Federal Flood Mapping
Guidelines Series

Federal Flood Mapping Framework

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NOTICE

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Additional Information

For more information about this document, please contact the Canada Centre for Mapping and Earth Observation of Natural Resources Canada: NRCan.Geoinfo.RNCan@Canada.ca.

FEDERAL FLOOD MAPPING GUIDELINES SERIES

The following documents are intended to inform any individual or organization involved with flood management in Canada:

1. **Federal Flood Mapping Framework**
2. Flood Hazard Identification and Priority Setting
3. Federal Hydrologic and Hydraulic Procedures for Flood Hazard Delineation
4. Federal Airborne LiDAR Data Acquisition Guideline
5. Case Studies on Climate Change in Floodplain Mapping
6. Federal Geomatics Guidelines for Flood Mapping
7. Flood Risk Assessment
8. Risk-based Land-use Guide: Safe use of land based on hazard risk assessment
9. Bibliography of Best Practices and References for Flood Mitigation

LIST OF ABBREVIATIONS AND ACRONYMS

CMHC: Canada Mortgage and Housing Corporation

CWCAA: Canada Water Conservation Assistance Act

DEM: Digital Elevation Model

DFAA: Disaster Financial Assistance Arrangements

ECCC: Environment and Climate Change Canada

FDRP: Flood Damage Reduction Program

FGP: Federal Geospatial Platform

FRFCP: Fraser River Flood Control Program

CIRNA: Crown-Indigenous Relations and Northern Affairs

DND: Department of National Defence

INFC: Infrastructure Canada

ISC: Indigenous Services Canada

LiDAR: Light Detection And Ranging

NDMP: National Disaster Mitigation Program

NRCan: Natural Resources Canada

PS: Public Safety Canada

PWGSC: Public Works and Government Services Canada

1.0 CONTEXT AND PURPOSE

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

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

Flooding is the temporary inundation by water of normally dry land, and it can occur in coastal and lake areas, along rivers, from stream blockages including ice jams, from failure of engineering works including dams, from extreme rainfall, rapid snow/ice melt or poor drainage characteristics, and other sources. Flood mapping that accurately delineates flood hazards, including those impacted by future conditions due to anticipated development or projected changes in climate, serves as the precondition for such mitigation activities and is therefore the first step to increasing community resilience with regard to flooding. Establishing a national approach to flood mapping will facilitate a common national best practice and increase the sharing and use of flood hazard information, thereby improving the foundation from which further mitigation efforts can be initiated.

The purpose of this document is to introduce the *Federal Flood Mapping Guidelines Series* documents and to provide a framework for how each fits into the overall flood mapping life cycle. Specifically, this document will provide a brief history of past and present flood mapping efforts in Canada, a brief summary of flood mapping roles and responsibilities, vision and principles for flood mapping guidance, and an overview of the contents of the suite of documents that make up the *Federal Flood Mapping Guidelines Series*. Together, these documents provide details on technical aspects of the following flood mapping related activities:

- Hydrologic and hydraulic investigation
- Flood mapping
- Risk assessment
- Estimating the effects of climate change forecasting on flood modelling
- LiDAR data acquisition, and
- Land use planning.

All documents in the *Federal Flood Mapping Guidelines Series* are intended to be evergreen and to be adapted as new technological and scientific developments emerge.

2.0 NOTE ON TERMINOLOGY

All *Federal Flood Mapping Guidelines Series* documents will apply the following definitions, derived from the both the Emergency Management Framework for Canada (EMFC 2017)[1] and National Disaster Mitigation Program (NDMP 2018) literature[2]:

> **Flooding:** The temporary inundation by water of normally dry land.
>
> **Flood Mapping:** The delineation of flood extents and elevations on a base map. This typically takes the form of flood lines on a map that show the area that will be covered by water, or the elevation that water would reach during a specified flood event. The data shown on the maps, for more complex scenarios, may also include flow velocities, depth, other risk parameters, and vulnerabilities.
>
> **Hazard:** A potentially damaging physical event, phenomenon or human activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation.
>
> **Risk:** The combination of the likelihood and the adverse consequences of a specified hazard being realized, including potential economic, social/cultural, environmental and human impacts.

It is recognized that provinces and territories may define these terms differently, and these definitions are not intended to be prescriptive outside the context of the *Federal Flood Mapping Guidelines Series* documents.

Also, it is important to note that during the Flood Damage Reduction Program (see Section 5) areas subject to designation were referred to as 'flood risk zones'. According to the terminology provided above, they would now be referred to as 'flood hazard zones'.

3.0 TARGET AUDIENCE

The documents contained in the *Federal Flood Mapping Guidelines Series* are to be used as a resource for flood mapping projects and activities undertaken across Canada. These guidelines aim to provide advice to provinces and territories, whose responsibility it is to provide technical guidance to implementing bodies, as well as individuals and organizations in Canada that need to understand and manage flood risks and their consequences to communities. They may include emergency management practitioners, flood risk managers, land-use and water resources planners, town planners, hydrologists, hydraulic engineers, geoscientists, geologists, infrastructure providers, water managers, and policy and decision makers, both within and outside of government.

Some provinces and territories may have already developed their own more specific guidelines and regulations regarding flood mapping and flood risk management, emergency management and land-use planning. The present guidelines are intended as a basis for further specification as defined by a province or territory.

[1] https://www.securitepublique.gc.ca/cnt/rsrcs/pblctns/2017-mrgnc-mngmnt-frmwrk/index-fr.aspx
[2] https://www.publicsafety.gc.ca/cnt/mrgnc-mngmnt/dsstr-prvntn-mtgtn/ndmp/index-en.aspx

4.0 IMPORTANCE OF FLOOD MAPS

Although there are many variations, all flood maps identify the boundaries of actual or potential flood events based on probability and likelihood and can be used to help identify the specific impacts of flood events on, for example, structures, people and assets. Flood maps serve as critical decision-making tools in flood mitigation, land use planning, emergency management and general public awareness. These maps typically provide information at large scales (1:1,000 to 1:25,000) about topography, land cover, infrastructure, flood hazards and flood risks. Flood maps produced under the Flood Damage Reduction Program (FDRP), which was administered from 1975 to 1998, serve to identify flood hazard areas that became "designated" under federal-provincial agreements. "Designated" flood hazard areas were subject to specified provincial/territorial flood mitigation measures with the aim of managing development in flood prone areas.

