Photo: Carie-Ann Lau

1.8 RIVERINE FLOODS

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RESILIENCE PATHWAYS

CO-CREATING NEW KNOWLEDGE FOR UNDERSTANDING RISK AND RESILIENCE IN BC

This article is part of the Resilience Pathways Report. The report has the following objectives: a) to share knowledge about existing practices and recent advances in understanding and managing disaster and climate risk in BC, including some information on relevant federal programs, and b) to provide insights on gaps and recommendations that will help build pathways to resilience in BC.

This article belongs to *Chapter 1 Understanding and Managing Climate and Disaster Risk: Hazard Threat*. To read all articles in the report, see DRRPathways.ca.

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1.8 RIVERINE FLOODS

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ABOUT RIVERINE FLOODS

DESCRIPTION

Floods are among the most commonly occurring natural hazards in BC and account for the second-largest portion of disaster recovery costs annually.[1] Typically, flooding occurs from September to February during the rainy season on the coast and from May to June during snowmelt (freshet) in the mountainous regions and major river basins of the province.

BC is drained by six major rivers: the Fraser, Columbia, Peace, Skeena, Stikine, and Liard. A number of smaller rivers also feed these major rivers or drain directly to the Pacific Ocean along the mainland coast, Haida Gwaii, and Vancouver Island. Watersheds, also called drainage basins or catchments, are bounded by the heights of land. The land channels rainfall and snowmelt to creeks, streams, and rivers, and eventually to outflow points such as reservoirs, bays, and the ocean. Typically, a watershed boundary will extend beyond one administrative/municipal boundary, requiring a degree of cooperation, strategic planning and management.

BC is susceptible to major weather events, such as atmospheric rivers originating in the Pacific. As warm, moist air collides with mountain ranges, it rises and cools, often causing heavy precipitation. In the spring, as temperatures warm and the snow melts, rivers rise and additional water from heavy rainfall often causes them to spill their banks. Heavy fall and early winter precipitation on the coast can cause rivers to flood low-lying regions. Faster-moving water, especially if it has entrained materials like rocks or logs, can be more damaging and can cause erosion or avulsions, which rapidly change the course of a river. Similarly, powerful waves on the shorelines of lakes and oceans have additional energy that can cause erosion and damage in the wave zone.

FLOOD TYPES

Each flood event tends to be unique, varying in likelihood, severity, and driving factors. In addition, climate change is increasing flood risks in many ways in different regions. Sea-level rise, changes in precipitation patterns, and land-use practices can exacerbate current and future flood events. When planning for flood mitigation, it is important to understand the different types of floods we face today, as well as in the decades to come. Characteristics of different flood types in BC are described in Table 1.

FLOOD HAZARD

Flood hazards are defined by their likelihood and magnitude (Figure

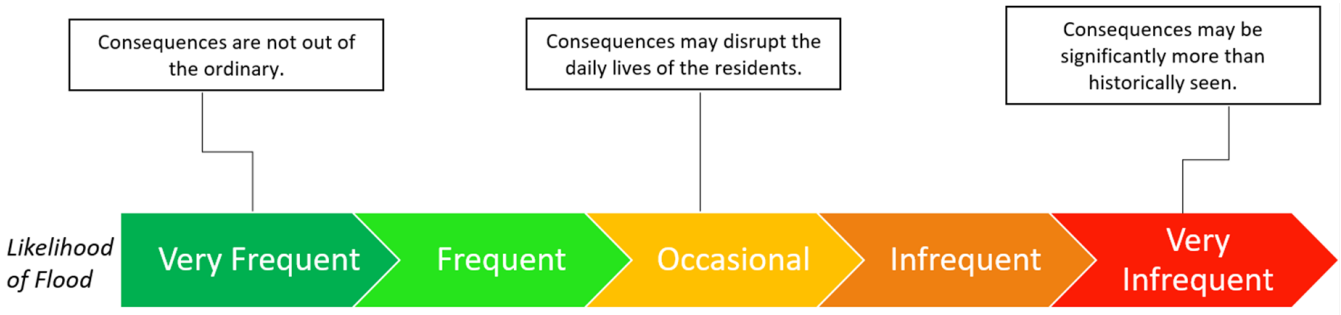
1). The magnitude can be further defined by the flood depth, velocity, and duration. Nuisance flooding in a basement is very different from moderate (>30 cm) or severe (>2m) flooding, which can cause significant to unrecoverable damage.

IMPACTS OF FLOODS

Communities, infrastructure, and buildings can be directly or indirectly impacted by floods (Figure 2). Impacts are not always just immediate; they can often persist for a number of years until the community has recovered. For instance, impacts on gas prices, food supplies, housing values, or fish populations can change over time as a result of the flood. These damages can be classified as tangible, where a dollar value can be assigned, or intangible, such as emotional stress, illness, loss of sense of community, or loss of life.

Table 1: Characteristics of different flood types (rivers and related).

Type of Floods	Description	Example in BC
Creek and river floods	Clearwater floods: high volumes of water from precipitation and/or snowmelt exceed the capacity of rivers or creeks and flow onto adjacent lands. Debris floods and debris flows: debris (soil, rocks, trees, etc.) is entrained in water flowing off steep slopes where normal channel capacity is exceeded, flowing onto adjacent land. Warning times are short, velocities are high, and entrained materials can become powerful projectiles. Ice Jam floods: these can result in higher water levels than open-water floods of comparable discharge.	In November 2021, an atmospheric river event delivered 300 mm of rain, melted an early fall snowpack, and was accompanied by strong winds. It resulted in widespread flooding and debris flows across southwestern BC.
Groundwater floods	Groundwater tables are unusually high due to higher-than-normal inflows or consistent precipitation. This can occur behind dikes as high-water levels in the river change the water gradient.	Widespread flooding in spring 2017 affected a number of communities, including First Nations communities in the Okanagan. Flooding led to high lake levels and associated high groundwater, causing evacuation from homes and spread of contamination from septic fields.
Lake floods	Water levels in lakes are higher than normal due to higher inflows and/or downstream blockages. This can be compounded by wind and waves.	In 2017, highest-water levels were recorded for Okanagan Lake and Kalamalka Lake. Record-setting rainfall combined with snowmelt saturated the ground and led to major flooding along nearby creeks, with over 1,200 docks destroyed and multiple shorelines eroded.
Dike or dam failure (anthropogenic)	Infrastructure fails and releases impounded water in an uncontrolled manner. Can also be caused by ground shaking and/or liquefaction due to an earthquake.	At Mt Polley, mine tailings from a dam breach in 2014 resulted in ~17 million m^3 of water and 8 million m^3 of tailings/materials dispersed.
Pluvial (urban drainage) floods	Heavy precipitation cannot be absorbed into natural landscapes or stormwater infrastructure, creating localized flooding.	In November 2018, heavy rains caused flooding over areas of southwestern BC, with almost 228 mm of rain; large volumes of water overwhelmed sewer systems, causing sewer backup and manhole lids to pop up.



