DATE: May 10, 2018

FILE: 7130-03

TO: Chair and Directors
Electoral Areas Services Committee

FROM: Russell Dyson
Chief Administrative Officer

Supported by Russell Dyson
Chief Administrative Officer

J. Warren (for)

RE: **Oyster River / Saratoga Beach Flood Risk Assessment**

Purpose

To present the Electoral Areas Services Committee with the Oyster River/Saratoga Beach Flood Risk Assessment Report, a National Disaster Mitigation Program (NDMP) Stream 1 project;

And, to seek approval to apply for Stream 2 funding through the Union of BC Municipalities - Community Emergency Preparedness Fund (CEPF) and/or the NDMP, for flood mapping of the Oyster River/Saratoga Beach project area.

Recommendation from the Chief Administrative Officer

THAT the board approve an application to be made to the National Disaster Mitigation Program and/or the Union of BC Municipalities Community Emergency Preparedness Fund for Stream 2 funding for flood mapping of the Oyster River/Saratoga Beach project area.

Executive Summary

- Stream 1 funding for the study ($76,000) was provided through the NDMP.
- Spatial maps were produced representing flood risk in the area and include climate change.
- The mapping in the report is for discussion, not for detailed planning or engineering design.
- Study states: "Development of a new (flood) map is an imperative and necessary next step".
- The report identifies flood mitigation and risk management strategies, as well as tools for the community to become more resilient and build capacity.
- The report meets the requirements of the Union of BC Municipalities Community Emergency Preparedness Fund and the NDMP to apply for Stream 2 funding for flood mapping.
- It is believed the opportunity to apply for CEPF and NDMP funding will be mid-late 2018.
- The cost for new flood hazard modelling and mapping is estimated to be $175,000.
- This was a collaborative effort between the Comox Valley Regional District (CVRD) and the Strathcona Regional District (SRD), with in-kind contributions of $4,700 from the CVRD and $500 from the SRD.
- The CVRD intends to apply for funding from the NDMP and CEPF to obtain new flood mapping for a more extensive area.

Prepared by:	Concurrence:	Concurrence:
G. Doerksen	*H. Siemens*	*T. I. Smith*
George Doerksen Deputy Emergency Program Coordinator	Howie Siemens Emergency Program Coordinator	T. Ian Smith MCE General Manager of Community Services

Stakeholder Distribution (Upon Agenda Publication)

Saratoga and Miracle Beach Residents' Association	✓
Strathcona Regional District	✓
Additional organizations that attended the stakeholder meeting Jan 16, 2018	✓

Background/Current Situation

The Oyster River/Saratoga Beach area is historically prone to flooding and is at risk from not only high river flows, storm surge, and rising sea levels, but a combination of all three occurring simultaneously. Short but intense rainfall events have been shown to actually change the course of the river.

Flooding has posed a significant threat to this region's environment, people, housing, economy, and infrastructure. The water well infrastructure and water quality have been threatened by past flooding. Within the area lie three active water service wells, plus infrastructure, which are owned and operated by the CVRD. These wells provide water to both regional districts and serve a resident population of about 3,000. This includes approximately 2,200 in the CVRD and 800 in the SRD. There is also one private water service well, plus infrastructure, which services 143 households, a mobile home park, resort, marina and campground.

The area also contains a very high use trail infrastructure, particularly within the SRD, that has been repeatedly eroded by the river during severe rainfall and high flow events.

In recognition of increasing disaster risks and costs, in 2014 the federal government developed the NDMP. The program addresses rising flood risks and costs, and building the foundation for future informed mitigation investments by investing in foundational flood mitigation activities (e.g. risk assessments and flood mapping), that could reduce, or even negate, the effects of flood events.

The NDMP is a merit-based program consisting of four project streams:

- Stream 1 - Risk Assessments
- Stream 2 - Flood Mapping
- Stream 3 - Mitigation Planning, and
- Stream 4 - Investments in Non-Structural and Small Scale Structural Mitigation Projects

In 2016 the CVRD determined a Flood Risk Assessment for the Oyster River/Saratoga Beach area was required and an application to the NDMP was submitted for $76,000 in Stream 1 – Risk Assessment funding.

The project boundaries are based on the Saratoga Miracle Beach Local Area Plan as defined in the 2011 CVRD Regional Growth Strategy, but also extend across the Oyster River into the SRD. This additional area includes a portion of the Oyster River community, the Glenmore Dike, and water service wells owned and operated by the CVRD.

The application to the NDMP was successful and, following the request for proposals process, the risk assessment contract was awarded to Ebbwater Consulting to achieve the following objectives:

1. To obtain a Flood Risk Assessment consisting of a collection of historical data and projections that would identify and detail existing hazards, potential hazards, future risks, likelihood of occurrence, and identify the community's vulnerabilities; and
2. To obtain a completed Risk Assessment Template. This is a requirement of the NDMP to move forward to Stream 2 – Flood Mapping.

These objectives were achieved. The final Flood Risk Assessment report (attached as Appendix A) and Risk Assessment Template (attached as Appendix B) were received May 3, 2018.

Report Highlights:

- The CVRD and SRD, should use the results of this study to support an application to the NDMP or to the CEPF to develop an appropriate model and mapping for the area. (Page 28)
- In summary, there is a significant flood risk in the region. Risk reduction should be a priority for the CVRD and the SRD, as well as for provincial authorities. (Page 46)
- 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. (Page 49)
- 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. (Page 49)
- 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. (Page 49)
- 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. (Page 50)

Stream 2 funding for flood mapping will provide the following:

- New up-to-date flood hazard modelling and mapping for the Oyster River/Saratoga Beach Area. This area was last mapped in 1984 and the information is outdated.
- It will provide a series of flood hazard maps based on an up-to-date understanding of the river and flood plain geometry, as well as an updated understanding of river hydrology and coastal hydrography (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.
- A further objective is to improve understanding of the erosion hazard through the development of flood erosion maps.

- Will support the development of flood mitigation plans and the design of any future flood infrastructure.

Policy Analysis

On October 28, 1991, Bylaw No. 1341 being "Electoral Areas A, B, and C Emergency Program Extended Service Establishment Bylaw, 1991" was adopted by the Comox Strathcona Regional District to establish an extended service for Electoral Areas A, B, and C to provide for preparation for emergencies.

Options

1. That the board accept the report (and included Risk Assessment Template) from Ebbwater Consulting titled Comox Valley Regional District Oyster River/Saratoga Beach Flood Risk Assessment Final Report and approve an application for Stream 2 funding via the National Disaster Mitigation Program and/or the Union of BC Municipalities Community Emergency Preparedness Fund.
2. That the board request changes or additional analysis be made.

Staff are recommending Option 1.

As identified in the 2015 to 2018 Strategic Priorities Chart, Schedule B, The Oyster River/Saratoga Beach Flood Risk Assessment is a Community Services Branch strategic priority.

Financial Factors

A grant of $76,000 was received through the NDMP. As agreed in the contract, in-kind contributions were provided in the amount of $4,700 from the CVRD, and $500 from the SRD. As required by the NDMP, all financial submissions were finalized as of March 31, 2018.

A detailed description of the deliverables for Stream 2 funding for flood mapping can be found in the Flood Mapping Scope of Work, Appendix F in the flood risk assessment. An estimated total cost for the scope of work presented is $175,000, which includes a small contingency of $15,000 to account for potential increases in cost resulting from high demands for these services at this time.

Legal Factors

Stakeholders and the community have raised concerns over how the results of this report may impact future planning, development, construction and insurance.

Section 4.7 of the report states: "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. High-level mapping was developed to support discussions with stakeholders and to support the development of a high-level risk assessment. The modelling and mapping is not suitable for planning or engineering design".

The Comox Valley Emergency Program is seeking approval to apply for funding to obtain flood mapping for this area through the NDMP and/or the Union of BC Municipalities Community Emergency Preparedness Fund. If approved and flood mapping is achieved, it is anticipated that the results will be suitable for consideration in planning and engineering design.

Regional Growth Strategy Implications

This project aligns with the goals and objectives of the Comox Valley Regional Growth Strategy, specifically Objective 8-F: Plan for climate change adaptation. Supporting policy is:

8F-2 Promote inclusion of climate change modeling and impacts in future infrastructure and resource studies.

Intergovernmental Factors

Although the study area that this report refers to is primarily within the CVRD, the boundaries do extend across the Oyster River into the SRD. This additional area includes a portion of the Oyster River community as well as the CVRD's water service wells and the Glenmore Dike. As such, the application for funding was a collaborative effort made on behalf of both the CVRD and SRD, with both providing in-kind contributions. The CVRD maintained control of the project and provided all project management.

If the request to apply for additional grant funding to obtain flood mapping for the project area is approved, the application will again be made on behalf of both the CVRD and SRD.

Interdepartmental Involvement

Planning and development services branch, corporate services branch, executive management and community services branch all provided input. The Comox Valley Emergency Program provided overall project management and preparation of this report.

As part of a separate, broader interdepartmental project, the CVRD intends to apply for funding from the NDMP and CEPF to obtain new flood mapping for a more extensive area. The funding would enable the CVRD to update the Floodplain Management Bylaw to reflect the recent amendment to the Provincial Flood Plain Guidelines in January 2018. This valuable data would be used to update other CVRD policies and bylaws such as the Official Community Plan and Zoning Bylaw to regulate and guide future development. Departments from engineering services, community services, planning and development services and corporate services will work together to ensure a coordinated approach.

Citizen/Public Relations

Staff has worked closely with stakeholders in the development of this report, including government, business, and community. Initial mapping presented for discussion at a stakeholder meeting raised concerns around future planning, development, construction and insurance. The report however identifies that, the modelling and mapping is not suitable for planning or engineering design. Moving forward we will continue to engage with stakeholders through report distribution and public education. If funding for flood mapping is approved, consultation with stakeholders will continue throughout the next phase.

Attachments:

Appendix A – "Comox Valley Regional District Oyster River/Saratoga Beach Flood Risk Assessment Final Report"

Appendix B –"Risk Assessment Information Template"

Comox Valley Regional District
Oyster River/Saratoga Beach Flood Risk Assessment
Final Report

May 3rd, 2018

ebbwater
CONSULTING

Cover Photo: Mouth of the Oyster River

Acknowledgements

The authors wish to acknowledge the backing of the Comox Valley Regional District and Strathcona Regional District staff who initiated the project and supported throughout. George Doerksen and Howie Siemens, both of the CVRD provided invaluable edits to the reporting. We also wish to thank the many public and stakeholder participants who contributed to the understanding of flood impacts in the region.

Support for this project came from the National Disaster Mitigation Program (NDMP) as part of its commitment to building safer and more resilient communities.

The report was written by Tara Sherman, P.Eng., Heather Murdock, P.Eng., and Nikoletta Stamatatou of Ebbwater Consulting. Hydrologic review was conducted by Silja Hund, M.Sc.. The report was reviewed by Tamsin Lyle, P.Eng., principal engineer with Ebbwater Consulting.

Executive Summary

The community of Oyster River / Saratoga Beach is working to become more resilient to floods and to lay the foundation for future flood mitigation plans. As an initial step, the Comox Valley Regional District (CVRD) and Strathcona Regional District (SRD) applied for and received funding from the National Disaster Mitigation Program (NDMP) to conduct a Stream 1 Flood Risk Assessment project. The NDMP is designed to progressively move communities towards disaster risk reduction by completing projects in each stream successively. A Stream 1 project – a risk assessment – is the first step in the process.

A risk assessment is simply a description of the combined impact of a hazard event (like a flood) and the likelihood of that event occurring. The objective of this project was to develop a risk assessment that would a) meet the needs to the NDMP and b) would support future flood mitigation planning in the community. To support this work a variety of tasks were completed to better understand the flood hazard and the impacts of flooding on the Oyster River / Saratoga Beach community in the present-day, and in future with climate change.

Hazard Assessment

A simplified hazard assessment for both the present day and with future climate change was made using available information, including old bathymetric data and hydraulic modelling updated with new understanding of hydrology and sea conditions. Both riverine and coastal flood hazard was considered for the present day and in future with climate change. The hazard information, which is high-level and not suitable for engineering design, is presented as a hazard extent map. This hazard extent mapping provides bounds for the impact assessment.

Impact Assessment

An impact assessment was conducted to understand the potential consequences of flooding in the community. A holistic approach, where a broad range of impact categories were considered was taken. This required a mix of quantitative and qualitative approaches to the analysis. In some cases, geospatial data (such as building footprints) was used to establish impacts. Whereas, in other cases, the analysis relied on qualitative information gathered from stakeholders. Some key findings of the impact assessment are:

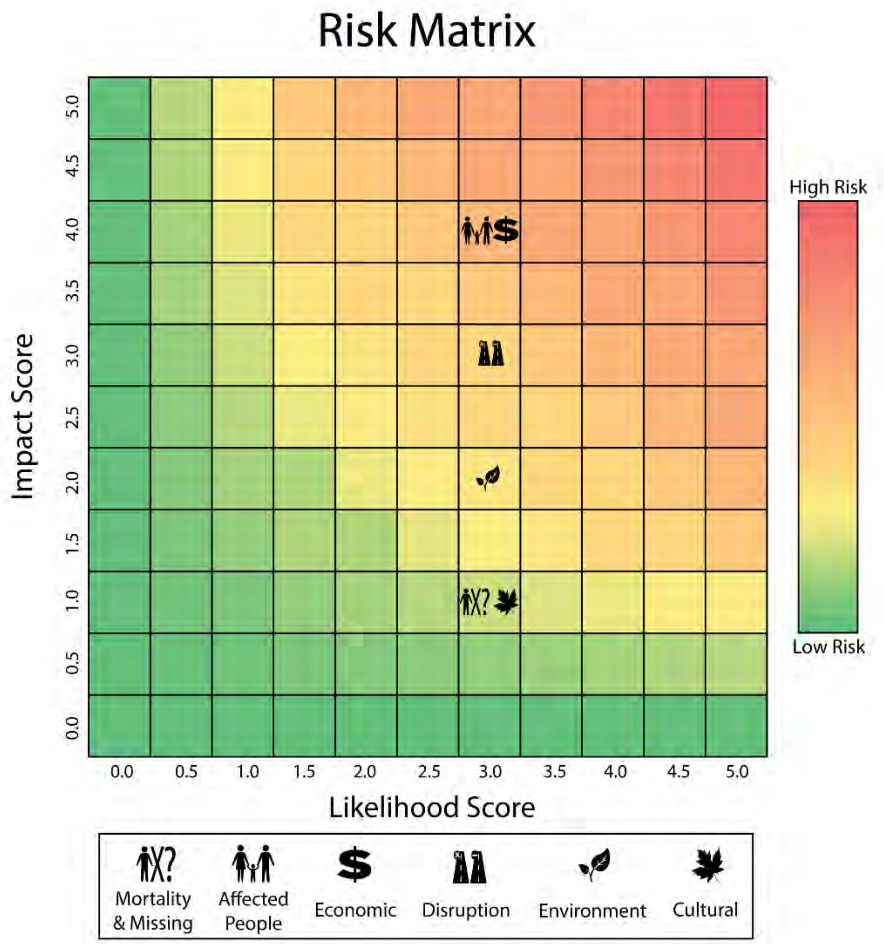
- Many people (approximately 550) would be affected by a flood, both in the present-day and in future. This is because of the relatively large population that resides on the flood hazard areas.
- The economic impacts of a flood would also be considerable. At present, the estimated value of exposed property in the floodplains is $226M. Further, there are several businesses that would be directly impacted by a flood – these were identified by stakeholders.

- Potential disruption of services is also a key impact that was identified through this work. There are several key access/egress roads that could potentially be cut-off by a flood, and there were also several well-heads within the floodplain – that if flooded could impact drinking water delivery to the community.

The analysis shows that there are many and diverse impacts and these are spread out across the entire floodplain. When considering all the impact categories – there are no identifiable hot zones (i.e. a single area where most impacts are noted) that could be the focus of future mitigation planning. Rather, the impact mapping shows that flood will affect all areas (both coastal and riverine) and that reach-scale planning would be appropriate.

Risk Assessment

A risk assessment was completed that combined the results of the impact assessment with an understanding of the likelihood of a present-day flood event and a future flood event with climate change. The results are presented in the graphic below.



It is clear from the above analysis that affected people and economic damage risk is significant in both the present-day and in the future with climate change. Disruption is also relatively significant.

In summary, there is a significant flood risk in the region. Risk reduction should be a priority for the CVRD and the SRD, as well as for Provincial authorities.

Recommendations and Next Steps

A number of recommendations and next steps are provided that will support the community in its journey towards flood resiliency. Chief among these is the need for the community to pursue funding to develop up-to-date, modern flood hazard mapping. A cost estimate for this work ($175k) is presented, along with a list of potential funding agencies. Materials appropriate to support grant applications (scope of work, completed risk assessment template form) are also provided.

Contents

ACKNOWLEDGEMENTS I

EXECUTIVE SUMMARY II

1 INTRODUCTION 1

1.1 PROJECT OBJECTIVES 1
1.2 REPORT STRUCTURE 1

2 PROBLEM STATEMENT 3

2.1 HISTORICAL FLOODS 3
2.2 PROJECT GEOGRAPHIC SCOPE 5

3 FLOOD RISK ASSESSMENT PRIMER 6

3.1 WHAT IS NATURAL HAZARD RISK? 6
3.2 WHAT IS A RISK ASSESSMENT? 6
3.3 RISK ASSESSMENT SCALE FOR OYSTER RIVER/SARATOGA BEACH 8
3.4 INDICATORS FOR RISK ASSESSMENT 10
3.5 IMPACT TYPES 11
3.6 IMPACT TYPES FOR OYSTER RIVER/SARATOGA BEACH 12
3.7 SUMMARY 14

4 FLOOD HAZARD 15

4.1 RIVERINE HAZARD OVERVIEW 15
4.2 COASTAL HAZARD OVERVIEW 15
4.3 HAZARD LIKELIHOOD 17
4.4 OYSTER RIVER WATERSHED CHARACTERISTICS 18
4.5 PREVIOUS HAZARD MODELLING 21
4.6 NEW HIGH-LEVEL HAZARD MODELLING 22
4.7 LIMITATIONS OF MODELLING AND MAPPING 28

5 EXPOSURE AND VULNERABILITY 29

5.1 METHODS 29
5.2 RESULTS 30
5.3 DISCUSSION 40

6 RISK ASSESSMENT 41

6.1 LIKELIHOOD SCORING 41
6.2 IMPACT SCORING 42
6.3 RISK SCORING 44

7 RESILIENCE PLANNING 47

7.1 STAKEHOLDER-IDENTIFIED RESILIENCE 47
7.2 BEST PRACTICE FOR FLOOD MANAGEMENT 48
7.3 IMPLEMENTING BEST PRACTICE THROUGH A STEP-WISE PROCESS 50

7.4 PROGRESS TOWARDS RESILIENCY IN OYSTER RIVER/SARATOGA BEACH 52

8 RECOMMENDATIONS 53

8.1 QUICK WINS FOR THE COMMUNITY 53
8.2 CONSIDERATIONS FOR FUTURE FUNDING STREAMS 54
8.3 LONG-TERM STEPS TO TAKE 55

9 CONCLUSIONS 56

10 GLOSSARY 57

11 REFERENCES 60

APPENDIX A RISK ASSESSMENT (GENERIC)

APPENDIX B COMPLETED RAIT FORM

APPENDIX C WORKSHOP MATERIALS

APPENDIX D HAZARD METHODS AND LIMITATIONS

APPENDIX E DATA SUMMARY

APPENDIX F FLOOD MAPPING SCOPE OF WORK

Figures

FIGURE 1: OYSTER RIVER FLOODING, DECEMBER 2014 (CAMPBELL RIVER MIRROR, 2014) 3
FIGURE 2: HIGH WATER ON OYSTER RIVER AT HIGHWAY 19 BRIDGE, DECEMBER 2014 (CAMPBELL RIVER MIRROR, 2014) ... 4
FIGURE 3: TIMELINE OF FLOOD EVENTS 4
FIGURE 4: FLOOD RISK ASSESSMENT AREA OF INTEREST 5
FIGURE 5: RISK AS A FUNCTION OF HAZARD, VULNERABILITY, AND CONSEQUENCE 6
FIGURE 6: SCALES OF RISK ASSESSMENT 7
FIGURE 7: NATIONAL RISK PROFILE IMPACT CATEGORIES 11
FIGURE 8: EXAMPLES OF DIRECT FLOOD IMPACTS THAT COULD BE SEEN IN OYSTER RIVER/SARATOGA BEACH 13
FIGURE 9: EXAMPLES OF INDIRECT FLOOD IMPACTS THAT COULD BE SEEN IN OYSTER RIVER/SARATOGA BEACH 14
FIGURE 10: COMPONENTS OF TOTAL WATER LEVEL 16
FIGURE 11: COMPONENTS OF SEA LEVEL RISE 17
FIGURE 12. EXPANDING FLOOD HAZARD AREAS UNDER SEA LEVEL RISE 17
FIGURE 13: OYSTER RIVER WATERSHED 19
FIGURE 14: SUMMARY HYDROGRAPHS FOR OYSTER RIVER (AT GAUGE) 20
FIGURE 15: SUMMARY MEAN MONTHLY FLOWS FOR OYSTER RIVER (AT GAUGE) 21
FIGURE 16: OYSTER RIVER FLOOD HAZARD MAP, MULTIPLE FLOOD SCENARIOS 27
FIGURE 17: HOTSPOT MAP OF AFFECTED PEOPLE AS REPORTED BY STAKEHOLDERS IN WORKSHOPS 31
FIGURE 18: POPULATION DENSITY IN OYSTER RIVER BY DISSEMINATION AREA FOR 0.5% AEP FLOOD HAZARD AREA 32
FIGURE 19: POPULATION DENSITY IN OYSTER RIVER BY DISSEMINATION AREA FOR 0.2% AEP FLOOD HAZARD AREA WITH CLIMATE CHANGE 33
FIGURE 20: ECONOMIC IMPACT OF FLOODING IN OYSTER RIVER AS REPORTED BY STAKEHOLDERS 34
FIGURE 21: ECONOMIC EXPOSURE IN OYSTER RIVER 0.5% AEP FLOOD HAZARD AREA 35

FIGURE 22: ECONOMIC EXPOSURE IN OYSTER RIVER 0.2% AEP FLOOD HAZARD AREA WITH CLIMATE CHANGE 36
FIGURE 23: DISRUPTION DUE TO FLOODING IN THE OYSTER RIVER FLOOD HAZARD AREA AS REPORTED BY STAKEHOLDERS ... 37
FIGURE 24: DISRUPTION DUE TO FLOODING IN THE OYSTER RIVER FLOOD HAZARD AREA 38
FIGURE 25: ENVIRONMENTAL CONCERNS DUE TO FLOODING WITH INPUT FROM STAKEHOLDERS..................................... 39
FIGURE 26: SUMMARY OF FLOOD RISK FOR PRESENT-DAY 45
FIGURE 27: KEYWORDS FROM RESIDENTS ABOUT WHAT WATER MEANS TO THEM 47
FIGURE 28: NATURAL HAZARD RISK.. 49
FIGURE 29: 8-STEP PLANNING PROCESS FOR FLOOD RISK REDUCTION... 51

TABLES

TABLE 1: SUMMARY OF RISK ASSESSMENT COMPONENTS 9
TABLE 2: EXAMPLES OF FLOOD IMPACT TYPOLOGIES 12
TABLE 3: ENCOUNTER PROBABILITIES FOR VARIOUS FLOOD LIKELIHOODS. 18
TABLE 4: WATERSHED AREA OF OYSTER RIVER TRIBUTARIES... 19
TABLE 5: ESTIMATED FLOWS FOR THE OYSTER RIVER AT THE MOUTH FOR THE FIRST 17 YEARS OF AVAILABLE HYDROMETRIC DATA 24
TABLE 6: ESTIMATED FLOWS FOR THE OYSTER RIVER AT THE MOUTH FOR THE LAST 20 YEARS OF AVAILABLE HYDROMETRIC DATA 24
TABLE 7: ESTIMATED FLOWS FOR THE OYSTER RIVER AT THE MOUTH FOR ENTIRE HYDROMETRIC RECORD 24
TABLE 8: FLOW ESTIMATES FOR OYSTER RIVER AT THE MOUTH WITH CLIMATE CHANGE 26
TABLE 9: LIKELIHOOD RATING FOR RISK ASSESSMENT 41
TABLE 10: IMPACTS RATINGS 42
TABLE 11: IMPACT SCORES FOR OYSTER RIVER/SARATOGA BEACH 43
TABLE 12: SUMMARY FOR PRESENT-DAY FLOOD RISK 44
TABLE 13: SUMMARY FOR FUTURE FLOOD RISK WITH CLIMATE CHANGE 44

LIST OF ACRONYMS

AEP	Annual Exceedance Probability
AHRA	All-Hazards Risk Assessment
AOI	Area of Interest
BC CEPF	BC Community Emergency Preparedness Fund
CGD	Canadian Geodetic Datum
CVRD	Comox Valley Regional District
DEM	Digital Elevation Model
DMAF	Disaster Mitigation and Adaptation Fund
FDRP	Flood Damage Reduction Program
GEV	Generalized Extreme Value
GIS	Geospatial Information System
HHWMT	Higher High Water Mean Tide
IPCC	Intergovernmental Panel on Climate Change
NDMP	National Disaster Mitigation Program
PCIC	Pacific Climate Impacts Consortium
PSC	Public Safety Canada
QRA	Quantitative Risk Assessment
RAIT	Risk Assessment Information Template
RIBA	Royal Institute of British Architects
SLR	Sea Level Rise
SRD	Strathcona Regional District
SS	Storm Surge
SU	Set-up
SWL	Still Water Level
UN	United Nations
UN-ISDR	United Nations Office for International Strategy for Disaster Risk Reduction
US NOAA	US National Oceanic and Atmospheric Administration
WSC	Water Survey of Canada

1 Introduction

Floods matter; they matter a lot. People whose homes are flooded or damaged will remember it for the rest of their lives; landscapes are changed forever; regional and national economies suffer. The community of Oyster River/Saratoga Beach is no stranger to flood issues, with recent and notable events in 2011 and 2014. Further, it is expected that flood hazards will become more severe in the coming years and it is important to understand and prepare for this.

In the wake of the Alberta and Ontario floods of 2013, the federal government established the National Disaster Mitigation Program (NDMP) in April 2015. The program has several priorities including providing support to provinces to identify and mitigate high-risk flood areas and to collect disaster risk information.

The Comox Valley Regional District (CVRD) and its neighbour, the Strathcona Regional District (SRD), were successful applicants to the NDMP and have embarked on a Stream 1 Risk Assessment Project. This will allow the regional districts to access additional flood mitigation and adaptation funds and can also serve as a stepping stone for the community to develop future flood mitigation plans.

1.1 Project Objectives

Best practice dictates that flood mitigation be achieved through a thoughtful, risk-based planning process based on community values and the consideration of a range of hazard levels. The **primary objective of the current project is to better understand the present-day flood risk in the community**. This will help to inform future flood mitigation efforts, including policy and emergency planning. It will also be used to inform the public and other stakeholders of the present-day and future risk from riverine and coastal flooding.

A secondary objective of this work is to position the CVRD and SRD to be able to capitalize on future funding programs through the **completion of a Risk Assessment Information Template (RAIT)**. A completed RAIT, or a variation of it, is a required component of federal (NDMP) and provincial (Community Emergency Preparedness Fund, CEPF) funding programs. These programs can provide support for flood science, flood planning, and both structural and non-structural flood mitigation.

Oyster River/Saratoga Beach is a beautiful place to live, work, and visit. A better understanding of flood risk in the community with a strong understanding of both hazard and vulnerability will help build a strong foundation for future work to mitigate the effects of flooding. Working towards a flood resilient future will help the community continue to prosper.

1.2 Report Structure

This report includes a discussion of the problems faced by the community (Section 2). This is followed by background information on flood risk assessment process and methods (Section 3). Next is a description of the flood hazard in the community, providing some historical context as well as a description of the estimated present-day and future (with climate change) hazard (Section 4). This is followed by an outline of community exposure and vulnerability to flood that provides both quantitative and qualitative measures of impact for various impact categories (Section 5). Next is a summary of flood risk—the combination of hazard, likelihood, and impact (Section 6). In addition to the risk information, there is a discussion of best practice for flood management (Section 7), that provides a basis for recommendations (Section 8), and a brief closing statement (Section 9).

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 NDMP program, and Appendix B, which provides a completed RAIT for the current NDMP program. The report also includes a summary of the stakeholder workshop 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.

2 Problem Statement

The Oyster River/Saratoga Beach community is an area that is historically prone to flooding from high river flows as well as coastal storm surge. With sea level rise affecting the coastal hazard severity and climate change influencing weather patterns, these sources of flood hazard are expected to increase for the community in the future.

Part of the Oyster River/Saratoga Beach community is located within the flood hazard area, exposing many important assets to the hazard. Specifically, certain infrastructure on which the community depends, such as the drinking-water extraction wells, is vulnerable to flooding. Both the flood hazard generally and the community vulnerability were identified as concerns by the clients at the outset of the project.

2.1 Historical Floods

The community of Oyster River/Saratoga Beach has faced several historic flood events, which prompted the construction of dikes for flood protection and the installation of riprap to prevent erosion. Several events in the last decade have caused renewed concern for flooding in several areas of the community. Most recently, in December 2014, rain in the Oyster River catchment resulted in the flooding of the river, which caused property damage. Photos from this event can be found below in Figure 1 and Figure 2.

