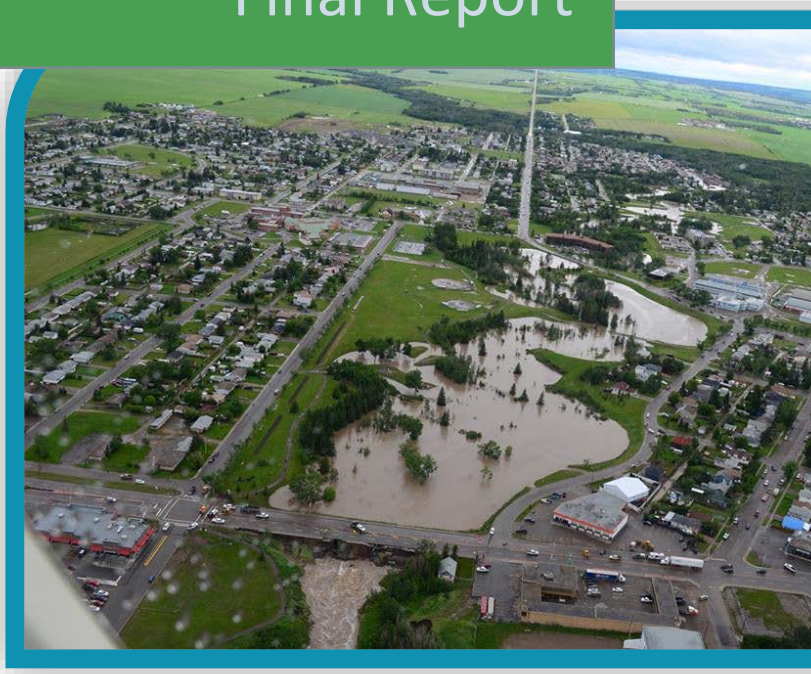
City of Dawson Creek
Flood Mitigation Planning
Final Report



August 14th, 2018

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Acknowledgements

Support for this project came from the British Columbia Government through what is now called the Community Emergency Preparedness Fund as part of its commitment to building safer and more resilient communities.

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The report was written by Heather Murdock, P.Eng and Nikoletta Stamatatou, M.Sc. with support from Tara Sherman, P.Eng, all of Ebbwater Consulting Inc. Erica Crawford of SHIFT Collaborative led the engagement process and wrote the workshop reports. The report reviewed by Tamsin Lyle, P.Eng, principal of Ebbwater Consulting Inc..

Executive Summary

Flood events in Dawson Creek have caused considerable damage and impact to infrastructure, the environment and the community more broadly. The City of Dawson Creek (City), along with other levels of government, have made significant effort to manage flood impacts over the last decade, and have expended millions of dollars on crossing upgrades, and hundreds of thousands on emergency response in the last few years alone. With some of the major structural works completed or underway, there is now a need to consider a broader suite of options to manage flood in the City.

Best practice dictates that flood mitigation be achieved through a thoughtful, risk-based planning process based on community values and with consideration of a range of hazard levels. The City of Dawson Creek have shown leadership through their willingness to work through a best practice approach as opposed to continued reliance on engineered and reactive measures for flood mitigation. A best practice approach will not only create a more resilient community in the long-term, but creates opportunity for senior-level government funding to support flood mitigation by aligning the outcomes and direction of this project with senior-level government policy direction.

To support the development of a flood mitigation plan, the City of Dawson Creek retained Ebbwater Consulting and SHIFT Collaborative in September of 2017 with support of a grant from the BC Community Emergency Preparedness Fund (CEPF).

Over the course of the project, based on the needs of the City and of the granting agency, along with what could and should be accomplished through this project, a series of objectives were evolved:

1. **Better understand hazard, vulnerability and risk.** Without an understanding of the hazard, vulnerability and risk posed by flooding to the community, it is not possible to robustly reduce flood risk. This project sought to develop a base understanding of flood risk in the City
2. **Lay foundation for stakeholder engagement**. Several recent flood events have highlighted the need to communicate flood risk and potential mitigation options to stakeholders and the public. This project sought to develop a common understanding of flood risk and potential risk reduction measures by engaging stakeholders and some members of the public.
3. **Lay foundation for future funding.** Funding programs for flood in Canada – both for foundational research and planning studies and for implementation of flood reduction measures – require that basic risk assessments are completed. This project sought to develop materials to support future funding applications, including risk assessments, project scopes and costings.
4. **Prepare framework for mitigation planning.** Understanding flood risk is merely the first step in developing and implementing a flood mitigation plan. This project sought to develop base information to support future mitigation work, and to layout a framework for the City to follow.
5. **Provide no regrets actions.** At this stage, without appropriate engineering studies, it is not prudent to make large structural mitigation recommendations; many of these types of projects can exacerbate the problem or increase flood hazard either upstream or downstream. And therefore, this project sought to provide a list of no-regrets planning, policy and education actions that can be implemented by the City to reduce flood risk.

Project Context and Problem Statement

Dawson Creek has experienced numerous flood events in the last decade that have increased the level of concern (Figure E-1). These events have flooded basements through sewer and water back up, homes have experienced overland flooding, and the city centre has been cut in half with roads, bridges, and culverts affected. It is expected that flood hazards will become more severe in the coming years with climate change and it is important to understand what the impacts of future floods will be, so that appropriate mitigation measures can be implemented.

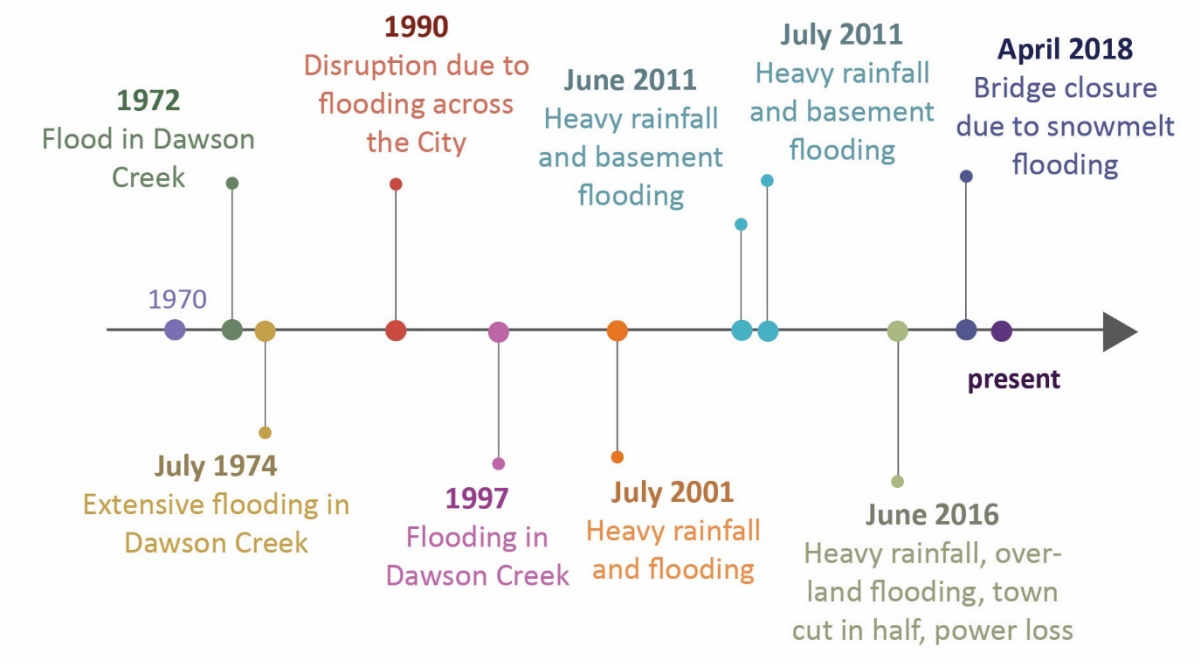

Figure E-1: Timeline of historical flood events in Dawson Creek

The City has responded to these many flood events and has invested significant resources and dollars in an effort to reduce flood damages. The work completed to date shows a clear commitment by the City and Province to mitigate flood impacts in the City. It should also be noted that the works have been generally reactive, in that significant expenditures are made in the aftermath of flood events, especially when damage has occurred to the infrastructure. This shows a clear commitment to the mantra of "build back better", which is to be applauded, but also highlights the fragmented, but very common, approach to flood management, where problems are addressed as they arise, rather than focussing on a comprehensive planning approach that identifies key areas of concerns, uses consistent data and models, and considers and evaluates multiple flood mitigation options. This current project has been created to address this gap and lays the groundwork for the development of a comprehensive flood plan and highlights the leadership at the City to work towards best practice rather than continuing to react to flood events.

Since 2004, the City of Dawson Creek as a local government within BC, has a responsibility to manage its lands for flood hazard. The City has made efforts to meet this responsibility, and as updated its Official

Community Plan (OCP) and related Development Permit Area (DPA) regulations to provide some guidance on development within flood hazard areas. The OCP and DPA provide high-level guidance that suggests a good direction for flood management. However, the language is weak (i.e. the use of the word *discouraged* as opposed to *prohibited*), and the guidelines are relatively vague (as opposed to specific). The City is currently in the midst of re-issuing its OCP. There is a good opportunity to improve the language and specifics within the DPA at this time; **proposed language to strengthen these policies is provided as a deliverable in this report**.

Flood management is primarily a local government responsibility. However, flood mitigation, especially structural flood mitigation projects, are generally far more expensive than local government budgets can stretch. In recent years, the Provincial and Federal governments have developed new granting programs to support flood mitigation planning as well as to implement flood management solutions. The overall mandates for these programs, show a clear directional shift in senior government funding for mitigation of flood and other natural hazards. Namely, senior government is shifting away from reactionary funding and from a focus on structural measures towards investing on long-term resiliency based on comprehensive risk-based plans. In order for the City of Dawson Creek to leverage these funds in future, the City needs to invest in the development of a comprehensive flood management plan. This current project lays the foundation for this type of work and will put the City in good stead for senior level government funding in future. Specific next steps towards an overall strategy of flood resilience are provided in this report along with a discussion of best practice; the City is showing by working towards best practice and doing "the right thing" rather than reactively relying on past methods for flood management.

Project Analysis and Results

Hazard Analysis

Flood hazard (i.e. and understanding of where, how deep and how fast water is expected to be) is a foundational piece of information for any flood mitigation plan. The City of Dawson Creek has a basic understanding of flood hazards, including a 0.5% Annual Exceedance Probability (AEP[i]) flood hazard map from the 1970s, which is used to define extents in local regulations. Further, a 0.5% AEP flood hazard extent and historical 2016 flood event extents were recently defined as a component of consulting engineering work to look at hydraulic design of various Creek crossings. These models and maps were suited to their purpose, however, flood risk assessment and mitigation planning is best done with hydraulic models and mapped designed for the purpose of flood management. In this case, modelling that shows extents – but also depths and velocities, and further models and maps that highlight the variation in hazard from different flood scenarios and likelihoods. To achieve this requires the development of detailed hydrologic and hydraulic analyses. Hydrologic analysis provides information on

[i] Annual Exceedance Probability or AEP describes the likelihood of a flood of a given size or large occurring in any year. In this case, a flood with a 0.5% chance of occurring in any given year; this is sometimes called a 200-year flood.

present-day and future (with climate change) estimates of the volume of water that might be expected. Hydraulic analysis establishes where the water will flow and how deep and fast it will be, and this generally requires the development of a hydraulic model. Inputs to a hydraulic model include an understanding of the river shape and other geomorphic characteristics (e.g., bed roughness), along with an understanding of conditions at the upstream end of the model (i.e., flow estimates) and at the downstream end of the model (usually water level estimates).

The scope of work for this project did not include a detailed hazard assessment, and there are therefore limitations associated with the results. However, the results of this project (a completed risk assessment) will provide the City with the information to support an application to funding programs to develop a flood hazard model and map that includes up-to-date information (e.g., bathymetric surveys), and meets current best practice and guidelines for flood modelling and mapping. **A deliverable of this project is a proposed scope of work and budget along with all other materials required for funding applications**.

In order to move this project forward, existing studies, models and maps, were leveraged to develop some high-level flood extent and depth maps suitable for community engagement and for risk assessment. A specific requirement of the risk assessment method used for this project was an understanding of different severities of flood events. Generally, older flood studies will only focus on a given historical event or a single severe event. While the impacts of a severe event may be large and wide spread, minor flooding can occur more often and cumulatively cause similar level of damage. Descriptions of these hazard events are presented in Table E-1. Some of these hazard levels may be tolerable more often and others may be tolerable rarely. The frequency of tolerance to different hazard levels could be assessed in the future.

Table E-1: Typical minor, moderate, and severe flooding descriptions

	Minor Flooding	Moderate Flooding	Severe Flooding
Description	Some overland flooding with depths around 10 cm. Generally, recedes within a couple of days. Sometimes described as nuisance flooding.	Moderate overland flooding with depths around 30 cm. Generally, recedes within a few days, although in some systems longer durations (1-2 weeks can be expected)	Extensive overland flooding with depths over 100cm. Depending on the system, flooding can last from days to weeks.

Flood hazard maps for each severity of flooding were produced. This modelling and mapping were developed to support the collection of exposure and vulnerability data at stakeholder workshops. The mapping is suitable for preliminary discussion; it is not suitable for detailed planning or engineering design.

The modelling showed that with increasing flows (to represent minor through severe floods), the flood extents, within the downtown core do not increase significantly; this is because the creek remains within the relatively deep and confined channel (Figure E-2). Outside of the downstream core, most notably near the confluence of Dawson Creek and South Dawson Creek, where the topography is gentler, the flood hazard extents expand significantly with the increasing flows. Further, the depths of water – are also much greater for higher flows. The preliminary mapping highlights this area (i.e. the confluence of the creeks) as being an area of high flood hazard that should be considered as a priority going forward. This is also highlighted as an area of high risk later in this report.

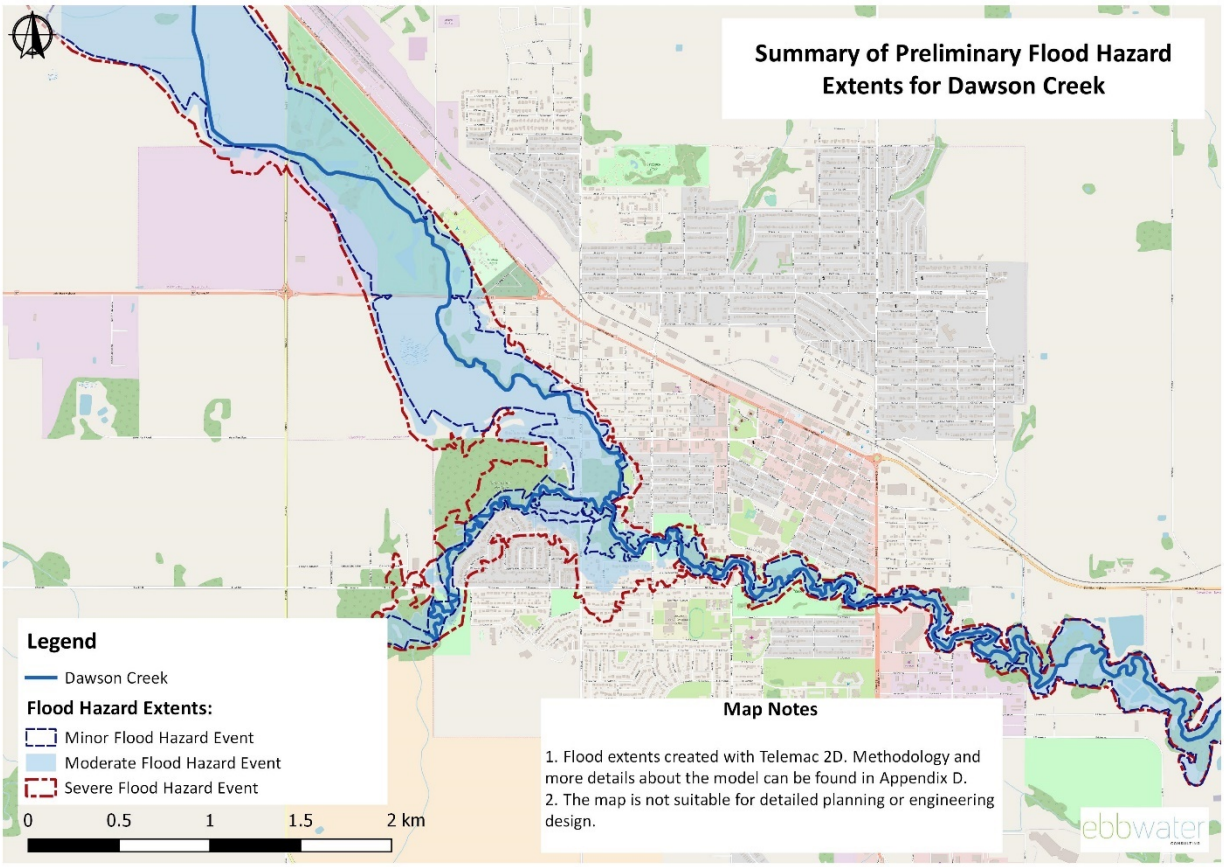

Figure E-2: Summary of extents for minor, moderate, and severe flood hazard

Exposure, Vulnerability and Impacts

A key component of any risk assessment and flood mitigation plan is an understanding of what is in the way of the water (the exposure), as well as an understanding of how each of the assets in the way of water will react and recover from being wet (the vulnerability). Vulnerability to flooding was explored with the community, through workshops, and by using available data sets, and recorded spatially. This information is invaluable in communicating the overall level of risk in future grant applications and can also be used to select the best flood mitigation options to actually work to reduce risk.

The following summarizes the results of the exposure and vulnerability analyses and includes some discussion for each of the six impact categories. These are assessed for minor, moderate, and severe flood hazard and presented spatially for the moderate flood.

Affected People

Impacts to people, as a result of temporarily or permanently losing shelter, employment or schooling is a key indicator of flood impacts. This is reported as hotspot mapping, based on stakeholder input, as well as a quantitative measure based on census information. This analysis highlights the directly affect community of people in and around the confluence of the creeks (Figure E-4), and those that are indirectly affected across the community at large (Figure E-5). This highlights the need to prioritise and consider the area of greatest impact (the creek confluence and 8th Avenue crossing), but also the need to consider solutions that will reduce impacts to the community at large.

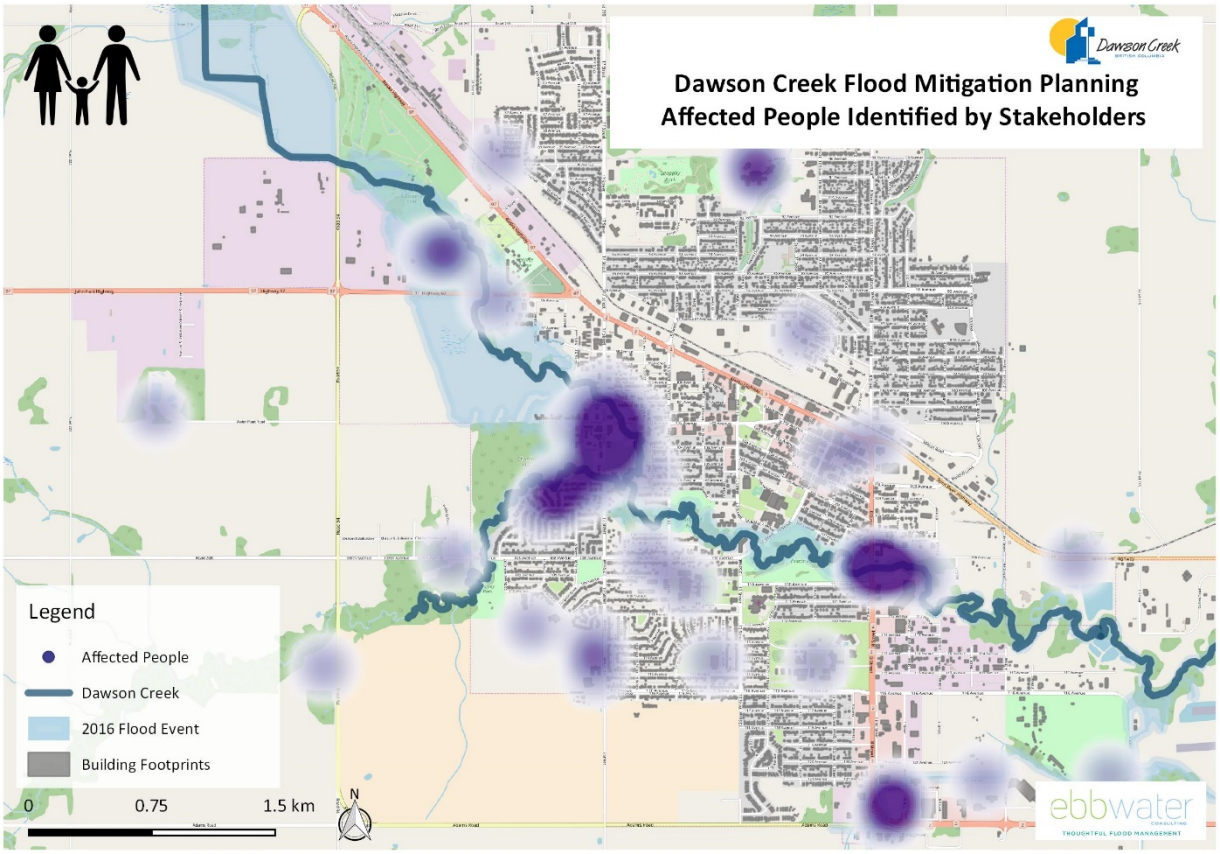

Figure E-3: Hotspot map of affected people as reported by stakeholders in workshops

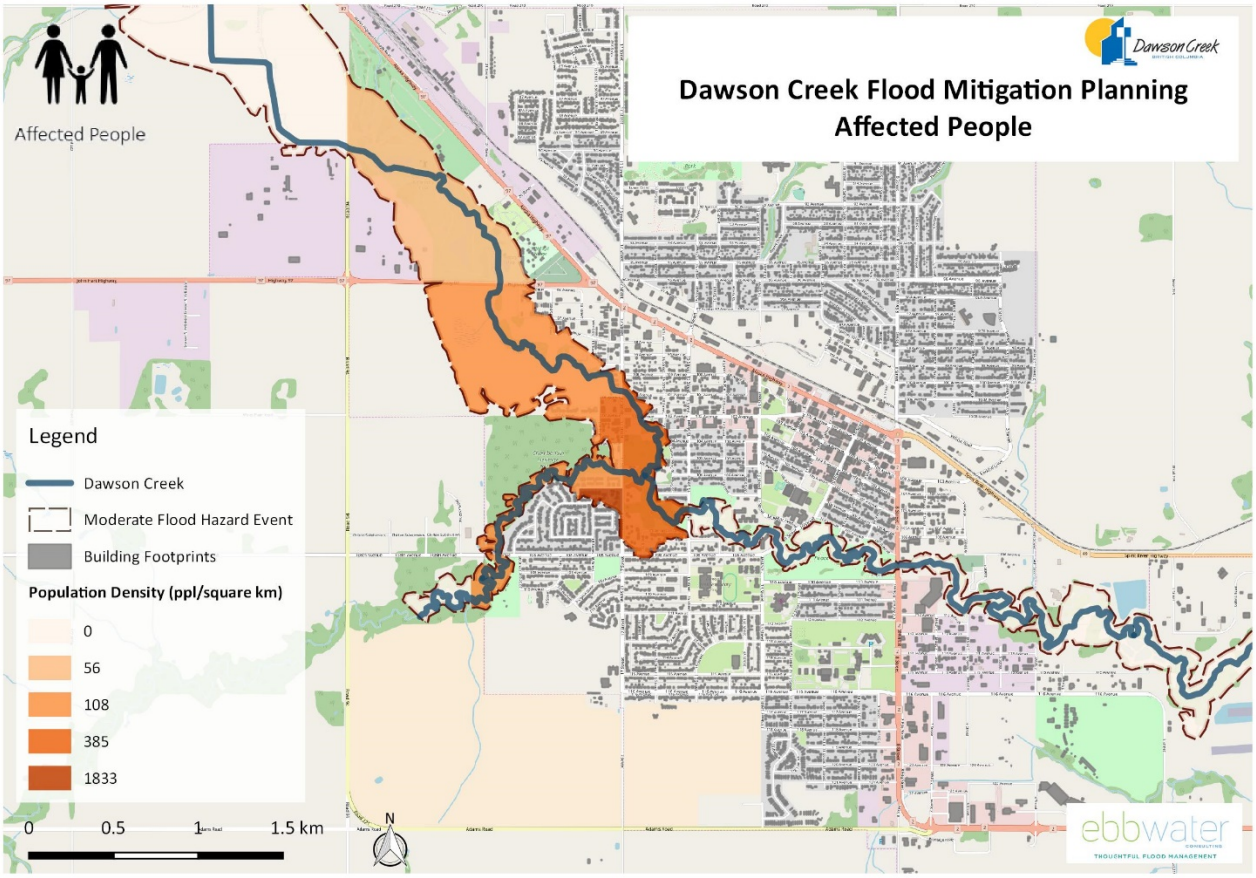

Figure E-4 Population density in Dawson Creek by dissemination area for moderate flood hazard

Table E-2: Affected people for minor, moderate, and severe flood hazard

Affected People		
Minor Flood Hazard	Moderate Flood Hazard	Severe Flood Hazard
158 people	276 people	693 people

Economic Impacts

Economic impacts are important to measure because they represent the effect that flooding can have on local livelihoods and commercial facilities. Further, economic impacts are often used to support the business case for flood mitigation planning and infrastructure. Figure E-5 shows the high-level hotspots of economic impacts for the community as reported by stakeholders in the workshop.

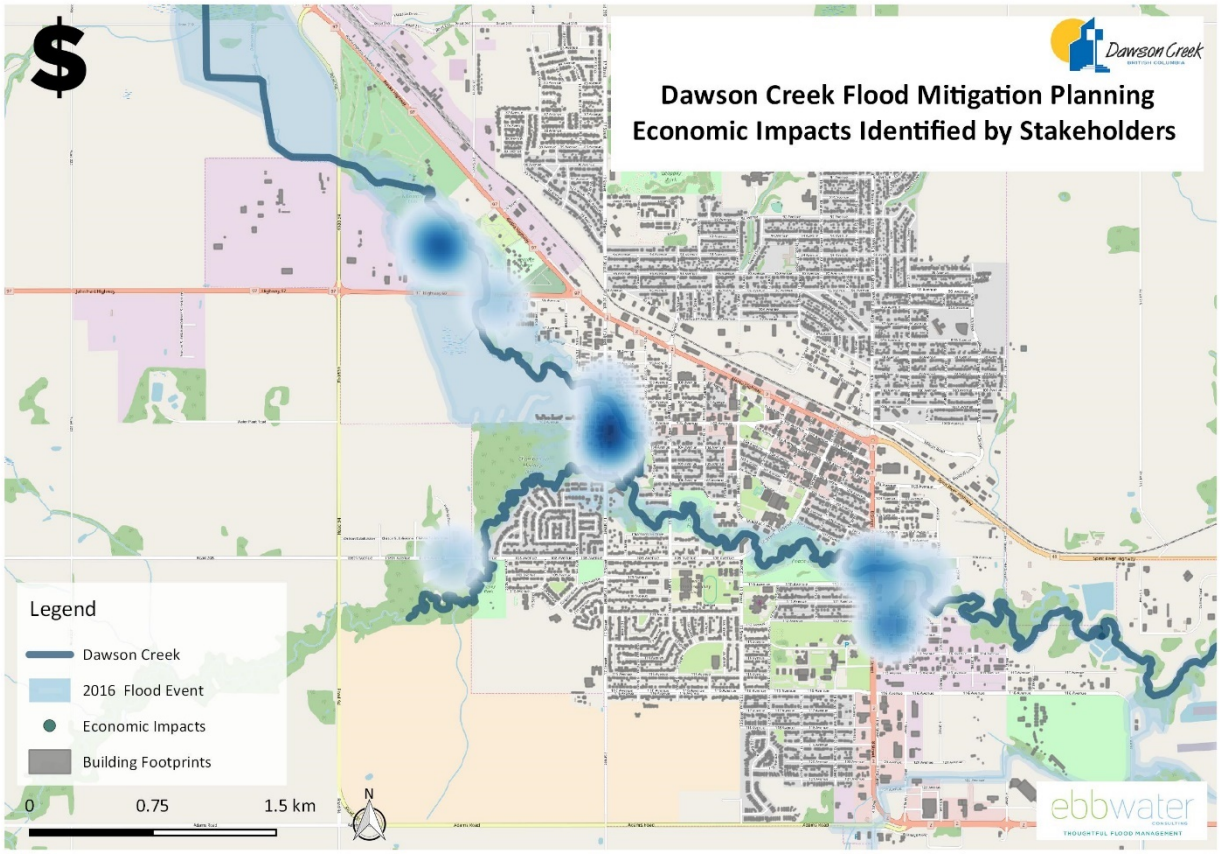

Figure E-5: Economic impact of flooding in Dawson Creek as reported by stakeholders

The value of property in the flood hazard area was calculated using the available BC Assessment Authority Roll data (from 2018). This provides a more quantitative estimate of economic impacts of flooding. The estimated value of property in the flood hazard area is **$75 M** for this the moderate flood scenario (Table E-3).

Table E-3: Economic - property value in flood hazard area

Economic – Property Value in Flood Hazard Areas		
Minor Flood Hazard	Moderate Flood Hazard	Severe Flood Hazard
$51 M	$75 M	$141 M

Disruption

Disruption due to flooding refers to the number of disruptions to basic services attributed to the disaster. It is important to consider this because it represents the effect of flooding on infrastructure, services, and

the people using those services. Disruption, as recorded from workshop participants, is shown in a high-level hotspot map in Figure E-6 and is also presented in Table E-4.

From this map, it can be seen that there is disruption recorded throughout the community. Some clear hotspots include bridges and creek crossings. Another hot spot is on the south end of the community where drainage from the bear mountain area (Ski Hill Creek tributary) drains into the town. Some disruption is due to power outages from linear infrastructure crossing the river being damaged. The transmission station for Dawson Creek is located on the north side of the City and so the south side of the City is vulnerable to power outages.

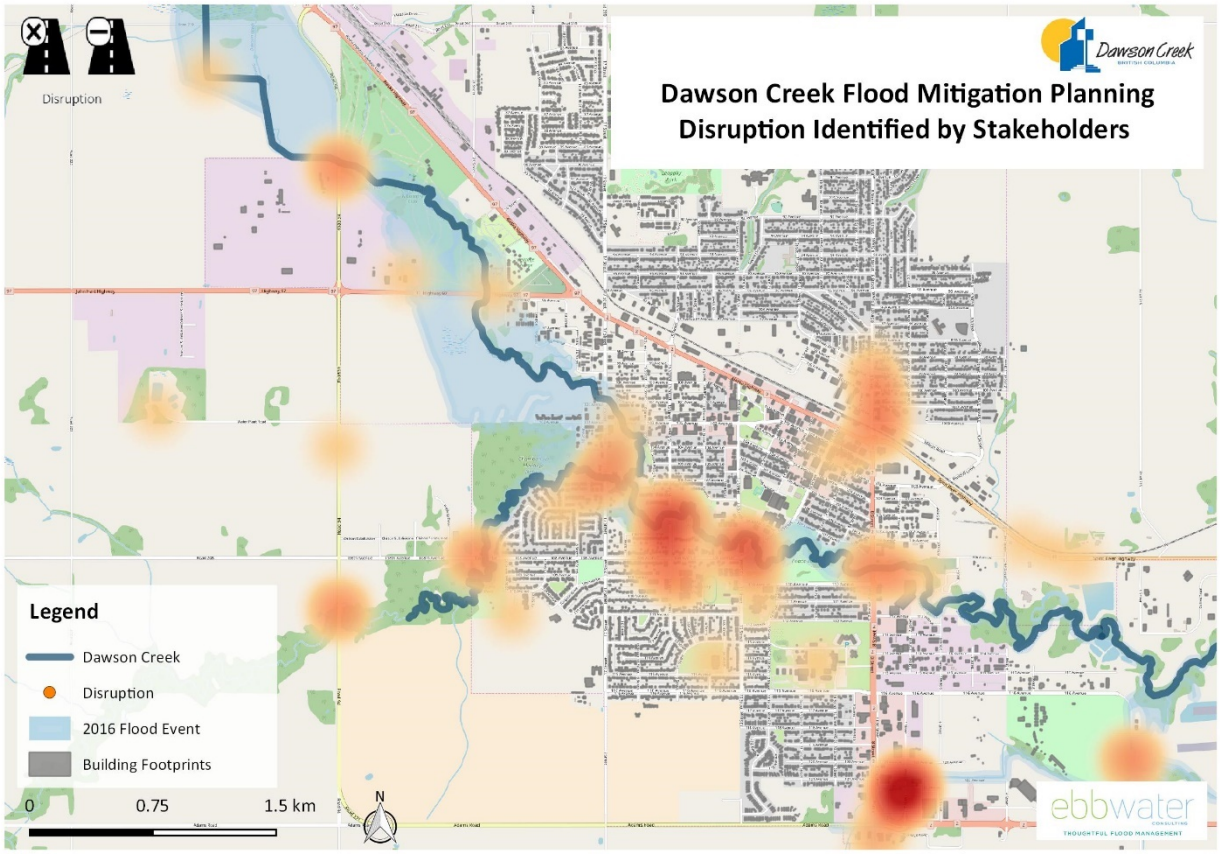

Figure E-6: Disruption due to flooding with input from stakeholders

Table E-4: Qualitative disruption for minor, moderate, severe flooding

	Minor Flooding	Moderate Flooding	Severe Flooding
Disruption	10% of creek crossings flooded, mostly local disruption.	80% of creek crossings flooded, significant local and regional disruption. Some residents likely displaced from homes for several days and disrupted for over two weeks. Emergency response likely needed for elderly and people with disabilities, etc.	100% of creek crossings flooded, extensive local and regional disruption. Some residents likely displaced for 1-2 weeks and disrupted for a month. Emergency response needed including possibly addressing utilities interruptions outside flooded area.

Environment

Floods can have an impact on the environment in a number of ways. Flooding can cause erosion, damaging vegetation along the water's edge, and flood water often spreads contaminants as they are picked up in the flood hazard area and transported. Several hotspots of environmental factors were identified by local stakeholders as shown in the high-level hotspot map in Figure E-7.

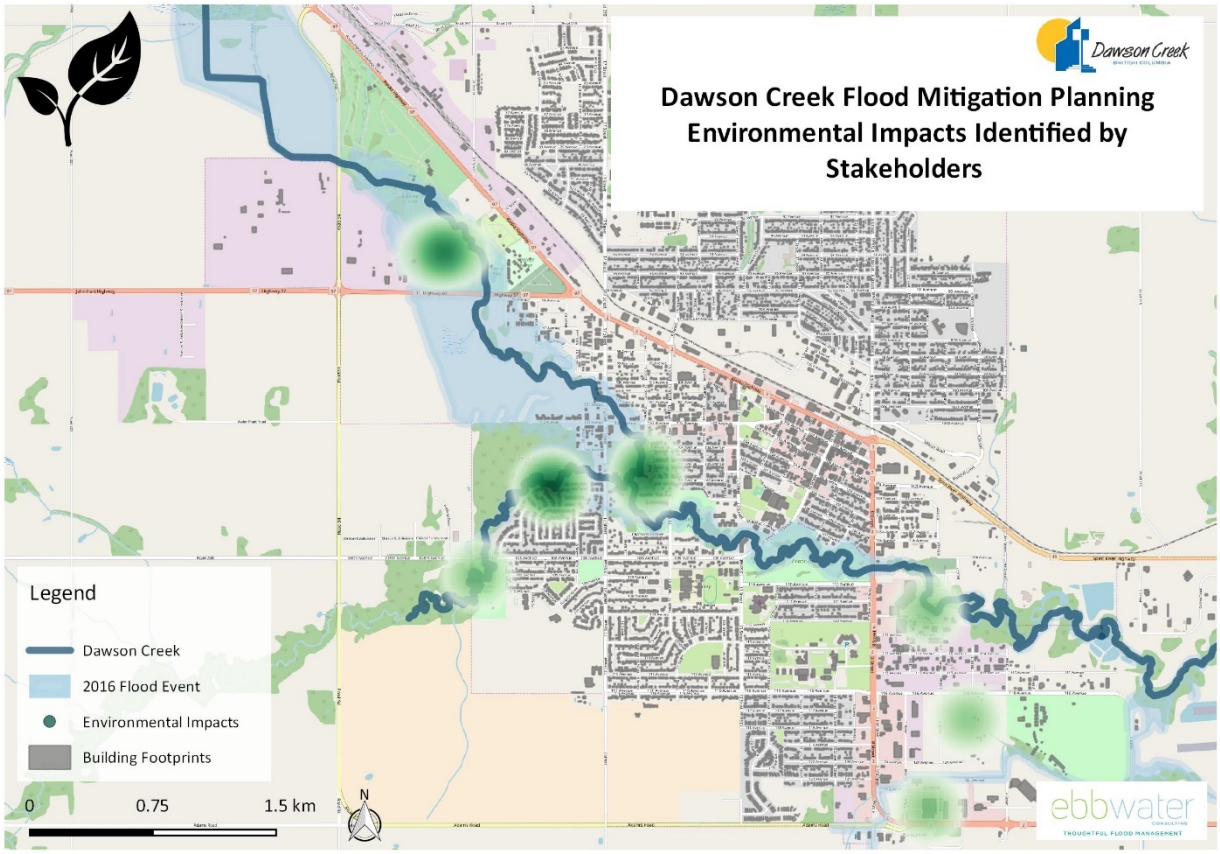

Figure E-7: Environmental impacts due to flooding with input from stakeholders

Direct and Indirect Impacts

In addition to the indicator specific indicator risk that are mapped above, impacts were also recorded based on being either direct (i.e. something that got wet) or indirect (an impact that occurred outside the flood hazard area, or after the flood event). The results of this analysis are presented in Figure E-8 and Figure E-9.

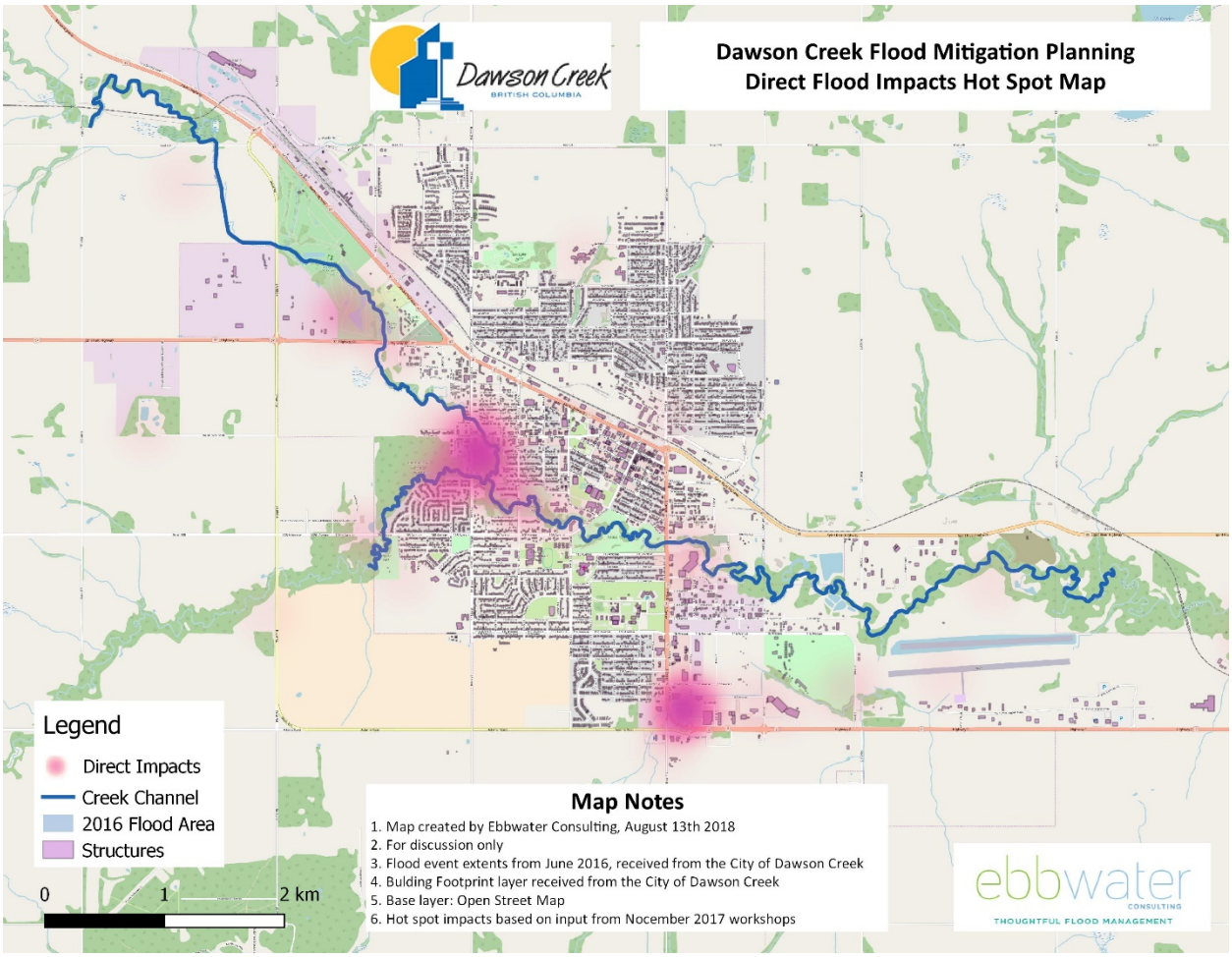

Figure E-8: Direct impacts due to flooding with input from stakeholders

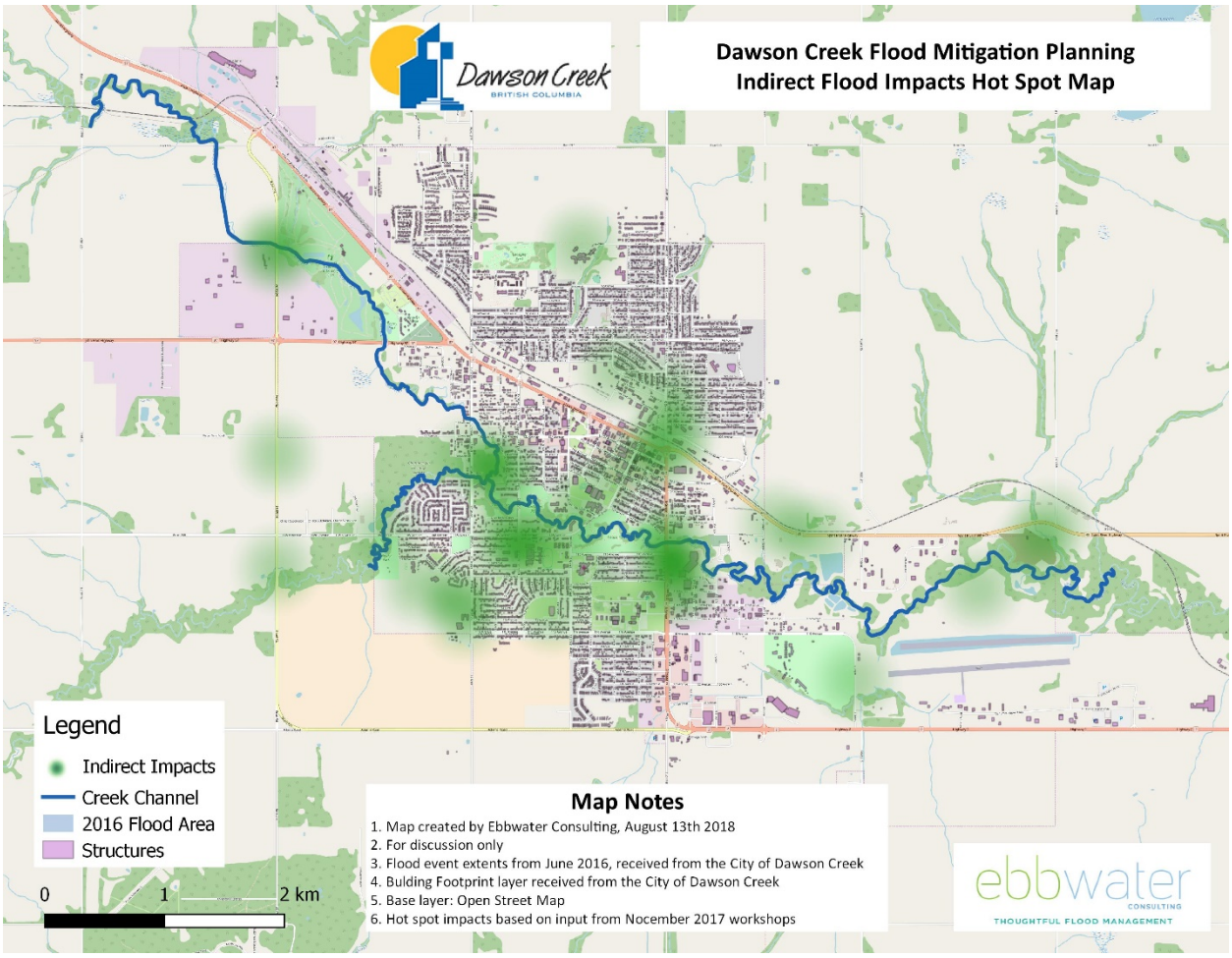

Figure E-9: Indirect impacts due to flooding with input from stakeholders

In summary, the maps for each of these impact categories paint a picture of where there are potential impacts of flooding and provide some context for thinking about what kinds of measures might be appropriate to address these issues. Simply, the risk analysis and hotspot mapping provide an indication of where efforts need to be targeted in order to get the biggest return on investment on any flood mitigation measures. Some specific commentary based on the results:

- There are significant impacts to people, the economy, and disruption. There are lesser impacts to the environment.
    - Impacts to people are dispersed; many community members were impacted by flooding regardless of where they lived in the City.
    - Economic impacts are clustered in three specific areas: at the 8th Street Bridge Crossing, at the 17th Street Bridge and 102nd Avenue Culver crossings, and upstream of the John Hart Highway crossing.
    - Environmental impacts are mostly concentrated in areas that are currently more naturalised.

- For most indicators, the difference in minor and moderate flood hazard is relatively minimal. Whereas severe flooding results in much greater impacts. This is primarily a result of the flood hazard extents not changing dramatically until a threshold volume is exceeded and the creek escapes the relative confinement of channel. This is not true for the quantitative measure of disruption, where disruption increases more linearly for the various flood hazard severities.
- Direct and indirect impacts are equally important.

Given the above the following notes can be made on how the results can inform future flood mitigation efforts:

- Apart from the economic indicator, which is clustered, most impacts are dispersed across the City. This indicates a need for regional-scale, planning-type tools to mitigate risk, rather than targeted segmented and specific responses.
- For economic impacts, along with the identified disruption impacts, the greatest impact and risk reduction will be achieved by managing the flood hazard in and around the 8th Street crossing; this is currently being managed by MOTI, who have slated this crossing for replacement starting in fall 2018.
- Given the significant impacts seen for more frequent, less severe events, it is imperative that these be considered in any decision process, rather than focussing on a single standard extreme event (such as a 0.5% AEP).
- Indirect and direct impacts are equally important; they should all be considered in any flood mitigation planning process.
- The geographically dispersed nature of the impacts highlights the need to work with neighbouring jurisdictions on any flood plan.

Flood Risk in Dawson Creek

The approach for this project was to conduct a true *risk assessment*. That is one that looks at both the *flood hazard* and *flood likelihood* (where the water will go and how often it will be there), as well as *vulnerability* (what is going to be affected by water). The risk assessment conducted for this project simply considers the combination of likelihood and impacts using a simple matrix (Figure E-10). This high-level risk assessment was done in line with the requirements for various funding programs, but also provides some early insights and quick wins to support planning and emergency management for flooding in the community.

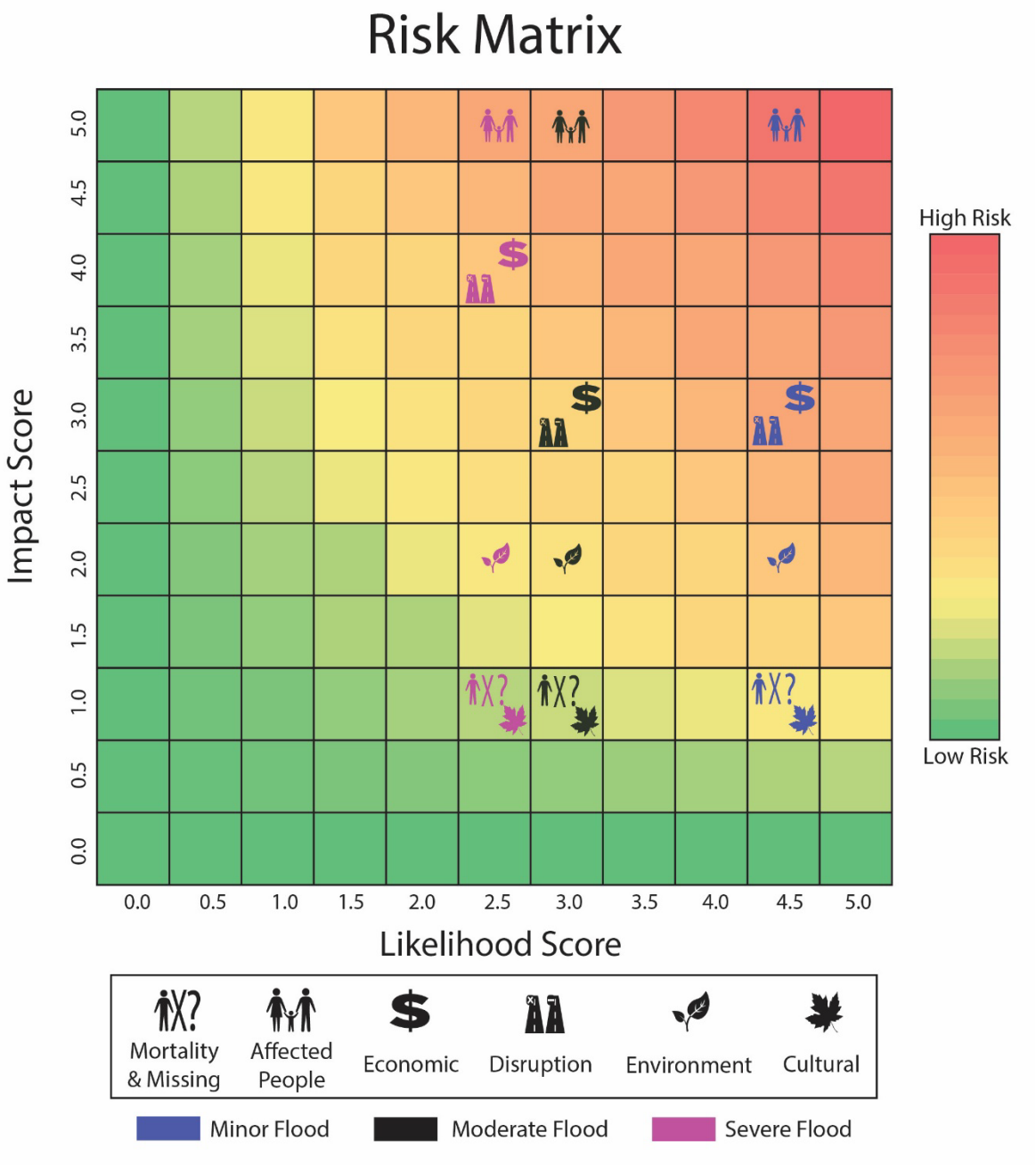

Figure E-10: Summary of flood risk for City of Dawson Creek

It is clear from the above analysis that affected people risk is significant in all cases. Disruption is also high for the moderate and severe flood hazard events. It is however less extreme for the minor flood event. In general, the flood extents for Dawson Creek are quite binary, meaning that up to a specific threshold the impacts are small as the channel is quite confined. Once the water is over the banks, the extents quickly increase; this can inform the selection of flood mitigation options.

Stakeholder Engagement

Building on the City of Dawson Creek's ongoing efforts to manage risk and build resilience, this project intentionally engaged a broad set of stakeholders at two points in the process. This served to build awareness & understanding of impacts and risk, and to begin to describe the elements and characteristics of a flood resilient community. Due to the nature of flood as a "wicked problem", engaging stakeholders in this type of a process is an essential first step towards understanding and building resilience for the community. Joint understanding, ownership, action and ongoing learning is essential for a community to become truly resilient.

Two stakeholder workshops were held, along with an open public meeting. Further to this engagement the project has a social media presence with a Facebook page that was updated regularly throughout the project. The key directions identified by stakeholders for enhancing community resilience to flood risk were:

- Engage in proactive and coordinated flood management
- Plan and build with floods in mind
- Explore opportunities for a watershed approach
- Strengthen emergency planning and management
- Develop a resilient community culture

The results of the engagement are reflected in the results of the analysis (the impact and risk assessment), and directly in the next steps and recommendations (i.e. stakeholder options are explicitly considered). Further the results of the engagement can be leveraged to support many of the next steps in the flood planning process.

Project Achievements, Next Steps and Recommendations

A general process for flood risk reduction and increased resilience, based on best practice for flood management is presented in this report. Progress towards completion of this process is summarised in Table E-5.

Table E-5: Summary of progress and next steps for flood risk reduction

Step		Progress	Next Step
1. Acknowledge problem and set the stage	100%	This step has been achieved through this project. Specific deliverables related to this step include the development of reports and maps that outline the problem, multiple stakeholder and public workshops, and ongoing engagement through social media.	

Step		Progress	Next Step
2. Identify and establish hazards	50%	This step has been achieved through this and other studies at a high-level. Future refinement is required in order to develop models and mapping suitable for flood planning (as opposed to structure design) that also meets current standards and guidelines.	Apply for funding to develop suitable flood modelling and mapping. Funding programs have been identified, and application materials developed to support this application.
3. Identify exposure and vulnerability	95%	This step has nominally been achieved through this project (see Section 5). However, this step should be seen as iterative – and should be revisited and refined in future as information is improved.	Review and refine in any future flood planning projects.
4. Identify consequence and risk	95%	This step has nominally been achieved through this project (see Section 6 and Appendices A and B). However, this step should be seen as iterative – and should be revisited and refined in future as information is improved.	Review and refine in any future flood planning projects.
5. Establish objectives and measures of success	50%	Preliminary information to support this step was gathered through stakeholder engagement exercises as part of this project. Additional effort to refine measures of success will need to be made in future.	On completion of, or in parallel to flood hazard mapping, source funding and initiate a broader flood planning process that includes the development of measures of success. See below for additional information.
6. Identify flood mitigation options	50%	A full toolbox of potential options used for riverine flood mitigation is presented in Section 8.2.4 and options voiced in engagement are presented in 7.4 . With additional technical information from refined flood hazard modelling and mapping, these options could be further screened for efficacy.	Ensure that all options are included in projects going forward. Specifically, any structural options (such as the removal of constrictions, debris removal, upstream inline or off-line storage, wetland restoration) needs to be included in hazard modelling projects. All options should be considered at a high-level in any planning project

Step	Progress	Next Step
		going forward. See below for additional information.
7. Identify preferred options	5%	A preliminary screening of options based on the findings of previous studies and this work is presented in Section 8.2.4.	To be completed as part of broader flood planning process once flood hazard mapping and modelling has been completed. See below for additional information.
8. Development Adaptive Implementation Plan	0%	None.	To be completed as part of broader flood planning process once flood hazard mapping and modelling has been completed. In the interim, funding and other opportunistic efforts to implement no regrets options should be made. See below for additional information.

The community of Dawson Creek is taking the right steps now to lay the groundwork for future studies and assessments as evidenced by the progress in Table E-5, there is however still progress to be made. More than 20 specific recommendations are provided to support progress on the overall strategy. Some of these measures are around communication with the public and building local capacity. Others relate to collecting better data for short- and long-term decision-making and completing additional technical studies. Priorities, basis and costings are presented for each.

Conclusions

The City of Dawson Creek faces a significant flood hazard and risk and seeks to reduce this risk to the community. This project, along with work previously conducted by the City, lays the groundwork for a flood mitigation plan. This is in addition to many specific gains in understanding flood risk in the community, and the development of deliverables that will support future work.

Five specific project objectives were evolved to support the City's needs. These have been addressed through this project as described below.

1. **Better understand hazard, vulnerability and risk.** This project provides a summary of previous work conducted to establish flood hazard, and also provides additional hazard information and mapping to consider multiple flooding scenarios. Further, this project collected and analysed multiple datasets of vulnerability and exposure information and provides both a summary understanding of risk (for multiple impact categories) as well as a spatial understanding of where the greatest flood risks are found in the community.

2. **Lay foundation for stakeholder engagement**. Throughout the course of this project several efforts were made to connect with stakeholders and the public. This included two workshops, a public meeting and the curation of a Facebook page that continues to be live. The approach for the engagement was to encourage stakeholders to take a thoughtful best management approach to flood mitigation as opposed to leaping to conclusions and actions.
3. **Lay foundation for future funding.** As a component of this project, appropriate materials – including two types of risk assessment, and a scope of work for a flood hazard mapping project – have been prepared (See Appendices A, B and F). This provides a solid base of information for the City to apply to various funding programs including the NDMP, the CEPF and the DMAF.
4. **Prepare framework for mitigation planning.** In addition to the base information collected, analysed and reported in this document. We have provided an overall planning framework for flood mitigation (see Section 8) to guide the City in its effort to reduce risk and increase resiliency. Tangible and specific next steps are also provided.
5. **Provide no regrets actions.** As part of the recommended actions, 6 no regrets actions have been identified. These are actions that have little or no cost and/or will definitely support or result in flood risk reduction.

Given the clear need for flood risk reduction, and the important steps and efforts the City has made to date, we encourage the City of Dawson Creek to continue on its journey to flood resiliency by continuing to engage and work with its citizens, by making applications for funding, and ultimately by implementing the planning framework.

Contents

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Tables

List of Acronyms

AEP	Annual Exceedance Probability
AHRA	All-Hazards Risk Assessment
BC	British Columbia
BC CEPF	BC Community Emergency Preparedness Fund
CBA	Cost-Benefit Analysis
DEM	Digital Elevation Model
DMAF	Disaster Mitigation and Adaptation Fund
DNV	District of North Vancouver
DPA	Development Permit Area
EMBC	Emergency Management British Columbia
FCL	Flood Construction Level
FDRP	Flood Damage Reduction Program
FHALUMG	Flood Hazard Area Land Use Management Guidelines
GCM	Global Climate Model
GDP	Gross Domestic Product
GIS	Geospatial Information System
INFC	Infrastructure Canada
IPCC	Intergovernmental Panel on Climate Change
MCA	Multi-Criteria Analysis
NDMP	National Disaster Mitigation Program
OCP	Official Community Plan
PCIC	Pacific Climate Impacts Consortium
PSC	Public Safety Canada
QRA	Quantitative Risk Assessment
RAIT	Risk Assessment Information Template
RCP	Relative Concentration Pathway
RIBA	Royal Institute of British Architects
SDM	Structured Decision Making
UN	United Nations
UN-ISDR	United Nations Office for International Strategy for Disaster Risk Reduction
WSC	Water Survey of Canada

1 Introduction

Floods matter; they matter a lot. People whose homes are inundated will remember for the rest of their lives; landscapes are changed forever; regional and national economies suffer. Floods are consistently Canada's most costly natural disaster (Office of the Parliamentary Budget Officer, 2016) with hundreds of millions of dollars of direct damages, in addition to enormous long-term impacts to the environment and to people. Flooding continues to pose a risk to Canada's economic vitality, infrastructure, environment, and citizens. The residents and authorities in the Dawson Creek area are no stranger to this, having experienced significant losses in 2011, 2016, stressful flood watches in 2017, and most recently disruption as a result of freshet driven closure of a bridge in April 2018.

Flood events in Dawson Creek have caused considerable damage and impact to infrastructure and the community. Homes and businesses have experienced overland flooding, and the city centre has been cut in half with roads, bridges, and culverts affected. With climate change, flood hazards are expected to increase in severity and frequency and will therefore continue to impact the community.

The City of Dawson Creek, along with other levels of government, have made significant effort to manage flood impacts over the last decade, and have expended millions of dollars on crossing upgrades, and hundreds of thousands on emergency response in the last few years alone. With many major structural works completed or underway, there is now a need to consider a broader suite of options to manage the residual risk of flood in the City.

Best practice dictates that flood mitigation be achieved through a thoughtful, risk-based planning process based on community values and considering a range of hazard levels. The City of Dawson Creek have shown leadership through their willingness to work through a best practice approach as opposed to a reliance on engineered and reactive measures for flood mitigation, which are prone to fail in the long-term or push the problem up- or downstream. This will not only create a more resilient community in the long-term but creates opportunity for senior-level government funding to support flood mitigation by aligning the outcomes and direction of this project with senior-level government policy direction.

To support the development of a flood mitigation plan, the City of Dawson Creek retained Ebbwater Consulting and SHIFT Collaborative in September of 2017 with support of a grant from the BC Community Emergency Preparedness Fund (CEPF).

1.1 Project Overview

This project seeks to support the City of Dawson Creek (the City) in taking a thoughtful and thorough approach to flood mitigation planning; this complements the structural efforts that have already been implemented. It strives to do this by developing a better understanding of flood risk in the community and to communicate both the risk and potential means to increase resilience to the City and stakeholders. This approach - to focus on understanding before reacting and making decisions - is based both on international best practice as well as lessons learned from other flood ravaged-communities in Canada. For example, reflecting on the 2013 floods in Southern Alberta the mayor of High River said the following:

"You have to try your best to calm down. You have to try your best to slow down because when I look back at how we rebuilt, most of us went too fast…"

– Mayor Craig Snodgrass of High River

Dawson Creek is a vibrant and growing city with an 'Open for Business' attitude and a strong sense of community. The City seeks to maintain a high quality of life for its residents, however, disruption due to flooding is a significant local challenge. Already, the City has started with efforts to address this challenge with infrastructure upgrades and studies. Now with the support of the CEPF grant there is an opportunity to lay the foundation for flood mitigation planning and chart a road map to further reduce flood risk in the community.

1.2 Project Objectives

Over the course of the project, based on the needs of the City and of the granting agency, along with what could and should be accomplished through this project, a series of objectives were evolved:

1. **Better understand hazard, vulnerability and risk.** Without an understanding of the hazard, vulnerability and risk posed by flooding to the community, it is not possible to robustly reduce flood risk. This project seeks to develop a base understanding of flood risk in the City
2. **Lay foundation for stakeholder engagement**. Several recent flood events have highlighted the need to communicate flood risk and potential mitigation options to stakeholders and the public. This project seeks to develop a common understanding of flood risk and potential risk reduction measures by engaging stakeholders and some members of the public.
3. **Lay foundation for future funding.** Funding programs for flood in Canada – both for foundational research and planning studies and for implementation of flood reduction measures – require that basic risk assessments are completed. This project seeks to develop materials to support future funding applications, including risk assessments, project scopes and costings.
4. **Prepare framework for mitigation planning.** Understanding flood risk is merely the first step in developing and implementing a flood mitigation plan. This project seeks to develop base information to support future mitigation work, and to layout a framework for the City to follow.
5. **Provide no regrets actions.** At this stage, without appropriate engineering studies, it is not prudent to make large structural mitigation recommendations; many of these types of projects can exacerbate the problem, or increase flood hazard either upstream or downstream. And therefore, this project seeks to provide a list of no-regrets planning, policy and education actions that can be implemented by the City to reduce flood risk.

1.3 Project Limitations

Given the available information, timing and resources there are limitations to the work completed in this phase. Many of these limitations can be addressed in future:

1. **Geographic scope.** This project was funded and led by the City of Dawson Creek, and as such the geographic scope of the project was the municipal boundaries. Flood management is generally

best considered at a watershed scale, and therefore the imposed boundaries of the project limited the analysis and recommendations.

2. **Hazard scope.** This project focussed on overland flooding from riverine sources (i.e. Dawson Creek). The City also faces flooding from other sources (pluvial and storm and sewer back-up), as well as erosion hazards. These additional hazards are discussed briefly in this report, but the focus remains on overland flooding from the creeks.
3. **Data and resources.** This project relied heavily on previously conducted work to inform the development of hazard mapping, and minimal analyses were conducted due to budget and data limitations. The hazard mapping in this report should be considered as a placeholder, that is suitable for initial engagement and risk analysis, but should not be use for detailed engineering planning or design.
4. **Stakeholder input.** Throughout this project, we sought to understand flood vulnerabilities as completely and richly as possible, this most mostly achieved through direct engagement with stakeholders and the public at two workshops, and through a Facebook page. The information collected through these sources is limited to the knowledge and input from those who participated; there are potentially some flood vulnerabilities and impacts that were not identified because a given stakeholder was not able to participate.
5. **Actions and next steps.** The primary objective of this work was to develop a better understanding of the problem and lay the groundwork for a robust and transparent plan, and purposely did not seek to provide engineering designs; jumping the gun and pre-determining a solution before fully understanding the problem will lead to failure. Further, the technical information required to develop and assess some flood mitigation options (especially structural works) was not available at this time, and therefore the recommendations are focussed on no-regrets flood mitigation options, and a discussion of deliberative next steps that will enable the community to select appropriate flood mitigation options that will reduce risk and increase resilience over time.

1.4 Report Structure

This report starts by providing context of the problem, including the hazard and geographic scope (Section 2) and explains best management practice given the project context (Section 3). Next is a description of the known technical aspects of flood hazard (Section 4) as well as the exposure and vulnerability to flood hazard (Section 5) as part of better understanding risk in the community. The results of a flood risk assessment are provided (Section 6) and lessons learned from engagement with local stakeholders (Section 7). Finally, recommendations going forward are provided (Sections 8 and 9) and conclusions provided (Section 10).

More detailed risk assessment outputs suitable for input into funding program templates are found in Appendix A, which provides tables of generic risk information that should be suitable for a renewed National Disaster Mitigation Program (NDMP) as well as for the Disaster Mitigation Adaptation Fund (DMAF), and Appendix B, which provides a completed RAIT for the current NDMP program. The report also includes a summary of the stakeholder workshops in Appendix C, a description of the hazard modelling approach in Appendix D, a full list of data used in the project in Appendix E, and a scope-of-work for future flood mapping in Appendix F. Also provided in Appendix G is some proposed language for

the OCP update for the City of Dawson Creek as it pertains to flood mitigation planning. Finally, Appendix H provides a summary of the social media engagement campaign and reach.

2 Problem Statement

Flood events in Dawson Creek have caused considerable damage and impact to infrastructure and the community; there have been numerous events in the last decade that have increased the level of concern. These events have flooded basements through sewer back up, homes have experienced overland flooding, and the city centre has been cut in half with roads, bridges, and culverts affected. It is expected that flood hazards will become more severe in the coming years with climate change and it is important to understand what the impacts of future floods will be.

2.1 Historical Floods

The City of Dawson Creek faced several historic flood events including severe flooding in 1974 and significant disruption due to flooding in 1990.

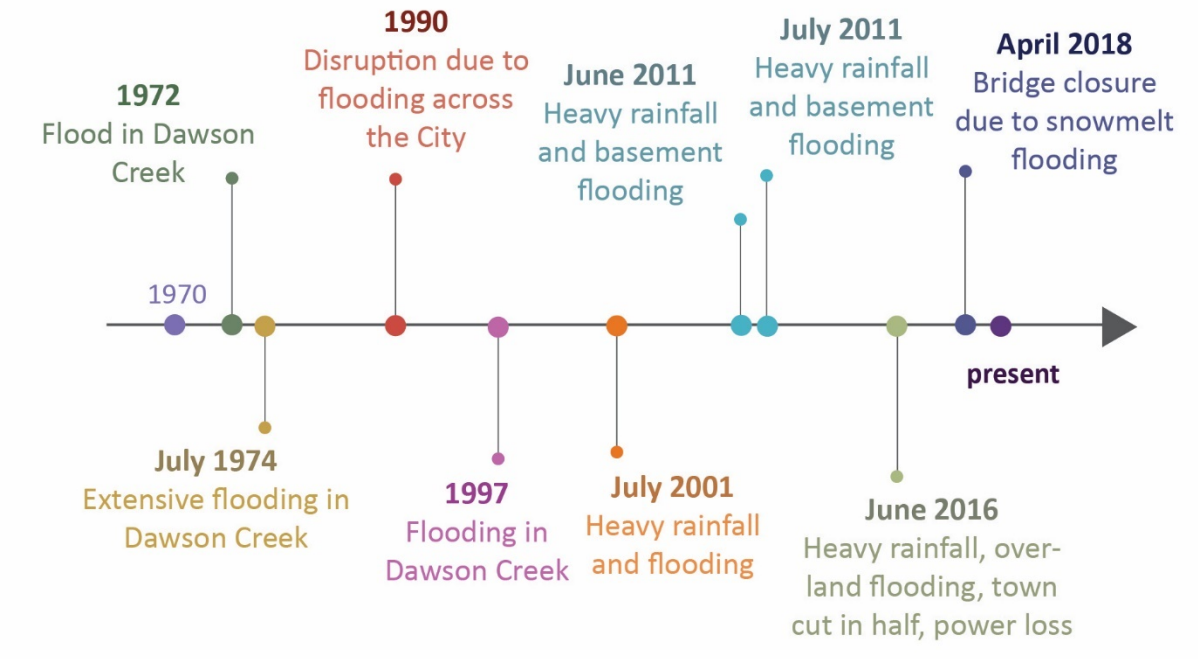


Figure 1: Timeline of historical flood events in Dawson Creek

Figure 2: Flooded street in Dawson Creek in 1990[2]

More recently heavy rainfall has caused sewer backup and flooded roads in the City. In 2011 two events in June and then again in July caused significant damage due to basement flooding and sewer backup. In 2016 overland flooding was a major issue, cutting the City in half when all the Creek crossings in the City were flooded. There was also power loss on the south side of the City with power infrastructure damaged. Figure 3 is an aerial photo taken during the 2016 flood event showing the extent of flooding which cut the City in half. Figure 4 shows some of the damage done but this flood with 8th Avenue damaged.

