Fraser Basin Council

Investigations in Support of Flood Strategy Development in British Columbia

Issue D1 Resources and Funding

FINAL REPORT

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Project #
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Dear Mr. Litke,

Subject: Investigations in Support of Flood Strategy Development in British Columbia
Issue D1 Resources and Funding
Final Report

We are pleased to submit our final report on Investigations D-1.1 and D-1.2 including a review of the cost estimates in Investigations' reports A-1, B-1 to B-6, C-1 and C-2 and a literature review of selected documents related to Benefit-Cost Analysis applied to Flood Management in BC.

Sincerely,
AECOM Canada Ltd.

JBergeron

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The project team would like to recognize the leadership of the Fraser Basin Council in leading this multi-consultants/stakeholders' initiative covering a comprehensive scope of flood management planning in BC. We would like to acknowledge the continuous support of Robert Larson, Ebbwater Consulting Inc., Project Manager, and Steve Litke and Frances Woo from the Fraser Basin Council. Their thorough review of the report and the thoughtful comments from George Roman, Alex Barnes and Mitchell Hahn of the BC MFLNRORD were greatly appreciated.

The project team consisted of:

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- Michelle Ajibola, PQS, Lead Verifier
- Janie Bergeron, P.Eng., M.Env., PMP, Project Manager

Executive Summary

Heavy rainfall, freshet and storm surges combined with climate change and structural (e.g. dike) failure lead to flooding, posing a serious risk to public health and safety. The British Columbia (BC) Government aims at reducing the impacts of flooding on people, communities and infrastructure in the province with initiatives like the Investigations in Support of Flood Strategy Development in British Columbia led by the Fraser Bain Council (FBC). This project is delivered in collaboration with consultants to address 11 issues and complete investigations covering four (4) themes: A: Governance, B: Flood Hazard and Risk Management, C: Flood Forecasting, Emergency Response and Recovery, and D: Resources and Funding. This report presents the results of Investigations D-1.1 and D-1.2 on Resources and Funding.

Investigation D-1.1

The investigation D-1.1 includes two tasks. Task 1 consists of a document review of the cost estimates presented in the reports of investigations A-1, B-1 to B-6, C-1 and C-2. The objective is to make recommendations on how to standardize the various cost estimates to make them indicative of the overall cost to implement the recommendations from the Investigations in Support of Flood Strategy Development in British Columbia. Using a matrix format, we described the characteristics of effective estimates and reviewed the cost estimates in the context of the following key aspects:

- Estimating Methodology
- Basis of Estimate
- Estimating Assumptions
- Exclusions from the Estimate
- Other Limiting Conditions
- Source Cost Data

The nine (9) reports use different costing strategies and basis such as benchmark from previous similar studies, \$/km, staff Full-Time Equivalents (FTE), consultant fees, survey and case study interviews, models, etc. There is a need to develop a spreadsheet tool including the cost estimates from all of the investigations' reports for more efficiency, accuracy and consistency in using common estimating basis e.g. FTE, timeframe, inflation and discount rate, etc. This Unified Estimate Tool would improve connectivity between the reports and perform dynamic applications such as scenarios.

The purpose of Task 2 is a more thorough analysis of the cost estimates in the Investigation B-2 report on flood hazard information, and sets out the next steps to refine the cost estimate, using the verified input data from the B-2 report and the Consultant’s supporting Memo.

Investigation D-1.2

One aspect of successful flood management is establishing long-term investment in proactive flood planning and mitigation activities. Because extreme flooding happens on an infrequent basis, often funding for flood activities tends to be post-disaster. These larger magnitude events are the ones that tend to drive policy and funding. The focus needs to shift to proactive, pre-disaster phases to reduce or avoid possible future flood losses. Decision makers seek evidence using defendable approaches to support spending today’s money for possible future flood damages.

The main technical approach used to support mitigation projects is Benefit-Cost Analysis (BCA). Benefits are the avoided direct and indirect damages and associated costs from flood events. BCA can be used during project selection to evaluate and compare potential projects. Individual BCA values can also be combined across funding sources and award cycles to summarize the overall benefits for entire funding programs.

This report summarizes the BCA approaches for flood mitigation activities described in a select group of publications and sources from Canada and the United States of America (USA) and their applicability to BC. It includes an analysis of concepts and definitions, sources for costs and tangible and intangible benefits as well as economic variables and consideration for First Nations and vulnerable populations.

Although there can be significant variation in BCRs between and within BCA studies, depending on the methods applied and the local circumstances, there is substantial evidence that flood mitigation measures can, on average, offer significant returns on investment. A recent nation-wide study in Canada (Public Safety Canada, 2019) reported that for every $1 invested in mitigation efforts, there could be savings of $7 to $10 in terms of avoided post-disaster recovery costs. Similarly, in the USA, riverine flood hazard mitigation has been found to save $7 on average for every $1 spent on federal mitigation grants (NIBS, 2019).

Benefit calculations are built on the foundation of flood hazard modelling and flood risk assessments of scenarios representing current-day pre-mitigation versus future post-mitigation. Any flood mitigation project can be modelled with BCA when it may impact future flood hazard severity or reduce asset damages. The modelling of benefit components includes structure and contents damages, displacement costs, business disruptions, and infrastructure sector-specific modelling, especially impacts to transportation and critical lifelines like water, sewer, and electrical power. Other types of benefits, such as public health, quality of life, and the environment, may also be documented, even when they cannot be quantified like other conventional benefits. The project selection process should keep in mind additional considerations beyond conventional benefits such as First Nations and other vulnerable populations and other qualitative criteria like risk reduction effectiveness, climate change, and outreach and partnerships.

There are a number of recommendations for British Columbia concerning BCA and other criteria to support flood mitigation projects. The BC Government should establish their own BCA standards and guidance related to projects in the province. This would provide clarity on the resolution of flood hazard modelling and flood risk assessments needed as input to a BCA and a consistent basis for methods used for benefit calculations. While existing tools like CanFlood[1] may be part of a solution, the BC Government may also want to examine other options to simplify conducting a BCA, especially for communities with limited staff capabilities. The BC Government should also explore their options concerning flood mitigation project selection and the use of more qualitative criteria. Pilot studies and testing of any proposed changes would provide a "sandbox" to turn these recommendations into reality.

The high-level analysis of funding spent on flood management activities between 2016 and 2020 in BC revealed that 91% of the funding was allocated to post-disaster (Issues C-2/C-3; 69%;$450M) and structural mitigation (Issue B-5; 22%;$140M). Therefore, a large majority of the funding over the last five years focused on structural mitigation and activities associated with response and recovery.

[1] https://github.com/IBIGroupCanWest/CanFlood

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List of Acronyms

AAD	Average Annual Damage
AAL	Average Annual Loss
BC	British Columbia
BCA	Benefit-Cost Analysis
BCR	Benefit-Cost Ratio
BRIC	Building Resilient Infrastructure and Communities
CEPF	Community Emergency Preparedness Fund
CIRNAC	Crown Indigenous Relations and Northern Affairs Canada
DFA	Disaster Financial Assistance
DFAA	Disaster Financial Assistance Arrangements
EAD	Estimated Annualized Damages
EGBC	Engineers and Geoscientists British Columbia
EMBC	Emergency Management BC
FBC	Fraser Basin Council
FCL	Flood Construction Level
FEMA	Federal Emergency Management Agency (USA)
FLNRORD	Forest, Lands, Natural Resource Operation and Rural Development (Ministry of)
FTE	Full-Time Equivalent
GIS	Geospatial Information System
IFMP	Integrated Flood Management Plan
MOTI	Ministry of Transportation and Infrastructure
NDMP	National Disaster Mitigation Program
NRCan	Natural Resources Canada
NIBS	National Institute of Building Sciences
PSC	Public Safety Canada
PV	Present Value
USA	United States of America
WTP	Willingness-To-Pay

Preamble

About This Initiative

Many communities in BC are working to better manage their river and coastal flood risks through a wide range of flood management activities. But current approaches to managing flooding are not always efficient, coordinated, equitable, or cost-effective.

The **Investigations in Support of Flood Strategy Development in British Columbia** is a province-wide initiative aimed at developing a comprehensive understanding of current challenges and opportunities relating to flood management across BC. The focus is primarily on riverine, coastal, and ice jam floods, although other types of flooding are recognized where appropriate. This initiative recognizes that flood management is a multi-faceted, ongoing process requiring the coordination of many organizations, agencies, and orders of government and linked with broader processes, including climate change adaptation and disaster risk reduction, among others.

The BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development retained the Fraser Basin Council to manage and coordinate research and engagement across a broad range of flood management issues relating to governance, hazard and risk management, forecasting, and emergency response and recovery. Consulting teams were retained to undertake research and technical analysis with input from experts, practitioners, and stakeholders from all four orders of government, the private sector, and other organizations. Each investigation produced recommendations to inform flood management program improvements at multiple scales and across many jurisdictions.

Investigations were undertaken across 11 interrelated issues under 4 themes:

	Theme A – Governance	
A-1	**Flood Risk Governance**	Review current governance and delivery of flood management activities in BC involving all four orders of government and non-government entities, identify challenges, and recommend changes to improve coordination, collaboration, and overall effectiveness.
	Theme B – Flood Hazard and Risk Management	
B-1	**Impacts of Climate Change**	Investigate the state of climate change information and new and existing tools that can support authorities in integrating climate change impacts in flood management.
B-2	**Flood Hazard Information**	Examine the state of flood mapping and dike deficiency information and recommend ways to fill current gaps in flood mapping and manage and maintain information about flood hazards and dike deficiencies.
B-3	**Flood Risk Assessment**	Explore approaches to completing flood risk assessments at various scales, methods for prioritizing risk reduction actions, and standards- versus risk-based approach to flood management.
B-4	**Flood Planning**	Examine the ability of local authorities to undertake integrated flood management planning and opportunities to improve capacity.
B-5	**Structural Flood Management Approaches**	Assess the potential for improvements to dike management, improve the capacity of diking authorities, and implement innovative structural flood risk reduction measures.
B-6	**Non-Structural Flood Management Approaches**	Investigate current and alternative approaches to managing development in floodplains and opportunities for implementing non-structural flood risk reduction actions.

	Theme C – Flood Forecasting, Emergency Response and Recovery	
C-1	**Flood Forecasting Services**	Identify gaps and opportunities for improvement in the province's flood forecasting services.
C-2	**Emergency Response**	Investigate roles, plans, and capabilities for flood response and opportunities for improving emergency response.
C-3	**Flood Recovery**	Examine approaches that would support recovery efforts and help reduce future flood risk.
	Theme D – Resources and Funding	
D-1	**Resources and Funding**	Investigate resource and funding needs associated with actions to strengthen flood management and evidence in support of proactive flood mitigation.

1 Introduction

1.1 Project Background

Heavy rainfall, freshet and storm surges combined with climate change and structural (e.g. dike) failure lead to flooding, posing a serious risk to public health and safety. One aspect of successful flood management is establishing long-term investment in proactive flood planning and mitigation activities. Because flooding happens on an infrequent basis, often funding for flood activities tends to be post-disaster. The focus needs to shift to proactive, pre-disaster phases. Decision makers seek evidence using defendable approaches to support spending today's money for possible future flood damages.

In 2016, the need to develop a Provincial Flood Risk Strategy was identified as a priority by the BC Ministry of Forest, Lands, Natural Resource Operation and Rural Development (FLNRORD). Following initial scoping, planning and information gathering in 2017-2018, the FBC was retained to manage and coordinate the Investigations in Support of Flood Strategy Development in British Columbia.

D-1: Resources and Funding is the final investigation to be completed with the primary purpose to summarize and analyze evidence regarding the business case for increased investment in flood mitigation activities in BC.

1.2 Project Description

The FBC awarded Issue D-1 on Resources and Funding to AECOM Canada Ltd.

The investigation D-1.1 includes two tasks. Task 1 consists of a general overview of the cost estimates from nine (9) investigations' reports (A-1, B-1 to B-6, C-1 and C-2) for accuracy and consistency, using a matrix to compare the following key estimating characteristics:

- Estimating Methodology
- Basis of Estimate
- Estimating Assumptions
- Exclusions from the Estimate
- Other Limiting Conditions
- Source Cost Data

Investigation D-1.1 provides general recommendations to connect the common elements of the cost estimates contained in the reports, as well as specific recommendations to refine the Investigation B-2 BC Flood Hazard Information estimates.

For Investigation D-1.2, a literature review of a selected group of publications and sources from Canada and the USA was completed to analyze BCA methods applied to most flood management projects including costs, tangible and intangible benefits, economic variables, and other considerations. For each element, their applicability to BC context was assessed.

2 Investigation D-1.1

2.1 Introduction on Flood Cost Estimation

2.1.1 Purpose

The objective of Investigation D-1.1 is to review the cost and resource data and estimation methods contained in Investigations' reports A-1, B-1 to B-6, C-1 and C-2 completed by various consultants, with the aim to recommend a consistent and defensible cost and resource estimation method that could be applied to the estimates contained in the reports. The list of reports is presented in Appendix B.

2.1.2 Estimating Requirements

The following instructions on cost estimates were provided to the consultants whose investigations included cost estimates (A-1, B-1 to B-6, C-1 and C-2) and upon which this investigation D-1 is based:

1. *For investigations where Class D cost and resource estimates are expected for identified options and/or recommendations, Class D estimate (±50%) is defined as: "A preliminary estimate which, due to little or no site information, indicates the approximate magnitude of cost of the proposed project, based on the client's broad requirements. This overall cost estimate may be derived from lump sum or unit costs for a similar project. It may be used in developing long term capital plans and for preliminary discussion of proposed capital projects." [Engineers and Geoscientists British Columbia].*
2. *Estimates should be based on rationale and indicate assumptions made.*
3. *Any operational costs should be provided on a per-year basis.*
4. *The BC Government, as one of the end users of these reports, intends to use the cost estimates provided in a future benefit-cost analysis (BCA). A BCA would in turn be used to inform decisions at the Provincial level.*
5. *At the draft report stage, it may be helpful for project teams to have a discussion with FBC (and perhaps FLNRORD) regarding costing needs, issues, and assumptions.*

In addition, FBC provided estimates to most consultants of provincial government full-time equivalent (FTE) for specific roles:

- $100,000 for engineer or geoscientist/policy/tech/PM
- $150,000 for specialist engineer or geoscientist
- $175,000 for manager

2.1.3 Approach

The overall approach for D-1.1 is divided into two steps:

1. Perform a review of the estimating sections of the nine (9) previous investigations reports, with a view of bringing them to a comparable standard and basis, identify deficiencies and provide recommendations on to how to deal with those issues. This information is more efficiently conveyed in a matrix format.
2. Analyze in more detail the cost and resource estimate for B-2 Flood Hazard Information and make recommendations on how they could be optimized.

2.1.4 Characteristics of Effective Estimates

While projects, by nature, are unique undertakings with particular challenges, the effective financial planning of complex projects share common characteristics:

1. A scope of work is broken down into discrete activities, itemized, and described in a logical sequence and order. A Work Breakdown Structure (WBS) is a critical tool in defining project requirements and the scope of work, and the WBS can also form the basis of a credible estimate.
2. Those items are typically drafted in a manner where a measurable quantity can be attached to that item, and that activity priced using a cost data source. For example, the estimated level of effort to map a floodplain area from Point A to Point B on a specific river may be 500 hours at an estimated average charge out rate of $150/hour. The basis of the estimate of that item (duration and charge out rate) could be an average of three or four competitive contractor estimates or quotes for that particular activity.
3. A defensible estimate for any project will follow a similar logical approach, where each activity comprising the scope of work will be itemized, quantified, and priced, until the complete project scope of work is expressed as a series of items.
4. The sum of these items generally comprises a net estimate, and to complete a project estimate, an overhead and profit allowance is made, together with a measurement contingency which is added to compensate for scope or pricing information that may not be known and described at the time of the estimate. In some circumstances, a common adjustment will also be made to compensate for price inflation during the project duration.
5. The estimate will clearly define limiting conditions, assumptions, and exclusions so that the basis of the estimate is understood.

The consultant estimates are reviewed to check whether the estimating requirements have been met, and generally, whether the estimates exhibit the characteristics of an effective estimate.

2.2 Document Review

The review of the Investigations' reports cost estimates is presented in a matrix format in the following Table 2-1 including, for all reports: summary, methodology, basis, assumptions, exclusions, limiting conditions, source data and outcomes. The Glossary at the end of this document contains definitions for key economic terms.

Table 2-1: Cost Estimates Review

	THEME A – GOVERNANCE	**THEME B – FLOOD HAZARD AND RISK MANAGEMENT**						**THEME C – FLOOD FORECASTING, EMERGENCY RESPONSE AND RECOVERY**	
	A-1	B-1	B-2	B-3	B-4	B-5	B-6	C-1	C-2
	Improving Collaboration and Coordination	Impacts of Climate Change	Flood Hazard Information	Flood Risk Assessment	Flood Planning	Structural Flood Management Approaches	Non-Structural Flood Management Approaches	Flood Forecasting Services	Emergency Response
Estimated Cost Summary	(Cost estimates revised 13 April 2021) Flood Governance – General Approach $1.85M One-time cost. Central Knowledge Hub – One-time costs $3.6M; Annual Costs $5.975M. Regional Support Hubs $2.475M per hub, annually (Six hubs $14.85M annually). Locally-driven flood management projects [TBC – noted that estimates may be contained in other reports].	One-time Cost $2,770,000 Annual Cost $1,410,000 per year.	Contains cost estimates for two elements: • Flood Mapping (subject to specification, p. 32) *MMM (2014) estimated that flood map coverage in BC was available for 2,656 km and that another 2,650 km should be mapped. A total cost of $48.2M was estimated for producing new maps. With $20M spent to date, this estimate would imply the remaining mapping cost is about $30M.* • Dikes, p. 55 *… the rating of all BC dikes is estimated to cost approximately $2.2 million, including a one-time allocation of 0.7 FTE of provincial staff to provide direction, input, and management of the necessary studies, including amendment of the EGBC flood assessment guidelines.*	Cost estimate for development and operation of an exposure/vulnerability database is summarized in Table 9, p. 67 Total ranging from low $920,000 ($820,000 corrected in report) to high $3,600,000 ($3,100,000 corrected in report). Table 9 read in conjunction with heat map indicator in Table 10, p. 68 ranking costs in terms of High (red, 10s of $M), Medium (yellow, $Ms) and Low (green, $1000s). Cost estimate for local, quantitative Flood Risk Assessments set out in Table 17, p. 87. Estimated budget ranges for each study type set out: • High-level/ small area - $50,000 to $100,000 • Moderate level/ local community - $100,000 to $150,000 • Comprehensive/ local community - $150,000 to $200,000 Bottom-up approach for a Province-wide Flood Risk Assessment contained in Table 18, p. 88: • Develop minimum standard $100,000 to $250,000 • Conduct Flood Risk Assessment (322 No.) ranging from $16,100,000 to $64,400,000 • Aggregation and Risk Prioritization of Flood Risk Assessments $150,000 to $200,000 Total ranging from $16,350,000 to $64,850,000. Similar detail provided in the Top-down approach on p. 102, total ranging from $4,450,000 to $15,240,000.	Cost estimates summarized with Appendix D: Table of Recommendations. Costs divided into sections: • Investigate Opportunities to Build Capacity Subtotal $2.3M to $3.3M per year • Investigate Content for a Provincial IFMP Guideline Subtotal $560,000 per year • Investigate IFMP Development Process (with other recommendation costs) Total Cost Estimate $2.9M to $3.9M per year	Cost estimate structure broken down into requirements, resources, and estimated costs. Activities divided into categories: Resources and Costs to Implement Potential Incentives and Requirements (Table 3, p. 27) Contract Costs $200,000; One-time Personnel $875,000; Annual Personnel Costs $120,000. Resources and Costs for Options to Increase Knowledge and Capacity (Table 5, p. 35) Contract Costs $1.35M; One-time Personnel $210,000; Annual Personnel Costs $570,000. Costs distinguished between: • Contract Costs (assumed to be external consultant). • One-time Personnel Costs, and • Recurring annual Personnel Costs.	Cost estimate ranges appear to be generally subject to the degree of governmental participation. Estimates set out in sections: • Additional cost for the proposed approaches for Provincial delivery of non-structural flood management (Table 2, p. 7) Annual Costs dependent on option. • Proposed recommendations to improve non-structural flood mitigation in BC. (Table 3, p. 13) Most costs estimated, some costs variable. • Proposed recommendations to support local government flood education campaigns. (Table 4, p. 17) One-time and Annual cost estimates.	The cost estimates describe systems with cost estimates provided by specialists: • Delft-FEWS Model (Figure 6-1) $60,000 • Systems integration model (Figure 6-2, which incorporates other BC-specific models, CLEVER and MIKE 21) $400,000 • Setup cost for debris-flow warning system ($50,000 to $100,000, depending on location) • Hydrometric gauge station costs ($30,000 to install plus $20,000/year to maintain)	Cost estimate divided into sections: Flood Response Plan at First Nation and Local Government levels $21.5M Increase staffing of FLNRORD Water Stewardship within local lead responder EOC $1.05M Increase staffing of Flood Assessment Unit $3.15M Increase staffing of EMBC PREOC with Flood Specialist/Coordinator $0.42M Increase staffing of Flood Issues Management Group/Flood Readiness Group $0.98M
Estimating Methodology	Distinguished between Contract and Staff for each section.	Lump Sum costs (One-time and Annual Costs) summarized in Table 10-2.	Lump Sum Costs: • Flood Mapping – set out in "Estimated Future Costs", p. 32, noting that remaining mapping costs estimated at about $30M, with the caveat that the estimate total seems low, and cannot be confirmed. • Dike Rating System – Table 4-4 sets out the estimated contract and personnel costs for: A. Dike Ratings [subtotal $2,345,000],	A summary of Lump Sum costs ranging from low to high, subject to depth of study (High-level, Moderate, or Comprehensive).	Lump Sum estimated costs. Each section broken down into activities; variables and factors impacting cost described, with a range of low to high cost estimate indicated for each activity ("roadmap step")	Lump Sum cost estimates for each described requirement and resource (resource expressed in terms of FTEs).	Lump Sum costs (One-time and Annual Costs) summarized, subject to option and variables.	Estimate conducted by BGC Engineering Inc., with support from a specialist Dutch research institute.	Activities described in each section, and bottom-line lump sum estimates indicated in each section, however no further breakdown of the composition of the estimate.

	THEME A – GOVERNANCE	**THEME B – FLOOD HAZARD AND RISK MANAGEMENT**						**THEME C – FLOOD FORECASTING, EMERGENCY RESPONSE AND RECOVERY**	
	A-1	B-1	B-2	B-3	B-4	B-5	B-6	C-1	C-2
	Improving Collaboration and Coordination	Impacts of Climate Change	Flood Hazard Information	Flood Risk Assessment	Flood Planning	Structural Flood Management Approaches	Non-Structural Flood Management Approaches	Flood Forecasting Services	Emergency Response
			and B. Other Recommendations: publicizing compliance information, increasing dike safety audits, and improving dike information file management [subtotal $180,000].						
Basis of Estimate	Based on staff effort (in terms of estimated FTE number)	A summary of activities arising from various investigations is extracted in Table 10-1. Those activities are summarized into actions and recommendations, which form the basis of the estimated amounts for each recommendation.	Benchmark unit rates derived from past studies by consultant and others.	Benchmark unit rates derived from past studies.	Actions and recommendations developed from survey responses and case study interviews.	Estimate derived from recommendations, requirements, and resources described for each activity.	Lump Sum estimates derived from funding budgets for programs of a similar scale. Some commentary provided from other jurisdictions.	Lump Sum amounts for the system types described in the report. The estimate includes a training component and one year of technical support.	Lump Sum estimates for each section (no further breakdown). Staff numbers noted where relevant.
Estimating Assumptions	Assumes a multi-year, Province-led, large stakeholder process.	Limited to the action and recommendation descriptions set out in Table 10-1 and Table 10-2.	• Flood Mapping – costs estimated on a 'recommended minimum' basis. Specification depending on "Complex - Higher Budget" or "Straightforward - Lower Budget" – project variables to be defined in order to support a credible estimate. • Dike Rating System – assumes that integration with FLNRORD Food Safety Management E-Licensing platform is feasible.	The cost estimate will be subject to the following factors: • Complexity of the database (e.g., how many different datasets are included, how accessible is the data download, how much development of a common data schema, and data alignment of existing data to that schema, has been conducted, etc.) • New datasets being developed to be integrated into the database.	Cost estimates are dependent on community size (measured in terms of community population)	Contract cost estimates unclear. Personnel cost estimates based on annual cost estimates provided by FBC.	Proposed activities and scale of work is described with Lump Sums summarized for each broad recommendation.	Other alternative systems and models are discussed in the report; however, the estimate assumes implementation of a FEWS system using the CLEVER model.	Estimating assumptions defined in advance of each section estimate. The description of the activities set out in each section estimate.
Exclusions from the Estimate	Set out in "Constraints and Issues" section, p. 76	Undefined.	• Flood Mapping –Options (depending on the level of Provincial Government involvement), is excluded. • Dike Rating System – Geotechnical work and Diking Authority staff time excluded from estimate.	The importance of a relevant risk assessment is noted several times. A risk assessment is likely to have an impact on the cost estimate.	Internal staff costs to manage external consultants. Flood mapping and consequence/risk assessment work is excluded – assumed to be covered under other investigations.	Additional costs to complete the current Fraser River dike design profile update project are excluded.	Potential cost savings (… "in the order of 20% to 40%...") arising from efficiencies as the Provincial Government is assumed to take a larger role.	Exclusions unclear.	Undefined.
Other Limiting Conditions	2-year time period.	Undefined.	Noted where relevant.	Noted throughout.	Noted in text.	The costs to develop and maintain workshop and knowledge material will depend on scope and content.	Cost estimates appear to be subject to the requirements to be defined by the Provincial Government.	Estimates are limited to the system described – other models are discussed, however the estimate based on the model is specifically defined.	Estimated costs are subject to community size (in terms of population).
Source Cost Data	Some cost data extracted from City of Vancouver and City of Surrey studies. DMAF program merit criteria and guidebooks.	Undefined.	Consultant cost benchmarks, and cost data arising from other studies.	Consultant cost data. Some potential data sources (ICI Society, BC Assessment) not responsive to the consultant inquiry. Some data sourced from an unnamed AI company and BGC Engineering Inc., a consultant on previous studies.	Cost data assumed to be from consultant and/or interview subjects.	Contract cost estimated assumed to be by consultant – source unnamed. Personnel time quantities assumed to be estimated by consultant. Personnel unit rates provided by FBC ($/ year).	Estimated costs are "… based on the dollar value of NDMP and CEPF funded projects over the past 5 years and estimated level of effort in support of a similar scale of annual projects."	BGC Engineering Inc. cost data incorporate into estimate.	Undefined.
Outcome	Lump Sum estimate totals provided for each section, based on estimated Contract costs and staff costs (basis	The basis of the estimated Lump Sums (One-time and Annual Costs) are not defined. Assumptions and Exclusions are undefined. Contingencies and Escalation are undefined.	Lump Sum Costs are summarized; however, the component elements of those sums are not further broken down, possibly due to the number of scope and specification variables. Estimates are likely to be more indicative in nature, until specific	Estimated cost estimate ranges are noted, with no or little detail on components and pricing. Contingencies and Escalation are undefined.	Lump sum cost estimates described ranging from low to high limits, however the basis and source of the lump sums are unclear. Contingencies and Escalation are undefined.	The basis of the estimated Lump Sums (One-time and Annual Costs) are not defined. Contingencies and Escalation are undefined.	The basis of the estimated Lump Sums (One-time and Annual Costs) are not defined. Prior funding may not be the most appropriate indicator of a current cost estimate – adjustments to make prior data relevant are not described.	Initial Costs are set out for the identified model types, however annual costs are undefined (one year technical support is included in the estimate, but not	Lump Sum total estimates are noted in each section, however, little detail on estimate composition. Contingencies and Escalation are undefined.

