WORK PLAN FOR

THE IDENTIFICATION OF MEASURES TO MITIGATE FLOODING AND THE IMPACTS OF FLOODING OF THE LAKE CHAMPLAIN AND RICHELIEU RIVER

Photos of the 2011 floods in Lake Champlain and Richelieu River, courtesy of the Lake Champlain Basin Program

Submitted by the
International Lake Champlain and Richelieu River Study Board
to the International Joint Commission

October 2, 2017

Executive summary

The record setting floods of 2011 in the Lake Champlain Vermont/New York basin in the United States. (US) and the Richelieu River in the province of Quebec, Canada, prompted the U.S. and Canadian governments to work together to identify how flood forecasting, preparedness and mitigation could be improved in the Lake Champlain-Richelieu River (LCRR) basin. In July 2013, the International Joint Commission (IJC) submitted the LCRR Plan of Study (PoS) to the Governments of Canada and the United States. The 2013 PoS outlined the work required in the LCRR basin in order to explore potential floodplain management solutions, identify a new flood forecasting system for the LCRR basin, and to provide a range of structural and non-structural flood prevention and mitigation measures. In 2015, the IJC LCRR Technical Work Group completed some initial tasks identified in the PoS. In 2016, the U.S. and Canadian governments decided to pursue Option B as described in the PoS to more fully explore the causes, impacts, risks, and solutions to flooding in the Lake Champlain-Richelieu River basin; this decision led to a reference to the IJC to conduct Option B activities, and for the IJC to create the International LCRR Study Board to oversee and conduct studies and work related to Option B. This Work Plan describes these activities, the time line of these activities and their costs.

The LCRR Study Board was created in 2017 and is comprised of an equal number of members from the U.S. and Canada. In addition, a full study governance structure was developed which includes study co-chairs, technical work advisory groups, public outreach and communications groups, study co-managers, and information technology and management support. The Study Board is responsible for overseeing and managing the study and ensuring that the government mandates are met.

The work outlined in Option B of the 2013 PoS and the associated 2016 governments' references to perform the work include seven objectives:

1. Evaluating the causes and impacts of past floods, especially the event of 2011.
2. Assessing the possibilities offered by the floodplain best management practices.
3. Evaluating possible adaptation strategies to the expected future variability in the water supplies.
4. Developing and making recommendations for implementing, as appropriate, an operational, real-time flood forecasting and flood inundation mapping system for the Lake Champlain-Richelieu River watershed.
5. Conducting an in-depth study of current social and political perception on structural and other mitigation measures to support and confirm the desirability of potential structural mitigation solutions.
6. Performing a quantitative and qualitative assessment of potential flood management and mitigation measures (non-structural and/or moderate structural works) and their impacts on important resources of the system: the wetland and fauna, recreational, domestic, industrial and municipal uses of water, shoreline and floodplain built environment and agriculture.
7. Developing resource response models that include basic indicators for water resources response to water levels fluctuations, with special attention on the data inventory and identification of thresholds. Climatic projections, wind wave and ice models, additional new data for the evolution of watershed physiographic characteristics over time and a complete digital terrain model will be produced to

allow the planning, evaluation and ranking of potential flood mitigation solutions, using a shared-vision approach.

The study will be 5 years in length and costs approximately $7 million Can and $5.5 million US.

The seven major objectives of the study require a multi-disciplinary, binational and interactive strategy to complete the goals of this study. This strategy is emphasized in the structure and governance developed for the study. A unique feature of this study is the emphasis placed on understanding social, political and economic drivers associated with flood mitigation and forecasting.

The development of new **hydraulic models** and **flood forecasting tools and systems** for forecasting water levels in Lake Champlain (LC) and Richelieu River (RR) is an integral product proposed in the study. These new models will be 2- and 3- dimensional (2D and 3D) in nature and will be integrated so they perform in a seamless manner. The models, in addition to recommended operational forecasting, will be used to evaluate potential flood management and mitigation measures, and evaluate how varying water levels influence response performance indicators (PIs) in the system. These PIs could include critical aquatic habitat or species, recreational uses, water intake and discharge points, economic values, and social perceptions.

A broad **social, political and economic analysis of flood management** will be evaluated in this study. Studies on social, political and economic values – whether actual or perceived – will be conducted so that final options and solutions will receive the broadest public support for implementation. Frequent interactions with various sectors of society and feedback and input from them will be gathered as part of the social, political and economic analysis.

An **analysis of various non-structural and structural flood mitigation measures** will be undertaken in the study. A review of existing practices, mitigation methods and structures will be performed. This review will focus both locally in the LCRR basin and what is reported in the existing literature. In addition, the effectiveness of these various measures in managing water levels will be tested with the new hydraulic and hydrologic models being developed, so that actual LCRR responses can be determined and evaluated.

The study is likely to produce recommendations for the implementation of not one, but a set of mitigation measures.

The hydraulic and hydrologic models will also be used to evaluate various water management scenarios using the response of important **physical, ecological and societal resource PIs**. These PIs will be identified in the study, computed on the basis of how they would have been impacted or reacted during the 2011 and past floods, and then compared with their response under the different flood mitigation measures considered. This will ensure that the ecological and societal concerns are taken into account when deciding on management options for flooding.

Collectively these activities will lead to **collaborative decision support tools** in the LCRR basin which will address flooding and flooding impacts. All of the important ecological, societal, and hydrologic information will be integrated into these tools so managers can make the best determinations of the appropriate actions to take.

The LCRR study will rely on strong and on-going communications and an effective public outreach. Throughout the entire study, resources will be devoted to sharing the work plans, new information and data, and possible ways to move forward, with communities in the basin, stakeholders and public officials.

During the course of the study, the Study Board will produce several reports, products and tools that will be made available for the benefit of basin communities and stakeholders. In 2021, the Board will deliver its final report to the International Joint Commission. The report will contain recommendations for structural and non-structural flood mitigation measures and an operational flood forecasting and mapping system. The recommendations will be thoroughly described and prioritized. Because the Study Board will have sought and considered stakeholders views on the acceptability and feasibility of the proposed measures, the expectation is that the measures will be viable and have the needed public and political support for implementation by the governments.

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1 Preamble

This International Lake Champlain and Richelieu River (LCRR) Study Work Plan, dated October 2, 2017, is respectfully submitted by the International Lake Champlain and Richelieu River Study Board to the International Joint Commission (IJC) who will in turn submit it to the Canadian and United States governments in response to the September 16 and 22, 2016 References by governments to the IJC.

This Work Plan under went public consultations in the summer 2017, in Canada and the United States, as well as an Independent Review by experts. This version of the final Work Plan reflects these inputs. The Work Plan will be reviewed on a regular basis and modified as needed to take into account the study's progress.

2 Acknowledgements

This Work Plan could not have been developed without the assistance of the members of the Study's Analysis Group and Technical Work Groups (AG and TWGs), the Public Advisory Group (PAG), the Study Managers and members of the Study Board. These individuals, appointed by the Study Board or the IJC, are listed in ***Annex 1***.

The members of the Study Board were appointed by the IJC to provide the expertise needed to orient and direct this study. Although most are employed by government agencies in both countries, all serve the IJC in their personal and professional capacities and not as representatives of their agencies, countries or organizations. The scope of work presented in this Work Plan were developed by the members of the AG, TWGs and PAG, and adopted by the Study Board and should not be considered as official opinions, positions, or commitments of any organizations, agencies or departments named in this report.

The Study Board also acknowledges the input from many members of the public and other organizations provided by the public review period. Their interests and feedback have helped to solidify the activities presented in this work plan.