Average Recurrence Interval (ARI)	Probability of Flooding in Each Year	Probability of Flooding over 25 Years	Probability of Flooding over 75 Years
100-yr	1%	22%	53%
200-yr	0.5%	12%	31%
500-yr	0.2%	5%	14%

Figure 1: Frequent small events pose different risks than large events that occur rarely. A 1 in 100-year flood is equivalent to a 1% annual chance or has a 22% chance of occurrence in a timeframe of a 25-year mortgage (Graphic: Natural Resources Canada).

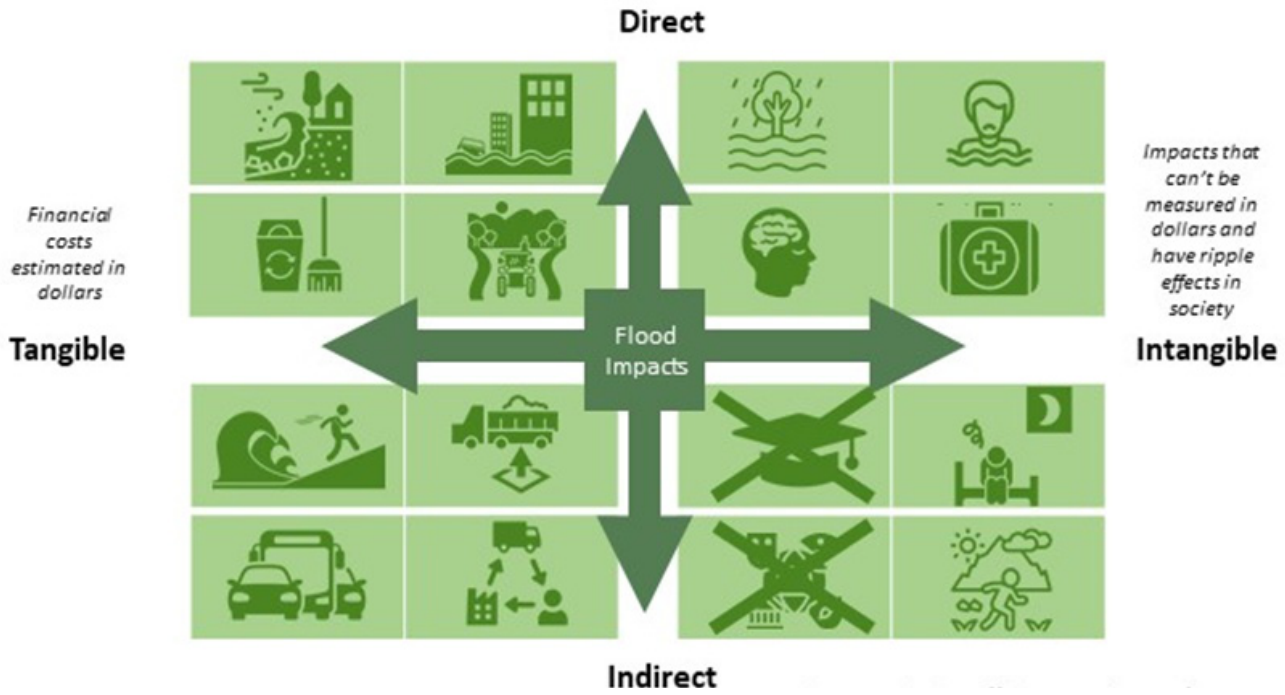


Figure 2: Communities can face a range of impacts from flooding. Adapted from the federal flood damage estimation guideline[4] (Graphic: Natural Resources Canada with icons from the Noun Project).

DISPROPORTIONATE IMPACTS OF FLOODS ON FIRST NATIONS IN BC

First Nations in BC are typically disproportionately affected by floods. BC Assembly of First Nations states: "Following the November 2021 floods and landslides, the First Nation Leadership Council called upon the provincial and federal governments to commit significant financial supports and resources to First Nations. From a pandemic to fires then to floods, First Nations have been forced to shoulder the impacts of colonial-induced climate extremes while navigating the challenges caused by COVID-19 without adequate support and resources."5 As such, the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) must be central to future flood adaptation conversations.

Infrastructure located near waterways are most at risk, such as wastewater treatment facilities. During floods, these facilities can be damaged, causing wastewater contamination downstream. Bridges, pipelines, culverts, piers, roads, rail lines, and dike structures can all experience damage during floods. Impacts to these structures can affect areas outside directly flooded areas. When floodwaters remain in contact with a building for a long time, extensive damage can occur. Damaged buildings reinhabited following a flood can lead to illnesses such as hepatitis A, salmonella, and respiratory illnesses.[2]

Fatalities from flooding are not uncommon. In 2020 alone, there were seven flood-related mortalities in BC. Long-term health effects include impacts on mental health, loss of employment, displacement and evacuation, impacts on normal life patterns, loss of valuables, and the uncertainty around recovery and who assumes the financial burden.

Recovery is unequal among people and populations, with more vulnerable individuals often facing more significant disruption and overall impacts. Floods stretch beyond the immediate crisis, and the most impacted often face systemic barriers to accessing recovery services. Despite experiencing significant impacts, communities can also support one another by providing unique empathy and collaboration.[3]

FLOODING THREAT AND PAST EVENTS

Rivers have always been lifelines for communities, figuring prominently in the history of BC. Many First Nations have stories of major flood events where people went to the highest mountains to escape flooding. Due to our climate and geography, as well as history and settlement patterns, many British Columbians must live with the risk that floods may strike and disrupt their lives. There is great variety in how floodwaters interact with communities and assets in areas at risk due to the regional and local geography, community setting, and the vulnerability of people and infrastructure (Figure 3).

More than 60 damaging flood events have been recorded since 1900 in the Canadian Disaster Database, with an estimated cost of $1 trillion. Note that costs for flood events are not well documented and are likely much higher than this value. Multiple agencies, including private insurance companies, collect flood impact data, much of which is not publicly available. Information on flood impacts allows planners to address them—allocating resources for monitoring, mitigation, and preparedness, and building resilient communities.

Canadian Disaster Database (CDD)[6] identifies some of the impacts and costs for 40 damaging flood events in BC. However, a review of historic damaging flood events in BC carried out by a research team at the Geological Survey of Canada identified 86 damaging flood events.[7] Limited information on flooding in Indigenous communities could be found in the database.

