

# BC Floodplain Maps Inventory Report

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THE UNIVERSITY OF BRITISH COLUMBIA  
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## Executive Summary

Floods cause significant damages to properties, human well-being, environment and pose an economic burden on governments. Flooding has a wide range of impacts on society and overall environment in the forms of damages to properties and infrastructure, injuries and deaths, among others. Contaminated floodwater tends to pollute potable water, canals and destroy crops and farms. Physical and emotional trauma are quite common among the victims of flooding, as well.

The extent of flood damages often gets magnified by unthoughtful choices of locations for settlement, incoherent land-use policies and the inability to enhance the resilience of communities to adapt to the unforeseeable challenges posed by floods. Consequently, the British Columbia Real Estate Association (BCREA) is interested in seeking solutions to improve awareness of the updated inventory of floodplain maps among governments, REALTORS® and consumers, and assess the impacts of senior government funding programs on the ability of communities to prepare and update maps.

With financial support from the Real Estate Foundation of British Columbia, BCREA and the University of British Columbia Okanagan (UBCO) jointly conducted this study to assess the current level of awareness of flood risks among the communities in BC. To accomplish this, we conducted a questionnaire survey with local governments and Indigenous communities to create a current inventory of BC floodplain maps, updating work done by BCREA in 2015.



The key findings of this study are as follows:

- A total of 109 local governments and First Nations responded to the survey, with a response rate of 32.3%.
- More than half of the communities have no or little in-house flood management expertise.
- Since 2015, 38.5% (N=42) of the communities created (N=23) or updated (N=19) floodplain maps; the remaining 61.5% (N=67) of the communities reported that they have not created or updated a floodplain map.
- The new or updated floodplain map is publicly available only for the 57.1% (N=24) of the communities.
- The most common reasons for not creating or updating floodplain maps were communities lacking access to funding, expertise, data, engagement and planning.
- Out of 23 communities that answered the question, 11 (47.8%) prioritize floodplain mapping highly or very highly.
- Only 20.5% (N=8 out of 39) of communities believe that updating floodplain mapping increases their liability to a high or very high degree.

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# 1. Introduction

Flooding has long been a major issue around the world. The frequency and magnitude of floods have been increasing in the past decades (Atta-ur-Rahman, Parvin, Shaw & Surjan, 2016; Eldho, Zope & Kulkarni, 2018). Especially high-intensity rainfall, decreased permeable areas, inadequate capacity of drainage, narrowing and straightening urban creeks, and climate change have increased the risk of urban flooding (Liao, Le & Nguyen, 2016).

Urban floods affected the largest number of people claiming 24% of deaths among all types of natural disasters in 2018 (OOSA, 2019). Examples of catastrophic urban floods, like the flooding in New Orleans (USA) in 2005 (Dixon, et al., 2006), the flooding in Queensland (Australia) in 2010-2011 (Karim, Kinsey-Henderson, Wallace, Arthington & Pearson, 2012), and the flooding in the Rio Grande do Norte (Brazil) in 2013 (Robaina, Kormann & Schirmer, 2013) all caused severe damages to both the population and the city infrastructure. In the last century, the frequency of urban flooding in Venice has increased from less than ten events a year to more than 60 events a year (Imboden, 2021).

In Canada, the reports of floods have increased in cities such as Kelowna (BC), Calgary (AB) and Montreal (QC) during the past years. In Kelowna, a series of consecutive floods, notably 2017, 2018 and 2019, presented a tremendous challenge for the existing infrastructure and urban planning process, making the community socially, economically and physically vulnerable. This also raises serious questions about the current resilience of the city against floods.

Often, the extent of flood damages gets magnified by unthoughtful choices of locations for settlement, incoherent land-use policies and inability to enhance the resiliency of cities to adapt to the unprecedented challenges posed by floods (Armenakis, Du, Natesan, Persad & Zhang, 2017; Nahiduzzaman, Aldosary & Rahman, 2015; Rahman, Aldosary, Nahiduzzaman & Reza, 2016). In Canada, the Disaster Financial Assistance Arrangements (DFAA) costs due to floods are estimated to have increased to over \$650 million a year from 2016 until 2021 (Canada, 2016). In 2013, Southern Alberta and the Greater Toronto Area witnessed the most expensive floods in Canadian history, resulting in property loss of as much as \$6 billion (City of Calgary, 2017) and \$1 billion, respectively (Insurance Bureau of Canada, 2018). In 2018, over 1,500 properties across a large area of Granby, Kettle, and West Kettle rivers, and Carmi region (southeast of Kelowna) in interior British Columbia were evacuated due to a major flood. Since 2016, the cities of Montreal and Kelowna, among others, have been repeatedly hit by flash floods that caused property damages, while disrupting daily mobility with very high financial, social and safety costs. The Central Okanagan region experienced record-breaking, rainfall-driven flash floods combined with the snowmelt and snowpack in 2017, 2018 and 2019. In 2019, Kelowna reported 52 locations that required rigorous repairs in infrastructure, costing approximately \$10.7 million (City of Kelowna, 2019).

Much-needed mitigation strategies might not be created unless governments collect first-hand information of residents' experience, perspectives in flood preparedness and update floodplain maps as part of their overall flood management planning (Chowdhoree, 2019; Ramsey, et al., 2019).

Floodplain maps provide important information that communities need for land use planning alongside helping property buyers make informed decisions. In 2015, the British Columbia Real Estate Association (BCREA) completed its first inventory of floodplain maps with support from the Real Estate Foundation of British Columbia. However, an updated, complete inventory of BC floodplain maps is needed that will help First Nations, the federal and BC governments, municipalities and regional districts understand the current state of floodplain maps across BC.

An updated inventory of floodplain maps is especially critical for current and potential real estate owners and REALTORS® to help them understand the flood risk associated with properties. That's why it is important for them to have access to this report, which is a composition of updated inventory of floodplain maps and a synthesis of the perceived risks of flood and their geographic variability across BC. BCREA initiated this project to update the inventory partly because of the creation of the National Disaster Mitigation Program (NDMP) in 2015. The NDMP provided significant funding for mapping projects, and BCREA wanted to determine whether more maps were generated, as a result.

## 2. Methodology

A questionnaire-based online survey was emailed to 186 local governments and 151 First Nations in British Columbia from November 24, 2020 to December 22, 2020. The information issued to the respondents included a URL link to an online questionnaire, along with consent and recruitment letters.

### 2.1 Questionnaire design

The objective of this survey was to collect information about the availability of floodplain maps, publication year, demographic and watershed information, nature and source of flood risk, use of floodplain maps and federal government's support to create floodplain mapping projects. Other technical information was also collected, such as techniques used to prepare the map (e.g., LiDAR, orthophoto, bathymetric), associated studies (e.g., topography, hydrology, infrastructure survey, land use, hydraulics), flood map types (flood depth, velocity, event, hazard), flood protection measures in place (flood protection infrastructure, drainage infrastructure), flood occurrence and damages in the past decade, availability of floodplain management plan, adequacy of flood protection measures, and inclusion of flood issues in municipal environmental awareness campaigns.

An online questionnaire was developed using UBC's survey tool (Qualtrics). The questionnaire provided for this survey consisted of open- and closed-ended questions asking the respondents to choose among various options. In some questions, a Likert scale was used to get said information in the question. According to the general rules of a well-constructed survey questionnaire, it must consist of several layouts/sections with the corresponding goal of each section. In this case, the questionnaire contained four sections including 29 specific questions in total.

- Section 1 included six questions aimed at getting general information, including the consent of the person, name of the community and respondent's designation.
- Section 2 comprised 16 main questions concerning flood maps and related studies.
- Section 3 consisted of four questions mainly on the model's topographic data, critical infrastructure, buildings and other assets that may be vulnerable to flood impacts.
- Section 4 included two final questions to obtain additional comments, suggestions and challenges the community faces regarding floodplain mapping activities

Further, the questionnaire was pilot tested with five individuals within the research team and participants. They tested the feasibility and validity of all the questions and the time it took to complete the survey (see Appendix A for the survey questionnaire).

## 2.2 Consent and recruitment letters

The consent letter provided a brief summary of the study, including sponsor, the purpose of the study, study procedure, questionnaire, potential risks and benefits, confidentiality and the contact details of the research team. This letter provided evidence of a participant's agreement to be involved in the study. It noted that

taking part in this study is voluntary. You have the right to refuse to participate in this study. If you decide to take part, you may choose not to answer any question in the interview. You may choose to withdraw from the study at any time without giving a reason and without any negative consequences to your employment or your relationship with the interviewer, UBC Okanagan, and/ or any other entity related to the study. In case you choose to withdraw from the study, data you provided shall not be used. By completing the online questionnaire, you are consenting to participate in this research.

## 2.3 Ethics approval

The behavioral research ethics approval to conduct this study was received from the University of British Columbia Human Research Ethics Board. The Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans Course on Research Ethics (TCPS 2: CORE) was completed by the research team involved in the survey and communicated to the participants. During this approval, the Ethics Board reviewed the research proposal, the procedure, recruitment and consent letter, email body and questionnaire.

## 2.4 Floodplain map survey and target organizations

The contact information of survey respondents was obtained from BC CivicInfo and previous contact records. The following steps were followed during the survey:

- On November 24, an introductory email along with a recruitment letter and a link to the online survey and consent form was sent to all BC local governments and First Nations.
- A reminder email after one week was sent to respondents that had not yet responded.
- A second reminder email after two weeks was sent to the respondents who had still not responded.

Three options were given to the respondents to complete the online survey:

- Complete the online questionnaire on their own and send it back by clicking the submit button.
- Schedule a telephone conversation (telephonic interview) with a UBCO research student.
- Schedule a one-to-one video meeting with a research student.

## 2.5 Analysis

Simple descriptive statistics was used to analyze and present quantitative data collected from the questionnaire survey. To be specific, frequency distributions along with percentages were calculated to summarize the quantitative data that were presented through bar diagrams and pie charts. The qualitative information was reviewed and sorted into tabular forms.

## 2.6 Limitations

The low survey response rate and differing extent of survey completeness are found to be the main limitations. For instance, information about the type of funding source, flood hazard covered by map, data used to create or update maps, type of datum and access to other flood maps were partially filled in by the respondents (see Section 3 for the details). Additionally, the potential for human error due to asking one individual to represent the available knowledge of an entire organization might have impacted the completeness of responses. However, to overcome the extent of this limitation, we did our best to invite appropriate personnel from each community to complete the survey, based on the best available knowledge about their capacity.

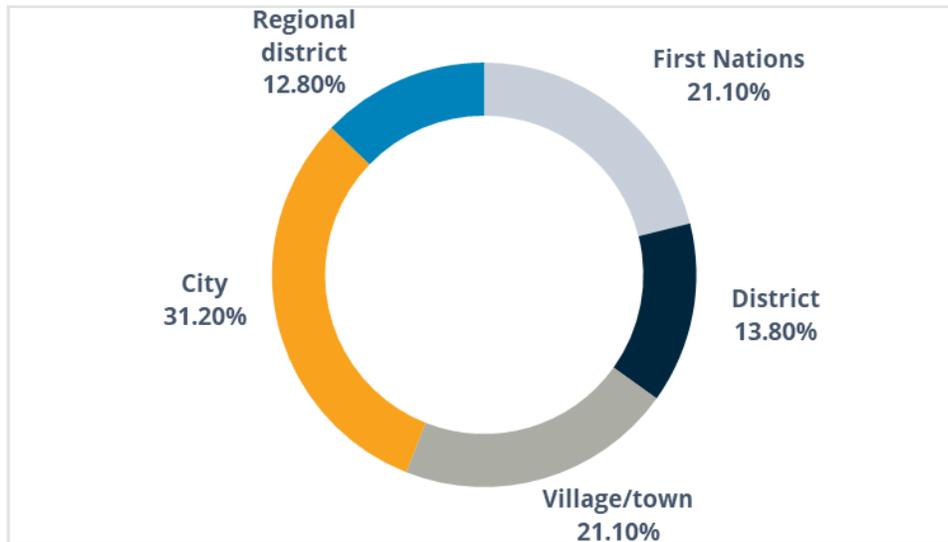
While this project is modeled on BCREA's research from 2015, the 2020 survey of local governments and First Nations included more questions; therefore, the two studies are not fully comparable. That being said, an attempt is made to comprehend the updated scenarios between 2015 and 2020 with a sense-making comparison. The data presented in this report represents the best available sample of information about the update and creation of floodplain maps in BC since 2015.

### 3. Results and discussions

#### 3.1 Participation

One hundred nine survey responses were received, amounting to a response rate of 32.3%. Figure 1 shows the response rate as per the community types. The highest responses (i.e., 31.2%) were received from cities, whereas the response rate from regional districts was the lowest with 12.8%.

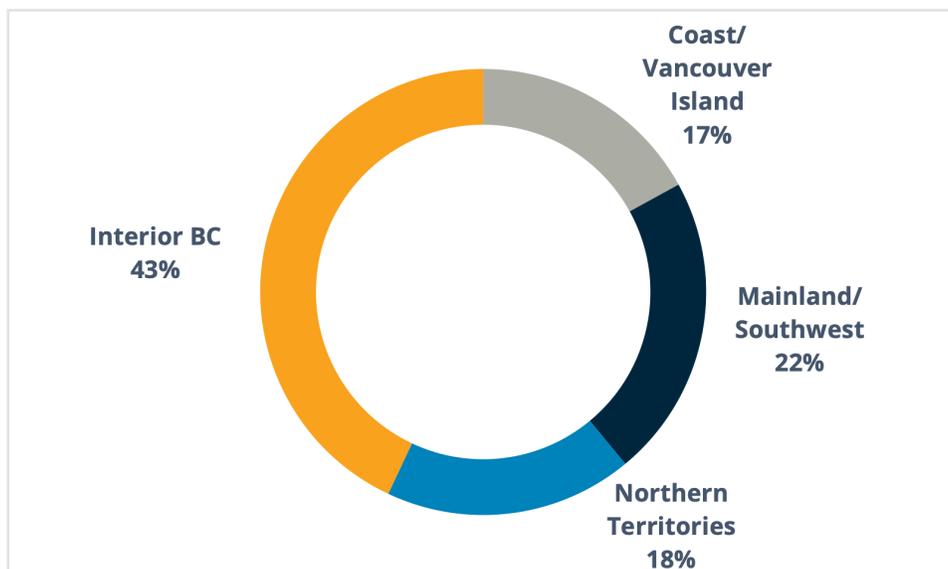
**Figure 1.** Response rate by type of governments (N=109)



As far as the region-specific response rate is concerned, the highest responses (43%, N=47) were from the Interior BC followed by Mainland/Southwest (22%, N=24), Northern Territories (18%, N=20) and Coast/Vancouver Island (17%, N=18) (Figure 2).

About 19% of the communities preferred to respond to the survey through telephonic conversations and video meetings.