	THEME A – GOVERNANCE	**THEME B – FLOOD HAZARD AND RISK MANAGEMENT**						**THEME C – FLOOD FORECASTING, EMERGENCY RESPONSE AND RECOVERY**	
	A-1	B-1	B-2	B-3	B-4	B-5	B-6	C-1	C-2
	Improving Collaboration and Coordination	Impacts of Climate Change	Flood Hazard Information	Flood Risk Assessment	Flood Planning	Structural Flood Management Approaches	Non-Structural Flood Management Approaches	Flood Forecasting Services	Emergency Response
	described in each section). Contingencies and Escalation are undefined.		project/s scopes and specifications can be defined. Contingencies and Escalation are undefined.				Contingencies and Escalation are undefined.	estimates for activities thereafter). Contingencies and Escalation are undefined.	
	Generally, across all reports – possible implication that Contingencies are excluded, and that the Lump Sums are current as at the date of the report.								

Some observations from Table 2-1 are common to the estimates contained in all the reports:

2.2.1 Class D Estimate Requirement

A typical Class D Estimate assumes that the project requirements and scope of work is reasonably defined to use as a basis for an estimate. However, in many cases, due to the variable nature of the work, the estimated costs set out in each section are probably best described as Preliminary or Indicative, meaning that pricing estimates are generally noted – but a more formal estimate is only likely to develop once the project requirements and scope can be more specifically defined.

2.2.2 Assumptions, Exclusions, and Other Limiting Conditions

The **basis of the estimates** is generally not clearly defined. In many cases, lump sums are noted as bottom-line estimates without supporting detail, and in such instances, it's not possible to review the composition of a lump sum amount.

Exclusions are also generally not clearly defined – for example, at a basic level, it is generally not stated whether Federal and Provincial Taxes have been accounted for, or whether taxes are excluded. Similarly, it is not known whether locational adjustments have been made.

Other costs can also be expected in many cases, given the nature of the work described in each theme (for example, public consultation, permitting, environmental monitoring, the impact of archeological discovery, etc.), however, the potential consequence of these elements is not explained and remain generally unknown.

It is unknown whether lump sum estimates include an **overhead and profit** element, or whether the estimate is on a 'net' basis, i.e., the bare labour, materials, tools, and equipment for that described activity.

There does not appear to be a compensating factor built into the estimate to account for estimating unknowns – often referred to as a **design or estimating contingency**.

Time – the impact of inflation over time is generally not clearly described, with the implication that all estimated costs are in current terms as at the date of the report. Annual operational costs are part of the estimating requirements, and it is assumed that those recurring annual costs too, are expressed in dollar terms as at the date of the report.

As far as the **source data** is concerned, in many instances, consultants noted lump sum amounts that are assumed to be derived from internal cost benchmarks, and given the nature of the projects, there exists very few direct, accessible, reference sources. As a consultant had pointed out, an example of a relevant, accessible database is BC Assessment, where it is possible to look up current assessed real estate values. However, a similar cost reference database does not exist for the services described in the reports, e.g., flood mapping. Where an estimate of government staff costs is relevant, the consultants did incorporate the annual FTE provided by FBC.

2.2.3 Closing

Given the early stage of project definition, the estimates contained in the consultant reports are better described as Indicative. When project requirements and the scope of work is further developed, then the cost estimates for those activities may progress to a more detailed Class D level.

2.2.4 Recommendations Arising from the Cost Estimates Review

The consultants have developed the estimates independently to suit the objectives and level of supporting detail in their respective report. The following recommendations are made in order to unify and enhance the relevance of the estimates:

2.2.4.1 A Unified Estimate Tool

The estimates should be extracted into a single application, for example, separate tabs for each estimate, and common factors and conditions, in one spreadsheet. A single source application would facilitate updating the estimates to maintain its relevance – the aim is to create a dynamic tool, to substitute the static point-in-time estimates in each report. See example in Appendix C.

2.2.4.2 Extract the Common Factors

Identify the common reference data and designate a single source to update those values – the estimates provided by FBC of government staff FTEs for specific roles is a good example of such inputs.

2.2.4.3 Identify Common Limiting Conditions

While the estimates in each report are driven by the content of that report, there are some assumptions, exclusions, and other conditions that will be common across all reports, for example, how Federal and Provincial Taxes are treated, how location specific conditions and overhead costs are dealt with, etc..

Common assumptions regarding company overhead and profit allowances can also be created as inputs.

Another common factor that can be introduced is a Project Contingency, which is an overall factor to compensate for conditions that may be unknown at the time of the estimate.

At the same time, financial assumptions can also be set out – for example, adjustments for inflation over time, the discount rate to express future dollar values in present day terms, etc.

2.2.4.4 Create the Estimates Incorporating the Common Factors

- Re-create the consultant estimates in a spreadsheet format, and incorporate references to the identified common factors, in a way that enables dynamic updating of those values.
- Differentiate between one-time initial costs and ongoing annual costs, and define the period of time applicable to annual costs.
- Incorporate project timelines so that estimates can be adjusted to compensate for inflation. If required, incorporate Net Present Value calculations to discount future annual costs to present day terms.

2.2.4.5 Outcome

The implementations of the recommendations will result in:

- A more suitable application for an estimating function.
- A tool that will improve connectivity between the reports.
- A dynamic application in place of the static estimates in the consultant reports to test scenarios and perform sensitivity analysis.

2.3 Specific Commentary on B-2 Flood Hazard Information Cost Estimates

The B-2 Flood Hazard Information report dated 16 March 2021 was completed by Northwest Hydraulic Consultants Ltd. Part of the objective of that report was to investigate the current state of flood mapping in BC, and following on from that, to report on cost estimates for a province-wide floodplain mapping program. That section is contained in section 3.2.4. Approximate Costs to Map BC (p. 30), with subsequent explanation in a follow-up memo dated 16 April 2021. Those documents make several key observations regarding the estimates.

2.3.1 Source Cost Data

The flood mapping cost estimate is approximate only, and subject to variable factors. Reliable source data is a key input into an estimate, and in this case, source data is limited due to the nature of the service, with the outcome that the consultant's benchmark unit rates for riverine mapping are based on 17 mapping projects in Western Canada. The outcome is the unit rates:

- Complex Mapping Projects - $15,000/km
- Straightforward Mapping Projects - $10,000/km

The consultant makes a clear distinction between "Complex" and "Straightforward", and this differentiation is further described in an activity breakdown of the resulting unit rates. Refer to Table 1 of the Memo in Appendix D.

Similarly, unit rates for coastal mapping were based on 10 projects/proposals, ranging from coastlines of over 1,000 km to less than 1 km. The outcome is a unit cost range between $1,500/km and $2,500/km. Costs to map specific sites can vary widely as the consultant notes a site-specific study (60 m coastline) with a resulting unit rate of $200,000/km. The source of the wide variance is attributed to the availability of data and information, and the specific requirements and specifications of the mapping project.

While cost information from past projects can be useful benchmarks in current estimates, historical cost data often is subject to adjustment in order to make that data relevant to the present circumstances. The adjustments to historical cost data are undefined. Anticipated adjustments include:

- Time
- Complexity and scale
- Scope
- Location
- Technology advancement
- Market conditions

2.3.2 Completeness of the Estimate

The completeness of the estimate includes accounting for the following factors:

Overhead and Profit
It is unclear whether the estimate is on a net basis (i.e., an estimate of the activities), or whether overhead costs and profit margins are included. Overhead costs and profit expectations can be a significant factor, and these elements should be accounted for it is realistic to expect that an external company assuming a contract will require a reasonable allowance for their overhead costs, and will expect to make a profit for their efforts.

Estimating Contingency

It is unknown whether a contingency is included in the estimate. A measurement or estimating contingency can be significant, especially at early stages of project definition. The level of the contingency is subject to the level of detail of the input information.

Inflation

It is known that prices generally rise over time, however it is unknown whether the estimates incorporate an adjustment for rising prices. The estimate does not explicitly state that it is a current cost estimate at the date of the report. Adjustments for rising prices over time are especially important when future costs are estimated (in this case, the annual costs which occur after the one-time cost estimates).

Estimate Outcome

The link between the bottom-line estimate ("… about $30M would need to be spent to complete the present cycle of mapping.") and the estimate breakdown is unclear ("Total Cost in First Year: $9,850,000; Subsequent Annual Cost: $6,005,000"). Adding to that inconsistency is the note that the $30M estimate seems low but cannot be confirmed.

2.3.3 Continuing Relevance of the Estimate

The estimate, as it stands in the B-2 report and supplemented by the Memo, is a static estimate – the variables cannot be tested or updated, and there is no connection between this estimate and the work in the other reports. A spreadsheet estimating application, as described in this report, can resolve this issue.

2.3.4 Centralized versus Decentralized Approaches to Flood Mapping

The Flood Mapping scope of work described in the B-2 report may be structured where the activities are coordinated and conducted by the Provincial Government (a centralized approach, where a large group creates and carries out the activities), or delegated to local authorities (a decentralized approach, where a smaller management group allocates and coordinates separate scopes of work to locally-based groups: towns, municipalities, districts, First Nations, etc.). From a cost management perspective, there are advantages and disadvantages to each approach, as presented in Table 2-2.

Table 2-2: Centralized vs Decentralized Approaches

Factors	Provincial Government (Centralized Approach)	Local Authorities (Decentralized Approach)
Standards	Easier to set and maintain one set of technical standards, software, reporting, etc.	May be more difficult and time-consuming to require different groups to comply with a common set of technical standards
Coordination and Management	A management group would be necessary in both approaches, however a larger coordinating effort is more likely to deploy resources effectively and conduct activities 'in-house'	May be possible to delegate some management activities to the local authority, however there is a risk of duplication of effort
Cost Certainty	Higher probability of cost certainty as staff rates and other resource costs can be more effectively managed	Cost uncertainty more likely because costs would tend to vary from location to location
Efficiencies of Scale	A large centralized organization generally has a greater chance of reaching an efficient economy of scale through repetition and specialization	Disparate local municipalities and groups may not have the optimal amount of resources necessary to achieve an efficient economy of scale

Factors	Provincial Government (Centralized Approach)	Local Authorities (Decentralized Approach)
Time	An 'in-house' approach is likely to take longer	May be able to save time by delegating scopes of work that may be undertaken simultaneously
Quality Control	Likely easier to maintain quality control standards	With contributions from different groups, there is likely to be a greater quality control effort

Ultimately, there are tangible and intangible trade-offs inherent in each approach.

2.3.5 Recommendations for B-2 Estimate

The estimates are of Indicative value only, given the nature of the work, variability in requirements and specifications, and the lack of project definition at the early planning stages. The source data requires further verification and adjustment so that the historical data is more relevant to the requirements and objectives described in the B-2 report.

The estimate should be re-structured so that inconsistencies are resolved, and that the estimate is complete in all respects, including accounting for the impact of time.

The approach selected to carry out the work (Centralized or Decentralized) will also have an impact on the estimate.

The estimate should be linked to the work in other reports so that the estimates can be updated as circumstances change. This action will better maintain the relevance of this estimate, and the estimates in the other reports.

3 Investigation D-1.2

3.1 Introduction on Economic Studies supporting flood planning and mitigation

3.1.1 Overview

One aspect of successful flood management is establishing long-term investment in proactive flood planning and mitigation activities. Because extreme flooding happens on an infrequent basis, often funding for flood activities tends to be post-disaster. These larger magnitude events are the ones that tend to drive policy and funding. The focus needs to shift to proactive, pre-disaster phases to reduce or avoid possible future flood losses. Decision makers seek evidence using defendable approaches to support spending today's money for possible future flood damages.

Decision makers from funding programs need to better understand the benefits of proactive planning and mitigation both from programmatic and economic aspects. Programmatically, it takes significant time and funding to conduct the various types of tasks needed for floodplain management such as developing flood plans, conducting flood studies and risk assessments, creating flood mapping, designing flood mitigation options, and selecting and implementing flood mitigation measures. Often these tasks have dependencies that require long-term planning. For example, a benefit-cost analysis of a mitigation project is conducted from previously developed risk assessments of multiple scenarios. Each of these scenarios are based on preceding flood modelling studies, which establish flood elevations for multiple probabilistic events of increasing severity. Therefore, a benefit-cost analysis is the end result of a series of prior studies, each of which may take a year or more to complete.

Economic aspects of flood planning and mitigation tend to focus on establishing estimates of benefits for projects. These estimates provide support to decision makers to justify the spending of today's money to reduce or avoid possible future expenses from floods. Because of this inherent uncertainty about the future, these economic aspects, and the methods used to derive them, need to be developed from established, defendable methodologies that have proven in the past to be reasonable.

3.1.2 Context

Another source of uncertainty and confusion when talking about ways to establish measures to support flood planning and associated mitigation is context. For example, many people have been in meetings where presenters may use the same or similar terms for a given concept that may mean different things to different audiences because of their context. For example, the climate change community uses the term “mitigation” to refer to efforts to reduce or prevent emission of greenhouse gases and the term “adaptation” to refer to the process and actions of adjusting to current or expected climate change and its effects. Many of the “flood mitigation projects” that are being discussed in this report and associated reports for BC from a flood management community context would be called “flood adaptation projects” from a climate change community context. This is only one example of where understanding the context of the source will change the interpretation of information.

Accounting for context carries over to citing and describing the information included in individual sources in this literature review. While many sources cited in this report do come from the same or similar context of the global and North American flood planning and management community, it is important to note some specific context concerns.

3.1.2.1 Primary Reference

The NRCan 2021a document *Federal Flood Damage Estimation Guidelines for Buildings and Infrastructure* was considered for the purposes of this report to be considered the primary reference for context. This decision was based on the close alignment of their document to this report's scope for the following aspects:

- Subject matter areas (flood planning and mitigation, damage estimation, benefit-cost analysis)
- Geographic (Canadian)
- Analysis Perspective (local Canadian community level)
- Recent publication

NRCan (2021a) includes the following context description (p.4):

A community achieves an elevated level of resilience when its risks are proactively managed, it is adequately prepared for known and potential disaster events and it demonstrates an ability to recover after such events have taken place. In order to become resilient, a community's mitigation planners must first understand risks and ensure their capacity to manage those risks.

Floods are commonly occurring natural hazards in Canada and account for the largest portion of disaster recovery costs on an annual basis. Mitigating flood risks is therefore key to increasing the resilience of affected communities. By proactively investing in flood mitigation activities, a community secures its future growth and prosperity, reducing the risk of significant disaster recovery costs, productivity losses, economic losses, destruction of non-monetary cultural assets, environmental damage, injuries and, deaths.

Throughout the following sections as the discussion goes into more in-depth topics, the NRCan (2021a) context will be used as the "standard" against which other references are compared. For example, several other references use the term cost-benefit analysis rather than benefit-cost analysis (BCA) used in NRCan (2021a). The term BCA will be used as the standard, since this is the term used in NRCan (2021a). Likewise, when NRCan (2021a) groups certain benefit types in certain categories, this context will be used to organize the outline of topics even when supporting references may group these benefit types in different ways.

3.1.2.2 Subject Matter Areas

The discussion in the following sections is intended to provide a brief review of methods that BC may consider to establish a standardized approach for economic analysis for flood planning and mitigation, specifically focusing on the use of BCA approaches. This flood-centric context is less comprehensive than a more generalized all hazards approach. Certain benefit types, such as avoided injuries or deaths that are less prevalent with flooding than other natural hazards, will contain less detail than a more comprehensive context would contain.

3.1.2.3 Geographic

Very few references were available for past studies in BC related to flood risk or BCA. Those few that were available in BC used alternative approaches to those described in NRCan (2021a) but were included in the literature review where appropriate. In many cases, other sources from other provinces or the federal government were more comprehensive and provided more complete description of methods.

Likewise, a number of references from the USA were used in the literature review. Because the USA has had flood planning and mitigation in place longer than Canada, many of the USA references helped to provide a more complete discussion on a topic. For example, the use of USA references for descriptions of flood mitigation project types, project useful lifetime default tables, or USA-based studies looking at flood code adoption. However, one should take caution in directly applying USA approaches in Canada, because of the major differences between how flood planning and management are conducted in each country. For example, most of the communities in the USA have multi-return period digital floodplain mapping and modelling available for riverine and coastal flood hazards. USA-based BCA methods were developed to directly leverage this data and assumes certain return periods are typically available to use in BCA software tools. Similar assumptions concerning USA flood insurance are also implicit in USA-based methods and the reasoning behind excluding "insurance savings" into BCA methods.

3.1.2.4 Analysis Perspective

The analysis perspective for the NRCan (2021a) methods is a local Canadian community, which includes private citizens, government agencies, and businesses. From an economics context, this perspective may be called the referent group. The reason defining this context matters is that it establishes the basis of what benefits and costs to include in a particular analysis.

For example, if the analysis perspective was only a certain governmental entity, such as a specific government agency, then the analysis would be limited to assets that the entity owns and maintains and funding sources they control. While this approach may sense for certain infrastructure systems (potable water, sewer, roads) within a city that traditionally are "self-funded" to address routine maintenance and replacement of assets, usually the severe damages caused by extreme flood events are beyond local budgets and require "outside" funding from province and federal sources.

Certain benefit types require careful consideration of the analysis perspective to provide consistency. This is especially true when trying to take into account business-related impacts of flood events. For example, how does one measure lost wages and revenue for a temporary closure of a restaurant for a week? From the worker's perspective, they may see a week with no pay. The business owner "saves" having not to pay workers for that week but loses any profit from that week and still must pay for the lease for the space. However, at the community perspective, should the lost wages even be included since one portion of the community sees a loss and another portion sees a "saving"?

These context considerations should be kept in mind as the following sections establish the major concepts and definitions for this literature review.

3.1.3 Concepts and Definitions

To better understand how BCA methods can be adapted for flood projects in BC, several key concepts and associated definitions need to be clarified before going into the detailed breakdown of specific aspects of BCA methods. This includes discussions on the following:

- Flood risk, including the terms used for the major flooding types in BC
- Benefit-cost analysis
- Flood mitigation project types where BCA is appropriate

3.1.3.1 Flood Risk

Section 2.0 of the NRCan (2021a) document defines risk as "The combination of the likelihood and the consequence of a specific hazard being realized; refers to the vulnerability, proximity or exposure to hazards, which affects the probability of adverse impact." Tools like flood maps and the modelling used to develop the maps provide different ways to show aspects of flood risks. These can include flood inundation or flood hazard map, which primarily map the flooding, or flood risk maps, which primarily show aerial trends of the vulnerability or damages from the flood hazards. Therefore, when the term "flood risk" or "flood risk assessment" is used, this refers to not only the flood hazard, but the modelling of the impact of flood on assets on concern.

Each type of flood hazard, from coastal storm surges to precipitation-driven stormwater flooding to major spring riverine flooding (see Glossary for definitions of flood types), use different modelling methods to determine flood inundation and associated flood depths for different events. From a flood risk and BCA context, mitigation actions may reduce damages from multiple types of flooding. For example, a dike along a tidal portion of a river may provide protection from both "upstream" coastal storm surges and "downstream" riverine floods. Therefore, the flood risk, and associated mitigation to that risk, needs to account for all flood hazard types in a given location.

3.1.3.2 Benefit-Cost Analysis

The USA FEMA document, Benefit-Cost Analysis (BCA) Reference Guide 2009, defines a BCA as follows:

A method for determining the potential positive effects of a mitigation measure and comparing them to the cost of the measure. With the FEMA BCA modules, the positive effect is a reduction in future damages from natural hazards. This is the benefit of mitigation. The BCA can also be used to compare alternative projects to determine the best alternative from a fiscal standpoint.

Some major concepts associated with BCA are described here below:

3.1.3.2.1 Benefits

Benefits are the avoided predicted future damages or associated costs for conducting a proposed mitigation project. The benefit calculation always includes a comparison of a current-day scenario (base-case) with one or more future scenarios where mitigation measures have been enacted. The modelling of these scenarios requires a flood risk assessment, where the impact of flooding on specific assets is required. Simply conducting modelling and producing flood maps of changes of flood inundation extent is not sufficient as the only input for benefit calculations.

3.1.3.2.2 Project Design

The design of the proposed mitigation project directly affects the flood risk assessment scenario for the future. The design of the project may change only the flood hazard severity, only the vulnerability of assets, or both. For example, a flood wall lessens the flood elevations for a certain range of events for those structures protected by the wall, so it would be modelled as a change in the flood hazard only. Elevating residential single-family houses in a neighborhood above the 100-yr or 1%-annual exceedance probability (AEP) flood elevation would be a mitigation project that only changes the vulnerability of assets.

3.1.3.2.3 Project Effectiveness

Almost all mitigation projects are not 100% effective in eliminating flood risk, resulting in some amount of residual risk. Each project will have lower and upper effectiveness limits where the presence of the mitigation will produce a difference in flood risk. For very small events, most assets at risk do not experience damages, so this establishes the lower effectiveness limit. For example, even a poorly maintained local stormwater drainage system can be expected to pass a 5-yr storm, so this would establish the lower effectiveness limit. For the upper effectiveness limit, unless a project entirely removes the flood hazard, such as a major drainage project that changes the flood channel location, or entirely removes assets at risk, such as structure acquisition projects, the expectation is that the project has an upper effectiveness limit established by its design. For projects that change the flood hazard, like flood walls, there is typically an upper effectiveness limit at some flood elevation (and associated event probability). In the case of a flood wall, once the flood wall is overtopped, the flood damages usually are modelled as the same as pre-mitigation conditions, meaning no additional calculated benefits. Mitigation projects focusing on asset vulnerability will also have design limits where the difference between pre- and post-mitigation go to zero or are very small for very large flood events.

Not all flood projects lend themselves to a BCA. Traditionally, BCAs are conducted on structural projects, but not on planning or flood hazard modelling studies. However, there are some notable exceptions to this, especially studies that look at changes in building codes or construction standards, where a "planning" study would result in physical changes to hazards and/or assets that can be modelled by a BCA. The next section will discuss this in more depth.

3.1.3.3 Flood Mitigation Projects

A BCA has traditionally been used to evaluate and justify structural flood mitigation projects that impact assets or the flood hazard, such as the investigations performed under B-5 Structural Flood Management Approaches. However, non-structural planning projects that study the impact of changes to flood design or building codes can also have a BCA performed. The following lists and defines the main eleven flood mitigation project types where a BCA can be performed with existing BCA methodologies. Most definitions are from USA FEMA (2009):

Acquisition
A mitigation project where an asset, usually a building and associated private land parcel, is purchased by a government entity as a mean to prevent future losses to property owners. Acquisition is usually combined with demolition to eliminate future damages completely by removing the building from the flood hazard area.

Channel/Drainage/Stormwater Improvements
Flood control structural projects focusing on modification of flow channels by widening, straightening, or stabilizing the banks or replacement of drainage infrastructure such as pipes and culverts.

Demolition
The destruction and removal of an acquired property as a means to eliminate future damages from natural hazards.

Dike/Levee/Barrier/Floodwall
A human-made structure between an asset and the flood source that blocks floodwaters from coming into contact with the asset. Examples include minor localized flood reduction projects and earth embankments or concrete floodwalls. Minor localized flood reduction projects or floodwalls may completely surround an asset or tie into high ground at each end.

Dry Floodproofing
Any combination of mitigation measures added to or incorporated into an asset below the design flood elevation to prevent flood damages. This approach completely seals the interior of a building by making the exterior walls substantially impermeable to the passage of floodwater. Although floodwater may touch or surround the asset, there are no damages and the interior remain dry. For existing assets, this is also known as retrofitting. Dry floodproofing is typically used in areas subject to short-duration, low-level flooding.

Elevation
The raising of a building to place the lowest floor at or above a designated Design Flood Elevation or Flood Construction Level on an extended support building or fill.

Flood Storage Areas
Flood control structural projects focusing on flood volume storage with minor localized flood reduction projects or detention and retention ponds.

Plans Changing Building Codes
A flood mitigation plan that studies the influence of proposed building codes on changes in asset vulnerability to flood hazards, such as adding freeboard design requirements for new residential structures.

Plans changing drainage/flood design standards
A flood mitigation plan that studies the influence of proposed changes to the design standards used for stormwater and flood infrastructures such as pipes, culvert, ponds, and dams.

Relocation
A mitigation measure designed to physically move a building to a new location outside of an identified floodplain.

Wet Floodproofing
Modification of a building to allow short-duration, low-level floodwaters to enter the building in a way that minimizes damage to the building and its contents.

The USA FEMA 2021 *Building Resilient Infrastructure and Communities (BRIC) Mitigation Action Portfolio (MAP)* provides examples of all of these types of mitigation projects. Within each project summary is information on how benefits calculations were performed for each individual project. The USA NIBS (2019) Study also includes a range of mitigation examples addressing code adoption and going above the code.

The following Table 3-1 summarizes the flood mitigation project types that can be modelled with BCA and whether that project type would be expected to change flood hazards and asset damages.

Table 3-1: Flood Mitigation Project Types that can be modelled with BCA

Mitigation Project Type	Flood Hazard Change	Asset Damage Change
Plans changing drainage/flood design standards	Y	Possible
Plans changing building codes	Possible	Y
Acquisition	N	Y
Channel/Drainage/Stormwater Improvements	Y	N
Demolition	N	Y
Dike/Levee/Barrier/Floodwall	Y	N
Dry Floodproofing	Possible	Y
Elevation	N	Y
Flood Storage Areas	Y	N
Relocation	N	Y
Wet Floodproofing	N	Y

These major project types can be designed and implemented in ways that influence how a BCA is conducted.

One major difference in selecting mitigation projects is between natural/green infrastructure and grey infrastructure (IBC, 2018):

Natural/Green Infrastructure
A strategically planned and managed network of natural lands, such as forests and wetlands, working landscapes, and other open spaces that conserves or enhances ecosystem values, and functions and provides associated benefits to human populations.

Natural infrastructure can be further defined as “fully natural” or “engineered” using the following criteria:

- Fully natural infrastructure (e.g., a wetland, forest or flood plain), once established, requires no human intervention or management.
- Engineered/green infrastructure, such as a water retention facility, can leverage natural processes but be optimized through human design and management. For example, an engineered retention storage project (a small reservoir) can intercept floodwaters and release them through an engineered outlet. The reservoir produces many of the same ecological benefits as, for example, a wetland, with the important distinction that water levels can be manipulated by human intervention.

Grey Infrastructure
Traditional human-engineered stormwater and flood infrastructure including dams and reservoirs, diversion channels, pipes and culverts, and dikes.

The distinction between these two types will be discussed in the next section concerning details on possible benefit sources.

3.2 Benefit-Cost Analysis Literature Review

A good overview of basic concepts for BCA can be found in Chapter 3 of *Benefit-Cost Analysis Guidebook, Guidelines for the Benefit-cost Analysis Of Highway Improvement Projects In British Columbia* (BC MOTI, 2014) and also in Unit 3 BCA training material from USA FEMA (2019). A specific Canadian BCA which will be used to illustrate concepts in this section is the *Benefit/Cost Analysis of Flood Mitigation Projects for the City of Calgary: McLean Creek Flood Storage* (Alberta Government, 2015a).

All of these references include the economics equations used for individual cost and benefit components and how components are combined for overall summaries of results. While upcoming sections will give more details on these components, several high-level concepts make sense to discuss initially.

Total Benefit
The Total Benefit represents the sum of all benefit components calculated for a project, typically represented as a present value (PV). Often this value will play a large role in the overall project evaluation and possible funding awards.

