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Best Practices in Western Canadian Flood Mapping

Findings of the WFMC expert workshop

Prepared for Natural Resources Canada

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PICS

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Executive Summary

Western Canada faces a variety of flood risks, from coastal flooding along the shorelines of British Columbia and the Yukon, to ice jam flooding in the colder regions. Flooding remains the costliest natural hazard in Canada, an issue that is growing in Western Canada as climate change alters flood behavior, and human development continues to expand.

Flood mapping has a long history in Western Canada, with five of the region's seven jurisdictions initiating flood hazard mapping efforts in the 1970s and 1980s. However, mapping activities largely declined between the early 2000s and 2015, leaving maps outdated. Recently, there has been a resurgence in flood mapping initiatives, with six jurisdictions actively conducting mapping projects and the seventh (Nunavut) currently developing its mapping approach. This renewed focus has fostered a wealth of expertise among practitioners, providing insight into current challenges and innovative solutions for flood mapping in the region.

To provide a space to share flood mapping knowledge, Natural Resources Canada (NRCan) organized the Western Flood Mapping Conference (WFMC), bringing together flood mapping practitioners and knowledge holders from across Western Canada. The conference aimed to facilitate '*collaborative solutions for Western flood mapping'.* On the second day, an expert workshop gathered forty-nine invited participants for discussions and activities focused on best practices in flood map design and application. The goal was to strengthen collaboration among experts and generate insights to guide future efforts in aligning best practices across the region. This report summarises the findings of the workshop. Final key recommendations are covered in ***Table 5***.

Workshop Findings

Common conditions enabling best practices in flood mapping

Participants shared their individual experiences of what the underlaying conditions are that allow best practice flood mapping to occur. From the common circumstances shared, ten overarching conditions were identified:

1. Place-based approach informed by local-risk reduction goals
2. Clear standardized & streamlined mapping process
3. Clear governance structure & effective team collaboration
4. Inbuilt project flexibility with room for reflection
5. Strong community engagement & public education
6. Opportunities for alternative communication of map information
7. Use of best available technology, methods, & research
8. Sufficient resourcing & external support
9. Prioritizing specialist engineer and local institution expertise
10. Meaningful inclusion of Indigenous peoples & traditional knowledge

Improving best practices in flood map production

The experts then delved deep into the breadth of factors that go into producing high quality flood maps of different types (riverine hazard, ice jam hazard, coastal hazard, and flood risk). Undertaking a group concept mapping activity, the experts scored the statements describing each factor based on their personal perspectives of the statement's current presence, importance, and feasibility of implementation. Final processed statement

numbers ranged between sixty-four and seventy-three for each flood map type.

- The statements relating to riverine flood hazard mapping had the highest overall perceived current presence, while flood risk mapping statements had the lowest presence score, likely related to the relatively new status of risk mapping in most jurisdictions.
- The perceived feasibility of improving statements was also highest for riverine flood hazard mapping, while it remained the lowest for ice jam flood hazard mapping, likely relating to the complexity of ice jam data collection and modeling.
- Seven main categories were identified across statements, based on the expert's own original groupings. These categories could then be compared across the four flood mapping types.

1. Clear communication of map information
2. Effective modeling methodologies
3. High quality data inputs
4. Successful engagement and collaboration in mapping efforts
5. Functional validation and uncertainty processes
6. Appropriate resources and support for map production
7. Consideration of climate change impacts

Notably, climate change remains under considered in most map types, scoring the lowest for current presence (except for coastal flood hazard maps), while clear communication of map information contained the most feasible statements to focus on, for better future implementation.

Improving best practices in flood map use

Finally, experts discussed how flood map use could be improved, with discussions of three topics:

1. Flood map use in policy and regulation
2. Public communication and engagement with flood maps
3. Equity and justice considerations in flood mapping

Current issues and solutions were identified for each of the three topics. Eight key recommendations that covered most solutions highlighted were identified:

1. Improve engagement of people who may face intersectional disadvantages

While many projects currently seek engagement, there are still communities being missed, often those who face intersectional disadvantages (e.g., remote communities, Indigenous communities, the elderly etc.). Current engagement efforts need to shift beyond community meetings to include more targeted engagement efforts that can reach the right people.

2. Treat communities as partners in the mapping process

Learning during a mapping project is a two-way street. There needs to be greater inclusion of local knowledge and opinions throughout mapping projects. This will improve the maps by ensuring they better meet end user needs, while also encouraging local support of map creation and resulting flood management decisions.

3. Prioritize alternative communication of map information

Experts mentioned that in their experience, end-user ability to interpret static maps has decreased, but their ability to work with multi-layer online interactive maps have improved. There needs to be prioritization of digital interactive maps. Map information sharing should also be occurring in new ways, taking advantage of social media and other medias for education.

4. Allocate resourcing that supports equitable map production and use

Experts discussed how it can be challenging for rural communities, or communities with no mapping or grant-writing experience to receive

resources (funding, staff, and mapping tools). Flexible funding that can be used to address inequity issues was mentioned as a solution, with more concentrated funding streams for communities who currently fail to access mapping help. Additionally, projects should have specific funding to allow for early and varied community engagement and education to ensure those who are exposed to flooding can benefit from the maps being made.

5. Have clearer guidance on the roles and responsibilities of governments in creating flood policy and regulation

There was variable participant opinion over what the roles of different governments should be in the creation or enforcement of map-related policy and regulation. However, it was clear that there needs to be clearer guidance on how different levels of government can or should be involved, and what is working where.

6. Create a database or repository of policy and regulation information

Following from the above recommendation, participants suggested an online database or repository of different regulation and policy approaches used across Canada and how these related to the flood maps being produced, for jurisdictional and local governments to draw from.

7. Seek greater collaboration between map creators and other experts

Attending the workshop were primarily experts in map creation, and many of them mentioned they would like to have greater collaboration with communication and marketing specialists. This could be within organizations internally, but also through external collaborations with others, such as the real estate industry.

8. Move towards a risk-based approach in map use decision making

Whether for policy and regulation design, or other flood management (e.g., hard mitigation structures), participants emphasized the need for risk understanding, moving beyond hazard estimation alone. This would require greater resourcing of flood risk mapping efforts, including guidance and funding.

Photo credit: Ignacio Aguirre

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List of Acronyms

AB - Alberta
BC- British Columbia
MB- Manitoba
NB- New Brunswick
NL- Newfoundland and Labrador
NT- Northwest Territories
NS- Nova Scotia
NU- Nunavut
ON- Ontario
QC- Quebec
SK- Saskatchewan
YT- Yukon
FDRP- Flood Damage Reduction Program
FHIMP- Flood Hazard Identification & Mapping Program
GCM- Group Concept Mapping
NRCan- Natural Resources Canada
WFMC- Western Flood Mapping Conference

Photo credit: ClimateWest

1. Background

In Canada, flooding is considered the most common and expensive natural hazard[1–3]. The damage that results from flooding it expected to grow as climate change alters flood behavior[4,5] and as Canadian populations increase by up to 52% by the year 2050[6], many of whom will reside in the 80% of cities that are partially built on floodplains[7]. To address this, careful preparation and flood risk understanding is required[3,8] which is where flood maps become vital.

In Canada, flood maps fulfil a range of roles. Flood maps provide a foundation for land use planning and regulatory decision making, enable improved emergency response measures, inform flood mitigation choices (e.g., structural defense installation)[9], and allow citizens and landowners to make more risk-informed decisions to protect themselves and their assets[10,11]. Given the diversity of flood map end-users, map creators often need to balance representing highly technical information with the need for easily interpretable spatial communication for broader audiences.

1a. Key mapping terminology

It is important to define the terminology used in Canadian flood mapping practice as terms are often used interchangeably.

Flood maps can be defined as "*maps that are used to identify land areas that are covered by water as a result of actual or potential flood events*"[12]. Within this broader definition there are different types of maps that display different information (***Table 1***), requiring assorted sets of data and types of expertise to create[13]. At the WFMC workshop, discussions were focused on flood hazard maps and flood risk maps, with limited mention of other flood map types.

In the modelling of flood hazard, the areas where floods may occur tend to be based upon certain return periods[14], or historic event records which are called the 'design flood'. In Canada, **the design flood** is defined as "*a specific flood magnitude that is used for delineating flood hazard areas*"[15].

The resulting area shown to be inundated by water in flood hazard modelling is then referred to as the **flood hazard area** (colloquially as the 'floodplain'). In Canada, it has been common in many jurisdictions to further separate the flood hazard area/ floodplain into the **floodway** (where the most destructive flow and depth is expected), and the **flood fringe** (where waters are expected to be shallower and slower)[16].

Table 1. *Definitions of common flood map types in Canada.*

Type of map	Definition
Flood inundation map	Simple map, showing the depth of waters that occurred during a past event, or potential water depths under a future flood event.
Flood hazard map	Shows the spatial distribution of theoretical floods of chosen probabilities, usually created through hydrologic and hydraulic modeling. These maps display potential water depth and sometimes other water behavior (e.g., velocity and flow direction).
Flood risk map	Shows the spatial distribution of flood impact or damage under certain flood hazard probabilities, based on how a flood will impact people, assets, and values.
Flood awareness map	Communication-focused maps that provide basic spatial information on flood hazard or risk, often including a historic flood inundation layer.

1b. The history of flood mapping in Canada

There has been a history of diverse map production in Canada, producing maps of variable content and spatial coverage across the country[12,17,18]. ***Figure 1*** provides a timeline of the major acts, programs, and funding that have influenced flood mapping since the Federal Government first became involved with the management of water, in 1953, under the Canada Water Conservation Assistance Act[19].

The Federal Flood Damage Reduction Program (FDRP) began in 1976 and was the first time flood mapping and resulting regulations became widely implemented in Canada[20]. While the program ended in the late 1990s, the FDRP agreements signed between jurisdictional and federal governments still influence the flood map strategies and adopted design floods used in jurisdictions to this day.

Since the conclusion of the FDRP, mapping slowed in many areas as responsibility shifted from being shared with the federal government, to resting with jurisdictional governments. In some jurisdictions, responsibility then further devolved to the municipal and Indigenous government levels (e.g., in BC), creating variability in mapping activities even within jurisdictions[21]. In many places, maps became outdated, with an estimated median age since flood maps were last updated being 18 years as of 2014[17].

There have been consistent calls for the improvement of Canadian flood maps in recent decades[22]. In response, several federal flood map funding initiatives were established[19], accompanied by federally backed guidelines[18,23], and general improvements to flood modelling methodologies[24,25]. NRCan has worked with Environment and Climate Change Canada, Public Safety Canada, Indigenous Services Canada, and others to lead several such initiatives. One major program is the Flood Hazard Identification and Mapping Program (FHIMP)[26], which, as of early 2025, has resulted in the assistance of more than 280 new flood mapping projects[26].

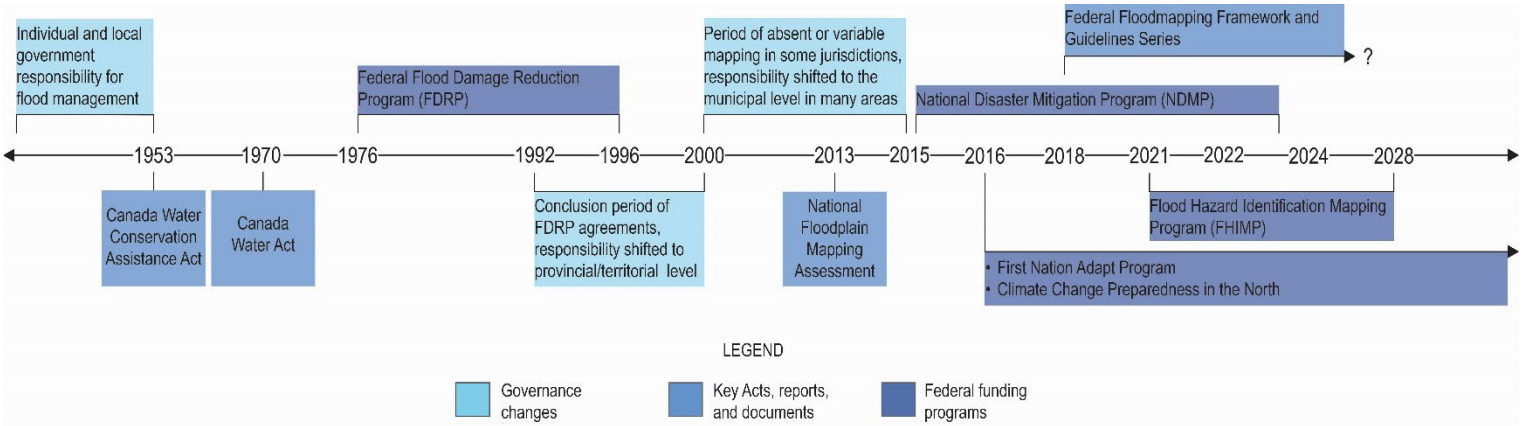


Figure 1. *Timeline showing major influences of Canadian flood mapping practice.*

1c. The current state of flood mapping in Canada

New and improved flood maps are now being made, but there remains a high level of diversity in the maps produced across Canada. Varying levels of government oversee map production, along with others such as conservation authorities and NGOs. Some governments have in-house mapping experts, while others engage private consultants. The insurance industry also undertakes its own flood hazard and risk mapping, but these maps are largely separate and typically remain undisclosed. Several reviews have been undertaken over the last decade seeking to understand the variation seen across Canadian flood mapping practice[10,12,17,27,28].

Ten jurisdictions originally produced maps under the FDRP, but these maps no longer hold provincial authority. Most of the ten jurisdictions have since replaced the FDRP maps with locally legislated maps or reference maps, with the exception of BC and NT who were still employing the FDRP designated maps as of 2024[28]. All jurisdictions are now producing flood maps under the FHIMP to some degree.

When it comes to the technical design of the flood maps, many jurisdictions currently rely on the design floods that they first established under their original FDRP agreements[12]. Six jurisdictions have a defined design flood within provincial legislation (SK, MB, ON, QC, NU, NL), while BC defines their design flood through professional governance legislation[28]. Two provinces define their design flood through provincial guidelines alone (AB and NB), and the remaining jurisdictions do not have a defined design flood. Eight jurisdictions also formally define the distinction between the floodway and fringe (AB, SK, MB, ON, QC, NB, NS, NL), while the remainder have no formal definition within their legislation[28].

While the transparency around mapping methodology has increased over time, there is still concern over the clarity and subjectivity of the decisions being made surrounding validation of modeling assumptions, or uncertainty disclosure[27]. Limited consideration for climate change impacts or the interactions of different flood types also remains an issue in modern maps[27].

When flood hazard maps are produced, there can remain barriers preventing the effective translation of these maps into risk-reducing action. It has been suggested that the current technical flood hazard maps that are typically created in Canada, while useful for technical experts, do not align well to the information needed by most end users[10,29]. There have been calls for a variety of solutions, including greater standardization of flood map production[22,30], and a shift towards greater production of flood risk maps over other mapping types[29,31].

1d. The Western Canadian context

Flood mapping approaches in Western Canada are diverse, influenced by the range of flood types that occur across the region, along with historic mapping activities and modern mapping governance arrangements. Riverine, ice jam, and coastal flood hazard are commonly mapped, although pluvial/stormwater flooding remains under-represented in mapping efforts.