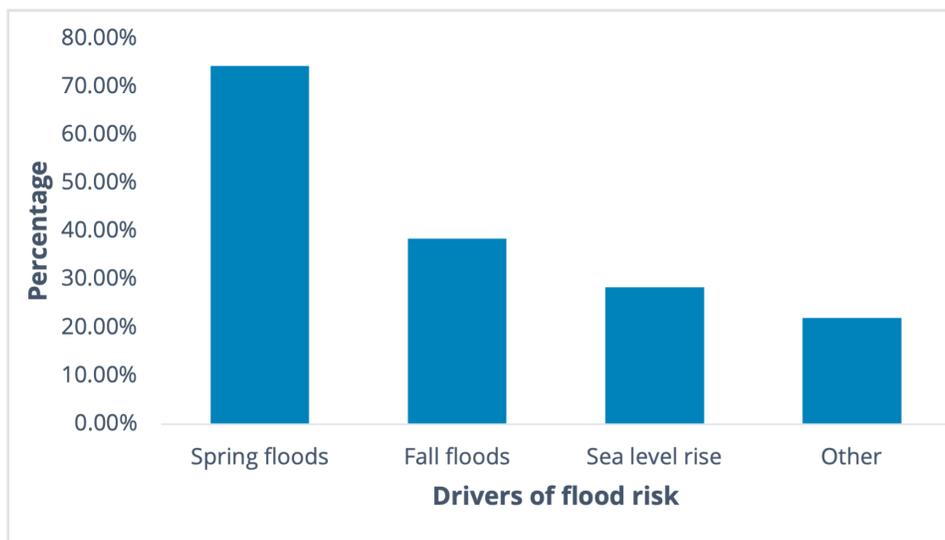
**Figure 2.** Geographical distribution of respondents (N=109)



### 3.2 Predominant drivers of flood risk

Survey respondents from 109 communities indicate that 74.3% (N=81) of flood risk is driven by spring floods, 38.5% (N=42) by fall floods, 28.4% (N=31) from sea level rise, and least from others with 22% (N=24) (Figure 3). A list of all the other drivers is shown in Table 1.

**Figure 3.** Drivers of flood risk (N=109)



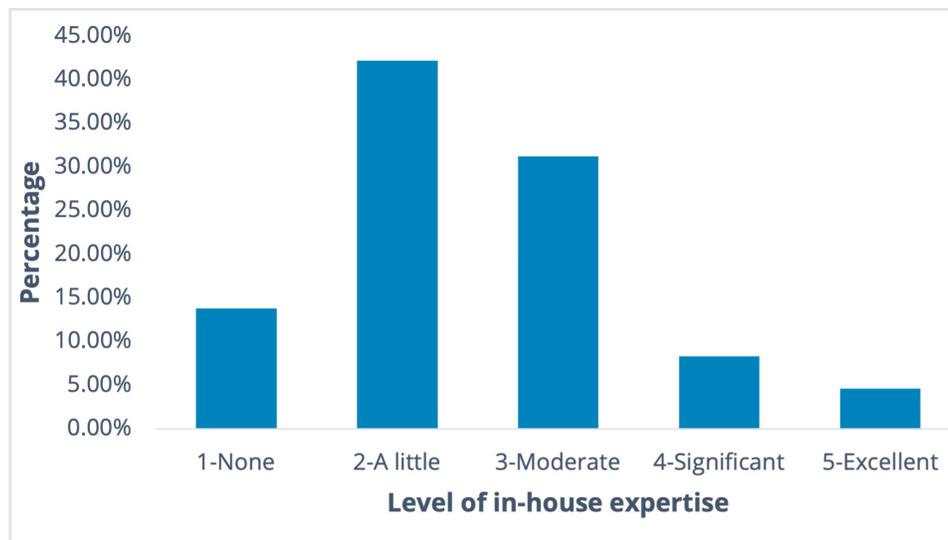
**Table 1.** Other drivers of flood risk (N=12)

N	Other drivers of flood risk
2	Heavy rainfall
2	Ice jams
1	Asset management
1	BC Hydro dam and canal
1	Climate change
1	Coastal storm flooding
1	Dam management
1	Debris flood
1	Debris torrent
1	Harvest of timber
1	Lake level rise
1	River floods
1	Steep creek hazards
1	Storm surge events (intertidal areas)
1	Storm surge events (winter)
1	Thunder storms
1	Tsunami
1	Underground streams
1	Wildfire effects

### 3.3 Level of in-house expertise

Most communities have a little (42.2%, N=46) to moderate (31.2%, N=34) in-house flood management expertise (Figure 4). Only 8.3% (N=9) of communities have significant expertise, and 4.6% (N=5) with excellent in-house expertise; however, 13.8% (N=15) of communities have no in-house expertise at all. The significant and excellent levels of in-house expertise exist in the communities from as early as 1994 and latest since 2017.

**Figure 4.** Percentage level of in-house expertise (N=109)



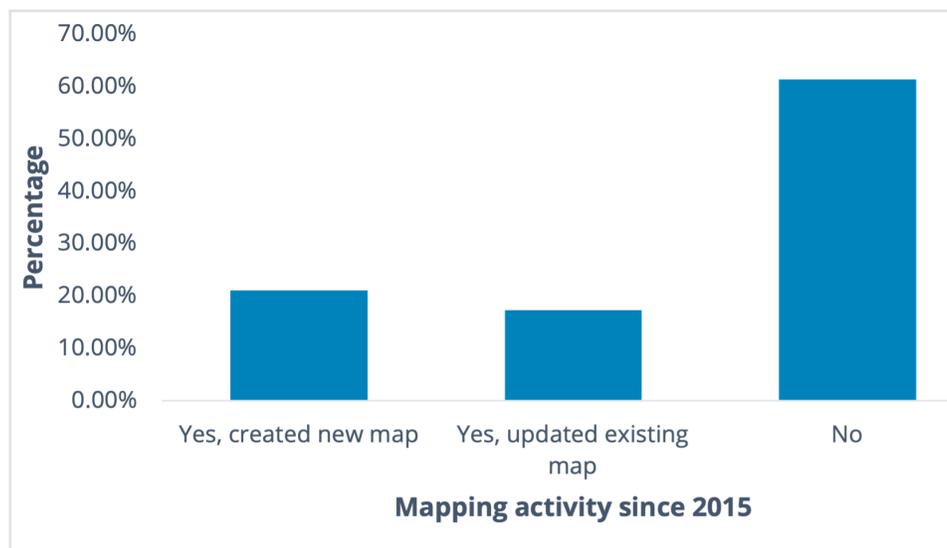
### 3.4 Creation or update of flood maps and studies

The survey response indicates that 21.1% (N=23) of communities created and 17.4% (N=19) updated existing floodplain maps since 2015 (Figure 5). However, the majority of the communities (61.5%, N=67) did not create or update floodplain maps since 2015. Therefore, these 67 communities skipped to Question #21 from Question #7 (see Appendix A for the questions).

Table 2 and Table 3 list information from the 40 communities out of 42 that provided the details of their new and updated floodplain maps, respectively, with a tendency to create new maps rather than update existing ones.

A total of 35 out of 42 communities provided brief descriptions of the projects that led to the creation and update of floodplain maps. Past flooding incidents and availability of grants/funding are the two most common reasons that led to the creation and update of floodplain maps. This information is summarised in Appendix B.

**Figure 5.** Percentage of new and updated maps since 2015 (N=109)



**Table 2.** List of new floodplain maps (N=23)

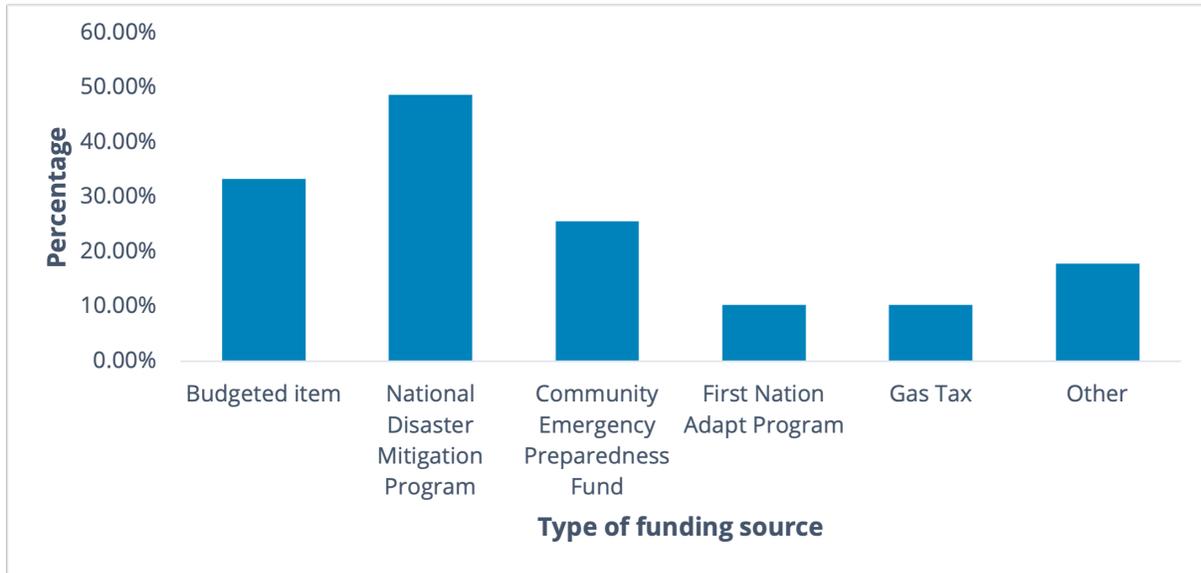
Local Government/ First Nation	New floodplain maps	Year created
Regional District of Bulkley Nechako	200-year floodplain mapping for a small area of the regional district	2019
Capital Regional District	Coastal flood inundation mapping (storm surge and sea level rise and tsunami)	2020
Regional District of Central Okanagan	Peachland and Trepanier Creeks floodplain mapping, Mission Creek floodplain mapping and hazard assessment, dam inundation studies for Crooked Lake and Swalwell Lake, Okanagan mainstem flood mapping for all of Okanagan Lake, Kalamalka Lake and Wood Lake	2015-2020
City of Chilliwack	Floodplain inundation map with flood construction levels	2019
Columbia Shuswap Regional District	Clearwater flood hazards	2019
City of Dawson Creek	River flood	2016 and 2020
Regional District of East Kootenay	Large river floodplain and hazard mapping	2019
Township of Esquimalt	Tsunami inundation areas map	2020
City of Grand Forks	0.5 Annual Exceedance Probability, topographical flood map	2019
Lil'wat Nation	50-, 100- and 200-year flood and hazard mapping	2018
Village of Lumby	Watershed map, 200-year flood depth year 2100 and 2200, flood mitigation plan	2019
Metlakatla First Nation	Tsunami risk mapping	2018
Town of Oliver		
Town of Osoyoos	GIS web mapping	2020
City of Penticton	Flood mapping for the two main creeks that run through the city	2018-2020
qathet Regional District (formerly Powell River Regional District)	Flood hazard area maps and coastal flood risk maps	2015-2018
City of Quesnel	Flood level maps	2019
Seabird Island Band	Flood and erosion protection	2018
Village of Telkwa	200-year flood inundation extents	2019
District of Tofino	Flood inundation, hazard, risk and emergency maps	2018
Upper Nicola Band	Flood inundation, hazard, risk	2018-2019
City of Vernon	Flood map or flood hazard map	2020-2021
District of West Vancouver	Flood construction level mapping	2020

**Table 3.** List of updated floodplain maps (N=19)

Local Government/ First Nation	Updated floodplain maps	Year updated
Village of Ashcroft	Schedule C Environmentally Sensitive and Hazardous Areas - Official Community Plan Bylaw No. 822	2018
Regional District of Central Kootenay	6 clearwater flood areas and 10 steep creeks	2019
Cowichan Valley Regional District	Fluvial and coastal	2008-2021
City of Fernie		
District of Hope	Coquihalla River floodplain map flood construction levels	2018
Kitimat Stikine Regional District	Floodplain mapping for the Skeena River and tributaries in the Terrace area	Ongoing
Kitsumkalum Band	Floodplain maps affecting reserve areas	2019-2020
District of Lake Country	Okanagan lake and river flood map	2019-2020
City of Langford	Official Community Plan - 200-year floodplain development permit area	2020
Metro Vancouver Regional District	Flood inundation maps	2018
City of Nelson	200-year flood map	2018
City of North Vancouver	Sea level rise mapping, updated floodplain mapping for Lynn Creek	2019 and 2020, respectively
Town of Princeton	200-year floodplain map	Currently underway
District of Squamish	Floodplain maps showing flood depth, flood elevation, velocity, hazard rating (combination of depth/velocity), social vulnerability and others	2015-2017
Squamish Lillooet Regional District	Digital	2018
Strathcona Regional District	River valley	2019
District of Vanderhoof	Floodplain bylaw 1174	2017
City of Victoria	Regional Coastal Flood Inundation Mapping Project	2020
Witset	Not sure of the type	2017-2018

The majority of the 39 communities that updated or created new floodplain maps since 2015 and responded to this particular question financed the projects through their own budgets (33.3%, N=13), the federal National Disaster Mitigation Program (48.7%, N=19) and the provincial Community Emergency Preparedness Fund (25.6%, N=10). The remaining funding was obtained from the First Nation Adapt Program (10.3%, N=4), federal Gas Tax (10.3%, N=4) and 17.9% (N=7) from others; i.e., Union of BC Municipalities, stormwater development cost charges funds, provincial funds and leveraged partnership (Figure 6). In total, 11 communities accessed more than one funding source including budgeted item, National Disaster Mitigation Program and Community Emergency Preparedness Fund.

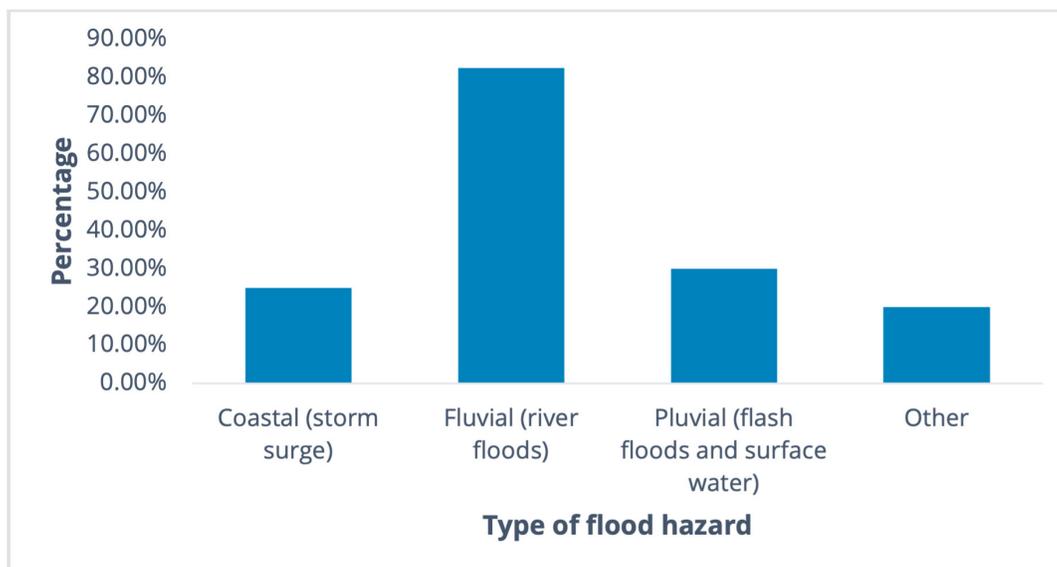
**Figure 6.** Type of funding source used by communities (N=39)



### 3.5 Type of flood hazard and coverage

For the 40 communities that updated or created new maps and responded to this question, 82.5% (N=33) of the maps related to river floods, 30% (N=12) to flash floods and 25% (N=10) to coastal floods (Figure 7 and Table 4). Fluvial (river floods) and pluvial (flash floods and surface water) are the common flood hazards that communities experience. A total of 17 communities chose more than one option, which implies that these communities have higher exposure and are vulnerable to different flood types.