Calculation of the total benefit, especially as a PV, requires a number of steps. First, a series of individual event analyses (risk assessments) are conducted, which establish individual benefit estimates for different return periods (event probabilities). Second, these individual results are combined to produce average annual loss (AAL) or average annual damage (AAD) (see example in Figure 3-8 in Section 3.2.3). Third, this annual value is converted to a present value applying economics equations including factors for discount rate and project useful lifetime (discount period). These concepts will be discussed in more detail in Section 3.2.3.

Benefit-Cost Ratio
Another value from a BCA that is also a consideration in many funding decisions is the Benefit-Cost Ratio (BCR), defined as:

BCR = Present Value of Benefits / Present Value of Cost

When the BCR exceeds 1.0, then a project is considered cost-effective where the benefits exceed the costs. The BCR provides a convenient unitless metric that can be used to summarize BCA findings and also to compare between alternatives, where higher BCRs represent higher returns than other alternatives. However, BCRs do not indicate which project maximizes benefits, and should not be the sole BCA measure relied on for decision making.

To calculate the BCR, both the costs and benefits are represented as a present value. For the cost, the calculation of the proposed project cost directly gives the PV cost. For benefits, the calculation becomes more difficult, because typically benefit calculation methods produce AAL AAD, which have to be converted to PV.

One noteworthy caution needs to be mentioned about comparing BCR values between different studies and reports and even different projects in the same study or report. As will be described in the following sections, every BCA and the resulting BCRs are based on project-specific choices concerning cost assumptions, benefit sources and methods, reasonable project useful lifetimes of mitigation components, and assumed discount rate. Any change in one or all of these variables will result in different BCR values. In general, BCR values will be higher for the following:

- Lower costs
- Higher benefits based on better mitigation effectiveness (better design) or including more potential benefit sources
- Longer project useful lifetime
- Lower discount rate

For example, the McLean Creek Flood Storage BCA (Alberta Government, 2015a) has tables of BCR values comparing high damage scenarios and low damages scenarios for three potential flood mitigation projects with designs for 100-year and 200-year protection/project effectiveness, resulting in twelve BCR values ranging from 0.83 to 2.07. This illustrates that there are not “typical” BCR values for project types or flood hazard types, but all BCR values are context-specific to the assumptions of a given project. Thus, a BCR can be a useful summary tool, but project choice should still consider other aspects of the BCA.

Although there can be significant variation in BCRs between and within BCA studies, depending on the methods applied and the local circumstances, there is substantial evidence that flood mitigation measures can, on average, offer significant returns on investment. A recent nation-wide study in Canada (Public Safety Canada, 2019) reported that for every $1 invested in mitigation efforts, there could be savings of $7 to $10 in terms of avoided post-disaster recovery costs. Similarly, in the USA, riverine flood hazard mitigation has been found to save $7 on average for every $1 spent on federal mitigation grants (NIBS, 2019).

The following sections will provide overviews of methods used to derive costs, benefits, the additional economic variables for a BCA, and additional considerations when conducting and comparing results from a BCA.

3.2.1 Costs

Previous sections of this report and many of the prior investigations across the three themes of Governance (Theme A), Flood Hazard and Risk Management (Theme B), and Flood Forecasting, Emergency Response and Recovery (Theme C) include discussion on how to estimate costs for flood mitigation projects. Since most BCAs are performed for structural projects, the following overview will focus on these types of projects.

The Alberta McLean Creek BCA report (Alberta Government, 2015a) shows a typical example of how cost estimates are developed for structural projects. Construction costs are split into major components of the project (general costs, main embankment, main spillway, auxiliary spillway, and road relocation). Additional main cost components look at geotechnical aspects, engineering and environmental costs, and overall contingencies. For the major construction components, the cost is built for unit costs and lump sums expected to perform the construction, such as mobilization, excavations, materials purchase, and actual construction activities.

The expectation for a BCA is that the cost estimate is reasonable and appropriate for what is being proposed. Mitigation grant review should include an independent engineering feasibility and cost evaluation that determine if the cost value is complete and that the proposed project can perform to the design scope. For example, if the project is installing a replacement culvert to pass a larger storm event, then the engineering review should look at the design calculations used to size the culvert.

One additional cost consideration for BCA concerns maintenance costs. Even though most mitigation funding sources do not cover any ongoing maintenance after a project is installed, the BCA needs to include any maintenance costs that directly impact the ongoing effectiveness of the project. For example, if a storage pond’s effectiveness assumes that it will be dredged every 5 years during a 75-year useful lifetime, then the BCA needs to include this maintenance cost as part of the overall cost.

3.2.2 Benefits (avoided losses)

Benefit calculations focus on those assets and land areas where a flood mitigation project will reduce damages. For projects that are exclusively changing the vulnerability of assets such as a neighborhood, the analysis focuses on only those specific assets. When the project changes the flood inundation, then the analysis can look at all assets within the area where the flood inundation and associated flood depth changes. The challenge of performing the benefit calculations is gathering the required data needed for the flood risk assessments for each scenario. Due to limited analysis budgets and data availability, typically a BCA will focus on only a subset of all possible benefit sources. The following two Figures 3-1 and 3-2 show slightly different approaches to describe the tangible and intangible flood damage sources one might consider as part of a benefit analysis.

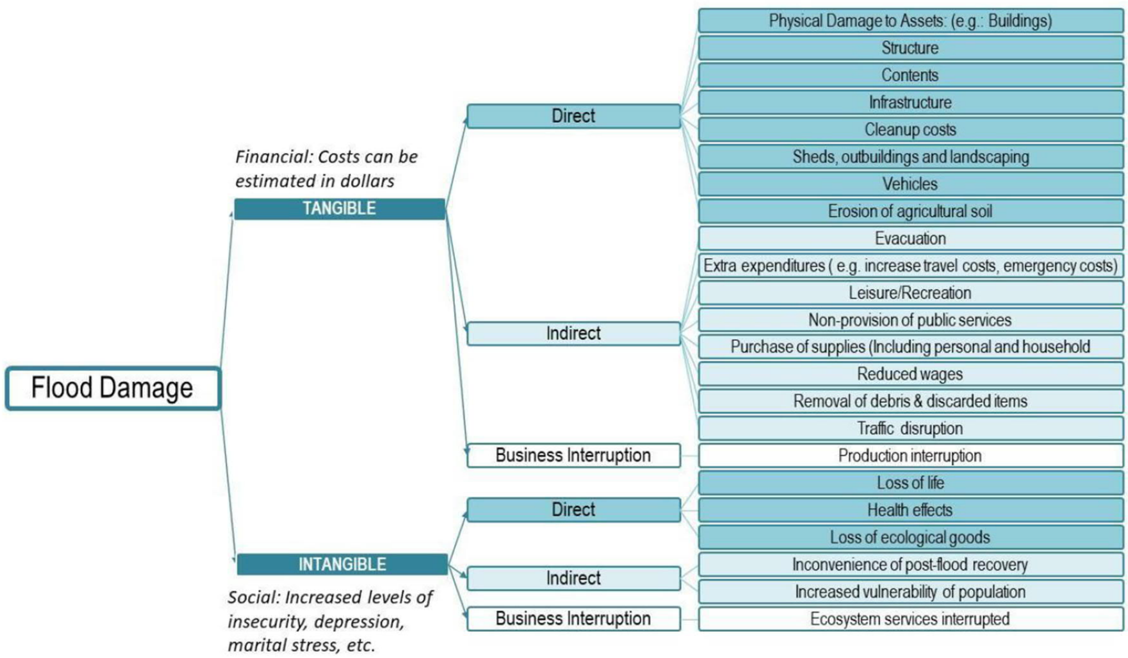

Figure 3-1: Types of Flood Damage from NRCan (2021a)

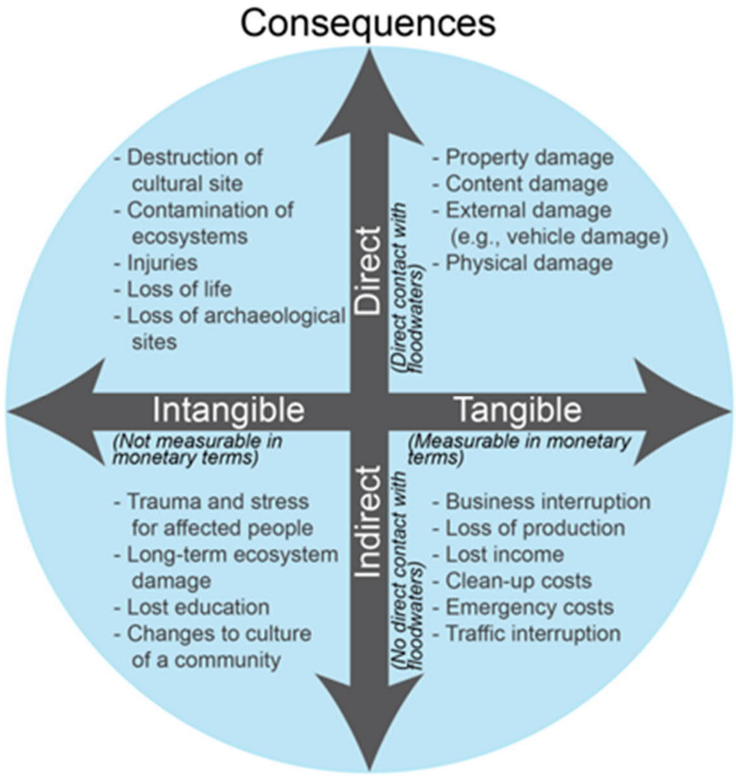

Figure 3-2: Types of Flood Consequences from NRC (2020)

Figure 3-1 comes from NRCan (2021a), and as mentioned earlier in the context discussion, will serve as the primary source for context of this literature review. Figure 3-2 comes from the 2020 document from the National Research Council of Canada (NRC) entitled *Coastal Flood Risk Assessment Guidelines for Buildings & Infrastructure Design Applications* (NRC, 2020). While the two figures are very similar, Figure 3-2 does clarify that direct damages can be thought as coming from physical damage from direct contact with floodwaters, where indirect damage or losses are not caused by direct floodwater contact. It also provides more detailed descriptions of some of the intangible loss categories.

3.2.2.1 Tangible Flood Damage

3.2.2.1.1 Structure and Contents Damages

Almost all flood risk assessments include an analysis of the structures and contents damages to buildings. The flood risk assessment methods discussed in the NRCan (2021a) report, all the Alberta risk assessment and BCA reports, the USA FEMA BCA and Hazus software tools, and the USA NIBS report all include methods for estimating the damages to buildings and their content. The key concept that allows this modelling is the flood fragility curve, typically developed as stage damage curve or a depth damage function. Figure 3-3 below shows an example of a curve from Alberta for a certain type of residential structure where the Y-axis represents water level within a structure above the finished floor and X-axis represents damages as dollars per structure floor area.

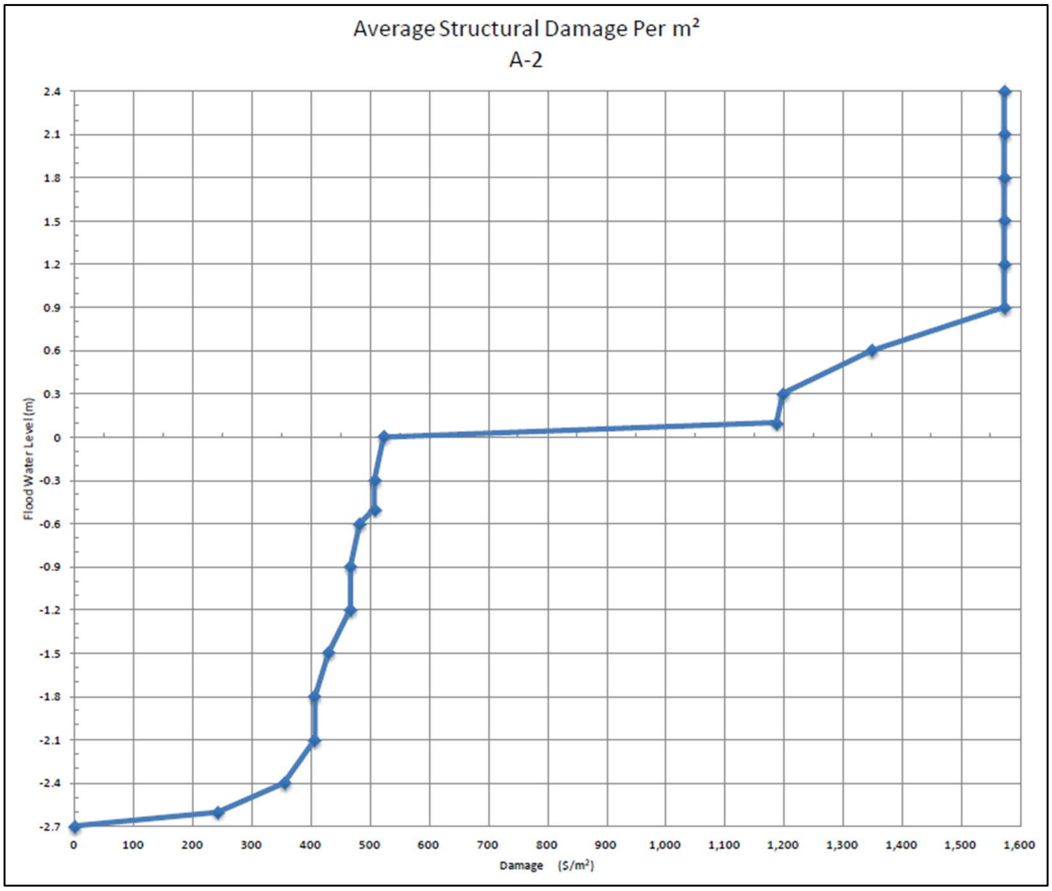

Figure 3-3: Example of Residential Structural Damage Curves (Alberta Government, 2015b)

This relationship of flood level to damage allows the analysis to estimate a structure-specific damage estimate when the flood inundation mapping is sufficiently detailed to determine structure-specific flood levels. The inherent geographic nature of this analysis means that all flood risk assessments need to use GIS technologies to derive the structure-specific flood information. Both CanFlood (NRCan, 2021b) and Hazus are built around GIS methods to help automate this. The USA FEMA BCA tool does not include GIS but assumes the user can enter structure-specific data such as flood elevations and first floor elevations.

A similar approach is used for building contents damages. Fragility curves are developed that relate flood levels to contents damages. For businesses, this may include typical building contents and warehouse inventory stored in the flooded location minus any potential salvage values.

While this approach can be performed on a structure-by-structure basis, typically modelling methods are developed where buildings are grouped into a set of categories. The analysis is then conducted where fragility curves and other building characteristics are assigned by category, which greatly aids in the automation of the analysis for large numbers of structures. For example, the following Table 3-2 shows for residential buildings some of the categories used by Alberta (first column) and the USA FEMA Hazus tool (second column).

Table 3-2: Comparison of Alberta and Hazus Residential Housing Types (NRCan, 2021a)

Alberta	HAZUS Codes	Floor Area (m^2)	General Description	Stories	Quality Options
AA	RES1	~372	Single-family dwelling with and without basement	1,2	Above, Custom
A	RES1	223-371	Single-family dwelling with and without basement	1,2,3,4	Above, Average
B	RES1	112-223	Single-family dwelling with and without basement	1,2,3,4	Above, Average, Below
C	RES1	<112	Single-family dwelling with and without basement	1,2,3,4	Above, Average, Below
D	RES2	~128	Mobile Home	1	Above, Average, Below
E	RES3A, 3B		Duplex, Triplex, Row townhouse	1,2,3*	Above, Average, Below
MA	RES3D, 3F or 3F		high rise apartment	2,3*	Above, Average, Below
MW	RES3C		walk up apartment	1,2*	Above, Average, Below

This table shows one approach used in Canada to classify structures to aid in a BCA. Expanding this to BC will need to account for the unique structure types and flood hazards found in BC. For example, this table does not have unique structure types for structures in coastal flood hazard areas, which may be built with different types of foundations (elevated with piers or piles in high storm surge areas). Adding those additional categories would then also require new fragility curves to better reflect expected damages from those types of structures.

3.2.2.1.2 Displacement

Another source of benefits included in many BCA studies is displacement costs. According to USA FEMA BCA, displacement costs are those costs when occupants (of residential, commercial, or public buildings) are displaced to temporary quarters while damage is repaired. These costs include rent and other monthly costs, such as furniture rental and utilities, and one-time costs, such as moving and utility hook-up fees. Appendix 6 of the NRCan 2021a document includes detailed discussion on both residential and business displacement. Similar to fragility curves, flood depth to displacement time curves can be established to allow structure-specific estimates of displacement time, as shown in the following Table 3-3:

Table 3-3: Estimated Average Residential Displacement Time (Days) (NRCan, 2021a)

Unit Type/Location	*DEPTH (m)*										
	0.1	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3
all apartments u/g parking	0	2	4	7	7	7	10	10	14	14	14
upper level low-rise	35	35	90	90	120	120	180	180	180	180	180
upper level high-rise	21	35	42	60	90	90	90	90	90	90	90
main floor units	60	90	120	180	180	180	210	240	270	300	300
single/semi/row main floor	90	120	180	210	240	270	300	300	300	300	300
single/semi/row basement	0	0	14	21	30	30	45	45	60	75	90

To use that information to calculate an economic value associated with displacement, the methods require additional supporting equations and default factors. The following Table 3-4 from NRCan 2021a shows an example of some of these additional factors.

Table 3-4: Example Residential Displacement Cost Factors (NRCan, 2021a)

Item	Cost
Hotel Room Per Night:	$166
One-time moving expenses:	$500
Apartment Rent/Month:	$1,220
House Rent/Month:	$1,695
Incidentals/Day/Person:	$50
Residents/Apartment:	1.3
Residents/House:	2.4
Percentage with friends/family:	50%
Max number of days in hotel:	14
Daily cost apartment	$148
Daily cost house	$203

For non-residential structures, one additional displacement consideration is functional downtime. Functional downtime is the portion of the displacement time when the “function” or services of an organization are lost or reduced. For example, if a government agency office is flooded and will require 6 months displacement to repair and reoccupy, it is likely the agency will locate temporary facilities to “reopen” to the public in 2 months. Therefore, the functional downtime, and the associated loss of function or service, is only 2 months and not the entire 6 months.

3.2.2.1.3 Business Disruption

Many flood risk assessment models also expand on the functional downtime concept to include additional sources of loss associated with business disruption. For residential buildings, this may be calculated as lost wages while being displaced from a flood event. For commercial buildings, calculations may look at lost productivity and/or revenues and economic factors like penalties for missed or late client orders. This can also include lost rental property revenues and other business-to-business losses. Similar approaches can be applied to governmental and non-profit buildings, where annual budgets are used to approximate “value to society” of the services lost during displacement or functional downtime. For locations where tourism is a major source of business, there may be high indirect impacts if flood events cause the closing of major tourist attractions.

Reducing insurance premiums may also be included in this category of benefits. For both residential and commercial flood insurance customers, flood mitigation projects could be expected to likely reduce insurance premiums in some way. However, sometimes updated flood risk studies may find higher risks, so premiums may go up. These calculations would need to be developed in consultation with the insurance industry in BC to know what type of projects they list as ways to reduce rate reductions.

3.2.2.1.4 Infrastructure Damages

Besides damages to buildings, the other major source of tangible benefits is avoided damages to critical infrastructure or lifelines. Many of these sectors have unique considerations for the benefits calculations of a BCA. The main infrastructure sectors listed in the USA FEMA BRIC MAT (defined as community lifelines) are listed in the Table 3-5 below along with some of the major benefits considerations for that sector. In many cases, there are methods and default values that have been established in Canada or the USA associated with past projects for specific sectors. The NIBS (2019) Study includes examples of infrastructure focused mitigation projects in Chapter 6 on Utilities and Transportation lifelines).

Table 3-5: Infrastructure Sectors and Tangible Benefits Considerations (NRCan 2021a, USA FEMA, 2021, 2019)

Community Lifelines	Selected Components	Tangible Benefit Considerations
Transportation	Roads, rail, bridges	-Costs associated with repairs and associated delays, detour times, and additional distances
Food, Water, Shelter	Potable water, sewage, and agriculture	-Cost associated with repairs to equipment and pipes, loss of service for water and sewer -Cost of damages to crops and agricultural buildings and associated loss of sales
Energy	Electrical power and fuel	-Cost of repairs to equipment and loss of electrical power
Safety and Security	Government services and law enforcement and fire	-Cost of repairs and loss of typical govt services -Cost of repairs and loss of police and fire services -Possible impacts to emergency services and response, cost of temporary housing and debris removal
Health and Medical	Hospitals and doctor offices	-Cost of repairs and loss of medical services, especially critical care -Associated mental health impacts of flood events
Hazardous Materials	Facilities and materials	-Cost of cleanups
Communications	Equipment and services	-Impacts to emergency services and response

3.2.2.2 Intangible Flood Damage

As stated in NRCan 2021a,

> *In addition to direct damage to property, a variety of secondary economic, social, and environmental impacts are caused by flood events. The benefit-cost approach to disaster mitigation assessments theoretically requires a complete enumeration of all gains/benefits and losses/costs associated with a project. In practice, however, it is not possible to identify, quantify, and monetize all potential impacts.*

The discussion in Section 3.1.2 on context issues helps to bring in some additional ideas and references to provide a broader discussion on intangible aspects. In the 2019 report *Addressing the New Normal: 21st Century Disaster Management in British Columbia* (BC Government, 2019), one area of consideration brought up, to broaden how to address hazard and disaster management in general, was to look at international approaches (p. 13):

We also considered international thinking on disaster management found in the Sendai Framework for Disaster Risk Reduction 2015–2030, a publication of the United Nations. Developed in the aftermath of the devastating earthquake and subsequent tsunami that took place in Japan in 2011, the publication includes a series of valuable insights that can and should inform any resulting changes the Province should make going forward following in the aftermath of the 2017 flood and wildfire season.

The Sendai Framework for Disaster Risk Reduction (United Nations, 2015) grew out of international efforts to provide goals and metrics to guide disaster risk reduction globally. In NRC (2020), they reference the Sendai Framework in the discussion on how to go beyond the direct physical damages to buildings and infrastructure to account for the wide range of economic, social, cultural, and environmental consequences of flood risk. They developed a list of six different indicator categories recommended for flood risk assessment to go beyond typical dollar loss calculations. The following Figure 3-4 from Ebbwater (2020) from their document on BC's Orphaned Flood Protection Structures includes definitions for these six indicators:

Indicator	Description
1. Affected People	This indicator portrays the number of people who are directly affected by a clearwater flood or geohazard. This may include people who are injured or suffer other health effects, are evacuated or displaced, or suffer direct damages to their livelihoods (e.g., their house is damaged). It does not include loss of life (which is assessed via the mortality indicator).
2. Mortality	This indicator describes the estimated number of deaths and missing persons due to a flood or geohazard caused by structure failure.
3. Economy	This indicator describes potential economic losses that result from a flood or geohazard. This includes the exposure of public and private buildings, as well as agricultural lands.
4. Damages to critical infrastructure and disruption of basic services	This is an indicator that describes consequences that can potentially have more widely spread cascading effects on society, such as damage to critical infrastructure and disruption of basic services. This can include damages to health facilities, emergency response facilities, governmental facilities, transportation infrastructure, roads, electrical systems, etc.
5. Environment	This indicator describes environmental consequences resulting from floods and geohazards. This includes the overflow or discharge of contamination sources into the receiving environment, in combination with damage to exposed environmental receptors such as sensitive areas that could be negatively affected. While flooding is an important component of many ecosystems and is a naturally occurring process, the contamination of flood waters by anthropogenic contamination sources as well as natural processes (e.g., erosion) can have detrimental consequences for sensitive ecosystems.
6. Culture	This indicator is used to describe consequences to the culture of a community; this includes both Indigenous and non-Indigenous cultural sites.

Figure 3-4: Indicators for flood and geohazard consequences from Ebbwater (2020)

While previous discussions in this literature review have covered the indicators for economy and damages to critical infrastructure and disruption of basic services (items 3 and 4 in Table 3-4), the other fours indicators merit a more in-depth discussion, provided in the following sections.

3.2.2.2.1 Affected People and Mortality

A BC project incorporating the Sendai Framework and the six indicators from Table 3-4 was the *Syilx Okanagan Flood and Debris Flow Risk Assessment* (Ebbwater, 2019), which says (p. 1):

The Sendai Framework for Disaster Risk Reduction (Sendai) addresses these critical issues; it is the global blueprint to help communities become more resilient to changes in natural phenomena such as flood and debris flows. Sendai's first priority is understanding risk, and this includes integrating Indigenous knowledge and scientific best practice to inform adaptation actions. The approach is supported by global and regional directives (e.g., United Nations Declaration on the Rights of Indigenous Peoples [UNDRIP], Truth and Reconciliation Commission, Abbott/Chapman Report recommendations, etc.).

This study used a collaborative approach (see Section 3.2.5.1 on First Nations for additional detail) to establish methods to qualitatively and quantitively measure the six indicators from NRC (2020) as shown in the following Figure 3-5:

Exposure Indicator	(Qualitative) Impacts – Example Guiding Question(s)	(Quantitative) Consequences – Proxy Data Sources
Environment	Where and how were ecosystems negatively or positively affected?	Contamination sources Environmental receptors
Culture	Were sensitive archaeological, fisheries, or other sites affected?	Cultural buildings *Syilx* and non-*Syilx* archaeological sites
Mortality	Not applicable	Census dissemination areas Building footprints
Affected People	Were people hurt, displaced, suffer emotional trauma, or affected in other ways (e.g. spiritually)?	Census dissemination areas Building footprints
Economy	What property was damaged, and/or which businesses were affected? How much did the response effort cost?	Land parcels Building footprints
Disruption	What was the critical infrastructure that was disrupted as a result of the event?	Major and minor roads, rail, gas, electricity infrastructure, and telecommunications

Figure 3-5: Exposure indicators and summary of supporting qualitative prompts for participants and quantitative data source (Ebbwater, 2019)

Qualitative impacts were developed based on workshops activities and watershed tours led by various *Syilx* Okanagan communities and their experiences with flood and debris flow. On the specific indicator of affected people, the qualitative impact asked about how disaster events caused physical or mental health impacts. Besides direct damages to structures, people mentioned loss of services such as clean water or roads, especially in rural areas. The quantitative approach compared census population density data, building locations, and hazard extents to provide a “metric” for that flood risk.

Mortality as an indicator is also shown in the figure, but was only measured quantitatively, not qualitatively. Typically, flood events have sufficient warning times to prevent most deaths within structures, but sometime injuries or death happen from trying to walk or drive vehicles through floodwaters with unknown depths. Within the context of this study, the mortality indicator used the same source information related to population densities as compared to flood hazard extents.

NRCan (2021a) also includes a discussion on the challenges on measuring impacts of flooding and disasters to public health. One of the few studies that have tried to measure this is *After the Flood: The Impact of Climate Change on Mental Health and Lost Time from Work, by Intact Centre on Climate Adaptation* (Intact Centre, 2018). In this study, the authors surveyed Canadian residents after a flood event to see if there were measurable changes in their mental health. They found that flooded households had significantly higher worry and stress, which would be expected to influence quality of life and ability to work. This may also then influence the health insurance industry with a greater need for counselling services and post-disaster recovery times. The study included commentary about how within the context of climate change, the higher likelihood of this flood stress may worsen over time. This would be caused by more traumatic events happening more often. The concept of climate change worsening flood risk also applies to the other tangible and intangible benefit categories, where the occurrence of flood events of a certain severity (flood flow or flood depth) will happen more often, which results in higher annualized damages and associated impacts.

