as for the mental health impacts to flood victims (intangible loss).

2.2.3.3 Flood Damage Models

The term *flood damage model* describes an integrated collection of components of the flood risk assessment process (Messner 2007), where the number of components and extent of integration varies by model. Many flood damage models have been developed by universities, governments, and the insurance industry to estimate the diverse types of damages. Most focus on direct damage[e]. Considering the economic and life-safety implications of the flood damage model results, surprisingly few studies have been published comparing or validating the different models (Jongman et al. 2012).

The literature contains a plethora of flood damage models with varying degrees of uniqueness in handling damage predictions in the complex and data-sparse world of flood risk. To put these different models into perspective, it is useful to distinguish between available model concepts and philosophies. A model's concept can be described as either *deterministic*, such that it produces a single damage value, or *probabilistic*, such that it includes a measure of randomness and uncertainty, manifested as a probability distribution of damages (Gerl et al. 2016). A model's philosophy is often described as either *empirical*, which means that it was developed from historical damage data, or *synthetic*, where it was developed from hypotheses of how damage occurs (Gerl et al. 2016). Which concept and philosophy is most appropriate depends on the: 1) scale; 2) objective; 3) resources available for the analysis; and 4) the data available (Messner 2007).

2.2.4 Flood Risk Reduction Measures

With a more complete suite of risk based decision-making tools clear, we can now explore the actual decisions or policy interventions that flood managers and individuals have at their disposal to reduce flood risk. These policies and projects are called *flood risk reduction measures* or *flood mitigation measures* and are combined to form mitigation scenarios in risk assessments (Figure 7). A few different taxonomical frameworks exist that provide useful perspectives:

- *Source Pathway Receptor (SPR):* Popular in the UK, SPR separates measures based on whether they reduce risk at the source (sustainable drainage, river regulation, etc.), the pathway (dikes, sand bags, etc.), or the receptor (risk awareness, emergency response, etc.) (Sayers 2012).
- *Hazard, Vulnerability, and Resilience:* This framework separates hazard-reducing measures (channel improvements, river regulation, etc.), vulnerability-reducing measures (floodproofing, disaster preparedness, etc.), from resilience, recovery or coping measures (flood insurance, emergency response, etc.) (Ghosh 2014).
- *Political Level:* This framework divides measures based on the political level of implementation; separating those measures implemented as top-down or government led (zoning, drainage, dikes, emergency response) — from those adopted by an individual or business (insurance, floodproofing, emergency planning) (ASCE 2014).
- *Structural vs Non-Structural:* The most widely-used framework in North America, this separates those engineered —structural — measures that seek to reduce the flood waters (i.e. exposure indicators) from those that seek to reduce the vulnerability of the assets (i.e. resistance indicators) (Zevenbergen et al. 2010).

[e] See Gerl et al. (2016) for list of 46 direct damage models, see Merz et al (2010) for list of direct damage models by sector, and see Messner et al. (2007) for categorization of 10 typical European models.

Given these frameworks, we can now discuss some typical measures in order of most to least effective in flood risk reduction (Sayers 2012; Honegger and Oehy 2016; ASCE 2014):

- *Land-use policy or zoning by-laws*: These soft measures are typically imposed by governments, in a top-down fashion, and can modify/limit the exposure and the hazard (Burby et al. 2000). By limiting the type and amount of development in the floodplain, these policies can influence the exposure of the community at the receptor level. By regulating the upstream land-use, these policies can influence the runoff at the source and therefore flood hazard. Stevens and Hanschka (2013) document the perverse incentives and failure of voluntary adoption of policies by municipalities in BC while Scott et al. (2013) discusses the challenges of imposing land-use changes on existing developments.
- *Structural flood control*: These measures are typically reactionary and implemented after development by governments to modify the pathway. Structural measures seek to reduce the magnitude or height of a flood event either through separation of hazards and assets (levees, dikes, floodwalls), increasing conveyance (river widening, flood bypass, debris removal, storm drainage), or attenuating the flood peak (reservoirs, wetlands).
- *Flood resilience measures*: These measures help the community withstand the shock, or reduce the loss of a flood event. Governments can apply these measures through policy intervention, or individuals and businesses can adopt them as practices to reduce the damage in the event of a disaster. Some examples are: 1) supply-chain resiliency measures (ensuring that essentials are available during a disaster); 2) electricity grid resiliency; 3) floodproofing (and/or related subsidies); 4) assisting private contingency planning; and 5) flood forecasting.
- *Emergency response systems*: These are the measures and plans typically established by governments that are triggered in response to a flood. Some examples are: 1) first responders; 2) emergency operations centers; 3) and temporary flood barriers.
- *Disaster recovery systems:* These are typically government-managed financial instruments or policies to help flood-affected communities return to normal, and include construction of temporary facilities, and funds or subsidies for reconstruction.

The task of the flood manager is to select the right set and level of measures from this menu that satisfy the values of their community. This is a never-ending and challenging task.

The above frameworks, decision making tools, and risk reduction measures describe the practical, day-to-day, aspects of flood management. To gain a deeper understanding — from which we can start to address the challenges to flood risk reduction in Alberta — we need more abstract, big-picture ways of framing flood risk.

2.3 A Systems View of Flood Risk

To better understand a modern society's interaction with flooding — and how to reduce harm — it is helpful to consider the processes and components that give rise to flood risk as interconnected and constantly changing. Such an approach is called *Systems Thinking* (Simonovic 2013; Zevenbergen et al. 2010; Sayers 2012). In other words, individuals, institutions, and the environment all affect each other and the level of flood risk. For example, development laws from a government could either incentivize or force individuals to convert parking lots to green space, which would increase the rainfall interception and therefore decrease the flood hazard. The reduced flood hazard would then allow the government to relax the development laws — starting the cycle again in reverse. If this seems complicated, we are on the right track. The interaction between unique and diverse stakeholders, organizations at different levels with overlapping authority, and the constantly changing and unpredictable environment, is axiomatically complex. Historically, flood management decisions often ignored this complexity, leading to unintended consequences; like an increase in flood risk over time.

Thinking in terms of systems forces us to consider the boundaries of flood risk: what is inside the system, or *endogenous*, versus what is outside it, or *exogenous*. For example, flood policy and inundation levels are most certainly endogenous to flood risk, while health care and social policy may be exogenous. The systems thinker must strike a balance between complexity, with boundaries that are drawn too wide, and simplicity, where problems are tractable but unrealistic. From a systems perspective, historical flood management could be described as overly simplistic, since it has only included factors like flood policy and flood hazard, while ignoring social and political values and land development in decision making. In this report, we have drawn our boundary around those areas with the most feasible opportunities for positive intervention: Alberta, flood hazard, flood policy, land development, insurance, politics, and land development— while factors and influences from areas like Saskatchewan, public health, individual behavior, the economy, geology, climate change, population growth, the weather, and the rest of the universe have been excluded[f]. While this is far from perfect, we feel it is the best balance considering our objectives and constraints.

2.4 Integrated Flood Management

To respond to the systems nature of flood risk, many advocate for *Integrated Flood Management* (IFM). This paradigm shift applies systems thinking to achieve a more sustainable use of floodplains through integrating land-use, water, and risk management into one decision-making framework (APFM 2009). In Canada, IFM has taken the form of: 1) subdividing jurisdictions among semi-governmental agencies by watershed; and 2) adopting a set of policy interventions to address water supply, environmental protection, recreation, and flooding within a single framework. In Alberta, these agencies are the Watershed Protection and Advisory Councils (WPAC) (Table 1), and they have little authority to regulate the floodplain or mitigate risk (Frechette 2016). In contrast, Ontario gave broad riverine flood management powers to the conservation authorities following Hurricane Hazel in 1954 (Conservation Ontario 2013). According to Katyal and Petrisor (2011), key aims of IFM are to:

- reduce vulnerability;
- improve prevention;
- integrate cutting-edge techniques;
- integrate sustainable measures/green technologies;
- combine defensive and preventing approaches;
- balance costs and benefits;
- address post recovery; and
- learn and evolve.

Figure 8 - From Riboldi (2014).

While useful in framing thinking around flood risk reduction, this list is neither very satisfying nor very instructive to practitioners. One explanation for this may be the breadth of IFM; a necessary trait considering the different stakeholder values and approaches that must be integrated. In addition to this fundamental challenge, Shrubsole et al. (2016) documents a series of interviews with water agencies across Canada and the practical challenges faced such as: 1) lack of funding; 2) lack of authority; and 3) lack of consultation with FN. Despite these challenges, strong IFM seems to reduce flood damage, as demonstrated by the large discrepancy in flood damage per capita in Ontario (strong IFM) versus Alberta (weak IFM) (Frechette 2016).

[f] This selection was informed by the systems work of Deegan (2007), the review of socio-environmental systems provided by Barendrecht et al. (2017), and the explanation for historical flood risk dynamics provided by Shrubsole (2013).

3 The Canadian Context: Pre-2013

Historical trends in Canadian flood management can be understood as a competition between levels of government each level following a cyclical process: disaster, response, inaction — similar to what Wilhite (2011) calls the "hydro-illogical cycle". Here we describe the major events in Canadian flood management on the provincial and federal levels since the early 20th century. For a more detailed description of the 1953 – 2013 period, see Shrubsole (2013). Shortly after the warnings issued by Shrubsole (2013), Canada was struck by the $940 million CAD2013 Toronto flood and the $4.875 billion CAD2013 Southern Alberta flood, the latter being the most expensive disaster in Canadian history at the time[g] (Public Safety Canada 2017). This dual disaster triggered a significant policy shift in Alberta and brought more evidence of the longer trending federal retreat.

Shrubsole (2013) describes four major eras of modern flood management in Canada:

1. federally-managed structural measures [1953-1970];
2. a federally-managed mix of structural and non-structural measures [1970-1998];
3. paralysis [1998-2006];
4. municipal and provincial measures [2006-2013].

Behind this timeline is a whipsaw of responsibility between different levels of government — what Harrison (1996) describes as "pass-the-buck syndrome" and attributes to Canada's federalist structure. Renzetti and Dupont (2017) point to the complicated web of jurisdictional authority between federal, provincial, municipal, and indigenous[h] governments, which leads to long negotiations, conflicting objectives, and an atmosphere of shirking responsibility. Regardless of the cause(s), from 2006, the Federal government has taken a backseat role in flood management, limiting itself to providing funding and best practices for municipally- and provincially-led measures.

Policies affecting flood risk in Canada operate on five basic inter-related levels (Figure 9). Global political influences have a minor impact on flood management in Alberta, contrary to Bangladesh for example, where flood management is intertwined with humanitarian aid from international donors (Brammer 2010), or the Netherlands, whose policies are a product of collaboration with members of the EU (Hoeksema 2006). In line with the literature, individual behavior is considered here only as an exogenous factor to flood risk — something government policy can be used to mitigate[i]. Possibly because of this view, there are insufficient data available on historical individual risk related behavioral trends in Canada. Therefore, we focus on national, provincial, First Nations, and municipal policies.

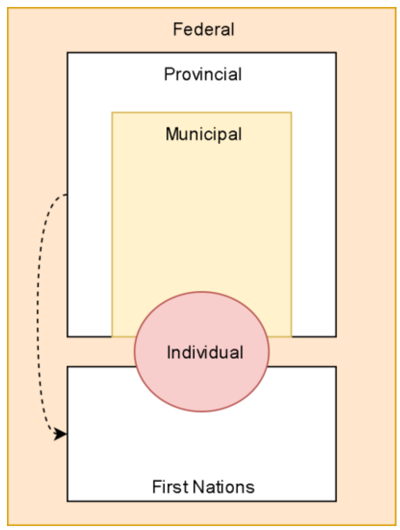


Figure 9 - Framework for political levels of flood risk reduction relevant to Canada. Dashed line indicates inconsistent jurisdiction and/or intervention.

Canada's 1982 *Charter of Rights and Freedoms* deliberately excludes the protection of private property, leaving governance to national and provincial legislatures (Alberta Land Institute 2014). In Alberta, the 1972 Alberta Bill of Rights provides additional protection to personal property, but only against provincial legislation; further, this protection can be overridden by the same legislature that would impose the infringement (Alberta Land Institute 2014). Therefore, the regulation of land-use in Alberta – against flood hazard in this case – has primarily been left to municipalities and provinces (Tarlock and Albrecht 2016).

[g] See section 5.3 for discussion on the 2016 Fort McMurray fire.
[h] Includes official and unofficial organizations of First Nations and Metis people operating on any political level.
[i] Canadian commentators have called for at-risk individuals to have more "responsibility and capacity in floodplain management and flood hazard mitigation" (Kumar et al. 2001, 35). However, the implied intended audience for their commentary is generally decision makers and researchers (like this report). Therefore, out of necessity, their analysis is framed from this top-down perspective.

3.1 Key Federal Programs (DFAA, FDRP, and NDMP)

The two most significant federal programs that shaped flood management in Alberta in the 20th and early 21st century were the Canada Flood Damage Reduction Program (FDRP) and the Disaster Financial Assistance Agreements (DFAA). Since 2015, the National Damage and Mitigation Program (NDMP) has been the modern policy vehicle for federal mitigation efforts[j].

Disaster Financial Assistance Agreements (DFAA)

With the DFAA, the federal government (Government of Canada (GOC)) assumed the role of insurer-of-last-resort through a cost-sharing scheme based on a sliding scale of losses per capita in the disaster-affected province (Government of Canada 2016b). Each province is responsible for managing, and setting rules for their own Disaster Recovery Program (DRP), which can submit claims to the federal DFAA and distribute compensation. Therefore, to understand how recovery works in Canada — and how it influences flood risk — one must consider both federal (DFAA) and provincial DRPs (see section 5.1). Prior to 2008, only uninsurable costs associated with restoring to pre-disaster conditions were federally eligible. This likely encouraged high-risk rebuilds and recurring disasters (Sandink et al. 2016).

Following the 2013 Southern Alberta Flood and the initial $2.8 billion federal obligation estimate (Government of Canada 2015c), an internal review by Frechette (2016) found that the annual cost of the program had risen substantially (Figure 10). They project a more than double increase in cost from $400 million (2005-2014) to $900 million (2016-2021) average per year[k]. Likely in response to this, the GOC has adjusted the cost-sharing formula for future payments to reduce their exposure to smaller events (Government of Canada 2015b).

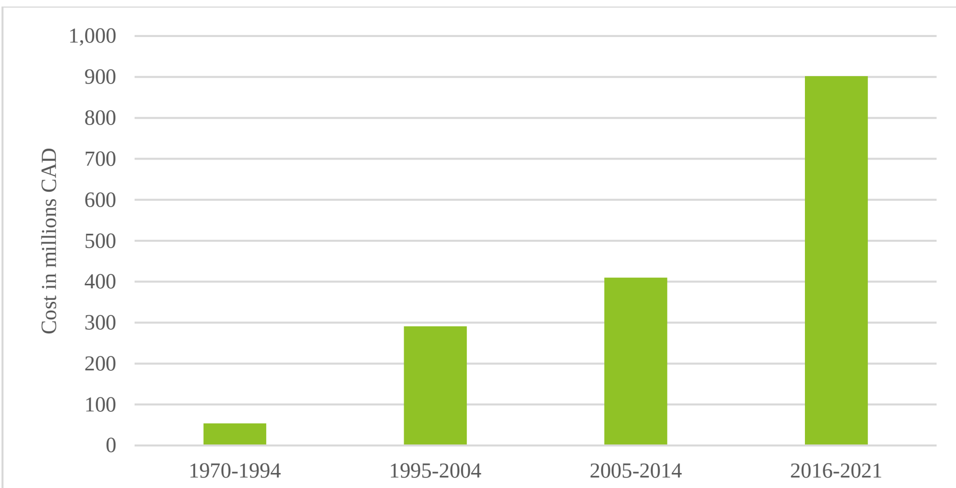


Figure 10 - DFAA annual cost to the federal government after Frechette (2016) for all disasters. Cost adjusted to 2014 dollars by GDP with the updated 2015 cost sharing formula. Future values based on model projections.

While the rising cost of natural disasters is a concern of the federal government, the 2015 DFAA policy change does not reduce risk, it only shifts the financial burden to the provinces. However, this shift may produce secondary risk reductions by providing additional incentives (or rather — reduced disincentives) to the provinces. Furthermore, provinces may interpret this rule change as a broader federal policy shift — signaling a continued retreat that adds incentives for the provinces to step in and fill the vacuum.

[j] See Appendix A for a more complete list of programs.
[k] Floods are the largest proportion by disaster at 27.71%. Alberta is the largest contributor at 28% for a total of $2.3 billion (Frechette 2016).

Flood Damage Reduction Program (FDRP)

The FDRP was primarily a nation-wide campaign to conduct flood hazard assessments (Young 2011). Flood hazard assessments combine a hydrological analysis, which produces a probabilistic representation of design flow, with a hydraulic analysis, that relies on mass and momentum conservation modelling (Alberta Environment 2011). This process creates *flood hazard maps*, which delineate the *flood hazard area* (FHA; or zone (FHZ)) for a given regulatory event or return interval. The FDRP guidelines further split this zone into the *floodway* — area that conveys most of the flood flow and therefore faces high-exposure, and the *flood fringe* — remaining reduced-exposure inundation area (see Figure 11). Land-use regulators could then use these maps to restrict the growth of flood risk in the floodplain. Both the FDRP and the DFAA continue to shape flood management in Alberta, the FDRP with its legacy of hazard maps, and the DFAA with its recovery payments and provisions.

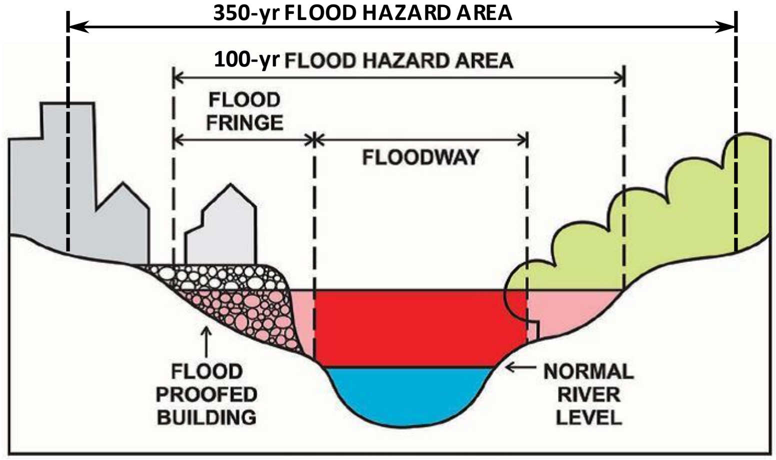


Figure 11 - Flood Hazard Area designations in Alberta. See text for definitions. Adopted from Alberta Government (2014g).

National Damage Mitigation Program (NDMP)

To reduce the risk more directly, the federal government announced the NDMP in 2015 — a cost-sharing program of $200 million over five years towards mapping and the facilitation of private insurance[l] (Government of Canada 2015d). However, when compared with the level of mitigation investment at the provincial level — for example, Alberta's $140 million in 2016 alone (Figure 3)— it is clear that the post-2013 policy environment in Canada has drifted further towards Shrubsole's (2013) "municipal and provincial measures" label. The GOC seems to be placing its bets on provincial efforts and private flood insurance[m].

3.2 Private Flood Insurance

Prior to the offering by the Beaufort Group in 2014, Canada was the only G8 country with no private flood insurance (Cryderman 2014). Not surprisingly, this anomaly led many commentators to conclude that expanding private overland flood insurance would be an effective way to reduce the ballooning DFAA payments discussed above. Considering these, flood insurance in Canada is a very active issue.

Young (2011, 69), writing two years before the 2013 floods, put it nicely:

> *If for example, Canada were to experience a flooding catastrophe or a series of severe flooding events in a short time frame, it would cause such a huge demand for disaster relief assistance payouts that it might later conceivably spur the government into seriously looking for other ways to mitigate losses of flood victims that do not further deplete the country's coffers.*

[l] For private homes, Canadian insurers make a distinction between overland flood insurance (water pathway is overland) and sewer backup (water pathway is internal; from the sewer). Sewer backup insurance has historically been widely available in Canada — many insurers paid 2013 flood victims through such policies (Thistlethwaite 2016). The remainder of this report is concerned with the emergence of private overland flood insurance policies.

[m] In their fall economic statement of 2016, the Government of Canada (2016a) announced 21.9$ billion over 11 years for 'Green Infrastructure' — some of which is allocated to flood risk reduction. However, the amount allocated for flood control, and the method of allocation, were not available.

Various explanations have been provided for why Canada had no private flood insurance prior to 2014:

- *Young (2011):* a lack of desire from all stakeholders, including the public;
- *Thistlethwaite and Feltmate (2013):* difficulty in predicting risk;
- *IBC (2015)*: ineffective hazard maps, adverse selection, and poor infrastructure;
- *Thistlethwaite (2016):* perceived lack of economic viability;
- *Sandink et al. (2016):* lack of flood loss data and hazard maps, proportion of high risk households, crowding out by the DFAA, and resistance among individuals to reduce risk.

More generally, the Canadian Property and Causality insurance market has become increasingly unattractive for international investors as investment yields have fallen while catastrophic losses (i.e. policy payouts) have risen over the same 20-year period (Calamai et al. 2016).

Despite these hurdles, following the 2013 floods the federal and provincial governments, the National Round Table on Environment and Economy, and various NGOs called for private flood insurance to increase its presence (Sandink et al. 2016). Furthermore, the consumer may be more receptive now — Oulahen (2015) found a high willingness to pay for private flood insurance amongst potential policy holders[n]. This shift in government and consumer attitudes has been felt by the industry. Through a series of interviews, Thistlethwaite (2016) documents: 1) the pressures felt by insurance companies following the 2013 Southern Alberta Flood to offer flood insurance for homes; and 2) the concerns of insurance companies around the regulatory uncertainty.

In reaction to the seemingly unavoidable emergence of flood insurance, in 2014 the Insurance Bureau of Canada (IBC) commissioned the *Financial Management of Flood Risk* report to identify the key requirements for establishing a viable private flood insurance industry in Canada. The recommended requirements included: 1) improving flood hazard maps; 2) increasing investment in flood defenses; 3) increasing private flood risk awareness; and 4) reducing government recovery payments (i.e. DFAA) (IBC 2015). With these requirements in hand, IBC began development of a National Flood Program which they hope the federal government will adopt to harmonize the interests of government, citizens, and the insurance industry (Floodlist News 2016; LexisNexis 2015). To support this program, IBC contracted LexisNexis and JBA consulting to conduct a nationwide flood hazard assessment using a single response-time based hydrological model to estimate peak flow (Faulkner et al. 2016), and two proprietary simplified 2D hydraulic models to calculate inundation (H. Smith 2016; Crossley et al. 2010) — the results have not been made public[o]. This effort identified 19% of Canadian homes as "at risk of flooding" (IBC 2016b). Further analysis by IBC showed 10% of homes would be uninsurable (Kennell 2016). Developing a solution for the uninsurable and managing the transition to full insurance uptake pose major challenges, especially in the absence of a coordinated national strategy (Sandink et al. 2016).

Strategy or not, private flood insurance is happening. As of writing, six companies offer overland flood insurance to homeowners in Alberta (Alberta Government 2016j). However, significant problems persist. As mentioned above, government recovery funds (DFAA) only pay for damages not 'reasonably' insurable. The scene is further complicated by homeowner misconception. In a recent survey by Square One (2016), 65% of Canadians (56% in AB) wrongfully believe their policy covers overland floods; Sandink et al. (2016) document similar results. Homeowners have been thrust into a regulatory grey zone clouded by misconception.

This challenge surfaced in New Brunswick when a study revealed that 47,000 homes may no longer be eligible for DRP funding as they are no eligible for flood insurance. In response, legislatures are scrambling to find a solution (Chilibeck 2016). Therefore, it is likely that flood disaster recovery payments during this transitional time will be affected by political calculations that include the scale and location of the disaster, the state of the provincial budget, and public attitudes. Considering the resulting uncertainty, the recovery from a major flood in the near future may be more chaotic than usual.

[n] This willingness was strongly correlated with risk awareness.

[o] The use of different assessment methods and models by the GOA for flood hazard mapping (1D) vs private insurance for premium determination (2D) — could result in conflicting risk estimates: causing confusion and inconsistent mitigation requirements.

Private insurance is considered by many as a remedy to the ballooning DFAA payments (Frechette 2016). Given the wording of the DFAA specifically to exclude damages covered by insurance (Public Safety Canada 2007), barring the unforeseeable, private insurance will undeniably reduce DFAA payments and taxpayer liability in the short-term. However, the more important consideration should be whether private insurance will reduce flood risk for the whole of society (rather than just government financial responsibility). Young (2011) addresses the question in detail, and raises the following issues:

- *Flood zone withdrawal:* The presence of flood insurance in the US and UK has not triggered withdrawal from the flood zone. This may be because financial considerations are insignificant compared with the trauma of the flood in decision-making. On the other hand, private insurance will likely provide for a more complete recovery (and therefore less decision-altering suffering) than government programs, which generally only pay for essentials (the DFAA model) — therefore reducing the relative incentive to withdrawal from the flood zone.
- *Financial sustainability:* As discussed by Thistlethwaite (2016) and Sandink et al. (2016), the financial viability of private insurance is far from certain. Therefore, insurance companies with small capital reserves may require government bail-outs after a large disaster, again transferring financial burden to tax payers.
- *The role of profit:* Private insurance is a for-profit venture, while Canadian disaster recovery programs are a public service. Insurance policies may therefore not align with the public interest — a tenet of flood management — with respect to excluding high hazard properties, setting affordable rates and premiums, and establishing appropriate capital reserves.
- *Incentivizing hazard mitigation:* A clear advantage private insurance may offer over government recovery payments is the incentivizing of private adaptation, such as floodproofing. Schemes to incentivize policyholders to reduce their own risk may be included in private policies. However, that private companies will design policies in such a way is not certain.

Clearly, the emergence of private flood insurance in Canada is a complex and important issue. However, few people had this on their mind June 18, 2013 as a low-pressure system settled over the Canadian Rockies — upstream of the largest city in Alberta.

4 The 2013 Southern Alberta Flood

The flood of 2013 had a profound impact on flood management in Alberta — and for the loved ones of the five people who lost their lives (Table 3) — the harm is indescribable.

Table 3 - Casualties of the 2013 Southern Alberta Flood (CBC News 2014).

Name	Age	Cause of Death
Lorraine Gerlitz	83	drowning
Dominic Pearce	52	drowning
Amber Rancourt	35	drowning
Jacqui Brocklebank	33	drowning
Robert Nelson[1]	41	motor vehicle accident

[1]Many authors only report four fatalities. This is likely because Robert Nelson died in an ATV crash while inspecting his neighbor's home for flood damage (CBC News 2014) — an indirect-intangible loss as defined above.

4.1 Hydrology

Pomeroy[p] et al. (2016) provides a description of the hydrological setting and subsequent warm, low-pressure system that stalled over the Bow, Elk (in BC), and Oldman River headwaters from June 19-22, 2013. High-elevation rainfall in excess of 300mm on snow, the subsequent rapid snowmelt over frozen ground, and synchronized runoff from the catchments contributed to extreme discharges. As a result, operators opened emergency spillways on the Barrier Lake Dam and the Cascade Dam on days two and three respectively, which intensified the flood wave. While this torrent destroyed many stream gauges, an analysis of records and data across the region by Pomeroy et al. (2016) calculated the flood on the Bow River in Calgary to be a 1:40-year event[q].

4.2 Response

Emergency-response practices and policies in place for the 2013 Southern Alberta Flood were largely influenced by the 2011 Slave Lake fire and subsequent recommendations laid out in KPMG (2012). In general, this left Alberta "relatively well prepared" according to outside experts interviewed by MNP LLP (2015)[r].

Twenty hours into the storm, on June 19, the Alberta Emergency Alert issued a "no significant flooding anticipated" warning, followed by a "flood watch" five hours later (MNP LLP 2015). Throughout the night and the next day, various municipalities began to issue their own flood warnings. However, the lack of coordination, jurisdictional uncertainty, and general confusion, led many upstream communities not to receive flood warnings until hours after road damage occurred — reducing their ability to evacuate (Pomeroy et al. 2016). How these inconsistent, confusing, and false-positive warnings influenced the flood damage remains an open question.

Over the next several days, 30 local state-of-emergencies were declared, as well as the first-ever provincial state-of-emergency in High River (MNP LLP 2015). The Provincial Operations Center (POC) was activated and elevated to its highest level for 24 days; it assumed authority for disaster response, dissemination of information, and coordination of key players. On day three, Op LENTUS 13-1 was initiated, bringing 2300 Canadian Armed Forces personnel and associated equipment to aid in relief and rescue (Government of Canada 2013a). On July 1st, 13 days after the start of the event, authority was transferred from the POC to the newly formed Flood Recovery Task Force (FRTF), which signaled the beginning of formal recovery efforts (MNP LLP 2015).

[p] John Pomeroy's personal account of the flood, from his home in Canmore, AB, is provided in Sandford and Freek (2014).

[q] Golder Associates (2014) calculated a preliminary return period of 80 years for the Bow River at Calgary.

[r] Following the disaster, the Province commissioned an external review by MNP — an accounting, tax and business consulting firm — to investigate the effectiveness of practices prior to 2015, and provide recommendations for future disaster response and recovery (MNP LLP 2015). The Calgary Emergency Management Agency commissioned a second report to evaluate the city's response (Vroegop 2014). We refer the reader to these reports for a more detailed account of response efforts, a timeline of events, and the challenges encountered.

4.3 Recovery

Recovery efforts were diverse, broad, and are now —four years later — still ongoing[s]. Programs, plans, and efforts were carried out on all political levels by actors including International NGOs, the GOC, the GOA, Municipal/FN governments, grass-roots volunteers, and individuals[t]. In general, the Government of Alberta (GOA) managed recovery efforts while the Government of Canada (GOC) provided compensation via the DFAA. A major exception was the City of Calgary, which developed its own programs to provide another layer of response (Vroegop 2014) and recovery (Danyluk et al. 2014).

The cleanup effort was immense. For example, the volume of solid waste sent to landfills increased by 20%[u]. In Calgary, the number of volunteers overwhelmed officials within three hours of the official request for help (McMurray 2013). The Calgary Herald (2013) documents the very emotional and compelling efforts of the 'tens of thousands' of volunteers.

Within the GOA, efforts were largely coordinated by the FRTF, a dual political and technocratic body given broad project funding and execution powers (Flood Recovery Task Force 2013b). The FRTF's work began with the development of the *Flood Mitigation Framework.* Approved by the provincial cabinet five days after the start of the storm, this framework laid out the conceptual role of the GOA, principles and elements that guided recovery, and a preliminary list of recovery metrics to track progress (Flood Recovery Task Force 2013a). Provincial policy was further refined a few months later in the *Flood Recovery Plan* with more detailed objectives and metrics, and the groundwork for additional plans related to stakeholder engagement, hazard mitigation, accountability, and mapping (Flood Recovery Task Force 2013b). The top-down, all-hands-on-deck approach of the province to recovery was widely perceived as successful (MNP LLP 2015); with the exception of FN housing reconstruction (see section 6.2) and the 2013 DRP (see below).

In September, 2014 the FRTF transferred recovery authority and administration back to the GOA ministries: *Municipal Affairs* (MA), which handles the ongoing DRP claims, and *Environment and Parks* (AEP)[v], which oversees mitigation and erosion control efforts (Auditor General of Alberta 2015a).

Disaster Recovery Program (DRP)

To understand the DRP that was established to aid recovery from the 2013 Southern Alberta Flood (2013 DRP), it is helpful to know the progression of historical DRPs in Alberta. In response to budget cuts in 1995, administration of the DRP was largely transferred from the GOA to LandLink, a private company purpose-built and run by the former executive director of the responsible ministry: MA (Auditor General of Alberta 2016). Prior to the 2013 Southern Alberta Flood, previously undisclosed provincial audits of LandLink uncovered poor performance and practices (D'Aliesio 2014) — a sentiment shared by some flood victims (Gerson 2011). Starting in 2003, the province opened the DRP contract for competitive bidding three times, and each time LandLink was the only bidder (MNP LLP 2015). With public outcry mounting over the 2013 DRP, the acting Minister broke ties with LandLink in April 2014[w], and began an accelerated transition of the DRP back to public management (D'Aliesio 2014). This transition, combined with the largest volume of claims in the history of the DRP, high staff turnover, and frequent changes to departmental policy in managing claims, likely hindered the performance of the 2013 DRP (Auditor General of Alberta 2016). Dissatisfaction was high amongst private applicants[x] (High River DRP Advocacy Committee 2016; MNP LLP 2015)[y]. Furthermore, a 2015 audit found inaccurate estimates and poor accounting during this period that resulted in a $756 million correction for the 2013 DRP estimate (Auditor General of Alberta 2015a).

[s] See Alberta Government (2014e) for a timeline of recovery efforts through mid-2014.
[t] See Appendix B for a complete list of official programs.
[u] Comparing the figures reported by municipal landfills for 2013 against the five year average (Alberta Government 2016e).
[v] Prior to the 2015 reshuffling, AEP was known as Environment and Sustainable Resource Development (ESRD).
[w] Prior to 2013, a report had been issued stating the need to restructure the DRP (KPMG 2012). This, combined with the frustration of 2013 victims over the process, possible conflicts of interest on the sole source contract (D'Aliesio 2014), and the desire to be seen as 'doing something' — may have influenced the Minister's decision. MNP LLP (2015) reports on the gag-order issued to staff during the 2015 election.
[x] The 18,013 private applicants represent only 17% of the total payout by dollars (AEMA 2016), and infrastructure and private business recipients were generally satisfied (MNP LLP 2015).
[y] Two internal audits investigated the performance of the 2013 DRP: Auditor General of Alberta (2016) focused on the transition while MNP LLP (2015) the overall effectiveness.

4.4 Damages

The Calgary Herald (2013) provides compelling photos of the destruction, and the Alberta Government (2013c) shows the extensive damage to provincial highways. Erosion was responsible for the majority of damage to public infrastructure — affecting rail bridges, highways, pedestrian bridges, and paths throughout the region (Pomeroy et al. 2016). In mountainous areas, debris flows caused significant damage (Pomeroy et al. 2016). However, the immediate and long-term direct impacts of inundation seem to have caused most of the total damage[z].

4.4.1 Total Tangible Estimate

Our research did not find any total final damage estimates, official or otherwise[aa]. The following description of damages, as given during a 2014 presentation from the director of the DRP program, is often quoted (Hale 2014):

- 5 deaths
- 14,500 homes damaged[bb]
- 10 health facilities damaged
- 80 schools damaged
- 100,000 people evacuated[cc]
- 3,000 businesses affected
- 30 communities affected
- 985 km of roads closed

Preliminary[dd] estimates for the total economic damage vary widely by amount, credibility, and completeness (Table 4). Five of the 13 estimates we identified cite Wood (2013), a news article of a press conference with the then-GOA-Finance Minister Doug Horner. To put this estimate into perspective, Minister Horner was asked if the estimate was final, to which he replied “Oh, hell no” (Wood 2013). However, the figures quoted in Wood (2013) of ‘over $5 billion’ to ‘approximately $6 billion’ seem to have stuck, as no alternate figures exist.

[z] This assumption is based in the observation that the majority share of the total flood damage came from within the City of Calgary — which had minimal damage from erosion. Our research did not find any comprehensive assessment of 2013 flood damage.

[aa] We reached out to both relevant ministries at the GOA. Both referred us to the “Alberta 2013-2014 flood recovery update” website, updated on May 14, 2014. This website lists the provincial program cost allocations, does not differentiate between mitigation and recovery, and does not include costs outside the provincial responsibility umbrella (e.g. costs incurred by the City of Calgary or the Canadian Armed Forces).

[bb] As of March 3, 2017 the DRP figure is 18,013 claimants (AEMA 2016)

[cc] MNP LLP (2015) repeats the same Hale (2014) figures, but in a separate section states 125,000 persons were evacuated.

[dd] Most damage estimates self-describe as ‘preliminary’. This is likely a result of ongoing recovery and acknowledgement of the limited scope of each estimate.

Table 4 - Total 2013 flood damage estimates found in the literature.

Reference	Date[5]	Amount[6]	Source/Method
Lewis (2013)	2013-06	"Preliminary estimates of damages range between $3-billion and $5-billion"	BMO analyst Tom MacKinnon
Wood (2013)[1]	2013-09	(a) '"province's finance minister now pegging the cost at $6 billion". (b) "Last month, the government estimated the total cost [...] at more than $5 billion."	News article (a) summarizing an interview with the Minister of Finance (b) none provided
Alberta Government (2014a)	2014-02	"rebuilding costs are estimated to exceed $6 billion"	none provided
Government of Canada (2014)	2014-04	"Economists project damage losses and recovery costs from the flood to exceed $6 billion"	Wood (2013)[2]
WaterSMART (2014)	2014-04	"estimated property damage exceeded $6 billion"	none provided
Alberta Government (2014d)	2014-05	"nearly $5 billion to recover and rebuild"	none provided
Danyluk (2014)	2014-06	"Estimates place the total costs for Alberta at $5 billion to $6 billion"	none provided
Davies (2016)	2014-07	"Capital damage from the Calgary area floods is estimated to have been at least CAD $6 billion"	Government of Canada (2014)
MNP LLP (2015)	2015-07	(a) "Current estimates place the damages at approximately $6 billion". (b) "Estimated total cost of the recovery [...] is over $5 billion"	(a) Government of Canada (2014) (b) none provided
Pomeroy et al. (2016)	2015-08	"Flood damage losses and recovery costs from the flood are projected to exceed CAD$6 billion"	none provided
Thistlethwaite (2016)	2016-05	"over $5 billion in damage"	Wood (2013)
Public Safety Canada (2017) (i.e. CDD)	2017-05	Estimated Total Cost $2,715,742,000	Primarily open sources cross referenced with government and private sources[3].
Guha-Sapir et al.(2015)	unknown	$5.869 billion 2013CAD[4]	'various sources'

1. *See text for discussion*
2. *Email correspondence with Environment Canada, the agency that published Government Canada (2014), confirmed Wood (2013) as the source of their estimate.*
3. *Reference information for this CDD entry confirmed with email correspondence. Federal DFAA payments are interim only. No estimate for: Provincial DFAA Payments, Provincial Department Costs, Municipal Costs, Other Government Departmental Costs, or NGO payments.*
4. *Converted using 2013 exchange rate.*
5. *Where available, latest revision or submission date of reference is reported here; otherwise, publication date.*
6. *Amounts are provided as reported unless otherwise stated. It is assumed that these are in 2013CAD.*

While a final estimate for all sources of monetary and non-monetary damage may not be achievable due to challenges in monetization and scant observations, the lower limit of the final total tangible damage is clearer. The Canadian Disaster Database (CDD) records an estimate of $2.2 billion 2013CAD as of February 2017 for the 2013 Southern Alberta Flood. In general, the CDD seems to prioritize its records in terms of breadth (recording all Canadian disasters) more than depth (reporting damage estimates from the many actors that incurred damage), often only including the federal share of DFAA payments[ee]. In this vein, the CDD 2013 Southern Alberta Flood estimate lacks some key damage sources (see note in Table 4). Searching through publicly available reports to fill in these gaps, we develop a lower limit estimate on recovery spending to date (Table 5) as a proxy for the lower limit of the final total tangible damage.

[ee] For example, provincial estimates have been publicly available since late 2013 for the Southern Alberta Flood entry, but have not been included in the CDD estimates. As another example, the provincial spending data for most major floods dating back to 1996 are not included.

Table 5 - 2013 lower limit final recovery spending estimate

Recovery	Expense Location (description)[1]	Source
$ 1,220,826,000	Alberta Government (non DRP)	(Alberta Government 2016e)
$ 1,595,174,000	Alberta Government (DRP estimate)[2]	(Alberta Government 2016g)
$ 1,700,000,000	Insurance Payments	(Public Safety Canada 2017)
$ 285,848,000	Calgary Estimate (non-DRP)	(City of Calgary 2016)
$ 45,000,000	Canadian Red Cross	(Canadian Red Cross 2017)
$ 693,000	High River Disaster Relief Fund	(Bev Warner 2014)
$ 1,400,000	United Way	(United Way Calgary 2017)
$ 1,900,000	Salvation army	(Schmidt 2014)
$ 4,200,000	Samaritans Purse	(Schmidt 2014)
$ 20,000,000	Parks Canada	(Derworiz 2014)
$ 4,875,041,000	**SUM**	

1. *Expense label where the recovery value is reported from. These expenses cover a range of recovery activities. Values are reported in such a way as to avoid double counting.*
2. *$1.015 billion is reported by the CDD for the federal share.*

4.4.2 What's Missing?

Even a cursory glance at Table 5 reveals this dollar figure only estimates a fraction of the loss. It excludes the hours spent on flood recovery by victims, private expenses not covered by the DRP, the trauma of losing a home, and the five people who lost their lives. In other words, Table 5 provides only a partial lower-bounds estimate for tangible damage and no estimate for intangible damages. Despite its desirability, a complete final estimate is not possible due to: 1) high resource demand to collect data from numerous and diverse sources; 2) recovery expenses used to rebuild beyond the antecedent conditions; and 3) subjective and unquantifiable nature of intangible and indirect damages (see section 2.2.3.2). Table 6 lists the categories we were unable obtain and include in our lower-bounds estimate.