[2] Source: City of Dawson Creek

Figure 3: June 2016 flood in Dawson Creek aerial image looking northwest. Dawson Creek is in the left half of image and flows from upper left corner to the lower center of the image.[3]

Figure 4: Aerial photo of damage to 8th avenue in Dawson Creek due to 2016 flood looking upstream (west)[4]

[3] Source: City of Dawson Creek
[4] Source: City of Dawson Creek
(footnote continued)

Most recently, in April 2018[5], the City of Dawson Creek experienced flooding due to snowmelt in the catchment. Figure 5 shows an event map of this with photos of flooding and the locations shown. There were extensive areas flooded in the upper catchment within the municipal boundary and several homes were flooded. The bridge on 17th Street was closed due to this flooding.

Figure 5: Event map for April 2018 flood event in Dawson Creek (images provided by the City)

These historic events paint a picture of the multiple components of flood hazard in the community. More minor flooding events can cause basement flooding, sewer backup, and some overland flooding. Whereas more severe flooding can cause significant disruption with flooded creek crossings and damaged utilities. **The solutions to flooding will need to consider the complex and dynamic hazard along with the specific impacts and risks in the community**.

2.2 Project Geographic Scope

The area of interest was defined by the client at the outset of the project as being within the municipal boundary of the City of Dawson Creek. As can be seen from the map in Figure 6, the watershed of Dawson

[5] This flood occurred after the majority of work for this project was complete; discussion of this event is limited.

Creek extends beyond the boundary of the municipality. For this study, only areas within the municipal boundary were considered for flood vulnerability, exposure, and impacts.

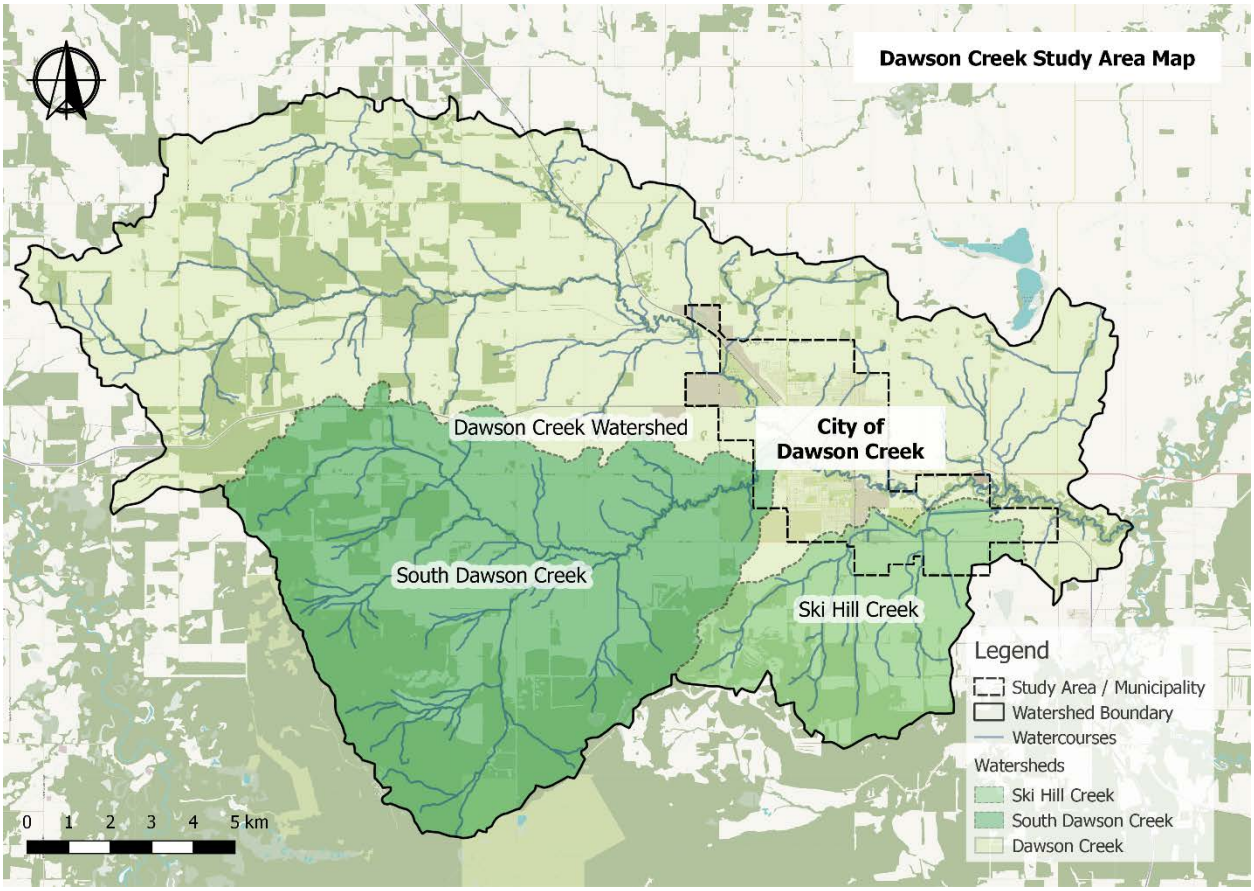


Figure 6: Watershed and study area

2.3 Recent Flood Management Actions in the City of Dawson Creek

The previous section summarises the recent history of flood hazard in the City. Given the frequency and severity of events, the City and senior level governments have invested heavily in improving conditions within the City (Table 1). This has primarily focussed on structural improvements to Creek crossings to increase the capacity of the channel and return the system to a more natural hydraulic regime. Significant funds have also been expended on emergency response efforts. The structural design projects have been supported by a number of studies (Table 2). Past projects are also shown in Figure 7.

Table 1: Recent structural flood mitigation projects in Dawson Creek

Project	Asset Owner	Date in Service	Approximate Cost[6]
Completed			
2011 Flood Response	City of Dawson Creek	n/a	$100,000
2016 Flood Response		n/a	$300,000
15th Street Crossing Removal and Disposal		June 2016	$61,000
15th Street Bridge Replacement		January 2017	$1.2 M
10th Street Bridge and Approaches		November 2017	$3.4 M
Rolla (Snake Pit) Road Temporary Bridge	Ministry of Transportation and Infrastructure	October 2016	Unknown
Planned			
Rolla (Snake Pit) Road Structure Replacement – Permanent Bridge	Ministry of Transportation and Infrastructure	Construction 2018-2020	Unknown
8th Street Bridge		Construction Fall 2018 to 2020	Unknown

Table 2: Recent reports and studies completed in Dawson Creek

Project	Proponent	Date	Project Owner
Dawson Creek Channel Assessment Post-June 2016 Flood	Urban Systems Ltd.	December 2016	City of Dawson Creek
Airborne LiDAR Mapping Dawson Creek	McElhanney Consulting Services Ltd.	January 2017	City of Dawson Creek
10th Street Bridge Design – Hydrotechnical Study	Opus International Consultants	April 2017	City of Dawson Creek
Drainage Master Plan	Opus International Consultants	May 2017	City of Dawson Creek
Dawson Creek – 200-Year Flood Routing Results	Urban Systems Ltd.	May 2017	City of Dawson Creek
Rolla Road 3 (Snakepit) Realignment and Structure Replacement	Urban Systems Ltd.	August 2017	Ministry of Transportation & Infrastructure

[6] Project costs sourced from: http://www.dawsoncreek.ca/category/tenders/

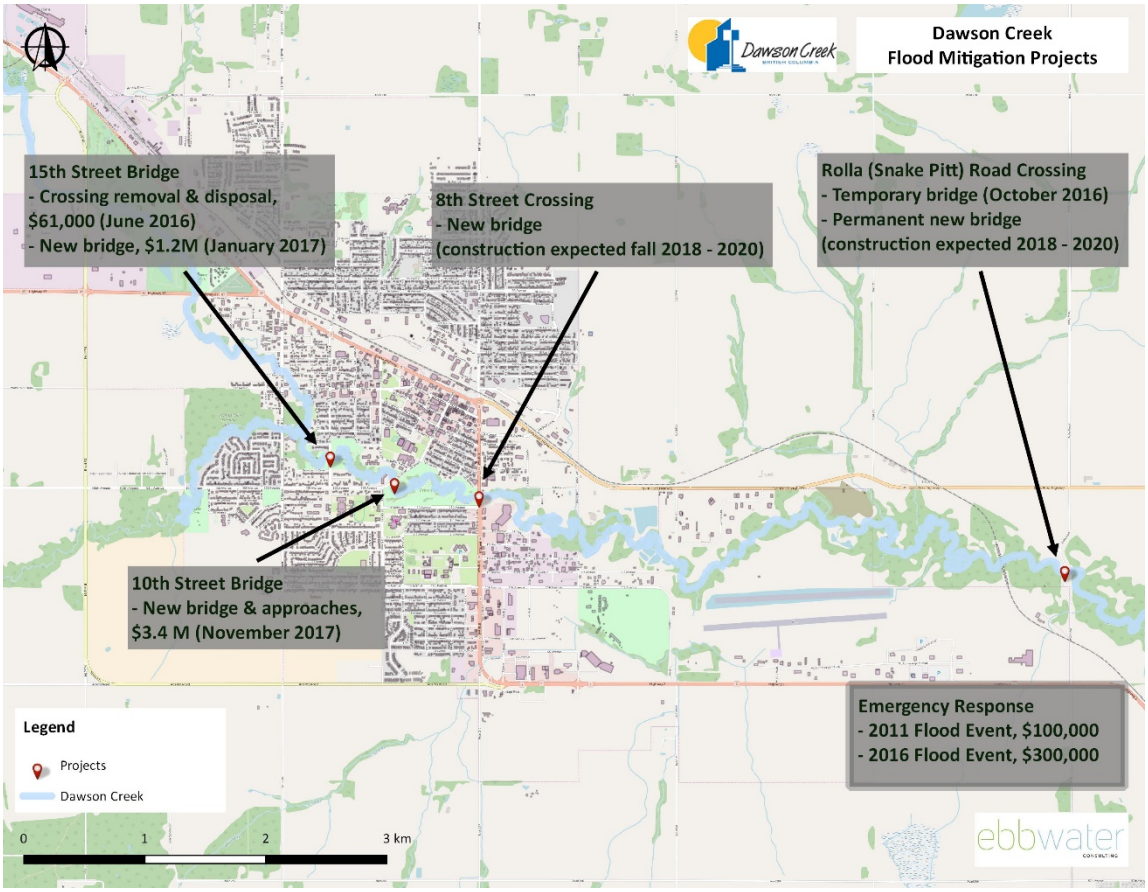


Figure 7: Summary of recent flood mitigation projects in Dawson Creek

The work completed to date shows a clear commitment by the City and Province to mitigate flood impacts in the City. It should also be noted that the works have been relatively reactive, in that significant expenditures are made in the aftermath of flood events, especially when damage has occurred to the infrastructure. This shows a clear commitment to the mantra of "build back better", which is to be applauded, but also highlights the fragmented approach to flood management, where problems are addressed as they arise, rather than focussing on a comprehensive planning approach that identifies key areas of concerns, uses consistent data and models, and considers and evaluates multiple flood mitigation options. This current project has been created to address this gap and lays the groundwork for the development of a comprehensive flood plan and highlights the leadership at the City to work towards best practice rather than continuing to react to flood events.

2.4 Regulatory Context

Since 2004, the City of Dawson Creek as a local government within BC, has a responsibility to manage its lands for flood hazard. This section outlines the regulatory requirements for the City as well as provides a summary of the current policy approach taken by the City. Of note here is that the City did not have a provincially designated floodplain prior to 2004, nor does it have any designated flood protection infrastructure. And therefore, the City has effectively always been a steward of its own floodplain and

flood management process. Whereas, many other regions, which did have provincially designated flood plains and flood protection infrastructure were up until the promulgation of the *Local Government Act* in 2004, reliant on the Province to manage development in the floodplains.

2.4.1 Provincial legislation and policy

Under the *British Columbia Local Government Act*, Local Governments are responsible for understanding and managing flood risk through land use planning and regulations. Two major policy approaches that relate to flood management, the Flood Hazard Area Land Use Management Guidelines and Development Permit Areas for Natural Hazards, are presented below. Additional regulatory tools such as the *Dike Maintenance Act*, are not currently relevant in the City of Dawson Creek, as there are currently no designated flood mitigation structures.

Flood Hazard Area Land Use Management Guidelines

Under the *Act,* Local Governments are *required to consider* the provincial Flood Hazard Area Land Use Management Guidelines (FHALUMG). Initially released in 2004, these are intended to support the development of land use management plans and decision-making regarding subdivision approvals in flood hazard areas (BC Ministry of Water Land and Air Protection, 2004). The guidelines were amended in 2018 to require that climate projections (initially only sea level rise, and therefore not directly applicable to Dawson Creek) are incorporated into building setbacks and flood construction levels (FCLs) (BC Ministry of Forests Lands and Natural Resource Operations, 2017). The 2018 amendment also includes new reference to the use of a long-term flood protection strategy (as prepared by a *qualified professional* defined by Engineers and Geoscientists British Columbia) as a means to relax FCL requirements. It should be noted that the FHALUMG are guidelines not regulations, and that they use a fair amount of weak language – for example, the development of planning areas and/or flood strategies need only be **considered** and are not mandatory. However, recent discussions with the Province suggest that there is renewed political will to tie the guidelines to future Disaster Financial Assistance (DFA) (Personal Communication with Inspector of Dikes, June 2018), and therefore it would be prudent to for the City to consider the FHALUMG in all planning processes in future.

Development Permit Areas

Development Permit Areas (DPAs) are a planning tool used by BC municipalities. They were originally promulgated in the 2004 *Local Government Act* (Section 919.1). As part of the LGA, local governments were given the authority to designate DPAs within their Official Community Plans (OCP) for various diverse purposes including:

- The protection of the natural environment, its ecosystems and biological diversity
- **The protection of development from hazardous conditions**
- The protection of farming
- The revitalization of an area in which a commercial use is permitted
- The establishment of objectives for the form and character of intensive residential development

- The establishment of objectives for the form and character of commercial, industrial or multi-family residential development

Further to this, the act was amended in 2008 to include three additional DPA purposes for climate action:

- The establishment of objectives to promote energy conservation
- The establishment of objectives to promote water conservation
- The establishment of objectives to promote the reduction of greenhouse gas emissions (BC Ministry of Community Sport and Cultural Development n.d.).

DPs must include contributions or objectives that justify the designation. And, must also provide guidelines for developers and homeowners can meet the requirements of the DPA. DPAs for natural hazards have been most notably used by the District of North Vancouver (DNV), who introduced a bylaw designating DPAs within the DNV Official Community Plan (OCP) in 2011; this was originally a result of a natural hazard death in the community that created a shift in thinking at political and staff levels. Development permits are required within the DNV for areas of wildfire, slope and creek hazards. Creek hazards include those arising from debris flow, debris flood and clearwater riverine floods. The success of this approach is not yet known, as DPAs are relatively new, and further are a long-term strategy aimed at mitigating risk as land is redeveloped. However, anecdotally, they are an effective tool to manage building scale responses to flood risk.

Additional Regulatory Options

Local governments in BC have several options to regulate land use within hazard zones in addition to OCPS and related DPAs. With regard to flood in particular:

1. **Floodplain Bylaw**: Traditionally, many communities had flood plain bylaws as this was historically regulated by the province. Floodplain bylaws are used to designate a floodplain area, which prior to 2004 required approval from the Provincial government, but can now be designated by the local government. Local governments can then specify and enforce setbacks and construction elevations within the floodplain.
2. **Zoning Bylaws** can also be used to regulate an individual parcel of land; Section 903 of the *Local Government Act* can regulate parcel configuration, the density of the land use, siting and standards of buildings and structures. These bylaws have been used historically for flood hazard areas to ensure public safety is maintained. Zoning bylaws are no longer promoted as a tool for flood management, the Provincial government cites the use of DPAs instead (BC Ministry of Forests Lands and Natural Resources 2014).
3. **Local Building Bylaws:** There is also provision under Section 694 of the *Local Government Act* for a local building by-law or permit process to require floodproofing.

2.4.2 City of Dawson Creek Legislation and Policy

The City of Dawson Creek currently manages its responsibilities for flood hazard management under the *Local Government Act* through DPAs within their OCP. The current DPA was developed in 2010 and

includes a map that describes the regulated flood hazard area and provides some basic information to guide development within this area. Specific relevant policies are:

> **Guideline 17.1**: Development on flood plains is discouraged, particularly lands along Dawson Creek which are known to be susceptible to flooding…"
>
> **Guideline 17.4**: No development shall take place that would result in erosion, sloughing, flooding, landslip, or excessive run-off and siltation…Mitigative measures may be used to meet this guideline.
>
> **Guideline 17.6**: Buildings, structures, and paved surfaces shall be located:
>
> a. Away from areas subject to erosion, sloughing, flooding, or landslip…

The OCP and DPA provide high-level guidance that suggests a good direction for flood management. However, the language is weak (i.e. the use of the word *discouraged* as opposed to *prohibited*), and the guidelines are relatively vague (as opposed to specific). The City is currently in the midst of re-issuing its OCP. There is a good opportunity to improve the language and specifics within the DPA at this time (see recommendations and example OCP language in Appendix G for more details).

In addition to the OCP, the City has information on the Development Permit Application process available to residents. These documents provide high-level guidance on what is required to meet the guidelines in the OCP. As for the guidelines themselves, these are relatively vague and non-specific, and arguably do not meet the requirement that developers and homeowners are provided guidelines to explain how they can meet the requirements of the DPA. For example, the DPA checklist requires that a geotechnical engineer prepare a report for hazardous area but does not provide guidance on what this report should include. The requirement for a geotechnical engineer, as opposed to a hydrotechnical engineer who would be more suited to understanding flood hazards, is likely derived from text provided by the Province when the *Local Government Act* was enacted. Some recommendations related to the OCP and DPA are provided later in this report.

2.5 Funding Context

The regulatory context above shows that flood management is primarily a local government responsibility. However, flood mitigation, especially structural flood mitigation projects, are generally far more expensive than local government budgets can stretch. In recent years, the Provincial and Federal governments have developed some new granting programs to support flood mitigation planning as well as to implement flood management solutions; these are summarised in Table 3.

Table 3: Summary of available funding programs for flood mitigation

Program	Owner	Comments
National Disaster Mitigation Program (NDMP)	Public Safety Canada (PSC) /Emergency Management British Columbia (EMBC)	This is a 5-year program (currently in its last cycle) designed to support flood mitigation through the funding of foundational research and planning (flood risk assessments, flood mapping, flood mitigation plans)

Program	Owner	Comments
Community Emergency Preparedness Fund (CEPF)	Union of BC Municipalities (with funding from EMBC)	This is a 2-year program (currently in its last cycle) that in part mirrors the NDMP. There are also additional funding streams for structural mitigation works and for emergency management/response and emergency social services
Disaster Mitigation and Adaptation Fund (DMAF)	Infrastructure Canada (INFC)	This is a 10-year program that has just been announced to fund natural hazard mitigation projects. This was envisioned as a complementary program to the NDMP – where foundational work including proposed mitigation options – is realised through DMAF funding. This program supports all-hazards (as opposed to the flood-focussed NDMP and CEPF) and has a basement funding allocation of $20M. Further, this program has a strong focus on green infrastructure and low-carbon resilience (as opposed to structural mitigation).

Common to all the current programs for both planning and structural mitigation are variations on the following criteria/requirements:

- A flood risk (either historic or based on a risk assessment) needs to be established.
- Any proposed project must show a reduction in risk.
- The proponent must show a commitment to flood preparedness, planning and mitigation.
- Any proposed project should contribute to or be based on a comprehensive, cooperative and regional flood mitigation plan.
- Any project must consider climate change (both mitigation of greenhouse gases and adaptation to climate futures).
- Any proposed project must demonstrate good value for money.

These criteria, along with the overall mandates for these programs, show a clear directional shift in senior government funding for mitigation of flood and other natural hazards. Namely, that senior government is shifting away from reactionary funding and from a focus on structural measures towards investing on long-term resiliency based on comprehensive risk-based plans. In order for the City of Dawson Creek to leverage these funds in future, the City needs to invest in the development of comprehensive flood management planning (see Section 3.0 for a description of what this is). This current project lays the foundation for this type of work, and should put the City in good stead for senior level government funding in future.

3 Best Management Practice Primer

To lay the foundation for flood mitigation planning best practice dictates that you should develop a strong understanding of risk and enable resilience. Dawson Creek has indeed taken an approach that reflects this best practice by going slow, committing to developing a better understanding of hazard and vulnerability, and talking with partners to do this work. This section provides background information on best practice for understanding and managing flood risk. This provides a framework for the results and recommendations presented later in this report.

3.1 Flood Management as a "Wicked Problem"

Flood management is a classic "wicked problem"[7]. It has a high degree of technical complexity, multiple dimensions of uncertainty, and multiple objectives. This is made worse by high stakes and high emotions, as there is often intense political scrutiny. More often than not, it is also limited by available resources (data, methods, time, money, and personnel).

Natural hazard risk is a challenging issue, especially with a changing climate. Best practice for flood planning and risk reduction requires a paradigm shift in thinking and management when compared to how flood has generally been managed in Canada. The approach described below works towards a best-practice approach, as informed by experience working in the Canadian context.

3.2 Best Practice Strategies

3.2.1 Work Collaboratively at a Watershed Scale

Flood, like many natural resource problems, is cannot be contained by jurisdictional boundaries. It is therefore imperative that decisions related to water and flood be made with consideration of the watershed scale of the problem. Ideally this should be through collaborative planning with neighbouring jurisdictions. The idea of collaborative watershed planning is particularly important for flood – as decisions made by individual communities to reduce their own risk, can in fact worsen conditions for their upstream and downstream neighbours. For example, the removal of a constriction that results in localised flooding upstream of the constriction, but also holds and slows the flow, can exacerbate the flood hazard downstream. Similarly, the construction of dikes to protect a downstream community, will raise local water levels adjacent and upstream of the dikes – thereby worsening conditions in a neighbouring community.

3.2.2 Plan for Risk Not Hazard

International best practice, in the form of the UN-ISDR Sendai Framework, provides some guidance on how to mitigate risks and increasing costs associated with natural disasters. A major tenet of this framework is a *risk-based* approach to disaster management, where hazard, vulnerability, likelihood, and

[7] A "wicked problem" is one that is difficult to solve because of contradictory or changing requirements. It was first described in 1967 by C. West Churchman.

consequence all play a role. This is a shift away from how floods have historically been managed in Canada, where the norm is to base design standards on a single hazard (often the 0.5% AEP event).

Common sense clearly dictates that an understanding of what is at stake (exposure and consequence) should play a role in any flood planning.

Further, it is important to not only consider impacts from future very rare events, but to also consider the impacts of much more frequent but lower-magnitude flood events of various return periods. These might have less impact individually, but the cumulative impact of multiple smaller flood events over time could be just as significant.

The full range of hazards, from frequent small events to rare large events, as well as the changing baseline, all need to be considered in flood mitigation planning. A more detailed description of risk assessment methods follows in Section 3.4.

3.2.3 Stop Fighting Nature, and Enable Resilience

The approach to dealing with floods has evolved with time. During the International Decade of Natural Disaster Risk Reduction, the UN expressed the view that the approach to disaster management was too compartmentalized and that flood protection in isolation was no longer appropriate. Complete protection from floods through the construction of dikes and dams, for example, is often too expensive and an inefficient use of resources. A more integrated resilience approach is increasingly being adopted (Schanze, Zeman, & Marsalek, 2006). Resilience refers to the resistance to a particular shock and the speed of recovery. Focusing on appropriate and cost-effective resistance to flooding combined with increased speed of recovery should be the focus. Peak flows and storms will continue to happen and flooding cannot be prevented, however, communities can become more resilient to these events.

3.2.4 Embrace Uncertainty

Climate is changing; this fact is known. However, the rate and pace of change in the region is not clear. This is best managed by acknowledging the uncertainty, and then explicitly designing for it. For example, for structural works, uncertainty should be included in freeboard calculations. Further, the structural responses should be designed to change over time (e.g., by purchasing larger rights-of-way for dikes, so that they can be raised and widened in future). All responses should be designed with the idea of "safe-failure" and multiple benefits, so that even if the infrastructure does not function for its initial purpose, it continues to provide value to the community.

3.2.5 Listen to Stakeholders and Consider Local Values

Communities do not want elaborate flood-control infrastructure, they want safe and prosperous places to live; this should be at the heart of any flood mitigation plan.

One strategy to reduce natural hazard risk while delivering additional value to the community is designing multifunctional spaces. This could be in the form of a park that is a recreation space when it is dry and a water retention area during heavy rainfall or peak flows. Areas where dikes have been constructed sometimes also incorporate trails or bike paths for recreation. This means integrating considerations of flood risk reduction into other capital infrastructure plans where appropriate. What form this should take

all depends on what the community wants and how this can be integrated with project needs and the available budget. To balance local needs, this plan should be developed in collaboration with the community and industry.

3.2.6 Make Good Decisions Based on More than Dollars and Cents

Risk reduction measures need to be cost effective, but sound decision-making needs to be based on more than just the price tag. Flood infrastructure should also provide benefits and minimize impacts to social, environmental, and cultural assets. If only direct losses to structures are considered in a benefit-cost assessment, then the result is generally the construction of dikes or seawalls. However, when ecological, recreational, and cultural values are considered meaningfully, the preferred mitigation option is rarely a piece of hard infrastructure that has an impact on the environment, blocks views, and requires long-term maintenance. Flood studies will often only consider direct impacts of flooding indicating the overlap between properties and water levels. However, considering the impact of flooding on critical infrastructure and emergency services is important for both more effective response planning, and for prioritizing the protection of key assets. Often these indirect impacts are intangible and cannot be monetized and are therefore discounted. A thoughtful decision process is imperative to create a community that will thrive into the future.

3.3 What is Natural Hazard Risk?

A solid understanding of the term “risk” is key to understanding the components of a risk assessment. **Risk** is a function of both the likelihood of an event occurring, and the consequences if that event occurs (Figure 8). **Consequence** is defined as fa function of the hazard (where and how big is the event?), and vulnerability (what’s in the way and how susceptible is it?). **Vulnerability** can be further described as a function of **exposure** (what’s in the way?), **resilience** (how will the system resist and recover?), and **mitigation** (what measures are in place to reduce damage?).

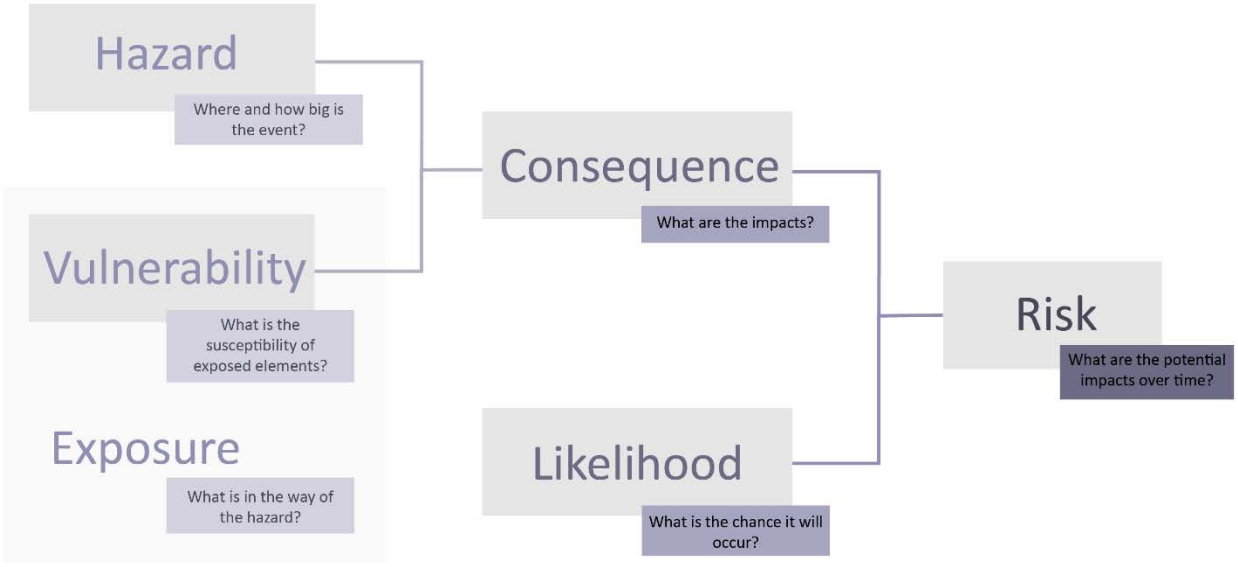


Figure 8: Risk as a Function of Hazard, Vulnerability, and Consequence

3.4 What is a Risk Assessment?

Given that risk is the combination of the likelihood of an event and its negative consequences, a risk assessment is essentially a methodology to determine the nature and extent of risk. This is done by analyzing potential hazards and evaluating existing conditions of vulnerability that together could potentially harm exposed people, property, services, livelihoods, and the environment on which they depend. A risk assessment can be qualitative or quantitative. For example, the national All-Hazards Risk Assessment (AHRA) is a qualitative tool that will help identify, analyze, and prioritize a full range of potential threats (Public Safety Canada, 2012) . This type of tool can be developed relatively quickly and cheaply at a national scale and is invaluable for prioritization exercises. However, to invest in disaster risk reduction, in particular through the use of land-use policy, requires a more robust methodology—ideally a fine-scale quantitative risk assessment. A quantitative risk assessment is one that uses measurable values of hazard, vulnerability, and likelihood to calculate risk and loss. The quantification of risk, although at times cumbersome, provides invaluable information for risk reduction through the provision of robust, transparent data for planning and decision-making.

The recognition of risk assessment (and quantitative risk assessment, in particular) as best practice for natural hazards risk mitigation means that, over the last couple of decades, an effort has been made in the disaster management community to develop tools to aid in quantitative risk assessment. These tools vary greatly, as is to be expected given the range of hazards, needs, and users (Figure 9).

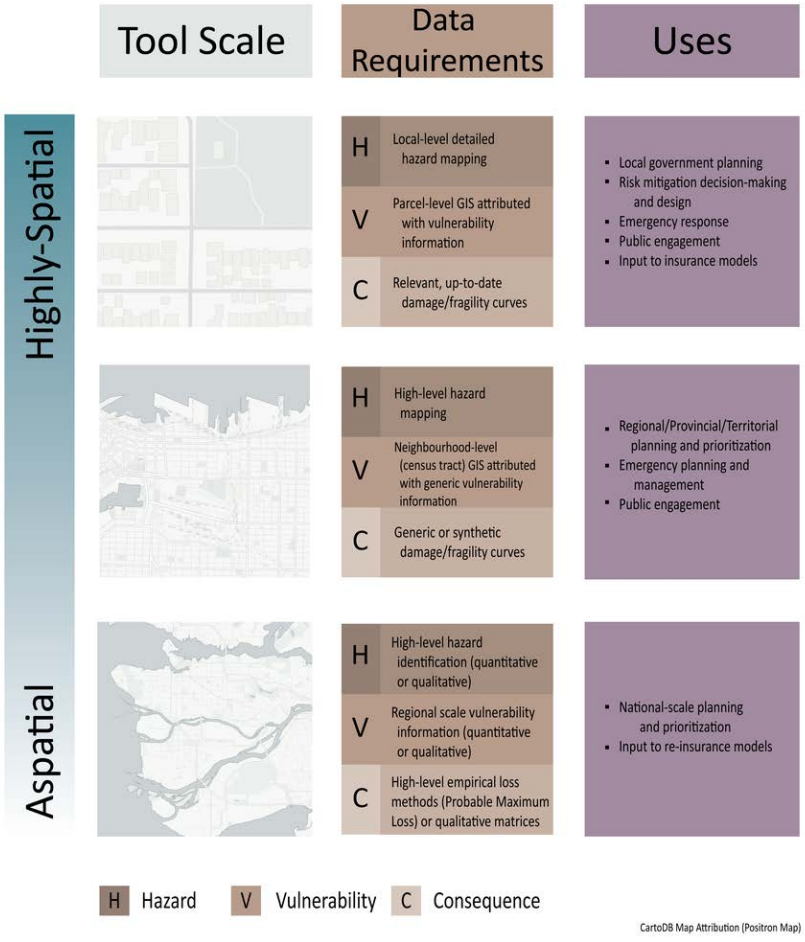


Figure 9: Scales of Risk Assessment

The choice of tool should be based on the overall objective of the study. For example, at a fine scale, an insurance company needs to know the likelihood of damage and loss to a single home that is seeking insurance. Whereas, at the other end of the spectrum, higher-level governments need information to help them prioritize the expenditure of resources and dollars. In the middle lies regional government, with the authority and responsibility to make land-use decisions, as well as to consider structural flood management (e.g., dikes). Each of these players will require different information, which points to a different methodology for flood risk assessment.

Another output of risk assessment tools that is particularly useful for all users, is the capacity to compare risk mitigation options and policies. For example, the long-term implications of decreasing vulnerability by retreating (moving people and assets) from the hazard versus adapting (decreasing the vulnerability of assets and improving resiliency) can be assessed.

The choice of methodology will depend not only on the desired outcomes of the research, but also on the amount of resources available to conduct the work, and on the available data. For example, there is no point conducting a fine-scale study without good information about individual buildings (materials, size, age, elevation, etc.) and the consequences of each type of building being damaged by the hazard.

3.4.1 Scenario-Based Risk

If a single event likelihood, for example an extreme event, is used to calculate damages and losses this is called a risk *scenario*. This is the most common type of assessment completed in Canada, as it is relatively

straightforward and requires only one hazard event be calculated and mapped. Scenarios are commonly used for emergency response planning, where large probable maximum events are used for exercises on the assumption that a plan for a catastrophic event will also be valid for smaller events. Scenarios have also traditionally been used to support hazard mitigation decisions because this simple standards-based approach is relatively straightforward to calculate.

3.4.2 Probabilistic-Based Risk

A probabilistic assessment is one that considers a range of hazard events and damage outcomes. The area under a curve (with likelihood and consequence as the axes) is integrated to give a full picture of risk. This approach is rarely used at present but is quickly being considered best practice as it provides an understanding of the impacts of frequent small events as well as infrequent large events. Probabilistic assessments can be resource intense; however, updates in technology and methods are slowly reducing the relative effort to conduct them.

3.4.3 Scenario vs. Probabilistic Approaches

Scenario approaches are the most commonly used – primarily because of the relative effort. However, probabilistic approaches are becoming more common – and are generally considered best practice. This is especially true with climate change, as some smaller and medium events become more common. Decisions can be affected by the approach taken (Lyle, 2016), and it is therefore important to choose an appropriate approach given the available resources, data and time.

3.4.4 Risk Assessment Scale for Dawson Creek

The City of Dawson Creek team has several objectives for this project. The goal is to develop a road map for flood mitigation planning in the community. To do this a broad understanding of risk was developed through consultation with a range of stakeholders and communication with members of the public. As part of driving this process forward, the team has also completed a risk assessment for the City of Dawson Creek. This will support future planning for disaster risk reduction, and for the purpose of a grand application and completed RAIT is provided. These two assessment methods are quite different as they fall at opposite ends of the scale (see Figure 9). The RAIT requirements[8] fall towards the aspatial end of the scale—as the intended purpose is to prioritize funding and resources across the province and/or country. Note that the RAIT also follows a scenario-based approach.

However, the development of future disaster risk reduction plans and the development of more refined mitigation options requires a finer-scale assessment; this level of assessment is what the community will ultimately need. A summary of the components required for these two separate risk assessment types is provided in

Table 4, with components focused on in this project highlighted in green.

[8] For the purposes of this project, we have assumed that the required deliverable will be the RAIT available from Public Safety Canada at the time of writing (see also Appendix B), but we are also mindful that this will likely be updated to be more in keeping with international best practice in future (Appendix A provides information suitable for an updated risk assessment form).

Table 4: Summary of risk assessment components

Risk Assessment Scale	Component	Availability/Comment
Highly-Spatial (for community planning and engineering design)	**Hazard** Detailed flood mapping.	**Not available.** Old mapping based on 1974 event, is outdated and unsuitable. Recent modelling for design of hydraulic structures and new mapping from this project work does not meet current guidelines or best practice (due primarily to limited bathymetric data and updated hydrology).
	Vulnerability/Exposure Fine-scale understanding of qualitative and quantitative exposure and vulnerability.	**Mixed availability.** Considerable data collected through this project.
	Consequence Detailed methods and data to combine hazard (depth of water) with exposure.	**Available.** General methods are available, although available methods for intangible consequences are weak.
Aspatial (for Provincial and National prioritization; suitable for the RAIT)	**Hazard** High-level identification and understanding.	**Available**. High level modelling and mapping completed.
	Vulnerability/Exposure Semi-quantitative understanding of basic exposure and vulnerability elements.	**Available**. Based on public data (census and other), as well as discussions with local governments.
	Consequence Qualitative understanding of the combination of hazard and vulnerability.	**Available.** Estimated through simple heuristic approaches for six elements of impact (see Section 3.5 below).

And so, given the available information, and the scope and resources applied to this project, a high-level risk assessment (suitable for the RAIT) has been completed. Further, initial detailed vulnerability and exposure information has been gathered—this will support a future detailed risk assessment, but in the meantime can be used to support stakeholder and public engagement. A detailed risk assessment cannot be completed at this time, primarily because the community lacks an updated flood map developed to current standards (Engineers and Geoscientists British Columbia, 2016). However, this high-level risk assessment can support an application to one of several funding programs to get sufficient funds to develop a flood map (with appropriate hydrology and hydrography, inclusive of climate change, and updated bathymetry of the river and topography of the flood hazard area). Please see the recommendations and conclusions in this report for further information.

3.5 Indicators for Risk Assessment

Risk assessment is shaped by the types of exposed elements that are considered. Given that the impacts of flooding are often widespread and diverse, best practice suggests that a broad spectrum of impacts should be considered. A common approach is to base impacts on the recently released UN document on indicators for disaster risk reduction (United Nations, 2016), which itself is based on the Sendai Framework indicators (UNISDR, 2015). These are as follows:

1. **People** – An indicator used to represent the number of directly impacted people (fatalities and/or missing). This indicator is often quantified.
2. **Affected People** – An indicator used to represent the number of people indirectly impacted by a flood. These are people who have had their homes, schools, businesses, and/or other services lost or disrupted. This indicator is often quantified.
3. **Direct Economic Impacts** – An indicator used to represent direct (i.e., as a result of being wet) losses that result from a flood. This primarily includes damage and reconstruction costs to public and private structures. This also generally includes the cost of flood response. This indicator is often quantified and monetized.
4. **Disruption** – This is an indicator that describes the potentially more widely spread impacts that can result from a flood (e.g., when a road is cut off, or when a substation is damaged). This is often represented simply as the number and type of Critical Infrastructure Units that are exposed. This indicator can be quantitative or qualitative.
5. **Environment** – This indicator is used to describe environmental impacts resulting from flood and is often considered to include both environmentally sensitive areas that are directly exposed (i.e., flooded) and the effects of contaminants that are released into the flood hazard area when industrial or other hazardous sites are affected. This indicator tends to be reported qualitatively, although new methods are being developed to monetize both the ecological value of the affected site and the cost of clean-up.
6. **Cultural** – This indicator is used to describe impacts to cultural sites and includes both indigenous and non-indigenous areas and items. This indicator tends to be reported qualitatively.

Figure 10: National Risk Profile Impact Categories

The above is not a complete list of impacts but provides a good starting point for review and discussion (see also Figure 10). For example, it does not fully cover indirect impacts (e.g., long-term health) or intangible impacts (e.g., human stress). However, given that most indirect and intangible impacts are difficult to quantify and to monetize, the above provides a

good starting point for a risk assessment. The categories are also the basis of the proposed National Risk Profile and will likely form the basis of future risk assessment requirements for federal and Provincial funding programs. The categories outlined above also fully meet the needs of the existing RAIT form.

3.6 General Impact Types

Beyond the gross indicators for risk mentioned above, there are many ways to categorize and consider flood impacts. As described below, not all these impact types are easy to estimate, but that does not mean they should not be considered. At a minimum, it is important to recognize what types of impacts have been considered in a risk assessment and to be explicit about those that have not.

3.6.1 Direct and Indirect Flood Impacts (or Consequences)

Flood impacts can also be grouped into direct and indirect impacts. **Direct** impacts describe all harm that relates to the immediate physical contact of water to people, infrastructure, and the environment. Examples include damage to buildings, impacts on building contents and other assets, damage to the environment, and loss of human life. **Indirect** impacts are those caused by the disruption of the physical and economic links in the region, as well as the costs associated with the emergency response to a flood. For example, business losses because of interruption of normal activities, or costs associated with traffic disruption when roads are impassable.

3.6.2 Flood Impacts (or Consequences) by Tangibility

The effect of a flood on the environment, human or community health, or the loss of life are difficult to quantify, and are therefore considered to be **intangible** impacts. On the other hand, the **tangible** dollar losses from a damaged building or ruined inventory in a warehouse are more easily calculated. This does not mean that tangible losses are more important than the intangibles, just that they are easier to quantify and assess. The inclusion of intangible impacts is desirable for the development of a robust flood risk assessment (Frank Messner et al., 2006). Table 5 provides examples of direct/indirect and tangible/intangible impact typologies.

Table 5: Examples of flood impact typologies

Flood Impact	Tangible	Intangible
Direct	• Building damage • Infrastructure damage • Content/inventory damage	• Loss of life • Health effects • Loss of habitat and environment
Indirect	• Loss of industrial production • Traffic disruption • Emergency response costs	• Inconvenience of post-flood recovery • Increased vulnerability of survivors

As we transition from a standards-based approach to flood planning and damage mitigation to a more holistic risk-based approach, there has been a significant increase in the knowledge base around flood consequences. The impacts of flooding are widespread and affect people, infrastructure, the economy, and the environment. Flood damage estimation, however, has traditionally been the domain of engineers, and, as such, has focused on economic valuation of infrastructure and building losses, leaving a large gap in knowledge regarding intangible impacts (F Messner & Meyer, 2006). This gap has increasingly been acknowledged, but there is still very limited validated research available, and tools to look at intangible impacts are largely undeveloped. It is known that when damages are monetized, buildings become priorities for flood mitigation, whereas when damage is expressed as the number of people affected by a flood (through stress or inconvenience), road flooding and resultant damage/closures become a mitigation priority (Veldhuis, 2011). The metrics chosen for assessing flood damage can deeply affect subsequent planning decisions. In effect, the non-inclusion of intangible impacts can affect priorities.

3.6.3 Impact Types for Dawson Creek

A comprehensive assessment of flood impacts includes direct and indirect impacts. However, as described above, it is more complex and resource intensive to assess some impacts. For this project, we approached the problem with a mix of quantitative and qualitative concepts and were able to capture some of the more intangible impacts by working with community stakeholders. The actual impact types are more fully described in Section 5.2, and an overview of the general types of flood impacts that were considered is presented below.

The City of Dawson Creek (City) has long-term historic and recent experience with impactful floods. In 2011 and 2016, significant damage was incurred to infrastructure, and in 2016 the City was divided in two by the overflowing Dawson Creek; this directly damaged buildings and infrastructure, but also resulted in significant disruption, stress and long-term economic impacts.

Direct impacts of flooding for the City of Dawson Creek include washed-out and/or flooded roads. This means that the structure of the road may be compromised due to floodwaters or it is simply impassable for the duration of the flood. The community depends on bridge crossings and is vulnerable to north-south access being cut off if these crossings are damaged or flooded. Some of these direct impacts are highlighted in Figure 11.

Figure 11: Examples of direct flood impacts in Dawson Creek

The recent flood events did not only affect roads and transportation infrastructure, however. Commercial and residential property was flooded as well as recreational spaces. Flooding outside of the municipal boundary also caused disruption as one of the key highway and rail connections was washed out as highlighted in Figure 12.

Figure 12: Flood impacts – direct

Indirect impacts of flooding include effects where a loss of service in one area means that something depending on that service cannot function. For the community, this includes things like traffic delays, loss of access, loss of recreation and the loss of utility services. It is important to include these impacts because they can sometimes be greater in terms of severity and duration than direct impacts. Some indirect impacts of flooding in Dawson Creek are highlighted in Figure 13.

Figure 13: Examples of indirect flood impacts in Dawson Creek

3.7 Future Improvements for Risk Assessment Methods

Risk assessment for natural hazards is a challenging and evolving field. The level of effort it takes to conduct a risk assessment is very dependent on the use of the information, but also on the available data and resources. Detailed quantitative methods for flood risk are in their infancy in Canada (Ebbwater Consulting, 2016), where underlying datasets for exposure are often unavailable, and valid methods for damage and loss calculations are not available for a Canadian-specific context. Further, there are few models to follow with regards to qualitative assessments—flood risk assessment in general is rarely practiced in this country. For this project, the team relied on methods that were developed in the last few years by the project team and used for clients across Canada; new methods were also developed specifically for this project. However, it should be noted that much of this work is leading edge and therefore requires significant innovation. We anticipate that these methods will be refined and improved in time by ourselves and other risk management professionals. The risk assessment provided in Section 6 meets and exceeds current best practice and is suitable for input into risk assessment templates required by various funding agencies. The results also provide foundational information that can be used to support future mitigation planning.

3.8 Process to Achieve Best Practice for Flood Management

In order to achieve and implement best practice in flood management, it is important to consider a planning process that will consider the various components of best practice as outlined above. An 8-step process for this is presented in Figure 14. This process takes a community from the acknowledgement of the flood hazard through to an implementation plan, with specific timelines, budgets and monitoring of measures of success. The results of this project, along with previous work conducted by the City, completes the earlier steps in the process, and provides the foundation for the City to move forward to the final step. Additional information on the progress against this 8-step process is found in Section 8.

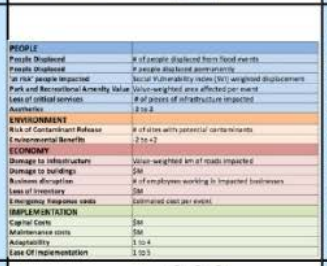
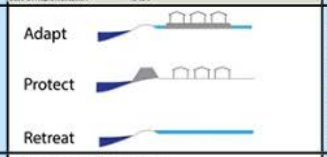
Step	Relevant Questions	Ideas	Explanation
1 Acknowledge Problem and Set the Stage	*Is flooding a problem? Is climate change going to affect us? What is our planning timeline? What opportunties and constraints exist*		With flood hazards affecting us now, and likely to increase in future. Planning to adapt is the only option. This first step involves investigating how communities may be affected, and defining the context and scope for planning.
2 Identify and Establish Hazards	*Where is the water going to be? How likely is it to be there? How often?*		Understanding where water is likely to be in future is key to planning for flood in a changing climate. Modelling of multiple events and timelines gives the best picture of future hazards.
3 Identify Exposure and Vulnerability	*What's in the way? What do we care about?*		Water itself is not a problem. It only becomes a problem when it interacts with human assets and infrastructure on the floodplain. Identification of what is in the path of water is a key step in adapatation planning. This step involves in-depth analysis of assets, infrastructure, communities and ecosytems that are subject to flooding.
4 Identify Consequence and Risk	*What are the potential impacts of flooding? What is the total risk over time?*		Good decisions get made when a full accounting of flood risks are known. This means considering risks to more than just infrastructure, but also indirect impacts of business interuption for example. It also means looking at a full spectrum of events from nuissance flooding to catastrophic flooding.
5 Establish Objectives and Measures of Success	*What do we want to achieve? How can we realistically measure our objectives*		A strong decision process is integral to making adaptation choices that will not only work, but will benefit the community in the long-term. Recognizing stakeholder values at this stage is key to finding solutions that are agreeable to all parties. This step involves meaningful engagement with stakeholders, planners, and decision makers to explore social, environmental, and economic considerations, and to decide how alternative adaptation scenarios will be assessed.
6 Identify Adaptation Options	*What adaptation options are suited to this hazard?*		As communities around the world grapple with flood and climate change, our ingenuity is increassing. There is a large toolbox of adaptation options available broadly falling under the three categories of adapt, protect and managed retreat.
7 Identify Preferred Options	*What are the best options to achieve success? When will these have to be implemented? What could be done to improve the option?*		The identificaion of preferred options is clearly the crux of any adaptation plan. A strong decision process, and a risk-based approach will ensure that options make sense. This type of approach may also show that in some cases, deferred decision-making is the best course of action.
8 Develop Adaptative Implementation Plan	*What are the priorities for adaptation? When should planning for implementation begin? How could projects be improved with better information?*		Planning for adaptation means defining specific actions, priorities, and timelines for implementation. This step explores when assets and communities may be affected, when planning and implementation of options must occur, and what monitoring and evaluation is needed to ensure that communities can adapt to changes over time.

Figure 14: 8-Step Planning Process for flood risk reduction

4 Understanding Flood Hazard in Dawson Creek

Hazard and the associated likelihood are key components of a risk assessment and flood mitigation planning — we need to understand what will get wet, and how probable it is. Flood hazard is best estimated through the development of detailed hydrologic and hydraulic analyses. Hydrologic analysis provides information on present-day and future (with climate change) estimates of the volume of water that might be expected. Hydraulic analysis establishes where the water will flow and how deep and fast it will be, and this generally requires the development of a hydraulic model. Inputs to a hydraulic model include an understanding of the river shape and other geomorphic characteristics (e.g., bed roughness), along with an understanding of conditions at the upstream end of the model (i.e., flow estimates) and at the downstream end of the model (usually water level estimates).

The following describes the general flood hazard for the City of Dawson Creek. The scope of work for this project did not include a detailed hazard assessment, and therefore there are considerable limitations associated with the information presented below (additional information on the flood hazard modelling and mapping is presented as Appendix D). However, the results of this project (a completed risk assessment) will provide the City with the information to support an application to funding programs to develop a flood hazard model and map that includes up-to-date information (e.g., bathymetric surveys), and meets current best practice and guidelines for flood modelling and mapping (EGBC Flood Mapping Guidelines and/or Federal Flood Mapping Guidelines for Hydrologic and Hydraulic Analysis). A proposed scope of work and budget for this is presented as Appendix F.

4.1 Riverine Hazard Overview

An understanding of flood hazard tells us where the water is going to go, and how high and how fast it will be. Along Dawson Creek, flooding typically occurs in the summer months with heavy rainfall in the catchment. If there is a snowpack present, then warm weather and intense rain can cause significant snowmelt that adds to the total volume of water. Finally, multiple consecutive days of rain can mean that groundwater levels are already high, and floodwaters will not be able to dissipate through infiltration.

4.1.1 Hazard Severity

Understanding the flood hazard in Dawson Creek involves considering multiple hazard levels and assessing the impacts. Often flood studies will only focus on a given historical event or a single severe event. It is important, however, to consider the effects of minor hazards as well as moderate and severe hazards (see Section 3.2.1 for additional information). While the impacts of a severe event may be large and wide spread, minor flooding can occur more often and cumulatively cause similar level of damage. Descriptions of these hazard events are presented in Table 6.

Table 6: Typical minor, moderate, and severe flooding descriptions

	Minor Flooding	Moderate Flooding	Severe Flooding
Description	Some overland flooding with depths around 10 cm. Generally, recedes within a couple of days. Sometimes described as nuisance flooding.	Moderate overland flooding with depths around 30 cm. Generally, recedes within a few days, although in some systems longer durations (1-2 weeks can be expected)	Extensive overland flooding with depths over 100cm. Depending on the system, flooding can last from days to weeks.

Some of these hazard levels may be tolerable more often and others may be tolerable rarely. The frequency of tolerance to different hazard levels could be assessed in the future.

4.2 Dawson Creek Watershed Characteristics

The City of Dawson Creek is within the watershed of the same name which drains an area of 274 km^2 from west to east emptying into the Pouce Coupé River. It has a mainstem length of 43.5 km and includes several tributaries (Ski Hill Creek, South Dawson Creek, Frondizi Creek and many unnamed tributaries).

Table 7: Tributaries of Dawson Creek

Tributary Watershed	Watershed Area (km^2)	Reach Length (km)
Dawson Creek Main Watershed	159.6	43.5
Dawson Creek South Watershed	87.2	20.95
Ski Hill Creek	27.4	8.35

While the city depends on the nearby Kiskatinaw River for its water supply, it is the Dawson Creek watershed that is relevant for the urban watershed and flood mitigation plan. It is relatively small, in comparison to the the Kiskatinaw River, whose watershed has an area of 3655 km^2. This means peak flows in the catchment are driven mostly by rainfall events in the area and less so by snowfall, although the April 2018 freshet event suggests that snowmelt driven events do occur. The study area with is shown in Figure 15 indicating the municipal boundary, watersheds, and location of WSC gauges.

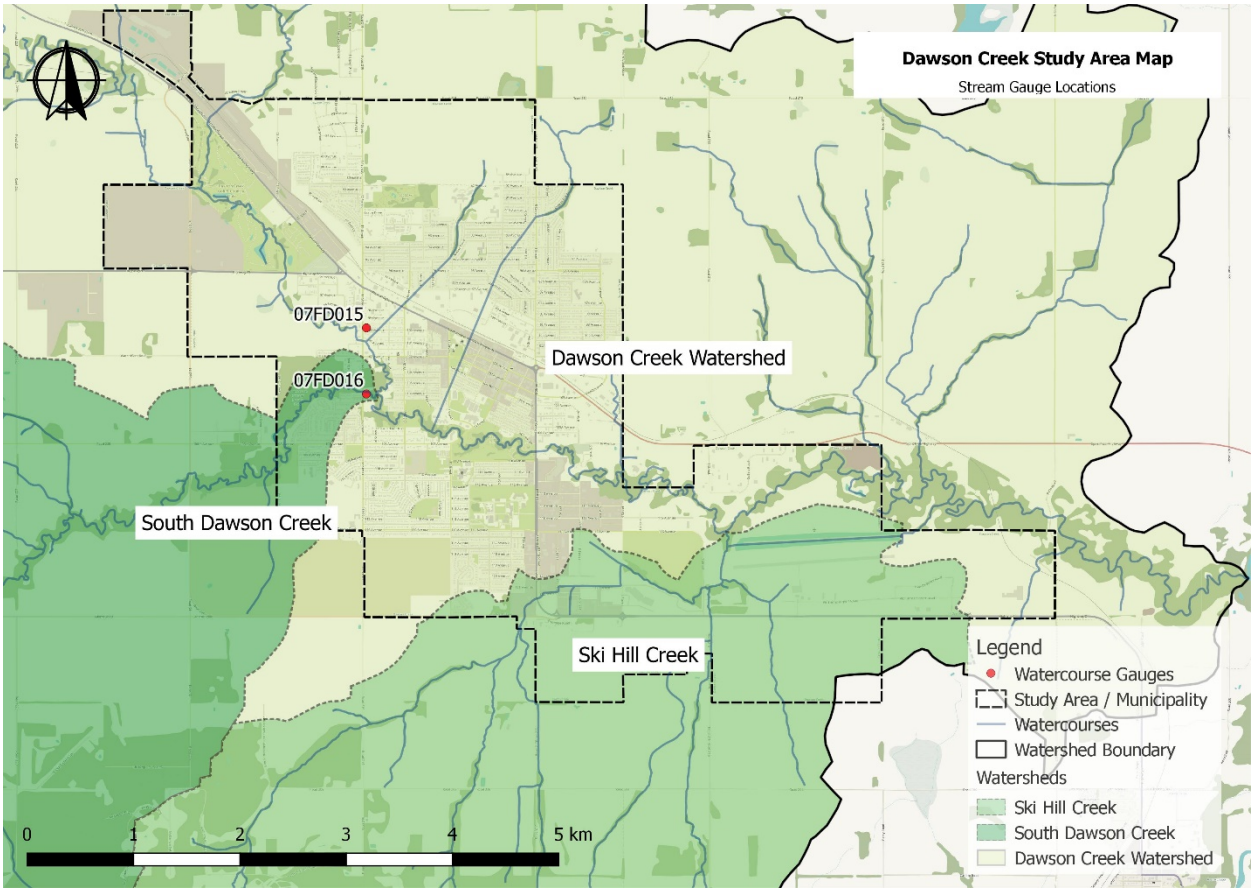


Figure 15: Dawson Creek gauge locations

The upper reach of the creek (within the study area) is relatively confined and straight. However, as the channel enters the urban area, it becomes more incised and sinuous. The river's average slope is 0.2% and the floodplain for upper Dawson Creek (upstream of confluence with South Dawson) is very wide – in excess of 600 metres in places – but narrows to 100-200 metres as the channel becomes more incised towards 8th Street. The bed material is primarily made up of cobbles, gravel and sand size particles and the surrounding vegetation is mainly tall grasses, shrubs, willows and overhanging trees.

4.3 Hazard Likelihood Concepts

The likelihood (or probability) of flood occurrence is a key component of understanding the hazard. The frequency of a particular event is tied to its severity. Minor food hazard events occur more frequently, and severe ones occur less frequently.

In this report hazard likelihood is expressed as an Annual Exceedance Probability (AEP). AEP refers to the probability of a flood event occurring in any year and represented as a percentage. For example, an

extreme flood that has a calculated probability of 0.2% of occurring in this or any given year is described as the 0.2% AEP flood[9].

Another way to think about flood likelihood is through the use of encounter probabilities, where it is possible to calculate the likelihood of encountering an event of a given size over a defined time period – for example the length of an average mortgage (25-years) or the lifespan of a human (75-years). Table 8 shows that for a 1% AEP event there is a 22% chance that an event of this size or greater will occur over a 25-year period. Understanding the likelihood of an event as well as the encounter probability of an event can support decisions related to flood management. For this project, we have considered multiple likelihood scenarios – and have reported them all using the AEP terminology.

Table 8: Encounter probabilities for various flood likelihoods.

Annual Exceedance Probability (AEP)	Indicative Return Period	Encounter Probability of Occurrence in 25 years	Encounter Probability of Occurrence in 50 years	Encounter Probability of Occurrence in 75 years	Encounter Probability of Occurrence in 100 years
100%	Annual	100%	100%	100%	100%
30%	Once every three years	100%	100%	100%	100%
10%	Once every 10 years	93%	99%	100%	100%
3%	Once every 33 years	53%	78%	90%	95%
1%	Once every 100 years	22%	39%	53%	63%
0.1%	Once every 1000 years	2%	5%	7%	10%

[9] It is emerging best practice to represent flood likelihoods with an AEP. In the past, flood hazard likelihood was commonly represented as an X-year return period. However, this tends to cause confusion regarding the frequency of an event with the lay public. For example, it is commonly understood that if a 100-year flood has occurred, it will not re-occur for another 99 years), which is incorrect.

4.4 Previous Studies

The City of Dawson Creek has mapped and modelled flood hazard for several purposes in the past. The 1974 floodplain was mapped and included in the Hazardous Conditions Development Permit Area for the City. The City of Dawson Creek does not, however, have a regulatory floodplain. Some areas of BC produced flood maps with modelling work by the BC Water Management dating back to the 1980s. Dawson Creek was not covered by this program. After damaging flood events in 2011 and 2016, the City commissioned some engineering studies to review various aspects of the creek hydraulics. The technical aspects of these studies are summarised below.

4.4.1 2016 200-Year Design Flow Report

In 2016, Urban Systems Ltd. (USL) was retained to provide an assessment of the June 2016 flood event. Part of this effort included developing extreme flow estimates for Dawson Creek and South Dawson Creek. USL conducted a regional hydrologic analysis to estimate flows for daily peaks, as well as for a future climate. Daily peak flows were calculated for both sites using regional data, and instantaneous flows were estimated by applying a peaking factor of 1.95. Further, a climate change factor of 1.25 was applied to the instantaneous flows to provide an indication of future expected flows. The results of USL's work is shown in Table 9.

Table 9: Flow estimates for Dawson Creek at Rolla Road (Urban Systems Ltd., 2016)

Annual Exceedance Probability (AEP)	Indicative Return Period (Presented by USL)	Daily Flow (m^3/s)	Instantaneous Flow (m^3/s)	Daily Flow with Climate Change Factor (m^3/s)
50	2-yr	13.7	26.7	33.4
42.9 (MAF)	2.33-yr	19.1	37.2	46.6
20	5-yr	29.2	56.9	71.2
10	10-yr	43.6	85.0	106.3
4	25-yr	52.1	101.6	127.0
2	50-yr	61.6	120.1	150.2
1	100-yr	71.0	138.5	173.1
0.50	**200-yr**	**80.8**	**157.8**	**197.3**
0.20	500-yr	92.7	180.8	226.0

4.4.2 2017 Hydraulic Assessment

Urban Systems Ltd. (USL) completed a hydraulic assessment of the crossings in 2017. The primary purpose of this work was to investigate the capacity of the crossings given backwatering that was observed during recent flood events. Given the project purpose, the hydrologic and hydraulic assessment focussed on the 0.5% AEP and the 2016 event, which is standard design practice for crossings in BC (as defined by the BC Ministry of Transportation and Infrastructure). The results of the hydrological assessment, as input to the hydraulic modelling are shown in Table 10; these are based on 2016 work completed by USL. Based on the updated 0.5% AEP design flows, the 2016 flood event was estimated to have a 10% AEP.

Table 10: Summary of flows used as input to 2017 hydraulic assessment (Urban Systems Ltd, 2017)

AEP	Dawson Creek (Upstream) (m^3/s)	South Dawson Creek (m^3/s)	Lower Dawson Creek (at Rolla Road) (m^3/s)
0.5	106	84	200
~10 (June 2016)	48-59	38-46	90-110

The hydrologic analysis was routed through a 1-D HEC-RAS model to better understand how a reduction in obstructions at the crossings affects water levels. The reporting notes that the obstructions increased water levels locally and increases flood extents.

Components of this model were used to inform the hazard mapping presented later in this report. However, it should be noted that this analysis and model, although appropriate for hydrotechnical investigations of crossings, for which it was designed, is not appropriate for flood mapping and would not meet newly developed best practice guidelines[10].

4.4.3 2017 Hydrotechnical Study for 10th Street Bridge Design

Opus International Consultants (Opus) completed a short hydraulic assessment with the purpose of designing a new bridge as a replacement for the existing 10th Street Bridge. The methodology used in this study was similar to the USL's analysis; however, the estimated flows were a bit lower in the latter. More specifically, the design 0.5% AEP with climate change factor for the 10th Street Bridge location is calculated at 173.2 m^3/s from Opus and at 162.4 m^3/s from USL including the recommended peaking factors in the report. This highlights the uncertainty associated with hydrologic analysis, especially for extreme events that consider climate change. Acknowledgement of this uncertainty is key to the development of robust flood mitigation plans (see Section 3.2.4)

[10] In the last 2 years, new guidelines have been developed to support a base standard for flood mapping in BC and in Canada. These include guidelines from Engineers and Geoscientists BC that focus on the qualifications and experience of the technical team, and even more recent hydrology and hydraulics guidelines from the Federal Government. These guidelines highlight the specific requirements and characteristics of the technical work required to develop flood maps and serve to illustrate how tools for flood mapping are different than other hydrotechnical tools used for crossing or other infrastructure design. All Professional Engineers working to develop flood maps must reference and adhere to these guidelines and should sign and seal a statement that they meet the standard of a qualified professional for flood mapping.

4.4.4 Climate Change Studies in the Region

In terms of climate change, there are different reports available for the region, however none of them manages to quantify the climate impacts on Dawson Creek. More specifically the different climate change tools and datasets available for the area are:

- The **Pacific Climate Impacts Consortium (PCIC) Regional Analysis tool** which shows the changes of precipitation under different Global Climate Models (GCMs) and Relative Concentration Pathways (RCPs).
- The **Pacific Climate Impacts Consortium (PCIC) Gridded Hydrological Model Output** which estimates the impacts of climate change on streamflow. However, the model was used *only for Peace River watershed* and it does not include Dawson Creek area.
- The **Northeast Water Tool** (NEWT) which covers particularly the current/historical streamflow. In terms of climate change this tool refers *only to changes in precipitation and temperature*.
- The Climate Change Implications for the City of Dawson Creek, (Watershed Steward, May 2012) report which indicates a potential for high peak events.

Due to the lack of more information at the time of reporting, the previously mentioned hazard modelling reports (2016, 2017) for Dawson Creek both apply a peaking factor of 25% to the peak design discharge to account for the uncertainties around the influence of climate change in the future events.

4.5 Hydrologic Approach and Results Summary for Hazard Mapping

The Dawson Creek watershed has limited data available to accurately calculate statistically valid flood flows or likelihoods; some limited historical data is available for gauges at two locations within the watershed. These Water Survey of Canada (WSC) hydrometric stations were located at Dawson Creek directly upstream of the South Dawson Creek tributary (Station # 07FD015) and at the South Dawson Creek tributary itself (Station # 07FD016) directly upstream of the inflow to Dawson Creek (Figure 15).

Flows for Dawson Creek were recorded for 14 years from 1981 to 1995 and flows for South Dawson Creek were recorded for 4 years from 1981 to 1985. The period of time during which flow rates were collected for the creek is too short for reliable statistical analysis. Further, portions of the data set are flagged as poor by the WSC. However, some general trends can be surmised from the data, and a summary of available flow data for both tributaries is shown in Figure 16.

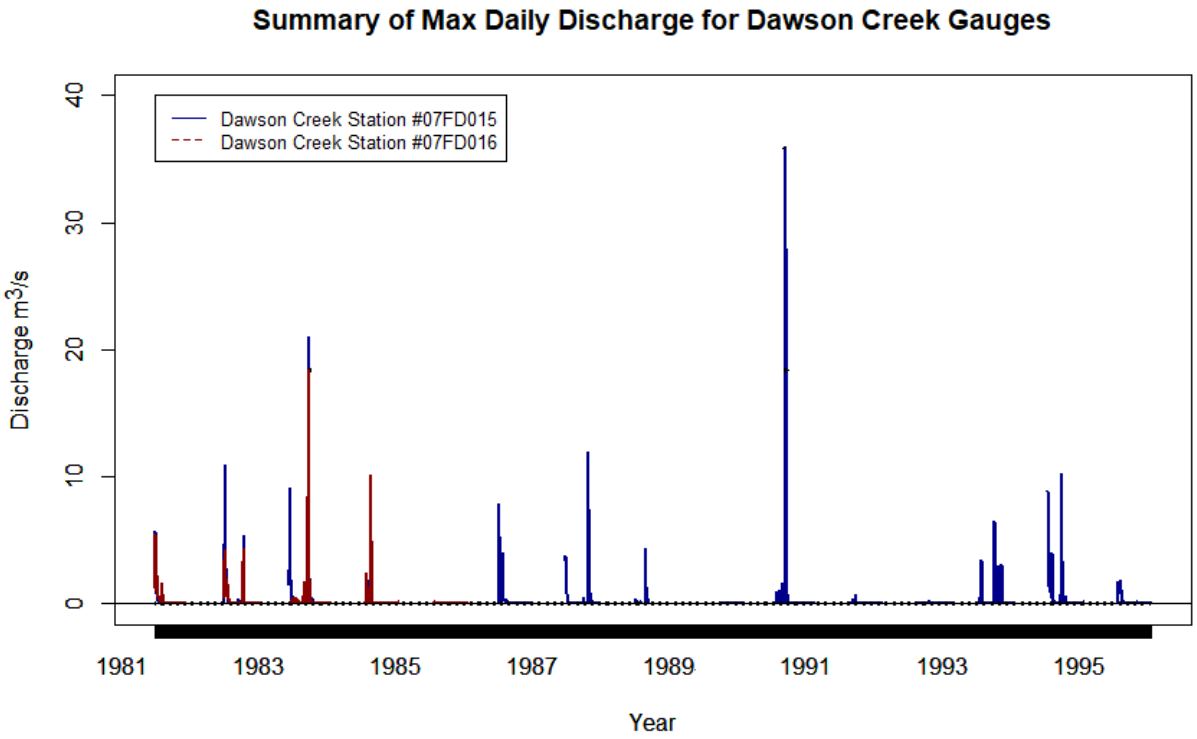


Figure 16: Summary of maximum daily discharge from Dawson Creek Gauges (Data Source: Water Survey of Canada)

The surveyed data, for the short period of overlap, shows general correlation between the two forks of the Creek (the mainstem and South Dawson Creek), which is unsurprising given their proximity and similar upstream watershed areas. Further, the data clearly records the peak flow events identified in Section 2 as causing impacts; specifically, 1990 and 1994. Other events with recorded impacts (1972, 2011, etc.) are outside the range of recorded hydrometric data.

4.5.1 Applied Hydrologic Design Flows

No detailed hydrologic analyses were completed as part of this work, partly due to resource limitations, but also because significant effort has already been made by others to estimate flows in Dawson Creek. Flows and annual exceedance probabilities for multiple likelihoods were selected for the purpose of high level hazard modelling and are based on work conducted by USL in 2016 and 2017.

Table 11 shows the flow estimates used in the hazard modelling for the purposes of this report. An indicative flood hazard severity (minor, moderate and severe) are used to represent a spectrum of flood events. The reliance on existing hydrologic reporting (which for the upstream boundaries of the modelling is limited to the 2016 event and a 0.5% AEP event) means that there are some limitations to this approach. Arguably, a 0.5% AEP flood would result in much greater hazard than a moderate flood as defined in Table 6. And therefore, the indicative hazard levels presented in this table were developed for this project, based on available information, and should not be universally applied. Further, they should be reviewed if and when more detailed hydrologic and hydraulic studies are conducted.