3.2.2.2.2 Environment

A number of the references included in this literature review included discussions on environmental impacts of flood hazards and ways to measure them. The following are four frameworks, or case examples, that attempt to address environmental benefits and costs.

Risk Matrix

One approach to environmental indicators and all six indicators described in NRC (2020) is the use of a risk matrix to calculate and display indicator findings. The concept of a risk matrix is shown in the Figure 3-6 below from NRC (2020):

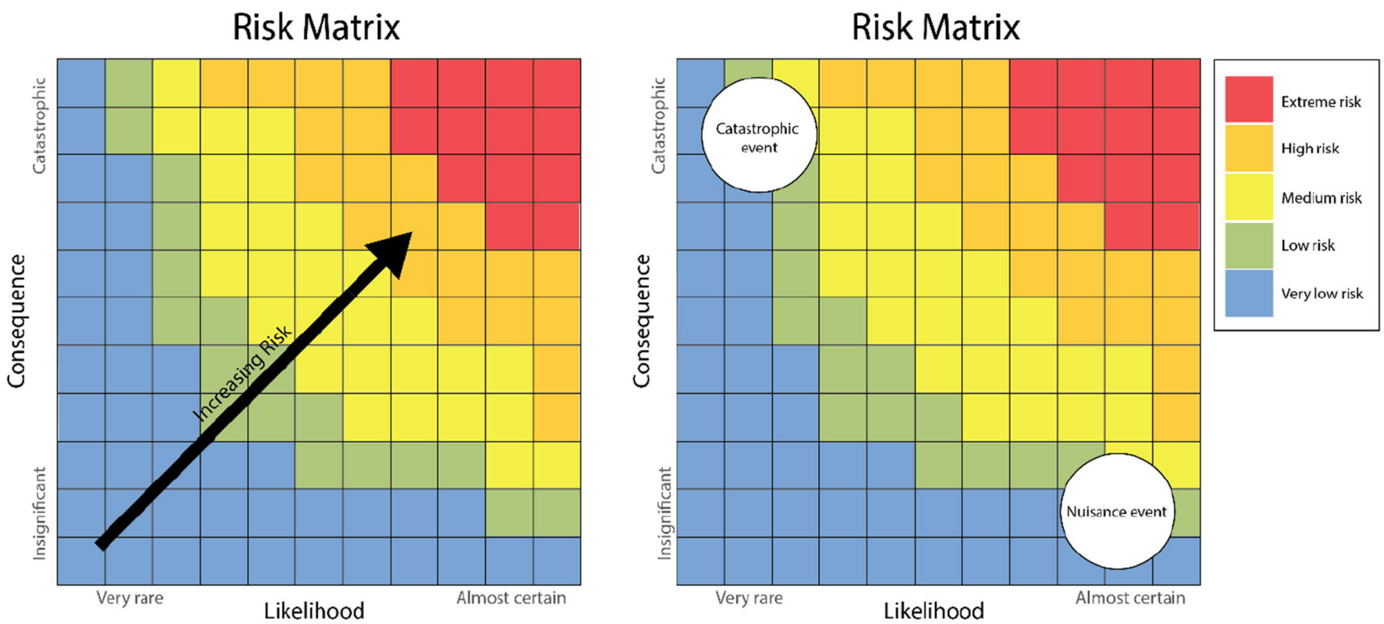

Figure 3-6: Risk as a function of likelihood and consequence – nuisance and catastrophic risk (NRC, 2020)

The matrix allows separate derivation of likelihood (X-axis) and consequence (Y-axis) based on available data to then provide an estimate of risk within a list of categories from very low to extreme. An example of an application of this approach was in Ebbwater (2020) report for BC's Orphaned Flood Protection Structures. The following Figure 3-7 shows an example how this approach could be applied to an individual location:

For each of these indicators, criteria were established to calculate the likelihood and consequence scores. Specifically for the environmental indicator, the count of number of potential contamination sources within the flood hazard extent was used for the score. Potential contamination sources were considered present for operations where fuel, chemicals or other toxic, persistent substances may be stored in large amounts. Analysis also took into account ecologically sensitive areas including mapping locations with species and ecosystems at risk, Parks (National, Provincial, local), Conservation Lands, Ecological Reserves, Protected Areas, and green spaces. *Syilx Okanagan Flood and Debris Flow Risk Assessment* (Ebbwater, 2019) used a similar approach to the Orphaned Structure report with a heavy focus on fish and fish habitat, and water quality. This included emphasis on specific ecologically sensitive areas like riparian ecosystems, human encroachment on wildlife habitat, and the legacy of mismanaged industrial wastes such as mine tailings.

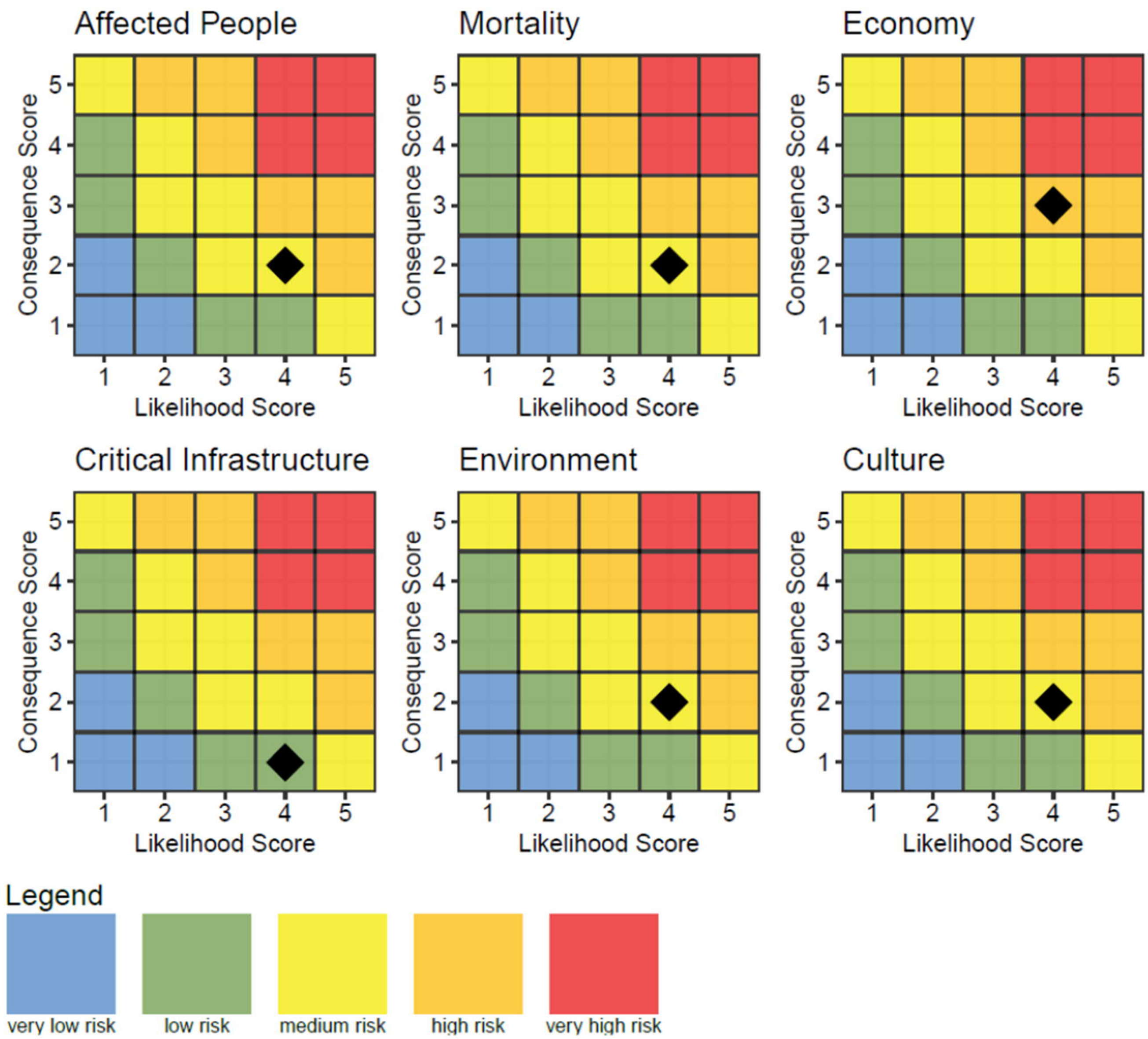

Figure 3-7: Use of risk matrix at a single location (black diamond represents rating) for indicators for flood and geohazard consequences (Ebbwater, 2020)

Willingness To Pay (WTP) Principle

The Treasury Board of Canada 2007 publication, *Canadian Cost-Benefit Analysis Guide: Regulatory Proposals*, provides a very different context on accounting for environmental impacts, in this case how changes to government regulations will impact a good or service and the associated sector of the economy. One important concept brought out in this publication is the willingness to pay (WTP) principle, which is defined as "The amount (demand price) that an individual is willing to pay for an incremental unit of a good or service measures its economic value to the demander and hence its economic benefit to the economy (p. 11)". Examples given for WTP include amount someone would pay to improve their health, avoid getting hurt, or obtain an environmental improvement. The publication goes on to include discussions on ways to estimate benefits from new regulations related to human health and ecological benefits. Human health benefits use the WTP idea to quantity benefits from avoiding or reducing death or injury or impacts to mental health such as tension or stress. To apply these concepts to flooding, additional research would be needed linking together flood hazards to specific environmental damages and then the WTP associated with the detrimental health impacts of that damage. For example, if a flood event causes a long-term degradation of a drinking water supply, then what would be the associated health costs from the poorer water quality.

Natural Infrastructure Context

The study *Combatting Canada's Rising Flood Costs: Natural infrastructure is an underutilized option* (Insurance Bureau of Canada, 2018), directly compared natural and grey infrastructure. Some of the areas of additional benefits for natural/green infrastructure over grey infrastructure included:

- Water quality
- Habitat creation/improvement
- Microclimate stabilization (reduce urban heat island)
- Air filtration
- Recreational amenity and aesthetic services
- Energy savings
- Carbon savings

USA BCA Approach

In addition, in the USA FEMA BCA Unit 3 training material (USA FEMA, 2019), the environmental benefits for green open space, riparian areas, wetlands, forests, and marine and estuary area are listed with USA-based benefit estimates by land area per year. Equivalent analysis could be examined for BC to develop some tangible benefit calculations for this typically intangible topic.

3.2.2.2.3 Culture

Cultural considerations closely align with the concept from environmental considerations of identifying sensitive areas. Cultural value can be associated with a number of structures and sites, especially areas with historic and heritage significance. These can range from a First Nations archaeological site to a church to a sports stadium. The definition of what are culturally important locations and what data are available to map those locations are the main tasks to measure flood impacts to these resources. In the Ebbwater (2020) report for BC's Orphaned Flood Protection Structures, the two main sources used to identify locations were 1) BC mapping of Civic Facilities, Child Care, and Education and 2) Archaeological and Heritage Site data for both Indigenous and Non-Indigenous sites. Ebbwater (2019) used a similar source for the quantitative consequences, but also qualitatively include ecological significant / traditional use locations such as fisheries. This overlapping of categories was an important consideration to the *Syilx* Okanagan people, who strongly value fish resources. The actual scoring approach used in Ebbwater (2019) made use of the risk matrix concept and the overlap of the cultural area with the flood hazard extent as described in previous sections.

3.2.3 Economic Variables (Useful lifetime, rate of return, etc.)

As mentioned earlier, to calculate the present value for benefits requires several additional economic variables to be defined. The end of a flood risk assessment is an average annual damage (AAD) for various scenarios. For example, the McLean Creek Flood Storage BCA in Alberta (Alberta Government, 2015a) produced the following AAD calculation for one of the scenarios for the Bow River (Figure 3-8):

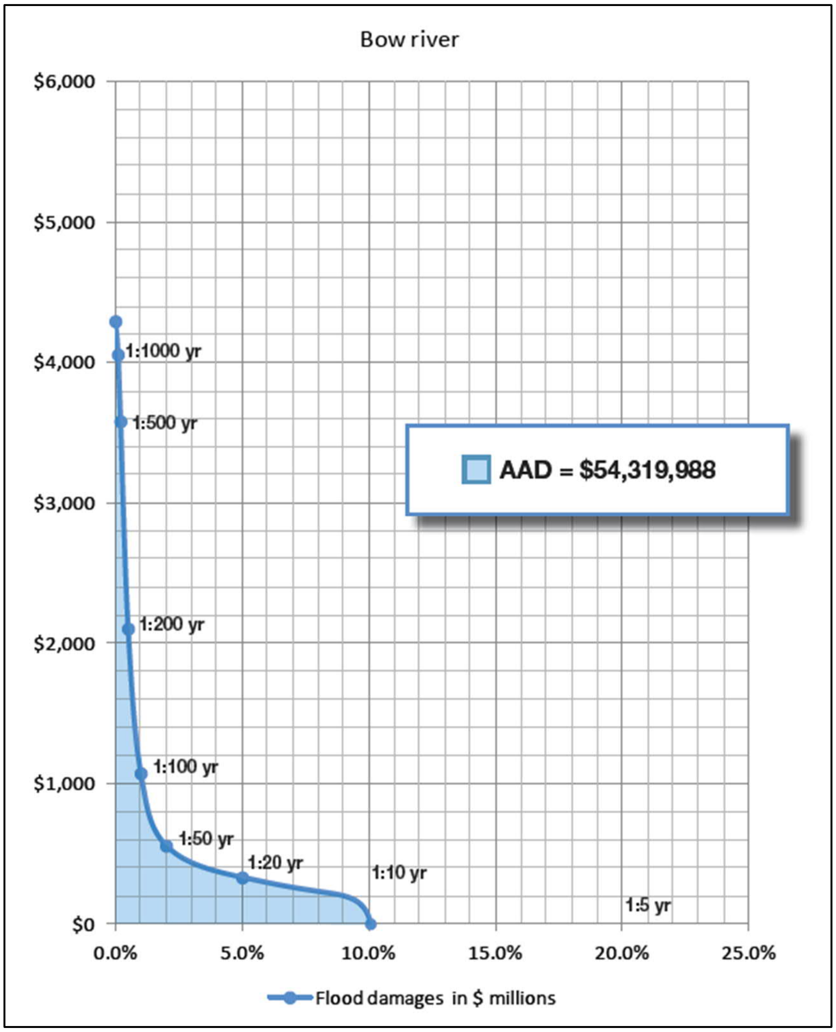

Figure 3-8: Flood Damages Probability Distribution, Bow River (Alberta Government, 2015a)

The area under this curve represents the AAD value shown of around $54 million. To go from the AAD to the PV, the values for the useful life and discount rate are needed.

3.2.3.1.1 Useful lifetime

The USA FEMA BCA Unit 3 Training (2019) defines the useful lifetime as the estimated amount of time that the mitigation action will be effective. This is not the same as the project design standard, but rather is a measure of how long the materials used in the project will last. For example, a culvert may be selected that is designed to only carry the 25-yr event (design standard), but the materials of the culvert may last 50 years (useful lifetime). The USA FEMA BCA Reference Guide 2009 includes a table of some of the default values established in the USA for typical flood mitigation projects. The Table 3-6below shows a subset of these values. There is no equivalent guidance in Canada on project useful lifetime, so BC will need to establish provincial defaults to support BCA in BC.

Table 3-6: Example Project Useful Lifetimes (USA FEMA, 2009)

Project Type	Useful Life Default (years)	Acceptable Limits (years)	Comments
Acquisition/Relocation	100	100	100 years represents total protection
Residential Elevation	30	30 - 50	Typical residential construction
Public Building Elevation	50	50 - 100	Assume custom designed structure for government use
Flood Walls	50	35 - 50	Assumes concrete construction
Culverts	30	25 - 50	Culvert with end treatment
Pump Station Structures	50	50	
Pump Station Equipment	5	5 - 30	Useful life from equipment manufacturer

3.2.3.1.2 Discount Rate

To convert annual value to present value also requires a value for the discount rate. According to the USA FEMA BCA Reference Guide (2009), the Discount Rate is defined as:

Used in FEMA Benefit-Cost Analysis to determine the “Net Present Value” of benefits. Discounting facilitates accurate comparisons of benefits that may occur in the future to the costs of a project that most often occur immediately or in the near term.

In the USA for FEMA projects, the federally required discount rate to be used is 7%. There is considerable debate both within the USA and Canada on the appropriate basis to establish the discount rate used for BCA. In the NIBS (2019) report, there is discussion on the influence of using the discount rate of 2.2% (the rate used for the final results summaries in the report) versus the higher rates used by USA federal agencies. Mathematically, the lower the rate used, the higher the PV benefits calculation, which results in higher BCR values. When comparing results between BCA reports, one should always check the assumed useful lifetime and discount rate before doing a comparison of BCR values.

In Canada, there does not appear to be any federally-mandated standard for discount rates to use in a BCA. According to *A Review and Recommendations for Canadian Life Cycle Cost Analysis (LCCA) Guidelines* (TAC, 2017), the current BC discount rate for transportation projects is 6%. This same document states the Alberta discount rate at 4%, which is the rate used in the Alberta benefit-cost analysis reports such as the McLean Creek Flood Storage BCA (Alberta Government, 2015a). According to the *Benefit-Cost Analysis Guidebook, Guidelines for the Benefit-Cost Analysis Of Highway Improvement Projects In British Columbia*, (BC MOTI, 2014), the discount rate in BC is prescribed by the BC Ministry of Finance. It is recommended for flood mitigation project BCA that BC use the same discount rate as used for transportation BCA initially, but discuss whether flood projects need their own decision process for establishing the discount rate.

3.2.4 Uncertainty

Almost all of the references reviewed included commentary related to uncertainty and ways to account for, or directly model, some aspects of uncertainty. Any modelling effort that attempts to represent some aspect of “reality” with a set of data and a series of equations will include uncertainty. While this brief literature review can not cover all aspects of addressing uncertainty, it is worthwhile to point out certain major issues that will need to be addressed to establish standardized BCA approaches in BC.

Sensitivity Analysis

One useful approach to identify the relative importance of individual variables in a calculation is a sensitivity analysis. Typically, a sensitivity analysis will change the value of an individual variable up or down by a given percentage and note the resulting relative change in the final output. This is repeated for other variables and the results compared to determine which input variables have a higher relative influence on the output. Related approaches may look to alter groups of input variables up or down at the same time, especially those that are known to be highly correlated. An extreme approach of this type of analysis is a called a Monte Carlo analysis, where probability distributions are assigned to each input variable of interest and then a large number of randomly generated scenarios are run through the equation or model of interest and outputs are compared. Monte Carlo approaches are often used to quantify uncertainty by producing expected variations or ranges in output values.

Flood Hazard Uncertainty
Flood hazards are difficult to model because they are continually changing. The probabilistic nature of flood events requires any modelling process to account for this, typically by fitting precipitation or river gauge data to specific types of probability distributions. However, this type of analysis traditionally has assumed the historic record is the best indicator of the future. References such as NRC (2020) include commentary on the impact of climate change to these modelling assumptions and the need to account for changing future conditions.

Asset Uncertainty
Detailed information about assets are needed to select the correct models or fragility curves to best approximate the damages from a flood event. Currently available data on assets such as residential structures or roads often may contain only a subset of the information needed to support a BCA. As mentioned earlier, the use of classification schemes like those shown in Table 3-2 are one way to simplify the data needs. The most critical asset attribute needed for flood risk modelling is the asset elevation, such as the first-floor elevation of a structure. When this elevation is compared to the flood depth information, it establishes the “in-asset” flood depth that typically is used by fragility curves to estimate flood damages. Appendix 21 of NRCan (2021a) includes a discussion on the uncertainty associated with structural classification approaches and fragility (stage-damage) curves.

3.2.5 Additional Considerations for Mitigation Project Selection

BCA is not the only criteria used to select how flood mitigation grant funded is awarded. As mentioned earlier, BCA studies are performed within a larger context where time and study budgets may limit whether benefit calculations focus on only a few sources or are more comprehensive. In many cases, if the BCR exceeds 1.0 by only including benefits from avoided building and contents damages, the analyst may stop at that point and focus on other portion of an overall grant application. Grant applicants with limited staff and experience with flood mitigation grant applications may be challenged to even perform this level of BCA. The following discussion will highlight some examples from the literature of additional considerations beyond BCA in grant selection.

3.2.5.1 First Nations

Ebbwater (2019) report has detailed documentation on the process used to bring First Nations perspectives into the flood planning and mitigation process. As mentioned earlier, the use of the Sendai Framework and the combination of qualitative and quantitative approaches for the six indicators allowed a large number of the *Syilx* Okanagan people to provide their stories and experiences to inform what the study included and how it was conducted. One of many unique perspectives documented in Ebbwater (2019) was the weaving of *Syilx* and western science ideas in the following Table 3-7:

Table 3-7: Common water-based threads identified by weaving *Syilx* perspective and western science ideas (Ebbwater, 2019)

Reasons to Respect Water	Consideration
1. Water is powerful	It will always find a way around obstructions. It is a source of power in many dimensions (e.g., political, social, spiritual, electrical, environmental).
2. Water is life	It is a part of, and sustains, humans and all life; it feeds and regenerates ecosystems in water and on land.
3. Water is connected	It connects living and non-living things in the past, present, and future. Water is affected by cumulative pressures.

Other references focused on the challenges of competing for disaster funding for First Nations. In the Public Safety Canada (2019) Study, *Evaluation of the National Disaster Mitigation Program*, the need for grant writing support for First Nations is raised. Since the applications for funding need to be submitted through Provincial or Territorial governments, First Nations need extra support to overcome challenges in the application process. For example, while First Nations can obtain match funds from the Crown Indigenous Relations and Northern Affairs Canada (CIRNAC) to match the NDMP contribution, the timing of the funding approvals between Public Safety and CIRNAC did not align. Another challenge for First Nations were reporting requirements, since the Provincial and Territorial governments were responsible for reporting on all projects within their jurisdiction, even if they didn't provide the matching funds.

Similar concerns were also brought out in the British Columbia Government (2017) *2017 Freshet and Wildfires (Provincial After-Action Review)*. In this report, there was the acknowledgment that emergency programs in First Nations communities have not been supported holistically, resulting in limited capacity regarding all areas, especially mitigation and preparedness.

3.2.5.2 Vulnerable populations

In *Weathering the Storm: Developing a Canadian Standard for Flood-Resilient Existing Communities*, (Intact Centre, 2019), the authors notes that the Government of Canada acknowledges that the environment can affect health, and that some populations in Canada are more vulnerable to environmental risks as a result of physical differences, behaviours, location and/or control over their environment. The Red Cross identifies the following ten populations in Canada as vulnerable:

1. Seniors
2. Persons with disability
3. Indigenous residents
4. Medically dependent persons
5. Low-income residents
6. Children and youth
7. Persons with low literacy levels
8. Women
9. Transient population
10. New immigrants and cultural minorities

The BCA methods do not account for the higher relative vulnerability of these populations when flooding happens. Canada/BC may want to look at introducing additional scoring criteria that identify locations with high concentrations of vulnerable populations. This type of analysis would ideally by performed by the Province and provided to applicants, rather than adding an additional analysis requirement to funding applications.

3.2.5.3 USA FEMA BRIC Qualitative Criteria Program

As part of the grant application material of the USA FEMA (2020) BRIC Program, there are a number of qualitative criteria that produce points in the overall grant review evaluation. These are summarized below.

Risk Reduction/Resiliency Effectiveness
Resilience refers to the ability to prepare for anticipated hazards, adapt to changing conditions, and withstand and recover rapidly from disruption. Also, the measure looks at how project reduce risks and to what level.

Future Conditions
These criteria look at whether the project includes anticipated future conditions both at a technical and quality level. For example, does the design address sea level rise as a design requirement or as part of the freeboard requirement of flood prevention practice.

Implementation Measures
This measure assesses whether the project plan appears realistic from a schedule and time frame and has lined up the partners and stakeholders needed for the project to be successful.

Population Impacted
This criterion is not just overall population but looks at the community-wide impacts of the project within the context of specific location. This also consider lifelines and locations of vulnerable populations.

Outreach Activities
This measure evaluated how the project was developed and the contributions of stakeholders and vulnerable populations to the options considered. Also, it looks at how the proposed project will allow better future outreach on flood mitigation in general to the community.

Leveraging Partners
The focus of this criteria is partnerships of all kinds. This may include financial support, outreach, and promotion of the project, involving non-governmental organizations and universities in the activities, and use of other funding sources.

3.2.6 CanFlood

One new tool that can calculate many of the tangible benefit categories (structure and contents damages primarily) included in this literature review is CanFlood. Released in May 2021, CanFlood supports flood risk assessment modeling within the open-source environment of QGIS (NRCan, 2021b). The following Figure 3-9 and Figure 3-10 summarize some tools included in CanFlood to conduct a flood risk assessment:

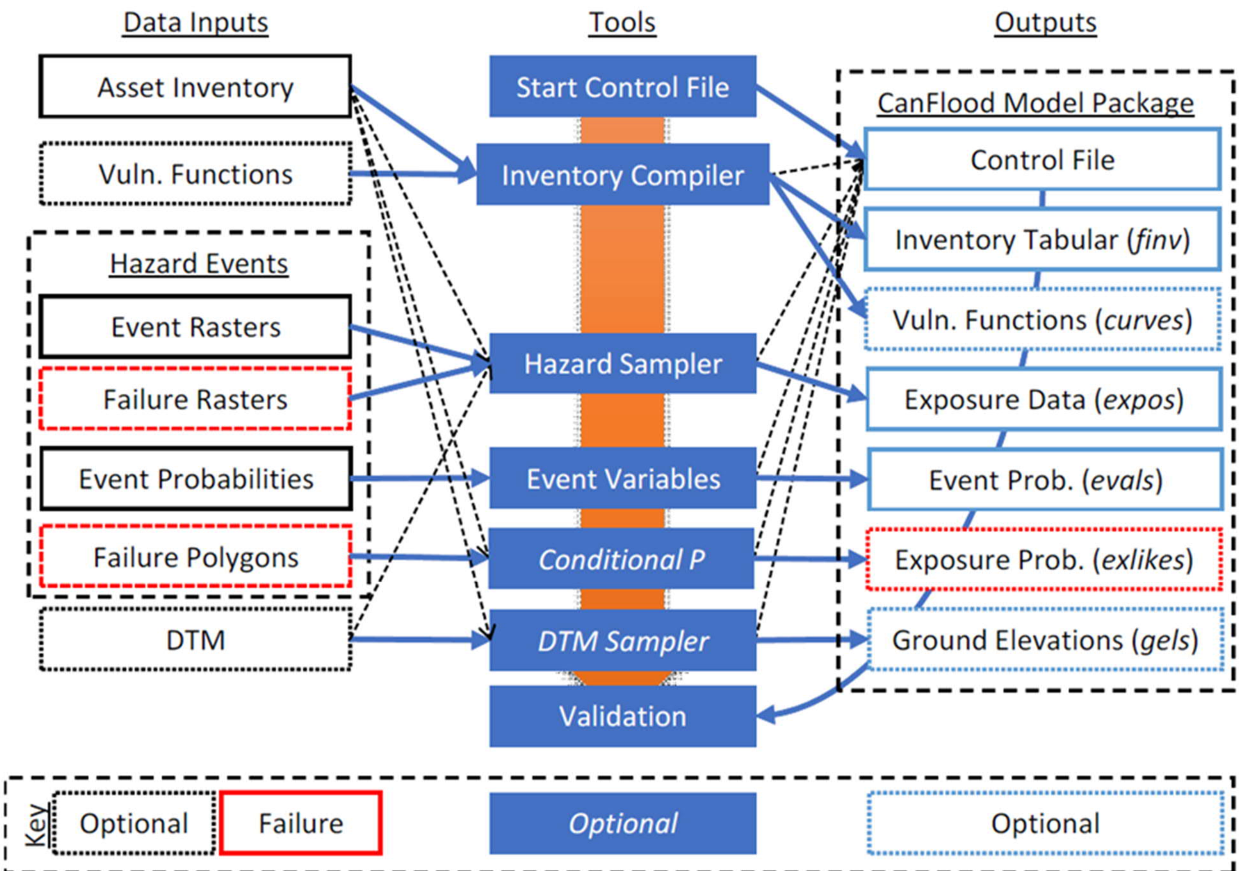

Figure 3-9: Typical model construction workflow using CanFlood's 'Build' tools (NRCan, 2021b)

CanFlood supports BCA with a separate calculation process that compares flood risk assessment results represented as estimated annualized damages (EAD). The user first defines a BCA scenario. The user then brings in the EAD results from the flood risk assessment and enters the economic variables. Finally, the user edits the BCA calculation spreadsheet with detailed information on project development and operating costs and additional benefits beyond the EAD calculated in CanFlood.

