

# An Integrated Flood Risk Management Strategy for the Lake Champlain- Richelieu River Basin

**International Lake Champlain - Richelieu River Study**

A WHITE PAPER TO THE INTERNATIONAL JOINT COMMISSION

*Submitted by*

Daniel Henstra, Ph.D.

Department of Political Science

University of Waterloo

March 2022



# ACKNOWLEDGMENTS

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The author thanks Angelica Alberti-Dufort, Caroline Larrivée, Bronwyn McIlroy-Young, and Leonard Shabman for the policy ideas they presented in the four Theme 4 White Papers, and for their insights on the flood risk management strategy presented here. The author also thanks Ted Yuzyk, Bill Werick, Syed Moin, members of the Study Board and the Independent Review Group (IRG) for their contributions to the paper and comments on the draft.

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# EXECUTIVE SUMMARY

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The Lake Champlain-Richelieu River (LCRR) basin is a geographically and culturally diverse region straddling the Canada-US border. The vast drainage area is susceptible to springtime flooding that affects both lakeside and riverside residents of New York, Quebec, and Vermont. The International Joint Commission's Lake Champlain-Richelieu River Basin Study Board has undertaken an extensive evaluation of both structural and non-structural approaches to reduce the impacts of flooding in the LCRR basin.

## STUDY FOCUS

As part of this effort, the Study Board adopted a flood mitigation framework centered on four mitigation themes:

- 1** Reduce extreme water levels on the Richelieu River and Lake Champlain.
- 2** Impeded flows/reduce inflows into Lake Champlain or the Richelieu River.
- 3** Improve flood response (emergency preparedness).
- 4** Modify floodplain management (adaptation to flooding).

A 2020 workshop on Floodplain Management Solutions in the LCRR Basin (Theme 4) identified four key areas that the Study Board should focus on for providing recommendations in its final report to the International Joint Commission. The Study Board then commissioned four White Papers, each of which focused on one of these topics. The White Papers compiled best management practices based on a literature review and interviews with experts. This report synthesizes the main ideas from these four White Papers and subsequent LCRR Study research to present principles and practices that could inform a cohesive flood risk management strategy for the LCRR basin.

Flood risk in the LCRR basin is the product of three elements: (1) a flood *hazard*, meaning riverine, coastal, or surface inundation of land that is normally dry; (2) the *exposure* of people, property, infrastructure, and economic activity in or near the flood hazard zone; and (3) the *vulnerability* of people and assets to harm from flooding. Flood risk management (FRM) is a strategic approach that aims to increase community resilience to floods. It involves implementing a range of policy tools that prevent and reduce flood hazards, limit flood exposure and mitigate social vulnerability to flood impacts.

The Study Board has identified several structural options to mitigate the flood hazard in the LCRR basin which, if implemented, would target an important element of flood risk (FMMM/HHM 2021). Because floods even greater than that of 2011 remain possible in the LCRR basin, there is a need for an integrated FRM strategy to reduce and manage flood risk by mitigating the exposure and vulnerability of people, property and infrastructure assets. This strategy should be guided by overarching principles and implemented through a mix of complementary policy tools.

## PRINCIPLES

An effective FRM strategy should:

- be based on a comprehensive and continuous assessment of flood risk (i.e., hazard, exposure, and vulnerability);
- implement a portfolio of risk reduction tools to avoid, accommodate, and retreat from flood risk; and
- openly communicate flood risk to stakeholders and the public.

## POLICY TOOLS

Drawing on the four White Papers, this report discusses four policy tools for flood risk management:

- *Flood maps* are a valuable resource for FRM, but they should be designed to target specific audiences, such as planners, versus the general public. Maps designed for public use should be dynamic, interactive, and user-friendly to achieve their full potential.
- *Flood risk communication* campaigns can increase flood insurance uptake, encourage local emergency management and inform potential buyers of at-risk properties, but messages should be designed using best management practices.

- *Floodplain management* can discourage occupancy of flood prone lands in anticipation of changes in future risk. However, existing development also faces flood risk, which should be reduced through protections whenever justified.
- *Flood insurance* can be an effective tool to speed post-flood recovery but securing widespread coverage will require sharing risk and responsibility between government and the private sector.

## IMPLEMENTATION

Effective implementation of an FRM strategy requires an understanding of the policies and programs in place, an evaluation of their current effectiveness, and the deployment of complementary policy tools that increase the resilience of communities in the LCRR Study area. Implementation can be enhanced through consultation, engagement, and collaboration, by clarifying and sharing FRM responsibilities, and by monitoring and evaluating outcomes.

## STUDY LEGACY PRODUCTS TO SUPPORT FRM IN THE LCRR BASIN

The Study Board has produced a wealth of data and tools to support the implementation of an integrated FRM strategy:

- the sophisticated LCRR flood forecasting system can produce real-time forecasts that predict Lake Champlain levels and wave heights and water levels in the Richelieu River, which can be used to drive warning systems and the forecasts can be used by regional and local emergency managers to plan for preparedness and response.
- the IJC's Climate Change Guidance Framework and decision scaling approach offer an innovative way to support decision making in the face of uncertainty around future climate change.
- the Study's Integrated Social, Economic, and Environmental (ISEE) modeling system provides more granular estimates of flood damages to the built environment than have been available to date.
- the ISEE system can evaluate the costs and benefits of risk reduction investments in the LCRR basin, such as the effects of a flood insurance design on the flood resilience of households and projected impacts on future disaster assistance payments.
- the Social, Political and Economic (SPE) Analysis Group's work on political feasibility and social acceptability of policy tools has concluded that there is broad support for Theme 4 policy solutions among emergency managers and planners. Its report suggests that equity in the distribution of resources, benefits, and costs associated with Theme 4 policy measures is a key concern among residential property owners. The SPE-AG also asserts that flood resilience should be a policy priority that is integrated into comprehensive plans, land use plans, regulations, zoning by-laws and other instruments that guide local decision-making.

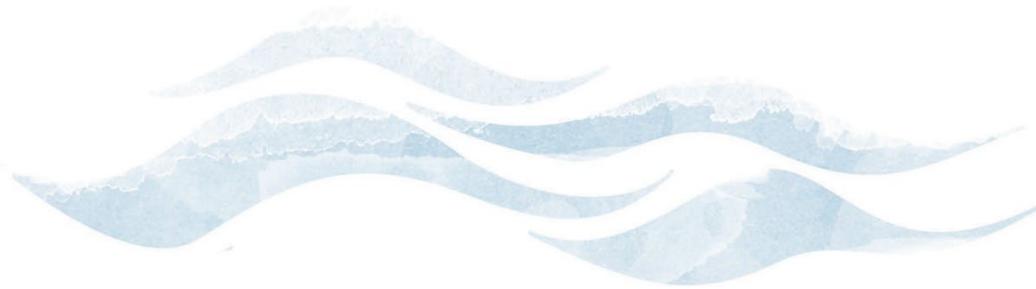


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## THE INTERNATIONAL JOINT COMMISSION

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Under the Boundary Waters Treaty of 1909 (the Treaty), the governments of the United States and Canada established the basic principles for managing many water-related issues along their shared international boundary. The Treaty established the IJC as a permanent international organization to advise and assist the governments on a range of water management issues. The IJC has two main responsibilities: regulating shared water uses; and investigating transboundary issues and recommending solutions.