Flood maps offer the following advantages to communities:

- Provide a cornerstone for land use planning and land use restrictions,
- Present information on flood hazard and flood risk to stakeholders and the general public,[3]
- Better inform emergency management practices,
- Enable community preparedness and mitigation strategies, and
- Empower citizens and property owners with information that allows them to make informed decisions related to flood risks.
- Support climate change adaptation

4.1 Types of Flood Maps

Although there is a high degree of flexibility in flood mapping practices, the *Federal Flood Mapping Guidelines Series* identifies four main types of maps that cover a wide spectrum of mapping activities. These are:

Inundation Maps: Maps that show the floodwater extent of real flood events, or that show potential floodwater coverage for flood events of different magnitudes. They are intended to aid in the management of emergency preparedness plans for communities situated within floodplains and flood hazard zones.

Flood Hazard Maps: Engineering maps that display the results of hydrologic and hydraulic investigations, including the extent of a regulatory design flood. These maps are used for regulatory planning purposes related to land use planning and flood mitigation.

Flood Risk Maps: Maps that show the flood hazard or inundation delineations along with additional socio-economic values, such as potential loss or property vulnerability levels. These maps serve to identify the social, economic and environmental consequences to communities during a potential flood event.

[3] For definitions of 'risk' and 'hazard' as applied in this document, see SECTION 2.0 NOTE ON TERMINOLOGY.

Flood Awareness Maps: Communication maps that serve to inform members of the public regarding the history of flooding in their communities, as well as the potential for future flooding and the risks that such flooding would pose to residential properties, businesses, cultural assets, infrastructure and human life. These poster-style maps include a range of additional content types, such as photographs, descriptive text and graphics.

It is important to recognize that, while widely used, these terms are applied differently in different jurisdictions. As such, all *Federal Flood Mapping Guidelines Series* documents will adhere to the descriptions provided above (which are elaborated in greater detail in the "Federal Geomatics Guidelines for Flood Mapping" document).

5.0 HISTORY

The past federal contribution to flood management efforts is large and warrants an historical context.

5.1 Early Federal/Provincial Programs

The first federal legislation to deal with water resource management and flooding was the Canada Water Conservation Assistance Act (CWCAA) which was instituted in 1953 and led to the construction of a number of small structural mitigation works. The last of these was completed in the early 1980s, although the CWCAA was superseded by the Canada Water Act (CWA) in 1970.

The Fraser River Flood Control Program (FRFCP) was established in 1968 by the federal and British Columbia governments to reconstruct and maintain dykes in the Lower Fraser Valley that were built following the 1948 Fraser River flood. The program ended in 1995.

Also, a series of federal-provincial agreements from the early 1950s to the 1970s resulted in the construction of a number of structural mitigation works throughout the province of Manitoba, including the Red River Floodway.

5.2 Flood Damage Reduction Program (FDRP)

A series of major flood events were the catalyst for the federal government to initiate the FDRP in 1976 under the Canada Water Act. The objectives of the FDRP were to reduce loss of life and suffering, major disruptions to regional economies and escalating disaster assistance payments. It represented a significant change in approach from an ad hoc structural response to flooding to a more comprehensive and equitable approach focusing on preventative and non-structural measures, such as flood mapping as a first step to inform further flood management and mitigation activities.

The FDRP was carried out under cost-shared federal-provincial-territorial agreements, negotiated by Environment and Climate Change Canada (ECCC) on behalf of the federal government. A central goal of these bi-lateral agreements was to inform decisions pertaining to developments in flood hazard areas. Other federal ministers were signatories to these agreements, including the Minister of Public Works and Government Services Canada (PWGSC) and the Ministers responsible for the Canada Mortgage and Housing Corporation

(CMHC), as well as the regional economic development agencies for the affected regions of the country.

The main products of the FDRP were engineering maps and public information maps (what are referred to in the *Federal Flood Mapping Guidelines Series* as 'Flood Hazard Maps' and 'Flood Awareness Maps', respectively). The engineering maps were the basis for zoning regulations which are used to manage development in flood-prone areas. In total, the program designated 320 flood-risk areas covering more than 900 communities. All flood-prone areas that were legally designated within the FDRP program are still valid indefinitely. Since the end of the active mapping phase of the FDRP in 1997, provinces, territories and other levels of government have continued flood mapping for new areas or updated previous mapping using their own resources.

5.3 National Flood Mapping Assessment

In 2013, Public Safety Canada (PS) commissioned a study on the state of flood mapping in Canada entitled *National Floodplain Mapping Assessment – Final Report* (MMM Group, 2014). The study results identified further needs for guidelines and practices regarding flood mapping. This study documented:

- International flood mapping best practices from seven countries (United Kingdom, Australia, the United States, France, Germany, Switzerland, and New Zealand),
- National flood mapping practices, with a view to identifying best practices,
- The current state of flood mapping in Canada, including details for each province and territory,
- A proposed standard and next steps, and
- An estimate of the cost of bringing Canada up to the standard recommended in the report for 90-95% of the population.

The scope of the study addressed only riverine flooding, not urban or coastal.

6.0 ROLES AND RESPONSIBILITIES

Table 1 - Flood management is inherently multi-faceted and involves a wide range of authorities and stakeholders, both within and outside of government. The following is a brief and informal overview of flood management roles and responsibilities, including relevant tools and resources where applicable.

Federal Government
Whereas the implementation of flood mitigation measures is mainly the responsibility of provincial/ territorial/local agencies, the federal government plays an important role in ensuring a broadly consistent national approach to flood mitigation. This involves establishing national flood mapping requirements, as well as basic criteria for geospatial data acquisition, management and dissemination. The federal government is committed to working with the provinces and territories on an ongoing basis through various federal-provincial-territorial forums related to Emergency Management, water resources and flood mapping, such as the Canadian Council on Geomatics (CCOG) and Senior Officials Responsible for Emergency Management (SOREM) to ensure Emergency Management policy/legislative coordination between all levels of government.

<table>
<tr><td colspan="2">Federal Geospatial Platform (FGP) and Open Maps

The FGP is an initiative of the Federal Committee on Geomatics and Earth Observations (FCGEO), a committee of over 20 departments and agencies that are producers and/or consumers of geospatial data, or have an interest in activities, requirements and infrastructure related to geomatics.

The Platform serves as a collaborative online environment where the Federal Government's geospatial data can be retrieved and viewed on maps to support evidence-based decision-making and foster innovation.