Figure 1: Oyster River Flooding, December 2014 (Campbell River Mirror, 2014)

Figure 2: High Water on Oyster River at Highway 19 Bridge, December 2014 (Campbell River Mirror, 2014)

As was the case in 2014, flooding in Oyster River/Saratoga Beach typically occurs in the months of November and December. The timeline of past events seen in Figure 3 highlights this trend. In 1975, a high discharge in the river caused bank erosion, and events in 1980 and 1990 caused property damage. In 2009, a dike break occurred and homes were flooded, while in 2010, a combination of high groundwater levels and river flooding posed problems. In 2011, the ocean levels also played a role with a combination of high tide and groundwater levels contributing to the flood hazard.

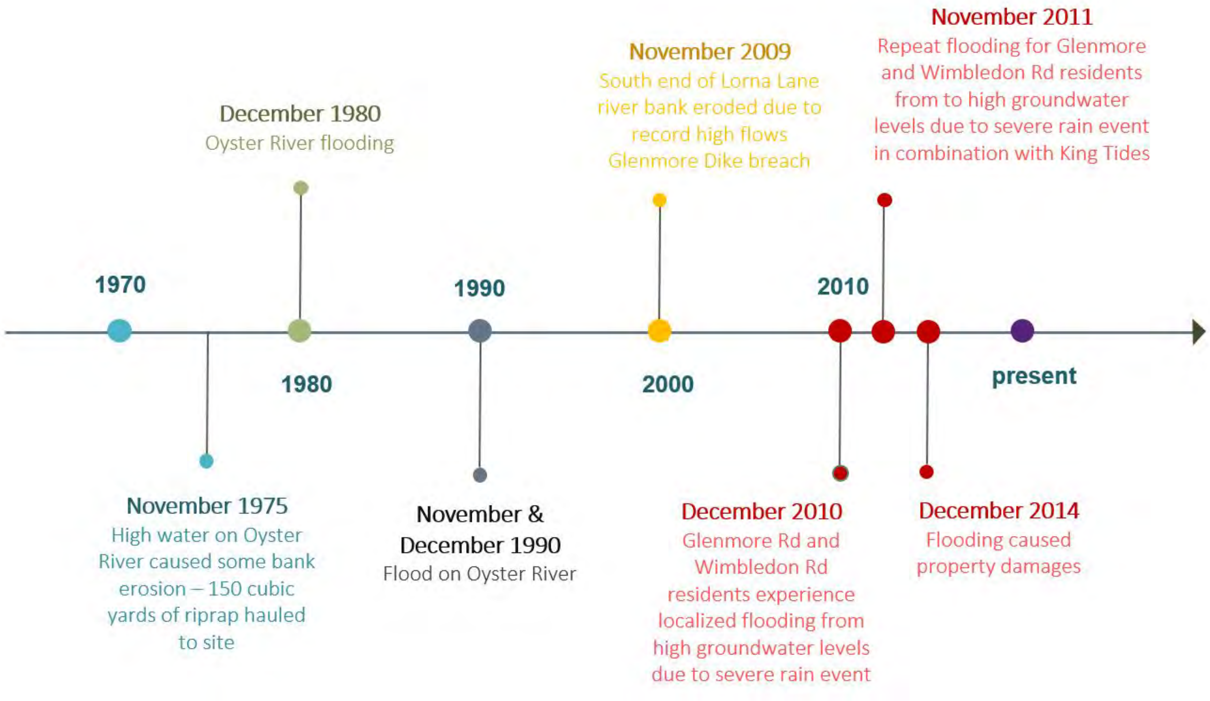


Figure 3: Timeline of Flood Events

These historic events paint a picture of the multiple components of flood hazard for the community. The solutions to flooding will need to consider the complex hazard along with the specific impacts and risks in the community.

2.2 Project Geographic Scope

The historic and recent flood events have prompted the local governments (CVRD and SRD) to begin to develop plans to mitigate risk in the area. Specifically, the CVRD and SRD identified that a flood risk assessment needed to be developed for the Oyster River flood hazard area (riverine flood) and Saratoga Beach (coastal flood) areas. The area of interest was defined by the client at the outset of the project and adjusted slightly to include an additional portion at the southern extent to better match with the CVRD planning area, and was extended northward, using the existing flood mapping, to bound the largest likely extent of future flooding. The focus of this project was limited to the Area of Interest (AOI) as shown in the map below (Figure 4).

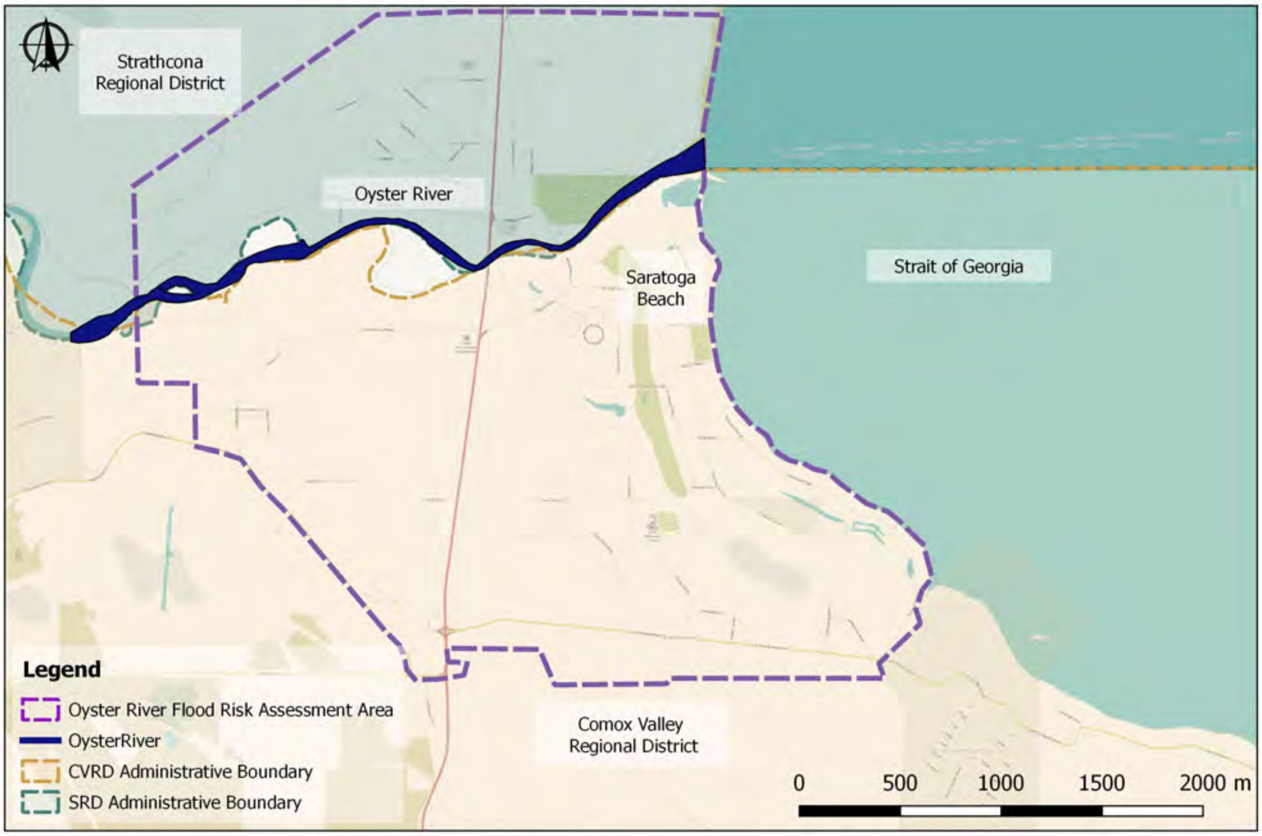


Figure 4: Flood Risk Assessment Area of Interest

3 Flood Risk Assessment Primer

This section provides background information on flood risk assessment in general and provides a framework for the rest of the report, which steps through the methods and results for each of the components of the risk assessment developed for the Oyster River/Saratoga Beach area.

3.1 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 5). **Consequence** is defined as a 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?).

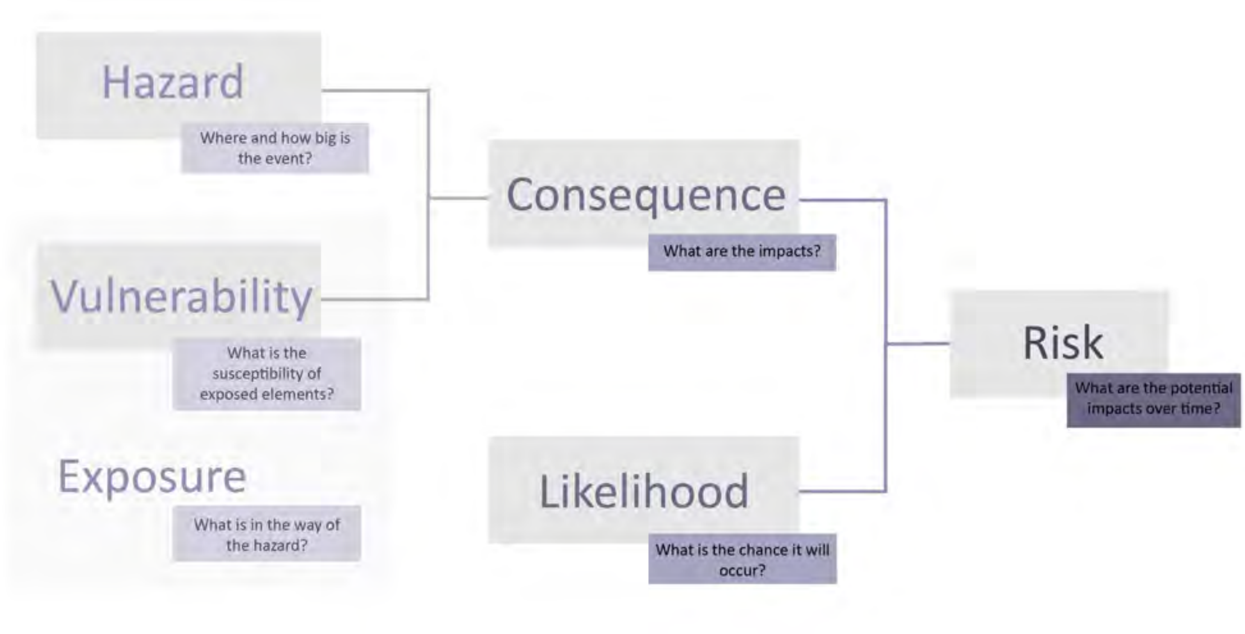
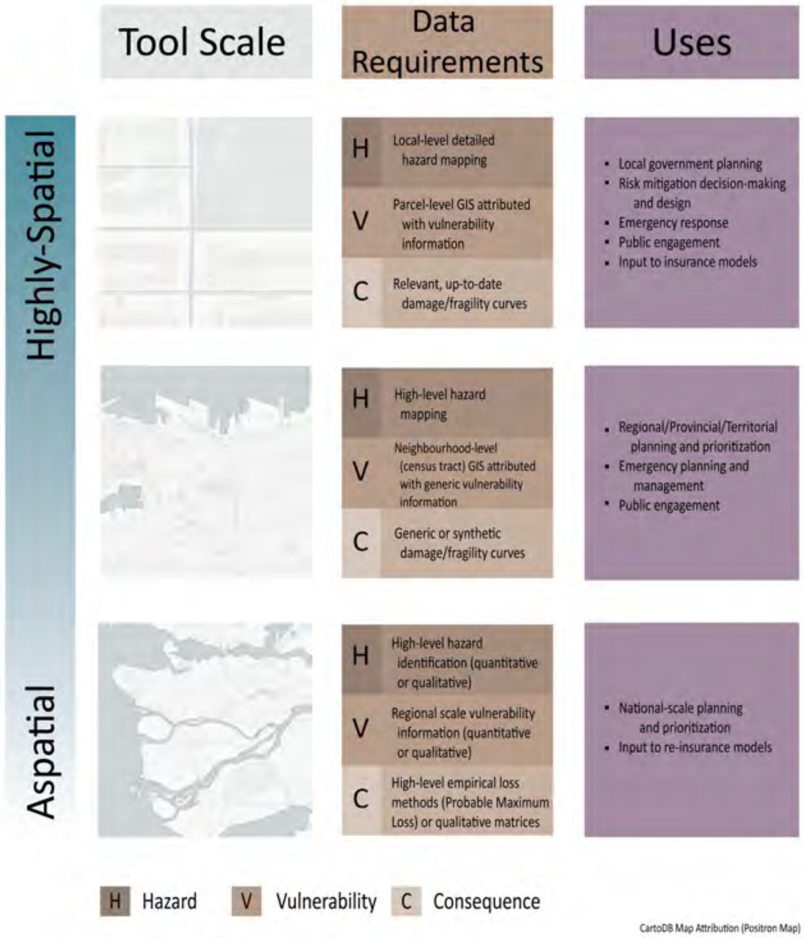


Figure 5: Risk as a Function of Hazard, Vulnerability, and Consequence

3.2 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 6).



CartoDB Map Attribution (Positron Map)

Figure 6: 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.

3.2.1 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.

3.2.2 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.

3.2.3 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.

3.3 Risk Assessment Scale for Oyster River/Saratoga Beach

The CVRD/SRD team has two objectives for this project. First, to complete a risk assessment that would support future planning for disaster risk reduction, and second, to complete a RAIT. These are quite different as they fall at opposite ends of the scale (see Figure 6). The RAIT requirements[i] fall towards the

---

[i] 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).

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 1, with components focused on in this project highlighted in green.

Table 1: 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 is not suitable, and new mapping from this and other work does not meet current guidelines or best practice.
	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 methods for intangible consequences are weak.
Aspatial (for Provincial and National prioritization; suitable for the RAIT)	**Hazard** High-level identification and understanding.	**Available**. Taken from old mapping and improved through preliminary inclusion of climate change.
	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 3.4 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.

3.4 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 7: 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 7). 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 and proxy 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.

3.5 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.

3.5.1 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.

3.5.2 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 2 provides examples of direct/indirect and tangible/intangible impact typologies.

Table 2: Examples of Flood Impact Typologies

Form of Damage/Measurement	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

Source: (Frank Messner et al. 2006)

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 and 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 Impact Types for Oyster River/Saratoga Beach

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, and an overview of the general types of flood impacts that were considered is presented below.

3.6.1 Summary of Direct and Indirect Impacts

Direct impacts of flooding for Oyster River/Saratoga Beach 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 two bridge crossings and so is vulnerable to north-south access being cut off if these crossings are damaged or flooded. Some of these direct impacts are highlighted below in Figure 8.

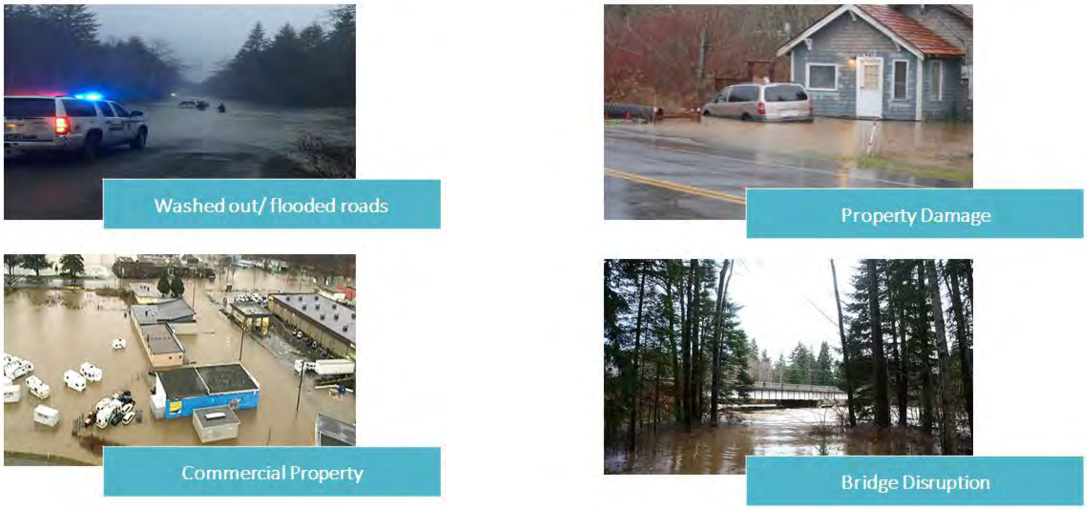


Figure 8: Examples of Direct Flood Impacts that could be seen in Oyster River/Saratoga Beach

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 loss of access to education, transportation disruption, loss of recreation, and drinking water contamination. 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 that might be seen in Oyster River/Saratoga Beach are highlighted below in Figure 9.

Figure 9: Examples of Indirect Flood Impacts that could be seen in Oyster River/Saratoga Beach

3.7 Summary

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 for recent clients (City of Vancouver, City of Dawson Creek, Public Safety Canada, Infrastructure Canada) and adapted for the Oyster River/Saratoga Beach area. 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 below meets and exceeds current best practice and is suitable for input into the RAIT form.

4 Flood Hazard

Hazard and the associated likelihood are key components of a risk assessment—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 means 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). For coastal areas, the process is similar and requires an understanding of the conditions in the ocean that are then translated into water levels on the shore.

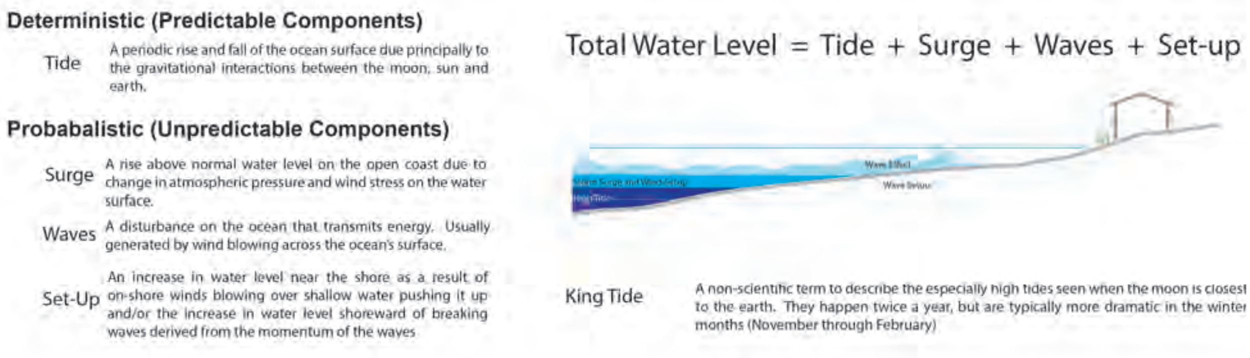
The following describes the general flood hazard for the Oyster River/Saratoga Beach area. The scope of work for this project did not include a detailed hazard assessment, and therefore there are considerable limitations associated with the information presented below. However, the results of this project (a completed risk assessment) will provide the client 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).

4.1 Riverine Hazard Overview

An understanding of flood hazard tells us where the water is going to go, how high it will be, and how fast. Along the Oyster River, flooding typically occurs in the watershed with heavy rainfall resulting from storms originating in the tropics in winter months. If there is a snowpack present, then warm weather and intense rain can cause significant snowmelt that adds to the total volume of water. In addition, high tides, king tides, or storm surges can affect the discharge capacity of the river. When the sea level is higher than normal, the water flowing down the river cannot discharge into the ocean easily (this is called "backwatering"). Finally, multiple consecutive days of rain can mean that groundwater levels are already high, and floodwaters will not be able to dissipate through infiltration. Unfortunately, the drivers of both high ocean levels and heavy rainfall events are the same, and therefore it is probable that both high flows and high ocean water levels will coincide.

4.2 Coastal Hazard Overview

Further to the hazard from the river (riverine hazard), present-day flood hazard results when water levels are higher than normal in the Strait of Georgia. Water levels in the ocean off the coast are a function of many components. Some of these components are deterministic (predictable), such as tides. Other components are probabilistic (unpredictable); these are factors that increase water levels as a result of storm events, which include storm surge, set-up, and waves. These are called residuals. For the probabilistic components, there is an understanding of the probability of a certain event occurring, but there is no ability to predict when it will occur. The total water level is the sum of all the components and represents the height of water (Figure 10).



Deterministic (Predictable Components)

Tide — A periodic rise and fall of the ocean surface due principally to the gravitational interactions between the moon, sun and earth.

Probabalistic (Unpredictable Components)

Surge — A rise above normal water level on the open coast due to change in atmospheric pressure and wind stress on the water surface.

Waves — A disturbance on the ocean that transmits energy. Usually generated by wind blowing across the ocean's surface.

Set-Up — An increase in water level near the shore as a result of on-shore winds blowing over shallow water pushing it up and/or the increase in water level shoreward of breaking waves derived from the momentum of the waves

Total Water Level = Tide + Surge + Waves + Set-up

King Tide — A non-scientific term to describe the especially high tides seen when the moon is closest to the earth. They happen twice a year, but are typically more dramatic in the winter months (November through February)

Figure 10: Components of Total Water Level

4.2.1 Sea Level Rise

In addition to the present-day coastal hazard from tides and storm events, sea level rise means that the still-water elevation of the oceans surrounding the CVRD and SRD will rise.

The Intergovernmental Panel on Climate Change (IPCC Working Group 1 2014) reports that ocean thermal expansion and glacial melt have been the dominant contributors to 20th century global mean sea level rise. Local relative sea level rise is a function of global sea level rise, but is also impacted by regional ocean currents and local geology (U.S. NOAA n.d.). Further, local relative sea level rise is impacted by local tectonics – local vertical land movements, either up (uplift) or down (subsidence), affects relative sea level rise. In Campbell River (the closest location on Vancouver Island for which there is data), the general trend is one of slow uplift (James et al. 2014), but robust projections are unavailable, and therefore are not generally included in analyses. The rate of sea level rise, globally and locally, is uncertain, but for planning purposes best estimates from when the project was initiated in 2012 were used. In general, a 1 metre increase in mean sea levels from the year 2000 to 2100 was used as the basis of the initial analysis (Ausenco-Sandwell 2011; Bornhold 2008); this is based on guidance documents from the Province of BC.

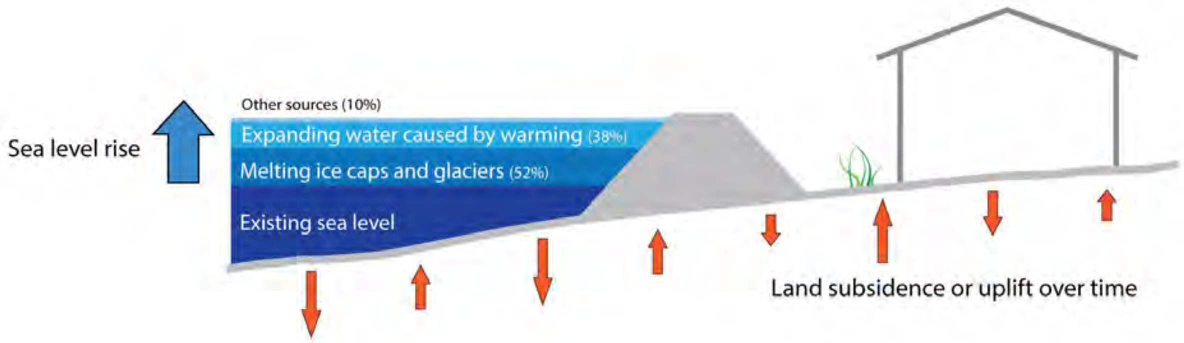


Figure 11: Components of Sea Level Rise

An increase in base ocean water level has implications for both the extent and depth of flooding (Figure 12). This has significant implications for the Saratoga Beach area.

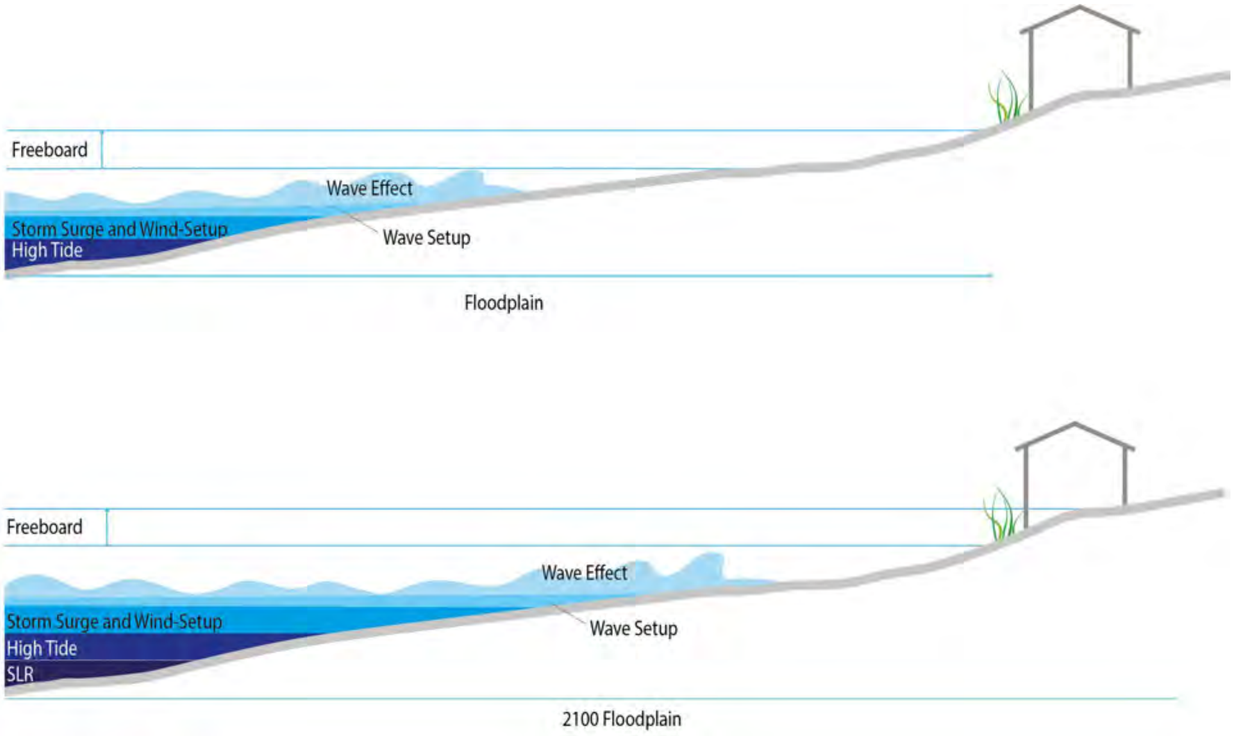


Figure 12. Expanding Flood Hazard Areas Under Sea Level Rise

4.3 Hazard Likelihood

In addition to an understanding of where water will go in a flood, it is important to consider the likelihood of an event occurring. This is generally represented as an Annual Exceedance Probability (AEP). Where, the AEP refers to the probability of a flood event occurring in any year, where the probability is expressed 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. 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 lay public (i.e. it is commonly understood that if a 100-year flood has occurred, it will not re-occur for another 99 years), and therefore best practice dictates the use of an AEP to describe flood likelihood. 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 3 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 3: 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 indicative	100%	100%	100%	100%
30%	Once every three years indicative	100%	100%	100%	100%
10%	Once every 10 years indicative	93%	99%	100%	100%
3%	Once every 33 years indicative	53%	78%	90%	95%
1%	Once every 100 years indicative	22%	39%	53%	63%
0.1%	Once every 1000 years indicative	2%	5%	7%	10%

4.4 Oyster River Watershed Characteristics

The Oyster River is located on the east side of Vancouver Island between Courtenay and Campbell River. It originates in the mountains of the Forbidden Plateau on Vancouver Island, and drains an area of about 376 km^2 before entering the Strait of Georgia (Figure 13). The Oyster River forms the boundary between the CVRD to the south and the SRD to the north. The Oyster River has several tributaries, which are listed in Table 4. The community of Oyster River is located just north of the river's estuary and Saratoga Beach is located to the south.