Why is this important? A full accounting of the tangible and intangible damages of the 2013 Southern Alberta Flood is important in making governments more accountable for their efforts to reduce flood risk, providing insight into how to prepare for similar events, and helping to guide decisions on allocating scarce public funds towards disaster mitigation. Finally, an accurate figure will help to put the 2013 Southern Alberta Flood policy transformation into perspective.

Table 6 - Known recovery categories not included in current total damage estimates for 2013 flood. Adapted from Jonkman et al. (2008).

Tangible - Direct
Federal search and rescue expenses
Non DFAA federal expenses
Municipal expenses
FN expenses
Structural damages not covered by DRP
Damage to personal possessions not covered by DRP
Damage to small businesses not covered by DRP or Insurance
Clean up costs not covered by DRP
Property damage not repaired or replaced
Lost inventory and/or crops not covered by Insurance
Volunteer time and resources
Unorganized private donations
Federal search and rescue resources
Tangible - Indirect
Business interruption (lost revenue or production)
Changes in production and consumption patterns
Non-governmental temporary housing (staying with family/friends)
Reduced wages
Intangible
Injuries/physical health
Infection/disease
Inconvenience
Damage to cultural sites
Environmental damage
Societal disruption
Psychological trauma (PTSD) of responders and victims
Lost opportunities
Loss of trust in public authorities
KEY
Estimate likely exists, but not publicly available
No existing estimate likely

5 Alberta Post-2013

From 1971 to 2015, Alberta was governed by the Progressive Conservative Association (PC) (see Figure 12 for timeline). In 2015, two years after the flood, the New Democratic Party (NDP) won a surprise election, which ended the longest uninterrupted provincial government in Canadian history (Ho et al. 2015). While flood control did not register on opinion polls at the provincial level (Archer and Maclean 2015), flood management was likely a concern in Calgary and High River[ff], and may have influenced how people voted. The relationship between politics and flood control was further complicated by mixed opinions on the then proposed $158 million PC backed Springbank project (discussed further in section 5.1), which the NDP did not initially support (City of Calgary 2015), although their position has since changed (Tucker 2016). Regardless, May 2015 ushered in a new era of center-left social democracy for the GOA followed six months later by the Liberals assuming office at the GOC.

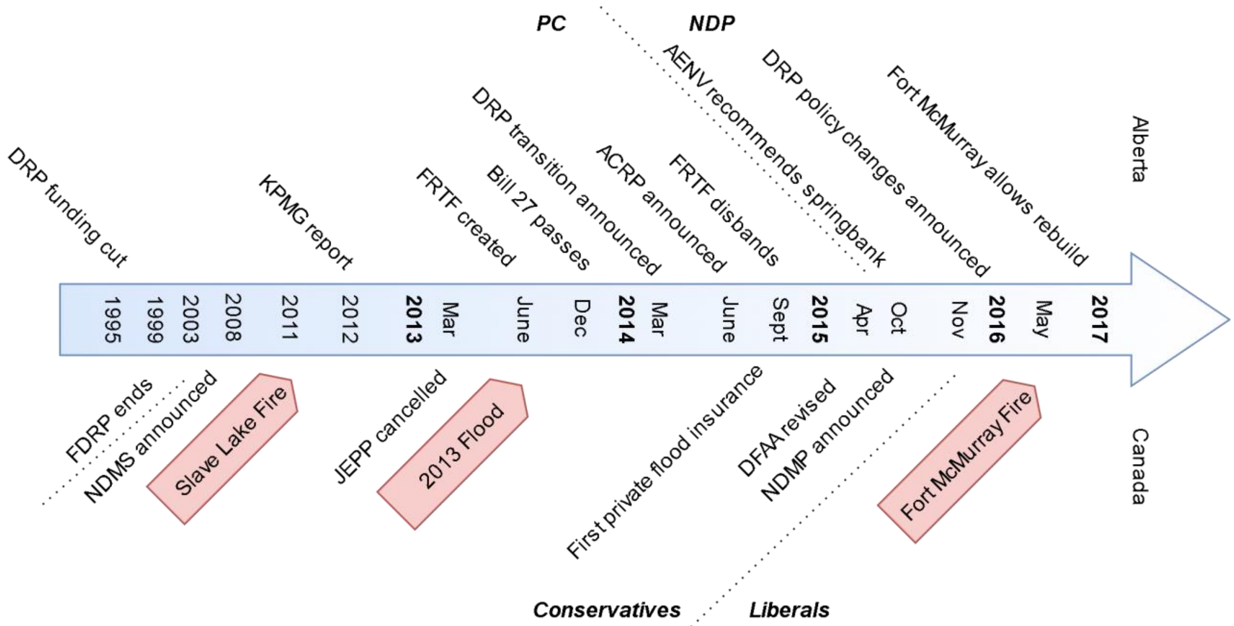


Figure 12 - Timeline of major policies and disasters relevant to flood management in Alberta. See text for details.

Post-2013, provincial flood management in Alberta has largely migrated temporary 2013 recovery programs, policies, and personnel towards semi-permanent hazard mitigation efforts. To provide guidance for these changes, both during recovery and beyond, the province issued the *Resilience and Mitigation Framework for Alberta Floods* (Alberta Government 2013d) and, shortly afterwards, *Respecting Our Rivers* (Alberta Government 2014a). Written for a general audience, these policy statements committed the province to: 1) a more integrated approach (see section 2.4); 2) a reliance on local and private initiatives; 3) improved modelling and forecasting; and 4) a risk-based approach (see section 2.2). While vague, these policy positions reflected many of the modernizations experts have recommended for decades (see section 8.1). To turn these policies into flood risk reduction for the politically-sensitive areas that had been under water in 2013, the province created the *Community Flood Mitigation Advisory Panel* (Lindseth 2013). This panel led the preliminary investigation and design of the major mitigation projects, and issued its recommendations in October 2013 (Stantec 2013), before transferring its duties to the provincial ministries (mostly AEP).

[ff]A claim supported by the promise from the outgoing government of $15 million in additional flood mitigation funding in these districts one month before the election (Dormer 2015).

5.1 Key Provincial Programs (FHIP, ACRP, WRRP, WMMI, and PFDAT)

Flood risk mitigation in Alberta post-2013 is separated into five basic programs that: 1) execute basin wide projects (WMMI); 2) fund local initiatives (ACRP and WRRP); or 3) provide decision tools (FHIP and PFDAT) [gg]. These programs work in concert to identify the hazards (FHIP), select the most effective mitigation measures (PFDAT), then mitigate with locally executed engineered flood control works (ACRP) and/or wetland and channel restoration (WRRP), or provincial-led new regional infrastructure (WMMI).

Flood Hazard Identification Program (FHIP)

Following the 1999 federal retreat from the FDRP (also known by its provincial name Canada-Alberta Flood Damage Reduction Program (CAFDRP)) (see section 3.1), the GOA took responsibility and transferred the program to the provincially funded Flood Hazard Identification Program (FHIP). From 1999 to 2014, the new FHIP continued to map the floodway and flood fringe using a 100-year regulatory event (Alberta Environment 2011). These maps were intended to provide municipalities with information to regulate development in their floodplains via local land-use by-laws (see discussion below on Bill 27). However, funding was inconsistent, and by 2014, only 55% of rivers in the province had been mapped (MMM Group 2014) with 21 of the 63 flood hazard maps older than twenty years[hh] (Auditor General of Alberta 2015a).

To address these concerns, three months after the 2013 flood the GOA announced $8.7 million in funding over seven years for the FHIP (Alberta Government 2013b). This massive effort includes six new hazard studies, which in 3 years will accomplish nearly half of what before took 30 years (Alberta Government 2017b). However, many authors (see section 8.1), the GOC, and the GOA staff, feel the existing guidelines require an update to provide more useful, robust, and complete hazard maps (Auditor General of Alberta 2015a). Given the political nature of changing the FHZ and the corresponding land-use-regulations, it is unclear whether, how, and/or when the GOA will update their mapping guidelines.

Provincial Flood Damage Assessment Tool (PFDAT)

In line with the post-2013 commitment to a risk-based approach towards protecting existing development, the province commissioned a new flood damage model for use in risk assessments. Completed in 2015, this Provincial Flood Damage Assessment Tool (PFDAT) leverages the model results (exposure indicators) obtained from studies similar to those conducted under the FHIP, GIS property data, and custom depth-damage curves to estimate the total annual expected damages for a mitigation scenario (IBI Group and Golder Associates 2015). These damage curves were developed from extensive property surveys of structures and their contents in Calgary and Edmonton not impacted by the 2013 Southern Alberta Flood. To transfer these curves in space (i.e. to other communities) and time, IBI Group and Golder Associates (2015) included modifiers based on local pricing indices and inflation indices. Indirect damages were estimated based on percentages of direct damage found in the literature (IBI Group and Golder Associates 2015).

Alberta Community Resilience Program (ACRP) and Watershed Resiliency and Restoration Program (WRRP)

To address local flood risks, the GOA created the ACRP and WRRP, which are both cost-sharing grant programs that rely on local stakeholders (e.g. Municipalities or FN) to assess the flood hazard, develop a preliminary design, and then apply to the GOA for partial funding (Alberta Government 2016c, 2017c). In this way, the province can both respect the autonomy of local communities and be selective in allocating resources towards flood mitigation.

[gg] See Appendix A for a complete list of programs.
[hh] In their review of international practices, MMM Group (2014) suggested maps be updated every 5 (urban) and 20 (rural) years to reflect changes in data collection technology, hydrology, land-use, and river morphology.

Water Management and Mitigation Infrastructure (WMMI or Special Projects)

Of the five dry storage-reservoirs proposed by the Community Flood Mitigation Advisory Panel, the GOA has continued development of two under their Water Management and Mitigation Infrastructure (WMMI) program (Alberta Government 2016f) to provide flood protection for the Highwood and Elbow River Basins. The most notable is the Springbank Reservoir, the former government's flagship flood mitigation project for the Elbow River running through Calgary. With a total estimated cost between $208 – $263 million, the province's 2015 risk assessment (using the newly developed PFDAT) determined it to be the best option, with a benefit/cost ratio between 1.32 and 2.07 (IBI Group and Golder Associates 2015)[ii]. The project has spawned a number of local advocacy groups, including both detractors (Koetsier 2017; DontDamnSpringbank 2017) and supporters (CRCAG 2017a).

5.2 The Risky Development Quagmire

Currently, Alberta's Municipal Government Act gives land-use planning authority to municipalities with no stipulations for flood risk mitigation (Alberta Government 2014g). In the aftermath of 2013, Alberta recognized this hands-off approach to land-use planning in the FHZ resulted in a patchwork of local land-use by-laws and high-risk developments[jj]. To halt the escalating risk, the PC government passed Bill 27, the *Flood Recovery and Reconstruction Act*. This Act gives the GOA more authority in restricting future development and repeat disaster recovery payments (Minister of Municipal Affairs 2013). While the PC government passed Bill 27 less than four months after the flood, the regulations enforcing it continue to face political delays under the NDP government (Shaye Anderson 2017). Further, despite a clause exempting certain high-risk communities like Fort McMurray and Drumheller under the pretext of future mitigation (Alberta Government 2015c), the regulations have faced sustained political opposition from local advocacy groups who feel the upcoming restrictions may adversely affect property values (Thomas 2017; CRCAG 2017b).

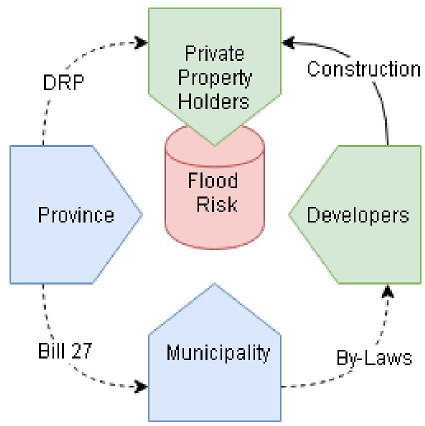


Figure 13 - Post 2013 floodplain development/flood risk influence diagram. The province influences private property holders through expectations of the DRP program and municipalities through expectations of the Bill 27 regulations. The municipalities then influence developers through the Bill 27-modified and other by-laws. Developers in turn create new property holders — the stakeholders directly generating flood risk. During rebuilds, the developers and the private property holders are the same entity.

The nuances of the DRP, expectations of future changes, and the applicability of the uninsurable clause also cast a long shadow over floodplain development and management decisions. These uncertainties have tangled with the uncertainty of the upcoming Bill 27 regulations, and changes to the hazard maps, to make construction in the floodplains a regulatory quagmire (Figure 13). However, such growing pains are to be expected and were only a minor annoyance considering the limited floodplain construction under consideration in early 2016 as the province was wrapping up flood recovery.

[ii] The City of Calgary has recently performed their own flood risk assessment, and found the Benefit/Cost ratio to be 3.22 (IBI Group and Golder Associates 2017).

[jj] Auditor General of Alberta (2015) provides one anecdote of a development in High River that was mapped and shown as in the floodway, yet had no land-use restrictions placed on it. Following the 2013 flood, the province spent approximately $21M to buy back the properties from the victims.

5.3 The Flood then The Fire

On May 1, 2016, unseasonably dry and hot conditions spread wildfire into Fort McMurray, triggering the second provincial state of emergency in the province's history (RMWB 2017). The fire destroyed approximately 2000 buildings and disrupted oil production. Preliminary estimates place the damages at $8.8 billion (Alam and Islam 2017). Particularly unfortunate are the residents of the Waterways neighborhood — aptly named as it sits mostly within the 40-year floodplain and suffers frequent flood damage (King 2016). It is likely this neighborhood was a major factor in the Provincial legislature's move to exempt communities like Fort McMurray from Bill 27 in 2013, three years before the fire destroyed 90% of it (RMWB 2017).

Caught between frustrated-homeless residents wanting to rebuild (McDermott 2016) and provincial policy (i.e. DRP eligibility and the uncertainty of Bill 27), the municipality (Regional Municipality of Wood Buffalo (RMWB)) began negotiating with the province on the rebuilding of the neighbourhood. Five months after the fire, the GOA issued two letters to RMWB stating: 1) Bill 27 does not restrict rebuilding in Waterways[kk]; and 2) DRP eligibility would ignore the fire rebuilds — so long as the municipality continued to pursue flood mitigation in a 'timely manner' (Scoble 2016). Towards this, the municipality commissioned a flood risk assessment using the PFDAT, and found no favorable permanent solutions (RMWB 2016). The situation is further complicated as the municipality awaits the results of a new flood hazard mapping study for the area (RMWB 2016). This anecdote illustrates: 1) the current regulatory uncertainty in floodplain development in Alberta; 2) the power of the DRP to encourage/discourage high-risk development; 3) bureaucratic inertia (flood mitigation planned before flood hazard mapping is complete); and 4) the failure of local government to protect public interests (tax payers) against a vocal minority (disaster victims).

[kk] Bill 27 has no regulatory effect anywhere until MA drafts and gains approval for the corresponding regulations. The province had previously indicated that these regulations won't apply to Fort McMurray or to rebuilds (Alberta Government 2014g).

6 First Nations

First Nations (FN) are the original nations of the Americas who signed government-to-government treaties with the English Crown, ceding territory for colonization and recognizing English sovereignty over those ceded lands (Government of Canada 2013b). In return, FN: reserved lands for themselves and rights of self-governance; contracted certain annuities; and were guaranteed protection from other colonial powers. However, FN were at a disadvantage during treaty negotiations due to the impacts of European colonization. Disease, policies of genocide, and overwhelming numbers of colonists with superior warfare technologies greatly diminished FN ability to secure the protections and resources needed to survive, let alone thrive at the same level as non-FN/settlers. The protections that were recognized were eroded and unilaterally interpreted and diminished. Under the British North American Act of 1867, the Crown transferred “legislative jurisdiction for Indians and lands reserved for the Indians” to the Federal Government[ll] (Government of Canada 2015a). In 1876, the Indian Act and subsequent amendments to the Act aimed at “enfranchisement,” a policy to compel Indians to renounce their Indian status (rights, culture, language, and religion) and become “civilized” members of Canada (Government of Canada 2017). Since the 1980s, and in accordance with the re-writing of the Canadian Constitution, policy has shifted toward Reconciliation, a recognition of FN rights, and negotiations on a government-to-government basis (Renzetti and Dupont 2017).

Renzetti and Dupont (2017) provide an overview of the evolution of FN/settler relations in Canada, and the resulting unique context for modern water policy. Relevant generalizations to flood management are: 1) FN tradition views the people “as part of, and not apart from or having dominion over, nature”; 2) FN seek to reclaim autonomy; and 3) FN have unique and heterogeneous cultural and governance values. Following the signing of treaty six, seven, and eight in the late 1800’s, the tribes in Alberta were compensated in part through confinement to *reserves* (Renzetti and Dupont 2017). Today, Alberta contains roughly 45 FN on 140 reserves (Government of Canada 2010), many incorporating some (mostly unmapped) floodplain.

6.1 What Flood Management Policy Looks Like on the Reserve

Due to the complex jurisdictional, cultural, and historical components of governance on reserve, we find it more useful to discuss each flood policy theme separately — as the expression in these themes tends more towards heterogeneity than homogeneity.

Land-Use

Land-use on reserves is governed by the Indian Act of 1876 and any treaties the individual FN signed with the GOC (Government of Canada 2012b). Under this complex legal structure, modern land-use policy on FN reserves is generally a mix of GOC and FN initiatives — denying the province any jurisdictional authority. In Alberta specifically, the Municipal Government Act — which legislates most provincial land-use policy — does not apply on reserves (Alberta Government 2016k), and thus neither does the recent legislation to limit floodplain encroachment: Bill 27. In summary, historical land-use policy has been applied largely on a case-by-case basis to each reserve (Government of Canada 2012b), without much consideration of flood risk.

Flood Hazard Mapping

Historically, flood hazard mapping on reserves was conducted under the FDRP by the provinces and a 1985 MOU declaring that flood hazard areas would only be mapped on reserves when requested by the community (Beasley 2010). In Alberta, this policy was further entrenched in 1989 under the FDRP’s provincial wing, the Canada-Alberta Flood Damage Reduction Program (CAFDRP), which explicitly excluded mapping on reserve lands (Government of Canada and Alberta Government 1989). As a result, many reserves, including the Stoney, Tsuut’ina, and Siksika, had no hazard mapping and extensive floodplain development prior to the 2013 Southern Alberta Flood (see Figure 14 for an example). Following the 2013 Southern Alberta Flood, the FHIP is now mapping the Bow and Elbow Rivers through the Stoney and Tsuut’ina reserves respectively (Onyshko 2015). How those maps will be used is less certain.

[ll] Aboriginal Affairs and Northern Development Canada (AANDC), formerly known as Indian and Northern Affairs Canada (INAC), has been the main federal organization exercising this authority.

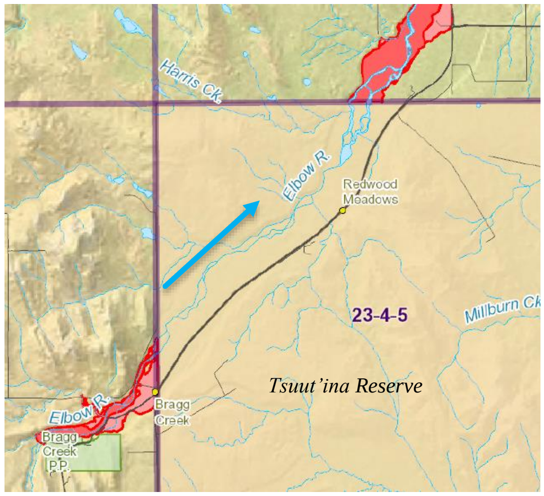


Figure 14 - Extract of the 1992 flood hazard map across the Tsuut'ina reserve just west (upstream) of Calgary, which suffered flooding in 2013. Areas in red are floodway and flood fringe. Blue Arrow is direction of flow along the Elbow River (UMA Engineering Ltd 1992).

On Reserve Housing

As part of the treaties from the late 1800's, the GOC took on the responsibility to provide on-reserve housing for FN. However, this responsibility is seen by the GOC as a policy issue, rather than a direct right of FN (Belanger 2016). Meanwhile, most provinces[mm] have distanced themselves from housing policies on reserves within their borders (Belanger 2016). Belanger (2016) discusses such complexities of FN housing at length, and attributes the continued lack of adequate housing on reserves to the aforementioned type of responsibility adopted by the GOC, the lack of consultation with FN, and the lack of participation by the provinces. Such systemic problems have led to appalling conditions on many reserves (Moe 2011), and for many to use the label "housing crisis". Such labels become painfully salient when these sub-standard homes are damaged by floods. For example, in Manitoba, Thompson et al. (2014) documents the Provincial decision in 2011 to divert flood waters onto the Lake St. Martin First Nation in order to reduce damage to non-FN communities. Despite this, the Government of Manitoba continued its policy of deferring FN housing issues to the GOC, resulting in over 1900 members still homeless six years after the flood (Indigenous and Northern Affairs Canada 2017b)[nn]. Likely in reaction to the negative portrayal in the media of the Lake St. Martin (and the Attawapiskat First Nation in Ontario) disaster, the GOA "bucked the trend" and took responsibility for disaster recovery on two of the affected FN reserves (Stoney and Siksika) following the 2013 Southern Alberta Flood (Belanger 2016).

6.2 The People Not in Calgary: FN Under the 2013 Flood

Stoney, Siksika, Piikani, and Tsuu T'ina were the FN communities directly affected by the 2013 Southern Alberta Flood. Although no official damage reports are available, Stoney and Siksika seem to have been particularly hard hit, estimates of 900 of 3494 and 700 of 2972 people affected, respectively (Alberta Government 2014c; Statistics Canada 2012). The situation was likely worsened by the delay and ineffectiveness of flood warnings. MNP LLP (2015) reported that some reserves did not receive warnings in time and others ignored them. This example demonstrates both a lack of infrastructure on the reserves, and challenges in applying systems designed for off-reserve communities to on-reserve communities.

[mm] Nova Scotia and British Columbia excepted (Belanger 2016).
[nn] Reconstruction is an ongoing partnership between the Government of Canada and the Government of Manitoba. On March 13, 2017 the GOC announced funding for an additional 150 homes (Indigenous and Northern Affairs Canada 2017a).

Thurston and Schill (2015) investigated the views and role of the media in recovery efforts — reporting a feeling by FN of their under-representation in mainstream media. The few news articles that were published on FN recovery efforts incorporated "subtle racism" by portraying FN people as perpetual victims and/or unappreciative. Furthermore, the different FN were typically lumped together, ignoring the differences among FN. While Thurston and Schill's (2015) investigation was limited to media perceptions, it provides a useful glimpse into broader Canadian views of FN, and draws our attention to similar problems in public policy.

As mentioned, in an unprecedented and highly-praised policy shift, the GOA decided to take responsibility for 2013 flood recovery on FN reserves, rather than wait for the often slow GOC programs to kick in (Belanger 2016). In the weeks following the 2013 Southern Alberta Flood, provincial DRP agents were deployed to assess the damages; they found that 136 and 548 homes needed reconstruction on Siksika and Stoney reserves, respectively (Alberta Government 2016a). To accomplish this reconstruction, the GOA signed a memoranda of understanding (MOU) with each FN in November and December of 2013 (Alberta Government 2014b) and committed $345 million over five years for FN recovery (Alberta Government 2014f). The MOUs established the Province as the project administrator and financier while the FN were responsible for the housing plans and community relations (Alberta Government and Stoney Nakoda Nation 2013; Alberta Government and Siksika Nation 2013).

However, the recovery program was not without its challenges[oo]. A 2014 internal audit found a lack of preparedness, experience, and systems in the GOA's approach to the reserve rebuilds (Auditor General of Alberta 2014). Fifteen months after the flood, the province transferred administration of the rebuild project on the Siksika reserve to the Siksika Nation (Jarvie 2016), which continued to develop the replacement neighborhoods through the Siksika Rebuild Team (SRT). To meet provincial requirements and economic constraints, the nine Siksika replacement neighborhood plans were significantly denser than the pre-flood housing (Siksika Rebuild Team 2017). Thirteen months after the SRT took over management, tribal members blockaded one of the neighborhoods, protesting the lack of transparency, accountability, and consultation (Zig Zag 2016). As a result of the forced delay, the Siksika Nation is now exposed to contract disputes, the majority of the displaced remain in temporary housing, and community cohesion has suffered (Zig Zag 2016). The Alberta experience provides evidence that provincial involvement is a necessary, yet insufficient condition, to making progress on the FN housing crises and disaster recovery.

[oo] This sentiment should be taken with the context that this was the first time the GOA had taken such an active role on a FN reserve and the general challenge of disaster recovery.

7 What the Managers Say

As we have seen, the Alberta flood policy landscape is diverse and dynamic. The opt-in nature of provincial programs, and the diversity of resources and risks in each community, lead to differing implementation and levels of effectiveness of flood policy. Furthermore, the 2013 floods triggered a dramatic cascade of flood policy shifts across all levels of government. As of early 2017, significant riverine flood mitigation projects are underway in Canmore, Calgary, High River, Medicine Hat, Whitecourt, and Fort McMurray (RMWB) (Table 7). To better understand the results of cultural, temporal, and spatial heterogeneities on the expression of flood policy, we surveyed 15 municipal flood managers. Specifically, we asked the people charged with flood management how paper policies translate down to real flood risk reduction.

Table 7 – Top 10 (by funding) active flood mitigation and erosion control projects in Alberta as of 2017.

Location	Name	Total Funding Estimate[1]	Reference
Canmore	Debris Dam at Cougar Creek	$43,747,565	"Alberta Government. 2015. "Flood Recovery Erosion Control Program." June 5. http://aep.alberta.ca/water/programs-and-services/2013-flood-recovery-programs/flood-recovery-erosion-control-program.aspx.
Bow Valley	Modified Operations Agreement with TransAlta[2]	$27,500,000	Government of Canada, Infrastructure Canada. 2016. "Infrastructure Canada - Infrastructure Canada Projects since 2002 - Alberta." January 28. http://www.infrastructure.gc.ca/map-carte/ab-list-eng.html."
Calgary	Bonnybrook Wastewater Treatment Plant - Flood Mitigation Program	$11,450,000	"Alberta Government. 2016. "Province, TransAlta Reach Agreement to Protect Calgary and Other Bow River Communities from Flood and Drought | Alberta.ca." April 27. https://www.alberta.ca/release.cfm?xID=416497AD8E5AF-C609-3404-6A349ADE5BB730BD.
RMWB	Lower Townsite Protection in Fort McMurray	$10,000,000	Alberta Government. 2017. "Alberta Community Resilience Program | AEP - Environment and Parks." http://aep.alberta.ca/water/programs-and-services/alberta-community-resilience-program/default.aspx.
Turner Valley	Decalta Bridge - Mitigation Project (Hwy 22)	$7,450,000	Alberta Government. 2017. "Alberta Community Resilience Program | AEP - Environment and Parks." http://aep.alberta.ca/water/programs-and-services/alberta-community-resilience-program/default.aspx.
Medicine Hat	Lions Park Overland Flood Protection	$7,011,750	Alberta Government. 2017. "Alberta Community Resilience Program | AEP - Environment and Parks." http://aep.alberta.ca/water/programs-and-services/alberta-community-resilience-program/default.aspx.
Calgary	52nd Street NW	$6,275,000	Alberta Government. 2015. "Flood Recovery Erosion Control Program." June 5. http://aep.alberta.ca/water/programs-and-services/2013-flood-recovery-programs/flood-recovery-erosion-control-program.aspx.
City of Edmonton	Malcolm Tweddle & Edith Rogers Dry Ponds	$6,270,000	"http://www.medicinehat.ca/index.aspx?page=1658
Whitecourt	River Erosion Control Project. Athabasca River @ Whitecourt	$6,239,888	Whitecourt. 2016. "Construction on the River Erosion Control Project Wraps for the Season." Town Of Whitecourt. November 21.
Canmore	Cougar Creek -Short Term	$6,200,000	Alberta Government. 2015. "Flood Recovery Erosion Control Program." June 5. http://aep.alberta.ca/water/programs-and-services/2013-flood-recovery-programs/flood-recovery-erosion-control-program.aspx.

[1]Estimate includes funding from numerous sources (e.g. GOA, GOC, Local, etc.)
[2]Compensation paid to TransAlta (reservoir operator) for loss in revenue due to agreed modifications to reservoir operations.

7.1 Survey Method

Municipal departments for the major at-risk communities across the province were solicited through their websites for participation in our online survey *Floods in Alberta: Management's Perspective*. The survey was conducted from April-May 2017. Ninety-three (93) questions were asked with four response formats: free-form, multiple choice, list, or range (i.e. 0-low to-4 high) (see Appendix D for questionnaire). Participants were instructed to skip a question if they felt uncomfortable answering or the answer too time consuming[pp]. Each section included space for participants to provide further comment with the last section reserved for additional open comments and closing thoughts. If a participant provided the same answer for all questions in a single category, the responses are excluded from the below results.

7.2 Survey Results

Fifteen (15) self-identified flood managers from nine municipalities participated on a condition of anonymity (both in name and jurisdiction). These municipalities collectively represent roughly one third of Alberta's population[qq]. Experience in flood management (in their jurisdiction) ranged from 1.5 to 28 years with an average of 11.9 years. Eight (8) of 15 identify as professional engineers and 5 of 15 identify as having a Master's degree in a related field.

[pp] 88% of questions had a participation rate 12 of 15 or better.
[qq] Calculated against the 2016 provincial population of 4,067,175 (Statistics Canada 2017a).

7.2.1 Land-use

Land-use policy is generally considered the most effective flood risk mitigation tool when applied consistently before at-risk development occurs (see section 2.2.4). To better understand this in Alberta, participants were asked to rate the effectiveness of current land-use zoning practices in limiting the growth of flood risk in their jurisdictions. Survey results showed that flood managers from 7 of 9 municipalities feel current land-use practices are very effective or better.

A challenge for mitigating flood risk through land-use policy has always been older developments in the floodplains without floodproofing (see section 2.2.4). These developments deserve special attention from flood managers as they are high-risk (high vulnerability; no floodproofing). This group is also of concern for policy makers as these stakeholders often resist extension of land-use restrictions to their property (see above discussion on Bill 27). To investigate the size of this high-risk group, participants were asked to estimate the number of exposed homes in the existing FHZ (100-yr), and an extended FHZ (350-yr) (see Figure 11). Assembled responses across the nine municipalities are shown in Table 8. The total population estimate of this stakeholder group, (e.g. residents between the two zones) represents roughly 0.5 to 1.2% of the collective municipal population[rr]. While this should be treated as no more than an order of magnitude estimate, it provides some quantification of both the number of homes for which no land-use policy currently regulates, and the level of objection communities may have to extending the FHZ per the recommendations of Public Safety Canada's *National Floodplain Management Framework* (MMM Group 2014).

Table 8 – Collective respondents view on the number of residential buildings in the flood hazard zone (FHZ). See Figure 11 for description of FHZ sub-areas.

	Lower Bound		Upper Bound	
	Floodway	**Flood Fringe**	**Flood Way**	**Flood Fringe**
100-yr FHZ	195	5,520	1,163	11,870
350-yr FHZ	484	8,600	3,365	19,275
difference	289	3,080	2,201	7,405
Total[1]		**3,368**		**9,606**

[1]Sum of floodway and flood fringe differences.

7.2.2 Risk Awareness

Understanding a manager's perceived level of risk for their jurisdiction can serve as a proxy measure to track the effectiveness, and space for improvement, of flood management measures towards reducing flood risk. Participants were asked to rate qualitatively their perception of flood risk before and after the 2013 Southern Alberta Flood. Survey results showed 6 of 14 feel there has been no flood risk reduction since 2013. However, if participants with less than 10 years of experience are excluded, this changes to 2 of 8 (feel there has been no reduction). Finally, 10 of 14 participants stated the near-future[ss] flood risk is moderate to high.

Responses	Risk Delta[1]
4	Significant
4	Moderate
6	None

[1] Respondents view on the level of real flood risk reduction (because of policy intervention) from pre-2013 to now.

[rr] Assuming two persons per residential building. This proportion doubles when a specific municipality is excluded from the analysis.
[ss] After flood control projects currently in development are complete.

Commenting on the current high-level of flood risk, one participant highlighted the gap in flood policy concerning basement damage:

> *Even if buildings are flood-proofed above ground, basements are not usually regulated, so there is still (or could be) considerable damage to parts of the building that are below the design flood elevation. To some who chose to live in these areas, this risk may be acceptable, but it may not be for others. It still does not reduce risk/potential damages enough in my opinion, and in some cases the government will still be expected to compensate the owners when these buildings' basements flood.*

7.2.3 Program Effectiveness

While the GOA has pledged $913 million towards flood management programs, our research did not find any efforts to measure the effectiveness of these programs. As a proxy for this, participants were asked to rate on a scale of 0 (never used) to 4 (extremely helpful) how helpful the major GOA and GOC programs are towards implementing flood risk mitigation in their jurisdiction[tt] (Figure 15). Results show participants feel Springbank and Special Projects are the most useful. On the other end of the spectrum, the NDMP and WRRP are viewed as relatively less useful.

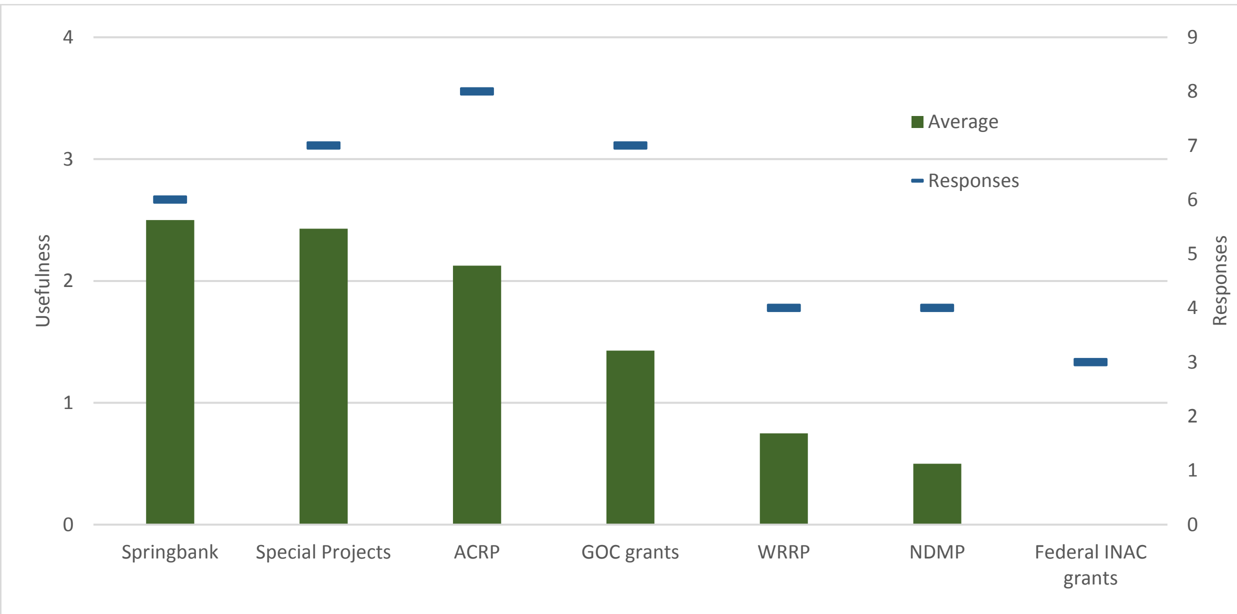


Figure 15- Participants view on the usefulness (average shown in green on the left axis and number of responses shown in blue on the right axis) of GOA and GOC programs.

One participant explained some of the pitfalls of the NDMP:

> *Municipalities need more funding from federal programs like NDMP, however, logistical challenges of the NDMP program (application process, quick deadlines, communication, delays on provincial agreements and granting of funds), and its focus on mapping and risk assessment (which some municipalities have completed) has diminished its usefulness in supporting mitigation measures that translate in to actual risk reduction in the short-term.*

[tt] After flood control projects currently in development are complete.

7.2.4 Roles and Responsibilities for Flood Risk Reduction

The interaction and responsibility-sharing between different levels of government and society is an important facet of flood risk reduction in Canada (see section 3). How this balance has been struck between the GOA, the GOC, and municipalities/FN has varied over time, and from community to community. Despite the significance and heterogeneity of these relationships, our research found no documented efforts to explore the optimal or appropriate balance of flood management responsibilities in Alberta. To explore this issue, participants were asked to rank each of the seven actors in Canadian flood management (see Figure 9 for a partial list) based on how they "think the world should be". Figure 16 shows the individual responses and the average of all responses. Responses showed a relative agreement that the GOA should have primary responsibility and NGOs should have the least responsibility (standard deviation (SD) 0.64 and 0.66 respectively). Results showed high agreement that the next two most responsible actors should be the Municipality and the GOC; however, there was less agreement as to the specific order of these two (SD 0.82 and 1.36 respectively).

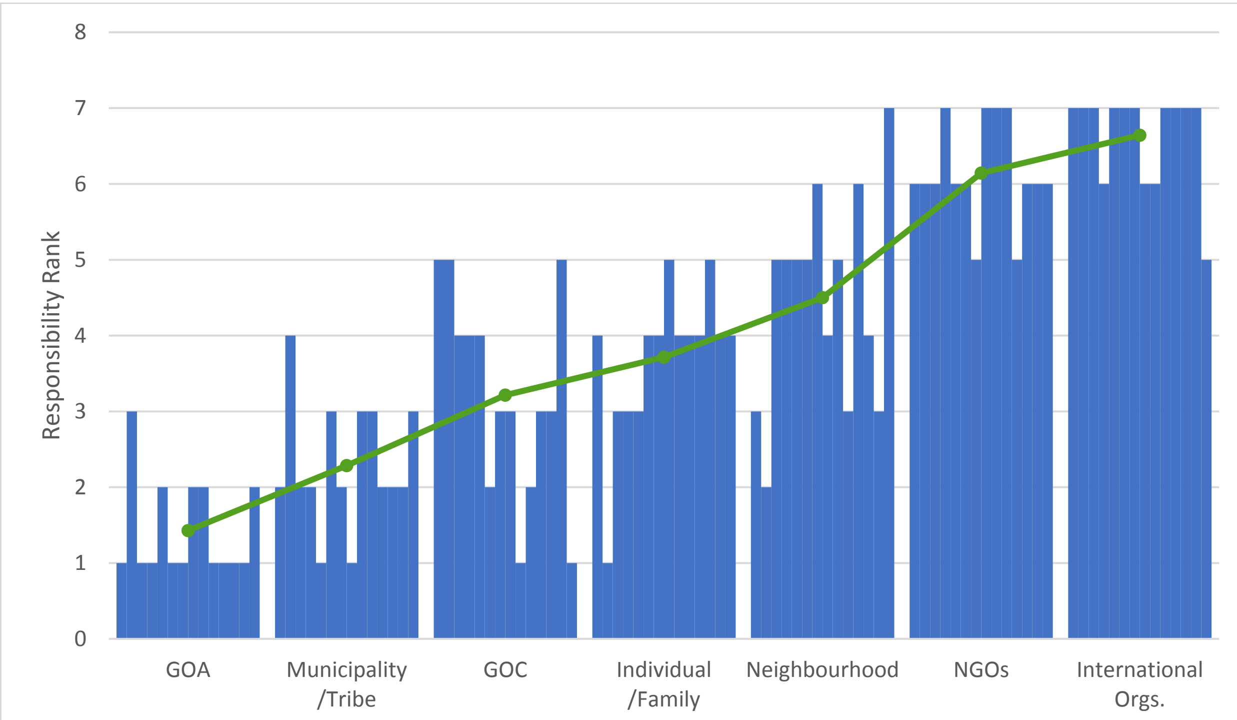


Figure 16 – Participants view on the ideal relative ranking (1 being most responsible and 7 being least responsible) of responsibilities of the main seven actors in flood risk reduction. Blue bars represent individual responses and green line the average.