DRIVERS OF RISK

LAND COVER AND DEVELOPMENT

The type of terrain and gradient of land influence how a watershed can flood. Land cover and channel changes from aggradation are the most significant factors. From meadows to forests to asphalt streets, each surface has a different level of perviousness or

Figure 3: November 2021, Sumas Prairie flood impacts agricultural areas, roads, and buildings (Photo: Carie-Ann Lau).

inherent ability to infiltrate water into the soil. Large-scale changes to land surfaces, such as the loss of wetlands, deforestation, and forest fires, can impact land perviousness. In cities, asphalt roads, rooftops, and pavement are largely impervious—greatly limiting the infiltration of water from rainfall and causing surface runoff. With heavier rainfall events and aging infrastructure, runoff can overwhelm stormwater systems as they channel the runoff to local creeks and rivers, leading to localized flooding and contamination.

Densification in floodplains across BC has led to increased flood risk. Increasing the projected density in floodplains will increase this risk. A recent report looks at communities across Canada with greater than 10,000 people where a significant number of buildings are in the floodplain. At the top of the list is the BC community of Chilliwack, where nearly half of the buildings in the city are located in the floodplain.[8]

DIKES

There are over 200 regulated dikes in BC protecting communities and infrastructure, and hundreds of unregulated dikes. A recent report indicates that approximately 160,000 hectares of land with thousands of buildings and significant critical infrastructure are situated behind dikes in BC communities.[9] With more than a hundred different authorities that manage these structures across BC, consistent maintenance is not carried out.

During severe floods, dikes can fail due to erosion, overtopping, or seepage. When the dikes were first constructed in floodplains, their presence encouraged development behind the dikes with the perception that the area was safe for building in, or "floodproofed." But dike failure can occur without warning and can have significant impacts. Despite the high design standards for dikes, there are almost no dikes (<5%) that currently meet these standards in BC. A significant amount of work and money over many decades is needed to bring these up to standard. Ultimately, the construction of dikes in some locations has had the perverse effect of putting the community at greater risk of catastrophic flooding when the flood eventually does occur.

GOVERNANCE

In BC, floods are governed by several orders of government and multiple sectors, ranging from coordinating roles to protecting and restoring fish habitat.[10] Local governments manage land-use development, for instance, by approving subdivisions and developments, and some of these are in floodplains. A lack of publicly available information and public awareness on where flood hazards exist has contributed to increased development in floodplains across BC. Although not intended specifically for flood protection purposes, the Agricultural Land Reserve (ALR) in BC protects approximately 4.6 million hectares of agriculturally suitable land by restricting non-agricultural uses.[11] Because many floodplains overlap with productive agricultural lands, the ALR has played a significant role in preventing additional flood risk from development in floodplains over the last 50 years. However, many critical agricultural resources remain in the path of potential floods, creating the risk of flood damage to BC's agriculture industry.

A lack of publicly available information and public awareness on where flood hazards exist has contributed to increased development in floodplains across BC.

CLIMATE CHANGE

In the mountainous regions of BC, climate change is projected to result in changes to the snowpack, loss of glaciers, thawing of the alpine permafrost, and an upward movement of the treeline. With an increase in extreme rainfall events, these changes are predicted to lead to increased flooding across the province.

Quantifying the effects of climate change on floods is challenging and evolving. Recent guidance is to expect that floods are likely to increase by about 20% in BC by the end of the century, depending on the type of flood.[12] Flood types may also change from snowmelt-driven floods to less predictable, winter storm–driven floods that are likely to coincide with high ocean levels. Where rivers and oceans interact, such as in the lower Fraser River, this can amplify water levels. Where forest fires occur, flooding and sedimentation are expected to increase.

UNDERSTANDING RISK

WHAT SOURCES HELP US UNDERSTAND HAZARD AND RISK

Due to the recent devastating floods in November 2021, most people in the province and beyond are now much more aware of the potential for flood risk and the broader systemic risks associated with flooding, such as the impacts to the supply chain. Other recent flood and high-water events that have occurred throughout BC, while not as disruptive at a provincial scale as the November 2021 floods, have brought the realities of flood risk home for many people.

Although not intended specifically for flood protection purposes, the Agricultural Land Reserve (ALR) in BC protects approximately 4.6 million hectares of agriculturally suitable land by restricting non-agricultural uses.

POST-DISASTER DAMAGE ASSESSMENT AND DATA COLLECTION

Following a damaging flood event, information is collected through a number of means (Table 2). This information is predominantly collected to inform financial payouts and response activities and is not always publicly accessible.

Post-disaster information is invaluable in supporting planning efforts to understand existing gaps and capacities with current and future flood management. The Commission for Environmental Cooperation recently developed a framework for use in Canada, the United States and Mexico to evaluate the economic impacts of floods. The methodology captures the costs of direct and indirect damages and losses following a flood event and could be more widely adopted for use in capturing and sharing post-disaster event information.[13]

HAZARD ASSESSMENT

Hazard information is typically depicted by flood maps, in the form of either high-resolution engineering models for use at the building site or community scale, or low-resolution national models used for nationwide planning and insurance. To model and map flood inundation, extents, depths, and velocities, a number of datasets are needed, including high-resolution elevation data. The Province of British Columbia provides access to available open-source LiDAR (Light Detection and Ranging) datasets through a web portal, and recently flown LiDAR data coverage across the province is continually expanding.[17] Data related to flood mapping can also be found on the Open Government portal.[18]

Between 1987 and 2003,[19] regulatory maps were generated by the Province to designate a 200-year return period (0.5% annual probability) floodplain map for many rivers and lakes. These maps have been used to establish Flood Construction Levels. These legacy flood maps are mapped to a 1 in 200-year probability.

Table 2: Post-disaster data collection for floods in BC.

Title	Purpose	Data Collected	Availability (Open/Closed)	Responsible Authority
Situational Reports	A coordinated collection of impacts and assessments developed by government agencies, primarily for operational emergency response activities.	Description of the threat/event, request for assistance, impacts on critical infrastructure and communities, and actions taken,	Dissemination varies	Public Safety Canada, EMBC, and local government Emergency Operation Centres
CatIQ[14]	Combines comprehensive insured loss and exposure indices from natural and human-caused disasters.	Physical damage, personal property, and non-physical damage (additional living expenses and business interruption).	Online subscription	Catastrophe Indices and Quantification Inc.
Canadian Disaster Database[15]	Tracks significant disaster events that meet damage criteria.	Where and when a disaster occurred; number of injuries, evacuations, fatalities; and estimate of costs.	Open	Public Safety Canada
Post-disaster Building Assessment[16]	Rapidly assesses the safety of buildings and allows people to remain or return to their homes and businesses.	Initial, rapid assessment and detailed building assessment.	Closed	Local community authorities

Flood maps do not cover the entire province, and many are decades old. This is problematic as river flow and geomorphology can change over time. In 2003, flood map development was devolved to local communities. This has led to the development of a range of map qualities and formats, many of which are not easily accessible or available in a central location.