# STAY CONNECTED, BE ENGAGED

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Want more information on the Lake Champlain-Richelieu River Study? Have a question for the Study Board?

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# 1 FLOOD RISK AND RESPONSE IN THE LCRR BASIN

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This report synthesizes the main ideas from four White Papers and subsequent LCRR Study research to present principles and practices that could inform a cohesive flood risk management strategy for the LCRR basin.

Flood risk is typically conceptualized as the product of three elements: (1) a flood *hazard*, meaning riverine, coastal, or surface inundation of land that is normally dry; (2) the *exposure* of people, property, infrastructure, and economic activity in or near the flood hazard zone; and (3) the *vulnerability* of people and assets to harm from flooding (Koks et al. 2015). Flood risk in the Lake Champlain-Richelieu River (LCRR) basin is evolving due to changes in these elements

Concerning the flood hazard, the Study Board's climate research establishes a credible threat from floods worse than 2011, even if the average yearly inflows to the lake trend downward over the next several decades because of higher temperatures (Lucas-Picher et al. 2021). Moreover, summer-fall extreme events could become more common (Riboust and Brissette 2015).

Regarding exposure, the number of residential buildings in the Richelieu River floodplain has grown since the 1940s, with peaks in the 1970s, 1990s, and 2000s, but the vulnerability of these properties varies by age. The Study Board's model of flood damages indicates that residential buildings added since the 1976 flood suffered little damage from flood levels seen in the basin in the 20th century, due in part to better siting and flood-proofing. Except for the 1998 and 2011 floods, 80-85 percent of flood damage was suffered by pre-1980 buildings. Even in the 2011 flood, buildings constructed before 1980 experienced more than 70 percent of the damage.

Finally, the Social, Political, and Economic Analysis Group (SPE-AG) has noted distinct pockets of concentrated vulnerability throughout the basin (ILCRRSB 2021). These are typically areas with a large proportion of elderly people, single-parent families, low-income households, and other sensitive populations who are likely to have lower capacity to cope with and recover from flood disaster impacts.

The Study Board has identified several structural options to mitigate the flood hazard in the LCRR basin which, if implemented, would target an important element of flood risk (FMMM/HHM 2021). However, because damages from more frequent floods have been mitigated by good floodplain management, there is less potential for the damage reduction benefits that might justify most structural projects. As a result, the Board will conditionally recommend further study of one or possibly two structural alternatives that are relatively inexpensive, but which also provide only a modest reduction in flood damages. As such, further flood risk reduction should focus on emergency flood response planning (Theme 3 of the LCRR study) and floodplain management (Theme 4 of the study).

In early 2020, a workshop on Floodplain Management Solutions in the LCRR Basin was held in Montreal, Quebec. The findings from this workshop were synthesized in a report submitted to the Study Board, which identified four key areas that the Study Board should focus on for providing recommendations in its final report to the International Joint Commission (Henstra and Shabman 2020). The four areas included flood risk mapping, flood risk communication, management of floodplain occupancy, and flood insurance. The Study Board then commissioned four

White Papers, each of which focused on one of these topics. The White Papers compiled best management practices based on a literature review and interviews with experts (Alberti-Dufort 2021a; 2021b; Henstra and McIlroy-Young 2021; Shabman 2021).

This report synthesizes the main ideas from these four White Papers and subsequent LCRR Study research to present principles and practices that could inform a cohesive flood risk management strategy for the LCRR basin. It begins by outlining several guiding principles of flood risk management drawn from published literature and professional practice. It then describes several flood-

related policy changes that have occurred or are underway in the three subnational jurisdictions that comprise the LCRR basin—New York, Quebec, and Vermont. Section 4.0 covers the four flood risk management tools examined in the White Papers, drawing out key findings for each. The fifth section discusses policy tool alignment and techniques to support effective implementation. Section 6.0 briefly discusses resources produced by the Study that could support the deployment of the flood risk management strategy outlined herein.



## 2 FLOOD RISK MANAGEMENT

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*Flood risk management (FRM)* aims to increase community resilience to floods by implementing a range of policy tools that prevent and reduce flood hazards, limit flood exposure, and mitigate social vulnerability to flood impacts (Sayers et al. 2014). Floodplain management research results across Theme 4, including the four White Papers and the integrated report authored by the SPE-AG, point to several overarching principles that should inform a non-structural FRM strategy for the LCRR basin, as follows.

### 2.1 ASSESS FLOOD RISK TO SUPPORT POLICY

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A critical first step for designing an effective FRM strategy is to assess the risk of flooding in a target area. New data and technology are available to generate more accurate estimates of the probability of occurrence and magnitude of damaging flood conditions, including the depth and duration of inundation, the velocity of moving water, expected wave height, and other variables. Similarly, increasingly sophisticated technology such as LiDAR or drone-based surveys of first floor elevations of structures in flood risk areas, combined with point data that indicate the precise location of buildings and critical infrastructure assets, can be harnessed to estimate economic exposure to flood damage.

The LCRR Study has developed the relevant datasets and has produced a stage-damage model for the basin. These resources are available to officials in New York, Quebec and Vermont, who could use the stage-damage model directly, or integrate the data into their own systems. The latter approach is preferable because the data could be augmented by adding more accurate first

floor elevations and updated as conditions change.

Finally, a wealth of sociodemographic data collected by numerous agencies is available to measure social vulnerability at reasonably small geographic units, such as the dissemination block used by Statistics Canada.<sup>1</sup> Indeed, the SPE-AG has generated a detailed analysis combining exposure, social sensitivity, territorial sensitivity, adaptive capacity, and accessibility to assess and quantify vulnerability of communities in the LCRR basin (ILCRRSB 2021). The results of a flood risk assessment, which are typically displayed as maps showing areas of higher and lower risk, offer a logical and transparent basis for consultation with relevant stakeholders about practical, feasible and economically efficient measures to reduce flood risk.

White Paper #1 offers a detailed analysis of hazard mapping, vulnerability mapping and risk mapping, which form the basis for the flood risk assessment (Alberti-Dufort 2021a). The Study's Integrated Social, Economic and Environmental (ISEE) modeling system offers a sophisticated instrument to assess the degree to which different flood risk mitigation measures could decrease damages to homes, businesses, infrastructure and the environment, using a range of performance indicators.

### 2.2 ACCEPT THAT ABSOLUTE PROTECTION IS IMPOSSIBLE AND PLAN ACCORDINGLY

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The LCRR basin is home to long-established, vibrant communities that house more than one million people (ILCRRSB 2019). Approximately 8 percent of the land area in the Canadian part of the basin and 5 percent of the United States part is urban or otherwise developed,

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<sup>1</sup> A dissemination block is defined by Statistics Canada as an area bounded on all sides by roads and/or boundaries of standard geographic areas. It is the smallest geographic area for which population and dwelling counts are distributed

and these communities are important sites of economic activity. In other words, significant benefits are derived from current occupation of floodplain lands in the Study area, and their unique value underscores the need to strengthen their resilience to flood impacts.

Governments and communities must acknowledge, however, that occupying floodplain lands carries an inherent risk of damage and loss. Although the level of this risk depends on the measures adopted to reduce flood hazards, exposure and vulnerability, some residual risk will always remain. Accepting this axiom from the outset is important, to manage public and political expectations about the practicality and feasibility of FRM interventions. Moreover, it motivates contingency planning for floods that will inevitably exceed design standards.