Different flood hazard mapping standards exist in each of the seven jurisdictions[12]. Some of the details of these standards are reported in results of a survey covered in Appendix 1 of this report. Figure 2 shows the variations in common flood mapping approaches (design flood standard and floodway/fringe) in each of the seven Western jurisdictions as of 2019. It should be noted that since 2020, YT has begun a flood hazard mapping program, using the 1:20, 1:100 and 1:200 design floods, and climate change scenarios, and that NU is currently in the process of designing their own mapping program. Additionally, some provinces (e.g., BC) require a mandatory 'freeboard' which is

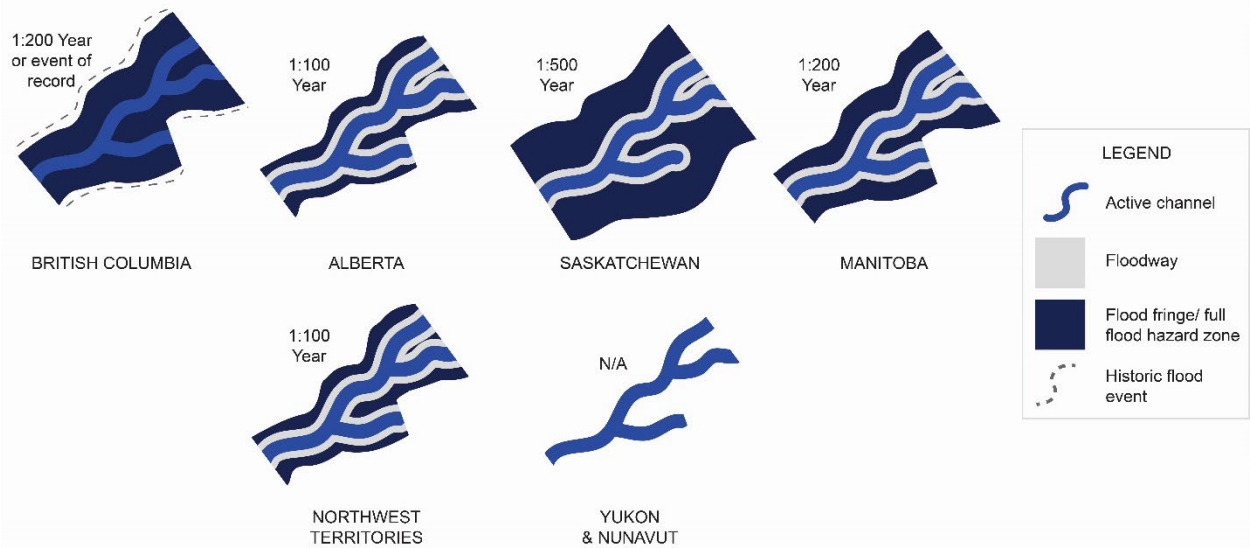


Figure 2. *Variation in jurisdictional flood hazard area and commonly used design floods as of 2019*[12].

a vertical distance added to the estimated flood level to account for uncertainties in flood levels.

1di. The results of the jurisdictional flood mapping survey

There has been a considerable amount of flood mapping progress in the Western jurisdictions since the last publicly available review was undertaken. A survey was sent out to representatives from each jurisdictional government ahead of the WFMC to gather some additional background information to guide workshop discussions. The results of this survey are covered in ***Appendix 1*** of this report.

1e. The Western Flood Mapping Conference expert workshop

The Western Flood Mapping Conference (WFMC) took place on the 19th & 20th of February 2025 in Calgary, Alberta. The WFMC was titled *'Uniting Minds, Mapping Futures: Collaborative Solutions for Western Flood Mapping'* and its organization was led by Natural Resources Canada (NRCan), ClimateWest, Pacific Institute for Climate Solutions, with support from the Western flood mapping steering committee.

Conference attendees came from the seven Western jurisdictions: British Columbia (BC), Alberta (AB), Saskatchewan (SK), Manitoba (MB), Yukon (YT), the Northwest Territories (NT), and Nunavut (NU) (***Figure 3***). The WFMC compliments a corresponding Atlantic flood mapping conference that took place in 2022 with attendees from the Atlantic jurisdictions[32]

Figure 3. *Map of the Western Canadian jurisdictions and location of the WFMC.*

WORKSHOP OBJECTIVES

The conference invited presenters to speak on a range of flood mapping topics, while the day two workshop focused on group discussions and activities for expert participant knowledge sharing. The main workshop objectives were to:

- Gather expert perspectives on best practices in Western Canadian flood mapping.
- Identify current barriers preventing best practice flood mapping, and to recognize potential solutions.
- Foster a sense of community between Western Canadian flood mapping practitioners.
- Create outputs that support future work looking to align best practices across Western Canadian flood mapping.

1ei. Workshop participation

Forty-nine invited participants attended the day two WFMC workshop, with an additional sixteen facilitators and note takers present. Invited participants were selected based on their role within flood mapping activities in Western Canada, with a range of sectors targeted across all seven jurisdictions. Attendees and workshop facilitators were invited to provide information on their place of work and sector to give an idea of who was in the room (***Figures 4*** & ***5***). The day was split into discussion of map production and map use (***Table 2***).

Participants were asked to complete consent forms for collection of qualitative data in the workshop. The details of the consent process are covered in ***Appendix 2*** of this report.

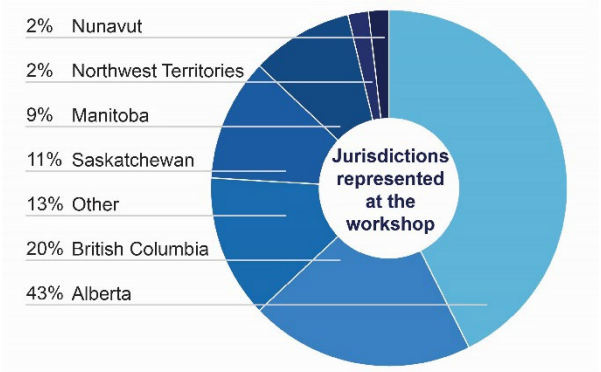


Figure 4. *Jurisdictions represented by attendees of the WFMC workshop.*

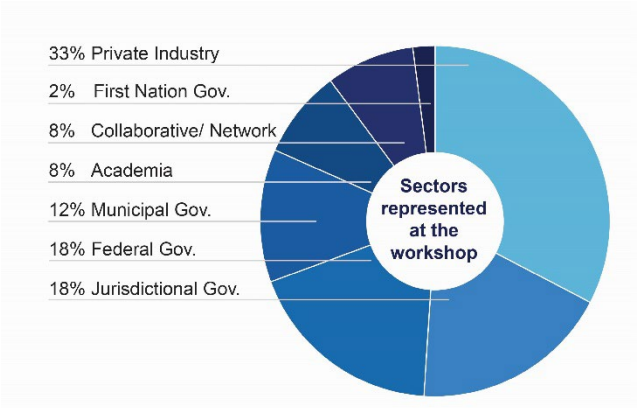


Figure 5. *Sectors represented by attendees of the WFMC workshop.*

Table 2. *The WFMC workshop agenda.*

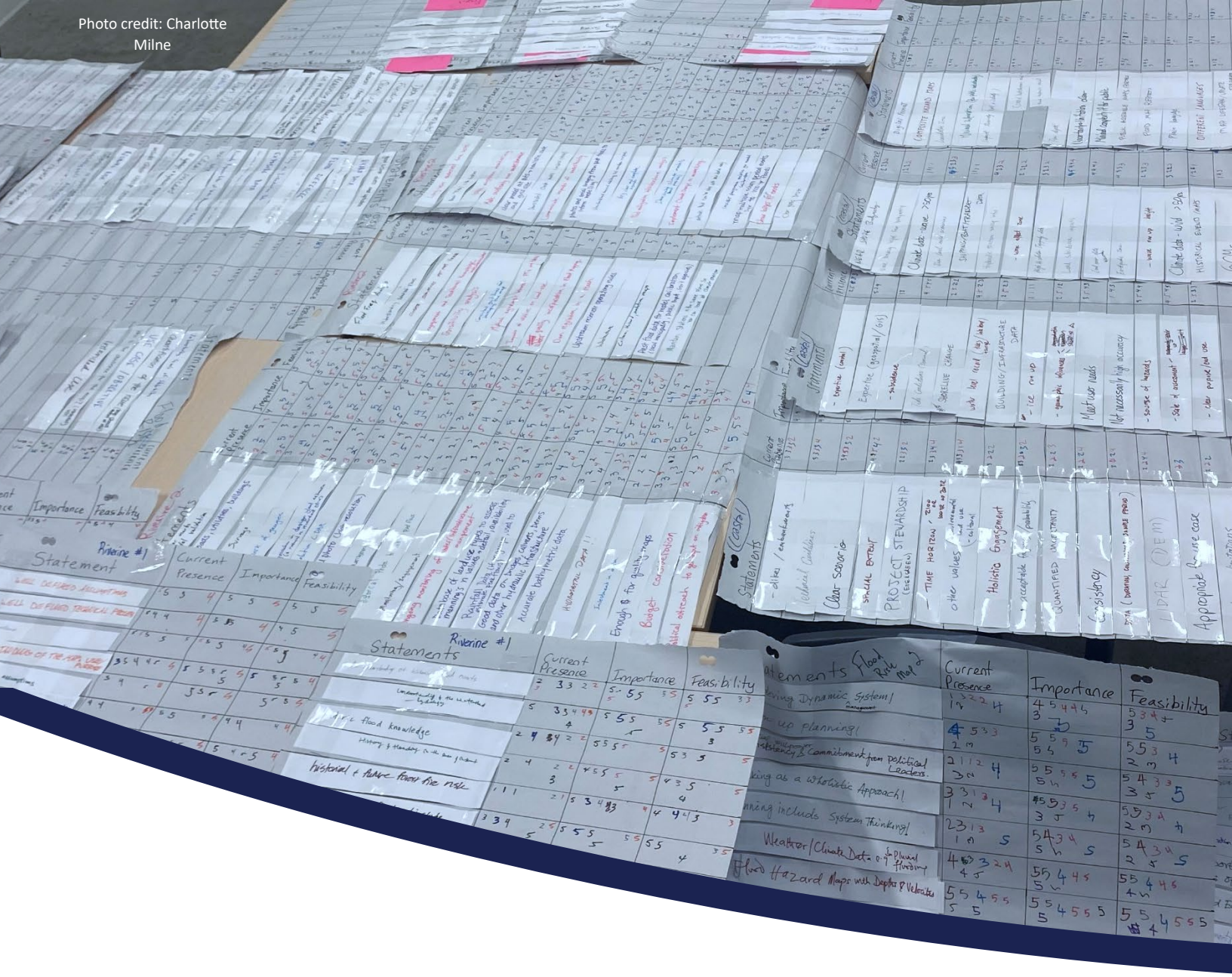
Time	Activity
8:30	Registration
9:00	Welcome & opening remarks
9:30	Presentations: Context, conference recap & terminology
PART ONE: Best practice in flood map production	
9:50	Activity: Promising practices appreciative interviews
10:25	BREAK
10:40	Activity: Group concept mapping best practices in different flood mapping types
12:20	LUNCH
PART TWO: Flood map uses, implications for best practice	
13:15	Speaker: Flood impacts on Sisika Nation Presentation: Ethical implications of flood mapping
13:55	Activity: World Café discussions of map use themes
14:45	Closing remarks
15:00	End

1eii. What was heard on day one of the WFMC

Over the first day of the WFMC conference presenters covered a range of topics, but several key gaps emerged through both the presentation topics and attendee questions. These gaps influenced the discussions at the workshop. The major issues discussed were:

1. Flood mapping in the region is still commonly focused on clearwater flooding, with the incorporation of geomorphic process or multi-hazard analysis becoming more common, but still infrequent.
2. Pluvial flooding is a major source of damage in many jurisdictions, but there is still uncertainty around how best to approach its mapping.
3. There remains a large amount of uncertainty about how to better translate maps into risk-reduction action (e.g., how to encourage implementation of regulation based on existing maps). Frustration was voiced by many around the lack of progress that has been seen since the recommendations for better implementation of maps were first highlighted, during the FDRP program.
4. Presenters and attendees spoke about the disconnect that is still seen between those who are creating maps, and those who are facing the worst flood impacts, in particular Indigenous communities.

Photo credit:
ClimateWest



2. Workshop Findings: Best practices in Western Canadian flood mapping

The workshop covered discussions and activities relating to best practices in the creation and use of flood maps in Western Canada. From the three main workshop activities we heard a wealth of information from the experts. In the following sections the key results of the WFMC workshop are summarized.

All quotes in the following sections are statements made by WFMC workshop participants.

2a. The underlying conditions that enable best practice flood mapping

To lay the groundwork for the day and get participants thinking about what best practices meant to them, we invited them to undertake appreciative interviews. From these interviews participants shared the common conditions they were hearing that allowed best practice flood mapping to occur in groups.

Based on the conditions reported by participants, ten overarching themes emerged that shared commonality across multiple groups. These conditions are summarized in ***Figure 6*** and described in the following section.

METHOD: Appreciative Interviews

Appreciative interviewing is a qualitative technique that seeks to bring out stories of success from participants and organizations[33]. At the workshop, participants partnered up and interviewed each other[34], sharing: *A story about a time they were involved in a flood mapping project that demonstrated promising practices.*

Partners then shared in groups of 4, before final groups of 6-8 came together to discuss the common conditions they had heard across the stories.

Figure 5. *Common conditions reported by participants as being important in the undertaking of promising flood mapping projects.*

a. A place-based approach informed by local risk-reduction goals

Many of the success stories shared had the common theme of being informed by local contexts, and in particular local risk reduction goals.

- Experts emphasized the importance of groundwork research into local contexts before starting a project, allowing an improved understanding of:
  - Local hazard behaviors (e.g., intersecting hazards).
  - Local emergency management approaches and mitigation efforts.
  - Future development plans.
  - Community capacity levels.
- They emphasized that a place-based approach focused on local risk-reduction goals led to more successful projects by:
  - Informing flood modeling with real-world local flood mechanisms.

- Adjusting maps to reflect future development areas.
- Tailoring maps for local emergency management.
- Incorporating local mitigation infrastructures into maps.

- Ultimately these approaches enhanced the map's value, increasing project motivation and community use.

> *"A measure of success is not just the existence of a map but its use in planning, regulation, and risk reduction"*

b. Clear governance structure & effective team collaboration

The importance of collaboration between the institutions leading map development and other government organizations was consistently brought up by our experts.

- Successful projects often involved early collaboration among experts from various institutions.
- Early and consistent collaboration allowed for project adjustments when needed.
- Clear roles and responsibilities were emphasized as being important in cases involving:
  - Flooding or mapping across municipal or jurisdictional borders.
  - Different types of flooding (e.g., riverine and coastal) requiring varied expertise.
  - International collaboration (e.g., with the U.S.).
- Knowledge-sharing events, like the WFMC, were stressed as key to fostering future collaborations.

> *"Technical solutions are only one part of the puzzle, multiple solutions are needed, where we work with other stakeholders for success"*

c. Strong community engagement and public education

Experts spoke a lot about how effective community engagement created success within the projects they were involved in.

- Experts highlighted two key success conditions:
  1. Community involvement in the mapping project (e.g., incorporating local knowledge, gaining support).
  2. Educating the public on how to use the final map products effectively.
- Community engagement worked best when started early to:
  - Identify gaps in local hazard knowledge.
  - Understand who is affected.
  - Determine stakeholder map needs.
  - Aid outside consultants unfamiliar with the area, especially in high-cost projects.
- Open communication was essential, including:
  - Creating a collaborative atmosphere.
  - Using different communication approaches for different stakeholders (avoiding a "one size fits all" method).
  - Encouraging community ownership over project success.
- Community education was crucial to ensure maps are effectively used, including:
  - Teaching general map-reading skills.
  - Explaining complex layers, such as climate change flood scenarios.

d. The use of best available technology, methods, and research

Our experts mentioned several technical and methodological conditions that allowed the projects they were involved in to achieve best practice.

- Experts highlighted the importance of leveraging advanced methodologies:
  - Coupled models (e.g., ice jam and hydraulics) help achieve more innovative hazard interpretations.
  - Expanding modeling scope to include non-traditional hazard factors like erosion

allowed for the creation of maps that better reflected real-world flood impacts.
    - Greater automation and speed in models, improved map use for emergency management applications.
- Encouraging academic freedom and experimentation was also key to fostering innovation in best practice hazard modeling.

e. Sufficient resourcing and external support

Experts understandably pointed to sufficient funding as a required condition.

- Flexible and fast-tracked funding improved project workflows and helped to address unique flood mapping challenges.
- Resource distribution ideally was based on need (both financial and skill-based) to ensure success across different locations.
- Local government support and public interest contributed to project success by providing internal resources (e.g., funding and expert staffing).
- Gaining political will and public support was essential and could be achieved by emphasizing the cost savings that come from improved flood understanding.

"Maps to action is hard and requires political will"

f. A clear standardized and streamlined mapping process

Experts were clear that the flood mapping process can be complex, and that clear guidance and standardization is often essential for best practices to be employed.