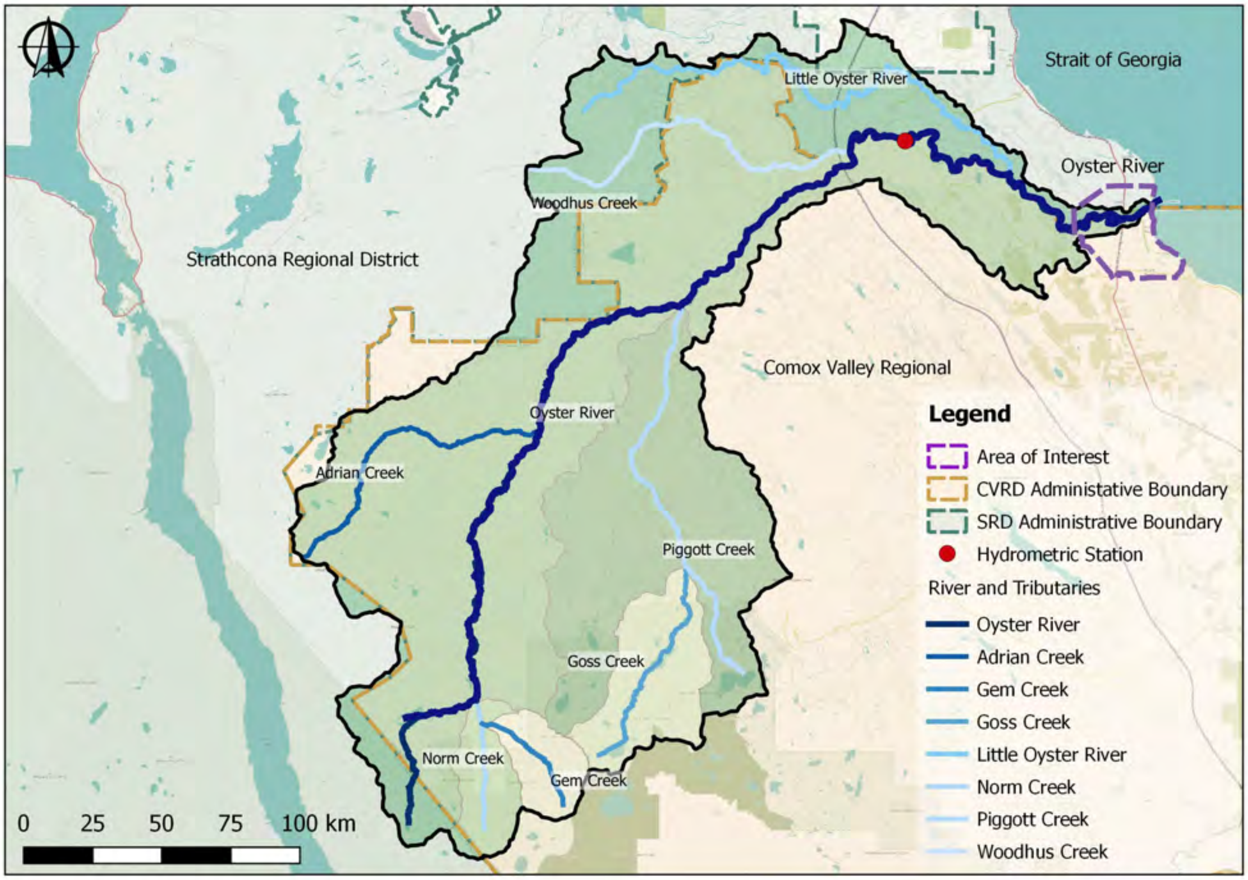


Figure 13: Oyster River Watershed

Table 4: Watershed Area of Oyster River Tributaries

Tributary Watershed	Watershed Area (**km^2**)
Little Oyster River	42 km^2
Woodhus Creek	37 km^2
Piggott Creek	91 km^2
Adrian Creek	40 km^2

The Oyster River Watershed is a relatively small watershed of about 376 km^2. Water Survey of Canada (WSC) has maintained a stream gauging station (08HD011) on the Oyster River below Woodhus Creek since 1974. The watershed area above the gauging station is about 298 km^2 and does not include the Little Oyster River watershed, which is a tributary of the Oyster River.

The Oyster River's streamflow is characterized by a high flow in November due to fall rains, and another high flow in May and June due to snowmelt from high elevations. Minimum flows generally occur between August and October (see Figure 14 and Figure 15).

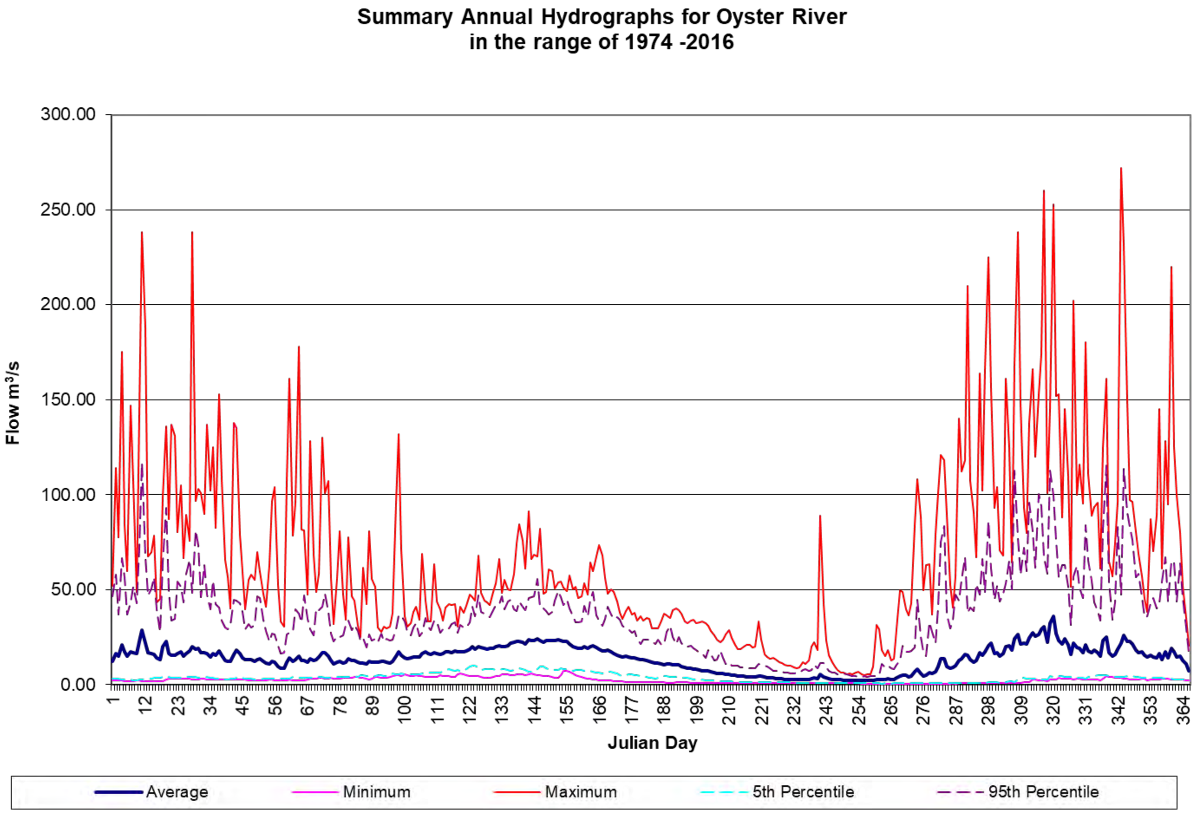


Figure 14: Summary Hydrographs for Oyster River (at gauge)

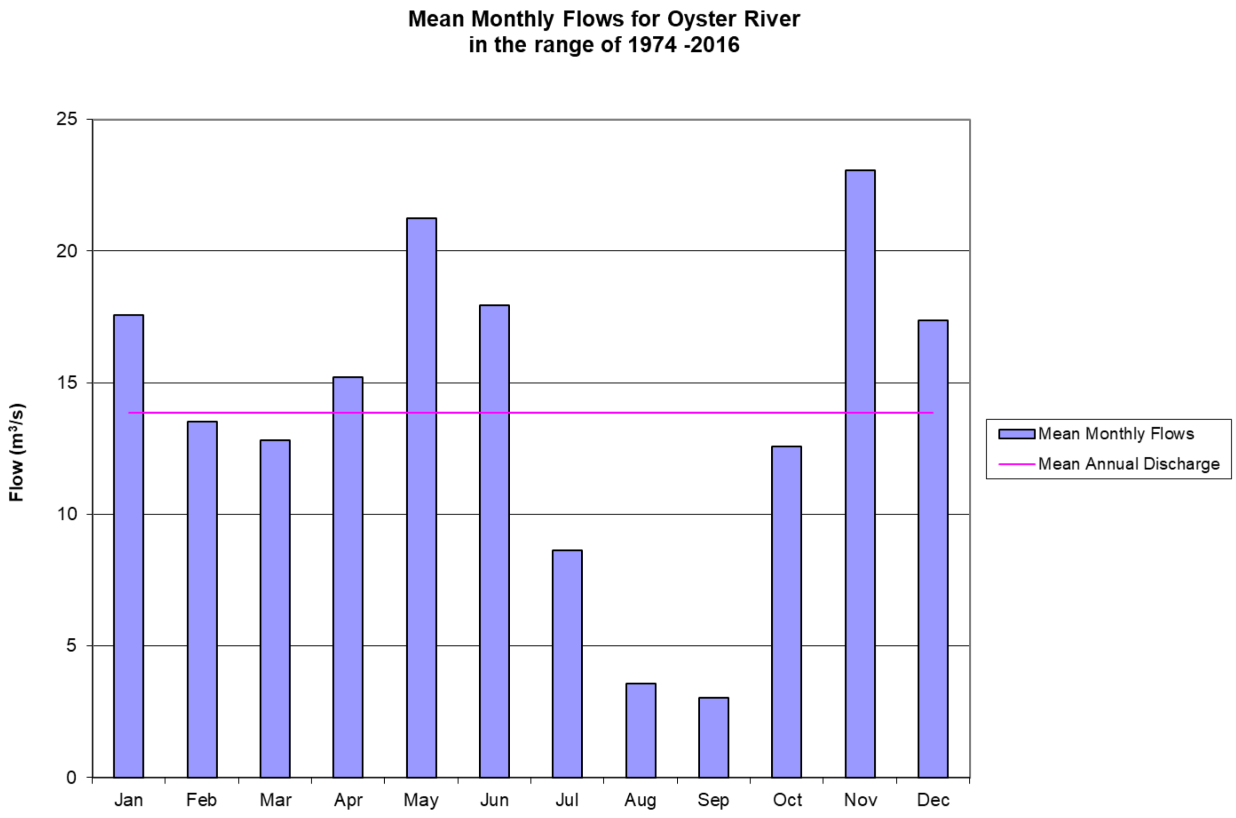


Figure 15: Summary Mean Monthly Flows for Oyster River (at gauge)

4.5 Previous Hazard Modelling

4.5.1 1984 Flood Hazard Area Mapping

Previous modelling work was done by BC Water Management Branch in 1984 as a part of the Floodplain Mapping Program. The report on this work included flood hazard area mapsheets and channel survey data (cross section and road profiles, HEC2 GR data files, bridge sketches, and plans showing location of cross sections)[ii]. This analysis, although best practice at the time, is outdated. River hydraulics are a function of the channel shape, and over the course of the last 34 years, the river bed has shifted[iii]. Also, erosion of the channel banks is known to have occurred. And therefore, the 1984 model and map are no longer valid and should be updated. Further, the hydrology calculated in 1984 was based on just a few years of record

---

[ii] The original HEC2 model from 1984 is available at the Ministry of Environment: EcoCat—The Ecological Reports Catalog (http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=2134). Oyster River Floodplain Mapping. Report ID 2134; Project #82FDC02/83FDC-02, including HEX2 GR Data files (Oyster River 1982).

[iii] No known bathymetric surveys have been conducted since 1984 that could be used for comparison. However, the general morphology of the river (braided gravel) suggests a dynamic (i.e. changing) river. This is confirmed in materials provided by the SRD and reviewed in the Dike Assessment Report (McElhanney 2017) that describe chronological changes to the river between 1975 and 2014.

(footnote continued)

at the WSC station and gave no consideration to climate change—this too needs to be updated for any new mapping. However, this does provide some high-level understanding of the hazard.

4.5.2 2017 Hydrotechnical Assessment of Glenmore Dike

In 2017, with funding from the Province, the SRD undertook an assessment of the Glenmore Dike. This assessment was completed in December 2017 by McElhanney Consulting Services Ltd.[iv]. This report includes a hydrologic assessment that uses a direct transfer of flow statistics from the WSC gauge (08HD011) to estimate design flows. A 0.5% AEP flow of 493 m^3/s is reported for the river at the dike. They also provide a design flow that incorporates consideration of climate change (567 m^3/s).

The dike assessment report includes a hydraulic analysis. A 2D HEC-RAS model was developed and run. The model details are only reported at a high level, and we are not able to provide commentary here. However, it is notable that the model was based on LiDAR, and that this would have limited the accuracy of the model within the channel (where the majority of flow conveyance is found). However, it is arguable that the modelling limitations did not affect the purpose of this model (to review the dike crest elevation).

4.6 New High-Level Hazard Modelling

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 community of Oyster River/Saratoga Beach. 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**.

The old model (1984 Provincial HEC-2) was updated to include new information. This means that the geometry from the 1984 model was used and extended to include additional flood hazard areas (based on LiDAR and DEM data provided by the client), and it was also updated with new hydrologic information.

The scope of this study was to build a simplified updated hydraulic model for the community of Oyster River/Saratoga Beach in order to update the approximate flood extents to consider climate change. The following outlines the approach taken to update the flood extents. More details are provided in Appendix D.

4.6.1 Model Geometry

A core component of a hydraulic model is the river and floodplain geometry. Generally, a hydraulic model would be developed after having collected and processed bathymetric and topographic data to represent the channel and floodplain respectively. However, as noted above, a complete updated data set of bathymetric and topographic data was not available. In the absence of new data – bathymetric data from the 1984 modelling project was used to represent the channel. The cross-sections from the 1984 model were improved in the floodplain areas with updated topographic information (LiDAR in the SRD and 1 m

---

[iv] Please note that the report was provided to Ebbwater Consulting at the end of January 2018—after the hazard modelling for this project was substantially complete.

contours in the CVRD). An updated 1-D hydraulic model was developed in HEC-RAS with this information. This was a simplified approach designed to provide an understanding of updated flood extents with climate change.

4.6.2 Model Verification

In the normal development of a hydraulic model, it would first be verified (i.e. checked to see if the overall model makes sense – does water flow downstream for example, does the model run, or does it have instabilities). Then, using available surveyed information from flood events, the model would be calibrated and validated. For 1-D HEC-RAS modelling this is usually done by adjusting the roughness coefficient (a mathematical representation of the friction across the river bed) until modelled and observed measurements match. If a second set of observed data is available – then the model would be validated, or checked, against this. However, in this case – no model calibration or validation occurred because the base information (the geometry) was known to be poor, and no observed data was available for calibration or validation. However, standard roughness coefficients (based on the field visit) were used, and the overall model was verified by comparing the results from new runs with previous (1984) modelling and mapping. Good agreement was found. Further, the model proved to be relatively insensitive to changes in roughness or flow – flood hazard is very much controlled by the channel and floodplain geometry. This again emphasizes the need for updated bathymetry, modelling and mapping.

4.6.3 Upstream Boundary

In order to provide information for the flow for the hydraulic model, historical hydrometric data from WSC was used[v] for the Oyster River below Woodhus Creek (08HD011), for 37 years in total (within the range of 1974–2016).

The return periods for the 50%, 20%, 10%, 5%, 2%, 1%, 0.5%, and 0.2% AEP events were calculated for the whole time series of average daily flows using a frequency analysis (with a GEV distribution). This data set was then adjusted to account for the additional watershed area below the gauge using a simple relationship based on relative areas.

The estimated return periods are presented for two periods of time in Table 5 and Table 6, below. The data set was split to both show the importance of the length of the data set (i.e. more data is better), but also serves to highlight how the anecdotal trend that flood hazard is worsening with time (climate change). The results indicated an approximate 10% to 30% increase in the flow between the first half of the data set and the recent half of data. The significantly lower estimated flow during the earlier period of study further supports the need for a new, up-to-date analysis. Table 7 shows the estimated flows for the entire hydrometric record; this information was used to support the flood modelling.

---

[v] https://wateroffice.ec.gc.ca/search/historical_results_e.html?search_type=station_number&station_number=08HD011&start_year=1850&end_year=2017&minimum_years=&gross_drainage_operator=%3E&gross_drainage_area=&effective_drainage_operator=%3E&effective_drainage_area=

Table 5: Estimated Flows for the Oyster River at the Mouth for the First 17 Years of Available Hydrometric Data

Years 1974–1976, and 1980–1994 (total of 17 hydrological years)

AEP	50%	20%	10%	5%	2%	1%	0.5%	0.2%
Estimated Flow (m^3/s)	271	320	348	369	390	402	411	419

Table 6: Estimated Flows for the Oyster River at the Mouth for the Last 20 years of Available Hydrometric Data

Years 1995–2015 (total of 20 hydrological years)

AEP	50%	20%	10%	5%	2%	1%	0.5%	0.2%
Estimated Flow (m^3/s)	291	355	397	433	474	500	522	548

Table 7: Estimated Flows for the Oyster River at the Mouth for Entire Hydrometric Record

AEP	50%	20%	10%	5%	2%	1%	0.5%	0.2%
Estimated Flow (m^3/s)	281	341	379	410	445	466	**484**	504

The results of the hydrological analysis were used as inflows to the upstream end of the hydraulic model. However, given the cursory nature of the analysis, these **should not be used for planning or engineering design**. A preliminary estimate of a 0.5% AEP flood event of 484 m^3/s was calculated. This is similar to the number reported in the dike assessment report (493 m^3/s). It should be noted that the analysis also clearly shows an increasing trend over time (i.e., the first half of the record results in a much lower number than using the second half of the record). This should be considered as part of any future hydrologic analysis.

4.6.4 Downstream Boundary

The boundary conditions for the hydraulic model were updated based on available data. No new analyses were conducted for this project, and instead we relied on data and analyses completed by others for neighbouring communities.

Boundary conditions in the downstream end of the river assumed a zero-water surface level, increased with a combination of extreme tide and storm surge. More specifically, according to a study conducted for the Town of Comox (Lazo Road)[vi] the adopted reference still water level (SWL) can be calculated based on the Higher High Water Mean Tide (HHWMT), Storm Surge (SS) and Set-Up (SU) as:

SWL = HHWMT + SS + SU = 1.5 + 0.5 + 0.8 = 2.8 m CGD (Present), as the chance of an extreme storm surge and maximum wave set-up coinciding with a very high astronomical tide is small.

[vi] http://comox.ca/modx/assets/pdfs/public works/capital projects/2016 Lazo Construction/Lazo Road - Wave Assessment.pdf

The approach used in the Town of Comox work is based on a simplified combined probability approach to developing total water levels and is appropriate for the purpose of the analysis. There are however limitations to this method and to the direct transfer of the results to the Saratoga Beach area:

- The storm surge (SS) estimate of 0.5 m is lower than that used by other local governments along the Strait of Georgia—storm surges in the order of 1.0 m have been recorded (at the Pt. Atkinson Gauge in West Vancouver). A lower number was used given the importance of the structure being considered. In any future modelling for the Saratoga Beach area, where arguably there are many assets at risk, a higher estimate should be considered.
- Set-up (SU) is very dependent on local bathymetric conditions—the shape of the beach slope affects how set-up develops. Therefore, there are significant limitations to transferring a set-up estimate from a neighbouring community where the coastal bathymetry is different.

New analyses, with specific reference to the Saratoga Beach area, should be conducted to improve the estimate of prior coastal water levels. However, in the short-term, given the objectives of this work (to develop initial mapping suitable to support conversations with stakeholders), the water level estimates from the Town of Comox are appropriate.

These boundary conditions are important for the modelling exercise to gain a better understanding of flood conditions for different sea levels, including future sea level rise with climate change.

4.6.5 Climate Change

Climate change is being felt in British Columbia and the impacts of the changes are evident both locally and globally. Our climate will continue to change in the coming years and the increasing temperatures and altered meteorological patterns will affect the hydrology of our rivers. Therefore, to have a better understanding of future flood hazard extent, an estimate of changing boundaries (streamflow and ocean level) was made. This analysis is simple and was based on readily available information. Additional work should be conducted to provide detailed local downscaled information as part of any future hydrologic modelling or flood mapping projects.

In general, to predict how Earth's climate will change, scientists use climate models based on both emissions scenarios (more or fewer greenhouse gases) and on climate modelling (computer models that make different assumptions). These are then downscaled using regional climate models.

Local downscaled datasets near our area of interest were available from Pacific Climate Impacts Consortium (PCIC). Simulated streamflow datasets were obtained for Campbell River[vii], as it was the closest available watershed where data is readily available. The data was produced by different combinations of climatic models and emissions scenarios. All eight different model outputs were compared and evaluated based on the Nash–Sutcliffe model efficiency coefficient, an evaluation criterion

---

[vii] Pacific Climate Impacts Consortium, University of Victoria, (Jan. 2014). Station Hydrologic Model Output. Downloaded from https://www.pacificclimate.org/data/station-hydrologic-model-output on November 2017.

that is commonly used to assess the accuracy of the models. Given the purpose of the modelling output was to bookend the flood hazard problem and consider a more extreme scenario, the A2 emissions scenario (see PCIC for details) was selected for analysis in this project. This scenario showed a 30% increase in flows, which was linearly applied to the Oyster River (Table 8).

Table 8: Flow Estimates for Oyster River at the Mouth with Climate Change

AEP	50%	20%	10%	5%	2%	1%	0.5%	0.2%
Estimated Flow (m^3/s)	365	464	538	611	708	783	858	**961**

Based on this, these estimates were transferred from Campbell River to the study area and new river inflows were calculated. Finally, with the new values for the model, a map of approximate flood extents for Oyster River, which takes into account climate change, was created (with a flow of 961 m^3/s).

At the downstream end, climate change will manifest as sea level rise (see Section 4.2.1 for additional information). As described above a 1 m increase in sea level is used. For the purposes of modelling, we can assume that the 2100 estimate of SWL will be (considering only the projected sea level rise, not the effects of increased storm intensity):

$SWL_{CC} = HHWMT + SS + SU + SLR = 1.5 + 0.5 + 0.8 + 1.0 = 3.8$ *m CGD (2100 scenario),* where SLR is the sea level rise.

As a summary, a map showing old and new flood extents can be seen below in Figure 16. The most extreme and rare event (0.2%) was used because the purpose of the modelling was to bookend the potential flood hazard area. The larger area was used in workshop materials and the initial risk assessment to ensure that a full complement of exposure data was collected – a smaller climate event might have resulted in missed data on the edges of the floodplain.

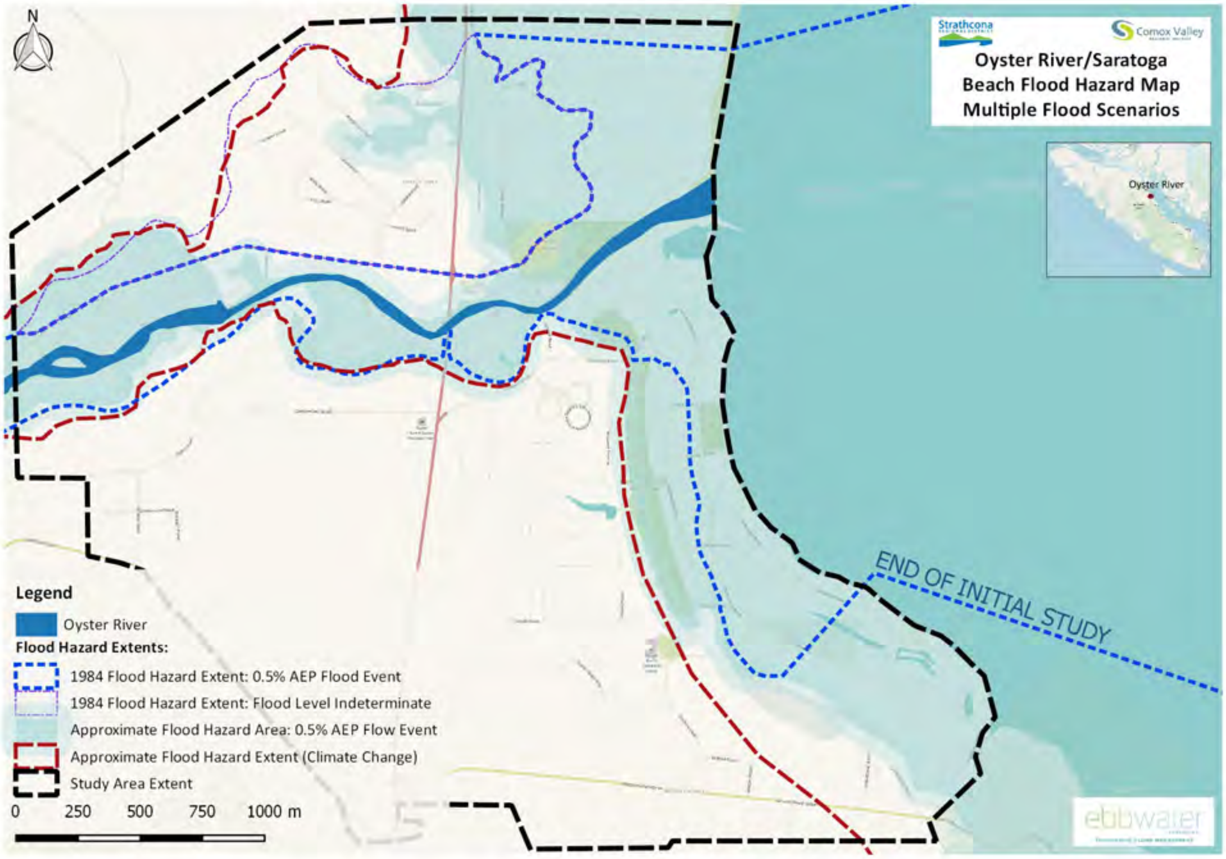


Figure 16: Oyster River Flood Hazard Map, Multiple Flood Scenarios

This map includes the flood hazard area extent form the 1984 mapping exercise along with a line showing an area where the flood level was not determined. (This was likely due to a lack of data or resources to complete the modelling work.) The flood hazard area extent based on the new modelling is provided for the current 0.5% AEP flood event. To give an idea of possible extremes, the 0.2% AEP flood event with climate change is also shown.

This provides a high-level overview of the extent of flood events of different severities. This is important because there is much uncertainty regarding future flooding and there are limitations with the study. Some of these limitations include a lack of data on the river's current geometry; the geometry of the river has inevitably changed since the 1984 study, and a new hydrometric study needs to be conducted in order for the results to be reliable. However, this analysis provides a good general understanding of where the water is likely to go during a very rare event now and in the future with climate change and sea level rise.

4.7 Limitations of Modelling and Mapping

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. High-level mapping was developed to support discussions with stakeholders and to support the development of a high-level risk assessment. **THE MODELLING AND MAPPING IS NOT SUITABLE FOR PLANNING OR ENGINEERING DESIGN**.

The CVRD and SRD, should use the results of this study to support an application to the National Disaster Mitigation Program (NDMP) or to the BC Community Emergency Preparedness Fund (CEPF) to develop an appropriate model and mapping for the area.

5 Exposure and Vulnerability

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). 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 methodology 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. Where quantitative (ideally spatial) data was available, a quantitative analysis was conducted. However, for some indicators, especially intangible ones, qualitative data was collected.

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 3.4), 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). Of note here is that different datasets and types were available for each project partner (i.e., the SRD and CVRD collect and maintain different types of data).

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 some indicators (especially the less tangible and the indirect ones), 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 workshop 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). 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 then transferred to a digital GIS database and ultimately recorded as hotspot maps. This qualitative information can be very rich and can also 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.

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 river 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. We have recommended that a geomorphologic study to map out future erosion be completed as part of any updated flood mapping project.

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 below (Figure 17) shows impacts to affected people, 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.

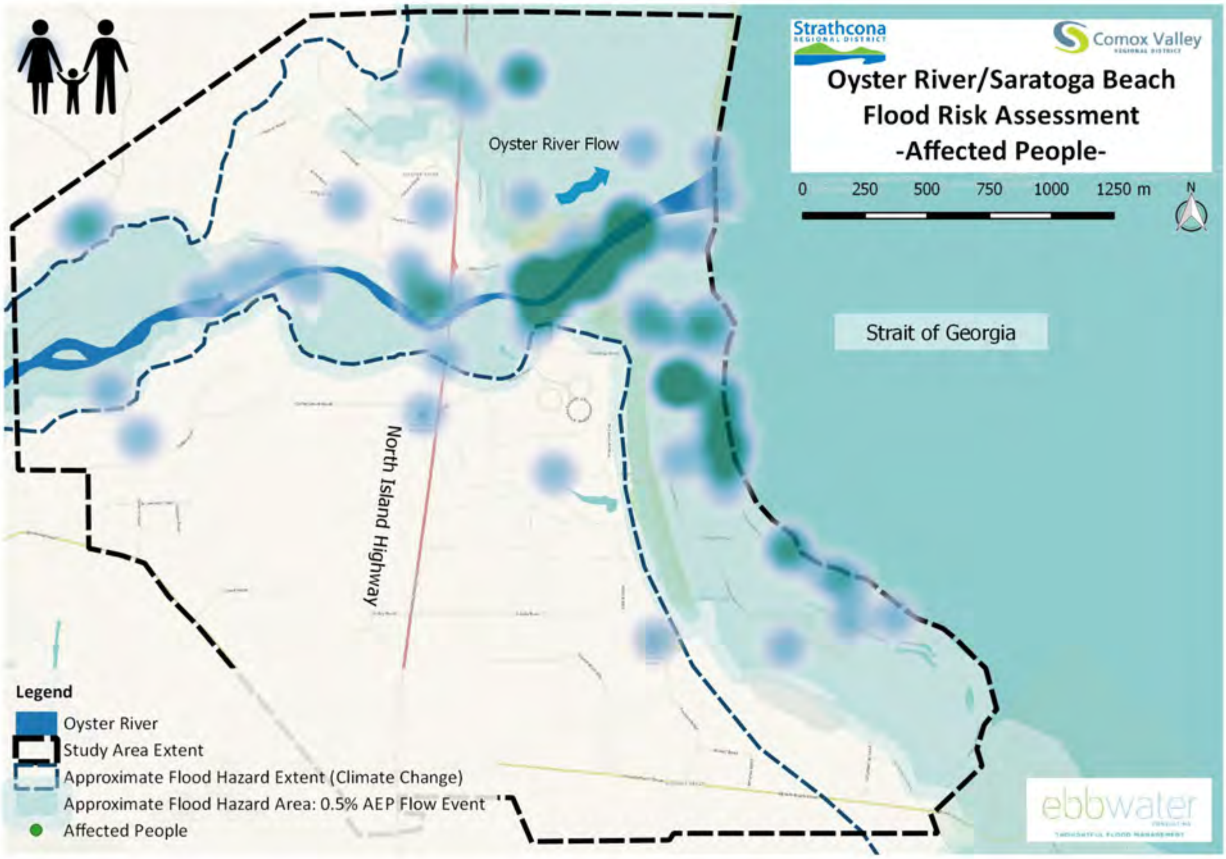


Figure 17: Hotspot Map of Affected People as Reported by Stakeholders in Workshops

The number of people affected was also mapped using the most recent Canadian census data and two flood scenarios. The maps below show an estimated percentage of the population affected by flooding in each scenario.