Historically, flood maps have been typically based on a single regulatory or design event, providing a limited understanding of the range of events that might occur. On some of the legacy maps, flood construction levels (FCLs) and flood setback areas are established to define where development can occur. Not all flood maps show FCLs or flood setback areas. FCLs also vary between communities.

Local governments and First Nations are responsible for but not required to develop floodplain maps. Those communities with more resources may provide online access to some of these maps. An initiative is underway to review and possibly compile flood maps developed under recent funding initiatives. Given that there are no standards for the development of flood maps, it will be challenging to integrate maps developed using differing standards. However, these maps could still be made accessible even if data sets are not fully integrated into one layer.

EXPOSURE

A National database on the physical exposure to natural hazards[20] provides information on the built environment. This dataset provides information on exposed assets—aggregate information on buildings and populations—that can be used in a risk assessment. Where more detailed, site-specific community information exists, the more detailed information should be used in the development of community-scale risk assessments.

RISK AND VULNERABILITY ASSESSMENT

Risk assessments require a comprehensive understanding of the flood hazard, exposure, and vulnerability and can be a combination of quantitative and qualitative models at a regional, community, or site-specific scale. Detailed community risk assessments are typically tailored to the individual needs of communities. For example, assessments can assist a community with: determining a return on investment of mitigation measures for use in a funding application; prioritizing areas within a community for mitigation; and helping the community understand the impact of a hazard.

Funding sources through the National Disaster Mitigation Program are currently supporting a number of flood risk assessments across BC.[21] In addition, researchers at several universities, including the University of British Columbia,[22] Simon Fraser University[23] and the University of Northern British Columbia,[24] provide a range of expertise on flood impacts and recovery.

While overland flood insurance has not historically been available in BC, since 2013 a number of insurance providers have developed national flood risk models to inform insurance policies that have been applied in BC.

CURRENT PRACTICE IN HAZARD AND RISK ASSESSMENT

Risk assessment practice puts hazard information into the context of impacts on communities and informs decision making from a risk-based perspective. Local and Indigenous governments are typically responsible for managing and conducting risk assessments and carrying out flood mitigation projects along with partners. Risk assessment tends to bridge the disciplines of engineering, community planning, and emergency management, and therefore the current practice is disparate. In BC, approximately 60 risk assessment studies have been completed to date, many of which are focused on southern BC.[25]

FLOOD MAPPING AND MODELLING

A national or provincial geospatial platform to host all publicly funded flood models and map outputs does not exist. A lack of public information is a liability to all involved with models; these should be accessible under the principle that some information is better than no information at all. Flood maps should cover multiple flood frequencies,

resolutions, and precisions to provide a comprehensive system of hazard and risk assessment for various purposes. Modelling a range of flood scenarios would take into account current and future flood hazards; in addition to future population and mitigation strategies, this can provide a community with a better understanding of the range of potential flooding, from nuisance to catastrophic flooding to future flood risks. Natural Resources Canada and Public Safety Canada are tasked[26] with developing a flood mapping portal that will aim to fill this gap at the national level.

A new federal flood hazard identification and mapping program,[27] led by Natural Resources Canada with support from the provinces and territories, will build on existing initiatives to support the development of flood hazard maps in high-risk areas across Canada. These products are anticipated to be part of the proposed web portal developed by Natural Resources Canada and Public Safety Canada that provides access to information on flood risks and best practices to protect homes and communities.[28]

RISK ASSESSMENT

Few communities in BC have developed flood risk maps that indicate who and what is at risk, and a provincial-scale flood risk assessment does not exist. Such an assessment would allow for the Province to highlight areas of concern to help support allocation decisions under funding programs or to identify communities that are at high risk but are not applying to funding programs due to capacity constraints.

There is no single database of information for the province that describes the population and built environment in a way that is suitable for flood risk modelling, and there is a shortage of vulnerability curves to support quantitative flood risk assessment. Developing such a database along with high-quality flood hazard data would provide the benefits of standardization and reduce efforts required to model flood risks on a one-off basis (for example, every time a study is done by a consultant on contract to a community). Although it may also reduce the opportunity for innovation in techniques and approaches, the value of standardized data would seem to outweigh this potential drawback while still leaving room for customization and innovation to address local idiosyncrasies.

A new open-source tool, CanFlood,[29] is available to assist flood risk modellers in conducting risk assessments. Rather than focus on a single design event, this risk-based approach takes into account the vulnerability of buildings and the full range of floods that can impact a community. Outputs of the CanFlood model can provide decision makers with quantitative information to optimize mitigation options for their community. Input data on the flood hazards and exposure needs to be added to the application. The CanFlood model was recently used in a flood risk assessment for the Lower Mainland; as part of this work, flood depth damage curves were developed to assess damage to buildings specific to the Lower Mainland region, and these curves are included in the CanFlood application.

A new report commissioned by the Fraser Basin Council provides insights as to the value and approaches for risk assessment in BC.[30]

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REDUCING RISK

RISK REDUCTION PRACTICE, POLICY, AND CAPABILITIES

Historic damaging flood events have influenced policy and legislation in BC. For example, the 1948 Fraser River flood led to the development of the 1948 federal-provincial Fraser River Board and the 1953 *Dike Maintenance Act*. The 1948 Columbia River flood led indirectly to the 1961 Columbia River Treaty. At the national level, the federal National Disaster Mitigation Program was created following the 2013 Calgary and Toronto severe flood events.

A draft discussion paper on flood risk and resilience in BC was developed in 2020 as part of efforts to develop a provincial flood strategy. This paper was informed by provincial ministries, Indigenous engagement, and local and federal government engagements. Further dissemination of the report through a public engagement process has, however, been delayed as the province addresses response and recovery to communities from the November 2021 floods and incorporates the lessons learned from that event.

GOVERNANCE

Many jurisdictions in BC play a role in flood risk reduction, including government agencies, critical infrastructure owners and operators, insurance companies, businesses, individuals, and homeowners (Table 3). Provincial legislation, regulations, and policies set out requirements and guidance for communities to manage their flood risk under the *Local Government Act*, the *Emergency Program Act*, and the *Dike Maintenance Act*.

Local government plays an extensive role in flood management, including floodplain designation, land-use planning, bylaws for non-structural measures, and emergency preparedness and response. When a state of emergency is declared, a higher level of government is responsible for supporting the response. These response actions are coordinated by emergency managers through Emergency Operation Centres

Figure 4: Federal Flood Guideline Mapping Series (Graphic: Natural Resources Canada).