Table 11: Flows for Dawson Creek and the South Dawson tributary used for flood hazard modelling

Indicative Flood Hazard Severity	Annual Exceedance Probability (AEP)	Indicative Return Period	South Dawson - Daily Max Flow (m^3/s)	Dawson Creek - Daily Max Flow (m^3/s)	Comment/Source
Minor	10%	Approx. 10-yr (2016 Flood Event without debris)	46	59	Sourced from USL 2017 Reporting
Moderate	0.50%	Approx. 200-yr	84	106	Sourced from USL 2017 Reporting
Severe	0.1	Approx. 1000-Year	168	212	Very extreme scenario used to represent upper bound, and to ensure a conservative buffer on data collection for exposure and vulnerability

4.5.2 Climate Change

Research on the effects of climate change on water resources in this region of the Peace River watershed indicate that mean seasonal stream discharge is expected to increase, in particular in the spring season. Research shows that for the period of 2020-2040 as compared to the period of 2000-2011 in is anticipated that there will be increased rainfall, but also increased temperature and snow melt with freshet occurring earlier in the spring season (Saha, 2015).

The BC Oil & Gas Commission has developed an easy to use tool to look at predicted changes in watersheds in the Northeast of B.C. known as the Northeast Water Tool (NEWT). The expected average monthly changes for both precipitation and snowpack are shown in Figure 17.

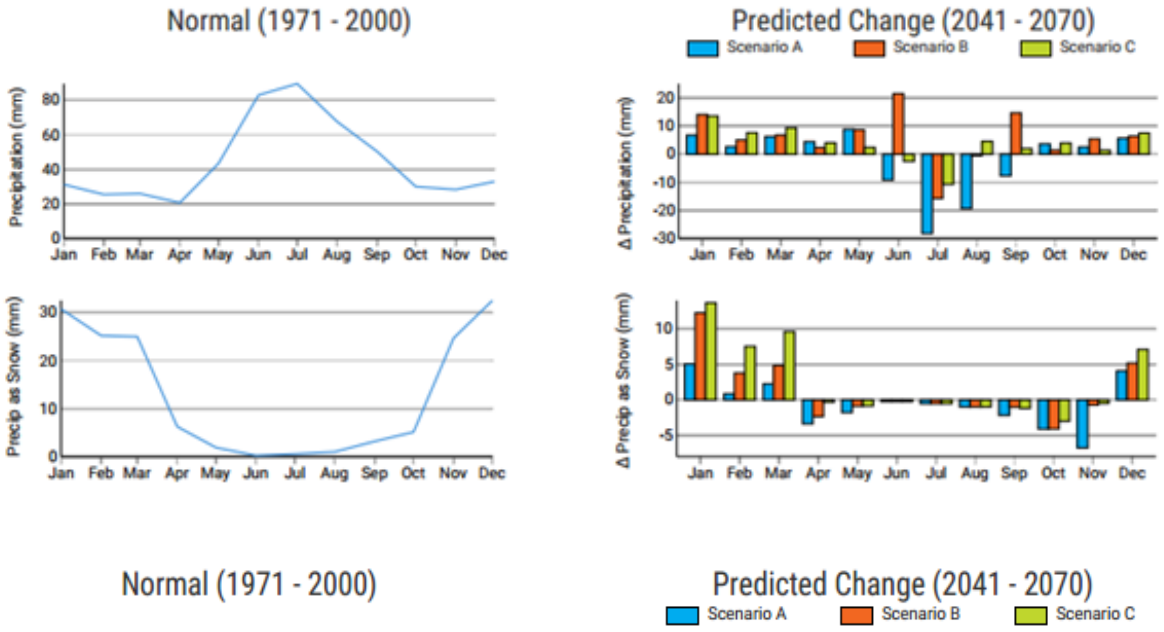


Figure 17: Normal monthly average precipitation and snowpack for the Dawson Creek watershed (left) and monthly average expected change (right) (Commission, 2017)

Generally, the region of northern B.C. is expected to become wetter with climate change and so any policies or measures should take this trend into account to ensure that policies will help Dawson Creek become more resilient to these changes and also achieve a good return on investment over the lifespan of proposed infrastructure. While Dawson Creek may be likely to experience less of an increase in stream flow due to snow melt as compared to larger watersheds in the region this is still a concern particularly for minor flooding. It should be noted as well that while overall the region is expected to become wetter, summer months will on average be dryer. This means that high flow extremes (floods) need to be managed in combination with low flow extremes (drought).

At this time, climate change is not explicitly considered in the hazard mapping. However, the severe scenario represents an upper bound, that should include climate futures. Detailed hazard mapping should explicitly include climate change as per best practice and guidelines.

4.6 New High-Level Hazard Modelling

Flood hazard (i.e. and understanding of where, how deep and how fast water is expected to be) is a foundational piece of information for any flood mitigation plan. The City of Dawson Creek has a basic understanding of flood hazards, including a 0.5% AEP flood hazard map from the 1970s, which is used to define extents in local regulations. Further, a 0.5% AEP flood hazard extent and historical 2016 flood event extents were recently defined as a component of consulting engineering work to look at hydraulic design of various Creek crossings. These models and maps were suited to their purpose, however, flood risk assessment and mitigation planning is best done with hydraulic models and mapped designed for the purpose of flood management. In this case, modelling that shows extents – but also depths and velocities,

and further models and maps that highlight the variation in hazard from different flood scenarios and likelihoods.

Given the above, we developed a simple 2-D hydraulic model (with no structures) using existing data and 1-D model information developed by others. This allowed for a more fulsome understanding of multiple flood hazard scenarios. The additional flood hazard scenarios were used in the risk assessment (i.e. risk scores were developed for minor, moderate and severe events), and provide useful information to guide future mitigation and increased resilience to all flood types (as opposed to a focus on just the extreme events). More detailed information on the model methods, verification, sensitivity and results are found in Appendix D.

The modelling shows that with increasing flows (to represent minor through severe floods), the flood extents, within the downtown core do not increase significantly; this is because the creek is remains within the relatively deep and confined channel (Figure 18). Outside of the downstream core, most notably near the confluence of Dawson Creek and South Dawson Creek, where the topography is gentler, the flood hazard extents expand significantly with the increasing flows. Further, the depths of water – are also much greater for higher flows. This highlights this area (i.e. the confluence of the creeks) as being an area of high flood hazard that should be considered as a priority going forward. This is also highlighted as an area of high risk later in this report.

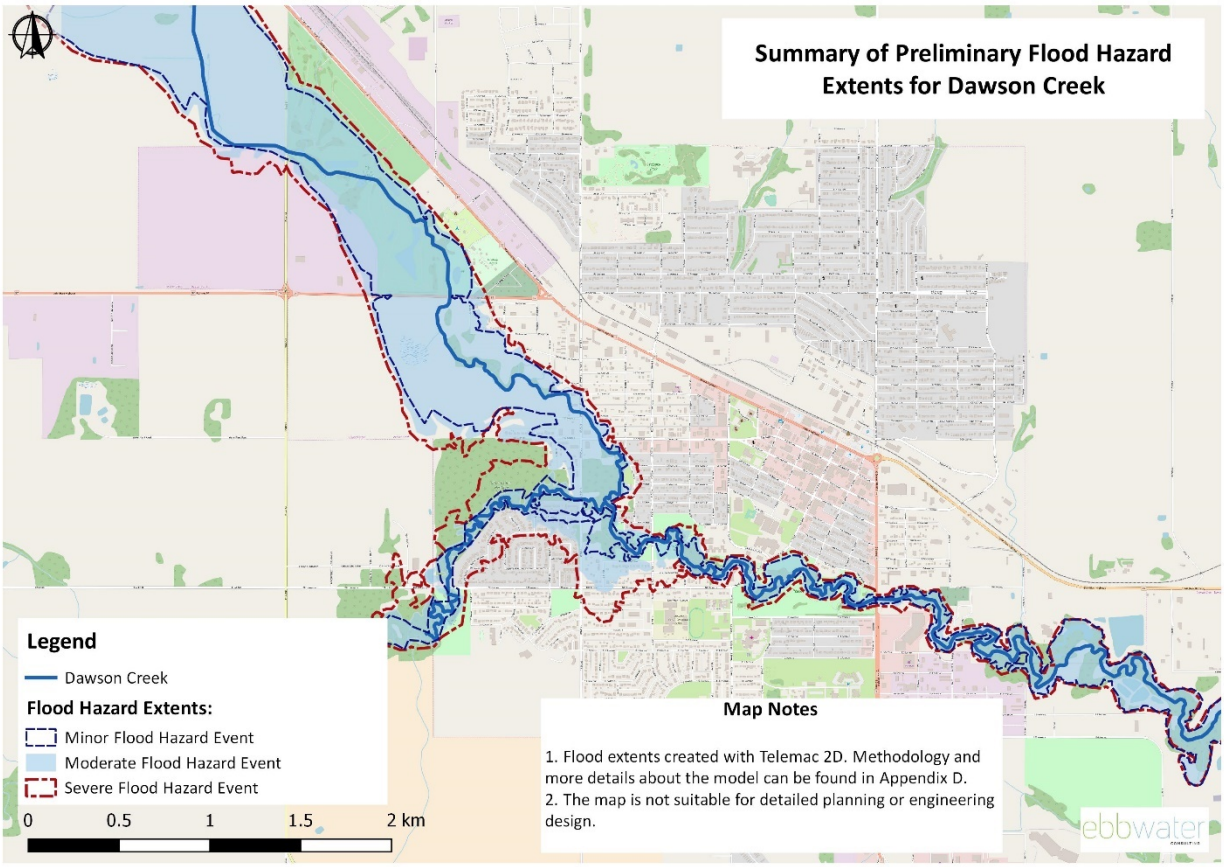


Figure 18: Summary of extents for minor, moderate, and severe flood hazard

The flood hazard event mapping shows that the extents are similar for the moderate and severe events while the extents for the minor event are much smaller. Most of the differences in extents are close to the confluence of Dawson Creek and the South Dawson Creek tributary. It should be noted that the Ski Hill Creek tributary has not been included in this model, nor has previous hazard modelling. Some impacts due to flows from the Ski Hill creek tributary, however, are included as they were reported by stakeholders.

4.7 Limitations of Modelling and Mapping

For this stage of the process and with the available resources, a high-level modelling exercise was completed. The modelling was conducted to provide high-level hazard mapping for the City of Dawson Creek. This modelling and mapping was developed to support the collection of exposure and vulnerability data at stakeholder workshops. The mapping is suitable for preliminary discussion; **it is not suitable for detailed planning or engineering design**.

As described at the outset of this section, the project scope, budget, and resources did not allow for a fulsome hazard assessment, nor the development of up-to-date flood mapping that meets best practice or guidelines. As mentioned previously high-level mapping was developed to support discussions with stakeholders and to support the development of a high-level risk assessment. More information on the limitation of modelling and mapping can be found in Appendix D and a **proposed scope of work to bring the modelling and mapping up to date is presented as Appendix F**.

5 Understanding Exposure and Vulnerability in Dawson Creek

A key component of any risk assessment is an understanding of what is in the way of the water (the exposure), as well as an understanding of how each of the assets in the way of water will react and recover from being wet (the vulnerability). Vulnerability to flooding was explored with the community and recorded spatially. As described in Section 3, estimating exposure and vulnerability, especially at a fine scale with consideration of tangible/intangible and direct/indirect impacts, is a resource-intensive exercise. For this project, a concerted effort was made to capture as many impacts as possible. The method to do this, along with the results of the analysis are presented below.

5.1 Methods

As described in Section 3, flood exposure and vulnerability can be calculated using a mix of quantitative and qualitative approaches, and both approaches were used for this analysis. For some assessment categories quantitative assessment was conducted. For example, census data was used to assess how many people would be affected by different levels of flood hazard severity. However, for some indicators, qualitative data was collected and used for the assessment. This was typically done for more intangible impacts or those for which more data was not available for the study.

5.1.1 General Methods for Quantitative Assessment

Quantitative assessments are generally considered more robust than qualitative ones, however they can only be conducted if appropriate data is available. For each of the indicators (see Section 3.5), a review of possible data was conducted to establish whether an assessment could be conducted (a full list of available data is provided in Appendix E).

Where spatial data was available (e.g., building locations and/or footprints), this was overlaid with the hazard mapping to identify assets within the flood hazard area. A simple hotspot analysis was completed in GIS to develop a map showing areas where impacts to the specific indicator are likely. Further, when appropriate, absolute numbers are reported.

5.1.2 General Methods for Qualitative Assessment

For the less tangible and indirect indicators, no hard datasets exist. Therefore, information on vulnerability to flooding was gathered with the participation of local community stakeholders. Impacts were recorded in a workshop setting (more details on the workshops can be found in Appendix C) and this information was organized and mapped by the consulting team. This allows for an understanding to be built around what gets affected when it floods and what are the consequences of some things getting wet.

Participants at the workshop were provided with some background materials on flood risk assessment and flood impact typologies (similar to the material presented in Section 3.6). They were then asked to mark on maps the location and type of impact that they had experienced or felt they might experience. Direct and indirect impacts were marked in different colours, and the category of impact (i.e. people, economy, etc.) was inferred from the information provided. This information was categorized and transferred to a digital GIS database and recorded as hotspot maps. This qualitative information can be very rich and can capture information that would otherwise be discounted. However, it should be noted that there are limitations to this approach – obviously, the diversity and number of stakeholders will affect

the outcome (i.e., if there are only business owners present then economic indicators might be noted, but other indicators such as environmental impacts might be missed). For this project, a large and diverse stakeholder group attended the workshop, and the information presented below is considered relatively robust.

5.2 Results

The following summarizes the results of the exposure and vulnerability analyses and includes some discussion for each of the six impact categories. These are assessed for minor, moderate, and severe flood hazard and presented spatially for the moderate flood.

5.2.1 People (Mortality and/or Missing)

For the purposes of this project, which focused on direct flood hazard (i.e., being wet), it was assumed that the potential loss of life is negligible, and no mapping is provided. Mortality from floods is rare in Canada, generally because people are given adequate warning and are able to evacuate. However, as additional hydraulic information is developed, and a better understanding of the river geomorphology is gained, it will be important to consider creek bank erosion as a potential hazard to people. Bank erosion or river avulsion can be sudden, and therefore there is a higher chance that a resident on the bank will not have warning. A geomorphologic study to map out future erosion could be completed as part of updated flood mapping project, and is presented in the proposed scope of work in Appendix F.

5.2.2 Affected People

The number of people affected by flooding is one of the impact categories that makes up the risk assessment and is related to impacts felt by people related to lost shelter, employment, schooling, etc... The map in Figure 19 shows impacts to affected people spatially, as reported by stakeholders at the workshop. This is represented as a hotspot map to provide a high-level representation of the location of the effects.

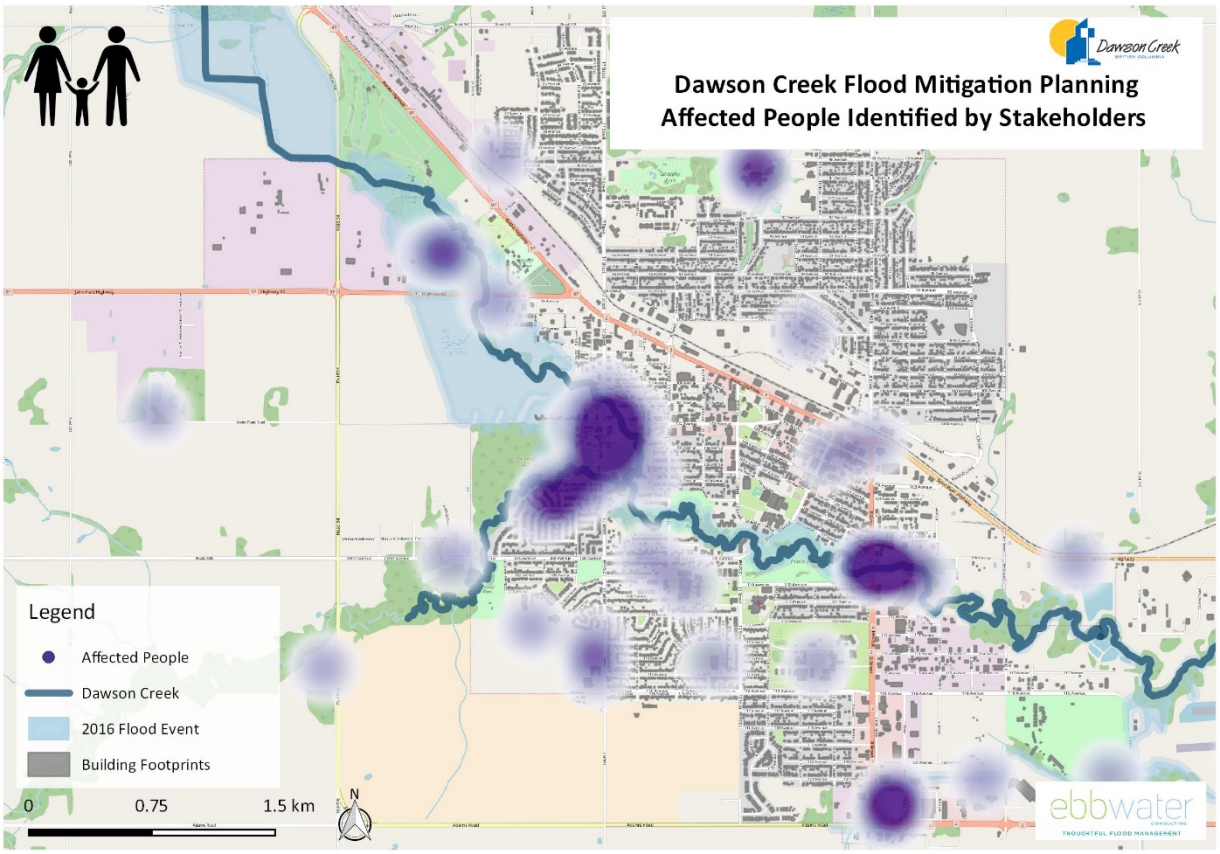


Figure 19: Hotspot map of affected people as reported by stakeholders in workshops

The number of people affected was also mapped using the most recent (2016) Canadian census data for the moderate flood scenario (0.5 AEP) as shown in Figure 20. For this flood extent, it is estimated that approximately 276 people would be affected. A summary of affected people for all hazard extents is provided in Table 12. These are estimates provided to give an idea of upper, middle, and lower bound approximations of affected people given that there is much uncertainty embedded within the data.

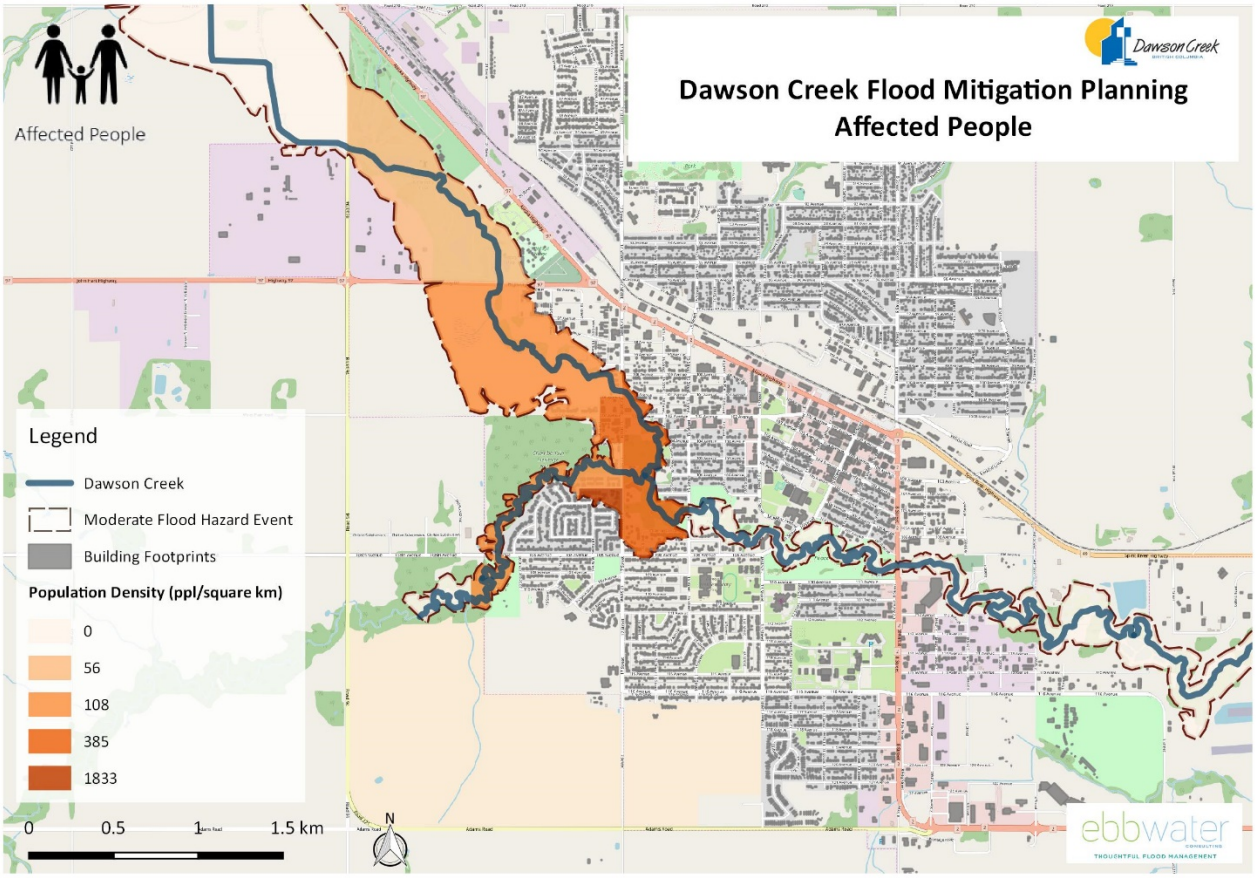


Figure 20: Population density in Dawson Creek by dissemination area for moderate flood hazard

Table 12: Affected people for minor, moderate, and severe flood hazard

Affected People		
Minor Flood Hazard	Moderate Flood Hazard	Severe Flood Hazard
158 people	276 people	693 people

5.2.3 Economic Impacts

Economic impacts are important to measure because they represent the effect that flooding can have on local livelihoods and commercial facilities. Further, economic impacts are often used to support the business case for flood mitigation planning and infrastructure. Figure 21 shows the high-level hotspots of economic impacts for the community as reported by stakeholders in the workshop.

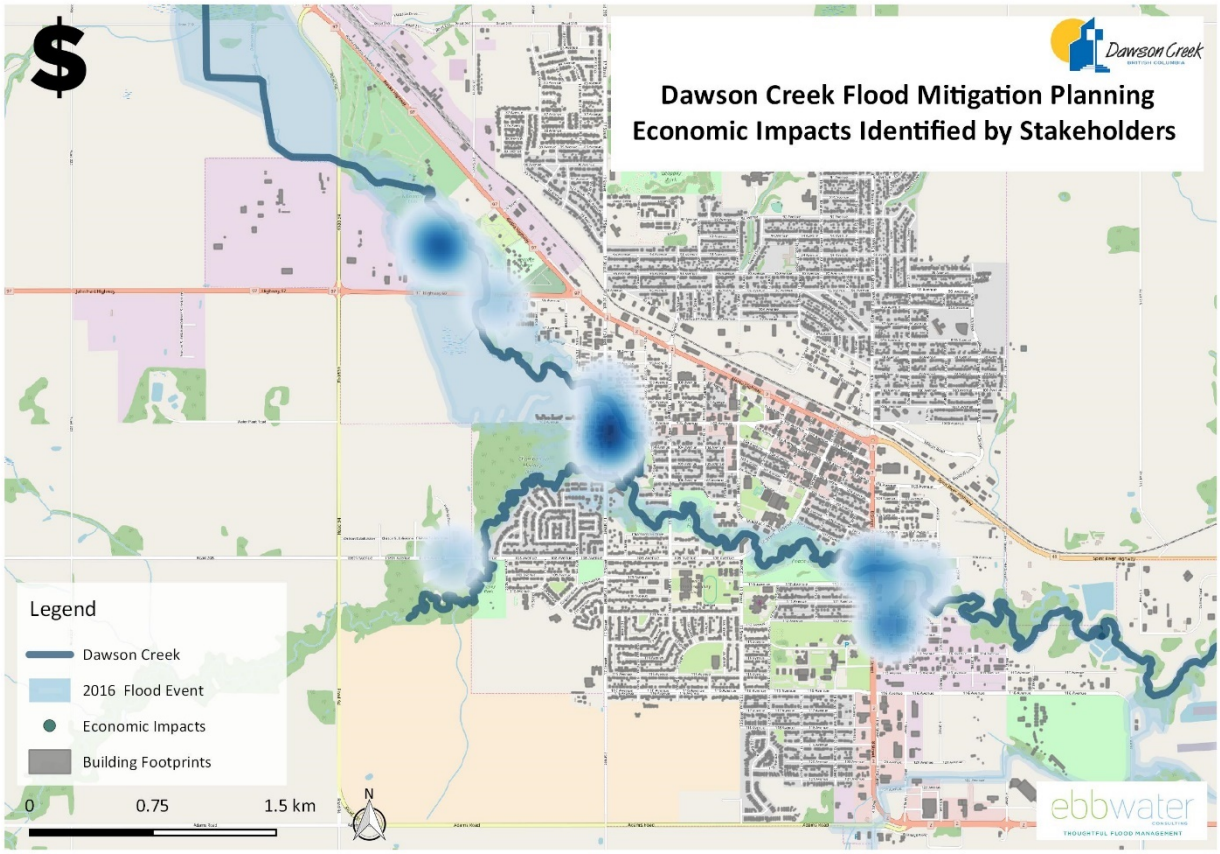


Figure 21: Economic impact of flooding in Dawson Creek as reported by stakeholders

The value of property in the flood hazard area was calculated using the available BC Assessment Authority Roll data (from 2018). This provides a more quantitative estimate of economic impacts of flooding. Figure 22 shows properties in the flood hazard area for the moderate flood hazard event (0.5% AEP). The estimated value of property in the flood hazard area is **$75 M** for this scenario.

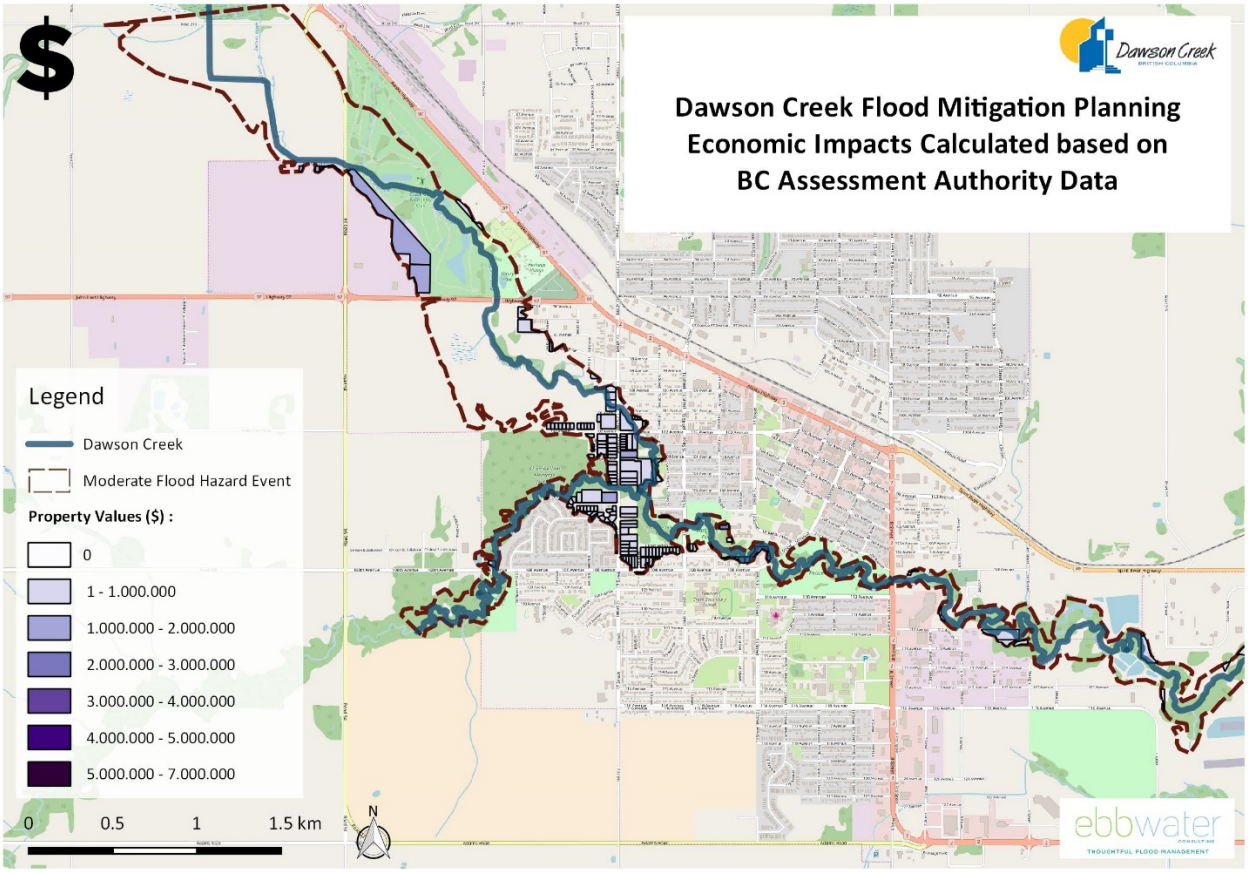


Figure 22: Economic exposure in Dawson Creek floodplain for moderate flood hazard

The calculations of property value within the flood hazard extent for all hazard events is summarized in Table 13. It should be noted that this is simply total property value in the flood hazard area and not a calculation of expected damage. To do this a more detailed assessment with updated depth-damage curves appropriate for Dawson Creek would be needed.

Table 13: Economic - property value in flood hazard area

Economic – Property Value in Flood Hazard Areas		
Minor Flood Hazard	Moderate Flood Hazard	Severe Flood Hazard
$51 M	$75 M	$141 M

5.2.4 Disruption

Disruption due to flooding refers to the number of disruptions to basic services attributed to the disaster. It is important to consider this because it represents the effect of flooding on infrastructure, services, and

the people using those services. Disruption, as recorded from workshop participants, is shown in a high-level hotspot map in Figure 23.

From this map, it can be seen that there is disruption recorded throughout the community. Some clear hotspots include bridges and creek crossings. Another hot spot is on the south end of the community where drainage from the bear mountain area (Ski Hill Creek tributary) drains into the town. Some disruption is due to power outages from linear infrastructure crossing the river being damaged. The transmission station for Dawson Creek is located on the north side of the city and so the south side of the city is vulnerable to power outages.

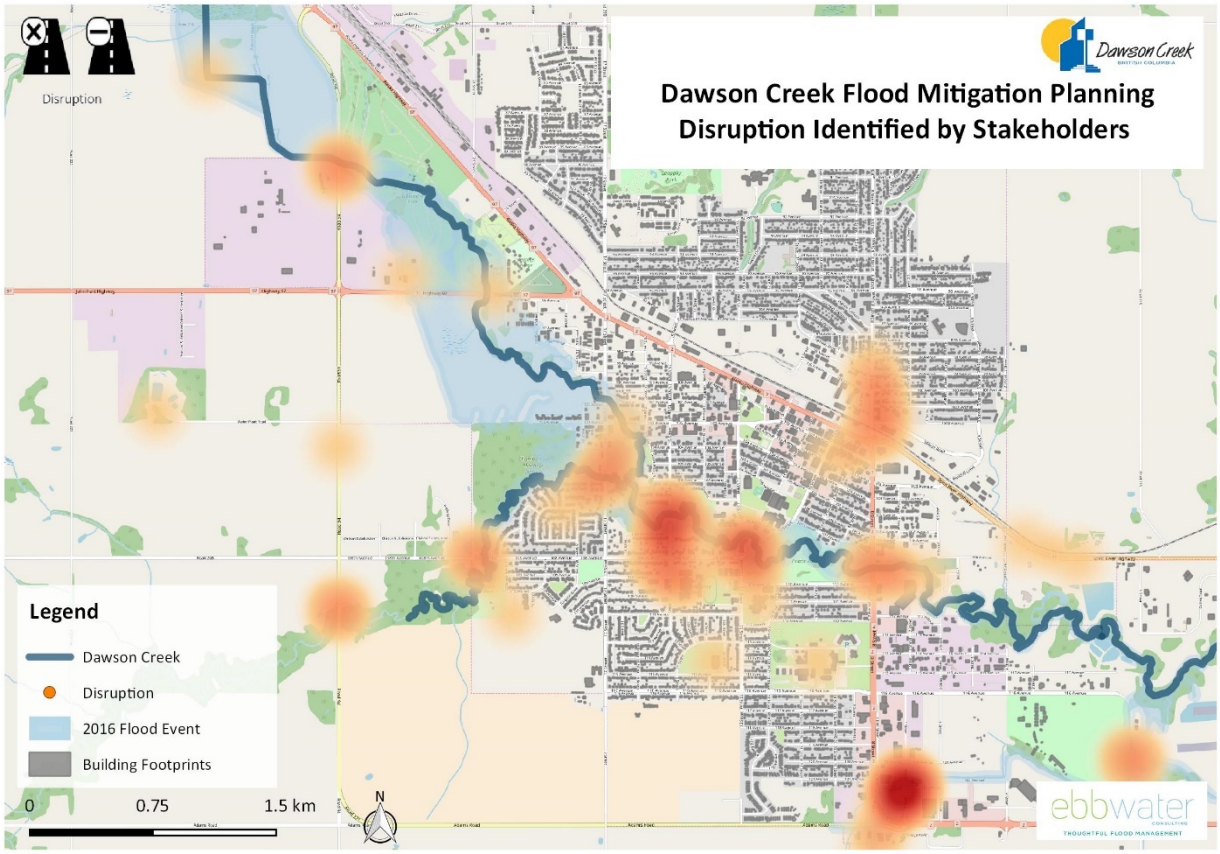


Figure 23: Disruption due to flooding with input from stakeholders

Disruption due to flooding was also studied in terms of the length of major and minor roads within the flood extent as shown in Figure 24. There are a number of both minor and major roads within the flood hazard area studied.

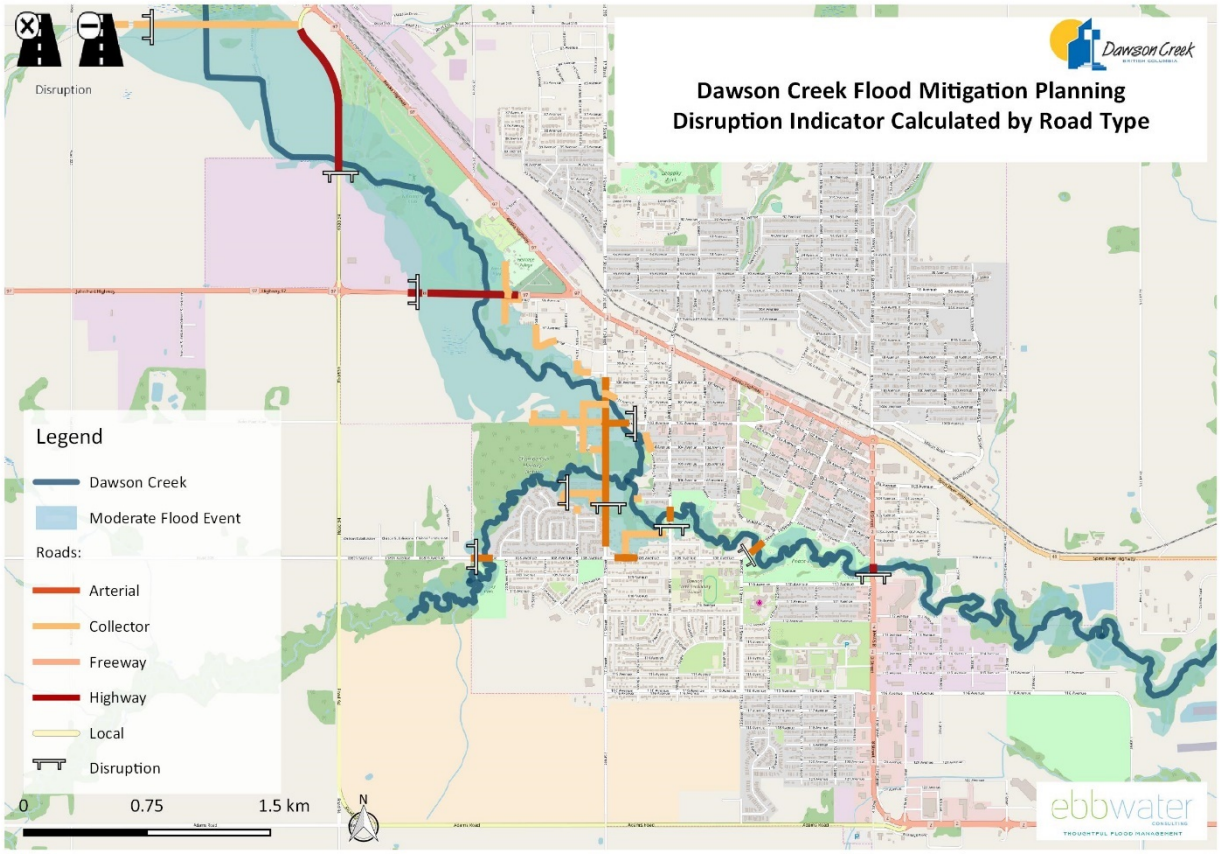


Figure 24: Disruption due to flooding for moderate flood hazard

Estimates of disruption to creek crossings for each hazard level is summarized in Table 14 and Table 15.

Table 14: Qualitative disruption for minor, moderate, severe flooding

	Minor Flooding	Moderate Flooding	Severe Flooding
Disruption	10% of creek crossings flooded, mostly local disruption.	80% of creek crossings flooded, significant local and regional disruption. Some residents likely displaced from homes for several days and disrupted for over two weeks. Emergency response likely needed for elderly and people with disabilities, etc.	100% of creek crossings flooded, extensive local and regional disruption. Some residents likely displaced for 1-2 weeks and disrupted for a month. Emergency response needed including possibly addressing utilities interruptions outside flooded area.

Table 15: Quantitative indicator for disruption for minor, moderate, severe flooding

Road Type	Factor	Minor Flooding		Moderate Flooding		Severe Flooding	
		Length (m)	Factored Length	Length (m)	Factored Length	Length (m)	Factored Length
Arterial	3	1567	4700	1693	5080	1693	5080
Collector	2	918	1836	1882	3763	2302	4604
Local	1	2913	2913	4421	4421	6257	6257
		TOTAL	**9450**	**TOTAL**	**13264**	**TOTAL**	**15941**

5.2.5 Environment

Floods can have an impact on the environment in a number of ways. Flooding can cause erosion, damaging vegetation along the water's edge, and flood water often spreads contaminants as they are picked up in the flood hazard area and transported. Several hotspots of environmental factors were identified by local stakeholders as shown in the high-level hotspot map in Figure 25.

This is a mostly qualitative assessment that give an idea of the location of the environmental impacts of flooding in the community. A more quantitative approach might include mapping sources of contaminants based on business licenses and obtaining more information about sources of pollutants in the watershed.

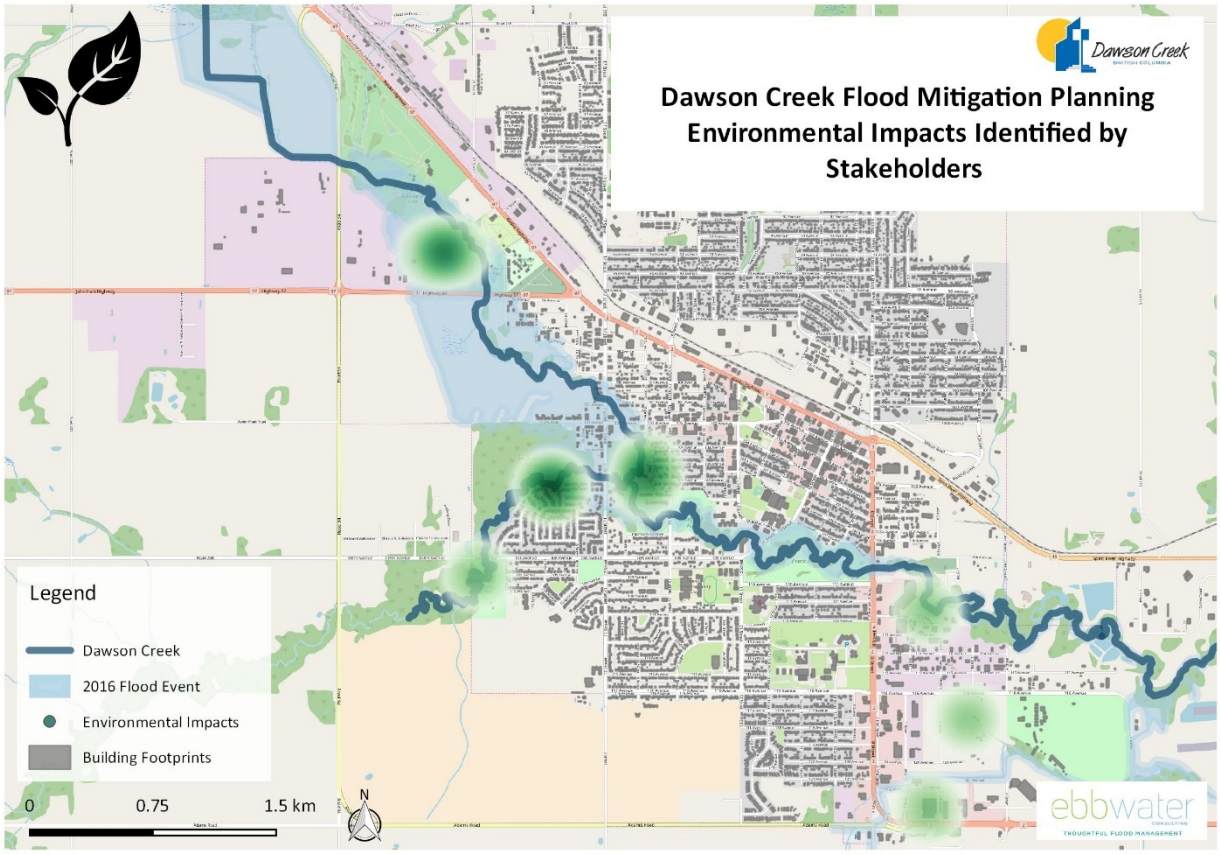


Figure 25: Environmental impacts due to flooding with input from stakeholders

5.2.6 Culture

As described in Section 3.5, flooding can cause impacts to cultural sites, including both indigenous and non-indigenous areas and items. No cultural impacts were identified by stakeholders, nor were any cultural sites noted on available exposure mapping. Because of this, no map is provided. However, the lack of data and information does not mean that there are no possible cultural impacts. If a risk assessment exercise is repeated in future (for example after the development of updated flood mapping) then a more concerted effort to include cultural (especially indigenous) knowledge should be made.

5.2.7 Direct and Indirect Impacts

In addition to the indicator specific indicator risk that mapped above, impacts were also recorded based on being either direct (i.e. something that got wet) or indirect (an impact that occurred outside the flood hazard area, or after the flood event). The results of this analysis is presented in Figure 26 and Figure 27.

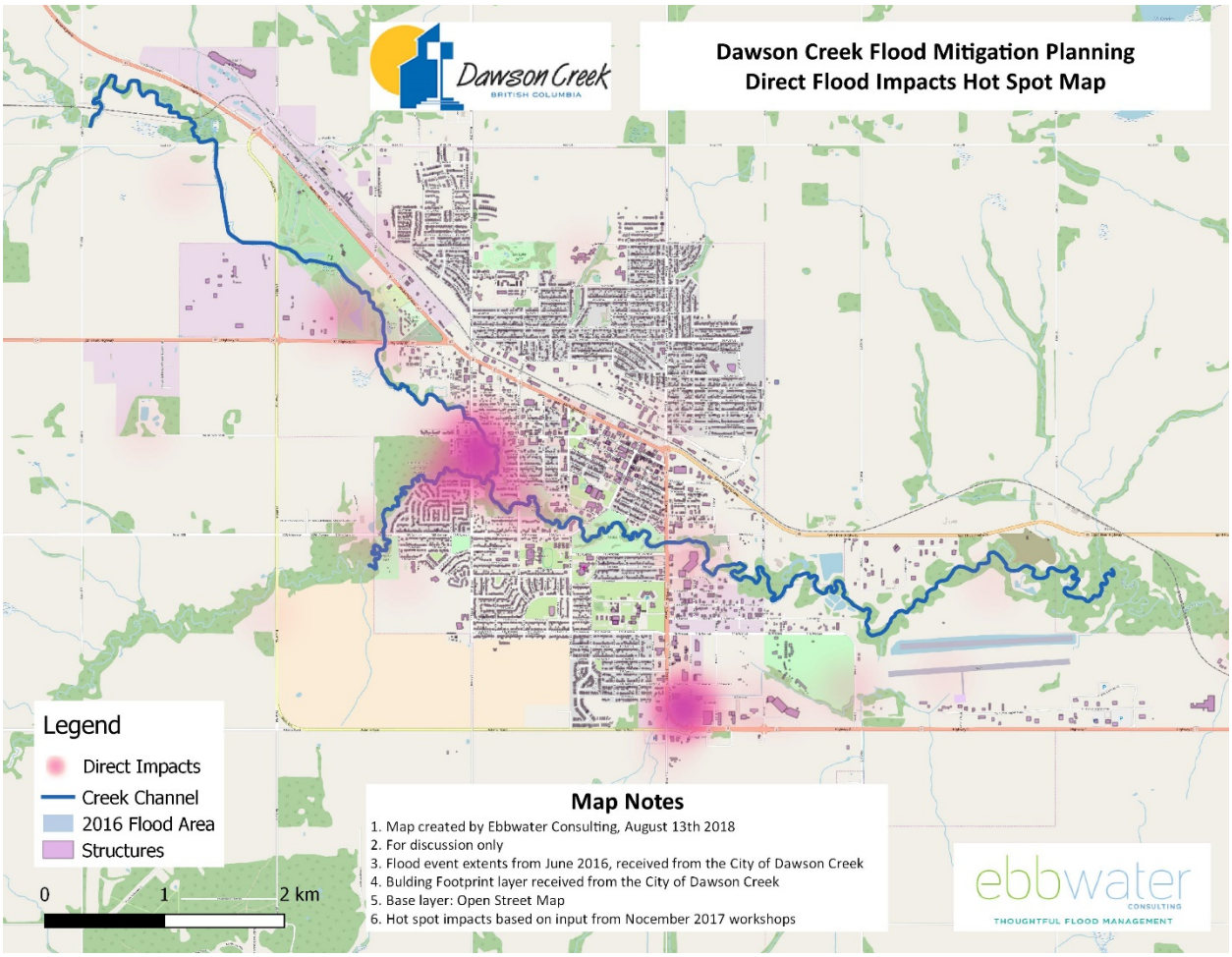


Figure 26: Direct impacts due to flooding with input from stakeholders

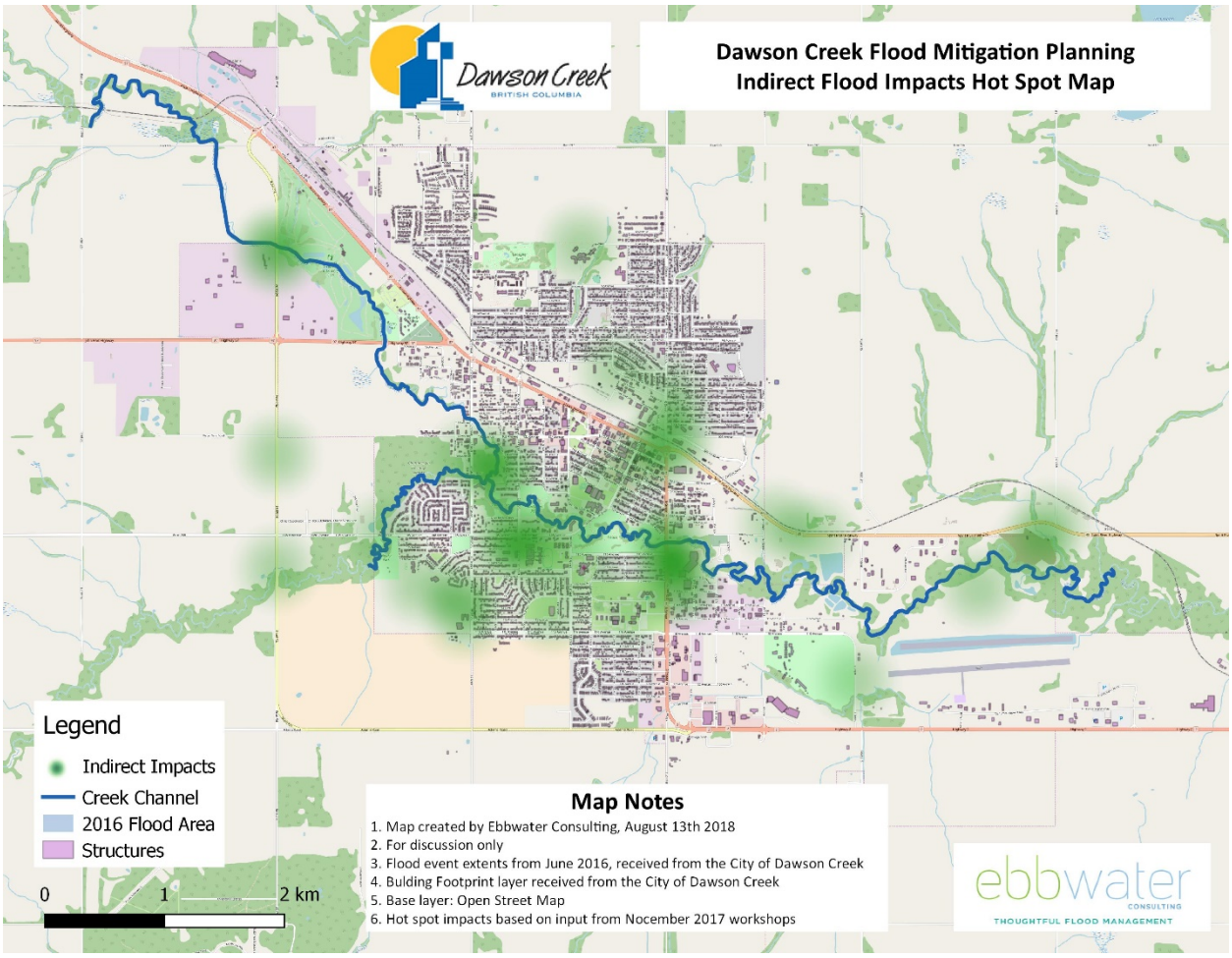


Figure 27: Indirect impacts due to flooding with input from stakeholders

The analysis of direct and indirect impacts shows that both are extremely significant. This highlights the need to consider indirect impacts (and the potential reduction in impacts) in any decision process. Many standard approaches to decision-making for flood – such as cost-benefit analyses – often discount or devalue indirect impacts. Further, the indirect impacts are very geographically dispersed – stretching to the edges and beyond the City boundaries. This highlights the need to work with neighbouring jurisdictions. Finally, the types of indirect impacts (which are further described in Section 7) show that some indirect impacts are not specific to flood (such as anxiety and isolation), and by working to consider and reduce indirect impacts, overall community resilience is improved.

5.3 Discussion

In summary, the maps for each of these impact categories paint a picture of where there are potential effects of flooding and provide some context for thinking around what kinds of measures might be appropriate to address these issues. Simply, the risk analysis and hotspot mapping provides an indication of where efforts need to be targeted in order to get the biggest return on investment on any flood mitigation measures. Some specific commentary based on the results:

- There are significant impacts to people, the economy, and disruption. There are lesser impacts to the environment.
    - Impacts to people are dispersed; many community members were impacted by flooding regardless of where they lived in the City.
    - Economic impacts are clustered in three specific areas: at the 8th Street Bridge Crossing, at the 17th Street Bridge and 102nd Avenue Culver crossings, and upstream of the John Hart Highway crossing.
    - Environmental impacts are mostly concentrated in areas that are currently more naturalised.
- For most indicators, the difference in minor and moderate flood hazard is relatively minimal. Whereas severe flooding results in much greater risk. This is primarily a result of the flood hazard extents not changing dramatically until a threshold volume is exceeded and the creek escapes the relative confinement of channel. This is not true for the quantitative measure of disruption, where disruption increases more linearly for the various flood hazard severities.
- Direct and indirect impacts are equally important.

Given the above the following notes can be made on how the results can inform future flood mitigation efforts:

- Apart from the economic indicator of risk, which is clustered, most impacts are dispersed across the City. This indicates a need for regional-scale, planning-type tools to mitigate risk, rather than targeted segmented and specific responses (see Section 8 for further discussion of what these are).
- For economic impacts, along with the identified disruption impacts, the greatest risk reduction will be achieved by managing the flood hazard in and around the 8th Street crossing; this is currently being managed by MOTI, who have slated this crossing for replacement starting in fall 2018.
- Given the significant impacts seen for more frequent, less severe events, it is imperative that these be considered in any decision process, rather than focussing on a single standard extreme event (such as a 0.5% AEP).
- Indirect and direct impacts are equally important; they should all be considered in any flood mitigation planning process.
- The geographically dispersed nature of the impacts highlights the need to work with neighbouring jurisdictions on any flood plan.

Overall recommendations to address these issues are presented in Section 8, which describes a planning process, and in Section 9, where specific actions are provided.

6 Understanding Flood Risk in Dawson Creek

The overall form of a risk assessment includes the combination of hazard likelihood with the consequences of that hazard (see Section 6). This is relatively straightforward if the underlying inputs are available. The focus of this project has been to develop a high-level complete risk assessment, and to begin developing suitable data sets and information for a detailed risk assessment. For the high-level assessment that has been completed, a simple combination of hazard likelihood and exposure is required to obtain a risk score.

The approach presented below is based on expected methods to be presented in future NDMP and DMAF program materials; it is also substantially based on best practice (see Section 3). It is a very simple approach to estimating risk using a matrix of scores. Scores are assigned to likelihood and impact, which are multiplied to give a risk score. A scenario-based approach has been taken here – where a single scenario (i.e. one likelihood) is used to represent risk; this is in keeping with the requirements of funding programs and is appropriate given the quality of the hazard information. However, if and when more refined hazard information is developed a probabilistic risk assessment should be considered.

6.1 Likelihood Scoring

A likelihood score is assigned based on the information in Table 16, which is drawn from work used to support updated materials for the NDMP. The more likely an event is to occur, the higher the score. The likelihoods are represented logarithmically, as this is generally assumed to represent the extreme value statistics of natural hazards. In this instance a likelihood score of 4.5 is given for minor flooding, a score of 3.0 is given for moderate flooding, and a score of 2.5 is given for severe flooding. These hazard events are used as upper and lower bounds - see notes in Section 4.3.

Table 16: Likelihood rating for risk assessment

Likelihood Score	AEP	Estimated Frequency (once every X years) (Indicative Lower Bound)
0.0	<0.001%	100,000
0.5	0.001% to <0.0033%	30,000
1.0	0.0033% to <0.01%	10,000
1.5	0.01% to <0.033%	3,000
2.0	0.033% to <0.1%	1,000
2.5	0.1% to <0.33%	300
3.0	0.33% to <1%	100
3.5	1% to <3.3%	30
4.0	3.3% to <10%	10
4.5	10% to <30%	3
5.0	>30%	<1

6.2 Impact Scoring

Similar to the likelihood scores, an impact scoring system was drawn from materials developed to support anticipated updates to the NDMP RAIT (Table 17). For each impact category a score from 1 to 5 is assigned, where 1 demonstrates the least (limited) impact, and 5 demonstrates the largest (catastrophic impact). Like the likelihood scoring, the quantitative measures are represented on a logarithmic scale. The quantitative measures are also presented using scalable systems – where impact is considered relative to a scale at which response might be expected; in this case the approximately the Peace Region. However, due to the lack of available economic data in terms of regional Gross Domestic Product (GDP), this is an approximation. Ratings for environmental and cultural impacts are qualitative and described with words only. Ratings for each of the impact categories was calculated or estimated based on the results of the exposure and vulnerability assessment described above.

Table 17: Impacts ratings for risk assessment

Level	Score	Measure
Mortality: Number of deaths and missing persons attributed to disasters, per 100,000 population		
Catastrophic	5	Deaths greater than 100 per 100,000
Major	4	Deaths greater than 10 but less than 100 per 100,000
Moderate	3	Deaths greater than 1 but less than 10 per 100,000
Minor	2	Deaths greater than 0.1 but less than 1 per 100,000
Limited	1	Deaths less than 0.1 per 100,000
Affected People: Number of directly affected people attributed to disasters, per 100,000 population		
Catastrophic	5	Affected people greater than 100 per 100,000
Major	4	Affected people greater than 10 but less than 100 per 100,000
Moderate	3	Affected people greater than 1 but less than 10 per 100,000
Minor	2	Affected people than 0.1 but less than 1 per 100,000
Limited	1	Affected people less than 0.1 per 100,000
**Affected People Score based on Calculation of Score = Affected People/Population of Peace Region * 100,000*		

Level	Score	Measure
Economic Consequences: Direct economic loss attributed to disasters in relation to approx. Peace Region GDP		
Catastrophic	5	Direct economic loss of 4% or more of GDP***
Major**	4	Direct economic loss of 0.4% to 4% of GDP
Moderate	3	Direct economic loss of 0.04% to 0.4% of GDP
Minor	2	Direct economic loss of 0.004% to 0.04% of GDP
Limited	1	Direct economic loss of <0.004% of GDP
***Economic Consequences Score based on Calculation of Score = Property Value in Flood hazard area/GDP of Peace Region * 100%*		
Critical Infrastructure and Disruption: Damage to critical infrastructure attributed to disasters		
Catastrophic	5	>100 of CI facilities damaged or disrupted
Major	4	>10 to 100 CI facilities damaged or disrupted
Moderate***	3	>1 to 10 CI facilities damaged or disrupted
Minor	2	1 CI facility damaged or disrupted
Insignificant	1	1 CI facility temporarily (<6hours) disrupted
CI facilities are represented by the CI sectors in the National Strategy for Critical Infrastructure (Government of Canada) and include: • Energy and utilities • Information and communication technology • Finance • Health • Food • Water • Transportation • Safety • Government • Manufacturing ***Critical Infrastructure included here are bridges, sewers and roads		
Environmental: Damage to the environment.		
Catastrophic	5	Catastrophic damage to environment.
Major	4	Major damage to the environment.
Moderate	3	Moderate damage to the environment.
Minor	2	Minor damage to the environment.
Insignificant	1	Insignificant damage to the environment.
Cultural: Damage to cultural or heritage assets.		
Catastrophic	5	Catastrophic damage to cultural or heritage assets.
Major	4	Major damage to cultural or heritage assets.
Moderate	3	Moderate damage to cultural or heritage assets.
Minor	2	Minor damage to cultural or heritage assets.
Insignificant	1	Insignificant damage to cultural or heritage assets.

Given the impact scoring table and the information gathered and presented in Section 5. The following impact scores were assigned to the City of Dawson Creek:

Table 18: Impact scores for Dawson Creek

Impact Category	Minor Flooding Impact Score	Moderate (Regulatory) Impact Score	Severe Flooding Impact Score	Comments
People (Mortality and Mission)	1	1	1	In all cases direct impacts to people are considered low.
Affected People	5	5	5	In all cases this score is high as a relatively high number of people will have homes or businesses impacted – especially when considering the scale of
Economic Consequences	3	3	4	Scores vary with the level of property value in the flood hazard area. This is significant when considered at the scale of the Peace Region.
Disruption	3	3	4	A moderate score is applied in all cases as a number of pieces of critical infrastructure are within the flood hazard areas.
Environment	2	2	2	The environmental impact is considered relatively low for all cases.
Cultural	1	1	1	No cultural impacts were noted, and a minimum score of 1 is applied.

The scoring in Table 18 is based on the available information and on the judgement of the consulting team. Given the qualitative nature of some of the measures, and the assumptions made (for example to scale the assessment to the Peace Region) it is arguable that the scores could be adjusted slightly. However, the overall assessment is within expected bounds and should be considered robust enough for the purposes of this project.

6.3 Risk Scoring

High-level risk scores for Dawson Creek are summarized in Tables for Minor, Moderate, and Severe Flood Hazard respectively.

Table 19: Minor flood risk assessment summary

Minor Flood Risk Summary			
Element	**Likelihood Score**	**Impact Score**	**Risk Score**
People (Mortality & Missing)	4.5	1.0	4.5
Affected People	4.5	5.0	22.5
Economic	4.5	3.0	13.5
Disruption	4.5	3.0	13.5
Environment	4.5	2.0	9.0
Cultural	4.5	1.0	4.5

Table 20: Moderate flood risk assessment summary

Moderate Flood Risk Summary			
Element	**Likelihood Score**	**Impact Score**	**Risk Score**
People (Mortality & Missing)	3.0	1.0	3.0
Affected People	3.0	5.0	15.0
Economic	3.0	3.0	9.0
Disruption	3.0	3.0	9.0
Environment	3.0	2.0	6.0
Cultural	3.0	1.0	3.0

Table 21: Severe flood risk assessment summary

Severe Flood Risk Summary			
Element	**Likelihood Score**	**Impact Score**	**Risk Score**
People (Mortality & Missing)	2.5	1.0	2.5
Affected People	2.5	5.0	12.5
Economic	2.5	4.0	10.0
Disruption	2.5	4.0	10.0
Environment	2.5	2.0	5.0
Cultural	2.5	1.0	2.5

This information is also presented graphically in Figure 28.

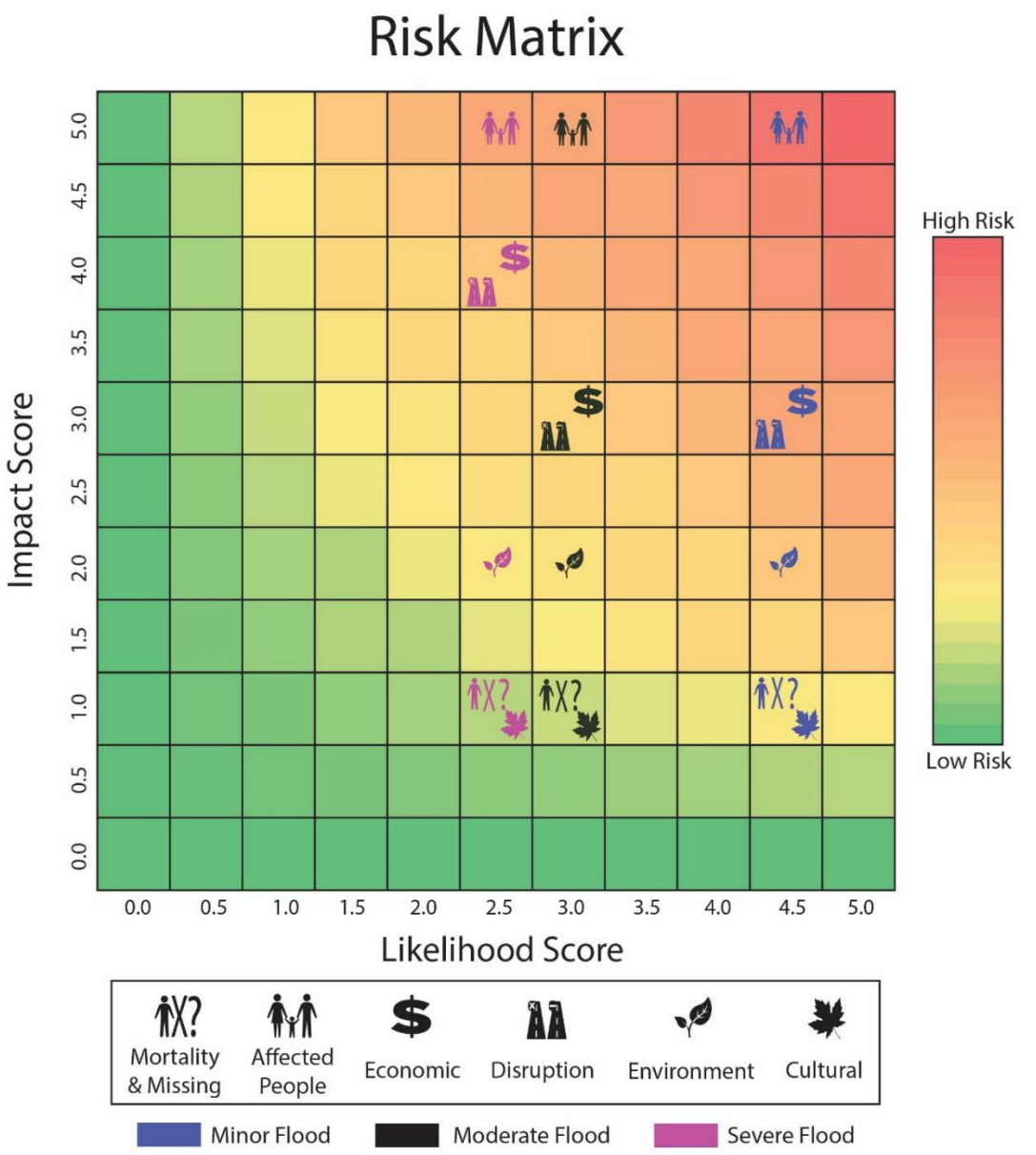


Figure 28: Summary of flood risk for City of Dawson Creek

It is clear from the above analysis that affected people risk is significant in all cases. Disruption is also high for the moderate and severe flood hazard events. It is however less extreme for the minor flood event. In general, the flood extents for Dawson Creek are quite binary, meaning that up to a specific threshold the impacts are small as the channel is quite confined. Once the water is over the banks, the extents quickly increase. Either there is a flood or there isn't, the increase is not gradual. This risk assessment, however, only takes into account flood extent and not depths explicitly. A high level, analysis of water depth changes was, however, conducted. It was found that while flood extents remain fairly similar beyond a given threshold the water depths increase significantly for more severe events. This means that a damage study with depth damage curves would be recommended for a detailed assessment. With this, you would likely see greater impact differences between the moderate and severe events.

7 Stakeholder Consultation and Community Resilience in Dawson Creek

Building on the City of Dawson Creek's ongoing efforts to manage risk and build resilience, this project intentionally engaged a broad set of stakeholders at two points in the process, in order to build awareness & understanding of impacts and risk, and to begin to describe the elements and characteristics of a flood resilient community. Due to the nature of flood as a "wicked problem", engaging stakeholders in this type of a process is an essential first step towards understanding and building resilience for the community. Joint understanding, ownership, action and ongoing learning is essential for a community to become truly resilient. The following summarises the results of stakeholder engagement and participation in this project. More detailed information, including workshop reports, is presented in Appendix C.

7.1 Flood Risk in Dawson Creek as a Wicked Problem

Flood management is a classic "wicked problem". It has a high degree of technical complexity, multiple dimensions of uncertainty, and multiple objectives. This is made worse by high stakes and high emotions, as there is often intense political scrutiny. More often than not, it is also limited by available resources (data, methods, time, money, and personnel). In our first session with stakeholders in Dawson Creek, participants identified many elements that make flood risk & management a "wicked problem" for the community, such as:

- Need to understand the 10,000 foot view, and local scale
- Managing upstream and downstream at the same time
- Managing both private property and the public interest
- Impacts of individual choice, will and interest, while trying to plan and act for the good of the whole
- Legacy of past decisions
- Requires out of the box thinking and action
- Contending with unintended consequences (e.g., removing culverts has influence on debris flows)
- Cascading effects and cumulative impacts of smaller decisions and actions
- Multi-jurisdictional complexity
- Have to learn as you go
- Providing effective support to vulnerable people in the moment
- Expectations are set, and there is a need for alternatives – have to make trade-offs

7.2 Local Experience of Flood Risk

As an early step in building shared understanding of flooding and its impacts, stakeholders and participants at a public forum were asked to share their personal stories of flood events. Key words shared in their stories are shown below:

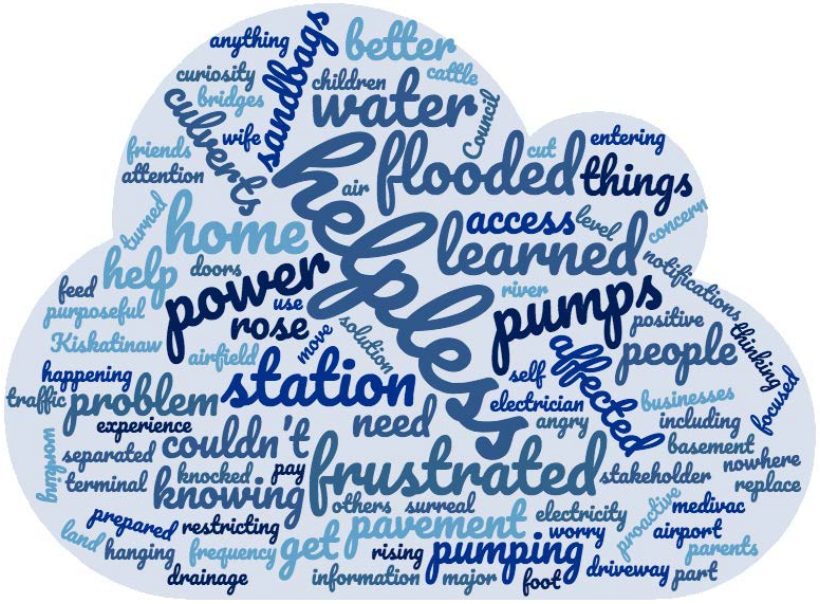


Figure 29: Keywords from stakeholders about their experiences with flooding

Figure 30: Key words from resident stories about recent floods

7.3 Components of a Safe, Prosperous and Resilient Dawson Creek

Communities do not want elaborate flood-control infrastructure, per se, they want safe and prosperous places to live; this should be at the heart of any flood mitigation plan.