The FGP has two faces: an internal site that can be found at gcgeo.gc.ca (internal government network), and a public site known as Open Maps (https://open.canada.ca/en/open-maps) on the Open Government Portal.</td></tr>
<tr><td rowspan="3">Public Safety Canada (PS)</td><td>PS is the primary federal agency responsible for disaster mitigation in Canada. As such, the PS portfolio contains a variety of initiatives related to emergency management.</td></tr>
<tr><td>National Emergency Management System (NEMS)

NEMS is a PS-led holistic online emergency management environment through which emergency management partners will coordinate efforts and improve decision-making across the four pillars of emergency management: prevention and mitigation, preparedness, response and recovery.

Public Safety will leverage NEMS to promote the Federal Flood Mapping Guidelines Series as a tool for use in future flood mapping activities.</td></tr>
<tr><td>Disaster Financial Assistance Arrangements (DFAA)

In the event of a large-scale natural disaster, the Government of Canada provides financial assistance to provincial and territorial governments through the DFAA, administered by PS.

Through the DFAA, assistance is paid to the province or territory when eligible expenditures exceed an established initial threshold (based on provincial or territorial population). A request for reimbursement under the DFAA is processed immediately following receipt of the required documentation of provincial/territorial expenditures and a review by federal auditors.</td></tr>
<tr><td>Natural Resources Canada (NRCan)</td><td>NRCan has actively contributed to the development of these guidelines by providing leadership, advice, expertise, and technical resources in the area of flood mapping and stakeholder engagement. NRCan's involvement follows from its pre-existing expertise regarding geomatics and natural hazards. In addition, NRCAN is developing work to better understand and operationalize the incorporation of climate change into flood mapping.</td></tr>
<tr><td>Environment and Climate Change Canada (ECCC)</td><td>ECCC is the federal agency responsible for the collection, interpretation and dissemination of standardized weather, climate, and water quantity data in Canada. These data contribute toward hydrologic, hydraulic, and hydrotechnical engineering analyses. In addition, ECCC carries out a foundational research programs to understand the weather and climate system, surface hydrology, and the science of climate change that can contribute to established best practices for considering climate change in the development of flood mapping.</td></tr>
</table>

Crown-Indigenous Relations and Northern Affairs (CIRNA)	Through a number of initiatives, CIRNA provides funding for local Indigenous communities to engage in various activities related to flood management, such as flood forecasting and water level monitoring, as well as the development of flood maps and implementation of flood mitigation measures.
Indigenous Services Canada (ISC)	ISC works collaboratively with partners to improve access to high quality services for First Nations, Inuit and Métis. ISC provides resources for First Nations communities to prevent, prepare for, respond to and recover from emergencies.
Infrastructure Canada (INFC)	INFC provides support for the mitigation of natural disasters, extreme weather events and strengthening climate resilience through a range of infrastructure funding programs, such as the Green Infrastructure Stream – Adaptation, Resilience, Disaster Mitigation Investments under the Investing in Canada Infrastructure Program, the Disaster Mitigation and Adaptation Fund and the Gas Tax Fund.
Department of National Defence (DND)	In the event of a national crisis, DND provides aid to a civil power, by joining provinces and territories with the objective to help Canadians in distress. DND provides resources and support to: 1. Identify and preserve essential municipal/provincial infrastructure; 2. Identify and preserve essential access routes (land, sea and air); 3. Assist in the voluntary evacuation of civilians; and 4. The provisions of essential logistics and material support.
Defence Research and Development Canada (DRDC)	Defence Research and Development Canada's (DRDC) ongoing contribution to flood mapping occurs through the Canadian Safety and Security Program (CSSP). CSSP is led by DRDC's Centre for Security Science (DRDC CSS) in partnership with Public Safety Canada. The CSSP's mandate includes objectives to strengthen Canada's ability to anticipate, prevent, mitigate, prepare for, respond to, and recover from natural disasters.
Provincial/Territorial	
Whereas the federal government plays an important role in ensuring that flood management across Canada is approached in a broadly consistent manner, provincial and territorial governments are ultimately responsible for overseeing flood mitigation efforts within their jurisdictions. Although each province and territory manages flood risks separately, with the involvement of different departments and ministries, these efforts invariably involve working with local municipalities or other water agencies to identify flood mitigation needs, establish priorities and implement initiatives, such as preparing and maintaining flood mapping. In many cases, responsibility for such activities is delegated primarily to the municipality or water agency. Depending on the jurisdiction, the following areas related to flood management can fall under the jurisdiction of provincial or territorial agencies: • Water management, • Emergency management and continuity of service, • Land use planning/zoning regulation,	

- Funding and implementation of watershed scale mitigation measures,
- Disaster recovery funding program administration,
- Insurance industry regulation, and
- Public outreach.
- Climate change resilience and adaptation

Coordination between the provincial/territorial and federal governments will occur through annual meetings of Ministers Responsible for Emergency Management, as well as regular meetings at Deputy Minister and senior official levels, such as Senior Officials Responsible for Emergency Management (SOREM).

Community/Municipal

It is at the municipal level that identification of flood risks and implementation of flood mitigation measures ultimately takes place and local governments, working in conjunction with provincial/territorial authorities, therefore play a central role in flood risk management.

Municipal roles can include:

- Water management,
- Emergency management and continuity of service,
- Land use planning/zoning regulation,
- Critical infrastructure design and utility operation,
- Public services, and
- Ownership/operation/insurance of public assets
- Climate change resilience and adaptation

Further, community outreach is a critical element of flood risk management and offers the following benefits to those involved in flood management:

- Allows flood authorities to draw on community knowledge of past flood events,
- Enables the sharing of flood risk information with the community, and
- Aids in establishing community support for flood-related initiatives.

Individuals

It is critically important that individuals be aware of flood risks and the steps necessary to address them, both in terms of preparation and response. It is therefore essential that such information be made available to them by municipal authorities, particularly through the use of Flood Awareness Maps and other public outreach tools.

Private Sector

Many private businesses are involved in flood mitigation efforts and/or are affected by the severe impacts of flooding. While it is essential that all private businesses be aware of flood risks and how to mitigate them, some businesses have greater responsibilities than others in terms of managing the impacts of flooding. In particular, it is essential that industries involved in land development adhere to land use regulations and policies, as well as ensure that their work is conducted in a manner that does not create or aggravate flood risks.