**Figure 7.** Type of flood hazard covered by map (N=40)

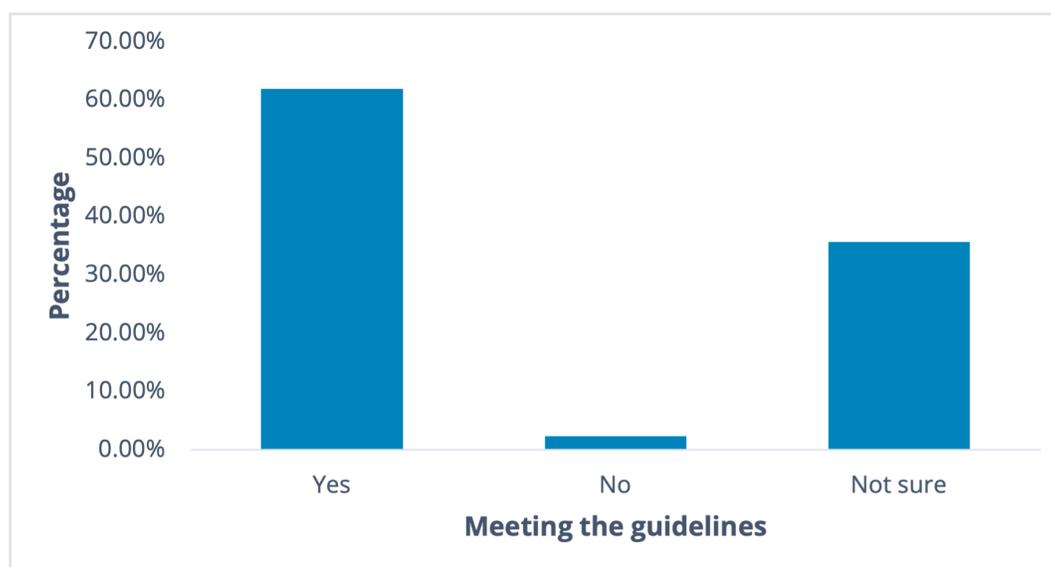


**Table 4.** Other flood hazards (N=6)

N	Other flood hazards
2	Steep creek alluvial fan hazards, debris flood or debris flow
1	Lake rise
1	Reservoir
1	Torrent flows and wave induced
1	Tsunami hazard

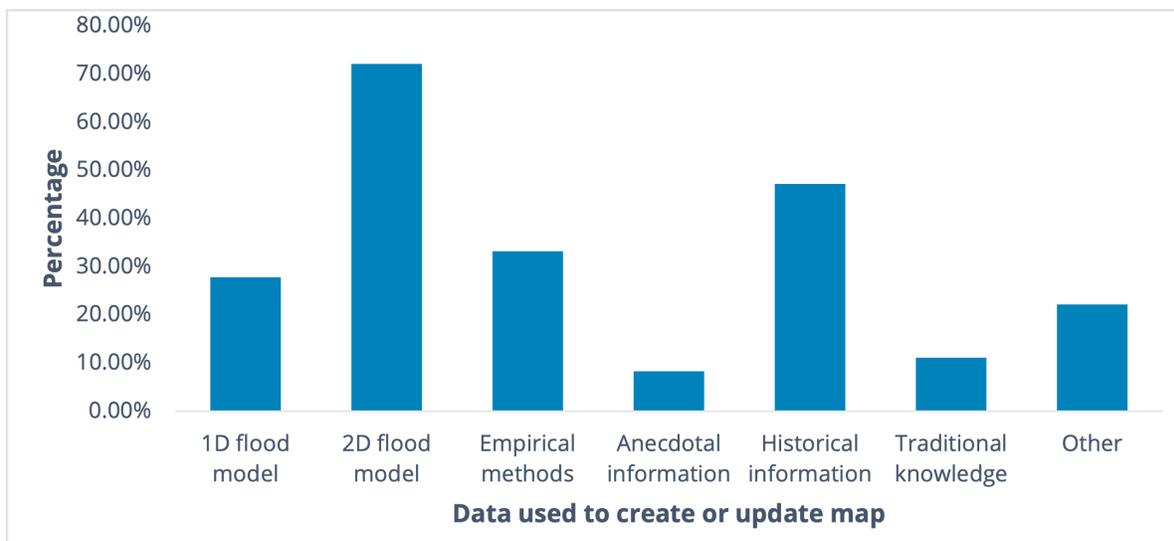
### 3.6 Meeting the guidelines

In total, 42 communities provided information about whether their flood map meets the BC Flood Hazard Area Land Use Management Guidelines. As shown in Figure 8, 61.9% (N=26) of these floodplain maps meet the guidelines, only 2.4% (N=1) do not and 35.7% (N=15) of communities were not sure, which might stem from the lack of in-house expertise or capacity.

**Figure 8.** Percentage of maps meeting provincial guidelines (N=42)

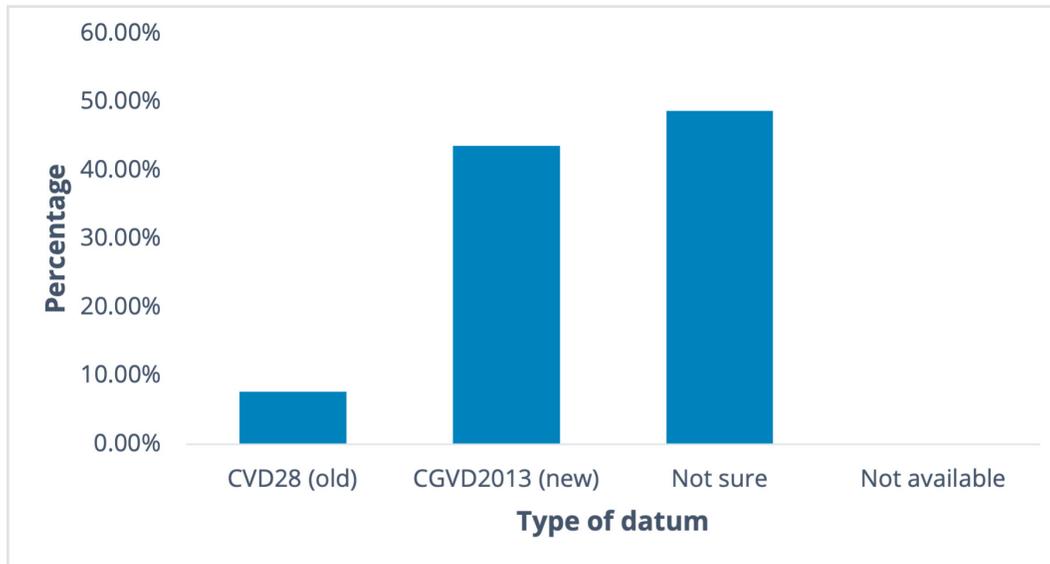
### 3.7 Data usage and sharing capabilities

The data used to create or update floodplain maps was 2D flood model by 72.2% (N=26) of communities, historical information by 47.2% (N=17), empirical methods by 33.3% (N=12), 1D flood model by 27.8% (N=10) of the communities. Further, anecdotal information (8.3%) N=3 and traditional knowledge (11.1%) N=4 were used by the least number of communities (Figure 9). Additionally, 22.2% (N=8) of the communities used other data (Table 5). Twenty-two communities used more than one data type and the most common combination was 2D flood model and historical information.

**Figure 9.** Data used by communities to create or update maps (N=36)**Table 5.** Other data used to create or update the floodplain maps (N=5)

N	Other data used to create or update maps
2	LiDAR
1	Bathymetric survey
1	Digital elevation model
1	Lake levels
1	Sea level rise flooding analysis
1	Surveyor reviewed river cross sections throughout the floodplain in the local jurisdiction

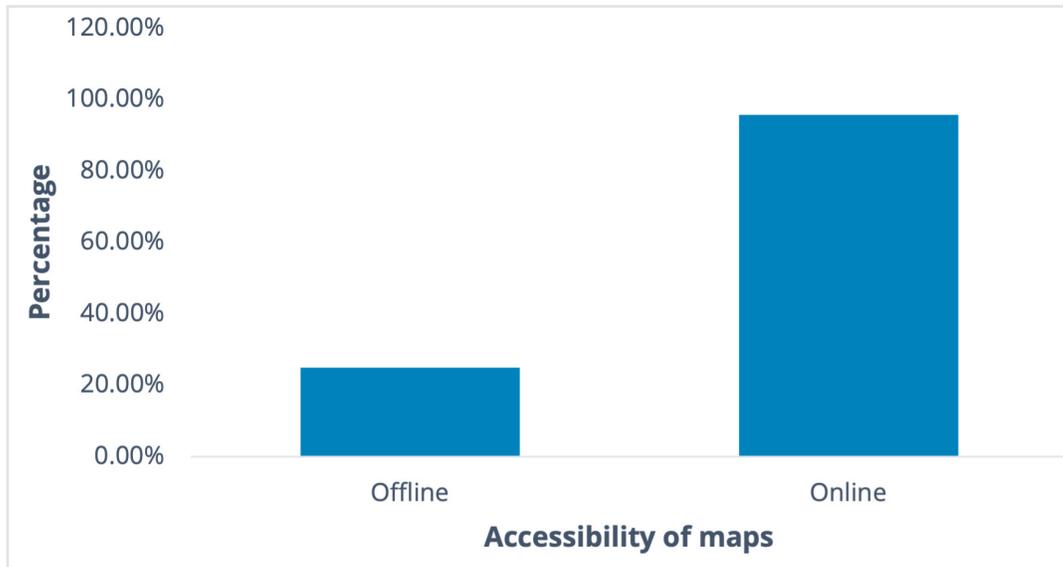
The datum used for the maps was reported by 39 (93%) out of 42 communities. The majority of the communities (43.6%, N=17) used CGVD2013 (Canadian Geodetic Vertical Datum of 2013) and CVD28 (Canadian Geodetic Vertical Datum of 1928) was used only by 7.7% (N=3) of the communities. However, 48.7% (N=19) were not sure about the type of datum they used for their maps (Figure 10). The application of datum to generate floodplain maps is technical knowledge which might not be known to everyone, especially communities without in-house expertise. Moreover, many communities have yet to update their floodplain maps with reference to the new datum, which was introduced in 2013.

**Figure 10.** Type of datum used by communities (N=39)

The floodplain map is publicly available only for 57.1% (N=24) of the communities (Figure 11). Of these 24 communities, the map can be accessed online for 18, offline for one community, and both online and offline for five (Figure 12). More details, including links, are available in Appendix B.

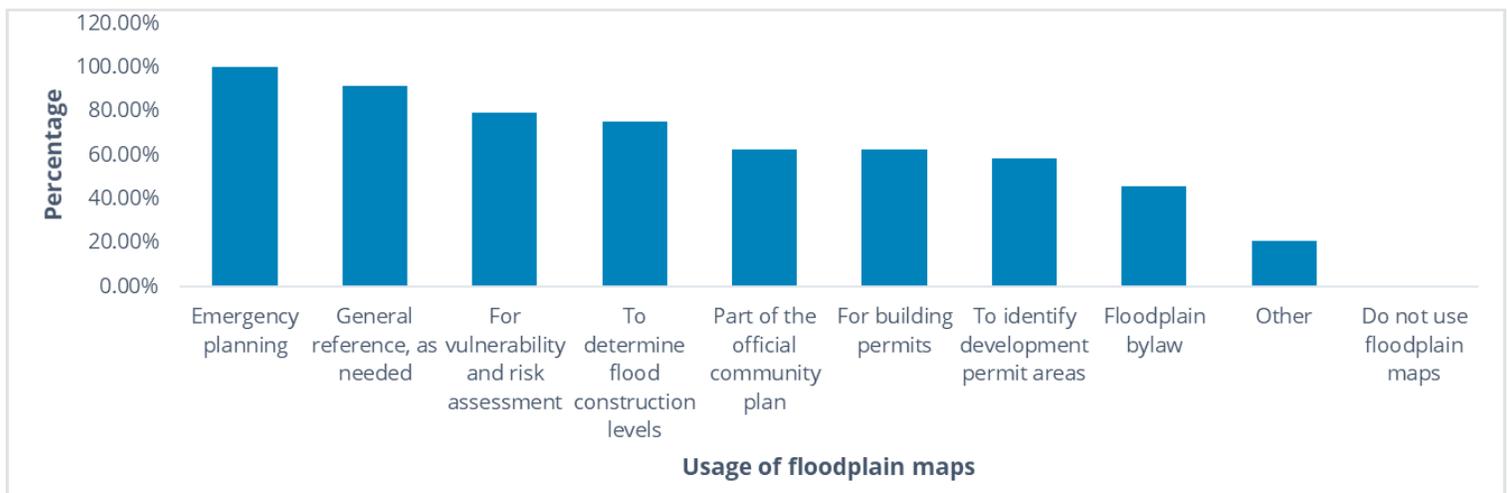
**Figure 11.** Public availability of maps (N=42)

**Figure 12.** Accessibility of maps (N=24)



The information from the floodplain map is very useful for communities, which use the maps for a range of various purposes. Of the 24 communities who responded to this question, 24 (100%) use floodplain maps for emergency planning, 22 (91.7%) for general reference as needed, 19 (79.2%) for vulnerability and risk assessment, 18 (75%) to determine flood construction levels, 15 (62.5%) as a part of the official community plan, 15 (62.5%) for building permits, 14 (58.3%) to identify development permit areas and 11 (45.8%) for floodplain bylaws (Figure 13). Besides, 20.8% (N=5) of communities use the maps for other reasons than mentioned above (Table 6).