One strategy to reduce natural hazard risk while delivering additional value to the community is designing multifunctional spaces. This could be in the form of a park that is a recreation space when it is dry and a water retention area during heavy rainfall or peak flows. Areas where dikes have been constructed sometimes also incorporate trails or bike paths for recreation. This means integrating considerations of flood risk reduction into other capital infrastructure plans where appropriate. What form this should take all depends on what the community wants and how this can be integrated with project needs and the available budget.

Stakeholders in Dawson Creek provided a robust list of considerations for what constitutes a safe, prosperous and resilient community:

- Personal resilience
    - Engagement, training (enhance understanding)
    - Recovery time
    - Addressing impacts such as post-traumatic stress disorder, anxiety and fear
    - Understanding the services available, what vulnerabilities are
- Knowing how to respond to crisis
    - Advance warning and communication systems
    - Response plans (community, individuals, businesses)
    - Business / employment continuity
    - Supportive behaviours (e.g.: don't get in the way or make it worse)
    - Communications within and outside the City
- Understanding the basin and creek, how these change over time and how flood risk changes as a result
- Smart development in the future (eg: decisions in flood hazard areas)
- Safe & reliable infrastructure
- Preparedness for areas at risk
    - Linking up emergency services
- Confidence to invest in business
    - Security about the future
- Insurance
    - Awareness of available insurance products and effects on disaster response funding

7.4 Stakeholder-Identified Opportunities for Building Resilience

Community resilience is a complex topic that has been researched and framed in many ways in different fields. This project uses a framework adapted from a number of sources, to describe key elements contributing to community resilience to flood risk. As you can see in Figure 31 this goes far beyond structural protection measures.

Figure 31: A resilient community framework.

(Adapted from: the Rockefeller Foundation Resilient City Framework; the City of Vancouver Healthy City Strategy; the Building Resilient Neighbourhoods Toolkit; and Zurich Insurance Community Flood Resilience Measurement)

Stakeholders were engaged in a two-step process to consider multiple values and interests of affected populations in the community, and then apply that insight into developing ideas for how to enhance community resilience. In the first step, participants formed groups to take on one of the following perspectives:

- Seniors, children and families
- Community leaders, decision-makers and infrastructure operators
- First responders
- Floodplain property owners (residential & business) and residents experiencing sewer backup

Each group then "mapped" the likely experiences and influences from this perspective, before, during and after both a smaller and larger flood event. This generated insights about key groups in the community that would be affected by, or responsible for planning and responding to, risk of a flood event. Those insights were then translated into possible actions to build community resilience, using the four categories in Figure 31, above. Details of both of these exercises are included in Appendix C (Workshop 2 Report), for reference in future flood and emergency response planning.

The key directions identified by stakeholders for enhancing community resilience to flood risk were:

Engage in proactive and coordinated flood management

- Invest in planning & coordination, proactively, across levels of government and across stakeholders to enhance effectiveness of decision-making and response capacity
- Support education and empowerment of stakeholders and individuals to take responsibility and be proactive where possible
- Learn from experience, and document this so that knowledge can be shared
    - ensure institutional knowledge can be passed on when there is staff turnover
    - share experience of past floods so current residents, stakeholders and staff are informed
    - translate learning from a flood event back into the preparation phase for next cycle

Plan and build with floods in mind

- Develop stronger land use policy & tools for areas in and around the floodplain
- Reduce vulnerable infrastructure in flood prone areas, while maintaining the community's connection to the creek
- Inform potential home buyers about flood risk
- Require and/or promote flood resilient building design and landscaping
- Conduct recovery planning – be ready to change course and/or build back better, when the opportunity arises
- Build more resilient / flexible infrastructure

Explore opportunities for a watershed approach

- Improve understanding of the watershed (e.g.: behaviour of creek & debris flows;
- Improve understanding of options to manage flood risk through watershed management (e.g.: upstream gauges & monitoring; potential for water retention)

Strengthen emergency planning and management

- Develop explicit mandates and budgets for emergency management and coordination
    - Consider a dedicated role for emergency planning, response & coordination
- Invest in capacity building of staff, and coordination of response
    - Consider how to draw on (and coordinate) resources available in the community (eg: human and knowledge)
- Plan for clear communications before, during and after flood events
- Contribute to a sense of calm by helping individuals and stakeholders to know what services are available and how needs can be met

Develop a resilient community culture

- Build engagement at a neighbourhood level to enhance resilience and enable an effective and safe community response during flood events
- Make space for concerns of residents and stakeholders to be heard & acknowledged
- Support individuals and neighbours to learn, take responsibility and take action
    - Enhance public engagement, education & communication

- Enable people to know what information is available so that they can make choices accordingly (eg: regarding emergency preparedness, flood risk to properties, insurance, etc.)
- Establish support groups
- Create emergency resource stations

7.5 Social Media Engagement

In addition to the workshops with stakeholders, and the introductory public meeting, a Facebook page for the project was set-up to provide some initial background information on flood risk in Dawson Creek generally, as well as to provide a venue to provide project updates. The Facebook page was primarily developed by Ebbwater but was supported and reviewed by City staff; it remains active. Additional information on the page content can be found in Appendix H.

The resource appears to have been successful and has reached almost 900 unique accounts since it was created in October 2017. The most successful post describes the results of the first workshop, where the impacts of flooding were recorded on maps. More analytics from the page are found in Appendix H.

7.6 Progress Towards Resiliency in Dawson Creek

The above discussion of best practice along with an understanding of some of the initial community values identified in the workshop and the outcomes of this study (risk assessment) mean that the region is well on the way to a more resilient future. Through this project, the City and stakeholders have acknowledged the problem and begun to develop awareness, have a basic understanding of the hazard, and have deepened their understanding of community values and vulnerabilities and risk relating to flooding. They have also begun to think about community resilience as a broader approach to flood risk and outlined some possible directions for making progress.

8 Flood Risk Reduction Process – Achievements and Next Steps

A general process for flood risk reduction and increased resilience, based on best practice for flood management is presented in Section 3.8. The following outlines how previous studies and this current study have progressed the City through the process.

Table 22: Summary of progress and next steps for flood risk reduction

Step		Progress	Next Step
1. Acknowledge problem and set the stage	100%	This step has been achieved through this project. Specific deliverables related to this step include the development of reports and maps that outline the problem, multiple stakeholder and public workshops, and ongoing engagement through social media.	
2. Identify and establish hazards	50%	This step has been achieved through this and other studies at a high-level. Future refinement is required in order to develop models and mapping suitable for flood planning (as opposed to structure design) that also meets current standards and guidelines.	Apply for funding to develop suitable flood modelling and mapping. Funding programs have been identified (see Section 9), and application materials developed (see Appendices) to support this application.
3. Identify exposure and vulnerability	95%	This step has nominally been achieved through this project (see Section 5). However, this step should be seen as iterative – and should be revisited and refined in future as information is improved.	Review and refine in any future flood planning projects.
4. Identify consequence and risk	95%	This step has nominally been achieved through this project (see Section 6 and Appendices A and B). However, this step should be seen as iterative – and should be revisited and refined in future as information is improved.	Review and refine in any future flood planning projects.
5. Establish objectives and measures of success	50%	Preliminary information to support this step was gathered through stakeholder engagement exercises as part of this project. Additional effort to refine measures of success will need to be made in future.	On completion of, or in parallel to flood hazard mapping, source funding and initiate a broader flood planning process that includes the development of measures of success. See Section 8.2.3 for additional information.

Step		Progress	Next Step
6. Identify flood mitigation options	50%	A full toolbox of potential options used for riverine flood mitigation is presented in Section 8.2.4 and options voiced in engagement are presented in 7.4 . With additional technical information from refined flood hazard modelling and mapping, these options could be further screened for efficacy.	Ensure that all options are included in projects going forward. Specifically, any structural options (such as the removal of constrictions, debris removal, upstream inline or off-line storage, wetland restoration) needs to be included in hazard modelling projects. All options should be considered at a high-level in any planning project going forward. See Section 8.2.4 for additional information.
7. Identify preferred options	5%	A preliminary screening of options based on the findings of previous studies and this work is presented in Section 8.2.4.	To be completed as part of broader flood planning process once flood hazard mapping and modelling has been completed. See Section 8.2.5 for additional information.
8. Development Adaptive Implementation Plan	0%	None.	To be completed as part of broader flood planning process once flood hazard mapping and modelling has been completed. In the interim, funding and other opportunistic efforts to implement no regrets options should be made. See Section 8.2.6 for additional information.

8.1 Achievements

The City has, through this project and others, has substantially completed Steps 1 through 4, although significant effort is required to refine the flood hazard modelling and mapping (Step 2). Further, this project has laid the groundwork for further steps by working with stakeholders to understand community values that can support the development of measures of success (Step 5) and by outlining and screening potential flood mitigation options (Step 6). The City can now move forward with a deliberative planning process that will result in an implementation plan. This section of the report outlines the general components for each of the remaining steps. Specific actions and recommendations for the City, given the problem context and funding opportunities are presented in Section 9.

8.2 Next Steps

8.2.1 Create an Internal Inter-Disciplinary City Working Group for Flood

In order to step through the process outlined above, there needs to be some co-ordination and accountability, to ensure the overall planning process will succeed. In addition, throughout the stakeholder engagement process, it was suggested several times that co-ordination, first within the City, and then with external stakeholders could be improved for flood response. We recommend that the City consider creating an internal working group for flood to include planners, engineers, watershed staff and emergency responders. This could be broadened to an external working group at a later stage. This group would be charged with implementing the next steps described here along with specific actions suggested in Section 9.0 of this report.

8.2.2 Refine Understanding of Flood Hazard

This work relied on outdated flood maps combined with hydraulic models designed for a different purpose to develop an understanding of flood hazard. This needs to be refined before moving on with flood planning and/or any flood mitigation design. A scope of work, based on leveraging existing studies, working collaboratively with neighbouring jurisdictions, and that meets current regulations and guidelines for flood mapping is presented as Appendix F. Further, materials to support a grant application to pay for flood mapping (i.e. a RAIT form) to either the NDMP and CEPF programs is presented as Appendix B. The City should submit an application to one or both of these programs this year (2018), as they are both currently slated to end.

8.2.3 Establish Objectives and Measures of Success

As outlined at the outset of this project, the City of Dawson Creek and its stakeholders, don't necessarily want elaborate flood-control infrastructure, they want safe and prosperous places to live and work. Identifying what success looks like for the community will enable the City to better make decisions about flood mitigation options.

The stakeholder values identified in this project (see Section 7.3) along with an understanding of what types of impacts and values can be measured (e.g. the results of the risk assessment – see Section 5) can form the basis of future measures of success. For example, community members expressed a desire to be able to personally respond quicker and better when it floods. A measure of success might be the average warning time (in hours or days) and the number of community members warned. This type of measure can then be used in later steps to evaluate flood mitigation options. Another example measure of success, based on the outcomes of the risk assessment, might be the reduction in disruption – calculated as a weighted-length of wetted roads – under different flood mitigation options.

The development of measures of success should be an integral part of mitigation planning – the next step for the City. Ideally, the City should work with stakeholders and/or the public to define these iteratively. Initially, the City staff could work with the results of the preliminary engagement (see Section 7.3) to develop some draft measures that could then be shared with stakeholders for refinement. For illustrative purposes, some example measures are presented in Table 23 and Table 24; these should not be used as is, but rather refined based on local conditions. In this example, measures are presented both for the

impacts of flood, which is considers the likelihood of the flood event, and for the impact of the measure itself, which is considered certain. Once measures are established, baseline conditions can be calculated. Mitigation options identified in later steps can then be compared against each other as well as the baseline condition. This approach provides a holistic, locally-specific means of understanding trade-offs between different flood mitigation options. This can complement or replace traditional benefit cost methods that tend to minimise indirect and intangible impacts of flood.

Table 23. Illustrative example performance measures for impacts per flood event

Performance Measures	Scale
PEOPLE	
People displaced temporarily	# of people displaced from flood events
"at risk" people impacted	Social Vulnerability Index weighted displacement
Park and recreational amenity value	Value-weighted area affected per event
Loss of critical services	# of pieces of critical infrastructure impacted
ENVIRONMENT	
Risk of contaminant release	# of sites with potential contaminants
ECONOMY	
Damage to infrastructure	Value-weighted km of roads impacted
Damage to buildings	$M
Business disruption	# of employees working in impacted businesses
Loss of inventory	$M
Emergency response costs	$M

Table 24. Illustrative example performance measures for implication of the flood-management action (or inaction)

Performance Measures	Scale
PEOPLE	
People displaced permanently	# of people displaced permanently (by sea level rise or flood-management action)
Aesthetics	-2 to + 2 (constructed scale)
ENVIRONMENT	
Environmental benefit	-2 to + 2 (constructed scale)

IMPLEMENTATION	
Capital costs	$M
Maintenance costs	$M/Year
Adaptability	1 to 4 (constructed scale)
Ease of implementation	1 to 5 (constructed scale)

8.2.4 Identify Mitigation Options

There is a myriad of potential options to reduce flood risk. As discussed earlier in this report, it is important to consider a broad spectrum of options rather than defaulting to the status quo. The following outlines generic flood mitigation options that should be considered in an initial screening. These are presented as overall strategies, more specific options, and finally as collective ideas (where multiple options are used concurrently).

Adaptation Strategies

Flood mitigation options are generally grouped into three or four broader categories. These are: "Adapt", "Protect", and "Retreat (see Figure 32). A further strategy is "Avoid", which is applicable only in areas where floodplains remain naturalized.

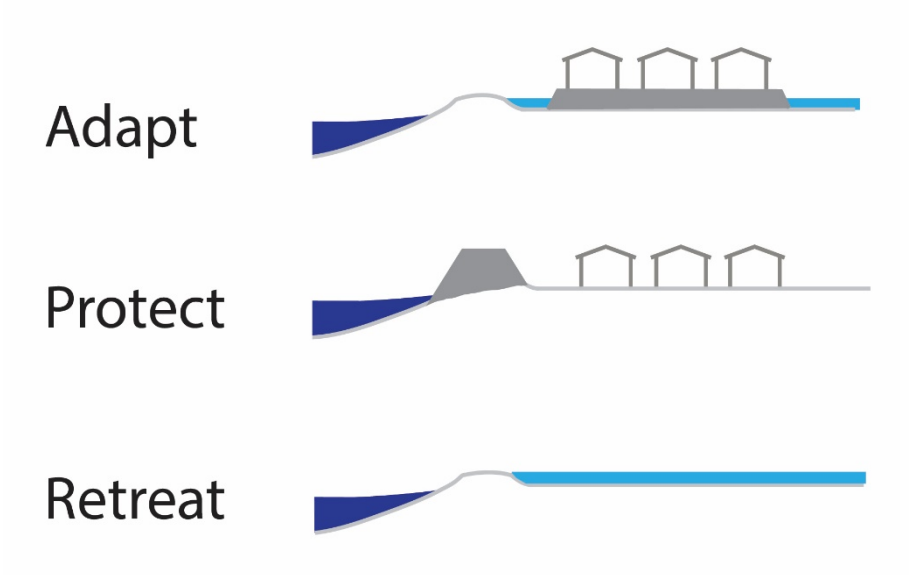


Figure 32. Three generic strategies for flood mitigation

Adapt

An Adapt strategy is one where a collection of options is used to reduce the exposure and/or sensitivity of vulnerable assets to a flooding event. Typical options used in an Adapt strategy include:

- Using planning options to ensure that no new critical infrastructure is built in at-risk areas of the zone.
- Careful regulation of sub-division and density approvals in floodplains to avoid increasing the zone vulnerability in future.
- Raising the physical height of City services (roads, water, etc.) over time and taking advantage of regular planned infrastructure turnover cycles.
- Incorporating flood-resilient design adjustments to building codes and using options and incentives to help residents and businesses improve property-level protection.
- Developing and implementing flood monitoring and warning systems.

Protect

A Protect strategy examines the consequences of applying particular options (usually dikes or berms) to reduce the hazard by preventing water from accessing valued elements in zones.

Retreat

A Retreat strategy is often considered a special form of exposure-reducing strategy in which vulnerable assets are actively moved away from particular areas over time. While not applicable in all areas, it may be viable to encourage the movement of vulnerable assets out of flood-prone areas. This might involve opportunistic buyouts as homes and businesses come up for sale over the next 40–60 years, with more aggressive buyouts 60–90 years from now; opportunistic removal of roads, other infrastructure, and contaminants as land is vacated; and aggressive re-naturalization in future.

Flood Mitigation Options and Initial Screening for Dawson Creek

Potential options may also be grouped by their source of implementation—whether regulatory, engineering, through building controls, emergency planning, and insurance options. Table 25 is an illustrative table of some of these techniques. This table also illustrates the potential applicability for the use of each adaptation option in each of the strategies discussed in the previous section.

Further, based on previous reporting, and on the findings of this project, and initial screening of options for Dawson Creek is presented.

Table 25. Illustrative table of adaptation options to mitigate riverine flooding

	Adaptation Option	Description	Applicability for Strategy			Initial Screening for Dawson Creek
			Protect	Adapt	Retreat	
Regulatory	Acquisition - Undeveloped Land	Buyout of property using public funds to sterilize area, thereby decreasing future assets at risk.			Y	Y
	Acquisition - Developed Land	Buyout of property or buildings using public funds to sterilize area, thereby decreasing future assets at risk.			Y	Y
	Relocation - Property	Moving of assets (buildings, businesses, people) out of floodplain.			Y	Y
	Relocation - Infrastructure	Moving of infrastructure (roads, services, etc.) out of the floodplain.			Y	Y
	Transfer of Development Potential	Transfer of allowable development potential to an alternate location out of the floodplain.			Y	Y
	Regulation of Land Use	Zoning bylaw, Development Permit Area or other option used to regulate land use within flood zone with the aim of decreasing vulnerability and risk.		Y	Y	Y
	Covenant on Title	Requirement that flood hazard be disclosed on property title.		Y	Y	Y
	Right to Flood	Provision in law that land be allowed to flood during high-water conditions.		Y	Y	Y
	Building Code	Provisions in code to increase flood resistance of new buildings through the use of flood-proofing or other property-level protections		Y		Y (with Provincial Support)
Engineering	Ring Dikes / Polders	Structural dike that rings a small area.	Y			Y
	Linear Dikes, Traditional	An embankment, wall, or fill piling constructed, assembled, or installed to prevent the flooding of land.	Y			N
	Multi-Use, or Super-Dikes	An average super-dike is 10 m high by 300 m wide. The extended width of the dike can be integrated into the urban fabric of the city by using the land to develop high-density housing, create a high-quality public realm along the waterfront, and by using the higher ground as a designated, lower-risk evacuation area.	Y	Y		N
	Obstruction/Constriction management	Removal of constrictions (e.g. from older crossings) or temporary obstructions (e.g. debris blockages) to return river to a more natural flow regime and reduce upstream water levels.	Y			Y
	Erosion Protection (Rip-rap/Dolos/etc.)	The main purpose of armouring (many variations) is to mitigate erosion by protecting existing river edges from high flows and velocities.	Y	Y		Y
	Natural Erosion Control (e.g., Wood, Grasses)	Placement of natural erosion-control materials, which, generally means the use of local native plants. This can reduce erosive energy and therefore the impact of flooding.	Y	Y		Y
	Constructed Wetlands	Wetlands can be constructed upstream or within the hazard reach with the goal of absorbing some of the flow volume.	Y	Y		Y
	Storage - inline	Upstream inline storage (i.e. dams) can be constructed to absorb some high flows, which can then be released slowly after the peak has passed	Y			Y
	Storage – adjacent and temporary	Temporary storage in floodplain areas (e.g. agricultural or recreational fields). This can be a relatively straightforward change in land use (see right-to-flood above), or can be an engineered approach, where small dikes or berms are design to spill and hold water (e.g. a waffle concept where excess water flows into a bermed field, and then spills into the next when it is full)	Y			Y
	Diversion Channels	Diversion channels are used as a river flood-management option. They are designed to take some or all of the flow and divert it around high-value areas. The Red River floodway in Winnipeg is an example of this technique.	Y			N

	Adaptation Option	Description	Applicability for Strategy			Initial Screening for Dawson Creek
			Protect	Adapt	Retreat	
Building Controls	Object Elevation	The elevation of an individual building above the expected flood level through the use of fill, stilts, or other structural means.		Y		Y
	Permanent Resistance (Dry Flood-proofing)	Products or actions, permanently in place, designed to stop water from entering buildings through existing openings or by penetrating walls.		Y		Y
	Temporary Resistance (Dry Flood-proofing)	Products or actions, deployed with appropriate warning times, designed to stop water from entering buildings through existing openings or by penetrating walls.		Y		Y
	Resilience (Wet Flood-proofing)	Building design and construction aimed at allowing floodwaters, but minimising damage. The use of flood-tolerant building materials (e.g., waterproof replacements for drywall) are an example of this option.		Y		Y
Emergency Planning and Management	Warning System	A program or automated system that provides a warning of impending flooding (hours to days to onset). More sophisticated systems use text messaging, but can also include media coverage, sirens, etc.	Y	Y		Y
	Evacuation and Response Planning	A program/plan for emergency response in the case of extreme flooding.	Y	Y		Y
	Public Education	Programs to educate the public about flood hazard, vulnerability and risk as well as the provision of resources that can aid the public in making good decisions about flood-risk reduction.	Y	Y	Y	Y
	Media Education	Programs to educate the media about flood hazard, vulnerability, and risk.	Y	Y	Y	Y (with others)
	Recovery Plans (Community Resiliency)	Programs or systems that are in place ahead of a flood event that will ensure a rapid post-event recovery.	Y	Y		Y
Economic and Insurance Options	Economic (Dis)incentives to Move Out of Floodplain	Until there is a flood, individual property owners have no incentive not to live in a floodplain. Economic (not insurance-based) options to incentivise home-buyers to buy outside the floodplain are not commonly used today but could be implemented in future. Further, the frequency of flooding increases, the value of homes in the floodplain may decrease as awareness around the risk and impacts of flooding increase.		Y	Y	Y (with others)
	Policies and Premiums	Flood insurance is widely used around the world as a means of exposure to flooding and is not available in Canada and specifically in Dawson Creek. Insurance can function because homeowners are provided with incentives (reduced premiums) for buying outside the floodplain or by implementing property-level-protections if they live within the floodplain. And, when a flood occurs, insurance monies can be used to partly recover losses		Y	Y	Y (with Insurance Industry)

The length of the table above, and the breadth of options presented, showcases that there are many ways to mitigate flood risk, and our traditional reliance on structural strategies has meant that many potentially better options have been ignored. Further, the initial screening highlights that the City of Dawson Creek has large toolbox from which to work, there are only a few options that should be eliminated at this time. It will be important to explore the full gamut of options in any future work, and to avoid focusing on a single option or option type too early in the process.

Adaptation Alternatives

The above laundry list of options should not be considered as a discrete list, where only one option is considered. Rather, a better alternative is to consider the bundling of options. This both allows for redundancy in flood risk reduction and for a particular alternative to have co-benefits (i.e. a group of options may provide a better opportunity for recreational or other ancillary benefits).

One way of thinking about this is to focus on major pieces of infrastructure or policy options, referred to in was "cornerstone" options. By this, we mean the foundational method of planning, either protection, adaptation, or retreat, without elaborating on secondary options that might be added later to improve performance of the cornerstone options. For example, a basic, traditional dike might be selected to protect an area, but it may be expected to have a negative impact on accessibility or aesthetics. This basic design could later be augmented by other features (e.g., landscaping, cycle paths, or other amenities), or by adding additional adaptation options for redundancy, ultimately improving the performance of the approach. For example, an alternative can be defined mainly in terms of the cornerstone option, and we assume that the performance of these options could ultimately be improved by integrating them with additional options at another level of planning (i.e., "brick" ideas as shown in Figure 33). These "refining" options would not be limited to any strategic category, but could be added thoughtfully on a case-by-case basis. For example, having identified a particular alternative as a preferred base solution, planners might later decide to elaborate on this with architectural features, redundant options from the adapt category, etc.

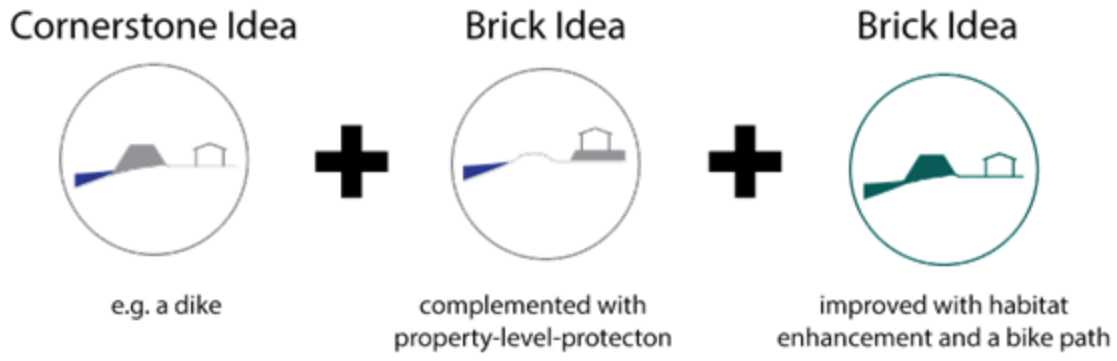


Figure 33. Development of robust alternatives

In addition to the generic ideas presented here, Dawson Creek should consider some of the options that were suggested by stakeholders and members of the community at the second workshop (see Section 7.4). Some of these are very much in line with the options presented in the table – for example, the desire to inform future home-buyers of the flood hazard. While others, are Dawson Creek specific, and are based on the lived experience of residents who have been flooded – such as developing support groups.

If the City moves forward to develop a flood mitigation plan, all of the generic (less those screened here) and Dawson Creek specific options should be considered.

8.2.5 Identify Preferred Options

The selection of flood mitigation options, and the process used to make decisions is a key consideration in any flood management project. A robust decision-making process is required to ensure that as many of the issues and uncertainties as possible are addressed. It is known that the choice of decision-making process can affect the outcome (Dean and Sharfman 1996). Therefore, the selection of an appropriate decision-making process that meets the specific needs of the City of Dawson Creek and other stakeholders is a key step in the development of a long-term strategy. Two such options are presented below for consideration.

Structured Decision Making

Structured Decision Making (SDM) is a framework for thinking critically about decisions that provides an organized approach to identifying and evaluating creative alternatives and making defensible choices in difficult decision situations. It is designed to engage stakeholders, technical experts and decision makers in a deliberative decision process, using best practices in decision making. Its goal is to both inform and actively aid decision makers, not to prescribe a solution or to develop a summary number or ratio.

A decision framework does not by itself select a preferred management option but provides insights about the decision by clarifying the things people care about, identifying creative alternatives, and exploring the trade-offs or choices that need to be made. SDM is designed to deliver insight to decision makers about how well their objectives may be satisfied by alternative courses of action, how risky some alternatives are relative to others, and what the core trade-offs between the available options are. It is designed to engage stakeholders, technical experts and decision makers in a decision process that is both analytical and deliberative, using best practices in decision making. An SDM process is designed to make complex choices more explicit, better informed, more transparent and more efficient.

The benefits of this type of an approach for flood planning is that it can fully engage stakeholders, especially diverse stakeholders with differing values, and it is good vehicle to develop new or improved options to those originally presented. The downsides of this type of approach is the level of effort required and the lack of an absolute decision at the end of the process; instead trade-offs are presented that requires decision-makers (usually senior city staff) to make a final call, albeit with a solid grounding and transparent information.

Scenario Analysis

Scenario analysis is a process of analyzing the future by looking at alternative outcomes. It is increasingly used for analysing long term uncertainties that are not readily quantifiable. Whilst there are many versions of scenario analysis, they all tend to be based around construction of a small number of contrasting yet internally consistent narratives about the future.

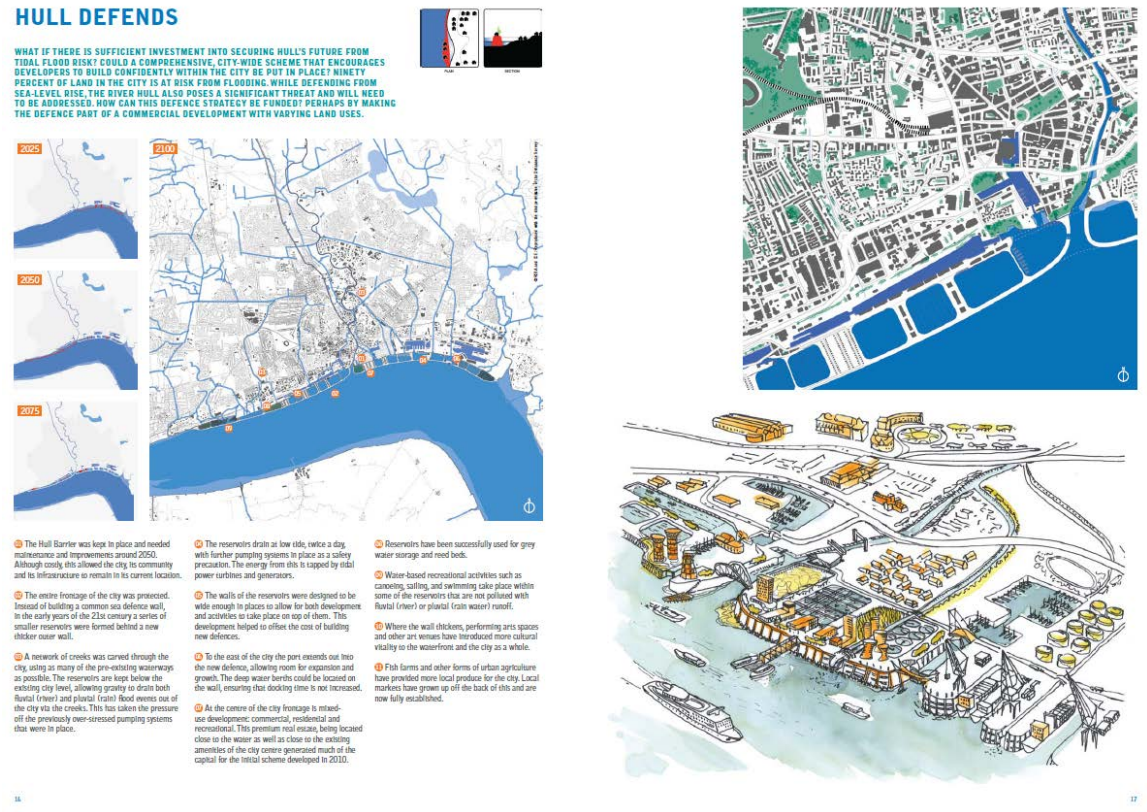


Figure 34: Example of single scenario used for analysis from ICE 2010

The benefits of this type of approach for flood studies that consider climate change is that it is generally easily understandable; it is based on narratives and graphics. A scenario analysis approach can also explicitly consider uncertainties. The downsides of this type of approach, especially when decisions need to be made in the near future, is that it does not by itself produce concrete decisions and next steps.

This type of approach is commonly used in Europe, especially for projects that include public participation. It is most famously used and supported by the UK Institute of Civil Engineers as well as by the IPCC.

Recommended Approach

Given that Dawson Creek faces a significant "wicked" flood hazard problem, that will intensify with climate change. And that many residents and stakeholders have been recently affected by flood – and want to be fully engaged in any process going forward. A decision tool that is transparent, manages uncertainty and allows for stakeholder involvement is suggested. We recommend an approach that combines scenario analysis (for its communication) and structured decision-making. The groundwork that has been laid by this project (i.e. the understanding of community values that can inform evaluation measures) is well suited to this approach.

8.2.6 Develop an Adaptive Implementation Plan

Once a preferred approach and mitigation options have been identified it is imperative that a plan be made to implement these actions. This plan should consider timelines, funding and opportunities and

constraints for implementation. Further, it is important that any implementation plan be adaptive to changing conditions – and allow the City to revisit earlier decisions.

9 Recommendations

The City of Dawson Creek has made some great progress towards flood resiliency as outlined in Section 8 and summarised in Table 26.

Table 26: Summary of progress towards flood resiliency

Step	Progress
1. Acknowledge problem and set the stage	100%
2. Identify and establish hazards	50%
3. Identify exposure and vulnerability	95%
4. Identify consequence and risk	95%
5. Establish objectives and measures of success	50%
6. Identify flood mitigation options	50%
7. Identify preferred options	5%
8. Development Adaptive Implementation Plan	0%

While the community of Dawson Creek is taking the right steps now to lay the groundwork for future studies and assessments, there are some additional actions that can be undertaken in the meantime. Some of these measures are around communication with the public and building local capacity. Others relate to collecting better data for short- and long-term decision-making. Some quick wins can involve thinking about spatial planning with available information. There is inherent uncertainty in flood risk assessments and there remains work to be done to refine the hazard modelling and build a database of vulnerability information.

As the City of Dawson Creek works towards becoming more resilient to flooding it is adopting international best practice by managing for risk and laying the foundation for future work through the current funding programs available. It will be important for Dawson Creek to think about future funding streams to carry out future modelling, and mapping work. With additional funding Dawson Creek can work towards becoming more resilient to flooding in the future with additional data collection, modelling, mapping, and capacity building in the community. The high-level risk assessment presented in this report suggests that the **risk is moderate to high** for Dawson Creek, and therefore it should be considered a priority community for future senior government flood mitigation funding and projects.

9.1 Commentary of Structural Options Identified by Stakeholders

9.1.1 8th Street (MOTI) Culvert Replacement

The culverts at the 8th Street crossing pose a clear constriction to the creek, and as a result water is held and backwatered upstream of the culverts, and on occasion results in the overtopping of the road. This was identified as potential flood mitigation option by stakeholders, as well as being a well-known and

identified issue more generally. The Province has committed to replacing this crossing with a bridge[11], and will begin work in fall of this year (2018), with completion in 2020.

The replacement of this bridge will be a major improvement – as it will reduce local hazard at the crossing and upstream, as well as open up and daylight the creek, which will have significant environmental benefits.

The replacement of this crossing will significantly impact the hydraulics and geomorphology of Dawson Creek. These changes should be addressed in any design. Specifically, upstream of the crossing, flows and energy in the system will increase as momentum will no longer be disrupted by the culverts. This will reduce water levels but increase velocities – and therefore the erosion hazard upstream may be increased. It will likely take years, if not decades, for the creek to come to a hydraulic and geomorphic equilibrium.

9.1.2 102nd Ave Culverts and 17th Street Bridge Upgrades/Replacement

The crossing of South Dawson Creek and Dawson Creek at the 102nd Ave Culverts and 17th Street bridge do pose a constriction on the Creek, and do cause a minor increase in water levels, in the order of 0.25 m on Dawson Creek and 0.3 m on South Dawson Creek (based on USL modelling), upstream of the crossings

The water levels in this reach have caused significant impacts to local residents and businesses. The flood hazard and risk in this area (identified in this report) should be reduced as part of any flood mitigation plan. However, we cannot recommend at this time that this be achieved through the removal or replacement of the crossings because:

- Any change at this crossing may exacerbate flood hazard downstream at the 8th Street crossing, where arguably impacts and risks of flooding are greater (as evidenced by results of impact and risk assessment). Changing the hydraulics, by opening up the channel, will likely increase the flow velocities and flow volumes downstream.
- The geomorphology of Dawson Creek is likely to change as a result of opening up the 8th Street crossing. It may take years or decades for the regime to stabilise. It would be precautionary to not create another shock to the system.
- Alternate options (such as property-level protection, repetitive loss property acquisition, insurance, etc.) may be considered superior options on completion of a comprehensive flood planning study.

In the interim, the City should support residents and business owners in this reach of the river to mitigate impacts of flooding by having response measures (such as flood barriers and bladders) ready to be deployed efficiently. Further recommendations on how to source and fund these ideas are presented below.

[11] http://prrd.bc.ca/board/agendas/2018/2018-20-247804065/pages/documents/06-D-1MOTI_June_28.pdf

9.2 Specific Actions

In addition to the overall strategy presented in Section 8, specific actions to achieve the steps of the overall strategy are presented below. These have been made in light of current needs (i.e. what are the specific next steps on the overall strategy), but also given the funding context. Some opportunistic and no-regrets actions, for which there are current funding programs available, are also noted.

Table 27: High priority actions

What/Step Addressed	Basis	Why	How
Flood hazard mapping **Step 2**	Without modern flood mapping no engineering design can take place, and funding opportunities will be greatly limited.	Develop flood hazard mapping that meets federal and provincial guidelines. Current mapping and models DOES NOT meet standards, and would limit ability of City to get funding for implementation for any flood mitigation works.	Funding for this work is available through the NDMP and CEPF (Stream 2). An application to the NDMP should be made by **August 31st**. Should this fail, an application the CEPF in the fall should be made as a back-up. A complete scope of work, and other supporting materials are provided as appendices to this report. **Cost**: $165k - $280k, funded through NDMP/CEPF
Tighten and improve hazard policies within OCP and DPA **Step 8 (Opportunistic)**	Existing language in old OCP is weak, and may result in increased risk through increased exposure on the floodplain.	The City is currently working on updating their OCP. This is an excellent opportunity to strengthen the OCP and DPA language to better align with best practice for flood mitigation.	Example language to consider as part of the OCP update process is provided as Appendix G. **Cost**: Minimal if pursued within current OCP process and if materials provided in Appendix G are used as a template.
Install hydrometric stations **Step 2**	Decisions, especially engineering decisions made in the absence of good data, can result in failure. Good, locally collected hydrometric data will inform modelling, mapping and potential future engineering works.	Dawson Creek is currently poorly metered. To better represent the hydrology of the river for future hazard studies, it would be best if gauges were installed within the City limits. This would also greatly support the calibration and	Hydrometric gauging can be cost-efficient given modern technology (Hund, Johnson, and Keddie 2016). Funding may be available to support this initiative through the CEPF.

What/Step Addressed	Basis	Why	How
		validation of a future hydraulic model. A hydrometric station linked to a real-time online webpage is also an extremely effective tool for public engagement and emergency response.	**Cost:** $15k to $100k depending on scope of services and if tied to a warning system.
Install a warning system **Step 8** **(No Regrets)**	The installation of a warning system is effectively a no-regrets solution. Further, better warning and communication was cited by stakeholders and the public as an option to pursue.	While floods often cannot be avoided, it is possible to move some of the things that matter out of the way with sufficient warning. With updated hazard information and gauges installed, a warning system could be built to alert the community to an oncoming flood. This can help to reduce disruption and overall damage, as people and some valuables can be moved out of the way of the water in time.	The CEPF considers warning systems and eligible project under its structural mitigation stream – this would be worth exploring as a potential funding source. **Cost:** $15k to $100k depending on scope of services and if tied to a hydrometric system.
Work with neighbouring jurisdictions to share technical information **Step 2**	Using consistent information will result in a better overall strategy, will be more efficient and collaboration on technical issues can foster longer-term collaboration.	At present, multiple studies have been conducted in the region to support different but connected projects (i.e. different crossings of the creek). Each of these studies applies different methods and uses different data, the discrepancies in design flows is noted earlier in this report.	Continue to work with others (MOTI) on projects that are underway (such as 8th Street crossing). Take initial steps to working with neighbouring jurisdictions, such as Chetwynd and PRRD, to apply consistent data and methods that also meet current guidelines and standards.

What/Step Addressed	Basis	Why	How
Collect data during flood events. **Step 2**			The City of Dawson Creek should make a commitment to collect data (water elevations, extents, velocities, as well as any damages)

Table 28: Medium and low priority actions

What	Basis	Why	How
Acquire repetitive loss properties **Step 8** **(No Regrets)**	Reducing exposure by removing assets from harms way is the surest means of reducing risk. However, obstacles (financial and political) can be significant, and therefore this is proposed as an idea that should be acted on once more education has been completed.	Reducing exposure by removing assets from harms way is the surest means of reducing risk	With support from Provincial and Federal partners. Funding for property acquisition is available through the NDMP (Stream 4). And the authors have confirmed that the Province will consider this type of application. An application should be made by August 31st. **Cost**: >$200k dependant on which properties. Funding might be available from Province of BC (see above)
Follow through on flood mitigation planning framework **Steps 5-8**	It will be imperative that the City follow through on a flood mitigation plan. However, this cannot be meaningfully done without a flood map (see above), and therefore this has a secondary priority.	Once more detailed, and up-to date flood hazard mapping is complete. The City should follow up with the development of an adaptive flood mitigation implementation plan as described in Section 8.	Funding for this type of work might be available under the NDMP if it is renewed (the 5th and final cycle is this year), or under the CEPF. These funding programs will require a completed flood map prior to the development of a flood mitigation plan.
Develop conceptual options for consideration **Steps 6**	It will be imperative that the City follow through on a flood mitigation plan. However, this cannot be meaningfully done	The City (potentially through the working group) should confirm and review the list of potential flood mitigation options that	As part of the stakeholder engagement process, several options were mentioned that should be considered and evaluated as part of a mitigation plan. These include debris

What	Basis	Why	How
	without a flood map (see above), and therefore this has a secondary priority.	should be considered as part of the flood mitigation plan.	removal in the channel and upstream storage options.
Flood response materials **Step 8** **(No Regrets)**	This is a no regrets option.	Sandbags are frequently used for short term flood response to build temporary flood barriers. This is a poor solution as they are one-time use item as they are installed once and then need to be disposed of because they become contaminated. Mobile flood barriers, however, are a better solution for temporary flood protection. The length of mobile flood barriers needed and then the locations that these would be effective can be tested with additional modelling.	There is potentially an opportunity to get funding to support these types of investments through the CEPF program.
Implement structural options **Step 8** **(Opportunistic)**	Structural options may not be preferred, however, if a structural option is developed and the timing coincides with the 2nd or 3rd intake for the DMAF program, this should be pursued.	If structural (including green infrastructure) options are identified as preferred in the planning process. The City should work with Provincial and Federal partners to fund their implementation.	Funding for this type of work is available through the DMAF (albeit with a basement $ value of $20M) and through a new Provincial program to be announced at UBCM in September 2018.

9.3 Quick Wins and No Regrets Actions

Many flood mitigation planning strategies take time and/or money to implement. These are outlined in the above. There are however some no-regrets actions that can be taken by the City immediately. This will serve to reduce risk and also ensure that momentum built throughout this process is not lost.

- **Continue to promote education and preparedness**; The City should continue to provide updates to stakeholders and residents on their efforts to act on flood mitigation planning. This could simply be updates to the Facebook page on grant applications and expected next steps.
- **Develop and nurture connections with partners**.
    - Flows into Dawson Creek originate outside of its municipal boundaries, and flood management is best considered at a watershed scale. Given this the City should consider co-operation with Peace River Regional District and an integrated regional planning approach.
    - Further coordination with infrastructure owners such as BC Hydro, and the Ministry of Transportation for the Province of BC would also benefit the project.
    - Work with the Insurance Bureau of Canada and local insurance agents to support residents in understanding their flood policies, and the potential likelihood that the DFA will no longer provide monetary support in areas where insurance is available (such as Dawson Creek)
- **Avoid any increase in flood risk**. The City of Dawson Creek council should consider a policy statement that the City will avoid increasing flood risk, specifically by zoning or developing areas that are in the currently recognised flood hazard area. This would provide a stopgap measure until the OCP is updated.

10 Conclusions

The City of Dawson Creek faces a significant flood hazard and risk and seeks to reduce this risk to the community. This project, along with work previously conducted by the City, lays the groundwork for a flood mitigation plan. This is in addition to many specific gains in understanding flood risk in the community, and the development of deliverables that will support future work.

Five specific project objectives were evolved to support the City's needs. These have been addressed through this project as described below. We feel that the objectives of the project have been well met.

1. **Better understand hazard, vulnerability and risk.** This project provides a summary of previous work conducted to establish flood hazard, and also provides additional hazard information and mapping to consider multiple flooding scenarios. Further, this project collected and analysed multiple datasets of vulnerability and exposure information and provides both a summary understanding of risk (for multiple impact categories) as well as a spatial understanding of where the greatest flood risks are found in the community.
2. **Lay foundation for stakeholder engagement**. Throughout the course of this project several efforts were made to connect with stakeholders and the public. This included two workshops, a public meeting and the curation of a Facebook page that continues to be live. The approach for the engagement was to encourage stakeholders to take a thoughtful best management approach to flood mitigation as opposed to leaping to conclusions and actions.
3. **Lay foundation for future funding.** As a component of this project, appropriate materials – including two types of risk assessment, and a scope of work for a flood hazard mapping project – have been prepared (See Appendices A, B and F). This provides a solid base of information for the City to apply to various funding programs including the NDMP, the CEPF and the DMAF.
4. **Prepare framework for mitigation planning.** In addition to the base information collected, analysed and reported in this document. We have provided an overall planning framework for flood mitigation (see Section 8) to guide the City in its effort to reduce risk and increase resiliency. Tangible and specific next steps are also provided.
5. **Provide no regrets actions.** As part of the recommended actions, 6 no regrets actions have been identified. These are actions that have little or no cost and/or will definitely support or result in flood risk reduction.

Given the clear need for flood risk reduction, and the important steps and efforts the City has made to date, we encourage the City of Dawson Creek to continue on its journey to flood resiliency by continuing to engage and work with its citizens, by making applications for funding, and ultimately by implementing the planning framework.

11 Glossary

Term	Definition	Source
All-Hazards	Referring to the entire spectrum of hazards, whether they are natural or human-induced. **Note:** For example, hazards can stem from geological events, industrial accidents, national security events, or cyber events.	PSC
All-Hazards Approach	An emergency management approach that recognizes that the actions required to mitigate the effects of emergencies are essentially the same, irrespective of the nature of the incident, thereby permitting an optimization of planning, response and support resources.	PSC
Asset-At-Risk	Refers to those things that may be harmed by hazard (e.g., people, houses, buildings, or the environment).	RIBA
Asset Inventory or Database	An inventory of assets-at-risk including the location, and sometimes vulnerability or resiliency measures.	
Critical Infrastructure (CI)	Processes, systems, facilities, technologies, networks, assets, and services essential to the health, safety, security, or economic well-being of Canadians and the effective functioning of government. The ten CI sectors in Canada are: Health; Food; Finance; Water; Information and Communication Technology; Safety; Energy and Utilities; Manufacturing; Government; Transportation.	PSC
Exposure	A measure of the amount of a structure, life, or other asset-at-risk that could be impacted by a potential hazard. Example: parts or all of houses, schools, and livestock on a floodplain are exposed to a potential flood.	
Flooding	Overflowing of water onto land that is normally dry. It may be caused by overtopping or breach of banks or defenses, inadequate or slow drainage of rainfall, underlying groundwater levels, or blocked drains and sewers. It presents a risk only when people and human assets are present in the area where it floods.	RIBA
Frequency	The number of occurrences of an event in a defined period of time.	PSC
Geohazard	A hazard of natural geological or meteorological origin (i.e., this does not include biological hazards).	
Hazard	A potentially damaging physical event, phenomenon, or human activity that may cause the loss of life, injury, property damage, social and economic disruption, or environmental degradation. Hazards can include latent conditions that may represent future threats, and can have different origins: natural (geological, hydrometeorological, and biological) or be induced by human processes. Hazards can be single,	UN-ISDR

	sequential, or combined in their origin and effects. Each hazard is characterized by its location, intensity, frequency, and probability.	
Hazard Assessment	Acquiring knowledge of the nature, extent, intensity, frequency, and probability of a hazard occurring.	MODFIED NDMP TO MATCH HAZARD
Hazard Inventory or Database	An inventory of the location, nature, and extent of influence of any potential hazards in an area of concern. Generally compiled as a GIS database.	NDMP TEAM
Natural Hazard	Natural process or phenomenon that may cause loss of life, injury, other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.	UN-ISDR
Likelihood	A general concept relating to the chance of an event occurring. Likelihood is generally expressed as a probability or a frequency of a hazard of a given magnitude or severity occurring or being exceeded in any given year. It is based on the average frequency estimated, measured, or extrapolated from records over a large number of years, and is usually expressed as the chance of a particular hazard magnitude being exceeded in any one year.	RIBA
Probability	In statistics, a measure of the chance of an event or an incident happening. This is directly related to *likelihood.*	PSC
Quantitative Risk Assessment	A *risk assessment* that is completed using quantified or calculated measures of risk.	
Resilience	The ability of a system, community, or society exposed to hazards to resist, absorb, accommodate, and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions.	UN-ISDR
Risk	The combination of the probability of an event and its negative consequences.	UN-ISDR
Risk Assessment	A methodology to determine the nature and extent of risk by analyzing potential hazards and evaluating existing conditions of vulnerability that together could potentially harm exposed people, property, services, livelihoods, and the environment on which they depend. Risk assessments (and associated risk mapping) include: a review of the technical characteristics of hazards, such as their location, intensity, frequency, and probability; the analysis of exposure and vulnerability, including the physical, social, health, economic, and environmental dimensions; and the evaluation of the effectiveness of prevailing and alternative	UN-ISDR

	coping capacities, with respect to likely risk scenarios. This series of activities is sometimes known as a risk analysis process.	
Risk Management	The systematic approach and practice of managing uncertainty to minimize potential harm and loss.	UN-ISDR
Vulnerability	The characteristics and circumstances of a community, system, or asset that make it susceptible to the damaging effects of a hazard.	UN-ISDR

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Appendix A Risk Assessment (Generic)

The following provides information to inform the completion of risk assessments template or form. It is based on the expected future form of the National Disaster Mitigation Program (NMDP) Risk Assessment Information Template, which could be used if the NDMP is renewed. It also includes relevant information for the completion of the natural hazard risk components of the Disaster Mitigation Adaptation Fund (DMAF). Further, this risk assessment provides a grounding on the baseline flood risk in Dawson Creek. Details on the methods and meaning of the risk assessment is presented in the main body of the report. This section merely provides hazard, exposure and risk scores that can be input directly into forms for the various funding agencies. Three risk scenarios are presented below, and include minor, moderate and severe flood events. Multiple scenarios allow for a more fulsome understanding of risk.

1 Minor Flood Assessment

These scores are calculated using the minor flood hazard extent (approx. 10% AEP) and exposure information within the exposed area. Details on the hazard and exposure are found elsewhere in the report. The selected score is highlighted in green.

Likelihood

Table 1: Likelihood rating for generic risk assessment for minor flooding

Likelihood Score	AEP	Estimated Frequency (once every X years) (Indicative Lower Bound)
0.0	<0.001%	100,000
0.5	0.001% to <0.0033%	30,000
1.0	0.0033% to <0.01%	10,000
1.5	0.01% to <0.033%	3,000
2.0	0.033% to <0.1%	1,000
2.5	0.1% to <0.33%	300
3.0	0.33% to <1%	100
3.5	1% to <3.3%	30
4.0	3.3% to <10%	10
4.5	10% to <30%	3
5.0	>30%	<1

Impacts

Table 2: Proposed impacts ratings for minor flooding

Level	Score	Measure
Mortality: Number of deaths and missing persons attributed to disasters, per 100,000 population		
Catastrophic	5	Deaths greater than 100 per 100,000
Major	4	Deaths greater than 10 but less than 100 per 100,000
Moderate	3	Deaths greater than 1 but less than 10 per 100,000
Minor	2	Deaths greater than 0.1 but less than 1 per 100,000
Limited	1	Deaths less than 0.1 per 100,000

Level	Score	Measure
Affected People: Number of directly affected people attributed to disasters, per 100,000 population		
Catastrophic	5	Affected people greater than 100 per 100,000
Major	4	Affected people greater than 10 but less than 100 per 100,000
Moderate	3	Affected people greater than 1 but less than 10 per 100,000
Minor	2	Affected people than 0.1 but less than 1 per 100,000
Limited	1	Affected people less than 0.1 per 100,000
**Affected People Score based on Calculation of Score = Affected People/Population of Peace River Regional District * 100,000*		
Economic Consequences: Direct economic loss attributed to disasters in relation to Peace River Regional District GDP		
Catastrophic	5	Direct economic loss of 4% or more of GDP***
Major	4	Direct economic loss of 0.4% to 4% of GDP
Moderate**	3	Direct economic loss of 0.04% to 0.4% of GDP
Minor	2	Direct economic loss of 0.004% to 0.04% of GDP
Limited	1	Direct economic loss of <0.004% of GDP
***Economic Consequences Score based on Calculation of Score = Property Value in Floodplain/GDP of Peace River Regional District * 100%*		
Critical Infrastructure and Disruption: Damage to critical infrastructure attributed to disasters		
Catastrophic	5	>100 of CI facilities damaged or disrupted
Major	4	>10 to 100 CI facilities damaged or disrupted
Moderate***	3	>1 to 10 CI facilities damaged or disrupted
Minor	2	1 CI facility damaged or disrupted
Insignificant	1	1 CI facility temporarily (<6hours) disrupted
CI facilities are represented by the CI sectors in the National Strategy for Critical Infrastructure (Government of Canada) and include: • Energy and utilities • Information and communication technology • Finance • Health • Food • Water • Transportation • Safety • Government • Manufacturing ***Critical Infrastructure included here are bridges, sewers and roads		
Environmental: Damage to the environment.		
Catastrophic	5	Catastrophic damage to environment.
Major	4	Major damage to the environment.
Moderate	3	Moderate damage to the environment.
Minor	2	Minor damage to the environment.
Insignificant	1	Insignificant damage to the environment.

Level	Score	Measure
Cultural: Damage to cultural or heritage assets.		
Catastrophic	5	Catastrophic damage to cultural or heritage assets.
Major	4	Major damage to cultural or heritage assets.
Moderate	3	Moderate damage to cultural or heritage assets.
Minor	2	Minor damage to cultural or heritage assets.
Insignificant	1	Insignificant damage to cultural or heritage assets.

Risk Summary – Minor Flood (Approx. 10% AEP)

Element	Likelihood Score	Impact Score	Risk Score
People (Mortality and Missing)	4.5	1.0	4.5
Affected People	4.5	5.0	22.5
Economic	4.5	3.0	13.5
Disruption	4.5	3.0	13.5
Environment	4.5	2.0	9.0
Cultural	4.5	1.0	4.5

2 Moderate Flood Assessment

These scores are calculated using the moderate flood hazard extents (Approx. 0.5% AEP) and vulnerability information in the exposed area.

Likelihood

Table 3: Likelihood Rating for Generic Risk Assessment

Likelihood Score	AEP	Estimated Frequency (once every X years) (Indicative)
0.0	< 0.001%	100,000
0.5	0.001% to < 0.0033%	30,000
1.0	0.0033% to < 0.01%	10,000
1.5	0.01% to < 0.033%	3,000
2.0	0.033% to < 0.1%	1,000
2.5	0.1% to < 0.33%	300
3.0	0.33% to <1%	100
3.5	1% to <3.3%	30
4.0	3.3% to <10%	10
4.5	10% to <30%	3
5.0	>30%	1

Impacts

Table 4: Proposed impacts ratings for moderate flooding

Level	Score	Measure
Mortality: Number of deaths and missing persons attributed to disasters, per 100,000 population		
Catastrophic	5	Deaths greater than 100 per 100,000
Major	4	Deaths greater than 10 but less than 100 per 100,000
Moderate	3	Deaths greater than 1 but less than 10 per 100,000
Minor	2	Deaths greater than 0.1 but less than 1 per 100,000
Limited	1	Deaths less than 0.1 per 100,000
Affected People: Number of directly affected people attributed to disasters, per 100,000 population		
Catastrophic	5	Affected people greater than 100 per 100,000
Major	4	Affected people greater than 10 but less than 100 per 100,000
Moderate	3	Affected people greater than 1 but less than 10 per 100,000
Minor	2	Affected people than 0.1 but less than 1 per 100,000
Limited	1	Affected people less than 0.1 per 100,000
****Affected People Score based on Calculation of Score =* *Affected People/Population of Peace River Regional District * 100,000*		

Level	Score	Measure
Economic Consequences: Direct economic loss attributed to disasters in relation to Peace River Regional District GDP		
Catastrophic	5	Direct economic loss of 4% or more of GDP***
Major	4	Direct economic loss of 0.4% to 4% of GDP
Moderate**	3	Direct economic loss of 0.04% to 0.4% of GDP
Minor	2	Direct economic loss of 0.004% to 0.04% of GDP
Limited	1	Direct economic loss of <0.004% of GDP
***Economic Consequences Score based on Calculation of Score = Property Value in Floodplain/GDP of Peace River Regional District * 100%*		
Critical Infrastructure and Disruption: Damage to critical infrastructure attributed to disasters		
Catastrophic	5	>100 of CI facilities damaged or disrupted
Major	4	>10 to 100 CI facilities damaged or disrupted
Moderate***	3	>1 to 10 CI facilities damaged or disrupted
Minor	2	1 CI facility damaged or disrupted
Insignificant	1	1 CI facility temporarily (<6hours) disrupted
CI facilities are represented by the CI sectors in the National Strategy for Critical Infrastructure (Government of Canada) and include: • Energy and utilities • Information and communication technology • Finance • Health • Food • Water • Transportation • Safety • Government • Manufacturing ***Critical Infrastructure included here are bridges, sewers and roads		
Environmental: Damage to the environment.		
Catastrophic	5	Catastrophic damage to environment.
Major	4	Major damage to the environment.
Moderate	3	Moderate damage to the environment.
Minor	2	Minor damage to the environment.
Insignificant	1	Insignificant damage to the environment.
Cultural: Damage to cultural or heritage assets.		
Catastrophic	5	Catastrophic damage to cultural or heritage assets.
Major	4	Major damage to cultural or heritage assets.
Moderate	3	Moderate damage to cultural or heritage assets.
Minor	2	Minor damage to cultural or heritage assets.
Insignificant	1	Insignificant damage to cultural or heritage assets.

Risk Summary (0.5% AEP Event)

Element	Likelihood Score	Impact Score	Risk Score
People (Mortality and Missing)	3.0	1.0	3.0
Affected People	3.0	5.0	15.0
Economic	3.0	3.0	9.0
Disruption	3.0	3.0	9.0
Environment	3.0	2.0	6.0
Cultural	3.0	1.0	3.0

3 Severe Flood Hazard

Scores for the sever flood hazard (approx. 0.1% AEP) are calculated using the flood extent and vulnerability information for exposed areas. This extent is a high-level estimate of the upper bound of flood risk in Dawson Creek.

Likelihood

Table 5: Likelihood rating for generic risk assessment

Likelihood Score	AEP	Estimated Frequency (once every X years) (Indicative)
0	< 0.001%	100,000
0.5	0.001% to < 0.0033%	30,000
1	0.0033% to < 0.01%	10,000
1.5	0.01% to < 0.033%	3,000
2	0.033% to < 0.1%	1,000
2.5	0.1% to < 0.33%	300
3	0.33% to <1%	100
3.5	1% to <3.3%	30
4	3.3% to <10%	10
4.5	10% to <30%	3
5	>30%	1

Impacts

Table 6: Proposed impacts ratings for severe flooding

Level	Score	Measure
Mortality: Number of deaths and missing persons attributed to disasters, per 100,000 population		
Catastrophic	5	Deaths greater than 100 per 100,000
Major	4	Deaths greater than 10 but less than 100 per 100,000
Moderate	3	Deaths greater than 1 but less than 10 per 100,000
Minor	2	Deaths greater than 0.1 but less than 1 per 100,000
Limited	1	Deaths less than 0.1 per 100,000
Affected People: Number of directly affected people attributed to disasters, per 100,000 population		
Catastrophic	5	Affected people greater than 100 per 100,000
Major	4	Affected people greater than 10 but less than 100 per 100,000
Moderate	3	Affected people greater than 1 but less than 10 per 100,000
Minor	2	Affected people than 0.1 but less than 1 per 100,000
Limited	1	Affected people less than 0.1 per 100,000
**Affected People Score based on Calculation of Score = Affected Population in Floodplain/GDP of Peace River Regional District * 100%*		

Level	Score	Measure
Economic Consequences: Direct economic loss attributed to disasters in relation to Peace River Regional District gross domestic product		
Catastrophic	5	Direct economic loss of 4% or more of GDP***
Major	4	Direct economic loss of 0.4% to 4% of GDP
Moderate	3	Direct economic loss of 0.04% to 0.4% of GDP
Minor	2	Direct economic loss of 0.004% to 0.04% of GDP
Limited	1	Direct economic loss of <0.004% of GDP
Critical Infrastructure and Disruption: Damage to critical infrastructure attributed to disasters		
Catastrophic	5	>100 of CI facilities damaged or disrupted
Major	4	>10 to 100 CI facilities damaged or disrupted
Moderate	3	>1 to 10 CI facilities damaged or disrupted
Minor	2	1 CI facility damaged or disrupted
Insignificant	1	1 CI facility temporarily (<6hours) disrupted
CI facilities are represented by the CI sectors in the National Strategy for Critical Infrastructure (Government of Canada) and include: Energy and utilities Information and communication technology Finance Health Food Water Transportation Safety Government Manufacturing ***Critical Infrastructure included here are bridges and drinking water wells affected		
Environmental: Damage to the environment.		
Catastrophic	5	Catastrophic damage to environment.
Major	4	Major damage to the environment.
Moderate	3	Moderate damage to the environment.
Minor	2	Minor damage to the environment.
Insignificant	1	Insignificant damage to the environment.
Cultural: Damage to cultural or heritage assets.		
Catastrophic	5	Catastrophic damage to cultural or heritage assets.
Major	4	Major damage to cultural or heritage assets.
Moderate	3	Moderate damage to cultural or heritage assets.
Minor	2	Minor damage to cultural or heritage assets.
Insignificant	1	Insignificant damage to cultural or heritage assets.

Risk Summary (Future with Climate Change)

Element	Likelihood Score	Impact Score	Risk Score
People (Mortality and Missing)	2.5	1.0	2.5
Affected People	2.5	5.0	12.5
Economic	2.5	4.0	10.0
Disruption	2.5	4.0	10.0
Environment	2.5	2.0	5.0
Cultural	2.5	1.0	2.5

Risk Graphic

The risk graphic in Figure 1 summarizes the impact scores for the three hazard severities assessed.

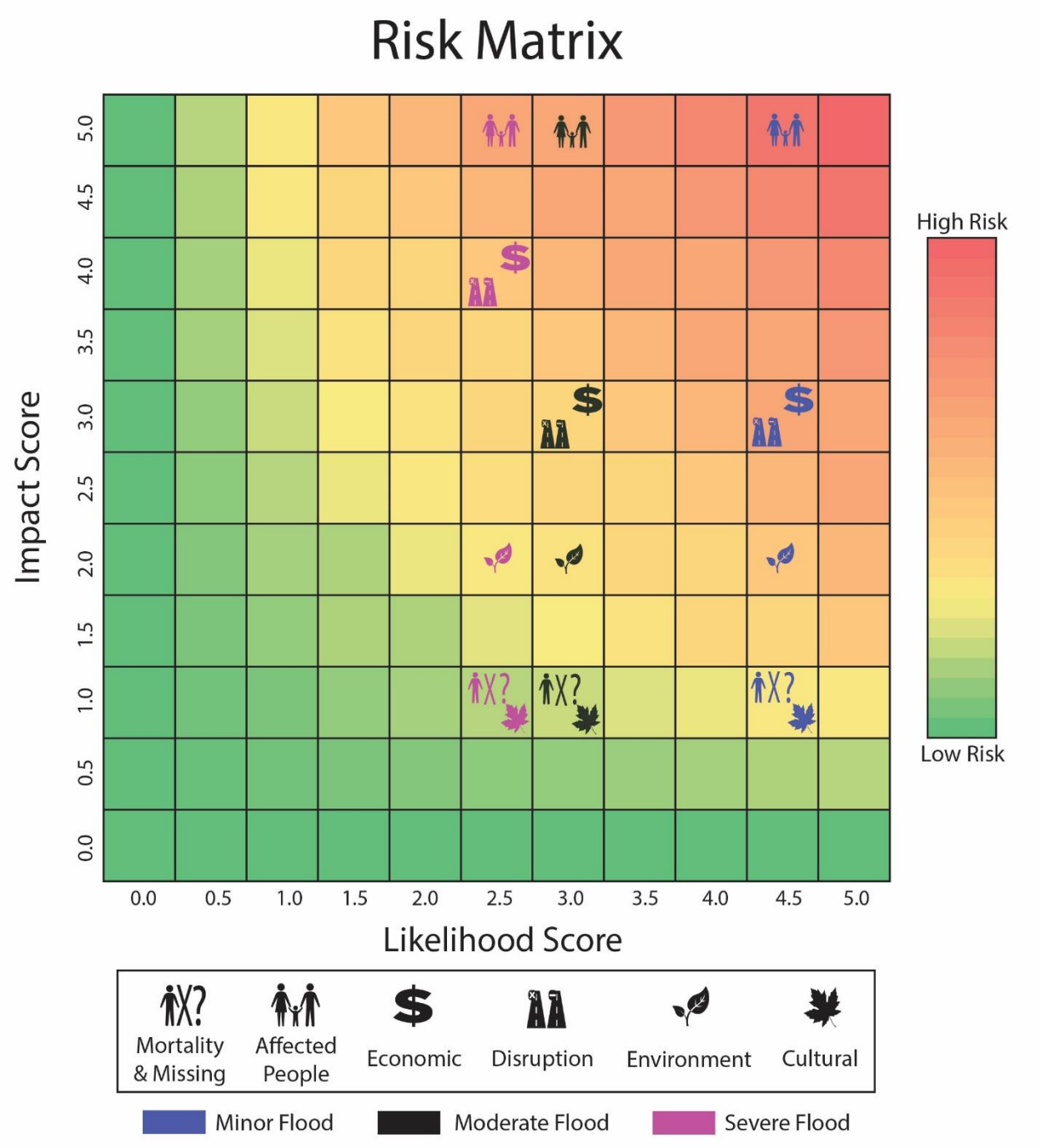

Figure 1: Summary Risk Graphic for Minor, Moderate, and Severe Flood Hazard for Dawson Creek

Appendix B Completed RAIT Form

Provided separately due to protection settings on RAIT form.

Appendix C Workshop Outcomes and Materials

Two workshops were conducted in Dawson Creek with local stakeholders to gather information, build location capacity, and report on project results. The workshops included:

1) Setting the Stage Workshop with local stakeholders- November 22nd 2017
2) Reporting Back Workshop with local stakeholders – February 21st 2018

In addition, the consulting team supported a public meeting with local community members in the evening of November 22nd 2017. For the two workshops the following materials are included:

- Workshop Agenda
- Workshop Report
- Workshop Slides

These materials are included in this appendix.

"Setting the Stage" Workshop #1

Dawson Creek Flood Planning
9:00 am – 2:00 pm, Wednesday Nov 22nd
Kiwanis Performing Arts Centre (KPac), 10401 10 St, Dawson Creek, BC

Objectives:

- Develop shared understanding of flood risk (hazard, exposure, vulnerability) and principles of best practice flood management
- Better understand stakeholder and community vulnerabilities & values as they relate to flooding and managing flood risk
- Enhance understanding across stakeholders, of the diversity of interests and values, and how they interconnect
- Nurture a sense of a community / regional approach to flood management (being in it together)

Time	Section
9:00 – 9:30	Set up and Registration
9:30 – 9:45	Welcome and Agenda Overview
9:45 – 10:00	Introduction to the project
10:00 – 10:20	Introductions around the room
10:20 – 10:50	Principles of Best Practice Flood Management
10:50 – 11:05	Living with Water
11:05 – 11:20	**BREAK**
11:20 – 12:05	Intro to flood risk in Dawson Creek
12:05 – 12:35	**LUNCH**
12:35 – 1:00	Flood risk & management as a "wicked problem"
1:00 – 1:40	Flood Impacts
1:40 – 2:20	Direct & Indirect Impacts
2:20 – 2:30	Closing

Dawson Creek Flood Mitigation Planning

Workshop #1: Setting the Stage – Summary Report

December 22, 2017

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1. Introduction to the Project

The City of Dawson Creek (the City) has experienced significant storm events that have caused considerable damage and impact to private and public assets and people. It is expected that flood hazards will become more severe in the coming years and it is important to understand what the impacts of future floods will be. In response, the City has engaged Ebbwater Consulting to better understand the present-day flood risk in the community. This improved understanding will be used in the future to develop plans for risk reduction.

Best practice dictates that flood mitigation be achieved through a thoughtful, risk-based planning process based on community values and considering a range of hazard levels. The objectives of the current project are to explore the flood hazard as well as the community infrastructure and values that could be impacted by flood. This project will also produce a specific deliverable that will support the community to apply for funding from senior governments to implement flood mitigation planning.

The table below, outlines the process and timeline for this project, to be completed by spring of 2018.

Stage	Timing	Objectives
Gap Analysis	Oct - Nov 2017	• Conduct a scan of existing materials related to flood management at the City of Dawson Creek, to highlight any gaps in data or technical analysis that influence future tasks
Setting the Stage	Nov – Dec 2017	• Engage stakeholders and the public, to increase awareness and understanding about current and potential future impacts of flooding in the area, and begin to identify areas of overlapping values and interests, and interconnected factors affecting vulnerability
Identify & Establish Hazards	Dec - Jan 2018	• Better understand the variety of flood-based hazards, as well as understanding the likelihood and magnitude of each hazard

Report back and Explore Vulnerability and Resilience	Feb 2018	• Report back to stakeholders on flood impacts and explore community vulnerability and flood resilience for a range of flood hazards
Identify Consequences & Risk	Feb – Mar 2018	• Combine all the information previously collected and calculated to develop a locally relevant risk assessment that can also be used as input for high-level risk assessments used as a prioritization mechanism by federal funding agencies
Establish next steps and apply for additional funds	Mar 2018	• Identify next steps to complete the flood mitigation plan and support the City in its application to various Disaster Mitigation funding programs

This report summarizes the process and findings of "Setting the Stage," which consisted of two in-person facilitated sessions with groups in Dawson Creek, on November 22nd, 2017. First, a longer half-day session gathered together a targeted group of stakeholders representing a range of interests and organizations relating to flood risk in the area. The second session was held in the evening, and provided a forum for members of the public to learn about the project and contribute to the identification of flood impacts in the community. The following summary draws together input from the stakeholder workshop and the public meeting.