	A	B	D	E	F	G	H	I
1			2021	2022	2023	2024	2025	2026
2			0	1	2	3	4	5
3	**Development Costs**							
4	Construction	$2,000,000	$1,000,000	$1,000,000				
5	Engin/Envir/Engag	$0						
6	Land	$0						
7								
8	**Total**	$2,000,000	**$1,000,000**	**$1,000,000**	**$0**	**$0**	**$0**	**$0**
9								
10	**Operating Costs**							
11	maintenance	$99,000			$1,000	$1,000	$1,000	$1,000
12	operation	$0						
13								
14	**Total**	$99,000	**$0**	**$0**	**$1,000**	**$1,000**	**$1,000**	**$1,000**
15								
16	**Grand Total Costs**	$2,099,000	**$1,000,000**	**$1,000,000**	**$1,000**	**$1,000**	**$1,000**	**$1,000**
17								
18	**Flood Loss Avoidance**							
19	baseline EAD	$15,288,273			$154,427	$154,427	$154,427	$154,427
20	option EAD	-$5,643,301			-$57,003	-$57,003	-$57,003	-$57,003
21	other monetized benefits	$48,712		=F23/2				
22								
23	**Grand Total Benefits**	$9,693,684	**$0**	**$48,712**	**$97,424**	**$97,424**	**$97,424**	**$97,424**

Figure 3-10: BCA Calculation Spreadsheet in CanFlood (NRCan, 2021b)

3.3 BC Flood Project Funding Review

Emergency Management BC (EMBC) provided for this literature review three BC flood project data tables including funding information primarily for the time period 2016 – 2020. The complete tables are provided in Appendix E. Each record in these tables was tagged by the authors of this report based on the eleven issue categories listed in Appendix A for all of the BC Flood Investigations. Because of lack of detail in project descriptions, these eleven categories were collapsed into eight issue groups (see summary table below).

Disaster Mitigation Unit (DMU) Table

The DMU Table includes records from funding from the National Disaster Mitigation Program (NDMP) and additional EMBC funding opportunities in a given year, listed as DMU Funding. This table included projects in seven of the eight issue groups.

Community Emergency Preparedness Fund (CEPF) Table

The CEPF Table only includes funding provided through the CEPF program administered by Union of British Columbia Municipalities. This includes projects funded through *Flood Risk Assessment, Flood Mapping & Flood Mitigation Planning*, which is capped at $150,000 per project from BC, and *Structural Flood Mitigation*, which is capped at $750,000 per project from BC. This table includes projects on five of the eight issue groups.

Disaster Financial Assistance (DFA) Table

The DFA table is the least detailed of the three tables provided by EMBC. Rather than listing individual projects, the table has individual year totals split between exclusively DFA BC funding and larger events (shown in bold) that qualified for federal support through the Disaster Financial Assistance Arrangements (DFAA) Program. Because individual projects were not listed, but this funding is primarily used either during a flood event (response) or in a post-disaster setting (recovery), all records were assigned to the "C-2 Emergency Response/C-3 Flood Recovery" Issue Group only.

Table 3-8 below summarizes the investment in flood mitigation from the Disaster Mitigation Unit and the Community Emergency Preparedness Fund. Table 3-9 presents the response/recovery costs from the Disaster Financial Assistance Program.

Table 3-8: BC Flood Project Funding Summary 2016-2020 - Mitigation Investment

Issue Groups	Funding Table	Total Funding in BC	Percent of Total	Comments
B-1 Impacts of Climate Change	DMU, CEPF	$1,549,250	0.8%	Project included when title showed climate topic
B-2 Flood Hazard Information	DMU, CEPF	$29,895,831	14.8%	Project included when title was primarily mapping or hazard analysis
B-3 Flood Risk Assessment/ D-1 Resources and Funding	DMU, CEPF	$13,510,434	6.7%	Project included when title mentioned risk assessment
B-4 Flood Planning/ A-1 Flood Risk Governance	DMU, CEPF	$12,009,049	5.9%	Project included when title primarily mentioned planning
B-5 Structural Flood Management Approaches	DMU, CEPF	$142,260,477	70.3%	Project included when funding source was for structural project or when title included mitigation
B-6 Non-Structural Flood Management Approaches	DMU	$2,300,000	1.1%	Project included when title mentioned non-structural projects
C-1 Flood Forecasting Services	DMU	$930,000	0.5%	Project included when title mentioned warning or forecasting
	Total	**$202,455,041**		

Table 3-9: BC Flood Project Funding Summary 2016-2020 - Response/Recovery Costs

Issue Groups	Funding Table	Total Funding in BC	Comments
C-2 Emergency Response/ C-3 Flood Recovery	DFA	$449,843,642	Assumed for all records in DFA table for last 5 years

Table 3-8 and 3-9 show several trends of note. First, post-disaster funding in C-2/C-3 from the DFA Table represents over 2/3 of the total funding. Second, for the other seven Issue Groups related to flood mitigation (B-1, B-2, B-3/D-1, B-4/A-1, B-5, B-6, and C-1), 70.3% was allocated to structural mitigation (B-5). Therefore, a large majority of the funding over the last five years focused on structural mitigation and activities associated with response and recovery.

Third, the second most funded flood mitigation issue is B-2 Flood Hazard Information projects associated with mapping and hazard analysis (14.8%) followed by B-3 Flood Risk Assessment/D-1 Resources and Funding (6.7%) and B-4 Flood Planning/A-1 Flood Risk Governance (5.9%). BC would benefit from shifting to larger investment in proactive flood planning and mitigation activities, thus reducing future post-disaster response/recovery costs.

Fourth, the data resolution greatly limits developing a more accurate picture of the split of funding into the Issue Groups. It is very likely that projects in C-2/C-3 included components that would fall under Theme B Issues. Even projects in tables like the CEPF Table likely include components in multiple Theme B Issues as well and not the single-Issue Group assigned to that project. For example, addressing impacts of climate change B-1 are often directly incorporated in B-3 Flood Risk Assessment and B-5 Structural Flood Management Approaches. Also, low-cost non-structural mitigation approaches (B-6) are commonly adopted by local governments or First Nations through implementation of recommendations following B-4 Flood Planning work, including regulating land use, enforcing building codes and public education.

3.4 Benefit-Cost Analysis Recommendations

3.4.1 BCA Methods and Data Sources

3.4.1.1 Establish Standards

BC government should expand on the discussion in this document and establish their own standards and guidance documents for BCA. While Alberta has led the way so far in establishing methods for flood mapping, flood risk assessment, and flood project BCA, many of their studies have become dated and are not comprehensive. For example, should the structure types established by Alberta for residential and non-residential buildings be used in BC? In the USA, modelling of structures impacted by coastal flooding often requires unique structure types and considerations (like foundation types), which may not be as important for inland riverine flooding.

3.4.1.2 Methods

Standards should address methods to use for costs and benefits, but also the review of those methods. All flood mitigation project reviews should include an engineering review of the proposed design and the associated costs. Benefit methods standards should be established for the main tangible and intangible benefit categories that BC wants included in all BCAs. This will likely include avoided damages to structures and their contents, displacement time, and business disruption. Individual guidance on specific infrastructure sectors and lifelines like transportation and water and sewer also should be established to provide more consistent analysis between BCA studies. The benefits review should look at the methods and types of benefits included in the analysis. All review standards should have allowable documentation types and sources established. Appendix A of FEMA Benefit-Cost Analysis Reference Guide (USA FEMA, 2009) includes example data documentation templates for different hazard mitigation types.

3.4.1.3 Unresolved Issues

Another component of establishing BC standards is having the discussions on unresolved issues, such as what discount rate should be used for BC flood mitigation projects. This also would apply to how to incorporate past flood mapping and modelling performed in BC into the calculations behind a BCA. Does existing mapping and modelling have a sufficient number of events to perform the multi-event analysis needed for a flood risk assessment? What databases does BC currently have for structures and infrastructure and do they contain enough detail to support flood risk assessment? A good starting point for these discussions would be the Project B-3 Flood Risk Assessment (from this series of Flood Investigations), exploring the challenges, opportunities and recommendations for flood risk assessment in more depth.

3.4.1.4 Tools

Another BCA Method consideration is whether CanFlood will work as the only flood BCA tool in BC or if additional tools need to be considered and/or developed. One challenge with more complex models is only a limited number of people have the background and experience to use them. In the USA, the FEMA BCA tool, which is Excel based, is less complex than the FEMA Hazus tool, which requires GIS knowledge to use. The choice of how complex a BCA tool becomes often will affect the number and types of people qualified to learn and use the tool.

3.4.2 Project Selection Criteria

3.4.2.1 Priorities

Besides standardizing BCA approaches, BC also needs to discuss the overall direction and focus of flood mitigation projects. The discussion on BCA methods show that methods will change depending on whether a project is mitigating flood hazard or asset damages. Does BC have priorities on project types or asset types (residential, commercial, governmental) that should be focus or part of funding selection criteria?

3.4.2.2 Unmet Needs

BC also needs to discuss how the mitigation grant process can be adjusted to address the unmet needs in the province. Populations like First Nations communities and other higher vulnerability population groups have felt overlooked in the past for mitigation grants. While the previous section gives some examples from the USA of additional qualitative criteria that can be incorporated into the grant award process, BC will need to determine how much flexibility is possible within federal grant frameworks with existing rules and regulations. Whether these other measures become official criteria or advisory screening methods, the BC government could enhance current funding processes by establishing more grant application training, providing more direct technical assistance to applicants, and funding more comprehensive studies that provide data province-wide.

3.4.2.3 Pilot Studies

A proven way to make these changes happen is to conduct pilot studies in BC. This may include starting a new grant application from scratch in a community and testing different BCA approaches to see what works best. This also could include changing how grant funds are evaluated and awarded.

4 Conclusion

This report presents the findings for Issue D1 on Resources and Funding.

Investigation D-1.1 highlights the gaps in the cost estimates from Investigations' reports A-1, B-1 to B-6, C-1 and C-2.

The main recommendations to standardize the cost estimates for accuracy and consistency are:

- Verify the consultants' input cost data, specifically, that adjustments are made to convert indicative pricing information into relevant cost data that can be incorporated into the estimate.
- Confirm that estimates are complete and that the following items are addressed: overhead and profit, contingencies, and inflation.
- Develop an estimating tool in a spreadsheet application to re-create the consultants' estimates, in order to improve connectivity between the reports and incorporate the ability to perform dynamic applications such as different scenarios, sensitivity analysis, etc. Appendix C includes an example of such a tool.

For Investigation B-2 on Flood Hazard Information, it is recommended that:

- The Consultant's indicative pricing is verified and adjusted to confirm that the resulting cost data is relevant to the estimate.
- The completeness of the estimate is confirmed.
- Inconsistencies are resolved.

The Investigation D-1.2 provides references and identifies gaps to perform Benefit-Cost Analysis applied to flood management in BC. The analysis of a limited number of selected publications led to the following recommendations for the BC government:

- Establish its own standards and guidance documents for BCAs applied to flood management on how to estimate costs and benefits.
- Establish economic variables such as useful lifetime and discount rate.
- Effectively involve First Nations and include First Nations values in BCA and/or through other qualitative approaches.
- Define any supplemental grant award criteria to include considerations like vulnerable populations.
- Develop/Recommend a tool to perform BCAs applied to flood management.
- Improve grant framework with pilot studies.

5 Glossary

Term	Definition
Adaptation	The practice of adjusting or taking actions to limit or reduce vulnerability to changing hazard risk. In the context of climate change impacts on coastal flood hazard risk, specific adaptation actions might include improved coastal zone management, changes to planning, permitting, codes and standards, structural design, and social preparedness.
Annual Exceedance Probability	The probability, expressed in percentage, of a flood of a given size being equalled or exceeded in any year. Accordingly, a flood that is estimated to recur once in 100 years (on average) has an AEP of 1/100 or .01 (1% AEP meaning a 1% chance of occurring in any year). A flood estimated to recur once in 500 years on average has an AEP of 1/500 or 0.002 (.2% AEP).
Coastal Flood	Seawater inundates lands in coastal zones. Causes: Storm surge, wind and wave action, tsunamis, high tides, sea level rise
Coastal Flood Hazard	A potentially damaging flood event (or multiple events) in coastal regions, which may cause damage to buildings and infrastructure, and/or the loss of life, injury, property damage, social and economic disruption, or environmental degradation.
Coastal Flood Risk	The combination of the probability of a coastal flood hazard event (or multiple events) and the associated negative consequences.
Contents Damages	The damages to the contents within a building, such as appliances, furniture, electronics, etc.
Contingency	In the context of an estimate, a Contingency refers to an allowance for conditions that may not be known or quantified at the time of the estimate.
Critical Infrastructure	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.
Damages	The financial and non-financial impacts/consequences of a hazard event. For buildings and infrastructure, this may include structural damage or loss of performance, or damages due to loss of serviceability/operability.
Dike	An embankment designed and constructed to prevent the flooding of land. A dike is supported by related works, such as floodboxes, gates and pumps that serve to hold back floodwaters while continuing to discharge water from behind the dike.
Direct Damages	The financial costs to repair or replace an asset to its pre-flood condition. Direct damages include structure and contents damages.
Disaster	A serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts.
Disaster Risk Reduction	The concept and practice of reducing disaster risks through systematic efforts to analyze and reduce the causal factors of disasters. Disaster risk reduction includes disciplines like disaster mitigation and preparedness.

Term	Definition
Escalation	Refers to the phenomenon of rising prices (inflation in the general economy) specific to a particular industry or sector of the economy.
Exposure	The presence of people, infrastructure, housing, or other assets-at-risk (or parts thereof) in places that could be adversely affected by hazards.
Flood and Flooding	The presence of water on land that is normally dry. Often used to describe a watercourse or body of water that overtops its natural or artificial confines.
Flood Construction Level	The minimum height required for a development to protect habitable living space from flood damage.
Flood Maps (Mapping)	Maps (Mapping) that display information related to a flood, such as the estimated extent of flooding, water depths, water velocities, flood duration or other information.
Flood Risk Assessment	Evaluation of a flood hazard (including the expected flood extent, depth and direction of flow) together with information about assets and people that are vulnerable to flooding to identify potential economic, social, cultural and environmental losses from flooding.
Floodplain	A floodplain is flat or nearly flat land that is susceptible to flooding from a watercourse, lake or other body of water.
Floodplain Management	Floodplain management includes policies and regulations intended to reduce flood risks associated with land use and development in floodplains and flood hazard areas.
Floodproofing	In reference to development, actions taken at the site or property level that reduce the vulnerability of buildings and their contents to flood damage.
Floodwall	A vertical artificial barrier designed to temporarily contain the waters of a river or other waterway. A floodwall is sometimes constructed instead of a dike in areas where space is restricted.
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.
Flood Hazard	A potentially damaging flood event that may cause the loss of life, injury, property damage, social and economic disruption, or environmental degradation.
Flood Mitigation	Steps to reduce flood damage by structural measures (such as dikes), non-structural measures (such as keeping populations and assets away from flood-prone areas or requiring floodproofing), or a combination of these measures.
Indicative	Describes that the source of information may be anecdotal and/or unverified. Such material would need to be further investigated before it can be used as an input to another activity or task.
Indirect Damages	The financial costs incurred as a result of a flood event. Indirect damages include flood fighting/mitigation, evacuation, temporary housing, employment and productivity losses, post-flood cleanup, etc. Areas outside the flood hazard may also experience indirect damages, such as business disruption.
Intangible Damages	The non-financial or otherwise non-quantifiable impacts due to a flood event including social, health, and environmental impacts. Areas outside the flood hazard may also experience intangible damages, such as due to the spill and transport of a deleterious material.

Term	Definition
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 (i.e., the Annual Exceedance Probability, AEP).
Losses	Equivalent to damages that occur as a result of a flood event, both tangible and intangible.
Lump Sum	Refers to a total, bottom-line estimate where a detailed breakdown of the specific tasks and/or resources is not available.
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.
Pluvial/Stormwater Flood	Extreme rainfall creates local flooding away from water bodies. Causes: Heavy rainfall exceeds the capacity of stormwater sewers culverts, and landscapes to absorb + convey flows, blockages in drainage systems.
Probability	In statistics, a measure of the chance of an event or an incident happening. This is directly related to likelihood.
Quantitative Risk Assessment	A risk assessment that is completed using quantified or calculated measures of risk.
Residual Risk	The risk that remains even when effective risk reduction measures are in place.
Residual Water Level	The difference between the absolute or total water level (as measured by a tide gauge) and the astronomical (tidal) component. As storm surge often represents the greatest contribution to the residual water level at a coastal site, the terms “storm surge” and “residual water level” are sometimes used interchangeably.
Resilience	The ability of a system (such as individual or multiple buildings or infrastructure assets), 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.
Risk	The combination of the probability of a hazard event and its negative consequences.
Risk Assessment	A method to determine the nature and extent of risk by analyzing potential hazards and evaluating existing conditions of vulnerability that together could potentially harm exposed buildings, infrastructure, people, property, services, livelihoods, and the environment on which they depend. Risk assessments (and associated risk mapping) include: a review of the technical characteristics of hazards, such as their location, intensity, frequency, and probability; the analysis of exposure and vulnerability, including the physical, social, health, economic, cultural, 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.
Riverine Flood	Water levels in a river, lake, or stream overflow onto adjacent lands or infrastructure. Erosion is also typical during these types of floods. Causes: intense rainfall, atmospheric rivers, rapid snowmelt, ice jams, structural or operational dam failure, natural dam failure/glacial outburst, debris floods in steep terrain, or two or more of the above (e.g., rain-on-snow events).

Term	Definition
Susceptibility	An asset that could be adversely impacted by exposure to a hazard is susceptible to the hazard. For example, a typical residential building is susceptible to damage from floodwaters. A properly constructed concrete landscaping wall that has some floodwaters around it may not be adversely impacted and is therefore not susceptible to a flood hazard.
Storm Surge	The increase (or decrease) in still water level at a coastal site due to meteorological conditions. Storm surge may include wind set-up (or set-down) and barometric set-up (or set-down).
Structural Damages	Damages to the structural systems of a building or infrastructure, such as walls, floors, heating and cooling systems, etc.
Tangible Damages	Measurable financial impacts due to a flood event.
Vulnerability	The characteristics and circumstances of a community, system, or asset that make it susceptible to the damaging effects of a hazard. For buildings and infrastructure assets, vulnerability is a product of both exposure and susceptibility to damage.

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Appendix A

List of all Investigations

Appendix A
Investigations in Support of Flood Strategy Development in BC

Theme A. Governance

Issue	Investigation
A-1 Flood Risk Governance	1. Identify the flood management services provided by each order of government in BC.
	2. Investigate the roles of non-government entities in flood management in BC.
	3. Identify challenges, gaps and limitations with current service delivery.
	4. Identify opportunities for improving collaboration and coordination within and across authorities and adjusting non-government entities' roles that would address challenges and improve efficiency and effectiveness.
	5. Recommend changes to support improved collaboration and coordination in flood management, including an analysis of benefits and costs/limitations for each recommendation.
	6. Investigate alternative options for distributing and integrating flood management responsibilities among authorities, including an analysis of benefits and costs/limitations for each option.

Theme B. Flood Hazard and Risk Management

Issue	Investigation
B-1 Impacts of Climate Change	1. Investigate the state of climate change science in relation to BC flood hazards and identify gaps and limitations in provincial legislation, plans, guidelines and guidebooks related to flood hazard management in a changing climate.
	2. Identify current sources of information and models used by experts in the province to predict future climate impacts and investigate opportunities for improved predictive modelling.
	3. Investigate the capacity of responsible authorities and other professionals and practitioners in the province to integrate climate change impacts and scenarios to inform flood planning and management.
	4. Investigate the legislative, policy, and regulatory tools available to responsible authorities in all levels of government for integrating climate change impacts in flood planning and management.
B-2 Flood Hazard Information	1. Investigate the current state of flood mapping in the province, including gaps and limitations. Recommend an approach to improve the spatial coverage, quality, utility and accessibility of flood hazard maps and other flood hazard information.
	2. Investigate the approximate level of effort to prepare flood hazard mapping to address current gaps for existing communities and future areas of development (including floodplain maps and channel migration assessments).
	3. Investigate the current state of knowledge related to dike deficiencies and recommend an approach to improve the quality, consistency, review, utility and accessibility of this information.
	4. Investigate the status of LiDAR standards for flood mapping and develop recommendations to improve standards if applicable.

Issue	Investigation
B-3 Flood Risk Assessment	1. Evaluate and compare the benefits and costs/limitations of taking a risk-based approach to flood management versus a standards-based approach.
	2. Investigate the effort required to develop and maintain a province-wide asset inventory and/or exposure dataset covering flood prone areas.
	3. Investigate approaches to completing a province-wide flood risk assessment, addressing effort required, level of detail, types of flood risk, current and future scenarios, scale, and any information required and data gaps.
	4. Investigate the level of effort to develop a coarse local-scale flood risk map based on available flood hazard map(s).
	5. Determine the effort required to undertake a local-scale comprehensive flood risk assessment for multiple types of flood hazards (e.g. riverine, coastal).and for varying degrees of available data on flood hazard, exposure, vulnerability and risk.
	6. Investigate methods for valuing the benefits and costs/limitations of flood risk reduction actions in a holistic and consistent manner and develop a framework for project prioritization that could be applied or adapted across the province to reduce flood risk.
B-4 Flood Planning	1. Investigate the ability of responsible authorities in the province to develop adaptation plans and strategies for flood management.
	2. Investigate opportunities to improve the knowledge and capacity of local authorities with regard to climate change adaptation and the benefits of proactive flood risk reduction.
	3. Investigate the potential content of a provincial guideline to support the development of local Integrated Flood Management Plans.
	4. Investigate the level of effort for a local authority to complete an Integrated Flood Management Plan and the possible role of the province in reviewing and/or approving these plans.
B-5 Structural Flood Management Approaches	1. Investigate opportunities to incentivize or require diking authorities to maintain flood protection infrastructure and plan for future conditions such as changing flood hazards.
	2. Investigate opportunities to improve the knowledge and capacity of local diking authorities with regard to dike maintenance.
	3. Investigate opportunities to improve coordination amongst diking authorities under non-emergency conditions.
	4. Investigate impediments to and opportunities for implementing innovative structural flood risk reduction measures, including the role of incentives and regulation.
B-6 Non-Structural Flood Management Approaches	1. Investigate past and current approaches to land use and development decisions in floodplains by local and provincial authorities.
	2. Investigate alternatives to the current approach to managing development in floodplains, including returning regulatory authority for development approvals in municipal floodplains to the Province, and provide an analysis of the benefits and costs/limitations of both local and provincial authority.
	3. Investigate impediments to and opportunities for implementing available non-structural flood risk reduction actions, including the role of incentives and regulation.
	4. Investigate the nature of an educational campaign for regional, local and First Nations governments to raise awareness of flood risk and possible risk reduction options.

Theme C. Flood Forecasting, Emergency Response and Recovery

Issue	Investigation
C-1 Flood Forecasting Services	1. Investigate current capacity, coverage, value, and gaps in flood forecasting services.
	2. Visualize where flood forecasting gaps exist and estimate costs for improvement to end users.
C-2 Emergency Response	1. Investigate the future direction of the Federal government related to a National Flood Risk Strategy and the future of Disaster Financial Assistance Arrangements
	2. Investigate the Province’s expanding role in providing flood response to First Nations.
	3. Investigate the status of local authority flood response plans and recommend an approach to manage, update and improve this information.
	4. Investigate flood response capabilities considering different flood hazards and different regions of the province.
	5. Investigate opportunities for improved organizational planning for emergency response in all levels of government.
C-3 Flood Recovery	1. Investigate the current status of coverage of existing overland flood insurance available to home-owners.
	2. Investigate the concept of "build back better" and impediments to implementation.

Theme D. Resources and Funding

Issue	Investigation
D-1 Resources and Funding	1. Investigate resource and funding needs associated with implementing recommendations to strengthen flood management in BC.
	2. Investigate evidence in support of investment in proactive flood planning and mitigation activities.

Appendix B

List of Investigations' Reports for D-1.1 Review

Appendix B

During March and April 2021, FBC provided the following documentation for review as well as a compilation of cost estimates dated April 7, 2021.