The Role of the Government of Canada (GOC)

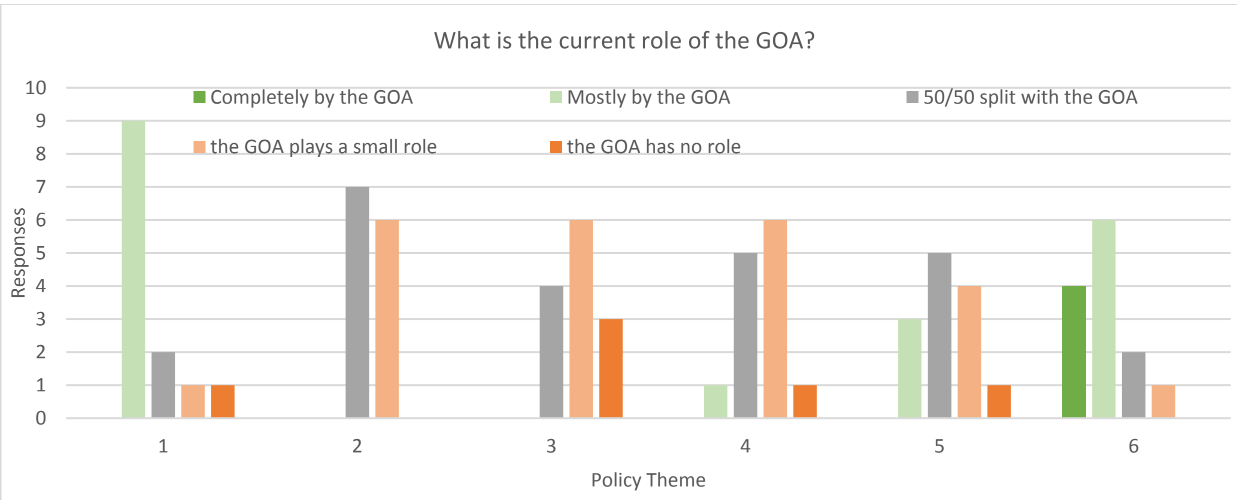
Participants were asked to provide their views on how the current role of the GOC should change in terms of: 1) funding for flood mitigation; 2) execution/construction of flood mitigation; 3) land-use/zoning practices in the flood hazard zone; 4) setting of standards and practices for flood control; 5) flood hazard mapping; and 6) regulating private overland flood insurance. With one exception, all participants said that the GOC's role should stay the same or increase with a majority responding that the GOC's role should increase. All participants stated that GOC funding for flood management should increase.

The Role of The Government of Alberta (GOA)

Participants were asked to rate the current role of the GOA, and how they felt this should change under the following policy themes (Figure 17):

1. funding for flood mitigation;
2. decision making and planning for flood mitigation;
3. execution/construction of flood mitigation;
4. land-use/zoning practices in the flood hazard zone;
5. setting of standards and practices for flood mitigation; and
6. flood hazard mapping.

Survey results showed that no participants wanted the GOA's role to decrease. Excluding one municipality and participants with three or fewer years of experience (8 of 13), all stated that funding was mostly from the GOA. Of those that stated funding is currently "mostly by the GOA" (9 of 13), 6 of 9 stated this role should increase. Eleven (11) of 12 stated the GOA's role in setting standards and practices should increase. All participants from cities with population under 65,000 (8 of 13) stated the GOA currently has a small to no role in execution/construction of flood mitigation. All participants with five or more years experience (6 of 12) stated the GOA's role in decision making and planning for flood mitigation should increase.



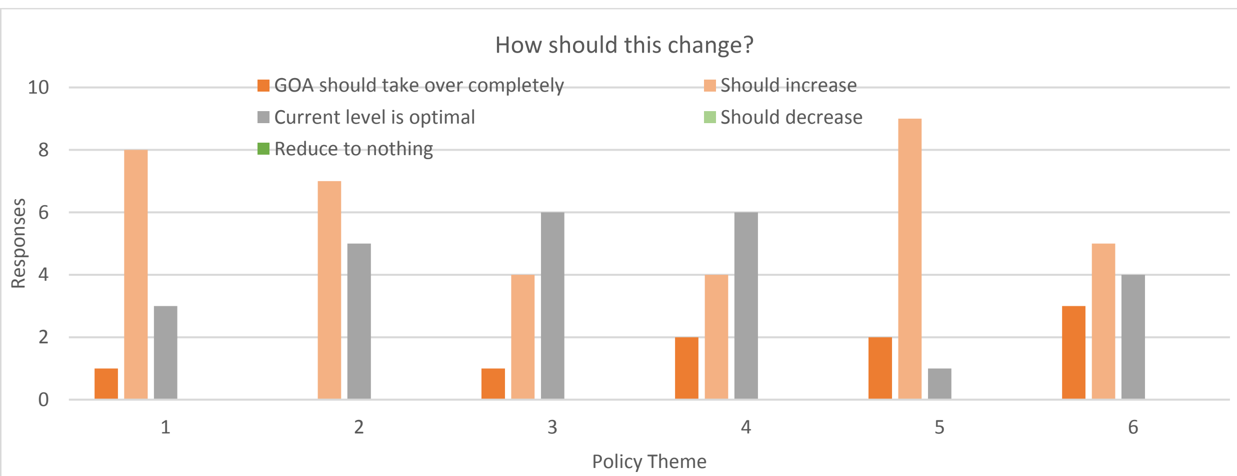


Figure 17 -Participants view on the role of the GOA and how this should change. See text (this section) for policy theme descriptions.

A common theme that emerged in the free responses was the differences between ministries within the GOA:

> *There is a need for more policy discussion and stronger policy setting by The Province/ Municipal Affairs (MA). The work municipalities do is reliant upon the mapping and policy set by the Province, as well as Provincial funding,* […] *updates to local mapping,* [and] *design standards*[;] *policy and mitigation works would be much easier if the Province would take a strong lead here sooner than later. Engagement and commitment from both AEP and MA, who has largely been reluctant to come to the table so far, is critical.*

7.2.5 Policy Improvements Since 2013

Following the 2013 Southern Alberta Floods, the GOA, in partnership with municipalities/FN, overhauled its approach to flood risk mitigation with two new grant programs (WRRP and ACRP), basin-wide infrastructure (Special Projects), renewed flood hazard mapping efforts (FHIP), and improved flood forecasting (see section 5). Bundled within these programs are many of the specific policy improvements called for in the past two decades (see section 8.1). To gauge Alberta's progress on these fixes, participants were asked to rate the implementation level (Figure 18) and effectiveness (not shown) of the following flood policy improvement recommendations found in the literature:

1. map unmapped flood hazard areas;
2. regularly update flood maps;
3. include climate change in flood maps;
4. increase return period for design storm;
5. include debris and groundwater hazards on flood maps;
6. use risk analysis (flood damage assessments) in planning;
7. improve flood forecasting;
8. prohibit new development in the floodway;
9. buy out existing high-risk developments;
10. create incentive programs for floodproofing;
11. improve public flood risk communication; and
12. consider differential vulnerability (age, gender, income).

While answers varied both across and within municipalities, a relative consensus emerged in the responses to two policy improvements: 1) 11 of 12 participants feel no action has been taken to include climate change in flood maps [#3]; and 2) 0 of 12 participants feel an incentive program has been introduced for floodproofing [#10].

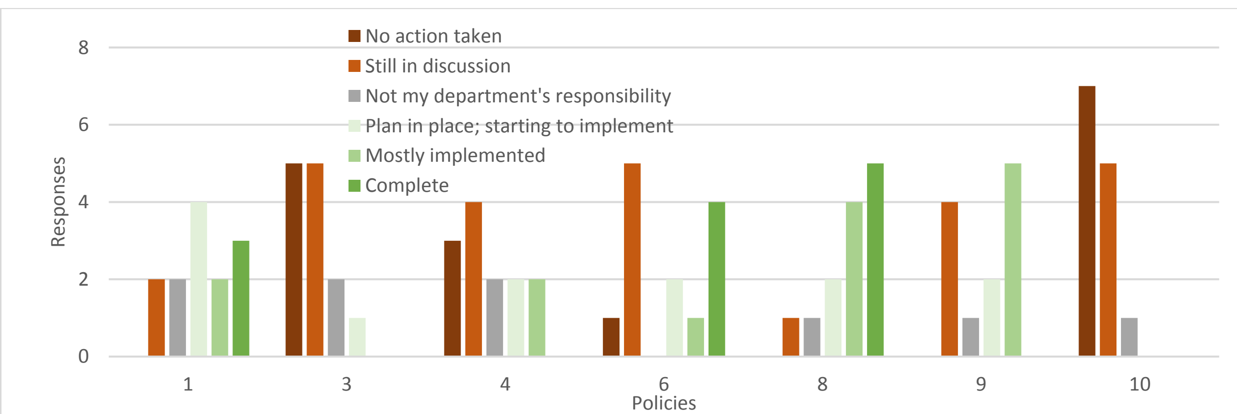


Figure 18 - Implementation of recommended flood policies since 2013. Five response/policy sets are omitted for clarity. See list (this section) for policy descriptions.

Of those policies that participants identified as implemented, prohibiting new development in the floodway [#8] was viewed as the most effective policy towards reducing flood risk among the set[uu], while improving public flood risk communication [#11] was seen as the least effective.

[uu] Based on the number of responses indicating 'Moderately […]' or 'Significantly […]' reduced flood risk.

One participant elaborated on the effectiveness and challenges of flood risk communication:

> *Overall, heightened personal awareness and experience has increased resiliency to flooding. After 2013 there was a lot of effort put into this, but we know there is still a large portion of the public unaware of their flood risk or emergency response. Due to funding, a lessened perceived sense of urgency as the time lapsed since the last flood increases, and corporate mechanisms, flood communication is decreasing with time, reducing the effectiveness of this measure. While public communication will not prevent flooding, it can increase warning time, giving people [time] to prepare their properties and move contents, improve the overall efficiency of evacuation and emergency response, increase public safety (if people are aware of the risks and know what to do), and can contribute to lower flood damages after an event. Experience has shown it is difficult to reach everyone - especially in large cities.*

7.2.6 Limitations of Flood Management

Flood managers face a myriad of obstacles in their efforts to reduce flood risk. To better understand these obstacles, participants were asked to rate how much the following factors limit their work to reduce flood risk (Figure 19):

1. funding;
2. staffing;
3. internal leadership;
4. political direction;
5. public support;
6. individual private citizens;
7. existing legislation/regulations;
8. uncertainty about future legislation/regulations;
9. the judicial system (courts);
10. lack of data (measurements);
11. lack of physical process knowledge (how do debris flows increase flood risk?); and
12. lack of social process knowledge (how do people respond to flood forecasts?).

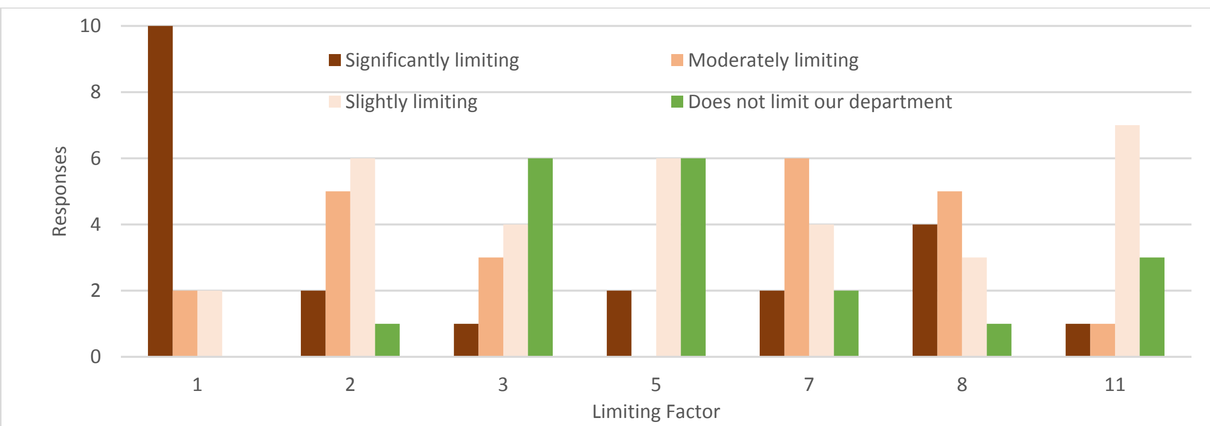


Figure 19 – Responses for the level of significance of factors in limiting flood risk reduction. See list (this section) for description of limiting factors. Some factor/response groups omitted for clarity.

While weighting varied both across and within municipalities, responses showed relative agreement in three areas: 1) all participants stated funding [#1] is a limiting factor, with 9 of 13 rating this limitation as 'significant'; 2) 12 of 13 stated staffing [#2] is a limiting factor; and 3) 11 of 12 stated uncertainty about future legislation [#8] is a limiting factor. On the other hand, internal leadership [#3] was viewed as less limiting. One participant elaborated on the political forces influencing these limitations:

> *In the absence of a flood event to generate the political will and granting sources, the* [flood mitigation] *work would not have been undertaken. There has been pretty good support from all stakeholders and that has remained consistent through the four years of our current council. New political representation may change that when balancing priorities and as people forget.*

7.3 Survey Analysis

The above survey results demonstrate some of the challenges as seen by municipal flood managers to flood risk reduction in their communities, and provide some hints at progress. These results also suggest flood risk will remain moderate to high after flood control projects currently in development are complete. This is not surprising considering lawmakers exempted Fort McMurray and Drumheller from Bill 27 regulations because of “significant existing development in a floodway” (Alberta Government 2015c). Furthermore, the survey suggests a sizeable number of at-risk[vv] residential buildings (3300 to 9600) fall outside the mitigation policies of the 100-yr FHZ. In summary, there remains a significant need for further flood mitigation in Alberta.

More alarming, the survey responses suggest that the policy course set post-2013 may not bring about *any* risk reduction for some communities. Many participants (6 of 14) stated no flood risk reduction has occurred in their municipalities, despite the $163 million spent to-date on flood mitigation by the GOA (see Figure 3). However, these responses were correlated with experience: the more experienced participants stated more risk reduction had occurred since 2013 than the less experienced. This could be due to the difference in observation periods between the more and less experienced groups, with the less-experienced lacking the pre-2013 exposure necessary to gauge the risk at that time. Regardless, this suggests we need to revisit the post-2013 approach to flood management in Alberta. However, such a rethink is unlikely considering fading public pressure (see section 8.1) and law-maker interest; or as one participant put it:

> *What is it going to take to see strict policy for development in flood hazard areas? Answer - very strong leadership, but most likely 1-2 more disasters.*

The participants did however shed some light on a potential path forward for flood risk reduction. In terms of the broad approach to flood risk reduction, participants feel the GOA should take primary responsibility away from municipalities; while both the GOC and GOA should increase their roles (in most areas surveyed) — especially in funding. This desire for more involvement from higher levels of government could be connected to the major limiting factors participants experience in their flood risk reduction work:

- *Funding:* The broader tax base of the GOC and GOA can provide more funding streams.
- *Staffing:* Participants indicated the GOA (specifically the AEP) has excellent staff and expertise.
- *Legislation Uncertainty:* Considering the most relevant legislation is developed by the GOA (Bill 27, FDRP) and potentially the GOC (insurance regulations), more direct involvement from these actors can reduce the uncertainty at the municipal level.

With respect to existing policy programs, participants feel that regional mitigation projects (Springbank and Special Projects) and the ACRP grant program are the most helpful. This also suggests the desirability of an increased GOA responsibility, as the regional mitigation projects are the only structural flood mitigation measures directly controlled by the GOA.

Beyond these broader concerns of how to structure flood management and policy execution, the survey also provides insight on specific policy actions. Participants stated that prohibiting new development in the floodway has been the most effective while flood risk communication had been the least effective measure. Furthermore, participants stated that no action has been taken to account for climate change or to incentivize property owners to floodproof. Therefore, preparing for climate change, launching an incentive program for at risk property owners to undertake floodproofing (DRP eligibility, property tax reductions, etc.), or re-visiting efforts to educate the public about flood risks — could be low-hanging risk reduction fruit for policy makers.

[vv] within a 350-yr zone.

8 Analysis

Having explored the context of flood management in Alberta and how the managers view this, we can now more closely examine, and analyze, some challenges facing flood management in Alberta.

8.1 Legacy Recommendations

Starting in the early 2000s, in response to the devastating 1997 Red River flood (Kumar et al. 2001), a steady trickle of prescriptive reports were published to address the escalation in flood damage across Canada. Following the 2013 Southern Alberta Flood, this trickle became a torrent. Many of these were commissioned and issued by various levels and branches of government — to which a myriad of private stakeholders also added their own reports and recommendations. Our literature review identified 26 publications released since 2001 with recommendations for improved flood management directly targeted at Canada or Alberta (see Appendix C). Upon reviewing these publications, we identified three recurring themes: 1) the role of socio-political groups and insurance (Figure 20); 2) the identification and mapping of flood hazards (Figure 21); and 3) management of the existing risk (Figure 22). To better understand the recurrence of these recommendations over time, we present these three figures showing the chronology of the summaries in Appendix C.

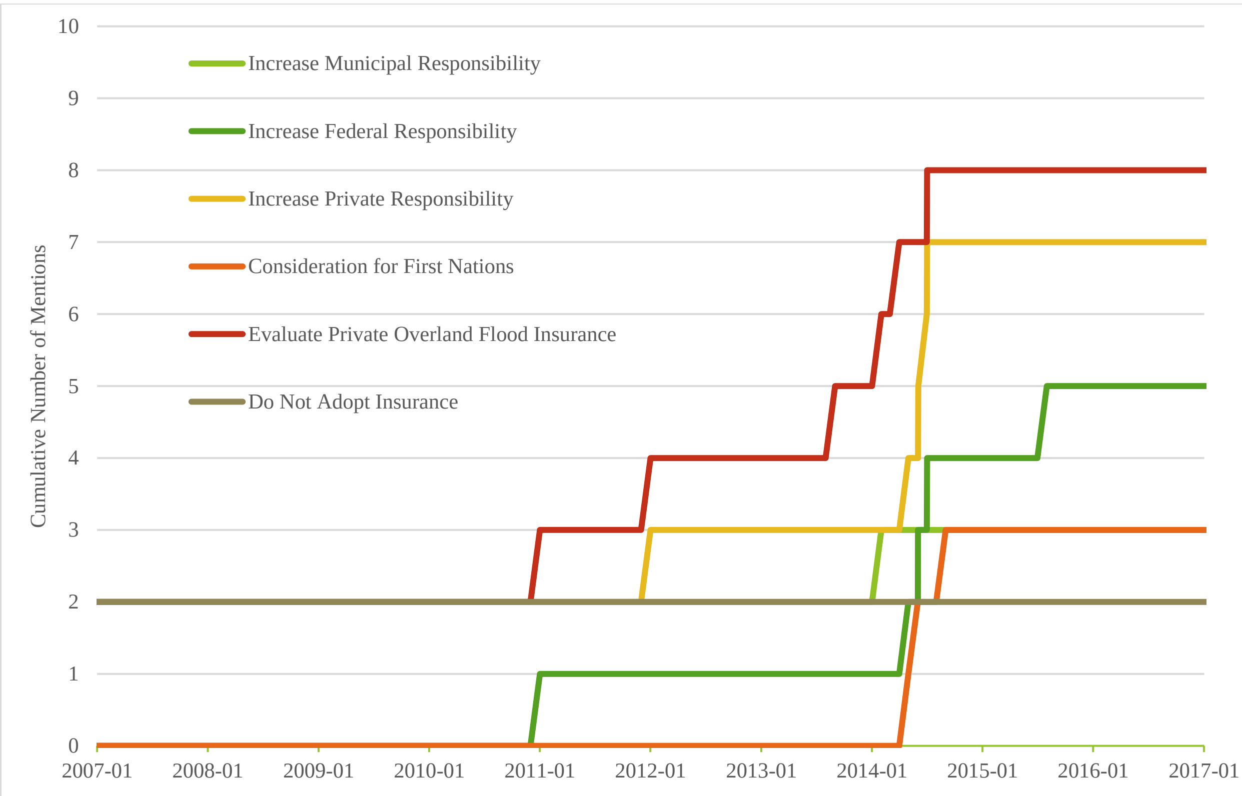


Figure 20 - Ten years of recommendations on the role of socio-political groups and insurance. Four reports were included in this analysis published prior to 2007-01. See Appendix C for details.

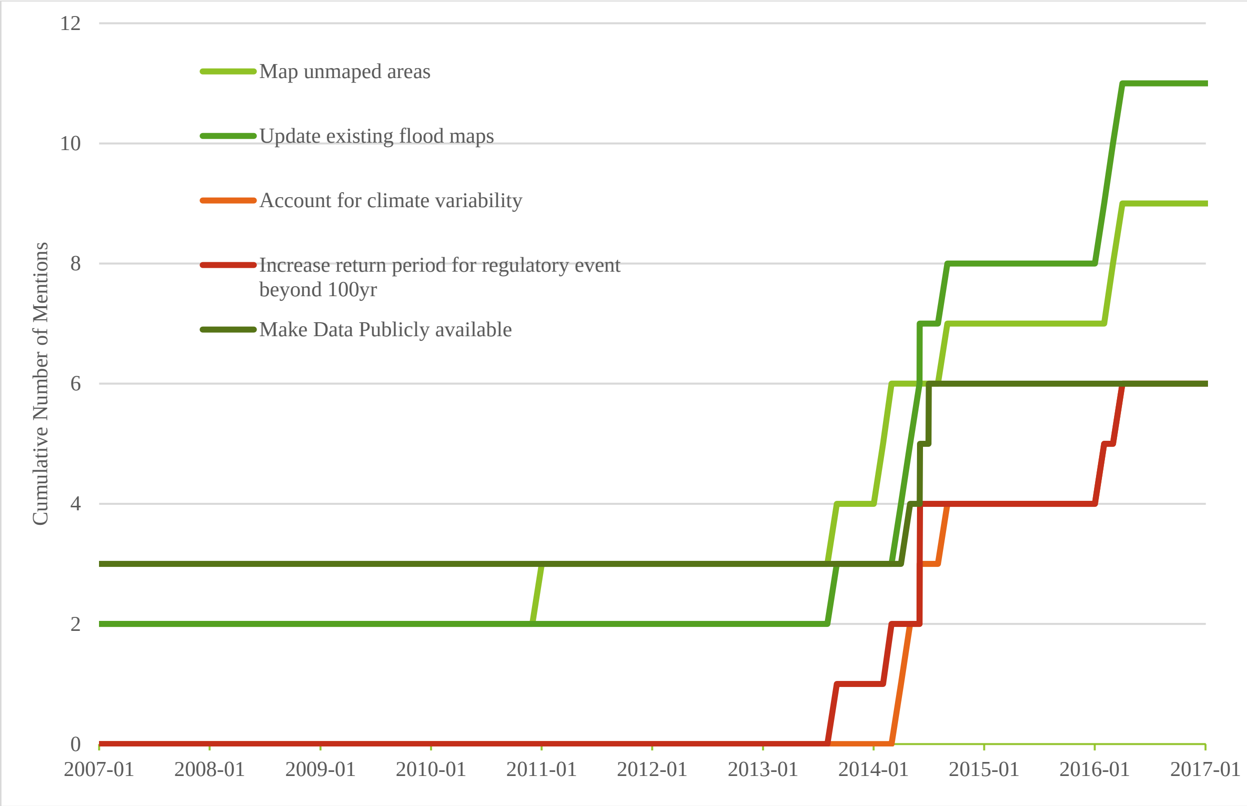


Figure 21 - Ten years of recommendations on defining and mapping flood hazard. See Appendix C for details.

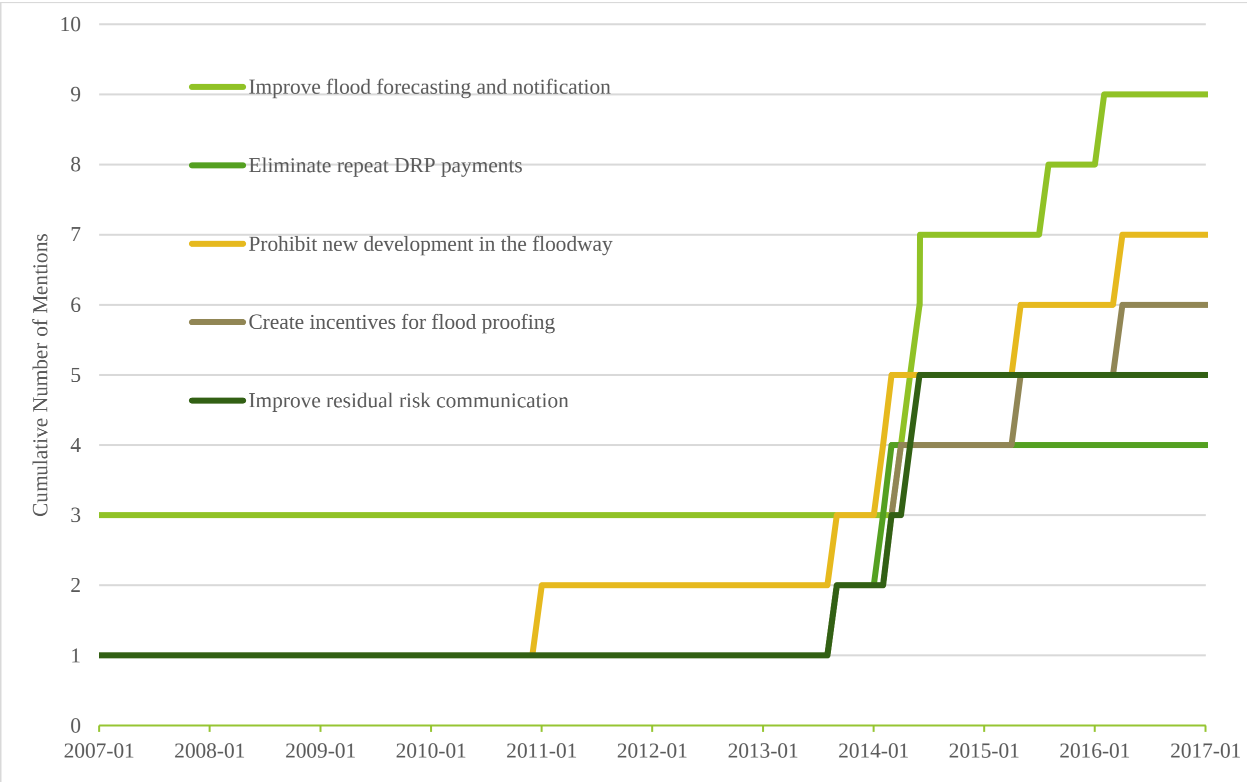


Figure 22- Ten years of recommendations on managing the existing risk. See Appendix C for details.

While this analysis wrongfully implies equal credibility among reports, does not completely reflect the many changes made since 2013 (see section 4), and ignores the nuances in the recommendations, it nonetheless provides a valuable perspective on the policies government should consider. Cumulative number of mentions can serve as a proxy for the level of consensus among commentators[ww], while timing can serve as a proxy measure of implementation or lack thereof.

From this analysis we can see that the recommendation to *improve residual risk communication* (Figure 22) was put forward by four reports shortly after the 2013 floods, but received no mentions thereafter. This suggests that the failures experienced during the 2013 Southern Alberta flood led commentators to recommend, with moderate agreement (4 of 25 mentions), improving risk communication— which managers have since implemented (no further mentions). This inference is further supported by the overhaul of provincial emergency response in 2014 (Alberta Government 2015d) and the survey results (see section 7). However, this example demonstrates that our analysis does not provide a measure for the effectiveness of the policy (see section 7 for a discussion of the participants view on the effectiveness of risk communication to-date).

Contrary to risk communication, *create incentives for flood proofing*, *increase return period for regulatory event beyond 100-yr*, and *account for climate variability* each received 5-6 mentions which continued well beyond 2014. This suggests these three policy recommendations also have moderate agreement among commentators yet have not been widely implemented. This conclusion is supported by the municipal flood manager survey results (section 7).

8.2 Public Interest

As photos and reports of the devastation began to spread, the 2013 Southern Alberta Flood quickly became the focus of the nation — Prince William even wrote a letter of support on day six (Calgary Sun 2013). Once flood response efforts shifted to recovery, community action groups formed to pressure governments further. However, it is widely accepted that as memories of a disaster fade, so too does the public's interest (Simonovic 2014), closing the window of opportunity for systemic improvement. Writing four years after the disaster, the falling trend of newspaper articles published related to flooding demonstrates the media is losing interest, and perhaps the public as well (Figure 23). This conclusion is supported by the similar falling trend observed in Google searches (Figure 24). This loss of attention has not gone un-noticed and is reflected in the GOA's spending plans (see section 8.9).

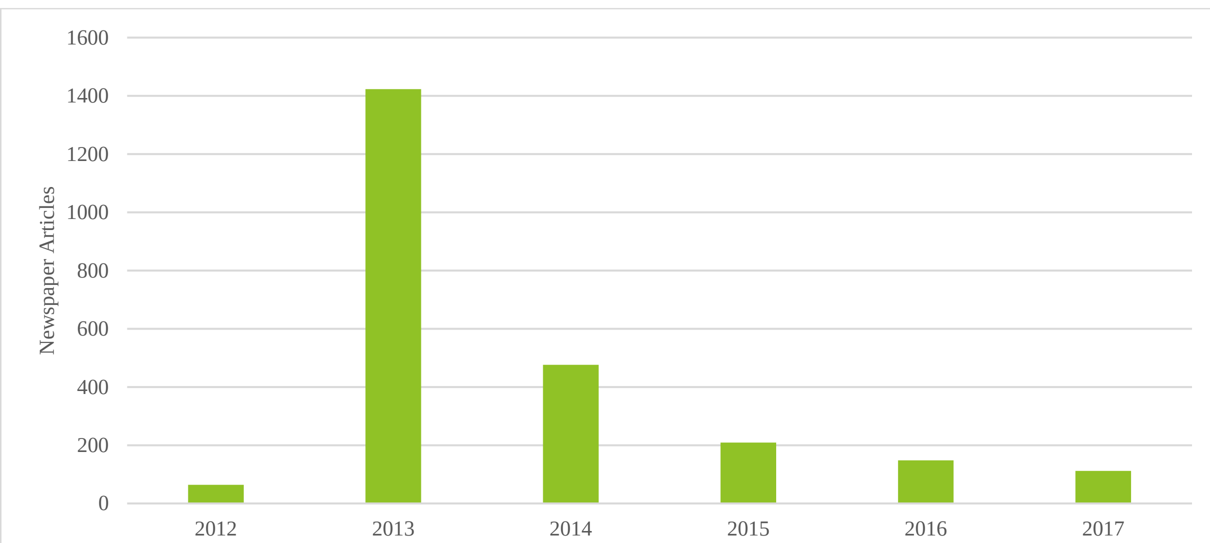


Figure 23 - Number of newspaper articles published in Canada related to "flood" and "Alberta". Values obtained from ProQuest (2017) with search boolean "all(alberta) AND all(flood)".

[ww] Level of consensus should be interpreted relatively rather than absolutely. The lack of absolute consensus among the 26 legacy recommendations may be explained by the wide range in objectives of the reviewed publications. For example, Auditor General of Alberta (2016) had the very narrow objective of auditing the 2014 DRP transition.

Figure 24 - Google Trend's search interest for 'Alberta Flood' in Alberta for the year before the 2013 Southern Alberta Flood to two years following. "Numbers represent search interest relative to the highest point on the chart for the given region and time. A value of 100 is the peak popularity for the term. A value of 50 means that the term is half as popular." (Google 2017)

8.3 Good Ideas, Bad Execution

Our research revealed 11 frameworks, strategies, platforms, and other non-binding flood management policy statements issued by governments since 2008 (Table 9). Most of these were state-of-the-art flood management policy at the time, and answered many of the calls contained in Appendix C. However, the execution of many of these commitments has been inconsistent as public pressure fades, political will diminishes, and funding dries up. For example, *Canada's Platform for Disaster Risk Reduction* advocated "the documentation of local events/disasters and to share this information" (Government of Canada 2012a, 18), which led Public Safety Canada (PSC) to launch the Canadian Disaster Database (CDD) in 2012 to catalogue and share disaster data from 1900-present (Government of Canada 2012c). However, every Albertan disaster record in the CDD for the last 22 years, with an estimated damage over $100 million, is incomplete (Public Safety Canada 2017).

Table 9 - Frameworks, strategies, and other non-binding flood management policy statements.

Date	Name
Federal	
2008	National Disaster Mitigation Strategy (NDMS)
2009	Canada's Platform for Disaster Risk Reduction (DRR)
2011	Emergency Management Framework for Canada
2014	National Floodplain Management Framework
2015	Sendai Framework for Disaster Risk Reduction (DRR)
2017	Federal Floodplain Mapping Framework
Provincial	
2013	Resilience and Mitigation Framework
2013	Accountability Framework
2013	Provincial Recovery Framework
2014	Respecting Our Rivers: Alberta's Approach to Flood Mitigation
Municipal	
2014	Calgary's Flood Resilient Future

8.4 Shooting with Our Eyes Closed

Alberta has embraced the risk-based approach for large flood mitigation projects. Currently, AEP employs the PFDAT and its synthetic depth-damage curves. While the PFDAT is likely the best available model for estimating flood damage in Alberta, it remains unvalidated. For context, Jongman et al. (2012) compared seven loss models (not including the PFDAT) against observed damages from a 2002 flood in Germany and a 2005 flood in the UK. They found that model predictions varied by a factor of ten (€34 vs €299 million). The highest prediction underestimated the damages of the UK flood by €236 million (€299 vs €535 million), while the two worst performers were synthetic models (like the PFDAT). For reference, the latest converted cost estimate for Springbank is €175 million[xx] — a total cost within just the error of Jongman et al. (2012)'s European comparison. Considering that a large portion of the currently pledged $913 million provincial flood management budget[yy] may be distributed using the PFDAT results, validating and improving it may be worthwhile. However, such work is only possible with better data for historical flood damage.

One possible source of this data may come from the post-disaster surveys of the DRP. However, as DRP payouts are not intended to restore to a pre-disaster level, damage assessment data only partially represent the tangible flood damage. Furthermore, to protect victim privacy, the Province aggregates the data before sharing it, which results in a lengthy case-by-case process (personal correspondence) and less useful data. For example, the authors have a request for data from the GOA that has been open for 11 months and counting. Additionally, our research found no data on intangible or indirect loss from any disaster in Alberta.

8.5 Transition Troubles

Flood management in Alberta does not suffer from a lack of policy solutions on paper, as this report clearly shows; the real challenges seem to be in achieving (see section 8.3) and transitioning between these paper solutions. For example, the 2016 Fort McMurray fire recovery occurred before the Bill 27 regulations were developed (causing confusion), and management changes to the DRP occurred mid-recovery in 2013 (likely reducing the program's performance). Disasters occur whether the systems designed to manage them are ready or not.

Further adverse effects of slow government policy making will likely be felt by the new FHIP guidelines (see section 5.1). For example, the public backlash following the post-2013 FHZ updates will certainly become more severe once those updates are made obsolete by new guidelines. This sentiment may have been reflected in the municipal manager survey result's (see section 7) suggestion that policy uncertainty is a major limitation to municipal flood risk reduction.

8.6 Top Down or Bottom Up?

Post-2013, the GOA pursues flood risk reduction on two political levels: *top-down* efforts with GOA regional projects (Special Projects and Springbank); and GOA-supported *bottom-up* municipal, FN, and private projects (ACRP and WRRP). Applied well, the two approaches can be complementary and draw from the full menu of flood risk reduction measures (see section 2.2.4). Currently, the only active top-down projects are continuations of projects launched under the FRTF — flood control for the areas hit by the 2013 Southern Alberta Flood. In other words, the province has not taken direct responsibility for mitigating risk outside the 2013 flood area (i.e. in basins other than the Oldman or the Bow). While this is in line with Canadian governance, it will be of little consolation to future flood victims whose municipalities were unable to limit development or install adequate flood control. Such challenges at the local level are likely when one considers the recent examples of local opposition to municipal mitigation efforts in Waterways (see section 5.3) and Calgary (Seewalt 2016). Even more suggestive, our survey shows that municipal flood managers also feel the GOA should take more responsibility in flood risk reduction.

[xx] Converted to match Jongman et al. (2012)'s 2010 EUR using exchange rates from World Bank (2017), inflation data from StatsCan (2014), and the $263 million 2015CAD project cost from IBI Group (2015).

[yy] Using the 2017 budget and all amounts pledged under Flood Recovery and Water Management Infrastructure in both the Fiscal and Capital plan (Alberta Government 2017a).

8.7 Unintended Consequences

A valuable mantra we borrow from Systems Thinking is the prevalence of unintended consequences when intervening in complex systems (see section 2.3). With flood management policies and land development as our system (similar to Figure 13), we can examine the unintended consequences of government relief (i.e. the DFAA). Created following a string of devastating floods in the '60s, the DFAA was intended as a policy to relieve the suffering of Canadian disaster victims (Shrubsole 2013). Nearly 50 years later, we can see how this well-intentioned policy has: 1) not curtailed development in the floodplain (see section 7.2.1); 2) discouraged the introduction of private insurance (Young 2011); and 3) incentivized perverse management practices of disaster programs (see section 4.3) — all of which unexpectedly *increased* flood risk and/or suffering of Canadian disaster victims.

8.8 Insurance

Private overland flood insurance has tremendous potential to reduce flood risk in Canada. Unfortunately, it also has the potential to increase flood risk if implemented poorly (see section 3.2). Regardless, the insurance industry will likely profit from its introduction[zz]. In separate unofficial estimates, the industry group Insurance Bureau of Canada (IBC) found 19% of homes are at risk of flooding (IBC 2016a), but that only 10% would be 'eligible' for coverage (Kennell 2016) — which we interpret to mean profitable for the provider at an affordable rate for the policy holder. Where the balance is struck between the 'eligible' and 'ineligible' will largely determine the profitability of the policies for the insurance industry, possibly at the expense of the homeowners and taxpayers. Partially for these reasons, every publication on the topic we reviewed called for some degree of government oversight. Unfortunately, governments have been slow to act on the issue[aaa].

Finally, our literature search found four recent journal publications and one Master's thesis addressing considerations and challenges for introducing flood insurance to Canada[bbb]. Three of the five publications are authored by writers with a history of funding ties to the insurance industry[ccc] — and did not include the word 'profit' or any discussion thereof. This suggests that more diverse voices and additional public research are needed on the subject.

8.9 A Political Problem

All the recommendations identified by our research (Appendix C) are technically feasible. The major challenges seem to be financial and political; a view also held by Shrubsole (2013) and our survey participants. The federal retreat from the FDRP, and now the DFAA, as well as the historical provincial budget cuts to the DRP and FHIP, are examples. More relevant, as recovery from the 2013 Southern Alberta Flood finishes, memories fade, and attention is drawn elsewhere (e.g. the 2016 Fort McMurray fire), investment in flood mitigation is falling (Figure 25). This is likely not the result of the GOA having 'fixed' the flood risk problem: Calgary remains largely unprotected while Springbank faces regulatory setbacks (Bowen 2017); many flood hazard mapping studies are still ongoing (Alberta Government 2017b); and municipal flood managers feel the risk remains moderate to high (according to our survey). Instead, this drop in planned spending is likely a result of the ebb and flow of public pressure following a disaster (or rather 'flow' then 'ebb') combined with declining government revenue and re-direction to other issues.

[zz] The latest release from IBC states that private property and casualty insurance companies in Canada self-reported $4.2 billion in profit for 2015 at a profit margin of 8.2% (IBC 2016a). For reference, farming in Canada had a profit margin of 6.4% in 2014 (Statistics Canada 2014).
[aaa] Meckbach (2017) reports that discussions between the federal government and stakeholders are ongoing.
[bbb] (Young 2011; Oulahen 2015; Sandink et al. 2016; Thistlethwaite 2016; Shrubsole 2013)
[ccc] None of the publications reviewed disclosed direct funding from the Insurance Industry.