**Figure 13.** Usage of floodplain maps (N=24)

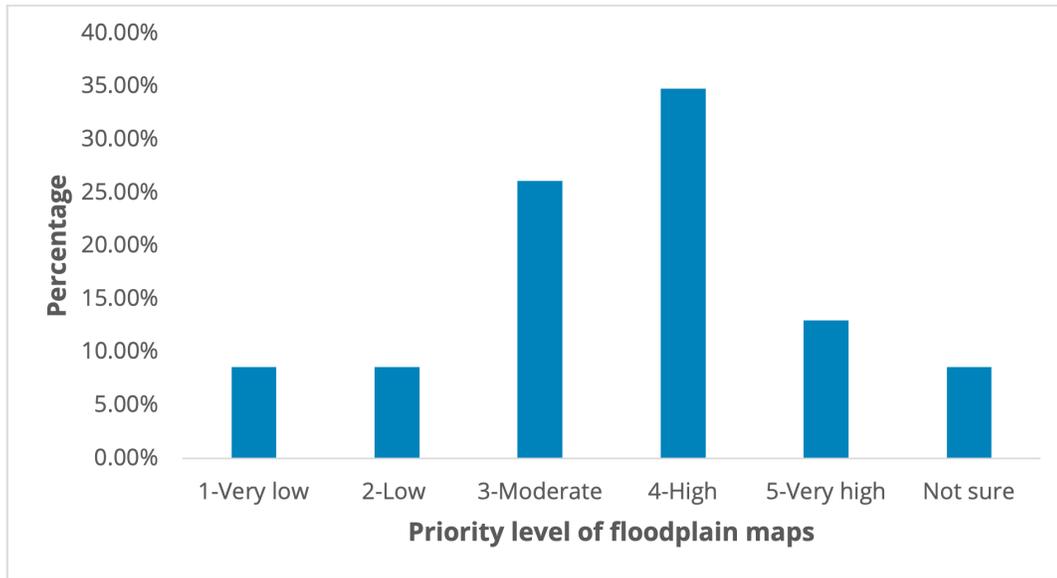


**Table 6.** Other uses of floodplain maps (N=3)

N	Other use of floodplain maps
2	Design of protective works
1	Asset management planning
1	Zoning bylaw development regulations

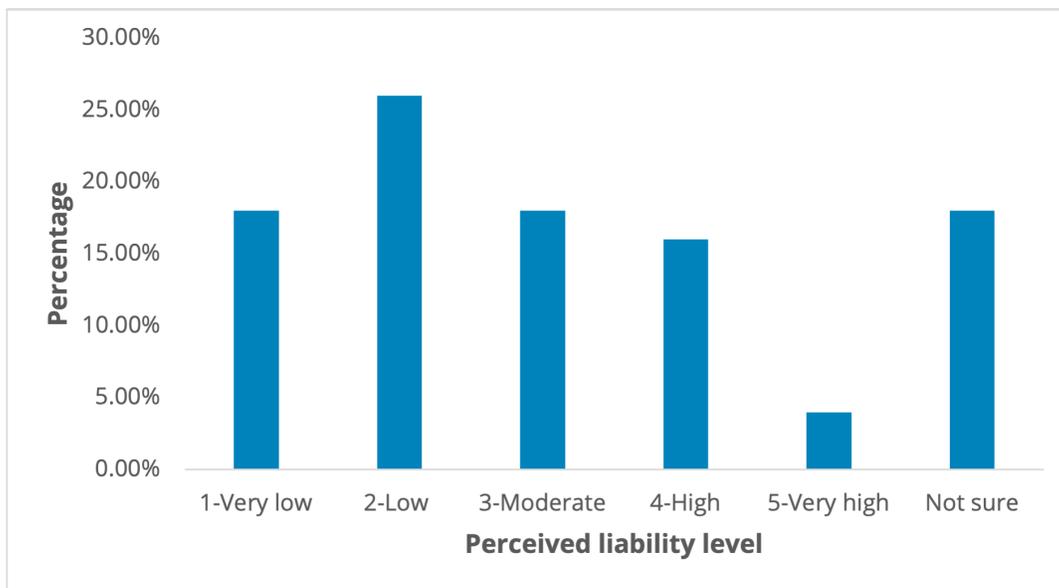
Twenty-three communities answered the survey question regarding how they prioritize floodplain mapping. As shown in Figure 14, only 13% (N=3) of communities are very highly prioritizing floodplain mapping and most communities prioritize mapping moderately (26.1%, N=6) to highly (34.8%, N=8).

**Figure 14.** The priority level of floodplain mapping (N=23)



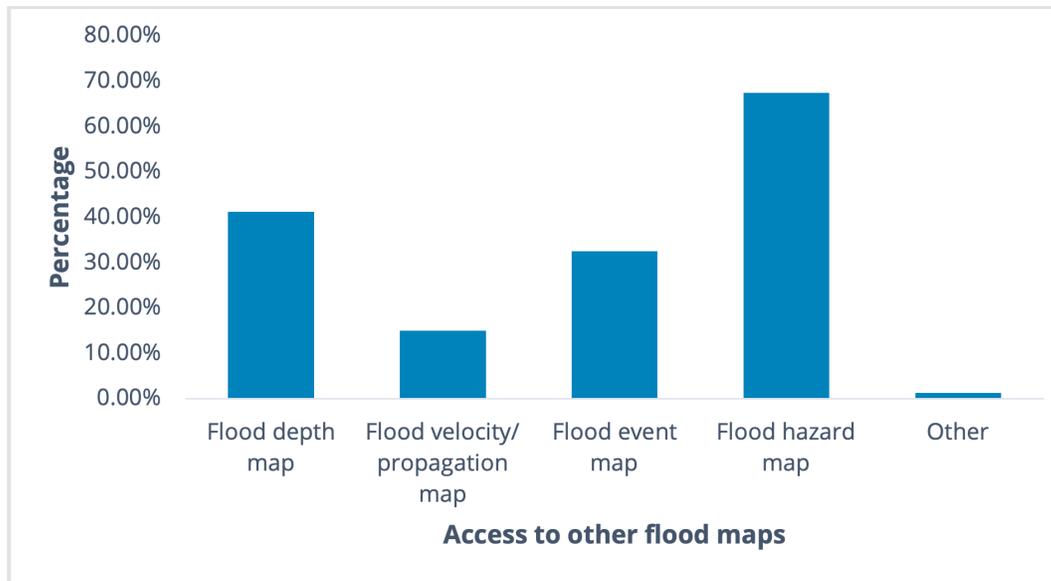
Further, 20.5% (N=8) of communities out of 39 believe that updating floodplain mapping increases their liability to a high or very high degree while 18% (N=7) of communities remain unsure (Figure 15).

**Figure 15.** Level of liability increase (N=39)



Out of the 80 communities that responded to this question, 67.5% (N=54) have access to flood hazard maps, 41.3% (N=33) to flood depth maps, 32.5% (N=26) to flood event maps and 15% (N=12) to flood velocity/propagation maps (Figure 16). Furthermore, only one community has access to a tsunami map. A total of 37 communities have access to more than one map: two types of maps are accessible to 19 communities while nine communities can access three types of maps. The remaining nine communities have access to four types of maps. This may lead communities to better gauge their vulnerability and prepare well for flood mitigation and adaptation.

**Figure 16.** Access to other flood maps (N=80)



The inventory of flood-related studies undertaken since 2015 in support of determining the spatial extent of a floodplain map is given in Appendix C. In total, 47 out of 109 communities have undertaken at least one flood-related study. The most common are hydrologic, hydraulic, flow and infrastructure studies (Table 7). Only 32 communities have access to any hydrological or hydraulic model or information of when communities last updated these models (Appendix D).

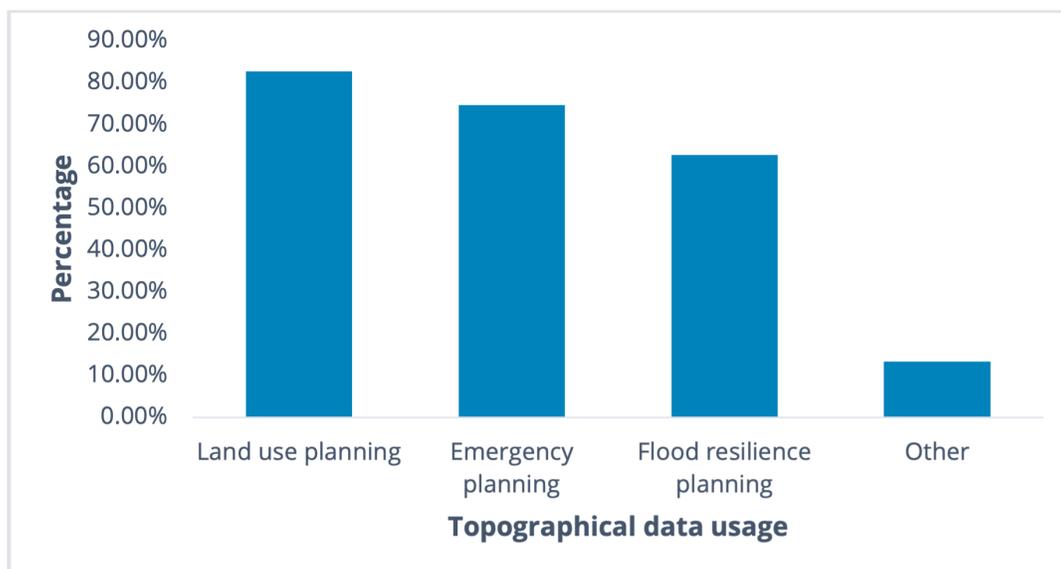
**Table 7.** Flood-related studies undertaken since 2015 (N=47)

Local Government/ First Nation	Topographical study	Infrastructure survey	Land use study	Weather or climate study	Flow studies	Hydrologic study	Hydraulic study	Needs assessment or gap assessment	Other	Total
Village of Belcarra										2
City of Burnaby	✓	✓		✓	✓		✓	✓		6
Village of Burns Lake									✓	1
City of Campbell River	✓	✓		✓	✓	✓	✓			6
Capital Regional District									✓	1
Regional District of Central Kootenay	✓	✓			✓	✓	✓			5
City of Chilliwack	✓					✓	✓			3
City of Cranbrook	✓	✓			✓	✓	✓			5
Columbia Shuswap Regional District								✓		1
Cowichan Valley Regional District	✓		✓	✓	✓	✓	✓	✓		7
City of Dawson Creek		✓			✓	✓	✓			4
City of Delta	✓			✓				✓		3
City of Fernie		✓					✓	✓		3
City of Fort St. John	✓				✓					2
City of Grand Forks	✓	✓	✓	✓		✓	✓		✓	7
Haisla Nation			✓							1
District of Houston						✓	✓			2
City of Kamloops				✓	✓	✓			✓	4
Kitimat Stikine Regional District			✓			✓	✓			3
District of Kitimat								✓	✓	2
City of Langford		✓	✓		✓			✓		4
Lil'wat First Nation								✓		1

Village of Lions Bay		✓				✓				2
Village of Lumby		✓				✓	✓	✓	✓	5
City of Maple Ridge								✓		1
City of Nanaimo				✓	✓	✓	✓			4
City of Nelson	✓	✓		✓	✓	✓	✓	✓		7
Peace River Regional District									✓	1
Village of Pemberton						✓				1
City of Penticton	✓	✓			✓	✓	✓		✓	6
City of Port Coquitlam		✓		✓	✓	✓			✓	5
qathet Regional District (formerly Powell River Regional District)	✓	✓								2
Town of Qualicum Beach	✓		✓	✓				✓		4
City of Richmond	✓	✓		✓				✓		4
District of Saanich		✓			✓			✓		3
Village of Silverton	✓									1
Spuzzum First Nation			✓							1
District of Squamish	✓		✓		✓	✓	✓	✓		6
Squamish Lillooet Regional District						✓			✓	2
City of Surrey	✓	✓	✓	✓	✓	✓	✓		✓	8
District of Tofino							✓			1
Tskwaylaxw First Nation			✓							1
Tzeachten First Nation			✓							1
Uchucklesaht Tribe Government									✓	1
Upper Nicola Band	✓	✓			✓					3
City of Vernon							✓			1
City of Williams Lake	✓	✓			✓	✓	✓	✓		6
<b>Total</b>	<b>19</b>	<b>20</b>	<b>11</b>	<b>13</b>	<b>19</b>	<b>21</b>	<b>21</b>	<b>15</b>	<b>11</b>	

The inventory of topographic data available to local governments and First Nations is given in Appendix E. Mostly this data was used for land use planning N=62 (82.7%), emergency planning N=56 (74.7%) and flood resilience planning N=47 (62.7%) (Figure 17). Only ten communities (13.3%) use topographic data for other purposes (Table 8).

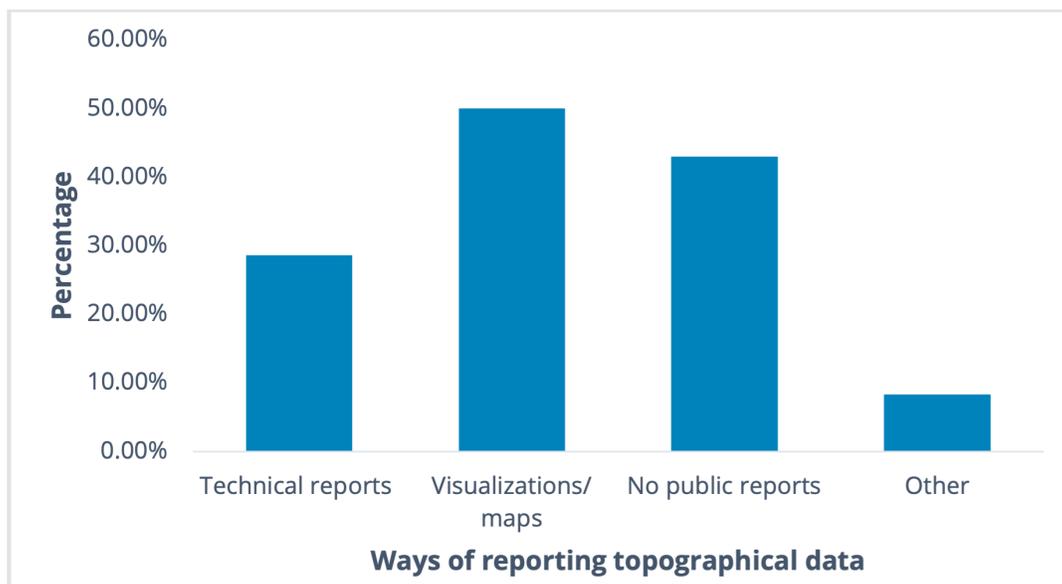
**Figure 17.** Purposes of using topographical data by communities (N=75)



**Table 8.** Other ways of using topographical data (N=6)

N	Other ways of using topographical data
2	Infrastructure
1	Ecological mapping
1	Flood response
1	Interface fire planning
1	Locate possible well sites
1	Nearly many aspects of the city's work
1	Subdivision review and approvals

For the 84 communities that responded to this question, topographic data is publicly reported mainly through visualization/maps (50%, N=42) and technical reports (28.6%, N=24) (Figure 18). Forty three per cent (N=36) of communities do not publicly report this data, and only 8.3% (N=7) use web-based GIS, websites, official community plans, social media and drainage study reports to report the data publicly.

**Figure 18.** Ways of reporting the topographical data (N=84)

In total, 48 communities provided information about infrastructure. Twenty-three per cent (N=11) had data about flood protection infrastructure, 25% (N=12) about drainage infrastructure and 52% (N=25) for both flood protection and drainage infrastructure. The list of collected data including erosion protection, watercourses, pump stations, flood gates and dikes is given in Appendix F.

### 3.8 Addressing challenges to floodplain mapping

Several challenges to floodplain mapping have been identified through this survey (Table 9).