Reference	Title	Description	Consultant	Report Date
THEME A – GOVERNANCE				
A-1	Improving Collaboration and Coordination	Review existing flood management governance in BC (including federal, Indigenous, provincial, and local governments, and the private sector), identify challenges, and recommend changes to improve effectiveness	Ebbwater Consulting Inc.	12 March 2021 (Revised cost estimate provided on 13 April 2021)
THEME B – FLOOD HAZARD AND RISK MANAGEMENT				
B-1	Impacts of Climate Change	Investigate the state of climate change information and the capacity of authorities to integrate climate change impacts in flood management	Associated Engineering	19 March 2021
B-2	Flood Hazard Information	Examine the state of flood mapping and knowledge of dike deficiencies in BC and recommend approaches to address knowledge and mapping gaps	Northwest Hydraulic Consultants Ltd.	16 March 2021
B-3	Flood Risk Assessment	Explore approaches to completing flood risk assessments at various scales and methods for prioritizing risk reduction actions	Ebbwater Consulting Inc.	15 March 2021
B-4	Flood Planning	Examine the ability of local authorities to undertake integrated flood planning and opportunities to improve their capacity	Kerr Wood Leidal Associates Ltd.	December 2020
B-5	Structural Flood Management Approaches	Assess opportunities to incentivize or require better dike management, improve the capacity of diking authorities, and implement innovative structural flood risk reduction measures	Northwest Hydraulic Consultants Ltd.	16 March 2021
B-6	Non-Structural Flood Management Approaches	Investigate options for managing development in floodplains and opportunities for implementing non-structural flood risk reduction actions	Northwest Hydraulic Consultants Ltd.	-Main Report 22 February 2021 -Supplemental Recommendations and Costs 5 April 2021
THEME C – FLOOD FORECASTING, EMERGENCY RESPONSE AND RECOVERY				
C-1	Flood Forecasting Services	Investigate flood forecasting services and opportunities to address gaps	BGC Engineering Inc.	23 March 2021
C-2	Emergency Response	Investigate roles, plans, and capabilities for flood response in the province and opportunities for improving emergency response	Red Dragon Consulting	30 January 2021

Appendix C

Unified Estimate Tool

FRASER BASIN COUNCIL

Investigations in Support of Flood Strategy Development in British Columbia

Cost Estimate

REFERENCE:
DATE:

COST ESTIMATE SUMMARY		INITIAL ONE-TIME COST	DISCOUNTED ANNUAL COST	TOTAL COST ESTIMATE
THEME A - GOVERNANCE				
A-1	Improving Collaboration and Coordination			
A-2	Consolidating Flood Management Responsibilities			
THEME B – FLOOD HAZARD AND RISK MANAGEMENT				
B-1	Impacts of Climate Change			
B-2	Flood Hazard Information			
B-3	Flood Risk Assessment			
B-4	Flood Planning			
B-5	Structural Flood Management Approaches			
B-6	Non-Structural Flood Management Approaches			
THEME C – FLOOD FORECASTING, EMERGENCY RESPONSE AND RECOVERY				
C-1	Flood Forecasting Services			
C-2	Emergency Response			
C-3	Flood Recovery			
TOTAL COST ESTIMATE (THEME A + B + C)				

COMMON FACTOR INPUTS

1	Cost Data	
1.1	Annual Government Staff FTE	
	Engineer or geoscientist/policy/tech/PM	$ 100,000
	Specialist engineer or geoscientist	$ 150,000
	Manager	$ 175,000
2	Constants	
2.1	Project Contingency	
3	Financial Factors	
3.1	Inflation Adjustment Rate	
3.2	Discount Rate	

COMMON LIMITING CONDITIONS

1 Assumptions
1.1
1.2

2 Exclusions
2.1 taxes
2.2
2.3

3 Other Limiting Conditions
3.1
3.2

THEME A - GOVERNANCE

A-1 Improving Collaboration and Coordination

		ONE-TIME COST ESTIMATE				ANNUAL COST ESTIMATE			
REF	DESCRIPTION	QUANTITY	UNIT	RATE	COST	QUANTITY	UNIT	RATE	COST

OVERHEAD & PROFIT					
ESTIMATING CONTINGENCY					
CURRENT COST ESTIMATE					
INFLATION ADJUSTMENT	Project Start Date	27-Apr-21		x TIME PERIOD years	
	Project Completion Date	27-Apr-21		NET PRESENT VALUE	
SUBTOTAL					
TOTAL ESTIMATE - ONE-TIME COST + ANNUAL COST					

SPECIFIC LIMITING CONDITIONS

1 Assumptions

1.1

1.2

2 Exclusions

2.1

2.2

2.3

3 Other Limiting Conditions

3.1

3.2

Appendix D

Memo - Draft Information Supplement to B-2

April 16, 2021

NHC Reference 3005405

Fraser Basin Council

Attention: Steve Litke, Director - Water Programs

Via email: slitke@fraserbasin.bc.ca

Re: Cost Estimates for Floodplain Mapping Program in BC
Draft Information Supplement to B-2

1 Introduction

For the *Investigations in Support of Flood Strategies in BC* currently underway by Fraser Basin Council (FBC) and as related to *Issue D-1: Resources and Funding,* Northwest Hydraulic Consultants Ltd. (NHC) was asked to provide some additional input on cost estimates for a province-wide floodplain mapping program in BC, initially investigated under *Issue B-2: Flood Hazard Information.* The proposed scope of work builds on costs developed and assumptions made for B-2 and, as specified by FBC, focusses on:

1. Additional details and assumptions that are the basis for the lump sum estimates previously developed, such as:
    - Quantities (distances, areas, etc.)
    - Exclusions, uncertainties and other limitations
    - Other cost variables associated with floodplain mapping projects
    - Cost data sources of the unit rates mentioned ($xx/km, etc.)
2. More detailed cost estimates for a BC-wide floodplain mapping program.
    - Refine and provide a more detailed breakdown of the B-2 cost estimates for a province-wide floodplain mapping program, including government staff FTEs, consultant/contractor labour, and other associated costs. (Full Time Employee - FTE costs for the provincial government are estimated as follows: $100K for engineer or geoscientist / policy / tech / PM; $150K for specialist engineer or geoscientist; $175K for manager.)
3. Additional commentary on:
    - Schedule for reviewing and updating floodplain maps on a province-wide basis, including relevant considerations.
    - Cost considerations of a centralized (e.g. led by a provincial agency) versus decentralized (e.g. led by local and First Nations governments) approaches to floodplain mapping across BC.

This memo summarizes the additional work completed and is based on floodplain mapping experience in the private sector. Costs for collecting Lidar are not considered.

2 Additional Cost Information

2.1 Background on B-2 Estimates

The cost estimates developed under B-2 for coastal and riverine projects are approximate only. To ensure that the projects reflect a consistent standard, we based the cost estimates on recent NHC projects and proposals. This led to small sample sizes and a bias towards larger studies. Recent government funded initiatives (typ. $150K budgets), unless supplemented by local authorities, have led to overview level assessments or simplified studies, not representative of the actual work required for detailed floodplain mapping assessments.

Floodplain mapping projects should be geared towards the watershed or coastline to be modelled and also the communities requiring the mapping. There is no 'one-size fits all'. Unit costs per length of river reach or coastline are more representative than the costs per area mapped. We were unable to develop representative unit area costs.

The riverine unit cost estimates were based on 17 mapping projects in the last 5-10 years, mainly in BC but a few in Alberta. River reach lengths ranged from the Bow River 120 km ($1,700K), Lillooet River 44 km ($600K), Skeena/ Kitsumkalum 25 km ($300K), Fort MacLeod 24 km ($360K) to reaches of about 7 km and costs of $130K or less. The variability in the project requirements and costs was significant. Recent work on the Fraser River was not included since floodplain maps were not developed. Table 1 shows the typical differences between complex and straightforward projects and the percentage of effort expended on each project component. Unit costs are generally higher for short reaches. Based on the projects reviewed, costs of $15,000/km for complex studies and $10,000/km for straightforward studies were arrived at.

The unit cost estimates for coastal mapping were based on about ten representative projects/proposals, ranging from coastlines of over 1,000 km to less than 1 km. Assuming a study reach of 25 km or more, the unit cost range was between $1,500/km and $2,500/km. In comparison, a site-specific study (60 m coastline) had a unit cost of $200K/km. Key factors affecting costs are the bathymetric data available and the type of wave analysis carried out.

Estimating the cost of a BC-wide mapping program is difficult because the adequacy of mapping produced by several recent overview level studies of flood/geo hazards and flood risk is not known. While these overview assessments are of value and may help to prioritize detailed mapping projects, they may not fulfill the primary function of detailed mapping, which is to delineate Flood Construction Levels (FCLs) and accurately outline flood extents. As a first step to identifying the areas to be mapped, the various mapping projects completed in recent years should be reviewed to see if they meet requirements or if additional work is necessary. Areas to be mapped in BC can then be identified/prioritized and the cost of a BC-wide mapping program estimated with more accuracy.

Table 1: Riverine floodplain mapping costs ($/km)

	Complex Project			Straightforward Project		
Project Component	**Description**	**Cost $/km**	**% Total**	**Description**	**Cost $/km**	**% Total**
Review of historic flood maps, reporting, past floods, HWM data	Large amount of data available	$ 750	5	Limited data available	$ 500	5
Bathymetric surveys/ site inspections	For 2D modelling - single/multi beam	$ 3,000	20	For 1D modelling - single beam	$ 2,000	20
DEM development	Detailed refinement by hand	$ 750	5	Simple interpolation between surveyed sections	$ 500	5
Hydrology and climate change	Regional and standard hydrology including detailed climate change assessment. Potential joint probability analysis	$ 1,500	10	Single station frequency analysis, flow ratio increase for climate change	$ 1,000	10
Geomorphology	Unstable channel, CMZ mapping, setback estimation	$ 2,250	15	Stable channel, limited sediment load	$ 1,000	10
Hydraulic model development, calibration/ validation	2D model software, flexible mesh development, multiple channels and flow splits. Wide floodplain.	$ 2,250	15	1D model software, typically single channel	$ 2,000	20
Model runs and dike breach modelling	Multiple breach locations	$ 750	5	Model runs (no breach modelling)	$ 500	5
Freeboard	Uncertainty analysis	$ 750	5	Application of standard values	$ 250	2.5
Mapping	FCL map, flood depth maps, flood hazard maps; 3 or more scenarios, composite breach mapping	$ 1,500	10	FCL map only, 1 scenario	$ 1,250	12.5
Reporting	Comprehensive technical summary	$ 1,125	7.5	Brief memorandum	$ 1,000	10
Presentations and public consultations	Presentation of results, development of display material	$ 375	2.5	No presentations or public consultations	$ -	0
Total Cost		**$ 15,000**	**100**		**$ 10,000**	**100**

2.2 Additional Detail on B-2 Estimates

The B-2 study developed two options for the provincial government to move forward on floodplain mapping. The present work has merged the two options as shown in Table 2. Government salary costs are as provided by FBC. The table assumes that the mapping projects will be completed by consultants but guided and reviewed by the provincial government, generally MFLNRORD. The approach is similar to that used in Alberta and we recommend that MFLNRORD contact the Alberta government to learn about operating costs, including advantages and disadvantages of the program from a government perspective.

As shown in Table 2, the cost of the program would be $9.9M in the first year, reducing to $6M in subsequent years. The one-time start-up cost would be $3.4M in contract funds and $0.4M in government funds. The annual cost would involve an estimated $5M in contract funds for developing mapping and $1M in government funds for coordination, management and quality assurance. In terms of government FTEs, a one-time requirement of 2.9 FTE and annual requirement of 7.3 FTE are estimated.

Optionally, a designated government group could be formed to complete all maps. The impacts on costs are not estimated here. Presumably, building up a new government group of qualified technical specialists could take time and be quite costly. (The pre-1998 government group involved with floodplain mapping, and related flood management work had a maximum full-time staff of about 40 engineers and technicians. A highly competent in-house survey team completed all bathymetric surveys.)

Table 2: Resources and costs to implement B-2 province-wide floodplain mapping recommendations

Ref. No.	Directed to	Recommendation	Resources	Contract Costs ($K)		Personnel/FTE Cost ($K)	
				One-time	Annual	One-time	Annual
1	GeoBC/ MFLNRORD	Develop a bathymetric survey standards document (riverine and coastal) to use as Terms of Reference. Cost based on refining general survey standards.	Contract funds	$40			
2	MFLNRORD	Retain consultant or professional association to develop and (ensure updating of) floodplain mapping standards (Terms of Reference) for BC. Coordinate with provincial/federal government floodplain mapping standards.	Contract funds. Estimated cost is a minimum. Set-up & Up-keep: 0.2 FTE coordination	$200		$10	$10
3	MFLNRORD / EMBC	Review recent floodplain maps for compliance with standards. Classify mapping as i) detailed; ii) overview level; or iii) sub-standard. Recommend additional work as required. (The cost is for review only, additional work to improve mapping is not included.)	Contract funds 0.1 FTE coordination	$200		$10	
4	MFLNRORD	Coordinate future flood studies on watershed/ regional basis to ensure consistent mapping standards and inclusion of FNs and smaller communities.	0.2 FTE ongoing coordination				$30
5	MFLNRORD	Map the Fraser River (Hope to ocean, including main tributaries) according to standards (2D	Contract funds (based on Chilliwack mapping.)	$2,500			

		model + dike breaching and composite mapping). Recommend appropriate design standards.	0.2 FTE (set-up and manage)			$17.5	$17.5
6	MFLNRORD	Map Lower Mainland coastal areas in locations where available mapping does not meet standards. Recommend appropriate design standards.	Contract funds (Assumes some communities are mapped.) 0.1 FTE	$500		$17.5	
7	MFLNRORD	Review available flood risk information and past flooding. Review FNESS (2000) high priority projects/past First Nation studies. Complete First Nations out-reach program. Develop a province wide map-by-river or map-by-coastline plan and prioritize future projects. Ensure that mapping developed will be useful and used as part of future Integrated Flood Management Plans (IFMPs) and/or other approaches to flood mitigation and risk reduction.	2.0 FTE 1.0 FTE (Alternatively contract funds $500K)			$300	$100
8	EMBC/ MFLNRORD	Develop a public facing, historic flood database, documenting observed flood information such as flows, flood levels and extents (including detailed high water mark surveys), photos and videos, damage summaries, transportation disruptions etc.	0.5 FTE to set-up 0.1 FTE to maintain			$50	$10
9	EMBC/ MFLNRORD	Complete the required BC mapping. (Provincial government program + contracting. Considering unknown status of mapping completed to date and rough unit cost estimates, values are highly approximate.)	4 FTE (@$150K) + 1 FTE (@$175K) Annual Contract Funds (Section 2.3)		$5,000		$600 $175

a	Sub-task:	Allocate adequate budgets for each project based on risk and hydraulic complexity.					
b	Sub-task:	Prepare detailed Requests for Proposal (RFPs) and manage the mapping contracts.					
c	Sub-task:	Provide technical input and review throughout projects under way to ensure quality assurance.					
d	Sub-task:	Sign-off on maps when completed. Publish reports and maps on provincial interactive website allowing users to enter their address to retrieve flood information.					
10	EMBC/ MFLNRORD	Provide ongoing quality assurance of flood studies. As flood studies are received for posting on the proposed web-portal, a group of qualified technical reviewers would ensure that all maps meet standards.	0.5 FTE				$50
11	MFLNRORD	Follow-up on uses of floodplain maps and coordination with communities.	0.3 FTE				$30
		Total Cost in First Year: $9,850,000 **Subsequent Annual Cost: $6,005,000**		**$3,440K**	**$5,000K**	**$405K** **2.9 FTE**	**$1,005K** **7.3 FTE**

2.3 Additional Commentary on Mapping Program

The B-2 report cited a cost estimate by MMM (2014) of $48.2M to complete a remaining 2,650 km of BC floodplain mapping (unit cost of $18,200/km), 2656 km already being mapped. Since roughly $20M has been spent in recent years on flood hazard projects, the B-2 report assumed that about $30M would need to be spent to complete the present cycle of mapping.

It should be recognized that floodplain mapping will continuously need to be updated. Rivers with active channels and high sediment loads may require more frequent mapping, say every 10 years or less. Maps for stable channels may need updating perhaps once in 20 years. Climate change is impacting the longevity of maps. Current climate change projections are highly uncertain and as conditions change map updates are required. Once reliable maps have been produced for an area, updating the information should take less effort than the initial development. New software products and streamlined methods may improve quality and increase efficiency.

The importance of collecting flood information (peak flows, high water marks, storm surge/ wave data) as highwater events occur cannot be overemphasized. This information helps indicate when new mapping is required and directly supports model calibration/validation.

Assuming the MMM total length estimate of 5,300 km of mapping required in BC is correct, and that 2/3 of this distance would benefit from complex riverine mapping and 1/3 of straightforward mapping, the total cost of one mapping cycle would be about $71M, based on NHC unit kilometre costs. Assuming maps need updating on average every 15 years, the annual contract cost of the mapping would be about $5M (Table 2). (Coastal costs are not treated separately here. A 2011 study for MFLNRORD suggested a total coastal mapping cost of $7.2M.)

If local authorities are required to adopt the mapping and introduce structural and non-structural flood mitigation measures, the Return-on-Investment from the mapping program is likely to be considerable.

Equally important is the mapping of alluvial fan and geohazards. This work was not costed as part of the present assessment.

In general, Local Governments and First Nations do not have the expertise nor the capacity to carry out decentralized mapping programs. Coordination between governments along the same river/coastline may be lacking. There is no economy of scale when mapping short separate reaches. Engineering consultants may adjust the scope of work to fit the budget available, resulting in overview level maps or in the worst case, substandard maps. Although mapping guidelines have been developed, these may not be sufficient to guarantee detailed maps are produced.

In our opinion, detailed maps are highly valuable to flood-prone communities. The maps must be prepared to consistent standards and reviewed by specialists familiar with mapping requirements. Mapping on a larger river-reach/ coastline basis provides economy of scale. A centralized approach, such as led by a provincial agency, is likely to improve the quality of mapping and to some extent reduce costs. Maps developed must be adopted by the communities and directly applied or their value is limited.

3 Closure

We trust this memo meets your present requirements. Let us know if you require any further information.

Sincerely,

Northwest Hydraulic Consultants Ltd.

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Appendix E

Financial Data on Disaster Mitigation Projects and Flood Response and Recovery Costs

Disaster Mitigation Unit (DMU) Table

Program Area	Region	Proponent	Stream	Project Name	Flood Map Produced	Managed By	Status	Provincial Cash Contributions	Federal (NDMP/ARDM) Cash Contributions	Other Cash/In-Kind Contributions	TOTAL Project Value	Issue Group
DMU Funding 2016-17	VIR	Capital Regional District		Port Renfrew and Pacheedaht First Nation Tsunami Siren Upgrade	N	DMU	Completed	$ 550,000	$ -	$ -	$ 550,000	C-1 Flood Forecasting Services
DMU Funding 2016-17	SWE	Chilliwack, City of		McGillivray Pump Station Upgrade	N	DMU	Completed	$ 4,200,000	$ -	$ -	$ 4,200,000	B-5 Structural Flood Management Approaches
DMU Funding 2016-17	VIR	Cowichan Tribes		Clem Clem Village Erosion Protection	N	DMU	In Progress	$ 720,000	$ -	$ -	$ 720,000	B-5 Structural Flood Management Approaches
DMU Funding 2016-17	VIR	Cowichan Valley Regional District		Koksilah Cowichan Bay Flood Mitigation	Y	DMU	Completed	$ 300,000	$ -	$ -	$ 300,000	B-2 Flood Hazard Information
DMU Funding 2016-17	SWE	Pemberton Valley Dyking District		Pemberton Valley Flood Mapping	Y	DMU	Completed	$ 600,000	$ -	$ -	$ 600,000	B-2 Flood Hazard Information
DMU Funding 2017-18	PROV	Avalanche Canada		Mountain Information Network (MIN) Implementation	N	DMU	Completed	$ 50,000	$ -	$ -	$ 50,000	B-2 Flood Hazard Information
DMU Funding 2017-18	NWE	Stewart, District of		Stewart Avalanche Risk Assessment	N	DMU	Completed	$ 80,000	$ -	$ -	$ 80,000	B-3 Flood Risk Assessment
DMU Funding 2017-18	NEA	Central Coast Regional District		Bella Coola Valley Risk Assessment and Flood Modeling	Y	DMU	In Progress	$ 500,000	$ -	$ -	$ 500,000	B-3 Flood Risk Assessment
DMU Funding 2017-18	SWE	Fraser Basin Council		LiDAR Acquisition for Lower Fraser & Harrison Channel Gravel Reaches	N	DMU	Completed	$ 100,000	$ -	$ -	$ 100,000	B-2 Flood Hazard Information
DMU Funding 2017-18	SWE	Fraser Basin Council		BC Storm Surge Forecasting System	N	DMU	Completed	$ 80,000	$ -	$ -	$ 80,000	C-1 Flood Forecasting Services
DMU Funding 2017-18	CTL	Okanagan Basin Water Board		LiDAR and Ortho-Imagery Acquisition for Okanagan Watershed	N	DMU	Completed	$ 950,000	$ -	$ -	$ 950,000	B-2 Flood Hazard Information
DMU Funding 2017-18	NWE	Stewart, District of		Bear River Structural Mitigation	N	DMU	Under Review	$ 500,000	$ -	$ -	$ 500,000	B-5 Structural Flood Management Approaches
DMU Funding 2018-19	SWE	Chilliwack, City of		S4a - Chilliwack West Dike (Right Bank, Sumas Prairie to Vedder Canal) upgrade	N	DMU	In Progress	$ 960,000	$ -	$ -	$ 960,000	B-5 Structural Flood Management Approaches
DMU Funding 2018-19	CTL	Okanagan-Similkameen, Regional District of		S2 - Park Rill, Horn Creek and Kearns Creek Watershed Flood Mapping	Y	DMU	In Progress	$ 125,000	$ -	$ -	$ 125,000	B-2 Flood Hazard Information
DMU Funding 2018-19	VIR	qathet Regional District		S2 - qathet Regional District Coastal Flood Mapping	Y	DMU	In Progress	$ 216,500	$ -	$ 20,000	$ 236,500	B-2 Flood Hazard Information
DMU Funding 2016	SWE	Abbotsford, City of		Fraser River: Matsqui Dyke Erosion Arc Bank Stabilization	N	DMU	In Progress	$ 4,000,000	$ -	$ -	$ 4,000,000	B-5 Structural Flood Management Approaches
DMU Funding 2016	CTL	Central Okanagan, Regional District of		Bellevue Creek Intake and Dike Improvements	N	DMU	Completed	$ 200,000	$ -	$ 100,000	$ 300,000	B-5 Structural Flood Management Approaches
DMU Funding 2016	VIR	Comox, Town of		Lazo Road Shoreline Protection and Restoration	N	DMU	Completed	$ 1,127,626	$ -	$ 563,815	$ 1,691,441	B-5 Structural Flood Management Approaches
DMU Funding 2016	SWE	Coquitlam, City of		Coquitlam Dike	N	FLNRO	In Progress	$ 7,650,000	$ -	$ -	$ 7,650,000	B-5 Structural Flood Management Approaches
DMU Funding 2016	SWE	Delta, Corporation of		Beach Grove Seawall Improvements and Foreshore Protection	N	DMU	Completed	$ 550,000	$ -	$ 275,000	$ 825,000	B-5 Structural Flood Management Approaches
DMU Funding 2016	SEA	East Kootenay Regional District		Fairmont Creek Debris Flow Mitigation Project - Phase 2 & 3	N	DMU	In Progress	$ 1,473,880	$ -	$ -	$ 1,473,880	B-5 Structural Flood Management Approaches
DMU Funding 2016	SWE	Fraser Basin Council		Lower Mainland Flood Management Strategy - Ongoing Phases	N	DMU	In Progress	$ 1,000,000	$ -	$ -	$ 1,000,000	B-4 Flood Planning
DMU Funding 2016	SWE	North Vancouver		Mackay Creek Flood Mitigation	N	DMU	Completed	$ 669,334	$ -	$ 430,666	$ 1,100,000	B-5 Structural Flood Management Approaches

Disaster Mitigation Unit (DMU) Table

Program Area	Region	Proponent	Stream	Project Name	Flood Map Produced	Managed By	Status	Provincial Cash Contributions	Federal (NDMP/ARDM) Cash Contributions	Other Cash/In-Kind Contributions	TOTAL Project Value	Issue Group
DMU Funding 2016	SWE	North Vancouver		Mackay Creek Flood Mitigation	N	DMU	Completed	$ 948,901	$ -	$ 451,099	$ 1,400,000	B-5 Structural Flood Management Approaches
DMU Funding 2016	CTL	Okanagan-Similkameen, Regional District of		Keremeos Area Dike Assessments	N	DMU	Cancelled	$ 50,000	$ -	$ -	$ 50,000	B-5 Structural Flood Management Approaches
DMU Funding 2016	SWE	Richmond, City of		Disaster Mitigation: Rebuild Pump Stations and Dike Upgrades	N	DMU	In Progress	$ 16,633,332	$ -	$ 8,316,668	$ 24,950,000	B-5 Structural Flood Management Approaches
DMU Funding 2016	CTL	Sicamous, District of		Sicamous Narrows Hydraulic Conductivity Assessment	N	DMU	Completed	$ 33,333	$ -	$ 16,667	$ 50,000	B-2 Flood Hazard Information
DMU Funding 2016	NWE	Stewart, District of		Flood Warning System	N	DMU	Completed	$ 50,000	$ -	$ -	$ 50,000	C-1 Flood Forecasting Services
DMU Funding 2016	VIR	Strathcona Regional District		Oyster River: Glenmore Dike Upgrade	N	DMU	Completed	$ 80,000	$ -	$ -	$ 80,000	B-5 Structural Flood Management Approaches
DMU Funding 2016	SWE	Surrey, City of		Colebrook Dike	N	FLNRO	In Progress	$ 10,400,000		$ -	$ 10,400,000	B-5 Structural Flood Management Approaches
DMU Funding 2016	SWE	Surrey, City of		Fraser River Flood Protection Works (Phase 2)	N	DMU	Completed	$ 5,120,000	$ -	$ 2,560,000	$ 7,680,000	B-5 Structural Flood Management Approaches
DMU Funding 2017	SWE	Abbotsford, City of		Fraser River Spur Construction	N	FLNRO	In Progress	$ 10,000,000	$ -	$ -	$ 10,000,000	B-5 Structural Flood Management Approaches
DMU Funding 2017	CTL	Cache Creek, Village of		Cache Creek Non-Structural Flood Mitigation	N	DMU	In Progress	$ 150,000	$ -	$ -	$ 150,000	B-6 Non-Structural Flood Management Approaches
DMU Funding 2017	NEA	Chetwynd, District of		Chetwynd Non-Structural Flood Mitigation	N	DMU	Completed	$ 150,000	$ -	$ -	$ 150,000	B-6 Non-Structural Flood Management Approaches
DMU Funding 2017	NEA	Dawson Creek, City of		Dawson Creek Non-Structural Flood Mitigation	N	DMU	Completed	$ 150,000	$ -	$ -	$ 150,000	B-6 Non-Structural Flood Management Approaches
DMU Funding 2017	SEA	Elkford, District of		Elkford Non-Structural Flood Mitigation	N	DMU	Under Review	$ 150,000	$ -	$ -	$ 150,000	B-6 Non-Structural Flood Management Approaches
DMU Funding 2017	SEA	Fernie, City of		Fernie Non-Structural Flood Mitigation	N	DMU	Completed	$ 150,000	$ -	$ -	$ 150,000	B-6 Non-Structural Flood Management Approaches
DMU Funding 2017	PROV	Fraser Basin Council		Orphan Dike Inventory	N	FLNRO	In Progress	$ 1,000,000	$ -	$ -	$ 1,000,000	B-2 Flood Hazard Information
DMU Funding 2017	SWE	Fraser Basin Council		Seismic Assessment of Lower Mainland Dikes	N	FLNRO	In Progress	$ 800,000	$ -	$ -	$ 800,000	B-5 Structural Flood Management Approaches
DMU Funding 2017	SWE	Fraser Basin Council		Fraser River Bathymetry Cross Section Survey	N	FLNRO	In Progress	$ 330,000	$ -	$ -	$ 330,000	B-2 Flood Hazard Information
DMU Funding 2017	SWE	Fraser Valley Regional District		Nicomen Island	N	FLNRO	In Progress	$ 6,000,000	$ -	$ -	$ 6,000,000	B-5 Structural Flood Management Approaches
DMU Funding 2017	SWE	Fraser Valley Regional District		Nicomen Island	N	FLNRO	In Progress	$ 4,500,000	$ -	$ -	$ 4,500,000	B-5 Structural Flood Management Approaches
DMU Funding 2017	SWE	Kent, District of		Hammersley Pump Station Expansion Upgrade	N	DMU	Completed	$ 3,654,909	$ -	$ -	$ 3,654,909	B-5 Structural Flood Management Approaches
DMU Funding 2017	CTL	Lumby, Village of		Lumby Non-Structural Flood Mitigation	N	DMU	Completed	$ 150,000	$ -	$ -	$ 150,000	B-6 Non-Structural Flood Management Approaches
DMU Funding 2017	SEA	Nelson, City of		Nelson Non-Structural Flood Mitigation	Y	DMU	Completed	$ 150,000	$ -	$ -	$ 150,000	B-6 Non-Structural Flood Management Approaches
DMU Funding 2017	CTL	Spallumcheen, Township of		Fortune Creek Dike Transfer	N	FLNRO	Under Review	$ 800,000	$ -	$ -	$ 800,000	B-6 Non-Structural Flood Management Approaches
DMU Funding 2017	SEA	Sparwood, District of		Sparwood Non-Structural Flood Mitigation	N	DMU	Completed	$ 150,000	$ -	$ -	$ 150,000	B-6 Non-Structural Flood Management Approaches
DMU Funding 2017	SWE	Squamish-Lillooet Regional District		Flood Hazard Mapping and Risk Assessment - Upper Squamish Valley	Y	DMU	Completed	$ 150,000	$ -	$ -	$ 150,000	B-6 Non-Structural Flood Management Approaches
DMU Funding 2017	NWE	Telkwa, Village of		Telkwa Non-Structural Flood Mitigation	N	DMU	Completed	$ 150,000	$ -	$ -	$ 150,000	B-6 Non-Structural Flood Management Approaches
DMU Funding 2017	SWE	Kent, District of		Agassiz Slough Protection		DMU	In Progress	$ 515,091			$ 515,091	B-5 Structural Flood Management Approaches