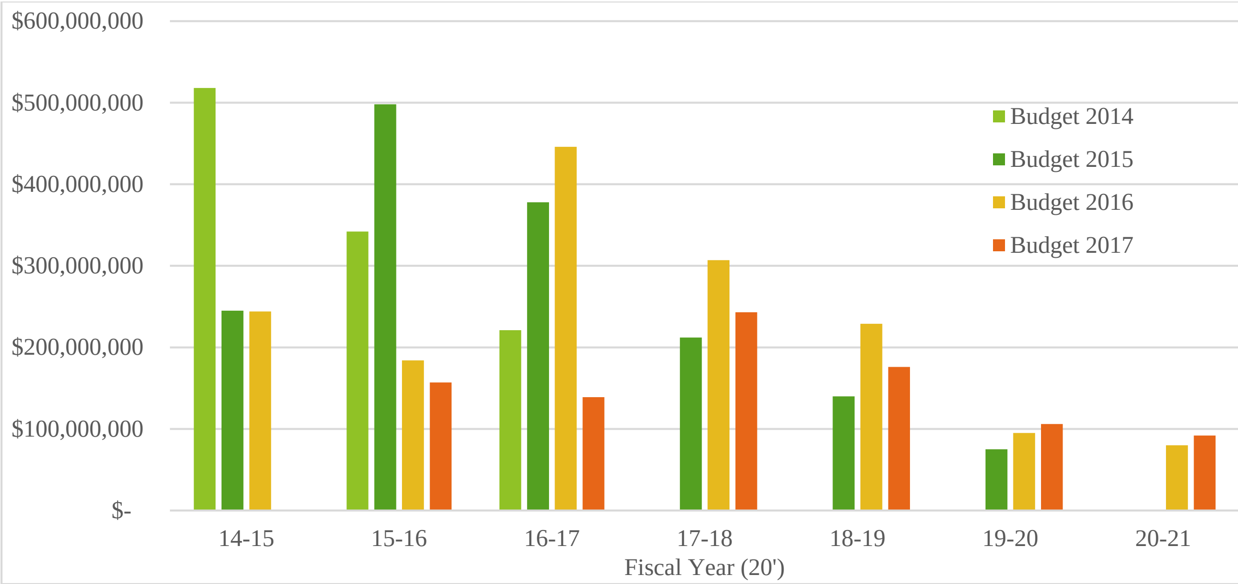


Figure 25 - Alberta Government 5yr Fiscal Plan for flood recovery and mitigation following the 2013 flood (Alberta Government 2016d, 2015a, 2014c, 2017a).

Hundreds of news articles from major outlets were reviewed as part of our research. While these represent only a fraction of those published on flood recovery, response, and mitigation, it is noteworthy that we found only one article[ddd] investigating government conduct[eee]. Considering the $3.3 billion in flood accounts handled by just the GOA, this level of public inquiry seems low. Perhaps the opaque and troubled management of the DRP by LandLink (see section 4.3) could have been addressed before the 2013 Southern Alberta Flood had the media shed more light on the conflicts-of-interest and single-bid contracts. A further example in support of greater inquiry is the scale and lack of oversight of the DRP following a large disaster. In 2015, an external audit found $62 million was allocated for payment without any documentation (Auditor General of Alberta 2015b). Furthermore, many of the smaller communities across Alberta may lack both the municipal resources to significantly reduce flood risk, and the media and governmental oversight to police the allocation of funds.

8.10 One Size Fits All

The Siksika and Stoney FN continue to suffer from the 2013 Southern Alberta Flood, with approximately 15% and 25% of their populations affected, respectively[fff]. The size of the direct and indirect damages were exacerbated by a host of policy failures: 1) a lack of hazard mapping and zoning restrictions failed to prevent extensive floodplain development; 2) flood warnings came too late or were not heeded, reducing the amount of time residents had to mitigate the damage (MNP LLP 2015); and 3) recovery efforts were slow compared with off-reserve[ggg]. While some of these shortcomings are being addressed (e.g. flood mapping of reserves) and some lack jurisdictional clarity, the GOA continues to rely on extending the coverage of existing programs to reserves[hhh], or abdicating responsibility to the GOC. Applying programs designed by and for off-reserve peoples to the reserves may be problematic because of jurisdictional and regulatory differences, cultural and economic differences, a lack of social cohesion and trust between settler and FN communities, and a mistrust of government by FN people.

[ddd] D'Aliesio, Renata. 2014. "Province Was Warned of Alberta Disaster Fund Problems." The Globe and Mail, June 27.

[eee] Many articles were reviewed that reported the findings of publicly available internal government audits.

[fff] For comparison, 7% of Calgary and 100% of High River residents were affected. Evacuation estimates are used as a proxy for 'affected'. As there are no reliable statistics for the number of evacuees, media reports were used (Ogrodnik 2013; Alberta Government 2014f). Population data was retrieved from 2011 census data from Statistics Canada (2017b).

[ggg] On the Siksika and Stoney reserves 7% and 64% of home reconstructions were complete as of 2016 (Alberta Government 2016a) compared with 95% in High River (McIntosh et al. 2016) where a higher proportion of structures were damaged.

[hhh] FNs are eligible to apply for the major provincial cost-sharing flood mitigation programs (ACRP, WRRP) (Alberta Government 2016c, 2017c) and the DRP (Alberta Government 2015b).

In general, the challenge of reducing flood risk on reserves seems underrepresented both in the literature and in GOA policy. Of the 25 legacy recommendations reviewed (see section 8.1), only three addressed management on reserves. While the GOA has no jurisdiction on reserves, their acceptance of limited responsibility for recovery and response has been widely praised. Despite this, of the 15 pages on AEP website dedicated to Flood Mitigation, FHIP, or ACRP — FN are only mentioned once[iii] (Alberta Government 2016h).

8.11 But Really…How Bad Is It?

Writing in early 2017, the landscape of flood management in Alberta would be unrecognizable to an observer from June 17, 2013 (a sentiment shared by the majority of senior municipal managers in our survey). The GOA has committed $913 million over six years to complete recovery efforts and fund mitigation efforts (Alberta Government 2017a). The ACRP has provided over $100 million in municipally-led flood mitigation projects and the WRRP has provided almost $20 million in restoration initiatives (Alberta Government 2016b). Work on Springbank is ongoing, and the GOA appears to be committed to the dam despite regulatory hurdles and public backlash (CBC News 2017). Bill 27, a necessary step to stop additional floodplain development, is law, even if it is a few decades late and the regulations enforcing it are yet to come. Private insurance is here, although uptake is less than 1% (Swiss Re 2016) and government guidelines are still in development. Finally, government staff seem committed to continue improvements. During the preparation of this report, provincial and municipal staff were helpful, transparent, and engaged. Most individuals encountered were also highly-qualified and knowledgeable. As a result, the authors are of the opinion that, given the right support, the departments will continue to guide Alberta away from the cycles of disaster.

[iii] With respect to the TransAlta reservoir operations agreement the mention is as follows: "What about the wells of other neighbours in the area including the Stoney Nakoda First Nation? To date, AEP has not received any additional concerns regarding wells" (Alberta Government 2016h).

9 Future Research

Despite the tremendous breadth of literature written on flood management in Alberta, there remain a few areas we see in need of additional attention.

9.1 Flood Management on Reserves

We lack a comprehensive understanding of how best to mitigate flood risk on FN reserves — or more accurately, how to adapt our knowledge on flood management as a whole to the special case of the reserve. The failures and accomplishments of the 2013 Southern Alberta Flood could provide such an opportunity. While some work has been done to analyze the experience of FN under this disaster and subsequent recovery efforts (see section 6), some major questions have yet to be addressed:

- What role did cultural and institutional racial biases play in hampering mitigation, emergency response, and recovery?
- What role did jurisdictional and legislative complexity play in hampering mitigation, emergency response, and recovery?
- What was the relative effectiveness of transferring rebuilding authority to the FN as opposed to leaving it with the GOA?
- Controlling for location and income, what was the differential vulnerability between on-reserve and off-reserve victims?

Addressing the above may help provide answers to some of the broader questions hampering flood risk reduction on reserves across Canada:

- How can flood management overcome or circumvent the deep institutional challenges and historical baggage that have mired modern government interventions on reserves?
- Given the lack of political will to reduce disaster risk off-reserve, how can we muster the political will to overcome the massive challenges of risk reduction on reserves?
- How do we adapt our existing tool kit of flood risk reduction measures (see section 2.2.4) to reduce flood risk on reserves?
- What is the optimum level of government intervention to reduce flood risk on reserves, and from which level of government?
- How can we harness, foster, and/or encourage the knowledge and resources of FN peoples to reduce flood risk on reserves?

9.2 Let the People do the Work

Alberta has a tremendous, as-of-yet untapped, resource to reduce flood risk: the people at risk. However, not enough is known about how Albertans can be encouraged to reduce their own risks. Filatova (2014) provides an overview of policy options for what they call *autonomous adaptation*, which includes such measures as premium reductions or floodproofing subsidies. Such measures could be a cost-effective and non-intrusive way to reduce flood risk, and have been recommended by numerous commentators (see section 8.1). However, our research did not reveal any work exploring the effectiveness of such measures in Alberta, or even Canada. This is an especially salient question considering the advent of private insurance — something supporters feel can encourage autonomous adaptation.

9.3 Flood Risk Dynamics

As each new generation of flood policy takes effect, it strikes a difficult balance between flood loss reduction and cost. This process is most obvious and codified in the risk-based approach recently adopted by the GOA on major projects using PFDAT. However, this balance typically does a poor job considering the needs and conditions of the future. Instead, the needs, values, and conditions of the present are projected into the future — what White and Haughton (2017) dub the 'tyranny of the present'. Falling into this trap is hardly surprising considering the uncertainty of social and environmental dynamics, and that until recently there was almost no accounting for the future (i.e. the transition from standards-based to risk-based in 2015 in Alberta). What is needed is a paradigm shift — a step beyond the risk-based approach — to develop policies that solve the problems of today and tomorrow; or at least remain flexible enough for tomorrow's solutions. While this is no easy task, it could start with a more robust inclusion of uncertainty and temporal dynamics into decision tools.

10 Conclusion

The earliest legacy recommendation (see section 8.1) reviewed was prepared following the 1997 Red River flood in Manitoba. The federal government convened a panel of experts, which met in 1999, with the objective to "protect Canadians from unacceptable flood losses in the future" (Kumar et al. 2001, 2). Their recommendations were sound, remain valid, and were largely unfollowed leading up to the 2013 Southern Alberta Flood. We were keenly aware of this failure-of-advice environment while writing this report and have done our best to avoid adding to the list of unfollowed recommendations. With that in mind, the reader will forgive us as we indulge with a few closing points.

Despite Kumar et al. (2001)'s recommendation, there remains a need for post-flood damage data to improve our decision making. Therefore, we recommend that policy makers: 1) incorporate more complete damage assessment data collection into DRP assessments; 2) conduct follow up assessments to collect intangible and indirect loss data (these could also be used to provide additional recovery services); 3) find a solution to the privacy requirements that prevent data from being shared openly without excessive aggregation; and 4) provide efficient access to this data. This data will help track the effectiveness of policy interventions and provide a foundation for the next generation of policies. We leave the requisite 'who' and 'how' questions of this challenge to the more able-minded.

The GOA has undertaken a massive effort towards, and remains committed to, flood risk reduction. However, many of the municipal flood managers surveyed, along with community action groups, feel the level of flood risk remains high. While there are many paths available to achieve this risk reduction, the current approach of the GOA to phase out funding the existing programs without a clear plan for replacement seems unlikely to achieve the necessary flood risk reduction. Our survey results present an alternate path: 1) plan for climate change; 2) incentivize property owners to floodproof; 3) increase funding from the GOC and the GOA; 4) shift the GOA to a leadership role; and 5) ensure that the GOA and GOC finalize policy quickly (Bill 27, FHIP, insurance regulations, etc.).

Ensuring that the introduction of private flood insurance works to reduce flood risk has shifted from a theoretical challenge to a practical one. The GOC's willingness to stay on the sidelines (thus far), while the insurance industry plays by their own rules, has likely not benefited the public. However, the government's apathy cannot be held solely responsible, and academia could play a larger role: to facilitate the adoption of more informed policy positions on flood insurance, there needs to be additional, data-informed, transparent examinations of the options.

Finally, FN people continue to suffer disproportionately from flood disasters[jjj]. To address this suffering, the GOC, GOA, and FN must overhaul flood management on reserves systematically, holistically, and collaboratively in a manner that recognizes and addresses the differences of each group. Making progress will require intimate knowledge of the unique cultural context on the reserves, which is something only the members have. Without such knowledge, the value of any truth claims and expert analysis are dubious[kkk].

In closing, we echo Shrubsole (2007, 117)'s concluding remarks which still ring true:

> *Institutional rather than technical factors lie at the heart of improved flood and hazard management in Canada.*

[jjj] While this is a very difficult statement to prove conclusively, the differences in housing rebuild rates and flood hazard mapping on-reserve vs. off-reserve imply disproportional suffering (see section 6). Regardless, disproportional suffering is not a necessary condition for policy improvement.

[kkk] The authors reached out to the Siksika and Stoney Nations without success.

11 Acknowledgements

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Appendix A - Major Non-Temporary Flood Risk Reduction Programs Relevant to Alberta

Name	Dates	Primary Type	Description	Ref
Government of Canada (Federal)				
Canada Water Conservation Assistance Act (CWCAA)	1953-1970	Mitigation	Senior levels of government could provide grants covering up to 75 per cent of the capital cost of structural adjustments.	1
Disaster Financial Assistance Arrangements (DFAA)	1970	Recovery	Disaster loss cost sharing agreement between provincial and federal governments	2
Canada Flood Damage Reduction Program (FDRP)	1975-2000	Mitigation	Cost sharing program for flood hazard mapping. Included stipulations for development in high risk zones.	3
Joint Emergency Preparedness Program (JEPP)	1980-2013	Response	Cost sharing program to invest in emergency response equipment, training, and operations.	4
Canadian Emergency Management College	1985-2012	Response	Federal facility and program for training of emergency response and management personnel.	5
Canadian Disaster Database (CDD)	2011	Mitigation	Database of significant disaster events collected from government and private sources.	6
Regional Adaptation Collaboratives Program	2007	Policy Research	cost-shared programme to reduce the risks and maximize the opportunities of climate change	7
Operation LENTUS		Response	Program for the deployment of Canadian Armed Forces for disaster response	8
National Disaster Mitigation Program (NDMP)	2015	Mitigation	Cost sharing program to reduce disaster impact. Focused on mapping and insurance.	9
Infrastructure Canada projects	2003	Mitigation	Collection of cost sharing programs managed by Infrastructure Canada where 'Disaster Mitigation' projects are eligible.	10
Annual National Roundtable on Disaster Risk Reduction	2010	Policy Research	Multi-stakeholder forum for discussing the implementation of the DRR platform	11

Name	Dates	Primary Type	Description	Ref
Government of Alberta (Provincial)				
Canada-Alberta Flood Damage Reduction Program (CAFDRP).	1989-1999	Mitigation	Created to standardize and cost-share production of flood hazard studies and mapping.	12
Alberta Environmental Support and Emergency Response Team (ASERT)		Response	Coordinates emergency response for high profile disasters in Alberta	13
Provincial Operations Centre (POC)		Response	Serves as the central coordination authority for high profile disasters in Alberta.	14
Alberta Emergency Management Agency Field Officer Program				15
First Nations Field Officers				16
GOA Business Continuity Program		Mitigation		17
Alberta Emergency Alert (AEA) system		Response	Electronic notification system for disseminating disaster warnings and response information to the public in Alberta	18
Disaster Recovery Program (DRP)		Recovery	Provincial counterpart to the DFAA. Manages the distribution of financial assistance to disaster victims in Alberta. A new "DRP" is created for each event (i.e. 2013 DRP), however the standalone term "DRP" generally refers to the collection of all such programs and processes.	19
Flood Hazard Identification Program. (FHIP)	1999-	Mitigation	Successor program to the CAFDRP. Executes, manages, and distributes flood hazard studies across the province.	20
Alberta Community Resilience Program (ACRP)	2014-	Mitigation	Municipal cost sharing program for the design and construction of projects that protect critical municipal infrastructure from flooding and drought.	21
Watershed Resiliency and Restoration Program (WRRP)	2014-	Mitigation	Municipal cost sharing program to improve natural watershed functions to build greater long-term resiliency to droughts and floods.	22
Agricultural Watershed Enhancement (AWE) Program			Provincial counterpart to the federal Growing Forward 2 program. Grant program to fund projects that increase sustainability through the restoration and protection of watershed function.	23
Modified Operations Agreement with TransAlta	2016	Mitigation	Agreement with TransAlta to modify reservoir use to improve flood mitigation functioning	24
Water Management and Mitigation Infrastructure (Special Projects)	2014-	Mitigation	Program overseeing region wide development of flood mitigation projects (e.g. Springbank)	25

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Appendix B – Major Temporary Programs Created in Response to the 2013 Southern Alberta Flood

Name	Budget ($ '000)	Spending ($ '000)	Description	Ref
NGO				
Salvation Army				
Alberta Flood Relief Financial Assistance Program			Financial assistance for those needs not met by other programs	1
Canadian Red Cross (CRC)				
Alberta Flood Response 2013		45,000	Individual assistance, home cleanup and repair, community support, and disaster preparedness.	2
Flood permit grant program				3
United Way				4
YWCA				5
Calgary Drop-In				6
Rehabilitation Centre				7
Samaritan's Purse			Distributed food and hygiene kits, for 1,000 evacuees from the Calgary Drop-In and Rehab Centre. Mobilize volunteers to help vulnerable homeowners with property reclamation and clean up.	8
Federal				
2013 DFAA	904,000		See text. Ongoing. Latest estimate of federal share is 904$M.	9
Op LENTUS 13-1			Canadian Armed Forces disaster assistance mission to provide aero-medical support and casualty evacuation.	10

Name	Budget ($ '000)	Spending ($ '000)	Description	Ref
Provincial				
Floodway Relocation Program (FRP)	137,000	81,500	Buyout program for heavily damaged homes. 160 homes were eligible. 78 homes participated in the program.	11
Mental health supports program			Increased mental health counselling, social services, family violence and addictions support for flood victims.	12
Payment Card Program		66,000	Immediate support as preloaded debit cards or cheques. Over 56,000 participants.	13
Temporary neighbourhoods			Five neighbourhoods constructed and provided as short term housing for flood victims.	14
Temporary Schools		46,000	Temporary classrooms and gymnasium for the three most damaged schools in High River and Calgary.	15
Municipal Staffing Capacity Funding		9,000	Funds to support additional staffing needs of municipalities.	16
Property Tax Relief Funding		6,700	Funds to support municipalities that granted property tax relief to flood victims.	17
Town of High River Long-Term Recovery Plan		46,200	Funding commitment (staffing and property tax relief) and recovery plan for High River through 2018.	18
Flood Recovery Loan Guarantee Program			75% Provincial backing for loans (up to 1$M) small businesses, and not-for-profit recovery and rebuilding	19
Flood Recovery Interest Rebate Program			4% interest rebates for Flood Recovery Loan Guarantee Program loans	20
Small Business Rebuilding Program			Program to extend DRP benefits to business with 21-50 full-time employees	21
2013 Southern Alberta DRP	1,595,174		See text. Funding for public works, small businesses, and individual recovery.	22
Flood Readiness Grant Program			Program to purchase flood readiness equipment (generators, pumps) for municipalities and the province	23
Flood Recovery Erosion Control Program (FREC)	264,000		Cost sharing program to repair erosion damage and fund mitigation projects.	24
Alberta Parks Flood Recovery		81,000	Funding for recovery, repair, and mitigation for Alberta Parks - mostly Kananskis ($60M) and Fish Creek ($16M)	25
Backcountry Trail Flood Rehabilitation Program	10,000		Restore back country motorized and non-motorized trail systems on public lands.	26
Southern Alberta FISHES Program	10,000		Restore aquatic environments and buffer against future floods through habitat enhancement.	27
First Nations housing program		191,000	interim housing, relocate, repair or rebuild homes.	28
Training and business procurement strategies		819	Funding to setup programs and hire staff to offer employment and training services	29
First Nations Consultation Capacity Investment Program		50	Additional funding to cover disruption in consultation process as a result of flooding.	30

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Appendix C – Reports and Guidelines for Flood Management in Alberta

Report	Date	Commissioned by	Relevant Area	Recommendations	Note
(Kumar et al. 2001)	2001-01	GOC	GOC	Create a comprehensive GOC cost-share program for flood management Flood risk maps should be kept accurate and up to date. Expand the use of GIS Increase hydrometric data collection Increase investment in flood forecasting Strengthen land use zoning enforcement in the floodplain Consider user taxes, flood insurance, and the user pay principle. Expand the responsible community to include the private sector Strengthen public education and build greater awareness at the community level Facilitate building relocation, flood proofing, and community resilience Improve the knowledge of impacts and the quality of data on flood losses. Expand post-audits of flood disasters Study flood risk communities and individuals Incorporate an integrated ecosystems approach Strengthen individual, community, and municipal responsibility Revise the DFAA	
(Alberta Government 2002)	2002-06	GOA	GOA	Complete flood hazard mapping GOA take responsibility for flood risk land use designation Inform homebuyers of flood risk Restrict provincial construction and land use on the floodplain Develop cost sharing programs for mitigation Exclude new development from DRP when in flood zone Do not pursue government funded insurance expand flood forecasting	
(Dan Shrubsole et al. 2003)	2003-01	Research institute with insurance industry funding	GOC	Increase involvement of municipal governments Increase collaboration with insurance industry Improve response and recovery programs Greater personal acceptance of responsibility by those living in floodplains	
(Groeneveld 2006)	2006-11	GOA	GOA	Coordinate the completion of flood risk maps develop a map maintenance program determination of the 1:100 year still water lake elevation for all gauged lakes Improve flood data collection make historic flood information available to the public designate flood risk areas notify potential buyers when property is in flood risk area prepare an information bulletin on flood zone planning for municipalities cease the sale of crown lands in known flood risk areas Provincially funded projects should adhere to flood risk guidelines Develop cost share programs for mitigation measures Modify DRP to prohibit recovery for new developments in flood risk areas Pursue DFAA amendments to fund developments in flood risk areas	

				Do not pursue provincially operated or funded flood insurance Support flood risk education programs Expand forecasting network to cover all at risk areas Extend flood risk maps to an emergency mapping program	
(Young 2011)	2011-01	None	GOC	establish defined, clear roles for all insurance stakeholders Provide incentives for flooding mitigation and preparedness use of risk-based premiums for insurance ensure that expansion and development are confined to flood-free zones Local officials should be criminally liable if development is allowed	
(Shrubsole 2013)	2012-01			map vulnerability significant sums of money are required to invest in projects exploring the desirability, feasibility and efficacy of flood insurance politicians need to engage the Canadian public better coordinate programmes and projects on a local or regional basis	
(Kovacs and Sandink 2013)	2013-09	Insurance industry	GOA	Implement the recommendations of the Groeneveld Report Prohibit new development in the floodway Buyout or protect existing developments in the floodway Discourage rebuilds and disqualify repeat DRP payments Increase the minimum level of protection beyond the 1:100yr level Communicate flood risk to at risk home owners Require flood proofing for at risk homes Create incentives for flood proofing	
(Alberta Government 2014)	2014-02	GOA	GOA	Consult with stakeholders across GOA Develop policy for debris related risks Accelerate mapping of new areas and high risk communities Introduce a relocation program prohibit development in floodways Evaluating potential for flood insurance Develop comprehensive engineering reports for high risk basins Accelerate approvals for mitigation infrastructure Update flood mitigation building and repair codes for homes Modify DRP to cover individual mitigation	1
(Simonovic 2014)	2014-02	None	GOC	Map and communicating flood risk Prohibit new development in the floodway. Offer to purchase land and property from homeowners Discourage victims from rebuilding Disqualify victims from future recovery payments Revisit 100-year design flood criteria Require additional flood proofing actions	
(WaterSMART 2014)	2014-04	???	GOA	Anticipate and plan for more extreme weather events better modeling and data management Perform Risk Assessments strengthen building codes for new developments in floodplains	

				Evaluate options for overland flood insurance Strengthen integrated flood management initiatives	
(Sandford and Freek 2014)	2014-05	???	GOC	Update flood prediction systems Update and improve flood maps Incorporate climate change variability into decision making Individuals need to be more active in mitigating flood risk Hydrologic cycle needs to be managed globally Focus more on natural restoration	
(Dillon Consulting Limited 2014)	2014-05	GOA	River Forecasting Unit	Support to Emergency Managers: Make data accessible, and understandable Improve public awareness and education Allocate resources, equipment, modelling and instruments to improve monitoring: Engage First Nations in the planning efforts	
(AMEC 2014)	2014-06	GOA	GOA	Communicate residual flood risk improve the flood forecasting and warning system Replace and upgrade telemetry outstations Flood defences should not increase downstream flood risk Develop and implement Basin wide Flood Management Plans Review all flood maps and revise those made without LIDAR data Develop an Emergency Response Plan for Stoney Nakoda First Nation Develop flood map for Siksika Nation and buyout properties in floodway major study be undertaken to estimate flood damages Major project proposals should include robust economic appraisal	
(MMM Group 2014)	2014-06	GOC	GOC Hazard Maps	Complete a National Risk Assessment to help establish mapping priorities. Develop Guidelines and refine Technical Standards. Minimum return period for Regulatory Event should be 350years. Consider updating maps every 5 (urban) and 20 (rural) years Mapping programs should include hydraulic data for Risk Assessments Address climate change in hydrological analysis	
(Danyluk et al. 2014)	2014-06	City of Calgary	City of Calgary	Increase the level of flood protection Improve emergency response, flood forecasting, and individual preparedness Perform risk assessments on proposed infrastructure Revise land use and zoning practices in the floodplains Develop and make available flood models, maps, and databases Establish a guiding framework for values and goals of flood management	
(Vroegop 2014)	2014-07	City of Calgary	City of Calgary	Emergency responders need to have more than one point of contact Improve communications with GOA, staff, and private sector Encourage private sector preparedness Build a volunteer network to better coordinate volunteers Prioritize mental health of emergency response staff	
(Sandink et al. 2016)	2014-07	None	GOC: Insurance	Develop a national approach to flood hazard assessments Improve quality and accessibility of flood loss data	

				Private property owners and tenants need to actively reduce flood risk Insurance Bureau of Canada should work directly with governments	
(Feltmate and Thistlethwaite 2014)	2014-09	Insurance industry	GOC	Develop new flood plain maps accounting for climate change Assess the preparedness of major cities Factor extreme weather/flood potential into infrastructure management	
(MNP LLP 2015)	2014-12	GOA	GOA	Develop an Emergency Management Staff Wellness Program Complete the update to the Alberta Emergency Plan Develop a Provincial Emergency Social Services framework redesign and implement changes to the Disaster Recovery Program new Provincial Operations Center refine and improve Government of Alberta Business Continuity Plans enhance and develop the Field Officer Program facilitate regionalisation of emergency management Support and focus emergency management capacity building in First Nations Pre-qualify vendors and create a standing offer/vendor of record list Improve emergency management response and recovery services. Improve communications and information passage	
(Feltmate and Moudrak 2015)	2015-05	Insurance industry	Calgary (1) Edmonton (2)	(1) Increase resiliency of: Banking/Financial Services, Retail Food Supply, Petroleum Supply, Electricity Supply, Backwater Valve, Commercial Real Estate (2) Increase resiliency of: Banking/Financial Services, Telecommunication, Transportation, Petroleum Supply, Electricity Supply, Backwater Valve Installation, Land Use Planning.	2
(Pomeroy et al. 2016)	2015-08	None	Unspecified	enhanced coordinated research program Coordinate efforts between jurisdictions watershed planning mechanisms such as a conservancy district Better prediction land-use zoning based on hazard mapping	
(Auditor General of Alberta 2016)	2015-09	GOA	GOA (AEMA)	Complete transition plan - acquire skilled managers and apply oversight	
(High River DRP Advocacy Committee 2016)	2016-01	Homeowners	GOA DRP	complete a thorough and open external review of the 2013 DRP Improve claims processing and administration (2 recommendations) Address systemic and operational issues (4 recommendations) Address public policy issues (4 recommendations)	3
(Frechette 2016)	2016-02	GOC	GOA	Update flood maps Increase the level of protection beyond the 100 year Consider groundwater in hazard maps Implement area-wide coordinated response to flood management Pursue more mitigation Improve flood forecasting Include climate change in hazard maps	

(Auditor General of Alberta 2015)	2016-03	GOA	GOA (AENV)	improve map updating and map unmapped areas update mapping guidelines implement flood risk assessment processes establish processes to cumulatively assess flood mitigation efforts	
(Feltmate 2016)	2016-04	Research institute with insurance industry funding	GOA	Floodplain Mapping Land-use planning Drainage System Maintenance Home Adaptation Audit Commercial Property Adaptation Audit Electricity Supply Emergency Preparedness and Response	2

Notes:

1. Document contains a mix of goals, accomplishments, and policy statements. Restated here, where possible, as a recommendation
2. The Feltmate series of reports provide a measure of preparedness or resiliency through collecting the opinions of government administrators. Themes receiving grade 'C' and below are presented as recommendations for improvement here.
3. Report contained detailed recommendations for improving the DRP under the three themes shown here.
4. Where multiple dates are available, the most relevant to the timing of the recommendations is provided here. In order of preference: 1) end of data collection/field investigation; 2) latest revision date; 3) publication date; 4) publicly available date.

Refer to Glossary in main report for acronym and key term definitions.

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Appendix D – Survey Questionnaire

Floods in Alberta: Management's Perspective

A University of Alberta survey of Alberta's flood managers by Seth Bryant

* Required

1. **Email address** *

INFORMATION and CONSENT

STUDY TITLE: Floods in Alberta: Management's Perspective

RESEARCH INVESTIGATOR:
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Associate Professor
University of Alberta
evan.davies@ualberta.ca
780 492 5134

BACKGROUND
-You have been selected to participate in this study based on your experience in, and/or influence on, flood management practices in Alberta.
-This study is funded by the Natural Sciences and Engineering Research Council of Canada (NSERC) and the Kule Institute for Advanced Studies at the University of Alberta. Your participation may support the graduate MSc thesis of Seth Bryant.

PURPOSE
-The purpose of this project is to better understand flood management practices in Alberta. This knowledge can help build a roadmap for future research activities, thereby improving future policies and reducing long-term flood risk in Alberta.

STUDY PROCEDURES
-Initial participation should take between 10 and 15 minutes. We may contact you for a follow-up.
-In rare cases, we may wish to quote you directly. However, we will contact you for permission prior to using your name or position directly. In such cases, a draft of the relevant section will be provided to you for context. We ask that you respond within 30 days with any concerns or corrections and to provide consent.

BENEFITS
-You will not directly benefit from participation in this study.
-The results of this research may benefit flood management policies in Alberta by identifying areas that need improvement and guiding future work to improve those areas.
-There are no costs involved with participation.

RISK
-There are no relevant risks associated with participation in this study.

VOLUNTARY PARTICIPATION
-You are under no obligation to participate in this study. Your participation is voluntary. You

are not obliged to answer any specific questions even if participating in the study.
-Even if you agree to be in the study, you can change your mind and withdraw at any time. If you choose to opt-out, contact the research team, and all of your responses will be destroyed.

CONFIDENTIALITY & ANONYMITY
-The feedback you provide may support the graduate thesis of Seth Bryant and other publications. Individual responses will be confidential. Only the research investigators and supervisors will have access to your individual responses.
-In rare cases, we may request permission to directly quote one of your responses. In this case, we will follow the procedure outlined above ('Study Procedures').
-Your responses will be kept on password protected systems. Only the research team will have access to these systems.
-You will be provided an electronic copy of all reports/publications developed from this study.
-We may use the data obtained from this study in future research. This future research will need to be approved separately by a research ethics board.

FURTHER INFORMATION
-The plan for this study has been reviewed for its adherence to ethical guidelines by the Research Ethics Board at the University of Alberta. For questions regarding participant rights and ethical conduct of research, contact the Research Ethics Office at (780) 492-2615.

CONSENT STATEMENT (for electronic participation)
By continuing, you confirm that you have read and understand the above. If you have any questions, please send them to sbryant@ualberta.ca prior to proceeding. By continuing in this survey, you confirm that you agree to participate in the research study described above. After completing this form, you may select "Send me a copy of my responses" to receive a copy of your responses and the above text.

2.
*

Check all that apply.

- [ ] I understand, agree to participate, and wish to continue

Let's Get Started

We know your time is valuable, so we designed this survey to be quick and pleasant. In this survey, we are interested in your personal opinion, rather than the official opinion of your department or ministry. If a question is too time-consuming please feel free to skip it. Space is provided at the end for additional comment.

Participation typically takes 10-15 minutes.

If a question seems unclear, try to interpret it how you think other people in your position may interpret it and/or leave a comment at the end. You may also skip the question.

If you do not recognize an acronym, please skip the question.

Each question is intended to elicit your personal perspective on flood management in Alberta.

If you wish to return to a survey page, do not use your browser's back button as your entries will be erased. Instead, use the buttons at the bottom of the survey page.

And finally, please feel free to answer honestly and candidly. Neither your name, department, or jurisdiction (i.e. GOA) will be published or linked to your responses (except in rare cases we may request to quote you - see previous).

Some Key Terms

The terms used in this survey follow those outlined in Alberta Environment (2011) 'Flood Hazard Identification Program Guidelines'. We have repeated and defined some additional key terms here for reference:

Flood risk - Combination of the likelihood of occurrence of a flood event (flood hazard) and the consequences of that event when it occurs (exposure)

Flood management - Program of corrective and preventative measures for reducing flood risk

Risk based approach - Incorporation of flood risk assessments into decision making

Flood control - Structural measures to reduce flood hazard

Design flood - Flood that is used to delineate the flood hazard area. In Alberta, this is typically a 100 year discharge.

Flood hazard area - Land area inundated by the design flood (per Alberta Environment (2011) 'Flood Hazard Identification Program Guidelines'). This is further divided into floodway and flood fringe.

GOA - Government of Alberta

GOC - Government of Canada

Skip to question 2.

About you

3. **What is your title, department, and jurisdiction?**
   i.e. 'Director of Public Works for the City of Calgary'

   ____

4. **How many years of experience do you have?**
   With respect to flood management in your jurisdiction. Not necessarily in your current position.

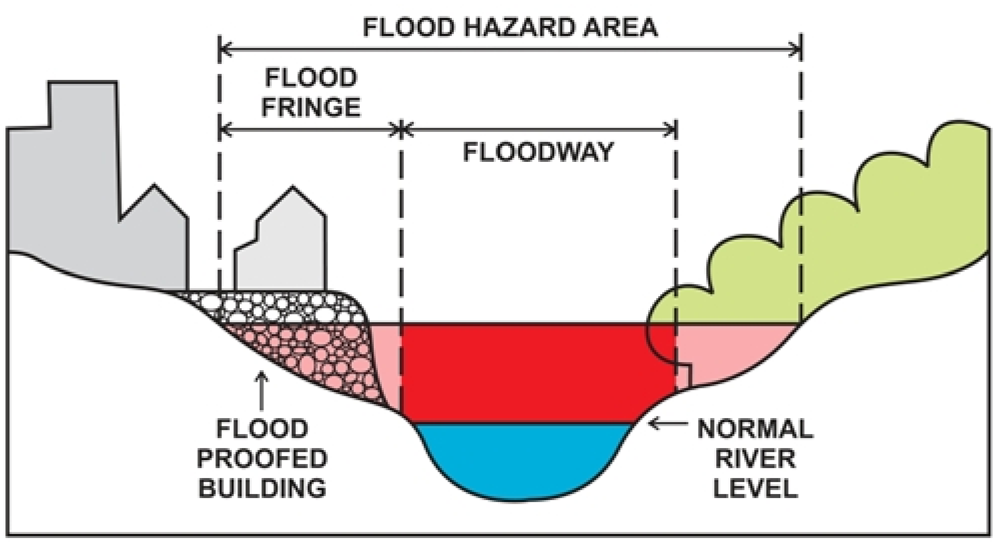
   ____

5.
Briefly describe your roles and responsibilities
With respect to flood management (i.e. "I manage our flood mapping projects").

6.
What are your qualifications?
Check all that are valid
Check all that apply.

- [ ] P.Eng
- [ ] RPP
- [ ] Bachelors degree (in a related field)
- [ ] Masters degree (in a related field)
- [ ] Doctoral degree (in a related field)
- [ ] Graduate degree (in an unrelated field)
- [ ] Undergraduate degree (in an unrelated field)
- [ ] Other: ____________________

Land Use



7.

How well do current land use (zoning) practices limit the growth of flood risk?

In reference to the application of modern policies (2013 to now) to new private development -- not necessarily the legislation or by-laws which are in place that may or may not be enforced consistently.

Mark only one oval per row.

	No effect in limiting future flood risk	Moderately effective, or intermittently effective	Very effective or almost always effective	Development never occurs unless it is fully flood proofed
in the Floodway	◯	◯	◯	◯
in the Flood fringe	◯	◯	◯	◯

8.

Since 2013, about how many new residential buildings have been PERMITTED in the flood hazard zone?

In your jurisdiction - including flood proofed and non-flood proofed buildings

____

9.

What percentage of these are (planned to be) adequately flood proofed?

To prevent damage from the 100yr design flood

____

10.

Comments for this section

____
____
____
____
____

Skip to question 10.

Qualitative flood risk in your jurisdiction

These questions are tough. We don't expect your responses to be quantitative. We're interested in your local opinion to help us better understand the thinking in your department and in similar departments across the province.

11.

Estimate the flood risk for the near future

In your jurisdiction - once flood control projects under development are complete - in a given year.

Mark only one oval.

- Extreme (high flood damage very likely)
- High
- Moderate
- Low
- Extremely low (very little flood damage and unlikely to occur)
- Am not actively engaged in flood management

12.

Estimate the flood risk as it was in 2013

In your jurisdiction - with respect to development (exposure) and flood control (mitigation) as it was prior to recent mitigation works. We're interested in gauging the change in flood risk from 2013 to now.

Mark only one oval.

- Extreme (high flood damage very likely)
- High
- Moderate
- Low
- Extremely low (very little flood damage and unlikely to occur)
- Was not engaged in flood management at the time

13.

How many residential buildings are currently in the flood hazard zone (100yr)

In your jurisdiction. Give your best approximation; regardless of the extent of flood mapping.

Mark only one oval per row.

	<10	10-100	100-500	500-1,000	1,000-5,000	5,000-10,000	>10,000
in the floodway							
in the flood fringe							

14.
What is your best guess as to how this may change as a result of: increasing the design flood to 350 years?
Mark only one oval per row.

	No change	Minor increase (~+10%)	Increase (~+50%)	Double (~2x)	More than double (~5x)	Massive change (~10x)
in the floodway	⬭	⬭	⬭	⬭	⬭	⬭
in the flood fringe	⬭	⬭	⬭	⬭	⬭	⬭

15.
Comments for this section

____

____

____

____

____

Programs

Rate the helpfulness of the following programs

On a scale of 0 to 4 with respect to implementing flood risk mitigation in your jurisdiction (after flood control projects currently in development are complete). Leave the question blank if you don't recognize the program.

16.
WRRP
Mark only one oval.

	0	1	2	3	4	
Never used or N/A	⬭	⬭	⬭	⬭	⬭	Extremely helpful in reducing flood risk

17.
ACRP
Mark only one oval.

	0	1	2	3	4	
Never used or N/A	⬭	⬭	⬭	⬭	⬭	Extremely helpful in reducing flood risk

18.
FRFCP
Mark only one oval.

	0	1	2	3	4	
Never used or N/A	◯	◯	◯	◯	◯	Extremely helpful in reducing flood risk

19.
Federal infrastructure grants
i.e. SCF, NRP, and/or MRIF
Mark only one oval.

	0	1	2	3	4	
Never used or N/A	◯	◯	◯	◯	◯	Extremely helpful in reducing flood risk

20.
NDMP
Mark only one oval.

	0	1	2	3	4	
Never used or N/A	◯	◯	◯	◯	◯	Extremely helpful in reducing flood risk

21.
Springbank
after completion
Mark only one oval.

	0	1	2	3	4	
Never used or N/A	◯	◯	◯	◯	◯	Extremely helpful in reducing flood risk

22.
Other provincial 'Special Projects'
Provincially managed projects (modified operations agreement with TransAlta, Highwood river basin works, etc.) after completion.
Mark only one oval.

	0	1	2	3	4	
Never used or N/A	◯	◯	◯	◯	◯	Extremely helpful in reducing flood risk

23.

Federal INAC grants

Mark only one oval.

	0	1	2	3	4	
Never used or N/A	⬭	⬭	⬭	⬭	⬭	Extremely helpful in reducing flood risk

24.

Other...

Add any GOA, GOC, or NGO program which helped reduce flood risk in your community. Rate its helpfulness using the same 0-4 scale as above.

25.

Comments for this section

The role of the Government of Canada (GOC)

26.
How frequently do you interact with GOC staff?
With respect to flood management issues in your jurisdiction. We're interested in technical rather than political contact.
Mark only one oval per row.

	No contact	< 2 /year	< 1/month	< weekly	daily or more
Public Safety Canada (PSC)	⬭	⬭	⬭	⬭	⬭
Indigenous and Northern Affairs Canada (INAC)	⬭	⬭	⬭	⬭	⬭
Natural Resources Canada (NRCan)	⬭	⬭	⬭	⬭	⬭
Environment and Climate Change Canada (ECCC)	⬭	⬭	⬭	⬭	⬭

27.
How should the GOC's role CHANGE?
With respect to your personal opinion and the current balance of roles in your jurisdiction.
Mark only one oval per row.