Insurers
The recent development of a private residential flood insurance market in Canada marks the emergence of a new and invaluable resource for individual property owners to manage flood risk. With the growth of this market, the insurance industry will come to play an increasingly important role in rebuilding efforts following major flood events. Further, coordination of flood-related data and knowledge between federal-provincial-territorial governments and the insurance industry will serve to advance all parties' interests.

7.0 VISION AND PRINCIPLES

A vision for Canadian flood guidance has been developed in order to enhance community resilience with regard to flood mitigation. It consists of the following elements:

- The development of a comprehensive understanding of hazard exposure in order to inform mitigation and preventative measures aimed at increasing the resilience of Canadian communities.
- The development of common principles and guidelines for flood mapping in order to address flood-specific knowledge requirements necessary to inform the management of Canada's most expensive and frequent hazard.
- The establishment of an inclusive process to provide consistent and usable body of information to support flood risk analysis and modelling.
- The establishment of consistent flood hazard information collection and mapping practices across Canada.

The following principles pertain to all documents in the *Federal Flood Mapping Guidelines Series*.

Key Principles	
Local	National guidelines will take regional considerations and priorities into account.
Accessible	Data, information and knowledge products related to topographic features, hydrologic and hydraulics characteristics, and the population and infrastructure at risk will be as accurate and accessible to relevant practitioners as possible.
Collaborative	Community engagement and collaboration between stakeholders are key to the development and implementation of effective guidelines.
Interoperable	Flood maps and risk data should be maintained in digital form so that they are sharable and interoperable with those related to other natural disasters (e.g. storm surges, wild fires, landslides, earthquakes, etc.).
Adaptable	Flood mapping will be adapted to suit changing conditions, including factoring climate change data, information and knowledge into the development of risk assessment tools and flood design events.

Evergreen	The *Federal Flood Mapping Guidelines Series* will evolve and be updated as new information, technologies and practices emerge.
Voluntary	Given that flood management is a provincial/territorial responsibility, adoption and use of the *Federal Flood Mapping Guidelines Series* is voluntary. Provinces and territories are encouraged to take into account any federal guidelines and consider whether these guidelines are appropriate to the provincial/territorial circumstances.

8.0 FLOOD MAPPING FRAMEWORK

The Flood Mapping Framework consists of all the components of the flood mitigation process, from flood hazard identification to the implementation of flood mitigation efforts. The following flow chart illustrates the relationship between these different components and links each of them to the relevant *Federal Flood Mapping Guidelines Series* document each of which is described in more detail in the subsequent sections. For an outline detailing the flood management process, please see Annex A.

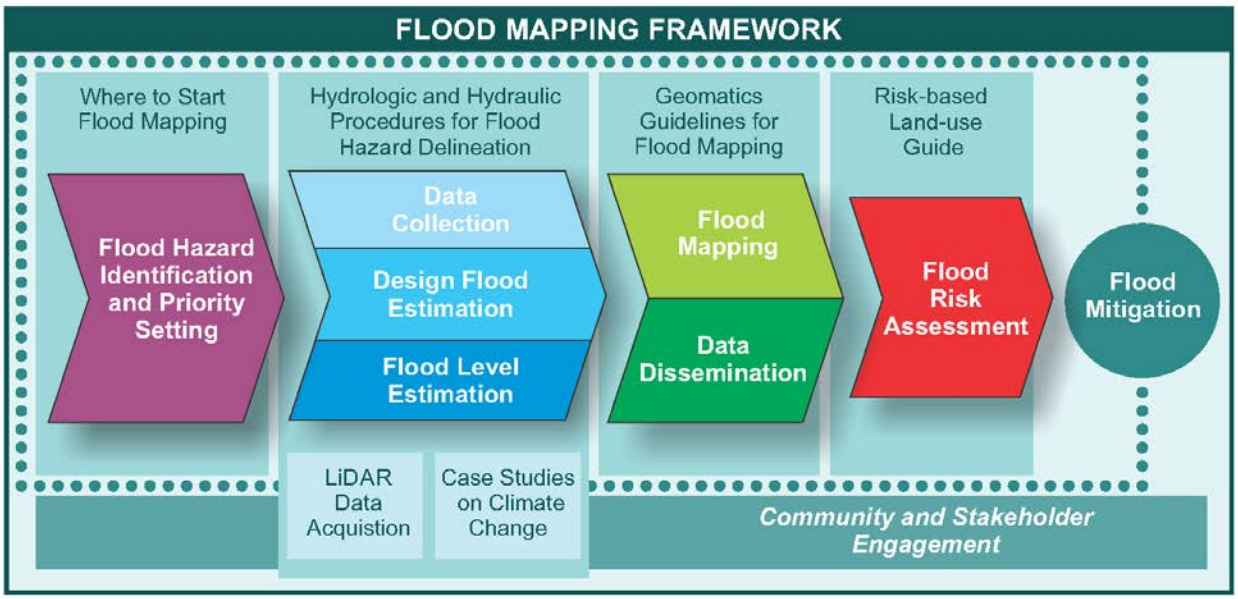

Figure 1: Flood Mapping Framework

In addition, the *Federal Flood Mapping Guidelines Series* also includes a Bibliography that contains references and best practices related to flood mitigation.

8.1 Federal Flood Mapping Framework

This document provides background and context on flood mapping in Canada, describes a vision and principles for flood guidance, and introduces the Federal Flood Mapping Guidelines Series. It provides a summary of each of the documents in the Series and explains how each document fits into the overall framework, including its place in the flood mapping cycle.

8.2 Flood Hazard Identification and Priority Setting

This document has yet to be developed. It will outline methods for determining where to conduct flood mapping and how to prioritize flood mapping projects.

8.3 Federal Hydrologic and Hydraulic Procedures for Flood Hazard Delineation

This document provides technical guidance on hydraulic and hydrologic procedures for preparing flood hazard maps in a Canadian jurisdiction, including standard of care, different types of flooding, guidelines for hydraulic and hydrologic analyses, and incorporation of non-stationary processes including climate change.

8.4 Federal Airborne LiDAR Data Acquisition Guideline

This document is to be used as a resource for the acquisition of base elevation data from airborne LiDAR data undertaken across Canada. This guideline aims to provide advice to federal, provincial and territorial departments, as well as individuals and organizations in Canada that need to understand and plan for airborne LiDAR data acquisition.

8.5 Case Studies on Climate Change in Floodplain Mapping

This collection of documents describes projects from across Canada where climate change has been incorporated into the floodplain mapping process. It will provide examples for practitioners to draw on and learn from others' experiences and will complement the climate change-related information and resources included in the "Federal Hydrologic and Hydraulic Procedures for Flood Hazard Delineation" document.