2. What We Did

Stakeholder Workshop:

This workshop brought together stakeholders from across the community to consider the nature of the flood risk in Dawson Creek and develop a deeper understanding of the impacts and overlapping values at play in flood management. The results will directly inform the project and development of the risk assessment in the early stages, and build capacity as a community to enhance resilience to the flood risk. The workshop included:

- Introductions to the project and stakeholders
- Key concepts: managing flood risk & building community resilience
- Overview of flood risk & management in Dawson Creek
- Understanding flood risk & management as a "wicked problem"

- Sharing stories from recent floods
- Mapping direct & indirect impacts

Stakeholders were invited from across sectors in order to assemble a group that could speak to the broad range of interests and values touched by flood risk. This included economic, social, environmental, physical, infrastructure and health & well-being values of the community. In total 21 stakeholders attended which included representative from the following organizations:

- Dawson Creek Chamber of Commerce
- Watershed Society
- City of Dawson Creek
    - Public Works
    - Engineering
    - Development Services
    - Planning
    - Water Treatment & Watershed Management
    - Fire Department
- Dawson Creek City Council
- Peace River Regional District Board of Directors
- Dawson Creek Airport
- Northern Health
- Provincial government:
    - Ministry of Forests, Lands, Natural Resource Operations & Rural Development
    - Ministry of Transportation

Public Meeting:

A public forum was held as an opportunity for residents to get informed about the flood mitigation planning process and how to be involved, learn about what the City is currently doing, and to contribute their knowledge of the impacts of flooding for the community. The evening began with three speakers who provided context to the discussions:

- Tamsin Lyle, Ebbwater Consulting: overview of the flood mitigation planning project
- Kevin Henderson, Dawson Creek Development Services: how the City is currently addressing and managing flood risk through policy, planning and infrastructure
- Gordon Smith, Dawson Creek Fire Department: experiences with preparedness and response to recent floods

The evening was attended by 23 community members, whose contributions are included below in the sections on “Sharing Stories” and “Direct & Indirect Impacts.”

3. What We Heard from Participants

Intentions and Questions for the Day

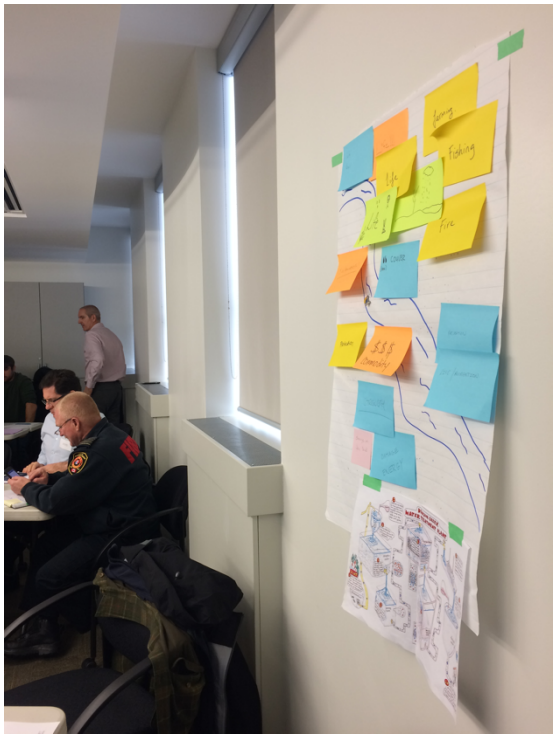
- Goals is to better understand:
    - the creek
    - connections with water quality in the Kiskatinaw
    - watershed health
    - local issues
    - impacts for citizens
    - impacts on roads, infrastructure, airport
    - future conditions & flood risk
- How to mitigate, be proactive, and become more resilient
- What is needed during flood events, and in the future?
- What is my role?
- Addressing community awareness
- Learning from the past
- Where to now?

What Makes for a Safe, Prosperous and Resilient Community?

- Personal resilience
    - Engagement, training (enhance understanding)
    - Recovery time
    - Addressing PTSD, anxiety, fear
    - Understanding the services available, what vulnerabilities are
- Knowing how to respond to crisis
    - Advance warning and communication systems
    - Response plans (community, individuals, businesses)
    - Business / employment continuity
    - Supportive behaviours (and don’t get in the way or make it worse)
    - Communications within and outside the City
- Understanding the basin, creek, how these change and the impacts on flood risk
- Smart development in the future (eg: decisions in flood risk areas)
- Safe & reliable infrastructure

- Preparedness for areas at risk
    - Linking up emergency services
- Confidence to invest in business
    - Security about the future
- Insurance

What Does Water Mean To You?



Water means many things to people – it is necessary for life, and enables many things we value and depend on, and yet it can also create great disruption and exert incredible force and destruction. Some of the core values and relationships that participants related to water included:

- Life
- Fire
- Farming
- Fishing
- Recreation
- Sustainability
- Commodity ($)
- Protection
- Strength
- Damage
- Energy
- Change on the land

How is Flood Risk & Management a "Wicked Problem"?

A "Wicked Problem" is one that is by nature complex; where the issues, challenges and what seems most important about it, depend on who you ask; where there is a range of possible solutions, each with their own consequences or impacts; and one that doesn't ever really stay solved but needs to be tended to over time as it evolves and changes. When asked what makes flood risk & management a "wicked problem" in Dawson Creek, participants answered:

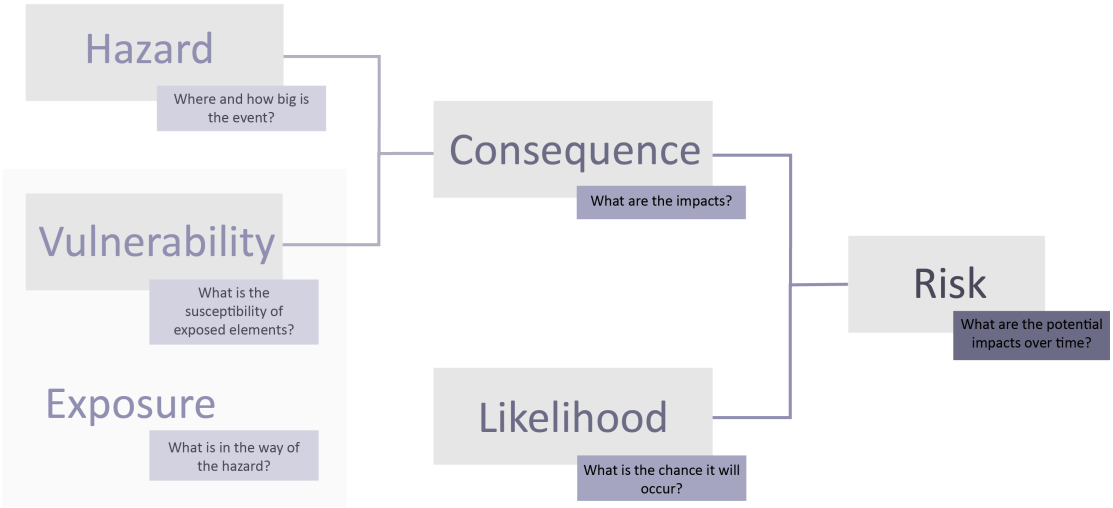
- Need to understand the 10,000 foot view, and local scale
- Manage upstream and downstream at the same time
- Managing private property and the public interest
- Impacts of individual choice & will
- Legacy of past decisions

- Requires out of the box thinking and action
- Contending with unintended consequences (eg: removing culverts has influence on debris flows)
- Cascading effects and cumulative impacts of smaller decisions/actions
- Multi-jurisdictional complexity
- Have to learn as you go
- Providing effective support to vulnerable people in the moment
- Expectations are set, and there is a need for alternatives – have to make tradeoffs

Flood Hazard & Risk in Dawson Creek

During the stakeholder meeting, four speakers addressed key aspects of understanding flood hazard and risk in Dawson Creek currently.

Tamsin Lyle of Ebbwater Consulting, provided context on the risk-based approach being taken to flood management in this project, which is based on international best practice. The core concept of risk as a product of hazard, exposure, vulnerability, consequence and likelihood was outlined, along with other key concepts from best practice, such as resilience, uncertainty, inclusion of stakeholders and local values, inclusion of direct and indirect impacts, and living with water. Some of these concepts were illustrated using an interactive model of a floodplain (see photos below) that participants were invited to engage with.



Kevin Henderson and Alex Wallace from City of Dawson Creek Development Services, provided participants with an understanding of how the City is currently addressing and managing flood risk through policy, planning and infrastructure.

And *Kayla Boyd, City of Dawson Creek's Watershed Technician*, provided context on connections with the Kiskatinaw watershed where the City draws its drinking water from.

At the public meeting, participants also heard from *Gordon Smith, Fire Chief for the City of Dawson Creek*, about experiences with preparedness and response to recent floods

Sharing Stories from Recent Floods

Participants reflected on their strongest memories of the recent flood events in Dawson Creek, sharing their experiences of who and what was affected, how they felt, any actions and decisions that were made, and what was learned.

Key words from stakeholders' stories about recent floods

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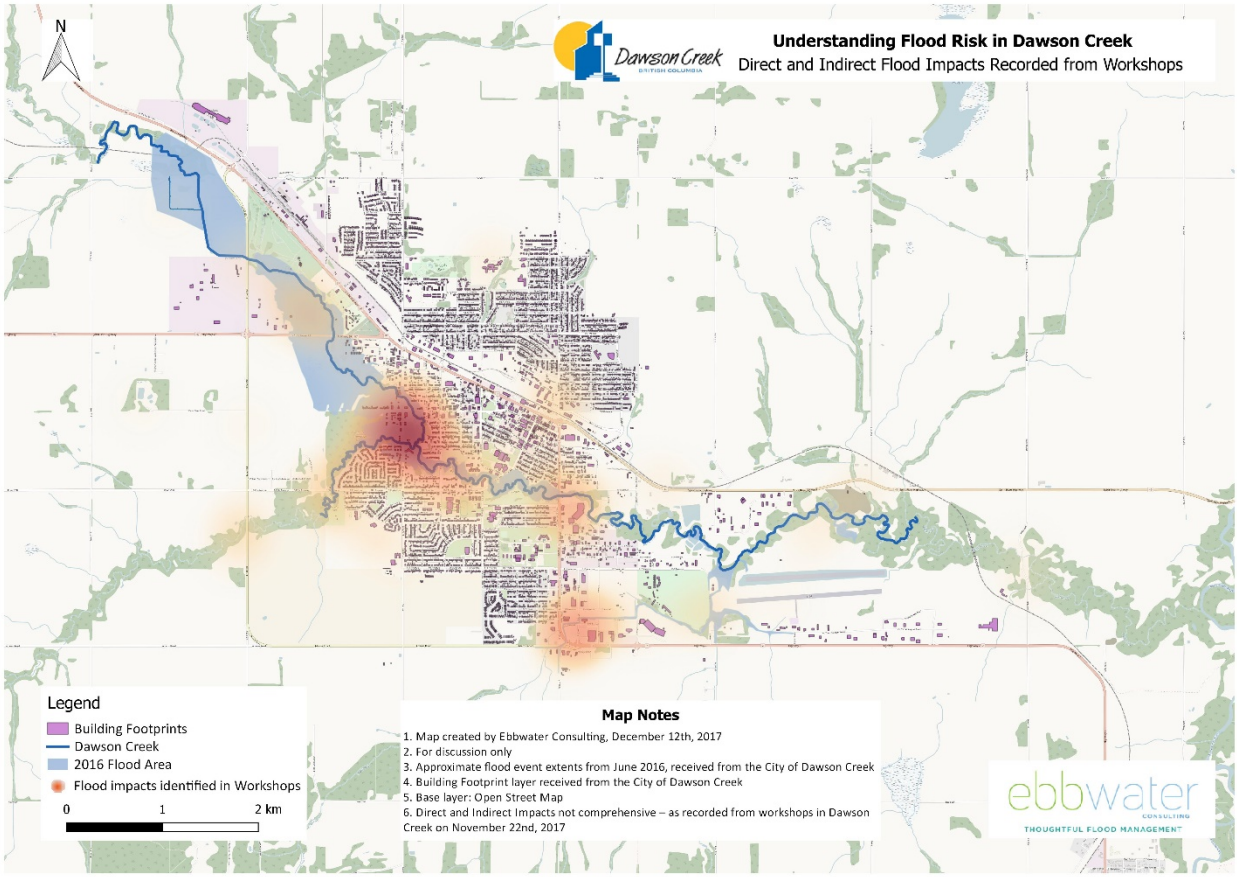
Key words from residents' stories about recent floods

Direct & Indirect Impacts

Sharing of these experiences led into in-depth small group discussions of impacts, which were mapped and (afterwards) digitized into GIS. The type of impacts documented are summarized below as Direct and Indirect impacts. Impacts that were not spatial (ie: could not be mapped to a specific location) were included in the data set but don't appear on the map.



Hot Spot Map of Flood Impacts

Direct Impacts	Indirect Impacts
Residential properties flooded, erosion	Personal stress Recovery Caring for elderly at flooded facility Property values decrease, insurance costs rise Sewage backups
Other private land flooded / eroded (eg: golf course, businesses)	Employment Building / land damage Potential impacts to cemetery
Transportation infrastructure flooding and damage (roads, trails, bridges, overpass) • Flooding • Wash outs • Manhole covers blown off	Traffic re-routed City divided (services / response disrupted; families divided) Access to services & other infrastructure blocked (eg: schools, hospital, grocery stores) Critical staff delayed / unable to deliver services (eg: teachers, doctor)
Other infrastructure affected • Sewage system backup • Shut down of water withdrawals from river • Drainage system ○ culverts washed out and damaged • Airport runway flooded	Potential contamination from wastewater lagoons, old city dump Power outage • Sump pumps not working • Elderly care facility • Access of planes to local airport
Alterations to the Creek, erosion	Debris piling up

4. Next Steps

In the next phase of the project, the consultant team will be integrating this information with other data to better understand the hazard, exposure, vulnerability and impacts due to flood in Dawson Creek. This will form the basis of a risk assessment and identification of possible options for enhancing the community's resilience to flood risk.

Managing Flood Risk in Dawson Creek

Stakeholder Workshop, November 22, 2017

Tamsin Lyle, P.Eng | Principal | Ebbwater Consulting
Erica Crawford | Adaptation Planner | SHIFT Collaborative
Heather Murdock, P.Eng | Project Engineer | Ebbwater Consulting

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Agenda

9:45 – 10:20	Introductions
10:20 – 11:00	Managing flood risk & building community resilience
11:00 – 11:15	**Break**
11:15 – 12:00	Overview of flood risk & management in Dawson Creek
12:00 – 12:30	**Lunch**
12:30 – 1:00	Flood risk & management as a “wicked problem”
1:00 – 1:40	Sharing stories from the floods
1:40 – 2:20	Mapping direct & indirect impacts

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Objectives

Develop shared understanding

- Flood risk
- Best practice principles

Learn about range of stakeholder and community vulnerabilities, impacts & values – what matters most, and why?

Better understand the shared stakes in flood management & decisions

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Introduction

Tamsin Lyle, P.Eng | Principal | Ebbwater Consulting

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Dawson Creek is not alone…

Mayor Craig Snodgrass of Town of High River's advice to flooded communities:

"*You have to try your best to **calm down**. You have to try your best to **slow down** because when I look back at how we rebuilt, most of us went too fast. You just go as hard as you can to get back some sense of normalcy, [but] if you go as hard and as fast as you can, you will make mistakes*"

http://www.cbc.ca/radio/checkup/blog/it-s-part-of-who-we-are-now-high-river-mayor-reflects-on-2013-s-devastating-floods-1.4105208

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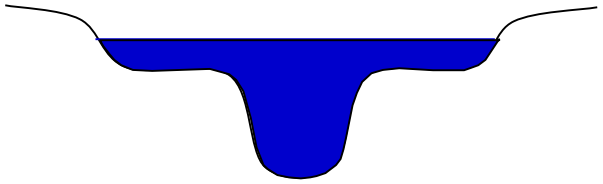
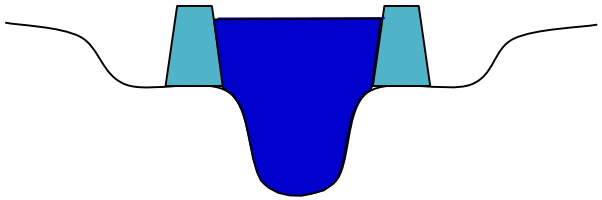
We also know that past practice hasn't served us well

Natural Condition



Dike Confinement, Realignment



Philadelphia Ledger, May 3, 1927

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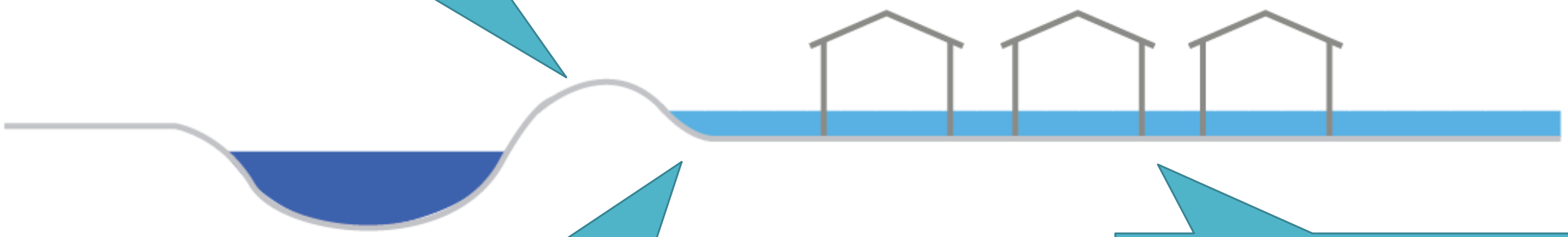
We need to understand the problem first

People:
Flood disasters affected 2.3 Bn and killed 157,000 people between 1995 and 2015 (UN, 2016)

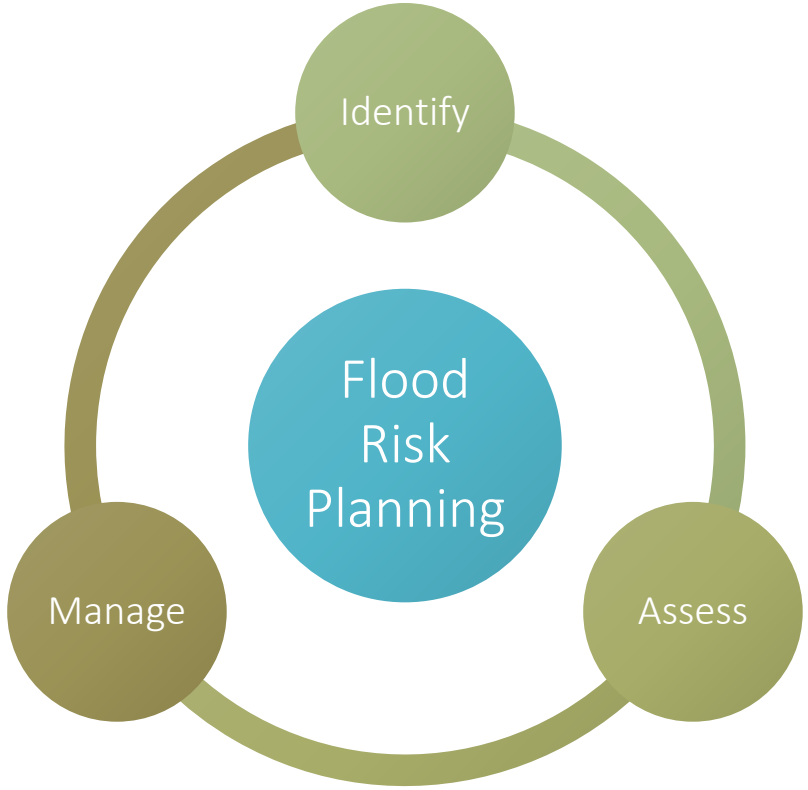
Infrastructure: "Integral US Trade Route, PTH-75 Closed" Red River Valley, 2011



Environment:
"Hurricane Katrina leaves legacy of industrial waste, raw sewage and oil spills" August 2005

Economy:
"Canada's GDP will be reduced by $2 billion as a direct result of the [Calgary] floods." June 2013

Once we understand, we can mitigate and improve community resilience



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We need you to help us understand!

Project Objectives:

1. To better understand Dawson Creek's flood risk – **non-prescriptive and community-led**
2. To complete a **prescriptive** flood risk assessment (Federal and Provincial) that will allow the community to apply for additional flood and disaster mitigation **funds**.

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What questions are you bringing
to this exploration of managing flood risk in Dawson Creek?

Introduce your partner:

Name, organization & one question

What makes for a safe, prosperous, resilient community?

Best Practice in Flood Management

Tamsin Lyle, P.Eng | Principal | Ebbwater Consulting

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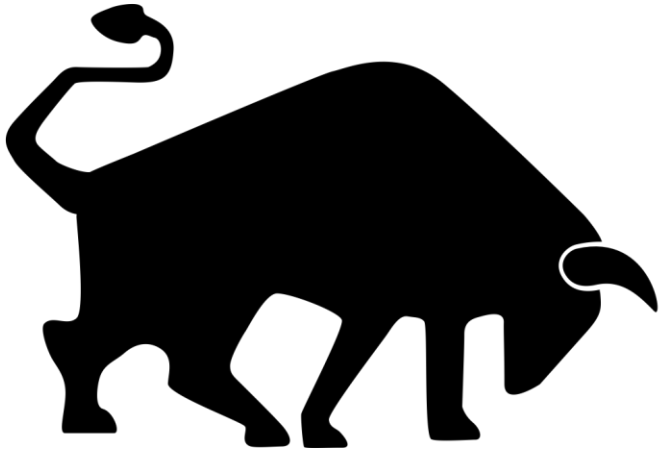
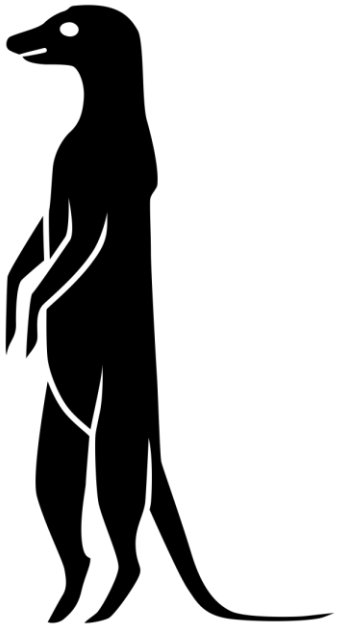
Flood management approaches





Are you a Bull, Ostrich or a Meerkat?

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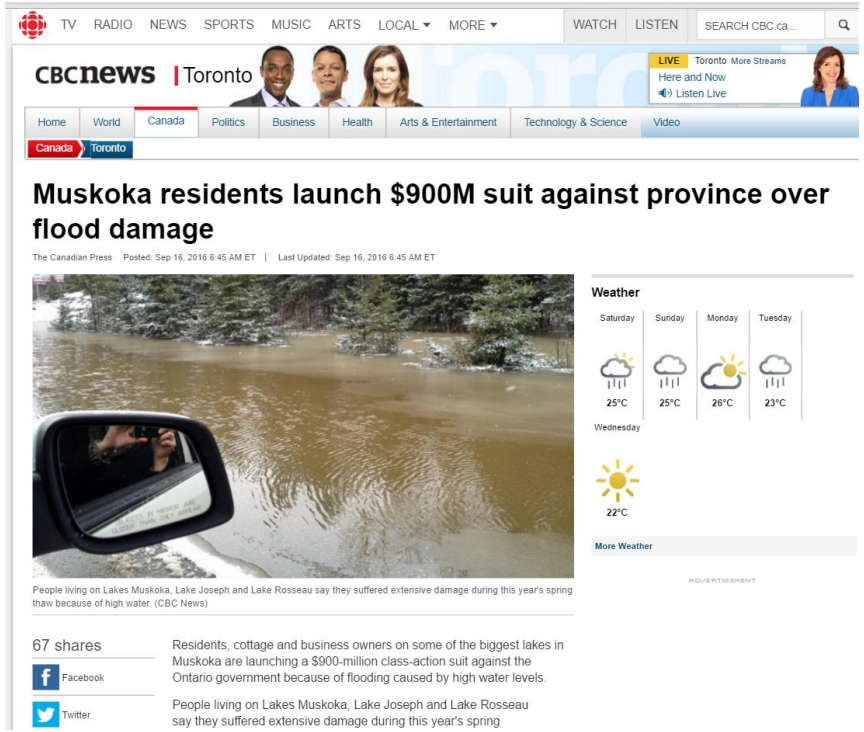
Why be a meerkat?

It’s the right thing (and might be the prudent thing)



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Muskoka residents launch $900M suit against province over flood damage

The Canadian Press Posted: Sep 16, 2016 6:45 AM ET | Last Updated: Sep 16, 2016 6:45 AM ET

People living on Lakes Muskoka, Lake Joseph and Lake Rosseau say they suffered extensive damage during this year's spring thaw because of high water. (CBC News)

Weather

Saturday	Sunday	Monday	Tuesday	Wednesday
25°C	25°C	26°C	23°C	22°C

More Weather

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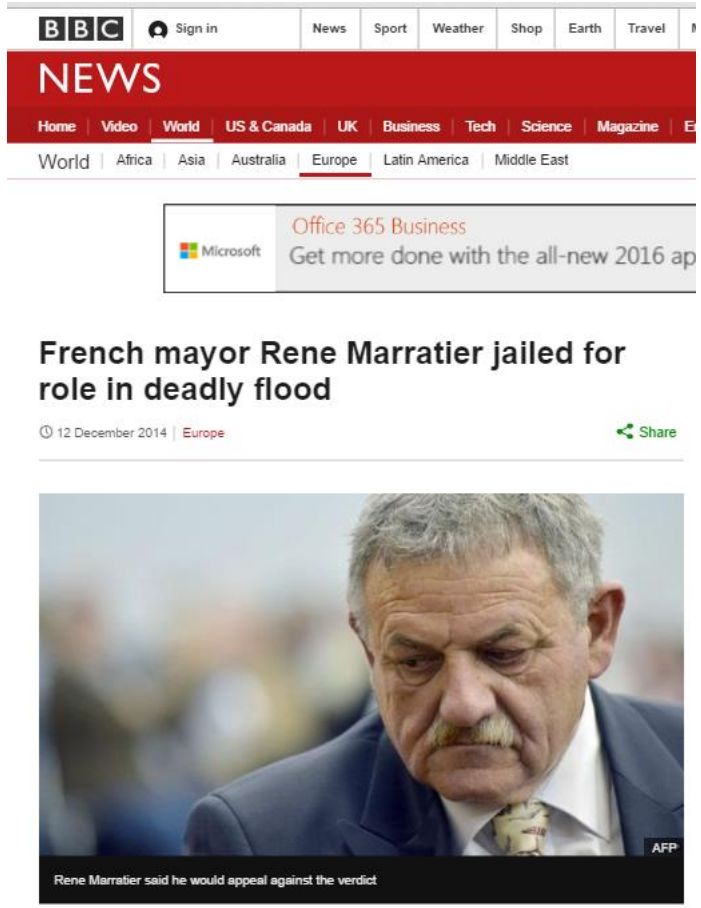
Residents, cottage and business owners on some of the biggest lakes in Muskoka are launching a $900-million class-action suit against the Ontario government because of flooding caused by high water levels.

People living on Lakes Muskoka, Lake Joseph and Lake Rosseau say they suffered extensive damage during this year's spring



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French mayor Rene Marratier jailed for role in deadly flood

12 December 2014 | Europe

Share

Rene Marratier said he would appeal against the verdict

AFP

The former mayor of a French seaside town has been sentenced to jail for four years for ignoring flood risks before a storm that killed 29 people.

Rene Marratier hid the risks to La Faute-sur-Mer to avoid putting off property developers, the court said.

The storm Xynthia hit western Europe in early 2010. The storm knocked down seawalls in La Faute-sur-Mer, leading to severe flooding.

Marratier called the verdict "unjust" and said he would appeal.

On Friday, the court said that Marratier knew La Faute-sur-Mer, a west coast resort in the Pays de la Loire region, was at risk of flooding.

However, he "deliberately hid" the risk so that he could benefit from the "cash-cow"

Let’s Go to Meerkat School!

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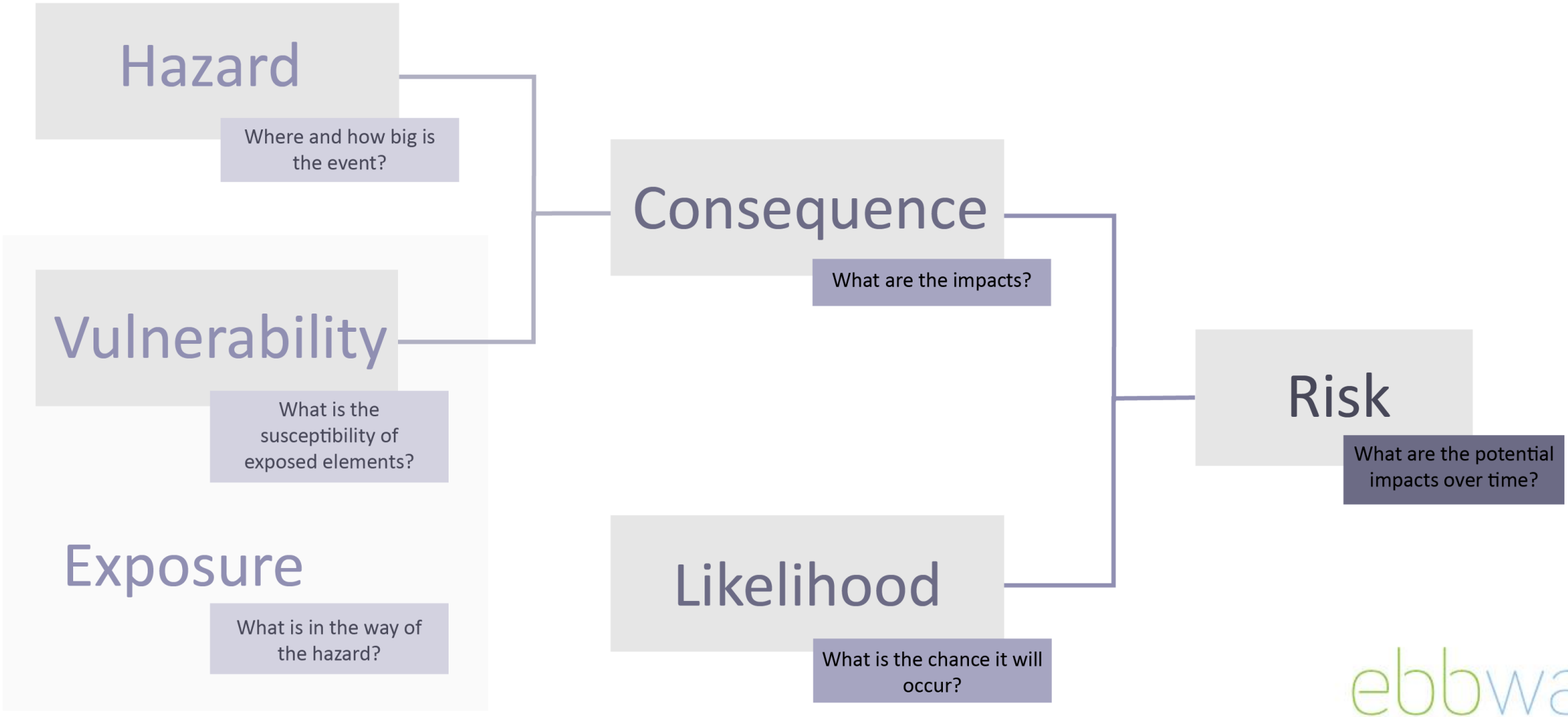
Meerkats Plan for Risk not Hazard



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Meerkats Enable Resilience

Reduce the Hazard

Block the water

Reduce Exposure

Stop things/people you care about getting wet

Reduce Sensitivity

Reduce impact of getting wet

- We can't fight nature
- We can't sterilise our floodplains

- We can reduce sensitivity to our built environment
- We can speed up our recovery
- We can safely fail instead of striving for the fail-safe solution

Meerkats Listen to People and Consider Values (…And stop thinking like engineers)

Talk to people; not just those you like

Image sources: West Coast Environmental Law

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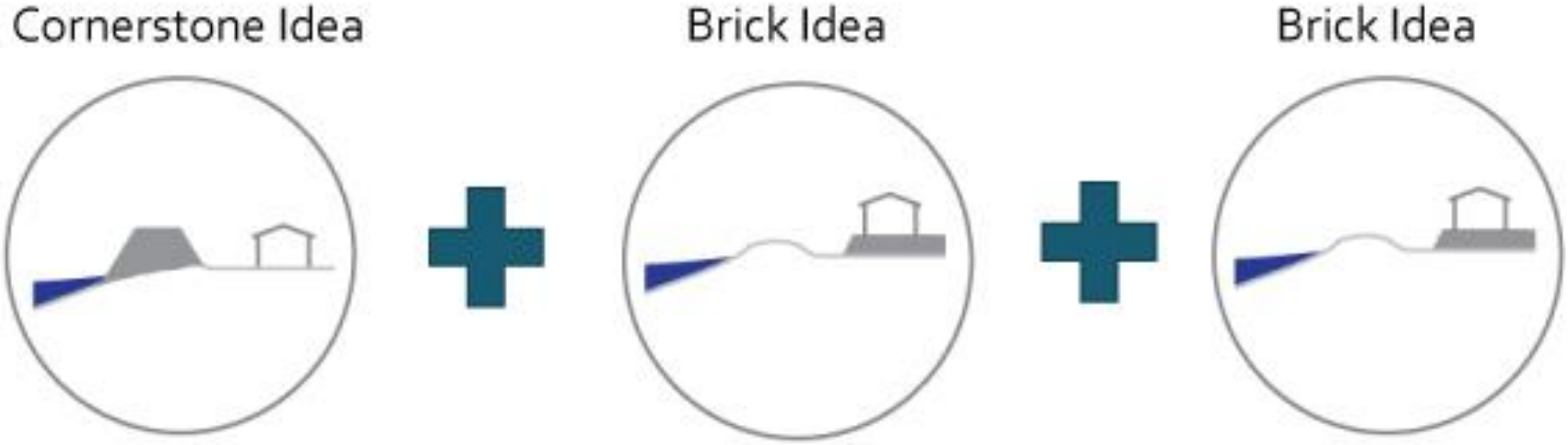
Meerkats Make Good Decisions
Look Beyond Dollars and Cents

PEOPLE	
People Displaced	# of people displaced from flood events
People Displaced	# people displaced permanently
'at risk' people impacted	Social Vulnerability Index (SVI) weighted displacement
Park and Recreational Amenity Value	Value-weighted area affected per event
Loss of critical services	# of pieces of infrastructure impacted
Aesthetics	-2 to 2
ENVIRONMENT	
Risk of Contaminant Release	# of sites with potential contaminants
Environmental Benefits	-2 to +2
ECONOMY	
Damage to Infrastructure	Value-weighted km of roads impacted
Damage to buildings	$M
Business disruption	# of employees working in impacted businesses
Loss of Inventory	$M
Emergency Response costs	Estimated cost per event
IMPLEMENTATION	
Capital Costs	$M
Maintenance costs	$M
Adaptability	1 to 4
Ease Of Implementation	1 to 5

Example measures for City of Vancouver, 2015. Developed with Compass Resource Management.

Meerkats Have a Back-Up Plan
Complementary Design with Co-Benefits



e.g. A dike

complemented with property-level-protection

improved with habitat enhancement and a bike path

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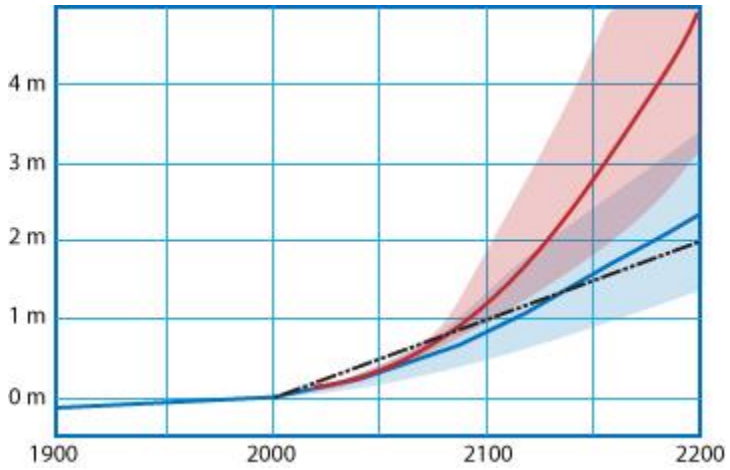
Meerkats Embrace Uncertainty

- Don’t rush in; preserve our options
- Strive for adaptive solutions that will work under many climate and development futures
- Avoid solutions that are single-minded or that remove future options

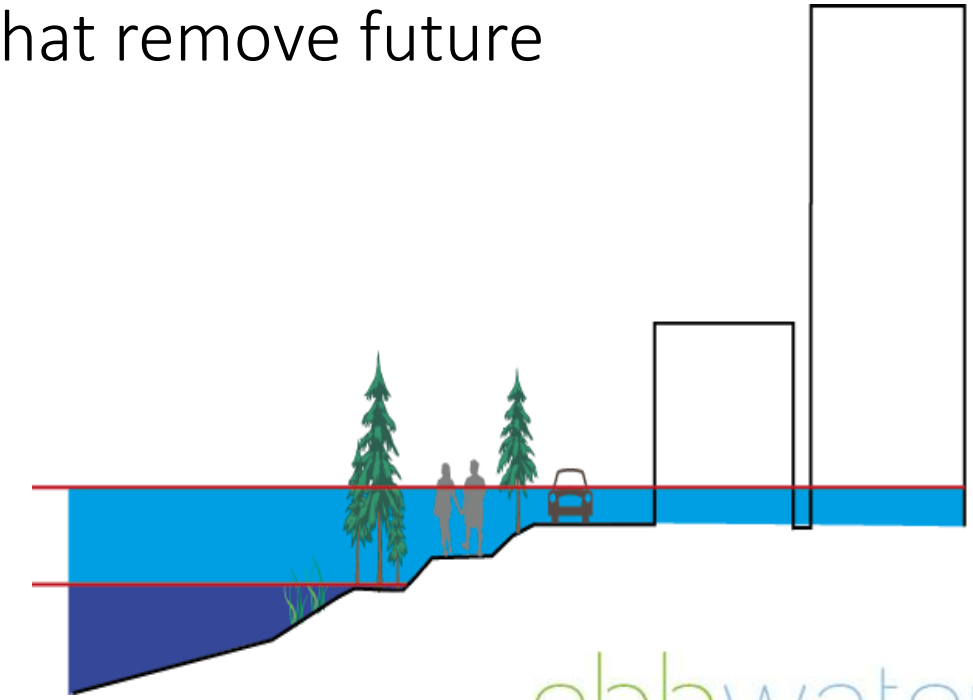


High end of range:

Overinvestment in protection

Low end of range:

Potential catastrophic impacts



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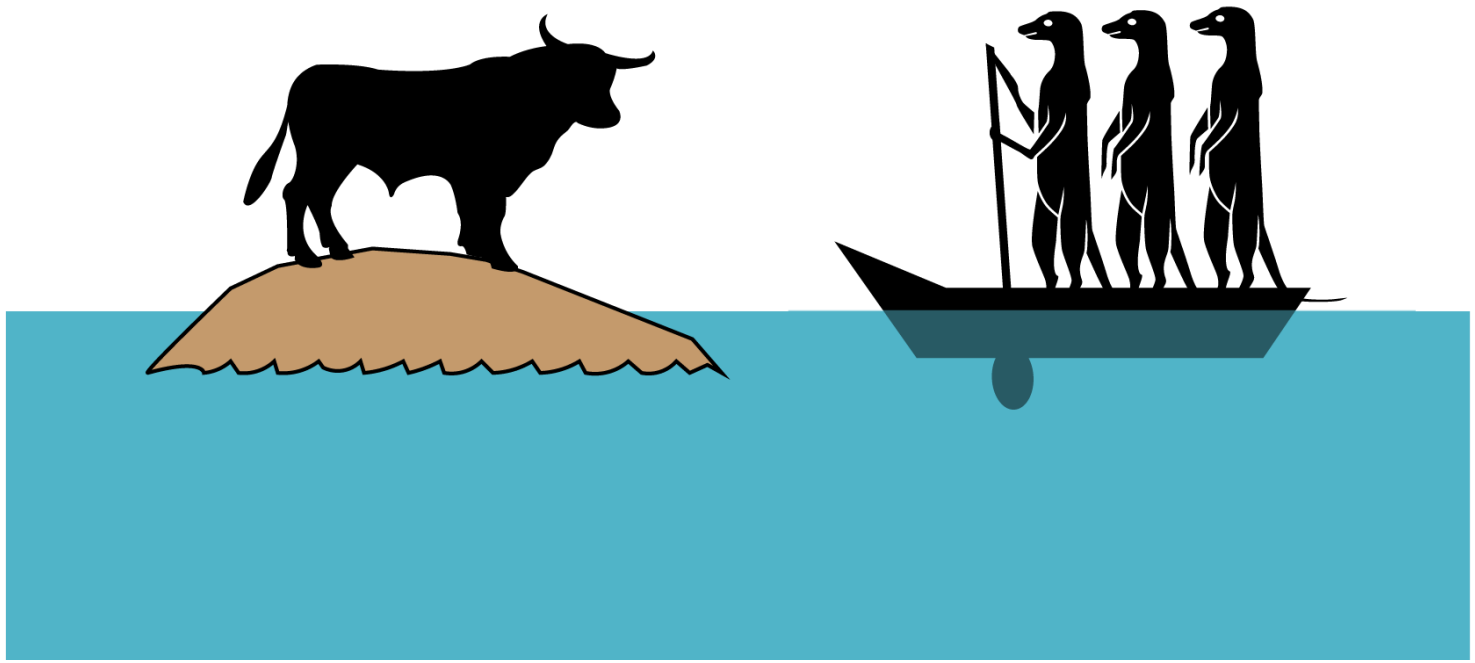
This is a challenge we are embracing

Meerkats Unite!
Bulls Be Gone! (Ostriches Too)



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What makes for a safe, prosperous, resilient community?

What does water mean to you?

Refreshment Break

The Context

Understanding the flood hazard, now and to come

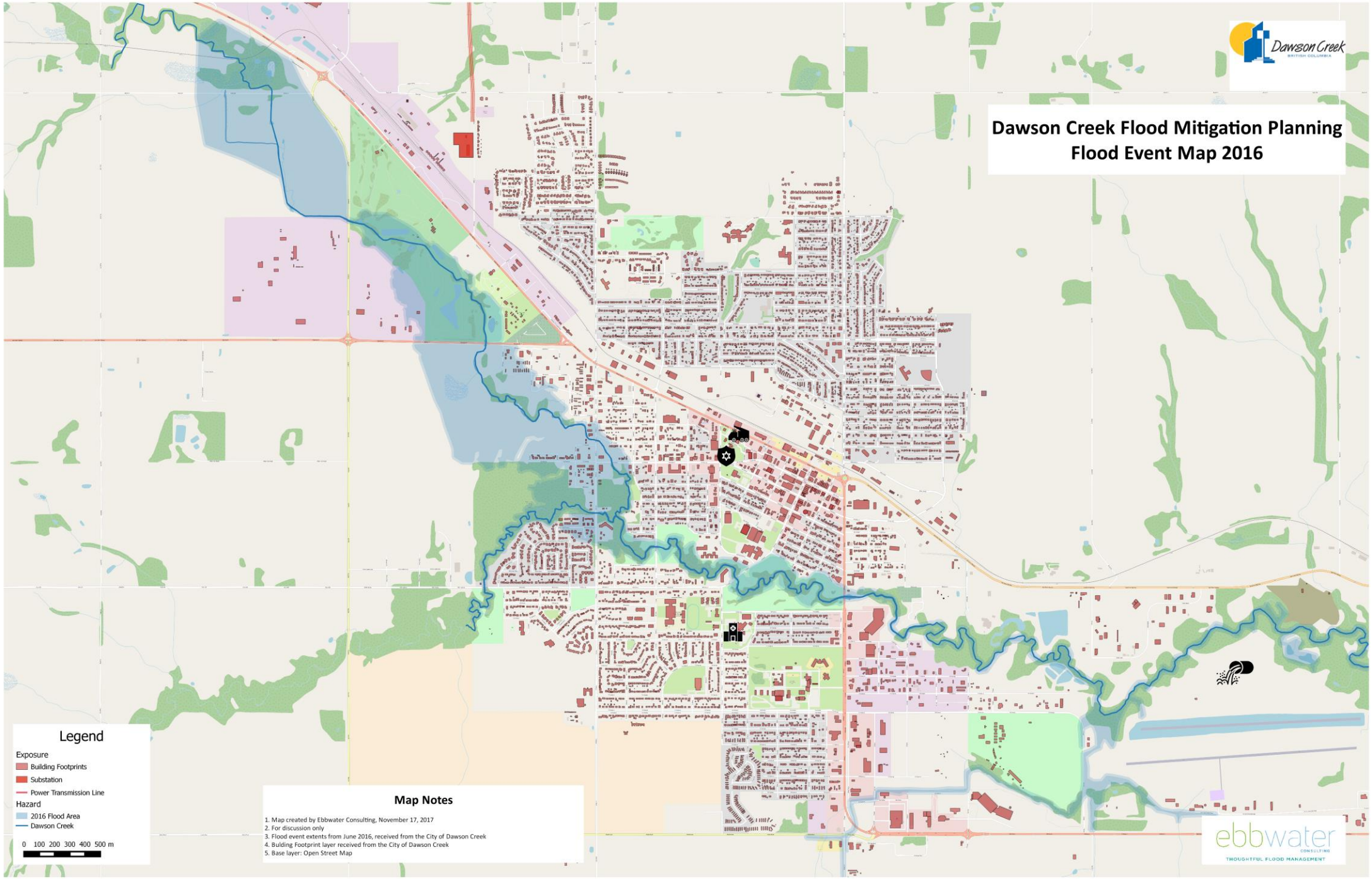
Tamsin Lyle, Ebbwater Consulting

Flood management in Dawson Creek

Kevin Henderson & Alex Wallace, Development Services, City of Dawson Creek

Considering flood from a watershed perspective

Kit Fast, Watershed Society, and Kayla Boyd, City of Dawson Creek


Dawson Creek Flood Mitigation Planning
Flood Event Map 2016
Legend
Exposure
Building Footprints
Substation
Power Transmission Line
Hazard
2016 Flood Area
Dawson Creek
0 100 200 300 400 500 m
Map Notes
1. Map created by Ebbwater Consulting, November 17, 2017
2. For discussion only
3. Flood event extents from June 2016, received from the City of Dawson Creek
4. Bulding Footprint layer received from the City of Dawson Creek
5. Base layer: Open Street Map
Dawson Creek
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THOUGHTFUL FLOOD MANAGEMENT

Flood hazards are not all the same…

Deep - Shallow

Fast-moving waters - Slow-moving waters

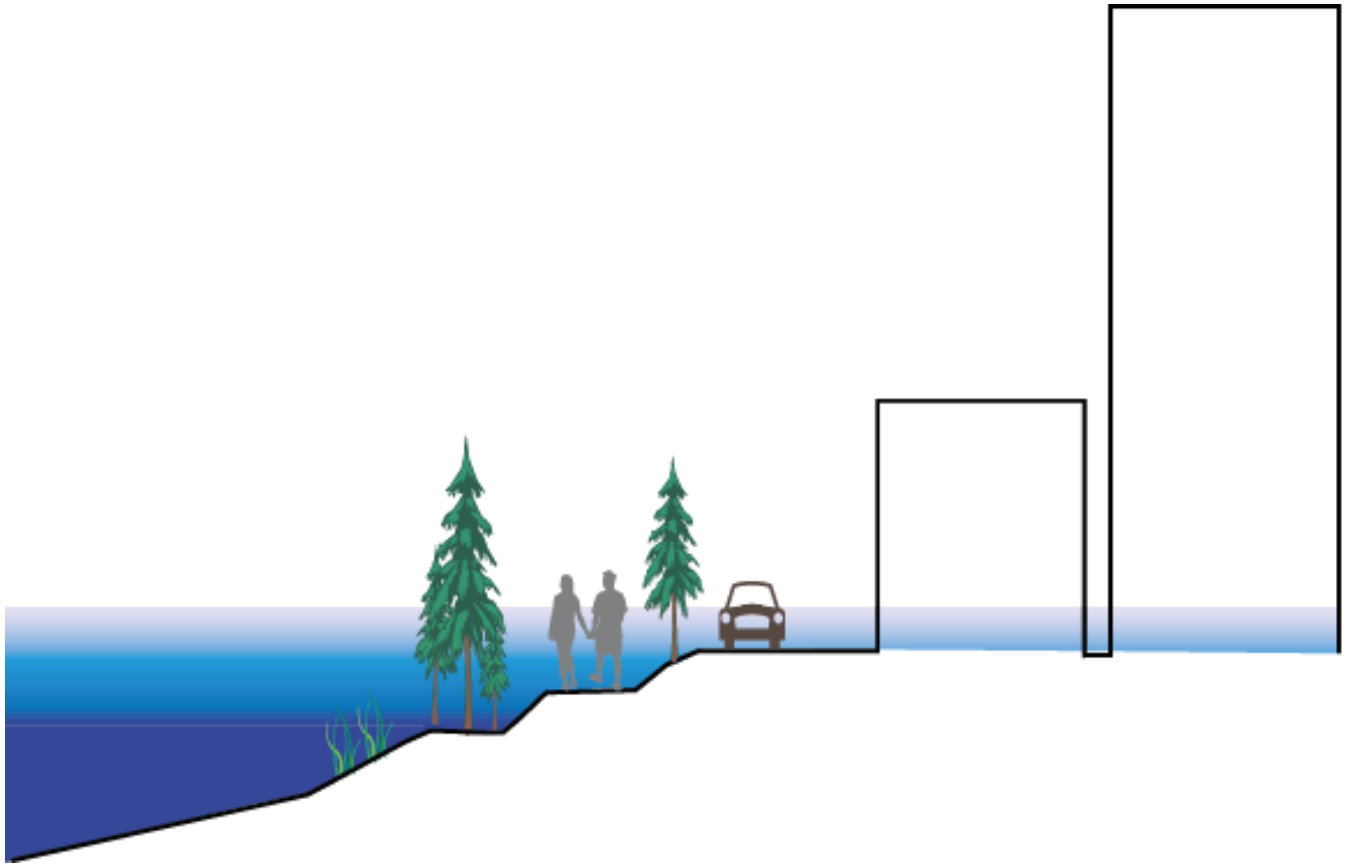
Frequent – Rare

Quick onset - Slow onset

Short duration - Long duration

…and are changing with time and climate

We need to think about multiple design conditions (or better yet throw design conditions away)



How does water flow?

Where will it go?

How will our actions change this?

Lunch Break

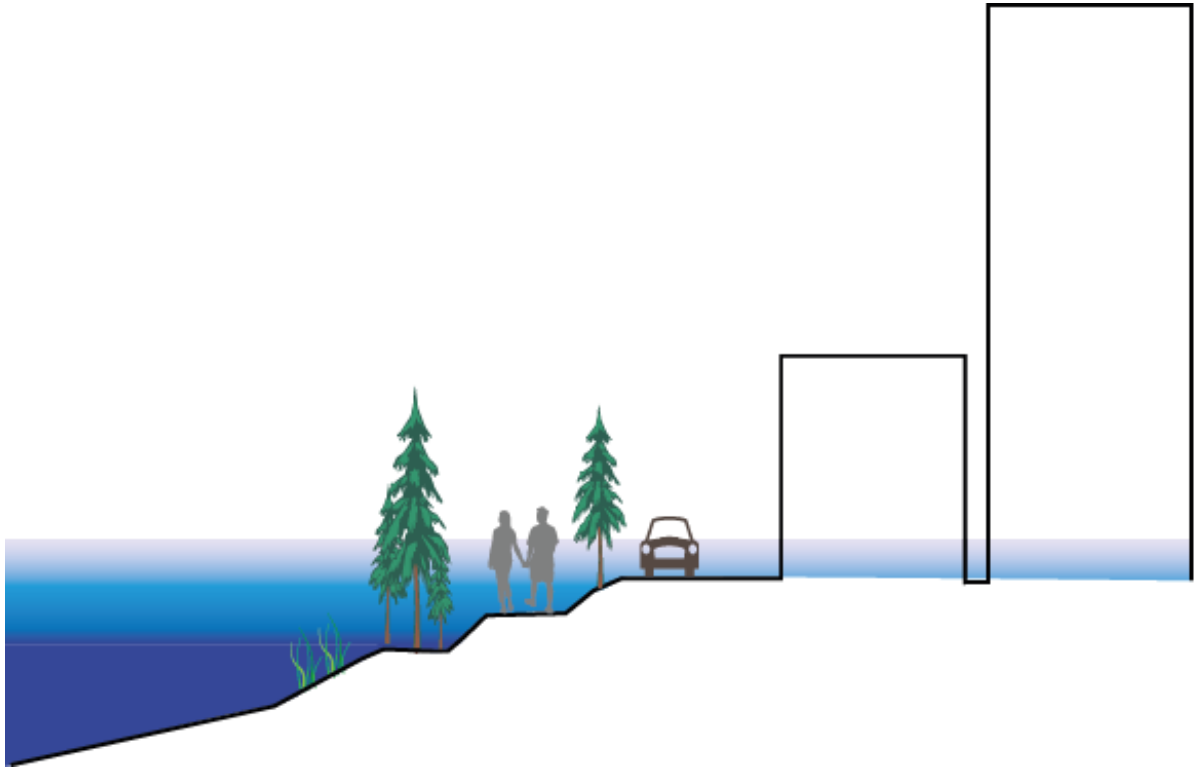
What is a “wicked problem”?

- Won’t stay solved
- Tangle of interconnected influences
- No single solution
- Answer depends on how and who you ask
- Many players and perspectives
- Moving target

Painting by Ani Magai

Flood management is a wicked problem

- High degree of technical complexity
- Multiple dimensions of uncertainty
- Multiple objectives
- High stakes, high emotions
- Intense political scrutiny
- High expectations for quality and transparency
- Limited resources in terms of time, money and personnel.



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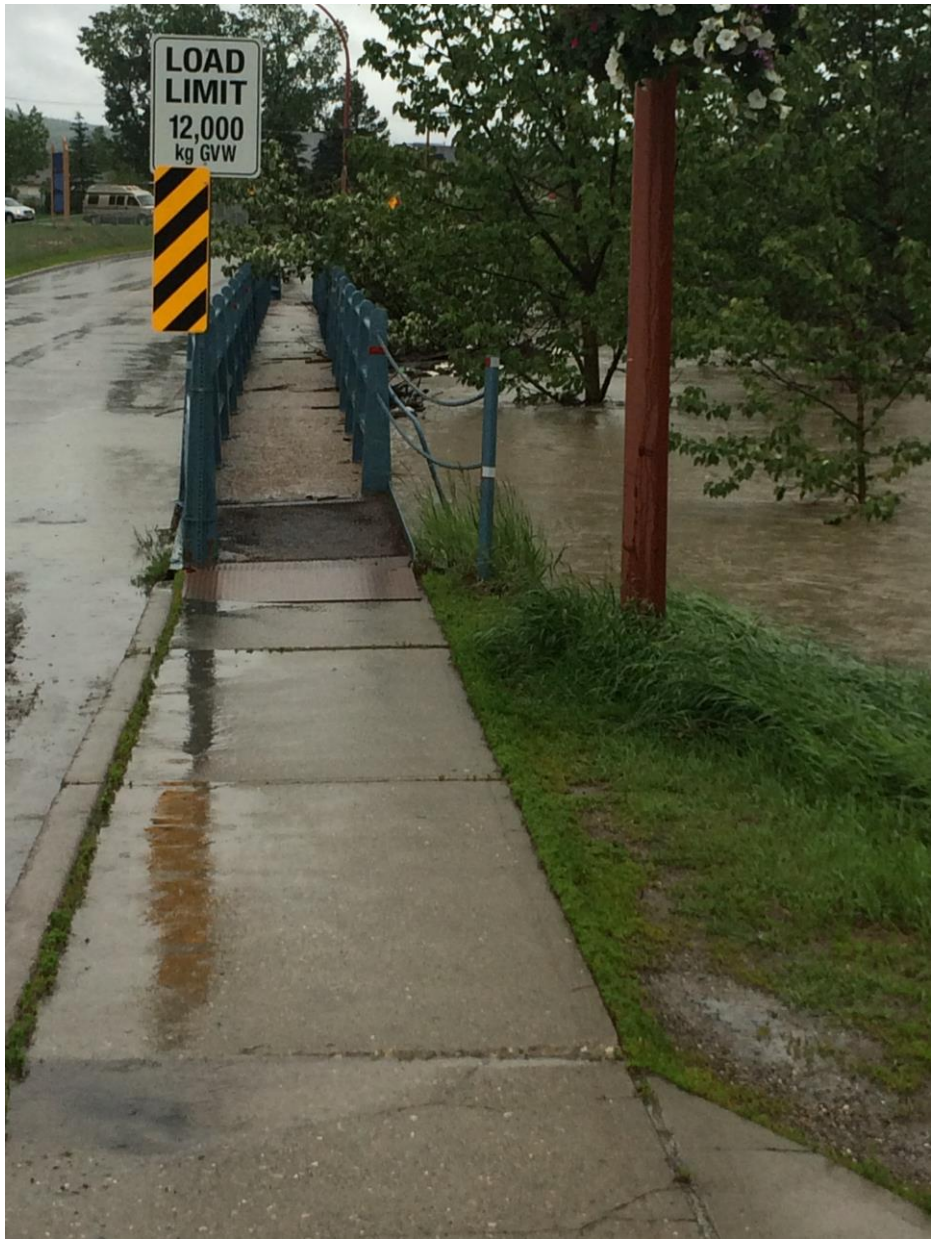
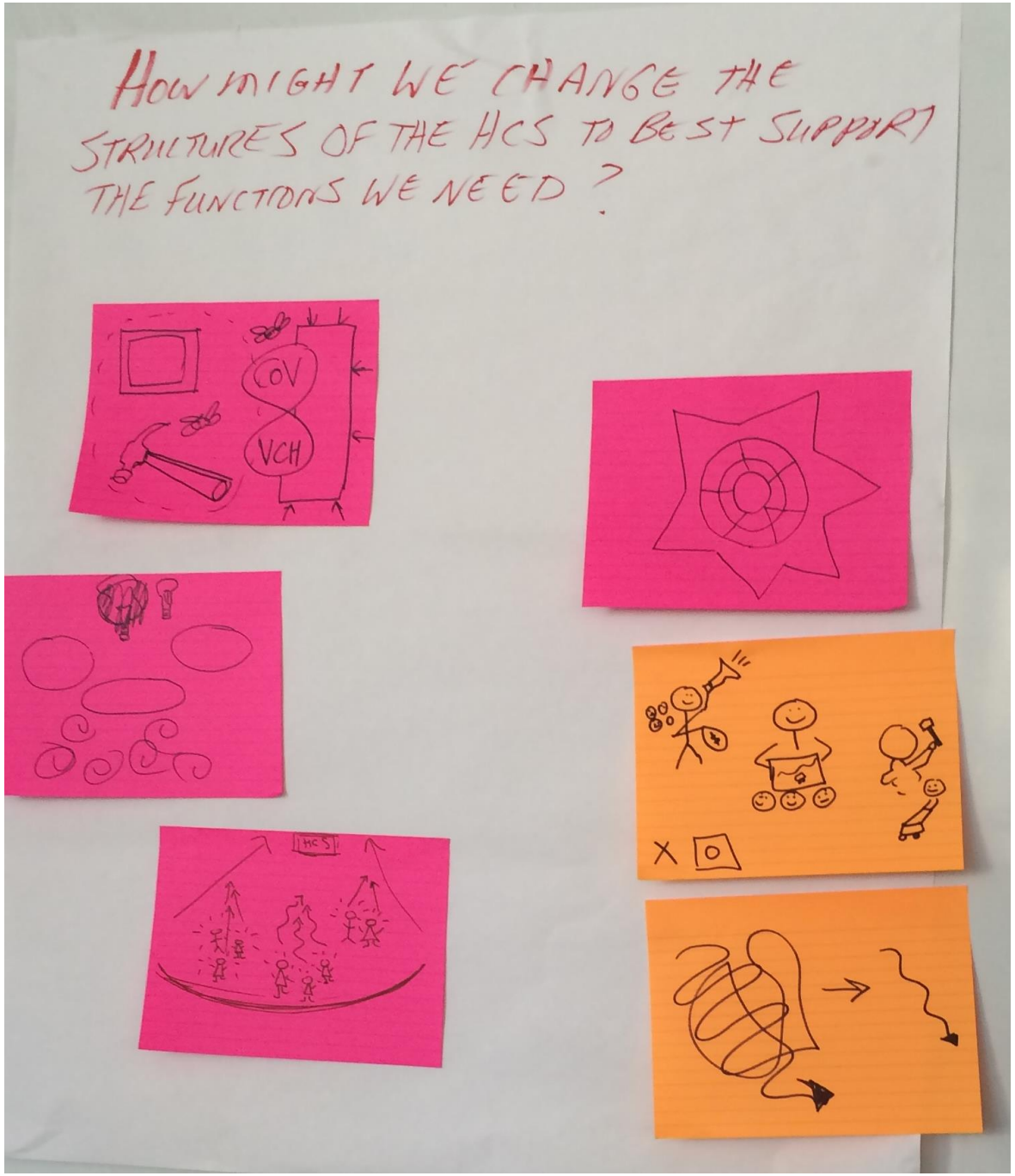


How have you experienced flood risk and/or management as a “wicked problem”?



Report Back: How would you draw it?

Impacts

Heather Murdock, P.Eng | Project Engineer | Ebbwater Consulting

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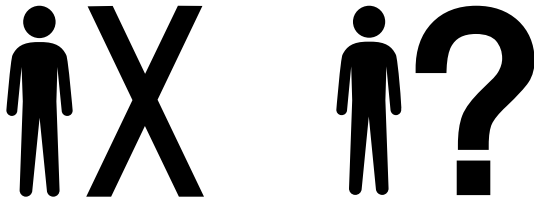
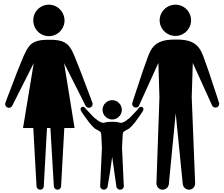
High-level impact categories

National Risk Profile

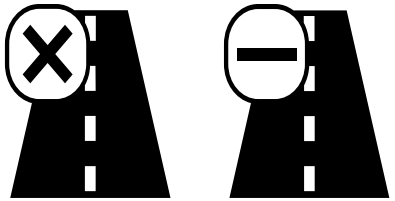


Mortality & Missing



Affected People

Economic



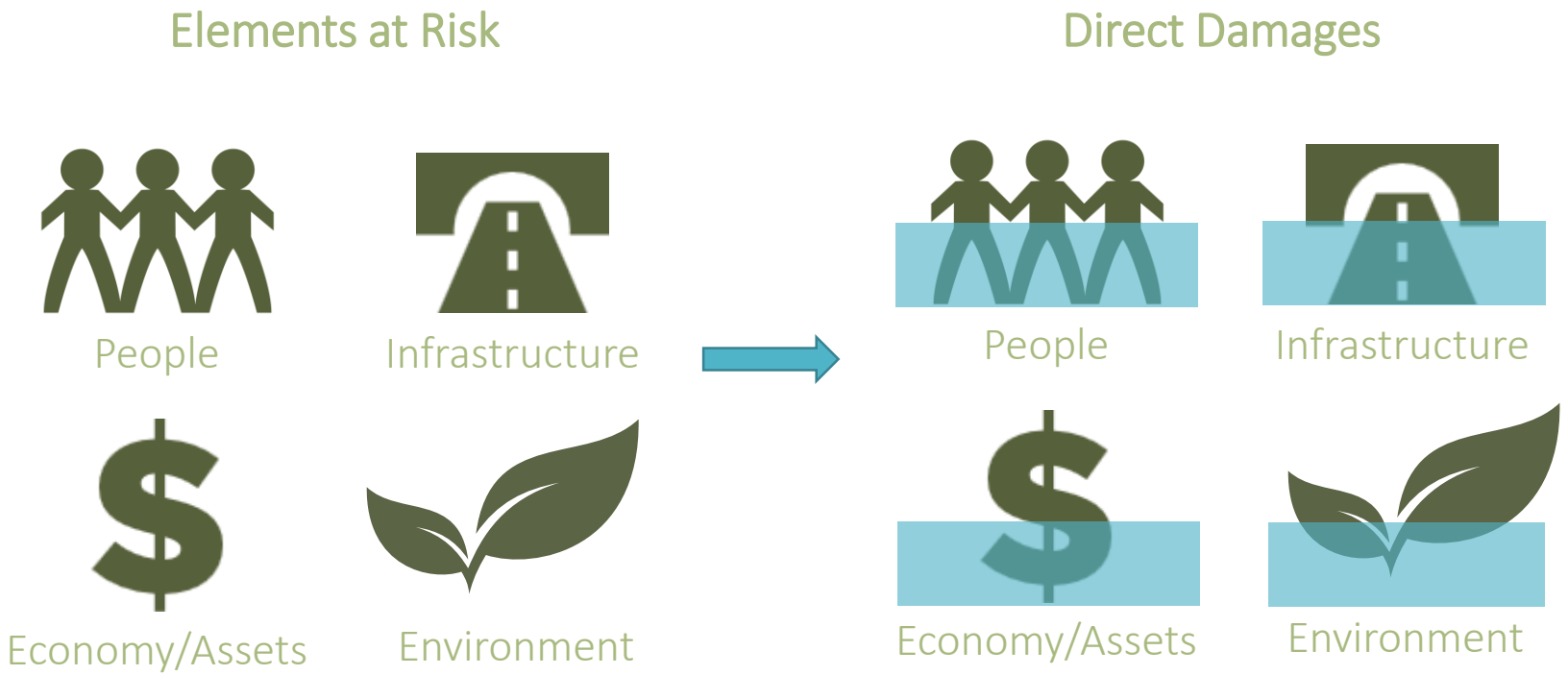
Disruption

Environment

Cultural*

Risk Assessment

A Multi-Disciplinary Task



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Dawson Creek Flood Mitigation Planning
Flood Event Map 2016

Legend

Exposure
- Building Footprints

Hazard
- 2016 Flood Area
- Dawson Creek

0 100 200 300 400 500 m

Map Notes

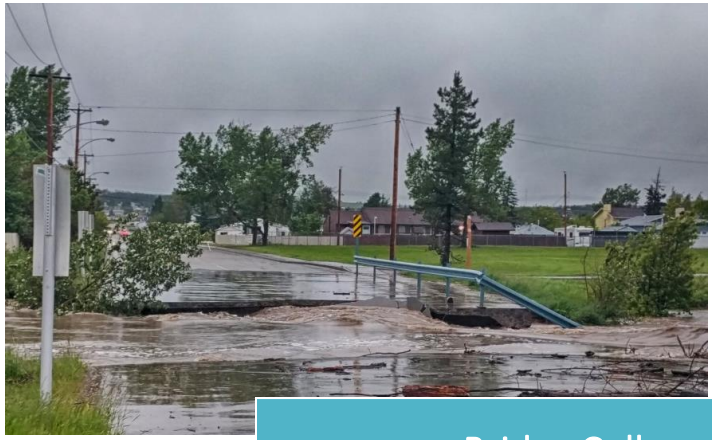
1. Map created by Ebbwater Consulting, November 17, 2017
2. For discussion only
3. Flood event extents from June 2016, received from the City of Dawson Creek
4. Building Footprint layer received from the City of Dawson Creek
5. Base layer: Open Street Map

Flood Impacts - Direct

Washed out/ flooded roads

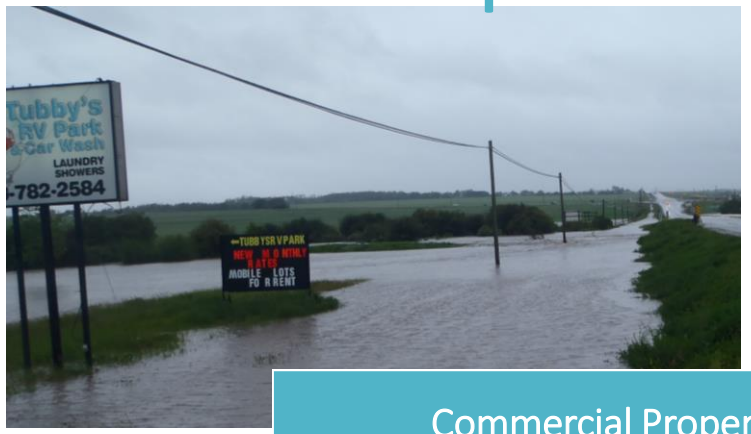
Exposed utilities

Washed out/ flooded roads



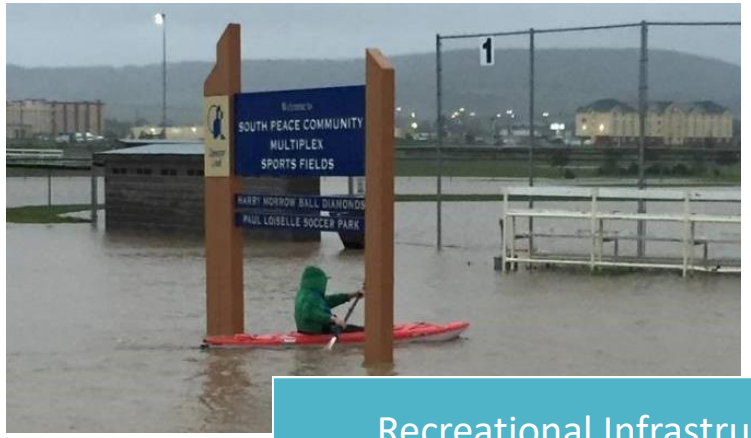
Bridge Collapse

Flood Impacts - Direct



Commercial Property

Residential Property



Recreational Infrastructure

Rail and Highway Access

What happens when the power goes out?