GUIDELINES TO SUPPORT FLOOD MAPPING

The Federal Flood Mapping Guideline Series (Figure 4) is a set of evergreen guidelines that support flood mapping activities.[31] The series includes guidance on the Flood Mapping Framework (2018), LiDAR Data Acquisition (2020), Bibliography of Best Practices and References for Flood Mitigation (2018), Case Studies of Climate Change in Floodplain Mapping (2018), Federal Hydrologic and Hydraulic Procedures for Flood Hazard Delineation (2019), Federal Geomatics Guidelines for Flood Mapping (2019), and Federal Flood Damage Estimation Guidelines for Buildings and Infrastructure (2021). New guidelines are being developed for flood land use and risk assessment that will be of value to practitioners and the Province of BC.

Engineers and Geoscientists of British Columbia provide professional practice guidelines for flood assessments and flood mapping.[32]

Table 3: Organizations and industries involved in flood risk management.

Organization	Type of Organization	Legal Mandate and Roles	Key Programs
Public Safety Canada	Federal government	Emergency preparedness and response with all orders of governments; assesses capabilities and priorities for mitigation, preparedness and response; develops plans and preparedness strategies; help Canadians prepare for and recover from floods in high-risk areas.	*Federal Emergency Response Plan* National Risk Profile (flood, earthquake, and wildfire) Requests for Federal Assistance Disaster Financial Assistance Arrangements Program Emergency exercises (tabletops) Flood Insurance Program Disaster and Climate Resilience Joint Committee for BC
Infrastructure Canada	Federal government	Infrastructure standards and funding.	Disaster Mitigation Adaptation Fund Natural Infrastructure Fund[33]
Natural Resources Canada	Federal government	With provinces and territories, develops flood maps for high-risk areas, develops a portal for access to information on flood risks, develops best practice guidelines, conducts research.	Flood Hazard Identification and Mapping Program Flood Mapping Portal Flood Mapping Guidelines Series Emergency Geomatics
Indigenous Services Canada	Federal government	First Nations emergency preparedness, management, and recovery that addresses climate change, impacts, and collaborative strategies.	First Nations Emergency Preparedness, Management and Recovery First Nations Adapt program Emergency Management Assistance Program
Environment and Climate Change Canada	Federal government	Weather forecasts, climate change projections, flood forecasting.	*Climate Data Strategy* Canada Water Agency Weather monitoring upgrades Climate change strategies *Freshwater Action Plan*

Organization	Type of Organization	Legal Mandate and Roles	Key Programs
Emergency Management British Columbia	Provincial government	Lead coordinating agency for all emergency management activities in BC.	BC Disaster Mitigation Programs[34]
Forests Lands Natural Resources and Rural Development	Provincial government	Provides tools, data, and water licensing; regulates dike safety and upgrades; provides flood forecasting and warnings.	*Environmental Management Act* *Local Government Act* Flood Mitigation Guidelines *Dike Maintenance Act* *Drainage, Ditch and Dike Act* *Water Sustainability Act* *Environmental Management Act* *Flood Hazard Statutes Amendment Act* *Land Title Act* *Community Charter* *Local Government Act* *Riparian Areas Protection Act and Regulation*
Ministry of Land, Water, and Resource Stewardship	Provincial government	Sets environmental objectives; manages cumulative environmental effects; and advances environmental sustainability, economic growth, and Reconciliation with Indigenous Peoples.	*Environmental and Land use Act* *Water Sustainability Act* *Flathead area water conservation Act* *Muskwa-Ketchika Management Areas Act* *Skagit Environmental Enhancement Act* *Wildlife Act*
Ministry of Transportation and Infrastructure	Provincial government	Promotes safety and efficient movement of people and goods.	New Building Canada Fund – Small Communities Fund
Ministry of Agriculture	Provincial government	Promotes production, marketing, processing, and merchandising of agriculture and aquaculture products; supports food security and enhancement of wild fish populations.	2021 Flood Recovery Program for Food Security

Organization	Type of Organization	Legal Mandate and Roles	Key Programs
Municipal Affairs and Housing Service	Provincial government	Supports local governments and residents to build vibrant and healthy communities.	Strengthening Community Fund Integrated Transportation and Development Strategy
Union of BC Municipalities		Offers funding programs for local governments and First Nations.	Canada Community Building Fund Community Emergency Preparedness Fund
Fraser Basin Council	Non-profit	Collaborates with federal, provincial, and local governments and First Nations, the private sector, and civil society for sustainability in the Fraser Basin and across BC.	Facilitation Education on flood hazard/risks

at varying levels of government. Homeowners and businesses are responsible for managing flood risk by knowing their flood risk and being aware, and through mitigation actions such as buying flood insurance. Ultimately, private-property owners are responsible for knowing their own flood risk in real estate transactions and for flood defences of their property.

GUIDELINES

Provincial flood land-use guidelines[35] provide good guidance on land-use planning and non-structural measures, including flood construction levels and setbacks and how to treat subdivisions versus redevelopment applications. These guidelines must be considered when local governments make bylaws.

New stormwater guidelines that address green infrastructure options are under development in BC.[36] The benefits of green systems are plentiful and include improving water quality, supporting water volume control, and reducing stormwater runoff.

Guidelines for the management of flood protection works in BC were developed in 1999[37] and provide guidance on engineered dikes.

INTEGRATED FLOOD MANAGEMENT

Given the impact of repeat flood events, some communities in BC are moving towards integrated flood and land-use management planning. This approach supports a portfolio of mitigation strategies. For instance, the community of Squamish has developed an Integrated Flood Hazard Management Plan (IFHMP), which supports the development of structural and non-structural measures together.[38] The community of Grand Forks is rebuilding post-flood using a range of mitigation approaches.

LAND-USE PLANNING

Land-use planning tools are an essential component of flood risk management and should include the integration of flood considerations into community plans, guides, and strategies, including waterfront revitalization plans, major infrastructure projects, capital plans, and open space/recreation plans. Zoning bylaws and regulations can prohibit certain building types and uses allowed within flood-prone areas. For instance, the District of North Vancouver has established development permit areas for creek areas to minimize flood hazards.[39]

For local stormwater flooding in urban areas, reducing the use of impervious surfaces, limiting urban sprawl, and decreasing stormwater runoff by retaining water on site and allowing it to infiltrate (through rain gardens, infiltration trenches, green roofs, porous pavement, and more) are key. The City of Vancouver established a

REBUILDING GRAND FORKS AFTER THE FLOOD

After devastating floods in 2018, Grand Forks and outlying communities along the Kettle and Granby rivers are building back stronger using an integrative approach and a combination of mitigation strategies. These include the buyout of 130 properties in high-risk floodplain areas to create natural floodplains for the river to occupy during floods, and the construction of dikes to protect other parts of the city. High-priority roads are being raised, floodplains and riparian areas restored, and residents assisted with relocation. Grand Forks is one of the first communities in BC to establish a buyout program to purchase homes in high-risk flood areas, leaving a large area of land that can be returned to its natural state.