As discussed in detail in White Paper #3, measures to reduce flood risk are often grouped into four main categories, including (1) protect, (2) avoid, (3) accommodate, and (4) retreat (Alberti-Dufort 2021b). Protection involves structural control systems such as dikes, floodwalls and diversion structures to separate flood waters from people, property and infrastructure. The Study Board has identified several structural protection options for the LCRR basin. However, it found no structural solution that could reduce most flood damages cost-effectively, so it is necessary to also consider measures from the other three categories, which aim to reduce exposure and vulnerability to flooding.

Avoidance strategies involve proactively adopting land use controls to prevent the construction of homes, community facilities and infrastructure assets in flood-prone areas, thereby limiting exposure to flood losses. Such controls can be highly effective in reducing flood risk, but they require regulatory enforcement through state and provincial land use policies and municipal by-laws that prohibit development of lands designated as flood risk zones.

In this Study area, improved floodplain management in the last several decades has minimized the exposure of new buildings within the delineated floodplain, but the

risk to older buildings continues and there is new risk from floods greater than that used to delineate the floodplain. The first challenge, therefore, is to determine the appropriate boundaries of the flood zone, within which development should be strictly controlled. In the 2011 flood, the city of Saint-Jean-sur-Richelieu reported that more than half of the damage sustained was to buildings outside the floodplain. Moreover, media reports indicated that some buildings were razed after being damaged in the 2011 flood but are being re-developed because the parcels are not within the 100-year floodplain, the current boundary for building controls in the basin. This is the second challenge—whether and how to avoid damages outside the delineated floodplain.

The accommodation approach recognizes that because many communities and infrastructure assets are already established in flood-prone areas, it is necessary to adapt to occasional flooding by implementing measures to limit the damage it might cause, such as raising or floodproofing exposed structures. A preliminary examination of such measures is being explored as part of the Study Board's comparison of flood insurance versus disaster relief. There are many examples of such practices from other countries, some of which are highlighted in White Paper #3 (Alberti-Dufort 2021b).

Where communities are subject to severe and repeated flooding, the “retreat” approach may be required, whereby homes and infrastructure are permanently relocated out of these areas, typically through government-funded property buyouts or land swaps. Relocation effectively reduces the exposure of people and property to flood hazards, but it requires careful planning guided by a holistic vision to avoid harm to community social cohesion. Relocations are generally also more expensive than elevating or floodproofing in place. Funding for relocation is available in New York, Quebec and Vermont if certain conditions are met, but homeowners may find it difficult to pay off mortgages and purchase new homes with the limited money governments presently provide.

## 2.3 OPENLY COMMUNICATE FLOOD RISK

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Effective implementation of FRM demands the active support of decision makers, asset owners, and the public, and a necessary first step is to communicate flood risk to these audiences. As discussed in White Paper #2, flood risk communication serves several important purposes (Henstra and McIlroy-Young 2021). First, it strengthens citizen awareness of flood risk, instills a sense of personal responsibility for risk reduction, and confers agency on individuals to protect themselves. Second, communicating flood risk can induce behavioral change by motivating target audiences to adopt property- or asset-level risk reduction measures. Finally, it can increase stakeholder and public support for other FRM tools, including regulations.

There is clearly a public appetite for flood risk information. In the United States, for instance, the real estate listings website Realtor.com now displays the flood risk for every home, based on “Flood Factor”, a GIS-based flood risk estimation program developed by First Street Foundation (Hersher and Sommer 2020). The ISEE model produces more accurate flood risk assessments than Flood Factor, but even these could be improved with better estimates of first floor elevations. An effort underway in Montreal to measure first floors may provide a template for other governments to follow.



## 3 POLICY CONTEXT

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It is important to recognize policy changes already underway in the LCRR basin that set the context for a flood risk management strategy. This section offers a brief overview of some of the government policy responses to recent flooding on both sides of the Canada-United States border.

### 3.1 QUEBEC

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The severe flooding in the Lake Champlain-Richelieu River Basin in 2011 was a catalyst for the government of Quebec to re-evaluate flood management policies and practices in the province. Indeed, the provincial government's recognition of the need for policy change was evidenced in its prompt establishment of "special intervention zones" (SIZ) for all municipalities along the Richelieu River just after the flood, which banned reconstruction in the 0-2 year flood zone and allowed reconstruction within the 2-20-year flood zone only if certain protective measures were adopted.

The urgency to explore policy reforms was underscored by major flooding in the spring of 2017, which prompted the Ministry of Public Security to draft a Plan d'action en matière de sécurité civile relatif aux inondations (Civil Protection Flood Action Plan) that contained 24 specific actions the provincial government would consider to strengthen flood management. Recommended actions included mandatory civil protection plans for all municipalities, financial support to improve municipal disaster preparedness, a framework of intermunicipal mutual aid, better management of flood zones and better flood risk communication with the public (Quebec 2018b).

One major initiative that emerged from the plan in 2018 was the INFO-Crue project, which aims to identify and map flood zones in southern Quebec. The five-year project, spearheaded by the Ministère de l'environnement et de la Lutte contre les changements climatiques (Ministry of the Environment and the Fight

Against Climate Change) (MELCC) in partnership with Ouranos, will incorporate climate change projections to develop tools and a flood forecasting system to support land use planning in several watersheds (Quebec 2018a).

Severe spring flooding occurred again in 2019, after which the SIZ development restrictions were tightened and extended. Beyond this application of the province's regulatory power, in recent years the government of Quebec has initiated a program of buyouts for severely damaged properties, undertaken a comprehensive effort to replace outdated flood maps using hydraulic modeling with bathymetry estimated from LiDAR, and funded an interdisciplinary network of government actors, scientists and academic researchers (RIISQ) to improve Quebec's flood protection and preparedness.

A new, comprehensive framework for flood management is under development, which proposes changes to provincial policy on land use along rivers and in known floodplains, as well as the creation of ten project offices on flood management that will lead planning at the watershed scale (Therrien et al. 2021). The framework would rely upon proposed legislation currently under review, which would confer new responsibilities and regulatory powers on the regional county municipalities (MRCs) and would implement new standards for flood protection structures. Finally, there have been many other policy changes related to flood management over the last few years, including new public safety requirements for municipalities, revised disaster financial assistance programs and improved recovery planning.

### 3.2 NEW YORK AND VERMONT

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On the US side of the border, policy and program changes have occurred at both the national and state levels that are relevant to the Study Board's findings and conclusions. Notably, significant changes to the National Flood Insurance Program that have been underway for

several years took effect in 2021. Dubbed “Risk Rating 2.0”, this policy change is designed to impose flood insurance premium rates that reflect an individual property’s flood risk, rather than the current approach, whereby a nationwide rating system is used to calculate expected losses for groups of structures with similar flood risk and structural features and the same rate is applied to all policies in these groups. In New York, Risk Rating 2.0 is projected to result in substantial premium increases (i.e., more than US\$20 per month) for 7 percent of policies, marginal increases (i.e., US\$0-US\$20 per month) for 61 percent of policies, and a decrease in premiums for 32 percent of policies (FEMA 2021a). Similar figures are estimated for Vermont: 8 percent of policies will have substantially higher premiums, 59 percent of policies will see premiums increase marginally, and premiums will decrease for 33 percent of policies (FEMA 2021b).