	GOC should take over completely	Should increase	Current level is optimal	Should decrease	Reduce to nothing
Funding for flood mitigation	⬭	⬭	⬭	⬭	⬭
Execution/construction of flood mitigation	⬭	⬭	⬭	⬭	⬭
Land use/zoning practices in the flood hazard zone	⬭	⬭	⬭	⬭	⬭
Setting of standards and practices for flood control	⬭	⬭	⬭	⬭	⬭
Flood hazard mapping	⬭	⬭	⬭	⬭	⬭
Regulating private overland flood insurance	⬭	⬭	⬭	⬭	⬭

28.
Comments for this section

____
____
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____
____

The role of the Government of Alberta (GOA)

29.

How frequently do you interact with GOA staff?

With respect to flood management issues in your jurisdiction. We're interested in technical rather than political contact.

Mark only one oval per row.

	No contact	< 2 /year	< 1/month	< weekly	daily or more
Alberta Environment and Parks (AEP)					
Indigenous Relations (IR)					
Municipal Affairs (MA)					

30.

What is the CURRENT role of the GOA?

With respect to the balance of flood management in the following areas in your jurisdiction.

Mark only one oval per row.

	Completely by the GOA	Mostly by the GOA	50/50 split with the GOA	the GOA plays a small role	the GOA has no role
Funding for flood mitigation					
Decision making and planning for flood mitigation					
Execution/construction of flood mitigation					
Land use/zoning practices in the flood hazard zone					
Setting of standards and practices for flood mitigation					
Flood hazard mapping					

31.
How should this CHANGE?
With respect to your personal opinion and the current balance of roles in your jurisdiction.
Mark only one oval per row.

	GOA should take over completely	Should increase	Current level is optimal	Should decrease	Reduce to nothing
Funding for flood mitigation	⬭	⬭	⬭	⬭	⬭
Decision making and planning for flood mitigation	⬭	⬭	⬭	⬭	⬭
Execution/construction of flood mitigation	⬭	⬭	⬭	⬭	⬭
Land use/zoning practices in the flood hazard zone	⬭	⬭	⬭	⬭	⬭
Setting of standards and practices for flood mitigation	⬭	⬭	⬭	⬭	⬭
Flood hazard mapping	⬭	⬭	⬭	⬭	⬭

32.
How is your department involved when the GOA develops new flood policy?
from 2013 to now
Mark only one oval.

- ⬭ No consultation.
- ⬭ No consultation. The GOA informs us of new policy after development.
- ⬭ The GOA asks my department indirectly for input during policy development.
- ⬭ The GOA asks my department directly for input during policy development.
- ⬭ The GOA works closely and collaboratively with my department during policy development.
- ⬭ Other: ____________________

33.
Comments for this section

____
____
____
____
____

Policy Improvements

Many recommendations and commitments were made following the 2013 flood. We want to know what has been done and what you think about it.

34.

Since 2013, rate the IMPLEMENTATION of the following

With respect to policies that effect your jurisdiction and that your department has accepted some responsibility to implement.

Mark only one oval per row.

	No action taken	Still in discussion	Plan in place; starting to implement	Mostly implemented	Complete	Not my department's responsibility
Map unmapped flood hazard areas	◯	◯	◯	◯	◯	◯
Regularly update flood maps	◯	◯	◯	◯	◯	◯
Include climate change in flood maps	◯	◯	◯	◯	◯	◯
Increase return period for design storm	◯	◯	◯	◯	◯	◯
Include debris and groundwater hazards on flood maps	◯	◯	◯	◯	◯	◯
Use risk analysis (flood damage assessments) in planning	◯	◯	◯	◯	◯	◯
Improve flood forecasting	◯	◯	◯	◯	◯	◯
Prohibit new development in the floodway	◯	◯	◯	◯	◯	◯
Buyout existing high risk developments	◯	◯	◯	◯	◯	◯
Create incentive programs for flood proofing	◯	◯	◯	◯	◯	◯
Improve public flood risk communication	◯	◯	◯	◯	◯	◯
Consider differential vulnerability (age, gender, income)	◯	◯	◯	◯	◯	◯

35.

For the implemented policies, how EFFECTIVE have they been at reducing flood risk?

If you indicated above that a certain policy is not yet implemented, or not your department's responsibility - select 'N/A'

Mark only one oval per row.

	N/A	Implemented, but negligible effect on flood risk	Slightly reduced flood risk	Moderately reduced flood risk	Significantly reduced flood risk	INCREASED flood risk
Mapping of unmapped flood hazard areas	◯	◯	◯	◯	◯	◯
Regularly updated flood maps	◯	◯	◯	◯	◯	◯
Higher (>100yr) return period for design storm	◯	◯	◯	◯	◯	◯
Including debris and groundwater hazards on flood maps	◯	◯	◯	◯	◯	◯
Use of a risk analysis (flood damage assessments) in planning	◯	◯	◯	◯	◯	◯
Improved flood forecasting	◯	◯	◯	◯	◯	◯
Prohibiting new development in the floodway	◯	◯	◯	◯	◯	◯
Buying existing high risk developments	◯	◯	◯	◯	◯	◯
Incentive programs for flood proofing	◯	◯	◯	◯	◯	◯
Enhanced flood risk communication	◯	◯	◯	◯	◯	◯
Consideration of differential vulnerability (age, gender, income)	◯	◯	◯	◯	◯	◯

36.

Comments for this section

Practical Flood Management

Good ideas remain just that if the right resources are not provided or barriers are too high.

37.

How do the following limit your work?

With respect to direct limitations on your department's flood risk reduction activities.
Mark only one oval per row.

	Significantly limiting	Moderately limiting	Slightly limiting	Does not limit our department
Funding				
Staffing				
Internal leadership				
Political direction				
Public support				
Individual private citizens				
Existing legislation/regulations				
Uncertainty about future legislation/regulations				
The Judicial system (courts)				
Lack of data (measurements)				
Lack of physical process knowledge (How do debris flows increase flood risk?)				
Lack of social process knowledge (How do people respond to flood forecasts?)				

38.
Comments for this section

Roles

39.
Who SHOULD be responsible for flood risk reduction?
Rank each of the 7 actors based on how you think the world should be.
Mark only one oval per row.

	1 (most responsible)	2	3	4	5	6	7 (least responsible)
GOA							
International Organizations (UN)							
GOC							
Neighbourhood							
Individual/Family							
Municipality/Band							
NGOs (Red Cross, etc.)							

40.
Comments for this section

Please share with us any ideas, comments, or complaints you have about flood risk and how it's managed in Alberta.

If we would like to quote any of your responses, we will contact you first to obtain permission.

41.
By your department?

42.
By the GOA?

43.
By the GOC?

And Finally...

44.
What question(s) should we have asked?
Tell us the answer(s) too if you're feeling generous.

Thank you!

We greatly appreciate your participation and trust. We are confident your answers will contribute to improving flood management in Alberta.

If we would like to quote any of your responses, we will contact you first to obtain permission.

If you know of anyone else who may be interested and/or qualified to participate in this survey, please let us know.

Once complete, you will be provided a copy of our report.

If you have any questions or additional comments, please feel free to contact the research team (sbryant@ualberta.ca).

☐ Send me a copy of my responses.

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).

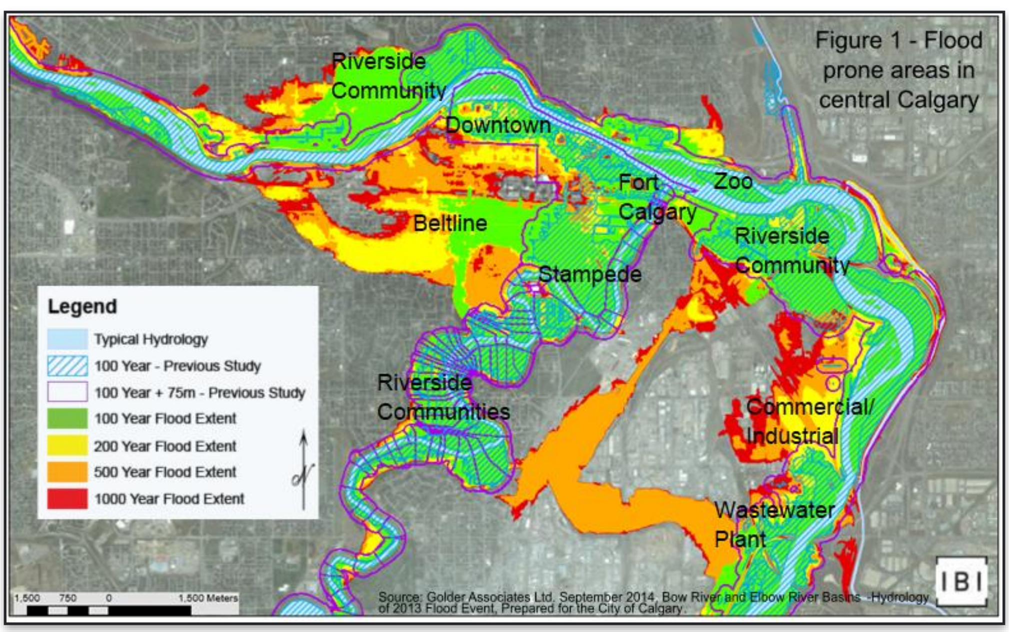
The 2013 floods in Southern Alberta were one of Canada's most costly natural disasters, resulting in loss of life as well as significant property damage, personal impact and social and economic disruption. The 2013 flood event emphasized the need to address flood risk in Calgary, protect public safety 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)



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.

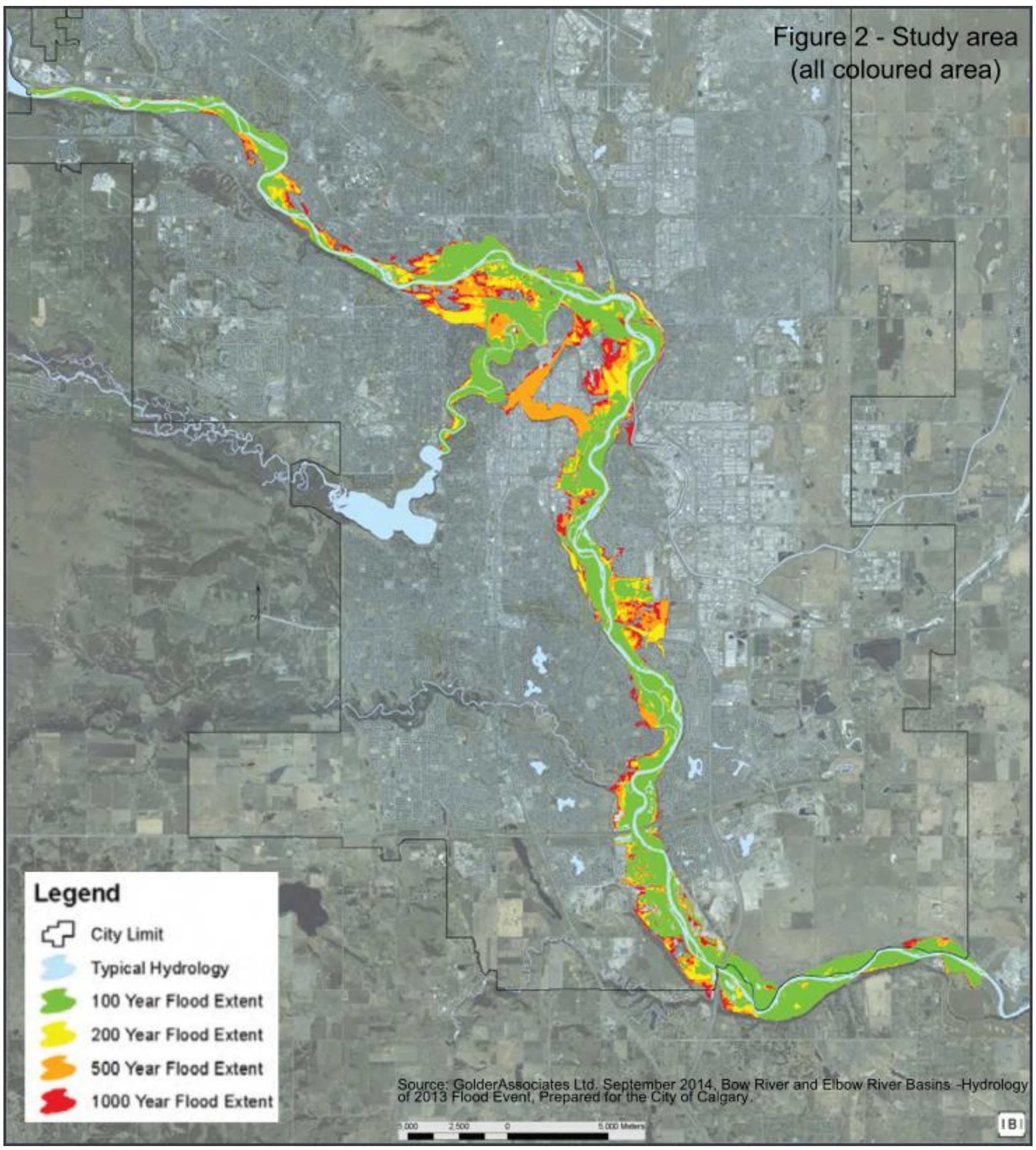


Figure 2 - Study area (all coloured area)

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.

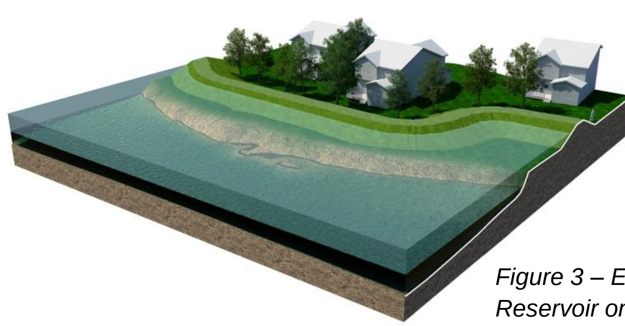


Figure 3 – Existing Glenmore Reservoir on the Elbow River (left) and conceptual flood barrier in a residential community (right).

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).

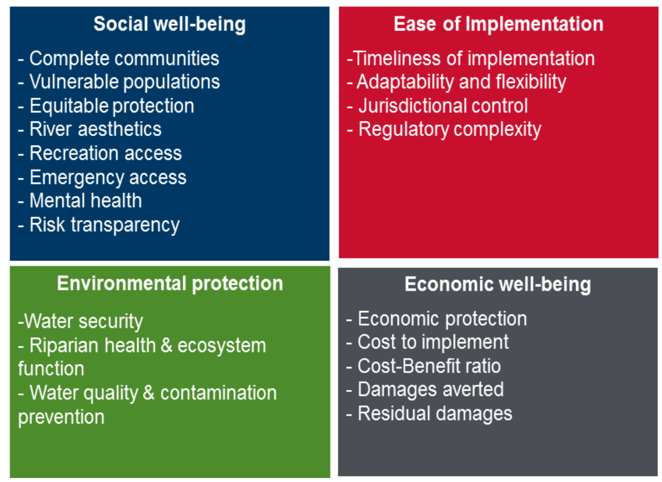


Figure 4 – Flood mitigation scenario sustainability assessment criteria

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.

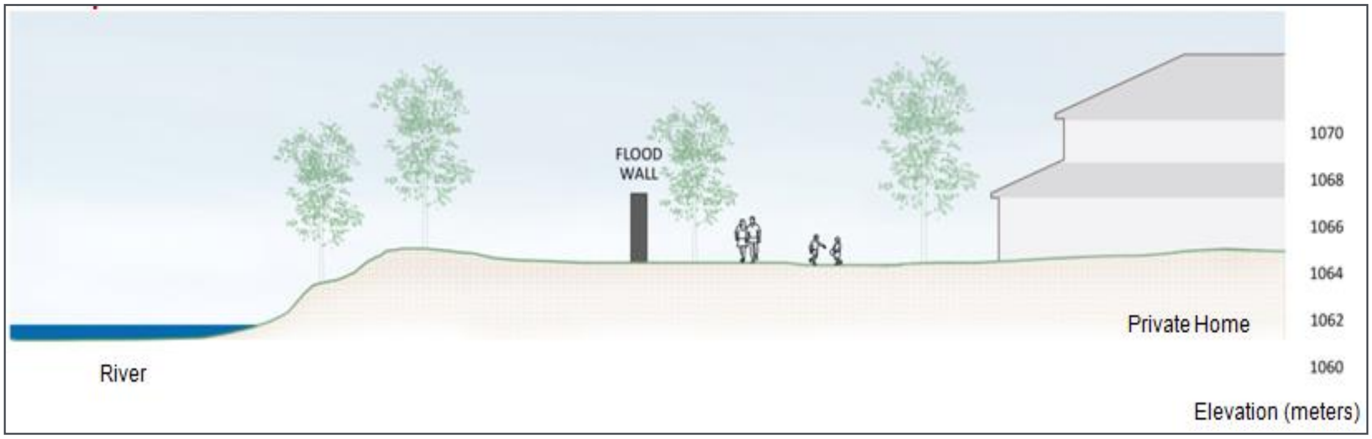


Figure 5 – Social and environmental impacts of 1:200 year flood barriers (illustrated here) were evaluated.

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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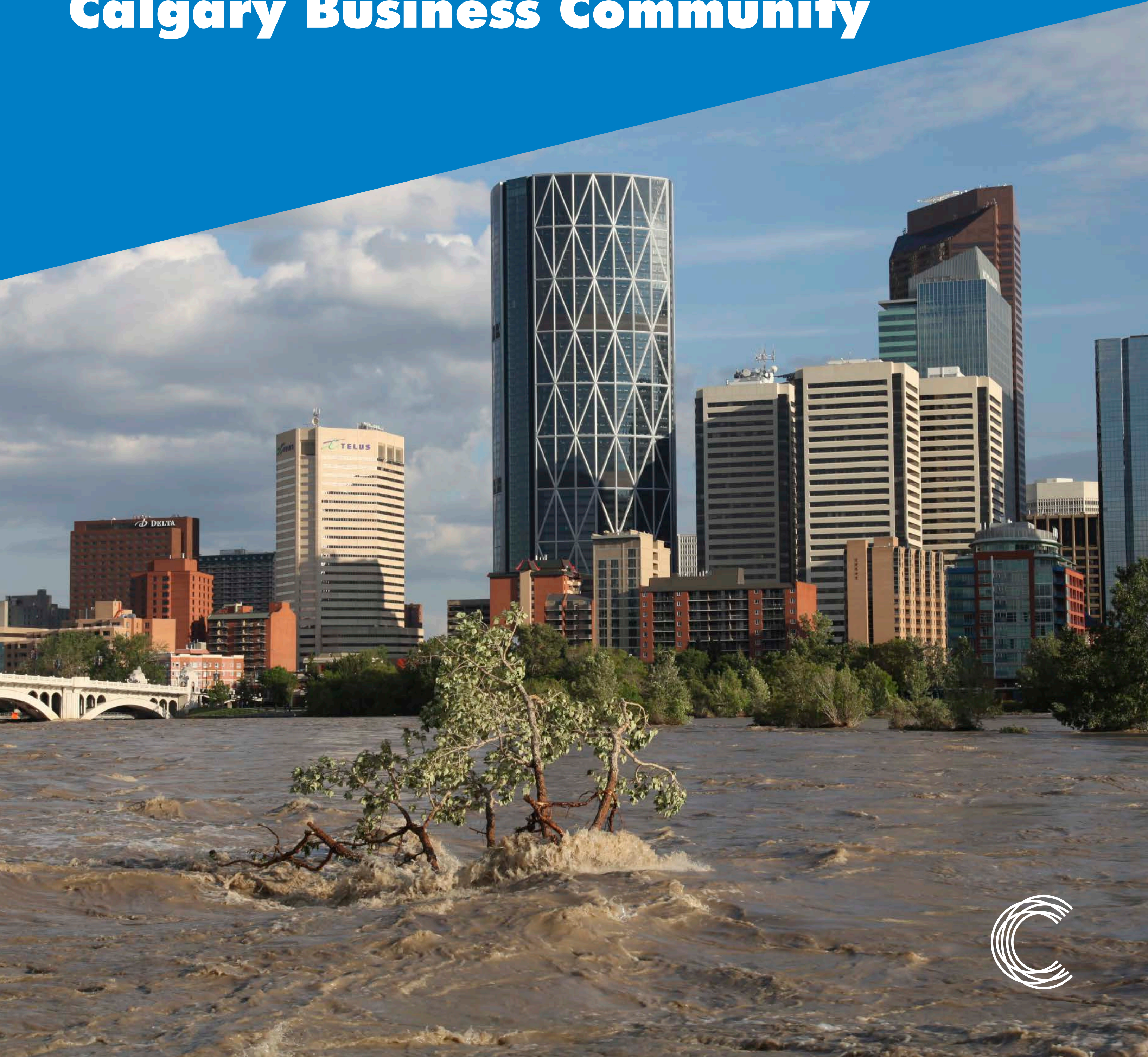
The full Flood Mitigation Options Assessment report can be requested by contacting 311.

For more information on flooding in Calgary, resiliency and mitigation,
please visit www.calgary.ca/floodinfo or contact 311.

Calgary Chamber

Flood Resiliency

Insights from a survey of the Calgary Business Community



The Calgary Chamber of Commerce has been working for 124 years to build a stronger and more prosperous Calgary business community. This mission took on a new dimension after the 2013 flood raged through the city's downtown core—damaging businesses, homes, property and public infrastructure.

Once the waters receded, Calgary had sustained unprecedented damage. With a nearly $6- billion-dollar price tag, the flooding in southern Alberta was deemed one of the most expensive natural disasters in Canadian history. Dozens of businesses were directly flooded, damaging their operations, their facilities and their equipment. In addition, thousands of businesses were harmed by days of lost productivity and sales, as well as supply-chain disruptions. Disasters such as these are felt both on the bottom line and in the morale of the business community.

More than a year later, the Calgary Chamber continues to play an essential role in helping businesses recover from the damage and build resiliency to minimize the impact of future events.

In line with this mission, the Chamber has conducted a survey of its members and the community at large to better understand the full impacts of the flood, and assess both disaster mitigation efforts and flood recovery programs. We hope that the passage of time has offered business owners a more holistic view of the impact the flood had on their community and livelihoods.

The survey asks questions about the effect of the flood, disaster preparedness activities and business owners' opinions on government support programs. In doing so, the survey allows us to identify key successes and highlight any shortcomings. The goal is to better understand the current level of disaster resiliency and to provide insights on how we can better prepare for future contingencies.

Only by knowing where we stand can we form effective plans on how to improve.

The key question that the survey attempts to answer in the face of all these disasters and seemingly random business interruptions is this: Just how resilient are we?

Specifically, the survey examines the role of both independent mitigation activities undertaken by businesses and the effectiveness of government programs that assisted in post-disaster recovery.

Resilient communities

From massive flooding in 2013 and the Calgary tree disaster of 2014 (an early September 2014 snowstorm that damaged or destroyed roughly one million trees-half the urban canopy) to a sweeping blackout in the downtown core in October 2014—over the past two years, Calgary has faced a host of unprecedented disasters and business interruptions. Yet, each time the citizens of Calgary were able to come back and resume their daily lives.

But does this make the city resilient?

In the most general sense, resiliency is the ability of a system to adapt and recover quickly from unexpected change or misfortune.

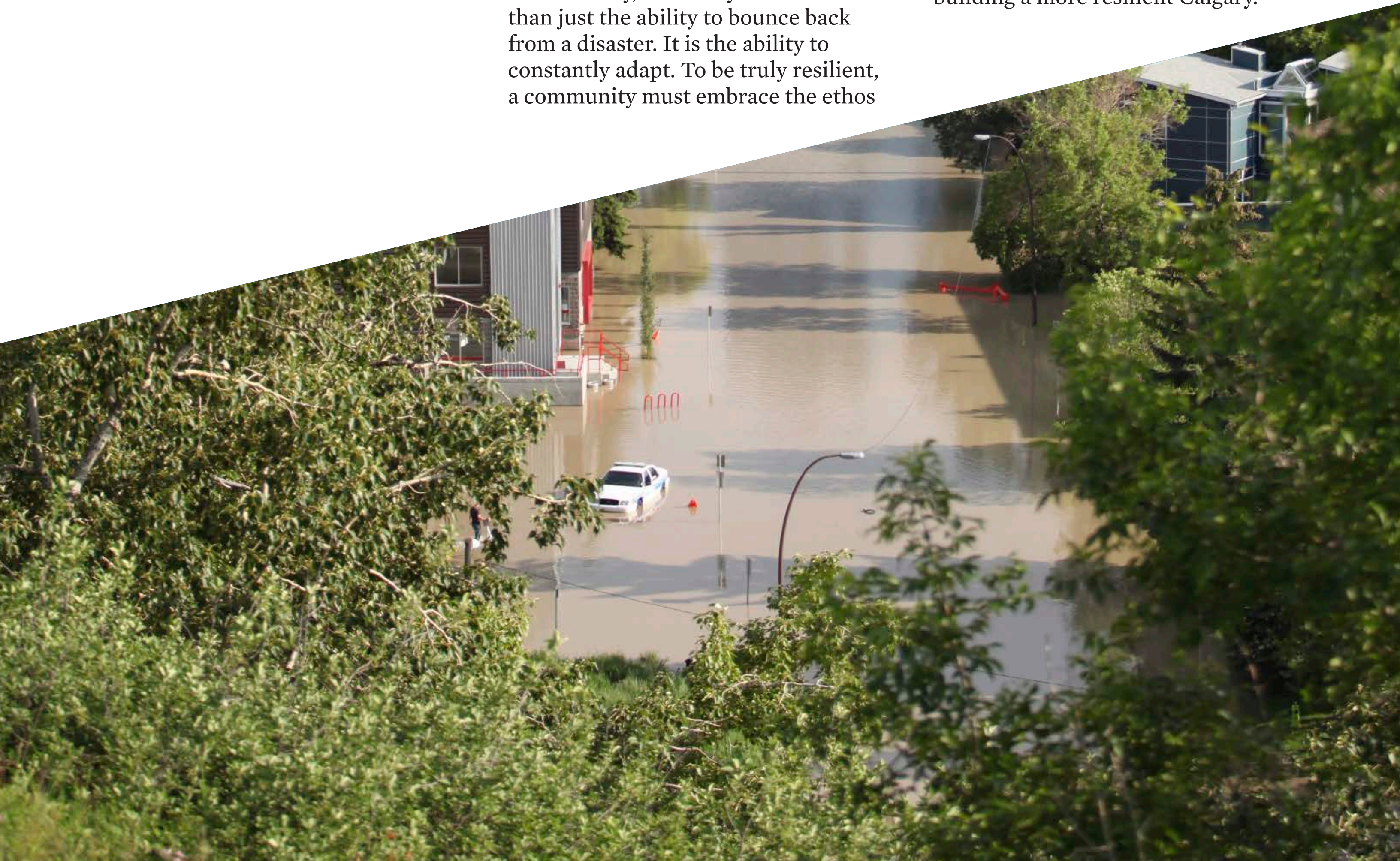
In a community, these shocks can come in the form of a natural disaster, infrastructure failures, man-made catastrophes and even sharp economic downturns. While all of these require unique responses, resiliency is having the capacity to face a broad array of challenges in an efficient and timely manner.

But for a city, resiliency is more than just the ability to bounce back from a disaster. It is the ability to constantly adapt. To be truly resilient, a community must embrace the ethos of preparedness, response, recovery and—perhaps most importantly—continued improvement. It requires all levels of government to coordinate with its citizens to properly prepare for unexpected challenges as well as individual efforts to minimize the damage caused in their own lives.

Resiliency is not something that takes place purely in the wake of a disaster; rather, it is an ongoing process. It requires the constant foresight to plan and execute innovative policies and robust strategies in dealing with the unforeseen.

A resilient community has the necessary resources and flexibility to withstand unforeseen hardship. Resiliency is a cyclical process of constant assessment, reassessment and improvement. A community cannot be truly resilient if it does not internalize the lessons learned from past misfortunes in an effort to mitigate future adversities.

In that sense, this report, as an assessment tool, also plays a role in building a more resilient Calgary.



Resilient businesses

To create a resilient city, both community and business resiliency must be built in tandem. Resiliency is vital in ensuring that Calgary businesses are not swept away by rising tides or unexpected storms. By building resilient businesses, Calgary can ensure economic and social strength and the long-term health of the business community.

For businesses, resiliency is important because of one simple truth: disasters and business interruptions are costly. Disastrous events such as the 2013 flood have significant repercussions, affecting every level of business, both directly and indirectly. Without proper foresight, these disasters can wreak havoc on their bottom line, or even worse—ensure that a business may never re-open.

Community resiliency can help minimize the human and capital costs of a disaster. Local emergency infrastructure is the first line of defence against shocks to a business. This includes fire departments, emergency communication and coordination of vital community resources. During a disaster, businesses rely heavily on the capabilities of the community at large.

The 2013 flood resulted in heavy economic costs, both for the community and individual businesses. Closure of businesses and other interruptions costs the economy 5.1 million work hours, and BMO Capital Markets estimated that the economic interruption was so large that it reduced Canadian GDP by $2 billion dollars.

Small businesses, especially in retail and food services, can see their entire inventory vanish. One Chinatown business owner told the CBC that the flood cost him $20,000 worth of food inventory and forced him to lay off five employees. Another restaurant in the Beltline (an inner city community) experienced eight days of lost revenue and $10,000 in lost inventory. These repercussions affect not only the business owners, but also their employees, their families and the community that relies on them for economic activity.

In the aftermath of a disaster, business owners suffer greatly. They are faced with large clean-up costs and damage to capital assets. The cost of fixing water damage and replacing vital machinery can be enough to put a business under. These tasks become more difficult when a disaster impacts an entire community, and there is a scarcity of resources and information. Then there are the economic costs associated with days of disrupted operations.

These costs can come in the form of forgone revenue and productivity as a result of closing the business down temporarily, not to mention spoilage of inventory and the time it takes for a customer base to return. Even losing valuable data, documents and IT infrastructure can hold a business back for weeks if not months.

It is the role of the government and local authorities after such a disaster to support businesses in their recovery efforts. In Alberta, this took the form of the provincial Disaster Recovery Programs (DRP). The DRP focused on providing both businesses and individuals with financial support to cover uninsured property damage, loss and other expenses. It was aimed specifically at helping those most vulnerable, including homeowners, tenants, non-profits and small businesses. In terms of resiliency, it also provided funding for mitigation activities in the event of another 1-in-100-year flood event.

More locally, the Calgary Chamber has worked extensively with the Calgary Emergency Management Agency (CEMA) to act as a resource for businesses facing these unexpected interruptions. CEMA plays a role in both communicating emergency information to disrupted communities and in providing valuable information on how to best prepare for the unexpected.

Through proper resiliency preparation, disaster mitigation and business recovery planning, businesses can see significant savings down the road. It can mean the difference between a temporary shutdown and the permanent closure of a business. One study estimated that 43 per cent of businesses affected by natural disasters never reopen, and of those that do, 29 per cent fail within two years.

Our survey asked questions about both of these programs (DRP and CEMA) in order to explore how they have been successful and how they could be more effective in the future. Just as businesses need to change and adapt to meet unexpected demands, so do the emergency programs that serve them.

Local governments and authorities have an important role in mitigating business interruptions because of the wide-ranging community implications. A disruption in economic activity on a large scale puts people's income and livelihood at risk, creating greater insecurity in an already precarious situation. It is also true that some financial impacts are not directly borne by a single geographic area. There are tertiary effects such as disrupted supply chains and distribution venues, not to mention loss of overall economic activity as community resources focus on recovery efforts.

While disaster mitigation and resiliency planning do not guarantee success, they do give businesses a fighting chance.

Survey insights

1. Resiliency matters

In the past two years, a majority of Calgary's businesses have faced some type of interruption. The most common interruption identified was flooding and extreme weather, followed by utilities, sewerage and electricity problems. This should come as no surprise considering the large emergencies that the city has endured in recent memory.

Sixty-four per cent of respondents had their business operations interrupted for one reason or another. Of those impacted, about one-fourth experienced interruptions for two reasons and 17 per cent for three or more reasons. Flooding and extreme weather were each identified by 45 per cent of respondents, and 28 per cent cited utilities, sewerage or electricity problems. This shows that business interruption is an important reality facing Calgary's business community and can have even broader economic implications.

These interruptions often come as a shock and have costly outcomes. Because of the frequency of these interruptions, building community resiliency is important so that businesses can survive and recover as quickly as possible. The fact that the majority of interrupted businesses are facing multiple shocks illustrates how resiliency must be also be a flexible concept. Resiliency does not mean being prepared for a single type of disaster, but rather having strategies in place to deal with the unexpected. Increased resiliency means that when 64 per cent of businesses face these interruptions, they have a minimal impact on their livelihood and the economic health of the community.

Resiliency does not mean being prepared for a single type of disaster, but rather having strategies in place to deal with the unexpected

Businesses Interrupted in the Last Two Years

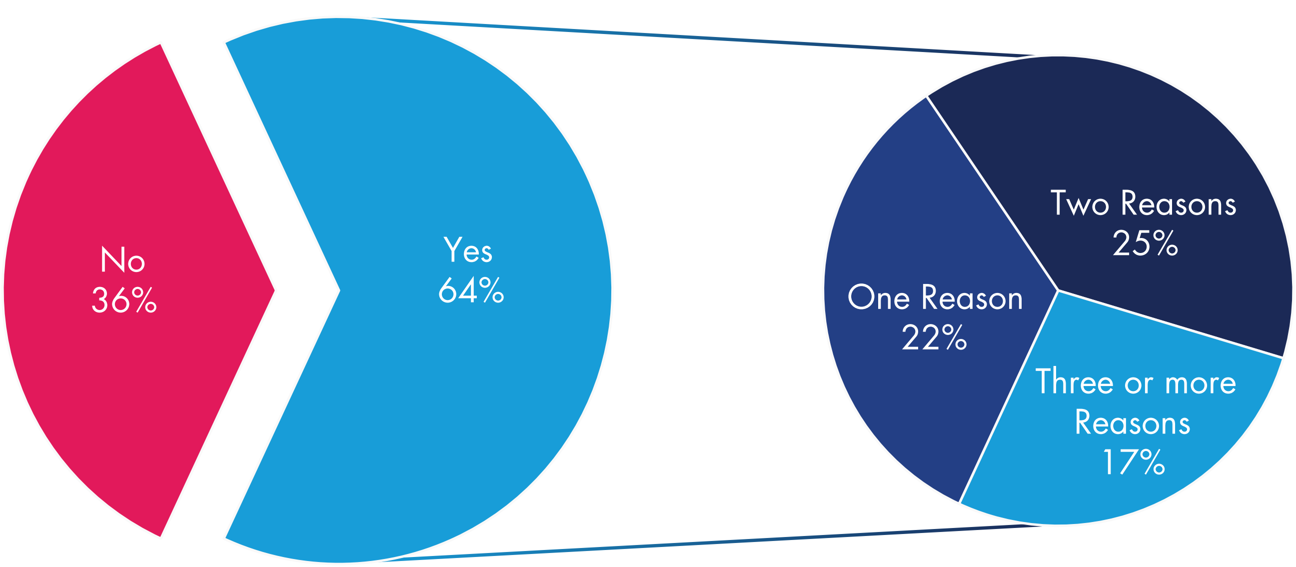


Figure 1: All respondents

2. 2013 flood: Widespread and varied impact

Of all the possible business interruptions, the 2013 flood had the most widespread impact. The flooding affected 41 per cent of all respondents. While the majority of respondents were not impacted by the flood, of those who did experience a business interruption over the past two years, 64 per cent cited the 2013 flood as one of them.

Yet, interruptions from the flood do not appear to be equally distributed amongst all businesses. Large businesses—those with more than 101 employees in Calgary—were more than twice as likely to have been impacted as the smallest of businesses (5 or fewer employees). Nearly 60 per cent, or three-fifths, of all large businesses in Calgary were impacted by the 2013 flood, while only 23 per cent of the smaller businesses were. For context, the largest group of companies comprises just under a third of all survey respondents and accounts for a significant amount of employment and overall economic activity in the city. Small businesses accounted for a quarter of respondents.

It does seem that as a business becomes larger, the more vulnerable it is to these business interruptions. This is important to keep in mind because it could have policy implications and should be a key factor in determining the types of mitigation activities undertaken by governments— and the mix of post-disaster services and relief programs offered.

The most common damage associated with the 2013 flood was a closure of offices, with 79 per cent of businesses impacted by the flood reporting this effect. This underscores the importance of disaster planning. Mitigation activities such as remote access abilities and cloud computing capabilities can minimize the financial damage a closure can cause.

Over a third of small-medium businesses (6 to 50 employees) and half of medium-large (51 to 100) businesses reported a loss of sales following the flood. The reality of a post-flood slump in sales and an overall drop in foot traffic highlights the importance of Chamber-supported programs such as "YYC is Open," which pushed for consumers to support local businesses hurt by the flood.

Percent of Businesses Impacted by 2013 Flood

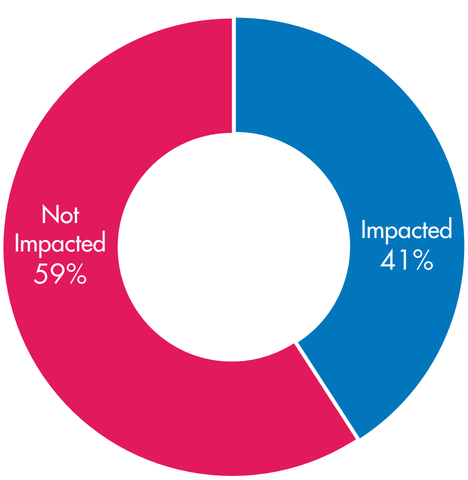


Figure 2: All respondents

Percent of Each Business Size Interrupted by Flood

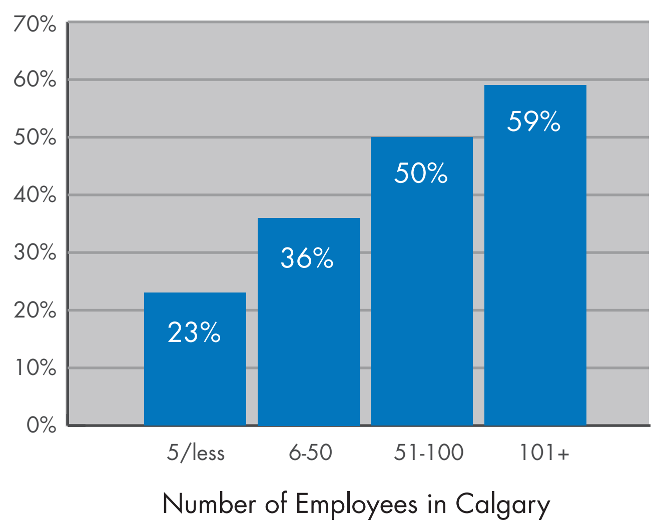


Figure 3: All respondents

3. Uptake in resiliency efforts

One clear highlight of our survey is that the vast majority of businesses in Calgary take the issue of disaster preparedness seriously. Before the 2013 flood, 75 per cent of companies had undertaken some sort of disaster preparedness, but this jumped to 88 per cent after the flood. The most common pre-disaster preparation was the storage of first-aid supplies in the office, followed by 52 per cent of businesses having off-site data backups. Having the capability to access data once a disaster has hit is a critical component of ensuring business continuity and minimizing downtime.

The biggest jumps were in the number of businesses reporting that they had developed an emergency communications strategy and remote operation abilities. This could suggest a direct response to the number of businesses forced to close their doors because of the flood. In an event such as a flood, the ability to communicate with both staff and clients and to be able to work remotely for as long as possible becomes paramount. It seems that businesses have internalized this danger, and many have taken proper precautions. Such a direct relationship, as the data suggests, indicates a strong resiliency mindset within the business community.

It is important to note that after the flood, 42 per cent of businesses impacted sought additional information, and that across all disaster mitigation best practices listed, each one saw an increase in participation. The number of companies not participating in any disaster preparedness activities fell by 50 per cent after the flood.

There are still areas for improvement, however. While there has been a relative rise in disaster mitigation activities, it appears that the business community still lags behind in uptake of the most important ones. Forty per cent of flood-impacted businesses still do not appear to have off-site storage of critical documents, remote operating abilities and protocols, or an emergency communication strategy. A majority did not seek out additional information about disaster planning and recovery. So while businesses may be making resiliency efforts, they are not taking advantage of the multitude of resources available to help inform them of best practices. Although business owners are the most aware of their specific business needs in the case of a disaster, 42 per cent do not have a disaster plan in place of any kind.