Disaster Mitigation Unit (DMU) Table

Program Area	Region	Proponent	Stream	Project Name	Flood Map Produced	Managed By	Status	Provincial Cash Contributions	Federal (NDMP/ARDM) Cash Contributions	Other Cash/In-Kind Contributions	TOTAL Project Value	Issue Group
DMU Funding 2018	PROV	Fire Chiefs Association of BC		Wildland Interface Community Structure Protection Pre-Plans	N	EMBC - OFC	In Progress	$ 450,000	$ -	$ -	$ 450,000	B-4 Flood Planning
DMU Funding 2018	PROV	Seismic Resilience Innovation Corporation		Prioritized Port-Earthquake Response System	N	DMU - Seismic Unit	In Progress	$ 250,000	$ -	$ -	$ 250,000	C-1 Flood Forecasting Services
DMU Funding 2018	SWE	Institute for Catastrophic Loss Reduction		Metro Vancouver Region Seismic Microzonation Mapping for Coquitlam and/or Surrey and Professional Practice Guidelines	N	DMU - Seismic Unit	In Progress	$ 3,700,000	$ -	$ -	$ 3,700,000	B-4 Flood Planning
NDMP - Intake 1	PROV	Emergency Management BC	S1	Public Education - Flood Hazard Checklist for Property Purchasers	N	DMU	Completed	$ 25,000	$ 25,000	$ 2,500	$ 52,500	B-4 Flood Planning
NDMP - Intake 1	PROV	Emergency Management BC	S1	Hazard, Risk and Vulnerability Analysis (HRVA) Tool Update	N	DMU	Completed	$ 50,000	$ 50,000	$ -	$ 100,000	B-3 Flood Risk Assessment
NDMP - Intake 1	SWE	GeoBC	S2	LiDAR - Lower Mainland Floodplain Mapping	N	DMU	Completed	$ 700,000	$ 700,000	$ 75,000	$ 1,475,000	B-2 Flood Hazard Information
NDMP - Intake 2	VIR	Comox Valley Regional District	S1	S1 - Oyster River/ Saratoga Beach Flood Risk Assessment	N	DMU	Completed	$ 38,000	$ 38,000	$ 5,700	$ 81,700	B-3 Flood Risk Assessment
NDMP - Intake 2	VIR	Cowichan Valley Regional District	S1	S1 - Lake Cowichan/ Youbou Torrent Flow Assessment	N	DMU	Completed	$ 97,250	$ 97,250	$ 14,500	$ 209,000	B-2 Flood Hazard Information
NDMP - Intake 2	SWE	Pitt Meadows, City of	S1	S1 - Flood Hazard Risk Assessment	N	DMU	Completed	$ 42,500	$ 42,500	$ 6,375	$ 91,375	B-3 Flood Risk Assessment
NDMP - Intake 2	NWE	Prince Rupert, City of	S1	S1 - Tsunami Flood Risk Assessment	Y	DMU	Completed	$ 225,000	$ 225,000	$ 30,000	$ 480,000	B-3 Flood Risk Assessment
NDMP - Intake 2	SWE	Squamish, District of	S1	S1 - Quantitative Risk Assessment for Squamish River Floodplain	N	DMU	Completed	$ 89,000	$ 89,000	$ 12,000	$ 190,000	B-3 Flood Risk Assessment
NDMP - Intake 2	SWE	Whistler, Resort Municipality of	S1	S1 - Integrated Flood Hazard Management Risk Assessment	N	DMU	Completed	$ 67,000	$ 67,000	$ 10,000	$ 144,000	B-3 Flood Risk Assessment
NDMP - Intake 3	SWE	Abbotsford, City of	S4b	S4 - Geotechnical (Seismic) Assessment of Abbotsford Dykes	N	DMU	Completed	$ 100,000	$ 100,000	$ 1,000	$ 201,000	B-3 Flood Risk Assessment
NDMP - Intake 3	SEA	Central Kootenay, Regional District of	S1	S1 - Flood and Geohazards Risk Review	N	DMU	Completed	$ 250,000	$ 250,000	$ 37,500	$ 537,500	B-3 Flood Risk Assessment
NDMP - Intake 3	SWE	Chilliwack, City of	S2	S2 - Floodplain Mapping	Y	DMU	Completed	$ 159,000	$ 159,000	$ 23,850	$ 341,850	B-2 Flood Hazard Information
NDMP - Intake 3	VIR	Cowichan Valley Regional District	S1	S1 - Coastal Sea Level Rise Risk Assessment	N	DMU	Completed	$ 45,000	$ 45,000	$ 6,750	$ 96,750	B-1 Impacts of Climate Change
NDMP - Intake 3	VIR	Cowichan Valley Regional District	S1	S1 - Regional Risk Assessment of Floodplain Areas	N	DMU	Completed	$ 50,000	$ 50,000	$ 7,500	$ 107,500	B-3 Flood Risk Assessment
NDMP - Intake 3	VIR	Cowichan Valley Regional District	S1	S1 - Regional Dam Safety Analysis and Risk Assessment	N	DMU	Completed	$ 128,000	$ 128,000	$ 19,200	$ 275,200	B-3 Flood Risk Assessment
NDMP - Intake 3	VIR	Cowichan Valley Regional District	S3	S3 - Koksilah/ Shu-hwuykwselu Stormwater Drainage Mitigation Plan	N	DMU	Completed	$ 100,000	$ 100,000	$ 15,000	$ 215,000	B-4 Flood Planning
NDMP - Intake 3	SWE	Delta, Corporation of	S1	S1 - Flood Protection System Risk Assessment	Y	DMU	Completed	$ 75,000	$ 75,000	$ 11,250	$ 161,250	B-3 Flood Risk Assessment
NDMP - Intake 3	SEA	East Kootenay Regional District	S2	S2 - Elk River Flood Mapping and Hydrology Study	Y	DMU	Completed	$ 125,000	$ 125,000	$ -	$ 250,000	B-2 Flood Hazard Information
NDMP - Intake 3	PROV	FLNRORD	S4b	S4 - Dike Consequence Classification	N	DMU	Completed	$ 150,000	$ 150,000	$ 20,000	$ 320,000	B-2 Flood Hazard Information
NDMP - Intake 3	PROV	FLNRORD	S4b	S4 - Climate Change Scenario Modeling for Fraser River Watershed	N	DMU	Completed	$ 125,000	$ 125,000	$ 8,000	$ 258,000	B-1 Impacts of Climate Change

Disaster Mitigation Unit (DMU) Table

Program Area	Region	Proponent	Stream	Project Name	Flood Map Produced	Managed By	Status	Provincial Cash Contributions	Federal (NDMP/ARDM) Cash Contributions	Other Cash/In-Kind Contributions	TOTAL Project Value	Issue Group
NDMP - Intake 3	CTL	Fraser Basin Council	S1	S1 - Thompson Watershed Multi-jurisdictional Assessment	N	DMU	Completed	$ 300,000	$ 300,000	$ 45,000	$ 645,000	B-2 Flood Hazard Information
NDMP - Intake 3	PROV	Fraser Basin Council	S2	S2 - Hydraulic Modelling and Mapping in BC's Lower Mainland	Y	DMU	Completed	$ -	$ 500,000	$ 510,000	$ 1,010,000	B-2 Flood Hazard Information
NDMP - Intake 3	SEA	GeoBC	S4b	S4 - Kootenay Lake Region LiDAR and ortho-imagery Acquisition	N	DMU	Completed	$ 790,000	$ 790,000	$ 118,500	$ 1,698,500	B-2 Flood Hazard Information
NDMP - Intake 3	SEA	Golden, Town of	S1	S1 - Kicking Horse River Ice Jam Flooding Risk Assessment	N	DMU	Completed	$ 42,000	$ 42,000	$ 5,000	$ 89,000	B-3 Flood Risk Assessment
NDMP - Intake 3	CTL	Lumby, Village of	S3	S3 - Flood Mitigation Plan	N	DMU	Completed	$ 112,800	$ 112,800	$ 11,400	$ 237,000	B-4 Flood Planning
NDMP - Intake 3	VIR	Nanaimo, Regional District of	S1	S1 - RDN and Town of Qualicum Beach Risk Assessment	N	DMU	Completed	$ 80,000	$ 70,000	$ 10,500	$ 160,500	B-3 Flood Risk Assessment
NDMP - Intake 3	VIR	Powell River Regional District	S1	S1 - Assessment of Coastal Hazards and Risks	N	DMU	Completed	$ 31,500	$ 31,500	$ 4,725	$ 67,725	B-3 Flood Risk Assessment
NDMP - Intake 3	SWE	Richmond, City of	S1	S1 - Steveston Island Flood Risk Investigation	N	DMU	Completed	$ 405,000	$ 810,000	$ 405,000	$ 1,620,000	B-3 Flood Risk Assessment
NDMP - Intake 3	SWE	Richmond, City of	S3	S3 - Flood Mitigation Strategy Update	N	DMU	Completed	$ 250,000	$ 250,000	$ -	$ 500,000	B-4 Flood Planning
NDMP - Intake 3	NWE	Stewart, District of	S4a	S4 - Bear River Small Scale Structural Mitigation	N	DMU	Under Review	$ 166,666	$ 166,666	$ 191,668	$ 525,000	B-5 Structural Flood Management Approaches
NDMP - Intake 4	VIR	Alberni- Clayoquot, Regional District of	S2	S2 - Somass Watershed Flood Management Program	N	DMU	Completed	$ 238,500	$ 261,500	$ 23,000	$ 523,000	B-4 Flood Planning
NDMP - Intake 4	CTL	Armstrong, City of	S1	S1 - Armstrong Risk Assessment	Y	DMU	Completed	$ 43,500	$ 49,500	$ 6,500	$ 99,500	B-3 Flood Risk Assessment
NDMP - Intake 4	VIR	Capital Regional District	S4a	S4a - Gardom Pond Dam Decommissioning	N	DMU	Completed	$ 214,500	$ 245,500	$ 31,000	$ 491,000	B-5 Structural Flood Management Approaches
NDMP - Intake 4	CTL	Central Okanagan, Regional District of	S2	S2 - RDCO Lakeshore Flood Mapping	Y	DMU	Completed	$ 126,000	$ 144,000	$ 18,000	$ 288,000	B-2 Flood Hazard Information
NDMP - Intake 4	SWE	Coquitlam, City of	S1	S1 - Mayfair Industrial Park Risk Assessment	N	DMU	Completed	$ 23,500	$ 26,500	$ 3,000	$ 53,000	B-3 Flood Risk Assessment
NDMP - Intake 4	VIR	Cowichan Valley Regional District	S2	S2 - Updated Cowichan Koksilah Flood Mapping	Y	DMU	Completed	$ 129,500	$ 145,500	$ 16,000	$ 291,000	B-2 Flood Hazard Information
NDMP - Intake 4	SEA	Cranbrook, The Corporation of the City of	S1	S1 - Flood Risk Assessment	N	DMU	Completed	$ 28,000	$ 31,700	$ 4,000	$ 63,700	B-3 Flood Risk Assessment
NDMP - Intake 4	SEA	Fernie, City of	S4a	S4a - Maiden Lake Dike Improvements	N	DMU	Completed	$ 732,500	$ 767,500	$ 35,000	$ 1,535,000	B-5 Structural Flood Management Approaches
NDMP - Intake 4	PROV	FLNRORD	S4b	S4b - Provincial Dike GPS Crest Survey	N	DMU	Completed	$ 390,000	$ 410,000	$ 20,000	$ 820,000	B-2 Flood Hazard Information
NDMP - Intake 4	PROV	FLNRORD	S4b	S4b - BC Regional Flood Frequency Analysis	N	DMU	Completed	$ 209,202	$ 239,798	$ 31,000	$ 480,000	B-2 Flood Hazard Information
NDMP - Intake 4	PROV	FLNRORD	S4b	S4b - Guideline on Probable Maximum Precipitation Estimation	N	DMU	Completed	$ 233,582	$ 268,418	$ 34,000	$ 536,000	B-2 Flood Hazard Information
NDMP - Intake 4	PROV	FLNRORD	S4b	S4b - BC Regional Precipitation Frequency Analysis	N	DMU	Completed	$ 239,207	$ 274,793	$ 36,000	$ 550,000	B-2 Flood Hazard Information
NDMP - Intake 4	PROV	Fraser Basin Council	S4b	S4b - Flood Preparedness and Mitigation Information Portal	N	DMU	Completed	$ 153,000	$ 174,000	$ 21,000	$ 348,000	B-2 Flood Hazard Information
NDMP - Intake 4	VIR	GeoBC	S4b	S4b - Vancouver Island and Sunshine Coast All Hazards Data Acquisition	N	DMU	Completed	$ 1,154,600	$ 1,193,400	$ 38,800	$ 2,386,800	B-2 Flood Hazard Information

Disaster Mitigation Unit (DMU) Table

Program Area	Region	Proponent	Stream	Project Name	Flood Map Produced	Managed By	Status	Provincial Cash Contributions	Federal (NDMP/ARDM) Cash Contributions	Other Cash/In-Kind Contributions	TOTAL Project Value	Issue Group
NDMP - Intake 4	NWE	Gitga'at First Nation	S1	S1 - Hartley Bay Tsunami and Flood Risk Assessment	N	DMU	Completed	$ 70,500	$ 74,500	$ 4,000	$ 149,000	B-3 Flood Risk Assessment
NDMP - Intake 4	CTL	Kelowna, City of	S1	S1 - Kelowna Major Systems Flood Risk Assessment	N	DMU	Under Review	$ 125,000	$ 125,000	$ 18,700	$ 268,700	B-3 Flood Risk Assessment
NDMP - Intake 4	SEA	Kimberley, City of	S3	S3 - Kimberley and Lois Creek Daylight Design	N	DMU	Completed	$ 73,500	$ 76,500	$ 3,100	$ 153,100	B-5 Structural Flood Management Approaches
NDMP - Intake 4	CTL	Nooaitch Indian Band	S4a	S4a - Nooaitch - IR 10 Erosion Mitigation Works	N	DMU	In Progress	$ 609,250	$ 774,750	$ 165,500	$ 1,549,500	B-5 Structural Flood Management Approaches
NDMP - Intake 4	CTL	Okanagan Nation Alliance	S1	S1 - Flood Risk Assessment	N	DMU	Under Review	$ 114,400	$ 240,600	$ 126,200	$ 481,200	B-3 Flood Risk Assessment
NDMP - Intake 4	CTL	Okanagan-Similkameen, Regional District of	S2	S2 - RDOS Okanagan River and Lakes Flood Mapping	Y	DMU	Completed	$ 273,000	$ 297,000	$ 24,000	$ 594,000	B-2 Flood Hazard Information
NDMP - Intake 4	NEA	Peace River Regional District	S1	S1 - PRRD Chetwynd Fringe Risk Assessment	N	DMU	Completed	$ 33,500	$ 36,500	$ 5,000	$ 75,000	B-3 Flood Risk Assessment
NDMP - Intake 4	NEA	Peace River Regional District	S1	S1 - PRRD Moberly Lake Risk Assessment	N	DMU	Completed	$ 33,500	$ 33,500	$ 5,000	$ 72,000	B-3 Flood Risk Assessment
NDMP - Intake 4	NEA	Peace River Regional District	S1	S1 - PRRD Pouce Coupe - Tomslake Risk Assessment	N	DMU	Completed	$ 30,000	$ 30,000	$ 4,500	$ 64,500	B-3 Flood Risk Assessment
NDMP - Intake 4	SWE	Samahquam First Nation	S4a	S4a - Flood Risk Mitigation for Q'aLaTKu7eM Village	N	DMU	Cancelled	$ -	$ 1,119,400	$ 1,119,400	$ 2,238,800	B-5 Structural Flood Management Approaches
NDMP - Intake 4	SWE	Shxw'owhamel First Nation	S1	S1 - Shxw'owhamel First Nation Flood Risk Assessment	N	DMU	Under Review	$ 20,000	$ 20,000	$ 3,000	$ 43,000	B-3 Flood Risk Assessment
NDMP - Intake 4	CTL	Spallumcheen, Township of	S1	S1 - Spallumcheen Flood Hazard Risk Review	N	DMU	Completed	$ 50,000	$ 50,000	$ 7,500	$ 107,500	B-3 Flood Risk Assessment
NDMP - Intake 4	SWE	Squamish First Nation	S2	S2 - Flood Modeling - Lower Capilano River	Y	DMU	Completed	$ -	$ 91,000	$ 103,000	$ 194,000	B-2 Flood Hazard Information
NDMP - Intake 4	SWE	Squamish-Lillooet Regional District	S1	S1 - SLRD Identification & Risk-based Prioritization of Flood Hazards	N	DMU	Completed	$ 256,100	$ 293,900	$ 37,800	$ 587,800	B-3 Flood Risk Assessment
NDMP - Intake 4	VIR	Strathcona Regional District	S1	S1 - Salmon and White Rivers Risk Assessment	N	DMU	Completed	$ 32,750	$ 37,250	$ 4,500	$ 74,500	B-3 Flood Risk Assessment
NDMP - Intake 4	VIR	Tofino, District of	S1	S1 - Tofino Coastal Flood Risk Assessment	Y	DMU	Completed	$ 80,000	$ 80,000	$ 12,000	$ 172,000	B-3 Flood Risk Assessment
NDMP - Intake 4	SWE	Vancouver, City of	S3	S3 - Locarno Beach Resilient Shoreline - Engagement and Design	N	DMU	Completed	$ -	$ 200,000	$ 230,000	$ 430,000	B-5 Structural Flood Management Approaches
NDMP - Intake 4	SWE	Vancouver, City of	S4a	S4a - Fraser River Flood Protection Project - East Fraser Lands - Phase 1	N	DMU	Completed	$ -	$ 1,430,000	$ 1,530,000	$ 2,960,000	B-5 Structural Flood Management Approaches
NDMP - Intake 5	SWE	Abbotsford, City of	S3	S3 - Nooksack River Overflow Flood Mitigation Plan	N	DMU	Completed	$ 125,000	$ 125,000	$ 10,000	$ 260,000	B-4 Flood Planning
NDMP - Intake 5	VIR	Capital Regional District	S2	S2 - Capital Region Coastal Flood Inundation Mapping	Y	DMU	Completed	$ 329,250	$ 375,750	$ 46,844	$ 751,844	B-2 Flood Hazard Information
NDMP - Intake 5	SEA	Central Kootenay, Regional District of	S2	S2 - Flood Hazard Mapping, Regional District of Central Kootenay	Y	DMU	Completed	$ 1,500,000	$ 1,500,000	$ 60,000	$ 3,060,000	B-2 Flood Hazard Information
NDMP - Intake 5	SEA	Columbia Shuswap Regional District	S1	S1 - Risk Assessment for the Columbia Shuswap Regional District (Eastern Portion)	N	DMU	Completed	$ 150,000	$ 150,000	$ 15,000	$ 315,000	B-3 Flood Risk Assessment
NDMP - Intake 5	VIR	Comox Valley Regional District	S2	S2 - CVRD Flood Mapping Project	Y	DMU	In Progress	$ 250,000	$ 250,000	$ 16,500	$ 516,500	B-2 Flood Hazard Information
NDMP - Intake 5	VIR	Cowichan Valley Regional District	S2	S2 - Cowichan Lake Rockslide Wave Induced Flood Assessment	Y	DMU	Completed	$ 165,000	$ 165,000	$ 24,750	$ 354,750	B-2 Flood Hazard Information

Disaster Mitigation Unit (DMU) Table

Program Area	Region	Proponent	Stream	Project Name	Flood Map Produced	Managed By	Status	Provincial Cash Contributions	Federal (NDMP/ARDM) Cash Contributions	Other Cash/In-Kind Contributions	TOTAL Project Value	Issue Group
NDMP - Intake 5	VIR	Cowichan Valley Regional District	S4b	S4b - Shawnigan Lake Flood Preparedness	N	DMU	Completed	$ 60,000	$ 60,000	$ 9,000	$ 129,000	B-4 Flood Planning
NDMP - Intake 5	SEA	Cranbrook, The Corporation of the City of	S2	S2 - City of Cranbrook/Joseph Creek - Flood Hazard Assessment	Y	DMU	Completed	$ -	$ 100,000	$ 100,000	$ 200,000	B-2 Flood Hazard Information
NDMP - Intake 5	NEA	Dawson Creek, City of	S2	S2 - City of Dawson Creek Flood Mapping	Y	DMU	Completed	$ 147,500	$ 147,500	$ 25,125	$ 320,125	B-2 Flood Hazard Information
NDMP - Intake 5	SWE	Fraser Basin Council	S1	S1 - Lower Mainland Flood Risk Assessment	N	DMU	In Progress	$ 340,000	$ 340,000	$ 45,000	$ 725,000	B-3 Flood Risk Assessment
NDMP - Intake 5	CTL	Fraser Basin Council	S4b	S4b - Thompson River Watershed LiDAR Acquisition	N	DMU	Completed	$ 741,707	$ 741,707	$ -	$ 1,483,414	B-2 Flood Hazard Information
NDMP - Intake 5	PROV	GeoBC	S4b	S4b - BC Riverine hazard Data Acquisition	N	DMU	Completed	$ 1,152,400	$ 1,152,400	$ 116,000	$ 2,420,800	B-2 Flood Hazard Information
NDMP - Intake 5	SEA	Golden, Town of	S2	S2 - Flood Mapping for the Town of Golden	Y	DMU	Completed	$ 135,000	$ 135,000	$ 4,600	$ 274,600	B-2 Flood Hazard Information
NDMP - Intake 5	SWE	Pitt Meadows, City of	S3	S3 - City of Pitt Meadows - Flood Mitigation Plan	N	DMU	Completed	$ 206,000	$ 243,000	$ 12,000	$ 486,000	B-4 Flood Planning
NDMP - Intake 5	NEA	Quesnel, City of	S2	S2 - Update Floodplain Mapping	Y	DMU	Completed	$ 120,900	$ 120,900	$ 10,000	$ 251,800	B-2 Flood Hazard Information
NDMP - Intake 5	SWE	Richmond, City of	S4a	S4a - Steveston Highway and No. 3 Road Drainage Pump Station (SHN3DPS)	N	DMU	Completed	$ -	$ 1,000,000	$ 1,000,000	$ 2,000,000	B-5 Structural Flood Management Approaches
NDMP - Intake 5	SWE	Squamish, District of	S3	S3 - Eagle Viewing/Seaichem Reserve Dike Master Plan	N	DMU	Completed	$ 135,000	$ 135,000	$ 20,000	$ 290,000	B-4 Flood Planning
NDMP - Intake 5	SWE	Vancouver, City of	S3	S3 - Southlands Flood Mitigation Plan	N	DMU	Completed	$ -	$ 345,000	$ 345,000	$ 690,000	B-4 Flood Planning
NDMP - Intake 5	SWE	Vancouver, City of	S3	S3 - Vancouver's Sea Level Rise Engagement and Design Challenge: Phase 1 (Planning	N	DMU	Completed	$ -	$ 100,000	$ 100,000	$ 200,000	B-1 Impacts of Climate Change
NDMP - Intake 5	SWE	Whistler, Resort Municipality of	S2	S2 - Whistler Flood Mapping	Y	DMU	Completed	$ 278,500	$ 278,500	$ 15,500	$ 572,500	B-2 Flood Hazard Information
								$ 109,789,970	**$ 22,420,482**	**$ 20,037,652**	**$ 152,273,103**	

Community Emergency Preparedness Fund (CEPF) Table
(Administered by Union of British Columbia Municipalities-UBCM)

Stream	EMBC Region	Proponent	Project Title	ood Map Produce	Application Statu	Funding Amount Approved	Total Project Value	Issue Group
Flood Planning 2017	CTL	Armstrong	Flood Mapping and Mitigation Planning	Y	Completed	$ 79,302.00	$ 79,302.00	B-2 Flood Hazard Information
Flood Planning 2017	NW	Bulkley-Nechako Regional District	Flood Risk Assessment, Flood Mapping, Flood Mitigation Planning: Ebenezer Flats	Y	Completed	$ 121,000.00	$ 121,000.00	B-3 Flood Risk Assessment
Flood Planning 2017	VIR	Campbell River	Flood Risk Assessment, Mapping, Mitigation Planning: Sea Level Rise Assessment	Y	Completed	$ 150,000.00	$ 348,000.00	B-1 Impacts of Climate Change
Flood Planning 2017	NEA	Central Coast Regional District	Flood Mapping: Bella Coola Valley Flood LiDAR Survey and Orthoimagery	Y	Completed	$ 150,000.00	$ 154,500.00	B-2 Flood Hazard Information
Flood Planning 2017	SEA	Central Kootenay Regional District	Flood Mapping: LiDAR Initiative	Y	Completed	$ 133,726.43	$ 134,626.43	B-2 Flood Hazard Information
Flood Planning 2017	CTL	Central Okanagan Regional District	Flood Mapping: Central Okanagan LiDAR Acquisition & Mission Creek Floodplain Mapping Update & Dike Breach Analysis	Y	Completed	$ 150,000.00	$ 150,000.00	B-2 Flood Hazard Information
Flood Planning 2017	CTL	Clinton	Flood Risk Assessment: Upper Clinton Creek Reservoir Dam Break Analysis	N	Completed	$ 10,000.00	$ 12,000.00	B-3 Flood Risk Assessment
Flood Planning 2017	CTL	Columbia Shuswap Regional District	Flood Mapping: Bastion Mountain Geomorphic Assessment	Y	Completed	$ 149,686.00		B-2 Flood Hazard Information
Flood Planning 2017	SEA	Grand Forks	Flood Risk Assessment, Flood Mitigation Planning: Grand Forks Floodplain Risk Assessment Project	Y	Completed	$ 67,500.00	$ 225,700.00	B-3 Flood Risk Assessment
Flood Planning 2017	CTL	Kelowna	Flood Mitigation Planning & Mapping: Mill Creek	Y	Completed	$ 150,000.00	$ 150,000.00	B-2 Flood Hazard Information
Flood Planning 2017	VIR	Nanaimo Regional District	Flood Mapping: Sea Level Rise Adaptation Program	Y	Under Review	$ 150,000.00	$ 220,000.00	B-1 Impacts of Climate Change
Flood Planning 2017	CTL	North Okanagan Regional District	Greater Vernon Lakeshore Flood Mapping and Shuswap River Flood Mapping	Y	Completed	$ 150,000.00	$ 165,000.00	B-2 Flood Hazard Information
Flood Planning 2017	CTL	Penticton	Flood Risk Assessment	Y	Completed	$ 66,500.00	$ 76,475.00	B-3 Flood Risk Assessment
Flood Planning 2017	VIR	Port McNeill	Flood Risk Assessment, Flood Mitigation Planning: Storm Water & Beach Drive Landslide Risk Assessment	N	Completed	$ 101,000.00	$ 101,000.00	B-3 Flood Risk Assessment
Flood Planning 2017	SWE	Richmond	Flood Mitigation Planning: Dike Master Plan Phase 5	N	Completed	$ 150,000.00	$ 200,000.00	B-4 Flood Planning
Flood Planning 2017	SEA	Salmo	Flood Mapping	Y	Completed	$ 150,000.00		B-2 Flood Hazard Information
Flood Planning 2017	VIR	Tahsis	Flood Risk Assessment, Flood Mapping, Flood Mitigation Planning: Sea level Rise Coastal Mapping Assessment	Y	Completed	$ 126,500.00	$ 126,500.00	B-1 Impacts of Climate Change
Flood Planning 2017	VIR	Tofino	Flood Mapping Project	Y	Completed	$ 150,000.00	$ 162,000.00	B-2 Flood Hazard Information
Flood Planning 2017	SWE	Vancouver	Flood Mitigation Planning: Fraser River Flood Management - Public Engagement Project	N	Completed	$ 150,000.00	$ 160,000.00	B-4 Flood Planning
Flood Planning 2017	VIR	Zeballos	Zeballos River Floodplain Modernization & Future Landslide Risk Assessment	Y	Completed	$ 150,000.00	$ 150,000.00	B-3 Flood Risk Assessment
Flood Planning 2019	SEA	Canal Flats	Kootenay River Flood Risk Assessment and Flood Mapping	Y	Completed	$ 150,000.00	$ 168,000.00	B-3 Flood Risk Assessment
Flood Planning 2019	NEA	Cariboo Regional District	Screening Level Floodplain Mapping, Thompson River Watershed & Floodplain Prioritization within CRD	Y	In Progress	$ 150,000.00	$ 150,000.00	B-2 Flood Hazard Information
Flood Planning 2019	VIR	Courtenay	Dike Replacement and Flood Protection Strategy: Phase 2	N	In Progress	$ 150,000.00	$ 150,000.00	B-4 Flood Planning
Flood Planning 2019	SEA	Greenwood	Flood Risk Assessment, Flood Mapping and Flood Mitigation Planning	Y	In Progress	$ 149,668.00	$ 149,668.00	B-3 Flood Risk Assessment
Flood Planning 2019	CTL	Keremeos	Similkameen River Regional Flood Risk Assessment, Flood Mapping & Flood Mitigation Plan.	Y	In Progress	$ 149,982.00	$ 149,982.00	B-3 Flood Risk Assessment
Flood Planning 2019	NEA	Kitimat-Stikine Regional District	Skeena and Lower Kalum River Channel Management Program Phase 2		In Progress	$ 98,000.00	$ 250,121.00	B-4 Flood Planning
Flood Planning 2019	SEA	Midway	Flood Risk Assessment, Flood Mapping & Flood Mitigation Plan	Y	Completed	$ 150,000.00	$ 159,317.00	B-3 Flood Risk Assessment