In Figure 18, the map shows the estimated affected population for the 0.5% AEP flood event. Within the 0.5% AEP flood hazard area it is estimated that approximately **550 people** would be affected.

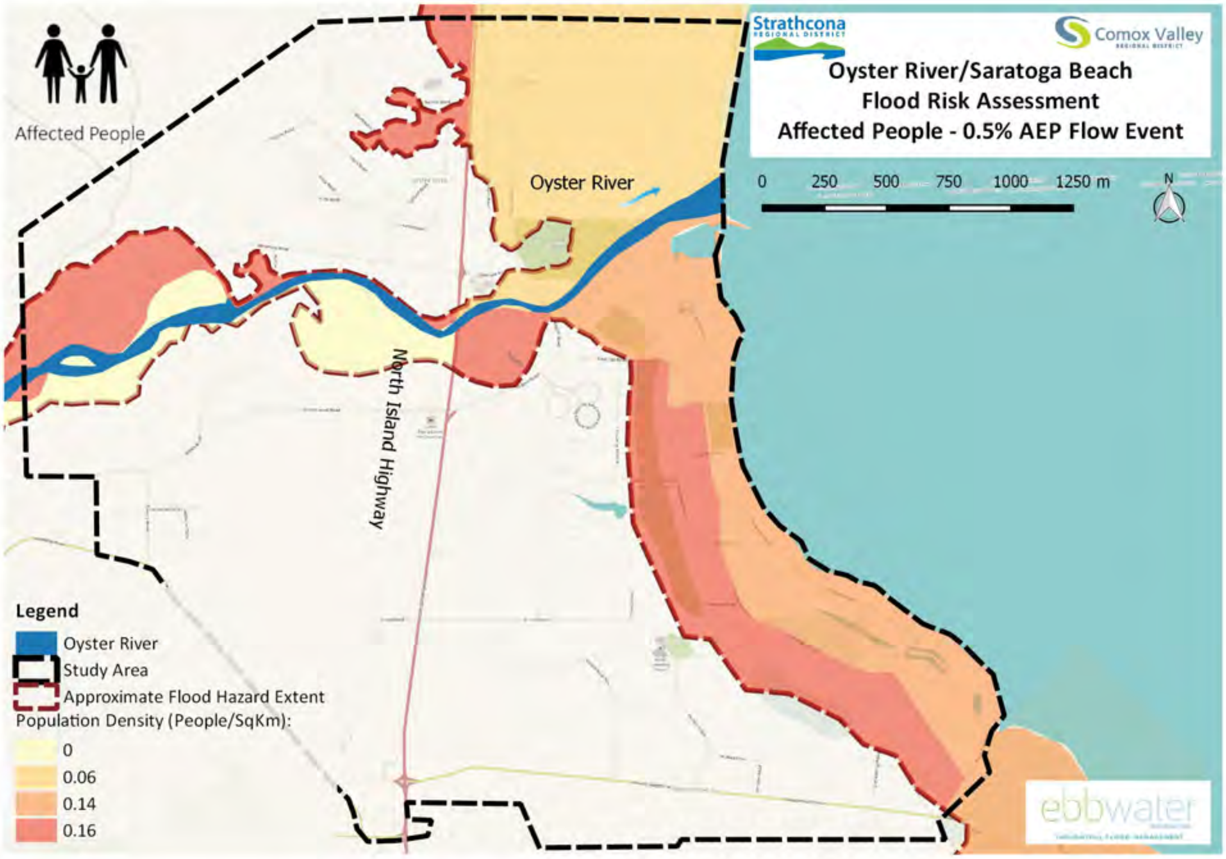


Figure 18: Population Density in Oyster River by Dissemination Area for 0.5% AEP Flood Hazard Area

In Figure 19, the map shows the affected population for the 0.2% AEP flood event with climate change as a high-level extreme scenario for consideration. For this flood extent, it is estimated that approximately **950 people** would be affected, a 72% increase over the present-day condition. This is stated to highlight the relative levels of exposure for the hazard extents studied. In general, this extent is not meant to be predictive, but rather to provide an upper bound of flood extent and impacts, given that there is much uncertainty embedded within the data.

Figure 19: Population Density in Oyster River by Dissemination Area for 0.2% AEP Flood Hazard Area with Climate Change

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 20 shows the high-level hotspots of economic impacts for the community as reported by stakeholders in the workshop.

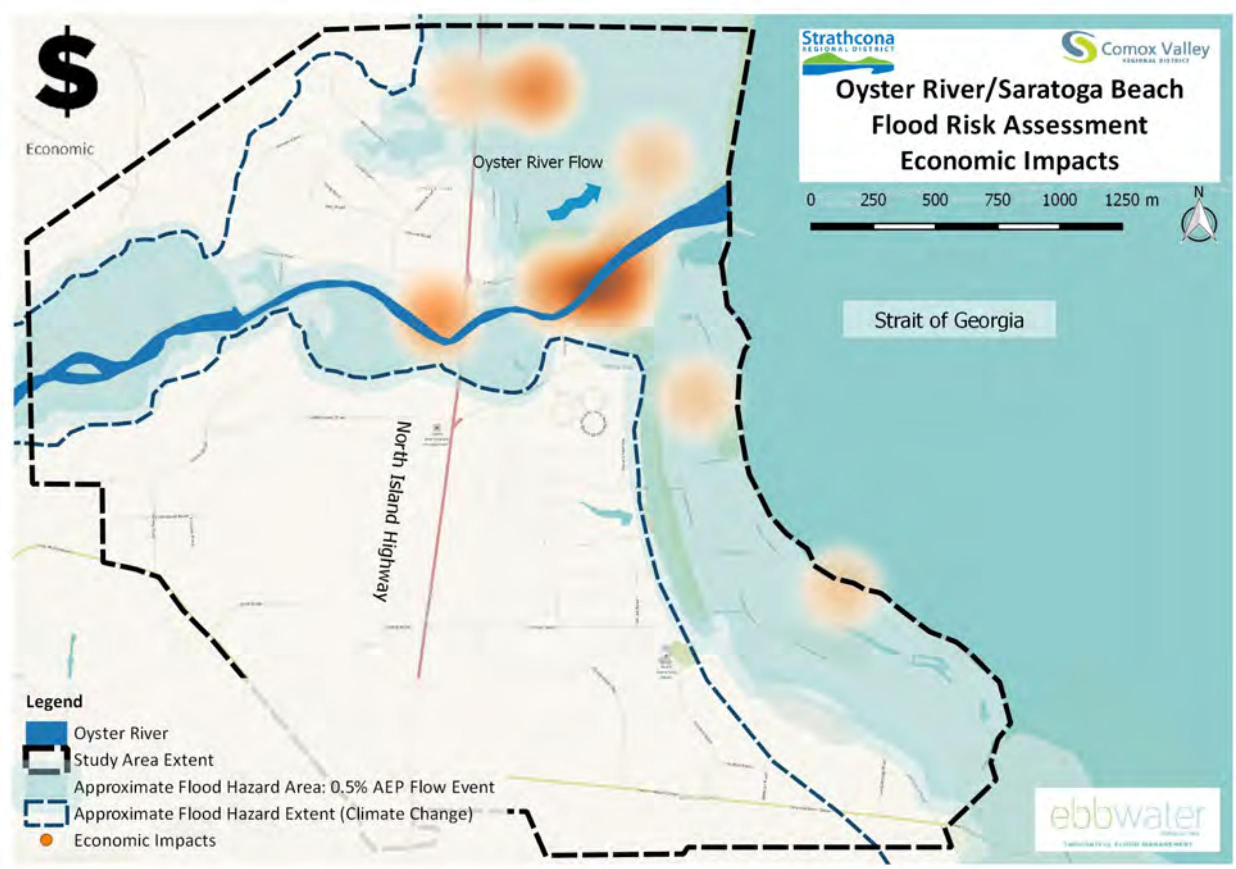


Figure 20: Economic Impact of Flooding in Oyster River as Reported by Stakeholders

The value of property in the flood hazard area was calculated using the available BC Assessment Authority Roll data, which provides a more quantitative estimate of economic impacts of flooding. Figure 21 shows properties in the flood hazard area for the 0.5% AEP flood event. The estimated value of property in the flood hazard area is **$226M for the 0.5% AEP flood event**.

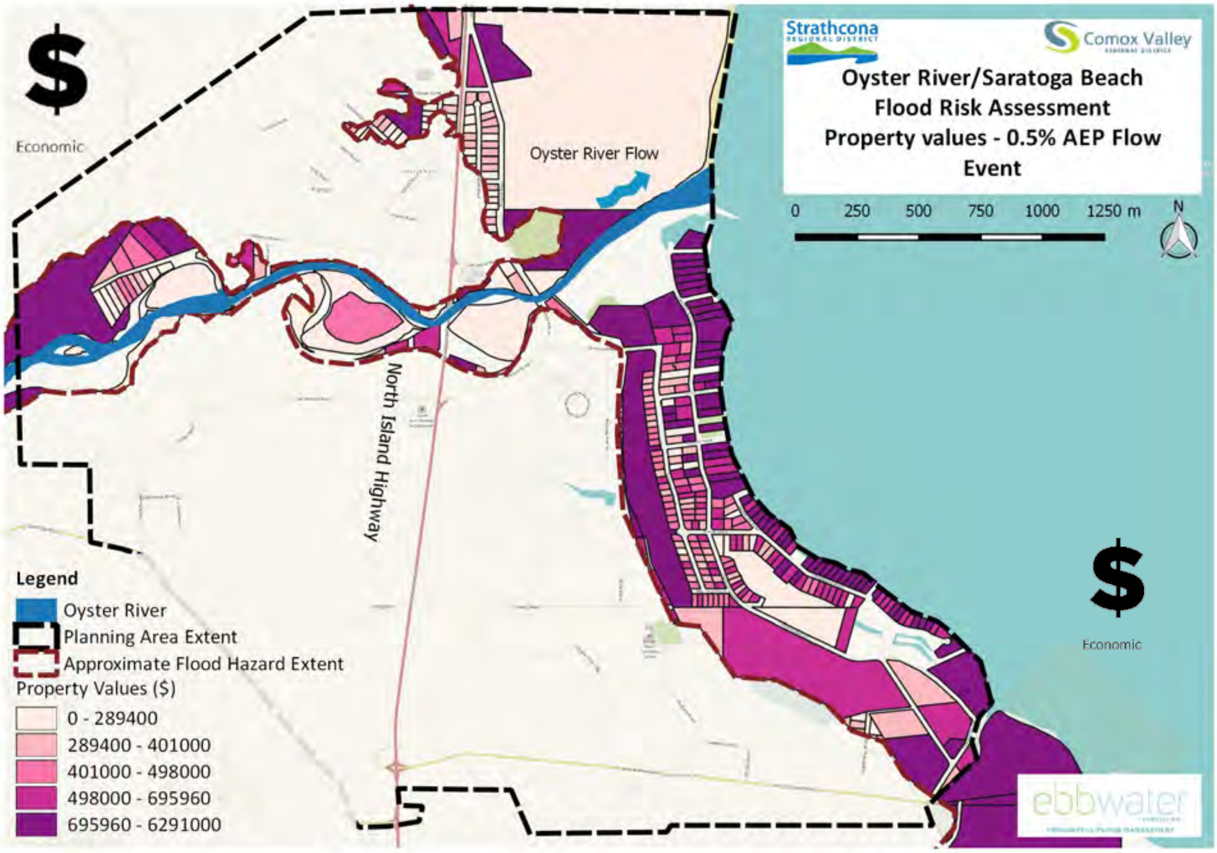


Figure 21: Economic Exposure in Oyster River 0.5% AEP Flood Hazard Area

Below, in Figure 22, is the property value in the 0.2% AEP flood hazard area with climate change, to provide an idea of an upper limit of exposure. It is estimated that the value of property within this flood extent is **$292M**. This highlights that between the current 0.5% AEP flood hazard area and the more extreme 0.2% AEP flood hazard area with climate change, the increase in property value exposed to flooding is 29%.

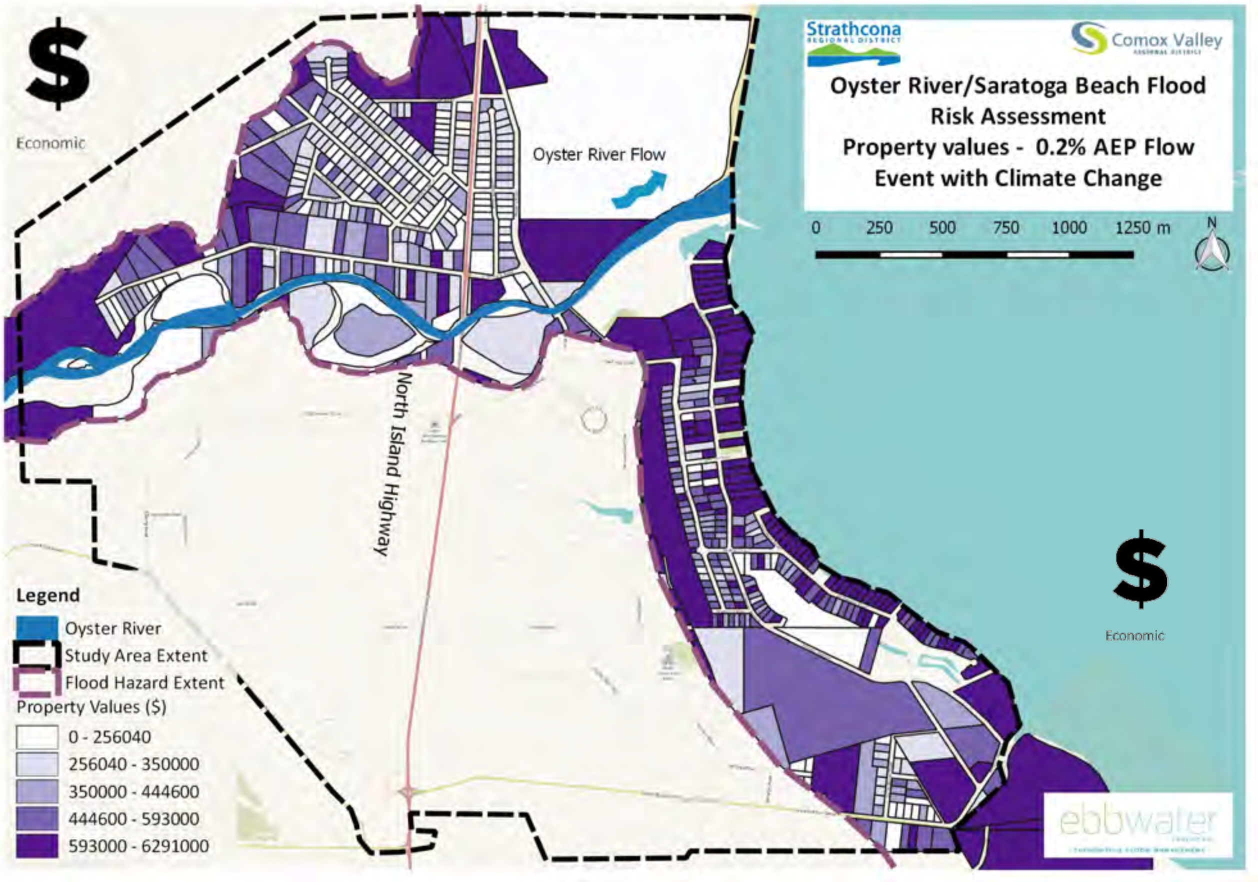


Figure 22: Economic Exposure in Oyster River 0.2% AEP Flood Hazard Area with Climate Change

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 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 hotspots for effects include areas along the coast, the bridge crossings, and drinking water facilities. There are some wells within the flood hazard area limits (1 in the present-day 0.5% AEP flood hazard area and 4 within the future 0.2% AEP flood hazard area). Should a flood occur, contaminated water (from overland sources) might enter the well heads.

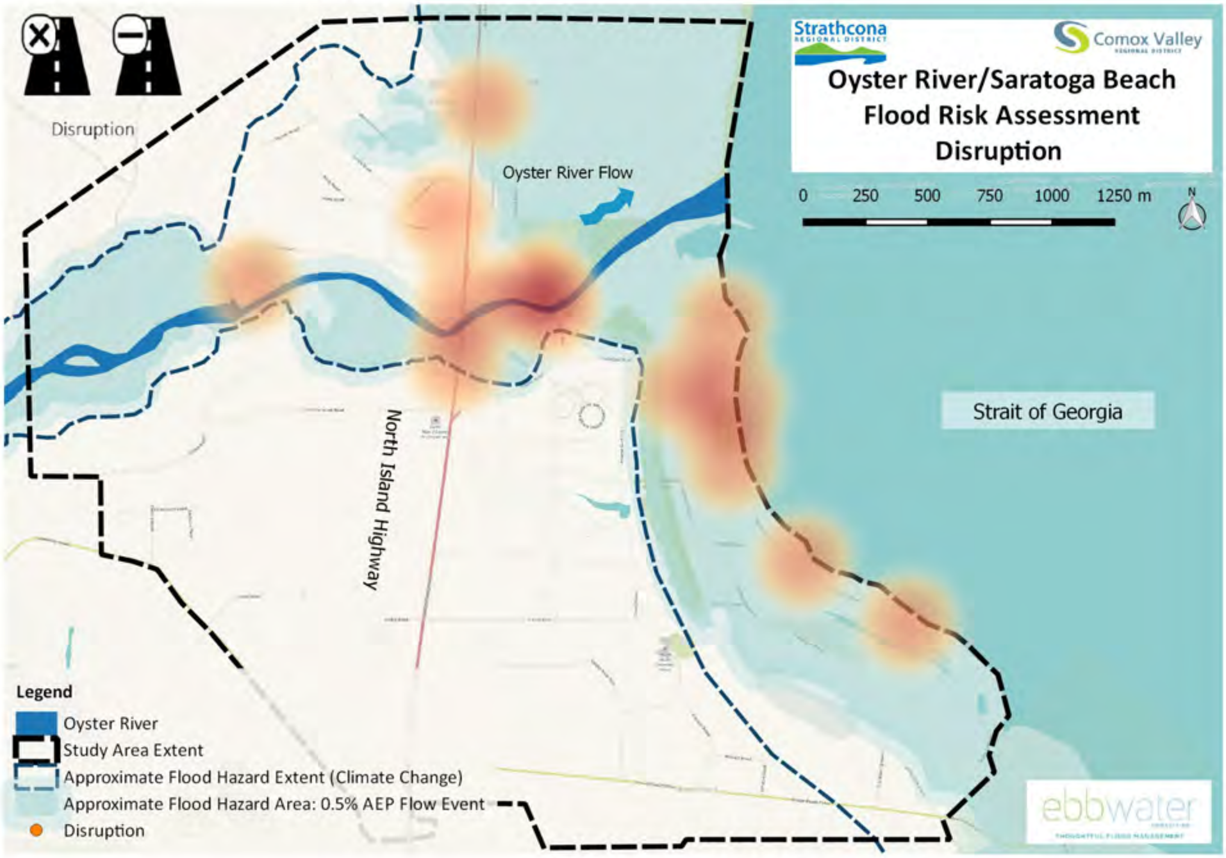


Figure 23: Disruption Due to Flooding in the Oyster River Flood Hazard Area as Reported by Stakeholders

Disruption due to flooding was also studied in terms of the length of major and minor roads within the flood extent for the 0.5% AEP present-day flood event as shown below in Figure 24. There are a number of both minor and major roads within the flood hazard area studied.

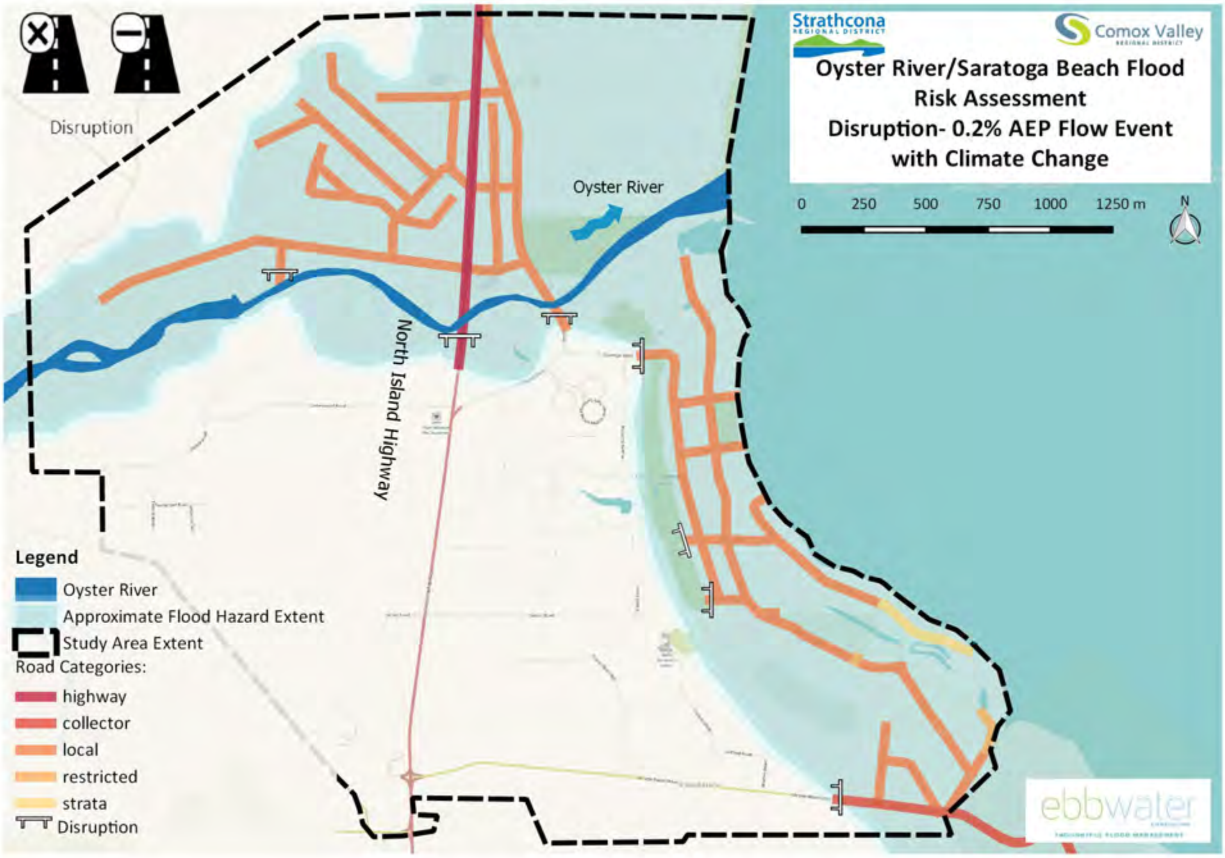


Figure 24: Disruption Due to Flooding in the Oyster River Flood Hazard Area

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 below in Figure 25.

These are qualitative indicators 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.

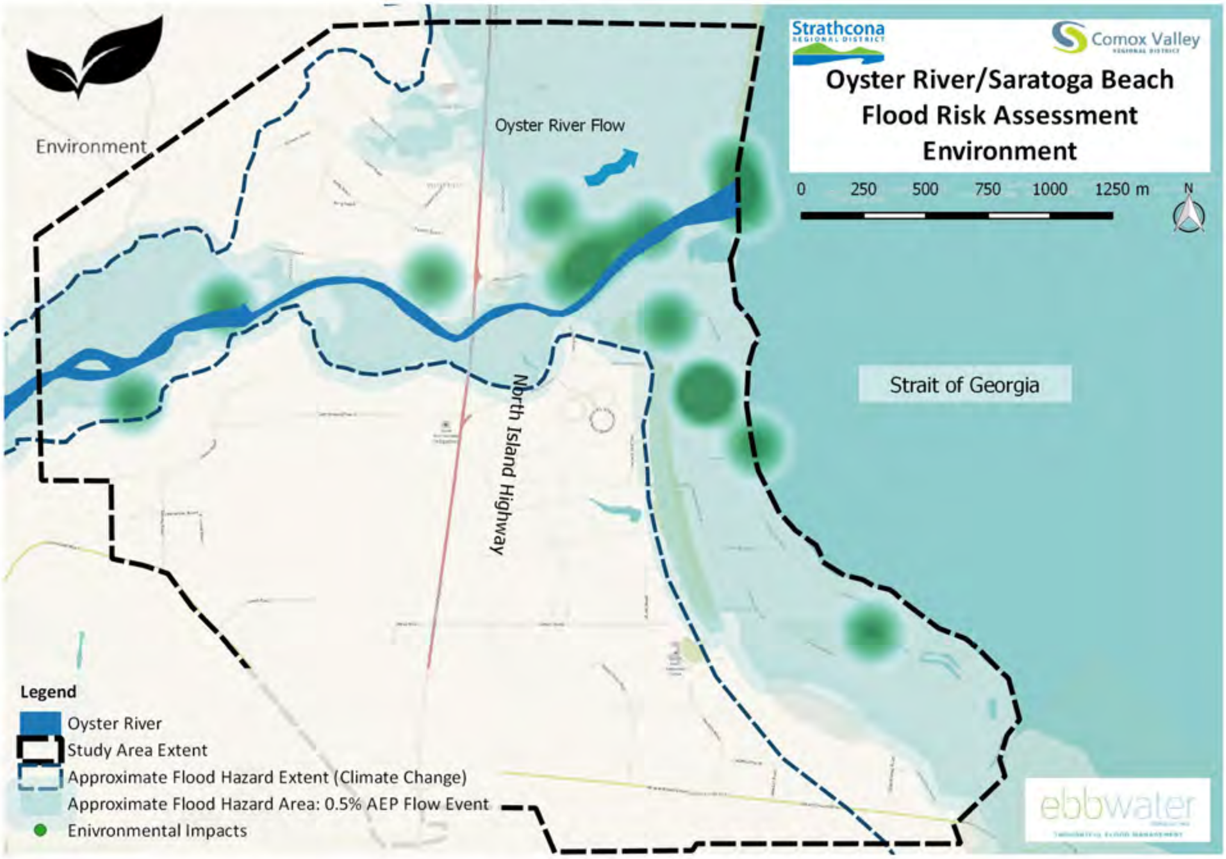


Figure 25: Environmental Concerns Due to Flooding with Input from Stakeholders

5.2.6 Culture

As described in Section 3, 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. And therefore, 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.

5.3 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. There are many and diverse impacts and these are spread out across the entire floodplain. When considering all the impact categories – there are no identifiable hot zones (i.e. a single area where most impacts are noted) that could be the focus of future mitigation planning. Rather, the impact mapping shows that flood will affect all areas (both coastal and riverine) and that reach-scale planning would be appropriate.

6 Risk Assessment

The overall form of a risk assessment includes the combination of hazard likelihood with the consequences of that hazard (see Section 3). 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 datasets 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 get 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 that uses a matrix-scoring approach; with scores 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 funders 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 9, 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 score of 3 is given for the present-day scenario (the 0.5% AEP event) and a score of 2.5 is given for the future climate change event (where a 0.2% AEP event was used to represent the more extreme end of the spectrum – see notes in Section 4.6.5).

Table 9: Likelihood Rating for Risk Assessment

Likelihood Score	AEP	Estimated Frequency (once every X years) (Indicative Lower Bound)
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 10). 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 Vancouver Island. 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 10: Impacts Ratings

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 Vancouver Island * 100,000*		
Economic Consequences: Direct economic loss attributed to disasters in relation to Vancouver Island 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 Vancouver Island * 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

Level	Score	Measure
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 2009) 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.

Given the impact scoring table and the information gathered and presented in Section 5. The following impact scores were assigned to the Oyster River/Saratoga Beach area:

Table 11: Impact Scores for Oyster River/Saratoga Beach

Impact Category	Present-Day Impact Score	Future (with Climate Change Score)	Comments
People (Mortality and Mission)	1	1	In both cases direct impacts to people are considered low.
Affected People	4	5	In both cases this score is high as a relatively high number of people will have homes or businesses impacted – especially when considering the scale of Vancouver Island.
Economic Consequences	4	4	A high score has been assigned in both instances given the exposed property values

			in the flood hazard area. This is significant when considered at the relative scale of Vancouver Island.
Disruption	3	3	A moderate score is applied in both instances as a number of pieces of critical infrastructure (well heads and bridge crossings) are within the flood hazard areas.
Environment	2	3	The environmental impact is considered relatively low for the present-day scenario but increases for the future scenario – where much more parkland is impacted.
Cultural	1	1	No cultural impacts were noted, and a minimum score of 1 is applied.