These are all critical activities in ensuring a business minimizes the impact of a disaster and is able to recover as quickly as possible. This underscores the importance of local organizations that work to educate and provide businesses with resources on how to properly prepare and develop effective strategies. There is still work to be done, but the general increase in overall resiliency shows these efforts have been fruitful.

A large majority of businesses appear to lack insurance to cover another major interruption, and there does not appear to have been a large scale uptake in such protections after the flood. The DRP, as mentioned earlier, was developed to help finance this uninsured damage. Private financial protections are important to ensure that the public does not end up bearing private costs. However, because of the complex nature of actuarial risks, there may be other underlying factors hindering uptake. Yet, it is important to note that in the event of another massive interruption, a new DRP-type program may be required, but may be more difficult to finance.

As discussed earlier, preparation for future disasters after one has already occurred is an essential component of building resiliency. The data does show increased overall resiliency in Calgary's business community following the 2013 flood. This is reflected in the fact that 81 per cent, a vast majority, of businesses impacted by the flood, agree they are better prepared today. The community, it appears, has made a concerted effort to mitigate the impact of future disasters and ensure that in the event of another 1-in-100-year event, it will be stronger and better prepared.

Percent of Impacted Businesses Who Undertook Mitigation Activities Before and After 2013 Flood

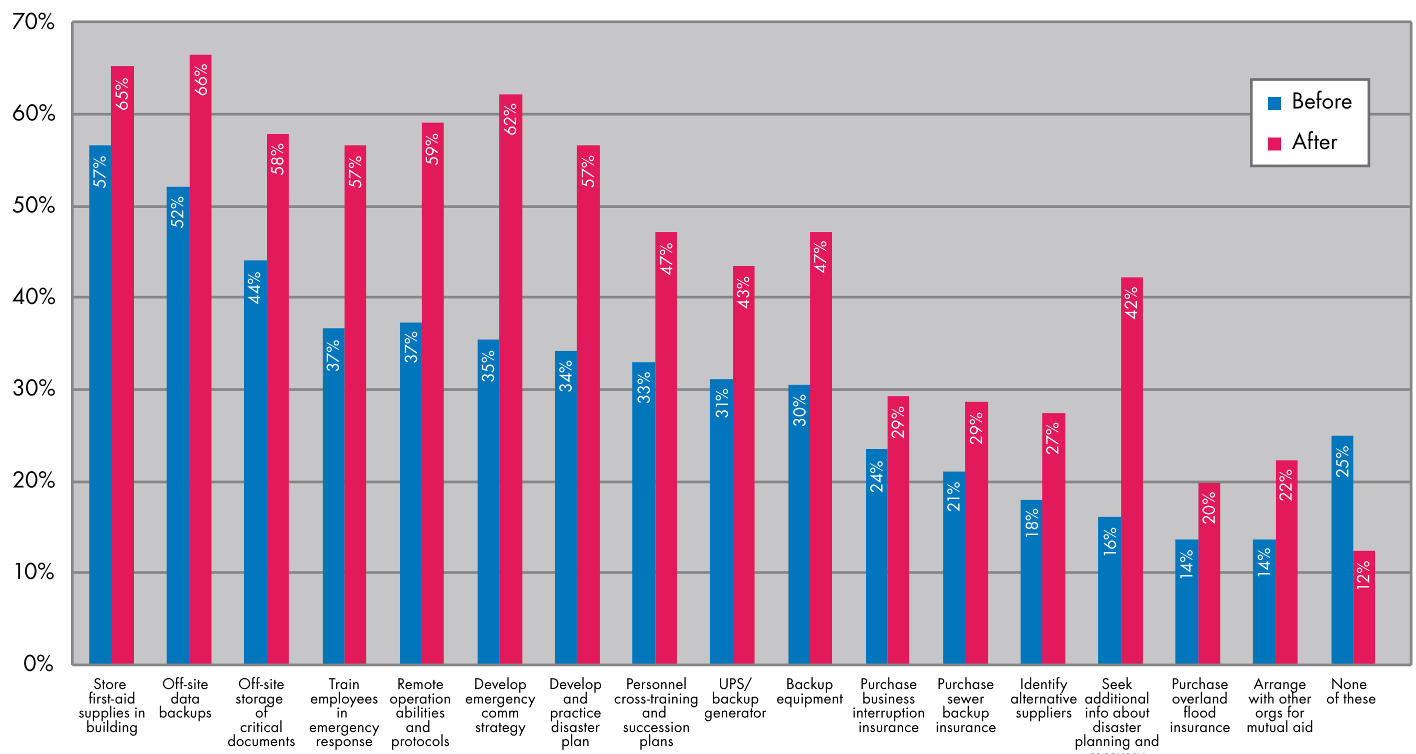


Figure 4: Impacted by 2013 flood

4. Communication gaps

When asked about support in relation to the 2013 flood, just under one-third of those impacted said they received communications from the Chamber. However, roughly one-third also said they were not recipients of support or communications from any of the listed programs or groups.

Two initial insights can be drawn from the data.

First, it highlights the fact that non-profits and other community organizations such as the Chamber play an important role in the city's overall resiliency. It appears that the Chamber has a very effective disaster communications strategy in place, one which seems to reach a broad intersection of Calgary's business community. More non-members actually report having received Chamber communications than members, so it would appear that this strategy is reaching past the organization's traditional circles and relative size.

Second, CEMA has been the most effective group in communicating information and providing updates.

Forty-one per cent of those respondents impacted by the flood received some type of updates from CEMA, and 14 per cent acknowledged receiving direct support. Yet, 32 per cent of respondents neither received communications from CEMA, the government or the Chamber nor received support—whether from CEMA, through the DRP or other local government programs.

While the low participation in the DRP, and support from other government programs or CEMA, may be a reflection of the nature of the business community's needs, communication during and after a disaster should be more broadly accessed. This is something independent of the level of impact from a disaster and should be a central component of any resiliency strategy. Federal and provincial government agencies, CEMA and the Chamber have been successful in their efforts but more remains to be done.

Percentage of Flood Impacted Businesses Who Received Aid

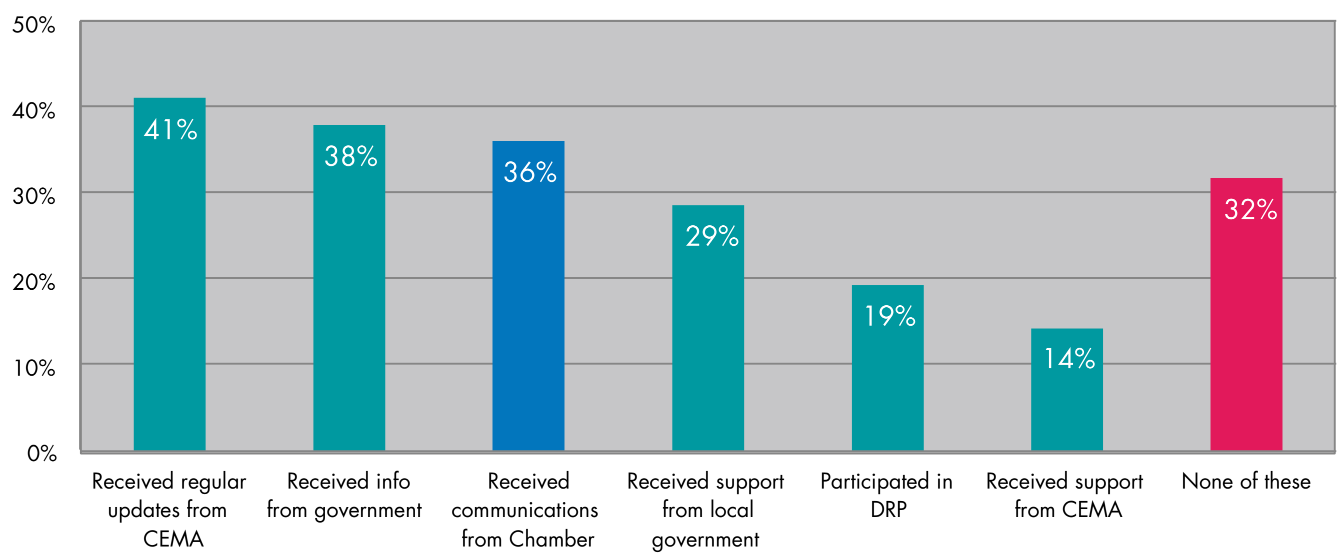


Figure 5: Impacted by 2013 flood

5. Overall confidence in government, with some exceptions

When asked about the government, 73 per cent of businesses impacted by the 2013 flood expressed confidence in the government's ability to handle another disaster of the same magnitude. This represents a significant majority. Such a strong number suggests overall satisfaction in the way in which governments (local, provincial and federal) dealt with the disaster.

However, it appears these numbers may be skewed toward large businesses. Those businesses with over 100 employees expressed above average confidence. General confidence decreases as the businesses get smaller (refer to graph). Of the small businesses, 43 per cent did not have confidence in the government in the event of a future disaster. One possible reason for the discrepancy between the opinions of the small and large businesses is that government services and programs may not be meeting their needs equally. It appears that those businesses with the largest pool of resources feel significantly more confident in their government.

This trend of government support favouring larger businesses over smaller ones also appears in the survey through questions about the DRP. While aggregate approval of the DRP is lower than that of government as a whole, over 60 per cent of those impacted by the 2013 flood feel the DRP provided support that helped their business recover, was easy to work with, and was reasonably timely. These are all very positive numbers for such a large program. However, a discrepancy again exists between the attitudes of large and small businesses.

There may be a number of contributing factors to this phenomenon. The first is the level of administrative burden associated with the DRP, pointing to an issue of overall accessibility and compliance costs. It may also result from the mix of government support offered; the program itself may serve one group better than another. It may also result simply from the level of need. However, the data is inconclusive in this regard, and further research must be conducted on specific experiences with the DRP to tease out the underlying mechanics behind this trend.

It does appear that those impacted by the flood are slightly more confident in a future government response than those not impacted. While only a slightly higher (five per cent) favourability rating, it suggests that businesses were not soured by their interactions with the government. Those businesses that were under the most pressure after the flood actually came out of the experience feeling more confident in the government's capabilities. This is a strong endorsement of the business community's perception of the government's disaster response and recovery policies.

Confidence in Government Response

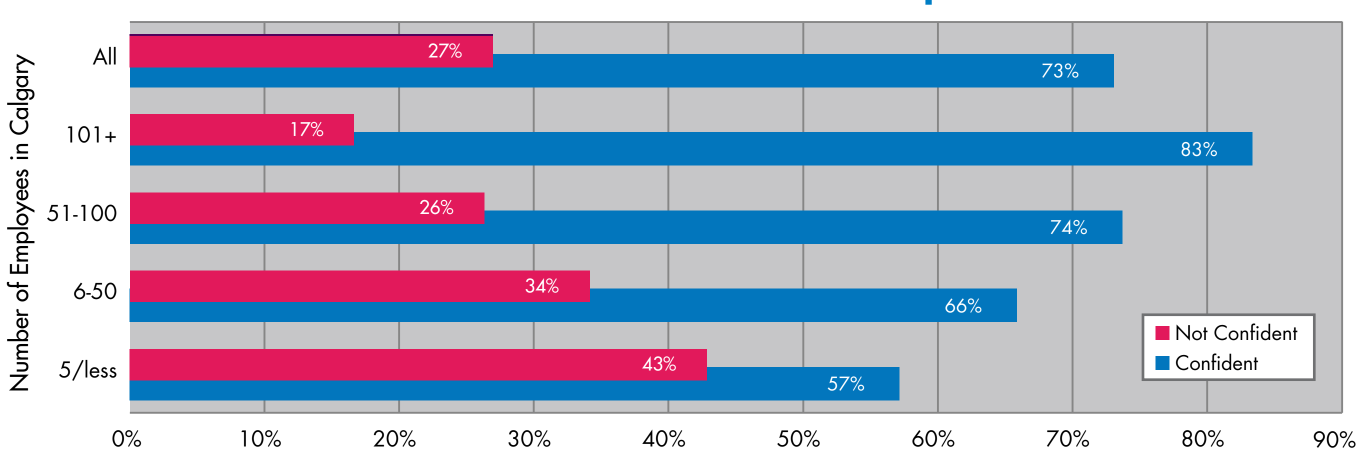


Figure 6: Impacted by 2013 flood

6. Future mitigation and preparedness efforts have popular support

One salient point for policy makers is that a good portion of businesses support disaster mitigation and preparedness activities. All respondents were asked, in the case of a future event such as the 2013 flood, which of the following areas should the government focus their efforts to best support business: flood/disaster mitigation, disaster preparedness, recovery, helping plan, or crisis/disaster management.

One-third said that disaster mitigation would best support their business, with another 22 per cent favouring disaster preparedness. So it would appear that in the business community as a whole, there is a feeling that mitigation and preparedness efforts on the part of the government offer them the most support.

There is, however, a split among those impacted and not impacted by business interruptions. Not surprisingly, those unaffected by any interruption in the last two years were less likely to believe that these efforts would be the most beneficial focus for the government. They appear to be more interested in recovery efforts and help in disaster planning. Even for those not interrupted and those interrupted but not impacted by the flood, the approval of these activities still sits around 50 per cent. As mentioned in an earlier section, those who experienced interruptions outnumber those who have not nearly two to one. Thus, the aggregation of respondents points to an overall favourability of the idea that mitigation and preparedness activities by the government would help their business the most.

It also would appear that once an interruption has occurred, a business is more likely to favour such programs. This could be rooted in the fact that once businesses have experienced interruptions such as flooding, they witness the effectiveness of these efforts first-hand.

Regardless, the data shows that the government efforts to support businesses in the case of a future event should be focused on mitigation and preparedness. There is popular support for these efforts, and considering large cleanup and recovery costs, it may be the most cost- effective approach as well.

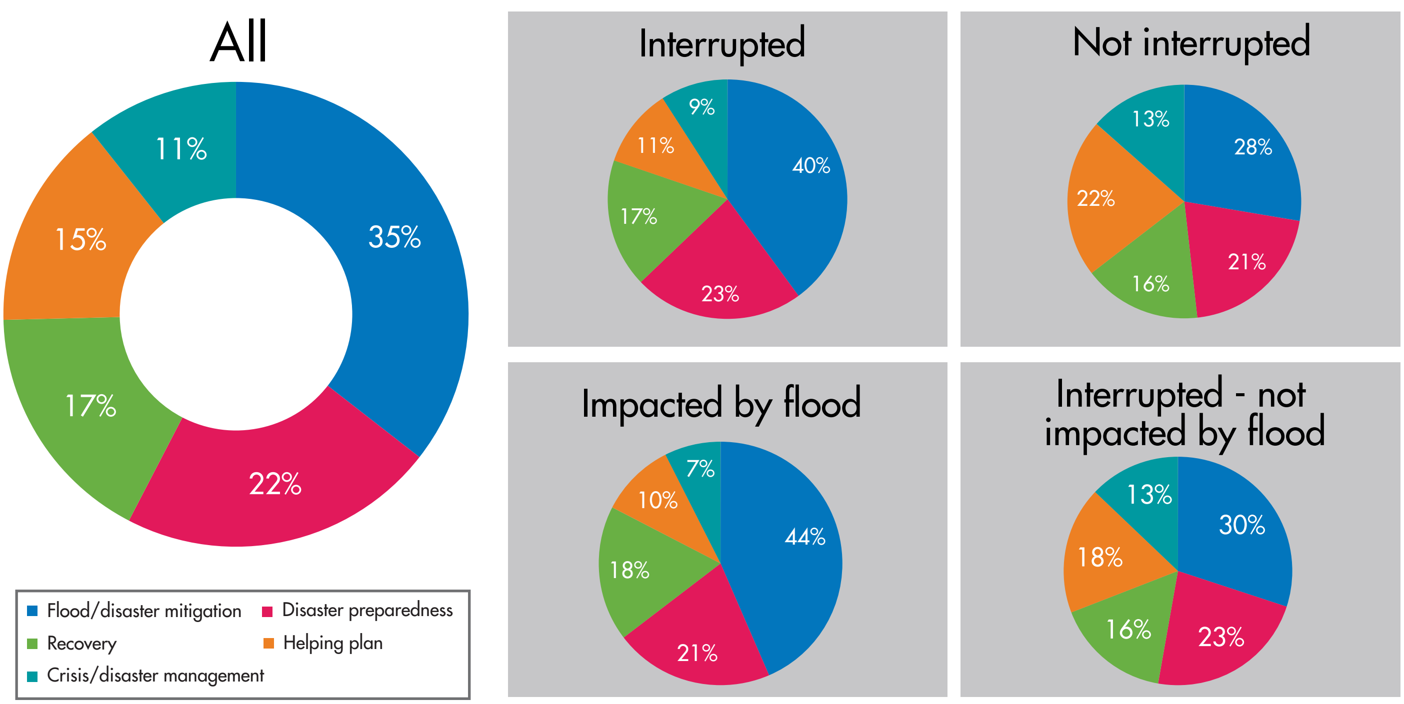


Figure 7

NEXT STEPS

Since the 2013 flood, the Chamber has worked hard to help businesses better prepare for future disasters. This includes efforts in conjunction with the CEMA to develop a handbook that outlines how businesses can prepare themselves for a natural disaster. As our survey shows, Calgary has taken major steps to increase its overall disaster preparedness, and businesses have a favourable view of the government's efforts. Yet, there is always room to improve because constant assessment and improvement are cornerstones of a resilient community.

Recommendations

One-third of flood-impacted businesses reported not having received any communications, whether from the Chamber, CEMA or other levels of government. This is cause for concern because government should reach out to and engage a broad section of citizens and businesses both during and after a disaster, regardless of how much need or damage the they experience. The information gleaned from the survey should be used as a baseline to compare communication strategies with those used in the blackout and "tree event," to evaluate their effectiveness and the value of policy changes.

While there has been a significant increase in resiliency activities, 68 per cent of impacted businesses did not seek out additional information on disaster planning and recovery. This information gap may lead to wasteful practices and leave businesses more vulnerable than they appear. Although it has been more than a year since the flood, the campaigns to provide businesses with the relevant information should continue to ensure that best practices are being implemented.

Generally, it seems that government assistance for businesses impacted by the flood was well received. However, there seems to be a disparity between the experiences of large and small businesses in the community. There must be a deeper assessment of the programs and their administrative burden to ensure that the needs of the entire community are met in a relevant and accessible manner.

In the event of another major event such as a flood, a DRP type program may once again be needed to cover uninsured damage. Research must be conducted on private mechanisms for protecting businesses against these large-scale interruptions. An assessment of current insurance barriers would be a significant first step.

Governments, both local and provincial, should further their efforts to build mitigation capacity and preparedness within the community. There is broad support among businesses for these efforts, and it would appear that this is the area that businesses feel the government can best help them in the event of another disaster.

Your Calgary Chamber

Following the flood, the Chamber took an active role in recovery and resiliency efforts. By analyzing the extent of the damage, mobilizing resources and helping to revitalize both customers and businesses, we helped ensure that Calgary businesses were able to recover in both the short and long term.

A business in Calgary affected by the flood was more than 50 times less likely to close than a similarly affected business in other North American jurisdictions—an accomplishment that Calgary's head of emergency management Chief Bruce Burrell recently credited in large part to the Chamber.

The centrepiece of our efforts was the Calgary Business Recovery Task Force—a partnership with 12 other community organizations, working to get businesses cleaned up and repaired as quickly as possible. The task force also worked to ensure business and investment came back to the flood-affected areas through the comprehensive local, national and international "YYC is Open" marketing campaign.

On July 31 2013, the Calgary Chamber hosted an all-day regional business recovery expo. This "one-stop shop" event consisted of an expo to help connect businesses in need and panel discussions that provided the necessary tools and information for flood-affected business owners to get back to pre-flood level business. The event drew 250 attendees and included 30 information booths set up to answer flood-related questions to help business owners successfully navigate the path to recovery.

Over a year later, most of the city has returned to normal operations, but there are many businesses that will remain closed or have just recently opened their doors to the public. Small businesses continue to need support. We continued our flood resiliency work in April 2014 by hosting a panel workshop focused on small business marketing and business interruption.

Even with the unexpected weather and power outages of the past few months, the Chamber has been unrelenting in its efforts to look out for the interests of the business community. We continue our work to ensure that the business community has a strong voice now and in the future.

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This report was developed with support from the

Alberta Government

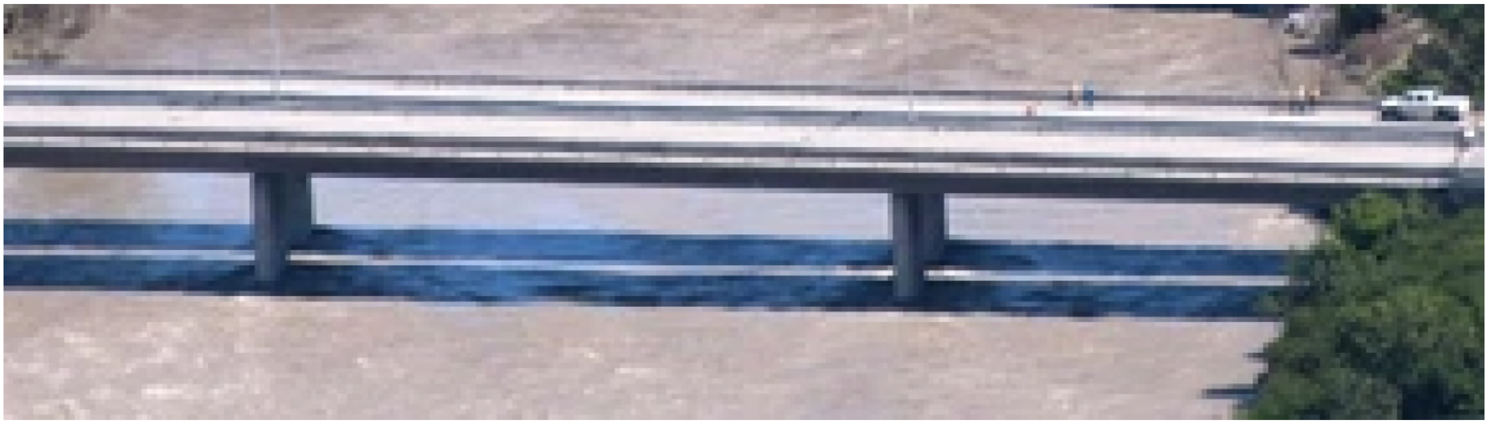
D-6

Local News

'Unprecedented' flood to blame for Bonnybrook Bridge failure, train derailment in June 2013: report

After blasting the federal government and Canadian Pacific in a train derailment and partial bridge collapse in Calgary last year, Mayor Naheed Nenshi is welcoming a report released Wednesday that blamed unprecedented flood water for the incident.

Bill Graveland, Clara Ho • The Canadian Press
Dec 18, 2014 • December 18, 2014 • 4 minute read



Crews work at the scene of a rail bridge collapse and railcars derailment over the Bow River, southeast of downtown Calgary, Alberta on Thursday, June 27, 2013. PHOTO BY LARRY MACDOUGAL /THE CANADIAN PRESS

After blasting the federal government and Canadian Pacific in a train derailment and partial bridge collapse in Calgary last year, Mayor Naheed Nenshi is welcoming a report released Wednesday that blamed unprecedented flood water for the incident.

An investigation and report by the Transportation Safety Board of Canada indicated the Bonnybrook bridge over the swollen Bow River gave way beneath a Canadian Pacific Railway train on June 27 as the city was trying to recover from high water that had washed over many neighbourhoods just days before.

Six tank cars, of which four were carrying highly explosive, toxic liquids, teetered on the failing bridge. They were unloaded and removed over two days and never went into the river.

“Unprecedented flooding of the Bow River was a major factor in this bridge failure. The bridge handled several major floods for over a century, but the river was not to be denied last June,” said George Fowler, a civil engineer who conducted the investigation.

“Intense, unprecedented flood water flow had attacked the shale, sandstone, bedrock and clay pier foundation — eroding and undermining it.”

Fowler said the bridge, which was built in 1897 and expanded in 1912, had been properly inspected by Canadian Pacific Railway.

During the incident, Nenshi had strong words for the rail giant and for the federal government. He questioned whether layoffs decreasing the number of inspectors with CP Rail had played a role.

He had also called for improved regulations on trains through the city, and noted that municipalities are powerless to regulate railways, as they fall under federal jurisdiction, yet “it’s my guys down there risking their lives to fix it.”

But in an e-mailed statement issued Wednesday after the report was released, Nenshi said he was pleased to now have “clear data” about what led to the bridge failure and train derailment. He also thanked the Transportation Safety Board of Canada for its “careful analysis of the bridge, inspection procedures, and the unified response from the City of Calgary Fire Department and CP.”

"Despite the frustration and danger the situation represented for our community, I am pleased to know that the TSB is confident that the work of our fire department was top-notch during the emergency," Nenshi added.

"I am also pleased to know that — while CP's inspection practices prior to the incident exceeded Transport Canada requirements — CP has revised its bridge inspection practices and inspector training program, and that it is investing in research to better inspect aging rail bridges."

Ward 9 Coun. Gian-Carlo Carra, who represents that area of the city, had similar comments about the report.

"I'm please to hear that the CPR was exceeding standards with regards to inspections and that they've subsequently raised the bar even further," Carra said in a statement. "I'm deeply gratified with the TSB's confirmation that Calgary's emergency response was second to none."

Fowler said inspections conducted on the bridge "exceeded regulatory requirements during the flood."

"Visual observations of the rail and track alignment, and service, would normally detect deviations. However, in this case, such inspections did not provide warnings of the sudden bridge failure," said Fowler.

"This bridge has been around since 1897 and in that time it survived several significant flooding events," he added. "There was no reason to believe this event would be any different."

Fowler said the true extent of the damage to the foundation wasn't known until repairs were underway two months later.

Railways fall within federal jurisdiction and are responsible for their own inspections. Fowler said CP has revised its bridge inspection practice and its inspector training program and is investing in research into early detection of erosion at railway bridges.

CP dismantled the Bonnybrook Bridge in autumn of 2013 and work on a new span was completed in April of this year. The damaged bridge pier has been replaced and reinforced with a new foundation.

In addition, Bonnybrook is one of five bridges that has been outfitted with a new SENSR automated technology, which provides real-time data to CP Rail's control centre on load, vibration and impact at any given time, said spokesman Martin Cej.

"We've been using that for the past 12 months or so. The rollout has been so successful, we will be rolling out to eight more bridges," Cej added.

An official with CP Rail welcomed the final report. President and chief operating officer Keith Creel said he agrees with the safety board that the City of Calgary's command structure worked well to get the site secure and to help remove the derailed cars.

"Our relationship with the first responders of the City of Calgary allowed us to co-ordinate efforts to work quickly and to safely remove the cars from the bridge," said Creel.

"CP is grateful to the Calgary Fire Department and other first responders and thanks them for their skill, effort and commitment to public safety."

TRENDING

1 COVID-19 Update: Canada to receive 640,000 doses this week | Applications to medical schools surge | Alberta's R-value rises

2 Fireball lights up Alberta's northern sky on Monday morning

3 'Playing with fire': Alberta's R-value creeps back above 1, signalling higher infection rate

4 From vaccines to pipelines to clean water on reserves, why Canada can't seem to get anything done

5 Though hospitalizations are falling, second stage of Alberta reopening not guaranteed: Kenney

with Video

D-7

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MENU

Blog

REMEMBERING THE NUMBERS

May 9, 2016 by CRC Action Group in News

Fatalities in Alberta

- 3 people drowned near High River and 1 person killed in a related accident
- 1 person drowned in Mission, Calgary

Alberta: compiled by the Canadian Press (2014)

- **$6 billion**: The Alberta Government's estimated cost for the flood. (Former Finance Minister Doug Horner)
- **30**: The number of communities the Government says were affected by flooding. (Source: The Alberta Government)
- **100,000**: The estimated number of people affected by flooding. (Source: The Alberta Government)

- **650,000**: The estimated number of work hours it took to get Calgary's damaged Saddledome ready for a concert event. (Source: Robert Blanchard, director of building operations for the Saddledome)

Calgary: compiled by CBC Calgary (2013)

- Number of City communities fully or partially evacuated: **32**
- Number of people forced out of their homes: **80,000**
- Number of meals provided at evacuation centres: **68,000**
- Number of city staff who assisted with emergency response and initial recovery: **7,000**
- Number of water rescues performed by Calgary Fire Department in first 24 hours: **400+**
  - The City expects its flood repair costs to top **$500 million** after widespread damages
  - Temporary berms constructed to protect infrastructure/communities: **16**
  - Number of ENMAX customers affected by flood (metered): **39,837**
  - LRT stations affected by flood: **5**
  - All LRT service restored: **13 days** after flood
  - Waste to City landfills in the weeks after flood: **98,000+ tonnes** (three years of landfill space)
- Floodwaters forced the closure of numerous roads, bridges and pathways.
  - Roadways closed by flood: **800 kilometres**
  - Bridges closed by flood: **20**
  - Pathways closed by flood: **93 kilometres**
  - Parks closed by flood: **30**
- Thousands of Calgarians worked overtime in the flood aftermath
  - Number of Edmonton firefighters who assisted the Calgary Fire Department: **160**
  - 311 phone calls in two weeks after flooding started: **100,000**
  - Visits to city website during flood period: **1 million hits**
  - Media releases issued during flood period: **140**
  - State of local emergency: **14 days**

Calgary: compiled by Calgary Chamber of Commerce (Flood Resiliency Report, 2014)

- Estimated lost work hours: **1 million**
- Estimated reduction in Canadian GDP: **$2 billion**
- **60%** of all businesses impacted by flood
- Large business in Calgary (>100 employees) were 2x as likely to have been impacted than smallest businesses (<5 employees)
- **60%** of all large businesses in Calgary were impacted
- *"It does seem that as a business becomes larger, the more vulnerable it is to these business interruptions."*
- **79%** of impacted businesses closed their offices for a period
- *"One salient point for policy makers is that a good portion of businesses support disaster mitigation and preparedness"*

Calgary: IBI-Golder Provincial Flood Damage Assessment Study, 2015

- Projected number of buildings impacted by a 1:100 year flood + 75m ground water zone (Bow and Elbow):
  - **5620** single-family residential dwellings
  - **728** semi-detached, triplex and townhouse dwellings
  - **275** multi-family apartment buildings
  - **564** non-residential (commercial, industrial and institutional buildings)

- Estimated "direct and indirect" damages (excludes "social" damages) from a 1:100 year flood on Elbow River only:
  - Residential **$344 million**
  - Commercial **$43 million**
  - Infrastructure **$157 million**
  - Stampede **$196 million**
  - **TOTAL $741 million**

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- Help us collect more letters for the NRCB – share our survey and social posts! January 27, 2021
- Draft Environmental Assessment Report for SR1 issued — a key milestone for the federal regulatory review January 22, 2021
- Friday (Jan 15) last day for feedback on flood inundation maps January 14, 2021
- New flood inundation maps released & Albertans invited to provide feedback January 4, 2021
- Summary of 2020 AGM December 22, 2020

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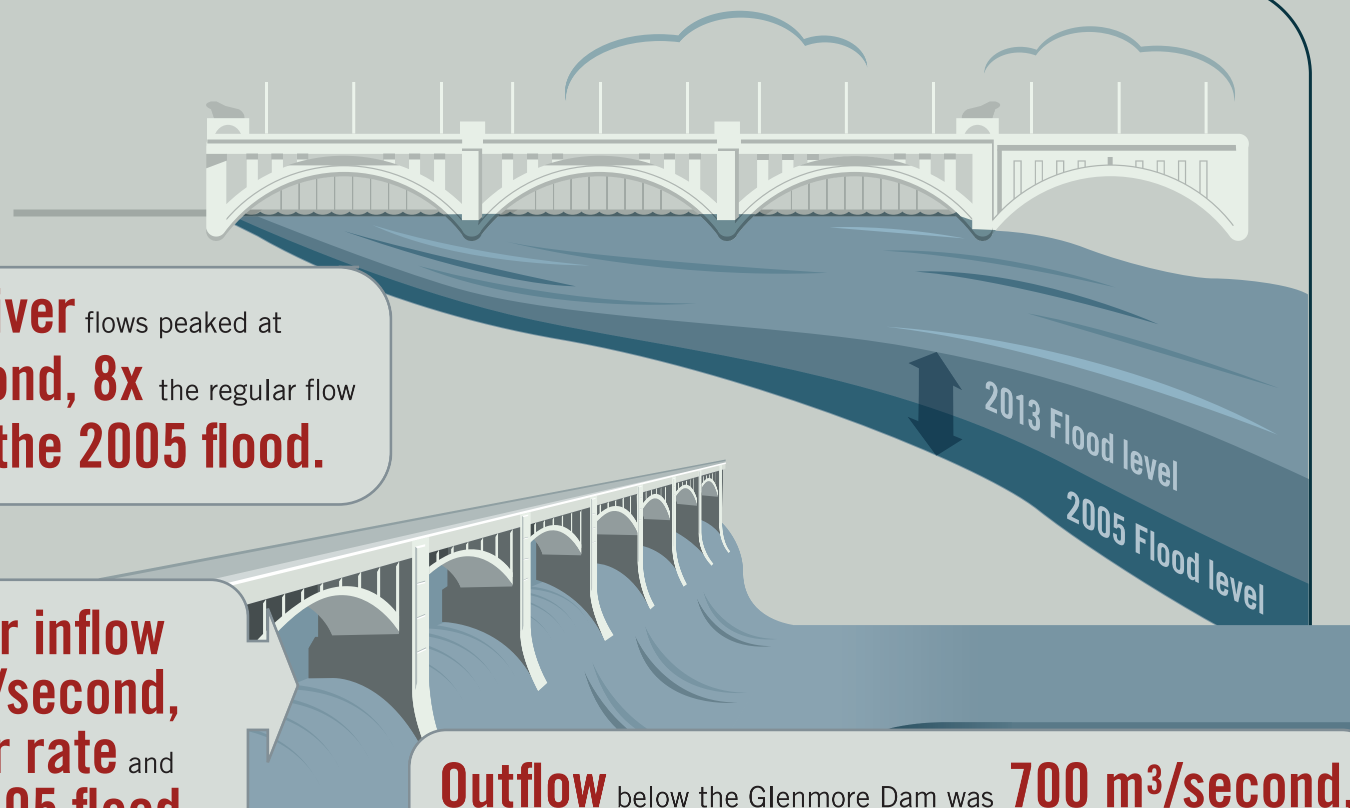
#YYCFLOOD JUNE 2013

1 THE FLOOD



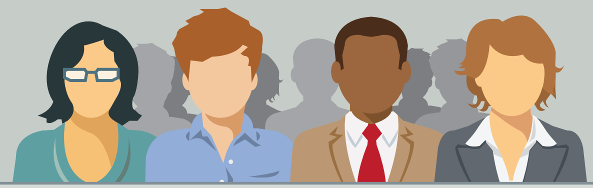
The Bow river flows peaked at **2,400 m^3/second, 8x** the regular flow and more than **3x the 2005 flood.**

The Elbow river inflow peaked at **1,240 m^3/second, 12x the regular rate** and more than **3x the 2005 flood.**

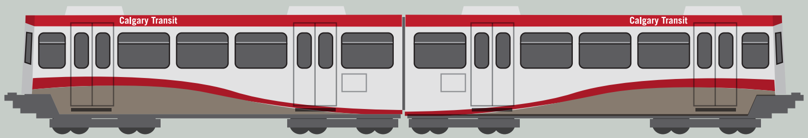
Outflow below the Glenmore Dam was **700 m^3/second,** about **7x normal** and about **2.5x the 2005 flood.**

2 THE FALLOUT

Evacuations in **26 communities affected 110,000 Calgarians.**

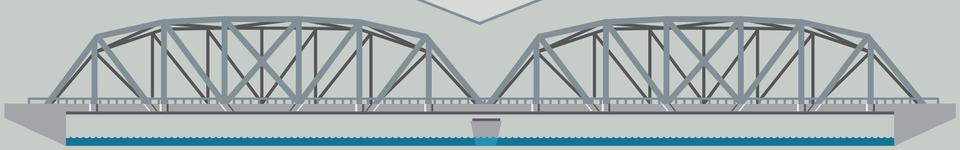


More than **1,600 people** registered at community support centres on the first day.

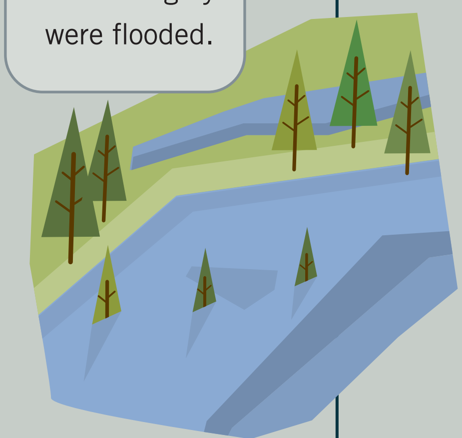


16 LRT stations were closed.

More than 20 bridges were closed.



30 parks across Calgary were flooded.



More than 50 bus routes were cancelled or detoured.

34,000 locations were without power.

3

THE RESPONSE

More than 100,000
calls received at 311.

More than 1.8 million web visits.

26 dogs
and **39 cats**
were returned to
their owners.

1,000 lane kilometres
of road swept downtown in 24 hours.

4 customer service centres established
which served **more than 6,855 customers**
for permits, property tax and more.

4

THE RECOVERY

100 metres of track were replaced in one week to re-open the south line of the LRT.

In 1.5 days, 0.3 lane kilometres of MacLeod Trail were **rebuilt.**

CONSTRUCTION AHEAD

80% of road network in affected areas **restored** in the first seven days.

More than 70% of parks have been partially or fully re-opened

More than 11,000 flood assessments completed.

INSPECTED

95% of requests for residential pumping completed in the first seven days.

Working with citizens and partners to rebuild a great city

#YYCONWARD

Notifications

COVID-19: State of public health emergency. Mandatory measures remain in effect provincewide.

Close

Southern Alberta FISHES Program

Southern Alberta FISHES Program – Overview

The Southern Alberta Fisheries Habitat Enhancement and Sustainability (FISHES) program focuses on fish habitat restoration.

On this page:

- About the program
- Related legislation
- Contact

About the program

The Southern Alberta Fisheries Habitat Enhancement and Sustainability (FISHES) Program is a 3-year $10 million program developed to mitigate the risks to the aquatic environment arising from the magnitude and extent of instream activities, authorized by the department of Environment and Parks (AEP), under the Expedited Authorization Process for Flood Recovery (EAPFR).

Program efforts will be directed at identifying areas of highest disturbance that are critical to maintaining aquatic productivity and fish populations at a watershed level. Habitat restoration projects which effectively mitigate flood-related impacts will be designed and constructed to:

- enhance affected habitat, thereby improving resiliency to subsequent high flow events over the longer term
- speed the restoration of degraded habitat following the 2013 and 2014 floods

The program is committed to effectively restoring and enhancing fish habitat by identifying the key factors which are limiting aquatic productivity in flood affected watercourses, within the South Saskatchewan River Basin.

Legislation

Existing FISHES Program projects are subject to the Expedited Authorization Process for Flood Recovery. For more information, see: Expedited Authorizations Process for Flood Recovery (EAPFR).

Program Information and Updates

To learn more about the FISHES Program, see: How the FISHES Program Works.

For the latest news and reports on the FISHES program and its Tier 1 and Tier 2 projects, see: FISHES Project Updates.

Related legislation

Alberta Queen's Printer

- *Public Lands Act*
- *Water Act*

Government of Canada Justice Laws Website

- *Fisheries Act*

Contact

Connect with the FISHES program:
Email: aep.fishes@gov.ab.ca

Klohn Crippen Berger

City of Calgary

Calgary Rivers Morphology Study

Summary Report

A03311B01

December 2017

Klohn Crippen Berger

December 22, 2017

City of Calgary – Water Resources
Mail code: #428
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Dear Mr. Slaney:

Calgary Rivers Morphology and Fish Habitat Study
Morphology Summary Report

We are pleased to submit the attached morphology summary report for the Calgary Rivers Morphology and Fish Habitat Study. Thank you for the opportunity to work with you on this interesting project. We trust that the results will provide useful guidance for management of Calgary's streams.

This report is an instrument of service of Klohn Crippen Berger Ltd. The report has been prepared for the exclusive use of the City of Calgary (Client) for the specific application to the Calgary Rivers Morphology and Fish Habitat Study. The report's contents may not be relied upon by any other party without the express written permission of Klohn Crippen Berger. In this report, Klohn Crippen Berger has endeavoured to comply with generally-accepted professional practice common to the local area. Klohn Crippen Berger makes no warranty, express or implied.