3 Introduction to the International Lake Champlain Richelieu River Study

3.1 Flooding of 2011

The Lake Champlain and Richelieu River basin (LCRR) (figure 3.1) experienced historically high flood levels in late April and May of 2011. Lake Champlain was above the U.S. National Weather Service (NWS) flood stage of 100 feet National Geodetic Vertical Datum of 1929 (NGVD1929) for a 68-day period that spanned from April 13 to June 19, 2011(Kiah et al., 2013).

Flood damages incurred as a result of the 2011 flood events had a severe impact on area residents (table 3.1), commercial enterprises, and governments at all levels within the affected region. Throughout the entire LCRR basin, about 4,000 homes were damaged, about $90M (in 2011 US and Canadian currency) in damages incurred and more than 40 municipalities were directly affected. 79% of the economic damages were recorded in Quebec (QC), 10% in Vermont (VT), and 11% in New York (NY). Impacts estimates for the U.S. were obtained from the Federal Emergency Management Agency (FEMA) for the U.S. and from the Ministère de la Sécurité Publique (MSP) for Québec (International Joint Commission, 2013). The flood damages were due to a combination of flood inundation, wind-driven waves, and shoreline erosion.

Table 3.1 Impact estimates from the 2011 Lake Champlain and Richelieu River Flood

Impact Estimates from 2011 Flood Event (as of January 2013)			
	VT	**NY**	**QC**
# People Evacuated	75 *(+426 from associated flash floods in tributaries)*	124	1 651
# Houses Affected	500	929	2375
# Municipalities Affected	8	5	27
Individual Claims	800	900	3000
Estimated Damages Reported	8 600 000	9 900 000	72 000 000

Note: Estimated damages are expressed in 2011 US and Canadian currencies.

Governments subsequently directed resources to mitigate damages, alleviate suffering and reconstruct the flood-affected areas. Scientists and engineers worked together to assess the degree of impact the flooding had on the region (environmental, financial, tourism, and recreation). Residents and governments continue to express the need for improved flood forecasting and to evaluate proper and relevant flood mitigation measures so that future flooding and subsequent flood damages can be minimized. (Castle et al., 2013)

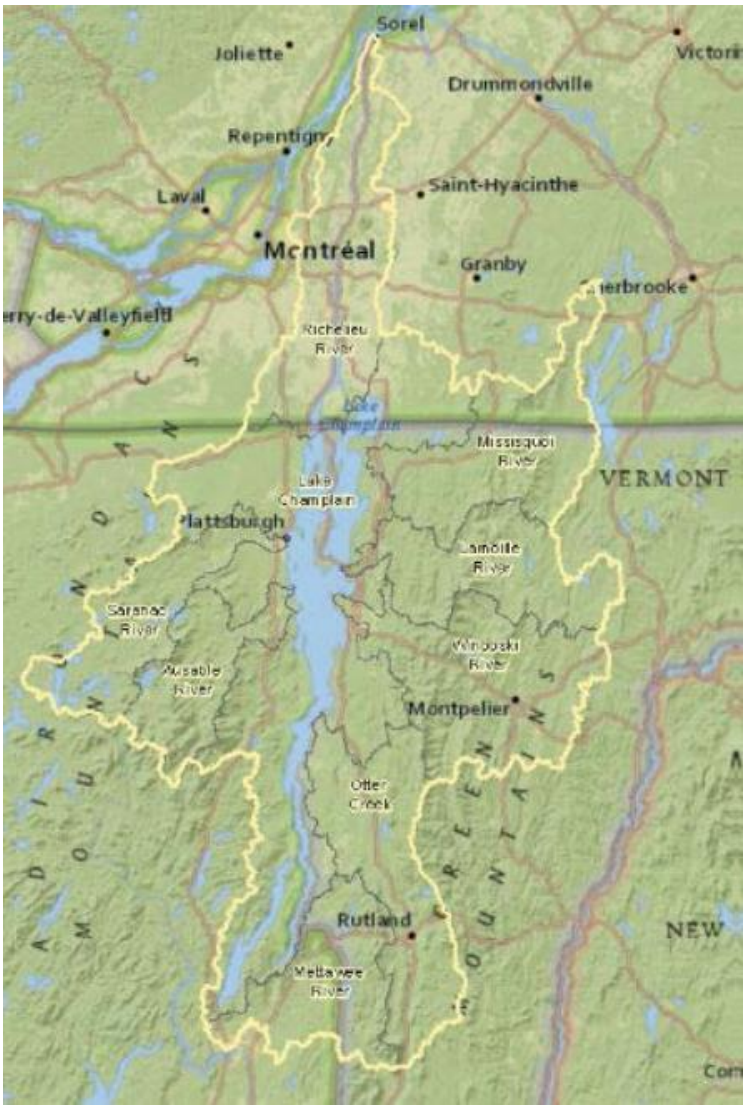

Figure 3.1 Lake Champlain-Richelieu River Basin

Over 100 years of water level and river discharge data have been collected in the study area with lake levels recorded at the United States Geological Survey (USGS) Lake Champlain at Burlington, VT lake gage 04294500 from 1907 to present and at the USGS Richelieu River (Lake Champlain) at Rouses Point, NY lake gage 04295000 from 1871 to present. Flows (discharge) have been recorded at Saint-Jean-sur-Richelieu, Qc, Canada stream gage 02OJ016 from 1972 to present.

Four major high water events of the 1900s are highlighted in Figure 3.2 while Figure 3.3 shows the impacts of the lake flows on the lake levels, with the highest lake levels recorded on May 6, 2011. The USGS reported that the lake level of 103.2 feet (31.5 m) NGVD29 at the USGS Richelieu River (Lake Champlain) at Rouses Point, NY gage 04295000 exceeded its previous record flood level of 102.1 feet (31.1 meters) (NGVD29) set in 1869. On the Canadian side, a maximal water level of 30.705 m (100.76 feet) was measured in St-Jean-sur-Richelieu by the

Geological Survey of Canada (GSC) on May 23, 2011. The previous maximal water level, measured in St-Jean-sur-Richelieu, was 30.368 m (99.64 feet) in 1993.