### New York

In 2018, New York State officials launched the US\$3 million Resilient NY program to improve community resilience to extreme weather that results in flooding (New York 2021). Administered by the Department of Environmental Conservation, the program uses advanced modeling to assess flood risk across the state and identify high-priority watersheds to target for flood mitigation measures. Based on a series of analyses, high-priority communities are considered for risk reduction measures including floodplain restoration, floodwater storage, small structural protections such as dikes and levees, and buyout programs to relocate people and property out of exposed areas. The list of watersheds includes several tributaries to Lake Champlain, including the Bouquet and Ausable Rivers (East and West Branches) in Essex County, the Mettawee River in Washington County, and the Great and Little Chazy Rivers in Clinton County.

### Vermont

Between 2010 and 2014, Vermont’s state legislature passed several pieces of legislation that mandated a River Corridor and Floodplain Management Program, which was adopted to protect the health, safety, and welfare of the general public from flood hazards (Vermont Agency of Natural Resources 2017). In coordination with the Federal Emergency Management Agency (FEMA) and local municipalities, the Department of Environmental Conservation was charged with mapping river corridors, meaning areas around and adjacent to river channels where fluvial erosion and channel evolution are most likely to occur. The maps have since been used by state floodplain managers to encourage municipalities to adopt river corridor protection bylaws as part of an “accommodate” approach to give the river increased access to its floodplain over time.

Vermont’s Emergency Relief Assistance Fund (ERAF) was created in 2014 to provide support to municipalities that adopt measures to strengthen their resilience to floods in the aftermath of a federally declared disaster (Vermont 2021a). Communities that participate in the NFIP, have adopted road and bridge standards and have produced both an emergency management plan and hazard mitigation plan are eligible for reimbursement of 12.5 percent of the cost of risk reduction measures. This state subsidy rises to 17.5 percent for communities that have also adopted a by-law to prevent development encroachment into river corridors. This program appears to have been effective in reducing flood risk: between 2014 and 2017, the number of municipalities with emergency management plans nearly tripled, and those with hazard mitigation plans nearly doubled (Pew Charitable Trusts 2016). In the Study area, 25 communities have adopted all the requirements to secure the highest ERAF subsidy of 17.5 percent (Table 1), and many others have achieved the 12.5 percent subsidy.

Table 1. Communities Receiving Full ERAF Subsidy by County

County	Community
Addison	Granville Orwell
Bennington	Bennington Manchester North Bennington Village Shaftsbury Sunderland
Chittenden	Bolton Charlotte Colchester Essex Essex Junction Village Hinesburg Jericho Milton Richmond Shelburne South Burlington Westford Williston Winooski
Rutland	Brandon Pawlet Proctor Shrewsbury

Source: (Vermont 2021b)

In summary, much work has been done or is underway in New York, Quebec and Vermont to reduce flood damages. These actions may increase the resilience of communities in the LCRR basin to manage small and medium-sized floods that inundate portions of the area. As noted, however, climate change, changing floodplain occupancy and shifts in the social vulnerability of the resident population suggest that flood damage even greater than that of 2011 is possible. This flood risk warrants continuing attention and, if it manifests, may require a multi-pronged approach to reduce flood hazards and vulnerability and to expand uptake of flood insurance by both households and businesses.



## 4 TOOLS OF FLOOD RISK MANAGEMENT

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In 2021, the Study Board commissioned four expert White Papers to examine four key areas that were highlighted as promising approaches to FRM, including flood risk mapping, flood risk communication, management of floodplain occupancy, and flood insurance (Alberti-Dufort 2021a; 2021b; Henstra and McIlroy-Young 2021; Shabman 2021). Each of these tools contributes to flood risk management by reducing exposure and vulnerability to flooding. This section summarizes key points from the four White Papers and draws out select conclusions related to each topic.

### 4.1 FLOOD MAPPING

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Flood maps are a critical decision support tool for planners, property developers, emergency managers, insurance companies and many other stakeholders who need to consider hazards to people and property. They are essential for setting and enforcing regulations that govern the use of land in flood hazard zones. They are also a potentially valuable resource to inform property-owners about flood risk and motivate them to buy insurance or implement property-level protection measures. In England, for example, residents use flood maps published by the national Environment Agency as part of their research when purchasing a house and negotiating flood insurance. As discussed in detail in White Paper #1, several best management practices concerning flood maps should be considered as part of a non-structural flood risk management strategy for the LCRR basin (Alberti-Dufort 2021a). The following are two key findings about flood maps.

#### 4.1.1 Create maps for targeted audiences

There are two main types of flood maps, which differ in their purpose, content and audience. Flood *hazard* maps indicate geographic areas that could be inundated by a flood of a particular magnitude (e.g., the “100-year flood” or “1 percent annual exceedance probability”). They sometimes include additional information, such as

the type of flood, water depths, and flow velocity. Flood hazard maps are typically used to support planning and engineering functions, such as setting zoning regulations and enforcing development standards. Although they provide a rational basis for public policies and administrative decisions, they typically contain highly technical data and lack information on potential adverse consequences associated with flooding. These characteristics limit their utility for strengthening public understanding of flood risk.

Flood *risk* maps include flood hazard information, but also depict assets at risk (e.g., structures; critical infrastructure) and include indicators of the adverse consequences associated with floods, typically denoted in terms of households affected, economic activity likely to be affected, and so on. With their enhanced detail, flood risk maps are valuable for stimulating policy dialogue about FRM, supporting decisions about strategic investments in structural and non-structural mitigation, informing insurance underwriting, and increasing public awareness of flood risk. Flood risk maps designed for public use typically share key characteristics that make them user-friendly. Generally, these maps are:

- *searchable*, so that users can find information specific to their property;
- *contextualized* to include identifiable places, landmarks, and historical events that help users visualize the likely spatial extent of future flooding;
- *legible*, so it is easy for the user to distinguish the extents of the flood zone;

- *understandable to a lay audience*, by using plain language or explaining technical terms;
- *holistic*, in that they note potential exposure of adjacent areas and projected expansion of inundation zones due to climate change or other factors; and
- *action-oriented*, in that they are linked to risk reduction advice.

Although the term “maps” has been used here, a dynamic, digital interface powered by a geographic information system (GIS) is much more valuable than conventional maps that offer only a static cartographic depiction of a geographic area that could be flooded. Such a GIS-based mapping system could incorporate multiple layers of information that could be tailored for different intended audiences. As an example, the United Kingdom Environment Agency maintains a dynamic, digital interface that citizens can search by postal code to receive a detailed report about flood risk to their property, as well as advice on measures to protect their home (United Kingdom 2021).

#### **4.1.2 Update and add more detail to flood maps**

Existing flood hazard maps in Quebec, New York and Vermont are of varying quality, and many are outdated. For instance, the Study has found that flood hazard maps are outdated for areas along the Richelieu River and the Canadian shores of Lake Champlain. Based on Study estimates of 1 percent Annual Exceedance Probability (1-in-100-year) discharge levels, current flood hazard maps in Quebec do not encompass the whole inundation zone.