The above scoring is based on the available information and on the judgement of the risk assessment team. Given the qualitative nature of some of the measures, and the assumptions made (for example to scale the assessment to Vancouver Island) 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 are summarized in Table 12, Table 13, and Figure 26 below.

Table 12: Summary for Present-Day Flood Risk

Element	**Likelihood Score**	**Impact Score**	**Risk Score**
People (Mortality and Missing)	3	1	3
Affected People	3	4	12
Economic	3	4	12
Disruption	3	3	9
Environment	3	2	6
Cultural	3	1	3

Table 13: Summary for Future Flood Risk with Climate Change

Element	**Likelihood Score**	**Impact Score**	**Risk Score**
People (Mortality and Missing)	2.5	1	3
Affected People	2.5	5	13
Economic	2.5	4	10

Disruption	2.5	3	8
Environment	2.5	3	8
Cultural	2.5	1	3

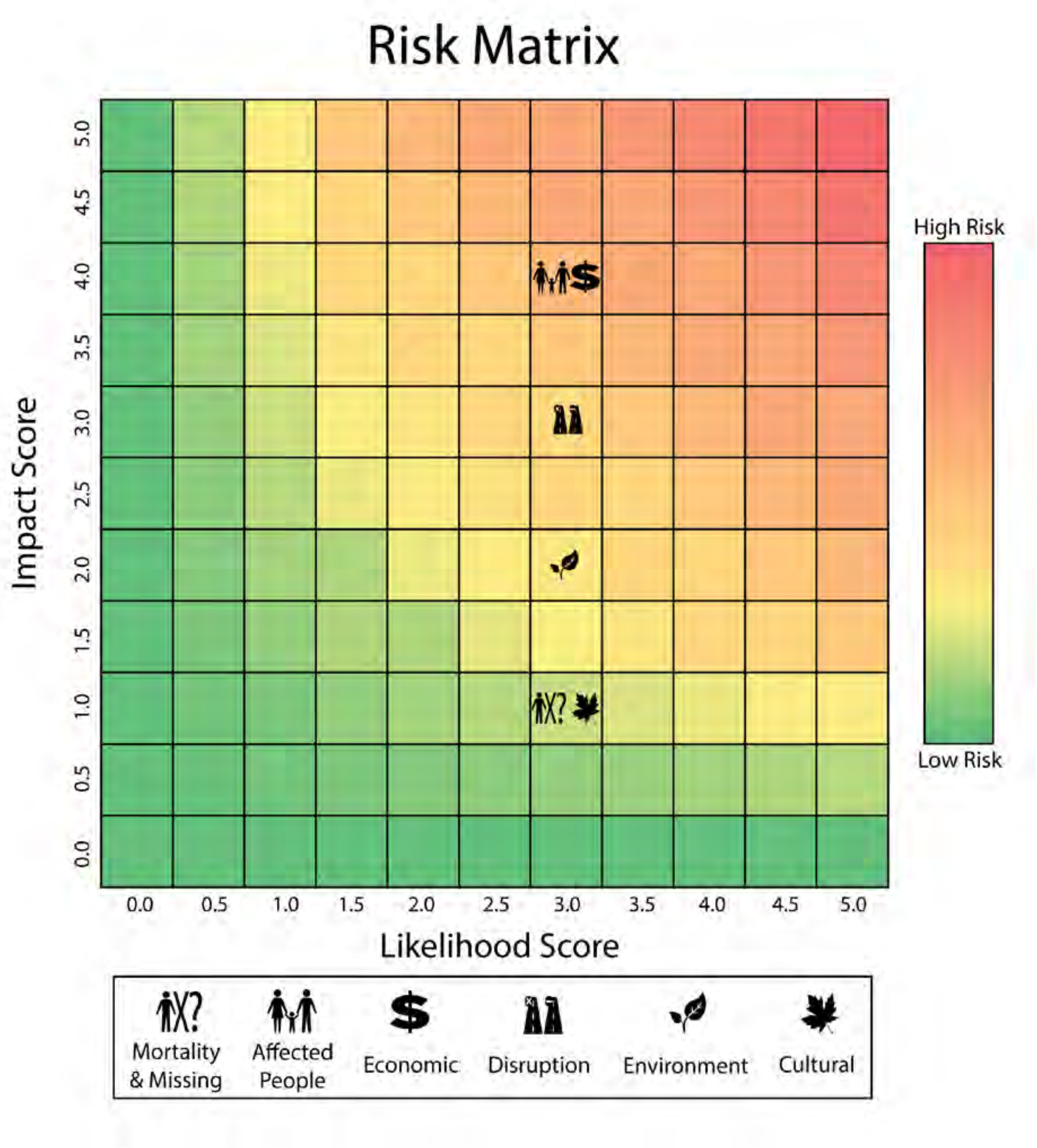


Figure 26: Summary of Flood Risk for Present-Day

It is clear from the above analysis that affected people and economic damage risk is significant in both the present-day and in the future with climate change. Disruption is also relatively significant. The overall difference between the two analyses (present-day and future) is limited for two reasons. First, the likelihood scores are slightly different because in this instance we have only considered a single scenario (i.e., the 0.5% AEP event in the present-day and 0.2% AEP event in the future), and because these are different for the present-day and for the future. This brings down the total risk score for the future event. However, this is not indicative of true risk, as a complete risk assessment would include consideration of multiple scenarios (frequent events, occasional events, and rare events) and an aggregate probabilistic risk would be calculated. Second, for the riverine flood hazard, the areal extent of flooding does not change dramatically with increased flows because of the shape of the land (the topography). But for the coastal areas, sea level rise significantly increases the coastal flood hazard area and therefore the exposure and risk.

In summary, there is a significant flood risk in the region. Risk reduction should be a priority for the CVRD and the SRD, as well as for Provincial authorities.

7 Resilience Planning

Oyster River is working towards the admirable goal of becoming more resilient to flooding. When a community is resilient to flooding, things can get wet and the community is able to cope with the water and recover quickly. This goes beyond simply thinking about structural protection measures for a single hazard, but instead focuses on building broader local capacity. The following section describes how the work conducted as part of this project can be used as a stepping stone for future flood resiliency. Specifically, the risk assessment information provides the foundation for understanding the problem, and secondly the workshop with stakeholders provided an opportunity to discuss measures of resiliency that are already under consideration by the community.

7.1 Stakeholder-Identified Resilience

To understand how Oyster River could become more resilient, the consulting team met with local stakeholders and members of the public. The team asked local stakeholders to identify what water means to them, which is summarized in the word cloud in Figure 27 below.

Figure 27: Keywords from Residents About What Water Means to Them

This highlights that local stakeholders are already thinking about the advantages of living near water (beautiful, habitat, life), as well as the hazard it presents (powerful, dangerous, unpredictable). Some are already thinking about how to manage such a hazard (preparedness, concern, complex) and some of the implications (climate, potable, necessary). Highlighting these relationships to water is helpful for setting the stage around discussions of resilience and capacity building.

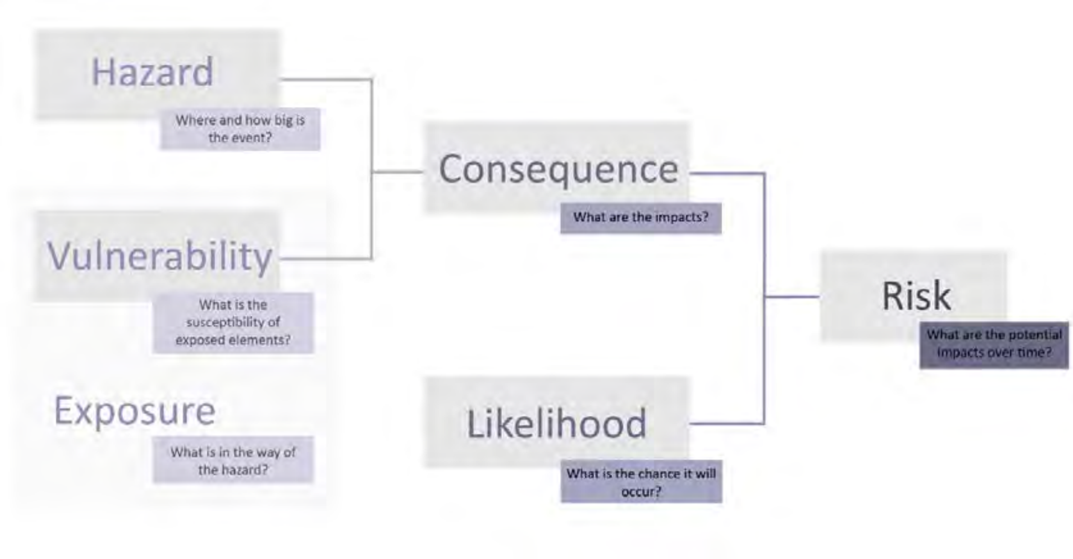
7.2 Best Practice for Flood Management

Flood management is a classic "wicked problem"[viii]. 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.

7.2.1 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 consequence all play a role (Figure 28). 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).



[viii] 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.

Figure 28: Natural Hazard Risk

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.

A further challenge related to the dynamic hazard is that with a rising sea level, flood events will be caused by a rise in the still water level, especially at high-tide conditions. Flooding may also be caused by water carried inland by storms. This effectively creates two design conditions that need to be considered in any analysis.

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 adaptation planning.

7.2.2 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, and 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.

7.2.3 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.

7.2.4 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.

7.2.5 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 and coastline that will thrive into the future.

7.3 Implementing Best Practice through a Step-Wise Process

Based on previous experience with local governments, we have adapted standard planning and adaptation processes into a clear 8-step process for flood risk reduction, as outlined in Figure 29.

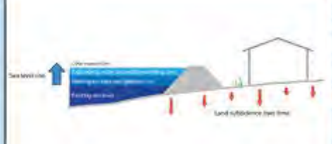
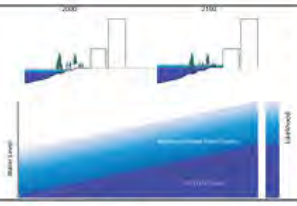
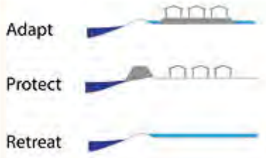
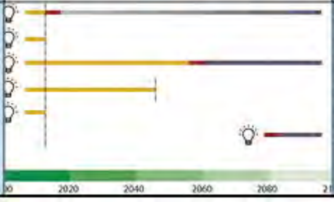
Step	Relevant Questions	Ideas	Explanation
1 Acknowledge Problem and Set the Stage	*Is climate change going to affect us?* *Is sea level rise a concern?* *What is our planning timeline?*		With sea level rise projections of 1 m or more by 2100, we can expect significant impacts on the BC Coast. Adaptation to increasing coastal hazards is necessary. The first step in planning to adapt 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?* *Will it be chronic or occasional?*		Understanding where water is likely to be in future is key to planning for sea level rise. This is a complex problem with multiple facets - some areas will become wet all the time, others that were once dry will be at the mercy of the tides, and still others now well inland will be subject to floods during storms. 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 and cataloguing of assets, infrastructure, communities and ecosytems that are subject to flooding. Engagement with stakeholders is also a key task at this stage.
4 Identify Consequence and Risk	*What are the potential impacts of flooding?* *How will it be impacted by chronic or occassional 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? Financial stability, safe community, complete community?* *How can we measure our objectives?*		In order to make decisions that reflect community values, indicators or measures that reflect these values need to be developed. 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 Options	*What adaptation options are suited to this hazard?*	 Adapt Protect Retreat	There is a large toolbox of adaptation options to sea level rise. These broadly fall under the three categories of adapt, protect and managed retreat. Where adapt strategies focus on developing responses that allow communities to live with occasional wetting. Protect strategies focus on building infrastructure to keep water away from vulnerable assets. Managed retreat describes strategies that slowly remove vulnerable assets from hazard areas.
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 identification of preferred options is the basis of an adaptation plan. A strong decision process, and a risk-based approach will ensure that options are suited to the community and the values established earlier in the process. In some cases, basic options from step 6 can be improved at this stage to better meet community needs, for example, by greening a dike, or adding a recreational ammenity - thereby ensuring that infrastructure options are beneficial even when there is no flood.
8 Develop Adaptive Management Plan	*What are the priorities for adaptation?* *When should planning for implementation begin?* *How could projects be improved with better information?*		Achieving an adaptated community 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 29: 8-Step Planning Process for Flood Risk Reduction

7.4 Progress Towards Resiliency in Oyster River/Saratoga Beach

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 community has acknowledged the problem and begun to develop awareness (Step 1), has a basic understanding of the hazard (Step 2), and has a fulsome understanding of the community vulnerabilities (Step 3) and of risk (Step 4). This puts the region in a good place to move forward to develop and select mitigation options that will improve the overall resiliency of the area. Some recommendations for next steps are presented in Section 8.

8 Recommendations

While the community of Oyster River is taking the right steps now to lay the groundwork for future studies and assessments, there are some additional things that can be done 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.

8.1 Quick Wins for the Community

While it is likely that future work will take place with support from NMDP funding, there are some things that the CVRD and the SRD, along with their partners, can start to consider. These are listed below:

- Additional gauging information
    - Currently Oyster River has one stream gauge located at the confluence of the river and Woodhus Creek. This means that flow from the little Oyster River Catchment is not captured. To better represent the hydrology of the river for future hazard studies, it would be best if a gauge were installed at a location downstream of the confluence of Oyster River and the Little Oyster River, potentially at the upper bridge crossing. This would also greatly support the calibration and validation of a future hydraulic model. Hydrometric gauging can be cost-efficient given modern technology (Hund, Johnson, and Keddie 2016). A hydrometric station linked to a real-time online webpage is also an extremely effective tool for public engagement and emergency response.
- Warning system and additional monitoring
    - 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.
- Education and preparedness
    - Education about flood risk can help the community build their own personal capacity and resilience to flooding. Awareness helps local residents know what to expect, what they can do if their property might be exposed, and how to prepare for recovery. The materials presented in this report provide a good starting point for any education. These could be made available to stakeholders and the public. Further, simple efforts to improve public awareness could be made by developing online tools, such as a StoryMap, which mixes flood hazard information with simple actions to improve personal resiliency. An example

map, recently developed for the City of Surrey (who are working at a different scale), is available here: https://surrey.maps.arcgis.com/apps/MapSeries/index.html?appid=c9907935a5c34260a01e1fdd84c8ade3
    - The two previous suggestions related to gauging and warning systems can also support education and engagement.
- Drinking water wells
    - As noted above, some wells are within the flood hazard area limits (1 in the present-day 0.5% AEP flood hazard area and 4 within the future 0.2% AEP flood hazard area). Should a flood occur, contaminated water (from overland sources) might enter the well heads. It would be prudent at this time to inform the well owners of this potential hazard, and to encourage them to plan for a flood. With appropriate warning, the well heads could be capped to minimize the potential for contamination.
- Recommendation for erosion and trail use
    - It was reported in the stakeholder workshop (and is evident by looking at the river) that bank erosion is a significant issue, especially on the left bank of the river in the SRD. In the short-term, the clients should monitor this erosion (ideally with surveys). This can both support trail management and emergency response, as well as future erosion mapping.
- Review policy and bylaws
    - It was outside the scope of this project to consider existing Regional District (RD) policy. However, it would be prudent for both RDs to review their existing flood policy and bylaws. Especially in light of recently promulgated guidance from the Province on land use regulations for flood hazard areas: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/integrated-flood-hazard-mgmt/flood_hazard_area_land_use_guidelines_2017.pdf
- Dike assessment recommendations
    - The recently completed dike assessment report should be reviewed by the SRD and the recommendations within this report considered.

8.2 Considerations for Future Funding Streams

As noted several times in this report, the Oyster River area currently lacks an up-to-date hydraulic model and mapping. The development of a new map is an **imperative and necessary** next step in any flood resiliency or risk reduction planning. The CVRD and SRD should submit an application for grant funding to develop a map. Two programs are currently available to support flood mapping:

1. The NDMP (Stream 2): It is anticipated that this program will be accepting applications mid-summer for the 5th and final cycle of the program. There is a chance that the program will be renewed for another 5-year term, however this has not yet been confirmed. The requirements of Stream 2 are a completed RAIT (provided in Appendix B).

2. The UBCM CEPF (Stream 2): It is anticipated that this program will accept applications in the fall of 2018, although no official announcement has been made to this affect. Last year (2017), the program had the same requirements as for the NDMP (i.e., a completed RAIT).

In addition to the completed RAIT, a brief scope of work and budget to develop a map has been prepared (Appendix E). This will support grant applications and can also be used to develop RFP materials in order to select a suitably qualified consultant team.

8.3 Long-Term Steps to Take

- Data collection for refined exposure modelling
    - As noted in this report, available data for exposure modelling was inconsistent. To support detailed future exposure and risk modelling, the community should consider improving and updating their GIS data.
- General flood resiliency
    - As noted above, the community has begun on the path of flood resiliency planning by completing this work. However, there are many steps yet to be undertaken. The community should continue to work their way through the steps to develop and implement a flood risk reduction plan. This should be reviewed and iterated periodically.

9 Conclusions

As the community of Oyster River/Saratoga Beach 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. Specifically, this work will enable the community to access funds for a future phase of the National Disaster Mitigation Program.

At the outset of the report, the project objectives were to develop a risk assessment suitable to support future grant applications, as well as to conduct research to support future more detailed risk assessments and general movement towards greater flood resiliency for the region. The results presented here meet these objectives, and we hope they will support the CVRD and the SRD in future work.

10 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
Assets-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; and Transportation.	PSC
Exposure	A measure of the amount of a structure, life, or other asset-at-risk that could be affected by a potential hazard. Example: parts or all of houses, schools, and livestock in a flood hazard area that 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	UN-ISDR

	represent future threats, and can have different origins: natural (geological, hydrometerorological, and biological) or be induced by human processes. Hazards can be single, 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
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
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	UN-ISDR

	exposure and vulnerability, including the physical, social, health, economic, and environmental dimensions; and the evaluation of the effectiveness of prevailing and alternative 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

11 References

Ausenco-Sandwell. 2011. *Climate Change Adaption Guidelines for Sea Dikes and Coastal Flood Hazard Land Use - Guidelines for Management of Coastal Flood Hazard Land Use*. BC Ministryof the Environment. http://www.env.gov.bc.ca/wsd/public_safety/flood/pdfs_word/coastal_flooded_land_guidelines.pdf.

Bornhold, Brian. 2008. *Projected Sea Level Changes for British Columbia in the 21st Century in Publication*. Government of Biritish Columbia.

Ebbwater Consulting. 2016. *Way Forward for Risk Assessment Tools in Canada Final Report*.

Engineers and Geoscientists British Columbia. 2016. “Flood Mapping in Bc.”

Government of Canada. 2009. *National Strategy for Critical Infrastructure*.

Hund, Silja V., Mark S. Johnson, and Tom Keddie. 2016. “Developing a Hydrologic Monitoring Network in Data-Scarce Regions Using Open-Source Arduino Dataloggers.” *Agricultural and Environmental Letters* 1(1): 0. https://www.agronomy.org/publications/ael/abstracts/1/1/160011.

IPCC Working Group 1. 2014. “IPCC Fifth Assessment Report (AR5) - The Physical Science Basis.” *IPCC*.

James, T S et al. 2014. “Relative Sea-Level Projections in Canada and the Adjacent Mainland United States.” http://geoscan.nrcan.gc.ca/starweb/geoscan/servlet.starweb?path=geoscan/fulle.web&search1=R=295574.

Lyle, T. 2016. “Is It Worth the Effort? A Case Study of Cumulative-Based Risk Assessment versus Scenario-Based Risk Assessment Methods for Sea Level Rise.” In *Society for Risk Analysis Symposium*, San Diego.

Messner, F, and V Meyer. 2006. UFZ Discus Flood Risk Management Hazards Vulnerability and Mitigation Measures *Flood Damage, Vulnerability and Risk Perception - Challenges for Flood Damage Research*. http://econstor.eu/bitstream/10419/45258/1/489068715.pdf.

Messner, Frank et al. 2006. *Guidelines for Socio-Economic Flood Damage Evaluation*.

Public Safety Canada. 2012. *All Hazards Risk Assessment Methodology Guidelines 2012-2013*. http://www.publicsafety.gc.ca/cnt/rsrcs/pblctns/ll-hzrds-ssssmnt/index-eng.aspx.

Schanze, Jochen, Evzen Zeman, and Jiri Marsalek. 2006. “Flood Risk Management.” *NATO Science Series* 67(IV): 319. http://download.springer.com/static/pdf/252/bok:978-1-4020-4598-1.pdf?auth66=1407342112_acecbb5a8389b785bdea31f24ffd3126&ext=.pdf.

U.S. NOAA. “Is Sea Level Rising?” http://oceanservice.noaa.gov/facts/sealevel.html.

UNISDR. 2015. “Sendai Framework for Disaster Risk Reduction - UNISDR.” (March): 1–25.

http://www.unisdr.org/we/coordinate/sendai-framework.

United Nations. 2016. *Working Text on Indicators Based on Negotiations during the Second Session of the Open-Ended Inter-Governmental Expert Working Group on Indicators and Terminology Relating to Disaster Risk Reduction*.

Veldhuis, J A E. 2011. "How the Choice of Flood Damage Metrics Influences Urban Flood Risk Assessment." *Journal of Flood Risk Management* 4: 281–87. http://doi.wiley.com/10.1111/j.1753-318X.2011.01112.x.

Appendix A Risk Assessment (Generic)

The following provides information that could be included in a risk assessment. It is based on the expected future form of the NMDP RAIT. Elements that should be included in the form are highlighted in green.

Risk (Present-Day)

These scores are calculated using the present-day flood hazard area extent for the hazard and vulnerability information.

Likelihood

Table 14: Likelihood Rating for Generic Risk Assessment

Likelihood Score	AEP	Estimated Frequency (once every X years) (Indicative Lower Bound)
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 15: Proposed Impacts Ratings

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

Level	Score	Measure
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 Vancouver Island * 100,000		
Economic Consequences: Direct economic loss attributed to disasters in relation to Vancouver Island 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 Vancouver Island * 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 2009) 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 (Present- Day)

Element	Likelihood Score	Impact Score	Risk Score
People (Mortality and Missing)	3	1	3
Affected People	3	4	12
Economic	3	4	12
Disruption	3	3	9
Environment	3	2	6
Cultural	3	1	3

Future Risk (Climate Change)

These scores are calculated using the future flood hazard area extent with climate change for the hazard and vulnerability information.

Likelihood

Table 16: 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 17: Proposed Impacts Ratings

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		

Level	Score	Measure
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 Vancouver Island * 100,000*		
Economic Consequences: Direct economic loss attributed to disasters in relation to Canadian 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 2009) 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.

Level	Score	Measure
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	3
Affected People	2.5	5	13
Economic	2.5	4	10
Disruption	2.5	3	8
Environment	2.5	3	8
Cultural	2.5	1	3

Appendix B Completed RAIT Form

Provided separately due to protection settings on RAIT form.

Appendix C Workshop Materials

- Workshop Agenda
- Workshop Participants List
- Workshop Presentation Slides

Agenda - Exposure Workshop

Oyster River / Saratoga Beach - Flood Risk Assessment
Tuesday January 16th, 2018 - 1pm to 4pm

Meeting Objectives:

- To build an understanding of flood management and risk assessment
- To build a shared understanding of flood hazard in the Oyster River/Saratoga Beach area
- Learn from the community about the specific assets and values that are susceptible to flooding

Agenda:

1:00	**Welcome and Introductions**
1:30	**Background on Flood Risk and Flood Management 101** - Flood management as a wicked problem
2:00	**Best Practices and Risk Assessment 101** - Global indicators of disaster risk reduction - Scales of risk mapping
2:30	**BREAK**
2:45	**Study Area Mapping Exercise** - Mapping the direct and indirect impact of flooding with stakeholders
3:50	**Closing and Next Steps**

List of Participants Present – Exposure Workshop

Oyster River / Saratoga Beach - Flood Risk Assessment
Tuesday January 16th, 2018 - 1pm to 4pm

Organization	Number of Participants
BC Government – Ministry of Forests, Lands, Natural Resource Operations, and Rural Development	1
BC Government - Ministry of Transportation and Infrastructure	1
CVRD Staff	4
Shelter Point Distillery	1
Electoral Area C	1
Fire Department	2
Local Residents	16
Mike Oviatt Trucking & Aggregate	2
Pacific Playgrounds Resort	2
Project Watershed	2
Recreation Sites and Trails BC	1
Saratoga and Miracle Beach Residents' Association	1
SRD Staff	4
Timber West	1

Total participants: 39 people

Oyster River/Saratoga Beach
Flood Risk Assessment

Tuesday - January 16th, 2018

Exposure Workshop – 1pm to 4pm

Tamsin Lyle, P.Eng | Principal | Ebbwater Consulting
Heather Murdock, P.Eng | Project Engineer | Ebbwater Consulting
Nikoletta Stamatatou| Hydrotechnical Analyst | Ebbwater Consulting

---

What have you signed up for?

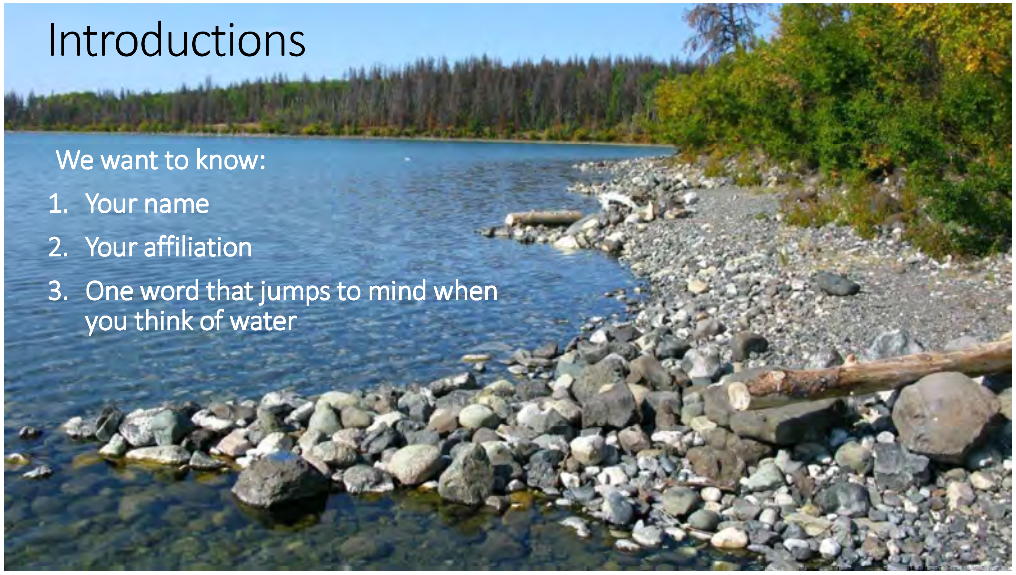
1. Introductions and a little bit of fun
2. Some hopefully engaging presentations
3. A break and some treats courtesy of the CVRD.
4. Some thinking...and some playing with stickies, pens and maps – we need your help!

Objectives:

A. To build a shared understanding of flood hazard in the Oyster River/Saratoga Beach area

B. Learn from the community about the specific assets and values that are susceptible to flooding.

Introductions



We want to know:

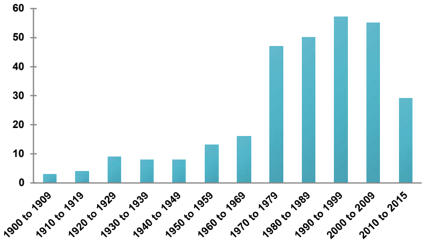
1. Your name
2. Your affiliation
3. One word that jumps to mind when you think of water

Some Basics:

Flood management 101

Risk assessment 101

Floods are a problem not to be ignored

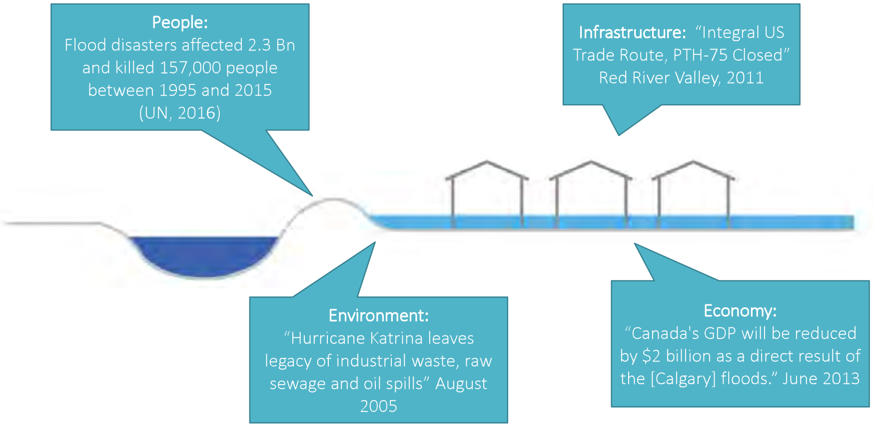


Flood Disaster Occurrences in Canada 1900-2015
(Canadian Disaster Database)

$2.4Bn losses annually
$673M paid by DFAA

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

That affect many things



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

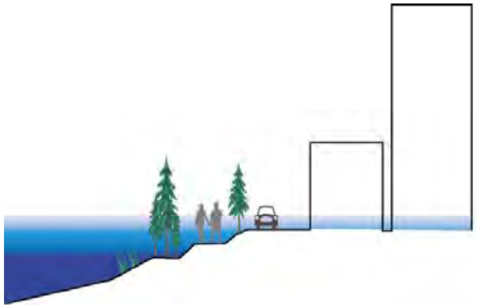
Infrastructure: "Integral US Trade Route, PTH-75 Closed" Red River Valley, 2011

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

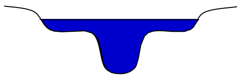
But…flood management is a wicked problem

- 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.