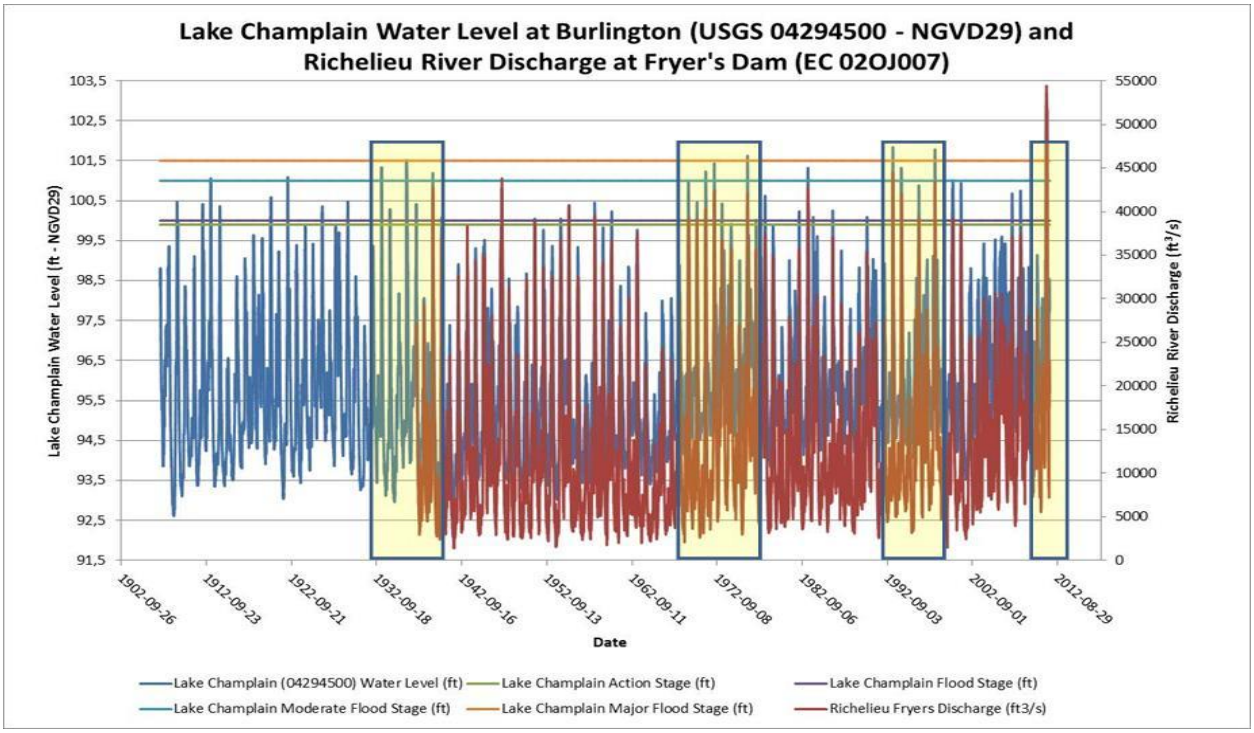

Figure 3.2 Historical Variation of Lake Champlain Water Levels and Richelieu River Discharge

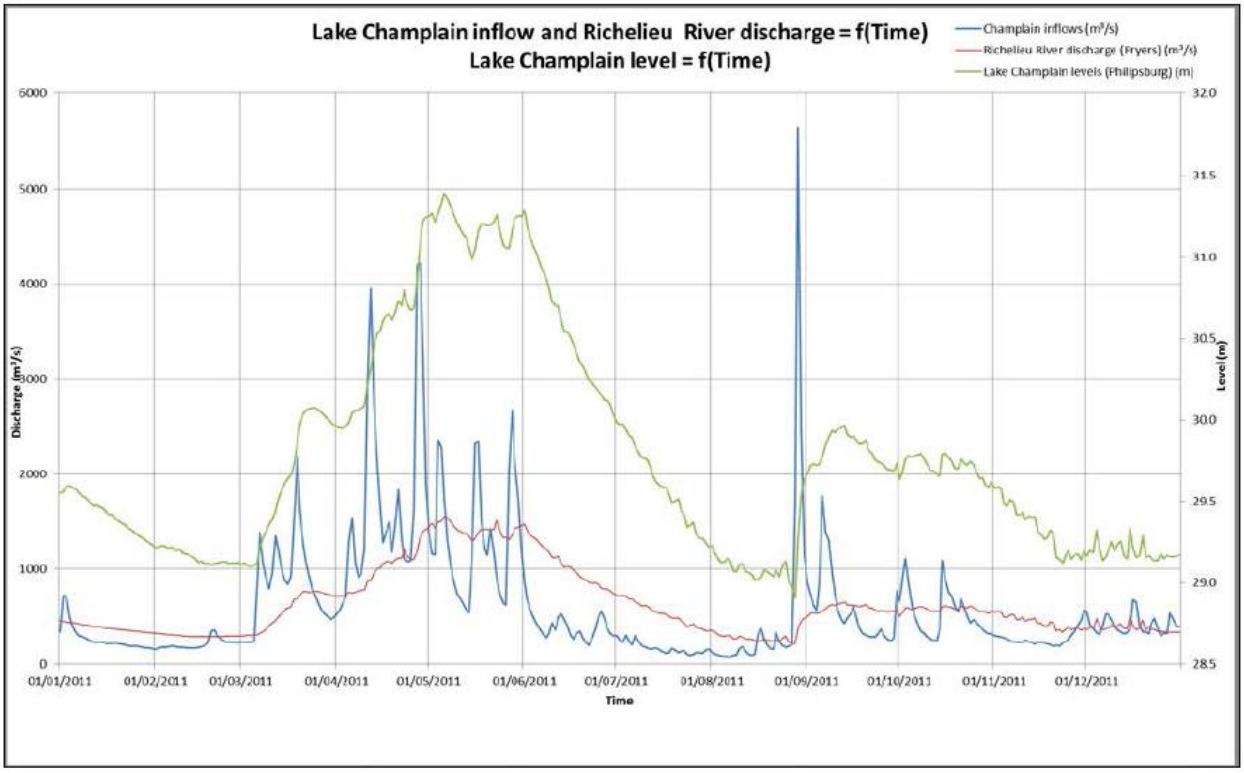

Figure 3.3 Influence of flows entering Lake Champlain on lake and river levels in 2011

3.2 Scope of Study: the governments' joint reference

In response to flooding in 2011, the Governments of Canada and the United States requested that the IJC review and make recommendations which include a comprehensive study of measures to mitigate flooding and the impacts of flooding in the LCRR basin. To answer this request, the IJC established in May 2012 the International LCRR Study Board and tasked with responding to the governments' request through a Plan of Study (PoS).

In July 2013, the IJC submitted the LCRR PoS to the Governments of Canada and the United States. The 2013 PoS: "The Identification of Measures to Mitigate Flooding and the Impacts of Flooding of Lake Champlain and the Richelieu River" (International Joint Commission, 2013), outlined the work required in the LCRR basin in order to explore potential floodplain management solutions and to provide a range of structural and non-structural flood prevention and mitigation measures.

In July 2014, the Governments provided the IJC with a joint reference, under Article IX of the Boundary Waters Treaty of 1909 to complete portions of the 2013 PoS. The IJC issued its final report to governments in accordance with this reference in December 2015 (International Joint Commission, 2015). This report describes the results of the initial 2-dimensional modeling of the upper Richelieu River and Lake Champlain, initial flood inundation maps for portions of the Lake Champlain shoreline and the Upper Richelieu River, results of corrected datum for critical water measuring locations and a pragmatic approach for future flood forecasting.

In September 2016, the Canadian and United States Governments followed up on the 2013 PoS and the July 2014 reference by providing the IJC with letters requesting a further reference on September 16 and 22, 2016 (http://ijc.org/en_/LCRR/Reference), to "complete the work outlined in Option B of the 2013 PoS to more fully explore the causes, impacts, risks, and solutions to flooding in the LCRR basin. The International LCRR Study Board has been created under the IJC Directive to the International Lake Champlain – Richelieu River Study Board (http://ijc.org/en_/LCRR/directive) to aid in fulfilling the terms of the 2016 joint reference.

The work outlined in Option B of the 2013 PoS and the associated 2016 references include seven elements listed below that characterize the present study.

1. Evaluating the causes and impacts of past floods, in particular the event of 2011.
2. Assessing the possibilities offered by floodplain best management practices.
3. Evaluating possible adaptation strategies to the expected future variability in the water supplies.
4. Developing and making recommendations for implementing, as appropriate, an operational, real-time flood forecasting and flood inundation mapping system for the Lake Champlain-Richelieu River watershed.
5. Conducting an in-depth study of current social and political perception on structural and other mitigation measures to support and confirm the desirability of potential structural mitigation solutions.
6. Performing a quantitative and qualitative assessment of potential flood management and mitigation measures (non-structural and/or moderate structural works) and their impacts on important resources of the system: the wetland and fauna, recreational, domestic, industrial and municipal uses of water, shoreline and floodplain built environment and agriculture.
7. Developing resource response models that include basic indicators for water resources response to water levels fluctuations, with special attention on the data inventory and identification of thresholds. Climatic projections, wind wave and ice models, additional new data for the evolution of watershed physiographic characteristics over time and a complete digital terrain model should also be produced to allow the planning, evaluation and ranking of potential flood mitigation solutions, using a shared-vision approach.