A risk assessment was required to apply for funding under the Disaster Mitigation and Adaptation Fund. Consultants were hired to assist the community with completion of the assessment and develop options for a plan to move forward on consultation with the community.

Rain City Strategy in 2019 to increase resilience through sustainable water management and improve natural and urban ecosystems and water quality.[40]

Land-use planning tools are an essential component of flood risk management and should include the integration of flood considerations into community plans, guides, and strategies, including waterfront revitalization plans, major infrastructure projects, capital plans, and open space/ recreation plans.

Subdivision controls can limit development by preserving riparian areas, protecting open spaces, limiting development on steep slopes, reconnecting rivers to floodplains, restoring and conserving wetlands, and establishing flood bypasses and setback dikes to give the river room to expand during flood seasons.

Provincially regulated zones, such as the Agricultural Land Reserve or conservation easements, are other regulatory tools that can be used. Flood risk management guidelines for locating new infrastructure facilities set out acceptable flood thresholds for new infrastructure. Adopting a similar approach in BC would be invaluable in limiting the development of critical infrastructure in floodplains.[41]

EDUCATING AND INFLUENCING BEHAVIOUR

The public plays a crucial role in managing flood risk to their properties and saving lives with timely evacuation. A flood preparedness guide developed by PreparedBC can assist individuals in setting up an emergency plan. It provides guidance on protecting one's home and property, understanding advisories and warnings, preparing a sandbag dike, rules for evacuation, returning home after the flood, what to expect, managing mould and health risks, psychological care, and insurance.[42] Flood-ready social media content developed by Emergency Management British Columbia can be used by organizations to communicate with the public on how to prepare before, during, and after a flood.[43] For agricultural producers in floodplains, a new Farm Flood Readiness Toolkit[44] has been developed to increase awareness and understanding of flood risks, identify vulnerable areas and components on a farm, identify measures to protect farmers' properties from flooding, and create a flood preparedness plan. However, these resources may not be universally accessible, especially to vulnerable individuals.

Bulletins and maps produced by the BC River Forecast Centre on current and forecast streamflow conditions provide advisories and warnings to the public and emergency managers.[45]

MANAGING FINANCIAL IMPACTS OF FLOODS

Provincial Disaster Financial Assistance (DFA) may compensate individuals, small businesses, farms, and charitable organizations for

essential uninsurable losses once a disaster is declared. To receive compensation, one must occupy the property as the principal residence (seasonal or recreational properties aren't eligible). Farms must be in development or established and owned and operated full-time by a farmer, where the majority of their income is derived from the farm. Insurance deductibles, non-essential and recreational items, and losses due to erosion and landscaping are not covered.

A separate provincial program exists for Indigenous and local governments to rebuild or replace essential public infrastructure to pre-disaster conditions. This program does not include preventative measures to guard against future damages, enhancements to projects, or eroded or damaged land except for essential access routes and the removal of debris.

When response and recovery costs exceed the provincial threshold, the DFA program receives funds from Public Safety Canada through the Disaster Financial Assistance Arrangements program. Eligible costs include evacuation, repairs, and restoration to public works, personal property, farmsteads, and small buildings. The program does not support repairs to non-primary dwellings, repairs eligible through insurance, damages to large businesses, loss of income, or economic recovery.[46]

DISASTER RECOVERY FUNDS IN BC BUDGET 2022

Following the damaging floods and wildfires of 2021, the BC 2022 budget,[47] allocated $2.1 billion to fund disaster recovery and future responses to wildfires and floods. The fund supports communities and critical infrastructure to build back better; $400 million is to be invested in 2022–2023 for Emergency Management BC to support people and communities, and $1.1 billion is for contingencies for disaster recovery costs over the next three years. (This is in addition to $5 billion allocated by the Government of Canada to help response and recovery efforts in BC.) Of the $600 million for operating and capital funds, $83 million is to be invested in a Climate Preparedness

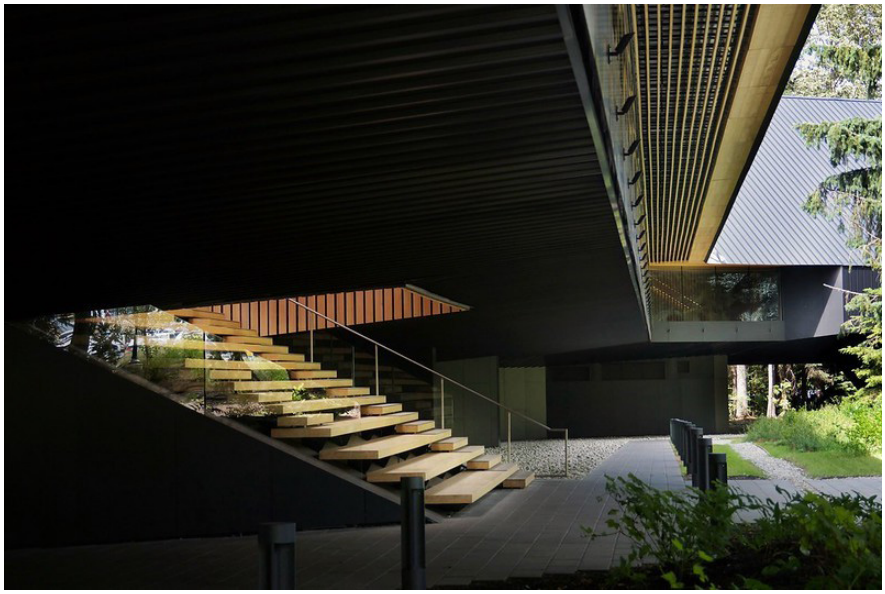

Figure 5: The Audain museum (Photo: Thomas Cartier/flickr).

FLOOD-RESISTANT STRUCTURES

Land-use planning and building design can allow us to live with water by allowing space for seasonal flooding and adapting to "having our feet wet." Approaches as diverse as parks and open spaces in floodplains, bringing in fill to build communities up beyond flood construction levels, leaving basements undeveloped, and requiring flood-resistant building design and construction are all effective means to reduce flood risks.