- Local guidelines were often crucial, as general ones (e.g., federal guides) did not provide locally relevant input for map requirements. Nova Scotia was cited as an example of good jurisdictional-level guidelines.
- Experts recommended an incremental process that builds on past work, like the Government of Alberta's collaboration with Calgary, which developed a range of flood maps that now serve as a framework for future mapping at lower costs.
- Clear guidance and a step-by-step process based on local priorities helped to minimize redundant mapping (e.g., duplicated or non-compliant maps).
- In the best cases, guidelines from both provincial and federal levels are relied on.

g. Inbuilt project flexibility with room for reflection

Across multiple stories emerged the idea of learning from mistakes.

- Successful projects were emphasized as iterative and adaptable, with space for community feedback and new relevant information.
- Retrospection and flexibility can be built into the project by:
    - Running initial trials to test mapping approaches and outputs locally.
    - Incorporating feedback from these trials.
- Quality control and validation also needed to be ongoing throughout the project's lifespan to ensure accuracy and reliability.

"We can learn new things from local people and from our own research, so having flexibility in your scope is key"

h. Opportunities for alternative communication of map information

Our experts identified that in many cases, projects were successful because the final map outputs were presented in ways that best served the community.

- Open-source maps were best, allowing them to be accessible whenever needed by all end users.
- Maps ideally included things like mitigation structure effects on flood behavior to reflect real-world scenarios accurately.
- Storytelling was important, as maps alone can be abstract; in the best cases maps were accompanied by anecdotes and stories to make them more communicable.

"Communication and telling a story is another essential success ingredient."

i. Prioritizing specialist engineer and local institution expertise

Some experts suggested that projects they were involved in showed best practice because there was careful prioritization of certain different expertise.

- Professional engineering expertise and individuals with deep institutional knowledge across different levels of government were essential for project success, especially in uncertain contexts where their professional judgement was required.
- Local expertise is crucial, particularly in areas lacking national data or models, as local experts with knowledge of flood behavior help make mapping projects possible.

j. Meaningful inclusion of Indigenous peoples and traditional knowledge

Many of the points shared by experts on the topic of community engagement ***(c.)*** were also relevant to meaningful inclusion of Indigenous peoples.

- Experts discussed how including traditional Indigenous knowledge in mapping projects was a key condition for success and culturally appropriate mapping practice.
- The current community of practice in Western Canada for involving First Nations in flood management and mapping was considered important, and experts felt this is where Canada can be recognized as a world leader.

Photo credit: ClimateWest

2b. Requirements of high-quality flood maps

The next goal of the workshop was to understand the specific factors that go into producing high quality flood maps, and if these factors are being successfully implemented in Western Canada. To understand this, we employed a Group Concept Mapping (GCM) method where the breadth of requirements to produce best practice maps could be understood, along with which requirements should be the focus in any future improvement recommendations.

METHOD: Group Concept Mapping

GCM is a mixed method assessment tool, where participants generate key ideas (statements) that relate to a prompt, before organizing and scoring these statements across predefined scales[35]. Typically, it is used for understanding complex systems[36].

An adapted GCM method was employed, where participant groups collaboratively came up with as many statements as possible that were true for the prompt: *What is required to make a high quality _____flood map?*

Participants were split into groups of 6-8 depending on which flood map type they held expertise in:

1. Riverine flood hazard maps (2 groups)
2. Ice jam flood hazard maps (2 groups)
3. Coastal flood hazard maps (2 groups)
4. Flood risk maps (1 group)

Participants then grouped their statements into categories and individually scored statements on a scale of 1(low) to 5(high) based on their perceptions of the 'current presence' (within the Western Canadian flood mapping system), 'importance' (for making high quality maps), and 'feasibility' (for greater implementation)[37].

2bi. GCM Results

The final statement counts produced by participants are shown in ***Table 3***. Separate groups who covered the same topic (e.g., riverine flood hazard groups one and two) had their statements combined, and all statements were cleaned, involving the combining of duplicate statements, and removal of statements deemed uninterpretable. Full cleaned statement lists for each flood map type can be found in ***Appendix 3*** of this report.

Participants in the riverine flood hazard groups scored their statements the highest with respect to both current presence and feasibility to improve. This likely reflects the fact that, to date, the majority of flood mapping attention in Western Canada has been devoted to clearwater riverine flood hazard mapping, therefore the practice is well established. In comparison, flood risk mapping statements had the lowest overall current presence ranking, likely reflecting the comparatively new status of flood risk mapping in the Canadian context. Additionally, ice jam flood hazard mapping was also rated the lowest for feasibility of improving identified statements, perhaps reflecting the complexity of ice jam data collection and modeling.

Table 3. *GCM participant numbers, statement numbers, and averaged scores for each map type.*

	Riverine	Ice Jam	Flood Risk	Coastal
Participant #	15	13	15	6
Original statement #	97	86	100	73
Clean statement #	73	65	72	64
Current presence av.	3.26	2.98	2.81	2.89
Importance av.	4.54	3.95	4.47	4.14
Feasibility av.	4.18	3.42	3.97	3.88

2bii. Common categories across flood map types

Participants created their own groups for their statements to show their understanding of how the factors that go into creating an ideal flood map fit together. Participant groups were examined across the four flood map types, and a final set of seven overarching categories that encompassed the groups were created to allow comparison of the findings across the different flood map types.

Figures 7, ***8***, and ***9*** show the averaged scores of statements within each category, and how they vary for each flood map type. ***Figure 7*** shows how each category scored on participant's perceptions of the statement's current presence in Western Canada for that flood type (in their experience). For example, 'clear communication of map information' is the top scoring category for riverine flood hazard mapping, but scores relatively low for coastal flood hazard mapping. Additionally, as might be expected, consideration of climate change impacts is low across riverine, ice jam, and flood risk maps, while it scored second highest for coastal flood hazard maps, reflecting the relative ease of considering climate change impacts on sea level versus other sources of flooding.

Figure 8 shows how each category scored on participant's perceptions of the statement's importance for allowing an ideal flood map to be created. Overall, the importance scores for all categories were lower for Ice Jam hazard mapping, with successful engagement and collaboration scoring particularly low, perhaps reflecting that data and methodology challenges are still the leading issue in the minds of practitioners seeking to understand this flood type.

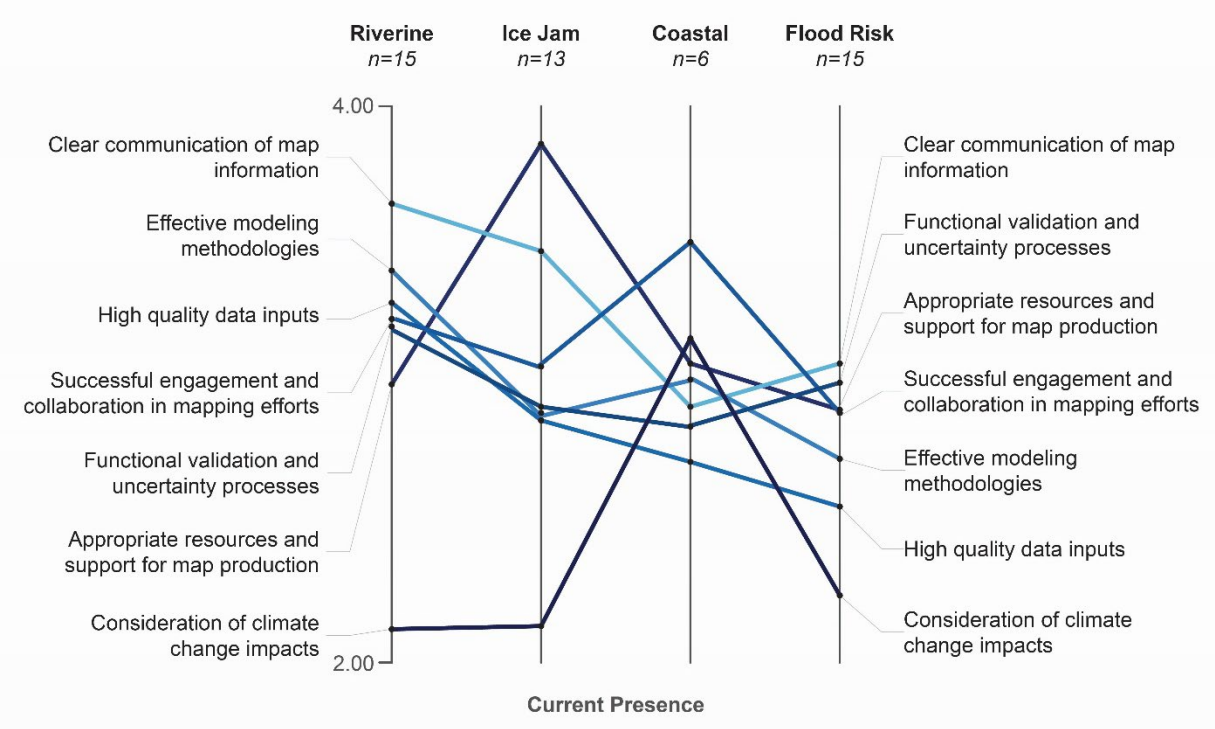


Figure 7. *Parallel coordinate plot of averaged 'current presence' scores for each GCM category across the different flood map types.*

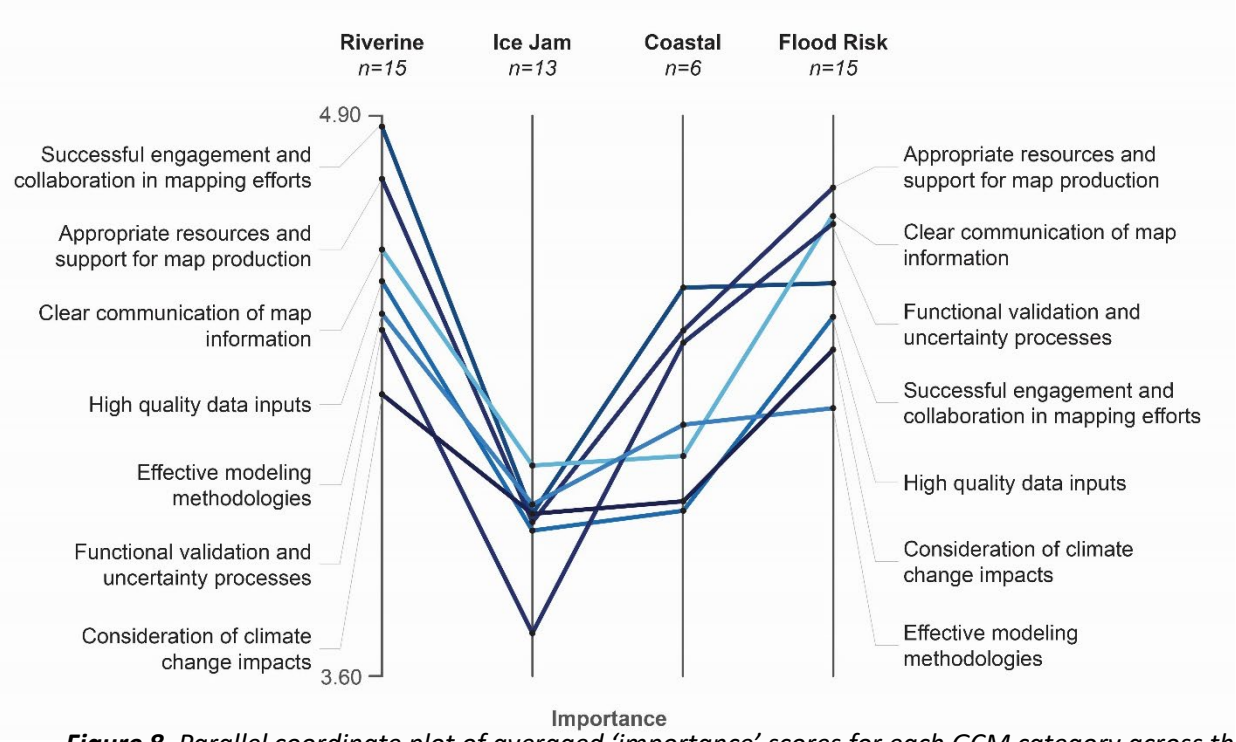


Figure 8. *Parallel coordinate plot of averaged 'importance' scores for each GCM category across the different flood map types.*

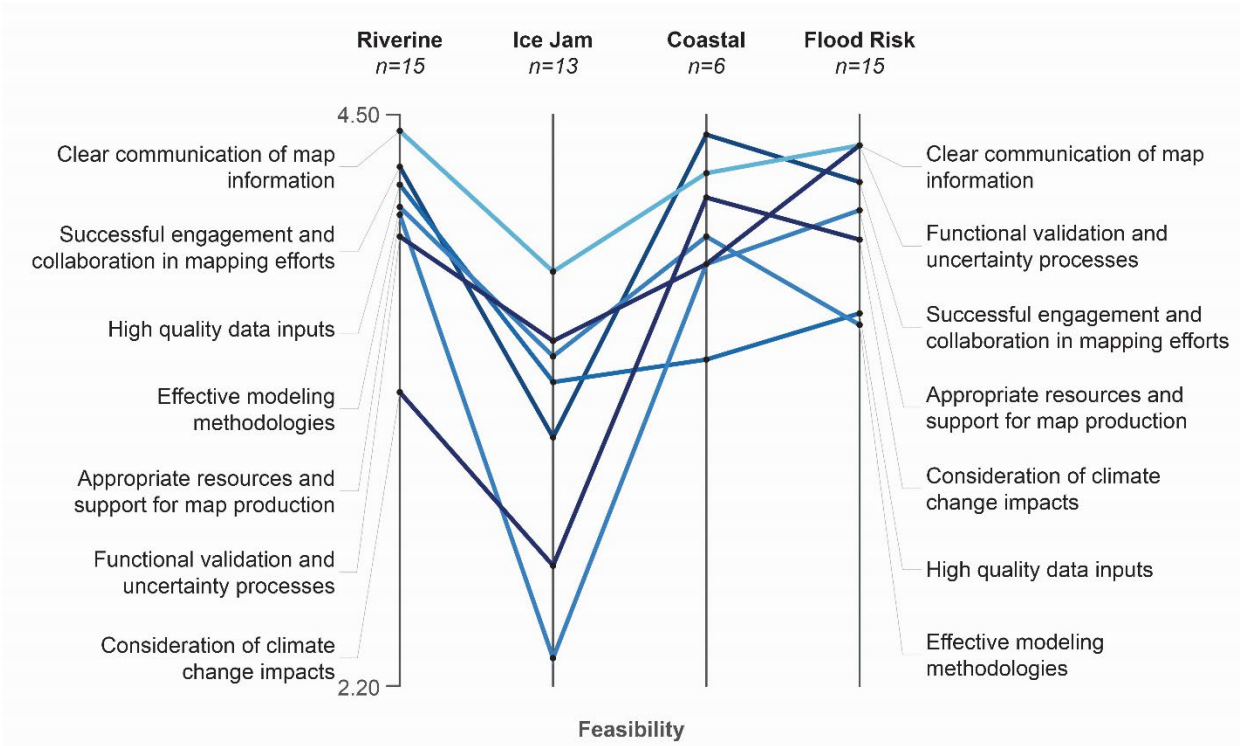


Figure 9. *Parallel coordinate plot of averaged 'feasibility' scores for each GCM category across the different flood map types.*

Finally, ***Figure 9*** shows how each category scored on participant's perceptions of the feasibility of the associated statements to be better incorporated into future flood mapping practice in Western Canada. In general, experts felt that clear communication of map information within the maps should be relatively feasible, while appropriate resourcing and consideration of climate change were recognized as more difficult to implement.

2biii. Go-zones for improved practice

To highlight key statements that can be prioritized for action, all statements within each flood map type were plotted based on their feasibility/importance. These plots then show quadrants (based on average scores), highlighting statements that fall into the 'go-zone' quadrant. For ***Figure 10***, the go zone represents statements that are both very important, and feasible to implement. None of the most feasible/important statements had a current presence score of 5, so all could be better implemented.

Table 4 shows the top 10 most feasible and important statements for each flood map type.