To support effective FRM, updating these maps using contemporary data, methods and technologies is advisable, and is already underway to some extent. Flood hazard maps should include information such as water depth, velocity, and the presence of control structures that could affect the water level in different areas. Moreover, maps could depict multiple flood

frequencies and incorporate historical events such as the 2011 flood. New technologies such as hydrological and hydraulic modeling using digital elevation models enable authorities to incorporate the best available knowledge for a better representation of flood zones. Notably, the Study Board has created a digital elevation model as well as a 2-dimensional hydraulic model for some sections of the Quebec portion of the LCRR basin, and these could be expanded to cover a broader territory. Part of this work is already underway in Quebec through the INFO-Crue project.

Flood hazard maps provide only a partial picture of flood risk. FRM planning decisions would be enhanced by better understanding and mapping the elements exposed to flooding, as well as the sociodemographic characteristics of people who are likely to experience flood impacts. As noted above, the SPE-AG has produced a comprehensive and detailed analysis of the vulnerability and resilience of local communities in the LCRR basin (ILCRRSB 2021). Moreover, this work has underpinned the development of performance indicators for the Study Board’s ISEE model, which assist in estimating the economic, social and environmental impacts of flooding, as well as flood risk maps showing potential loss of accessibility due to inundation of the road network under different flooding scenarios.

A final best practice for flood maps is to represent the potential influence of climate change on flooding, as the government of Quebec is in the process of doing through the INFO-Crue project. There are many evolving methods for integrating climate change-informed design water levels into flood maps (Khaliq 2019), but they typically involve statistical frequency analysis on high water flows to generate adjusted return periods or annual exceedance probabilities. These estimated design flows can then be used as inputs in hydraulic models to generate potential flood estimates to inform planners and communities about possible future flood scenarios.

## 4.2 FLOOD RISK COMMUNICATION

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Residents on both the Canadian and US sides of the LCRR basin have low awareness of flood risk, which suggests that they might be unprepared for flood emergencies and unlikely to adopt property-level flood protection measures to limit damage. Reducing exposure and vulnerability to flood impacts may therefore require a coordinated, comprehensive flood risk communication campaign to raise awareness and engage the public (Henstra and McIlroy-Young 2021).

Flood risk communication can achieve numerous goals related to floodplain management. First, communication fulfills the government's responsibility to inform and engage citizens in FRM. Second, it shares some responsibility for risk management with the public and can encourage individuals to take action to reduce their flood risk. Third, flood risk communication supports other floodplain management tools, such as flood risk maps, which provide a visual reference of flood-prone areas. Similarly, by equipping people with a better understanding of the potential social and economic impacts of flooding, flood risk communication can strengthen public and political support for regulating development on floodplain lands. Finally, voluntary uptake of flood insurance by households is often low, so flood risk communication can be a valuable support for making residents aware of their protection gap.

The specific message of a flood risk communication campaign depends on a government's policy objectives, and it is therefore best determined by public authorities in consultation with community groups. In the LCRR Study area, however, there are at least three areas of FRM that could be strengthened and supported through flood risk communication, as follows.

### 4.2.1 Communicate the importance of flood insurance

As noted in Section 5.4 below, uptake of flood insurance appears low among property owners in the Study area. It is well-documented that demand for flood insurance is often muted because property owners perceive little

danger of flood damage or expect that any losses will be covered by disaster assistance (Kunreuther and Pauly 2004). Moreover, property owners in the LCRR basin lack access to flood risk assessment tools to determine whether flood insurance is a good investment. Flood risk communication is therefore important to make residents aware of their flood risk, remind them that government disaster assistance is rarely sufficient to cover all damage costs, and encourage residents to insure their property against flood risk.

### 4.2.2 Encourage flood emergency response planning

Properties outside the designated 100-year floodplain face some risk from floods that exceed the design recurrence interval. In these areas, the infrequency of the flood hazard might make traditional floodplain restrictions unfeasible, but the risk of damage is nevertheless significant. In these areas, flood risk communication could be used to inform residents of the risk and encourage communities to implement comprehensive flood emergency response measures in advance.

### 4.2.3 Inform potential buyers of at-risk properties

Flood risk communication could better inform potential buyers about the risk of flooding to properties they are considering for purchase. There is a public need for information. In Canada, for instance, nearly 90 percent of respondents to a national survey agreed that sellers should be required to inform potential buyers about flood risk (Ziolecki et al. 2020). In the United States, it has been observed that the requirement for mortgaged properties in the floodplain to have flood insurance is not always communicated or followed. If informed in advance, homeowners can more legitimately be expected to share in the responsibility for managing flood risk by, for example, buying flood insurance or adopting property-level flood protection measures.

#### 4.2.4 Best management practices for flood risk communication

White Paper #2 presents numerous best management practices from international experience to inform the design and delivery of an effective flood risk communication campaign (Henstra and McIlroy-Young 2021). Specifically, it identifies five recommendations for the design of an effective campaign, including:

- *Leverage calendar milestones and attention-focusing events:* Time campaigns to correspond with significant dates or seasonal markers to attract attention and make information more salient. Be prepared to act when concern is highest immediately after a flood event.
- *Employ multiple media:* Harness traditional print sources, online platforms and in-person methods to increase reach and align the messaging objective with the medium.
- *Use mobile apps to support flood preparedness and response:* Employ apps to achieve instantaneous and wide-reaching communication.
- *Distribute and amplify messages through trusted sources:* Extend messaging through trusted, familiar figures and organizations to increase reach and uptake.
- *Evaluate outcomes:* Plan ahead to assess whether stakeholders were satisfied with the conduct of the communication campaign and whether it had the intended impact.

International research offers several best management practices when designing and framing flood risk messages, including:

- *Profile the audience:* Understand audience demographics and characteristics, such as residential versus business property owners, and adapt messaging accordingly.
- *Promote benefits and anticipate barriers to action:* Research what factors will motivate or inhibit people to take the desired action. Promote benefits and address barriers.
- *Keep messages simple:* Avoid overwhelming or confusing the audience by keeping communication materials brief and to-the-point.
- *Make it understandable:* Use plain, simple language. Avoid technical or mathematical explanations and jargon, such as “fluvial” or “inundation zone”.
- *Explain flood risks clearly:* Frame risk in a way that is meaningful to the public (e.g., 26 percent chance of flooding over a 30-year mortgage, rather than 1 percent annual probability).
- *Keep the message positive:* Frightening or sad messaging can cause people to discount or ignore the content. Use an optimistic tone to engage audiences and inspire action.
- *Use evocative imagery:* Images that reflect a positive tone and depict individuals engaging in the desired behavior are more effective than scenes of devastation.
- *Make the message memorable:* Where appropriate, use playful, humorous, or catchy messaging that will stick in the mind of the target audience.

## 4.3 MANAGEMENT OF FLOODPLAIN OCCUPANCY

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One of the most effective ways to reduce flood risk is to avoid future exposure of people and property to flood hazards. Avoidance requires a land use planning strategy designed to manage the occupation of flood-prone lands, which includes the imposition of legal restrictions on the location, type, scale and density of development. Any such strategy must begin with a comprehensive understanding of flood risk, including the expected magnitude and areal extent of flood hazards, the exposure of property and infrastructure assets, and the social vulnerability of exposed populations.