8.6 Federal Geomatics Guidelines for Flood Mapping

This document covers the Flood Mapping and Dissemination components of the Flood Mapping Framework. It contains information on the different types of flood maps and outlines methods for acquiring, managing and disseminating these maps and associated geospatial data.

8.7 Flood Risk Assessment

This document is currently under development and will provide technical guidance on conducting flood risk assessments in Canada.

8.8 Risk-based Land-use Guide: Safe use of land based on hazard risk assessment

This document provides guidance to communities in using risk-based methodologies for the purpose of land-use planning.

8.9 Bibliography of Best Practices and References for Flood Mitigation

This document contains lists of Canadian and international references and case studies pertaining to hydrology and hydraulics, climate change, risk assessment and flood mapping. The purpose of this document is to provide a consolidated list of reference materials intended as further resources for practitioners involved in flood mapping.

9.0 STAKEHOLDER AND COMMUNITY ENGAGEMENT

Stakeholder and community engagement in flood mapping is a process that can be worthwhile and beneficial to those producing maps, and those affected by flooding. This process typically involves flood hazard identification and priority setting, collecting data and estimating design flood and flood levels, flood mapping and data dissemination, and conducting a flood risk assessment that contributes to effective flood mitigation. The community can be engaged at all stages and their input can shape the overall process.

A detailed description of the stakeholder and community engagement process is included as Appendix 1. This reference provides background information on flood mapping and its processes within the Canadian context, and existing practices for engaging communities in the flood mapping process. The steps at which this involvement is most crucial is emphasized, and the potential benefits and considerations of applying federal flood mapping guidelines are discussed. Also included is a summary of lessons learned from current practices and recommendations for how to best engage community members in the flood mapping process moving forward.

10.0 FUTURE WORK

As outlined above, there are a number of planned *Federal Flood Mapping Guidelines Series* documents scheduled for publication and updates. These documents will provide further guidance to those involved in flood mapping in Canada.

11.0 GLOSSARY OF FLOOD MAPPING TERMINOLOGY

The following glossary is intended as a consolidated reference for all of the *Federal Flood Mapping Guidelines Series* documents.

Annual Exceedance Probability (AEP): the annual likelihood of a flood occurring, expressed as a fraction of 1.0. The 0.01 AEP flood is equivalent to both the 1% annual probability flood, and the 100-year return period flood, although the term AEP is less misleading than the concept of return periods to many people.

Base Map: A map that depicts cultural features (e.g. roads, railroads, bridges, water features, place names and administrative boundaries).

Catchment: Also known as drainage area, drainage basin or watershed. It is the area of land draining to a particular location and includes the upstream drainage area of the main waterway as well as any tributary streams.

Climate Change: Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use.

Cross-section: A survey string of channel and floodplain elevations that is taken perpendicular to the main flow direction in a river.

Coastal Flooding: Coastal flooding can be defined as flooding associated with a defined shoreline along an ocean. This can be due to a combination of high tides, storm surges, waves, rising sea levels and riverine flooding.

Design Flood: A specific flood magnitude that is used for a design purpose, including delineating Flood Hazard Areas. In Canada, the 0.01 AEP flood is used as the minimum Design Flood for delineating Flood Hazard Areas, and many jurisdictions use higher magnitude floods (e.g. 0.005 AEP flood) or Design Storms. The Design Flood is usually expressed as flow in metres per second, and hydraulic analysis is then used to calculate the corresponding floodwater elevation and extent.

Design Storm: A rainfall time-series input, based on an historic event or synthesized using intensity-duration-frequency curves, that is used to calculate flow and to delineate a Flood Hazard Area. In Canada, Design Storms are often used instead of Design Floods in jurisdictions where an historic event was of higher magnitude than the Design Flood.

Designated Flood Risk Area: Areas that were delineated under the Flood Damage Reduction Program (FDRP) as being inundated by a regulatory flood event and formally recognized by federal and provincial governments.

Digital Elevation Model (DEM): A file with terrain elevations recorded for the intersection of a fine-grained grid and organized by quadrangle as the digital equivalent of the elevation data on a topographic base map.

Digital Terrain Model (DTM): A land surface represented in digital form by an elevation grid or lists of three-dimensional coordinates.

Drainage Area: See **Catchment**.

Flood Awareness Map: Communication maps that serve to inform members of the public regarding the history of flooding in their communities, as well as the potential for future flooding and the risks that such flooding would pose to residential properties, businesses, cultural assets, infrastructure and human life. These poster-style maps include a range of additional content types, such as photographs, descriptive text and graphics.

Flood Fringe Areas: The area between the Floodway and the delineated extent of flooding for a Design Flood. In Canada, the Flood Fringe Area is often defined as having a flood depth below 1 metre and a flood velocity less than 1 metre per second.

Flood Hazard Area: The delineated extent of flooding for a Design Flood (e.g. 0.01 AEP flood), which includes the ‘Floodway’ and the ‘Flood Fringe Area’.

Flood Hazard Management: The operation of a program of corrective and preventative measures for reducing flood damage, including, but not limited to, development plans, emergency preparedness plans, flood-control works, and land use regulations.

Flood Hazard Map: A flood delineation at a given location, based on the flood’s anticipated magnitude (e.g. its depth, horizontal extent, and flow velocity) and its annual exceedance probability. It shows the extent of the regulatory flood hazard, often including two zones: floodway and flood fringe areas. This type of map is used for regulatory planning purposes.

Flood Inundation Map: Maps that show the extent of actual floods or potential floodwater coverage during flood events of different magnitudes (AEPs). They are intended to aid in the management of emergency preparedness plans for communities situated within floodplains and flood prone areas.

Flood Mitigation: A sustained action taken to reduce or eliminate long-term risk to people and property from flood hazards and their effects. Mitigation distinguishes actions that have a long-term impact from those that are more closely associated with preparedness for, immediate response to, and short-term recovery from specific events.

Floodplain: A low-lying, relatively flat area of land adjacent to a river or stream that is subject to flooding. Floodplains are generally made up of alluvium (sand, silt, and clay) deposited by past flood events.

Floodplain Map: A map showing areas near to a waterbody (e.g. river or lake) that are predicted to be inundated during flood events.

Flood Protection: Any combination of structural and non-structural additions, changes, or adjustments to structures, which reduce or eliminate risk of flood damage to real estate or improved real property, water and sanitation facilities, or structures with their contents.