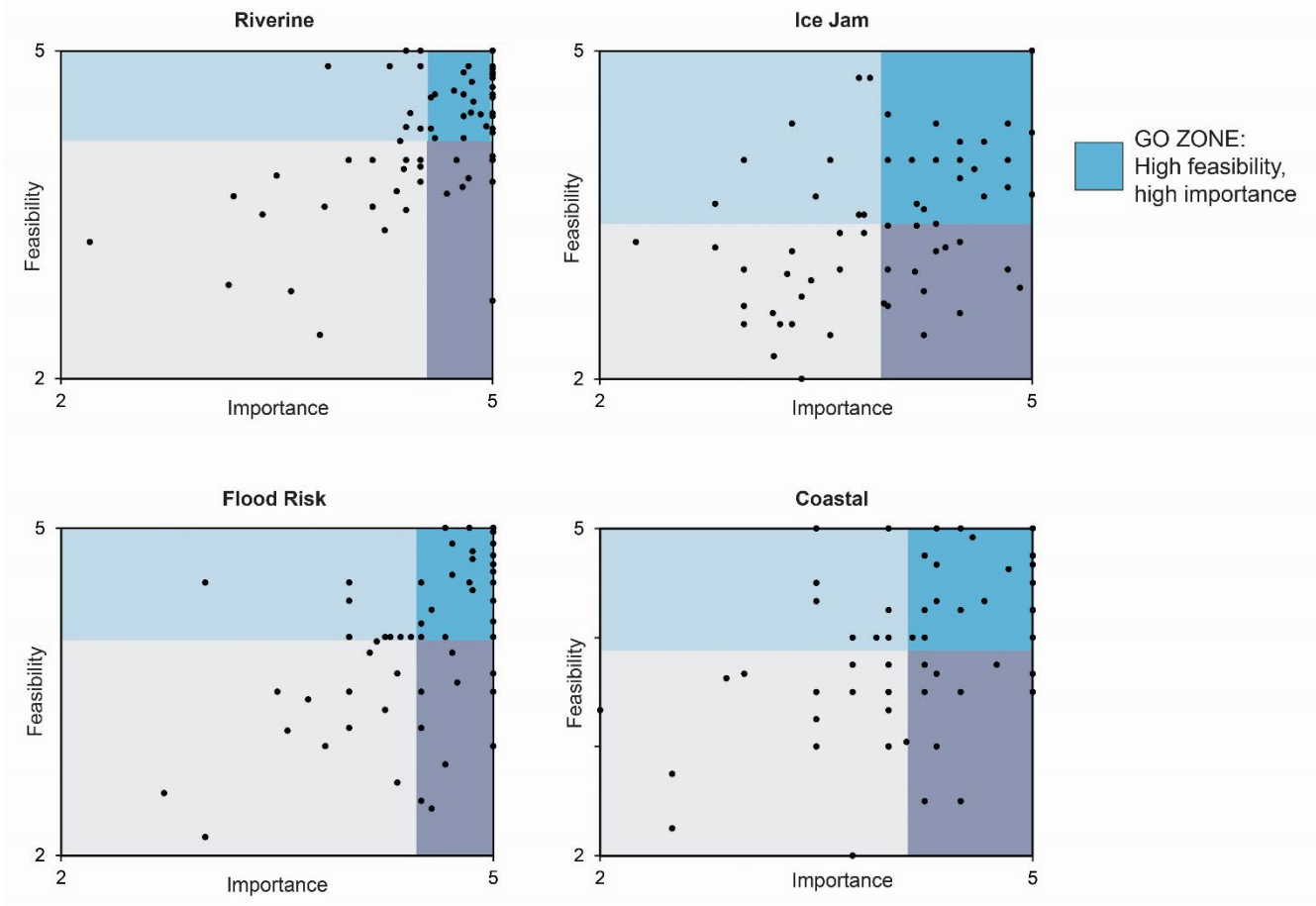


Figure 10. *Go-zone plot, showing the importance and feasibility scores of all statements for each flood map type.*

Table 4. *Top ten most feasible and important statements for each of the four flood map types.*

	Riverine	Ice Jam	Coastal	Flood Risk
1	Accurate flood frequency analysis	Accurate depth rasters	Accurate modeling of inundation zone	Quantification of damage, with maps showing the extent of the risk
2	Inclusion of spring freshet in modeling	Room for innovation and flexibility in modeling method	Accompanying flood map reports	A clear methodology/process
3	Very clear and complete legends	Map to be delivered with its associated files (technical reports, model files etc.)	Produced by people with geospatial/GIS expertise	Peer review of methodology/process
4	Available base data (e.g., roads, utilities, buildings)	High quality LiDAR data	Careful consideration of the spatial boundary of maps	Quality control testing
5	A clear understanding of map use/purpose	Accurate inundation polygons	Clear documentation of datum	Accurate and available exposure data
6	Consideration of drainage alterations downstream	Map to be available in static formats (PDF) and editable (GIS files)	Accurate estimation of flow depth	Accurate and available hydrology data
7	Air photo libraries provided by provincial governments	An appropriate approach to quantify uncertainty	Use of appropriate design events	Transferable data and model
8	Well defined assumptions in the mapping process	Hydrology assessment to rely on statistical analysis for dominant flood mechanism identification (frequency, breakup)	Inclusion of seasonal tidal conditions	Appropriate resources to produce risk maps
9	Knowledge of what drives the flooding for modelling	Inclusion of academic research	Clear purpose and planning for meeting end user needs	A clear end use/purpose for the risk mapping
10	High quality terrain surveys	Inclusion of most of the components required for an open water model	Incorporation of impact of climate change	Adding enough details to the flood risk maps to be easily understood

Photo credit: Quinn Philippe

2c. Improvement of flood map use in Western Canada

In the afternoon, the workshop focus shifted towards discussion of how map use could be improved. Based on initial discussions with the WFMC steering committee, identified knowledge gaps in the literature, and what was discussed at the Atlantic flood mapping conference, a decision was made to focus a World Café activity on three broad topics:

1. Map use in policy and regulation
2. Public communication and engagement with flood maps
3. Ethics and justice considerations in flood mapping

METHOD: World Café

World Café discussion is an assessment tool often used in settings with lots of participants to guide discussion and validation of themes in a topic of interest[38]. Large groups separate into smaller groups, moving through progressing rounds of dialogue, in an informal discussion setting[39].

In our World Café activity, participants moved through discussions on the identified topics, and over three rounds were asked[40]:

1. WHAT? (What are the issues, challenges, questions, parties involved or missing?)
2. SO WHAT? (What matters here, what are the important themes, patterns, insights?)
3. NOW WHAT? (What steps can we take to improve things in the context of flood mapping?)

We heard a wealth of information over the hour-long discussion. The information has been separated into current issues and suggested solutions that were identified by the expert participants.

2ci. The role of flood maps in policy and regulation

Policies seeking to reduce the exposure of communities, whether through information alone or regulations that restrict/alter development, rely on flood maps[41]. Currently, the policies and regulations that are made based on flood map information differ across Canada[12]. During the FDRP, there was a certain level of standardization of regulation creation and enforcement[42]. However, since the conclusion of the FDRP, flood hazard zone regulation and enforcement responsibility altered, and in some jurisdictions shifted to the municipal level (e.g., BC, AB).

One thing that became apparent over the first day of the WFMC conference is that attendees felt there is a disconnect between the production of maps and their success in being implemented in real-world risk reduction. In general, the link between flood maps and human development improvements is often weak and is a challenge that is frequently faced by the flood management community[43].

To better understand the causes of the disconnect between mapping and regulation in Western Canada we invited workshop participants to share their thoughts on the topic, and their identified issues and solutions are shown in ***Figure 11***.

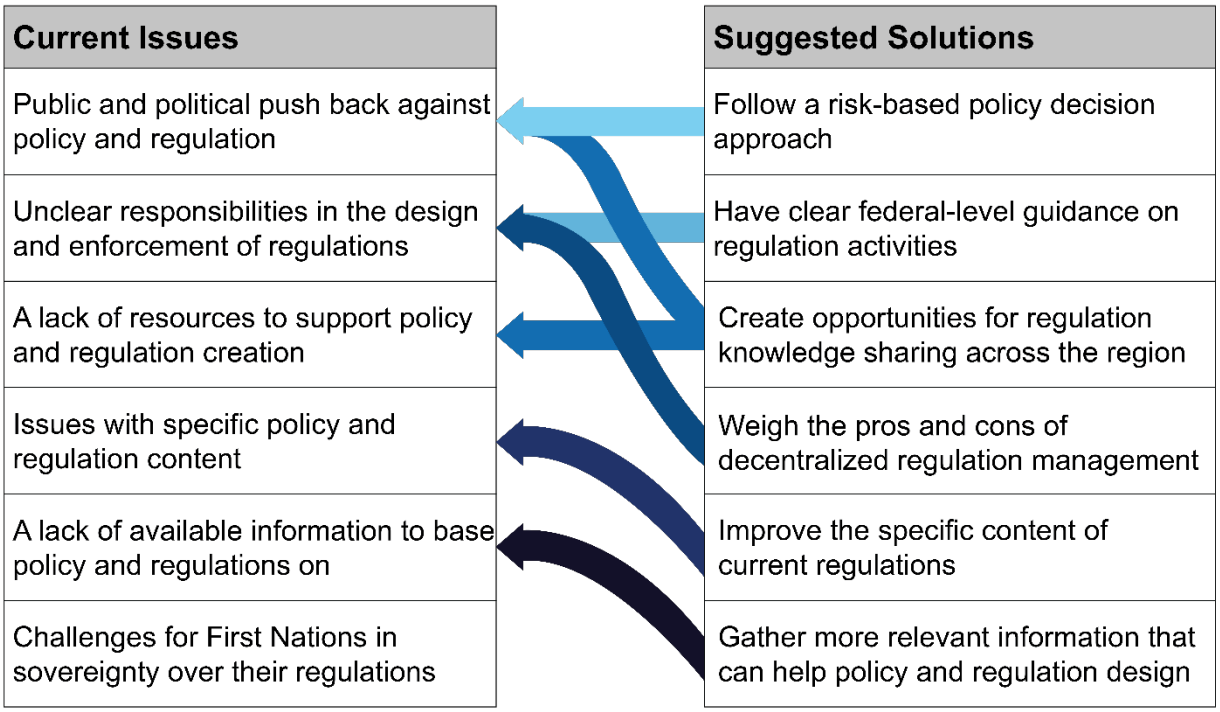


Figure 11. *Summary of the policy & regulation issues and solutions identified by participants. Arrows indicate the relation of each solution to the suggested issues (based on the context provided by the participants).*

CURRENT ISSUES: POLICY & REGULATION

a. Public and political push-back against policy and regulation

A main issue raised was related to public unwillingness for regulations to be put in place.

- People want to continue to build where they have built in the past and don't want to adjust their current properties.
- There is often fear and misconception around what new regulations will mean for communities. This can result in the hiding of map information in the worst cases.
- It is not just from the public, there is often strong commercial interest in the promotion of available land (even if that land is hazardous).
- There can also be local political pushback as concerns over the loss of economic growth in an area may be higher than concerns for future flood damages. This political hesitance can be at the jurisdictional and municipal levels.

> *"The law has never been published, so what does that signal?"*

b. Unclear responsibilities in the design and enforcement of regulations

Lots of experts brought up the uncertainty that surrounds the responsibility for the implementation and enforcement of policy and regulations.

- In cases where jurisdictional governments have control over certain flood areas, but local municipalities have other controls, there is often patchy regulation.
- There was also uncertainty around who should cover the costs of regulations. When regulations impact individual households, is there a cost sharing program to support them? And where does this money come from?
- Often municipalities face too much public push back when they seek to enforce regulations,

some want federal input to be able to come in and solve this issue, while others want to avoid too much external pressure. When mapmakers or higher levels of government do become involved, they are often told they lack the local understanding to be helpful.

- Even within individual governments, it can be unclear who is responsible for what. This has been found in NWT, where mapping and implementation of the maps occurs across two different departments.
- Additionally, many maps are produced by consultants who often don't have the incentive to seek out ways for maps to be more useful for regulation purposes.

c. A lack of resources to support policy and regulation creation

Resource constraints were highlighted, with many policy issues (e.g., a lack of local relevance) stemming from limited funding for local research and engagement.

- Larger cities tend to have stronger regulations, while smaller municipalities often lack the resources to develop or enforce them.
- Experts questioned how municipalities would afford the costs of new regulations and how much funding could realistically be allocated for flood management efforts that result from regulation.

d. Issues with specific policy and regulation content

Even when regulations have been previously enacted to reduce flood risk, there have been issues with their design.

- Current policies often do a poor job of appropriately differentiating between cases. For example, the regulations applied to a hospital should be different to those applied to a house. Similarly, regulations need to suit a range of landowners, from large-scale developers to individual homeowners.
- There is often a lack of real-world policy relevance. Policy creators can set goals that are too difficult to meet under current systems (this was seen in the construction of Drumheller's dikes). This has occurred in the past when there is little collaboration between the policymakers/planners and the engineers and land-use decision-makers.
- Finally, when financial mechanisms exist to encourage regulation adherence, these regulations often fail to be enforced.
- Mostly, experts raised questions about the range of regulations that exist in Western Canada, and how the specifications within are made. Uncertainty remained around things such as which design flood should be selected for regulation and whether mitigation infrastructures (e.g., dikes) should alter regulations.

e. A lack of available information to base policy and regulations on

In some areas there has not yet been enough flood mapping to translate the hazard information into effective policy or regulation.

- This was noted as especially true for smaller watercourse across Western Canada.
- Furthermore, many flood hazard maps aren't yet showing anything other than clearwater flooding, while things like erosion are causing large amounts of damage and need to be considered to create effective policy solutions.
- It is also often unclear how updating flood maps (or introducing them at all) will interact with local regulations that already exist.

f. Challenges for First Nations in sovereignty over their own regulations

Unique to First Nations is the challenge of balancing the need for sovereignty and self-autonomy over the regulations made within their territories, with the need for resources and support to do so.

SUGGESTED SOLUTIONS: POLICY & REGULATION

a. Improve the specific content of current regulations

Experts brought up many adjustments that could potentially improve current regulation approaches:

- Jurisdictional level policies need to be based upon a clear design flood (1:100year or higher) and need to include climate change impacts at least for consideration.
- Maps are currently changing at faster rates (e.g., automatic updates etc.) so the regulations that are based on them need to have space for adjustment, to avoid being too rigid.
- In terms of specific regulations that should exist, experts raised the common ideas of building heights, set back advisories, limits on new development, and other building codes. However, additional points were also raised, with people pushing for new ideas such as 'room for the river' being included in enforced regulation, along with things like land-cover type that could alter roughness/flood behaviour (e.g., the Netherlands).
- Additionally, experts were interested in how insurance could act as a compliance lever, bringing up the US FEMA example. If insurance could only be offered to those making appropriate flood risk development decisions, then it would incentivise change. Although the experts were also wary of the potential for insurance schemes to encourage repetitive loss loopholes rather than real risk reduction in the long term.
- Additionally, experts raised that any compliance levers should be designed to prevent future worsening of risk, not punish those who already own/reside in flood prone areas unaware.

b. Have clearer federal-level guidance on regulation activities

Experts raised that there needs to be clearer guidance on what regulation options and standards there should be from jurisdictional or even federal governments. However, many felt that this should be guidance only, and should not involve top-down regulation.

- The benefits of a guideline approach would be the flexibility that comes with it. If some basic guidance could be offered it would mean municipalities don't have to wait for all local mapping and policy efforts to be perfect but instead could act now to begin reducing risk.
- Key to any approach would be agreement between different levels of government on the level of guidance taken.
- To encourage greater connection of flood maps to regulation currently, the current federal and jurisdictional flood map funding could come with stronger requirements to make sure the maps are appropriate for regulation purposes.

c. Weigh the pros and cons of decentralized regulation management

Building on the concept of guidance, one of the only areas where participants gave conflicting solutions was regarding who should be responsible for regulation and policy creation.

- Some suggested the division of responsibility amongst different levels of government is a good thing, as it allows municipalities the opportunity to create regulations as they see fit (as is currently done in Alberta and Saskatchewan).
- Others however called for greater federal involvement, as municipalities still struggle with the responsibility of helping during flood recovery. If the federal government is supporting recovery, perhaps they should have an influence on the regulations that are chosen.
- At the jurisdictional level, it was also suggested that there needs to be clear coordination or regulation to ensure consistency and fairness, and to level the playing field for municipalities with less resources.