Elevated structures, such as the Audain museum built in the floodplain of Fitzsimmons Creek in Whistler, are elevated by one storey above grade to avoid damage from debris during a flood (Figure 5).

and Adaptation Strategy, which includes expansions to climate monitoring networks, additional capacity for the BC River Forecast Centre, the provincial floodplain mapping program, collecting building data, supporting expertise for climate risk mitigation, and climate-ready transportation networks; $30 million in grants will help safeguard BC's watersheds.

MANAGING FLOOD PROTECTION

In BC, there are more than 1,100 kilometres of regulated dikes, half of which are in the Lower Mainland.[48] A number of non-structural and small-scale infrastructure projects are currently funded under the National Disaster Mitigation Program, including projects such as decommissioning the Gardom Pond Dam in the Capital Regional District and raising a dike at the City of Fernie. The Disaster Mitigation and Adaptation Fund (DMAF) supports large-scale infrastructure projects to manage natural disasters. For example, the City of Richmond is being supported by a DMAF fund of $13.7 million to support the development of 2.6 kilometres of dike improvements and upgrade five drainage pump stations.[49]

The Adaptation, Resilience and Disaster Mitigation (ARDM) program is also funding flood mitigation infrastructure projects for individual communities (up to $10 million) and joint applications submitted by multiple communities (up to $20 million). The program has a total of $81.9 million in federal and provincial support for projects that increase structural capacity and/or natural capacity with the intent of reducing or avoiding flood damages.

MANAGING FLOOD PROTECTION DURING RESPONSE

If information and alerts are available, instant dams and berms can be installed to divert flood water and protect infrastructure. Elongated flexible tubes (known as "tiger dams" by one manufacturer) can be stacked and filled end to end with water to protect infrastructure from flooding. These have been widely used in BC as an effective means to hold back waters during a flood. For instance, the Ministry of Transportation and Infrastructure set up one of these structures during the November 2021 flood in the Sumas Prairie.[50] These reusable structures are set up quickly by trained personnel and can be used instead of sandbags to hold back the water up to a certain depth when waves, debris, and water velocity are manageable (Figure 6).

FLOOD WARNING TIMES

The amount of advance warning provided before a flood changes the impact it has on a community. With sufficient advance warning times, temporary mitigation efforts, such as sandbags and tiger dams, can lessen impacts. However, the ability to provide advance warnings depends on the type of flood and characteristics of the watershed. For some floods on larger lakes, there may be a week or a month of lead time to prepare for the event. On some larger rivers, one or two days' notice prior to flooding is the best that can be expected under ideal circumstances. However, for many small creeks and rivers, advance

Figure 6: Inflatable flexible tubes set up during the November 2021 flood (Photo: BC Ministry of Transportation/flickr).

warning time is much shorter, on the order of hours to even minutes, and in some cases, it may not be possible to get the word out in advance of flooding at all. It may be impossible to predict exactly how flood events unfold; however, it is possible to identify areas more likely to flood due to locations within floodplains as well as the condition of existing flood infrastructure. BC's system of flood watches and warnings provides some indication of elevated flood risk conditions developing and is an important public safety notification tool, but it generally cannot be used to predict the exact severity and timing of flood events at specific sites.

GAPS IN REDUCING RISK

FRAGMENTED FLOOD RISK GOVERNANCE

Many jurisdictions are involved in flood management. With flexible regulation and targets for enforcement and a lack of clear understanding of roles and responsibilities, this has led to fragmented flood risk governance.[51]

Lack of funds, staff limitations, competing priorities, and in-house expertise can vary widely between communities resulting in a lack of equity between communities to address flood risk.

Historically, the focus on flood risk has been reactive. This needs to change to focus on recovery and disaster resilience before the next flood event.

In addition, a lack of incentives for local and regional governments to manage flood risk through land-use planning and non-structural measures has led to a focus and reliance on costly structural measures.

Many jurisdictions are involved in flood management. With flexible regulation and targets for enforcement and a lack of clear understanding of roles and responsibilities, this has led to fragmented flood risk governance.

The *Local Government Act* states that "If a local government considers that flooding may occur on land, the local government may, by bylaw, designate the land as a flood plain."[52] The flexibility in the wording means that some communities may not designate areas as floodplains, especially where flood maps do not exist. When flood management occurs at the community scale, without proper engagement with neighbouring communities, management decisions upstream can have damaging effects on downstream communities.

As part of Reconciliation, strengthening and working with First Nations leadership related to flood management and compliance with the United Nations Declaration on the Rights of Indigenous Peoples needs to be prioritized. Many Indigenous communities are exposed to greater flood risks due to forced relocation in floodplains, and systems are lacking to operationalize UNDRIP.

GUIDELINES ARE LIMITED

Provincial flood guidelines are limited in scope. Guidelines are also just that—guidelines, not requirements—and there is no path for enforcement or incentives.

A historical focus on structural mitigation, including the building of dikes and dams, has tended to encourage development behind these structures, putting people, buildings, and infrastructure at risk. Dikes are costly (both financially and to local ecosystems) and need to be maintained and upgraded to withstand seismic shaking during earthquakes and prevent flooding.

There is a need for an integrated flood planning guideline that includes structural and non-structural measures, addresses climate change, land-use change, and ensures First Nations involvement. An integrated approach would allow for safe flooding in some areas to add "room for the river" and allow rivers to interact across their floodplains and create rich habitats and flood-safe communities. Measures should also address erosion protection, mitigate for multi-hazards where possible, and explore green technologies and bioengineering.

Forestry practices and related legislation and policy may not adequately address the impacts of

forest harvesting on flood risks in some watersheds, such as higher-elevation forests with significant snowpack, and changes to snow dynamics and peak flows—although some uncertainties likely remain, and this is an evolving science.[53]

FUNDING IS INADEQUATE

Funding programs are often oversubscribed and limited to specific adaptation and mitigation measures. Funding programs also typically prioritize high-quality applications rather than the highest-risk areas. This leads communities without resources to complete sophisticated applications at a disadvantage. Some at-risk communities may not even apply to access these programs due to the complexities in putting together proposals and a lack of staff capacity.

There is a lack of funding programs that allow for nature-based mitigation approaches. Many of the rebuilding-focused funding programs are for structural approaches (though Infrastructure Canada has recently opened a new fund for natural infrastructure[54]). Current funding programs could lead to maladaptation by preventing the implementation of a portfolio of adaptation approaches. Historically, private and public insurance funded projects that rebuild to the pre-disaster condition. The program was revised in April 2022 to limit financial assistance to one occurrence. Future claims may not be accepted, and owners are expected to undertake mitigation measures to protect against future floods.[55]

Managed retreat (such as property buyout) is not funded, and buyout programs are difficult to implement as systems are not in place to support effective implementation and funding for land acquisition.