**Table 9.** Challenges to floodplain mapping (N=48)

Challenges	N	Context
Lack of expertise, knowledge and information	22	Lack of knowledge, expertise and updated information to help prepare floodplain maps, update official community plan and emergency plan, and assess vulnerability and risk. Substantial data gaps in infrastructure records due to lack of updated floodplain data and mapping
Lack of funding	18	Lack of funding from the provincial government for mapping and planning
Lack of staff capacity	6	Lack of staff in stormwater management and workload issues
Lack of time	4	Lack of time to update and create floodplain mapping
Uncertainty in prediction	3	Difficult to predict the impacts of failure of permanent flood protection structures, behaviour of tsunami and flood damage
Climate change denial	1	Lack of acceptance of sea rise and climate change
Political barriers	1	Political barriers to implement this change
Lack of engagement and planning	1	Lack of engagement and planning, especially during the lock-down time due to COVID-19

Along with the challenges mentioned in Table 9, 25 communities suggested solutions. The most common suggestion (N=9) was to collect data in order to upgrade the floodplain and hazard mapping and floodplain management bylaws. This would provide information about the flood hazard parameters, including flood inundation zone, maximum flood depth, flow velocity and evacuation requirements which would help the community to make appropriate decisions on infrastructure assessment, hazard and mitigation planning. Another suggestion was that the Government of BC needs to undertake a comprehensive process to update floodplain mapping throughout the province. Other suggestions included:

- emergency response plans (N=6),
- risk assessment (N=4),
- flood protection infrastructure (N=2),
- a comprehensive management system to reduce the impacts of flooding (N=1),
- industry standard practices (N=1),
- prioritize the flood hazard areas for appropriate land use planning (N=1).

In various waterfront communities, flooding of developed areas can occur due to a combination of natural conditions and land use activities, and more flooding is to be expected with climate change. As such, most of these communities are committed to the proactive management of flood hazards. In response to this risk, one community initiated a three-phase regional floodplain management plan to reduce flood risk, improve emergency response and increase resiliency to climate change. The overall objective was to develop a better understanding of flood risk within the community to reduce the likelihood of damage from flooding. The three phases are:

- (i) developing a regional floodplain management that identifies the flood hazards and establishes the scope and priorities of phase 2 and 3,
- (ii) conducting flood hazard and risk assessment and flood mapping, and
- (iii) creating flood risk mitigation strategies.

## 4. Conclusions

It has been observed that there is a vast need of updating and upgrading floodplain and hazard mapping in British Columbia. More than half of the communities (56%) out of 109 have no or a little in-house flood management expertise. In total, only 38% of the communities created or updated floodplain maps since 2015. The most common issues for communities not creating or updating floodplain maps were lack of access to funding, expertise and time. Topographical, infrastructure survey, flow, hydrologic and hydraulic flood studies were mostly undertaken since 2015 to help determine the spatial extent of floodplain maps. Moreover, LiDAR and orthophoto were found to be the most common types of topographical data used by the majority of communities.

Land use plays a vital role in flooding, though only 62% of the maps created since 2015 meet the British Columbia Flood Hazard Area Land Use Management Guidelines. Some municipalities are not aware of where to locate any information that would relate to the floodplain mapping. Small communities are significantly dependent on provincial and federal funding to carry out floodplain-related projects. There is a need for trained staff to understand the complex data and triangulate that with pertinent information from the communities to gauge their level of flood exposures. As well, from a consistency, planning and cost management perspective, there is a lot of work to be done at the regional, provincial and national scales.

In total, 109 responses were received in 2020 with a moderate response rate (32.3%) which is 12.8% higher than 2015. This itself is an indication that awareness about the mitigation of flood risk is increasing. More responses were received from First Nations, Villages/Towns and Cities in 2020. However, less participation was observed from Districts and Regional Districts than 2015. Such variation could be attributed to the fact that not all communities across BC perceive flood risk on a similar magnitude because their exposure varies. A future study should consider the relationship between the nature of risk perceptions by the communities and their needed actions to mitigate flood risks. This relationship partly explains the nature and type of corresponding actions such as updating or creating floodplain maps.

This project has resulted in an inventory which offers a current state of floodplain maps in BC communities. The inventory presents detailed information about the type of data, flood hazard, floodplain maps, usage and challenges to create or update the floodplain maps. This information will help BCRA as a roadmap and priority for local, regional and First Nations governments to understand and raise awareness on the importance of floodplain maps. More efforts such as proper guidelines for the development and upgrading of floodplain maps, standardization of data and information, strong and sufficient financial and technical support will all improve the condition of floodplain mapping in British Columbia.

## References

- Armenakis, C., Du, E., Natesan, S., Persad, R. & Zhang, Y. (2017). Flood risk assessment in urban areas based on spatial analytics and social factors. *Geosciences*, 7(4), 123.  
<https://doi.org/10.3390/geosciences7040123>
- Atta-ur-Rahman, Parvin, G. A., Shaw, R. & Surjan, A. (2016). Cities, vulnerability, and climate change. *Urban Disasters and Resilience in Asia*, 35–47.  
<https://doi.org/10.1016/B978-0-12-802169-9.00003-3>
- Canada. (2016). Estimate of the average annual cost for disaster financial assistance arrangements due to weather events. OTTAWA, ON: Office of the Parliamentary Budget Officer.
- Chowdhoree, I. (2019). Indigenous knowledge for enhancing community resilience: An experience from the south-western coastal region of Bangladesh. *International Journal of Disaster Risk Reduction*, 40, 101259. <https://doi.org/10.1016/j.ijdrr.2019.101259>
- City of Calgary. (2017). The flood of 2013. Calgary.  
<https://www.calgary.ca/uep/water/flood-info/flooding-history-calgary.html>
- City of Kelowna. (2019). Flooding.  
<https://www.kelowna.ca/city-services/safety-emergency-services/flooding>
- Dixon, T. H., Amelung, F., Ferretti, A., Novali, F., Rocca, F., Dokka, R., Whitman, D. (2006). Subsidence and flooding in New Orleans. *Nature*, 441(7093), 587–588.
- Eldho, T. I., Zope, P. E. & Kulkarni, A. T. (2018). Urban flood management in coastal regions using numerical simulation and geographic information system. *Integrating Disaster Science and Management: Global Case Studies in Mitigation and Recovery*, 205–219.  
<https://doi.org/10.1016/B978-0-12-812056-9.00012-9>
- Imboden, D. (2021). High tides and flooding in Venice, Italy.  
<https://europeforvisitors.com/venice/articles/acqua-alta.htm>
- Insurance Bureau of Canada. (2018). Toronto Flood Causes over \$80 Million in Insured Damage. In Insurance Bureau of Canada.  
<https://www.newswire.ca/news-releases/toronto-flood-causes-over-80-million-in-insured-damage-692706351.html>

- Karim, F., Kinsey-Henderson, A., Wallace, J., Arthington, A. H. & Pearson, R. G. (2012). Modelling wetland connectivity during overbank flooding in a tropical floodplain in north Queensland, Australia. *Hydrological Processes*, 26(18), 2710–2723. <https://doi.org/10.1002/hyp.8364>
- Liao, K. H., Le, T. A. & Nguyen, K. Van. (2016). Urban design principles for flood resilience: Learning from the ecological wisdom of living with floods in the Vietnamese Mekong Delta. *Landscape and Urban Planning*, 155, 69–78. <https://doi.org/10.1016/j.landurbplan.2016.01.014>
- Nahiduzzaman, K. M., Aldosary, A. S. & Rahman, M. T. (2015). Flood induced vulnerability in strategic plan making process of Riyadh city. *Habitat International*, 49, 375–385. <https://doi.org/10.1016/j.habitatint.2015.05.034>
- OOSA. (2019). Flooding affected more people in 2018 than any other disaster type report shows. 2 Jul 2019. <https://reliefweb.int/report/world/flooding-affected-more-people-2018-any-other-disaster-type-report-shows>
- Rahman, M. T., Aldosary, A. S., Nahiduzzaman, K. M. & Reza, I. (2016). Vulnerability of flash flooding in Riyadh, Saudi Arabia. *Natural Hazards*, 84(3), 1807–1830. <https://doi.org/10.1007/s11069-016-2521-8>
- Ramsey, M. M., Muñoz-Erickson, T. A., Mélenhez-Ackerman, E., Nytch, C. J., Branoff, B. L. & Carrasquillo-Medrano, D. (2019). Overcoming barriers to knowledge integration for urban resilience: A knowledge systems analysis of two-flood prone communities in San Juan, Puerto Rico. *Environmental Science and Policy*, 99, 48–57. <https://doi.org/10.1016/j.envsci.2019.04.013>
- Robaina, L. E. de S., Kormann, T. C. & Schirmer, G. J. (2013). Zoning of flooding in urban alegrete - Rio Grande do Sul - Brazil. *Geociencias*, 32(2), 346–355.

# Appendix A: Survey Questionnaire

## BC Floodplain Maps Inventory Survey

Format: this will be an online survey.

Thank you for taking time to complete this survey in support of developing a current inventory of floodplain maps in British Columbia – it should take you about 15 minutes. The British Columbia Real Estate Association (BCREA) is reaching out to communities and First Nations to gain a better understanding of the availability and use of floodplain maps in BC. The University of British Columbia Okanagan (UBCO) is collaborating with BCREA to conduct this survey. At the conclusion of this work, we will prepare and provide you with a summary report.

UBCO may follow up with you for clarification. BCREA and UBCO will only use the information gathered through this survey to assemble an inventory of BC floodplain maps and prepare a summary report.

Please contact Manjot Kaur, [manjot.kaur@ubc.ca](mailto:manjot.kaur@ubc.ca) if you have any questions.

### About You and Your Community

1. Are you consenting to participate in this research?

- Yes
- No

2. Name of your community/ First Nation: \_\_\_\_\_

3. Your position: \_\_\_\_\_

4. Flood risk in your community is predominantly driven by: (choose all that apply)

- Spring floods
- Fall floods
- Sea level rise
- Other (please explain)

5. What level of in-house flood management expertise do you have in your organization?

- 1-none
- 2-a little
- 3-moderate
- 4-significant
- 5-excellent

6. If you answered 4 or 5 to question 5, since what year have you had this expertise in house?

### **Flood Maps and Studies**

7. Has your community created and/or updated a floodplain map since 2015?

- Yes, created new map
- Yes, updated existing map
- No, please skip to Question 21.

8. Please specify the type of floodplain map you created or updated.

9. What year did you create or update the map?

10. What types of flood hazard are covered by your map? (choose all that apply)

- Coastal (storm surge)
- Fluvial (river floods)
- Pluvial (flash floods and surface water)
- Other (please explain)

11. Does your map meet the BC Flood Hazard Area Land Use Management Guidelines?

- Yes
- No
- Not sure

12. Briefly describe the project or event that led to the creation or update of the floodplain map.

13. What funding sources were used to create or update the floodplain map? (choose all that apply)

- Budgeted item
- National Disaster Mitigation Program
- Community Emergency Preparedness Fund
- First Nation Adapt Program
- Gas Tax
- Other (please describe)

14. If known, what data were used to create or update the floodplain map? (choose all that apply)

- 1D flood model
- 2D flood model
- Empirical methods
- Anecdotal information
- Historical information
- Traditional knowledge
- Other (please specify)

15. What datum does your map use?

- CVD28 (old)
- CGVD2013 (new)
- Not sure
- Not available

16. Is the floodplain map publicly available? If no, please skip to question 20.

- Yes
- No

17. Please describe how the map can be accessed.

- Offline (Paper copy)
- Online (web link):

18. How does your community use floodplain maps? (choose all that apply)

- General reference, as needed
- Part of the official community plan (OCP)
- Emergency planning
- For vulnerability and risk assessment
- To identify development permit areas
- To determine flood construction levels
- For building permits
- Floodplain bylaw
- Other (please explain)
- Do not use floodplain maps

19. How does your community prioritize floodplain mapping relative to other projects?

- 1-very low
- 2-low
- 3-moderate
- 4-high
- 5-very high
- Not sure

20. To what extent do you believe updating floodplain mapping increases your community's liability?

- 1-very low
- 2-low
- 3-moderate
- 4-high

- 5-very high
- Not sure

21. Which other flood maps does your organization have access to, if any? (choose all that apply)

- Flood depth map
- Flood velocity/propagation map
- Flood event map
- Flood hazard map
- Other (please specify)

22. Please describe any flood-related studies undertaken since 2015 in support of determining the spatial extent of a floodplain.

Type	Describe study, cost and funding source	Date undertaken (month and year)
Topographical study		
Infrastructure survey (size of bridges and culverts, etc.)		
Land use study		
Weather or climate study		
Flow studies (e.g., data collection)		
Hydrologic study (a study to establish the amount of flow)		
Hydraulic study (a study to establish where water might go)		
Needs assessment or gap assessment		
Other		

## Data

The following questions will help provide a better understanding of any data and tools that might be available to support regional floodplain mapping. BCREA is particularly interested in spatial data regarding the potential extent and depth of flooding, as well as critical infrastructure, buildings and other assets that may be vulnerable to flood impacts. Please list and describe to the best of your ability any data available to your community in this regard.

23. Please describe any models your community has access to (e.g., hydrological, hydraulic, etc.) and when they were last updated.

24. Please identify the details of the topographic data to which your community has access.

<b>Type</b>	<b>Date of data</b> (month and year)	<b>Area of coverage</b> (description, available formats)	<b>Describe capabilities you may have to share the data</b> (licensing, publicly available, through data-sharing agreement)
LiDAR			
Orthophoto			
Bathymetric			
Hydrographic			
Other			

25. How do you use the data described in question 23 internally? (choose all that apply)

- Land use planning
- Emergency planning
- Flood resilience planning
- Other (please describe)

26. How do you publicly report the data described in question 23?

- Technical reports
- Visualizations/maps
- No public reports
- Other (please describe)

27. Please list any mapped or other data your organization may have regarding the location and characteristics of flood protection and/or drainage infrastructure such as dikes, erosion protection, watercourses, drainage networks, pump stations, flood gates, etc.

<b>Type of infrastructure</b>	<b>Describe and include date of data</b> (month and year)	<b>Describe capabilities you may have to share the data</b> (licensing, publicly available, through data-sharing agreement)
Flood protection infrastructure		
Drainage infrastructure		

**Final Questions**

28. If you have any suggestions or additional comments regarding this survey or floodplain mapping efforts in your community, please provide them.