- Regardless of the different proposed solutions, one message was clear: there should be a clearer delineation of the roles and responsibilities when it comes to policies and regulations based on flood map information.

d. Gather more relevant information that can help policy and regulation design

Experts raised the point that currently there remains a lack of information to base policy and regulation on, and suggested some areas to focus on:

- Maps need to be more frequently updated or adapted to automatically be updated based on new information. It would help to have some kind of strategy on update frequency.
- Additionally, there needs to be guidance on how to better gather real-world flood information during/directly following a flood event. This would allow policies to be informed by 'real-world' and localized information.
- Finally, there needs to be guidance on how to better gather real-world flood information during/directly following a flood event. This would allow policies to be informed by 'real-world' and localized information.

e. Create opportunities for regulation knowledge sharing across the region

A clear solution mentioned several times was the desire for professionals across different jurisdictions and municipalities to have an overview of what regulations are being used around Canada:

- Some suggested a 'database' that includes the specifications being used in regulations/bylaws and how these relate to the flood maps being produced.
- Experts felt this is something that could be driven at the federal level, it wouldn't be the federal government telling people what regulations to adopt, rather, offering a wide variety of examples and best practices.
- In addition to some form of database, experts said that there needs to be more discussion about the role maps play in regulation generally.

> *"A database of the rules and flood levels and maps being used would be helpful. It would help to inform people about the tools at other levels that people use."*

f. Follow a risk-based policy decision approach

Experts asserted that for effective and equitable policy and regulation to occur, there needs to be a shift towards risk-based regulation.

- This will require continued focus on shifting from flood hazard to flood risk mapping.

2cii. Public communication and engagement with flood maps

Appropriately communicating flood map information with the public improves flood risk awareness, in turn enabling informed decision making[10] and self-empowered action[44]. Direct engagement with the public on flood mapping projects will help with communication and can also lead to greater local support of a mapping project and resulting flood management efforts[45]. Many flood mapping projects in Western Canada do currently incorporate communication and engagement in their workplans, and there has been a recent focus on the topic with the release of the 'Indigenous Engagement Guidelines for Flood Mapping'[46], as part of the Federal Flood mapping Framework and Guideline Series. However, communication of flood map information remains a challenge in Canada[1,10]. Diverse and nebulous flood mapping terms can cause misunderstandings[47], the technical information contained within hazard maps may not suit public needs[29], while at times communities are simply unable to access undisclosed maps[41].

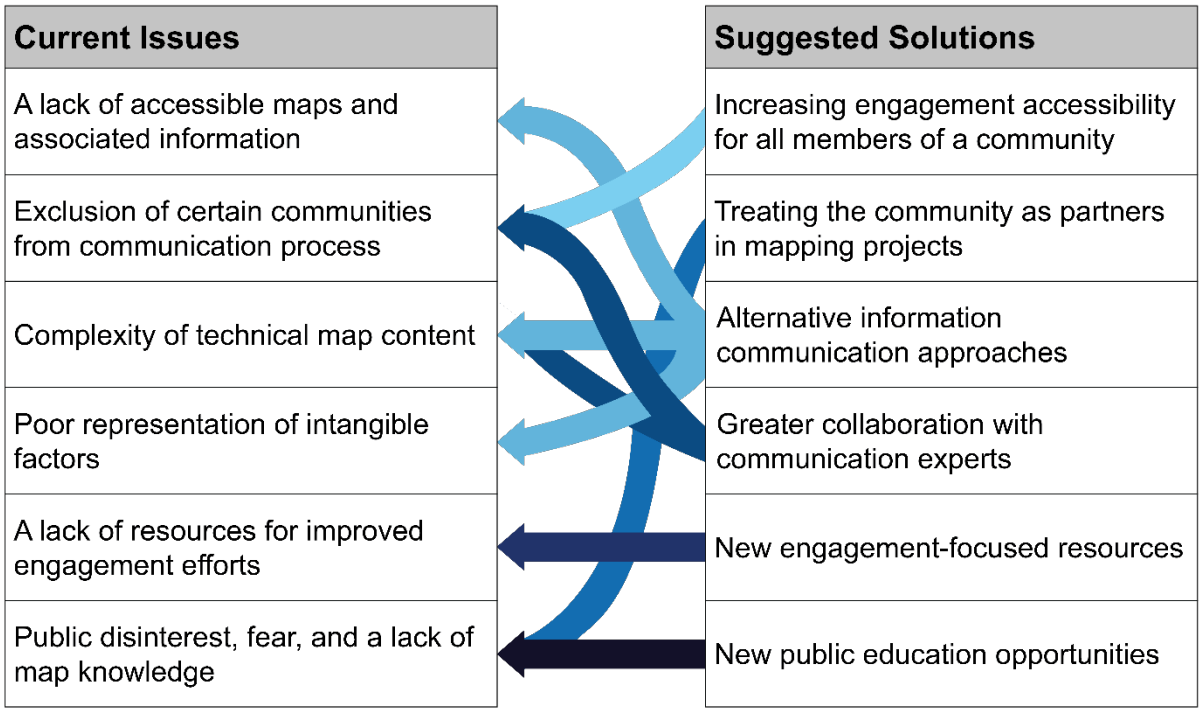


Figure 12. *Summary of the communication & engagement issues and solutions identified by participants. Arrows indicate the relation of each solution to the suggested issues (based on the context provided by the participants).*

Expert participants at the workshop shared their thoughts on the current issues and possible solutions for public communication and engagement in Western Canada (***Figure 12***).

CURRENT ISSUES: COMMUNICATION & ENGAGEMENT

a. A lack of accessible maps and associated information

Experts spoke about the public's limited access to crucial, risk-reducing information, and about the disconnect between the creation of flood maps and their accessibility to end-users.

- Information gaps exist in both the content of flood maps and the supplementary information provided alongside them.
- Flood managers and infrastructure operators also need better access to maps for flood warnings and emergency response.
- While there is a push to share more flood hazard information, there is a lack of guidance on personal risk reduction options within this information. The public needs clearer accompanying information on how to mitigate their own flood risks.

b. Exclusion of certain communities from the communication process

Communication about mapping projects often fails to reach all affected communities.

- High immigration and travel rates in Western Canada create language barriers and unfamiliarity with local hazards. Little is currently done to address these accessibility issues.
- Certain groups, such as youth, are also excluded due to the need for additional translations of mapping findings.

- Developers and regulators are well informed about the benefits of mapping projects, but the public primarily receives negative information about how maps may impact them, also creating another form of exclusion.

> *"We tend to separate engineering from communication. There isn't interconnection- Communication can't be an afterthought"*

c. Complexity of technical map content

Experts highlighted that flood maps and reports are too technical for many to understand.

- There is a lack of simple terminology, making key concepts difficult to grasp.
- Return periods and probabilities are not well explained or intuitive for the public.
- Poorly explained complex map information can shock the public, leading to backlash rather than increased awareness.
- This issue is especially critical when communicating how climate change accelerates flooding in many areas.

d. Poor representation of intangible factors

While only mentioned briefly, experts discussed the current lack of ability to communicate intangible assets in both hazard and risk mapping in Western Canada, despite these assets being important to the public.

e. A lack of resources for improved engagement efforts

Experts agreed that engagement is important but highlighted that it is often limited by resource constraints.

- Budget and time restrictions prevent meetings between communities and project leaders as frequently as either side would want.
- Confusion exists around the roles of engagement due to multiple layers of management in mapping projects.
- The engineering and communication processes are often siloed, reducing effectiveness.
- Resourcing and collaboration challenges have often led to a lack of a clear engagement strategy, with community engagement at times treated as an afterthought rather than an integral part of the process.

f. Public disinterest, fear, and a lack of map knowledge

One of the most discussed issues was the public's risk perceptions and knowledge. Experts felt that even when appropriate communication is attempted, it can still be faced by public disinterest.

- Experts spoke about the challenges of trying to engage with communities who showed a disinterest in learning about their flood risk, acknowledging that often this is related to past negative experiences with the consequences of flooding.
- Additionally, there are even greater issues when the public become apprehensive about map creation entirely, with concerns around property values. This can even translate into legal issues.
- Aside from disinterest or fear, experts also had found that people's ability to interact with physical maps (hardcopy or PDF) has decreased over time, although they acknowledged that ability to navigate interactive online maps has improved.

> *"People's ability to interact with maps has changed over time, people don't know how to interact with maps anymore, but they are getting better with digital maps"*

SUGGESTED SOLUTIONS: COMMUNICATION & ENGAGEMENT

a. Increasing engagement accessibility for all members of a community

Experts emphasized the need to make it easier for the public to engage with mapping projects.

- Improved engagement can be achieved by prioritizing regular check-ins and updates throughout the entire lifecycle of the project. There should be open communication channels so the public can share their thoughts with the project team, even if they can't attend town halls or meetings in person.
- For these updates to be effective, experts stressed the importance of creating a comprehensive communication strategy at the project's outset, which includes various formats to ensure accessibility.
- The engagement style should be more proactive, with maps and related information actively brought to diverse communities, rather than requiring people to search for it.
- Communication should focus on explaining the different stages of the mapping process and their significance, rather than just highlighting the potential negative consequences of the final product.
- One suggested approach to increase engagement is to establish multi-sector committees to ensure diverse representation throughout a project, with these committees guiding how communication strategies can be best tailored in the community.
- Translating information into different languages was also recommended to better reach immigrant communities.
- Finally, to build trust, experts emphasized the importance of addressing emotional factors, recognizing that communities might feel fear or anger about floods (adjusting communication to be trauma-informed).

b. Treating the community as partners in mapping projects

Experts acknowledged that in the past, engagement has often centred on educating local communities, rather than treating them as partners in the process who also hold valuable flooding insights.

- Local knowledge should be leveraged to improve map relevance, and the communities should be consulted on how they want their knowledge to be used within the mapping process.
- There should be a structured process for the gathering of local knowledge and revision of the project by the public. Experts suggested something like a survey that can easily be sent out, and where communication approaches can garner direct feedback (e.g., are people understanding the maps?).

c. Alternative information communication approaches

Many of the solutions suggested by our expert participants revolved around alternative ways of communicating the map information itself.

- Many suggested greater representation of information that could lead to informed end-user decision making within the maps. This would involve inclusion of potential losses (e.g., risk mapping) that can include financial losses, and other losses too based on local community values.
- Uncertainty and probability need to be better explained, with terms adjusted as necessary to help the public understand that floods can still occur at any time. Additionally, it is important to discuss what maps do not show (e.g., the cumulative effects of different hazards).
- It was suggested multiple times that online, interactive tools are essential, as many people now prefer to interact with maps this way. This could include multiple layers, allowing end-

users to seek the information they are most interested in.

- Simplified language is key. The Province of Alberta has developed terms to try and close the gap between public understanding and expert terminology. The language around return periods and probabilities were identified as especially confusing for the public. It was suggested that probabilities (e.g., 1% chance of flood per year) should be relied on instead and could be adapted to fit into mortgage time periods as well (e.g., 30year) to address public financial asset concerns.
- Finally, focusing on stories was suggested. While having the maps was important, it was raised that it is equally essential to have information that speaks to local experiences and emotions. The City of Calgary is already experimenting with this.
- Accompanying the map communication suggestions was the assertion that technical precision cannot be lost. It is fine to communicate information in new ways, but graphical precision should still match model precision.

" We need to turn facts into stories."

d. New public education opportunities

Beyond general updates on mapping projects, experts emphasized the need for increased educational opportunities to help communities understand floods and how to interpret maps. This is especially important in communities where there is resistance to flood information.

- Most suggestions focused on practical ways to raise flood awareness, such as incorporating flood map concepts into school curriculums and using visible signage in public spaces.
- It was mentioned that this education should focus on the positive outcomes of mapping and flood management (e.g., avoided costs) to raise public interest.
- Experts highlighted the potential of social media and traditional media as educational tools. Platforms like TikTok and Instagram were suggested as low-cost ways to raise local awareness.
- To further promote education, experts recommended partnering with realtors, mortgage brokers, and insurance agencies, who have a vested interest in fostering flood-aware communities.
- Finally, experts cautioned against assuming that local communities and decision-makers lack a deep understanding of flood risks. Education efforts should be two-way, fostering dialogue rather than taking a one-sided approach.

e. New engagement-focused resources

To support their suggested solutions, experts noted that there would need to be additional resources.

- A sustained funding stream that supports the continued creation of new flood maps, but that also encourages a robust communication strategy was suggested.
- Additionally, there were calls for more information on tactics for engaging with communities, with recommendations on what approaches work best.

f. Greater collaboration with communication experts

To enhance communication and engagement efforts, experts suggested greater collaboration with established communication professionals.

- This process may be handled in-house if such teams already exist (e.g., City of Calgary currently leverages their communication team), but it can also involve external partners in real estate and other sectors who may have communication expertise.
- Additionally, this process enables a more efficient engagement approach that can be

aligned with past and future projects to prevent community engagement fatigue.

2ciii. Equity and justice in flood mapping

Equity and justice have historically been under considered in flood management globally[48], contributing to many of the socio-economic drivers of unequal flood risk distribution that are seen today. Given that flood maps directly influence other flood management decisions, along with local community flood risk awareness, it becomes essential to consider the role that flood mapping can play in either alleviating or exacerbating inequities in flood management.

Equity and justice are often raised when discussing flood risk maps or flood vulnerability maps as these map types, when designed well, can directly consider the intersectional disadvantages that different populations may be facing[29,49]. However, equity and justice remain equally as integral to consider in flood hazard mapping, given that hazard maps are far more prevalent and relied upon in the policies and regulations that may affect communities. Decisions on where hazard mapping is undertaken, and how this mapping influences local regulation decisions can have negative outcomes for those who face the greatest intersectional disadvantages if equity isn't carefully considered[50,51].

Participants shared their thoughts on how equity and justice influence their mapping activities in Western Canada (***Figure 13***).

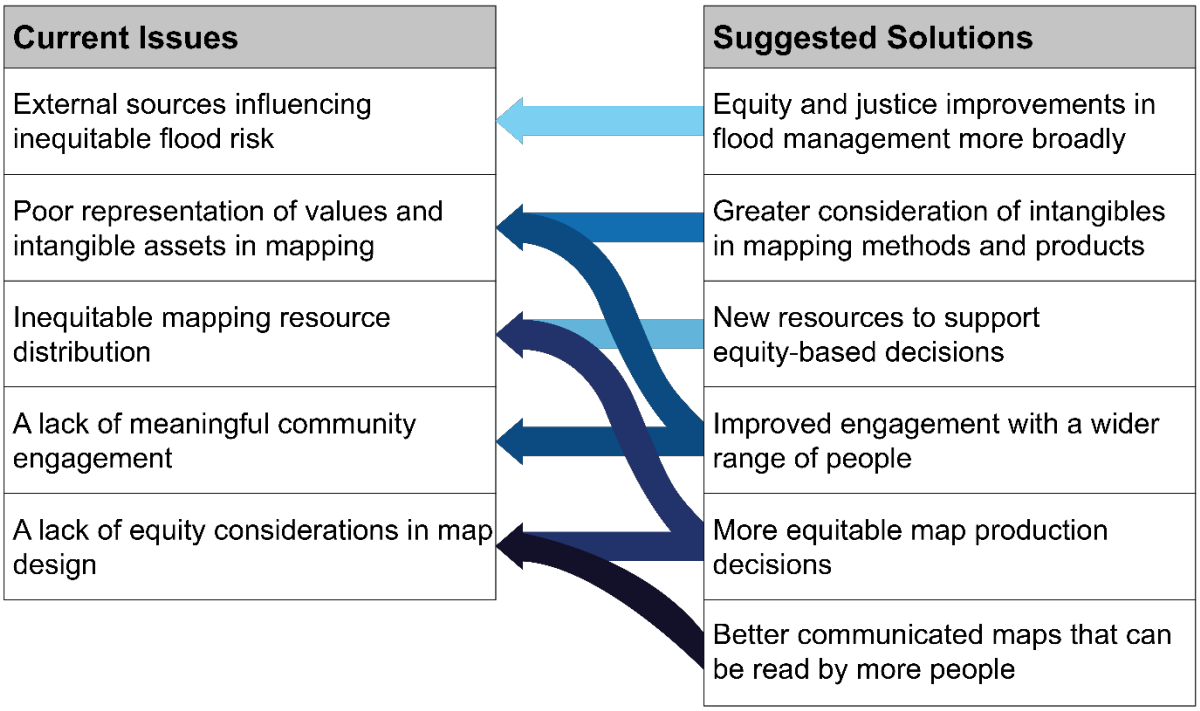


Figure 13. *Summary of the equity & justice issues and solutions identified by participants. Arrows indicate the relation of each solution to the suggested issues (based on the context provided by the participants).*

CURRENT ISSUES: EQUITY & JUSTICE

a. External sources influencing inequitable flood risk

Experts spoke about various sources leading to uneven flood risk distribution:

- Water management was frequently brought up, with the holding or removal of water from one area altering the flood risk in others. This was also related to water quality issues and other compounding sources of vulnerability.
- Flood insurance was also highlighted as a major source of inequitable flood risk, with concerns raised over the fact that people in high-hazard areas, who are often lower-income, are unable to secure flood insurance, even when forced to reside in those areas (e.g., First Nations). On the other hand, in some areas with very high-value properties, such as waterfront locations, a large proportion of recovery funds are received.
- Experts also raised concerns over the impact of inequitable policies and regulations that may not be designed to help those who face a variety of disadvantages.

b. Poor representation of values and intangible assets in mapping

Currently when flood risk maps seek to represent damage, they largely display economic impacts alone. While important, experts raised concerns around how other intangible assets and values (e.g., environment, human health, spiritual sites) are still being poorly represented in most mapping efforts.