The Tricky(ier) Part

Direct Impacts

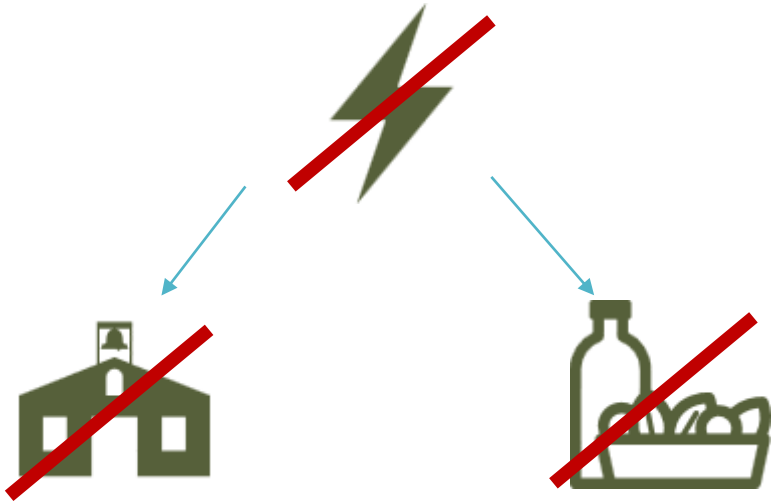
People

Infrastructure

Economy

Environment

Indirect Impacts
(Cascading Effects)



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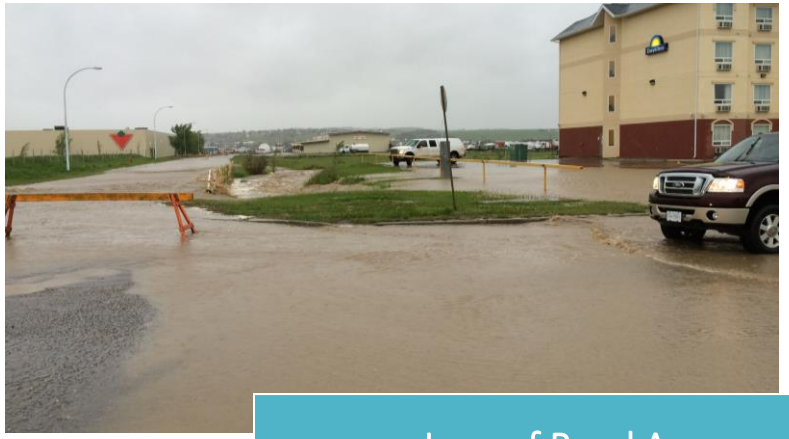
Flood Impacts - Indirect

City Cut In Half



Loss of Road Access

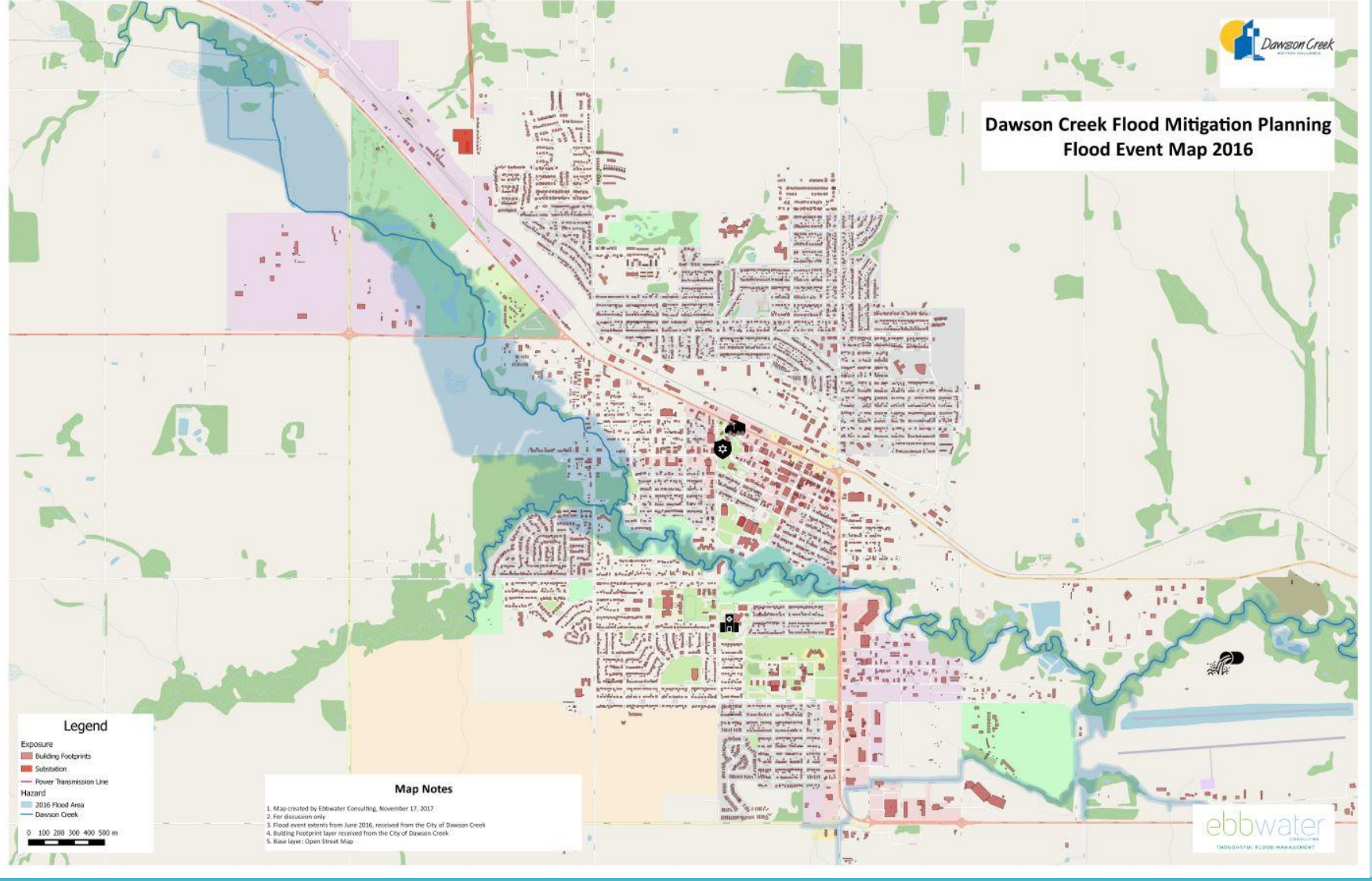
Loss of Recreation

Loss of Utility Service

Sharing Stories from the Floods

Sharing Stories of the Floods

1. Individually: reflect using the worksheet (5 min)
2. Storytelling & Deep Listening (3 min each)
3. Group Discussion at your table (10 min)
   - What was new? What surprised you?
   - Connections to other impacts?
   - What about the rest of the system?

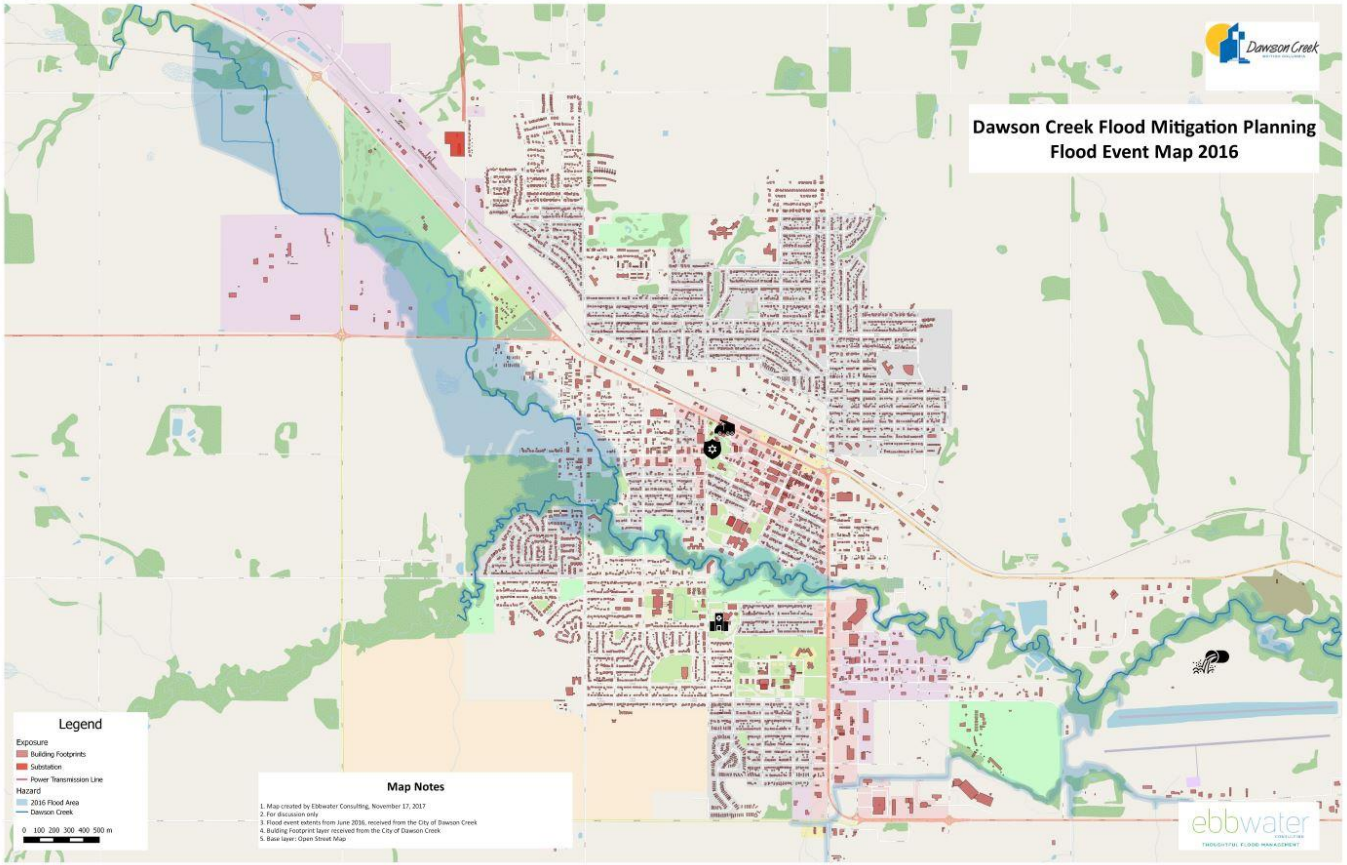


Mapping Direct & Indirect Impacts

Mapping Direct & Indirect Impacts

1. Write impacts on sticky notes (1 per sheet) & place on map:
   - Direct Impacts – BLUE
   - Indirect impacts – ORANGE

2. Group discussion at your table (20 min):
   - What matters, and why?
   - What connections do you notice with what matters to others?
   - Any upstream/downstream connections?
   - What is missing? What questions do you have?



What stood out?

What matters the most?

What do we (consultants) need to know?

Next Steps…

Looking ahead….we'll be back to make sure we heard you right.

November 2017	Nov 2017 – Jan 2018	Feb/Mar 2018	Spring 2018
Understanding exposure by learning about community values and impacts (**this event**)	Analysis of flood hazard, exposure and risk	Confirmation and ground truthing with community	Reporting and grant fund applications

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Thank You!

erica@shiftcollaborative.ca
tamsin@ebbwater.ca
heather@ebbwater.ca

SHIFT
shift to a better world

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Agenda

Managing the Flood Risk in Dawson Creek:

Reporting Back: Dialogue with Stakeholders

Wednesday Feb 21st, 2018
10:00 am - 3:00 pm
Kiwanis Performing Arts Centre (KPac), 10401 10 St, Dawson Creek, BC

Approx. Time	Activity
9:45 – 10:00	Registration
10:00 – 10:15	Welcome & overview
10:15 – 10:45	Report back & review of findings from workshop #1
10:45 – 11:15	Future hazard, vulnerability, & planning for resilience
11:15 – 12:00	Exploring impacts & vulnerability across the community
12:00 – 12:30	***Lunch***
12:30 – 1:10	Journey mapping and feedback on flood impacts
1:10 – 1:40	Planning for a flood resilient community
1:40 – 1:50	***Break***
1:50 – 2:45	Game of Floods: decision-making and tradeoffs
2:45 – 3:00	Closing

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SHIFT shift to a better world

Dawson Creek Flood Mitigation Planning

Workshop #2: Reporting Back – Summary Report

March 29, 2018

Table of Contents

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SHIFT shift to a better world

1. Introduction to the Project

The City of Dawson Creek (the City) has experienced significant storm events that have caused considerable damage and impact to private and public assets and people. It is expected that flood hazards will become more severe in the coming years and it is important to understand what the impacts of future floods will be. In response, the City has engaged Ebbwater Consulting to better understand the present-day flood risk in the community. This improved understanding will be used in the future to develop plans for risk reduction.

Best practice dictates that flood mitigation be achieved through a thoughtful, risk-based planning process based on community values and considering a range of hazard levels. The objectives of the current project are to explore the flood hazard as well as the community infrastructure and values that could be impacted by flood. This project will also produce a specific deliverable that will support the community to apply for funding from senior governments to implement flood mitigation planning.

The table below, outlines the process and timeline for this project, to be completed by spring of 2018.

Stage	Timing	Objectives
Gap Analysis	Oct - Nov 2017	• Conduct a scan of existing materials related to flood management at the City of Dawson Creek, to highlight any gaps in data or technical analysis that influence future tasks
Setting the Stage	Nov – Dec 2017	• Engage stakeholders and the public, to increase awareness and understanding about current and potential future impacts of flooding in the area, and begin to identify areas of overlapping values and interests, and interconnected factors affecting vulnerability
Identify & Establish Hazards	Dec - Jan 2018	• Better understand the variety of flood-based hazards, as well as understanding the likelihood and magnitude of each hazard

Report back and Explore Vulnerability and Resilience	Feb 2018	• Report back to stakeholders on flood impacts and explore community vulnerability and flood resilience for a range of flood hazards
Identify Consequences & Risk	Feb – Mar 2018	• Combine all the information previously collected and calculated to develop a locally relevant risk assessment that can also be used as input for high-level risk assessments used as a prioritization mechanism by federal funding agencies
Establish next steps and apply for additional funds	May 2018	• Identify next steps to complete the flood mitigation plan and support the City in its application to various Disaster Mitigation funding programs

This report summarizes the process and findings of the "Reporting Back" step, where a similar group of stakeholders to Workshop #1, was engaged in a one-day session to review and provide feedback on results from "Setting the Stage" and "Identify and Establish Hazards." This group was also facilitated through a process to deepen understanding of community vulnerabilities and resilience to a range of flood hazard and across various affected populations.

2. What We Did

This workshop brought together stakeholders from across the community, with the aims of:

- Reporting back on findings and subsequent analysis from first stakeholder workshop
- Exploring impacts and vulnerability for a range of flood hazard levels and for different indicators of vulnerability
- Enhancing understanding of planning for flood resilience and making trade-offs
- Enhancing understanding across stakeholders, of the diversity of interests and values, and how they interconnect
- Nurturing a sense of a community / regional approach to flood management (being in it together)

This workshop will inform the development of the risk assessment, and build capacity as a community to enhance resilience to the flood risk. The workshop included:

- Review of findings and analysis since Workshop #1
- Understanding the flood hazard and vulnerability "hotspots"
- Overview of planning for resilience
- Journey Mapping the experience of different affected populations / groups in hypothetical flood scenarios
- Generating insights and opportunities for building resilience of the community to the flood risk

Stakeholders were invited from across sectors in order to assemble a group that could speak to the broad range of interests and values touched by flood risk. This included economic, social, environmental, physical, infrastructure and health & well-being values of the community. In total 21 stakeholders attended which included representative from the following organizations:

- Dawson Creek Chamber of Commerce
- Farmers Advocacy
- Ducks Unlimited
- City of Dawson Creek
    - Public Works
    - Engineering
    - Development Services
    - Planning
    - Water Treatment & Watershed Management
    - Fire Department
- Dawson Creek City Council
- Peace River Regional District Board of Directors
- Dawson Creek Airport
- Provincial government:
    - Ministry of Forests, Lands, Natural Resource Operations & Rural Development
    - Ministry of Transportation

3. What We Heard from Participants

Review of Concepts and Findings from Workshop 1

Early on in the day, participants were provided with a blank template and invited to assemble the elements of risk as introduced in the first workshop, as a review of this concept that is central to the project:

Figure 1: Risk exercise during workshop in Dawson Creek

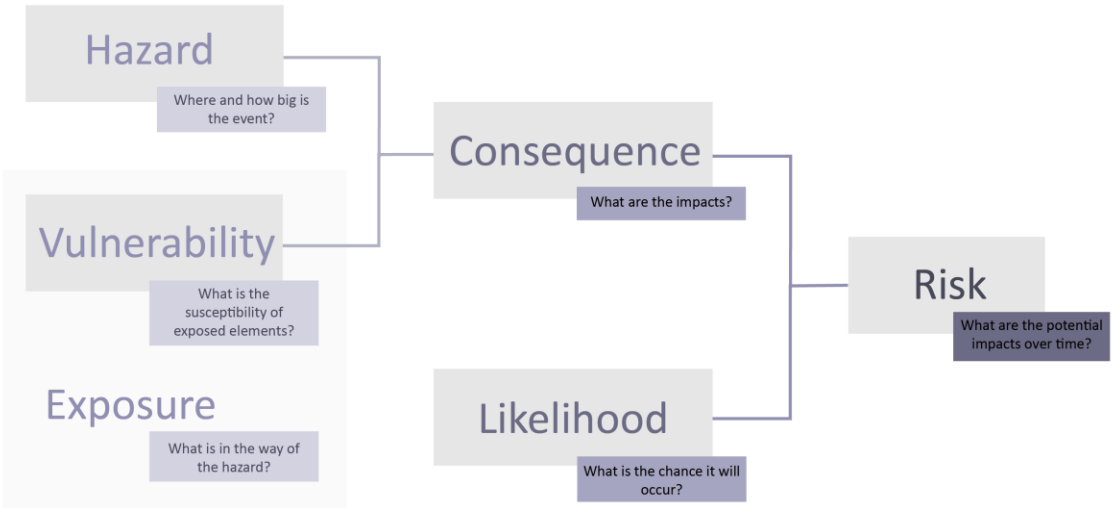

Figure 2: Multiple components of flood risk

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SHIFT shift to a better world

They were then engaged in reviewing and providing feedback on a number of maps showing impacts and vulnerability "hotspots" in the community, which were compiled from the results of workshop #1.

Figure 3: Reporting back on and confirming flood impacts in Dawson Creek

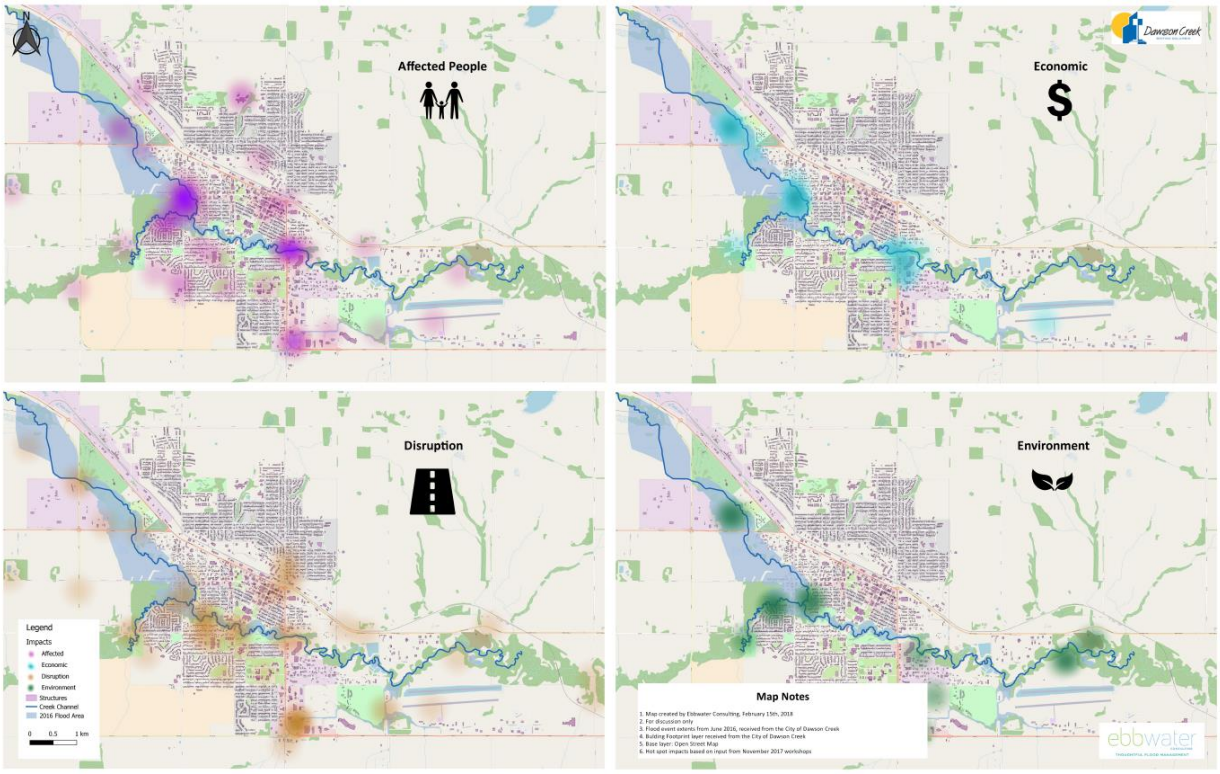


Figure 4: Figures used in reporting back workshop

The remainder of the day focused on deepening our shared understanding of vulnerabilities in the community from different perspectives, things to consider in planning for a flood resilient community, and consideration of the tradeoffs to be made in that process.

Journey Mapping

This began with a "journey mapping" exercise where each table took on the perspective of an affected group in the community:

- Seniors, children & families
- Community leaders & decision-makers; Infrastructure operators
- First responders
- Floodplain property owners (residential, business) & residents experiencing sewer backup

From the perspective of this affected group, participants then mapped out the particular experiences, actions and context for the time prior to a flood event, during each of a smaller and more extreme flood hazard event, and then following a flood event. The full set of notes from this journey mapping exercise is included here as Appendix A, as a reference for future flood and emergency management planning.

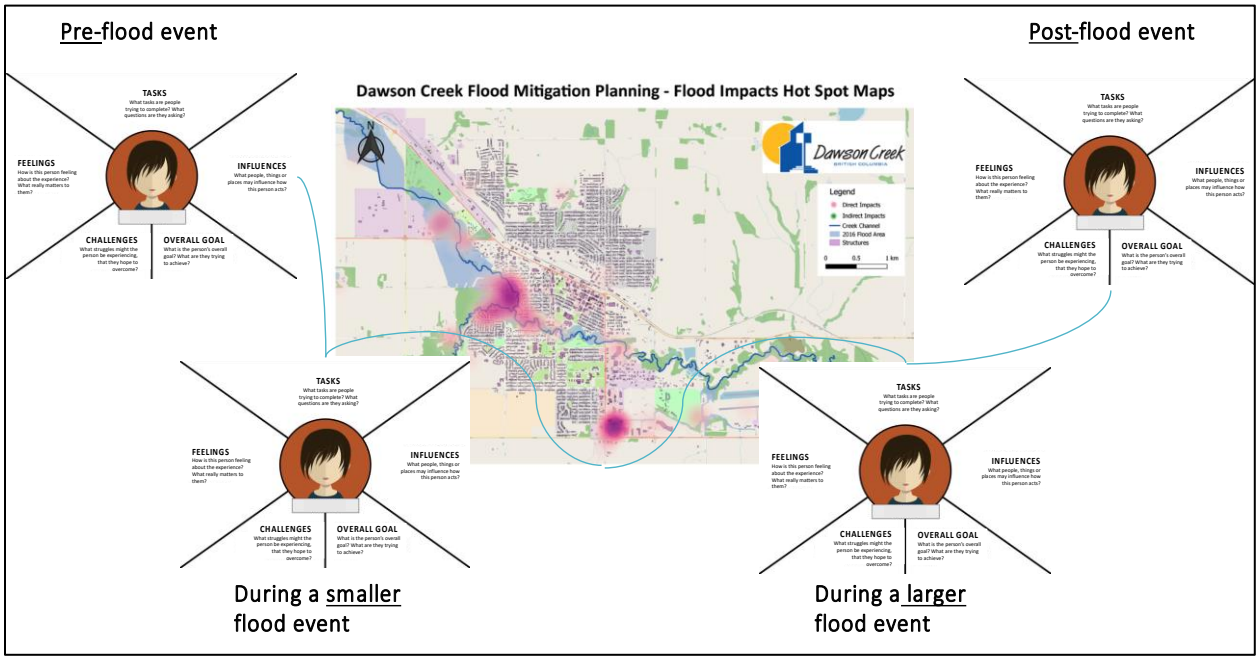


Figure 5: Journey Mapping through the phases of the flood risk cycle - Empathy map design adapted from Paul Boag, https://boagworld.com/usability/adapting-empathy-maps-for-ux-design/

Planning for a Flood Resilient Community

Drawing on insights and opportunities identified through the Journey Mapping process, groups identified key actions and decisions that were important from the perspective of planning for a flood-resilient community (organized into four key areas):

Table 1: Key actions and decisions important for a flood resilient community

Natural & Built Environment	Leadership & Strategy

• Land use planning
  ○ Review OCP as it impacts land around vulnerable areas
  ○ Effective Long term planning
  ○ Stronger floodplain
  ○ How do we move high risk "items" away from the creek, but not create separation in the community? Build low risk infrastructure that still promotes community
  ○ Reduce vulnerable infrastructure in the flood prone areas
  ○ Informing potential home-buyers in floodplain zone / hotspot area
  ○ Innovative design and landscaping
• Watershed management
  ○ More research about the creek (debris, fish, pollution from floods)
  ○ Beavers (upstream water mgmt)
  ○ Consider off-channel storage vs upgrading crossings
  ○ Increase wetland areas for moderating peaks
  ○ Consider upstream hydrology to reduce runoff
  ○ Have to look at the entire watershed to solve the problem
• Infrastructure
  ○ Construction and maintenance of appropriate infrastructure
  ○ Resilient infrastructure; water storage areas, debris catches, stormwater and subdivision level and hard surfaces; space for water
  ○ Building with floods in mind (bridges)- 8th Street bridge
  ○ Building resilient structures to handle floods
• Recovery planning
  ○ Build back better (but funding won't go to this)
	• Emergency Management & Strategy
	  ○ Dedicated EM staff and robust EM program
	  ○ Coordinators for response plans
	  ○ Budget and mandate for EM – put this in all job descriptions
	  ○ Emergency management planning
	  ○ City takes lead for emergency prep plan and training
	  ○ Emergency response plan (flooding) and communication
	• Coordinated & Proactive Flood Management
	  ○ Flood management & EM needs to become a priority and explicit in strategic plans
	  ○ Use opportunities of awareness / urgency when impacts happen
	  ○ Accountable decision-making by chosen or appointed leadership
	  ○ Coordination across levels of govt
	  ○ Processes, checklists
	  ○ Individuals to take leadership, make decisions, be proactive, don't wait and just respond
	  ○ Coordinated plan pre-flood (all levels of government)
	• Educated and empowered stakeholders
	  ○ Education dos and don'ts
	  ○ Bring awareness to the community of being prepared and what to do in these situtions
	  ○ Enabling through education
	  ○ Realistic public expectation
	  ○ Enable / educate individual home owners / renters to be proactive

Human Health & Well-Being	Social, Economic and Cultural

• Support individuals to take responsibility and action
  ○ Develop a public education program (eg: Effective emergency services means staying off the roads)
  ○ Feeling safe by feeling informed, educated – know who is held accountable and who to turn to with questions
  ○ Knowledge of where to go for help / emergency services, who to call
  ○ Being and feeling safe and included
• Calming sense that all appropriate services are meeting the needs
  ○ Hospitals, etc have practiced emergency preparedness actions
  ○ Ensure emergency responders on both sides of town
  ○ Coordinated emergency services (NHA, SAR, FD, etc)
  ○ Emergency resource stations
  ○ Adequate supplies / resources for emergency services
  ○ Ensure that the main buildings are accessible and running; volunteers at hospitals or at fire hall
	• Develop culture of resilient community
	  ○ Community: neighbourhood engagement
	  ○ Build support networks between existing community organizations for flood emergency situations
	  ○ Knowing that your community / neighbours will all "come together"
	  ○ Active community – neighbourhood engagement
	  ○ Public engagement prior to anniversary of event; so that whole community has a refresher of potential risks
	  ○ Place for concerns to be heard, acknowledged, addressed
	• Enable learning & action
	  ○ Public emergency preparedness campaign
	  ○ Support / knowledge groups
	  ○ Education
	  ○ Clear & accurate communication pre & during events
	  ○ Support groups
	  ○ Learn from mistakes and document for knowledge sharing
	• Affordable
	• Diversify revenue generating businesses

Bringing it all Together: Game of Floods

At the end of workshop #2, participants had the opportunity to integrate the two days of learning and engagement in the form of a customized board game created for this project. "Game of Floods – River Edition" was adapted from an original version designed for a coastal setting[1], to resemble the context in Dawson Creek. The game invited teams to take turns using limited resources to propose flood risk reduction measures and consider tradeoffs in their choices. Each individual assumed the role of someone in the community (eg: Mayor, Fire Chief, resident, infrastructure operator, business owner, etc), and consider which approaches to risk reduction would meet that person's interests. At the same time, the group needed to consider interactions and tradeoffs across their individual strategies, to enhance flood resilience for the entire community. Different groups discovered the benefits and limitations of their various approaches to working more collaboratively, or advancing isolated strategies to achieve individual goals.

[1] https://www.marincounty.org/depts/cd/divisions/planning/csmart-sea-level-rise/game-of-floods

Figure 6: Game of Floods Session during the reporting back workshop in Dawson Creek

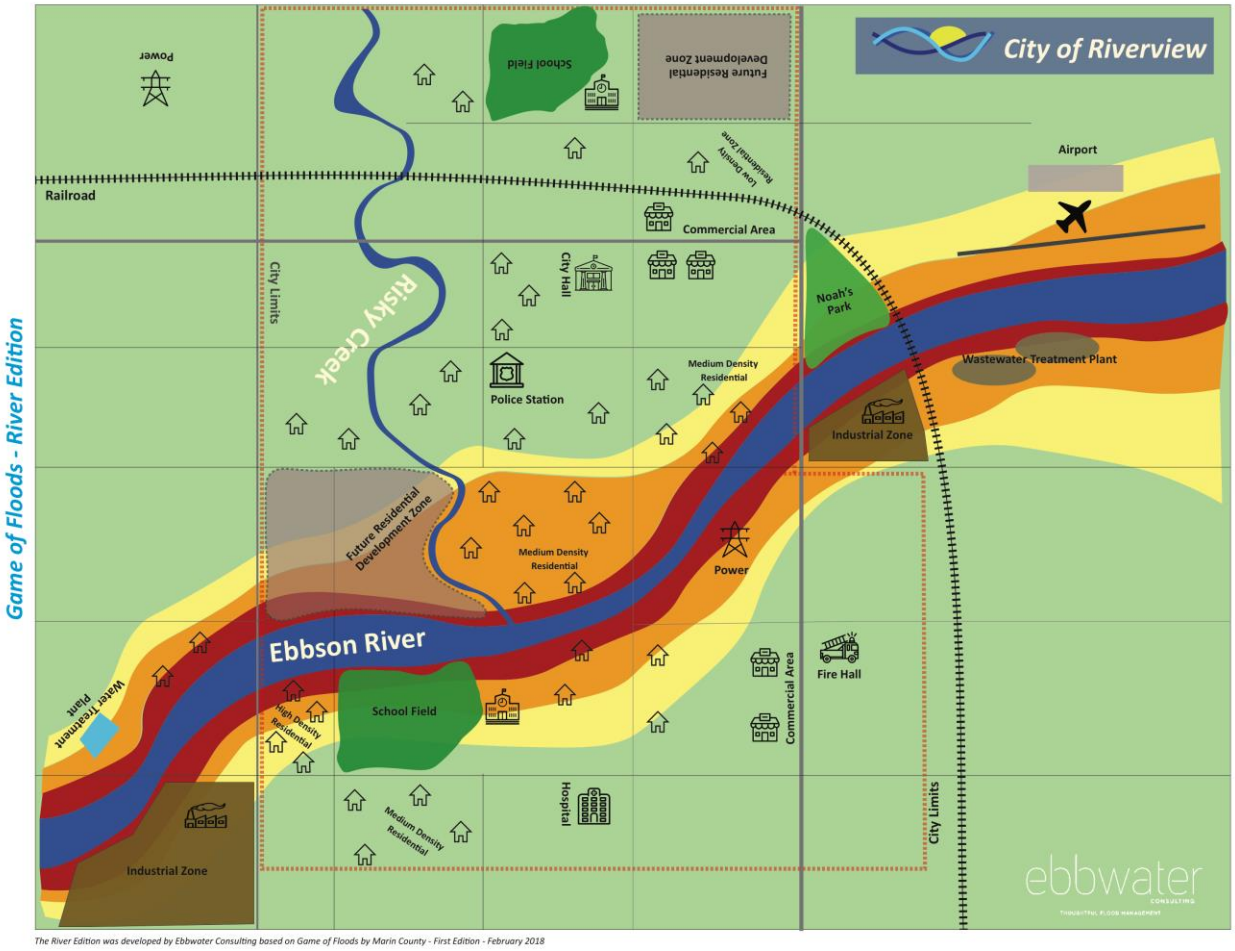


Figure 7: Game of Floods - River Edition (gameboard)

Insights & Opportunities

Key messages emerging from the day included:

- Plan and build with floods in mind
  - Stronger land use policy & tools for areas in and around the floodplain
  - Reduce vulnerable infrastructure in flood prone areas, while maintaining community's connection to the creek
  - Inform potential home buyers about flood risk
  - Require / promote flood resilient building design and landscaping
  - Recovery planning – be ready to change course and/or build back better, when the opportunity arises
  - Resilient infrastructure

- Improve understanding of the watershed and options to manage flood risk through watershed management (eg: upstream gauges & monitoring; behaviour of creek & debris flows; potential for water retention)
- Strengthen emergency planning and management
    - Develop explicit mandates and budgets for emergency management and coordination
        - Consider a dedicated role for emergency planning, response & coordination
    - Invest in capacity building of staff, and coordination of response
        - Consider how to draw on (and coordinate) resources available in the community (eg: human and knowledge)
    - Plan for clear communications before, during and after flood events
    - Contribute to a sense of calm by helping individuals and stakeholders to know what services are available and how needs can be met
- Proactive and coordinated flood management
    - Invest in planning & coordination, proactively, across levels of government and across stakeholders to enhance effectiveness of decision-making and response capacity
    - Support education and empowerment of stakeholders and individuals to take responsibility and be proactive where possible
    - Learn from experience, and document for knowledge sharing
        - ensure institutional knowledge can be passed on when there is staff turnover
        - share experience of past floods so current residents, stakeholders and staff are informed
        - translate learning from a flood event back into the preparation phase for next cycle
- Develop a culture of a resilient community
    - Build engagement at a neighbourhood level to enhance resilience and enable strong response during flood events
    - Make space for concerns to be heard & acknowledged
    - Support individuals and neighbours to learn, take responsibility and take action
        - Public engagement, education & communication
        - Enable people by knowing what information is available so that they can make choices accordingly (eg: regarding emergency preparedness, flood risk to properties, insurance, etc)
        - Support groups
        - Create emergency resource stations

4. Next Steps

Workshop #2 provided an opportunity to gather additional input on flood hazards, impacts and vulnerabilities, and begin to formulate potential paths for planning for a more flood resilient community. Participants considered a range of perspectives and interests and the tradeoffs and benefits of different courses of action, as well as encountering the dynamics of isolated versus collaborative decision making. The results of this workshop and other work to date, will form the basis of a risk assessment and identification of possible options for enhancing the community's resilience to flood risk. In addition, a range of key stakeholders in the community has had the opportunity to deepen their understanding of taking a resilience approach to flood risk management, empowering them to be part of building a more flood resilient community in future phases of this work.

Workshop Report Appendix A

Seniors, Children & Families

	Pre-Event	Small Event	Large Event	Post-Event
Goals	Keep Safe Leave hazardous areas Be prepared, have a place to go	Community based solutions Want to help	Safety Security Financial security	Reinstate normalcy Plan to return to normal Don't let it happen again / mitigate
Challenges	Technology (will people be warned?) Lack of preparation Lack of education	Isolation Communication Technology Confusion about insurance	Restricted access Vulnerable in a power outage Where do I evacuate? Knowing when to evacuate (spatial level vulnerability) technology	If I can't do work, who can help? Resources may be overwhelmed
Tasks	Fill prescriptions Identify vulnerable population: coordinate with EM/ER (prioritize who comes first) Emergency supplies	Help people / incentivize back flow valves	Grabbing photos / pets / valuables Trying to collect and communicate with family evacuate	Find information When to go back? What do I need to do?
Influences	Mobility challenges Isolation, separation Technological ability		Do I have support network Level of knowledge Level of hazard	Health / vulnerability / mobility Age of children Extent of damage Family/friend network Finances
Feelings	Apathy Nothing Anxious, spring is coming Anticipation Overwhelmed (no solution) Will I be rescued?	Frustrated Economic worries & stress (insurance / losing insurance) Want to help neighbours / friends helplessness	Scared Stressed Adrenaline Overwhelmed Need to do something Surprised Helpless	Depressed Relieved How long will this last? What are next steps? Stressed (which may grow with time)

	Do I have anyone to communicate with? Who do I call?			
Insights & Opportunities	Flood mapping with zones on city website, tied to alerts and things to do Use EM education at schools to get households prepared Have a plan, enact with enough warning	Know where resources are and use them (eg: seniors org call people who know where spare pumps are)	Communication: real time hazard mapping – telephone pole Creating disaster routes and communicating where they are	Support groups / counselling Get people targeted info Create connections Create resource stations (food, red cross etc)

First Responders

	Pre-Event	Small Event	Large Event	Post-Event
Goals	Plan ahead: preparedness, safety More comprehensive approach: discusions sooner Be overly prepared	Take care of people Respond restrict areas	Same	Pre-planning for next event Recovery (get back to normal) – access, needs
Challenges	How much to act proactively… versus… crying wolf syndrome	Can't stop flooding	Multiple events close together Safety Lack of safety awareness Spontaneous resources / help (how to coordinate?) Coordinating across organizations (PRRD< health, schools, highways)	Complacency Capacity Staff turnover (loss of memory) Documenting Documentation / access to flooding
Tasks	Preparedness for safety of community members Plan respond, recover: big picture Measurement, numbers (to improve)	Phone calls: fire hall is first point of contact Smaller scale response, but same things as larger Staffing, monitoring, distributing resources	Resources to adapt to disrupted transportation Interrupted services Respond to anything Recording / tracking evacuations Door knocking, evacuations	Debrief: learn from event EOC has to review damages Use prior info / knowledge to target affected areas

	Anticipate best you can with info you have Anticipating worst case scenarios Plan to stage resources Learning from past experience	Tend to sewer backup: support for people leaving their homes Managing voyeurs: increases impacts	Notifying public / communication Think ahead to recovery: get community back to normal Assimilating information	
Influences	Political pressure: do it right, for cheap Tradeoffs Balance crisis management with also fulfilling fire response Unanticipated impacts Responsible fiscally Timing (of season, of the day), social media (blows up, can be good or bad!) A few days of notice (or not) Uncertainty Big picture: links to recovery Public: inquiries, noise, expectations Unknown: we don't know either! Staffing, resources: need urgency to get funds Public is panicking	Certain properties are flooded every time: no insurance Lack of awareness of insurance Short duration (eg: ½ hour storm) Not very visible Lack of awareness of floodplain by property owners People think it's not dangerous (added impacts from drivers' wakes)	Emergency plans of other orgs Responding to unexpected things Unpredictable Individuals adding to dangers Distributing resources SAR: interested, but limited Corporate / institutional memory (what happens when they retire?) Paying attention to now and future at same time People want to help: more resources, but not coordinated	
Feelings	Concern, worry Pressure of expectations Anxiety Unknown: will it flood? When? Pressure to improve, learn from events Can't control / predict	"not again" (by people affected)	Stress Burnout	Impacts tend to be less traumatic than other work for 1st responders

Insights & Opportunities	Communication with public (inform, educate, connect with resources) -- understanding, expectations, roles, in real time Learn from past experience More comprehensive planning needed Dedicated emergency planning role, coordinator – bring resources, roles, people together Dedicated lead on emergency (not also Fire Chievf at same time – hard to play both roles) – these people have families and homes too Post-event support	Communication: what to do and not to do Education about insurance	Delineation of tasks, coordination of orgs, resources Managing longer duration impacts lasting longer Managing resources available and tending to other priorities	Maps of affected areas: pre=planning Documented processes Staff knowledge / memory: turnover New opportunities for training, preparedness Translation of learning into processes, documentation, organization

Leaders & Decision-makers & Infrastructure operators

	Pre-Event	Small Event	Large Event	Post-Event
Goals	Be proactive in minimizing events Be prepared as a city Work to engage residents in being prepared – clear expectations Develop a clear response plan and engage / educate the public	Monitoring benchmarks	Maintain life safety Dealt with well, plans implemented Don't lose anyone	Through to event as a cohesive and hopeful community Build further resilience Event made us strong Rebuilding a better normal
Challenges	Cost: finding revenue streams to support mitigation and preparedness		Controlling and communicating up to date and accurate info	Public criticism Unreasonable expectations

	Staff education and training What is the decision tree			Failure of residents to assume reasonable responsibility Cost of rebuilding
Tasks	Understanding potential impacts Scope Gather resources Develop public education program Establish clear expectations Staff planning / education Monitor snow/water levels and forecast Establish metrics for hazard level and impacts Post event communication plan Recovery plan	Implement communication plan Implement emergency management plan Monitor event & benchmarks (river levels) Recording resident reporting	Info gathering Identify indicators of a large flood event How is it impacting infrastructure and residents Implement emergency plan Communication for public Assessment of infrastructure status Evacuation centres Mobilizing reources to assist evacuees Communications centre activated	Debrief Inventory of events Engage the community in a debrief Damage assessment Implement recovery plan Update and adjust plans with lessons learned and best practices
Influences	Residents Budget (financial resources, capacity)	Panicked residents Unanticipated consequences	Crisis managmenet	
Feelings	Scope of responsibility Managing expectations of residents Overwhelmed by scale of challenge	Urgency Is this the end? Uncertainty about how event will progress	Urgency Concerned, unplanned, unknown Risk to staff, equip & training	Relief, frustration, blame game
Insights & Opportunities	Develop public education program – let them know what is being done by City, what is their part			

	Staff emergency plan and education Managing community expectations Develop mitigation strategies and implement as able, manpower Additional monitoring and gauging in upstream areas			

Floodplain Property Owners (business or residential)

	Pre-Event	Small Event	Large Event	Post-Event
Goals	Establish checklist to be as prepared as possible Achieve personal relief that individuals have done everything possible to protect themselves Set up hotlines / emergencies	Make sure we are prepared Make sure all neighbours are aware Evacuation plans	Understand how to react when event occurs Safety, personal, family, pets, neibh ours Minimize damages	Safety Get back to normal Personal timelines to always prepare for the future, reminders in calendar etc
Challenges	How do homeowners know that they are in a floodplain? Notification Cost to prepare Jurisdiction Knowing when to leave (get out) Not panic	Can't get insurance What is the solution Lack of knowledge Neighbours on vacations, not there to help Trusting that others are doing their jobs (first responders) and knowing not to rush into things	Knowing extent or impacts of flood Knowing if schools are closed, how to get to services, should we stay put or help… Financial securities to be "prepared" Public transport	Timelines for insurance Cleanup Time off work to clean up Seniors, where to stay, new rental income if you can't stay in your house
Tasks	To understand what a flood realy means or what living in a floodplain means	Make sure all tools, utilities, equipment is ready in advance	Contact friends, family, ensure they are safe and healthy	Health of all individuals involved How to know how to proceed with damages

	Ensure your property / belongings / family / friends are protected Understanding previous floods, where to go, how to get places Set up network of contacts, friends, family, emergencies	Make sure personal belongings are prepared Get to know your neighbours Develop priorities	Develop process, figure out priorities	Develop personal processes for the future, tailor to individual needs
Influences	Incentives from the city, for installing sump pumps, backflow valves, etc	Debris management Knowledge	Communication: how to know if it's a big flood? How is drinking water influenced? Individuals "feel" safe Exposure during event	Learn from the event, what happened, what can they do better
Feelings	Anxiety How do we know if what we have done is enough? Fear Are we covered with insurance? Helplessness	Anxiety Financial fear Not again Anger Why haven't the solutions already been taken care of Resentment	Anxiety Are we safe? Panic	Overwhelming Devastated Hurt Anger frustration
Insights & Opportunities	Engineered weak spots Report of the history of Dawson Creek floods (new people to DC can really understand what floods are about and how they can affect people) Renters: how are they affected?	City to send reminders		How to know where to start, who do they contact? Pro-active

Dawson Creek

Reporting Back Workshop

Wednesday - February 21st 2017 – 10am to 3pm

Tamsin Lyle, P.Eng | Principal | Ebbwater Consulting

Erica Crawford| Co-Founder | SHIFT Collaborative

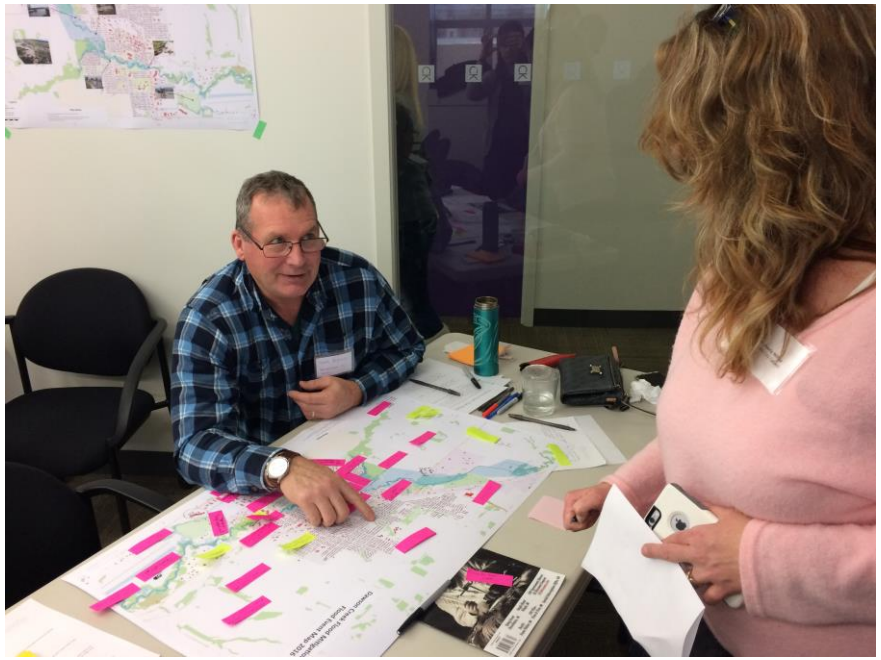
Heather Murdock, P.Eng | Project Engineer | Ebbwater Consulting

SHIFT
shift to a better world

ebbwater
CONSULTING
THOUGHTFUL FLOOD MANAGEMENT

Reporting Back from Setting the Stage

Playing with River Model



Identifying Impacts

Dawson Creek is not alone…

Mayor Craig Snodgrass of Town of High River's advice to flooded communities:

"*You have to try your best to **calm down**. You have to try your best to **slow down** because when I look back at how we rebuilt, most of us went too fast. You just go as hard as you can to get back some sense of normalcy, [but] if you go as hard and as fast as you can, you will make mistakes*"

http://www.cbc.ca/radio/checkup/blog/it-s-part-of-who-we-are-now-high-river-mayor-reflects-on-2013-s-devastating-floods-1.4105208

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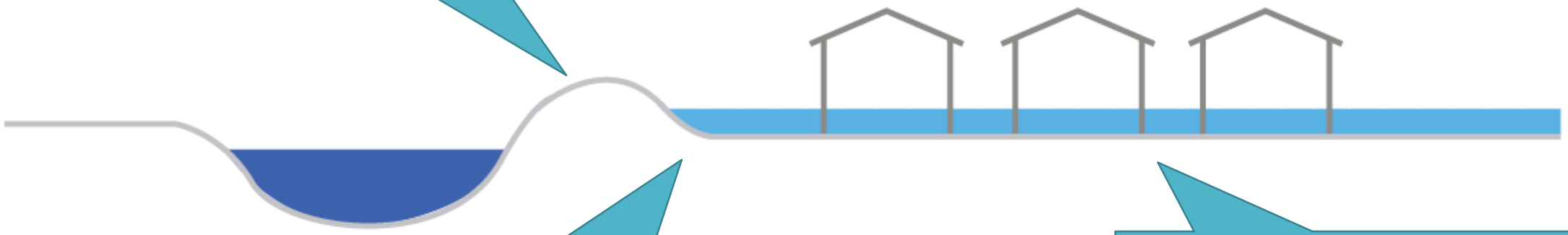
We need to understand the problem first

People:
Flood disasters affected 2.3 Bn and killed 157,000 people between 1995 and 2015 (UN, 2016)

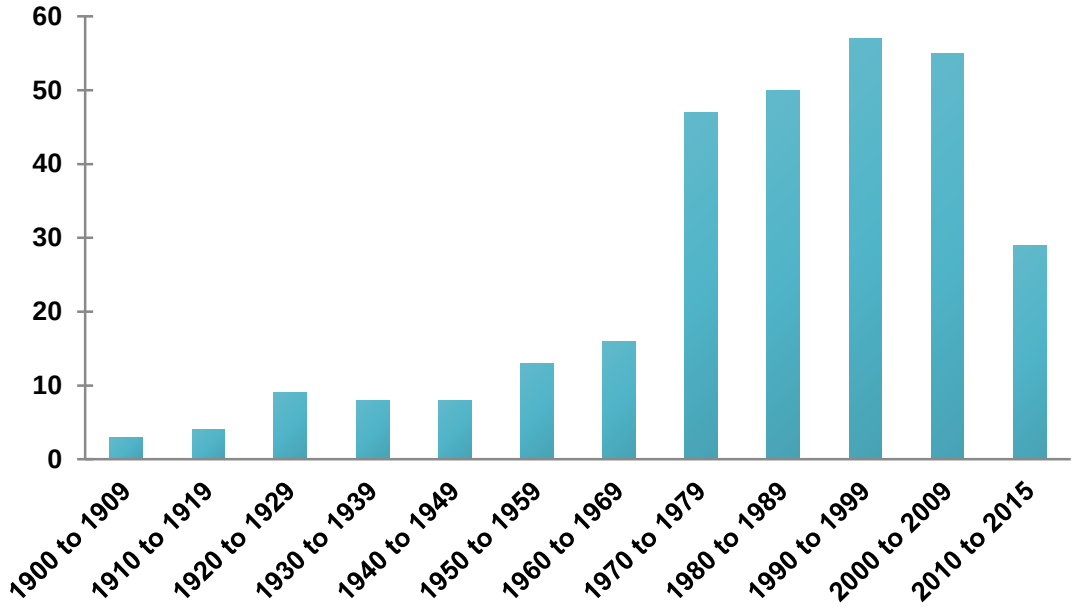
Infrastructure: "Integral US Trade Route, PTH-75 Closed" Red River Valley, 2011



Environment:
"Hurricane Katrina leaves legacy of industrial waste, raw sewage and oil spills" August 2005

Economy:
"Canada's GDP will be reduced by $2 billion as a direct result of the [Calgary] floods." June 2013

Floods are a problem not to be ignored



Flood Disaster Occurrences in Canada 1900-2015
(Canadian Disaster Database)

$2.4Bn losses annually
$673M paid by DFAA

Annual Loss Estimate from Government of Canada
(Parliamentary Budget Office 2016)

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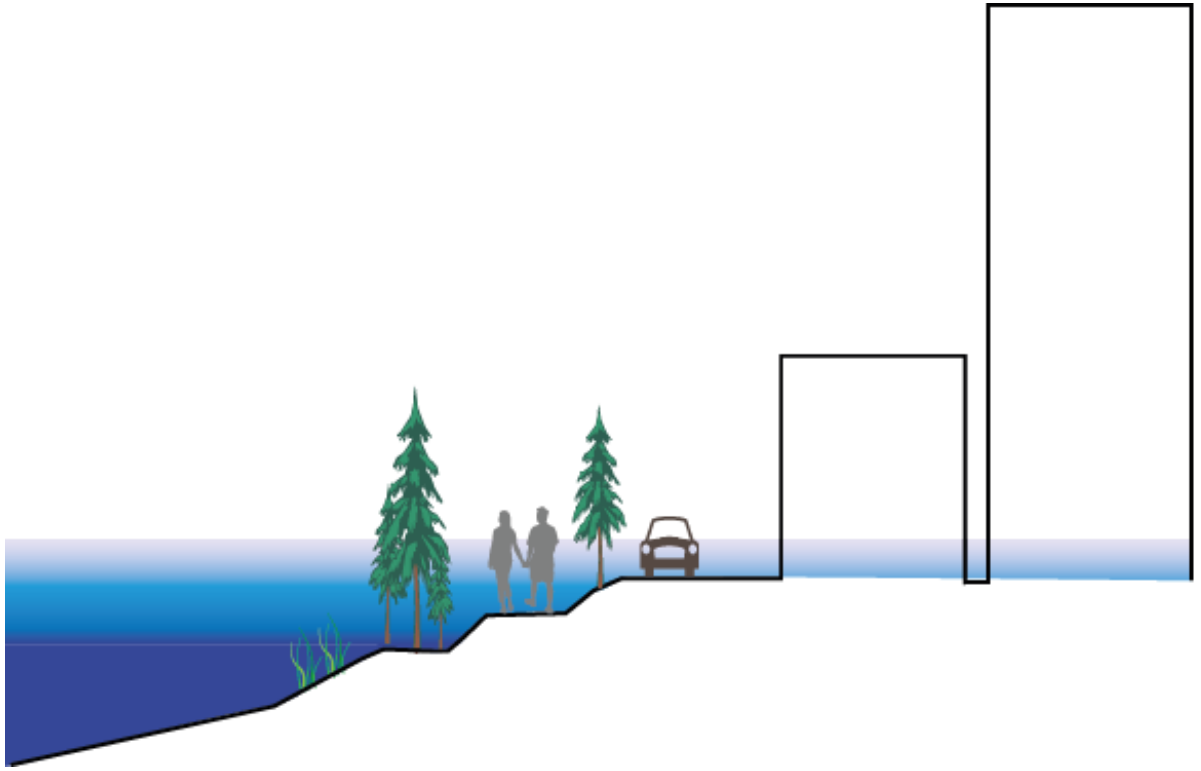
But…flood management is a wicked problem

- High degree of technical complexity
- Multiple dimensions of uncertainty
- Multiple objectives
- High stakes, high emotions
- Intense political scrutiny
- High expectations for quality and transparency
- Limited resources in terms of time, money and personnel.



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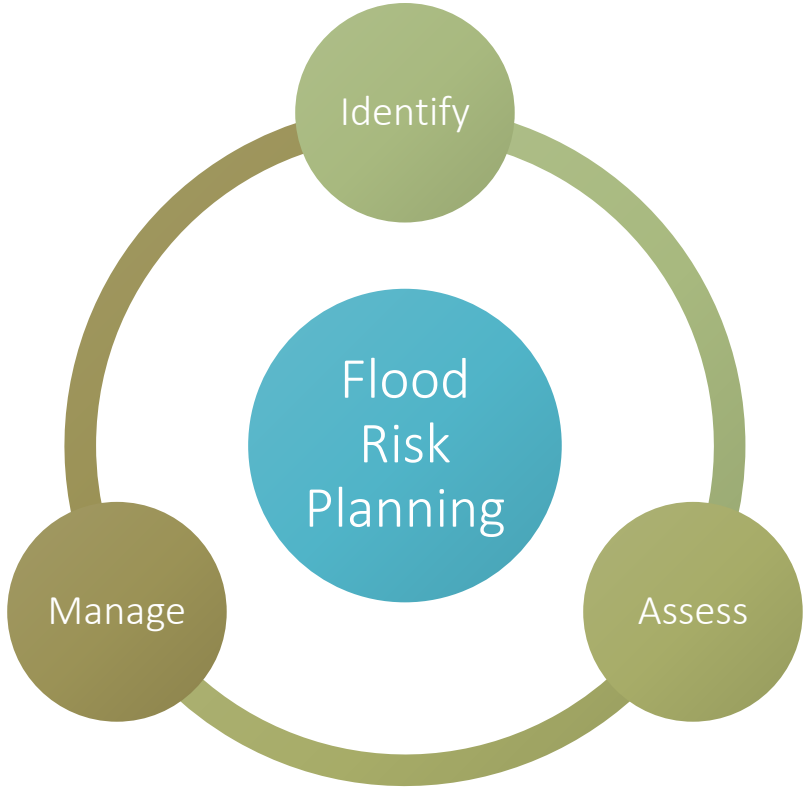
Once we understand, we can mitigate and improve community resilience



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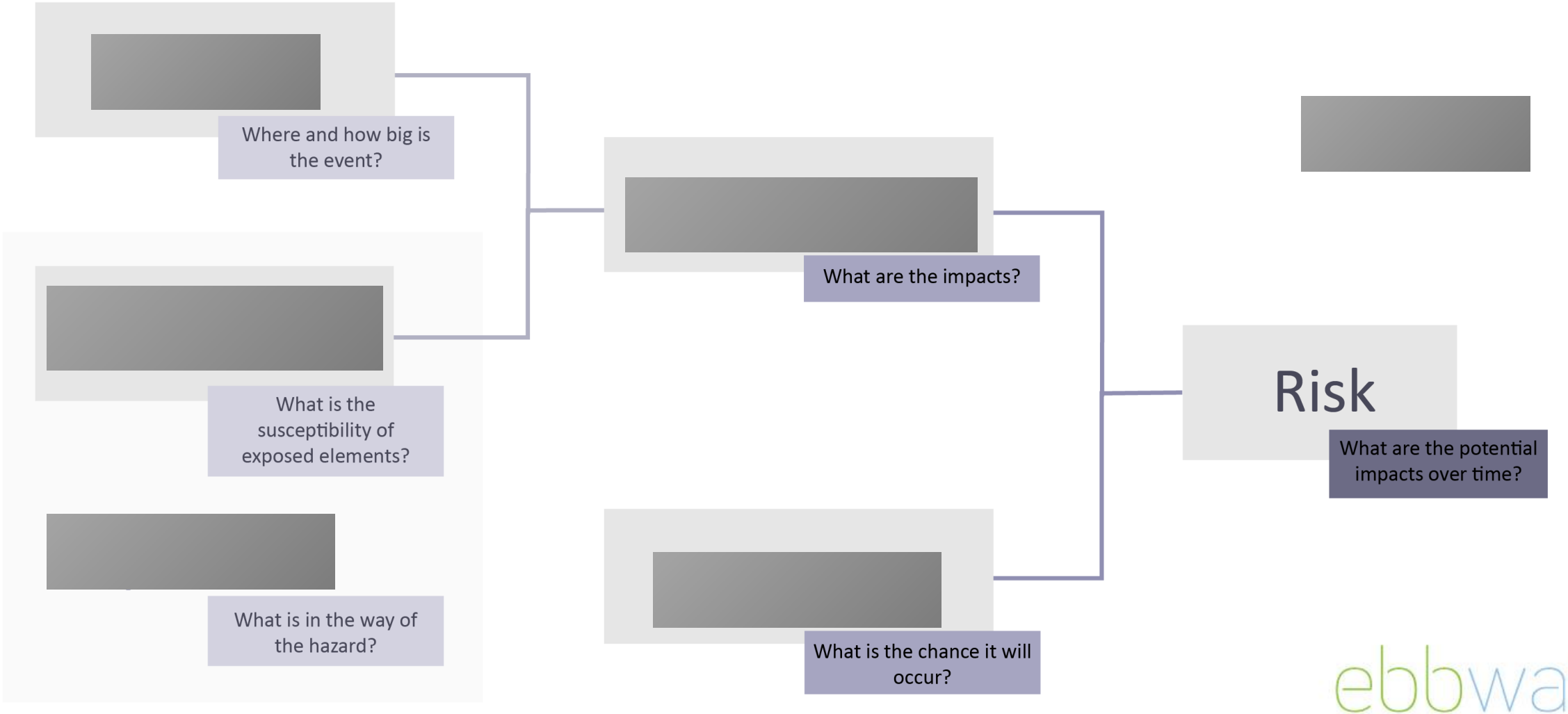
Plan for Risk not only Hazard!



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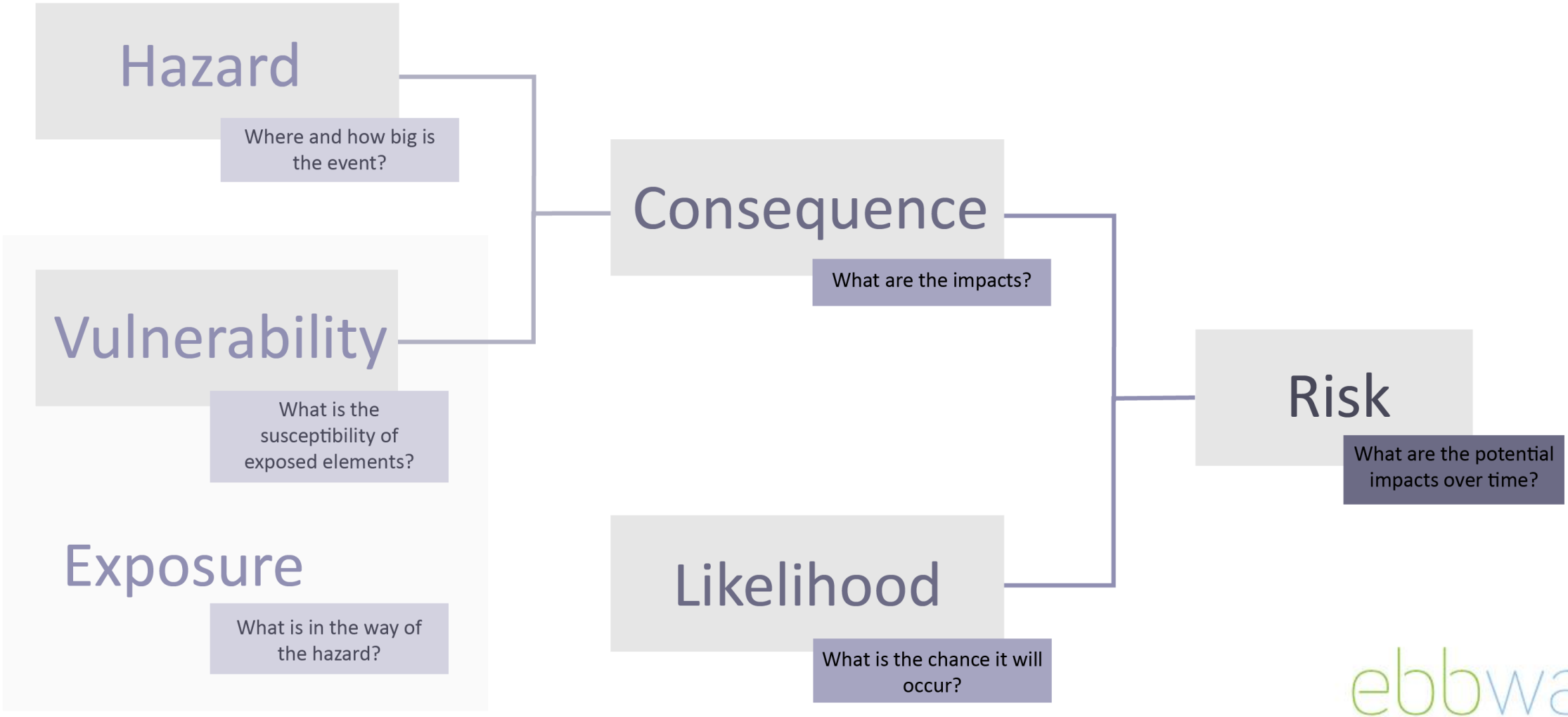
Did you remember?



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We need you to help us understand!

Project Objectives:

1. To better understand Dawson Creek's flood risk – **non-prescriptive and community-led**
2. To complete a **prescriptive** flood risk assessment (Federal and Provincial) that will allow the community to apply for additional flood and disaster mitigation **funds**.

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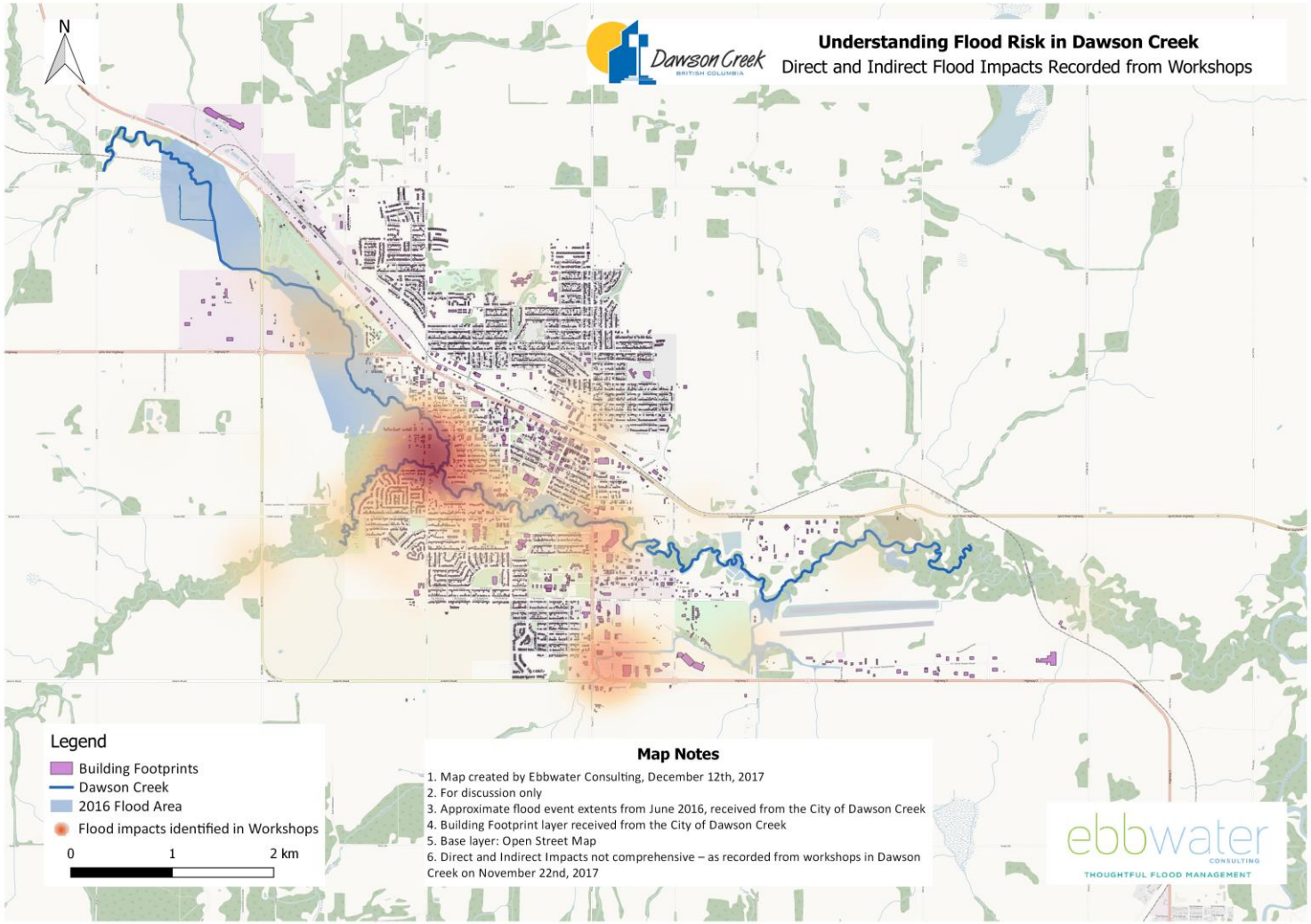
Some of what we heard



Enable Resilience

Reduce the Hazard

Block the water

Reduce Exposure

Stop things/people you care about getting wet

Reduce Sensitivity

Reduce impact of getting wet

- We can't fight nature
- We can't sterilise our floodplains

- We can reduce sensitivity to our built environment
- We can speed up our recovery
- We can safely fail instead of striving for the fail-safe solution

Meerkats Consider

Focus on the decision process not the solution

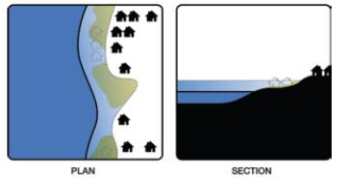
Location: False Creek — **Impacts by Flood Scenario**

	Scale	Dir	PROTECT Sea Barrier	PROTECT Raised Seawall	PROTECT Partial Dike	ADAPT Planning Tools
PEOPLE						
People Displaced - Flood Events	# of people displaced	L				
People Displaced - Permanently	# of people displaced	L				
at risk' people impacted	SVI weighted displacement	L				
Park and Recreational Amenity Value	Value-weighted area affected per event	L				
Loss of critical services	# of pieces of infrastructure impacted	L				
Aesthetics	-2 to 2	H				
ENVIRONMENT						
Risk of Contaminant Release	# of sites w/ potential contaminants	L				
Environmental Benefits	-2 to 2	H				
ECONOMY						
Damage to Infrastructure	Value-weighted km of roads impacted	L				
Damage to buildings	$M	L				
Business disruption	# employees in impacted businesses	L				
Loss of inventory	$M	L				
Emergency response costs	$M	L				
IMPLEMENTATION						
Capital Costs	$M	L				
Maintenance costs	$M	L				
Adaptability	1 to 4	H				
Ease Of Implementation	1 to 5	H				

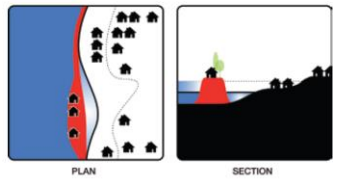
Best performance
Worst Performance

Example Structured Decision Making Consequence Table

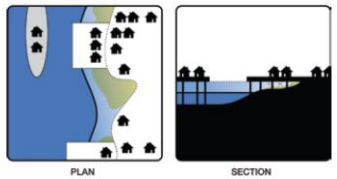
(For City of Vancouver 2015, with Compass Resource Management)



RETREAT?