29. Please describe any challenges your community faces regarding floodplain mapping activities.

## Appendix B: Inventory of floodplain maps created or updated since 2015

Local Government/ First Nation	Type of map	Year created/ updated	Project/event leading to map	Funder	Data used	Accessibility
Village of Ashcroft	Schedule C Environmentally Sensitive and Hazardous Areas - Official Community Plan Bylaw No. 822	2018	Update of Official Community Plan Bylaw prompted the floodplain mapping update. This process included public engagement, existing document and plan review and the new bylaw drafting.	Budgeted item, First Nation Adapt program, Gas Tax, other		Both online and offline <a href="https://bit.ly/3w68vgj">https://bit.ly/3w68vgj</a>
Regional District of Bulkley Nechako	200-year floodplain mapping for a small area of the regional district	2019	Grant funding to undertake a Flood Mitigation Study for the Ebenezer Flats area near the Town of Smithers.	National Disaster Mitigation Program (NDMP)	2D flood models, empirical models, historical information	Both online and offline, currently unavailable
Capital Regional District	Coastal flood inundation mapping (storm surge and sea level rise and tsunami)	2020	Grant funding.	NDMP	1D flood models, 2D flood models	<a href="https://bit.ly/3hxkik1">https://bit.ly/3hxkik1</a>
Regional District of Central Kootenay	6 clearwater flood areas and 10 steep creeks	2019	2012 Johnson's Landing landslide. Grant funding used to prioritize risk areas and subsequently produce updated mapping for areas deemed highest risk.	Budgeted item, NDMP, Community Emergency Preparedness Fund (CEPF)	2D flood models, historical information	<a href="https://bit.ly/3uTBNPa">https://bit.ly/3uTBNPa</a>

Local Government/ First Nation	Type of map	Year created/ updated	Project/event leading to map	Funder	Data used	Accessibility
Regional District of Central Okanagan	Peachland and Trepanier Creeks floodplain mapping, Mission Creek floodplain mapping and hazard assessment, dam inundation studies for Crooked Lake and Swalwell Lake, Okanagan mainstem flood mapping for all of Okanagan Lake, Kalamalka Lake and Wood Lake	2015-2020	2017 flooding event.	Budgeted item, NDMP, CEPF	1D flood models, 2D flood models, historical information	<a href="https://bit.ly/3brVCVU">https://bit.ly/3brVCVU</a>

Local Government/ First Nation	Type of map	Year created/ updated	Project/event leading to map	Funder	Data used	Accessibility
City of Chilliwack	Floodplain inundation map with flood construction levels	2019	Comprehensive management system to reduce impacts of flooding from the Fraser River during the freshet and from the Vedder River during the fall/winter season. City's most recent flood management work includes development of its own multi-purpose flood model and floodplain mapping for the Fraser and Vedder Rivers. This work is an extension of and in collaboration with the Fraser Basin Council's initiative to develop a Lower Mainland Flood Management Strategy.	CEPF	2D flood models, historical information	
Columbia Shuswap Regional District	Clearwater flood hazards	2019	Grant funding for risk assessment and collection of data.	NDMP		
Cowichan Valley Regional District	Fluvial and coastal	2008-2021	Climate adaptation and risk reduction program, support for the program grew after a flood in 2009 demonstrated that the flood mapping process was accurate and provided strategic planning information.	Budgeted item, NDMP, Gas Tax, leveraged partnerships	1D flood models, 2D flood models	Best to request however, this is one portal <a href="https://bit.ly/3hyKVom">https://bit.ly/3hyKVom</a>
City of Dawson Creek	River flood	2016 and 2020	2016 flood event created a map of extent. For 2020, we had a consultant set up flood maps and flood mitigation measures.	Budgeted item, Union of BC Municipalities	2D flood models, empirical models, historical information	Both online and offline

Local Government/ First Nation	Type of map	Year created/ updated	Project/event leading to map	Funder	Data used	Accessibility
Regional District of East Kootenay	Large river floodplain and hazard mapping	2019	2013 large flood event, combined with out-of-date and inaccurate historical floodplain mapping.	NDMP	2D flood models	Both online and offline <a href="https://bit.ly/2QjILOt">https://bit.ly/2QjILOt</a>
Township of Esquimalt	Tsunami inundation areas map	2020	Recognition of hazards associated with tsunamis, so hired a consulting firm to model the tsunami inundation areas.	NDMP	Digital elevation model and sea level rise flooding analysis	<a href="https://bit.ly/3wbMih7">https://bit.ly/3wbMih7</a>
City of Fernie			2013 flood of record, availability of grant funding and out-of-date maps.	NDMP	1D flood models	<a href="https://bit.ly/3unWe5j">https://bit.ly/3unWe5j</a>
City of Grand Forks	0.5 Annual Exceedance Probability, topographical flood map	2019	Moderate flooding in 2017, record flooding in 2018, availability of grant funding.	CEPF, Gas Tax	1D flood models, 2D flood models	
District of Hope	Coquihalla River floodplain map, flood construction levels	2018	Development pressures in and around the Coquihalla River. The flood construction levels had not been assessed since floodplain management was under the purview of the province.	Budgeted item	2D flood models, historical information	
Kitimat Stikine Regional District	Floodplain mapping for the Skeena River and tributaries in the Terrace area	Ongoing	Skeena River Channel Management Program.	Budgeted item	2D flood models, empirical models, anecdotal information, historical information	

Local Government/ First Nation	Type of map	Year created/ updated	Project/event leading to map	Funder	Data used	Accessibility
Kitsumkalum Band	Update floodplain maps affecting reserve areas	2019-2020	Our Land Use Plan directed us to do this work.	First Nation Adapt program	Empirical models, historical information	
District of Lake Country	Okanagan lake and river flood map	2019-2020		Others (not specified)		
City of Langford	Official Community Plan - 200-year floodplain development permit area	2020	Revised stormwater development cost charges bylaw 2012 began more detailed ongoing analysis of floodplain mapping and projected infrastructure improvements.	Budgeted item, NDMP, CEPF, stormwater development cost charges	2D flood model	<a href="https://bit.ly/33J7TBd">https://bit.ly/33J7TBd</a>
Lil'wat Nation	50-, 100- and 200-year flood and hazard mapping	2018	Collaboration of Squamish Lillooet Regional District, Village of Pemberton, Pemberton Valley Diking District and Lil'wat Nation addressed the need for data on our river.			<a href="https://bit.ly/3bK5Txd">https://bit.ly/3bK5Txd</a>
Village of Lumby	Watershed map, 200-year flood depth year 2100 and 2200, flood mitigation plan	2019	2017 flood event, availability of grant funding.	NDMP	2D flood models, historical information, traditional knowledge	Both online and offline <a href="https://bit.ly/3eLvasp">https://bit.ly/3eLvasp</a>
Metlakatla First Nation	Tsunami risk mapping	2018	Coastal Vulnerability Studies, a project funded by the federal government and involving ten other coastal communities.	CEPF, First Nation Adapt program	Empirical models	

Local Government/ First Nation	Type of map	Year created/ updated	Project/event leading to map	Funder	Data used	Accessibility
Metro Vancouver Regional District	Flood inundation maps	2018	Fraser freshet potential flooding is becoming more frequent. Need to update for infrastructure and residences.	Budgeted item	2D flood models	
City of Nelson	200-year flood map	2018	Grant funding.	Provincial funding	1D flood models, 2D flood models, historical information	
City of North Vancouver	Updated sea level rise mapping, updated floodplain mapping for Lynn Creek	2019 and 2020, respect -ively		CEPF	2D flood models	
Town of Osoyoos	GIS web mapping	2020	2017 Osoyoos Lake flood.	Budgeted item	LiDAR and Osoyoos Lake levels	
City of Penticton	Flood mapping for the two main creeks that run through the city	2018-2020	Part of the master planning process to rehabilitate two creeks.	Budgeted item	2D flood models	
Town of Princeton	200-year floodplain map	Currently underway		CEPF	2D flood models, empirical models, historical information, traditional knowledge	

Local Government/ First Nation	Type of map	Year created/ updated	Project/event leading to map	Funder	Data used	Accessibility
qathet Regional District (formerly Powell River Regional District)	Flood hazard area maps and coastal flood risk maps	2015-2018		Budgeted item, NDMP, Gas Tax		<a href="https://bit.ly/33GWLvs">https://bit.ly/33GWLvs</a>
City of Quesnel	Flood level maps	2019	Grant funding.	NDMP	2D flood models, empirical models, historical information, bathymetric survey, LiDAR	Soon
Seabird Island Band	Flood and erosion protection	2018	Risk of flooding in high-water and run-off years, river levels, back flooding into Maria Slough, land loss due to erosion.	NDMP, CEPF	2D flood models	
District of Squamish	Floodplain maps showing flood depth, flood elevation, velocity, hazard rating (combination of depth/velocity), social vulnerability and others	2015-2017	Significant community growth, known flood vulnerability and updated provincial guidance with respect to sea level rise.	Gas Tax	1D flood models, 2D flood models, empirical models	<a href="https://bit.ly/3fmWVXB">https://bit.ly/3fmWVXB</a>
Squamish Lillooet Regional District	Digital	2018	Grant funding.	NDMP	1D flood models, 2D flood models	

Local Government/ First Nation	Type of map	Year created/ updated	Project/event leading to map	Funder	Data used	Accessibility
Strathcona Regional District	River valley	2019	Emergency preparedness planning, input into GIS systems, budgeting for future investigations or mitigation and land use planning.	NDMP	Empirical models, historical information	Online (link not provided)
Village of Telkwa	200-year flood inundation extents	2019	Flood mitigation planning report completed by consultant.	NDMP	2D flood models, historical information	<a href="https://bit.ly/2SThflv">https://bit.ly/2SThflv</a>
District of Tofino	Flood inundation, hazard, risk and emergency maps	2018	Risk from coastal flooding due to storms and tsunamis. This risk is changing with sea level rise and other climate-change induced impacts.	NDMP	2D flood models	<a href="https://bit.ly/33JlKaL">https://bit.ly/33JlKaL</a>
Upper Nicola Band	Flood inundation, hazard, risk	2018-2019	2017 freshet caused widespread damage at Nicola Lake Indian Reserve.	First Nation Adapt program	2D flood models, historical information	
District of Vanderhoof	Floodplain bylaw 1174	2017				<a href="https://bit.ly/3ofdtou">https://bit.ly/3ofdtou</a>
City of Vernon	Flood map or flood hazard map	2020-2021	2017 and 2018 flood events.	CEPF	1D flood models, 2D flood models, empirical models, anecdotal information, historical information, traditional knowledge	

Local Government/ First Nation	Type of map	Year created/ updated	Project/event leading to map	Funder	Data used	Accessibility
City of Victoria	Regional Coastal Flood Inundation Mapping Project	2020	Awareness of sea level rise and tsunami risk.	Budgeted item, NDMP	1D flood model, 2D flood model, empirical methods	<a href="https://bit.ly/3hqMFQB">https://bit.ly/3hqMFQB</a>
District of West Vancouver	Flood construction level mapping	2020	Delineating a development permit area for coastal flooding.	Budgeted item	Empirical models	
Witset	Not sure of the type	2017-2018	Flood event.			Offline

## Appendix C: Inventory of flood-related studies undertaken since 2015

Type	Local Government/ First Nation	Describe study, cost and funding source	Date undertaken
Topographical	City of Burnaby	LiDAR survey, Byrne Creek topographic and bathymetric survey	2019-2020
	City of Chilliwack	LiDAR	2018-2019
	City of Campbell River	Approximately \$20,000	2018-2019
	City of Cranbrook	\$200,000, 50/50 funding from National Disaster Mitigation Program (NDMP)	September 2020
	Cowichan Valley Regional District	LiDAR acquisition and surveys, in excess of \$500,000, multiple sources	Multiple dates from 2006 to 2019
	City of Delta	LiDAR survey, \$20,000, general revenue and utilities	2018
	City of Fort St. John	Slope stability report in some higher risk locations in the city	July 2020
	City of Grand Forks	LiDAR data acquisition, budget funded	2016
	Regional District of Central Kootenay	NDMP	2019
	City of Nelson		December 2018
	City of Penticton	LiDAR data collected under other projects	Updated every 5 years
	qathet Regional District (formerly Powell River Regional District)	Landslide and fluvial hazard studies	2015, 2018
	Town of Qualicum Beach	Waterfront master plan, town and province	2016
	City of Richmond	Dike survey, operating budgets	Occurs yearly on a 5-year cycle
	Village of Silverton	LiDAR	2020 by regional district
	District of Squamish	LiDAR data, \$15,000, municipal taxation	Approximately 2015
	City of Surrey	Digital elevation model (DEM) yearly and fly LiDAR every few years - have an app that can predict flood extents based on projected water levels	Last LiDAR, 2018; last DEM, spring 2020
	Upper Nicola Band	First Nation Adapt program	2018-2019
	City of Williams Lake	Flood risk assessment, hazard mapping and mitigation planning, \$150,000	2020-2021

Type	Local Government/ First Nation	Describe study, cost and funding source	Date undertaken
Infrastructure survey (size of bridges and culverts, etc.)	Village of Belcarra	Drainage study	2017
	City of Burnaby	Various asset inventory collection projects (e.g., retaining walls and culverts); the city has a fairly complete inventory infrastructure in GIS, which is constantly being updated	Ongoing
	City of Campbell River	Approximately \$20,000	2020
	City of Cranbrook	\$200,000, 50/50 funding from NDMP	September 2020
	City of Dawson Creek	\$4 million	2020
	City of Fernie	Flood mitigation plan - surveyed all existing dikes and culverts, \$150,000, Emergency Management BC (EMBC) Disaster Mitigation Program for non-structural projects	2019
	City of Grand Forks	Survey undertaken as part of floodplain mapping program	2018
	Regional District of Central Kootenay	NDMP	2019
	City of Langford	Surveyed for all new items	2017
	Village of Lions Bay	Infrastructure master plan	
	City of Nelson	Flood mitigation, floodplain mapping report	December 2018
	City of Penticton	Review of existing drawings	
	City of Port Coquitlam	Asset management plan	2020
	qathet Regional District (formerly Powell River Regional District)	Drainage study - qRD/Ministry of Transportation and Infrastructure partnership	2018
	City of Richmond	No study needed; information in GIS	
	District of Saanich	Asset management investment plan study, \$57,200, capital funding	Ongoing
	City of Surrey	Bridges inspected yearly - culverts surveyed when doing studies; flood boxes inspected yearly with dikes	Annual
	Upper Nicola Band	First Nation Adapt program	2018-2019
	City of Williams Lake	Conducted over the year (no asset management plan)	2018-2020

Type	Local Government/ First Nation	Describe study, cost and funding source	Date undertaken
Land use study	Cowichan Valley Regional District	Landslide, torrent flow and rockfall risk assessments	2018-2021 (in progress)
	City of Grand Forks	Airphoto assessment undertaken as part of study	2018
	Haisla Nation	Land use plan	In progress
	Kitimat Stikine Regional District	Greater Terrace agricultural area plan land use and agricultural land base	
	City of Langford	Official Community Plan (OCP) updated regularly with updated floodplain mapping	
	Town of Qualicum Beach	Waterfront master plan, town and province	2016
	Spuzzum First Nation		2020
	District of Squamish	OCP update, \$100,000, municipal taxation	2018
	City of Surrey	City has an OCP and has ongoing or various neighbourhood concept plans that look at existing and proposed land uses	Multiple years and multiple studies/plans
	Tskwaylaxw First Nation	Consultant, \$50,000+	
	Tzeachten First Nation	Updated existing land use plan, own-source funded	2016

Type	Local Government/ First Nation	Describe study, cost and funding source	Date undertaken
Weather or climate study	Village of Belcarra	EMBC data	Monthly reporting
	City of Burnaby	Study of the impacts of climate change on precipitation and stormwater management, Metro Vancouver	2018
	City of Campbell River	Approximately \$50,000	2020
	Cowichan Valley Regional District	Funded Pacific Climate Impacts Consortium downscaled assessment for region, approximately \$100,000	2017
	City of Delta	Annual forecast update, \$10,000, utilities	2020
	City of Grand Forks	Climate impact study, funded by Disaster Mitigation and Adaptation Fund (DMAF) for confirming flood construction/protection level for new dikes	2020
	City of Kamloops	Three weather monitoring stations, funded internally	2019-present
	City of Nanaimo	5 rain gauges throughout city	Since 2010
	City of Nelson	Flood mitigation, floodplain mapping report	December 2018
	City of Port Coquitlam	Intensity-duration-frequency curve assessment	September 2020
	Town of Qualicum Beach	Waterfront master plan, town and province	2016
	City of Richmond	Wave run-up analysis, flood protection management strategy/road weather information systems/UBC study	2017/2018/2019
	City of Surrey	Various climate studies - coastal looked at sea level rise and precipitation changes, overall review of all city rainfall and downscaling - just added weather monitoring station in Boundary Bay to track winds, etc. and merge with new ocean mets station being installed in the bay	2013 - 2015