> *"If it can't be measured in money, do we currently care?"*

c. Inequitable mapping resource distribution

Experts identified a range of map-related resources that they felt are not being distributed in a fair manner.

- They identified that there is a lack of data in certain communities, and that often it is the remote or inaccessible communities who are situated in more hazardous areas. The hydrological models that are supported for use in areas with less resources may also not be suitable for local hazard types and requirements, but there may not be the local expertise or funds to outsource for additional help.
- Communities who have the budgets to better respond to floods tend to be the ones receiving mapping resources. These communities can also enter into cost-sharing agreements, where others might be completely reliant on external funding to complete their maps.
- There is also an information issue, with variable awareness of funding programs and mapping guidance between municipalities and jurisdictions. In smaller municipalities, there may not be someone specifically tasked with grant applications, so applications are predominantly coming from municipalities that do have the internal expertise.

d. A lack of meaningful community engagement

Currently despite greater engagement, Indigenous knowledge and concerns are still largely excluded from maps. In many cases, engagement still means taking the finished maps to communities, rather than involving them in a meaningful way where their knowledge and opinions can shape the mapping process.

> *"Public engagement is often just a token exercise"*

e. A lack of equity considerations in map design

Experts felt that maps are generally still doing little to address equity and justice issues.

- If the decision of where to map is based upon cost vs benefit, areas with lower value

developments and housing will continue to have fewer maps, and then fewer resulting risk management efforts or future resources.
- Currently many maps contain arbitrary lines with boundaries that end without clear decisions on how this could impact local communities.
- There are many socio-economic factors that should influence how maps are being produced and who will read them. Are age and language and other factors being considered when maps are being made?

SUGGESTED SOLUTIONS: EQUITY & JUSTICE

a. Equity and justice improvements in flood management more broadly

Experts pointed out that some equity and justice issues aren't directly related to the maps, but that there needs to be better consideration for how flood management more broadly is influencing communities.

- They asserted that the emergency management and flood management decisions that are made based on maps need to consider local cultural needs.
- That any mitigation decisions involve an equity lens and look at where management is most needed, informed by more than a cost-benefit approach alone.
- Greater education and awareness are needed for decision makers and those in power on how equity and injustice can alter people's flood risk.
- Greater attention needs to be paid to insurance and enforcement of floodplain regulations everywhere.

b. Greater consideration of intangibles in mapping methods and products

If flood risk mapping is being undertaken, experts discussed the need for greater analysis of intangible values and assets.

- Current models largely fail to capture all values (e.g., environmental, cultural, social) and need to include a wider range of data to allow representation of these factors. This requires greater community input so that things like cultural needs are understood.
- It also requires the prioritization of intangible factors in the mapping process. This needs to be accompanied once again by education of decision-makers and people in power to communicate the benefits of funding this work.

c. New resources to support equity-based decisions

For these solutions to be implemented, resources need to be appropriately allocated.

- There needs to be more equitable funding for where mapping is most needed, not just where governments have the resources to be applying for grants. A suggestion was a specific funding stream for small municipalities generally, to help them also have in-house mapping and flood management staff.
- More equitable funding needs to be complemented by greater support for the development and planning of flood mapping projects. While current guidelines are helpful, there is still a lack of information on how smaller communities can leverage existing products, models, and data to undertake their own projects.

d. Improved engagement with a wider range of people

Experts asserted that to create more equitable flood mapping and flood management, there needs to be a rethinking of current engagement approaches.

- They suggested a formalized engagement process that is included in the workflow and scope of projects, which is, in turn supported by the funding mechanisms and guidelines provided by the federal government. A key part

of the workflow is that engagement needs to occur earlier.

- Additionally, they suggested that engagement techniques needed to change to become more equitable and inclusive. Door-to-door canvasing, phone calls and advertisement around communities could help increase awareness beyond traditional townhall meetings that may remain inaccessible to some people.
- To ensure the right people are reached, community leaders could be identified who know which groups might be most impacted by floods locally. This should be accompanied by educating the leaders and decision-makers on why engagement with the wider community on the maps is so essential to the process.
- Finally, when First Nations and Indigenous communities are engaged in mapping processes, they need to be involved early so their sovereignty can be respected and their preferences (e.g., place names) can influence the creation of the maps.

"Formalizing community engagement as part of the process can be useful. Consultants can't add extra engagement steps if they are not included in the contract."

Photo credit: Ignacio Aguirre

e. More equitable map production decisions

Experts suggested there needs to be greater transparency around how map production is being prioritized.

- They stated it needs to move towards being based upon risk, rather than population density or pre-existing resource bases.
- To ensure that projects are meeting the needs of communities, there could also be a risk-management analysis process following map creation, to ensure communities are benefiting.

"Projects should be subjected to risk-management analysis"

f. Better communicated maps that can be read by more people

If the maps are inaccessible or unusable for the wider community, it remains an equity issue. Experts have suggested a range of map design adjustments that could help:

- First, by understanding community needs, the maps can be tailored to reflect the information that is most desired.
- Map content and terminology must be communicated in an accessible way, making the maps easier to understood and more approachable.
- Map access needs to be improved, offering both digital and paper formats, along with local events to communicate and distribute them to everyone.
- Reflect local community place names, landmarks, and assets of interest to make the maps more locally relevant and easy to read.

3. Conclusions

Western Canada has seen a surge of new flood mapping activity in recent years, helping create a wealth of new flood hazard and risk understanding throughout the region. With these increased mapping efforts has come identification of issues currently faced by the practitioners creating and using flood maps, along with creative solutions that could help improve mapping best practice.

This report summarises the findings of the WFMC workshop, representing the opinions of expert practitioners from across Western Canada. The key recommendations of this report have been broken into 'map design' and 'map use' categories in ***Table 5***, based upon the GCM and World Café activity results, respectively.

In addition to the recommendations, a few interesting findings emerged from the workshop results. The GCM activity revealed the importance of discerning between different flood map types when making conclusions about the current state of flood maps in Western Canada. For instance, experts who described the factors relevant to the production of high-quality riverine flood hazard maps scored their statements higher in current presence than experts discussing other flood map types, with flood risk mapping scoring the lowest. Similarly, experts scored the riverine flood hazard mapping statements as highest in feasibility to implement, while ice jam flood hazard mapping scored lowest. These map type and flood type differences should be considered during any future efforts to improve map design, with particular attention given to map types that scored lower on the current presence or feasibility scales.

Another interesting theme across the results of all three workshop activities was the consistent mention of the importance of non-technical factors in successful flood mapping. Both the appreciative interviews and GCM invited open-ended participant discussion, where groups could debate any aspect of flood map design or process they liked. While various forms of data availability and methodology advancement were brought forward as important, a large proportion of the discussions were devoted to topics such as community engagement, resourcing, governance, and translation of maps into effective flood risk reduction activities. This discussion trend may reflect two things 1) that recent efforts to advance data availability and mapping methodology guidance have been proving helpful to mapping practitioners, and 2) that participants felt that successful flood mapping practice in Western Canada is limited by current administrative practices (whether local or national) just as much as the availability of data or appropriate mapping methods.

With recent efforts at the federal level to offer guidance on the topics of Indigenous engagement[46], flood hazard education tools[52], and land use in flood risk areas[53], NRCan and other agencies are aware that jurisdictions and municipalities are seeking assistance on these topics. Moving forward, the importance of things like community engagement and equitable resource distribution need to be reflected in the guidelines and funding opportunities offered at both the federal and jurisdictional levels. If the recommendations highlighted in this report can be prioritized, not only will flood map content be improved, but more useful maps that can be effectively utilized for flood risk reduction goals will be achieved.

Table 5. *Key recommendations for the improvement of map design and map use in Western Canada. Time horizon indicates whether the recommendation would be relatively quick to adjust (e.g., immediately within new mapping projects/ guidance efforts), or whether the recommendation will need to be implemented over the long-term. Responsibility for implementation covers the federal government (F Gov.), jurisdictional governments (J Gov.), more local governments (L Gov.) and individual map producers or consulting agencies (Indiv.). Map design recommendations are summarized from the 'go-zone' most feasible and important statements found during the GCM activity, while map use recommendations come from the World Café discussions.*

Map Design							
Key Recommendations	**Description**	**Time Horizon**		**Responsibility for implementation**			
		Short -term	Long -term	F Gov.	J Gov.	L Gov.	Indiv.
A clear understanding of map use or purpose	• Prior to, and throughout map creation, experts asserted the need for clear discussion of purpose to ensure the final design can complement all required uses. • A potential step here is the requirement of intended map use to be more clearly explained at the funding stage.		✓	✓	✓	✓	✓
High quality data inputs	• Of the data inputs that were mentioned across the four different map types, experts mentioned terrain surveys, base data (e.g., buildings, infrastructure), air photos, exposure data, and LiDAR data as being the most feasible data types to make more available. • It was suggested that all jurisdictional governments should provide updated air photo libraries.		✓	✓	✓		
Peer review and quality control	• This recommendation was specific to flood risk mapping, where the experts asserted that there needs to be review and testing of the methods chosen to represent flood damage.		✓		✓	✓	✓
Clear documentation of datum	• This was frequently mentioned, related to problems that arise when local communities are employing a different datum to the updated 2013 datum, creating transference issues. • Experts asserted that it is important to discuss datum use with communities and display the datum employed.	✓			✓	✓	✓
Maps produced in various formats	• To ensure maps can be updated regularly, but also easily shared, experts asserted there should be a requirement for multiple map forms to be designed and shared. • Final map outputs should be consistently accompanied by reports that cover all the maps details (including uncertainty and quality control disclosure).	✓			✓	✓	✓
Clear map details	• Experts pushed the importance of clear and complete legends, along with additional details within the map design, specific to reader use (e.g., definitions)	✓			✓	✓	✓
Inclusion of academic research/ latest methodology advancements	• There should be space for the latest research and methodologies to be incorporated into mapping guidelines.		✓	✓	✓		
Well defined uncertainty and assumptions	• Experts felt it is feasible to encourage more clearly defined uncertainty in all map types being produced, along with any other methodological assumptions that are made in the mapping process. • This could be accompanied by greater guidance on how best to disclose this.		✓	✓	✓	✓	✓
Room for flexibility and adjustment in the methods followed	• While standards and guidelines are important, these need to be flexible enough to allow adaptation where required. • This is where local and professional expertise need to be relied upon for best judgement.		✓	✓	✓	✓	✓

Map Use							
Key Recommendation	**Description**	**Time Horizon**		**Responsibility for implementation**			
		Short -term	Long -term	F Gov.	J Gov.	L Gov.	Indiv.
Improve engagement of people who may face intersectional disadvantages	• While many projects currently seek engagement, there are still communities being missed, often those who face intersectional disadvantages (e.g., remote communities, Indigenous communities, the elderly etc.). • Current engagement efforts need to shift beyond just community meetings to include more targeted engagement that can reach the right people.		✓		✓	✓	✓
Treat communities as partners in the mapping process	• Learning during a mapping project is a two-way street. • Experts asserted that the inclusion of more community knowledge and opinion throughout mapping projects would improve the maps to better meet end user needs and would encourage greater local support of map creation and any resulting flood management.		✓		✓	✓	✓
Prioritize alternative communication of map information	• Experts mentioned that in their experience, end-user ability to interpret static maps has decreased, but their ability to work with multi-layer online interactive maps have improved. There needs to be prioritization of digital interactive maps. • Map information also should be occurring in new ways, taking advantage of social media and other new formats for education.		✓		✓	✓	✓
Allocate resourcing that supports equitable map production and use	• Experts discussed how it can be challenging for rural communities, or communities with no mapping or grant-writing experience to receive resources (funding, staff, map tools). • Flexible funding that can be used to address inequity issues was mentioned, with more concentrated funding streams for communities who currently fail to access mapping help. • Additionally, projects should have specific funding to allow for early and varied community engagement and education to ensure those who are exposed to flooding can benefit from the maps being made.		✓	✓	✓	✓	
Have clearer guidance on the roles and responsibilities of governments in creating flood policy and regulation	• There was variable participant opinion over what the roles of different governments should be in the creation or enforcement of map-related policy and regulation, but it was clear that there needs to be clearer guidance on how different levels of government can or should be involved, and what is working where.	✓		✓	✓	✓	
Create a database or repository of policy and regulation information	• Following from the above recommendation, participants suggested an online database or repository of different regulation and policy approaches used around Canada, for jurisdictional and local governments to draw from.	✓		✓			
Seek greater collaboration between map creators and other experts	• Attending the workshop were primarily experts in map creation, and many of them mentioned they would like to have greater collaboration with communication and marketing specialists. • This was suggested as being possible within organizations internally, but also through external collaborations with groups such as the real estate industry.	✓			✓	✓	
Move towards a risk-based approach in map use decision making	• Whether for policy and regulation design, or other flood management (e.g., hard mitigation structures), participants emphasized the need for risk understanding, moving beyond hazard estimation alone. • This requires greater resourcing of flood risk mapping, including guidance and funding.		✓	✓	✓	✓	

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Appendix 1. Jurisdictional Survey Results

We heard back from representatives of six of the seven Western jurisdictions (SK did not respond). Results are representative of flood mapping that the jurisdictional governments are involved in and are not necessarily representative of more localized or private flood mapping efforts that are going on without jurisdictional government involvement.

Flood map types:

- Of the 6 respondents, 5 jurisdictions (YT, BC, NT, MB, AB) are undertaking **flood hazard mapping** (NU is still in the planning phase of their flood mapping program)
- 3 were also undertaking **inundation mapping** (YT, NT, BC)
- AB was the only jurisdiction also undertaking **other mapping types** (e.g., flood risk and flood awareness mapping).

Funding sources:

- All 6 have received major project funding from the **FHIMP**
- 3 (YT, MB, AB) also receiving **additional federal funding** from other programs
- Only NT reported additional **local funding** as another major project funding source.

Flood types being considered:

- In the jurisdiction's hazard and/or inundation mapping all 5 undertaking mapping consider **riverine** and **ice jam** flood types
- YT and BC also consider **coastal** flooding
- Only BC reported **pluvial** flood consideration in their maps at this stage.

Other considerations in flood maps:

- YT, BC, and AB are considering both **geomorphic processes** and **flood mitigation structures** in their mapping
- YT, NT, and BC are considering **climate change** influences on flood hazard behavior.
- In NU, a scoping study to identify coastal flooding, erosion, riverine, pluvial/runoff, climate change and ice jam flooding is underway.

Tracking of mapping activities:

- All 5 jurisdictions undertaking mapping were tracking their map outputs in some form.

Regulations based on mapping:

- Both YT and NT currently **don't have regulations** as the mapping programs are relatively new.
- In both BC and AB, **regulation is controlled at the municipal level**, with the provincial governments offering support for implementation.
- In AB, the province undertakes most of the mapping and then municipalities choose how to use this information.

- In MB their flood maps are used for the determining of **Flood Protection Levels**, particularly in developments within Designated Flood Areas.