This Work Plan presents approaches, goals and activities needed to complete the tasks identified in Option B of the 2013 PoS. This Work Plan will be updated on an annual basis to reflect progress, results of completed work and the development of the latest science and techniques that may be developed as a result of the study.

Abrief history of the IJC activities in the LCRR basin can be found at: http://ijc.maps.arcgis.com/apps/MapJournal/index.html?appid=369677f6abbf4d82b34bc7c744cb3c26. In particular, the 1973 IJC study and the resulting deferral of further studies and mitigation measures underscores the need for the present study to include an assessment of the likelihood of implementation of recommendations that will result from this study.

The geographical scope of the study area addressed in this study is the entire LCRR basin with the downstream limit controlled by the influences of the Saint Lawrence River regime. Study tasks will focus primarily on the Lake and River and their adjoining shorelines and flood areas.

4 Organization of the study – Governance Structure

The detailed description of the study's governance structure is provided in ***Annex 1*** and summarized below.

- **Study Board**: The Study Board is responsible for providing oversight to study activities and ensuring that study activities will meet the goals of the references and directives of the IJC's International LCRR Study. The IJC has appointed an equal number of members from Canada and the United States to the Study Board and named a member from both Canada and the United States to be the Co-chairs of the Study Board. The Co-chairs are jointly taking a leadership role in planning and implementing the Study Board's mandate. On behalf of the Board, the Co-chairs have authority and responsibility for the study.
- **Study Managers**: Two study managers, one from Canada and one from the United States, are responsible for the effective management of the study as overseen by the Study Board. The Study Managers will keep fully abreast of the work of the different groups and function as liaisons between the Study Board and those groups. The Study Managers will facilitate and support the collaborations and the relationship among partner and government organizations associated with the study. The Study Managers are responsible for communicating to the different groups the direction of the Study Board and assisting in general administrative and financial/contractual tasks, including providing briefings to the Study Board on tasks identified by the Co-chairs.
- **Public Advisory Group (PAG):** PAG Members are appointed by the IJC after consultation with the Study Board. The two PAG Co-Chairs, one from Canada and one from the United States, will direct the PAG as well as serve on the Study Board. The PAG is an advisory group and an important means of engaging the public in the study on an ongoing basis.
- **Communication Working Group (WG):** This working group will provide study support. guidance, direction and a timely review of key Study Board communication activities and products (such as news releases), will assist in the development of communication plans and outreach products (such booklets, web content), and will ensure coordination of activities and continuity of communications across the Study groups. It will bring together various individuals from IJC staff involved in communications, the PAG, the technical work and analysis groups as well as watershed organizations.
- **Independent Review Group (IRG)**: The IRG has been established by the IJC to ensure that independent technical reviews are carried out as required during the Study process.
- **Information Management function:** An Information Management/Information Technology (IM/IT) Support Group, under the Study Managers' supervision, will consolidate pertinent data and information needs. The IM/IT group will develop data acquisition plans, organise and oversee data acquisitions, and make available all data produced by the study.
- **Technical Working Groups (TWGs) and Analysis Group (AG)** are responsible for the planning and the implementation of the seven activities outlined in the reference. Members working groups will be appointed by the Study Board. Each TWG or AG are composed of two Co-Leads, one from Canada and one from the United States. The Study Board will strive to have an equal number of U.S. and Canadian members on each group.
    - ***TWG or AG Co-Leads***: With the guidance from the Study Board Co-Chairs, Study Managers and in collaboration with other TWG or AG members, the Co-Leads are responsible for the development of work plans for their respective TWG or AG,

including projection of resources requirements, and for the execution of the work plans, in accordance with the timetable and budgetary constraints set by the Study Board.

- ***TWG or AG members***: are responsible for the execution of projects and are invited to provide advice or critical input for the successful delivery of the Work Plan.

The different tasks identified in the 2013 PoS can be separated amongst three TWGs and one AG:

- A Social, Political, Economic (SPE) AG,
- An Hydrology, Hydraulics and Mapping (HHM) TWG,
- A Flood Management and Mitigation Measures (FMMM) TWG and
- A Resource Response (RR) TWG.

The resulting LCRR Study governance structure is shown on figure 4.1.

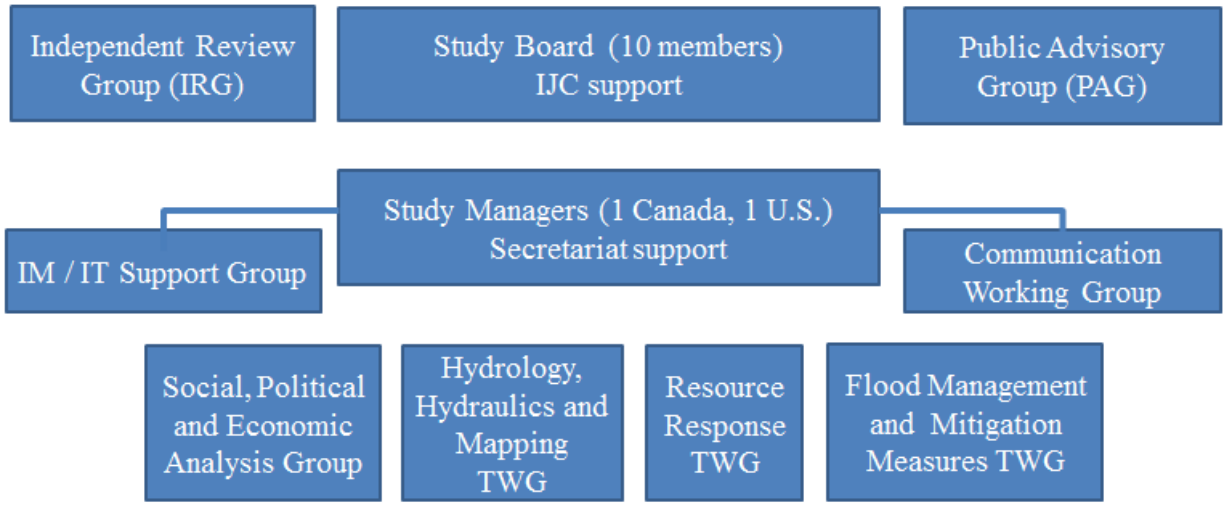

Figure 4.1 LCRR Study Governance Structure

5 Plan to achieve the objectives of the study

Each element of the Governments joint reference will be addressed by identifying data requirements, updating needed data, and refining and combining scientific concepts, models and tools to generate new knowledge. Throughout the study, public opinions, Government agencies and stakeholder perspectives will be sought to foster communication and participation at all levels on both sides of the border.