Flood Risk Map: Maps that contain the flood hazard or inundation delineations along with additional socio-economic values, such as potential loss or property vulnerability levels. These maps serve to identify the social, economic and environmental consequences to communities during a potential flood event.

Flood Risk: Flood risk is a combination of the likelihood of a flood event occurring (**Flood Hazard**) and the social or economic consequences of that event when it occurs (the exposure to the flood hazard).

Floodway: The channel and adjacent area where flood depths and velocities are greatest and most destructive. In Canada, the Floodway is often defined as having a flood depth above 1 metre and flood velocity greater than 1 metre per second.

Flow: The rate of flow of water measured in volume per unit time – for example, cubic metres per second (m^3/s). Flow is different from the speed or velocity of flow, which is a measure of how fast the water is moving – for example, metres per second (m/s).

Freeboard: A vertical height of water added to calculated flood elevations to provide additional protection from flooding, or to account for uncertainty from sources including climate change and data limitations.

Hydraulic Analysis: An engineering analysis of flow scenarios carried out to provide estimates of the water surface elevations and behaviour for selected recurrence intervals.

Hydraulics: The study of the dynamics of movement of a given amount of water in a watershed.

Hydrologic Analysis: An engineering analysis of a flooding source carried out to establish peak flood discharges and their frequencies of occurrence.

Hydrology: Scientific study of the movement, distribution, and quality of water as it relates to the land.

Infiltration: The penetration of water through the ground surface into the sub-surface soil.

Lake Flooding: Flooding associated with a defined shoreline along a lake. This can be due to a combination of high water levels, waves, storm surges and riverine flooding.

Light Detection and Ranging (LiDAR): A remote sensing technology which uses lasers to collect accurate continuous elevation data.

Peak Flow: The maximum flow occurring during a flood event measured at a given point in the river system (see **Flow).**

Pluvial Flooding: The temporary inundation by water of normally dry land, usually caused by extreme rainfall events and not necessarily near to water bodies. Pluvial flooding is common in urban areas where water temporarily accumulates due to more rainfall entering an area than can be removed by infiltration into the ground and discharge through infrastructure (e.g. storm sewers).

Regulatory Flood: A specific flooding event designated as the Design Flood in a certain jurisdiction.

(Relative) sea-level change: the change in sea level that is observed or experienced relative to a fixed location on land. Relative sea-level change is the combination of absolute/global sea-level change and vertical land motion. Land uplift decreases relative sea-level rise and land subsidence increases relative sea-level rise.

Return Period: Annual Exceedance Probability expressed in terms of years, rather than annual probability of a specific flood occurring. For example, the 0.01 AEP is equivalent to the 100-year return period flood.

Riverine Flooding: The temporary inundation by water of normally dry land adjacent to a river and caused by rainfall, snowmelt, stream blockages including ice jams, failure of engineering works including dams, or other factors.

Runoff: The amount of precipitation or water deriving from snowmelt and rainfall that drains into the surface drainage network to become streamflow; also known as rainfall excess.

Stage: Equivalent to water level measured with reference to a specified geodetic datum.

Still Water Level: The elevation of the water if all gravity waves are at rest. This is the elevation that is measured in the field in a stilling well.

Storm Surge: The increases in coastal water levels above predicted astronomical tide level (i.e. tidal anomaly) resulting from a range of location-dependent factors including low atmospheric pressure, wind and wave set-up and astronomical tidal waves, together with any other factors that increase tidal water levels.

Velocity of Floodwater: The speed at which flood waters are moving, typically measured in metres per second (m/s).

Watershed: See Catchment.

Water level: The mean elevation of the water when averaged over a period of time long enough (about one minute) to eliminate oscillations caused by surface gravity waves which have periods in the order of a few seconds.

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APPENDIX 1: Stakeholder and community engagement

1.0 Introduction

Flood mapping, depicting boundaries of historical and potential flood events can be a critical tool in reducing the impacts of flooding in Canadian communities (Public Safety Canada, 2017). Flood maps assist in crucial decision-making regarding land use planning and restrictions, flood mitigation strategies, awareness and preparedness of the general public, and emergency management (Natural Resources Canada, 2017).

Effectively involving Canadian residents in the flood mapping process is a critical component in establishing community-level understanding of flood risk (White, Kingston, & Barber, 2010). The Federal Minister for Public Safety and Emergency Preparedness, Ralph Goodale, stated at the National Roundtable for Flood Risk on November 16, 2017 that "Prevention can and should begin at the individual level". As more responsibility for their own protection and recovery after flood events is shifted onto Canadians, residents should become more actively engaged in flood risk management (White, Kingston, & Barber, 2010).

Community engagement should be encouraged throughout the flood mapping process as shown in Table 1.

Flood Mapping Framework Phase	How can a community be involved?
Flood Hazard Identification and Priority Setting	• Learn about the project and the need for maps • Provide feedback on understanding of the need • Hazard identification and priority setting – what is important to the community? • Identify concerns • Establish trust and transparency – build support and further participation
Data Collection	• Provide local and traditional knowledge (photographs of historical floods, flood-prone areas) • Identify risk areas
Flood Mapping Data Dissemination: Draft Public Release Phase	• Provide feedback on preliminary maps and cartographic design, usability, relevance • Provide feedback on how to release data publicly (GIS files, paper maps) • Build support for use of maps for planning purposes
Flood Mapping Data Dissemination: Validation Phase	• Confirm local and traditional knowledge • Confirm relevance and usability of maps and distribution methods (GIS web portal, paper maps, online maps) • Build support for use of maps for planning purposes
Flood Risk Assessment	• Help prioritize where to focus attention to reduce risk to the community • Support for decision-making process and outcomes

Table 1: Community Involvement in the Flood Mapping Process

2.0 Existing Processes for Engaging Communities in the Flood Mapping Process

The purpose of this section is to describe community engagement activities on flood mapping in Canada, including town hall and public meetings, information booths, website and social media updates, workshops and focus groups, and incorporating local and traditional knowledge.

2.1 Town Hall and Public Meetings

Town hall and public meetings provide opportunities for local governments, organizations, stakeholders, and technical experts to discuss projects with community members. These types of meetings can facilitate well-informed citizen engagement and deliberation that is directly relevant to decision-makers and can create opportunities for action, including informing planning and policy (Lukensmeyer & Brigham, 2002). Town hall and public meetings can provide opportunities for discussion, feedback, and engagement on flood mapping and understanding flood risk.