Design floods commonly used:

- YT creates maps displaying the **1:20**, **1:100**, and **1:200** yr design floods.
- NT uses a minimum of the **1:100** and often also the **1:200**yr flood in their maps.
- BC uses the **1:200**yr flood, although if there is a local historic **flood of record** that is greater that is used instead.
- Manitoba employs the **1:200**yr flood
- AB uses the **1:100**yr flood for planning purposes but also provides longer return periods for additional awareness (e.g., **1:200**, **1:500**).

Current mapping challenges:

- Both NT and NU mentioned a **lack of hydrometric data** as a challenge, and that other than local knowledge there are communities with no data.
- YT mentioned the **complexity** that comes with mapping ice jam behavior and both YT and NT mentioned the challenges that arise with **communication** of complex information in their communities, especially without clear regulation purpose.
- NT mentioned **funding challenges** (meeting the 75:25 agreements), and difficulties with covering costs in more remote communities.
- In BC, challenges mostly emerged due to the lack of involvement by the provincial government in flood mapping activities in previous decades. This resulted in **outdated local guidelines** that couldn't be relied on, a lack of clear understanding in many communities about **roles and responsibilities** in mapping governance, and **procurement challenges** as large scale mapping was required to cover historic gaps, but this created additional technical and budgetary spending issues.

Jurisdictional best practices:

- Both YT and NT highlighted their **community engagement efforts** as being strong and effective.
- BC highlighted that their recent projects have been able to be completed **across jurisdictional boundaries** and have included information that can be particularly useful for **emergency response** measures (e.g., flood velocity).
- AB highlighted than their local **technical guidelines** as something that the province considers to be a best practice.

For recent more detailed summaries of the diversity of mapping practice seen between Canadian jurisdictions refer to Stantec Consulting (2024)[28] and Vidrio-Sahagún et al. (2025)[27].

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Appendix 2. Workshop Consent Form

Expert opinions on best practices in Western Canadian flood mapping

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Purpose: The purpose of this study is to understand what the current best practices are for flood mapping in Western Canada. NRCan and our study team are particularly interested in the perceptions of flood mapping experts (people who work closely with flood maps) from different jurisdictions. This study will translate the discussions and activities that are taking place over day two of the Western Flood Mapping Conference into key recommendations for improving current flood mapping practice in Canada. The results of this study will contribute to a PhD dissertation, and the student involved is being paid by NRCan to complete this work. NRCan will have access to anonymized versions of the data collected in the workshop.

You have been invited to participate in this study as you are attending the Western Flood Mapping Conference, and you have been identified as an expert.

Study Procedures: If you agree to participate in this study, you will participate in a roughly 6-hour workshop (including a lunch break) and will answer questions and undertake activities relating to:

- Your opinion on best practices for the creation of flood hazard maps.
- Your personal experiences with past flood mapping projects in your jurisdiction.
- Your opinion on current challenges relating to the use and regulation of flood maps in Canada, and your perceptions on how things might be improved.

All questions will be asked in a group context where you will have the opportunity to discuss with other experts. The group activity will involve a method called 'Group Concept Mapping', where as a group you will identify various statements relating to idealized flood hazard mapping, before organizing and ranking the statements.

By consenting to take part in the workshop, you also consent to be sent a survey in the weeks following the workshop which will outline the initial findings of the workshop and will ask for any additional comments or changes you might wish to see. This survey will take approximately ten minutes to complete.

Eligibility: You must be 18 years or older and attending at least one day of the Western Flood Mapping Conference. You have been invited to participate due to your career and its relevance to flood mapping in Western Canada.

Confidentiality: If you agree to take part in the workshop you will be partaking in group discussions and activities so your identity will be known to others in the room, and we cannot control what information is discussed outside of the room. However, we encourage all participants to refrain from disclosing the contents of the discussion

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outside of the workshop. In any research outputs that come from this work your responses will be anonymized. We will ask you for some personal information such as your name and career for our record keeping and to understand who is in the room. All data that includes your name will be kept in an encrypted and password-protected format.

Consent: Your participation in this study is entirely voluntary and you may refuse to participate or withdraw from the study at any time. You have the right to choose to not answer some or any of the workshop or survey questions, and to withdraw from the group activity at any stage. While you may leave, once the workshop discussions and group activities have begun, you will be unable to withdraw any data you have provided given the interactive group format, making it impossible to distinguish who provided what information.

By signing your consent here, you agree to the use of anonymized quotes and paraphrased explanations of the things you say and write. We encourage you to keep this information sheet for your records. Please feel free to ask the investigators any additional questions that you have about the study.

Research Outputs: Members of our research team will analyse, interpret and write about the things you share with us (the data). These results will be written up in a report for Natural Resources Canada in the following months. Additionally, the results will be used in peer-reviewed academic journal and conference outputs, and to inform a chapter in a PhD dissertation; viewable open-access online in UBC's institutional repository, cIRcle (https://circle.ubc.ca/).

In all the above outputs, your identity will be anonymized. We will not share any personal information about you publicly. We would be happy to share any publications with participants, so please let the research team know if you would like to receive updates and articles resulting from this work.

Contact Information for the Study: If you have any questions or would like further information about this study, please contact Charlotte Milne at cmil137@mail.ubc.ca

Contact for Concerns about the Rights of Research Participants: If you have any concerns or complaints about your rights as a research participant and/or your experiences while participating in this study, contact the Research Participant Complaint Line in the UBC Office of Research Ethics at 604-822-8598 or if long distance e-mail RSIL@ors.ubc.ca or call toll free 1-877-822-8598. The file number for this project is H24-03801.

Participant Printed Name

Participant Signature Date

Appendix 3. Total GCM Statements for Each Map Type

Table 6. *Total GCM statements provided by participants for riverine flood hazard mapping. Note, category is based upon original participant grouping of statements.*

Code	Statement	CP av.	Impt. av.	Feas. av.	Final Category
1	A clear link between scientific methodology/results and final simplified results	2.25	4.00	4.00	Clear communication of map information
2	Clear symbology for easy interpretation	3.60	4.80	4.60	Clear communication of map information
3	Interactive web map for accessibility	4.00	4.50	4.00	Clear communication of map information
4	Understanding of maps use/purpose	4.33	5.00	4.83	Clear communication of map information
5	Very clear and complete legends	4.33	4.83	4.86	Clear communication of map information
6	Map multiple return period events 2-yr to 1000-yr floods	4.50	4.50	5.00	Clear communication of map information
7	Show larger return period events	4.00	4.50	4.86	Clear communication of map information
8	Clear graphic design	3.33	5.00	4.57	Clear communication of map information
9	Clear model outputs (realistic scale and grid size)	4.33	4.50	4.29	Clear communication of map information
10	Communicate impacts of uncertainty in understandable ways	1.75	4.25	3.36	Clear communication of map information
11	Maintain stations in the same places so you can look at climate change	2.60	4.80	4.20	Climate change considerations
12	Climate scenarios fit for purpose	1.60	3.80	2.40	Climate change considerations
13	Implement climate change in modelling	2.17	4.17	3.57	Climate change considerations
14	Consideration of drainage alterations downstream	3.80	4.80	4.80	Effective modelling methodologies
15	Water quality incorporation in flood mapping	2.00	3.60	2.80	Effective modelling methodologies
16	Well defined technical process striving for excellence	4.63	4.73	4.63	Effective modelling methodologies
17	Consistent approaches in design flood estimation methodology (natural vs. recorded flow)	2.57	4.57	4.57	Effective modelling methodologies
18	Standardized manual editing 2.0 model outputs	2.80	3.20	3.67	Effective modelling methodologies
19	Flood frequency analysis	4.60	5.00	5.00	Effective modelling methodologies
20	Understanding naturalized flows	3.60	5.00	3.80	Effective modelling methodologies
21	Sensitivity analysis	4.20	4.80	4.40	Effective modelling methodologies
22	Methods that can easily be updated with new data	2.83	4.33	3.71	Effective modelling methodologies
23	Downscaled climate models (updated CMIP6, or best possible)	3.05	4.38	3.92	Effective modelling methodologies
24	Past flood data for model calibration (local municipality, public input, government agencies)	2.80	4.40	3.54	Effective validation and uncertainty processes
25	Photos and aerial imagery from past floods to inform modelling	2.92	4.17	3.57	Effective validation and uncertainty processes
26	Consistent performance metrics for model calibration	3.00	3.83	3.57	Effective validation and uncertainty processes
27	Well defined assumptions	4.03	5.00	4.78	Effective validation and uncertainty processes
28	Understanding of error/confidence	2.50	4.60	4.60	Effective validation and uncertainty processes
29	Criteria, hazard, inundation maps (different)	4.00	4.40	4.00	Effective validation and uncertainty processes
30	Ongoing engagement and collaboration	3.50	5.00	4.40	Engagement and collaboration in mapping efforts
31	Know the places that are important to people	3.50	5.00	4.00	Engagement and collaboration in mapping efforts
32	Engagement for and use of traditional knowledge implementation	2.93	4.87	4.53	Engagement and collaboration in mapping efforts
33	Political outreach to get input on mitigation	3.00	4.60	4.20	Engagement and collaboration in mapping efforts
34	High quality/ resolution LiDAR	3.75	4.92	4.42	High quality data inputs
35	Accurate Bathymetric data and topographic data	3.30	4.50	3.94	High quality data inputs
36	Available vegetation data	2.60	4.00	4.00	High quality data inputs

37	Land use categories in data (forested, urban, industrial)	3.80	4.40	5.00	High quality data inputs
38	Soils data from ministry of agriculture	1.40	2.20	3.25	High quality data inputs
39	Available terrain surveys	3.86	4.86	4.71	High quality data inputs
40	Good aerial photos (high resolution)	3.71	3.86	4.86	High quality data inputs
41	Database of land use types to assess Mannings 'n' values (detailed and available)	3.57	4.43	4.43	High quality data inputs
42	Understanding of the watershed's hydrology	3.83	5.00	4.67	High quality data inputs
43	Weather monitoring data to verify hydrology (snowfall, rainfall, runoff)	3.25	5.00	4.00	High quality data inputs
44	Inclusion of spring freshet	4.50	5.00	5.00	High quality data inputs
45	Probable flood warning due to precipitation	3.50	5.00	4.25	High quality data inputs
46	Available ADCP (Acoustic Doppler Current Profiler) data (flow and velocity)	3.00	4.75	4.00	High quality data inputs
47	High Water Marks and flood profiles for model validation	3.08	4.79	3.75	High quality data inputs
48	Available flow data/ gauge data	3.07	5.00	4.04	High quality data inputs
49	Available rainfall data (if no gauges, used to estimate peak flows)	3.00	4.57	4.29	High quality data inputs
50	Available hydrometric data	3.00	5.00	4.43	High quality data inputs
51	Long-term observed time series	3.50	5.00	2.71	High quality data inputs
52	Consideration of flash flood behavior	3.67	3.50	3.86	High quality data inputs
53	Wildfire migration monitoring consideration	1.17	3.17	2.86	High quality data inputs
54	Detailed crossing information (Bridges and culverts)	3.67	4.83	3.83	High quality data inputs
55	Water control structure data (including dam operations within reaches)	3.40	4.40	4.30	High quality data inputs
56	Inclusion of flood mitigation infrastructure data (profile elevation, location, condition, consequences of breach)	3.77	4.85	4.43	High quality data inputs
57	Base data-roads, utilities, buildings	4.14	5.00	4.86	High quality data inputs
58	Ongoing monitoring of water/infrastructure management	3.07	4.36	4.17	High quality data inputs
59	Good data on bridges, culverts, berms, and other hydraulic infrastructure	3.57	4.29	4.86	High quality data inputs
60	Upstream reservoir operating rules considered	2.80	5.00	4.60	High quality data inputs
61	Knowledge of what drives the flooding	4.00	5.00	4.75	High quality data inputs
62	An understanding of historical flood events	2.88	4.96	4.31	High quality data inputs
63	Historical and future fire risk	1.30	3.40	3.50	High quality data inputs
64	Air photo libraries provided by provincial governments	4.60	5.00	4.80	High quality data inputs
65	Long term support and stewardship of the maps	3.75	5.00	3.80	Resources and support for map production
66	Experience and knowledge in map production	5.00	5.00	4.60	Resources and support for map production
67	Using latest technology	3.50	4.17	4.00	Resources and support for map production
68	Sufficient time to produce maps	3.17	4.50	3.80	Resources and support for map production
69	Sufficient funding to produce quality maps	2.72	4.68	3.69	Resources and support for map production
70	Clear data management/storage	2.17	5.00	4.29	Resources and support for map production
71	Investment in data	1.50	4.83	3.83	Resources and support for map production
72	Consistent guidelines for developing the maps	3.20	4.80	4.40	Resources and support for map production
73	Mutual agreement between jurisdictions and Federal government	2.00	4.80	4.60	Resources and support for map production

Table 7. *Total GCM statements provided by participants for ice jam flood hazard mapping. Note, category is based upon original participant grouping of statements.*

Code	Statement	CP av.	Impt. av.	Feas. av.	Final Categories
1	Map to be delivered with its associated files properly (technical reports, model files etc.)	3.17	4.33	4.33	Clear communication of map information
2	Map to be available in digital formats of PDF (static) and editable (GIS files)	4.50	4.50	4.17	Clear communication of map information
3	What maps would look like if mitigation options were included	1.60	4.00	3.40	Clear communication of map information
4	Consider outcome of the map	3.75	3.60	4.00	Clear communication of map information
5	Key information and labels on maps	4.40	4.00	3.40	Clear communication of map information
6	Incorporating climate change impacts on hydrology	2.14	3.97	2.69	Climate change considerations
7	Hydrology assessment to rely on statistical analysis for dominant flood mechanism identification (frequency, breakup)	2.83	4.17	4.00	Effective modelling methodologies
8	Understanding of flood mechanism (freeze-up, breakup, mid-winter)	3.04	4.60	3.92	Effective modelling methodologies
9	Incorporating multiple approaches for data collection for modelling and mapping	4.00	3.83	3.50	Effective modelling methodologies
10	An ice jam flood frequency analysis	3.12	5.00	3.68	Effective modelling methodologies
11	Room for innovation and flexibility in method	3.75	4.00	4.42	Effective modelling methodologies
12	Go back to traditional hydraulic analysis using new approaches (e.g., machine learning, and deep learning)	1.33	3.33	4.33	Effective modelling methodologies
13	Ice jam specific hazard criteria	3.17	3.50	3.67	Effective modelling methodologies
14	Incorporating river ice processes in hydrological models	1.50	4.00	2.67	Effective modelling methodologies
15	Ice-jam specific model	3.42	4.50	3.83	Effective modelling methodologies
16	A 2D model for ice jam simulation	2.17	3.33	3.17	Effective modelling methodologies
17	Advanced methods (e.g., machine learning)	1.00	3.00	3.00	Effective modelling methodologies
18	Methodology for getting water levels on maps	3.20	4.20	3.60	Effective modelling methodologies
19	Monte carlo analysis	2.00	3.00	2.67	Effective modelling methodologies
20	Inundation polygons	4.00	5.00	4.25	Effective modelling methodologies
21	Hydrologic assessment of flood management based on open water and ice jam scenarios (historical)	4.25	4.25	2.40	Effective modelling methodologies
22	Robust methodology for modelling	3.60	4.20	3.40	Effective modelling methodologies
23	Documenting assumptions	3.25	3.80	4.75	Effective validation and uncertainty processes
24	Careful representation of uncertainty	2.43	3.30	2.96	Effective validation and uncertainty processes
25	Approach to quantify uncertainty	3.00	4.67	4.17	Effective validation and uncertainty processes
26	Well-calibrated hydraulic model	3.00	3.00	2.50	Effective validation and uncertainty processes
27	Provincial/territorial expertise in map creation	3.33	3.67	3.33	Engagement and collaboration in mapping efforts
28	Collaboration with community, experts and practitioners to come up with an approach for mapping	3.33	4.00	3.00	Engagement and collaboration in mapping efforts
29	Inclusion of local knowledge	2.96	4.25	3.55	Engagement and collaboration in mapping efforts
30	Inclusion of academic research	5.00	4.50	4.00	Engagement and collaboration in mapping efforts
31	Inclusion of Indigenous knowledge of past floods	1.58	3.47	2.90	Engagement and collaboration in mapping efforts
32	Public education/ engagement plan	2.75	3.80	3.50	Engagement and collaboration in mapping efforts
33	True commitment to revising after feedback	2.25	4.25	2.80	Engagement and collaboration in mapping efforts