Type	Local Government/ First Nation	Describe study, cost and funding source	Date undertaken
Flow studies (e.g., data collection)	City of Burnaby	Still Creek hydraulic study is underway and being completed by Metro Vancouver; the city has various drainage models for the Big Bend Area and catchments flowing into this area	Various
	City of Campbell River		2018/2019
	Regional District of Central Kootenay	NDMP	2019
	City of Cranbrook	Ongoing flow monitoring at Joseph Creek above Phillips Reservoir for approximately 20 years	Annual
	Cowichan Valley Regional District	Hydrometric network installation, snow pillow, approximately \$400,000, Gas Tax, partnerships	Multiple years 20+
	City of Dawson Creek		2020
	City of Fort St. John	Floodplain mapping	November 2020
	City of Kamloops	2 stream monitoring stations, funded internally	2017-present
	City of Langford	Flow level monitors from which water levels are downloaded	Ongoing
	Village of Lumby	Floodplain mapping update and earthwork assessment	May 2018
	City of Nanaimo	1 storm flow monitoring station and 9 level sensors throughout city	2018
	City of Nelson	Flood mitigation, floodplain mapping report	December 2018
	City of Penticton	Level data from the creeks	Ongoing
	City of Port Coquitlam	Inflow and infiltration	2015
	District of Saanich	Flow monitoring framework study, \$18,800, capital funding	Ongoing
	District of Squamish	Integrated Flood Hazard Management Plan, \$475,000, Gas Tax - Community Works Fund	2015-2017
	City of Surrey	Permanent monitoring stations for flow, stage and rainfall, just added weather and about to install coastal/tidal station - annual costs to maintain about \$200,000	1997-present
	Upper Nicola Band	First Nation Adapt program	2018-2019
	City of Williams Lake	Flood emergency event	2020

Type	Local Government/ First Nation	Describe study, cost and funding source	Date undertaken
Hydrologic study (a study to establish the amount of flow)	City of Campbell River	Approximately \$50,000	2018-2019
	Regional District of Central Kootenay	NDMP	2019
	City of Chilliwack		2018-2019
	City of Cranbrook	\$200,000, 50/50 funding from NDMP	September 2020
	Cowichan Valley Regional District	Currently in prep for release - establishment of regional hydrometric network	In progress
	City of Dawson Creek		2020
	City of Grand Forks	DMAF-funded study; undertaken same time as climate impact study to determine inflow characteristics	2020
	District of Houston	\$25,000, district budget	August 2019
	City of Kamloops	For 10 subbasins in city limits, 4 have updated master watershed plans, \$100,000 per basin, funded internally	2013-present
	Kitimat Stikine Regional District	Skeena River Channel Management	2019, ongoing
	Village of Lions Bay	UBC is currently undertaking a hydrology study of our two primary watersheds	Ongoing
	Village of Lumby	Floodplain mapping update and earthwork assessment	May 2018
	City of Nanaimo	Buttertubs Marsh modelling	2017
	City of Nelson	Flood mitigation, floodplain mapping report	December 2018
	Village of Pemberton	Hydraulic analyses to estimate the Lillooet River flows corresponding to the 50-, 100- and 200-year flood events, including the 200-year flood incorporating projected climate change impacts by the end of the century	August 2018
	City of Penticton	Model developed	2018-2020
	City of Port Coquitlam	Hydraulic model and drainage system study	2015
	District of Squamish	Integrated Flood Hazard Management Plan, \$475,000, Gas Tax - Community Works Fund	2015-2017
	Squamish Lillooet Regional District	Hydrogeomorphic hazard and risk assessment in the Seton Portage area	2017
	City of Surrey	Integrated stormwater management plans for the whole city, updated every 12-15 years; low land strategic plan and coastal flood adaptation plan, all of which need to be regularly updated as science advances; each study typically costs \$200,000 to \$300,000 and usually involves hydraulic assessment	1980-present
City of Williams Lake	Flood emergency event, \$200,000	2020	

Type	Local Government/ First Nation	Describe study, cost and funding source	Date undertaken
Hydraulic study (a study to establish where water might go)	City of Burnaby	Integrated stormwater management plans for various drainage catchments; Big Bend master drainage plan 2019	Various
	City of Campbell River	Approximately \$50,000	2018-2019
	Regional District of Central Kootenay	NDMP	2019
	City of Chilliwack		2018-2019
	Cowichan Valley Regional District	Groundwater budget assessment, south Cowichan, Cowichan River coupled model, roughly \$150,000 and \$50,000	
	City of Cranbrook	\$200,000, 50/50 funding from NDMP	September 2020
	City of Dawson Creek		2020
	City of Fernie	Elk River and Fairy Creek floodplain mapping report	2017
	City of Grand Forks	Undertaken as part of floodplain mapping	2019
	District of Houston	\$25,000, district budget	August 2019
	Kitimat Stikine Regional District	Skeena River channel management	2019, ongoing
	Village of Lumby	Floodplain mapping update and earthwork assessment	May 2018
	City of Maple Ridge	North and South Alouette Rivers floodplain study, \$75,000	February 2016
	City of Nanaimo	Buttertubs Marsh modelling	2017
	City of Nelson	Flood mitigation, floodplain mapping report	December 2018
	City of Penticton	Model developed	2018-2020
	District of Squamish	Integrated Flood Hazard Management Plan, \$475,000, Gas Tax - Community Works Fund	2015-2017
	City of Surrey	Done with the Integrated Stormwater Management Plan work and the various lowland studies whether overall or subwatershed functional plans; Coastal Flood Adaptation Strategy work included this with dike breaches, etc.; current DMAF construction has these models updated to make sure proposed construction can adapt to future conditions and not affect existing drainage patterns	1980-present
	District of Tofino	Coastal Flood Mapping: coastal modelling of storm-induced flood hazard conducted using a continuous simulation approach (joint probability); flood construction level and Sea Level Rise Planning Area maps developed for the present-day and the future, \$148,010, Community Emergency Preparedness Fund	April 2018
	City of Vernon	Drainage infrastructure prioritization plan, \$105,000, Gas Tax	2019
City of Williams Lake	Some in the river valley flooding	2020	

Type	Local Government/ First Nation	Describe study, cost and funding source	Date undertaken
Needs assessment or gap assessment	City of Burnaby	Byrne Creek nature-based solutions study	Underway in 2020
	Columbia Shuswap Regional District	Part of NDMP risk assessment	November 2019
	Cowichan Valley Regional District	Regional scan, \$200,000, NDMP	2016-2019
	City of Delta	Public Infrastructure Engineering Vulnerability Committee (PIEVC) study, \$60,000	2017
	City of Fernie	Flood mitigation plan, \$150,000, EMBC Disaster Mitigation Program for non-structural projects	2019
	District of Kitimat	\$10,000	2019
	City of Langford	Every 5 years with development cost charges bylaw	Ongoing
	Lil'wat First Nation	Emergency Management: Risk Assessment Gap Analysis, Emergency Management Assistance Program	March 2020
	Village of Lumby	Floodplain map	May 2019
	City of Nelson	Flood mitigation, floodplain mapping report	December 2018
	Town of Qualicum Beach	Waterfront master plan, town and province	2016
	City of Richmond	Flood protection management strategy	2019
	District of Saanich	\$68,400, capital funding	September 2020
	District of Squamish	Integrated flood hazard management plan, \$475,000, Gas Tax - Community Works Fund	2015-2017
	City of Williams Lake	Water, sanitary, sewer modelling, \$150,000 each	2015-2020

Type	Local Government/ First Nation	Describe study, cost and funding source	Date undertaken
Other	Village of Burns Lake	Minor lakeshore and creek flooding	
	Capital Regional District	Coastal flood inundation mapping study	August 2020
	City of Grand Forks	Municipal natural assets initiative study on floodplain function	2017
	City of Kamloops	Flood response plan, operational plan for actions based on flood levels, funded internally	Updated annually, initially begun 2015
	District of Kitimat	Dike survey by Ministry of Forests, Lands, Natural Resource Operations and Rural Development	2019
	Peace River Regional District	Risk assessment, \$150,000	2019
	City of Penticton	Master plan for both creeks	2018-2020
	City of Port Coquitlam	Asset management plan	2020
	Squamish Lillooet Regional District	Catiline Creek debris-flow hazard and risk assessment	2015
	City of Surrey	Flood studies also include pump stations, floodbox performance and links to neighbouring local governments and First Nations; funding from the drainage utility at the city and development cost charges where new development may have an impact on flood structures	
	Uchucklesaht Tribe Government	Hydrodynamic model and wave models run	March 2019

## Appendix D: Details of models to which communities have access

Local Government/ First Nation	Models
City of Burnaby	All the information available to the community (public) are on the city's Open Data Portal <a href="https://bit.ly/3eOL1H2">https://bit.ly/3eOL1H2</a>
City of Campbell River	2018-2019 comprehensive package of analysis of sea level rise and flood risk from storm surge (marine) and rainfall (riverine) events.
Regional District of Central Kootenay	These models were created for us during the work done by consultant in 2019 for 16 areas in our regional district.
City of Chilliwack	A consultant developed the Chilliwack 2D hydraulic model using the US Army Corps of Engineers' HEC-RAS (v 5.0.6) software and a digital elevation model (DEM) built with LiDAR and survey data collected between 2016 and 2018. Additional spatial data utilized for DEM development included dike, bridge and other hydraulic structure information.
Cowichan Valley Regional District	Risk assessments carried out using the federal asset database for the eastern coastal zone, Shawnigan Lake, Cowichan Lake Riverbottom Road area, and the Cowichan Koksilah Floodplain areas. These have all been updated under the National Disaster Mitigation Program over the past few years.
City of Cranbrook	1D/2D Personal Computer Storm Water Management Model (PCSWMM) model, 2D hydraulic model; updated September 2020.
City of Dawson Creek	Access to numerous GIS layers and maps of creek hydrology, flood extents, depth and hazard area.
Doig River First Nation	Flow monitoring for water management decisions.
City of Fernie	2017 1D hydraulic model used in the development of the 2017 floodplain mapping.
City of Fort St. John	Some hydraulic modelling for major events but unsure of currency of this data.
City of Grand Forks	Hydrologic watershed model (RAVEN model) and hydraulic model in the city.
City of Kamloops	Watershed Master Plans include hydrologic modelling (usually PCSWMM) of the drainage system within the basin. While this is 1D data, it could be used as a basis for 2D modelling of the stream systems of the stream watersheds. Four have been completed to date.
District of Kitimat	See the BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development maps for the Skeena region <a href="https://bit.ly/3uj8nmN">https://bit.ly/3uj8nmN</a>
Kitimat Stikine Regional District	Project for the Terrace area nearing completion.
City of Maple Ridge	Consultant has a hydraulic model developed for the city of the North and South Alouette Floodplain.
City of Nelson	Flood Mitigation, Floodplain Mapping Report, December 2018.
City of North Vancouver	Combined hydrological-hydraulic model in-house - rain flow in city drainage infrastructure is updated annually.

Local Government/ First Nation	Models
Village of Pemberton	Consultant developed a Disaster Risk Management of the valley including the river channels, LiDAR from the province was used. Along with some bathymetry data from the Lillooet River from Lillooet Lake to the Forest Service Road bridge and the tributary rivers.
City of Penticton	Models for both major creeks and full LiDAR topographical information for Penticton and the creek catchments. At this stage, the data exists to do further modelling.
City of Port Coquitlam	Drainage model and system study – 2015.
City of Richmond	West Richmond Drainage model and East Richmond Drainage model.
City of Surrey	Coastal Flood Adaptation Strategy work, which was a model of all our lowlands and sea level rise, storm surge and precipitation changes. Currently updating the model with our Disaster Mitigation and Adaptation Mitigation Fund works.
District of Squamish	1D river models for the Squamish, Mamquam, Cheakamus and Stawamus Rivers. 2D model for the Squamish/Mamquam River floodplain and coastal wave model.
Squamish Lillooet Regional District	Digital data showing extent of the floodplain; this was determined in a study using 1D and 2D modelling.
District of Tofino	Tofino Comprehensive Coastal Flood Risk Assessment: Hazard Modelling Scenarios and Methods. The work is part of the Tofino Flood Hazard Mapping project, whose output is being used within the Tofino Comprehensive Coastal Flood Risk Assessment. The information is meant to be shared within the Comprehensive Coastal Flood Group to compare scenarios and methods used to obtain weather and tsunami flood maps on the BC coast. The Simulating Waves Nearshore (SWAN) wave model was used to estimate waves approaching each reach over the entire historical record. The model was forced with water levels, wave and wind conditions from local measurements. The wave run-up was estimated using the Direct Integration Method, as detailed in the US Federal Emergency Management Agency Flood Hazard Guidelines for the Pacific Coast. The RiCOM hydrodynamic modelling software was used for tsunami hazard to Tofino.
Uchucklesaht Tribe Government	Wind-generated wave model, tsunami hydrodynamic model – 2019.
Upper Nicola Band	Digital elevation model – 2019.
City of Victoria	All the project GIS data should be available through the Capital Regional District.
District of West Vancouver	2018 LiDAR data (0.1 m accuracy) - topography data study are bathymetry from Canadian Hydrographic Services wind and tide data from nearby climate stations.
City of White Rock	The Surrey Coastal Flood Adaptation Study covers areas adjacent to White Rock.