Moreover, because of the dynamic nature of these elements, a land use planning strategy should not be static, but should rather be regularly monitored and evaluated based on principles of adaptive management and continuous learning. To these ends, White Paper #3 offers several best management practices drawn from international literature and experience, as follows (Alberti-Dufort 2021b).

### 4.3.1 Update land use regulations based on flood risk

At the heart of a floodplain land use planning strategy are questions about the level of flood risk that society is willing to tolerate and the sectors that should be prioritized for expansion and protection. Assessing, mapping and publicly communicating flood risk are a starting point for answering these questions, offering a rational basis for selecting FRM measures (i.e., protect, avoid, accommodate or retreat), and assisting in directing scarce public resources to areas with highest risk. The comparative measurement of flood risk and its visual depiction through maps that clearly divide land into risk zones are especially important for building public and political support for more contentious FRM options, such as the construction of protective structures or relocation.

A risk-based land use planning strategy should account for contingencies to protect against future flood risk. One

important factor is climate change, which is affecting the nature and dynamics of the LCRR flood regime. Another is topography: considering the flatness of some of the land along the Richelieu River, for instance, it would be prudent to factor wind effects into floodplain designations, since a strong south wind could expand the inundated area considerably. A final consideration is protection of existing wetlands, which provide natural protection against flood damage, while also offering co-benefits, such as improved water quality (Rousseau et al. 2021).

### 4.3.2 Shield development in high-risk flood zones

Considering that parts of the LCRR basin are already developed and existing communities will continue to grow, a floodplain management strategy should embrace the “accommodate” approach by adapting the built environment to coexist with water. Adaptation in this context might require retrofitting structures to protect them from riverine flooding, mainly by sealing penetrations through basement walls, raising the elevation of the main floor level, reinforcing walls, using flood-resistant materials, and backfilling around the perimeter. Governments can encourage property owners to undertake this work by offering incentives such as grants (targeted, non-repayable funds to motivate behavior), subsidies (funds to supplement private investment in exchange for performance requirements) and credits (rebate on other financial obligations, such as property taxes, to encourage behavior).

## 4.4 FLOOD INSURANCE

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Insurance offers several potential benefits as a tool to manage flood risk. First, it is an efficient means to finance household recovery from flood damages because insurance payments are typically extended more promptly than government disaster assistance. Second, allocating a portion of the loss to policyholders through a deductible can enable insurers to extend coverage to a broader population. Third, private flood insurance shares the responsibility for FRM beyond governments,

by engaging the private resources of insurers and property owners themselves. If they are offered a premium discount, for example, households might be encouraged to make investments in loss prevention. White Paper #4 explores the potential for flood insurance in the Study area, offering several concrete ideas for incorporating this important tool into a non-structural floodplain management strategy and for encouraging its uptake among residents (Shabman 2021).

#### **4.4.1 Investigate the state of flood insurance in the LCRR basin**

Several factors influence the effectiveness of insurance as a tool of FRM, including availability, affordability, and the uptake rate among flood-exposed households. To be a viable tool of FRM, flood insurance requires broad uptake (or “market penetration”), so that insurers can spread losses across a broad pool of policyholders. Poor availability and affordability of insurance contribute to low uptake and therefore reduce its effectiveness in managing the financial exposure of property owners to flood damages.

Although flood insurance is available to nearly all US property owners through the National Flood Insurance Program, data indicate no policies in effect in the Study area along the Lake Champlain shoreline. Insurance against overland flooding such as the overflow of lakes and rivers is relatively new in Canada, and it is offered only by private insurers who decide independently where and at what price it will be available. Because the Study area along the Richelieu River is an area of high flood risk, it is unlikely that flood insurance is currently being offered or purchased. Moreover, even if flood coverage is available to homeowners, it might be offered at a premium rate so high that few would be able or willing to pay them. A first step towards integrating flood insurance as an element of floodplain management in the LCRR basin, therefore, is to obtain precise measures

of its availability, affordability, and uptake among the roughly 3,000 properties at high risk of flooding along the Richelieu River.

#### **4.4.2 Negotiate a layered arrangement that shares financial liability for flood damages**

White Paper #4 offers a conceptual framework for layered coverage that would share the responsibility for insuring flood risk for existing properties between government and private insurers (Shabman 2021). The first layer of coverage would be a provincial government program that offers compensation up to a low limit (e.g., \$10,000 per event), which would cover all property owners within a community. The province might choose to charge a fee for the coverage. Property owners would be permitted to opt out of the coverage under certain conditions and be responsible for paying to repair damages equal to the Layer 1 coverage. The payout would be issued based on a “parametric trigger”—a predetermined measure of flood severity such as water height—which would involve low administrative costs and allow for a swift payout.<sup>2</sup>

The second layer of coverage would be offered as a default in all homeowners’ policies and issued by a pool of private insurers. This standard indemnity-based policy,<sup>3</sup> would be bounded between the Layer 1 coverage limit and an upper limit on payouts (i.e., in effect, Layer 1 acts as a deductible). With claims exposure bounded by these limits, private insurers could offer Layer 2 coverage at premiums that were both profitable and affordable. For some, the cost of insurance premiums competes with essential household budget items, and for those property owners the pool would be directed to offer means-tested premium discounts and governments would reimburse the pool for forgone premium revenue. Policyholders could opt out of the default coverage and be responsible

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<sup>2</sup> The alternative to parametric coverage, discussed in the paper, would be for private insurers to pay all claims up to the layer 2 limits (see layer 2 discussion, and for governments to reimburse the private insurer for an amount equal to the Layer 1 coverage limit, or the damage paid, whichever is smaller.

<sup>3</sup> Indemnity-based insurance refers to a policy that covers an insured party for actual losses (typically to a specified limit) in exchange for a fixed premium.

for the damage repair costs up to the Layer 2 cap.

Layer 3 would be a revised version of existing disaster financial assistance programs, whereby affected property owners would receive public compensation for damage costs that exceed the second layer cap. Although the details of such an arrangement would require further study and negotiation, this three-layer model could provide robust financial protection for property owners in high-risk flood areas of the basin, while also limiting the economic liability of governments as property owners paid a modest fee in Layer 1 and the premium in Layer 2.

#### 4.4.3 Use multiple levers to motivate flood insurance purchase

A key role for governments on both sides of the border is to secure widespread insurance coverage, including in high-risk areas. In the layered coverage design, coverage is provided by default and the role of government is to discourage opting out. Flood maps designed for a public audience that include features such as a searchable

interface, recognizable landmarks, historical consequences, and lay terminology, can be useful to make people aware of flood risk and accept the need for insurance.

As part of the LCRR Study, a model was developed to compare flood insurance to disaster relief in the Upper Richelieu floodplain. It is based on ISEE evaluations of damage at each building over the historic flow period. This model was continually modified to consider related measures that would help both quantify and mitigate the costs insurers would bear under the three-layer model, by changing the breakpoints between layers, subsidizing rates for low-income property owners, and finally, reducing damages through Theme 1, 3, and 4 measures. The model, as it stands now, is a prototype for dynamically formulating and evaluating structural and non-structural flood damage reduction measures that would increase flood resilience directly by reducing impacts, and indirectly by making flood insurance more attractive to owners, government, and insurers alike. Figure 1 shows a screen capture of the model.