Study objectives will be completed by experts assigned to the TWGs/AG. These groups will combine their respective strengths to execute tasks and report on each study objective. The technical and analysis groups will also interact with the public to receive input on public/stakeholder perceptions and needs. These interactions will include PAG and Communication WG associated with the study so that the final major recommendations from the study for flood mitigation and forecasting have the greatest opportunities to succeed (figure 5.1)

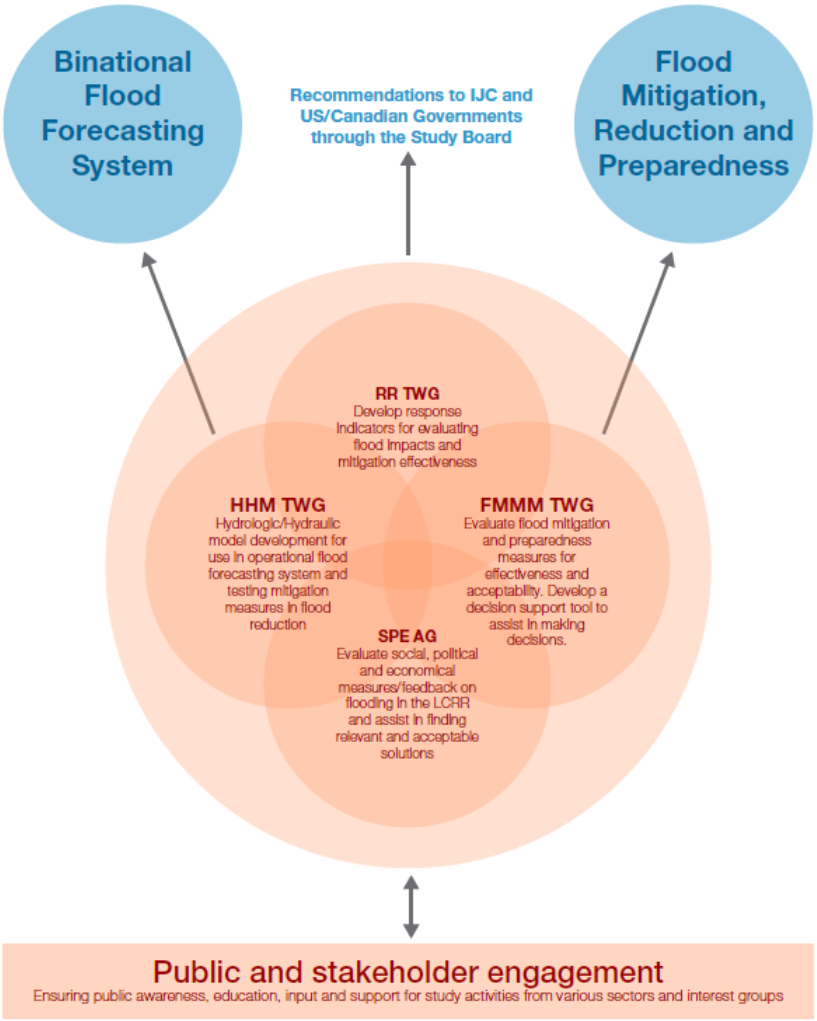

Figure 5.1 Schematic of Basic Work Flow Processes to achieve the 2 Major Products of the Study

The Study's priorities and activities have also been shaped by input from the public meetings and written comments during the summer of 2017. In the U.S., especially in Vermont, public input strongly stressed the value of using natural flood plain and river processes to help store high-flows on the landscape and to slow down the delivery of water to Lake Champlain. In Canada, the need to decrease water input to the river during floods, to store and slow down water on the land and in buffer zones and to give space to the river were also mentioned. Comments received in Canada often mentioned the need to look at methods to improve timely conveyance of high flows and flood waters downstream in the Richelieu River and to remove impediments to flow so that flood impacts could be minimized. On both sides of the border, the public expressed concerns about the quantity and quality of wetlands, water quality issues, the protection of shorelines and flood plains, bank erosion and sedimentation as well as property loss and the protection of homes. A summary of major comments received during the public review period will be available at IJC website shortly.

Based on these public inputs, and striving to optimize resources and not duplicate work, study work in the United States will take leadership in developing and assessing flood mitigations measures that are slowing the release of flood waters from Lake Champlain tributaries to the Lake, while study work in Canada will take leadership in developing and assessing flood mitigation measures that could improve the conveyance of flood waters downstream in the Richelieu River. Common approaches for assessment, model and data use, and other tools, will be practiced in both nations so others can replicate, enhance and/or apply methodologies for their own needs. Strategies to address those areas of leadership will be discussed binationally to ensure mutual agreement on the scientific principles and methodologies to be utilized. Other mitigation measures such as preventing shoreline loss will be addressed in both the US for Lake Champlain and Canada for the Richelieu River.

Early in the study, the modeling work will provide a thorough understanding of how Lake Champlain and the Richelieu River respond hydrologically and hydraulically to climatic forcing. The ensemble of modeling work, tools and knowledge-based assessments are the building blocks of the study and will be integral in addressing the Governments' joint reference. This understanding will support an analysis of the causes and impacts of large floods in Lake Champlain and the Richelieu River and assist in documenting best practices and possible adaptation strategies and allow for the simulation of structural and non-structural flood mitigation measures. Recommendations for a state-of-the-art flood prediction and real-time flood plain mapping system will be developed and submitted to the governments by the Study Board.

An in-depth study of current social and political perceptions on structural and other mitigation measures will be undertaken. It will be include the development of economic and environmental PIs integrated in a collaborative decision support tool (CDST). This will help in assessing and communicating the relative value of flood mitigation measures. The aim of this task is to converge toward technically and economically feasible measures, that are also socially and politically acceptable.

The public is and will remain involved at strategic milestones of this study, notably through the efforts of the PAG, to obtain input and to register concerns regarding flooding and potential management and mitigation measures.

Information management and technology will be required throughout the study and adapted to achieve its different goals to support the different TWGs and AG in accomplishing their objectives and to enable the communication of study findings and recommendations.

The study work plan was submitted to an IRG for third party review. The IRG will also be called upon to assess the quality of key developments and publications throughout the study and to ensure scientific soundness. Major comments from the IRG and responses will be provided at IJC website in the near future.

The following sections provide information on each of the study objectives. Each objective will state which Reference item it addresses, provide a description of the study objective, identify the lead and responsible TWG and describe the scope of work under the objective. The scope of work entails a description of work tasks, which TWG will be performing that task, an estimated budget and timeline for completion. Each task is numbered and can be cross referenced in the summary table for that objective.

Throughout this section budget tables are provided. Canadian budgets are expressed in Canadian dollars and according to the financial year for the Canadian federal government (April 1 to March 31), while the U.S. budgets are expressed in U.S. dollars and according to the U.S. financial year (October 1 to September 30). In these tables, each column represents a financial year where, for example, "YR1 17-18" is representing the 2017-2018 financial year for Canada (top table) as it corresponds to financial (Fiscal) Year 18 (FY18) for the U.S. (bottom table).

5.1 Numerical modeling of the LCRR to support evaluation of proposed flood mitigation measures

This objective consists of the development of hydrologic and hydrodynamic models of the Lake Champlain and the Richelieu River that will be used to analyze and evaluate the capacity of proposed flood mitigation measures and their potential impacts on Lake Champlain and the Richelieu River. These models will support other study activities such as retrospective analysis of the 2011 flood event, the historical Net Basin Supply (NBS), described in section 5.2, extreme hydroclimate scenarios, the collaborative decision support tool and the flood forecasting and real-time mapping system

Lead: HHM TWG

Scope of Work:

Task HHM1: Hydrometeorological & other ancillary data collection: This task involves the collection of hydrometeorological data and the creation of a data catalog for flood modeling and analysis in the basin: This includes the development of a digital elevation model (DEM) in the basin (including collection of new topographic and bathymetric data to fill gaps or update older data), gridded datasets for model input (such as land use/cover and vegetation), and collection of meteorological and hydrologic datasets for model calibration and validation. Calibration and validation of the model will include the deployment of meteorological stations, water level stations, and wave buoys. Specific work tasks include:

- Collection and development of a database structure of all historical meteorological. streamflow and water level gage data over the basin. This data will be needed for operating and calibrating the various river and lake models to be developed for this study.