There is a lack of funding programs that allow for nature-based mitigation approaches. Many of the rebuilding-focused funding programs are for structural approaches.

OPPORTUNITY

RECOMMENDATIONS

Table 4 summarizes some key recommendations that can be taken to make BC more flood resilient into the future.

THE CHALLENGE

Cross-border flooding: The many jurisdictions needed to effectively work together to understand and mitigate flood risks and build resilience across jurisdictions (e.g., Nooksack River flood risks) makes this a complex issue to address. In addition, the legislation in Canada and the United States addresses risk differently, which can further complicate issues.

Intellectual property issues: Ownership of information and data limits who can access data or information. This makes modelling, and mapping flood risks a challenge. In particular, critical infrastructure owners and operators may be hesitant to share information due to security-related concerns. There is a need to address OCAP (Owner Control Access and Possession) principles[58] when handling, sharing, and working with data from Indigenous communities.

Media reports: Many media descriptions of the November 2021 floods characterized them as "unprecedented," yet many of these areas have experienced repeated, predictable, devastating floods. For example, the Nooksack River also flooded into Canada in November 1990, and experts as well as the international Nooksack River Task Force were well aware of these flood risks. Large catastrophic events have happened in the past and continue to happen in the same places. These events must be identified as anticipated, not "unprecedented" events.

Table 4: Recommendations.

Recommendation	Description of Impact	Priority Level	Capabilities Needed
Understanding Risk			
1. Complete publicly available flood maps for all flood-prone communities in BC for current and future conditions.	Areas of high flood risk are identified using a consistent approach, and inaccuracies are minimized.	Critical	Technical
2. A province-wide flood risk assessment that includes a range of mitigation scenarios and captures information on historical events.	Mitigation and adaptation reduce impacts effectively, and communities are more equitably resilient to flood risks. Post-event data and forensic data informs an understanding of future impacts and risk reduction measures.	Necessary	Technical
3. Provincial guidelines are expanded to include an integrated approach and move beyond structural mitigation, including natural approaches, land-use planning tools, and visualization tools.	Communities and practitioners have increased awareness and guidance to address a range of mitigation approaches that take into account the health of the ecosystem.	Critical	Technical
4. Mortgage lenders, appraisers, and the public are aware of flood risks, including at the time of sale, lease, or rental of a property.	Individuals and the real estate industry are aware and can adapt to and prepare for flood risks.	Critical	Technical
Risk Governance and Building Back Better			
5. Coordinate governance structures to manage, share, and update regional maps in areas prone to flood hazards; make high-level decisions about flood risk mitigation; and monitor progress and changes within the catchment area.	Supports the creation of an integrated flood management strategy. The BC DRR Hub concept note provides details on the benefits of a collaboration hub.[56]	Critical	Technical, Financial
6. Regional growth strategies, official community plans, development permit areas, zoning bylaws, floodplain regulations, subdivision bylaws, servicing bylaws, and building codes take into account natural hazard risks and consider natural infrastructure and open spaces as flood resilience tools.	Land uses and building codes consider flooding and climate change impacts.	Critical	Legislation, Technical
7. Expand strategic and comprehensive funding to allow for an integrated approach to flood risk management.	Allows funding to expand support for a variety of options, including managed retreat and nature-based solutions.	Critical	Technical, Financial

Recommendation	Description of Impact	Priority Level	Capabilities Needed
Risk Governance and Building Back Better			
8. Update dike management to include a provincial repository of dike information and assign owners to orphaned dikes.	Support dike maintenance, upgrades, and audits; streamline emergency response and recovery planning and actions; increase the public's risk awareness.	Critical	Technical, Financial
Preparedness, Response and Recovery			
9. Improve and expand flood forecasting and early warning systems.[57]	Communities and emergency responders are better prepared to respond to and cope with floods.	Critical	Technical, Financial
10. All flood-prone communities have capacities for emergency response and have flood response plans.	Communities are better prepared to manage and respond effectively to floods.	Critical	Financial

RESOURCES

BC AND CANADA

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Natural Resources Canada. "Building Regional Adaptation Capacity and Expertise Program." Accessed June 17, 2022. https://www.nrcan.gc.ca/climate-change-adapting-impacts-and-reducing-emissions/building-regional-adaptation-capacity-and-expertise-program/21324.

2. A series of reports that looks at current issues, challenges, and opportunities for flood management in BC.

Fraser Basin Council. "Investigations in Support of Flood Strategy Development in BC." Accessed June 17, 2022. https://www.fraserbasin.bc.ca/BC_Flood_Investigations.html.

3. A portal that provides information on flood risk management for Fraser River flood and coastal flood hazards and risks in the Lower Mainland.

Floodwise in BC's Lower Mainland. "Your information portal on flood risk management." Accessed June 17, 2022. https://floodwise.ca/.

4. A community of practice to that supports best practices and solutions to treat the land in a shore-friendly way.

Stewardship Centre for British Columbia. "Green Shores – how it works." Accessed June 17, 2022. https://stewardshipcentrebc.ca/green-shores-home/gs-about/how-it-works/#:~:text=Green%20Shores%20is%20Science%2DBased,transport%20processes%20and%20natural%20areas.

5. A guide to regional decision making for the Regional District of Central Okanagan on non-structural flood mitigation.

Ebbwater Consulting. *Non-structural Flood Mitigation Resource Guide*. Regional District of Central Okanagan, 2021. Accessed June 17, 2022. https://www.rdco.com/RDCO-Flood-Resource-Guide_20211216.pdf.

6. A review of the current understanding of flood buyout programs in Canada and managed retreat with lessons learned from the buyout program in Grand Forks following the 2018 floods.

Le Geyt, Melissa. "Expanding the adaptation toolbox: Exploring managed retreat in Grand Forks, BC." MSc diss., University of Waterloo, 2022.

7. A tool to create a community disaster resilience plan for all hazards.

Justice Institute of British Columbia. "Increase Disaster Resiliency in Your Community." Accessed July 15, 2022. https://cdrp.jibc.ca/.

INTERNATIONAL

8. Principles to achieve strategic flood management that could be applied across jurisdictions in BC.

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9. A public-private partnership led by the Nature Conservancy that provides resources to support an integrated and collaborative approach to enable communities and the environment to rethink floodplains.

Floodplains by Design. "Reducing risks, restoring rivers." Accessed June 17, 2022. https://www.floodplainsbydesign.org/.

10. A resource to help property owners and buyers assess strategies to reduce flood risk. This resource is intended for decision makers in the United States, but some of the learning can be used by Canadian property owners and buyers.

Reduce Flood Risk. "Reduce your flood risk." Association of State Floodplain Managers. Accessed June 20, 2022. https://www.reducefloodrisk.org.

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