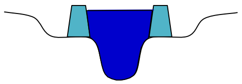


That historically we have managed with arrogance
Man Will Conquer Nature

Natural Condition

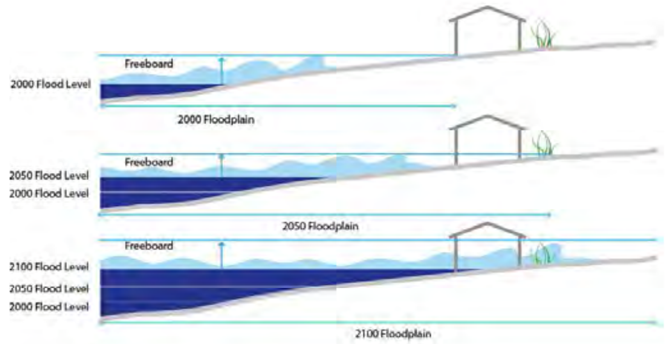


Dike Confinement



Philadelphia Ledger, May 3, 1927

Climate is a catalyst for change!



In the US, a 45% increase in spatial extent of the 100-Year floodplains is projected by the year 2100 (NFIP 2014).

Good Flood Management

Tackling a "Wicked Problem" with good decision making informed by good science and good people

Are you an Ostrich or a Meerkat?

Why be a meerkat?

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

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

67 shares

Residents, cottage and business owners on some of the biggest lakes in Muskoka are launching a $900 million class action suit against the

French mayor Rene Marratier jailed for role in deadly flood

Rene Marratier said he would appeal against the verdict

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 in 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.

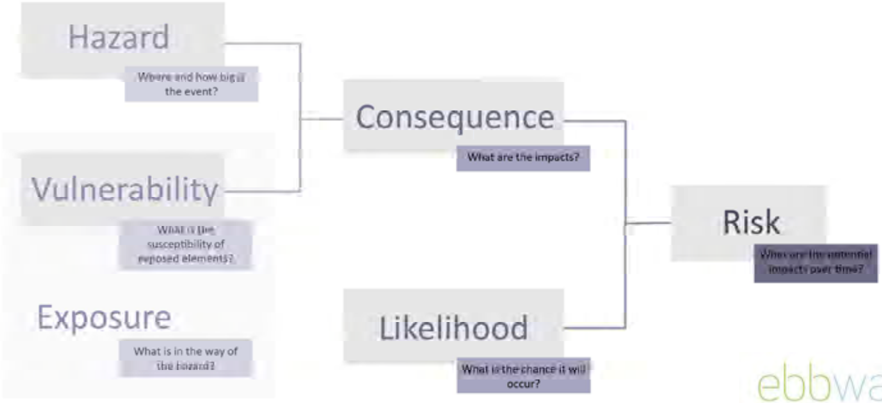
Marratier called the verdict "unjust" and said he would appeal.

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!

Meerkats Consider Risk not Hazard



Hazard

Where and how big is the event?

Vulnerability

What is the susceptibility of exposed elements?

Exposure

What is in the way of the hazard?

Consequence

What are the impacts?

Likelihood

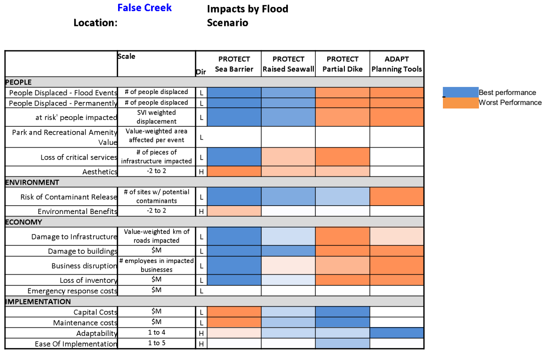
What is the chance it will occur?

Risk

What are the potential impacts over time?

Meerkats Consider

Focus on the decision process not the solution



	False Creek		Impacts by Flood			
Location:			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

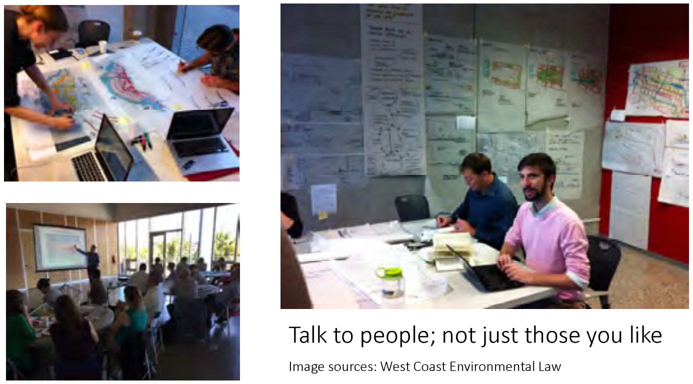
Example Structured Decision Making Consequence Table

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

Scenario Building

(Institute of Civil Engineers 2010)

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



Talk to people; not just those you like

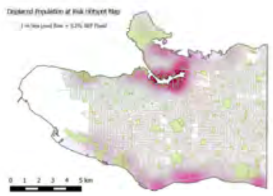
Image sources: West Coast Environmental Law

Consider more than dollars and cents

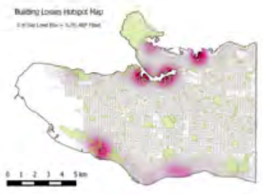
PEOPLE	
People Displaced	# of people displaced from flood events
People Displaced	# people displaced permanently
'at risk' people impacted	Social Vulnerability Index (SVI) weighted displacement
Park and Recreational Amenity Value	Value-weighted area affected per event
Loss of critical services	# of pieces 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.

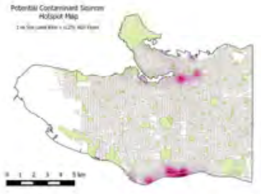
Because, the Story Changes the Question…



People

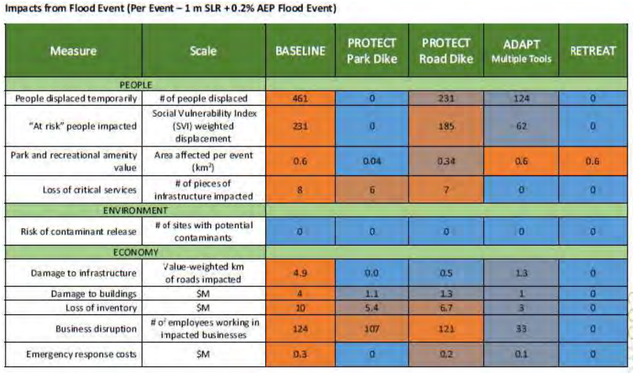


Economy



Environment

….And the Response

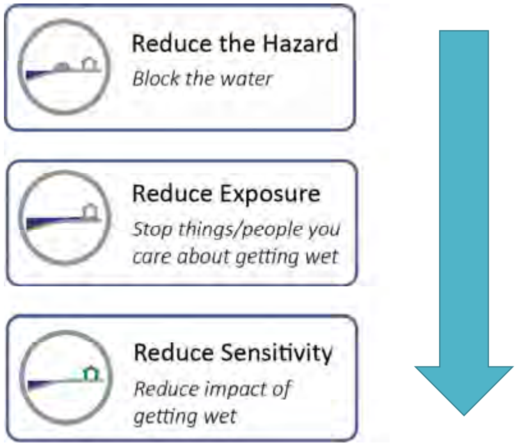


Impacts from Flood Event (Per Event – 1 m SLR + 0.2% AEP Flood Event)

Measure	Scale	BASELINE	PROTECT Park Dike	PROTECT Road Dike	ADAPT Multiple Tools	RETREAT
PEOPLE						
People displaced temporarily	# of people displaced	461	0	231	124	0
"At risk" people impacted	Social Vulnerability Index (SVI) weighted displacement	231	0	185	62	0
Park and recreational amenity value	Area affected per event (km^2)	0.6	0.04	0.34	0.6	0.6
Loss of critical services	# of pieces of infrastructure impacted	8	6	7	0	0
ENVIRONMENT						
Risk of contaminant release	# of sites with potential contaminants	0	0	0	0	0
ECONOMY						
Damage to infrastructure	Value-weighted km of roads impacted	4.9	0.0	0.5	1.3	0
Damage to buildings	$M	4	1.1	1.3	1	0
Loss of inventory	$M	10	5.4	6.7	3	0
Business disruption	# of employees working in impacted businesses	124	107	121	33	0
Emergency response costs	$M	0.3	0	0.2	0.1	0

Example consequence table for City of Vancouver, 2015. Developed with **Compass Resource Management**.

Meerkats Enable Resilience



Reduce the Hazard
Block the water

Reduce Exposure
Stop things/people you care about getting wet

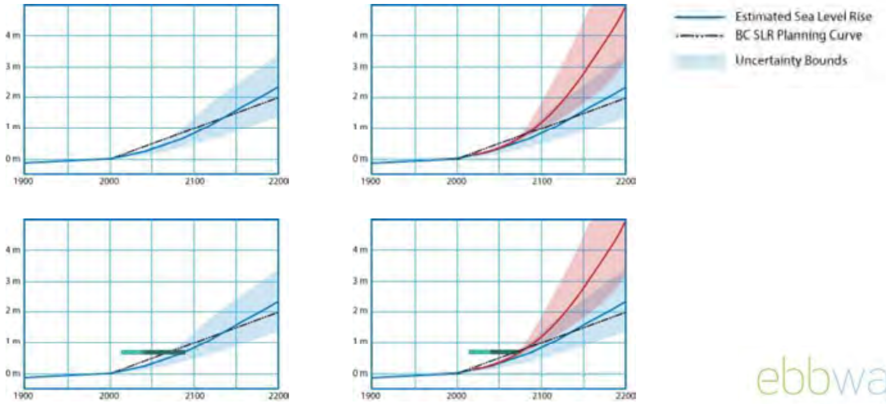
Reduce Sensitivity
Reduce impact of getting wet

- 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

A Meerkat Dilemma

Our Design Targets are Moving



Meerkats Embrace Uncertainty

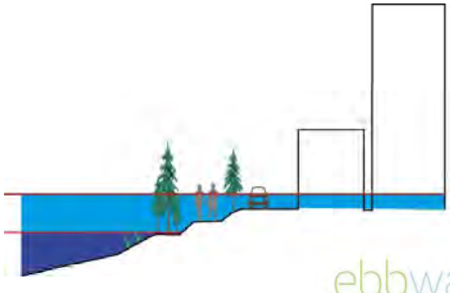
- Strive for adaptive solutions that will work under many climate and development futures
- Avoid solutions that are single-minded or that remove future options
- Consider infrastructure lifecyles

High end of range:

Overinvestment in protection

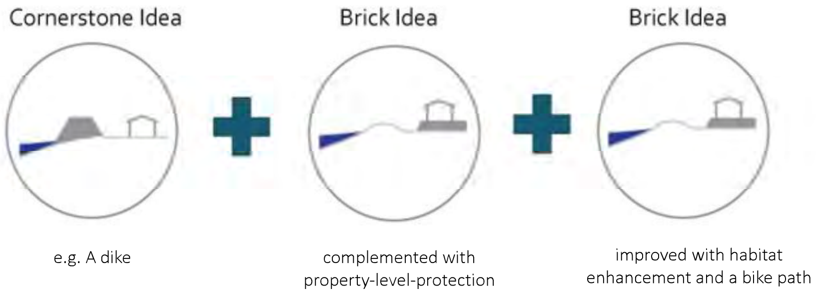
Low end of range:

Potential catastrophic impacts



Meerkats Have a Back-Up Plan

Complementary Design with Co-Benefits



Cornerstone Idea

e.g. A dike

Brick Idea

complemented with property-level-protection

Brick Idea

improved with habitat enhancement and a bike path

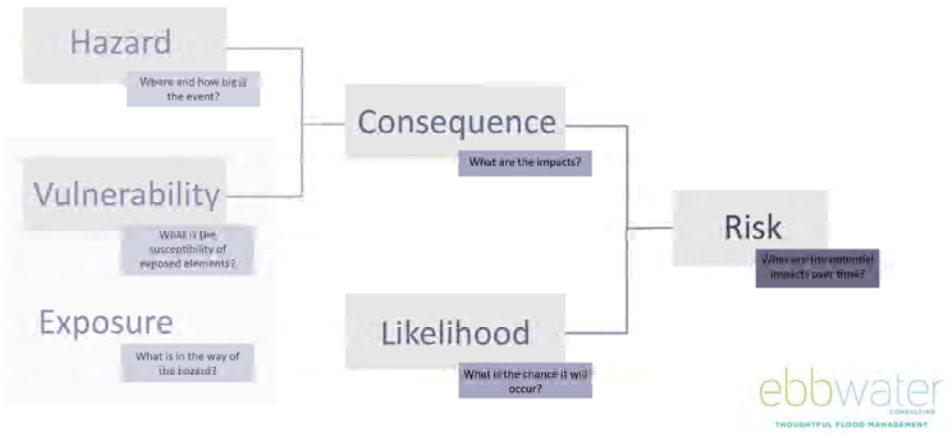
Meerkat School – What did we learn?

How to Do the Right Thing

- **Focus on the opportunities and be brave** (climate change can be good)
- **Plan for risk not hazard**
  - Consequences matter
- **Enable resilience**
  - Focus on recovery
- **Embrace uncertainty**
  - Strive for adaptive solutions that will work under many climate and development futures
  - Avoid solutions that are single-minded or that remove future options
- **Listen to other species**

Meerkats Unite!
Ostriches Be Gone!

Let's Review Risk Again



	Tool Scale	Data Requirements	Uses
Highly-Spatial		H Local-level detailed hazard mapping V Parcel-level GIS attributed with vulnerability information C Relevant, up-to-date damage/fragility curves	• Local government planning • Risk mitigation decision-making and design • Emergency response • Public engagement • Input to insurance models
		H High-level hazard mapping V Neighbourhood-level (census tract) GIS attributed with generic vulnerability information C Generic or synthetic damage/fragility curves	• Regional/Provincial/Territorial planning and prioritization • Emergency planning and management • Public engagement
Aspatial		H High-level hazard identification (quantitative or qualitative) V Regional scale vulnerability information (quantitative or qualitative) C High level empirical loss methods (Probable Maximum Loss) or qualitative narratives	• National-scale planning and prioritization • Input to re-insurance models

H Hazard V Vulnerability C Consequence

CartoDB Map Attribution (Positron Map)

Risk is scale dependent

Global Indicators of Disaster Risk Reduction

A-1	Number of deaths and missing persons attributed to disasters, per 100,000 population
B-1	Number of directly affected people attributed to disasters
C-1	Direct economic loss attributed to disasters, relative to GDP
D-1	Damage to critical infrastructure attributed to disasters
D-5	Number of disruptions to basic services attributed to disasters

Canada's National Risk Profile *(a work in progress)*

High-level impact categories
(Keep these in mind for later)

Mortality & Missing

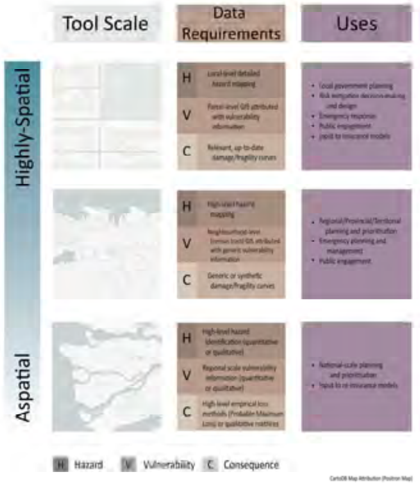
Affected People

Economic

Disruption

Environment

Cultural*



Highly-Spatial

Aspatial

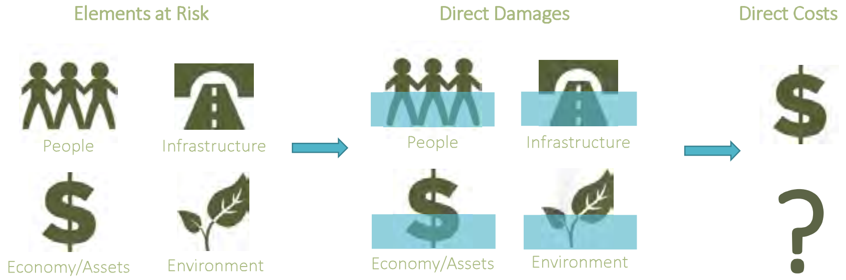
Tool Scale	Data Requirements	Uses
	H Local-level detailed hazard mapping V Parcel-level GIS attributed with vulnerability information C Relevant, up-to-date damage/fragility curves	• Local government planning • Risk mitigation decision-making and design • Emergency response • Public engagement • Input to insurance models
	H High-level hazard mapping V Neighbourhood-level (census tract) GIS attributed with generic vulnerability information C Generic or synthetic damage/fragility curves	• Regional/Provincial/Territorial planning and prioritization • Emergency planning and management • Public engagement
	H High-level hazard identification (quantitative or qualitative) V Regional scale vulnerability information (quantitative or qualitative) C High level empirical loss methods (Probable Maximum Loss) or qualitative matrices	• National-scale planning and prioritization • Input to re-insurance models

H Hazard V Vulnerability C Consequence

CartoDB Map Attribution (Positron Map)

What scale is useful for local government planning?

The problem is that it is resource intensive
A Multi-Disciplinary Task



Elements at Risk

People

Infrastructure

Economy/Assets

Environment

Direct Damages

People

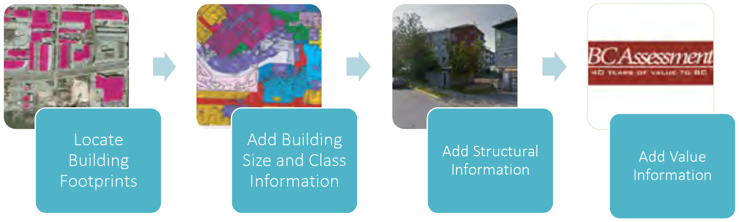
Infrastructure

Economy/Assets

Environment

Direct Costs

Calculating Direct Damages
To one type of infrastructure…it's data and resource intensive



Locate Building Footprints

Add Building Size and Class Information

Add Structural Information

Add Value Information

Calculating Direct Damages

Theoretically Simple....

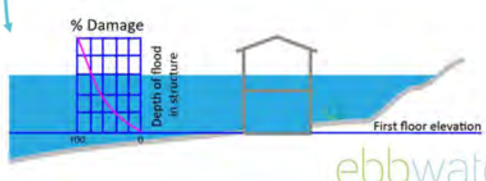
Infrastructure

People

Economy/Assets

Environment

2011 Great Japan Earthquake and Tsunami



ebbwater CONSULTING THOUGHTFUL FLOOD MANAGEMENT

Calculating Direct Losses

Theoretically Simple....

Infrastructure

People

Economy/Assets

Environment

The Cost Of Flooding

Total Losses $39,150 2,000 Square Foot Home

Estimates are for illustrative purposes only and should not be used to estimate any actual flood loss. A flood certified insurance adjuster making a room-by-room item-by-item, detailed estimate of covered flood damage is the only estimating method approved by and acceptable to the National Flood Insurance Program. These estimated costs are based on an average U.S. home of 1,000 and 2,000 square feet, built on a slab and with typical household items. Costs vary from State to State and home to home.

The Cost Of Flooding

Total Losses $62,880 2,000 Square Foot Home

Estimates are for illustrative purposes only and should not be used to estimate any actual flood loss. A flood certified insurance adjuster making a room-by-room item-by-item, detailed estimate of covered flood damage is the only estimating method approved by and acceptable to the National Flood Insurance Program. These estimated costs are based on an average U.S. home of 1,000 and 2,000 square feet, built on a slab and with typical household items. Costs vary from State to State and home to home.

https://www.floodsmart.gov/floodsmart/pages/flooding_flood_risks/the_cost_of_flooding.jsp

What happens when the power goes out?

The Tricky(ier) Part

Direct Impacts

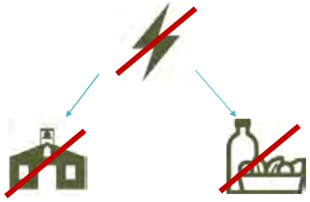
People

Infrastructure

Economy

Environment

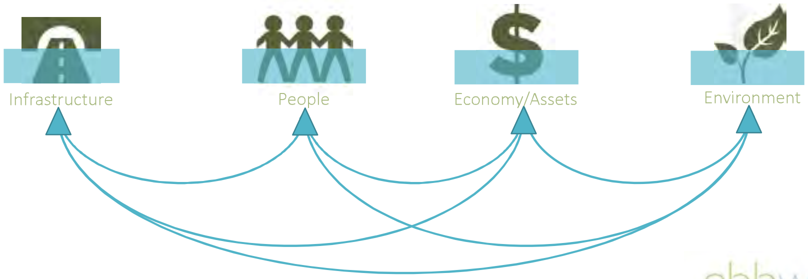
Indirect Impacts
(Cascading Effects)



ebbwater CONSULTING THOUGHTFUL FLOOD MANAGEMENT

Calculating Indirect Losses

No longer even theoretically simple, but just because it is difficult – doesn’t mean it shouldn’t be done.



Infrastructure

People

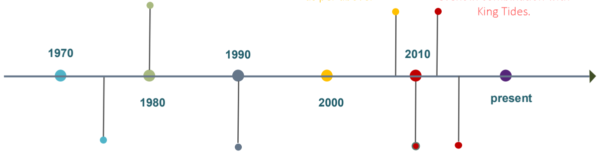
Economy/Assets

Environment

ebbwater CONSULTING THOUGHTFUL FLOOD MANAGEMENT

Which brings us to Oyster River/Saratoga Beach

Where we know it floods



Dec 6 and 26, 1980
Oyster River floods - Vancouver Island flood.

November 16, 2009
South end of Lorna Lane river bank eroded due to record high flows
Glenmore Dike breach as per above.

Nov 24-27, 2011
Repeat flooding for Glenmore Rd and Wimbledon Rd residents from to high ground water levels due to severe rain event in combination with King Tides.

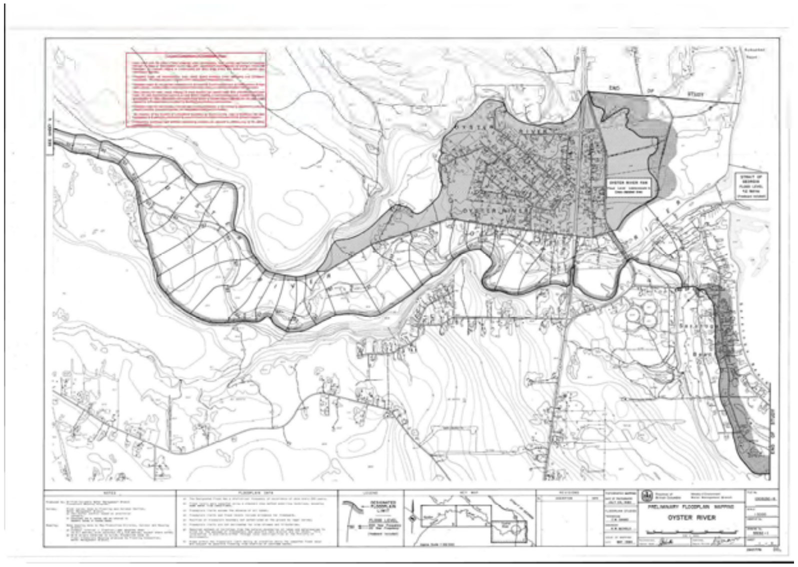
November 5, 1975-
High water on Oyster River caused some bank erosion – 150 cubic yards of riprap hauled to site.

Nov 10-12 and Dec 1990
Flood on Oyster River.

Dec 24- 27, 2010
Glenmore Rd residents experience localized flooding from high ground water levels due to severe rain event
Wimbledon Rd residents localized flooding from high of ground water levels due to severe rain event.

Dec 8-12, 2014
Major flooding on Vancouver Island and the Lower Mainland has caused property and content damages.
http://www.comoxvalleyrd.ca/EN/main/departments/emergency-services/disaster-flood-relief.html

ebbwater
CONSULTING
THOUGHTFUL FLOOD MANAGEMENT



National Disaster Mitigation Program

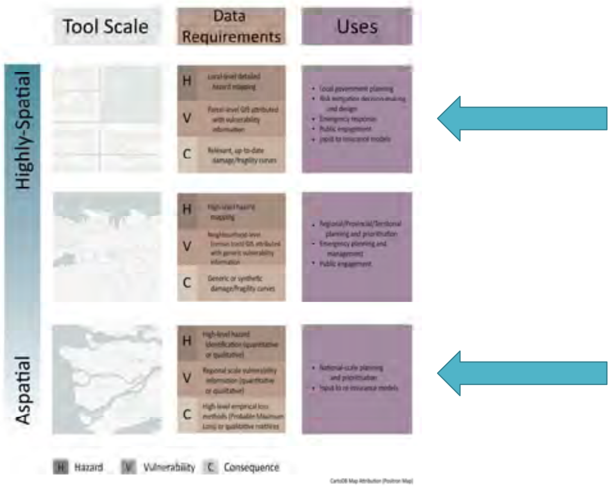
Risk Assessment
Flood Mapping
Mitigation Planning
Non-structural Works

ebbwater
CONSULTING
THOUGHTFUL FLOOD MANAGEMENT

National Disaster Mitigation Program

Risk Assessment → Flood Mapping → Mitigation Planning → Non-structural Works

---



	Tool Scale	Data Requirements	Uses
Highly-Spatial		H Local-level detailed hazard mapping V Parcel-level GIS attributed with vulnerability information C Relevant, up-to-date damage/fragility curves	• Local government planning • Risk mitigation decision-making and design • Emergency response • Public engagement • Input to insurance models
		H High-level hazard mapping V Neighbourhood-level (census tract) GIS attributed with generic vulnerability information C Generic or synthetic damage/fragility curves	• Regional/Provincial/Territorial planning and prioritization • Emergency planning and management • Public engagement
Aspatial		H High-level hazard identification (quantitative or qualitative) V Regional scale vulnerability information (quantitative or qualitative) C High level empirical loss methods (Probable Maximum Loss or qualitative matrices)	• National-scale planning and prioritization • Input to re-insurance models

H Hazard V Vulnerability C Consequence

CartoDB Map Attribution (Positron Map)

What the community needs for planning → this project is creating the building blocks for a future analysis.

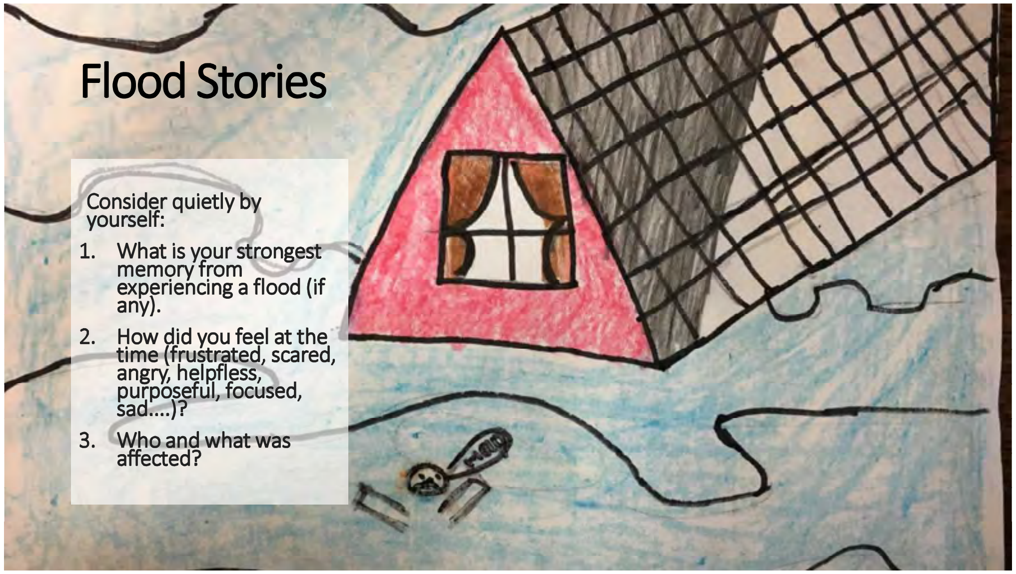
What the funder needs for planning → this project will have a deliverable of a RAIT.

What have we accomplished so far…

1. We’ve learnt a little about your river and town (we have more to learn!)
2. Collected data from your town
3. Delved into old dusty data and computer models
4. Talked to people with shiny new data and models
5. Done a lot of math and mapping

Break time!