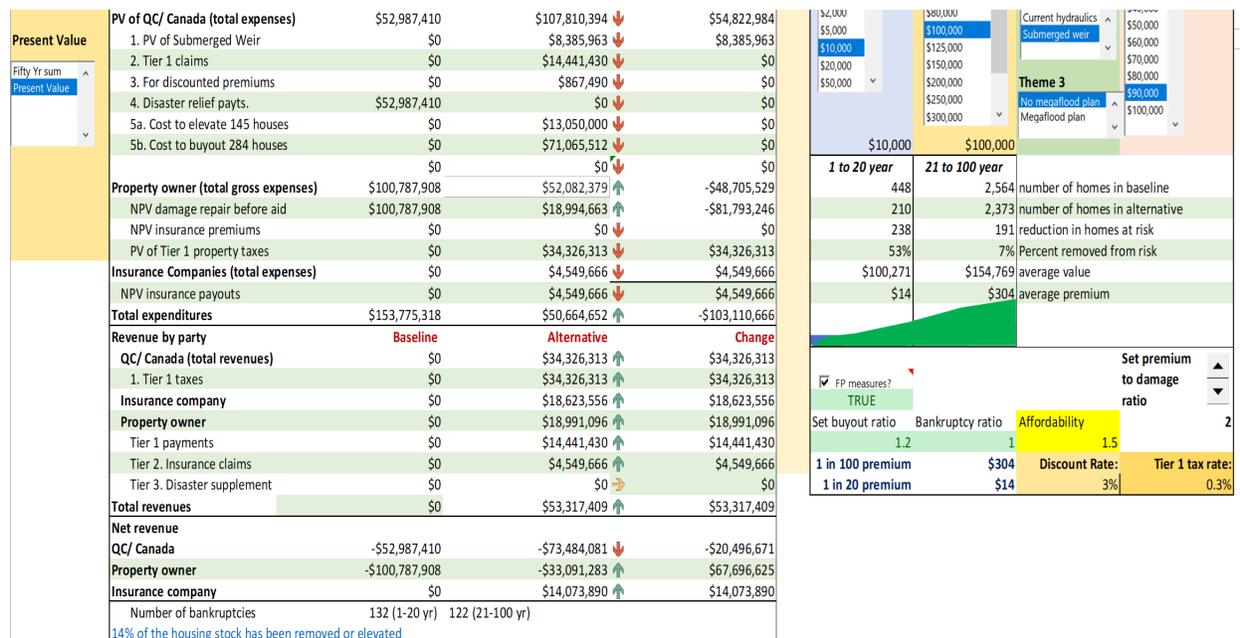


Figure 1. Simulation of shift from disaster financial assistance to flood insurance based on post-flood financial support to property owners along the Richelieu River.

# 5 IMPLEMENTATION

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To this point, this paper has focused primarily on the suitability of individual FRM tools, but experts assert that FRM is best achieved through a combination of multiple policy tools. Indeed, coupling policy instruments in strategic ways enhances their collective impact on flood risk reduction. The effectiveness of flood maps, for instance, depends heavily on the flood risk communication campaign designed to make people aware of flooding and seek out further information about how to mitigate their exposure and vulnerability. Similarly, flood insurance is unlikely to be viable in the long term without controls on the use of flood-prone lands to ensure no further exposure. This section discusses strategies to ensure effective implementation of an integrated FRM strategy in the LCRR basin.

## 5.1 ALIGNING POLICY TOOLS

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A key consideration when combining multiple policy tools is to ensure a coherent mix, meaning that they should be designed to be mutually reinforcing, without working at cross purposes. Avoiding policy incoherence requires careful selection of tools guided by clear policy goals, incremental implementation through pilot projects, continuous monitoring of policy performance and adjustments where feedback indicates that they are warranted. As public authorities evaluate the effectiveness of policy interventions and receive feedback from implementing agents and stakeholders, they should incorporate this knowledge into subsequent policy design. A negative assessment of performance or sustained negative feedback creates an opportunity to substitute one instrument for another, or to issue new directives to implementors to adjust their interactions with target populations.

Aligning policy tools among the local, regional, and national authorities that govern the basin is also important to avoid negative consequences. For instance, the design and dissemination of map products should be aligned to ensure a consistent understanding of flood

zones and relevant terminology. Similarly, land use regulations should be aligned among neighboring jurisdictions to contain potential negative spillover effects that could increase flood risk. Finally, consistency in flood risk communication messaging is another area where efforts could be aligned.

This alignment could be achieved in subtle ways, such as a shared or interoperable GIS system, or through more formalized efforts, such as a binational, impartial Transboundary Flood Network as proposed by the SPE-AG, which could facilitate information-sharing and knowledge transfer among the governments in the LCRR basin (ILCRRSB 2021).

## 5.2 ACHIEVING EFFECTIVE IMPLEMENTATION

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Implementation is perhaps the most complex and difficult part of an integrated FRM strategy because it requires coordinating the actions of numerous implementing agencies and pursuing multiple objectives in a changing social, economic and political landscape. The following are best practices for implementation drawn from published literature and professional practice.

### 5.2.1 Consult, engage and collaborate

Public consultation is important for understanding behavior regarding flood risk, informing citizens of the flood threat they face, and collecting local knowledge about flooding and its impacts. Involving the public in FRM decision-making can also increase individual responsibility and strengthen the social acceptability of policy choices. Municipal officials have a key role to play here, by tailoring flood risk information for local residents and communicating information in ways the public will understand.

The effectiveness of the FRM strategy can be enhanced through collaboration with stakeholders involved in floodplain management, who have knowledge, authority and resources to contribute to risk reduction. Collaboration increases the collective capacity to achieve objectives by harnessing a diverse range of knowledge and skills, and it increases the legitimacy of policy decisions because many organizations are consulted and support these choices.

As White Paper #3 points out, a network analysis revealed 172 organizations engaged in water management in the Quebec part of the LCRR basin alone. Among these organizations, 35 specifically identify flooding as a priority and 24 have a wide network of relationships with other organizations, indicating a strong capacity for collaboration. This collaboration can be organized and sustained through many different mechanisms, such as advisory committees, working groups, deliberative workshops, and interactive forums. Given the number of actors involved, however, effective implementation might require a more formalized body, such as the Transboundary Flood Network noted above.

### 5.2.2 Clarify and share responsibilities

Multiple societal actors are relevant to FRM, and coordination is necessary to clarify their roles and responsibilities to ensure that they support a common objective, rather than duplicating efforts or working at cross purposes, which can reduce the effectiveness of FRM. A core principle of FRM is that responsibility must be shared among stakeholders, including property owners themselves. A central concern is the appropriate division of responsibility for mitigating flood risk before an event and paying for recovery after a flood event.

Sharing responsibility for FRM is important, because it spreads the cost of risk reduction measures, ensures those who are protected by publicly funded flood controls pay their “fair share,” and creates an incentive for individuals and groups to take independent action to mitigate their flood risk and prepare for recovery after a flood. Distributing responsibility among a range of

stakeholders improves efficiency by lowering the burden on government spending, enhances legitimacy because a breadth of interests is represented, and strengthens effectiveness by creating multiple streams of policy implementation.