This will build upon on earlier data collection efforts, be initiated in October 2017 and conducted throughout the study as new data is available. A central database of all these data will also be created. The requirements for hydrometeorological data from study members will be performed.

- Collection of new river and lake data. A variety of new data collection activities are planned; these include:
  - Bathymetric survey of the Richelieu River downstream of Fryers rapids to the St. Lawrence River.
  - Ice data collection and synthetized map of thickness and distribution in the Richelieu River. Create maps of average ice growth and distribution, for implementation in the 2D hydrodynamic model.
  - Creation of synthetic maps of the aquatic vegetation in the Richelieu River for calibration and validation of the 2D hydrodynamic model and equivalent Manning's friction coefficient.
  - Conduct survey of water levels and currents in the Richelieu River using ADCPs and water stage data collection.
  - Support continued operation of three weather stations on Lake Champlain - Burton, Diamond, Colchester Reef - and expand to 1 additional location - Isle la Motte. This will provide real-time weather data delivery across Lake Champlain for a 2 year period, 2018-20.
  - Install two to three streamflow gages to cover areas of unknown inflow to Lake Champlain for a 3-year period, 2018-20.
  - Establish 2 wave buoys with meteorological stations in Lake Champlain and its Inland Sea and operate for the period.
  - Perform water level data collection at the Malletts Bay causeway for a 1 year period starting in 2018.
  - Observe LC temperature profiles by installing thermistor strings for use in 3D model temperature validation for a 2-year period starting in 2018.
  - Conduct hydrographic survey and process data around critical Lake Champlain causeways to inform modeling of lake circulation and flooding; to be done in 2018. This will build upon previous studies characterizing the hydraulics around structures in Lake Champlain.
- Completion of a seamless DEM set (Lidar and bathymetry) with Canadian and US data for the entire LCRR basin. A seamless DEM having a 10 m grid for the entire basin (3/2018) – will evolve and expand over the duration of the study with the new incoming bathymetric and topometric data from other tasks (03/2018 and beyond for updated versions).
- Establish the return interval period flow and lake level statistics for different flooding events using existing discharge/lake level data series available the basin. Recurrence interval estimations for the 2011 Lake Champlain flood levels are provided by Olson and Bent in their 2013 report (Olson and Bent, 2013)

Task HHM2: Hydrological & meteorological modeling: For this task, both U.S. and Canadian distributed hydrologic models will be calibrated to recently acquired data and will include a five year historical time series that includes the 2011 flooding event. These models will be used to calibrate inflows to the lake for forecasting as well as analysis of the impact of the 2011 floods. The hydrologic models will be driven by high resolution meteorological model output. The

distributed hydrologic models will incorporate land use characteristics and hydraulic stream routing in order to model hydrologic flow through the basin and into Lake Champlain and Richelieu River.

Specific work tasks include:

- High-resolution wind simulations during seiche events for Lake Champlain and Richelieu River. This will consist of high resolution models for the 2011 flood event and other events at a resolution of 2.5 km or 250m (HRDPS or finer). Hourly wind and precipitation forecasts for 30 one-day events of interest will be produced in 2018.
- Winds bias correction of RDPS with higher resolution winds (HRDPS or finer). Statistical models for downscaling wind forecasts. Will use near-surface wind forecasts to build a statistical downscaling method that will be used in hydrodynamic models with low-resolution wind fields on Lake Champlain and the Richelieu River basin. Downscaling methodology and Python code will be prepared.
- Development of Watroute hydrological model over the LCRR basin. This hydrological model configuration is designed for calibration, validation and simulation of scenarios (MESH platform) and hydrological model configuration designed for operational forecasting (GEM-Hydro platform).
- Calibration and validation of WATROUTE model. Includes Obtain optimal parameter development for SVS and WATROUTE models that maximize the quality of stream flow simulation for each tributary of Lake Champlain and the Richelieu River, while providing realistic simulations of snow cover.
- Hydrological model development and application to determine water supplies for Lake Champlain. Distributed hydrologic models will be calibrated and used to create a 5-year historical time series of inflows to LC, including 2011, and for use in generating net basin supply statistics (NBS).

Task HHM3: 2D Hydrodynamic model development (flood mitigation analysis model): This task comprises the development of a 2D high resolution, unstructured hydrodynamic model with a grid reaching down to 10 m spacing or less to simulate water levels in the basin as driven by hydrologic inflows and wind data. This high resolution model, based on the existing H2D2 model developed by ECCC, will be used to analyze flood levels that flow from Lake Champlain into the Richelieu River and the impact flood mitigation measures have upon water levels and their impacts. Based upon the new data catalog previously established, a modeling suite will be developed that covers the lake and upper river as well as a lower river model set-up. The modeling system will incorporate structures that impact flooding on Lake Champlain and the Richelieu River, including causeways, culverts, dikes, and drains. These models will be calibrated with historical data and used to recreate the 2011 event time series. The modeling system will then be used to analyze the LCRR basin under the effect of proposed flood mitigation solutions. This task includes the development of the hydraulic baseline condition representing the 2017 hydraulics of the LCRR. This task will include the production of updated flood plain delineations and mapping based on the flood levels as analyzed in the HHM1 task.

Specific work tasks include:

- Develop 2D unstructured hydrodynamic model for Lake Champlain and from Rouses-Point to Chambly Rapids.

- Develop 2D unstructured hydrodynamic model of the Richelieu River from Chambly basin to St-Lawrence River.
- Calibration and validation of the wind seiche for 2D hydrodynamic models, done in 2018.
- Definition and simulation of static hydrodynamic scenarios for use in flood mitigation solution analyses and for creating updated static flood inundation maps.

Task HHM4: Development of extreme hydroclimate scenarios: This entails the development a suite of hydroclimate scenarios that result in extreme conditions in the system, including increased flood levels and worsened drought conditions. A coarse scale hydroclimate model will be driven by global and regional climate modeling methods and will be analyzed to produce scenarios which will generate daily records of net basin supply (NBS), or total inflows, to the lake for extreme hydroclimate conditions in the LCRR basin. These scenarios will be used to analyze flood mitigation solutions and the response of the ecosystem to these measures. This work will also provide information necessary for evaluating possible adaptation strategies to the expected future variability in the water supplies/water quantity in the LCRR basin.

- Hydroclimatology of the LCRR basin and Climate change scenario analysis (production of scenarios) using hydrodynamic models. Scenarios of extremes in NBS caused by various hydroclimate scenarios, Model output will be delivered and updated several time during the study.

Budget and timeline are reflected in table 5.1 for Canada and the U.S.

Table 5.1 Timeline and budget estimates for numerical modelling of the LCRR system in the context of past and future flooding events

Numerical modeling of the LCRR system - Canadian Budget (Can K$)							
Id	**Tasks**	**YR1**	**YR2**	**YR3**	**YR4**	**YR5**	**TOTAL**
		17-18	**18-19**	**19-20**	**20-21**	**21-22**	**CA k$**
HHM1	Hydrometeorological & basic modelling & data collection	145	50	0	0	0	**195**
HHM2	Hydrology & meterology modeling	70	145	155	0	0	**370**
HHM3	2D hydrodynamic (flood mitigation) model development	20	95	135	30	0	**280**
HHM4	Hydroclimatology scenarios	45	40	40	40	0	**165**
TOTAL		**280**	**330**	**330**	**70**	**0**	**1010**

Numerical modeling of the LCRR system - US Budget (US K$)							
Id	**Tasks**	**YR1**	**YR2**	**YR3**	**YR4**	**YR5**	**TOTAL**
		17-18	**18-19**	**19-20**	**20-21**	**21-22**	**U.S. k$**
HHM1	Hydrometeorological & basic modelling & data collection	370	70	0	0	0	**440**
HHM2	Hydrology & meterology modeling	50	50	0	0	0	**100**
HHM3	2D hydrodynamic (flood mitigation) model development	60	120	60	0	0	**240**
HHM4	Hydroclimatology scenarios	25	25	0	0	0	**50**
TOTAL		**505**	**265**	**60**	**0**	**0**	**830**

5.2 Evaluating the causes and impacts of past floods, especially the event of 2011

This study objective directly addresses the Governments' Reference item 1: *Evaluating the causes and impacts of past floods, especially the event of 2011*.