Flood Stories

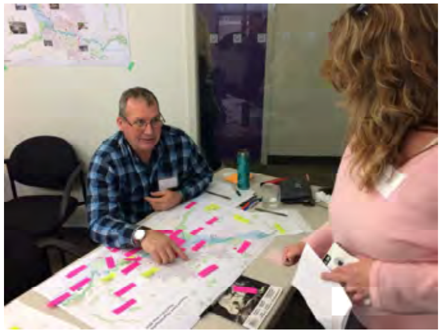


Consider quietly by yourself:

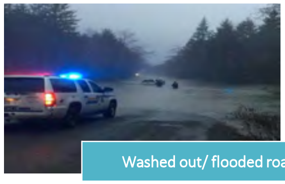
1. What is your strongest memory from experiencing a flood (if any).
2. How did you feel at the time (frustrated, scared, angry, helpless, purposeful, focused, sad....)?
3. Who and what was affected?

Map Exercise:

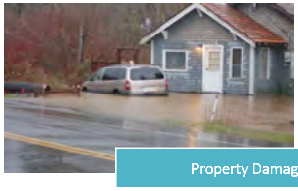
Sharpen your pencils



Flood Impacts - Direct

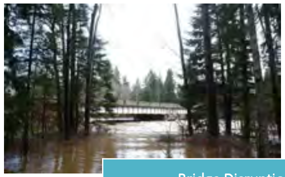


Washed out/ flooded roads



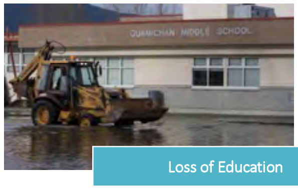
Property Damage

Commercial Property



Bridge Disruption

Flood Impacts - Indirect



Loss of Education

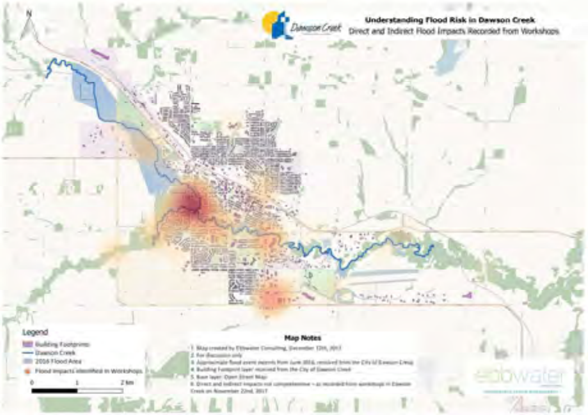
Disrupted supplies

Loss of Recreation

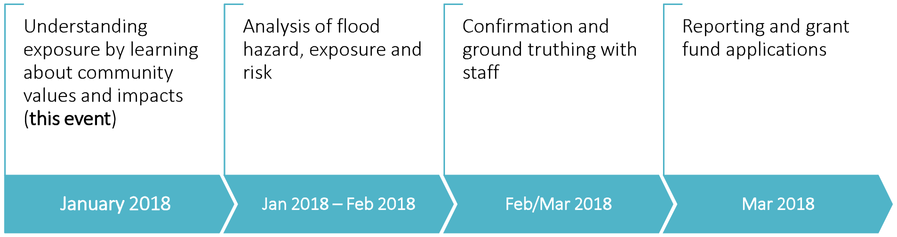
Well Contamination

Map Exercise:

Where does this get us?



Looking ahead.....



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

Thank You!

Appendix D Hazard Methods and Limitations

1 Introduction

For the purposes of conducting a flood risk assessment in Oyster River and Saratoga Beach, a hydraulic model was developed. The flood hazard extents from this updated model were used to support the collection of exposure and vulnerability information at a workshop with stakeholders. As part of this task a flow model of the Oyster River was constructed. The extents of this model are from area close to the Glenmore Dike to the outflow of the river where it meets the Strait of Georgia. Model runs included a present day scenario and a future scenario with sea level rise. This part of the report details the model development and simulated results for the two flood scenarios studied.

2 Model Overview

A 1-dimensional (1D), steady flow, hydraulic model was developed using HEC-RAS 5.0 software. The current version of HEC-RAS 5.0 was released by the U.S. Army Corps of Engineers Hydrologic Engineering Center in September 2016. The model was used to simulate the hydraulics of the Oyster River during extreme flood events.

HEC-RAS can calculate water surface profile properties for steady and unsteady flows, including subcritical, supercritical, or mixed flows. The computational procedure is based on the solution of the one-dimensional energy equation. Energy losses between two nearby cross sections are computed by friction (Manning's equation) and contraction/expansion (coefficient multiplied by the change in velocity head). For areas where the water surface profile changes rapidly, the momentum equation can be used. These situations include mixed flow regime calculations (i.e., hydraulic jumps), hydraulics of bridges, and evaluating profiles at river confluences (stream junctions) (Hydrologic Engineering Center, 2016).

3 Model Development

3.1 Bathymetry/topography

One meter LiDAR derived contours were provided by the Strathcona Regional District; however, the extents of this data were mostly limited to the SRD area. It included the river but did not extend very far south beyond the banks of the river. Another limitation is that LiDAR data does not capture the bottom surface of the river channel; therefore, a bathymetric survey was necessary for this study. Due to the lack of any other source of updated bathymetry data, the existing provincial government model developed for the 1984 floodplain mapping was used. Over the course of the last 34 years, the river bed has likely changed, nevertheless, this piece of information was sufficient for a high-level modelling exercise. The extents of the available bathymetry end close to the river banks, therefore, in order to represent the full extent of the floodplain a digital elevation model (DEM) was created. This was done using contours provided by the SRD and CVRD.

3.2 River Cross Sections

The geometric data needed for our analysis consisted of cross-section elevation data, reach length, and information for bridges. All the data were obtained by the HEC2 GR model of the 1984 Floodplain map developed by BC Water Surveys Unit and Canada, British Columbia Water Management Branch. The HEC2 GR model is an old version of HEC-RAS river modelling software, which is not compatible with any recent software. The old model files and plans were reviewed, and new geometry files were created manually in HEC-RAS.

A total of twenty cross-sections were obtained using historical data and were placed perpendicular to the predominant flow path along the channel, and left and right overbanks along each reach. The cross-sections in the original model had variable spacing, ranging from 10 m (distance used in the area of the bridges) up to 590 m for a reach.

Cross-section elevation data from the old model of 1984 during this time ranged from -4.57 m to 23.76 m. It is worth noting that the elevations of the channel bottom surface have most likely changed during the years. This is why a new bathymetric study would be a key piece of information needed for any future studies. Figures 1 and 2 show the cross-section geometry of the Oyster River.

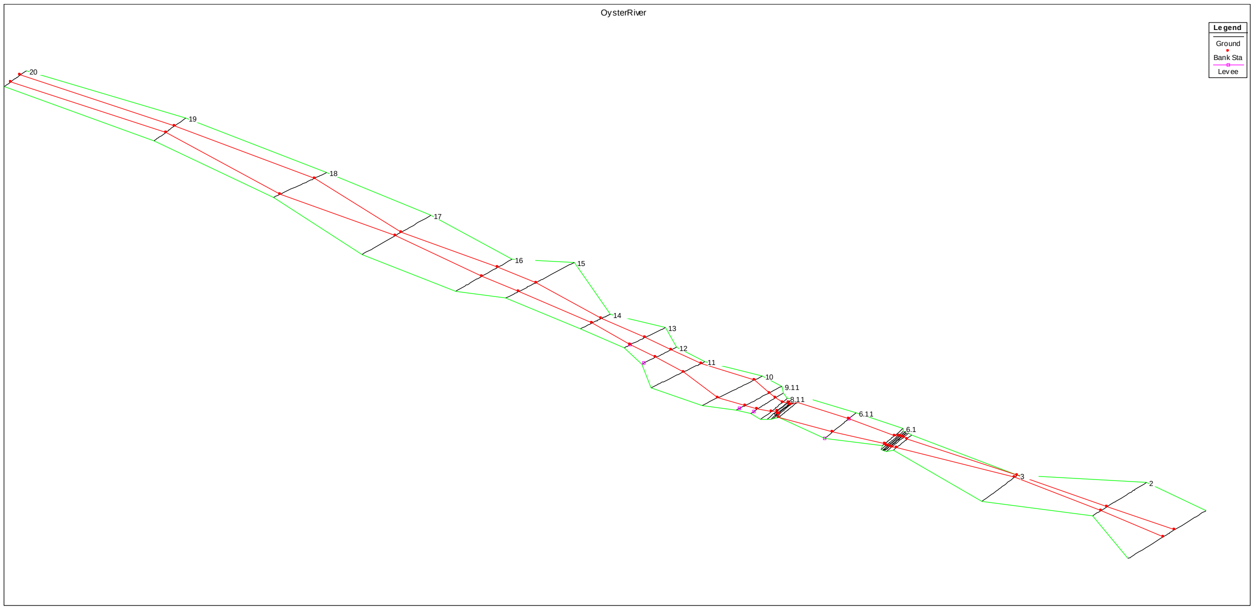


Figure 1: River's cross sections location

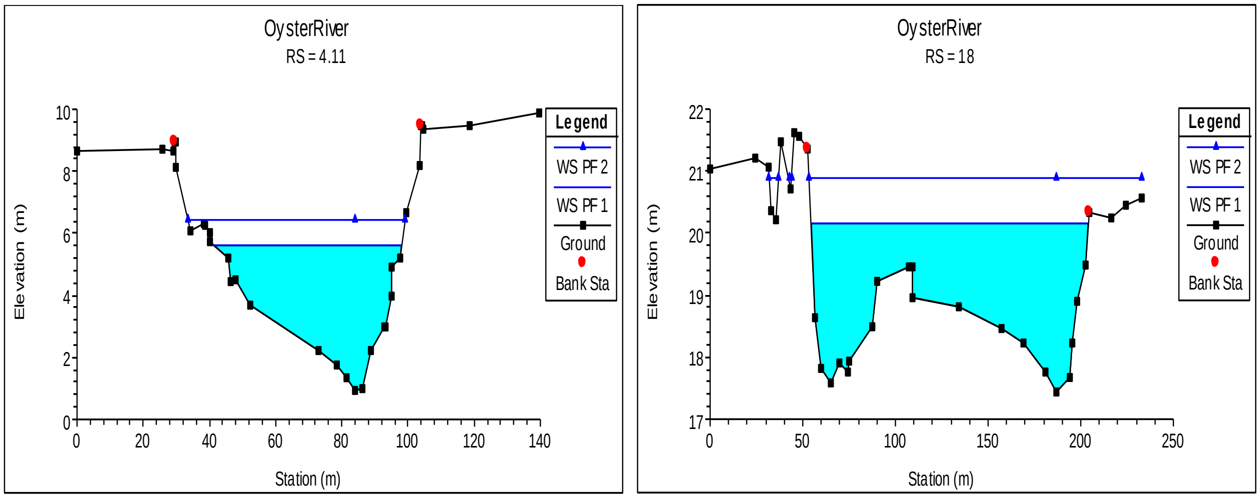


Figure 2: Cross section 4 and 18 of Oyster River

3.3 Hydraulic Structures and Bridges

The available historical data included information on the three bridges along the Oyster River, two of which are within the city limits. The bridges were modeled within HEC-RAS based on the geometry provided by the 1984's surveyed data. The data source for each crossing is included in the original HEC2 model from 1984 (in the form of bridge sketches), which is available in the Ecological Reports Catalogue on the BC Government Website. It should be noted that, the information on pier configurations, low chord, and deck elevations is historical and therefore it is possible to have changed since 1984.

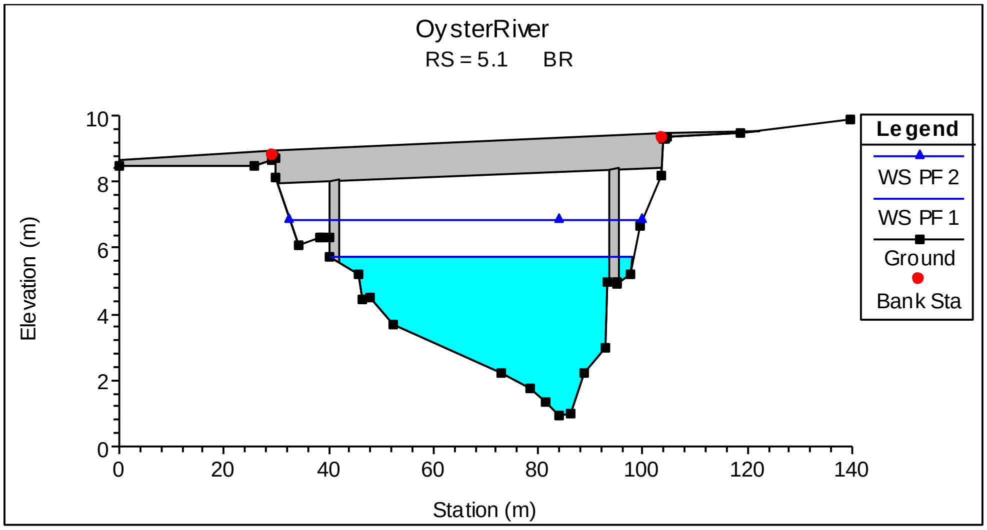


Figure 3: Example of Bridge Cross section (Old Highway Bridge)

3.4 Hydrometric Data and Boundary Conditions

HEC-RAS model and available flow records for the Oyster River at Woodhus Creek were used to simulate flows at cross-section sites within the study area and can be found in Section 4.4.2 of the main report. Other data needed for the modelling exercise included steady state flow data and the boundary conditions which can be found in Section 4.6.1 and 4.6.2 of the main report.

3.5 Calibration and Validation

No data was available for model calibration, therefore a literature review and engineering judgement were used to establish an estimation for channel roughness. In this instance for simplicity, roughness was kept constant across the whole domain and was set to a Manning's n value of 0.04 for channel roughness and of 0.08 for the overbank roughness respectively. This is a reasonable estimate for a gravel and sand channel bed.

Generally, the model represents the real system well. The flood extents of the 1984 NDNP for the 0.5 AEP (1:200 Year) Flood Discharge Estimates were used for a high-level validation of our model. These extents along with the extents from the output of the updated model are shown below in Figure 4. It is worth noting that there was no report accompanying the Preliminary Floodplain Mapping and therefore the hydrological analysis and the associated flow estimates used in the development of the 1984 flood map are unknown. In terms of hydrologic record, it should be noted that the Oyster River gauging station had only a few years of data when the 1984 mapping was complete. As shown in section 4.4.2 of the main report, the estimated flows of the first half or our record (which corresponds to the dates of the study) are significantly lower than the second half. Given the fact that the flow analysis shows a positive trend through the years, the preliminary map of 1984 seems to be in accordance with our results.

Figure 4: Map of Oyster River/Saratoga Beach with the extents from the 1984 model and updated high level modelling

3.6 Floodplain Modelling

The final stage of the flood extent estimation for this study included of analyzing the results from the HEC-RAS model within QGIS. Since the model wasn't georeferenced, this was done manually with the help of the old floodplain map which depicted the location and the numbering of the cross sections. The DEM was filled accordingly to the estimated water levels in each cross section.

3.7 Model Limitations

The present model was constructed by Ebbwater Consulting as part of an effort to create updated flood hazard extents of the Oyster River within the two regional districts. 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 extracted from the old floodplain map, and the focus of this model was low-frequency flood events. Some of the limitations of this study include:

- Topographic information: SRD and CVRD provided us with 1m contours of different resolutions. SRD obtained these datasets from a LiDAR survey; however, the scale and the extent of this study weren't sufficient for detailed floodplain mapping.

- Flow information: no hydrograph was provided for validation or modelling purposes.

- Calibration data: no data from a recent flood event (flood extents and associated flows).

- River geometry information: no updated bathymetric data, old datasets were used that were not very detailed and are not representative of the current terrain (especially in the banks of the river which have signs of erosion). Also, the extents of the current geometry from the survey end fairly close to the river banks and the program could not model the floodplain on its full extent.

- Dike information: The existing dike was not included in the updated modelling effort as it's condition and geometry were not provided.

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. The model scenarios are presented below in Table 1.

Table 1: Model scenarios for extreme events

Run Number	Upstream Boundary	Boundary Conditions	Comments
E-1	50% AEP Peak Flow (Steady State)	Upstream: *281 m^3/s* Downstream: *2.8 m (SWL)*	Peak Flow as calculated in previous studies
E-2	20% AEP Peak Flow (Steady State)	Upstream: *341 m^3/s* Downstream: *2.8 m (SWL)*	Extreme peak flow (see the differences in the extents)
E-3	10% AEP Peak Flow (Steady State)	Upstream: *379 m^3/s* Downstream: *2.8 m (SWL)*	Compare flood extents
E-4	5% AEP Peak Flow (Steady State)	Upstream: *410 m^3/s* Downstream: *2.8 m (SWL)*	Better simulation of the real flood events
E-5	2 % AEP Peak Flow (Steady State)	Upstream: *445 m^3/s* Downstream: *2.8 m (SWL)*	Peak Flow as calculated in previous studies
E-6	1% AEP Peak Flow (Steady State)	Upstream: *466 m^3/s* Downstream: *2.8 m (SWL)*	Extreme peak flow (see the differences in the extents)
E-7	0.5% AEP Peak Flow (Steady State)	Upstream: *484 m^3/s* Downstream: *2.8 m (SWL)*	Compare flood extents
E-8	0.2% AEP Peak Flow (Steady State)	Upstream: *504 m^3/s* Downstream: *2.8 m (SWL)*	Better simulation of the real flood events
E-9	0.2% AEP Peak Flow with climate change(Steady State)	Upstream: *961 m^3/s* Downstream: 3.6 *m (SWL)*	Extreme peak flow

4.2 Results (profiles)

The E-8 and E-9 model scenarios were selected for the purposes of flood mapping. The corresponding profile plots are shown in Figure 5 and Figure 6.

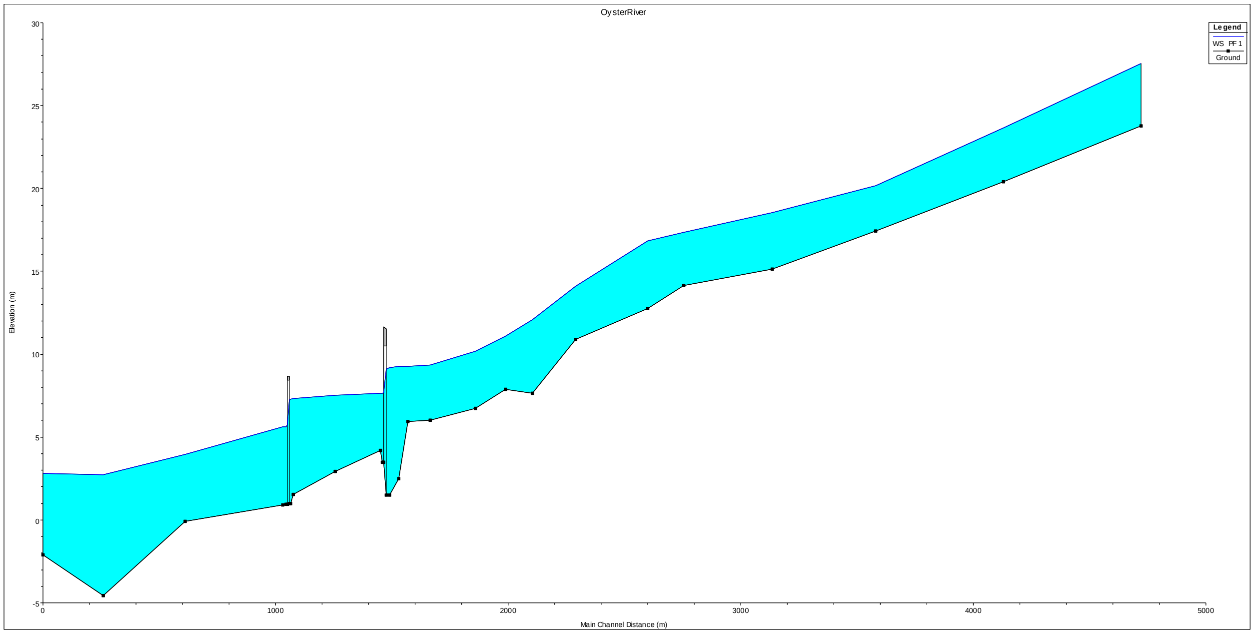


Figure 5: Profile Plot - Water Elevation for E-8 scenario

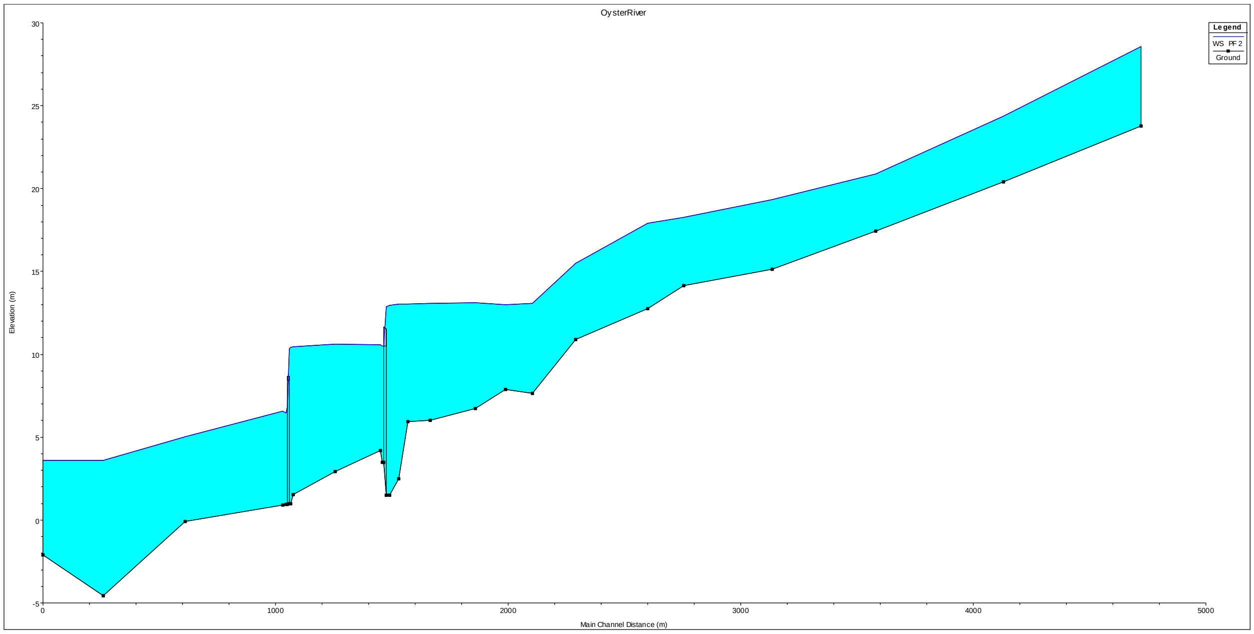


Figure 6: Profile Plot - Water Elevation for E-9 scenario

5 Conclusion and Future Improvements

Ebbwater Consulting has completed a model of the Oyster River support the collection of exposure and vulnerability at stakeholder workshops as part of an agreement with the Strathcona and Comox Regional Districts. The model extends from the Glenmore Dyke to the Straight of Georgia.

The model reasonably predicts high-level flood extents and flows; however, it was not intended for any engineering or regulatory applications. Although this model provides a good foundation and general understanding of the flood extents along the Oyster River, further improvements are recommended to increase its accuracy. Suggested future improvements include the following:

- Incorporating a 2D model to better capture the flood extents within the region. A new study extent is under discussion.
- LiDAR data of higher resolution which will cover the whole area (decide which is this area based to if the river is confined further upstream and in general try to find the smallest possible area in order for the 2D model to be improved.
- Refining the geometric data, bathymetric survey of the river, and updated bridge geometry, in the new study area extents.
- Updated dyke information to be incorporated to the study.
- Erosion and sentiment transport.
- Hydrograph- rating curve.
- Roughness.

These improvements in data sets and additional data could be used to produce a more detailed model for future use by the regional districts.

Appendix E Data Summary

	DATA CATEGORY	DATA DESCRIPTION	DATA TYPE	SOURCE	COMMENTS
EXPOSURE DATA	Topography	Coastline	shp	Received from Comox Valley, 2017-11-02	
	Topography	Administrative Boundaries	shp	Received from Comox Valley, 2017-11-02	
	Topography	Ditches	shp	Received from Comox Valley, 2017-11-02	
	Buildings	Number of Houses	shp	Received from Comox Valley, 2017-11-02	
	Buildings	Hydrants	shp	Received from Comox Valley, 2017-11-02	
	Buildings	Park Assets	shp	Received from Comox Valley, 2017-11-02	
	Buildings	Park Trails	shp	Received from Comox Valley, 2017-11-02	
	Land Use	Provincial Park	shp	Received from Comox Valley, 2017-11-02	
	Land Use	RegionalPark	shp	Received from Comox Valley, 2017-11-02	
	Environmental	Sensitive Ecosystem Inventory	shp	Received from Comox Valley, 2017-11-02	
	Water System	Water Service Areas	shp	Received from Comox Valley, 2017-11-02	
	Topography	Streams	shp	Received from Comox Valley, 2017-11-02	
	Wells	Valve	shp	Received from Comox Valley, 2017-11-02	
	Water System	Main Water System	shp	Received from Comox Valley, 2017-11-02	
	Dikes	Dike	shp	Received from Comox Valley, 2018-1-17	
	Pumping Stations	Watutco Pumping Station	shp	Received from Comox Valley, 2018-1-17	
	Main Water System	Watutco Main Water System	shp	Received from Comox Valley, 2018-1-17	

	DATA CATEGORY	DATA DESCRIPTION	DATA TYPE	SOURCE	COMMENTS
	Property Values	Assessed Property Values (to be associated with Parcel Map)	xlsx	Received from Comox Valley, 2018-3-14	
	Topography	Cadastral Line	shp	Received from Comox Valley, 2017-11-02	
	Building Footprints	SRD -Oyster River Area Building Footprints	shp	Received from Strathcona Regional District (SRD), 2017-11-21	
	Property Values	Assessed Property Values-Parcel Map	shp	Received from Strathcona Regional District (SRD), 2017-3-12	
	Roads	Partial Information About Roads in BC	shp	Downloaded from Digital Road Atlas BC, 2017-11-02	
	Parcel Map BC	Parcel Map BC Extract for CVRD	gdb	Downloaded from https://catalogue.data.gov.bc.ca/dataset/parcelmap-bc-parcel-fabric , 2018-3-13	
MODELLING DATA	Topography	1m Contours	shp	Received from Comox Valley, 2017-11-02	
	Orthos	2016 Orthophoto	.tfw; tif	Received from Comox Valley, 2017-11-02	
	Contours	1m Contours	gbd	Received from Strathcona Regional District (SRD), 2017-11-17	LIDAR data-cover just a small part of the CVRD region
	Cross section Profile Statements (Oyster River 1982)	Geometry File-Input for HEC-RAS	txt	Downloaded from http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=2134	Date Published: May 1984
	Bridge Drawings for Oyster River 1982	Bridge Geometry	pdf	Downloaded from http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=2135	Date Published: May 1984
	Oyster River Floodplain Mapsheet 5532-1	Floodplain Maps	pdf	Downloaded from http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=2136	Date Published: May 1984

	DATA CATEGORY	DATA DESCRIPTION	DATA TYPE	SOURCE	COMMENTS
	Oyster River Floodplain Mapsheet 5532-2	Floodplain Maps	pdf	Downloaded from http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=2137	Date Published: May 1984
	Oyster River Floodplain Mapsheet 5532-3	Floodplain Maps	pdf	Downloaded from http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=2138	Date Published: May 1984
	Thalweg Profile for Oyster River 1982	Geometry File-Input for HEC-RAS	pdf	Downloaded from http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=2139	Date Published: May 1984
	Uncontrolled Mosaic Showing XS Locations for Oyster River 1982	XS Locations	pdf	Downloaded from http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=2140	Date Published: May 1984
	Flow Data for Oyster River Woodhus Creek	Flow Data	xlsx	Downloaded from https://wateroffice.ec.gc.ca/mainmenu/historical_data_index_e.html	Date Published: May 1984
	Simulated Streamflow Datasets for Campbell River	Climate Change Data	xlsx	Downloaded from https://www.pacificclimate.org/data/station-hydrologic-model-output	Date Published: Jan. 2014

Legend

🟦	Data from CVRD
🟩	Data from SRD
🟨	Downloaded Data

Appendix F Flood Mapping Scope of Work

Modelling/Mapping Purpose

The CVRD/SRD wish to develop new up-to-date flood hazard modelling and mapping for the Oyster River/Saratoga Beach Area. This area was last mapped in 1984; this information is outdated and needs to be updated. 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 and coastal hydrography (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. 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.

Geographic Scope

The model will consider both riverine and coastal flood hazard in the community and cover the extents shown in the figure below.

Detailed Tasks

The following outlines anticipated tasks required to meet the project objectives.

A. Bathymetric Data Collection ($50k)

Hydraulic modelling and mapping is extremely sensitive to the data used to develop the river and floodplain geometry. The last known survey of the river was conducted prior to 1984. Bathymetric surveys of the river for an approximately 4.5 km reach as noted in the figure above will be required. The exact type of survey (boat vs. wading and section vs multi-beam) is not specified, as this will depend on the modelling approach. In addition to river bathymetry, contingent on potential availability of low-tide LiDAR, it may also be necessary to conduct some nearshore bathymetric surveys of the coast. This will support coastal modelling. Limited water elevation information should be collected as part of this study to support model calibration and validation.

B. Topographic Data ($5k + existing materials)

There is currently LiDAR and contour data available for the area. And, the Province has recently suggested that it will fly new LiDAR for the coastal regions of Vancouver Island in 2018 to support flood mapping.