Specific goals of town hall and public meetings include:

- communicating information to the public;
- gathering local and traditional knowledge;
- discussing key questions and community concerns;
- providing results of technical studies; and,
- presenting and discussing maps (NPCA, 2017a).

2.2 Information Booths

Information booths and displays in the community are a common form of public outreach for municipalities and organizations. They can be used to inform the public about flood mapping projects, upcoming meetings, opportunities for involvement, and can contribute to opportunities in raising public awareness regarding flood risks and mitigation.

2.3 Website and Social Media Updates

Providing information and interactive learning opportunities online improves accessibility in the flood mapping process, and increases accessibility for remote and under-resourced communities facing flood risks. The possibility to submit feedback online may also increase participation from residents that are hesitant to express their concerns in public settings.

2.4 Workshops and Focus Groups

Workshops and focus groups are effective ways to consult and involve communities throughout the flood mapping process (Duffy, 2011). It is important to recognize that communities are end-users of flood maps, and involving them in design and development can enhance the communicative power and overall effectiveness of the maps, particularly if these maps will be made public (Meyer, et al., 2012). Workshops and focus groups enable the public to participate in discussions and activities, and to provide valuable feedback on flood maps before they are finalized and published. Mapping workshops and exercises facilitate engagement by giving the public opportunities to develop and strengthen comprehension and comfortability.

2.5 Incorporating Local and Traditional Knowledge

Although flood maps are generally produced using specialized technical methods, there are still opportunities for communities to engage in map production. Local and traditional knowledge can play an important role in validating, augmenting, and challenging expert knowledge including through personal experience with previous flooding events and local land issues (McEwen & Jones, 2012; Resource Person #4, 2017; Resource Person #7, 2017; Resource Person #8, 2017). This information can be obtained through public participation in the flood mapping process, and can contribute to improved accuracy and quality of final maps, as well as improved trust in the process and the final product (Meyer, et al., 2012). Bringing together local knowledge can help to target potential problem areas and solutions and may contribute to risk reduction.

3.0 Benefits and Challenges of Including the Public in the Flood Mapping Process

3.1 Benefits of Including the Public in the Flood Mapping Process

Engaging the public in the flood mapping process can benefit jurisdictions by improving trust and transparency between community members, leaders, and stakeholders, by improving accuracy and effectiveness of flood maps, and by increasing risk awareness.

3.1.1 Increased Trust and Transparency

Encouraging a dialogue between the public and authorities, such as the two-way communication that takes place during town hall and public meetings, helps to establish rapport and trust between actors (IIED, 2009; Wehn, Rusca, Evers, & Lanfranchi, 2015). When communities trust project leaders and stakeholders, they are more likely to be supportive of and responsive to the information that is published and distributed (National Research Council, 2012). When trust is established, communities are more likely to take action to reduce their flood risk, and to adhere to flood evacuation protocols (Wehn, Rusca, Evers, & Lanfranchi, 2015; Meyer, et al., 2012; National Research Council, 2012). Fostering relationships of trust therefore reinforces community resiliency.

3.1.1 Improved Accuracy and Effectiveness of Flood Maps

Engaging the public in flood mapping initiatives can empower residents. Engaged communities and individuals can support flood risk management by informing decisions about what their governments can do to mitigate the risks identified by the mapping processes. Local and traditional knowledge can supplement technical information, by identifying areas of discrepancy and encouraging the revision of certain map or model areas (McEwen & Jones, 2012). Because the general public are end-users of certain flood maps, such as flood awareness maps, gathering public feedback on the aesthetics and usability of the maps throughout the design process via workshops and focus groups can improve resiliency (Meyer, et al., 2012).

3.1.2 Increased Community Understanding of Flood Risk

Helping communities to become more aware of flood risk and the resources available to them, is one of the main benefits of engaging communities in the mapping process. By providing opportunities for the public to obtain information, jurisdictions can help to develop a better overall understanding of the need for flood mapping and regulation of development in floodplains (Merz, Thieken, & Gocht, 2007). Once communities have a greater understanding

and awareness of their flood risk, they are more likely to be motivated to take action to reduce their risk and to support flood mapping projects (White, Kingston, & Barber, 2010).

3.2 Challenges of Including the Public in the Flood Mapping Process

Involving the public and communities in the flood mapping process also has its challenges, including public opposition to the project, and time and financial costs.

3.2.1 Project Opposition

Because updating flood maps can impact land use designations, building permits, home insurance costs, and home values, some residents may not support flood mapping projects that they perceive will have negative impacts on their property (Cooke Insurance Group, 2017; Forrest, 2017; Resource Person #3, 2017; Resource Person #4, 2017; Resource Person #8, 2017). However, this backlash can be anticipated and planned for, which may in turn result in a better engagement process.

Despite potential resistance, experts agree that the benefits of engaging communities in the flood mapping process outweigh the challenges. The public have the right to be aware of their flood risk, and to be equipped with the knowledge and understanding to help them protect themselves, their families, and their properties, against flood damages (Press, 2017; Resource Person #1, 2017;Resource Person #8, 2017).

3.2.2 Time and Financial Costs

It will require additional time and funding to incorporate community engagement and input into the flood mapping process, possibly extending project timelines (Wouters, Boys, & Wilson, 2011; Irvin & Stansbury,2004). However, public engagement can be cost-effective in the long run, because community support can result in action to reduce flood risk and future flood damages (Resource Person #5, 2017; Cooke Insurance Group, 2017). Floodmaps have been shown to have a return on investment of 2:1, and the costs of informing and involving the public during the mapping process have been shown to reduce time and money spent on public opposition (BC Real Estate Association, 2014; Campbell, 2016a; Resource Person #5, 2017).

4.0 Critical Steps in the Flood Mapping Process that Benefit from Public Input

Public engagement can benefit the flood mapping process at various stages, including at the onset of a project, throughout the map production phase, and before final map publication.

4.1 Project Onset

Engagement at the onset of a project generally has objectives of introducing the project to the public, answering preliminary questions, hearing concerns from residents, and gathering feedback (Campbell, 2016b). Public feedback has the capability to influence and shape the deliverables of the project (Resource Person #4, 2017). Providing opportunities for public information and engagement at the earliest stage of the project can help to build support for the project, to motivate future participation in the project, and to ease public tensions (Urban Systems, 2017).