DEFEND?



ATTACK?

Scenario Building

(Institute of Civil Engineers 2010)

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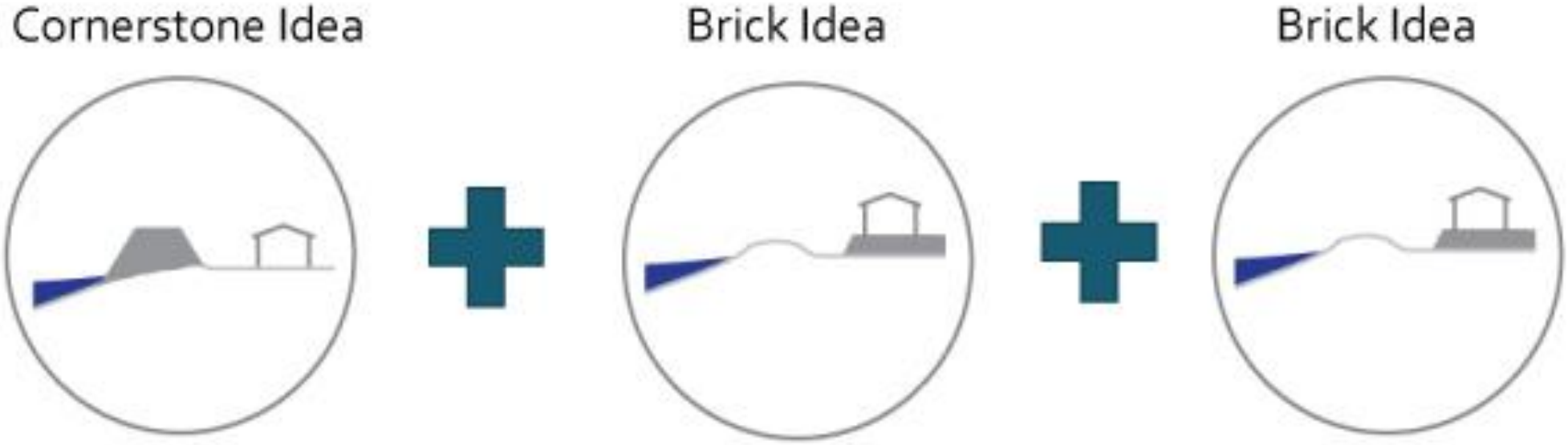
THOUGHTFUL FLOOD MANAGEMENT

Make Good Decisions
Look Beyond Dollars and Cents

PEOPLE	
People Displaced	# of people displaced from flood events
People Displaced	# people displaced permanently
'at risk' people impacted	Social Vulnerability Index (SVI) weighted displacement
Park and Recreational Amenity Value	Value-weighted area affected per event
Loss of critical services	# of pieces of infrastructure impacted
Aesthetics	-2 to 2
ENVIRONMENT	
Risk of Contaminant Release	# of sites with potential contaminants
Environmental Benefits	-2 to +2
ECONOMY	
Damage to Infrastructure	Value-weighted km of roads impacted
Damage to buildings	$M
Business disruption	# of employees working in impacted businesses
Loss of Inventory	$M
Emergency Response costs	Estimated cost per event
IMPLEMENTATION	
Capital Costs	$M
Maintenance costs	$M
Adaptability	1 to 4
Ease Of Implementation	1 to 5

Example measures for City of Vancouver, 2015. Developed with Compass Resource Management.

Have a Back-Up Plan
Complementary Design with Co-Benefits



e.g. A dike

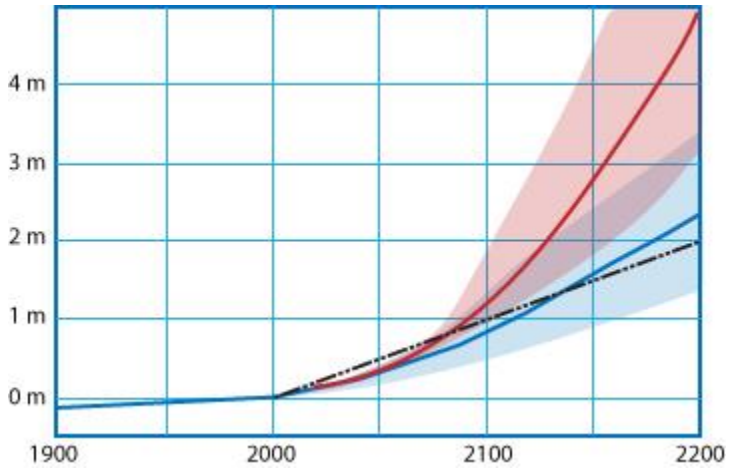
complemented with property-level-protection

improved with habitat enhancement and a bike path

ebbwater CONSULTING
THOUGHTFUL FLOOD MANAGEMENT

Embrace Uncertainty

- Don’t rush in; preserve our options
- Strive for adaptive solutions that will work under many climate and development futures
- Avoid solutions that are single-minded or that remove future options

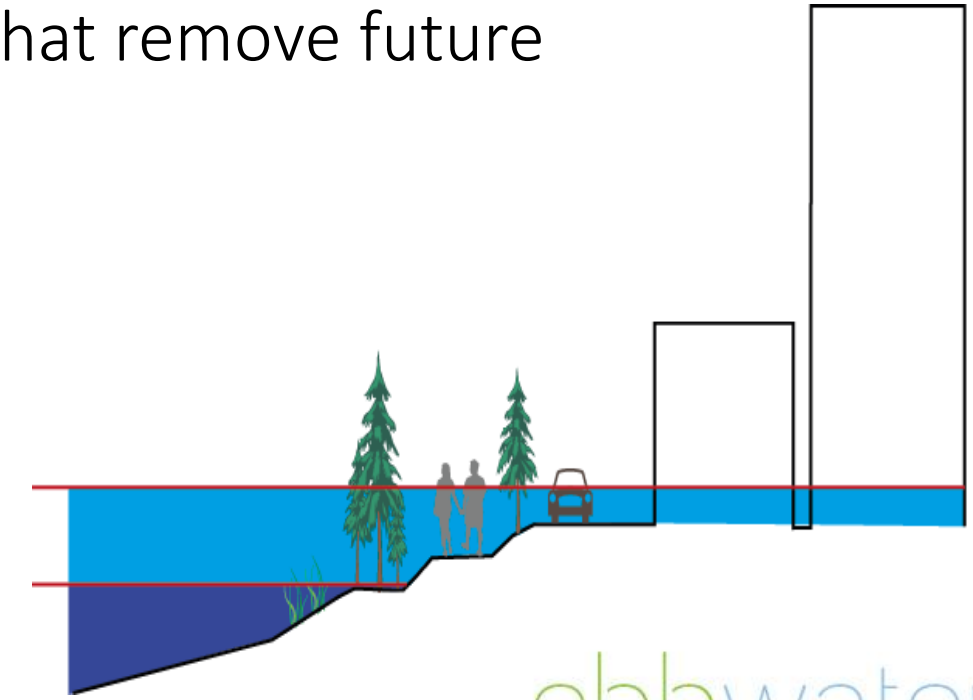


High end of range:

Overinvestment in protection

Low end of range:

Potential catastrophic impacts



ebbwater CONSULTING

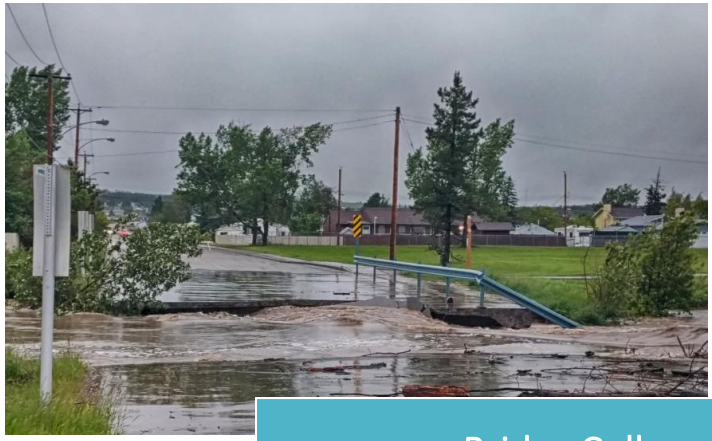
THOUGHTFUL FLOOD MANAGEMENT

Flood Impacts - Direct

Washed out/ flooded roads

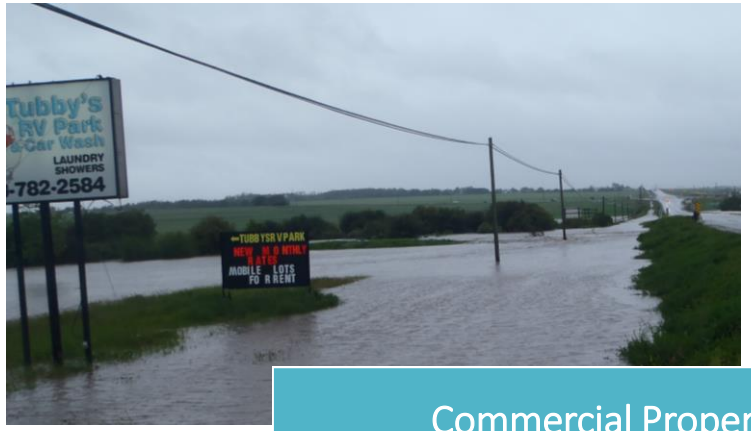
Exposed utilities

Washed out/ flooded roads



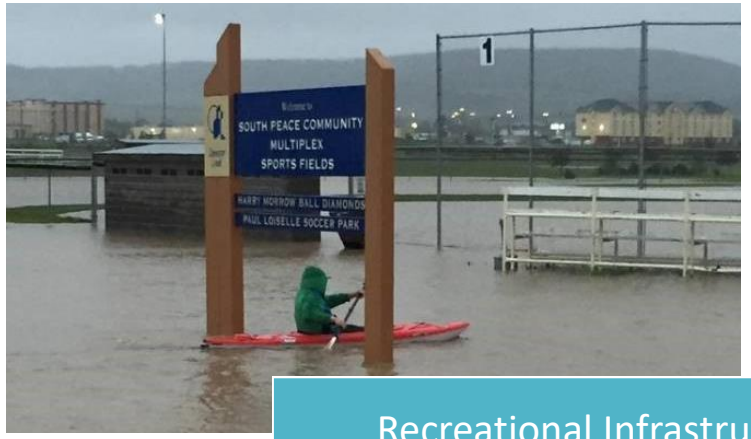
Bridge Collapse

Flood Impacts - Direct



Commercial Property

Residential Property



Recreational Infrastructure

Rail and Highway Access

What happens when the power goes out?

The Tricky(ier) Part

Direct Impacts

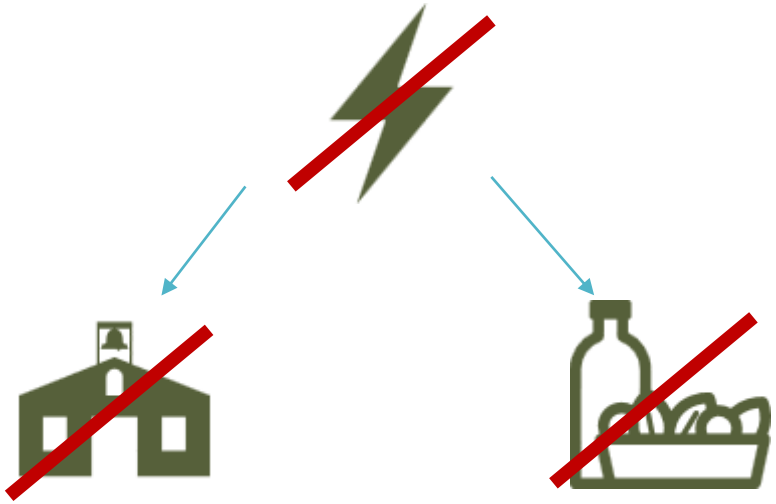
People

Infrastructure

Economy

Environment

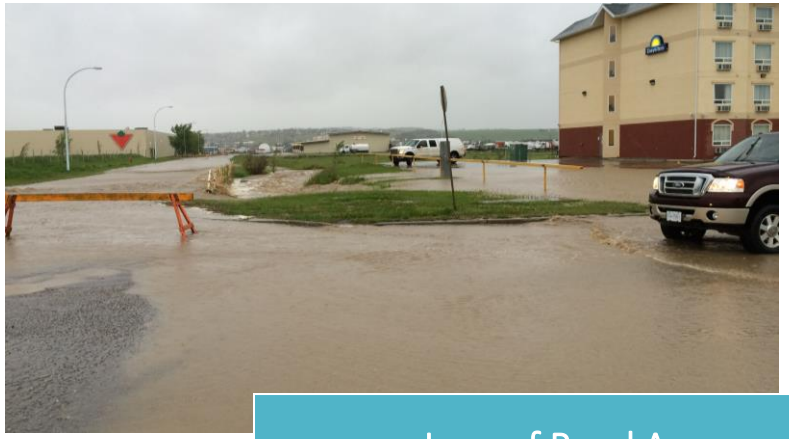
Indirect Impacts
(Cascading Effects)



ebbwater CONSULTING
THOUGHTFUL FLOOD MANAGEMENT

Flood Impacts - Indirect

City Cut In Half

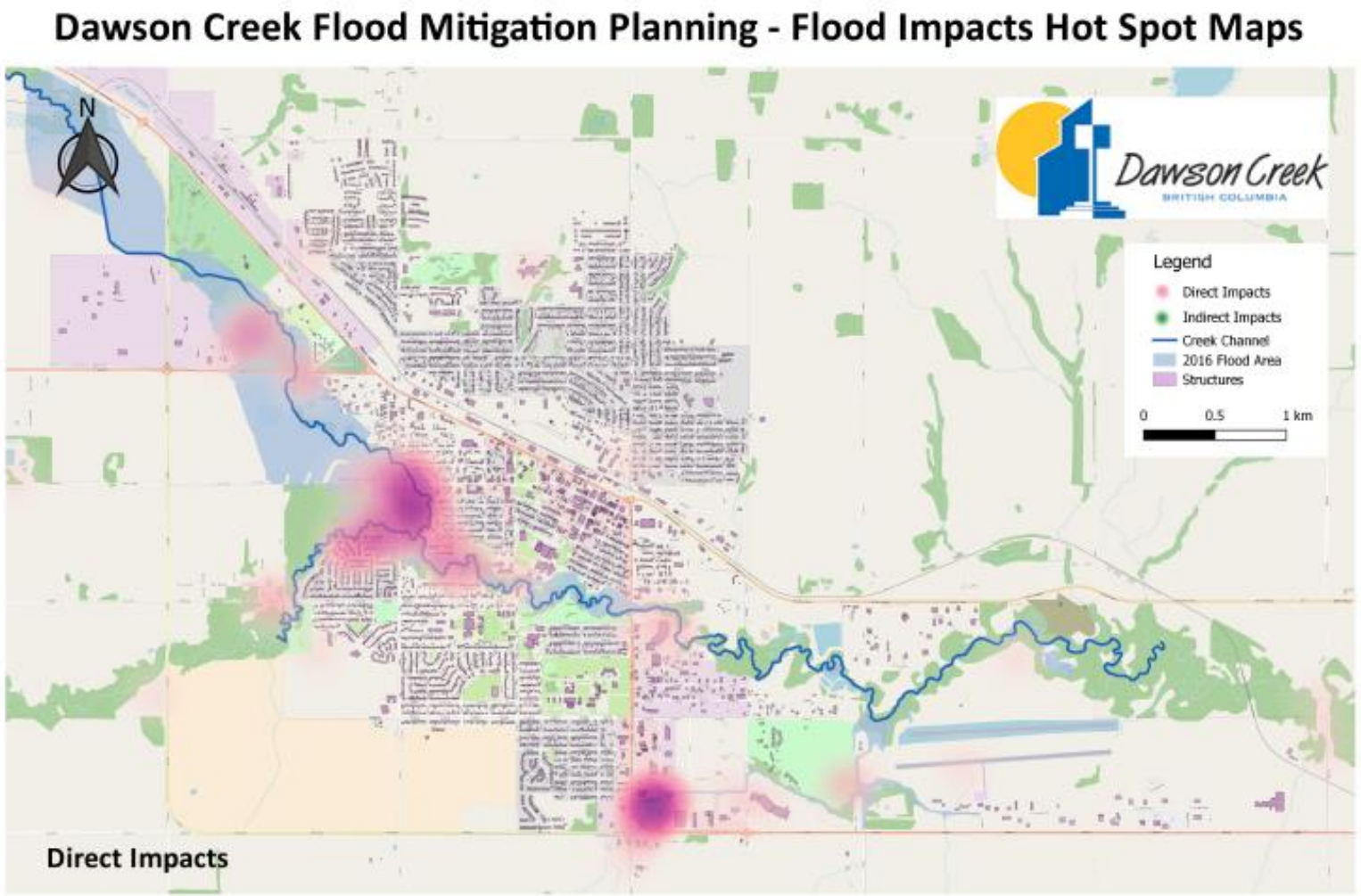


Loss of Road Access

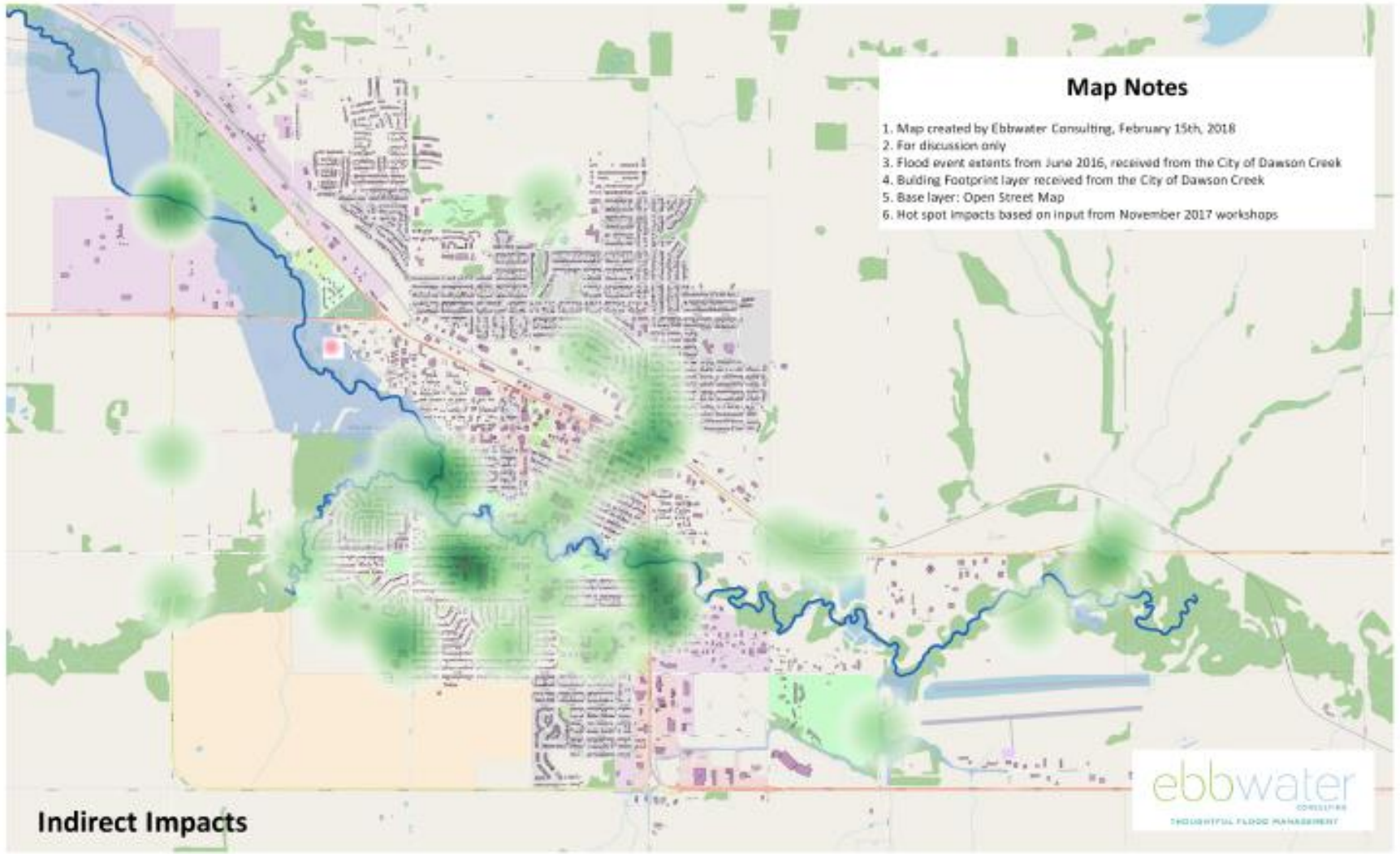
Loss of Recreation

Loss of Utility Service

Direct Impacts

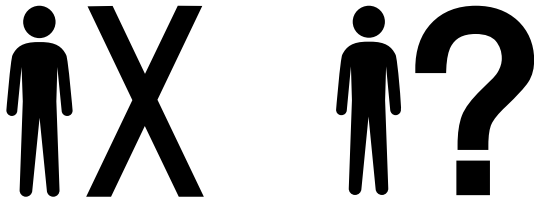


Indirect Impacts

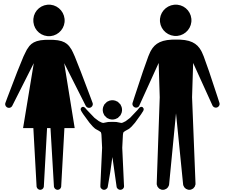


High-level impact categories

National Risk Profile

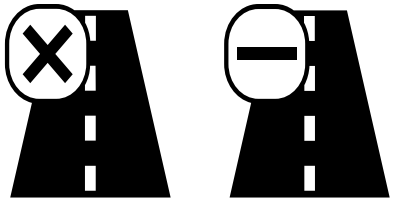


Mortality & Missing



Affected People

Economic



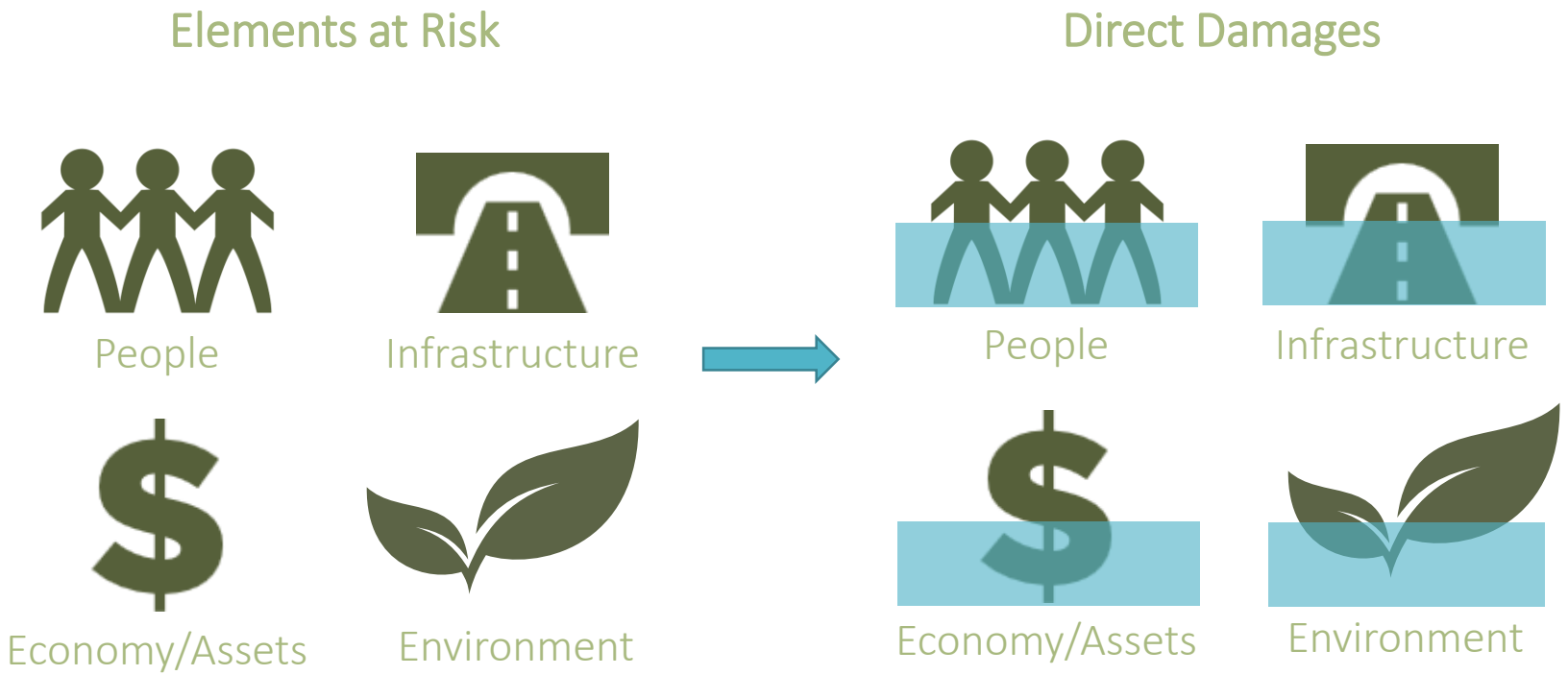
Disruption

Environment

Cultural*

Risk Assessment

A Multi-Disciplinary Task



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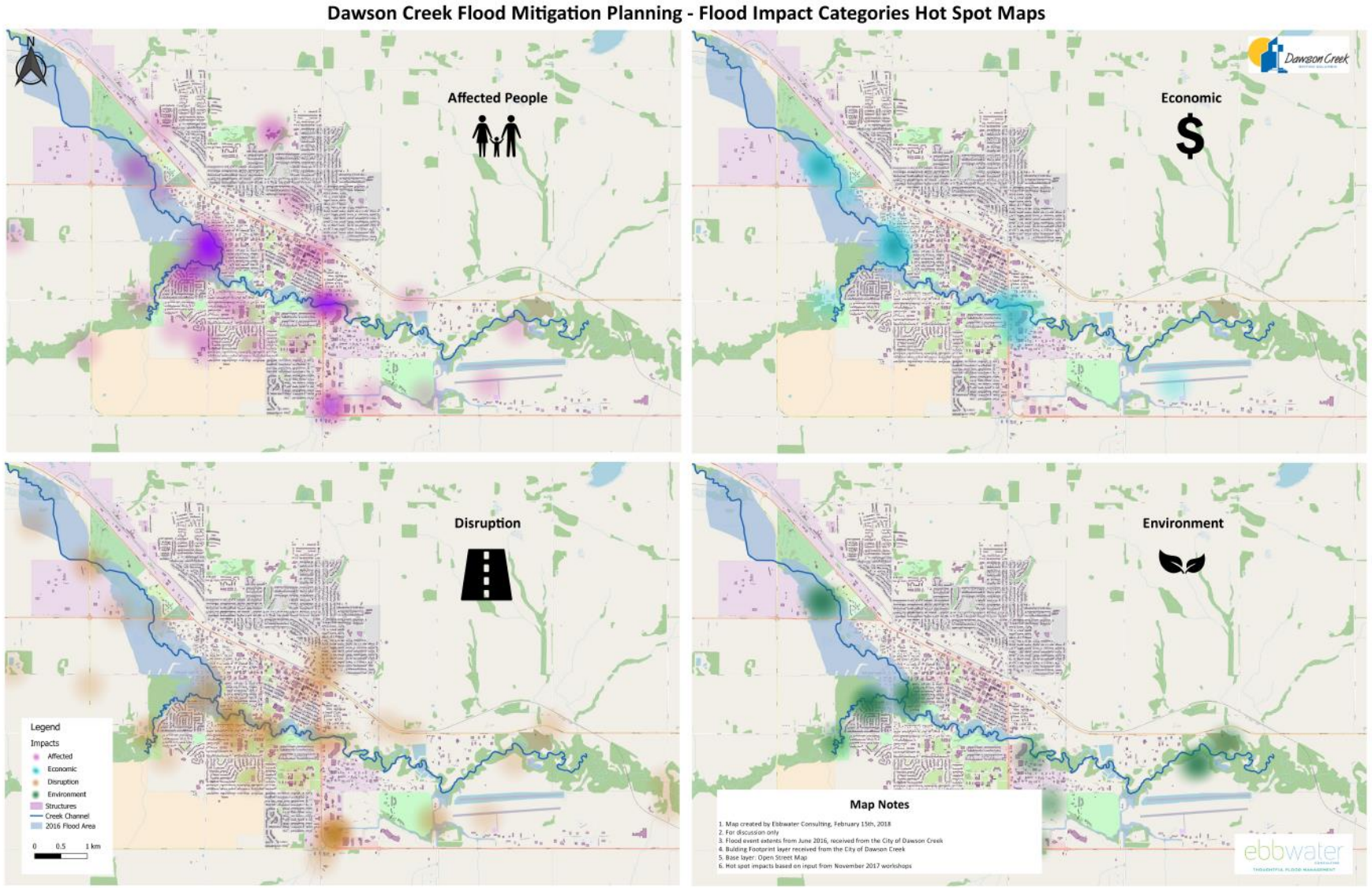
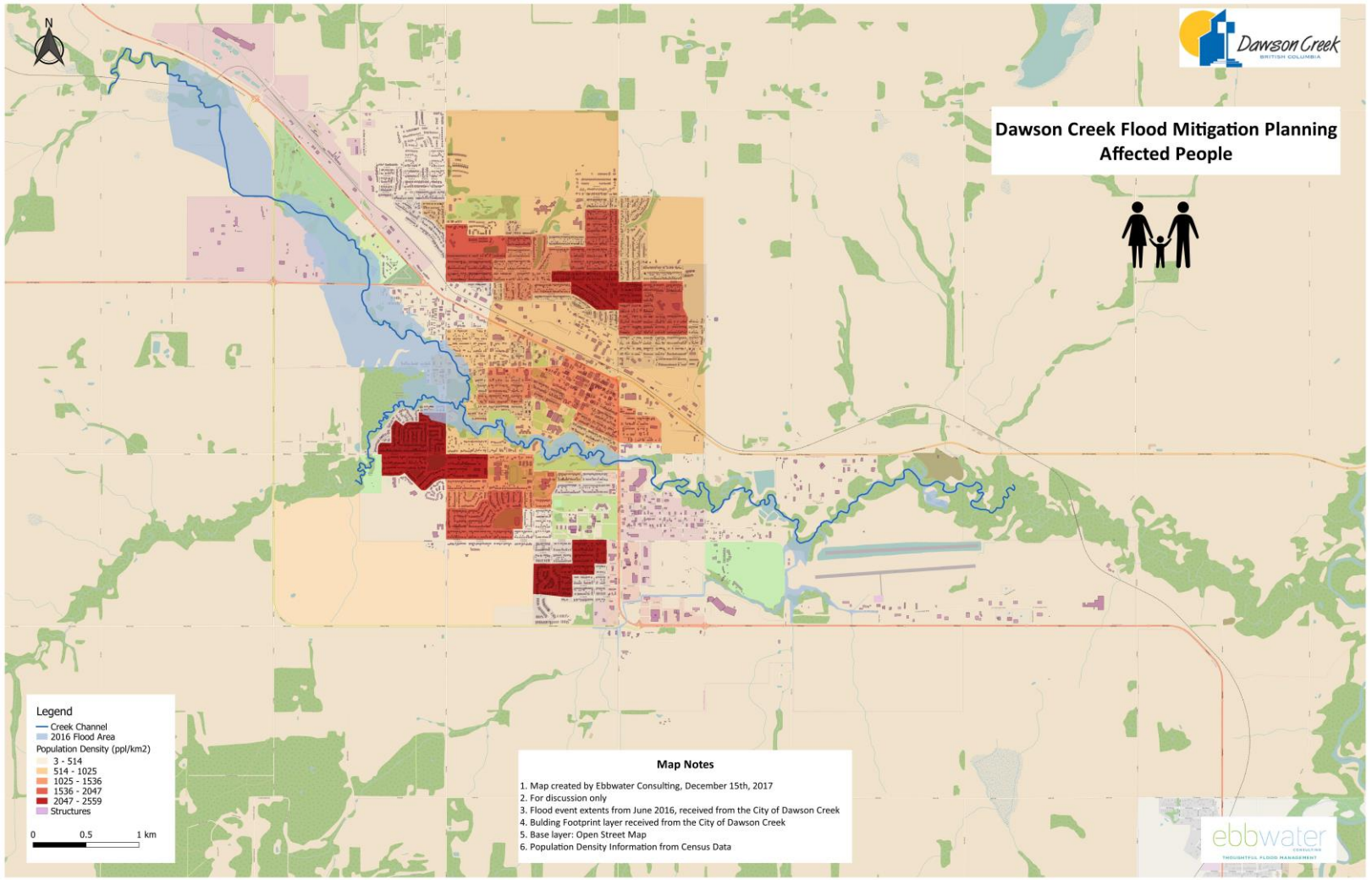
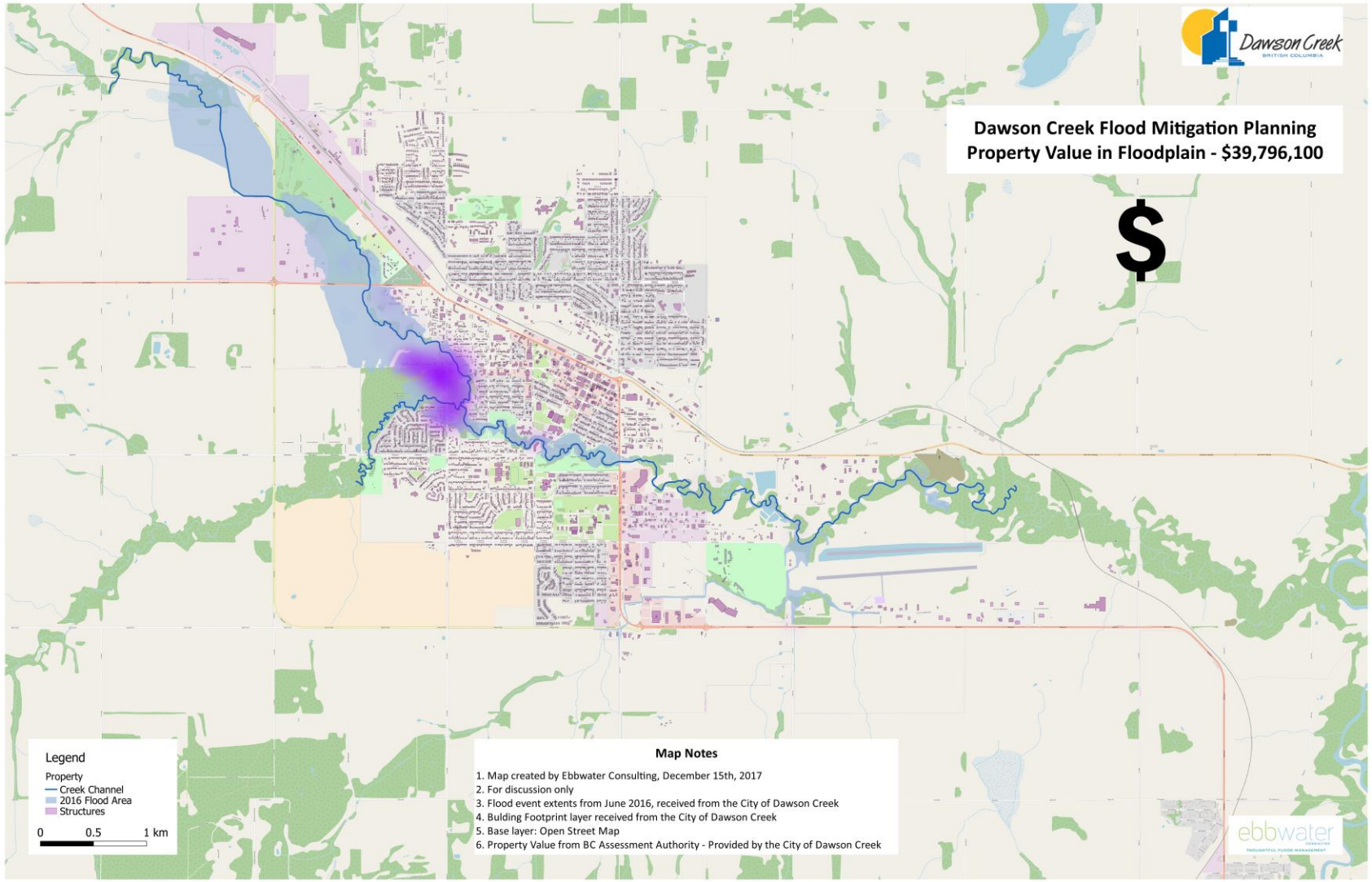
Impact Categories



Affected Population



Economic Exposure

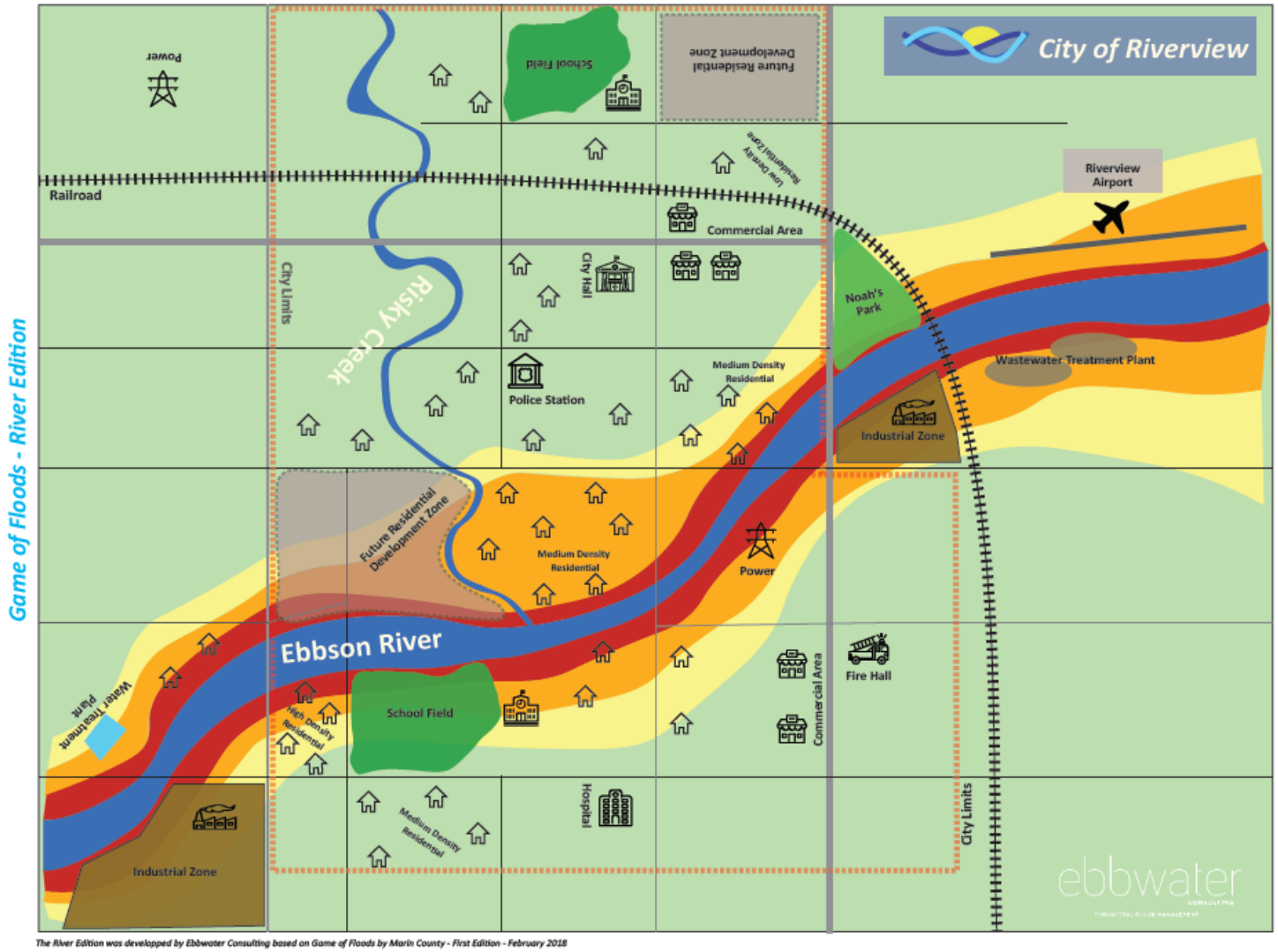


	Minor Flooding (0-10 cm)	Moderate Flooding (20-40 cm)	Severe Flooding (80-100 cm)
[illegible]	Water laps up at doorstep, may enter the house through crawlspace/basement windows, flood garages.	Water in house to 20-40cm depth on main level, crawlspaces/basements likely flooded.	Extensive flooding in house to depths of 80-100cm and extensive flooding in crawlspaces/ basements.
Damage	No significant damage to residential structures, though damage to contents may occur in garages and crawlspaces. Damage likely less than 200 $/m^2	Moderate damage to structures, higher damage to contents in basements and main level, including furnaces and water heaters, major appliances. Damage likely 200 – 300 $/m^2	Considerable damage to structure, extensive damage to content, most major appliances, electronics, furniture on main level and in basements. Damage likely 580 – 610 $/m^2
Disruption	Residents not likely required to leave their homes, but will need to clean up yards and possibly basements. Disruption likely over a week. Limited emergency response.	Residents likely displaced from homes for several days and disrupted for over two weeks. Emergency response likely needed for elderly and people with disabilities, etc.	Residents likely displaced for 1-2 weeks and disrupted for a month. Emergency response needed including possibly addressing utilities interruptions outside flooded area.

Game of Floods

Game of Floods – River Edition

Serious Gaming

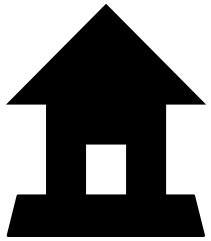


Game Play

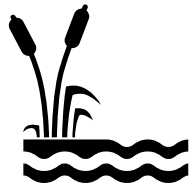
Scoring the Game

Legend	-3	-2	-1	0	+1	+2	+3

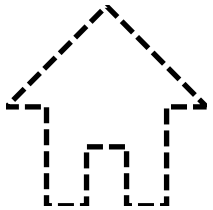
Measure Category/Impact Category	Measure	Cost	Mortality & Missing	Affected People	Economic	Disruption	Environment	Cultural	Quant
Adapt	Raise 5 Buildings/FCL	($)	+1	+1	+2	+1	0	0	
	Raise or move Critical Infrastructure	($)	0	+2	+2	+2	0	0	
	Wet proof 5 buildings (elevated electrical,	($)	0	+2	+2	+1	0	0	



Raise Buildings



Upstream Retention
Restore Wetland Area



Strategic Retreat from floodplain

Some Examples

Raising Critical Infrastructure

Temporary Flood Wall

Thank You!

Appendix D Hazard Modelling Methods and Limitations

1 Introduction

Flood hazard (i.e. and understanding of where, how deep and how fast water is expected to be) is a foundational piece of information for any flood mitigation plan. The City of Dawson Creek has a basic understanding of flood hazards, including a 0.5% AEP flood hazard map from the 1970s, which is used to define extents in local regulations. Further, a 0.5% AEP flood hazard extent and historical 2016 flood event extents were recently defined as a component of consulting engineering work to look at hydraulic design of various Creek crossings. These models and maps were suited to their purpose, however, as described in the main body of this report, flood risk assessment and mitigation planning is best done with hydraulic models and mapped designed for the purpose of flood management. In this case, modelling that shows extents – but also depths and velocities, and further models and maps that highlight the variation in hazard from different flood scenarios and likelihoods.

Given the above, we developed a simple 2-D hydraulic model using existing data and 1-D model information developed by others. This allowed for a more fulsome understanding of multiple flood hazard scenarios. The additional flood hazard scenarios were used in the risk assessment (i.e. risk scores were developed for minor, moderate and severe events), and provide useful information to guide future mitigation and increased resilience to all flood types (as opposed to a focus on just the extreme events).

The extents of the model include areas upstream of the City center, and a downstream location approximately at the Dawson Creek Airport. Model runs included flows for a minor, moderate, and severe flood hazard. Due to a lack of data climate change was not explicitly included, however, this range of flood hazard severities is meant to give an idea at a high level of what Dawson Creek could reasonably expect to address. This Appendix includes an overview of the of high level model (Section 2), details on the development of the model (Section 3), an overview of model results (Section 4), and finally some conclusions and recommendations for future improvements to the flood hazard modelling work (Section 5).

2 Model Overview

In the present study a TELEMAC-2D model was used to determine the flood hazard extents in the area. TELEMAC-2D is a part of open TELEMAC-MASCARET system, a suite of finite element computer program owned by the Laboratoire National d'Hydraulique et Environnement (LNHE) in France. TELEMAC-2D has been used in the study of many large rivers and estuaries in Canada such as the Columbia River, the Red River floods, the St-Lawrence around Cornwall and Montréal, and the Manicouagan estuary, as well as in several rivers in Europe such as Loire, Elbe, Gironde, and Thames. It is a widely employed and well-known

2D model which uses a finite-element scheme based on triangular grid elements. TELEMAC-2D performs two dimensional hydraulic calculations with the help of Saint-Venant equations of momentum and continuity, derived from the Navier-Stokes equations by taking the vertical average. The program computes results for each node of the computational mesh. This modelling software was selected as one of two commonly used open-source 2D hydrodynamic models available (the other being HEC-RAS2D, which is relatively new).

3 Model Development

The present chapter briefly describes the model development process. The model extent at the upstream boundary of Dawson creek is to the north west of the City centre, slightly downstream of Road 223. The downstream extent is approximately at the location of the Dawson Creek Airport. The upstream extent of the model for the South Dawson Creek tributary is downstream of Road 94 and upstream of 108 Avenue. The model extents were selected based on the requirements of the client, and on available data.

3.1 Model Bathymetry

A digital elevation model (DEM), provided by Urban Systems Ltd. (from their 2017 modelling and reporting related to hydraulic structure design), formed the basis of the 2-D hydraulic model. According to Urban Systems Ltd reporting, the DEM was generated in ArcMap (GIS), using the LiDAR and GPS survey information.

The model was developed in BlueKenue, a program from the Canadian Hydraulic Centre, and was later run using theTELEMAC-2D. The DEM's geographical coordinates is EPSG: 26910 - NAD 83 UTM (Universal Transverse Mercator) Zone 10 and its horizontal resolution is 0.5m x 0.5 m.

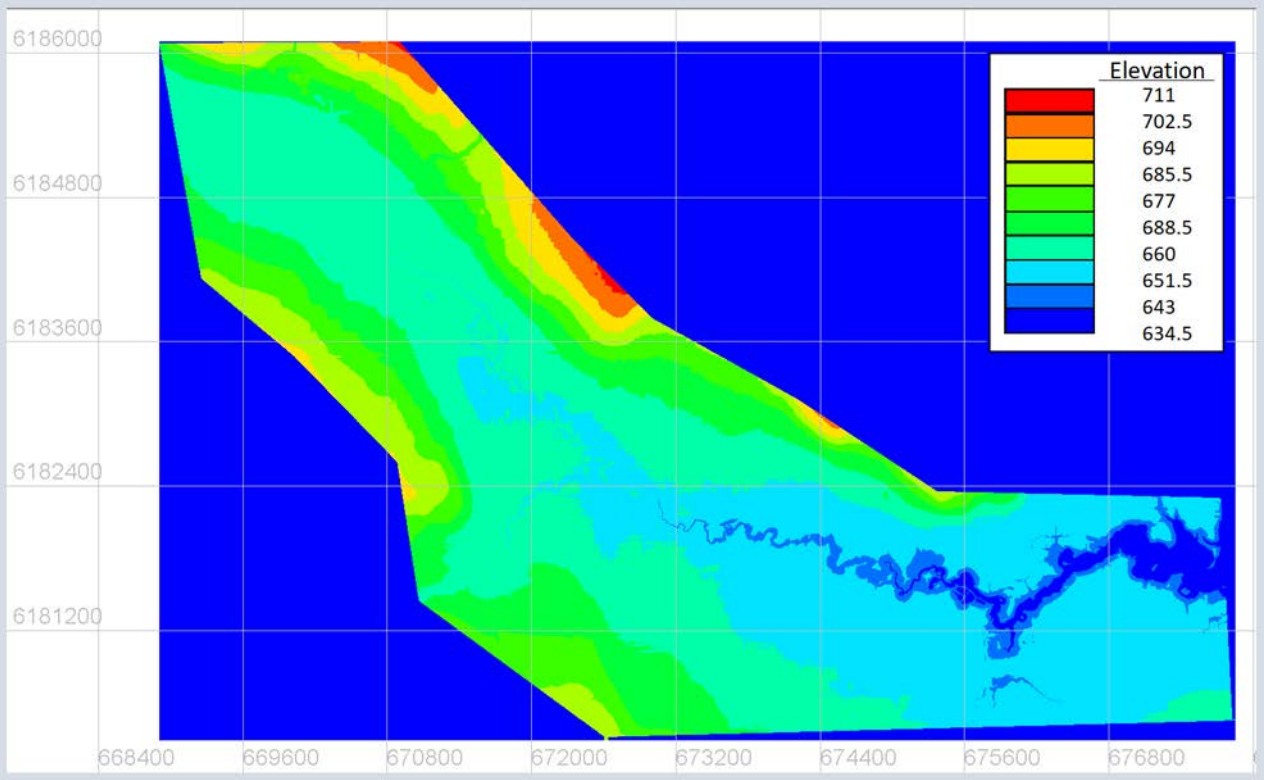


Figure 1: Model bathymetry shown in BlueKenue

3.2 Model Mesh

In 2D models, the mesh is used to represent the river bathymetry and the topography of the surrounding area. TELEMAC 2D allows variable mesh resolution and therefore, areas which need a higher bathymetric accuracy can be well handled. The mesh size is also in important parameter in the model definition, and the choice of its size is a compromise between the model accuracy, the model stability, and the time calculations. A finer grid allows better representation of the system and is able to incorporate details such changes in the bathymetry, whereas a coarser grid will be less accurate but will be more efficient in terms of computational time. In the present study, the mesh was developed using BlueKenue and is shown in Figure 2. The mesh is relatively dense, with an average element length of 12 m. This density was selected based on the geometry of the creek (to manage accuracy) and on the size of the area (to managed computational time), and consideration of the Courant Condition, which relates model times steps to actual water velocities (to manage model stability). Channel Mesher, another program, was also used in the mesh to properly align it against banklines. This aids in model robustness by aligning flow parallel to the features.

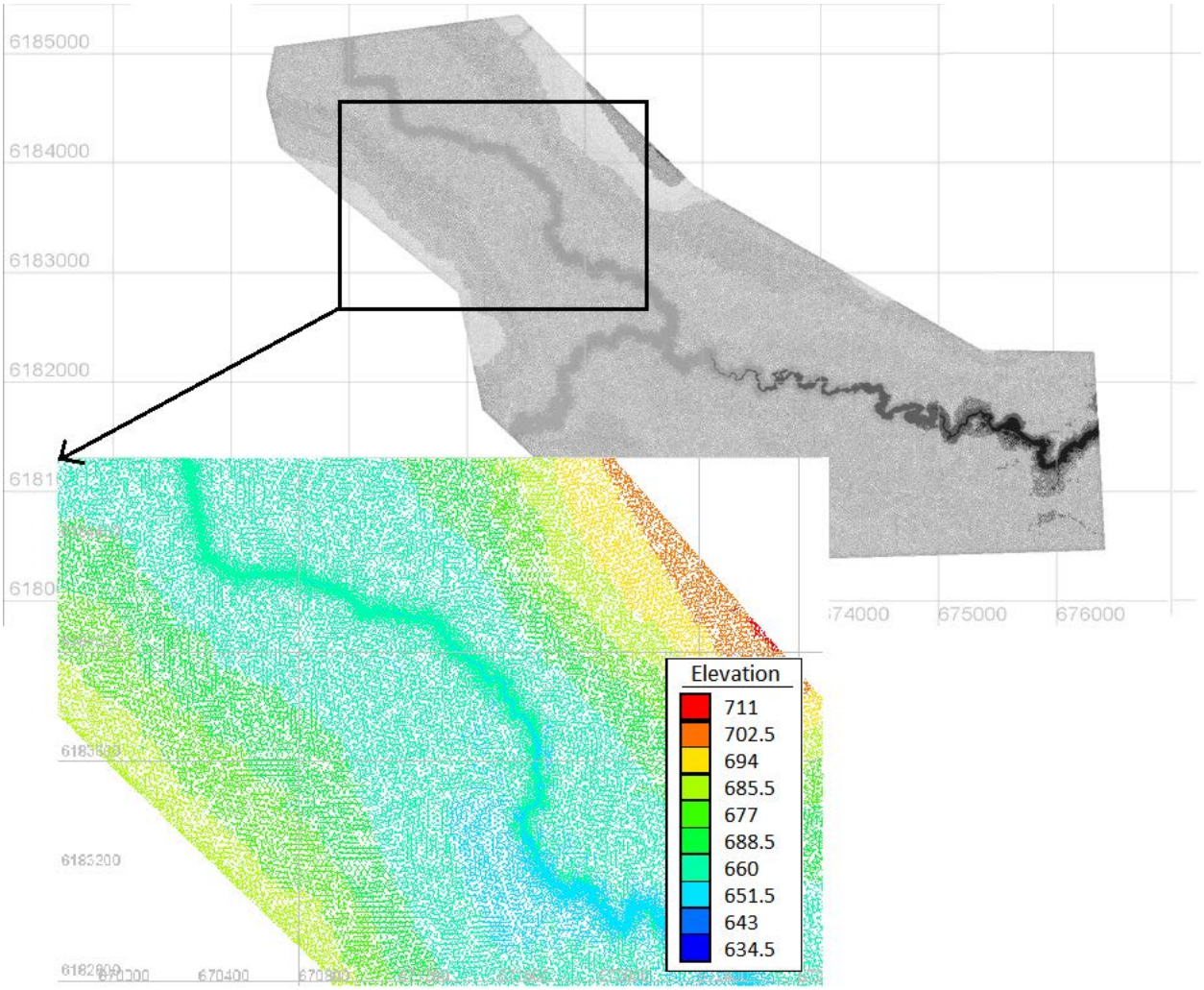


Figure 2: Model mesh for Dawson Creek developed with BlueKenue

Blue Kenue assigns an elevation to each of the 3 nodes of the triangular elements based on the DEM. At these nodes the velocity vector and water depth are computed. Within the creek a triangle size of the order of 4 m was chosen. This finer mesh within the banks of the channel helps to increase the accuracy of results for the creek area. The geographic system in which the model was prepared is UTM (Universal Transverse Mercator) Zone 10.

3.3 Model Verification

Continuous stage-flow information was not available for model calibration, and therefore literature review and engineering judgement were used to establish the major variable in a 2-D model – channel roughness. 2-D models are generally sensitive to geometry, but not very sensitive to channel roughness. However, areas with shallow water outside the channel banks are highly sensitive to this variable.

In this instance for simplicity, roughness was kept constant across the whole domain and was set to Strickler coefficient Ks=22 m^3/s, which is equivalent to a Manning's n value of 0.045 (value which was also used in previous studies in the area), a reasonable estimate for a gravel and cobble channel bed.

To test the friction coefficient a manual sensitivity analysis was completed for the model. The Strickler coefficient was varied by ±50%, and the model was run for Scenario E-1. The results of his analysis showed that the model is quite sensitive to variations in the Strickler coefficient. Most of the differences in the flood hazard extent were observed in the area of the confluence of the main river with its tributary. However, the most significant differences were evident in the change of water surface elevations which in some areas along the flood hazard extents showed a 0.3 m change.

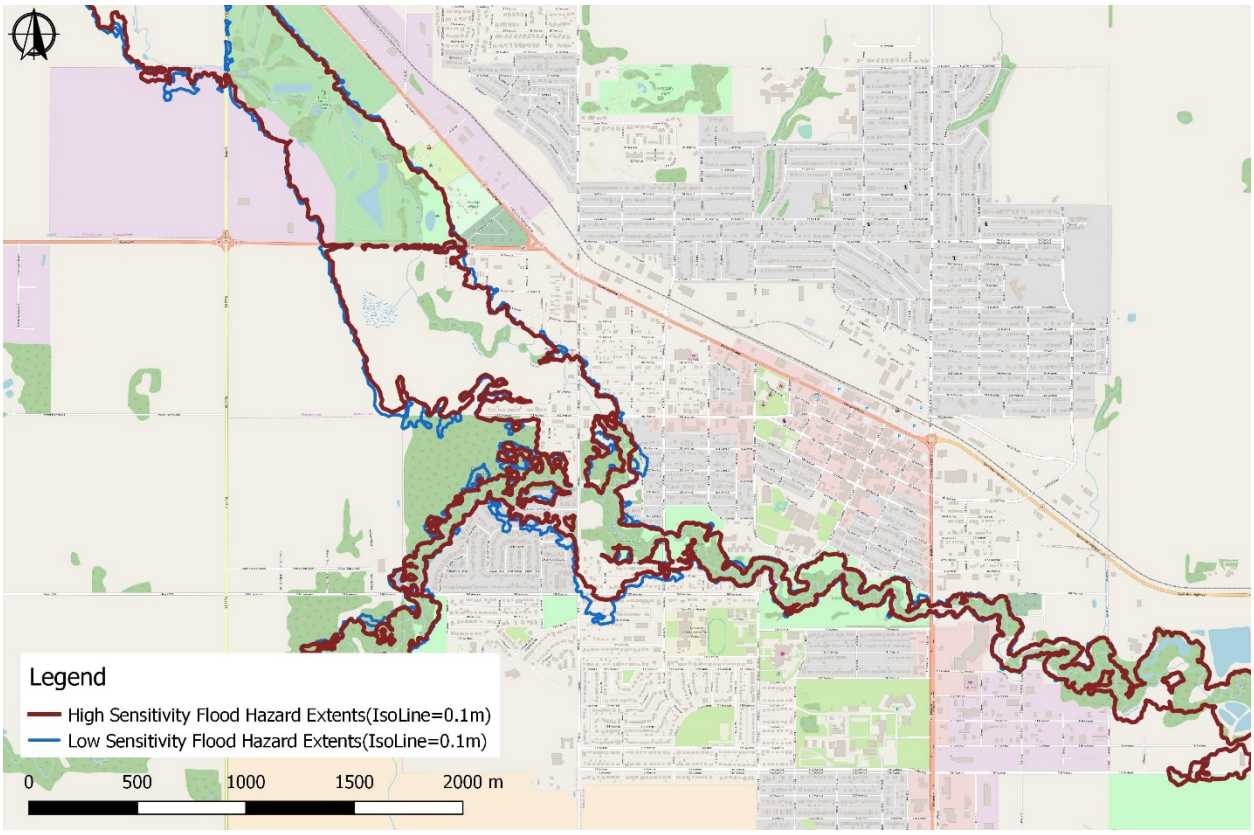


Figure 3: Sensitivity analysis of roughness. Results for Dawson Creek TELEMAC-2D model

For validation, the results of the study were compared to water extents from the June 2016 flood. Although the exact return period for the June 2016 flood is unknown, the comparison showed similar extents between the two events (see Results Section for a description of the modelled versus observed extents for 2016).

3.4 Model Prescribed Boundaries

The model was run with prescribed flow at the upstream boundary and prescribed elevation downstream. The prescribed flow of the main scenario was the 0.5% AEP flow, which was estimated to be 106 m^3/s for Dawson Creek and 84 m^3/s for the South Dawson Creek tributary (see main body of report for hydrologic analysis and results). We also simulated an extreme event with peak flows equal to 168 m^3/s for South Dawson Creek and 212 m^3/s for Dawson Creek upstream of South Dawson Creek (R-2) in order to see the differences in the flood extents. The prescribed starting elevation for the downstream boundary for all model runs was equal to 648 m, which was estimated based on the channel geometry, slope and normal flow. Please note that the downstream boundary was set far downstream of the area of interest to allow the model to allow the model to adjust in the modelled reach. The model was run with constant boundary conditions until a steady state was reached for scenarios R-1 to R-3. For the unsteady simulation, R-4 a simple triangular hydrograph was used, with a peak flow equal to the 0.5% AEP.

3.5 Model Limitations

The present model was developed by Ebbwater Consulting to provide a high-level understanding of the range of flood hazards to be considered for Dawson Creek. This model was developed for preliminary discussion; therefore, use of this model at finer scales such as for detailed planning or engineering design is not recommended. Channel bathymetry within this model was obtained by the DEM and the focus of this model was low-frequency flood events. Some of the limitations of this study include:

- **Topographic information**: The DEM was obtained by LiDAR and GPS survey information and was generated in GIS. However, data on the processing and vertical resolution of the DEM was not provided and likely an alternative process for removing buildings is needed.
- **Bathymetric information**: Survey was limited in just a few cross sections along the river- not enough bathymetric data was available to properly represent the channel. Channel geometry is important for hydraulic modelling for flood, as a large percentage of flow is generally conveyed in the channel.
- **Hydrometric and hydrologic information**: There is currently no active gauge on the Creek in the vicinity of Dawson Creek. Historic flow data is very limited and of poor quality.
- **Calibration/Validation data**: No surveyed data from flood events (flood extents, elevations and associated flows) were available for calibration. Some limited information is available for 2016; but no flows or elevations were available. Dawson Creek staff collected more detailed information during the April 2018 event, which could be used for future model calibration and validation.
- **Hydraulic crossings**: Updated bridge information (deck chord elevations and any pier and erosion protection that encroaches into the channel) is required for more detailed modelling.

- No **blockage from debris** was assumed in any downstream bridge/culverts. This should be considered in future modelling

4 Model Results

4.1 List of Runs and Boundary Conditions

Using the available hydrology and topography data the new hazard extents were calculated as part of this project. In the model we didn't consider crossings or other restrictions of the flow. The model scenarios are demonstrated in Table 1.

Table 1: Model scenarios for extreme events

Run Number	Upstream Boundary	Comments
R-1 (Moderate Event)	0.5% AEP - Steady State	Peak Flow as calculated in previous studies
R-2 (Severe Event)	0.1% AEP - Steady State	Extreme peak flow (see the differences in the extents)
R-3 (Minor Event)	10% AEP) 2016 Flood Event Flow (Steady State)	Also used for model verification.
R-4 (Moderate Event-Unsteady Simulation)	0.5% AEP) -Hydrograph	Usage of Peak Hydrograph for better simulation of the real flood events

4.2 Results

Runs R-1 and R-2 of the model represent the 0.5% AEP and a hypothetical extreme event. With the unsteady flow simulation (R-4), we modelled the behaviour of the Dawson Creek river during the flood. For that, the model was run for a period of 1 day to show the water depth variation over time. The overflow phenomenon was accentuated in the upstream direction of the river, and the results show several floodplain zones. Finally, we modelled the 2016 flow event, as calculated in Dawson Creek Channel Assessment Post-June 2016 Flood. Note that any differences between the simulated and real flood events can be attributed to the debris which caused extensive flood in 2016 and to the cross-sectional area of crossing openings (culverts and bridges) that restrict the flow in the river.

The R-1, R- 2 and R-3 model scenarios were selected for the purposes of showing the variation in flood hazard for different flow events; this was used to better understand the total risk (see main report for

information on the use of multiple hazard scenarios to represent risk). The differences among the water depths for each selected location are shown in Figure 4 and Figure 5.

The modelling shows that with increasing flows (to represent minor through severe floods), the flood extents, within the downtown core do not increase significantly; this is because the creek is remains within the relatively deep and confined channel. Outside of the downstream core, most notably near the confluence of Dawson Creek and South Dawson Creek, where the topography is more gentle, the flood hazard extents expand significantly with the increasing flows. Further, the depths of water – are also much greater for higher flows. This highlights this area (i.e. the confluence of the creeks) as being an area of high flood hazard that should be considered as a priority going forward. This is also highlighted as an area of high risk in the main body of this report.