While the RR TWG will lead the effort, this objective will draw heavily on the analysis of the 2011 flood event produced by the HHM TWG, and on the work from the SPE AG to document flooding impacts from the social, political and economic perspectives (see below), including water use, land use, and related policies and practices amongst other topics.

The resulting report will describe the basin conditions that led to the 2011 event, the physical processes that took place, and the ensuing wide ranging consequences of the flooding. This will include a description of the historical Net Basin Supply (NBS). The report will also pay attention to the relationship between basin communities and their environment in the context of flooding and include recognized benefits of flooding for the natural environment, together with shorelines and floodplains in areas where the environment has undergone extensive human alterations.

Contextual narratives will be incorporated into this report to foreshadow the use of Performance Indicators (PIs), including case studies of agricultural impacts, structural damages (stage-damage curves), environmental consequences, and recreational use changes as well as descriptions of community responses to the 2011 flooding. For example, see resources produced by the US Environmental Protection Agency supporting and documenting smart growth implementation in Vermont (US EPA 2014 a, b).

Lead: RR TWG

Scope of work:

Task HHM5: Hydrometeorological analysis of past floods: This will be an analysis of the causes and impacts of past floods, especially the event of 2011: The analysis of hydrological conditions and factors will be done to describe natural flood vulnerability in the basin, variables that led to flooding, and how the basin has been altered by anthropogenic development. HHM will conduct a hydrometeorological analysis of past events by examining physical data records from these events, including a flood frequency analysis based on inflow data.

Tasks include:

- Historical Simple Water Balance Model. Includes the creation of a simple water balance spreadsheet model for the basin that can be used for preliminary analysis of hydrologic responses to possible mitigation solutions and creation of net basin supplies.
- Hydrometeorological flood analysis. Conduct flood analysis of historical flood events within basin, including hydrological conditions and factors that describe natural flood vulnerability and variables that lead to flooding and how anthropogenic development has altered basin.

Task SPE1: Historical and analysis of flooding from a social, political, economic, and public health perspective: This will build a historical perspective on flooding from social, political, economic, and public health perspectives, including land use and related policies and practices amongst other topics, focussing on the 2011 flooding. This task includes an accounting of public and individual health impacts of the 2011 flood, including major casualties, emotional and psychological stress, and impacts to vulnerable community members (e.g., children, elderly, poor, those with disabilities). The identification and documentation of financial damages to

businesses, regional economic activity, as well as to private and public infrastructures will also be carried out.

Four major outcomes from this work are:

- Demographic profile of the basin;
- Economic analysis of damage from past floods, with emphasis on 2011;
- Adaptation after floods observed in economic and demographic trends of the basin ;
- Social and public health impact analysis of past flood events.

This information will facilitate development of a baseline reference scenario against which flood mitigation measures can be compared.

This analysis will be based, primarily, on gathering and reviewing existing data sources. Methodologies include document analysis of reports from local government agencies and others involved in flood planning and response. Examples organizations from which documents may be public health, social service, planning and emergency response organizations, insurance companies, chambers of commerce, individual businesses, municipalities and others. Products include a written report that outlines major findings from past floods with particular emphasis on 2011.

Tasks SPE2, Press review of past floods, and SPE3, Inventory of existing studies with relevant social, political and economic information, will be incorporated into the analysis of past flooding events in the LCRR as information becomes available and timelines match.

Task RR1: Review of impacts of past floods on resources: The RR TWG will conduct a review of the impacts of past floods, especially the event of 2011, on ecological and societal resources in the system. To do so, a survey of the literature and available data will be conduct. The review will pay particular attention to the direct impacts of flooding on public and private property as well as the erosion of lake shorelines, river banks, and property loss. It will review the cumulative impacts of past flood control measures, flow conveyance activities, and flood and floodplain management practices on resources in the system as well as modifications to the landscape that may exacerbate flooding such as the spread of impervious surfaces, straightening of streams, removal of riparian and lowland forests, and forms of ditching and drainage enhancements. Finally, it will provide a review of the past adaptive behaviors of resource managers and communities in riparian corridors in anticipation of floods.

Budget and timeline are reflected in table 5.2 for Canada and the U.S.

Table 5.2 Timeline and budget estimates for evaluating the causes and impacts of past floods, especially the event of 2011

Evaluating the causes and impacts of past floods, especially the event of 2011 - Canadian Budget (Can K$)							
Id	**Tasks**	**YR1**	**YR2**	**YR3**	**YR4**	**YR5**	**TOTAL**
		17-18	**18-19**	**19-20**	**20-21**	**21-22**	**CA k$**
HHM5	Hydrometeorological analysis of past floods	10	0	0	0	0	**10**
SPE1	Historical analysis of flooding from a social, political and economic perspective	40	45	0	0	0	**85**
RR1	Review of impacts of past floods on resources	30	20	0	0	0	**50**
TOTAL		**80**	**65**	**0**	**0**	**0**	**145**

Evaluating the causes and impacts of past floods, especially the event of 2011 - US Budget (US K$)							
Id	Tasks	YR1	YR2	YR3	YR4	YR5	TOTAL
		17-18	18-19	19-20	20-21	21-22	U.S. k$
HHM5	Hydrometeorological analysis of past floods	0	40	0	0	0	**40**
SPE1	Historical analysis of flooding from a social, political and economic perspective	25	20	0	0	0	**45**
RR1	Review of impacts of past floods on resources	15	25	0	0	0	**40**
TOTAL		**40**	**85**	**0**	**0**	**0**	**125**

5.3 Conducting an in-depth study of current social and political perception of flood mitigation measures

This study objective directly addresses both governments' reference item 3: *Evaluating possible adaptation strategies to the expected future variability in water supplies* and item 5: *Conducting an in-depth study of current social and political perception on structural and other mitigation measures to support and confirm the desirability of potential structural mitigation solutions.*

Lead: SPE AG

This component of the study will produce a social, political and economic analysis of current perceptions on mitigation measures and environmental considerations by documenting residents' and stakeholders' current perceptions and relationships to flooding and the potential mitigation solutions. It will also document the current multilevel and bilateral water governance related to flooding and explore alternative arrangements.

This component is essential to maximise the likelihood of converging toward acceptable flood mitigation measures as the study progresses.

The study will largely involve social, political, and economic analyses that will rely on various surveys and focus groups. These activities go beyond Public Advisory Group (PAG) meetings or open public meetings organized by the International LCRR Study Board.

There is a need to specifically reach-out to local elected officials, public servants and technical experts such as municipal planners and public works professionals to interact and gain feedback from these professionals in a coordinated manner. It is suggested that lists of stakeholder groups that hold expertise in the study topics and inviting these professionals in the LCRR region within these groups to join the effort. As volunteers show interest in participating, local groups can be created for surveys and participating in focus groups, among other activities.