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2017-12-22

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City of Calgary

Calgary Rivers Morphology Study

Summary Report

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1 INTRODUCTION

1.1 Study Aim

Calgary is home to rivers, creeks, and ephemeral and intermittent watercourses which constitute valuable assets to the community and the environment. These streams serve multiple functions, including fish and wildlife habitat, municipal water supply, recreational opportunities, aesthetic value, flood conveyance, and stormwater and wastewater conveyance routes. However, the streams also create hazards such as flooding, erosion, and slope instability.

Management of the streams, considering their varied functions and risks, is complex. Wise management of these important assets requires a good understanding of each stream and the important factors affecting it, including hydrology, hydraulics, sediment, and society. Based on that understanding, the objective of good management is to take full advantage of the benefits of the streams while reducing the associated risks.

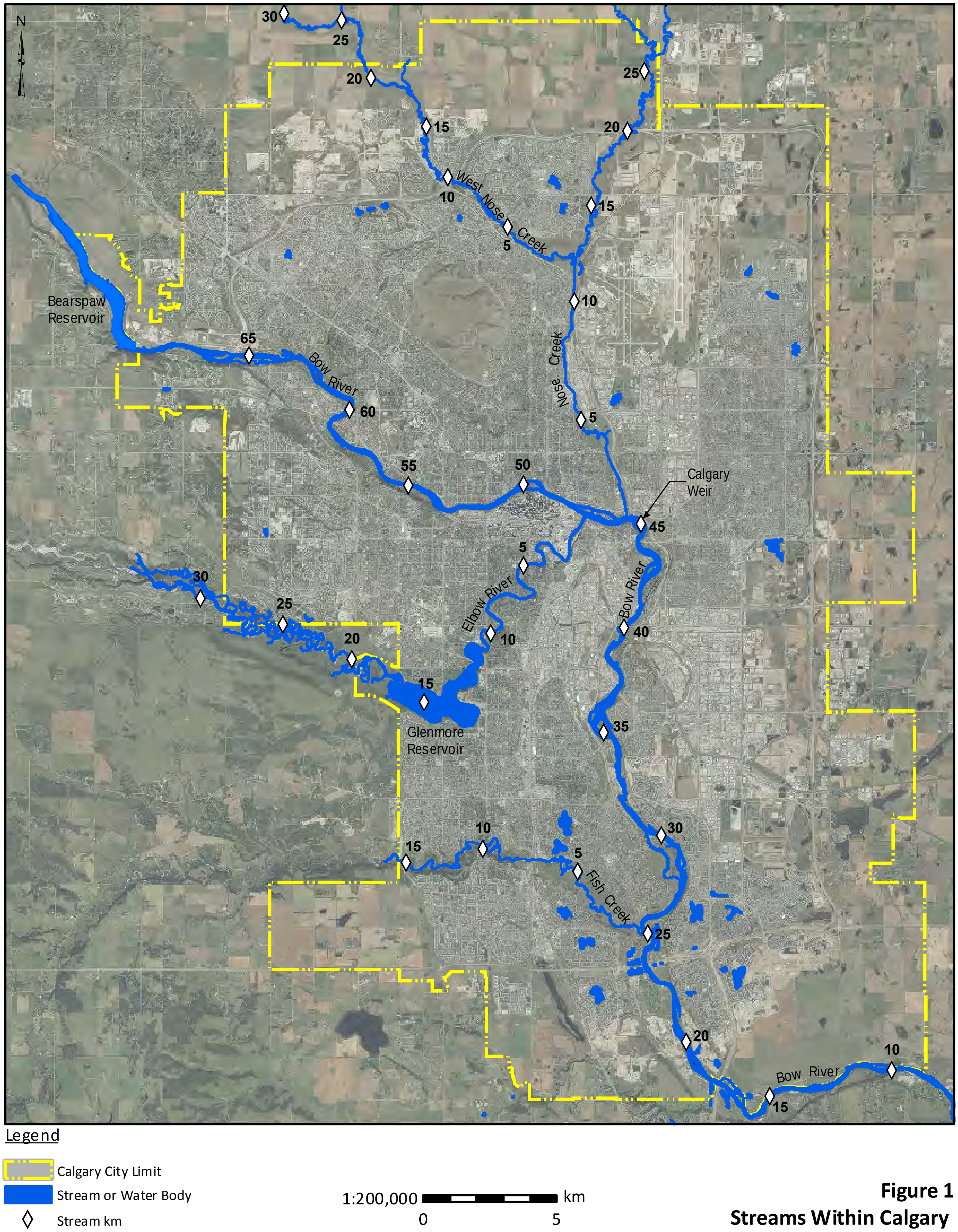
Bow River near downtown Calgary

One of the less studied and less understood aspects of stream management is morphology: the study of stream forms, and the processes of sediment erosion, transport and deposition responsible for channel development, evolution and change. The morphology of a stream is related to the material through which the stream flows, the water and sediment conveyed in the stream, the adjacent vegetation, ice effects, and human interventions such as the construction of dams, bridges and bank protection works.

To improve its understanding of the morphology of Calgary's streams, the City of Calgary commissioned the Calgary Rivers Morphology and Fish Habitat study. The project goal is to obtain an understanding of how the morphologies of the Bow River, Elbow River, Fish Creek, Nose Creek and West Nose Creek (Figure 1) were affected by the 2013 flood, how they have recovered since the flood, and how they are likely to evolve in the future, and to use that understanding to:

- Identify future erosion risks to property, infrastructure and flood defense assets;
- Identify locations where sediment accumulation may create channel obstructions that increase the probability of flooding in vulnerable areas; and
- Optimize future fish habitat compensation investments.

The study is intended to inform the City's ice flood abatement program, the Riparian Strategy, Parks Master Plan, Pathways Master Plan, future bridge, riverbank stabilization, and fish habitat enhancement project designs, and management of stormwater inflows to ephemeral streams.



File: Z:\A\CGY\Alberta\A03311B01 CoC Calgary Morphology & Fish\400 Drawings\GIS\MXD\Report\Fig 1_Streams within Calgary - for summary report.mxd

Figure 1
Streams Within Calgary

1.2 Study Basis and Methods

A major focus of the study is the development of an improved understanding of the morphological processes and history of Calgary's streams. The main report includes an extensive introduction to the current state of the science of gravel-bed river morphology in general, as well as a review of the factors affecting the morphology in Calgary's streams in particular. Those factors include the geological history, hydrology, vegetation, ice effects, and human actions that have culminated in the current forms of the streams in Calgary. The various factors are assessed based on a review of historical airphotos from 1924 to 2014, available literature and data, and field investigations. Maps showing the history and current condition of each stream are provided in Appendix I. (Appendices mentioned in this summary report are attached to the main morphology report.)

Based on the understanding of the history and current condition of each stream, future risks are identified and assessed. The risk assessment is structured around three natural morphological processes that have the potential to damage existing infrastructure. The processes are:

- Bank erosion;
- Avulsion (i.e. abrupt relocation of a stream channel); and
- Sediment deposition.

Bank erosion and avulsion may threaten existing infrastructure directly. Sediment deposition, particularly when followed by natural vegetation colonization, may present a threat by reducing the stream's conveyance capacity, which results in increased frequency of flooding upstream and increased potential for erosion of adjacent banks.

The threats are evaluated using a series of historical airphotos from 1924 to 2014 (provided in Appendix II). Maps indicating the locations, likelihood and severity of each of these threats along the creeks and rivers in Calgary are also provided in Appendix I.

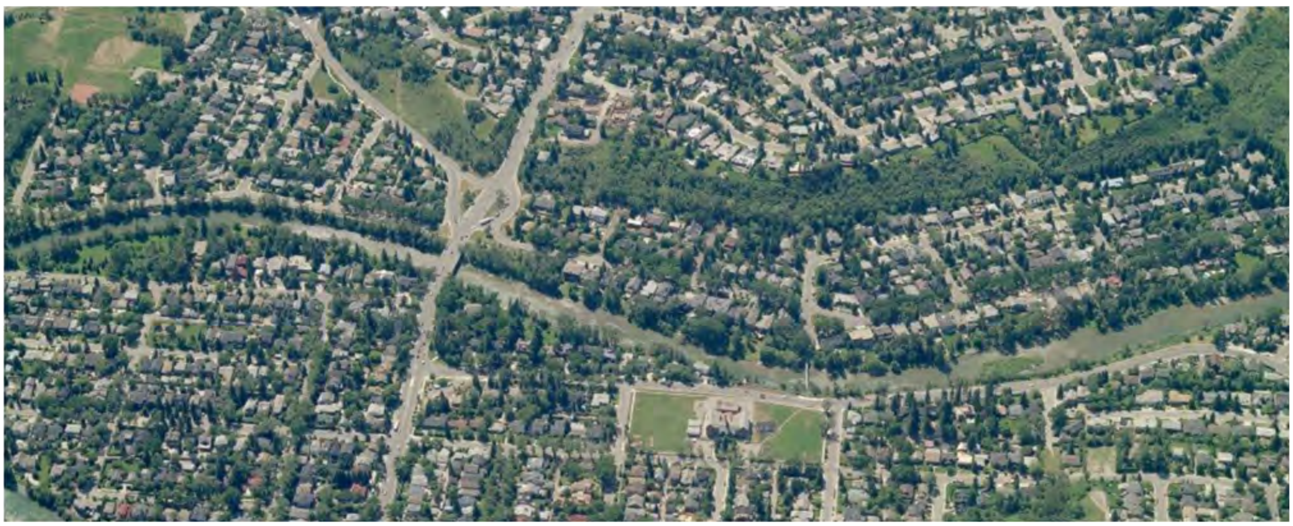
The City and the project team identified a number of potential interventions that could reduce or mitigate the identified risks. Intervention projects are evaluated and prioritized considering economic,

Avulsion on the Elbow River upstream of Glenmore Dam

environmental, and social factors in a Triple Bottom Line (TBL) analysis, and conceptual designs for two specific example projects are advanced.

Findings and recommendations are summarized below for each of the study streams: the Bow River, Elbow River, Fish Creek, Nose Creek, and West Nose Creek, as well as ephemeral and intermittent streams.

This summary report distills the results of a complex and voluminous study to a relatively few pages. Explanations, details, figures, sources, and a glossary of technical terms are provided in the main report.



Urban development along the Elbow River

2 VISION AND RECOMMENDATIONS FOR CALGARY'S STREAMS

2.1 Vision

Erosion, avulsion, and sedimentation are natural morphological processes that change the course of a stream over time. Meander beds develop, elongate, migrate downstream, and are cut off. In an urban area, these processes have the potential to cause significant damage to infrastructure developed along the stream. Historical urban development has frequently ignored the potential for channel movement, constructing infrastructure on the entire floodplain and down to the river bank as it existed at the time of the development. When the erosion threat is recognized, usually after damage has occurred, a typical response is to "restore" the damaged streambank and then "protect" it in an attempt to prevent future damage. The river engineering works are costly, and often have unintended consequences that exacerbate other erosion problems downstream.

The cost of erosion damage and erosion protection works can be substantial. In Calgary, the City's annual cost for riparian and bank protection projects is approximately $500,000[1]. During the 2013 flood alone, the cost of erosion damage, including repairs to damaged infrastructure, emergency bank protection works, and fish habitat projects required to offset the habitat impacts of the emergency bank protection works, was approximately $100 million[(2)].

Bank erosion on the Bow River

In recent times, there has been increasing recognition of the value of leaving room for the river, usually for ecological reasons. That recognition is reflected in the City's adoption of increased setback distances in its Environmental Reserve Setback Guidelines and land use bylaw. Imposing a development setback has benefits for water quality, fish habitat, riparian habitat, and public access. However, it can also have important benefits in terms of reducing the long-term cost of erosion damage and erosion protection works, and these benefits are often not well-recognized.

It is clearly impractical to restore the forms and dynamics of the stream channels to their natural conditions throughout Calgary, because of the high value of adjacent properties and infrastructure. However, some reaches remain relatively natural, and at other locations the adjacent infrastructure is relatively inexpensive (e.g. pathways). Leaving room for the stream, or allowing it to reclaim a portion of the floodplain, is less expensive than attempting to control the stream channel evolution in the short term, and generates financial, ecological, and social benefits in the long term.

With these considerations in mind, the vision of this study is that Calgary's streams will be managed to maintain natural morphological processes where they have not already been disrupted, and to allow the streams to restore those processes wherever doing so can be done without serious financial, societal, or environmental impacts. Where river engineering interventions are required in order to protect valuable infrastructure or to reduce the potential for flood damage, those works will be designed to minimize disruptions to the natural morphology. In the long term, the streams will become more natural, reducing costs of flooding and erosion damage and erosion protection works, and providing better water quality, improved aquatic and riparian habitat, and more opportunities for public interaction with the river environment.

Gravel deposition at the Hillhurst-Louise Bridge

The City has already taken some measures in this direction, but more can be done. This study identifies a number of specific actions that could be taken immediately to reduce the risks of flooding and erosion damage in Calgary. The study seeks to identify which river interventions are essential to protecting key infrastructure, and which interventions, though seemingly natural responses to apparent risks, should be avoided.

Implementing the actions necessary to achieve long-term resilience will take some time and, while a start can and should be made immediately, some steps may not be feasible until existing pieces of infrastructure (such as some bridges or bank revetments) reach the end of their useful lives.

2.2 Recommendations

The following subsections provide recommendations for valley development and river engineering interventions in line with the vision described above, that are applicable to all of the streams in Calgary. Recommendations specific to each stream are provided in subsequent sections of this report.

2.2.1 Consider the Morphological Impacts of Development

For any river engineering project such as a bridge, bank protection, outfall, or fish habitat enhancement project, the potential impact of the project on channel morphology should be considered carefully. Such consideration is already part of the project approval process under Alberta's *Water Act*, but historically many projects may not have received sufficiently thorough attention to morphological aspects. Many historical projects have had significant negative downstream consequences that presumably were not anticipated by the designers.

2.2.2 Increase Development Setbacks

The City has two guidelines related to development setbacks from the stream channels. When an area is zoned, the City specifies an Environmental Reserve setback. The primary benefit of the ER setback is presented as a reduction in contaminated runoff to the stream. The benefits of more open space for public access, and allowance for bank erosion, are seen only as possible incidental benefits of the policy.

Existing Development Setback Guidelines in Calgary

Stream	Environmental Reserve Setback[1] City (2007c) (m)	Land Use Bylaw Building Setback[2,3] City (2007a) (m)
Bow River	50	60
Elbow River	50	30
Nose Creek	50	30
West Nose Creek	30	30
Ephemeral and Intermittent Streams	6	Not specified

1. Increase the setback by 1.5 m per percentage of slope over 5%.
2. From the stream bank. Buildings must also be at least 6 m from the edge of the floodway.
3. For new construction. Redevelopments, where the land was not vacant in 1985, are only subject to the 6 m setback from the floodway.

Secondly, the land use bylaw specifies a minimum setback for new building construction. The context of this requirement indicates that the primary purpose of the setback is to reduce flood damage.

Flood damage, water quality, and ecological values are important considerations in the selection of a development setback, but the substantial benefits of a morphological setback should also be recognized. Existing setback limits are clearly inadequate for long-term protection against morphological risks, as was demonstrated by the 60 m of erosion that occurred during a single flood at Inglewood in 2013.

In principle, given sufficient time, the stream could occupy any position across the entire valley bottom. (Valley bottoms are delineated on the mapping in Appendix I.) However, the stream mobility is sufficiently low in many places that reserving the entire valley bottom for the river may be unnecessary in any reasonable planning timeframe. Based on these considerations, it is recommended that:

- New development, or substantial redevelopment, anywhere in the valley bottom should be limited to projects that could readily tolerate erosion and flooding damage, such as pathways and parks, unless site-specific geomorphological, hydrotechnical, and geotechnical assessments are conducted to show that the particular site is appropriate for the proposed development.
- When relatively low-value infrastructure such as a pathway is damaged or threatened by stream processes, the City's default reaction should be to move or replace the infrastructure further from the stream. Bank repair and armouring should not be allowed unless careful consideration reveals no other feasible option. Moving the infrastructure would often involve a lower capital cost, and is preferable from a morphological point of view because it has less potential for negative downstream consequences.

- The City should be alert for opportunities to enlarge the river corridor in areas of existing development (e.g. when infrastructure nears the end of its useful life).

2.2.3 Increase Bridge Openings

Bridges often constrict the channel and floodplain to a narrow opening, producing high velocities associated with bed erosion and downstream sediment deposition. Consequently, bank protection is usually constructed through the bridge opening, and often upstream and downstream of the bridge as well.

Most Calgary bridges do not constrict the river channel itself at normal levels, but the effect of the bridge abutments and approaches can be substantial during a flood. For example, the serious erosion that occurred downstream of the Ivor Strong Bridge during the 2013 flood was at least partially a consequence of the bridge constriction shown on the adjacent photograph.

Bow River flow constriction at Ivor Strong Bridge during the 2013 flood

Side channels, which can provide good fish habitat as well as flood conveyance, are often blocked by bridge approaches.

Bridge piers and abutments can also direct the flow in a different direction than it would have taken naturally, increasing bank erosion risk downstream.

As a result of these varied effects, many of the sites where river engineering interventions are most needed are in the immediate vicinity of a bridge.

Hydrotechnical design guidelines for river crossings typically focus on hydraulic capacity, with little consideration of morphological factors. However, the Calgary Transportation Plan identifies channel morphology as one of the waterway constraints to be considered when planning a bridge site.

The (US) Federal Highways Administration (FHWA) provides detailed guidance[3] related to morphological assessments at river encroachments such as bridges. When selecting a bridge site on a meandering river, FHWA suggests that the following questions should be addressed:

1. What has been the rate and mode of migration of the meander?
2. What is the probable future behavior, as based on the past?
3. Is the site at a pool, riffle, or transition section?

4. Is meander cutoff probable?

When selecting a specific bridge opening and pier design, the designer should consider not only hydraulic, structural, geotechnical, environmental, and road alignment factors, but also stream morphology. A larger opening is obviously better from a morphological perspective. A larger opening reduces flow constriction during floods, consequently reducing downstream velocities and the potential for downstream erosion and bank migration, as well as upstream depths and sedimentation. A large opening is also desirable from an ecological perspective as the bank provides a wildlife migration corridor.

Bridges over the Bow River

Based on these considerations, it is recommended that:

- Bridge designs should consider the changes in downstream velocity and shear stress due to the bridge constriction, and either reduce the changes to an acceptable level through provision of a sufficient bridge opening, or mitigate the changes by providing downstream bank protection works. These changes are particularly important at discharges high enough to transport significant amounts of bed material.
- The configuration of the bridge abutments and alignment of the piers should be selected considering their effect on downstream flow direction during both moderate and flood discharges.

2.2.4 Construct Appropriate Bank Protection

As discussed in Section 2.2.2, bank protection should not be an automatic reaction to bank erosion. However, where it is not feasible to allow natural bank erosion to occur, bank protection may be required. The City commissioned the development of design guidelines for bank protection works[4] which provide a basis for design.

An important point to be considered in the design of bank protection is that established vegetation can be highly resistant to erosion while providing wildlife habitat cover, a food source for the aquatic environment, and desirable aesthetics. The City's guidelines indicate a maximum permissible shear stress of 100 – 140 Pa for willows more than two years old. For comparison, the equivalent values for riprap are 100 Pa for a D_{50} of 150 mm and 190 Pa for a D_{50} of 300 mm. Riprap or a similar robust treatment may be needed at the toe of the slope, where the greatest shear stress typically occurs and where vegetation establishment is difficult because of submergence and ice effects, but vegetation may provide sufficient protection to the higher portion of the slope.

The existing vegetation line on a bank serves as an indicator of the level above which a vegetated bank can usually survive, although this should be evaluated on a site-specific basis.

2.2.5 Do Not Dredge the Channel

Wholesale dredging of stream channels has sometimes been suggested as a strategy for reducing flood risk along the Bow and Elbow Rivers in Calgary. This report recommends some site-specific gravel bar reshaping projects, but a major dredging program is not recommended because dredging would have a limited duration, limited effectiveness, and small flood damage reduction benefits compared to the enormous financial, environment, and social costs.

Timber crib wall with riprap toe on the Elbow River

2.2.6 Provide Gravel Nourishment

Many of the potential interventions in the Bow and Elbow Rivers involve gravel removal from bars or islands. Regulatory requirements specify that the removed gravel must be replaced somewhere in the river. Returning the gravel to the river is desirable from an ecological point of view, because the gravel provides a desirable substrate for fish habitat, compared to larger cobble, bedrock or clay till. Returning the gravel to the river is also desirable from a morphological point of view, because the placed gravel compensates to some extent for the interruption of upstream sediment supply by Glenmore and Bearspaw dams.

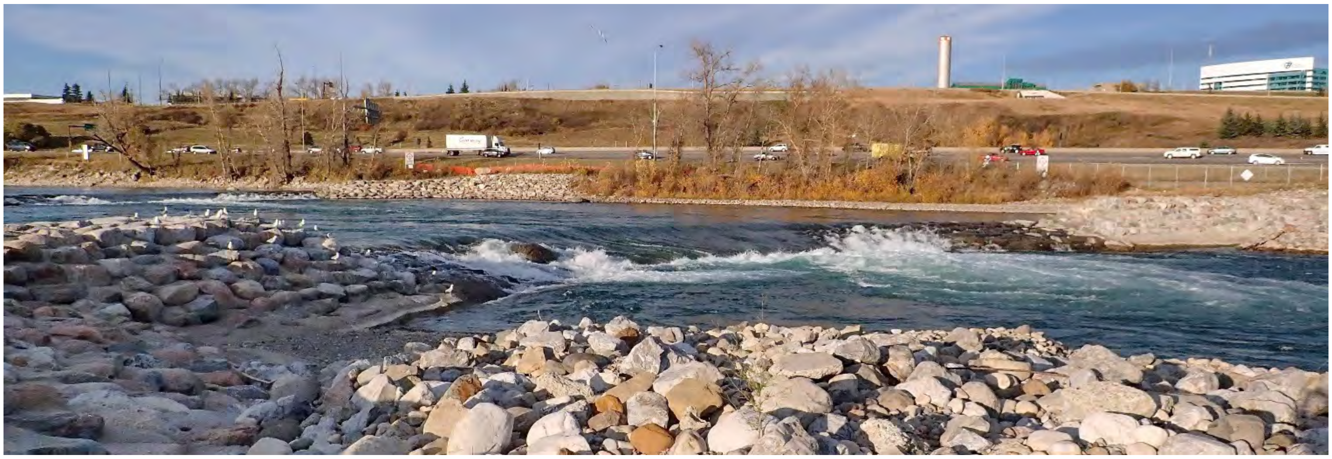
Gravel relocation plans should be developed prior to initiating bar reshaping projects, so that an integrated flood, erosion, and habitat plan for each river is developed and followed. Gravel nourishment locations near the dams are preferred, because that is where the impact of upstream sediment removal on both fish habitat and stream morphology is most pronounced. Selection of gravel nourishment locations should consider the potential for increased flood risk created by local sediment accumulations.

2.2.7 Construct Stormwater Ponds for Small Streams

Stormwater contributions can have significant impacts on stream morphology. Current stormwater guidelines in Calgary limit peak discharges and total discharges into the streams. New developments include stormwater ponds to comply with the guidelines. Older developments are sometimes retrofitted with stormwater ponds as well.

In assessing the impact of stormwater releases on stream morphology, the magnitude and duration of peak stormwater releases relative to stream discharges is a key factor. Increases in baseflow resulting from stormwater releases are inconsequential.

If the City elects to retrofit older systems with stormwater ponds, the expenditure should be focused on reducing releases to the smaller creeks, because the impacts of stormwater peaks are relatively large on the small creeks. Stormwater releases to the Bow and Elbow Rivers have very little effect on river morphology.



Harvie Passage on the Bow River

3 BOW RIVER

3.1 History

The Bow River valley was cut by glaciers through sandstone, siltstone, and mudstone bedrock. The river formed an irregularly meandering channel within the valley flat, through gravel also deposited by glacial activity. The bedrock is exposed at a few locations in the valley walls and river bed. The bedrock is somewhat erodible and does not appear to have a significant influence on the river profile. Bedrock does affect the river planform in some places, interrupting meander progression and creating abrupt bends in the river, often with high eroding banks.

Dam across the Bow River upstream of the Hillhurst – Louise Bridge, 1924

The earliest available airphotos of the Bow River, taken in 1924 – 26, indicate a highly mobile channel, probably due to several large floods that had occurred over the past few decades. There are many side channels, bare gravel bars, and eroding banks with little riparian vegetation.

Early settlers exploited the river as a transportation corridor, notably for logging, as logs were floated down the river from Kananaskis to a sawmill in Eau Claire. The Calgary Water Power Company constructed a dam approximately 4 m high in the late 1880s across the Bow River upstream of Prince's Island to divert water to the sawmill and to develop head for hydropower generation. The dam was abandoned after the mill ceased operation in 1945 and subsequently removed, but the effects of the dam likely contribute to the unusually large sediment deposit at the Hillhurst – Louise Bridge today.

The Calgary Weir was constructed on the Bow River in 1908 to provide water via the Western Headworks Canal to irrigators in an area that later became the Western Irrigation District. Irrigation diversions from the river can amount to a significant proportion of the flow in summer, but have little influence on peak discharges and morphology.

Seven dams were constructed on the Bow River and its tributaries upstream of Calgary over the period 1912 to 1955, primarily for hydropower purposes. Bearspaw Dam, the closest dam to Calgary, was constructed in 1954 and cut off the upstream supply of coarse sediment to the river in Calgary. Operation of the upstream dams and reservoirs results in somewhat lower discharges during the summer and higher discharges in winter than would occur naturally.

By 1924, there were already 14 road and rail bridges across the Bow River in Calgary, and as of the end of 2015, there were 35 bridges spanning the main channel. Bridge approaches typically constrict flood flows, producing scour through the bridge openings and bank erosion downstream, and often block side channels that would otherwise provide fish habitat. Significant erosion and corresponding sedimentation occurred at several bridges during the 2013 flood.

Bearspaw Dam on the Bow River

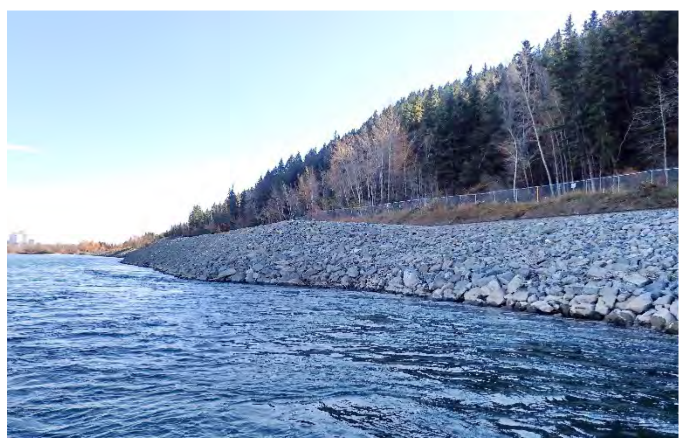
A pool (the ice anchor) was excavated in the river upstream of Prince's Island in 1953 to reduce ice jam flood risk. The pool has substantially filled in since that time but ice jams are largely controlled by the operation of Bearspaw Dam.

There were no major floods (except ice jam floods) on the Bow River between 1932 and 2013. During that time, it appears that Calgarians became complacent about living next to the river. Urban development occupied much of the river valley upstream of the Calgary Weir. The river was partially infilled in some reaches to provide room for development. At many other places, gravel was extracted, either from the river itself or from the valley immediately adjacent to the river. Gravel extraction interrupted sediment movement, and gravel pits adjacent to the river provide potential avulsion routes.

The long period without major floods, and with some changes to the annual hydrograph because of the upstream dams, resulted in a decrease in average channel width through vegetation encroachment. The number of active side channels also decreased.

With the development of valuable infrastructure immediately adjacent to the river, there was a perceived need for erosion protection. By 2014, bank protection works, primarily riprap, covered 36% of the river bank upstream of the Elbow River within Calgary, and 16% of the banks downstream.

Over the last few decades, there has been increasing recognition of the ecological value of the Bow River and the need to protect its water quality and aquatic and riparian habitat. As a result, in 2007 the City imposed setbacks of 50 to 60 m from the river for new development.



Riprap bank protection along the Bow River

The 2013 flood caused significant flooding and erosion damage in Calgary. The average channel width increased, but the current channel is still narrower than it was in 1924-26.

3.2 Current Condition

Extending approximately 645 km in length, the Bow River begins in the Rocky Mountains at Bow Lake, travelling through the foothills, passing through Calgary, and into the prairies before joining the Oldman

River to form the South Saskatchewan River. Calgary is located roughly midway along the river length, and approximately 50 km of the Bow River is contained within the city limits of Calgary as shown on Figure 1.

Geology and Planform

Upstream of Calgary, the Bow River channel generally follows an irregular meander pattern, but there are braided and entrenched reaches as well. The river has formed an irregularly meandering channel within the valley flat, through gravel deposited by glacial activity.

The channel is frequently confined by valley walls upstream of the Elbow River confluence and occasionally in the downstream channel. The bedrock, consisting of sandstone, siltstone, and mudstone, is exposed at a few bank locations.

Bedrock outcrop along the Bow River

There are frequent islands, numerous point bars, and occasional mid-channel and side-channel bars. The meandering channel planform is consistent with expectations based on the discharge and sediment regime, indicating that the channel is unlikely to change to a braided form.

Hydrology

Spring and summer snow and glacier melt, and early summer rainfall, contribute most of the water conveyed by the Bow River, with peak discharges usually occurring in June and minimum flows occurring through the winter. Summer peaks are reduced, and winter low flows are raised, by the operation of the dams constructed on the Bow River and its tributaries upstream of Calgary, but those effects are minor.

The flood history of the Bow River is unusual, in that of the nine largest floods in the record, eight occurred in the 54-year period 1879 - 1932, and none in the 80-year period 1933 - 2012. The long period without significant floods resulted in little sediment movement, vegetation encroachment on the channel, and a reduced channel width over the last century. Future floods similar to the 2013 event would tend to widen the channel.

Urban stormwater runoff from 168 outfalls on the Bow River can generate significant peak flows on the river but those peaks are smaller than, and not synchronized with, peak river discharges. Therefore, the impact of stormwater inflows on morphology is considered to be negligible. However, stormwater inflows can cause localized scour holes, and contribute fine sediment to the river which can impact water quality and the aquatic environment.

Water withdrawals for municipal water supply are small relative to the river discharge, and are inconsequential from a morphological perspective.

The Bonnybrook, Fish Creek, and Pine Creek wastewater treatment plants release treated effluent to the Bow River but these releases have no effect on peak discharges, and little effect on morphology except for localized thermal effects on the adjacent bank.

Ice has little or no effect on the morphology of the Bow River in Calgary.

Gravel has been mined from the river and floodplain at numerous locations, with significant effects on sediment transport and river planform.

Bed Material and Sediment

Fine sediment sources above Calgary appear to be fairly evenly distributed across the catchment. Suspended sediment concentrations in Calgary are very low. Total suspended load in the Bow River at the Calgary hydrometric station is in the range of 30,000 t/a, which represents much lower sediment yields than most rivers in Canada. The low sediment load is likely due to the gravel bed and banks, a mountainous or vegetated upstream catchment, and sediment removal at upstream dams.

Coarse sediment is contributed to the Bow River from mountainous tributaries but does not reach Calgary because of Ghost and Bearspaw Dams.

Gravel bank of the Bow River

On average, the surface layer of bed material in the Bow River has a median diameter (D_{50}) in the range of 80 to 90 mm and a D_{90} of 190 mm. Subsurface material has an average D_{50} of 40 mm and a D_{90} of 140 mm. Armour ratios are typically between 2 and 4, indicating that most of the bed is heavily armoured rather than paved. Therefore, the bed in many locations can, and will, be mobilized during larger than normal floods and the channel shape may change. This was evident in the 2013 flood when bed and bank scour occurred, and large gravel bars were deposited.

However, bed material movement is small in volume and is sporadic. Significant bed material transport in the Bow River occurs only at discharges in the range of 500 to 800 m^3/s (approximately a 1:4 year to 1:8 year event upstream of the Elbow confluence; 1:3 year to 1:5 year event downstream). Mean annual bedload transport within Calgary is likely in the range of 100 to 1200 m^3/a.

Although coarse sediment arriving from upstream is captured in Bearspaw Reservoir, the loss of that sediment supply has until now produced little or no downstream channel incision. The lack of incision is likely a result of several factors, including bed armouring, a period of 80 years without significant floods; and grade controls such as natural bedrock and clay till exposures in the river bed. The time scale of downstream channel incision and paving is very slow because of the sporadic nature of sediment transport in a gravel bed river. There is little noticeable difference between sediment gradations upstream and downstream of the Elbow River confluence, and there is no indication of coarsening gradations over time.

Channel Dimensions

The bankfull discharge in the channel is approximately 500 m^3/s above the Elbow River confluence and 600 m^3/s below the Elbow, roughly halfway between the 1:2 year and 1:5 year discharges. During a 1:2 year flood, the channel top width is approximately 120 m upstream of the Elbow and 180 m downstream, and the mean depth is about 2 m. The channel slope through Calgary is 0.0018. Except for the downstream width, these values correspond reasonably well to regime relationships for gravel-bed rivers[5], indicating that the channel is in regime despite the long history without significant floods, flow regulation by upstream dams and reservoirs, and encroachment by Calgary's development. The downstream channel is wider than would be expected based on regime relationships.

Bank erosion in Inglewood during the 2013 flood. The blue line shows the pre-flood bank.

The 2013 Flood

The 2013 flood, approximately a 1:80 year event[6], eroded river banks and deposited gravel on a number of bars and islands in the Bow River. Bank erosion removed up to 60 m (laterally) of bank in Inglewood downstream of Cushing Bridge, damaging utilities and a road and raising concerns for the safety of several residences. Erosion damage also occurred at Home Road, 19th Street NW, Sunnyside, Langevin Bridge, the Calgary Zoo, Douglasdale, Diamond Cove, and Pine Creek. These erosion sites were repaired on an emergency basis to prevent further damage.

An avulsion occurred through a former gravel pit on the floodplain at Carburn Park. Some bank protection was constructed there on an emergency basis but the site remains a concern.

Sediment deposition raised gravel bars, leading to concerns about future flood levels, particularly if the bars become densely vegetated. The vegetation and higher gravel bar levels reduce the hydraulic conveyance capacity of the river, producing higher water levels upstream. Sites of particular note are at Tenth Street, Centre Street, Bowness, upstream of Crowchild Bridge, and downstream of Harvie Passage.

More generally, the effect of the flood was to widen the river channel by scouring bank vegetation, although the channel is still narrower than it was in 1924. The flood produced barren bars that may revegetate, producing an opportunity to manage the revegetation to promote desirable species (willows and poplars) and discourage undesirable vegetation (reed canary grass and noxious weeds).

Bow River avulsion through a former gravel pit at Carburn Park during the 2013 flood

3.3 Vision and Recommendations

The Bow River is a vital asset to Calgary. It provides a large portion of Calgary's water supply, highly valued fish and wildlife habitat, recreational opportunities both in the river and on the adjacent floodplain, flood conveyance, and wastewater and stormwater conveyance routes.

Along some reaches of the Bow River, particularly through Calgary's downtown, the river is already constrained to a narrow corridor between high-value infrastructure on both banks. In these reaches, the river must be managed within the available corridor, and management interventions such as bank protection and gravel bar reshaping may be necessary and provide good value. Elsewhere, though, there are still opportunities to provide room for the river as envisioned by this study.

TransAlta, the City and other stakeholders should consider the adoption of a flow regime downstream of Bearspaw Dam that would promote colonization by favorable plants such as balsam poplar and sandbar willow, and discourage further invasion by reed canary grass and other undesirable plants. The flow regime would involve ramping the discharge down slowly after the early summer peak to sustain the growth of desirable vegetation.

One of the largest uncertainties in the Bow River morphology is the estimate of bed material transport. The estimate has a large influence on the estimated lifespan, and consequently the benefit-cost analyses, of potential instream interventions such as gravel bar reshaping and fish habitat enhancement projects. To reduce the uncertainty, bed material movement should be measured, using acoustic instruments, repeated bathymetric surveys, bed load samplers, and/or other methods, and the results should be used to calibrate sediment transport equations.

3.4 Risks and Potential Interventions

Many morphological risks and potential interventions were identified along the Bow River. The majority of the risks relate to bank erosion, although the most severe bank erosion issues were addressed on an emergency basis immediately after the 2013 flood. There are fewer sedimentation risks but the potential flooding damage associated with those sedimentation risks is high. There are only a few relatively low-priority avulsion risks.

Bow River at Tenth Street

Four specific interventions to reduce future flood damage by mitigating sedimentation risks have been assessed. The interventions would consist of reshaping gravel bars and conducting associated fish habitat enhancement and other works. The projects are listed below in order of priority based on the TBL analyses. Project locations are shown on Figure 2, referenced by number.

1. The Centre Street Bridge Project. Cost estimate: $1.1 million. This project is already underway in conjunction with other instream work.
2. The Tenth Street Bridge Project (2). Cost estimate: $6.9 million. A conceptual design for this project is provided in Appendix VIII.
3. The Crowchild Project. Cost estimate: $4.6 million. The City has prepared a conceptual design for this work as discussed in the main morphology report.
4. The Bowness Project. Cost estimate: $3.8 million. A concept for the project is presented in the main report.

Other recommended reach-specific interventions (or non-interventions) include:

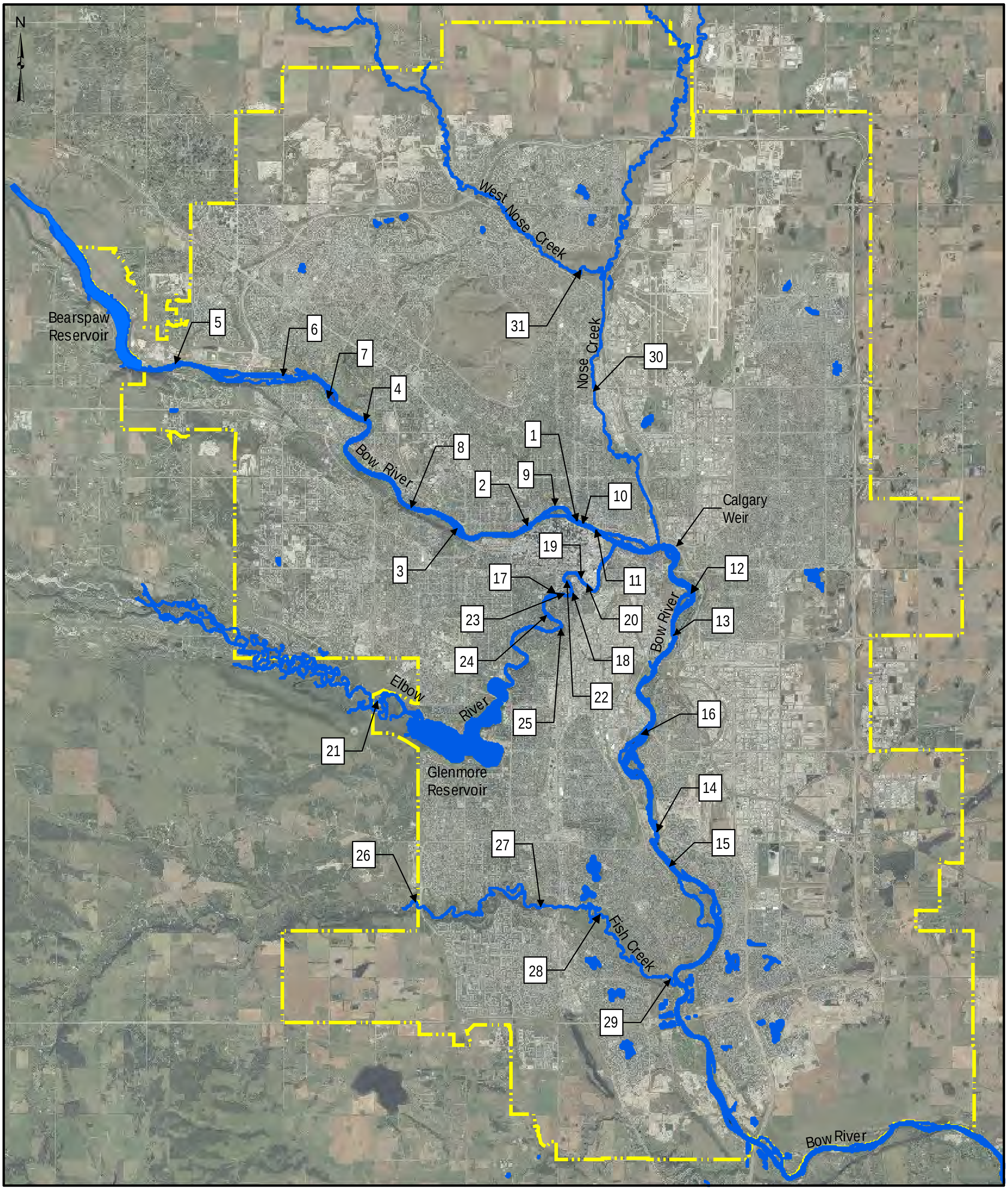
5. Monitor the left bank in the Keith West reach (km 68.3 – 68.1)[7] during future floods and be prepared to intervene if erosion threatens the water main;
6. Repair the erosion protection on the north abutment of the 85th Street Bridge (km 64.4 – 64.0);
7. Relocate the pathway (rather than armouring the bank) in the Bowmont reach (km 62.5 – 61.5);
8. Accept bank erosion at Point McKay (km 55.8 – 55.4);
9. Conduct additional hydraulic analyses of flow patterns and flood levels at Prince's Island using a two-dimensional model to assess possible means of reducing flood damage in Sunnyside (km 50.4 – 49.0);

10. Do not armour the left bank downstream of Centre Street Bridge (km 48.6) unless the upper pathway or roadway are threatened;
11. Monitor sediment deposition at the upstream end of St. Patrick's Island (km 48.0 – 47.5);
12. Monitor erosion at Outfall B8A (km 43.0);
13. Work with the railway to monitor and respond to future erosion at Sanctuary Road (km 41.4 – 41.1);
14. Conduct a study to evaluate options to address the complex erosion, avulsion, and sedimentation risks at Carburn Park (km 37.0 – 34.7);
15. Provide erosion protection below the Ivor Strong Bridge (km 32.6 – 32.3);
16. Assess the possibility of damage to buried utilities in the event of bank erosion upstream of the Sue Higgins Pedestrian Bridge (km 31.2 – 31.0).