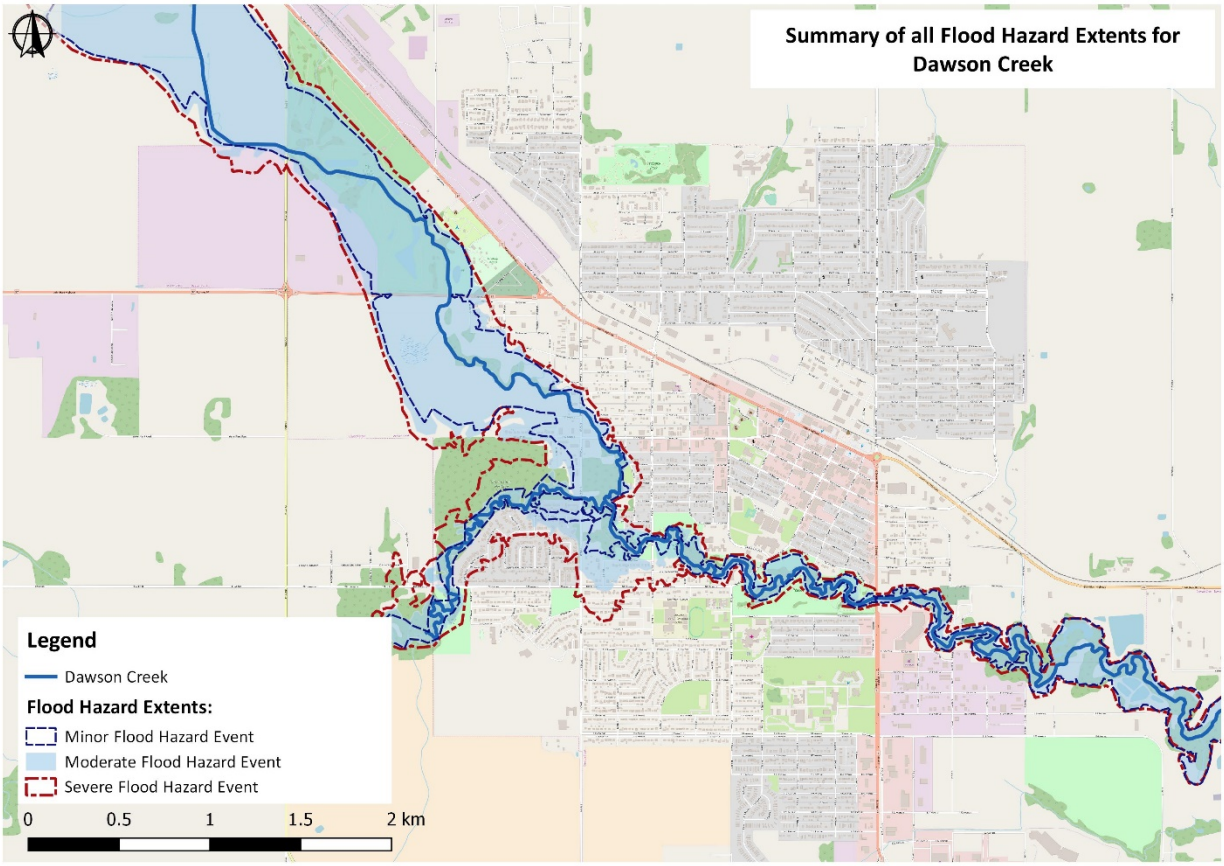


Figure 4: Modelled flood hazard extents for minor, moderate and severe flooding

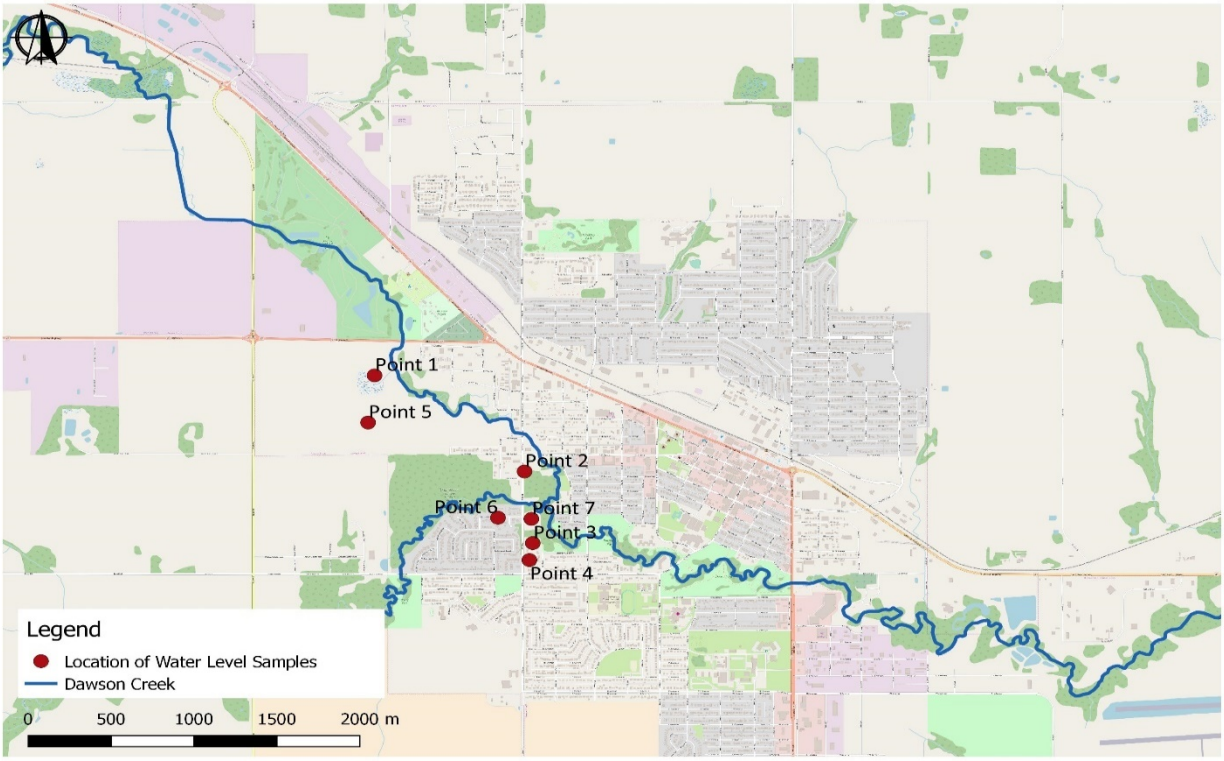


Figure 5: Location of the points used for water level reporting

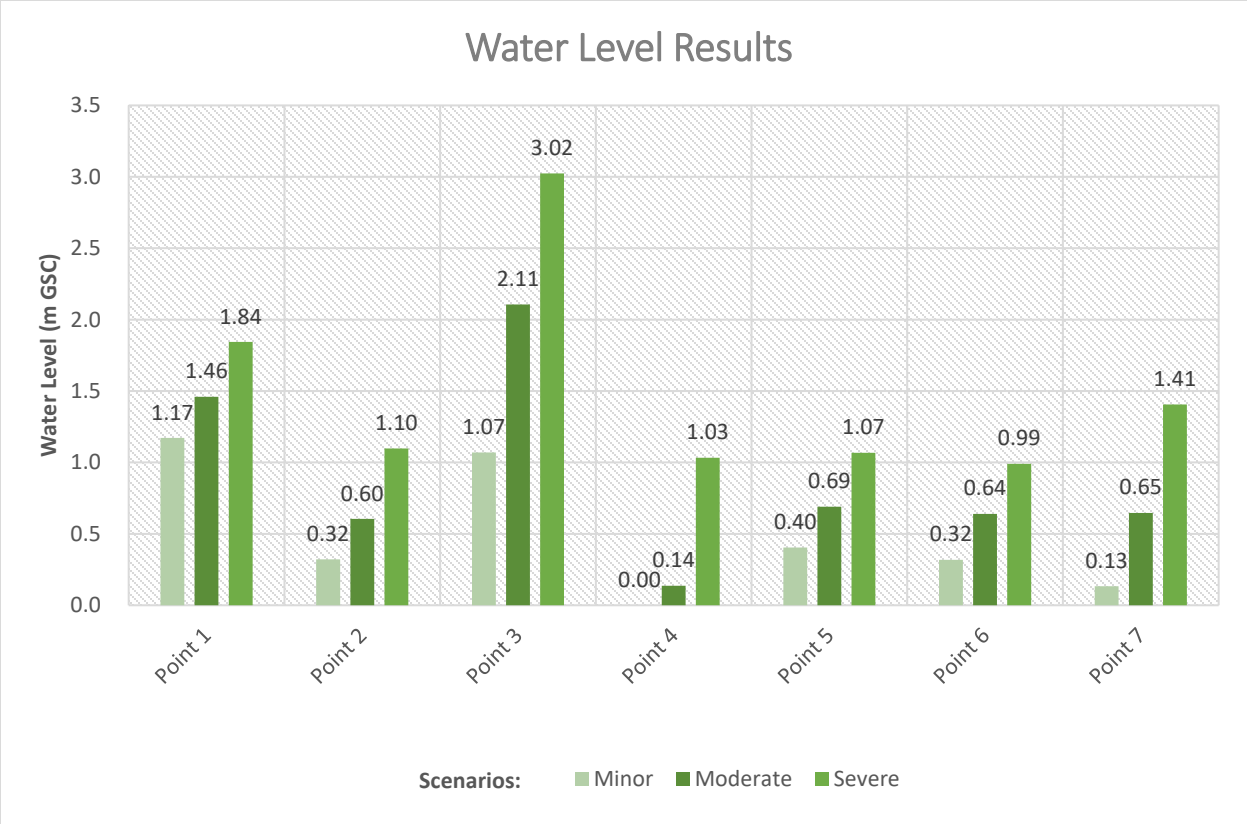


Figure 6: The variations of the water levels for the different scenarios

5 Conclusion and Future Improvements

Ebbwater Consulting has completed a scoping model of the Dawson Creek to support the collection of exposure and vulnerability at stakeholder workshops as part of work to support the understanding of flood risk for the City of Dawson Creek. Further, the model shows how varying flood flows affects the hazard – and therefore the risk in the community.

The model reasonably predicts high-level flood extents and flows for different flood hazard severity levels for minor, moderate, and severe flood hazard. However, it should not be used for any engineering or regulatory applications. Although this model provides a good foundation and general understanding of the flood extents along the Dawson Creek, further improvements are recommended to increase its accuracy. Suggested future improvements include the following:

- LiDAR data of higher resolution which will cover the whole area.
- New DEM to be corrected to account for buildings.
- Refining the geometric data, bathymetric survey of the river, and updated bridge geometry, in the new study area extents.

- Erosion and flow with debris.
- Detailed hydrologic study, supported by installation of hydrometric gauges on the Creek.
- Detailed model calibration and validation (using hydrometric information).

These improvements in data sets and additional data could be used to produce a more detailed model for future use by the City of Dawson Creek. Additional details, including a scope of work and estimated budget to complete this work is provided as Appendix F.

Appendix E Data Summary

The following provides a list of data used to support the reporting.

Legend

Modelling Data
Topographic Data
Exposure Data

	DATA CATEGORY	DATA DESCRIPTION	DATA TYPE	SOURCE	COMMENTS
MODELLING DATA	Watersheds		pdf	Received from Dawson Creek, 2017-08-24	
	Dawson Creek Limited Watershed Assessment - Hemmera Envirochem In.c	Report	pdf	Received from Dawson Creek, 2017-08-24	Date Published: 2006
	Climate Change Impacts and Adaptation - Adaptation Planning Approaches and State of the Climate Science, Dawson Creek - Tom-Pierre Frappe-Seneclauze, Ellen Pond The Pembina Institute	Report	pdf	Received from Dawson Creek, 2017-08-24	Date Published: 2012

	DATA CATEGORY	DATA DESCRIPTION	DATA TYPE	SOURCE	COMMENTS
	Northeastern British Columbia, Climate Risk Assessment for the Oil & Gas Sector - David Marshall, Jim Vanderwal & Vanadis Oviedo – Fraser Basin Council; Jennifer Pouliotte – BC Ministry of Environment, Climate Action Secretariat; Dr. Ian Picketts & Lonnie Wake – Quest University Canada	Report	pdf	Received from Dawson Creek, 2017-08-24	Date Published: 2015
	North East Water Tool	Tool	html		
	Flooding.xlsx		csv	Received from The City of Dawson Creek, 2017-08-24	Date: 2017
	Dawson Creek - 200-year flood routing results - Urban Systems	Report	pdf	Received from Dawson Creek, 2017-08-24 & Urban Systems, 2017-09-22	Date Published: 2017-05-01
	200-yr Design Flow for Dawson Creek and South Dawson Creek - Urban Systems	Report	pdf	Received from Dawson Creek, 2017-08-24	Date Published: 2016-12-01
	Dawson Creek Channel Assessment Post-June 2016 Flood - Urban Systems	Report	pdf	Received from Dawson Creek, 2017-08-24	Date Published: 2016-12-01

DATA CATEGORY	DATA DESCRIPTION	DATA TYPE	SOURCE	COMMENTS
Flood	1974 Floodplain	shp	Received from Dawson Creek, 2017-09-08	The Accossiated (AEP is not mentioned)
Flood	2016 Flood Area	shp	Received from Dawson Creek, 2017-09-08	
Flood	Stormsheds	shp	Received from Dawson Creek, 2017-09-08	
Flood	HEC-Ras Model	Model files, HEC-Ras	Received from Urban Systems, 2017-09-22	Includes technical Memo on Model
Flood	Cross-sections, Survey Data from Tryon Group	Survey Data (csv)	Received from Urban Systems, 2017-09-22	Date: 2016-11-15
Flows	Daily Peak flows for Dawson Creek, for different AEPs	Table	Received from Dawson Creek, 2017-08-24	From the 200-yr Design Flow for Dawson Creek and South Dawson Creek.

	DATA CATEGORY	DATA DESCRIPTION	DATA TYPE	SOURCE	COMMENTS
TOPOGRAPHY	Elevation Data	Terrain, processed by US (from LiDAR) to GeoTiff (LiDAR_Terrain.Terrain.srf_50cm_grd.tif)	Raster (tif)	Received from Urban Systems, 2017-09-22	GeoTiff of terrain data, processed by Urban Systems from LiDAR ground data.
	Elevation Data	LiDAR	LiDAR (xyz, las)	Received from Dawson Creek, 2017-08-30	
	Elevation Data	Contours (1 m), 2016	shp	Received from Dawson Creek, 2017-09-08	Data not Complete
	Elevation Data	Contours 2013	shp	Received from Dawson Creek, 2017-09-08	Date: 2013
EXPOSURE DATA	Planning	Official Community Plan (Report)	pdf	Received from Dawson Creek, 2017-08-24	Date Published: 2010
	Planning	Zoning Bylaw (Report)	pdf	Received from Dawson Creek,	Date Published: 2011

DATA CATEGORY	DATA DESCRIPTION	DATA TYPE	SOURCE	COMMENTS
			2017-08-24	
Planning	Sanitary Sewer Master Plan (Report)	pdf	Received from Dawson Creek, 2017-08-24	Date Published: 2013
Planning	Drainage Master Plan (Report)	pdf	Received from Dawson Creek, 2017-08-24	Date Published: 2017
Planning	Drainage Master Plan - Appendix A Manhole Field Survey Report (Report)	pdf	Received from Dawson Creek, 2017-08-24	Date Published: 2017
Buildings	Building Footprints	shp	Downloaded from OSM HOT	Date Downloaded: 2017-08-24
Buildings	Property Damage from the 2011 Flooding	pdf map	Received from Dawson Creek, 2017-08-24	
Buildings	Flooding complaints from 2011 flooding	excel database, with addresses	Received from Dawson Creek, 2017-08-24	
Orthophotos	2016 Orthophotos (10cm)	.jgw; jpg; .pmi	Received from Dawson Creek, 2017-09-08	
Flood	June 2011 Flooded Properties	shp	Received from	

	DATA CATEGORY	DATA DESCRIPTION	DATA TYPE	SOURCE	COMMENTS
				Dawson Creek, 2017-09-08	
	Land Use	Land Use	shp & excel with code description	Received from Dawson Creek, 2017-09-08	
	Buildings	Structures - Building Footprints	shp	Received from Dawson Creek, 2017-09-08	
	Property Values	Property Values	csv	Received from Dawson Creek, 2018-02-15	
	Census Data	Census Dissemination Blocks	shp	Downloaded from Census mapper, 2017-09-26	Date: 2011
	Roads	Roads	shp	Downloaded from Digital Road Atlas, 2018-04-30	
	Photos	Drone Photos	jpg	Received from Dawson Creek, 2018-04-27	Date: 2018-04-26
	Photos	Flood Photos	jpg	Received from Dawson Creek,	Date: 2018-04-26

	DATA CATEGORY	DATA DESCRIPTION	DATA TYPE	SOURCE	COMMENTS
				2018-04-27	
	Photos	2016 Floods	jpg	Received from Dawson Creek, 2018-02-22	Date: 2016

Appendix F - Flood Mapping Scope of Work

The following provides a proposed scope of work to develop an up-to-date flood hazard map series, that meets best practice as defined by Federal and Engineers and Geoscientists of BC guidelines. for the City of Dawson Creek. The intention of the information below is to support an application to the BC NDMP or CEPF programs. Budgeting is based on best available information at the time of writing (May 2018) and is subject to change.

1 Modelling/Mapping Purpose

The City of Dawson Creek wish to develop new up-to-date flood hazard modelling and mapping for the Dawson Creek. The City has a map from 1974 that supports local regulations and has more recently retained consultant engineers to develop hydraulic models of the Creek. However, the available models were developed for different purposes (e.g. hydraulic design of crossings) and do not meet best practice as defined by Federal Technical Working Group on Flood Mapping and Engineers and Geoscientists of BC guidelines. This area was also identified as being moderate to high risk in a recently completed flood risk assessment and should be a considered a priority mapping project.

The objective of the modelling and mapping project would be to develop a series of flood hazard maps based on relevant and up-to-date understanding of the river and flood plain geometry, as well as an updated understanding of river hydrology (with consideration of climate change). It is expected that a 2D model will be developed to support an understanding of local depths and velocities, and any overland flow paths. Further, information gathered in 2017-2018, along with previous reporting, suggests that there are important hydraulic linkages between the natural system and the City drainage system, and therefore the modelling will also include sewers and urban drainage. A further objective of the project is to improve understanding of the erosion hazard through the development of flood erosion maps. Updated modelling and mapping will support the community to develop flood mitigation plans and support the design of any future flood infrastructure.

1.1 Geographic Scope

The model will consider riverine flood hazard in the community and cover the extents shown in Figure 1. These extents were determined based on the modelling exercise that has been carried out and the area of interest as defined by the client.

Three reaches are included in this estimate:

1. Dawson Creek – main channel
2. South Dawson Creek - tributary

3. Ski Hill Creek - tributary (Bear Mountain drainage)

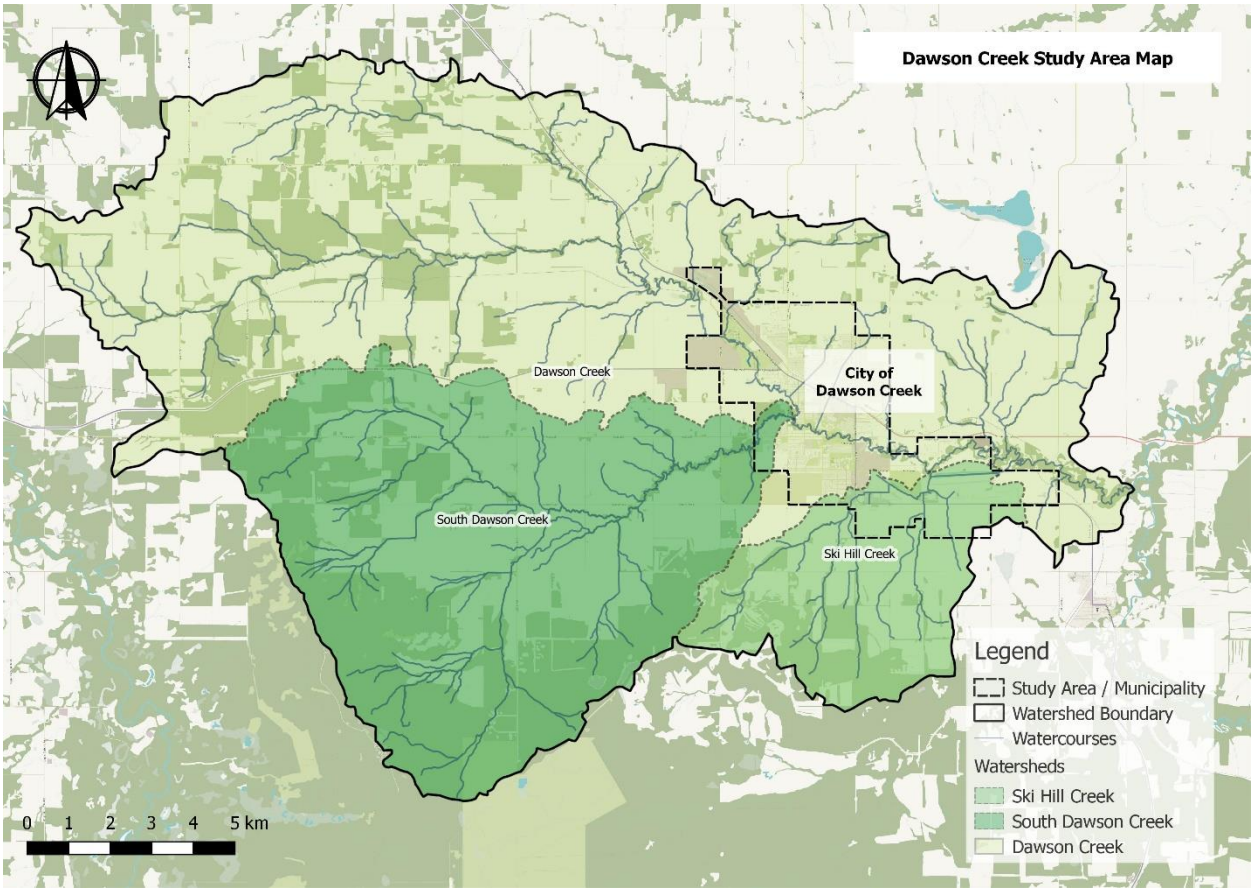


Figure 1: Dawson Creek Watershed, tributary and municipal boundary

1.2 Data Collection

The following outlines requirements for data collection required to meet the project objectives. Approximate budgets for each item are also presented.

1.2.1 Bathymetric Data Collection ($25k)

Hydraulic modelling and mapping is extremely sensitive to the data used to develop the river and floodplain geometry. Due to the limited number of cross sections surveyed for the previous models, more data should be collected. Bathymetric surveys of the river for an approximately 20 km reach (along with tributaries) within the new model area noted in Figure 2.

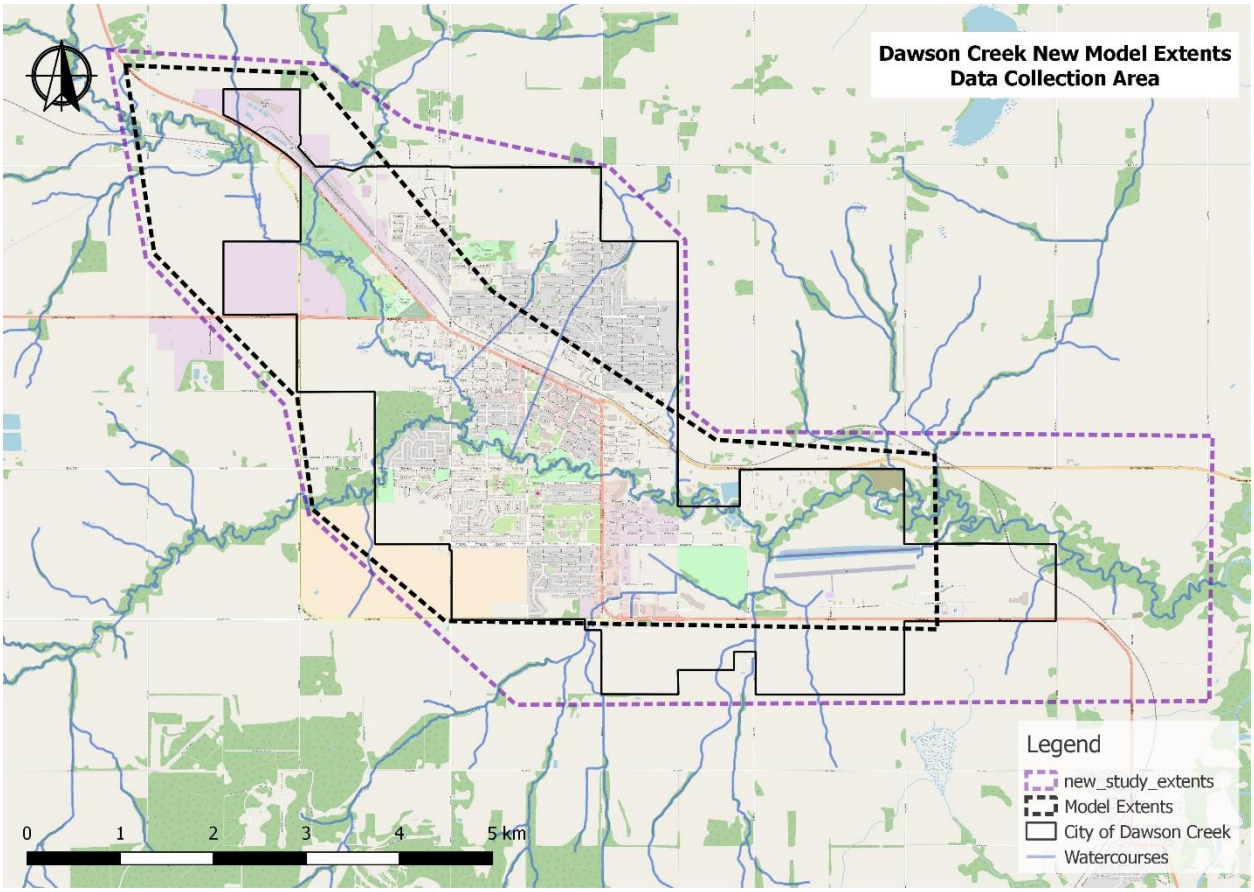


Figure 2: Proposed model extents showing area for new data collection

The proposed extents for the new model include extending the modeled reach of Dawson Creek downstream of Rolla Road. For the new bathymetric survey 200 to 250 cross sections should be surveyed; this is based on the total length of channel and a cross-section spacing in the order of the channel width – this will provide a robust understanding of the channel shape. However, the final decision for the number of cross sections should be made by the modelling team, and there may be a possibility of reducing the number of sections in areas of lower hazard (i.e. the reach downstream of the Airport). The budget estimate for the survey includes some time for data processing.

The exact type of survey (boat vs. wading and section vs multi-beam) is not specified, as this will depend on the modelling approach. Limited water elevation information should be collected as part of this study to support model calibration and validation as well.

1.2.2 Topographic Data ($5k + existing materials or $17k for new LiDAR)

There is currently LiDAR and contour data available for the area, however detailed metadata was not available to confirm the quality and appropriateness for flood modelling. For the purposes of this scope of work, it is assumed that LiDAR – that meets new Federal Specifications

(https://geoscan.nrcan.gc.ca/starweb/geoscan/servlet.starweb?path=geoscan/shorte.web&search1=R=304669) is available.

However, if it does not meet the specifications then new LiDAR should be flown for an area equivalent to 34km^2 and approximately $20k budgeted for this.

A. Option 1: Use existing LiDAR - $5k
B. Option 2: Fly new LiDAR + processing - $20k

This estimate for new LiDAR is for the area shown in the proposed new model extents in Figure 2. The extension as compared to the old LiDAR includes sections of the creek that are adjacent to critical infrastructure such as the airport and Rolla road as well as the full extents of the municipality for the purpose of incorporating urban drainage modelling.

1.3 Flood Analysis and Mapping

More detailed modelling should be conducted for flood in Dawson Creek. This should include more detailed fluvial modelling (2D) along with an integration of the urban drainage system (1D). This project seeks to develop a series of maps to support multiple future projects, and therefore requires updated hydrologic analyses that consider climate change. A series of proposed tasks are provided below:

1.3.1 Hydrologic Analyses ($25k)

A hydrologic analysis of extreme flow events will be conducted using appropriate hydrologic techniques (gauge analyses, regional analyses, hydrologic modelling). At a minimum it is expected that estimates of flows for the 50%, 20%, 10%, 2%, 1%, 0.5% and 0.2% AEP events will be developed for the present day. Further, climate projections, for some AEP events will be calculated for each decade through the year 2100.

1.3.2 Hydraulic Modelling ($50K to $150K)

An updated hydraulic model(s) for the riverine flood hazard areas will be developed. The model should meet standards of best practice as described in the EGBC Flood Mapping Guidelines; preferably the model will be developed using 2D methods and be hydrodynamic. The model (or models) should be calibrated and or validated using information collected during bathymetric surveys (at a minimum). This would be the basic modelling update (Option 1).

Preferably the model should also take into account the urban stormwater system and the inflow from the Ski Hill creek tributary should be included (Option 2).

To fully capture the natural of flood hazard in Dawson Creek the Sanitary System should also be included in the model. This is important for Dawson Creek as sewer backup is a significant issue during flood events (Option 3).

A number of model runs is anticipated but will be at the discretion of the modeler. However, multiple events (see hydrologic and hydrographic analyses above) should be modelled. Climate change scenarios must also be considered. The hydraulic modelling should be properly documented, signed and sealed as per EGBC guidelines.

A. Option 1: Updated Hydraulic Modelling - $50K
B. Option 2: Updated Hydraulic Modelling with urban drainage - $100 K
C. Option 3: Updated Hydraulic Modelling with urban drainage and sanitary sewer - $150K

This model (or models) should have the following characteristics:

- Suitable for modelling the effect of upstream storage. This should be for both storage in the upper reaches of the catchment as well as within the municipality. For storage within the municipality the golf course or areas upstream will likely be studied.
- Suitable for modelling the benefits of a wide variety of flood mitigation alternatives including both structural as well as non-structural mitigation.
- Include crossings and be suitable for design purposes.

1.3.3 Geomorphic Analyses ($25k)

The results of initial studies (City of Dawson Creek Flood Mitigation Planning, Ebbwater Consulting 2018) noted that erosion and channel migration are important and consequential hazards within the City. Erosion mapping (at a decadal, or multiple-decadal scale) is required to better manage this hazard in future. Erosion mapping will be completed by a suitably qualified Professional Geoscientist, using appropriate methods (historic mapping and photos, empirical estimates, etc.).

1.3.4 Mapping ($25k)

The modelling will be used to support the development of an atlas of flood and erosion hazard mapping. The mapping should be suitable for multiple purposes – for detailed engineering design for example, but also to support near-term and long-range planning, as well as for public engagement. A mix of interactive digital and more traditional pdf (or paper) maps is anticipated. Flood hazard mapping, as well as flood erosion and debris mapping will be completed.

1.4 Qualifications

Hydraulic modelling and mapping is a highly specialized field. This work should be conducted by an appropriately qualified professional (or team of professionals) as described in the EGBC Guidelines for Floodplain Mapping. Any professional (or team) should sign and seal a statement declaring that they meet the specifications of a qualified professional prior to beginning work.

1.5 Estimated Cost

An estimated total cost for the scope of work presented above is $165k to $280k. This includes a small contingency of $15k to account for potential increases in cost resulting from high demands for these

services at this time. These estimates are exclusive of GST and any other applicable taxes. This is also broken down by task above with different options for topographic data and modelling efforts (see brackets beside tasks). The cost estimates are based on recently completed projects in the region and high-level quotes collected. Actual costs will vary based on available information and the approach taken.

Appendix G Proposed Language for OCP and DPA

The City of Dawson Creek is developing a new Official Community Plan (OCP) which is an important planning tool that will shape the future of the community. As part of this, policies and Development Permit Areas (DPAs) should be specified with flood, natural hazard, and climate resilience in mind. This appendix draws on work completed by the Columbia Basin Trust to support local governments in their efforts to adapt to climate change. The Official Community Plan Policies Supporting Climate Resilience document is available online and includes OCP language to enhanced climate resilience. This was developed with the support of local governments across British Columbia, industry experts (including Ebbwater Consulting), and academics. The details included in this appendix relate to OCP policies for climate resilience, hazardous areas, and emergency management (Section 1) as well as DPAs for steep slope hazard, flood hazard, and professional reports (Section 2). These sections include the language that is most relevant for flood mitigation planning and natural hazard management in Dawson Creek. However, additional sections may be helpful to integrate climate resiliency into other sections of Dawson Creek's new OCP.

1 Official Community Plan Policies

Official community plans set the vision for a community over a five to twenty year period. They articulate a community's objectives and policies on land use, community development and operations. More specifically, they must include the location of different land uses, restrictions on the use of land subject to hazardous conditions or that is environmentally sensitive to development, and the location and phasing of road, sewer and water systems.[1]

Policies in OCPs are important in two ways. First, they establish the vision for future growth and development in a community, taking into account infrastructure and environmental protection needs, which provides a map for orderly and planned land use changes. Second, they provide guidance to staff, including the subdivision approving officer and elected decision makers. This guidance function can be enhanced by specific metrics for monitoring how well an OCP is achieving its goals. However, it is important to note that OCP policies are rarely enforceable. Although bylaws must be consistent with OCPs,[2] courts will defer to local councils to determine what is consistent or inconsistent with an OCP.[3] Therefore, specific and mandatory OCP policies are more likely to be enforceable than broad and voluntary ones.

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[1] *Local Government Act*, R.S.B.C. 1996 c.323 s.877.

[2] *Ibid*, s.884.

[3] See, for example, *Residents and Ratepayers of Central Saanich Society v Central Saanich* 2011 BCCA 484 (leave to appeal to SCC dismissed).

1.1 Climate Resilience (General Policies)

1.1.1 Overview

Local governments are increasingly aware of the ways in which climate change can impact their infrastructure, operations and community planning. Local governments are addressing climate change in a variety of ways, including undertaking climate-specific planning that may relate to risk assessment, climate vulnerability or resilience planning to establish priorities for action. Policies may also relate to public education and awareness, as well as emergency management for extreme climate events. They may include direction to consider climate change in decision-making at both the staff and council levels.

1.1.2 Policy Provisions

The policies in this section are adapted from the following OCPs: Castlegar (Chapter 7), Rossland (Chapter 14), Kaslo (Chapter 17), Slocan (Chapter 5), Fernie (Chapter 7), Elkford (Chapter 4), Saanich 4.1.1, North Vancouver (District) Chapter 10, Victoria (Chapters 12 & 18), and Richmond (Part 2.5 & Chapter 2).

1. Develop and regularly update a Climate Adaptation Plan that:

- assesses and prioritizes potential future climate risks across all aspects of the [Name of local government];
- recommends adjustments to plans, policies and operations that strengthen community resiliency to future climate risks; and
- includes targets and monitoring activities.

Fernie OCP Policy 7-B.1, 7-B.2, 7-B.3:

- Prepare a *Climate Change Adaption Plan* to better understand how Fernie is exposed to future climate risks and identify and assess actions to increase community resilience.

Slocan OCP Objective 5.1.5

2. Improve the implementation of the Climate Adaptation Plan by taking an adaptive management approach, for example by instituting environmental performance objectives, targets and monitoring.

Richmond City Centre Area Plan (at 2-62) on Adaptive Management:

- Adaptive management is a systematic process of learning to continually improve management policies and practices over time. Recognizing the dynamic conditions of natural and social systems, this approach enables the City to continually strengthen policies based on assessments of local performance, outcomes of action taken and evolving best practices.

3. Conduct cost-benefit analysis of long-term climate adaptation measures to ensure the social, economic and environmental benefits outweigh the costs.

4. Develop and regularly update a Community Energy and Emissions Plan that identifies policies, targets and actions for reducing greenhouse gas emissions and increasing energy efficiency and resiliency including, but not limited to, conservation and diversification.

5. Consider climate change and resilience in all long-term decision making processes, such as when undertaking long range planning and reviewing land use development patterns, infrastructure standards and flood management policies, to ensure adequate climate risk management and the optimization of investment opportunities.

Elkford Objectives 4.1.1-4.1.2

- Impacts of land use, development and all other community activities on climate change…are considered in all future Council decisions. By using climate change as a decision making framework, Council and citizens will be able to identify and act on opportunities to mitigate future impacts of climate change
- Bids, tenders and contracts for planning and development in the District shall make reference to climate change and utilize as a resource the Climate Change Adaptation Strategy.

Kaslo Policies 17.2.3 & 17.2.7

- Council shall consider climate change, its potential impacts, and mitigation measures when reviewing new development applications and undertaking long-term planning initiatives.

Fernie Policy 7-B.6

- Consider future climate change impacts and adaptive responses in long-term planning and development decisions

6. Enhance partnerships with senior, regional and local governments, public agencies, community organizations, businesses and individuals for the efficient and effective coordination of climate resilience planning, policies and initiatives, including risk and vulnerability assessment of local climate impacts.

Rossland Policy 14.2.17

- Seek opportunities to develop strategies to reduce vulnerability to and adapt to climate change impacts in collaboration with federal and provincial agencies, the Regional District of Kootenay Boundary, research organizations, the academic sector

7. Strengthen community resilience by increasing local self-reliance and resource (food, energy, and water) security.

8. Raise community awareness of climate resilient actions that can be implemented at home, such as water conservation, FireSmarting and on-site stormwater management.

9. Support and encourage the Provincial Government to enhance tools and information available to help communities better manage climate risks, including but not limited to weather and climate monitoring, climate projections, design guidelines and planning support.

Kaslo Policy 17.2.2

- Council shall support and encourage Provincial Government initiatives to enact legislation to provide local governments with the necessary tools to better address climate change and energy efficiency issues.

1.2 Hazardous Areas

1.2.1 Overview

The presence of steep slopes, creeks, ravines, floodplains, avalanche paths and forested lands combined with occasional extreme weather activity make many communities susceptible to natural hazards including landslides, debris flows, floods, avalanches and wildfires. Projected increases in winter precipitation, the frequency of extreme rainfall events and wildfires could all contribute to increased frequency of landslide and debris flows. Likewise, increases in winter temperatures, rain-on-snow events and increases in freeze/thaw cycling could increase avalanche frequency in some locations. Projected increases in summer temperatures, very hot days, longer warm spells, reduced summer precipitation, fuel accumulation and pest outbreaks may contribute to increased wildfire frequency. These hazard areas can be centres of commercial, social, economic and / or ecological assets and activity, which are subject to damage when natural hazard events occur. Planning in natural hazard areas should improve the resilience of property and infrastructure while protecting the safety and wellbeing of citizens.

1.2.2 Policy Provisions

The policies in this section are adapted from the following OCPs: Elkford (Chapters 5-7), Fernie (Chapters 4 & 7), Castlegar (Chapter 18), Kelowna (Chapters 6 & 7), District of North Vancouver (Schedule B) and from B.C. Ministry of Forest Lands and Resource Operations Flood Hazard Land Use Management Guidelines (2014 Proposed Amendments).

1. Account for future climate projections when developing and implementing natural hazards development permit areas to address landslide, flood, debris flow and / or avalanche risks.

> **Example:** In 2013 the Regional District of East Kootenay completed a Regional Flood Hazard Study (Phase 1) to prioritize flood hazard areas, describe potential effects of climate change on flood hazards, and outline a framework to implement a regional flood management plan. With respect to climate change and flood risk, the report concluded that the RDEK is likely to see an increase in debris flow, debris flood and flood activity; increased peak discharge in creeks and streams; and reduced effectiveness of existing dikes and flood infrastructure.

2. Develop and implement measures to reduce risks of landslide, flood, debris flow and avalanche to existing buildings and infrastructure.

> **Note:** Resources and guidance on hazard area mapping and management are provided in Appendix B.

3. Continue to update hazard area mapping (e.g., avalanche zones, floodplain areas) to ensure that mapping for hazard area development permit areas remains current and the highest levels of public safety and health are maintained.

4. Develop tools to aid in risk management (e.g. vulnerability and risk mapping and risk assessments) to help reduce overall risk of natural hazards to people and property.

5. Communicate hazardous area risks to residents, particularly those who are exposed and vulnerable to risks.

6. Acquire chronically flooded properties.

7. Establish a second layer of setback flood defence behind primary flood defence barriers where possible.

8. Development in steep slope hazard areas shall consider the potential increase in landslide and erosion risk associated with increased extreme precipitation events.

Elkford Objectives and Policies 5.9.2 & 7.4.1

- Prevent new subdivision development on slopes over 30 degrees as climatic changes may lead to an increase in peak flows and glacial melt may increase the risk of erosion and landslides on steep slopes.

Castlegar Policy 18.4

- Prevent development within areas adjacent to steep slopes (greater than 30 per cent), areas of soil subsidence, rock fall, land slip or erosion hazards which are known or suspected.

9. Require as a condition of development approval, subdivision, or the issuance of a building permit in high risk flood and debris flow hazard areas, the registration of restrictive covenants to ensure that:
    - purchasers are made aware of flooding issues and the ongoing role that property owners must assume to protect their investment given climate variability; and
    - The [Name of local government] is saved harmless in the event of damage to individual properties as a result of flooding.

Fernie Policies 4-B.7 & 7-B.5

- Include climate and hydrological changes, trends and risks in all environmental risk assessment processes, including implications for flooding levels and extreme precipitation events.
- Review and update existing floodplain mapping and management bylaws to account for climate change…

Castlegar Policy 18.4

- Protect against damage associated with flooding events by encouraging agricultural, park and open space recreational land uses in the floodplain.

Elkford Objectives and Policies 5.9.2 & 7.4.1

- Update the floodplain designation and related mapping to incorporate new climate science and projections.
- Accommodate passive uses in floodplain areas, such as parks and trails.

1.3 Emergency Management

1. Use a risk management framework to identify climate risks, set priorities, and decide on strategies to manage risks.

2. Work with Emergency Management B.C. and local service organizations to prepare for and respond to emergencies created by extreme weather events, and to consider how climate change will affect future preparedness and response.

3. Maintain and regularly update [Name of local government] hazard, vulnerability and risk assessments, and consider these studies in plans, policies, bylaws and decisions for maintenance, upgrades and replacement of public and private property.

4. Prepare and maintain a transportation master plan that supports climate resilience by, for example, ensuring appropriate emergency access and egress.

5. Support the development of a regional emergency transportation system by partnering with regional and provincial agencies in the identification of an integrated network of road, water and air transport facilities defined as critical infrastructure to be upgraded and maintained to retain functionality following a damaging climate event.

2 Development Permit Areas

Note: The DPA justifications and guidelines in this section do not provide comprehensive DPA regimes. They focus solely on provisions that directly promote climate resilience. They should not be relied on as complete codes for DPAs.

Development permit areas support community resilience by providing local governments with site-specific control over the layout and design of development. Local governments can designate development permit areas (DPAs) for a variety of purposes with the intent of imposing site-specific conditions on development within those areas. Purposes of DPAs include protection of the natural environment, its ecosystems and biodiversity, protection of development from hazardous conditions, and establishment of objectives to promote water conservation and the reduction of greenhouse gas emissions.[4] Land within a DPA must not be subdivided or construction started unless the owner obtains a development permit from the local government. Used as a supplement to zoning, DPA guidelines set out in the OCP provide direction to staff on how development should be shaped through compliance with development permits.

For DPAs designated for protection of the natural environment, ecosystems and biodiversity, a development permit may:

- specify areas of land that must remain free of development, except in accordance with any conditions contained in the permit;
- require specified natural features or areas to be preserved, protected, restored or enhanced in accordance with the permit;
- require natural water courses to be dedicated;
- require works to be constructed to preserve, protect, restore or enhance natural water courses or other specified natural features of the environment;
- require protection measures, including that vegetation or trees be planted or retained in order to:
    - preserve, protect, restore or enhance fish habitat or riparian areas,
    - control drainage, or
    - control erosion or protect banks.

For DPAs designated for protection from hazardous conditions, a development permit may:

- specify areas of land that may be subject to flooding, mud flows, torrents of debris, erosion, land slip, rock falls, subsidence, tsunami, avalanche or wildfire, or other hazard, as areas that must remain free of development, except in accordance with conditions in the permit;
- require, in an area that the permit designates as containing unstable soil or water that is subject to degradation, that no septic tank, drainage and deposit fields or irrigation or water systems be constructed;
- in relation to wildfire hazard, include requirements for the character of the development, including landscaping, and the siting, form, exterior design and finish of buildings and other

[4] The jurisdiction for DPAs is set out in sections 919.1 and 920 of the *Local Government Act*, R.S.B.C. 1996 c.323.

structures; and
- in relation to wildfire hazard, establish restrictions on the type and placement of trees and other vegetation in proximity to development.

Finally, for DPA guidelines that establish objectives to promote energy and water conservation and the reduction of greenhouse gas emissions, a development permit may include requirements for:
- landscaping;
- the siting of buildings and other structures;
- the form and exterior design of buildings and other structures;
- specific features in the development;
- machinery, equipment and systems external to buildings and other structures; and
- restrictions on the type and placement of trees and other vegetation in proximity to the buildings and other structures in order to provide for energy and water conservation and the reduction of greenhouse gases.

Note: If a local government wishes to require applicants to provide additional information in the form of studies or technical reports they must designate a Development Approval Information Area pursuant to sections 920.01 and 920.1. There is no jurisdiction under DPAs for local governments to request information of an applicant beyond information typically found in an application such as the applicant's name and property. See section 3.10 below for more information.

Below are descriptions of what is required under sections 919.1 and 920 of the *Local Government Act* to establish credible DPAs:

1. Designation of the DPA in the OCP:
    a. The extent of the DPA must be delineated. Ideally, DPAs are identified through mapping. However, written designations can roughly identify the area in the short-term until detailed mapping is undertaken to clearly identify the boundaries of the DPA. Absent mapping there may be disagreement about whether or not a DPA applies to a parcel or part of a parcel, therefore detailed mapping of natural areas, hazards, and other features will make DPAs significantly stronger.
    b. Justification for the designation: Justification means describing the special condition or objective for the DPA, for example for hazards how the DPA will reduce risk to life and property. Justification requires evidence that supports the designation of the DPA, such as a technical study or staff memo that identifies special features or hazards.

2. Guidelines on how the objectives for the DPA will be met:
    a. Guidelines set out the requirements that applicants must follow to receive a development permit from a local government. They can be suggested standards or mandatory requirements.

3. Conditions under which a development permit is not required:
    a. Typically called exemptions in the OCP or zoning bylaw, these are routine or unique situations where a development permit would be redundant or deemed unnecessary.
    b. Typical exemptions include:

i. Maintenance of public works and emergency works;
ii. Non-structural repairs or renovations to a permanent structure provided that there is no expansion of the buildings footprint, and provided that such repairs or renovations do not increase the gross floor area of the structure;
iii. Replacement or repair of an existing deck, provided the locations and dimensions do not change;
iv. Routine maintenance of existing landscaped and lawn areas;
v. Habitat creation, streamside restoration or similar habitat enhancement works in accordance with [Name of Local Government] bylaws; and
vi. Planting of vegetation, except for the planting of trees within 10 metres of the top of a steep slope.

c. Each local government has unique administrative processes, development activities, ecological conditions and geology that will warrant a different set of exemptions. It is up to each local government to assess, through practice, what type of development in what areas warrant additional DPA conditions.

The following section provides examples of DPA guidelines including protection of the natural environment, hazardous areas (wildfire, flood/debris flow, avalanche and steep slope), and energy and water conservation. Generic guidelines that are important to any DPA regime, such as monitoring and performance bonding, have not been included. Likewise, technical guidelines such as tree replanting requirements and specifications for registered professionals that are relevant to DPAs in general are not reproduced. It is important to note that although DPAs aim to achieve water and energy conservation in buildings, they cannot exceed the standards set by the provincial Building Code.

Best practices for DPAs relate to promoting a connected and functioning natural environment, avoiding hazards and understanding the impacts of new development. Maintaining connectivity between ecosystem elements across the private land base is one of the primary purposes of DPAs for protection of the environment. This promotes resilience and provides ecosystems more latitude to adapt over time. Local governments also seek to understand the impacts of new development or their suitability for a particular site, particularly in relation to steep slope, wildfire or flooding hazards, by requiring that applicants provide studies and opinions from registered professionals. The ability to request this information comes with designating all DPAs as development approval information areas (Section 3.10) under section 920.01 of the *Local Government Act*. Local governments can ensure that the implementation of DPA conditions is achieved by mandating that applicants post security and monitor new infrastructure and site conditions with explicit direction to fix any plantings or infrastructure that fails.

Some local governments also put users on notice that the DPA guidelines require the industry to step up to a new standard or to be creative. Two examples are provided below.

City of Dawson Creek DPA guideline for water conservation in Multi-Family, Commercial and Light Industrial areas (at 16-25):

- "Note: These guidelines will involve a higher level of technical rigour and expertise in landscape and irrigation design (for multifamily/ICI sectors only) compared to current typical practice. This may present some challenges initially, however they will also serve to stimulate capacity building for implementation of best practices".

District of North Vancouver Energy and Water Conservation and Greenhouse Gas Emissions Reductions Development Permit Areas encourage integrated performance-based design (at 115):

- "These guidelines are not intended to be a definitive listing. Rather, they suggest issues to be considered and designers may respond to these guidelines in a variety of different ways. Creativity is encouraged. Except where specific standards are referenced, these guidelines are not prescriptive. Designers are directed to consider a variety of synergistic approaches, particularly, passive design strategies, rather than active mechanical systems, to reduce a building's energy and water consumption and greenhouse gas emissions and improve occupant thermal comfort."

It should be noted that the DPA guidelines provided below are quite broad and general in nature, rather than specific and prescriptive. This approach has been taken for a variety of reasons, namely:

1. Every community has different priorities as well as different climatic and environmental conditions. As such, hazards will manifest locally in different ways and varying guidelines will be needed to manage risk appropriately; and
2. The use of DPAs, and the requirement for Professional Reports (Section 3.11) and Development Approval Information Areas (Section 3.10) which require professionals to assess risks and make recommendations in hazardous areas in site specific in nature. The reliance on professionals can reduce the workload on municipal staff and reduce liability for the local government.

2.1 Steep Slope Hazard

2.1.1 Overview

A DPA enacted to address slope hazards (including land slip and rock falls) may specify areas of land that cannot be developed, and may include requirements respecting the character of development, including landscaping and the siting, form, exterior design and finish of buildings and other structures.

2.1.2 Guidelines

The guidelines in this section are adapted from the following OCPs: Castlegar (21st Street), Fernie (Avalanche), District of North Vancouver (Protection of Development from Slope Hazards, Schedule B Part 4) and Kelowna (Hazardous Conditions).

The following guidelines could be applied in the Slope Hazard DPA:

1. Applicants may be required to provide a hazard or risk assessment report prepared by a qualified professional, pursuant to the [Name of Local Government] Development Approval Information Area designation.

2. Reporting by the qualified professional should reference APEGBC Legislated Landslide Assessments for Proposed Residential Developments in B.C.

3. Any structural mitigation measures must be designed by a qualified professional.

4. Development should minimize any alterations to steep slopes, and the development should be designed to reflect the site rather than altering the site to reflect the development.

5. Terracing of land should be avoided or minimized and landscaping should follow the natural contours of the land.

6. Buildings, structures and landscaping should be located as far as reasonably possible from steep slopes.

7. Potential slope hazard areas should remain free of development, or if that is not possible then mitigation should be undertaken to reduce to reduce risk and conditions should be imposed as necessary to reduce potential hazard as determined by a qualified professional.

8. The construction of structures, pathways/trails, driveways, utilities, drainage facilities, septic fields, swimming pools, hot tubs, ponds, landscaping or other uses at or near the top or base of steep slopes should be avoided. A minimum 10 metre buffer area from the top or base of any steep slope should be maintained free of development except as otherwise recommended by a qualified professional. On very steep slopes, this buffer area should be increased.

9. Vegetation should be maintained and/or reinstated on the slopes and within any buffer zone above the slopes or along pre-existing drainage channels.

10. The base of slopes should not be undercut for building, landscaping or other purposes except in accordance with the recommendations of a qualified professional.

11. For homes at the base of slopes, it is preferable for bedrooms to be constructed on the downslope side of the home.

12. Designs should avoid the need for retaining walls, particularly to minimize cutting of the uphill slope. Large single plane retaining walls should be avoided. Where retaining walls are necessary, smaller sections of retaining wall should be used. Any retaining structures in steeply sloped areas must be designed by a qualified professional.

13. Any structural mitigation measures must be designed by a qualified professional.

14. Water should be diverted away from slopes, yards and structures in a controlled manner and ponding should be avoided near slopes.

15. Property, roof drainage and landscaping should be designed and maintained to shed water away from steep slopes.

16. Rock fall mitigation recommendations by a qualified professional will be provided for rock fall hazards on the subject, adjacent and potentially affected properties.

17. Disturbed slopes should be reinforced and re-vegetated, especially where gullied or where bare soil is exposed. Planting should be done in accordance with the recommendations of a Landscape Architect or Registered Professional Forester, and a permit issued by the [Name of local government].

18. The extent of paved or hard-surfaced areas should be limited, and absorbent or permeable surfaces should be used instead to encourage infiltration where appropriate and reduce runoff.

19. Any development within the Steep Slope DPA will have a restrictive covenant registered on title identifying the land as hazardous.

Castlegar 21st Street Steep Slope DPA Guidelines

- Applications for DPA shall be accompanied by a report certified by a Professional Engineer or Geoscientist. A Surface and Foundation Drainage Plan may be required which shows that storm water will be appropriately collected and discharged…
- No excavation of filling shall be undertaken, nor any building or permanent structure erected, constructed or placed except in accordance with the recommendations in the report.
- Minimize the removal of trees.
- Minimize slope alterations and retain the natural terrain and topography of the site.
- Avoid any disturbance of native vegetation and wherever possible retain existing native vegetation…
- May require the registration of restrictive covenants for areas that have been identified as hazardous.
- Require rock fall mitigation recommendations for rock fall hazards

2.2 Flood Hazard (including debris flow and debris flood)

2.2.1 Overview

A DPA enacted to address flood hazards (including mud flows and torrents of debris) may specify areas of land that cannot be developed on, as well as include requirements respecting the character of development, including landscaping and the siting, form, exterior design and finish of buildings and other structures.

2.2.2 Guidelines

The guidelines in this section are adapted from the following OCPs: Castlegar (21st Street), Fernie (Avalanche), District of North Vancouver (Protection of Development from Slope Hazards, Schedule B Part 4) and Kelowna (Hazardous Conditions).

1. Applicants may be required to provide a hazard or risk assessment report prepared by a qualified professional, pursuant to the [Name of Local Government] Development Approval Information Area designation.

2. Reporting by the qualified professional should reference APEGBC Guidelines for Legislated Flood Assessments in a Changing Climate

3. Development should:
    a. Be constructed in a location and manner that will maximize the safety of the residents and property;
    b. Be located in the least hazardous part of the site;

c. Comply with flood construction requirements identified by a qualified professional in hazard or risk assessment report;
d. Not include habitable space below the flood construction level specified by the qualified professional;
e. Not increase the hazard, vulnerability or risk to other properties or structures;
f. In connection to renovations to an existing permanent structure, where reasonable, raise the habitable space to flood construction levels.

Example: The District of North Vancouver, being an early adopter of development permits for hazard management, and having suffered a fatality from a recent event (2005 Berkley Landslide), has one of the most comprehensive natural hazard management programs in the province. Many resources are available online: http://www.dnv.org/article.asp?c=1024.

2.3 Professional Reports

2.3.1 Overview

Local governments are increasingly providing more detail to applicants and their consultants as to what they expect in professional reports. This section sets out some examples of information requirements for professional reports that relate to increasing climate resilience. The guidelines set out in this part provide a subset of the information local governments may detail in their DPA guidelines for professional reports.

2.3.2 Guidelines

The guidelines in this section are adapted from the following OCPs: District of North Vancouver (Schedule B Part 4), Kelowna (Natural Environment, Chapter 12), Richmond (Chapter 12)

1. Assessment reports should address the potential for fire, landslip, rockfall, slope failure, debris flow, debris flood or flooding, or other hazard and the impact of the proposed development on or by such natural hazard conditions should be analyzed and assessed.

2. Assessment reports should consider climate projections to a future time period commensurate with the life-cycle of the infrastructure that may be affected (e.g. >50 years for residential building), and the impacts future climate will have on the proposed development.

3. The appropriate method of assessment and level of effort should be determined by the applicant's qualified professional based on all the relevant circumstances, including, without limitation, the type of hazard, the nature and extent of proposed development, the particular development permit designation(s), and local site conditions.

4. Where a potential for loss of life exists, the applicant's qualified professional may be required to provide a detailed quantitative risk assessment using the risk tolerance criteria or factor of safety calculations in respect of the proposed development.

1. Understanding Flood Risk in Dawson Creek Facebook Page

A Facebook page was created by Ebbwater Consulting Inc. (Ebbwater) to help communicate with the Dawson Creek community on the topic of understanding flood risk in the community.

The page can be accessed at the following URL: https://www.facebook.com/DawsonCreekFloodRisk

In addition an page on the City website highlighting the key information can be found here: http://www.dawsoncreek.ca/departments/infrastructure/water-environmental/understanding-flood-risk/

Two title options were considered for the page. They are as follows:

1) Dawson Creek Flood Mitigation Planning (also the Project Title)
2) Understanding Flood Risk in Dawson Creek (specific to this phase)

Since the facebook page is about communicating and understanding flood risk in Dawson Creek the second title was selected.

The following contact information was provided for the page:

Contact: dawsoncreekflood@ebbwater.ca

Website: www.dawsoncreek.ca

Story Arc: Dawson Creek has experienced significant flooding in recent years and is working towards becoming a flood resilient community in the future.

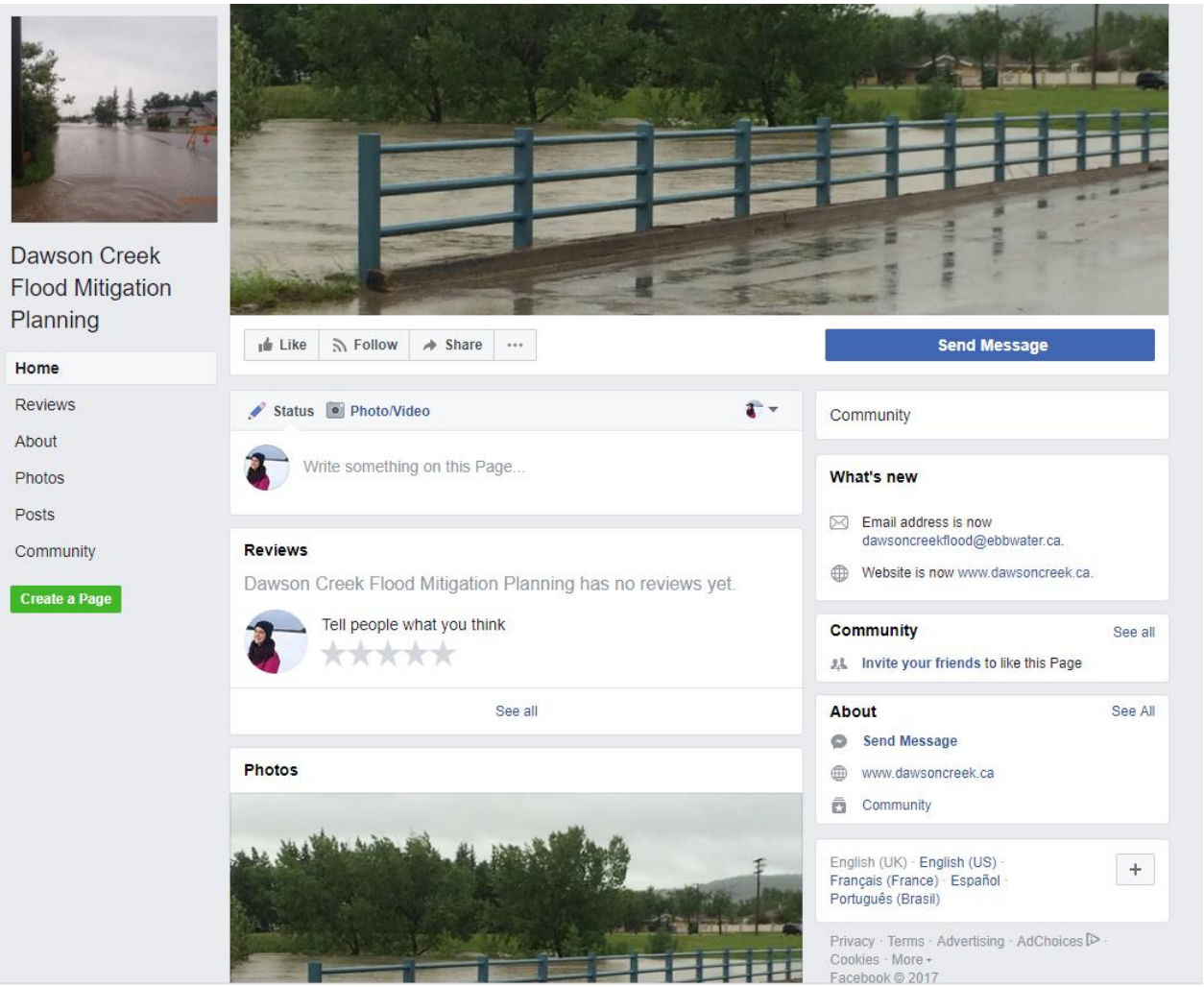
Source of Photos: Transferred to Ebbwater Consulting from the City of Dawson Creek and the Fire Chief

Page Format Options:

Several format options were provided including:

1. Series of Photo posts with text
    a. Easy to comment and share
    b. Overall quite interactive
2. Series of notes with embedded photos
    a. More like a series of blog posts but on facebook
    b. Also easy to share
3. Some photos could also be organized into a timeline format
    a. Example of Timeline of Flooding for the City of Surrey
    b. This timeline is old but is provided as an example of the concept

Page Draft:



Proposed Text and Photos:

On June 24th, 2011 the Dawson Creek Watershed experienced heavy rainfall and as a result many homes were flooded. Some of the flooding was due to water overtopping the banks of the creek but much of it was basement flooding due to sewer backup. Also, several roads, businesses and city properties experienced flooding:

Figure 1: Flooded property on 101st ave - Dawson Creek June 2011

Figure 2: High water - Dawson Creek June 2011

Figure 3: Flooded 17th Street - Dawson Creek June 2011

Figure 4: Flooded 17th Street - Dawson Creek June 2011

POST 2

Dawson Creek experienced a second storm within a month on July 9th, 2011, and roads crossing the creek were flooded again. During both flood events in 2011 it was still possible to travel from the north side to the south of the creek within the City center as 8th street remained open.

In response to the flooding of 2011, the City embarked on the development of a Sanitary Sewer Master Plan, which was finalized in January 2013. This included plans for upgrades to the City's sewer infrastructure.

Figure 5: Flooded 17th Street Looking North - Dawson Creek July 2011

POST 3

In June 2016, the Dawson Creek catchment again experienced heavy rainfall and the City was once more flooded. This time there was significant overland flooding and sewer backup. Flooding on 8th street along with other roads in the centre restricted north/south travel, cutting the City in half.

With flooded homes and businesses, as well as damaged roads and bridges, the recovery effort from this event was significant. Some of the reconstruction efforts included bridge replacements and road repairs.

Figure 6: Photo of Flooded Dawson Creek in June 2016

Figure 7: 8th Street in Dawson Creek during flood event - June 2016 (While this is an interesting representation of the flood it looks like it wasn't filmed from the safest location – don't forget that safety is a primary concern during a flood. Remember, turn around, don't drown! More information on flood safety can be found here: http://www.nws.noaa.gov/os/water/tadd/

Figure 8: Flooded 15th Street Crossing - Dawson Creek June 2016

Figure 9: 8th Street in Dawson Creek following flood event - June 2016

The City of Dawson Creek received a grant from Emergency Management BC earlier this year and is now working with a consultant team to begin working on a comprehensive flood mitigation planning study to better understand both the flood hazard for Dawson Creek and the vulnerability in the community. A deeper understanding of flood hazard, vulnerability and risk will support future work to mitigate impacts of flood in Dawson Creek.

This project began in September 2017 with information gathering to better understand the nature of flood hazard in the City – where does the water come from, when does it flood, where does the water go, where might it go in future?

The project team is now working to better understand how floods impact the unique circumstances of Dawson Creek. As a first step, workshops were hosted on November 22nd, 2017 with City staff, council, local authorities and the public.

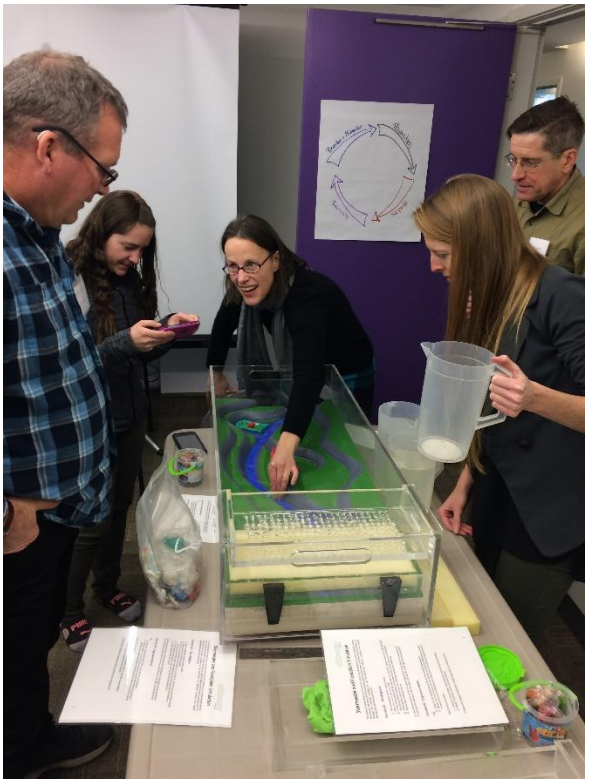


Figure 10: Understanding floods - Workshop participants test measures in physical river model

Figure 11: The Fire Chief tests a flood mitigation measure in the physical river model

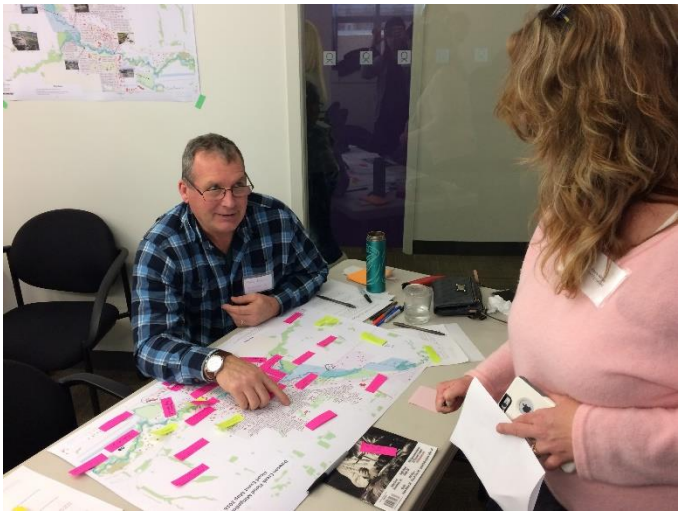


Figure 12: City Councillors discuss direct and indirect flood impacts in flood workshop

Figure 13: Dawson Creek residents hear about flood response and planning at public meeting

Figure 14: Dawson Creek residents share their stories from the recent flood events and map impacts

Flood impact information was collected during the workshops and has been digitized. The map below shows the hot spots for flood impacts in Dawson creek as well as the approximate flood extent from the 2016 event; hotspots are areas where many impacts of flooding were noted in close proximity to each other – the darker the spot, the greater the number of recorded impacts. If you experienced a direct impact (i.e. your house was flooded, your place of business was flooded) and it's not currently shown on the map – we'd appreciate hearing from you. Please send details of the impact (what was wet? when did it occur? how long did it last?) to dawsoncreek@ebbwater.ca, and we'll use the information in future work.

This information on impacts will be used together with more detailed information on flood frequency, extents, and depths to develop a risk assessment in Spring 2018. This risk assessment will be used to support future grant applications, and to help the City identify suitable flood mitigation measures and to help prioritise actions.

2. People Reaches and Page Analytics

Since the page was launched in December 2017 both Ebbwater and the City of Dawson Creek staff have updated the page. The people reached and engagement on each post is summarized in the table below. This table shows the page analytics as of August 11th 2018.

Table 1: Facebook page analytics for the Understanding Flood Risk in Dawson Creek facebook page

All posts published

Reach: Organic/Paid | Post clicks | Reactions, comments & shares

Published	Post	Type	Targeting	Reach	Engagement	Promote
25/04/2018 15:43	**Road Closure & FREE Sandbags/Sand** Due to this			98	15 3	Boost Post
10/01/2018 17:57	Scroll down for the start of the story and click through the posts			25	21 3	Boost Post
10/01/2018 14:50	Flood impact information was collected during the November			706	263 23	Boost Post
10/01/2018 14:40	In July 2017 the City of Dawson Creek received a grant from			17	16 1	Boost Post
10/01/2018 14:30	During the June 2016 flood 8th Street in Dawson Creek			36	21 1	Boost Post
10/01/2018 14:20	In June 2016, the Dawson Creek catchment again experienced			2	10 0	Boost Post
10/01/2018 14:10	Dawson Creek experienced a second storm within a month on			0	11 0	Boost Post
10/01/2018 14:00	On June 24th, 2011 the Dawson Creek Watershed experienced			1	7 0	Boost Post
10/01/2018 12:10	Flooded property on 101st ave - Dawson Creek June 2011			1	7 0	Boost Post

The most popular post by far is the flood impact map produced from the workshop with 706 people reached and 263 people engaged. After that, the post about sandbags during the spring 2018 flooding. Reached 98 people and engaged 15. Finally the post with the video of 8th ave during the 2016 flood event also reached many with 36 reached and 21 engaged.

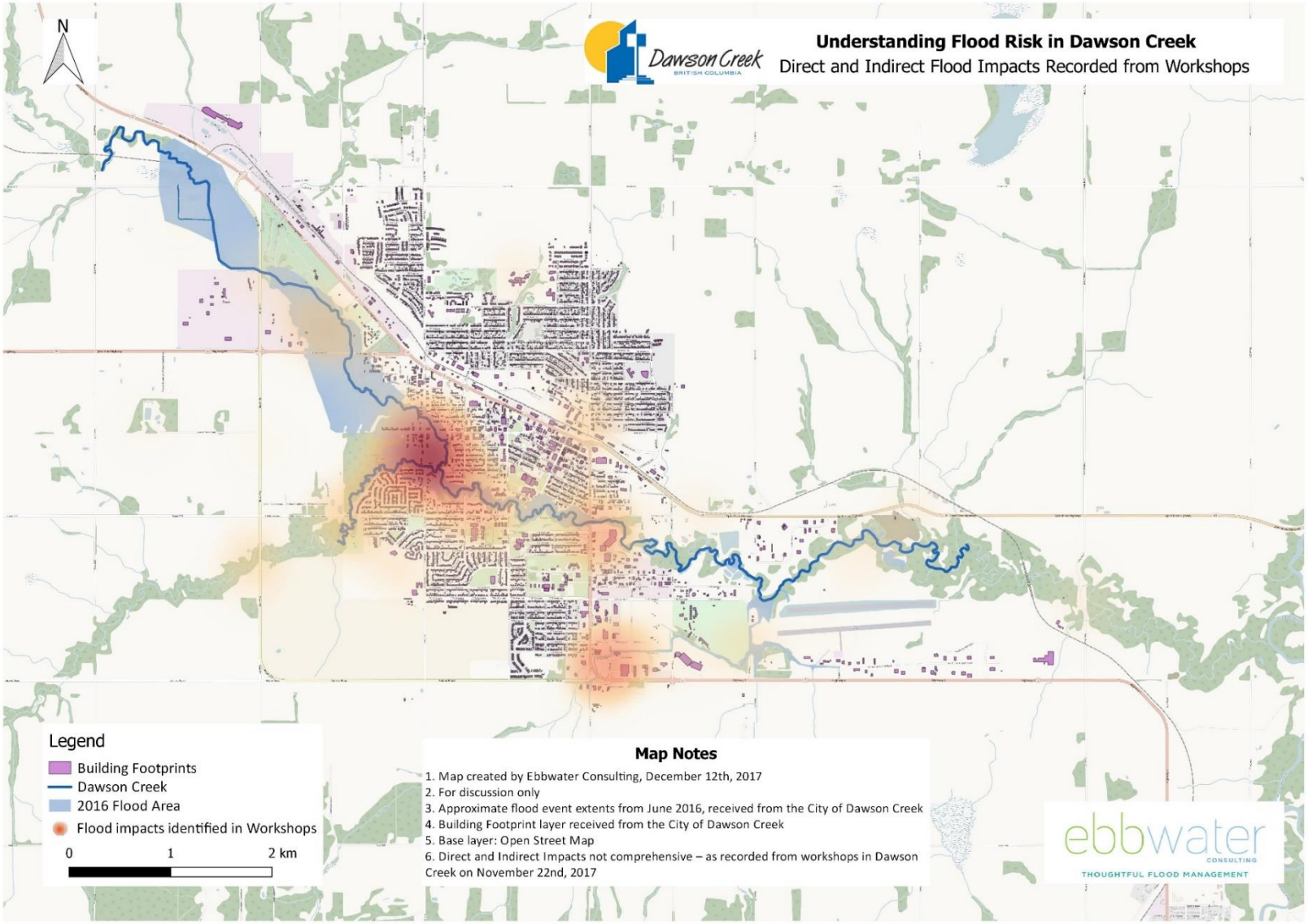


Figure 15: Hot spot map of flood impacts provided on the facebook page