The process of formally distributing FRM responsibilities should be participatory and deliberative, to increase buy-in from stakeholders and the public. Moreover, there are several normative principles for the effective allocation of responsibility in governance arrangements that can be applied to FRM (Mostert 2015):

- actors should be assigned risk management responsibilities based on their capacity to carry them out.
- responsibilities should be allocated in ways that minimize social costs to society.
- those responsible for creating or exacerbating risk should bear some responsibility (e.g., local governments that allow development in flood-prone areas) and constituencies with an interest in managing the risk should also absorb some responsibility (e.g., property owners living in high-risk flood areas).
- the scope of assigned responsibilities should align with the scale of the risk (e.g., municipalities are responsible for urban flooding associated with their stormwater systems).
- responsibility should be assigned to actors with closest proximity to the risk and at the lowest level of a governance arrangement, assuming they have sufficient competency and capacity.
- actions that are closely related should be evaluated to determine if they can be managed by one actor or should be assigned to separate actors.

- allocation of responsibility should be transparent and clearly communicated to stakeholders.
- allocation of responsibilities should be stable and only shifted after careful consideration and emergence of new evidence.

Distributing responsibilities too widely can sometimes lead to confusion about accountability. Although there are many benefits to sharing FRM responsibilities, it must be acknowledged from the outset that governments are ultimately accountable for the costs and benefits of FRM.

### 5.2.3 Enable informed decisions

It is important that flood information is readily accessible to government (including decision makers, flood risk managers, land-use planners, and emergency managers), nongovernment entities (including infrastructure providers, insurers) and communities, to provide the basis for informed decisions on investing in floodplains and managing flood risk.

As laid out in White Paper #3, there are several decision support tools that can assist with selecting and prioritizing FRM measures to ensure they are effective, efficient, and resilient. Cost-benefit analysis, for instance, offers information on whether and to what extent the costs of an FRM measure exceed the costs of inaction, to assess the feasibility of the intervention. Multi-criteria analysis goes beyond economic considerations, weighing also social, political and environmental impacts to choose among multiple options. Furthermore, as explained in Section 7.0 below, the LCRR Study Board has produced multiple datasets and tools to compare and evaluate different measures to reduce flood hazards and vulnerability.

### 5.2.4 Monitor and evaluate outcomes

Given the complexity and uncertainty surrounding FRM, a flexible and adaptive approach is required to increase knowledge and refine actions over time. As the SPE-AG has explained, such an “adaptive management”

approach involves engaging stakeholders, modeling existing understanding and implementing actions, but also monitoring their effects and learning from them to improve outcomes through repeated iterations. Ideally, this approach would be achieved through initial pilot projects followed by monitoring and performance assessment; subsequent policies would then be implemented incrementally and designed with flexibility to allow them to be reversed in the event of negative consequences.

For instance, among LCRR residents surveyed by the SPE-AG, only about 6 percent in Quebec and about 10 percent in New York and Vermont perceived a very high or high likelihood that they would experience lake or river flooding at home in the next ten years, with slightly higher risk perception among those with flood experience (ILCRRSB 2021). This finding suggests that a flood risk communication pilot project could be initiated to test the effectiveness of different messages and transmission channels in increasing awareness of flood risk.



## 6 STUDY LEGACY PRODUCTS

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Since its inception in 2016, the Lake Champlain-Richelieu River Study Board has produced a wealth of data and several tools to support the implementation of an integrated FRM strategy for the LCRR basin. First, the Study has supported an enhanced flood forecasting system, developed by the US National Oceanic and Atmospheric Administration and the Quebec MELCC (Chiasson 2021b). The system, which includes an upgraded hydrologic model, a hydrodynamic model, and a wind wave model, will enable real-time forecasts to predict Lake Champlain levels and wave heights, and to predict water levels in the Richelieu River. The data produced by the LCRR flood forecasting system will be useful for regional and local emergency managers to plan for preparedness and response.

Second, the Study has adopted a sophisticated approach to account for the uncertainty around how climate change affects the hydrology of the basin. Based on the IJC's Climate Change Guidance Framework, the Study has incorporated a process of "decision scaling," which is designed to make the optimal and most efficient use of climate change projections to aid in prioritizing risks and choosing among adaptation options (Chiasson 2021a). The Study's final climate report will present the results of this decision scaling analysis, which will provide

an additional support for designing, evaluating, and refining an integrated FRM strategy for the basin.

Third, the Study's Integrated Social, Economic and Environmental (ISEE) modeling system offers a GIS-based flood risk evaluator tool with property-level granularity. Incorporating numerous spatial and temporal data—roads, building types, building values, elevation, and so on—ISEE can be used to estimate flood damages throughout the basin as water levels change and as different mitigation measures are adopted to decrease exposure and vulnerability. For instance, the ISEE system is being used by the Study Board to compare the economic costs and benefits associated with flood insurance versus disaster assistance programs.

Finally, the work of the Social, Political and Economic Technical Working Group (SPE-AG) offers a rich analysis of the LCRR basin as a complex social system and provides context for understanding the political feasibility and social acceptability of policy tools to reduce flood risk. This work has included mapping the institutional arrangements relevant to FRM across the basin, surveys of emergency managers, planners and the public, and social vulnerability analysis to identify areas of high susceptibility to flood impacts.

The SPE-AG integrated report (ILCRRSB 2021) offers a comprehensive set of recommendations that should be reviewed in its entirety, but several key points stand out for this report:

- 1 There is broad support for Theme 4 policy solutions among emergency managers and planners, recognizing that they must be implemented with sensitivity to local conditions.
- 2 Equity in the distribution of resources, benefits and costs associated with Theme 4 policy measures is a key concern, especially in how they might affect property values or complicate real estate transactions. Open dialogue and transparency with residents about the rationale for policy measures and their potential impacts will be critical to secure and maintain public legitimacy.
- 3 Flood resilience should be integrated as a policy priority into comprehensive plans, land use plans, regulations, zoning by-laws, and other instruments that guide local decision-making. Doing so will ensure the objective remains durable between flood events.
- 4 Theme 4 policy and planning actions should be implemented incrementally through pilot projects. These projects should be monitored and evaluated for their social, political, economic and ecological impacts before being “scaled up” to the basin as a whole.

Although these resources offer a valuable baseline for the development and implementation of an FRM strategy, they must be made accessible for users, accompanied by appropriate guidance, and supported through ongoing training for personnel.



## 7 CONCLUSION

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Reducing and managing flood risk in the LCRR basin requires an integrated strategy that targets (1) the flood hazard, (2) the exposure of people, property, infrastructure and economic activity in or near the flood hazard zone, and (3) the vulnerability of people and assets to harm from flooding. Several potential structural options to reduce the flood hazard have been identified, but an integrated strategy to mitigate flood exposure and vulnerability is also needed.

This paper has presented ideas for an integrated FRM strategy that were generated from Theme 4 research, including the four expert White Papers, the work of the SPE-AG, and other analysis conducted by the Flood Management and Mitigation Measures (FMMM) Technical Working Group. Specifically, it outlined three principles of FRM, explained four concrete policy tools to reduce exposure and vulnerability, discussed several considerations for effective implementation, and identified support resources produced by the LCRR Study. In combination, these elements should assist the governments acting in the LCRR basin to design and execute effective, coherent, and durable strategies for flood risk management.



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