At one other reach of interest, Carburn Park – Riverside (km 37.0 – 34.7; Location 17), a separate study has been commissioned by the City.

George C. King Bridge over the Bow River at St. Patrick's Island

File: Z:\A\CGY\Alberta\A03311B01 CoC Calgary Morphology & Fish\400 Drawings\GIS\MXD\Report\Fig 2_Reaches of Interest - for summary report.mxd



Legend
Calgary City Limit
Stream or Water Body
1 Reach or Location Number

1:200,000 km
0 5

Figure 2
Reaches of Interest and Potential Intervention Locations

4 ELBOW RIVER

4.1 History

The Elbow River is similar to the Bow in terms of its geology, hydrology, bed material, and morphology. Like the Bow, the Elbow River valley was cut by glaciers through sandstone, siltstone, and mudstone bedrock. Bedrock is exposed at a number of locations in the valley walls and river bed within Calgary, especially immediately downstream of Glenmore Dam. The valley subsequently filled with gravel, which now forms most of the river bed and banks. As the current flows in the Elbow River is much smaller than in the pre-glaciation period, the river channel meanders across the fluvial channel gravels, resulting in a series of abandoned oxbows, for example at Weaselhead, Stanley Park and Roxboro Park.

Urban development occurred along the Elbow River beginning in the late 1800s, and the first bridge across the river was likely constructed in 1882. Floods in the late 1800s and early 1900s caused significant damage to bridges and adjacent property. However, between 1932 and 2013, there was only one flood (in 2005) greater than a 1:10 year event. Despite the earlier floods, urban development extends very close to the river bank for much of the length of the Elbow in Calgary.

Preparation for Roxboro Subdivision, 1912[8]

An interesting example of detrimental urban development occurred in 1912, when a water jet was used to wash material down from the surrounding high ground to fill an oxbow channel of the Elbow River in preparation for construction of the Roxboro subdivision. The pump was operated ten hours per day for three months.

Glenmore Dam was constructed in 1930-32 to provide a reliable water supply to the citizens of Calgary and is still used for that purpose. The dam reduces the supply of coarse sediment in the river downstream. Possibly as a result, the downstream bed material at the surface is generally coarser than upstream. Despite the reduction in sediment supply, the Elbow River downstream of Glenmore Dam shows no evidence of reach-scale incision. Incising has been limited by the armouring process, the presence of grade controls such as bedrock and erosion-resistant clay till in the river bed, and the very slow response of a gravel-bed river in the absence of significant floods.

The Elbow River channel has narrowed since the time of the earliest available maps and airphotos. The channel narrowing is the result of infilling as well as vegetation colonization of side channel bars and point bars during the long period of time without significant floods. The 2013 flood resulted in some channel widening, but it is still narrower than in the 1920s.

Glenmore Dam

Bank protection works have been constructed on 24% of the banks of the Elbow River downstream of Glenmore Dam. Over half of the protection is riprap, and most of the remaining protection consists of retaining walls.

As of 2015, there are 20 road, rail, and pedestrian bridges on the Elbow River downstream of Glenmore Dam. Some of the downtown bridges constrict the river and raise upstream flood levels. During a 1:100 year flood, the MacDonald Bridge creates a water level rise of approximately 1 m, and the combination of the Stampede Park Access Bridge, LRT Bridge, and Victoria Bridge raise the upstream water level by approximately 0.5 m(9). The backwater effects persist upstream approximately 1 km from the MacDonald Bridge and 0.6 km from the Stampede Park Access Bridge. Increasing the conveyance capacity through those bridges could reduce flooding toward downtown and improve sediment transport.

4.2 Current Condition

Geology and Planform

The Elbow River originates approximately 120 km west of Calgary at Elbow Lake in Kananaskis Country. From there it flows eastward to its confluence with the Bow River in Calgary. Along its length, the river transitions from a steep mountain stream to a braided channel flowing across a broad floodplain through the foothills and downstream to Glenmore Reservoir. Immediately upstream of Glenmore Reservoir, the river is a highly active meandering channel flowing through gravels deposited by glacier activity. There is significant channel shifting and frequent avulsions.

Downstream of Glenmore Dam, the river morphology changes to a much less active single-thread channel, frequently confined by mixed sandstone, mudstone and siltstone bedrock valley slopes, with glacial tills, and lacustrine deposits. The sandstone is erosion resistant, forming escarpments along the river, while the other materials are more erodible. This section of the Elbow River was formed during advances and retreats of glaciation in the Pleistocene Epoch, and gives it a distinct geological history compared to the upstream section.

There are locations where the bed is formed of bedrock or erosion-resistant clay till, but effects of the bedrock on the channel profile are not pronounced. The meandering channel planform is in accordance with expectations derived from the literature based on the discharge and sediment regime.

Major slope instabilities along the river have been stabilized, and consequently are not expected to have significant morphological consequences. Toe erosion and minor bank instabilities continue at various locations.

Hydrology

Bedrock outcrop on the Elbow River

Spring and summer snow melt contributes most of the water conveyed by the Elbow River, with peak discharges occurring in late May or in June, and minimum flows occurring through the winter. Floods are typically the result of rain, or rain on snow. Glenmore Dam operation has little effect on the annual hydrograph, but municipal withdrawals from the reservoir result in slightly smaller reservoir outflows than inflows year-round. The effect of withdrawals is negligible from a morphological perspective.

Glenmore Dam and Reservoir have historically had no significant effect on peak discharge for events less than 150 m^3/s (approximately 1:5 year flood), but have had an effect on events between 150 and 220 m^3/s. Reservoir storage is too small to have an appreciable impact on severe floods (say the 1:50 year flood or larger) unless the hydrograph shape is favorable as was the case in 2013.

Stormwater inflows from 96 outfalls have only a very minor impact on the river flow regime relative to morphology, but contribute fine sediment to the river, with water quality and aquatic habitat implications, and cause localized scour holes.

Bed Material and Sediment

Most of the sediment transported by the river into Glenmore Reservoir is suspended load, derived from bank and riparian erosion in the lower part of the catchment. The mean annual total load (mostly suspended load) contributed to the reservoir is in the range of 60,000 – 75,000 m^3. Downstream of Glenmore Dam, suspended sediment concentrations are typically less than 20 mg/L.

Bed load entering the reservoir is estimated to amount to 750 m^3/a. Downstream of Glenmore Dam, bedload transport is likely insignificant below a discharge of approximately 200 m^3/s (1:8 year flood) and increases quickly at discharges above 475 m^3/s (1:50 year flood). The mean annual bed load transport capacity is likely in the range of 240 m^3/a.

Bed material upstream of Glenmore Dam consists of gravel with a D_{50} in the range of 16 to 35 mm.

Bed material downstream of Glenmore Dam is highly variable, with D_{50} values of the surface material ranging from 15 to 196 mm and averaging 65 mm. The subsurface material is somewhat finer, with a D_{50} of 31 mm, similar to the material upstream of the dam, indicating armouring in response to the change in sediment supply due to the dam.

Side channel of the Elbow River near Mission Bridge

Armour ratios vary from less than 1 to over 4, indicating a range of armouring conditions from no armouring to paved.

Channel Dimensions

Downstream of Glenmore Dam, the bankfull depth corresponds approximately to the 1:2 year discharge of 63.9 m^3/s. At that discharge, the average river width is 43 m, the mean depth is 1.3 m, and the mean velocity is 1.2 m/s. The reach slope is 0.0018.

These values correspond well to regime relationships for gravel-bed rivers, indicating that the channel is in regime despite the long history without significant floods and the existence of Glenmore Reservoir. The slope is somewhat flatter than the regime slope of 0.0025.

Over the last century, the length of secondary channels (or side channels) along the river has decreased from 20% to 10% of the river length because of the lack of significant floods, the reduced sediment load from upstream, vegetation encroachment, and the construction of bank protection works or other instream encroachments.

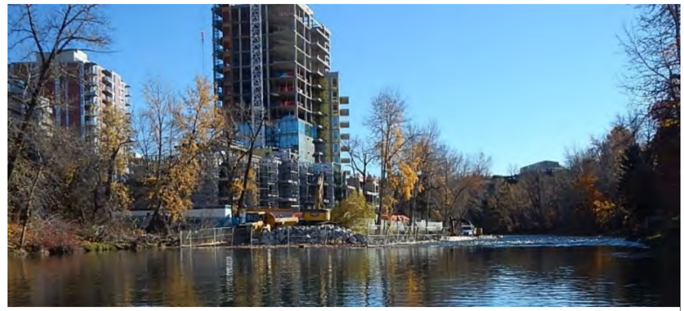
The 2013 Flood

The 2013 flood peak downstream of Glenmore Dam was estimated to be greater than a 1:100 year event upstream of Glenmore Reservoir, and approximately a 1:90 year event downstream[10]. Four bridges were damaged and had to be replaced. Bank erosion occurred at the Water Survey of Canada hydrometric station; 25th Avenue Bridge; Lindsay Park; and the Stampede Pathway. These sites were repaired quickly after the flood. Other bank erosion repairs completed after the flood include Stanley Park and St. Mary's High School.

Other morphological impacts of the flood were scour beneath at least five of the bridges, with associated gravel deposition downstream; and sediment deposition at several other locations, including the upstream end of Mission Island where a side channel inlet was blocked.

4.3 Vision and Recommendations

The Elbow River provides a large portion of Calgary's water supply, highly valued fish and wildlife habitat, recreational opportunities both in the river and on the adjacent floodplain, flood conveyance, and stormwater conveyance routes.



Development adjacent to the Elbow River

Opportunities to provide room for the river are much more limited on the Elbow River within Calgary than on the Bow, because existing high-value development has encroached on the river floodplain.

Management of Glenmore Dam and Reservoir should consider the adoption of a flow regime to promote colonization of gravel bars by favorable plants such as balsam poplar and sandbar willow, and to discourage invasion by reed canary grass and other undesirable plants. There is less potential for vegetation colonization on the Elbow than on the Bow, because the Elbow has proportionately much fewer gravel bars.

One of the largest uncertainties in the Elbow River morphology, like that of the Bow River, is the estimate of bed load transport. Measurement of bed material movement in the Elbow River would provide valuable information for future analyses and designs.

4.4 Risks and Potential Interventions

Very few significant morphological risks were identified on the Elbow River. Upstream of Glenmore Reservoir, there are many threats but little infrastructure, while downstream of the Glenmore Dam there is high-value infrastructure but very little risk of erosion or sedimentation, and no identified risk of avulsion.

Bank protection along the Elbow River in Mission

The highest-priority intervention on the Elbow River, based on the TBL analyses, is the Mission Bridge Capacity Improvement Project (Location 17 on Figure 2). A vegetated island under Mission Bridge and a coarse bar immediately downstream of the bridge raise upstream flood levels. The estimated cost for design, environmental studies, regulatory submissions, and construction to lower the island is $1.9 million. A conceptual design for the project is provided in Appendix VIII.

Growth of the left bank point bar above and through Scollen (25th Avenue) Bridge (18) is limiting the hydraulic capacity of the bridge, and increasing upstream flood levels. Improving the hydraulic capacity at the bridge would provide flood damage reduction benefits. The estimated cost for the Scollen Bridge Capacity Improvement Project is $0.7 million. The City has commissioned a separate study that may include this work.

The Erlton Floodway Outlet (19) eroded in 2013 and is expected to erode again the next time the floodway operates, but the cost of preventing that erosion is higher than the net present value of repairing it when it occurs.

Other recommended reach-specific interventions (or non-interventions) include:

20. Investigate the potential to reduce future flood damage by increasing the hydraulic capacity of bridges on the Lower Elbow River, particularly MacDonald Bridge and the Stampede Access Bridge, through structural modifications or replacement.
21. Provide erosion protection for Grey Eagle Drive upstream of Glenmore Reservoir which is threatened by a migrating meander bend.
22. Investigate the potential to reduce flood damage by improving the geometry of the inlet to the Erlton Floodway.

23 – 25. Monitor sites where moderate erosion threats exist and the existing bank protection is uncertain. These include Mission South (23), 34th Ave. SW (24), and Stanley Park South (25).

Elbow River in Elbow Park

5 FISH CREEK

5.1 History

Fish Creek originates in the foothills of southern Alberta, approximately 45 km west of its confluence with the Bow River in Calgary. Approximately half of the Fish Creek catchment lies in the foothills and half in the prairies. There are minor dams on the tributaries of Fish Creek, but there are no significant dams or reservoirs on the main stem.

In contrast to the other study streams, Fish Creek within Calgary is relatively unaltered by urban development. The valley has been designated as Fish Creek Provincial Park, the largest urban park in Canada. Very little bank protection or channel realignment has been constructed.

The generally natural state of the creek channel and valley is in stark contrast to the urban development that has extended to the banks of the Bow River, Elbow River, and Nose Creek. Consequently, little bank protection has been constructed along the creek, except at City and park infrastructure, and the channel is more free to migrate laterally and change its course. Channel-related issues within the park are typically limited to local pedestrian bridges (which are erosion susceptible) and legacy issues relating to historic land clearing.

There are nine pedestrian bridges, four road bridges and one rail bridge across Fish Creek within Calgary. One pedestrian bridge was washed out during the 2013 flood.

Approximately 800 m of Fish Creek upstream of Macleod Trail (km 7.5) was straightened before 1962, possibly to improve the approach to the Macleod Trail bridge and the railway bridge upstream. That realignment reduced the channel length by almost 200 m. The channel is now redeveloping a more sinuous planform.

Fish Creek realignment upstream of Macleod Trail

5.2 Current Condition

Geology and Planform

The Fish Creek channel upstream of Calgary consists mostly of a meandering to tortuously meandering single-thread channel with evidence of historical meander bend movement and cutoffs.

Fish Creek flows through fluvial channel gravels deposited by glacier activity, overlain with fluvial overbank silt-sized sediment deposited during overbank flooding. Within Calgary, the channel form consists of irregular meanders occasionally confined by the valley walls.

Bedrock outcrop on the bank of Fish Creek

Bedrock outcrops are visible in a few locations on the valley walls. The river profile suggests that bedrock outcrops may be controlling the river grade in some locations, although no bedrock is currently visible in the bed of the creek. Slope instabilities are prevalent along the south (right) valley wall upstream of Macleod Trail. Where the Fish Creek channel is adjacent to those slopes, continuing instability provides an ongoing sediment supply to the creek.

The Fish Creek channel was relatively wide and active in 1926, likely because of previous large flood events. The channel then decreased in width and became more laterally stable until the 2005 and 2013 floods produced significant sediment and channel movement. However, the contemporary channel is still narrower and more laterally stable than it was in 1926.

The meandering channel planform is in accordance with expectations derived from the literature, based on the discharge, slope, and sediment regime.

Hydrology

Flow in Fish Creek is highest in April through June in response to snow melt and spring and summer rainfall. Peak discharges occur through the summer, but the three highest peaks in the record all occurred in June. Major floods occurred in 1915, 2005, and 2013. The 2005 instantaneous flood discharge was by far the highest recorded peak, due to the breach of a reservoir spillway on a tributary near Priddis.

Stormwater inflows from 13 outfalls can have a significant impact on the creek flow and fine sediment regime relative to morphology. Limiting stormwater inflow peaks on Fish Creek would be more beneficial than on the Bow and Elbow Rivers, where stormwater is a smaller component of the total discharge.

The lack of streamflow monitoring near the mouth of Fish Creek produces considerable uncertainty in assessing the hydrology of the creek within the city. However, that uncertainty is only a minor concern because of the scarcity of infrastructure adjacent to the creek.

Bed Material and Sediment

Both fine and coarse sediment is readily available from the upstream channel, unstable slopes and bank erosion. Fine sediment is also supplied by stormwater outfalls.

Bedload transport is likely minor below a discharge of approximately 34 m^3/s (the 1:5 year flood at Priddis) but is substantial at higher discharges.

Fish Creek bed material

Channel Dimensions

Within Calgary, the water width of Fish Creek is typically 15 to 20 m, while the unvegetated channel width is 15 to 40 m. The channel slope is 0.0047. These values correspond well to regime relationships, indicating that the channel is in regime despite the long history without significant floods. The slope is somewhat steeper than the regime slope of 0.0025.

The 2013 Flood

The 2013 flood peak in Fish Creek was not as high as in 2005, but still amounted to more than a 1:100 year event at Priddis. The return period within the city is unknown, but may have been lower. One pedestrian bridge and some pathways were washed out. Compared to the Bow and Elbow, flood damage was relatively minor, largely because of the limited development near the creek.

5.3 Vision and Recommendations

The existing functions of Fish Creek within Calgary focus on environmental and social benefits, including fish and wildlife habitat and public park land. The creek also provides flood conveyance, and an urban stormwater conveyance route to the Bow River.

Existing management of the creek and surrounding floodplain as a provincial park supports these functions well, and the vision of the current study is that the existing management system continues. Additional attenuation of urban runoff and corresponding sediment controls should continually be explored to reduce urban runoff impacts on Fish Creek.

There is less hydrologic, hydraulic and morphological information available for Fish Creek than for the Bow and Elbow Rivers. Although the lack of information is less important on Fish Creek because of the smaller amount of infrastructure there, an improved understanding of the hydrology of Fish Creek within Calgary is desirable to support future management. That understanding should be improved by:

- Establishing a hydrometric monitoring station near the mouth of the creek; and
- Updating current flood frequency estimates[11].

5.4 Risks and Potential Interventions

Morphological risks identified along Fish Creek within Calgary relate primarily to erosion and avulsion. Although urban development in the valley has been limited, infrastructure susceptible to erosion risks includes road crossings, pedestrian crossings, and buried utilities. Specific risks and interventions are as follows, with the numbers illustrating the locations on Figure 2:

26. Meander bend progression upstream of the 37th St. Bridge (km 15.6) is threatening to damage the north abutment of the bridge. Erosion protection should be provided upstream of the bridge. The City should advise Alberta Transportation of the potential risk for inclusion in the Calgary Southwest Ring Road project.
27. A meander bend is progressing toward Outfall F3A and will likely eventually damage the outfall and/or upstream stormwater pipes. The City should monitor Fish Creek movement at Outfall F3A after future flood events and should consider relocating the outfall if, and when, it is required.
28. An unusual bend development at km 5.4 is progressing toward a buried ATCO pipeline and Telus cable. Continued progression of the bend could potentially expose and undermine the pipeline and cable, depending on the burial depths which were not obtained for this study. The City should notify ATCO and Telus about potential risks to their infrastructure.
29. An avulsion at the mouth of Fish Creek (km 0.4) would lower the downstream end of the channel by more than 1 m, resulting in channel bed lowering and increased bank erosion upstream. Upstream pipelines and bridges might be damaged. Risks to buried infrastructure and bridges near the mouth due to the potential avulsion should be assessed.


Fish Creek in Fish Creek Park

6 NOSE CREEK

6.1 History

Nose Creek is an unregulated tributary of the Bow River that originates near the Town of Crossfield, and flows south through the City of Airdrie, to its confluence with the Bow River in Calgary near the Calgary Zoo. In contrast to the Bow and Elbow Rivers and Fish Creek, the Nose Creek catchment consists entirely of prairie terrain. Nose Creek is a prairie stream with bed and banks composed primarily of clay and silt.

Nose Creek is fed by numerous ephemeral and intermittent streams. Its largest tributary is West Nose Creek, which joins Nose Creek in Calgary as shown on Figure 1.

Nose Creek has been straightened, diverted and channelized extensively over the past several decades to accommodate construction of Deerfoot Trail and other urban and agricultural developments. The realigned channel is much shorter and steeper than the original. Almost none of the predevelopment channel still exists downstream of the West Nose Creek confluence. In contrast to the Bow and Elbow Rivers, only 2% of the Nose Creek channel bank has been armoured.


Realigned reach of Nose Creek

Urban development has also affected the catchment, producing higher stormwater inflows to the creek, higher nutrient loadings, and reduced overbank flood storage.

The channel has incised over the past century in response to stormwater inflows and channel realignment, and incision is expected to continue. Continued incision could threaten the integrity of adjacent infrastructure such as pipelines, cables, stormwater outfalls, bridges, and pathways.

6.2 Current Condition

Geology and Planform

The surficial geology along Nose Creek consists primarily of silt with some gravel, overlying the sandstone and siltstone bedrock. The channel upstream of Calgary consists mostly of a meandering to tortuously meandering single-thread stream in a 100 m wide valley. Bedrock is exposed in the banks at several locations in the upper reach of the creek within Calgary, and the creek profile is likely partially bedrock controlled.

Bank erosion along Nose Creek

Within Calgary, the channel is relatively deep and narrow compared to gravel-bed streams, and much of it is straight due to channel realignments. The channel is quite stable laterally, with only minor erosion or slope stability issues.

Hydrology

The median annual Nose Creek hydrograph peaks in April due to snowmelt and the associated groundwater discharge. Streamflow remains moderately high in May, and then drops through the remainder of the summer. Flood peaks can occur at any time during the summer.

Stormwater inflows from 57 outfalls in Calgary have a significant impact on the creek flow and fine sediment regime, increasing flood peaks by up to three times and raising normal flows, and therefore affect the creek morphology, water quality, and ecology. The lack of long-term streamflow monitoring in Nose Creek above Calgary and at the mouth produces uncertainty in assessing the hydrology of the creek within the city, particularly in terms of stormwater contributions.

Bed Material and Sediment

The creek bed and banks consist primarily of silt and clay, with scattered areas of coarser material.

Fine sediment is available from bed and bank erosion, and from stormwater outfalls. Very little coarse sediment is contributed to the stream.

Channel Dimensions

Within Calgary, the typical water width is in the range of 5 to 10 m. The channel slope is a fairly uniform 0.0012.

The 2013 Flood

The magnitude of the 2013 flood on Nose Creek was not measured. Subsequent outfall inspections found some damage that is believed to be the result of the flood, but no other erosion or flooding damage was reported.

6.3 Vision and General Recommendations

A general morphological risk on Nose Creek is the risk of continued channel incision due to urban stormwater contributions and historical channel realignments, which could threaten buried and adjacent infrastructure. The channel profile suggests that the channel has not yet reached a condition of dynamic equilibrium, and therefore additional incision should be expected.

The potential for incision would be reduced if the channel was able to erode laterally to regain the channel length lost to past realignments. However, the tight constraints on Nose Creek will prevent meandering for much of its length downstream of km 12.2. The lack of channel shifting documented by the air photo analyses also suggests that recent flood discharges on Nose Creek have been insufficient to drive channel migration, likely because of the flat channel gradient, heavily vegetated channel banks, and the depth to which the channel has already incised.

The potential for incision could be addressed in isolation. However, the ultimate vision for Nose Creek is a more comprehensive and far-reaching intervention, consisting of a complete urban stream restoration program. The morphology and ecology of Nose Creek are both currently degraded, and possibly degrading further, due to the hydrologic effects of urbanization coupled with the legacy of past creek realignments. This makes Nose Creek a candidate for restoration that would address current hydrologic, morphologic, water quality and ecological problems while improving aesthetics and providing enhanced recreational opportunities such as bird-watching. Essentially, this would mean turning Nose Creek from a drainage ditch into a valuable piece of multi-functional, green infrastructure.

A stream restoration program would improve the ecological value of the creek by providing increased riparian, wildlife, and aquatic habitat value along an ecological corridor. Wherever possible, the stream corridor should be widened and future encroachment within the riparian corridor should be avoided. Segments of the stream that have historically been straightened and channelized should be rehabilitated by re-establishing a natural meandering channel, where space is available.

Increased channel length will result in increased aquatic and riparian habitat quality and quantity, and increased flood attenuation potential. Where bank protection is necessary, banks should be treated with bioengineering works rather than hard structures, wherever feasible. Additional stormwater retention and sediment removal systems should be constructed to treat urban runoff, in cooperation with upstream entities, particularly the City of Airdrie. Noxious weeds should be removed, and healthy riparian vegetation should be planted and nurtured. West Nose Creek, which has been less affected by urban development than Nose Creek, would serve as a model of what the restored creek could look like, and could be used to provide design guidance. A restoration program would align well with the City's riparian uplift initiative.

One specific element of the stream restoration program would be to provide additional check structures or grade control structures along the channel to raise the typical water surface profile and eventually raise the stream bed as sediment would accumulate upstream of the structures. Analysis and design of the check structures should consider the following factors:

- Historical changes in channel cross section;
- Burial depths of existing pipelines and cables beneath the creek;
- The potential for increased flood damage along the creek due to the check structures;
- Effects of the check structures on fish, fish passage, and fish habitat; and
- The possibility of using beaver dams as check structures by promoting beaver populations.

Investigation of historical changes in channel cross section could involve an attempt to retrieve and resurvey cross sections surveyed in the early 1980s[12] to gain a more specific understanding of the rates of channel incision and narrowing.

An important gap in the current management of Nose Creek within Calgary is knowledge of the magnitude and effect of stormwater inflows. Creek management would be enhanced by a better understanding of the impacts of stormwater. Possible actions that would support a better understanding include:

- Initiation of a systematic streamflow monitoring program upstream and downstream of the urban Calgary reach of the creek. The City recently initiated streamflow monitoring at the mouth.
- Calibration of a catchment model based on the streamflow monitoring and precipitation and snowmelt monitoring.

6.4 Risks and Potential Interventions

No high- or moderate-priority site-specific morphological risks were identified on Nose Creek.

Continued channel incision on the lower portion of the creek (Location 30 on Figure 2) is a threat to buried pipelines and cables, and to stormwater outfalls, bridges, pathways and other infrastructure adjacent to the creek. However, that threat does not appear to be a high priority, because historical incision rates appear to be low as they have caused relatively little bank instability.

Nose Creek near Elks Golf Course

7 WEST NOSE CREEK

7.1 History

West Nose Creek is a major tributary of Nose Creek that originates in the Municipal District of Rocky View, northwest of Calgary, as shown on Figure 1. The main stem of West Nose Creek is approximately 55 km in length and descends 177 m from its source to its confluence with Nose Creek near Deerfoot Trail, directly west of the Calgary International Airport. The upper reaches of West Nose Creek are primarily agricultural and grazing lands. Within the City of Calgary, West Nose Creek passes through natural areas, golf courses and residential areas.

West Nose Creek bed and bank vegetation

Like Nose Creek, West Nose Creek is a prairie stream. The creek bed and banks consist of a variety of materials, but clay and silt are the most common.

The West Nose Creek channel is largely unaltered by urban development, with only minor realignments. Most of the realignments that have occurred are within City limits.

The downstream 3.8 km of the channel appears to have incised and widened since the catchment was urbanized.

7.2 Current Condition

Geology and Planform

The surficial geology along West Nose Creek consists primarily of silt with some gravel, overlying sandstone and siltstone bedrock. Bedrock is exposed in the banks at several locations on the left bank in the upper reach of the creek within Calgary. The creek profile has an unusual concave-down shape because of bedrock controls.

The West Nose Creek channel upstream of Calgary consists mostly of an irregularly meandering single-thread prairie stream in a 100 m wide valley. The channel is quite stable, with only very minor erosion or slope stability issues.

Hydrology

The median annual West Nose Creek hydrograph is highest in April and then decreases gradually through the summer and fall. Historical flood peaks have occurred before August. Flow is usually continuous between April and October.

The University of Calgary reactivated a discontinued streamflow station on West Nose Creek at the City boundary and has operated it since 2003. However, there is no active government-operated streamflow station on West Nose Creek, and no streamflow station of any kind near the mouth. Consequently there is no definitive information on stormwater inflows within the city. Stormwater inflows from 18 outfalls in Calgary are likely much less significant on West Nose Creek than on Nose Creek based on catchment area, but may still be important to the creek hydrology (in terms of both floods and normal flows), and therefore affect the creek morphology, water quality, and ecology.

West Nose Creek channel

Bed Material and Sediment

The creek bed and banks consist primarily of silt and clay. Fine sediment is available from bed and bank erosion, and from stormwater outfalls. Some coarse sediment is contributed to the stream from bank erosion.

Channel Dimensions

Channel top widths are typically 3 m, increasing to 5.5 m in Confluence Park at the downstream end of the channel. The average channel slope is 0.0023, but the upstream portion of the reach is flatter, with a slope of 0.0016, and the downstream reach is steeper at 0.0031.

Effect of the 2013 Flood

Recorded discharges at the hydrometric station indicate that the 2013 flood was the highest event recorded on West Nose Creek since 1982. However, no damage was reported.

7.3 Vision and General Recommendations

The City land use plans for West Nose Creek have included the establishment of extensive riparian reserves, parks and golf courses. These plans have produced a creek and valley that serve as a model of a well-planned urban stream, providing valuable benefits to the surrounding residents and the local ecosystem. The vision for West Nose Creek is that the existing stream management and stream corridor would be maintained so that the creek will continue providing those benefits into the future. The current development pattern that includes only limited development on the floodplain should continue.

The morphological threat of continued channel incision in the downstream reach of West Nose Creek should be included in any study of incision rates and potential interventions in Nose Creek.

The primary data gap in the current management of West Nose Creek within Calgary is the magnitude and effect of stormwater inflows. Creek management would be enhanced by a better understanding of the impacts of stormwater. Possible actions that would support a better understanding include:

- Initiation of a systematic streamflow monitoring program at the downstream end of the creek, in concert with continued streamflow monitoring at the City limits;
- Calibration of a catchment model based on the streamflow monitoring and precipitation and snowmelt monitoring;
- An update of the 2003 stream corridor assessment[13], to quantify morphological changes since the previous study and to assess how those changes confirm, or could be used to refine, the predictions made by that study; and

Development near West Nose Creek

- Characterization of base flow in the creek, possibly by base flow measurements or by detailed cross section surveys that include delineation of the edge of vegetation.

7.4 Risks and Potential Interventions

No high or moderate-priority site-specific morphological risks were identified on West Nose Creek.

Continued incision and widening in the downstream reach of the channel (Location 31 on Figure 2) may pose a threat to gas pipelines and pathway bridges. The threat appears to be a low priority, because historical incision and widening rates have been low.

West Nose Creek near the mouth

8 EPHEMERAL AND INTERMITTENT STREAMS

8.1 Definition and Occurrence

Ephemeral and intermittent watercourses represent an important subset of urban streams, characterised by the fact that water flows along them only rarely and briefly. These characteristics make the hydrology, geomorphology, water quality and ecology of an ephemeral watercourse especially sensitive to urbanization. Ephemeral streams provide flood conveyance functions as well as stormwater conveyance routes, and they either provide wildlife habitat, recreational opportunities, and aesthetic value, or could do so if managed appropriately. Consequently, special measures are required to protect ephemeral streams from the adverse impacts of urbanization. Similarly, restoration of ephemeral watercourses degraded by past urban development presents particular challenges.

Keystone Creek, an ephemeral stream in northeast Calgary

Ephemeral watercourses may be found throughout Calgary, including areas that were developed prior to current legislation governing stormwater runoff and environmental quality, and also in headwater basins around the perimeter of the city, where development is currently concentrated. Hence, there is an immediate need for guidance both on protecting unaffected ephemeral streams from proposed urban infill and expansion, and on restoring degraded ones.

8.2 Protection Guidance

Ephemeral streams are generally thought of as being less stable than perennial streams and this suggests that protecting their morphology requires that they be allowed space in which to adjust to prevailing conditions, respond to flood events and evolve more generally. This can be problematic, because developers are, entirely understandably, reluctant to cede land that could otherwise be developed to make room for urban streams - especially ones that could easily be buried or piped and built over.

Ephemeral streams are covered by the portion of the City's setback guidelines that requires a 6 m setback from a 1st order stream, defined as "typically a vegetated 'draw' that conveys flow primarily during periods of moderate to heavy rainfall and may not contain flow during other periods." This definition is open to a range of interpretation and a clearer definition would strengthen the City's management of ephemeral streams. The City recently commissioned a mapping project[14] to identify existing ephemeral streams, which should assist in providing clarity both to City management and to developers.

A key element of protecting ephemeral and intermittent streams is to provide a buffer between the channel and the surrounding urban development. The Government of Alberta's *Stepping Back from the Water*[15] recommends a vegetated filter strip 6 m wide for the protection of water quality on each side of a first-order stream. The 6 m width is consistent with the City's specified 6 m setback. However, the provincial guide indicates that the vegetated filter strip is only one component of a buffer strip. Other components mentioned in the guide address considerations such as groundwater, slope stability, and flooding. The approach recommended by *Stepping Back from the Water* seems to provide a good basis for protection of ephemeral streams in Calgary, but it should be modified to include explicit consideration of morphological aspects as well. The buffer should include a channel migration zone of sufficient width to accommodate cyclical planform changes and evolutionary trends.

9 CONCLUSION

Work in and around the streams in Calgary and elsewhere has historically paid scant attention to morphology. Infrastructure has been constructed at erosion-susceptible locations, river engineering works have contributed to downstream erosion damage, and sediment transport has been disrupted resulting in upstream flood damage. In addition to the financial costs, these actions have had environmental and ecological consequences.

The thesis of this study is that it would be best, from both financial and environmental perspectives, to allow Calgary's streams to meander and evolve naturally wherever possible, rather than attempting to control the migration. When infrastructure is damaged or threatened, the default response should be to move or replace the infrastructure at a less susceptible location, rather than armouring the stream bank. Where development has not yet encroached on the river, the default assumption should be that stream could occupy any position in the valley. Therefore, new development, or substantial redevelopment, anywhere in the valley bottom should be limited to developments that could readily tolerate erosion and flooding damage, such as pathways and parks, unless site-specific geomorphological, hydrotechnical, and geotechnical assessments are conducted to show that the particular site is appropriate for the proposed development. When bridges are replaced, or new bridges are constructed, the selection of the bridge opening should consider the impact of the bridge on morphological processes such as channel migration, erosion, and sediment transport. When any river engineering project, including bridges, bank protection, and fish habitat enhancement projects is designed, the effect of morphological processes on the project, and the effect of the project on morphological processes, should be thoroughly considered.

If these recommendations are followed, Calgary's streams will evolve to become more natural over time, reducing costs of flooding and erosion damage and protection works, and providing better water quality, improved aquatic and riparian habitat, and more opportunities for public interaction with our rivers and creeks.

NOTES

[1] F. Frigo, City, pers. comm.

[2] F. Frigo, City, pers. comm.

[3] Federal Highways Administration. 2001. *River Engineering for Highway Encroachments: Highways in the River Environment.* Hydraulic Design Series Number 6. National Highway Institute, U.S. Department of Transportation. Publication No. FHWA NHI 01-004. https://www.fhwa.dot.gov/engineering/hydraulics/pubs/nhi01004.pdf.

[4] AMEC Environment and Infrastructure. 2012b. *Design Guidelines for Erosion and Flood Control Products for Streambank and Riparian Stability Restoration*. Submitted to the City of Calgary, Water Resources. Project No. CW2098.

[5] Bray, D. I. 1982. Regime Equations for Gravel-Bed Rivers. In *Gravel-bed Rivers*. Wiley, Chichester, UK, 517-542.

[6] Golder Associates Ltd. 2014. *Basin-Wide Hydrology Assessment and 2013 Flood Documentation: Bow River and Elbow River*. Report prepared for Alberta Environment and Sustainable Resource Development (ESRD) and The City of Calgary.

[7] Specific locations along the streams are identified in this study by stream km. Stream km are shown on the maps in Appendix I of the main report, and increase in the upstream direction.

[8] Glenbow Archives NA-2957-3.

[9] Golder Associates Ltd. 2015. *Bow River and Elbow River: Hydraulic Model and Flood Inundation Mapping Update*. A report to City of Calgary, Water Resources and Alberta Environment and Parks, River Forecast Section. Report No. 13-1326-0054.

[10] Golder (2014).

[11] It is understood that flood frequency estimates for Fish Creek have been updated but the results have not been released publicly.

[12] Alberta Environment. 1983. *Calgary Floodplain Study*.

[13] Westhoff Engineering Resources, Inc. 2003. *West Nose Creek Stream Corridor Assessment, Phase 2*. Prepared for the City of Calgary, Wastewater. June 2003.

[14] AMEC Foster Wheeler Environment & Infrastructure, Tannas Conservation Services, and Intelligent Futures. 2017. *Ephemeral and Intermittent Stream Maps*. A report to the City of Calgary, Water Resources.

[15] 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*. Regional Science and Planning, Alberta Environment and Parks, Government of Alberta, Calgary.

SPRINGBANK OFF-STREAM RESERVOIR

Why SR1?

Following the 2013 flood, the Government of Alberta began exploring the available options for flood mitigation along the Elbow River. Of the available options, the Springbank Off-Stream Reservoir (SR1) was chosen for a number of reasons.

- It will have a lower environmental impact;
- It will be less expensive;
- It will be quicker to build;
- It will be closer to Calgary, providing greater protection and ease of operations.

The updated net project cost of SR1 is approximately $372 million.

The Environmental Impact Assessment (EIA) for the project is nearing completion and will be submitted in October 2017. This review will take approximately one year, allowing construction to begin in late 2018.

SR1 is scheduled to be operational by the end of 2020.

The alternative project that has been examined for the EIA is at McLean Creek. Detailed design and planning work estimates that building the McLean Creek project would cost approximately $34 million more than SR1.

McLean Creek would be more expensive, have a greater environmental impact, take longer to build and would be at risk of failure if a flood occurred during construction.

CITY OF CALGARY (2013)

Kamp Kiwanis

In 2013, the flood caused significant damage to Kamp Kiwanis, with most of the on-site buildings flooded.

A portion of the camp lies beyond planned SR1 infrastructure and camp access to the Elbow River will continue. Alberta Transportation will continue to work with Kamp Kiwanis to explore future uses in the area to ensure that the thousands of annual visitors can continue to enjoy the camp as they have for decades.

Land Acquisition

Following consultation, landowners were notified in July 2017 that Alberta Transportation will move forward with the offer to purchase any quarter-section parcel of land touched by the SR1 project footprint.

Land outside of the project footprint would only be purchased by Alberta Transportation at the landowners' request.

There are 22 residences within the total offer. Only five residences exist within the required 3,610 acres needed for the project.

Tsuut'ina Nation

Relevant and informed consultation with Indigenous groups is an important element of all projects that the Government of Alberta undertakes. For SR1, consultation and engagement continues to occur with 13 separate Indigenous groups.

Consultation and conversations about SR1 have been ongoing with the Tsuut'ina Nation since 2014. The project sits approximately 1.5 kilometres north of the Nation boundary.

Alberta Transportation and the Tsuut'ina Nation have formed a technical committee for flood protection at Redwood Meadows, which would serve to protect the Tsuut'ina Nation.

Consultation

Public and stakeholder consultation has also been ongoing since 2014. During this time, the Government of Alberta has responded to hundreds of inquiries taken part in the following consultation efforts:

- Small group/one-on-one meetings/facilitated presentations with affected landowners
- Ten public open houses
- Over 60 meetings with stakeholders including Bow River Basin Council, Elbow River Watershed Partnership, Alberta Environment and Parks Water Collaborative, Calgary River Communities Action Group, Calgary Regional Partnership and the Western Irrigation District
- Meetings with Rocky View County and City of Calgary Administration
- Meeting with industry/utility groups.