## Appendix E: Inventory of topographic data available to local governments and First Nations

Type	Local Government/ First Nation	Date of data (month and year)	Area of coverage (description, available formats)	Describe capabilities you may have to share the data
LIDAR	City of Burnaby	2018	Entire city	AutoCAD, Esri
	City of Campbell River	2019	Entire city	Publicly available
	Capital Regional District	Fall 2019	Majority of CRD (minus some Juan de Fuca)	No ability to share, but contact province (GeoBC)
	Regional District of Central Kootenay	2018	Unclassified LAS	Owned by the Province of BC, no ability to share
	Regional District of Central Okanagan	February 2020	All of the Okanagan	
	City of Chilliwack	2016-2018	City boundaries	
	Columbia Shuswap Regional District	October 2019	Low-lying areas near water bodies	GeoBC data sharing agreement
	Cowichan Valley Regional District	2006, 2014, 2016, 2019	Primarily the Cowichan River, eastern coastal zone, 2014 major portions of the CVRD	Open data and data sharing agreements
	City of Cranbrook	July 2019	All watersheds entering the city, TIFF format	Data sharing agreement possible
	City of Delta	April 2020	All of Delta	Data sharing
	Regional District of East Kootenay	2018	Most valley bottoms	
	City of Fernie	2018	Approximately city limits	Data sharing agreement
	City of Fort St. John	2019	City limits	Data sharing agreement
	City of Grand Forks	2016	100 m outside city limits; raw data and 1 m digital elevation model	Data sharing
	Haisla Nation	As needed		
	District of Hope	2012	Fraser Valley Regional District	Yes
	District of Invermere	March 2015	Community and watershed	None
	District of Kitimat	2017/2020	District	Data sharing
	City of Langley	Spring 2009	City boundaries plus 100 km +/-	No share
	Village of Lions Bay	2013	Entire community	Limited
District of Logan Lake	2018			

Type	Local Government/ First Nation	Date of data (month and year)	Area of coverage (description, available formats)	Describe capabilities you may have to share the data
LiDAR	Village of Lumby	May 2017	1 m gridded digital elevation model with breaklines and orthophotos; UTM NAD 83, Zone 11 horizontal datum and CGVD13 vertical datum data	
	City of Maple Ridge	2014	Most of city	Share with consultants
	Metlakatla First Nation	2019	Entire region	Not sure
	City of Nanaimo	2016	City wide	Publicly available
	City of North Vancouver	2018		Data sharing
	City of Penticton	2019	All of the city and creek catchment areas	Available
	City of Port Coquitlam	2019	City wide	
	Town of Princeton	July 2005		
	qathet Regional District (formerly Powell River Regional District)	2020		
	Town of Qualicum Beach	July 2005		Public
	City of Quesnel	2018	Entire city	
	Village of Radium Hot Springs	July 2013	Radium Village, Riparian Areas Regulation	Data sharing
	City of Revelstoke	2019	City boundaries	Internal/agreement
	City of Richmond	2020	Entire city	Data sharing agreement
	District of Saanich	2013	Entire city	Data sharing agreement
	Village of Silverton	2020	Regional district	Contract with province limiting access and only raw data
	District of Squamish	Approximately 2015	All of Squamish	Data sharing agreement with contractor; may be able to share subject to data sharing agreement
	Sts'ailes	2017	Harrison River, 50 km	Can share under appropriate circumstances
	City of Surrey	2009, 2013, 2017, 2018	Entire city	Open data - anybody can have it
	Village of Telkwa	May 2012		
City of Terrace	May 2019	Entire lands within municipal boundary	Own data - working to have this accessible on web-based mapping	

Type	Local Government/ First Nation	Date of data (month and year)	Area of coverage (description, available formats)	Describe capabilities you may have to share the data
LiDAR	District of Tofino	August 2015	District jurisdiction (52 km <sup>2</sup> ), digital elevation model – 1.5 m resolution - Shapefile and AutoCAD DWG format - delivered as one file per project tile Elevation Contours – 0.5 m resolution - Shapefile and AutoCAD DWG format – delivered as one file per project tile Orthophoto Imagery – 15 cm resolution - geoTIFF format, with accompanying TIFF world files - delivered as one file per project tile; LiDAR data report - overview of project specifications, methodology and accuracies achieved - PDF format	Shareable through agreement
	Tskwaylaxw First Nation	1993	Traditional territory	
	Uchucklesaht Tribe Government	January 2016	Treaty settlement lands	Unsure
	Upper Nicola Band	2019	Portion of Nicola Lake Indian Reserve 1	Limited
	City of Vernon	July 2005	City of Vernon	Data sharing agreement
	City of Victoria	2019		Data sharing agreement
	District of West Vancouver	2018	Entire municipality	Publicly available
	City of Williams Lake	2019	Entire city limits and some regional coverage	Not public, for city projects only through GeoBC

Type	Local Government/ First Nation	Date of data (month and year)	Area of coverage (description, available formats)	Describe capabilities you may have to share the data
Orthophoto	City of Burnaby	2020	Entire city	Esri
	City of Campbell River	2018	Entire city	Publicly available
	Capital Regional District	Various	Various	Data sharing agreement
	Regional District of Central Kootenay	Many different years	Most of the district	Some ability to share depending on the source
	Regional District of Central Okanagan	February 2019	All of the Okanagan	
	City of Chilliwack	2016	City boundary	
	Columbia Shuswap Regional District	October 2019	Low-lying areas near water bodies	GeoBC data sharing agreement
	Cowichan Valley Regional District	2016, 2019	Regional	Provincial data and open source CVRD
	City of Cranbrook	July 2019	City boundary	Data sharing agreement possible
	City of Dawson Creek	2016	City, TIFF	Web map
	City of Delta	April 2020	All of Delta	Data sharing
	Regional District of East Kootenay	Various	Most of the city	
	City of Fernie	2018	Approximately city limits	Data sharing agreement
	City of Fort St. John	July 2019	City limits	Public online mapping
	City of Grand Forks	2016	100 m outside city limits, 15 cm geotiff	Data sharing
	Haisla Nation	As needed		
	Halfway River First Nation	2016	Reserve	Publicly available
	District of Invermere	March 2015	Community and watershed	None
	City of Kamloops	2012, 2017, 2020	City boundaries	Data sharing agreement
	District of Kitimat	2017/2020	District	Data sharing/public (kitimap)
	City of Langford	June 2019	Region wide	Not available
	City of Langley	April 2020	City boundary plus 1 km +/-	Metro Vancouver
	District of Logan Lake	2016		
	City of Maple Ridge	2020	Entire city	Online CMR GIS
	Metlakatla First Nation	2010	Entire region	Not sure
	Regional District of Mount Waddington	April 2016	Settlement	Full capability
	City of Nanaimo	2020	City wide	Publicly available
	City of Penticton	2019	City of Penticton and creek catchments	Available

Type	Local Government/ First Nation	Date of data (month and year)	Area of coverage (description, available formats)	Describe capabilities you may have to share the data
Orthophoto	City of Port Coquitlam	2020	Entire city	
	qathet Regional District (formerly Powell River Regional District)	2017		
	Town of Qualicum Beach	2019		Public
	City of Quesnel	2018	Entire city	
	Village of Radium Hot Springs	July 2013	Radium Village, DWG, shape, JPEG	
	City of Revelstoke	2005-2019	City boundaries	Internal/agreement
	City of Richmond	2020	Entire city	Data sharing agreement
	District of Saanich	2019	Entire city	Data sharing agreement
	City of Salmon Arm	2016		
	District of Squamish	2019	All of Squamish	Publicly available
	City of Surrey	Every year	All of Surrey	Open data - free for all
	Takla Lake First Nation	Various years	Takla territory	BC Government
	Village of Telkwa	2012		
	City of Terrace	May 2019	Entire lands within municipal boundary	Available on Terramap online web-based mapping
	District of Tofino	August 2015	District jurisdiction (52 km <sup>2</sup> ) orthophoto imagery – 54 images – 15 cm resolution - geotiff format, with accompanying TIFF world files - delivered as one file per project tile	Shareable through agreement
	City of Trail	September 2010	City boundaries	
	Uchucklesaht Tribe Government	January 2008	Treaty areas	Not sure
City of Vernon	2018	City of Vernon	Publicly available	
City of Victoria	2019		Data sharing agreement	
City of Williams Lake	2019	Entire city limits and some regional coverage	Public	

Type	Local Government/ First Nation	Date of data (month and year)	Area of coverage (description, available formats)	Describe capabilities you may have to share the data
Bathymetric	City of Campbell River	2019	Campbell River estuary, limited shoreline bathymetry in other locations	Publicly available
	Capital Regional District	Various	Coast around CRD	Not able to share, but contact Canadian Hydrographic Service direct
	City of Chilliwack	2017	Portion of Fraser River-River left	
	Cowichan Valley Regional District	2016, 2020	Cowichan River, Cowichan Lake	Open data
	City of Grand Forks	2020	Within city limits	Data sharing
	District of Kitimat	1982	District	
	City of Maple Ridge	2006/2014	Part of Alouette River	Would have to confirm ownership
	City of Penticton	2018-2019	Limited information on both creeks	Available
	qathet Regional District (formerly Powell River Regional District)	2020		
	Town of Qualicum Beach	2013		Owned by contractor
	City of Quesnel	2019	Section of Fraser River	
	City of Richmond		Steveston Island, some along north dike	Data sharing agreement
	District of Squamish	Various	Various	Limited
	Sts'ailes	2017	Harrison River	Can access, and potentially share under data sharing agreement
	City of Surrey	2017	Serpentine and Nicomekl Rivers	Need to ask, but open to all
	Takla Lake First Nation	Various years	Takla territory	BC Government
	Village of Telkwa	August 2018		
	District of Tofino	September/ October 2018	Templar Channel - total survey area covered for this project approximately 1,242 ha and ranged from depths of 2 m above chart datum and 33 m below chart datum	Shareable through agreement
	Uchucklesaht Tribe Government	August 2020	All Treaty area foreshore	Unsure
	City of Williams Lake	2020	Williams Lake, Williams Lake River	City owned; shared with consultants as required

Type	Local Government/ First Nation	Date of data (month and year)	Area of coverage (description, available formats)	Describe capabilities you may have to share the data
Hydrographic	City of Cranbrook	September 2020	1D/2D PCSWMM model for all watersheds entering city	Data sharing agreement possible
	City of Dawson Creek	2020	City, TIFF	Internal only
	City of Kamloops	2019	City boundaries	Data sharing agreement
	District of Kitimat	1982		
	City of Langford	Ongoing using lake level monitors	All significant lakes, streams	Used to answer public question
	City of Penticton	Ongoing	Creek height in specific locations	Available
	Town of Qualicum Beach	2013		Owned by contractor
	City of Surrey	Since 1997	Variety of creeks, rivers throughout Surrey	On flow works for any to obtain data
	District of Squamish	2015-2017	All of Squamish's rivers	Willing to share
	City of Williams Lake	2021	Williams Lake River	Through the flood hazard, mitigation and risk assessment study
Other	Cowichan Valley Regional District		West coast of region	Open data can be sourced from the University of Victoria
	City of Kamloops	2005	City boundaries	Data sharing agreement
	District of Kitimat	2019	River dikes	Ask Ministry of Forests, Lands, Natural Resource Operations and Rural Development
	City of Surrey		Key locations throughout Surrey - cannot use flow monitors in areas with back flow	Some on flow works, other needs to be requested and is available free

## Appendix F: Data regarding the location and characteristics of flood protection and/or drainage infrastructure

Type of infrastructure	Local Government/ First Nation	Description, including date (month and year)	Describe capabilities you may have to share the data
Flood protection infrastructure	City of Burnaby	Dikes, flood gates and gauges (updated on an ongoing basis)	PDF
	Village of Burns Lake	Monitor freshet and rain events	
	City of Chilliwack	Updated annually	
	City of Cranbrook	Some ditch and erosion protection structures in GIS	Mapping publicly available online
	Columbia Shuswap Regional District	Flood protection works	BC open data license
	Cowichan Valley Regional District	Multiple date ranges: 2013, 2014, 2015	Data sharing agreement
	City of Dawson Creek	GIS data	Internal only
	City of Delta	Data collected from 1999 to 2019	Data sharing
	City of Fernie	2019	Data sharing agreement
	City of Fort St. John	GIS mapping	Data sharing agreement
	City of Grand Forks	Underway as part of Disaster Mitigation and Adaptation Fund, design complete 2021 and diking done 2022	Data sharing
	Halfway River First Nation	1994	
	District of Hope	Provincial maps	Public
	District of Invermere	Two provincially registered dikes	None
	City of Kamloops	GIS location data of dikes	Data sharing agreement
	District of Kitimat	Dikes constructed over several years (construction drawings and record drawings)	Data sharing
	Kitimat Stikine Regional District	Provincial floodplain mapping completed in the early 1980s	Available on provincial website

Type of infrastructure	Local Government/ First Nation	Description, including date (month and year)	Describe capabilities you may have to share the data
Flood protection infrastructure	Regional District of Central Kootenay	Old data, orphan dikes	Data sharing agreement
	City of Langford	In-house cityview map	Not shareable to public
	Lil'wat First Nation	Some very old riprap areas and a short dike on the Birkenhead; some woody debris was placed in the Birkenhead to divert watercourse	
	Village of Lions Bay	Channelization works and debris retention structures	Limited
	Village of Lumby	May 2018	Public
	City of Maple Ridge		City public GIS site
	Metlakatla First Nation	2020	
	City of Nanaimo	Various weir structures at pond outlets throughout city	Can be requested by public
	City of Port Coquitlam	Dike locations and attributes	Can be shared
	City of Richmond	December 2020 (constantly updating data)	Data sharing agreement
	Village of Silverton	1970s era	No engineering data, no sharing
	District of Squamish	Dikes, flood boxes, pump stations, regularly updated	All available through open data site
	Squamish Lillooet Regional District	Dikes (2020)	Can be made publicly available
	Sts'ailes	Dike on Chehalis River built in 2005	Data sharing agreement
	City of Surrey	Shown on city COSMOS mapping system	Open data
	Town of Qualicum Beach	Waterfront Master Plan, 2016	Public
	City of Vernon	Sedimentation ponds	No public information
	City of Williams Lake	May 2021	Will be public document

Type of infrastructure	Local Government/ First Nation	Description, including date (month and year)	Describe capabilities you may have to share the data
Drainage infrastructure	Village of Belcarra	Drainage study, 2017	Digital copy
	City of Burnaby	All of the city's drainage infrastructure is available through open data or in the online city map, CAD, Esri	Internet Explorer/Chrome
	City of Chilliwack	Updated annually	
	City of Cranbrook	GIS map of drainage infrastructure and watercourses - updated September 2020	Data sharing agreement possible
	Columbia Shuswap Regional District	BC Freshwater Atlas	BC open data license
	Cowichan Valley Regional District	2014 Cowichan sediment management strategy	Open
	City of Dawson Creek	GIS data	Internal only
	City of Delta	Data collected and updated, 2019-2020	Data sharing
	City of Fernie	2020	Data sharing agreement
	City of Fort St. John	GIS mapping	Data sharing agreement
	City of Grand Forks	Variable mapping and condition assessment, ad hoc updates with complete 2018 condition assessment of downtown storm system	Data sharing
	Haisla Nation	Subdivision drainage plans	Shareable
	City of Kamloops	GIS location and characteristic data for city-owned infrastructure	Data sharing agreement
	District of Kitimat	Dikes constructed over several years (construction drawings and record drawings)	Data sharing
	City of Langley	Current +/-	Data sharing
	City of Langford	In-house cityview map	Not shareable to public
	Lil'wat First Nation	Old drainage that was damaged in a flood and not repaired properly and formed a lake	
	Village of Lions Bay	Minimal ditches and pipework	Limited
	Village of Lumby	May 2018	Public
	City of Maple Ridge		City public GIS site
	City of Nanaimo	Watercourses and drainage network city wide	Available for download on city website
	City of Nelson	Storm mapping	
District of New Hazelton	Storm drainage mapping/assessment management, June 2017		

Type of infrastructure	Local Government/ First Nation	Description, including date (month and year)	Describe capabilities you may have to share the data
Drainage infrastructure	City of North Vancouver	Part of asset inventory, 2020	
	City of Penticton	Full stormwater GIS for the piped system	Available
	City of Port Coquitlam	Full inventory of all drainage infrastructure, GIS shape files and spreadsheets	
	Village of Radium Hot Springs	Master drainage plan, 1992	Data sharing
	City of Richmond	December 2020 (constantly updating data)	Data sharing agreement
	District of Saanich	Various	Web-based GIS
	City of Salmon Arm	Current	
	District of Squamish	Drainage pipes, culverts, ditches, pump stations, etc., regularly updated	Available through open data site
	City of Surrey	Shown on city COSMOS mapping system	Open data
	City of Terrace	Storm system infrastructure	Online Terramap web-based mapping
	City of Vernon	Watercourses	
	City of Victoria	Kept current	Online data catalog
	District of West Vancouver	2018, ongoing	Publicly available
	City of Williams Lake	Updated annually as projects are completed, GIS	