34	Local support	2.50	3.40	2.75	Engagement and collaboration in mapping efforts
35	Involvement of ice experts/specialists	3.00	4.83	3.75	Engagement and collaboration in mapping efforts
36	GIS (tools and skillsets)	4.00	3.60	2.40	Engagement and collaboration in mapping efforts
37	Most things required for an open water model	3.33	4.83	4.00	High quality data inputs
38	Available tree scar data	1.17	3.33	2.50	High quality data inputs
39	Awareness of sources of ice available to form a jam	2.67	4.33	3.17	High quality data inputs
40	Water levels data during ice jams (continuous freeze-up and breakup)	2.75	4.92	2.83	High quality data inputs
41	High water mark data	2.75	4.50	3.25	High quality data inputs
42	High quality cross-section and bathymetry data	3.00	4.67	3.67	High quality data inputs
43	High quality LiDAR	4.00	4.83	4.33	High quality data inputs
44	Remote-sensing data (space-borne, air-borne, web cams)	3.00	3.83	3.33	High quality data inputs
45	Annual checklist of critical info collected during the critical flood time	2.00	4.33	4.00	High quality data inputs
46	Spatial scope consideration (upstream and downstream boundaries)	4.00	4.00	4.00	High quality data inputs
47	Historical data on pluvial flooding effect on accelerating ice jam flooding	1.00	3.25	2.50	High quality data inputs
48	Available temperature records	3.75	2.25	3.25	High quality data inputs
49	Ice jam flood elevations (highwater elevations)	2.75	4.40	3.20	High quality data inputs
50	Good quality flow gauges installed	3.00	3.67	3.33	High quality data inputs
51	Collect information on flood mitigation structures into mapping ice jam floods	2.75	3.88	4.75	High quality data inputs
52	High quality imagery	3.50	2.80	3.60	High quality data inputs
53	Consideration of hydropower operations	3.25	3.80	3.50	High quality data inputs
54	Existing flood berm information	3.50	3.00	4.00	High quality data inputs
55	Good historical data set showing location of ice jam toe and extents	1.83	3.21	2.21	High quality data inputs
56	Anecdotal data of flood extents during ice jams	3.50	3.67	3.00	High quality data inputs
57	Historic event information, including water levels and areas frequently impacted	2.21	4.19	2.98	High quality data inputs
58	A setting where ice jams are a dominant flood mechanism	3.17	4.33	4.00	High quality data inputs
59	Clear understanding with supporting narrative of the river ice regime	3.08	4.33	3.42	High quality data inputs
60	Understanding of flow conditions during jam events	2.67	4.83	3.00	High quality data inputs
61	Inclusion of local ice removal systems	2.40	2.80	3.20	High quality data inputs
62	Clear datum decision	3.80	3.20	2.60	High quality data inputs
63	Accurate depth rasters	2.75	5.00	5.00	High quality data inputs
64	Prioritization of which community to map	3.75	4.50	2.60	Resources and support for map production
65	Appropriate funding	4.00	3.40	2.00	Resources and support for map production

Table 8. *Total GCM statements provided by participants for coastal flood hazard mapping. Note, category is based upon original participant grouping of statements.*

Code all	Statement	CP av.	Impt. av.	Feas. av.	Final Category:
1	Appropriate for use case (place based)	3.00	4.00	3.50	Clear communication of map information
2	Clear documentation of datum	4.25	5.00	4.75	Clear communication of map information
3	Produced in digital format	4.00	4.00	5.00	Clear communication of map information
4	Inundation zone	4.25	5.00	5.00	Clear communication of map information
5	Impact security (depth x velocity)	2.50	3.50	4.50	Clear communication of map information
6	Flow depth	3.75	4.25	4.75	Clear communication of map information
7	Minimal complexity for public communication	2.58	3.92	4.00	Clear communication of map information
8	Publicly accessible map portal	2.75	5.00	4.25	Clear communication of map information
9	Accompanied by flood map reports	3.75	4.50	5.00	Clear communication of map information
10	Different languages available	1.25	2.50	2.75	Clear communication of map information
11	Annotation in the maps (evacuation routes)	1.50	3.75	3.75	Clear communication of map information
12	Clear documentation for a variety of end users	2.50	4.00	4.25	Clear communication of map information
13	Open source	1.75	4.00	4.00	Clear communication of map information
14	Global Climate Models considered	2.67	3.00	3.67	Climate change considerations
15	Effect of climate considered	3.67	5.00	4.67	Climate change considerations
16	Considered time horizon (2100, 100years, 200 years)	3.20	4.25	3.50	Effective modelling methodologies
17	Acceptable frequency/probability/return periods	2.50	4.33	3.67	Effective modelling methodologies
18	Consistency in methodology	2.50	4.00	3.33	Effective modelling methodologies
19	Not prioritising high-accuracy over other factors	2.67	2.00	3.33	Effective modelling methodologies
20	Considers the source of hazards	4.00	5.00	4.50	Effective modelling methodologies
21	Composite hazard modeling	2.00	3.75	4.00	Effective modelling methodologies
22	Wave modelling	3.33	4.33	4.67	Effective modelling methodologies
23	Multiple clear scenarios included for decision making	3.33	4.83	4.63	Effective modelling methodologies
24	Joint probability with other events (river flow etc.)	3.00	4.67	4.33	Effective modelling methodologies
25	Coastal hydrodynamic modelling	3.25	4.50	4.25	Effective modelling methodologies
26	Fluvial hydraulic modelling	3.75	4.50	4.25	Effective modelling methodologies
27	Joint probability of analysis of surge and level	2.75	4.00	3.75	Effective modelling methodologies
28	Clarity on limitations	2.00	5.00	3.67	Effective validation and uncertainty processes
29	Uncertainty quantified and clear	2.88	4.13	3.04	Effective validation and uncertainty processes
30	Quality control of method	3.00	4.67	4.33	Effective validation and uncertainty processes
31	Ground truthing	2.67	4.33	4.33	Effective validation and uncertainty processes
32	Produced by people with coastal expertise	3.25	5.00	4.25	Engagement and collaboration in mapping efforts
33	Produced by people with geospatial/GIS expertise	4.67	4.33	5.00	Engagement and collaboration in mapping efforts
34	Holistic community engagement	2.63	4.17	4.00	Engagement and collaboration in mapping efforts
35	Inclusion of dikes/ embankments	2.80	3.50	3.50	High quality data inputs
36	Inclusion other values (environmental, land use, cultural)	2.80	3.50	4.33	High quality data inputs
37	Ice run up data	1.00	2.50	2.25	High quality data inputs
38	Design events available	4.25	5.00	4.75	High quality data inputs
39	Clear data (continuous, sample period, duration)	3.25	4.00	3.00	High quality data inputs
40	High quality LiDAR (DEM)	3.00	4.33	3.00	High quality data inputs
41	Inclusion of seasonal tidal conditions	4.50	4.25	4.75	High quality data inputs
42	Consideration of past shoreline change	3.50	4.00	3.50	High quality data inputs
43	Good water level records (tides & surges, lake levels)	3.50	5.00	4.00	High quality data inputs
44	Building and infrastructure data	3.00	4.25	4.25	High quality data inputs
45	Near shore bathymetry	2.25	4.25	3.75	High quality data inputs
46	Consideration of wave breaking height for bathymetry	1.75	4.25	2.50	High quality data inputs
47	Climate data for wave changes (>50yrs)	1.00	3.75	2.00	High quality data inputs
48	Different sea level rise scenarios	2.75	4.00	3.00	High quality data inputs

49	Shipping and boat transport data inclusion	1.00	3.75	2.00	High quality data inputs
50	Hydraulic structure survey information	2.75	3.50	5.00	High quality data inputs
51	Consideration of wave effect zone	2.00	4.75	3.75	High quality data inputs
52	High resolution topography data	2.50	4.50	3.50	High quality data inputs
53	Inclusion of land subsidence impacts	3.13	2.88	3.63	High quality data inputs
54	Accurate land cover data	4.00	3.50	4.50	High quality data inputs
55	Consideration of earthquake zones	3.25	3.50	3.00	High quality data inputs
56	Wave run up height	2.50	4.00	3.50	High quality data inputs
57	Climate data for wind changes >50years	2.25	4.50	2.50	High quality data inputs
58	Inclusion of historical events/ maps	1.50	3.50	3.25	High quality data inputs
59	Careful consideration of the spatial boundary of maps	3.83	4.58	4.92	High quality data inputs
60	Map lifespan and update frequency considered	1.75	3.75	3.50	Resources and support for map production
61	Technical guidelines available	3.20	4.25	4.00	Resources and support for map production
62	Continuing, evergreen project stewardship	2.40	4.00	3.75	Resources and support for map production
63	Clear purpose and planning for meeting end user needs	3.50	5.00	4.75	Resources and support for map production
64	Appropriate financing	4.50	5.00	3.50	Resources and support for map production

Table 9. *Total GCM statements provided by participants for flood risk mapping. Note, category is based upon original participant grouping of statements.*

Code	Statement	CP av.	Impt. av.	Feas. av.	Final Category:
1	Clear end use/purpose for risk mapping (flood mitigation strategy decision or municipal storm infrastructure asset planning)	3.77	5.00	4.96	Clear communication of map information
2	The map treated as only one part of a larger public process	3.00	4.50	4.50	Clear communication of map information
3	Consideration of flood risk mapping end user/ audience	3.14	5.00	4.33	Clear communication of map information
4	Quantification of the issue (map shows the extent of the risk)	3.33	4.83	5.00	Clear communication of map information
5	Clarity around flood terminology including hazard, exposure, vulnerability, likelihood, risk	2.64	4.57	4.25	Clear communication of map information
6	Agreement on "easy to understand" final mapping products	2.86	4.43	4.00	Clear communication of map information
7	Flood risk maps that are independently interpretable to understand	3.40	5.00	4.60	Clear communication of map information
8	Adding enough details to the flood risk maps to be easily understood	3.71	4.71	4.86	Clear communication of map information
9	Classify the hazards, risks, and damage	2.57	5.00	4.14	Clear communication of map information
10	Communicating uncertainty to end-users	2.29	3.57	3.14	Clear communication of map information
11	Includes climate change scenario impact on flood risk factors	2.24	4.36	4.00	Climate change considerations
12	Consideration of time period of validity (nonstationary)	2.50	3.00	4.50	Effective modelling methodologies
13	Agreed priority for either monetary vs public safety risks	3.57	5.00	4.86	Effective modelling methodologies
14	Equally importance of technical and non-technical components of a project	2.00	2.71	2.57	Effective modelling methodologies
15	Clean, documented process	3.00	5.00	5.00	Effective modelling methodologies
16	For risk to life maps: effect of flood warning included	2.00	4.00	1.00	Effective modelling methodologies
17	Loss functions (consequence in $ or something else more equitable)	2.83	4.67	2.83	Effective modelling methodologies
18	Residual risk considered	2.00	5.00	3.00	Effective modelling methodologies
19	Includes categorization of impact (depth of flooding, critical infrastructures flooded)	3.00	4.00	4.33	Effective modelling methodologies
20	Consequence analysis	2.00	5.00	3.50	Effective modelling methodologies
21	Place specific direct depth-Damage curves (place specific)	3.67	4.33	3.67	Effective modelling methodologies
22	Social impacts analysis	2.17	3.83	3.00	Effective modelling methodologies
23	Uncertainty bands of damage functions	1.50	3.00	2.17	Effective modelling methodologies
24	Vulnerability curves	2.67	4.00	3.17	Effective modelling methodologies
25	Planning includes holistic, systems thinking	2.38	4.19	3.96	Effective modelling methodologies
26	Prioritization of vulnerability elements within the risk map	3.57	5.00	4.86	Effective modelling methodologies
27	2D hydrologic and hydraulic model (refined quantification of issue)	3.00	4.00	4.00	Effective modelling methodologies
28	High quality flood inundation with a full distribution of return periods	4.29	5.00	4.67	Effective modelling methodologies
29	Other hazard integration	2.50	3.50	3.50	Effective modelling methodologies
30	Flood hazard maps with depth and velocity	4.86	4.86	4.71	Effective modelling methodologies
31	Integrated pluvial and fluvial flood hazard in flood risk maps	1.29	4.29	4.00	Effective modelling methodologies
32	GIS post processing supports (QA/QC, cleaning up the 'noise' in the model)	3.50	4.00	4.50	Effective validation and uncertainty processes
33	Process to ensure data does not conflict	2.50	4.50	4.50	Effective validation and uncertainty processes
34	Ground truthing	2.00	4.50	3.50	Effective validation and uncertainty processes
35	Peer review process	3.25	5.00	5.00	Effective validation and uncertainty processes
36	Quality control of chosen method	3.50	5.00	5.00	Effective validation and uncertainty processes

37	Use of common sense in development of map	3.00	5.00	4.67	Effective validation and uncertainty processes
38	Limitations understood	3.31	4.86	4.43	Effective validation and uncertainty processes
39	Clear agreement of risk calculation and method	2.71	4.29	4.00	Effective validation and uncertainty processes
40	Define limitations of risk mapping	3.29	4.71	3.86	Effective validation and uncertainty processes
41	Economic expertise	2.50	4.67	4.00	Engagement and collaboration in mapping efforts
42	Local knowledge of different stages of map development	4.00	4.00	4.00	Engagement and collaboration in mapping efforts
43	Engaging stakeholders early to gain support for map development	2.63	4.50	4.13	Engagement and collaboration in mapping efforts
44	Understanding the goals of stakeholders	3.17	4.83	4.50	Engagement and collaboration in mapping efforts
45	Take ownership for own community	2.00	4.14	3.86	Engagement and collaboration in mapping efforts
46	Communication with all levels of community	3.00	4.71	4.57	Engagement and collaboration in mapping efforts
47	Communication with transboundary communities	3.00	4.71	4.57	Engagement and collaboration in mapping efforts
48	Flood defences included	2.75	4.25	4.00	High quality data inputs
49	Consideration of dikes and their failure mechanisms	2.00	4.25	3.33	High quality data inputs
50	Accurate municipal asset and infrastructure data/mapping (governmental infrastructure)	2.58	4.75	3.58	High quality data inputs
51	Exposure data available	2.00	5.00	5.00	High quality data inputs
52	Data on basement/foundation drain connections to stormwater	1.14	4.57	2.43	High quality data inputs
53	Social data (e.g., population metrics) available	2.17	3.83	3.00	High quality data inputs
54	Need for good quality property data	2.17	4.50	3.17	High quality data inputs
55	Accurate land use data/maps available	2.17	4.50	3.17	High quality data inputs
56	Vulnerability functions of desired risk map	1.67	3.00	2.17	High quality data inputs
57	High quality, up to date LiDAR data	4.83	5.00	4.67	High quality data inputs
58	Hydro data available	3.33	5.00	5.00	High quality data inputs
59	Good quality air photo/LiDAR information from a flood event to 'proof' data if model map	2.00	4.33	2.67	High quality data inputs
60	Accurate representation of water management facilities	3.25	4.50	4.00	High quality data inputs
61	Weather and climate data for flooding	3.29	4.86	4.79	High quality data inputs
62	Up to date development data (maintenance, as-builts)	1.75	4.00	3.50	High quality data inputs
63	Responsive to new developments	2.50	5.00	4.50	High quality data inputs
64	Measuring upstream and downstream flood behavior	4.00	4.00	4.00	High quality data inputs
65	Data recovery options available	3.00	4.50	2.50	Resources and support for map production
66	Transferable data and model	2.67	4.67	5.00	Resources and support for map production
67	Bottom up planning	3.33	5.00	3.67	Resources and support for map production
68	Political willpower (consistency and commitment from political leaders)	2.14	5.00	4.00	Resources and support for map production
69	Transparent municipal asset management	2.83	3.71	3.43	Resources and support for map production
70	Appropriate funding	2.20	5.00	4.60	Resources and support for map production
71	Qualified staff involved	3.75	5.00	4.75	Resources and support for map production
72	Resources (funding, expertise qualified)	3.33	5.00	5.00	Resources and support for map production