4.2 Map Production Phase

Public engagement during this phase enables opportunities for community members to provide input on draft maps and map design, and to contribute local and traditional knowledge to the flood mapping process (McEwen & Jones, 2012; Lieske, Wade, & Roness, 2014; Amec Foster Wheeler, 2015). Public engagement throughout the map production phase can enhance the maps' effectiveness in meeting end-user needs by educating the public on technical aspects of a project, and can promote trust and credibility towards the ultimate support of the maps themselves (Meyer et al., 2011; Meyer, et al., 2012).

4.3 Before Final Publication

Jurisdictions can also choose to engage the public towards the end of a flood mapping project, before final maps are published and distributed. Public outreach can address final questions and concerns, gather final comments on the aesthetics and usability of maps, and educate the public on project outcomes (Merz, Thieken, & Gocht, 2007). Connecting with communities before final map publication can help to diminish future tensions and public opposition. (Campbell, 2016a).

5.0 Potential Benefits and Considerations of Standardized Federal Guidelines

5.1 Benefits of Using One Standardized Federal Guideline

A standardized federal guideline can help to promote consistency and fair opportunities for public participation across the country. A guideline with best practices can provide project leaders with a baseline of tools and resources on how to engage communities effectively (Lee & Drubin, 2016). A standardized guideline can help to build a sense of community amongst project leaders, by establishing common practices between organizations (Lee & Drubin, 2016). A standardized federal guideline can also encourage jurisdictions to engage the public in the flood mapping process.

5.2 Considerations of Using One Standardized Federal Guideline

It is important to recognize that each community has unique traits and demographics, and one standardized guideline for community engagement might not meet the needs and wants of all communities. Demographics can influence how the public best receives information and can influence accessibility of engagement activities. Guidelines for community engagement should be flexible and so that engagement activities can be catered to unique community needs.

Communities may require a lesser or greater degree of public outreach and engagement to raise awareness and support for flood mapping, based on frequency of flooding events. A standardized guideline should acknowledge the need for varying levels of community engagement, based on the desired outcomes, community knowledge, experience, and perceptions of flood risks.

Each community has its own project timelines, fiscal budgets, and staffing capabilities, and the depth of community engagement will change depending on these factors (Klein, Jackson, & Simpson, 2010). A standardized guideline should provide a spectrum of engagement opportunities for jurisdictions to choose from, depending on their available resources.

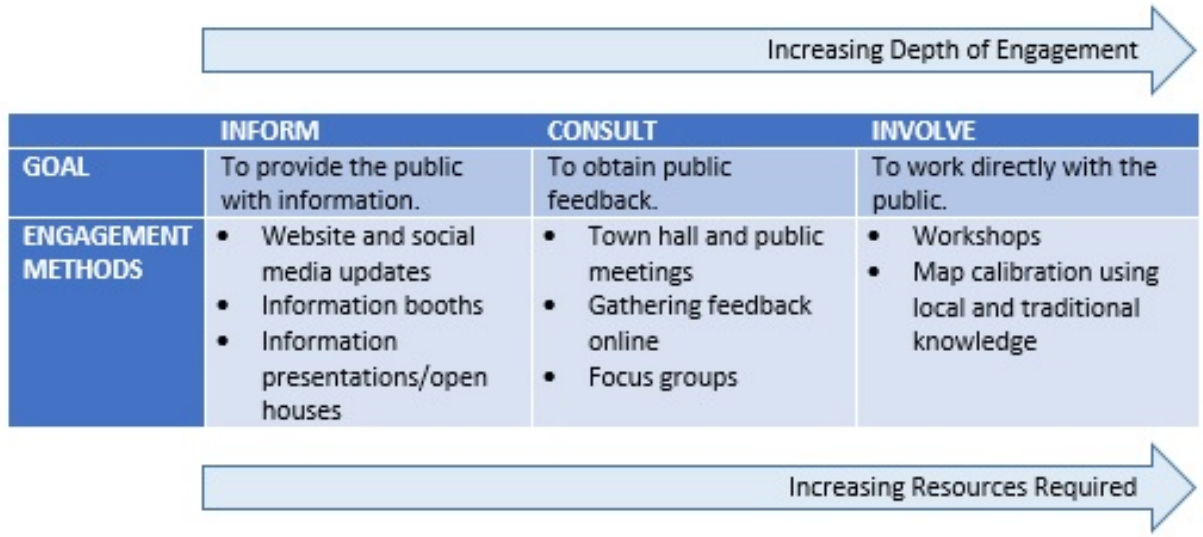

Figure 3: Community Engagement Spectrum (IAP2, 2017)

6.0 Lessons Learned and Recommendations

Listen to the needs and wants of each community, as each community is unique. Experts agree that every mapping process is unique, in terms of the characteristics of the watershed, the purpose of the exercise and the characteristics and needs of the community itself. To avoid barriers and waste of resources, project leaders are encouraged to connect with communities early on to understand and establish specific community requests and sensitivities, to explain the purpose of the process and the maps to be generated, and to design an engagement process that best fits with these needs.

1. **Make engagement tools interactive.** Incorporating interactive components into engagement methods, such as interactive online maps, videos, animations, or hands-on activities, can increase the comprehension of subject matter and help to generate interest in the project. Using several different tools and platforms for public engagement enables project leaders to reach wider audiences (or communities) of diversified demographics, and addresses issues of accessibility by creating materials that vary in format and delivery channels according to user needs. Creating adaptable engagement material in also cost-effective.

2. **Incorporate a communications or consultations stream facilitator into the project team.** Facilitators can work with both engineers and technical staff, as well as with community members from a wide range of backgrounds to practice effective communication and engagement between parties. Facilitators can help to structure the preparation and delivery of technical information and materials in ways that can be understood by the general public. Effective and comprehensible communication is critical for carrying out meaningful engagement with communities in the flood mapping process.

3. **Make project information, resources, and deliverables available online.** Certain recent flood mapping projects are beginning to upload relevant information online, increasing public accessibility. Online accessibility helps to keep the public informed throughout the flood mapping process, it sustains public interest and establishes accountability and transparency, fostering trust between parties.

ANNEX A: Integrated Flood Management Process

Below is a graphic outlining the process involved in flood risk mitigation and management. This graphic includes more detail than Figure 1: Flood Mapping Framework, contained in Section 8 of this document. This graphic was adapted from a diagram provided by Dave Murray, P.Eng., AScT, CPESC, Principal, Water Resources Engineer at Kerr Wood Leidal Consulting Engineers.

Figure 1: Integrated Flood Management Process