Community Emergency Preparedness Fund (CEPF) Table
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Stream	EMBC Region	Proponent	Project Title	ood Map Produce	Application Statu	Funding Amount Approved	Total Project Value	Issue Group
Flood Planning 2019	SWE	Mission	Flood Risk Assessment, Flood Mapping & Flood Mitigation Plan	Y	In Progress	$ 150,000.00	$ 150,000.00	B-3 Flood Risk Assessment
Flood Planning 2019	VIR	City of Nanaimo	Jump Creek & South Fork Dams Inundation Study	Y	In Progress	$ 150,000.00	$ 200,000.00	B-2 Flood Hazard Information
Flood Planning 2019	SWE	North Vancouver City	Lynn Creek Flood Risk Assessment and Reduction Management Plan	?	In Progress	$ 150,000.00	$ 150,024.00	B-4 Flood Planning
Flood Planning 2019	CTL	Okanagan-Similkameen Regional District	Similkameen River Regional Flood Risk Assessment and Flood Mapping Project	Y	In Progress	$ 138,957.00	$ 138,957.00	B-3 Flood Risk Assessment
Flood Planning 2019	CTL	Peachland	Flood Risk Assessment and Mitigation Plan for Okanagan Lakeshore	?	In Progress	$ 145,000.00	$ 145,000.00	B-3 Flood Risk Assessment
Flood Planning 2019	SWE	Pemberton	Lillooet River Floodplain Flood Mitigation Planning	N	Completed	$ 150,000.00	$ 400,590.00	B-4 Flood Planning
Flood Planning 2019	CTL	Penticton	Flood Mitigation Plan	Y	In Progress	$ 59,000.00	$ 67,850.00	B-4 Flood Planning
Flood Planning 2019	CTL	Princeton	Similkameen River Regional Flood Risk Assessment, Flood Mapping & Flood Mitigation Plan	Y	In Progress	$ 149,940.00	$ 149,940.00	B-3 Flood Risk Assessment
Flood Planning 2019	SWE	Squamish	Squamish River Dike - Judd Slough Dike Seismic Risk Assessment and Mitigation Strategy	?	Completed	$ 150,000.00	$ 183,290.00	B-4 Flood Planning
Flood Planning 2019	SWE	Squamish-Lillooet Regional District	Lillooet River Floodplain Flood Mitigation Planning	?	In Progress	$ 150,000.00	$ 150,000.00	B-4 Flood Planning
Flood Planning 2019	CTL	Thompson-Nicola Regional District	Screening Level Flood Mapping in the Thompson River Watershed	Y	Completed	$ 150,000.00	$ 150,000.00	B-2 Flood Hazard Information
Flood Planning 2019	VIR	Tofino	Tsunami Risk Mitigation Plan	N	In Progress	$ 150,000.00	$ 162,000.00	B-4 Flood Planning
Flood Planning 2019	VIR	Ucluelet	Flood Mapping Project	Y	Completed	$ 150,000.00	$ 165,000.00	B-2 Flood Hazard Information
Flood Planning 2019	CTL	Vernon	Upper and Lower BX Creek Flood Risk Assessment, Mapping and Flood Mitigation Planning - Phase 1	Y	In Progress	$ 149,600.00	$ 204,000.00	B-3 Flood Risk Assessment
Flood Planning 2019	SWE	Whistler	Fitzsimmons Creek Flood Mitigation	Y	Completed	$ 146,900.00	$ 151,900.00	B-5 Structural Flood Management Approaches
Flood Planning 2020	CTL	Cache Creek	Flood Mitigation Plan		In Progress	$ 147,170.00	$ 147,170.00	B-4 Flood Planning
Flood Planning 2020	NEA	Cariboo Regional District	Flood Hazard Mapping and Risk Assessment Inputs: Multiple Areas		Completed	$ 150,000.00	$ 150,000.00	B-3 Flood Risk Assessment
Flood Planning 2020	CTL	Central Okanagan Regional District	Mitigation: RDCO Regional Floodplain Management Plan - Ph. 3		In Progress	$ 150,000.00	$ 150,000.00	B-4 Flood Planning
Flood Planning 2020	CTL	Chase	Floodplain Mapping		In Progress	$ 125,420.00	$ 125,420.00	B-2 Flood Hazard Information
Flood Planning 2020	VIR	Comox Valley Regional District	Comox Valley RD Coastal Flood Mitigation Plan		In Progress	$ 150,000.00	$ 150,000.00	B-4 Flood Planning
Flood Planning 2020	VIR	Cowichan Tribes - 642	Flood Mitigation Planning		In Progress	$ 149,900.00	$ 164,000.00	B-4 Flood Planning
Flood Planning 2020	VIR	Cowichan Valley Regional District	Cowichan Koksilah Floodplain Geodata BC Update and Program Outreach		In Progress	$ 91,004.00	$ 91,004.00	B-4 Flood Planning
Flood Planning 2020	CTL	Enderby	Flood Mapping and Risk Assessment		In Progress	$ 120,000.00	$ 130,750.00	B-3 Flood Risk Assessment
Flood Planning 2020	NWE	Hazelton	Flood Risk Assessment, Flood Mapping and Flood Mitigation Plan		In Progress	$ 150,000.00	$ 162,615.00	B-3 Flood Risk Assessment
Flood Planning 2020	SWE	Hope	Lower Coquihalla River - Climate Change Flood Mitigation, Risk Assessment and Floodplain Mapping Project		In Progress	$ 150,000.00	$ 150,000.00	B-1 Impacts of Climate Change
Flood Planning 2020	VIR	Ka:'yu:'k't'h'/Che:k'tles7et'h' First Nations	Assessment and Mapping: Northwest Vancouver Island Tsunami Mapping Project		In Progress	$ 150,000.00	$ 150,000.00	B-2 Flood Hazard Information
Flood Planning 2020	CTL	Kamloops	Downtown Peterson Creek Study		In Progress	$ 150,000.00	$ 150,000.00	B-2 Flood Hazard Information
Flood Planning 2020	SWE	Kent	Flood Risk Assessment and Flood Mitigation Planning		In Progress	$ 147,600.00	$ 147,600.00	B-3 Flood Risk Assessment
Flood Planning 2020	NWE	Kitimat	Kitimat River Flood Mapping Study		In Progress	$ 150,000.00	$ 225,000.00	B-2 Flood Hazard Information
Flood Planning 2020	SEA	Kootenay-Boundary Regional District	Flood and Geohazard Risk Assessment for the Boundary Region		In Progress	$ 149,845.00	$ 163,150.03	B-3 Flood Risk Assessment
Flood Planning 2020	SWE	Kwantlen First Nation - 564	Lower Mainland Coast Salish First Nation Flood Risk Assessment		In Progress	$ 150,000.00	$ 789,000.00	B-3 Flood Risk Assessment
Flood Planning 2020	VIR	Ladysmith	Mitigation: Stocking Lake Dam Design Study		In Progress	$ 150,000.00	$ 193,392.00	B-5 Structural Flood Management Approaches

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Stream	EMBC Region	Proponent	Project Title	od Map Produce	Application Statu	Funding Amount Approved	Total Project Value	Issue Group
Flood Planning 2020	NEA	Lhoosk'uz Dene Government (Kluskus)	South Dakehl Nation Alliance Flood Risk Assessment		In Progress	$ 150,000.00	$ 160,000.00	B-3 Flood Risk Assessment
Flood Planning 2020	SWE	Lil'wat Nation	Grandmother slough - Flood Risk and Environmental Assessment and Mitigation Planning		In Progress	$ 150,000.00	$ 150,000.00	B-3 Flood Risk Assessment
Flood Planning 2020	NWE	Masset	Masset Flood Risk Assessment and Mapping		In Progress	$ 121,358.00	$ 121,358.00	B-3 Flood Risk Assessment
Flood Planning 2020	CTL	Merritt	Detailed Flood Hazard Mapping: City of Merritt		In Progress	$ 150,000.00	$ 150,000.00	B-2 Flood Hazard Information
Flood Planning 2020	VIR	Nanaimo Regional District	Englishman River Flood Hazard Mapping		In Progress	$ 150,000.00	$ 300,000.00	B-2 Flood Hazard Information
Flood Planning 2020	SWE	New Westminster	Floodplain Management Strategy Update		In Progress	$ 150,000.00	$ 150,000.00	B-4 Flood Planning
Flood Planning 2020	NWE	Nisga'a Lisims Government	Adaptation of the Nisga'a Nation to the Impacts of Climate Change		In Progress	$ 150,000.00	$ 150,000.00	B-1 Impacts of Climate Change
Flood Planning 2020	NWE	North Coast Regional District	Flood Risk Assessment and Mapping for Tlell and Sandspit		In Progress	$ 148,019.49	$ 150,000.00	B-3 Flood Risk Assessment
Flood Planning 2020	SWE	North Vancouver District	Upper Mackay Creek Flood Mitigation Plan		In Progress	$ 150,000.00	$ 150,000.00	B-4 Flood Planning
Flood Planning 2020	VIR	Nuchatlaht	Northwest Vancouver Island Tsunami Mapping Project		In Progress	$ 150,000.00	$ 150,000.00	B-2 Flood Hazard Information
Flood Planning 2020	NEA	Peace River Regional District	Flood Mapping for Chetwynd Fringe, Moberly Lake and Tomslake-Pouce Coupe Rural Area		In Progress	$ 150,000.00	$ 150,000.00	B-2 Flood Hazard Information
Flood Planning 2020	NWE	Port Clements	Flood Risk Assessment and Mapping		In Progress	$ 88,509.00	$ 88,509.00	B-3 Flood Risk Assessment
Flood Planning 2020	VIR	qathet Regional District (Powell River)	Coastal Flood Mapping - Phase 2		In Progress	$ 150,000.00	$ 150,000.00	B-2 Flood Hazard Information
Flood Planning 2020	NWE	Queen Charlotte	Village of Queen Charlotte Flood Risk and Mapping		In Progress	$ 142,113.37	$ 142,113.37	B-3 Flood Risk Assessment
Flood Planning 2020	SWE	Richmond	Risk Assessment and Mapping: Hydraulic Modeling and Seismic Assessment Project		In Progress	$ 150,000.00	$ 150,000.00	B-3 Flood Risk Assessment
Flood Planning 2020	VIR	Sayward	Flood Mapping: Salmon River Floodplain Modernization		In Progress	$ 150,000.00	$ 150,000.00	B-2 Flood Hazard Information
Flood Planning 2020	SWE	Seabird Island Band	Seabird Island Maria Slough Flood Mitigation Planning Project		In Progress	$ 150,000.00	$ 150,000.00	B-4 Flood Planning
Flood Planning 2020	NWE	Smithers	Bulkley River Erosion and Flood Mitigation Assessment and Design		In Progress	$ 122,933.00	$ 122,933.00	B-5 Structural Flood Management Approaches
Flood Planning 2020	SWE	Squamish-Lillooet Regional District	Upper Paradise Valley Flood Risk Assessment and Flood Hazard Mapping		In Progress	$ 150,000.00	$ 150,000.00	B-3 Flood Risk Assessment
Flood Planning 2020	VIR	Strathcona Regional District	Northwest Vancouver Island Tsunami Mapping Project		In Progress	$ 150,000.00	$ 150,000.00	B-2 Flood Hazard Information
Flood Planning 2020	VIR	Tahsis	Flood Mitigation Preliminary Design Project		In Progress	$ 149,895.00	$ 149,895.00	B-5 Structural Flood Management Approaches
Flood Planning 2020	CTL	Thompson-Nicola Regional District	Thompson River Watershed Flood Hazard Mapping and Risk Assessment: Mulitiple Areas		In Progress	$ 150,000.00	$ 150,000.00	B-3 Flood Risk Assessment
Flood Planning 2020	SWE	Vancouver	Engineering Design Reference for Shoreline Flood Protection		In Progress	$ 150,000.00	$ 150,000.00	B-4 Flood Planning
Flood Planning 2020	CTL	Vernon	Lower BX Creek and Vernon Creek Flood Risk Assessment, Mapping and Flood Mitigation Planning		In Progress	$ 149,950.00	$ 216,150.00	B-3 Flood Risk Assessment
Flood Planning 2020	CTL	Whispering Pines/Clinton Band	Mitigation Planning: Shoreline and Dike Revetments and Repairs		Pending	$ 150,000.00	$ 150,000.00	B-4 Flood Planning
Flood Planning 2020	NEA	Williams Lake	Williams Lake and River Valley Flood Risk Assessment, Flood Mapping and Mitigation		In Progress	$ 150,000.00	$ 150,000.00	B-3 Flood Risk Assessment
Flood Planning 2020	VIR	Zeballos	Planning: Zeballos Slope Hazard Mitigation Feasibility Study		In Progress	$ 150,000.00	$ 150,500.00	B-4 Flood Planning
Structural 2018	CTL	Cache Creek	Quartz Road Culvert Upgrade		Withdrawn	$ 750,000.00	$ 900,000.00	B-5 Structural Flood Management Approaches
Structural 2018	NEA	Chetwynd	Windrem Creek & Widmark Creek Debris Barriers & Gravel Traps		In Progress	$ 717,100.00	$ 717,100.00	B-5 Structural Flood Management Approaches
Structural 2018	SWE	Chilliwack	2018 Fraser River Bank Erosion Protection		Completed	$ 750,000.00	$ 750,000.00	B-5 Structural Flood Management Approaches
Structural 2018	SWE	Delta	Boundary Bay Dike Foreshore Upgrade - West of 96th St		In Progress	$ 749,157.50		B-5 Structural Flood Management Approaches
Structural 2018	SEA	East Kootenay Regional District	Hill Road Dike Erosion Protection		In Progress	$ 749,928.00	$ 1,099,928.00	B-5 Structural Flood Management Approaches

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Stream	EMBC Region	Proponent	Project Title	ood Map Produce	Application Statu	Funding Amount Approved	Total Project Value	Issue Group
Structural 2018	SEA	Golden	Kicking Horse River Ice Monitoring Program	N	Completed	$ 425,000.00	$ 425,000.00	B-5 Structural Flood Management Approaches
Structural 2018	SEA	Invermere	Toby Creek Erosion Protections and Bank Stabilization		In Progress	$ 396,750.00	$ 396,750.00	B-5 Structural Flood Management Approaches
Structural 2018	CTL	Kamloops	Sewage Treatment Centre Dike Repair		Completed	$ 154,270.00	$ 154,270.00	B-5 Structural Flood Management Approaches
Structural 2018	SEA	Kaslo	River Dike and Bank Remediation Plan		In Progress	$ 304,869.00	$ 304,869.00	B-5 Structural Flood Management Approaches
Structural 2018	CTL	Kelowna	Spencer Road Mill Creek Drainage Improvement Project		Completed	$ 750,000.00	$ 988,725.00	B-5 Structural Flood Management Approaches
Structural 2018	SWE	Maple Ridge	Road 13 Dike Improvements		In Progress	$ 74,735.00	$ 157,430.00	B-5 Structural Flood Management Approaches
Structural 2018	SWE	New Westminster	Boundary Road Pump Station Rehabilitation		In Progress	$ 750,000.00		B-5 Structural Flood Management Approaches
Structural 2018	CTL	North Okanagan Regional District	Structural Flood Mitigation for RDNO Drinking Water Facilities		Completed	$ 405,000.00		B-5 Structural Flood Management Approaches
Structural 2018	SWE	North Vancouver District	Mission Creek Debris Basin		Completed	$ 663,000.00	$ 663,000.00	B-5 Structural Flood Management Approaches
Structural 2018	CTL	Penticton	Penticton Creek Structural Flood Mitigation		In Progress	$ 750,000.00	$ 950,000.00	B-5 Structural Flood Management Approaches
Structural 2018	SWE	Pitt Meadows	Flood Protection - Pump Station Backup Generators		In Progress	$ 678,200.00	$ 678,200.00	B-5 Structural Flood Management Approaches
Structural 2018	VIR	Strathcona Regional District	Glenmore Road Dike Upgrades - Oyster River		Completed	$ 441,000.00	$ 441,000.00	B-5 Structural Flood Management Approaches
Structural 2019	VIR	Colwood	Lookout Brook Dam Upgrade	N	In Progress	$ 750,000.00	$ 1,451,950.00	B-5 Structural Flood Management Approaches
Structural 2019	VIR	Cowichan Tribes - 642	Clem Clem Village - Cowichan River Erosion Protection	N	In Progress	$ 750,000.00	$ 1,000,000.00	B-5 Structural Flood Management Approaches
Structural 2019	SEA	Fernie	Mountainview Dike Upgrade Phase 1	N	In Progress	$ 750,000.00	$ 750,252.00	B-5 Structural Flood Management Approaches
Structural 2019	CTL	Kelowna	Strathcona Area Flood Prevention Project	N	In Progress	$ 289,100.00	$ 400,000.00	B-5 Structural Flood Management Approaches
Structural 2019	SWE	Lil'wat Nation	Pole Yard Dike Upgrade	N	In Progress	$ 750,000.00	$ 800,000.00	B-5 Structural Flood Management Approaches
Structural 2019	CTL	Lumby	Shields Ave Dike Upgrades	N	In Progress	$ 750,000.00	$ 869,000.00	B-5 Structural Flood Management Approaches
Structural 2019	CTL	Merritt	Voght Street Structural Flood Mitigation Project	N	Completed	$ 750,000.00	$ 1,967,973.00	B-5 Structural Flood Management Approaches
Structural 2019	NWE	Metlakatla First Nation - 673	Metlakatla Coastal Erosion Protection Project - Beach 4	N	In Progress	$ 750,000.00	$ 750,000.00	B-5 Structural Flood Management Approaches
Structural 2019	VIR	North Cowichan	Canada Ave Flood Gate	N	In Progress	$ 750,000.00	$ 1,916,429.00	B-5 Structural Flood Management Approaches
Structural 2019	SWE	North Vancouver District	Kilmer Creek Restoration & Daylighting	N	In Progress	$ 750,000.00	$ 2,839,760.00	B-5 Structural Flood Management Approaches
Structural 2019	CTL	Peachland	Structural Flood Mitigation from 4th Street to Swim Bay	N	In Progress	$ 750,000.00	$ 850,000.00	B-5 Structural Flood Management Approaches
Structural 2019	SWE	Pemberton	Arn Canal Upgrades	N	In Progress	$ 750,000.00	$ 900,000.00	B-5 Structural Flood Management Approaches
Structural 2019	CTL	Penticton	Penticton Creek Structural Flood Mitigation - Reach 3A & 3B	N	In Progress	$ 750,000.00	$ 2,960,000.00	B-5 Structural Flood Management Approaches
Structural 2019	SWE	Pitt Meadows	Fenton Pump Station Replacement	N	In Progress	$ 739,740.00	$ 1,103,500.00	B-5 Structural Flood Management Approaches
Structural 2019	SWE	Richmond	Flood Protection and Dike Upgrades	N	In Progress	$ 750,000.00	$ 1,000,000.00	B-5 Structural Flood Management Approaches
Structural 2019	SWE	Squamish-Lillooet Regional District	Lillooet River Sediment Removal & Landslide Monitoring Equipment on Mt Currie	N	In Progress	$ 750,000.00	$ 750,000.00	B-5 Structural Flood Management Approaches
Structural 2019	NWE	Telkwa	Bulkley River Flood Protection Improvements	N	In Progress	$ 739,961.00	$ 739,961.00	B-5 Structural Flood Management Approaches
Structural 2019	SWE	Abbotsford	Cannell Lake Dam Remediation	N	In Progress	$ 493,178.00	$ 493,178.00	B-5 Structural Flood Management Approaches
Structural 2019	CTL	Armstrong	Meighan Creek Bypass	N	In Progress	$ 730,370.00	$ 775,830.00	B-5 Structural Flood Management Approaches
Structural 2019	SWE	East Kootenay Regional District	Cold Spring Creek Debris Flood Mitigation Project	N	In Progress	$ 750,000.00		B-5 Structural Flood Management Approaches
Structural 2019	SWE	Squamish	Xwu'nekw Park Sea Dike at Mamquam Blind Channel	N	Withdrawn			B-5 Structural Flood Management Approaches
Structural 2020	SWE	Abbotsford	Matsqui Dyke Sinkhole Full Repair Project	N	In Progress	$ 750,000.00	$ 1,150,000.00	B-5 Structural Flood Management Approaches
Structural 2020	SWE	Vancouver	Southlands Tide Gates Replacement Program	N	In Progress	$ 750,000.00	$ 750,000.00	B-5 Structural Flood Management Approaches
Structural 2020	CTL	Vernon	BX Creek Sedimentation Pond	N	In Progress	$ 747,000.00	$ 1,943,731.00	B-5 Structural Flood Management Approaches
Structural 2020	NEA	Williams Lake	River Valley Wastewater Treatement Plant / Jackpine Slide Erosion Protection	N	In Progress	$ 750,000.00	$ 771,800.00	B-5 Structural Flood Management Approaches
Structural 2020	VIR	Zeballos	Slope Hazard Mitigation	N	In Progress	$ 750,000.00	$ 750,000.00	B-5 Structural Flood Management Approaches
						$ 39,494,336.79	**$ 50,181,937.83**	

Disaster Financial Assistance (DFA) Table

Eligible Damage	Event	Total Expenditure	Federal Share	Estimate	Ministry & Response Costs	Private Sector Costs	Local Govt	Included in Summary	Issue Group
Flooding	General 2020/21	1,326,666		Estimate Only		1,189,677	136,989	Y	C-2 Emergency Response or C-3 Flood Recovery
Flooding	General 2019/20	1,942,969		Estimate Only		1,641,416	301,553	Y	C-2 Emergency Response or C-3 Flood Recovery
Flooding	**2018 Freshet**	**190,358,209**	**140,087,000**	Estimate Only	178,430,162	8,993,508	2,934,539	Y	C-2 Emergency Response or C-3 Flood Recovery
Flooding	General 2018/19	2,513,120				976,789	1,536,331	Y	C-2 Emergency Response or C-3 Flood Recovery
Flooding	**2017 Spring Flooding**	**94,064,389**	**54,396,000**	Estimate Only	74,693,691	3,860,142	15,510,556	Y	C-2 Emergency Response or C-3 Flood Recovery
Flooding	General 2017/18	410,054				121,182	288,872	Y	C-2 Emergency Response or C-3 Flood Recovery
Flooding	**2016 June Flooding**	**156,476,741**	**111,355**	Estimate Only	153,582,782	1,192,667	1,701,292	Y	C-2 Emergency Response or C-3 Flood Recovery
Flooding	General 2016/17	2,751,494			-	1,977,544	773,950	Y	C-2 Emergency Response or C-3 Flood Recovery
Flooding	General 2015/16	3,388,169				1,459,976	1,928,193	N	C-2 Emergency Response or C-3 Flood Recovery
Flooding	General 2014/15	3,408,209			-	1,773,026	1,635,183	N	C-2 Emergency Response or C-3 Flood Recovery
Flooding	**2013 June Flooding**	**21,785,495**	**10,573,000**	Estimate Only	16,781,016	589,254	4,415,225	N	C-2 Emergency Response or C-3 Flood Recovery
Flooding	General 2013/14	264,674			-	179,035	85,639	N	C-2 Emergency Response or C-3 Flood Recovery
Flooding	General 2012/13	1,975,851			-	1,331,376	644,475	N	C-2 Emergency Response or C-3 Flood Recovery
Flooding	**2012 Freshet**	**12,978,487**	**4,206,411**	Audited Payment	10,822,976	948,222	1,207,289	N	C-2 Emergency Response or C-3 Flood Recovery

Disaster Financial Assistance (DFA) Table

Eligible Damage	Event	Total Expenditure	Federal Share	Estimate	Ministry & Response Costs	Private Sector Costs	Local Govt	Included in Summary	Issue Group
Flooding	General 2011/12	397,011			-	289,077	107,934	N	C-2 Emergency Response or C-3 Flood Recovery
Flooding	**2011 September Flooding**	**20,598,541**	**9,799,925**	Audited Payment	20,598,541	-	-	N	C-2 Emergency Response or C-3 Flood Recovery
Flooding	**2011 June Flooding**	**64,764,966**	**49,257,516**	Audited Payment	61,779,423	1,352,858	1,632,685	N	C-2 Emergency Response or C-3 Flood Recovery
Flooding	General 2010/11	1,045,648			-	1,009,403	36,245	N	C-2 Emergency Response or C-3 Flood Recovery
Flooding	**2010 September Flooding**	**64,643,738**	**50,104,179**	Audited Payment	61,644,158	2,088,783	910,797	N	C-2 Emergency Response or C-3 Flood Recovery
Flooding	General 2009/10	1,814,371			-186,355	1,814,371	186,355	N	C-2 Emergency Response or C-3 Flood Recovery
Flooding	General 2008/09	84,961			-	84,961	-	N	C-2 Emergency Response or C-3 Flood Recovery
Flooding	**2009 Extreme Weather**	**15,459,712**	**3,596,036**	Audited Payment	8,701,586	2,725,741	4,032,385	N	C-2 Emergency Response or C-3 Flood Recovery
Flooding	General 2007/08	8,074,791			6,485,912	1,216,494	372,385	N	C-2 Emergency Response or C-3 Flood Recovery
Flooding	**2007 Freshet**	**17,875,029**	**4,861,308**	Audited Payment	15,439,125	2,071,754	364,151	N	C-2 Emergency Response or C-3 Flood Recovery

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