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.

Boundary Conditions

An understanding of the boundary conditions is imperative for the development of a hydraulic model and mapping. This project seeks to develop a series of maps to support multiple future projects, and therefore requires updated hydrologic analyses that consider climate change and updated hydrographic (coastal) analyses that consider sea level rise.

A. 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.

B. Hydrographic ($15k + reliance on existing materials)

A coastal analysis of extreme events will be conducted using appropriate techniques (localized coastal modelling, simplified analysis). At a minimum it is expected that estimates of water levels for the 50%, 20%, 10%, 2%, 1%, 0.5% and 0.2% AEP events will be developed for the present day. Further, sea level rise, for some AEP events will be calculated for each decade through the year 2100. Several coastal flood mapping projects that might support this effort are underway in the region (e.g. coastal modelling of all the RDN, spot coastal modelling in the Town of Comox and Campbell River); these should be leveraged for this project.

Hydraulic Modelling ($40k)

An updated hydraulic model(s) for both the coastal and riverine flood hazard areas will be developed. The model should meet standards of best practice as described in the EGBC Flood Mapping Guidelines, and will likely 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).

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 – and consideration of the joint probability of coastal and riverine events occurring simultaneously must be considered. Climate change scenarios must also be considered.

The hydraulic modelling should be properly documented, signed and sealed as per EGBC guidelines

Mapping ($25k)

The modelling will be used to support the development of an atlas of flood 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 mapping will be completed.

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.

Estimated Cost

An estimated total cost for the scope of work presented above is $175k – this includes a small contingency of $15k to account for potential increases in cost resulting from high demands for these services at this time. This is also broken down by task (see brackets beside tasks). The cost estimates are based on recently completed projects in the region. Actual costs will vary based on available information and the approach taken.

Public Safety Canada
Sécurité publique Canada

Ottawa, Canada
K1A 0P8

UNCLASSIFIED

National Disaster Mitigation Program (NDMP)
Risk Assessment Information Template

Risk Event Details		
Start and End Date	Provide the start and end dates of the selected event, based on historical data.	Start Date: 200yrs design event End Date: 200yrs design event
Severity of the Risk Event	Provide details about the risk, including: • Speed of onset and duration of event; • Level and type of damaged caused; • Insurable and non-insurable losses; and • Other details, as appropriate.	The chosen event is a simulated/design flooding event in Vancouver Island in the south western part of British Columbia was caused by heavy rains. We chose this event due to lack of historical data. In general in Oyster River area we can easily witness: - Riverine flooding near the river, as well as flooding to high groundwater levels - Debris flows/ bank erosion - Continued over almost two months, with increasing water levels due to continued warming temperatures, melting snowpack, heavy rainfalls and saturated ground. - Local roads closed due to flooding - Property damages - Non accessible businesses - Groundwater contamination/Water quality issues (wells)-septics - Closing of public beach areas
Response During the Risk Event	Provide details on how the defined geographic area continued its essential operations while responding to the event.	A design event is being used (200 yrs return period) due to lack of historical information in terms of flood extent and related flow estimations as well as information about emergency response during past events.
Recovery Method for the Risk Event	Provide details on how the defined geographic area recovered.	A design event is being used (200 yrs return period) due to lack of historical information in terms of flood extent and related flow estimations as well as information about recovery during past events.
Recovery Costs Related to the Risk Event	Provide details on the costs, in dollars, associated with implementing recovery strategies following the event.	A design event is being used (200 yrs return period) due to lack of historical information terms of flood extent and related flow estimations. In the past the regional district asked for design work for flood control on the Oyster River (1991) and later in the same year the Oyster River area flood repair work (P.E.P.) was done and the construction of Phase 1 of the Oyster River Dyke was completed. However, the Glenmore Dike breached in 2009 following repeated flooding in Glenmore Rd from to high ground water levels due to severe rain event in combination with King Tides. No cost information available.

Recovery Time Related to the Risk Event	Provide details on the recovery time needed to return to normal operations following the event.	A design event is being used (200 yrs return period) due to lack of historical information in terms of flood extent and related flow estimations as well as information about recovery during past events.

Public Safety Canada Sécurité publique Canada

Ottawa, Canada
K1A 0P8

UNCLASSIFIED

National Disaster Mitigation Program
Risk Assessment Information Template

Risk Event Identification and Overview	
Provide a qualitative description of the defined geographic area, including: • Watershed/community/region name(s); • Province/Territory; • Area type (i.e., city, township, watershed, organization, etc.); • Population size; • Population variances (e.g., significant change in population between summer and winter months); • Main economic areas of interest; • Special consideration areas (e.g., historical, cultural and natural resource areas); and an • Estimate of the annual operating budget of the area.	- Regional District of Strathcona and Regional District od Comox Valley, located in Vancouver Island, South-Western part of British Columbia (BC) - The Oyster River Watershed, a relatively small watershed of about 376 km2. - Includes the community of Oyster River and Saratoga Beach. Comox Valley, the Comox Valley has a population of 66,527 and covers an area of 2,425 square kilometres. The Strathcona Regional District has a land area of 18,329.948 km² and a 2016 census population of 44,671 inhabitants. - Main water bodies: Comox Lake, Courtenay River, Oyster River, Puntledge and Tsolum Rivers (CVRD) Campbell River, Campbell Lake and Buttle Lake (SRD) - Land use: residential, commercial, agricultural. rural areas and forest resources in high elevation plateau areas. - Main economic areas of interest: Tourism, Forestry and Manufacturing industries, as well as health care services for the large portion of retired and elderly residents in the region. Agriculture production is primarily found from the Comox Valley south.
Methodolgies, processes and analyses	

National Disaster Mitigation Program
Risk Assessment Information Template

Provide the year in which the following processes/analyses were last completed and state the methodology(ies) used: • Hazard identification; • Vulnerability analysis; • Likelihood assessment; • Impact assessment; • Risk assessment; • Resiliency assessment; and/or • Climate change impact and/or adaptation assessment. *Note:* It is recognized that many of the processes/analyses mentioned above may be included within one methodology.	Hazard Mapping: Ministry of Environment, BC Water Surveys Unit and Canada, British Columbia Water Management Branch, during the Floodplain Mapping Program (1984): 200-year preliminary floodplain mapping from 1984. ---> The floodplain mapping in the regional district is over 30 years old (therefore, does likely not represent the current (and future) situation, and it does not cover all the floodplains. Peak Streamflows: - Water Survey of Canada (Environment Canada) has maintained a stream gauging station (08HD011) on the Oyster River below Woodhus Creek since 1974. The watershed area above the gauging station is about 298 km2, and does not include the Little Oyster River watershed which is a tributary of the Oyster River. There was also another gauging station (08HD002 Oyster River near Campbell River, drainage area = 363 km2) in operation between 1914 and 1917. Climate Change: - University of Victoria Pacific Climate Impacts Consortium - Station Hydrologic Model Output for Campbell River (nearest River) - OWSDP completed climate and hydrologic modeling. future scenario modeling using climate data from CGCM2 (A2) climate model, HadCM3 (A2), CGCM3(B1), for 2011-2040. Summary based on 3 studies above: climate in Vancouver Island will warm. Summer precipitation will likely decreases, and winter precipitation will increase. Snowmelt to occur earlier with lower meltwater runoff due to more rain generated runoff during the winter. Magnitude of extreme peak flows is project to increase.

Hazard Mapping

To complete this section:

- Obtain a map of the area that clearly indicates general land uses, neighbourhoods, landmarks, etc. For clarity throughout this exercise, it may be beneficial to omit any non-essential information from the map intended for use. Controlled photographs (e.g. aerial photography) can be used in place of or in addition to existing maps to avoid the cost of producing new maps.
- Place a grid over the maps/photographs of the area and assign row and column identifiers. This will help identify the specific area(s) that may be impacted, as well as additional information on the characteristics within and affecting the area.
- Identify where and how flood hazards may affect the defined geographic area.
- Identify the mapped areas that are most likely to be impacted by the identified flood hazard.

Map(s)/photograph(s) can also be used, where appropriate, to visually represent the information/prioritization being provided as part of this template.

National Disaster Mitigation Program
Risk Assessment Information Template

Hazard identification and prioritization	
List known or likely flood hazards to the defined geographic area in order of proposed priority. For example: (1) dyke breach overland flooding; (2) urban storm surge flooding ; and so on.	(1) Storm surge flooding (2) Heavy rainfalls (3) Riverine flooding (4) Groundwater -induced flooding (5) Debris flows (6)Dyke breach overland flooding In 1975 a high discharge in the river caused bank erosion and events in 1980 and 1990 caused property damage. In 2009 a dike break occurred and homes were flooded, while in 2010 a combination of high ground water levels along with river flooding posed problems. In 2011 the ocean levels also played a role with a combination of high tide, ground water, and levels contributing to the flood hazard.
Provide a rationale for each prioritization and the key information sources supporting this rationale.	(1) King Tides in particular problematic in combination with severe rain event (2011) (2) Historically led to flooding in combination to riverine flow, 1990 (3) Historically led to flooding, 1990 (4) Glenmore Rd residents experience localized flooding from high ground water levels due to severe rain event 2010 (5) In particular problematic in combination with severe rain event (6) Dyke breach
Risk Event Title	
Identify the name/title of the risk. An example of a risk event name or title is: "A one-in-one hundred year flood following an extreme rain event."	Flooding in Oyster River/Saratoga Beach typically occurs in the months of November and December. The event described is a one-in-two hundred year flood following an extreme rain event.
Type of Flood Hazard	
Identify the type of flood hazard being described (e.g., riverine flooding, coastal inundation, urban run-off, etc.)	Riverine flooding, (including storm surge)
Secondary hazards	

Describe any secondary effects resulting from the risk event (e.g., flooding that occurs following a hurricane).	Severe rainfall, particularly if accompanied by high tides. Severe rainfall can cause an extensive flooding and high groundwater levels. High tides will further exacerbate this issue. Heavy precipitation also results in debris flows and bank erosion in the river.
Primary and secondary organizations for response	
Identify the primary organization(s) with a mandate related to a key element of a natural disaster emergency, and any supporting organization(s) that provide general or specialized assistance in response to a natural disaster emergency.	Regional District of Comox Valley-Strathcona - Emergency Operations Centre In general in BC, Local Authorities are responsible for primary response. The provincial agency, Emergency Management BC (EMBC) supports local authority response and coordinates province response. If local authorities become overwhelmed by the magnitude of an event, EMBC will assume the lead role for the response. Provincial agencies that support response are dependent on the impact and effect. For example, the Ministry of Environment will assist with environmental contaminants, Ministry of Health with water quality issues and Ministry of Agriculture with livestock and agriculture. The Ministry of Forests plays a pivotal role in leading the technical oversight of water stewardship, flooding and mapping. External agencies will assist during catastrophic events (e.g. military, inter-provincial resources, Red Cross, etc.)

Risk Event Description	
Description of risk event, including risk statement and cause(s) of the event	
Provide a baseline description of the risk event, including: • Risk statement; • Context of the risk event; • Nature and scale of the risk event; • Lead-up to the risk event, including underlying cause and trigger/stimulus of the risk event; and • Any factors that could affect future events. *Note:* The description entered here must be plausible in that factual information would support such a risk event.	Most of the flooding in Oyster River/Saratoga Beach typically occurs in the months of November and December and are caused by heavy rains in combination to high groundwater levels and or tides. - Flooding occurred from the river. - The event is a 1:200-year return period event - Events of that magnitude or higher are likely to occur increasingly in the future, with a warming climate (snowmelt), increased winter precipitation, and increasing peak flows.

National Disaster Mitigation Program
Risk Assessment Information Template

Location	
Provide details regarding the area impacted by the risk event such as: • Province(s)/territory(ies); • Region(s) or watershed(s); • Municipality(ies); • Community(ies); and so on.	- Regional District of Comox Valley-Strathcona, located in South-Western of British Columbia (BC) - Many of the communities and rural areas within the CVRD experienced flooding - Water levels rose in the Oyster River
Natural environment considerations	
Document relevant physical or environmental characteristics of the defined geographic area.	- The Regional District of Comox Valley-Strathcona is characterized by moderate slopes. The upper part of the catchment is mountainous and it becomes more flat as the river approaches the outflow. - Population is mostly concentrated near the river and the sea with most desirable property and real estate adjacent to the sea -> i.e., much infrastructure near the sea and floodplains -> susceptible to flooding
Meteorological conditions	
Identify the relevant meteorological conditions that may influence the outcome of the risk event.	Oyster’s River streamflow is characterized by a high flow in November due to fall rains, and another high flow in May and June due to snowmelt from high elevations. Minimum flows generally occurred between August and October and another high flow in May and June due to snowmelt from high elevations. Also, high ground water levels due to severe rain event in combination with King Tides can increase the probability of riverine flooding.

Seasonal conditions	
Identify the relevant seasonal changes that may influence the outcome of the risk assessment of a particular risk event.	The main seasonal changes that are relevant for the generation of the high streamflows that led to the flooding event are the warming temperatures in Spring and related snowmelt. Furthermore, high spring rainfalls coincided with high groundwater levels, increasing the total streamflow and contributing to saturated ground, that in turn increased surface runoff.

Nature and vulnerability	
Document key elements related to the affected population, including: • Population density; • Vulnerable populations (identify these on the hazard map from step 7); • Degree of urbanization; • Key local infrastructure in the defined geographic area; • Economic and political considerations; and • Other elements, as deemed pertinent to the defined geographic area.	Population Density and degree of urbanization: Population density and degree of urbanization varies throughout the regional districts. It is higher in the centres of City and near Saratoya Beach. Vulnerable populations: - A major geographical issue facing response groups in the area during an emergency is that there are many isolated communities where notification and evacuation is difficult. - The region has a large proportion of senior or elderly residents (21.8% for SRD and 33.5% for CVRD) of total regional population, Statistics Canada, 2001). Elderly residents are in particular vulnerable during a flood event, as they are not as mobile, might live alone, have limiting conditions, need appropriate health services and may experience transfer traumas. - Low income groups are also vulnerable. In the regional district, low income population in the area ranges from 6.5% to 7%. The state of emergency requires funds and resources that low-income people might have no access to. Economy: - The top industries in the SRD and CVRD are Tourism, Forestry and Manufacturing industries and agriculture. Tourism contributes a significant share of revenues in the region. Further, the large share of retired and elderly residents int he region has propagated the need for more health services and facilities.

National Disaster Mitigation Program
Risk Assessment Information Template

Asset inventory	
Identify the asset inventory of the defined geographic area, including: • Critical assets; • Cultural or historical assets; • Commercial assets; and • Other area assets, as applicable to the defined geographic area. Key asset-related information should also be provided, including: • Location on the hazard map (from step 7); • Size; • Structure replacement cost; • Content value; • Displacement costs; • Importance rating and rationale; • Vulnerability rating and reason; and • Average daily cost to operate. A total estimated value of physical assets in the area should also be provided.	Critical assets: - Septics and wells near the Oyster River. The community experienced a damaging flood in December of 1980 and following this a 200-year floodplain map was developed in 1984. Within the floodplain extends of this map are residential areas, infrastructure and notably the four wells that provide water to about 3,000 people. This service area includes about 2,200 people in the CVRD and 800 people in the SRD. Flooding in this area has in the past led to water quality issues and trail erosion issues. - Food supplies throughout the region. - Many communities are limited to one access/ evacuation route. Cultural assets: - Many provincial parks located along lake and river shores (including campgrounds and RV parks) The estimates on replacement or displacements costs are yet available as disaster financial assistance claims are still being processed.
Other assumptions, variability and/or relevant information	
Identify any assumptions made in describing the risk event; define details regarding any areas of uncertainty or unpredictability around the risk event; and supply any supplemental information, as applicable.	The described event is based on a design event due to lack of historical information. Due to lack of new bathymetry data, the bathymetric survey from 1984 (Flood maps of 1984) was used. Thus, a new floodplain map with updated data needs to be developed in order to properly mitigate the risk of flooding.
Existing Risk Treatment Measures	
Identify existing risk treatment measures that are currently in place within the defined geographic area to mitigate the risk event, and describe the sufficiency of these risk treatment measures.	A dyke exists in the region. The dike was breached during a previous flooding event, in 2009.

National Disaster Mitigation Program
Risk Assessment Information Template

Likelihood Assessment	
Return Period	
Identify the time period during which the risk event might occur. For example, the risk event described is expected to occur once every X number of years. Applicants are asked to provide the X value for the risk event.	The risk event described is expected to occur once every 200 years.
Period of interest	
Applicants are asked to determine and identify the likelihood rating (i.e. period of interest) for the risk event described by using the likelihood rating scale within the table below.	

Likelihood Rating	**Definition**	
5	The event is expected and may be triggered by conditions expected over a 30 year period.	3
4	The event is expected and may be triggered by conditions expected over a 30 - 50 year period.	
3	The event is expected and may be triggered by conditions expected over a 50 - 500 year period.	
2	The event is expected and may be triggered by conditions expected over a 500 - 5000 year period.	
1	The event is possible and may be triggered by conditions exceeding a period of 5000 years.	

Provide any other relevant information, notes or comments relating to the likelihood assessment, as applicable.	

Impacts/Consequences Assessment

There are 12 impacts categories within 5 impact classes rated on a scale of 1 (least impacts) to 5 (greatest impact). Conduct an assessment of the impacts associated with the risk event, and assign one risk rating for each category. Additional information may be provided for each of the categories in the supplemental fields provided.

A) People and societal impacts

	Risk Rating	Definition	Assigned risk rating
Fatalities	5	Could result in more than 50 fatalities	1
	4	Could result in 10 - 49 fatalities	
	3	Could result in 5 - 9 fatalities	
	2	Could result in 1 - 4 fatalities	
	1	Not likely to result in fatalities	
Supplemental information (optional)			
Injuries	5	Injuries, illness and/or psychological disablements cannot be addressed by local, regional, or provincial/territorial healthcare resources; federal support or intervention is required	1
	4	Injuries, illnesses and/or psychological disablements cannot be addressed by local or regional healthcare resources; provincial/territorial healthcare support or intervention is required.	
	3	Injuries, illnesses and/or psychological disablements cannot be addressed by local or regional healthcare resources additional healthcare support or intervention is required from other regions, and supplementary support could be required from the province/territory	
	2	Injuries, illnesses and/or psychological disablements cannot be addressed by local resources through local facilities; healthcare support is required from other areas such as an adjacent area(ies)/municipality(ies) within the region	
	1	Any injuries, illnesses, and/or psychological disablements can be addressed by local resources through local facilities; available resources can meet the demand for care	
Supplemental information (optional)			

		Risk Rating	Definition	Assigned risk rating
Displacement	Percentage of displaced individuals	5	> 15% of total local population	1
		4	10 - 14.9% of total local population	
		3	5 - 9.9% of total local population	
		2	2 - 4.9% of total local population	
		1	0 - 1.9% of total local population	
	Duration of displacement	5	> 26 weeks (6 months)	1
		4	4 weeks - 26 weeks (6 months)	
		3	1 week - 4 weeks	
		2	72 hours - 168 hours (1 week)	
		1	Less than 72 hours	
Supplemental information (optional)				
B) Environmental impacts				
		5	> 75% of flora or fauna impacted or 1 or more ecosystems significantly impaired; Air quality has significantly deteriorated; Water quality is significantly lower than normal or water level is > 3 meters above highest natural level; Soil quality or quantity is significantly lower (i.e., significant soil loss, evidence of lethal soil contamination) than normal; > 15% of local area is affected	3
		4	40 - 74.9% of flora or fauna impacted or 1 or more ecosystems considerably impaired; Air quality has considerably deteriorated; Water quality is considerably lower than normal or water level is 2 - 2.9 meters above highest natural level; Soil quality or quantity is moderately lower than normal; 10 - 14.9% of local area is affected	
		3	10 - 39.9% of flora or fauna impacted or 1 1 or more ecosystems moderately impaired; Air quality has moderately deteriorated; Water quality is moderately lower than normal or water level is 1 - 2 meters above highest natural level; Soil quality is moderately lower than normal; 6 - 9.9 % of area affected	

	2	< 10 % of flora or fauna impacted or little or no impact to any ecosystems; Little to no impact to air quality and/or soil quality or quantity; Water quality is slightly lower than normal, or water level is less than 0.9 meters above highest natural level and increased for less than 24 hours; 3 - 5.9 % of local area is affected	
	1	Little to no impact to flora or fauna, any ecosystems, air quality, water quality or quantity, or to soil quality or quantity; 0 - 2.9 % of local area is affected	
Supplemental information (optional)	In most of the previous flooding events in the area: - Many river banks eroded due to the high streamflows - Regional parks and beaches had to be closed due to flooding and damages - Wells and septics are located in proximity of the river in the regional district, and were impacted by the high water levels, and contaminated waters.		

C) Local economic impacts

	Risk Rating	**Definition**	**Assigned risk rating**
	5	> 15 % of local economy impacted	3
	4	10 - 14.9 % of local economy impacted	
	3	6 - 9.9 % of local economy impacted	
	2	3 - 5.9 % of local economy impacted	
	1	0 - 2.9 % of local economy impacted	
Supplemental information (optional)	- Many access roads had to be closed, many stores and businesses were inaccessible or had to temporarily shut down.		

National Disaster Mitigation Program
Risk Assessment Information Template

D) Local infrastructure impacts

	Risk Rating	Definition	Assigned risk rating
Transportation	5	Local activity stopped for more than 72 hours; > 20% of local population affected; lost access to local area and/or delivery of crucial service or product; or having an international level impact	2
	4	Local activity stopped for 48 - 71 hours; 10 - 19.9% of local population affected; significantly reduced access to local area and/or delivery of crucial service or product; or having a national level impact	
	3	Local activity stopped for 25 - 47 hours; 5 - 9.9% of local population affected; moderately reduced access to local area and/or delivery of crucial service or product; or having a provincial/territorial level impact	
	2	Local activity stopped for 13 - 24 hours; 2 - 4.9% of local population affected; minor reduction in access to local area and/or delivery of crucial service or product; or having a regional level impact	
	1	Local activity stopped for 0 - 12 hours; 0 - 1.9% of local population affected; little to no reduction in access to local area and/or delivery of crucial service or product	
Supplemental information (optional)			
Energy and Utilities	5	Duration of impacts > 72 hours; > 20% of local population without service or product; or having an international level impact	1
	4	Duration of impact 48 - 71 hours; 10 - 19.9% of local population without service or product; or having a national impact	
	3	Duration of impact 25 - 47 hours; 5 - 9.9% of local population without service or product; or having a provincial/territorial level impact	
	2	Duration of impact 13 - 24 hours; 2 - 4.9% of local population without service or product; or having a regional level impact	
	1	Local activity stopped for 0 - 12 hours; 0 - 1.9% of local population affected; little to no reduction in access to local area and/or delivery of crucial service or product	

Supplemental information (optional)			
Information and Communications Technology	5	Service unavailable for > 72 hours; > 20 % of local population without service; or having an international level impact	1
	4	Service unavailable for 48 - 71 hours; 10 - 19.9 % of local population without service; or having a national level impact	
	3	Service unavailable for 25 - 47 hours; 5 - 9.9 % of local population without service; or having a provincial/territorial level impact	
	2	Service unavailable for 13 - 24 hours; 2 - 4.9 % of local population without service; or having a regional level impact	
	1	Service unavailable for 0 - 12 hours; 0 - 1.9 % of local population without service	
Supplemental information (optional)			
Health, Food, and Water	5	Inability to access potable water, food, sanitation services, or healthcare services for > 72 hours; non-essential services cancelled; > 20 % of local population impacted; or having an international level impact	1
	4	Inability to access potable water, food, sanitation services, or healthcare services for 48-72 hours; major delays for nonessential services; 10 - 19.9 % of local population impacted; or having a national level impact	
	3	Inability to access potable water, food, sanitation services, or healthcare services for 25-48 hours; moderate delays for nonessential services; 5 - 9.9 % of local population impacted; or having a provincial/territorial level impact	
	2	Inability to access potable water, food, sanitation services, or healthcare services for 13-24 hours; minor delays for nonessential; 2 - 4.9 % of local population impacted; or having a regional level impact	
	1	Inability to access potable water, food, sanitation services, or healthcare services for 0-12 hours; 0 - 1.9 % of local population impacted	

Supplemental information (optional)			
Safety and Security	5	> 20 % of local population impacted; loss of intelligence or defence assets or systems for > 72 hours; or having an international level impact	1
	4	10 - 19.9 % of local population impacted; loss of intelligence or defence assets or systems for 48 – 71 hours; or having a national level impact	
	3	5 - 9.9 % of local population impacted; loss of intelligence or defence assets or systems for 25 – 47 hours; or having a provincial/territorial level impact	
	2	2 - 4.9 % of local population impacted; loss of intelligence or defence assets or systems for 13 – 24 hours; or having a regional level impact	
	1	0 - 1.9 % of local population impacted; loss of intelligence or defence assets or systems for 0 – 12 hours	
Supplemental information (optional)			

National Disaster Mitigation Program
Risk Assessment Information Template

E) Public sensitivity impacts

	Risk Rating	Definition	Assigned risk rating
	5	Sustained, long term loss in reputation/public perception of public institutions and/or sustained, long term loss of trust and confidence in public institutions; or having an international level impact	2
	4	Significant loss in reputation/public perception of public institutions and/or significant loss of trust and confidence in public institutions; significant resistance; or having a national level impact	
	3	Some loss in reputation/public perception of public institutions and/or some loss of trust and confidence in public institutions; escalating resistance	
	2	Isolated/minor, recoverable set-back in reputation, public perception, trust, and/or confidence of public institutions	
	1	No impact on reputation, public perception, trust, and/or confidence of public institutions	
Supplemental information (optional)			

Confidence Assessment

Based on the table below, indicate the level of confidence regarding the information entered in the risk assessment information template in the "Confidence Level Assigned" column. Confidence levels are language-based and range from A to E (A=most confident to E=least confident).

Confidence Level	Definition	Confidence Level Assigned
A	Very high degree of confidence Risk assessment used to inform the risk assessment information template was evidence-based on a thorough knowledge of the natural hazard risk event; leveraged a significant quantity of high-quality data that was quantitative and qualitative in nature; leveraged a wide variety of data and information including from historical records, geospatial and other information sources; and the risk assessment and analysis processes were completed by a multidisciplinary team with subject matter experts (i.e., a wide array of experts and knowledgeable individuals on the specific natural hazard and its consequences) Assessment of impacts considered a significant number of existing/known mitigation measures	
B	High degree of confidence Risk assessment used to inform the risk assessment information template was evidence-based on a thorough knowledge of the natural hazard risk event; leveraged a significant quantity of data that was quantitative and qualitative in nature; leveraged a wide variety of data and information including from historical records, geospatial and other information sources; and the risk assessment and analysis processes were completed by a multidisciplinary team with some subject matter expertise (i.e., a wide array of experts and knowledgeable individuals on the specific natural hazard and its consequences) Assessment of impacts considered a significant number of potential mitigation measures	

C	Moderate confidence Risk assessment used to inform the risk assessment information template was moderately evidence-based from a considerable amount of knowledge of the natural hazard risk event; leveraged a considerable quantity of data that was quantitative and/or qualitative in nature; leveraged a considerable amount of data and information including from historical records, geospatial and other information sources; and the risk assessment and analysis processes were completed by a moderately sized multidisciplinary team, incorporating some subject matter experts (i.e., a wide array of experts and knowledgeable individuals on the specific natural hazard and its consequences) Assessment of impacts considered a large number of potential mitigation measures	C
D	Low confidence Risk assessment used to inform the risk assessment information template was based on a relatively small amount of knowledge of the natural hazard risk event; leveraged a relatively small quantity of quantitative and/or qualitative data that was largely historical in nature; may have leveraged some geospatial information or information from other sources (i.e., databases, key risk and resilience methodologies); and the risk assessment and analysis processes were completed by a small team that may or may not have incorporated subject matter experts (i.e., did not include a wide array of experts and knowledgeable individuals on the specific natural hazard and its consequences). Assessment of impacts considered a relatively small number of potential mitigation measures	
E	Very low confidence Risk assessment used to inform the risk assessment information template was not evidence-based; leveraged a small quantity of information and/or data relating to the natural risk hazard and risk event; primary qualitative information used with little to no quantitative data or information; and the risk assessment and analysis processes were completed by an individual or small group of individuals little subject matter expertise (i.e., did not include a wide array of experts and knowledgeable individuals on the specific natural hazard and its consequences). Assessment of impacts did not consider existing or potential mitigation measures	

Rationale for level of confidence	
Provide the rationale for the selected confidence level, including any references or sources to support the level assigned.	This risk assessment is based on a design flood event due to lack of related historical information.

Key Information Sources	
Identify all supporting documentation and information sources for qualitative and quantitative data used to identify risk events, develop the risk event description, and assess impacts and likelihood. This ensures credibility and validity of risk information presented as well as enables referencing back to decision points at any point in time. Clearly identify unclassified and classified information.	Regional District of Strathcona http://www.strathconard.ca/ Regional District of Comox Valley https://www.comoxvalleyrd.ca/
Description of the risk analysis team	
List and describe the type and level of experience of each individual who was involved with the completion of the risk assessment and risk analysis used to inform the information contained within this risk assessment information template.	This RAIT was completed by Ebbwater Consulting. Ebbwater Consulting is a BC-based engineering company well known for its expertise in flood management and flood risk assessments.