Scope of work:

Task SPE2: Press review of past floods: Commencing with the 2011 floods, this task will identify and locate: (a) the ways in which floods and risks are presented and represented in the media and other community conversations; (b) the various flood-related issues reported therein; (c) the actors who appear to be concerned by these problems; (d) the concerns, demands, proposals, and actions; and (e) any other information relevant to the understanding of the local and regional situations.

Task SPE3: Inventory of existing studies with relevant social, political and economic information: This will establish, with the help of designated interlocutors, an inventory of all existing studies on the basin from which the group can extract valuable social, political, and economic information and data: This information will be aggregated into an annotated bibliography.

Task SPE4: Vulnerability and resilience of local community assessments: This task will map the LCRR population and critical infrastructures related to flooding in order to develop a better understanding of the vulnerability and resilience of local communities. This will shed light on the diversity within and among local communities (including households) located in flood-prone areas as well as those exposed to other forms of losses from floods. This analysis should point out the main sensitivities and adaptive capacities related to flooding that exist within communities.

More specifically, the proposed approach aims to develop a better understanding of the vulnerability and resilience of local communities impacted by flooding. On the basis of recent census of population and other datasets such as first floor data (gathered by RR TWG), available LIDAR data, damage data, infrastructure data, etc., the main socio-economic features of these communities at the finest territorial scale (e.g. dissemination area, DA) will be highlighted. Such an approach will shed light on the diversity among local communities and households in the flood susceptible areas, and point out the main features of their sensitivity and adaptive capacity to flooding. Overall, the analysis will focus on the following four areas:

- Geographic vulnerability: people with structures in floodplains;
- Social vulnerability: demographic groups such as age, low income, people living alone, single parents, ethnic, language, and differently-abled groups will be considered;
- Procedural vulnerabilities: those with limited access to support services and planning and decision-making agencies;
- Structural vulnerability: infrastructures that would be damaged by flooding;
- Economic vulnerabilities: those with economic interests that would be damaged by flooding.

Task SPE5: Risk perception analysis: Mixed-methods research will be conducted to characterize the representations and concerns of local communities in regard to their living environment, as well as their concerns about flooding and land planning. The view is that with proper survey data and analysis (from the RR TWG), it is possible to better understand how citizens, emergency responders, decision makers, and other actors recognize and react to disaster risk and thus how risk awareness can impact long-term resilience. The SPE will also explore the relationships and gaps between perceived risk and actual risk. This information will shed light as to how residents rebuild and adapt their houses post-disaster as well as inform themselves in regards to adaptation methods.

The following methodological approaches will be combined to accomplish these outcomes:

- Document analysis of media reports and municipal meeting minutes;
- Literature review of prior studies related to flooding, economics, politics and social vulnerability in the region;
- Interviews, focus groups, design charrettes, surveys and other qualitative and quantitative methods of social science;
- Geographic Information Systems (GIS), map making, analyses, and any other means that inform risk perception.

Budget and timeline are reflected in table 5.3 for Canada and the U.S.

Table 5.3 Timeline and budget estimates for conducting an in-depth study of current social and political perception on flood mitigation measures

In-depth study of current social and political perception on flood mitigation measures - Canadian Budget (Can K$)							
Id	Tasks	YR1 17-18	YR2 18-19	YR3 19-20	YR4 20-21	YR5 21-22	TOTAL CA k$
SPE2	Press review of past floods	17	0	0	0	0	**17**
SPE3	Inventory of existing studies with relevant social, political and economic information	13	0	0	0	0	**13**
SPE4	Vulnerability and resilience of local communities assessment	10	40	0	0	0	**50**
SPE5	Risk perception analysis	0	35	35	30	0	**100**
TOTAL		**40**	**75**	**35**	**30**	**0**	**180**

In-depth study of current social and political perception on flood mitigation measures - US Budget (US K$)							
Id	Tasks	YR1 17-18	YR2 18-19	YR3 19-20	YR4 20-21	YR5 21-22	TOTAL U.S. k$
SPE2	Press review of past floods	12	0	0	0	0	**12**
SPE3	Inventory of existing studies with relevant social, political and economic information	8	0	0	0	0	**8**
SPE4	Vulnerability and resilience of local communities assessment	0	50	0	0	0	**50**
SPE5	Risk perception analysis	0	50	30	5	0	**85**
TOTAL		**20**	**100**	**30**	**5**	**0**	**155**

5.4 Development of a collaborative decision support tool (CDST)

This study objective directly addresses the governments' reference item 7: *Developing resource response models that include basic indicators for water resources response to water levels fluctuations, with special attention on the data inventory and identification of thresholds. Climatic projections, wind wave and ice models, additional new data for the evolution of basin physiographic characteristics over time and a complete digital terrain model should also be produced to allow the planning, evaluation and ranking of potential flood mitigation solutions, using a shared-vision approach.*

Lead: FMMM TWG

A *collaborative decision support tool* (CDST) and associated tools will utilize information and data derived from a variety of models: These will include hydrological, hydraulic, environmental and economic models the results of which will be used to conduct an evaluation of flood mitigation measures. Associated tools (simplified models) will be built to help visualize and explain the impacts of various measures detailed in the CDST.

To support this modelling, extensive data will be required. Some pertinent data sets and maps may include: flood maps, local zoning ordinances, high water mark data, floodplain maps, building floor elevations, floodplain delineations, wetland mapping, percolation testing and groundwater zones, geological profiles and maps, water quality and extensive socio-economic data. These sources of data and maps will be discussed and refined with the other TWGs in the context of the metrics and performance indicators (PIs) that will be utilized to evaluate the various alternatives. Uncertainty in the data will be addressed and characterized.

Baseline

The PIs for the LCRR basin in its present state, *i.e.* without any new flood mitigation measures, will be computed on a temporal series of water level and flows to form the "baseline" to which will be compared to the PIs computed based in simulating the various flood mitigation measures. In a first approximation, two different time series will be used: the short "2011 event" (hourly to daily averaged data), and the historical NBS (Net Basin Supply) series of levels and discharge from 1950 to 2017 (daily mean to quarter-monthly mean). Climate change NBS series will be incorporated in the baseline series that will be used to assess the effect of climate change on flood mitigation measures.

Scope of work:

Task RR2: Iterative review and selection of performance indicators: Using an iterative process, a review of potential PIs will be conducted in collaboration with SPE AG and FMMM TWG for the evaluation of resource responses to flood management and mitigation measures. The PIs will be linked to recreational, domestic, industrial and municipal water uses, the shoreline and floodplain built environment, agriculture and the natural environment (vegetation and fauna). They will be oriented around a) the Richelieu River, b) the flood forecasting system, and c) Lake Champlain.

There will be several steps in this iterative process. 1) A small group of PIs will be developed during the first year of the project. These PIs (such as stage-damage curves and shoreline erosion), among others, will address the main concerns of local populations that where heard during the public meetings (e.g. loss or damages to houses, number of days that people are flooded, etc.). 2) This set of PIs will then be used by FMMM TWG to initiate a set of discussions with decision-makers and stakeholders about potential flood management and mitigation measures. 3) This will help focus selection of measures for which there is interest for implementation in the basin. 4) Outcomes of these discussions will provide direction as the RR TWG focuses its efforts on the selection and development of a second group of PIs that hold the most promise for the assessment of the impacts of mitigation measures on key resources. This will also help RR TWG configure an integrated tool to assess the resource responses. These steps may be repeated during the study, as potential measures are more fully defined.

Additional PIs will also address water uses, the shoreline and built environment, agriculture, and the natural environment. At this stage, it is not possible to assess the number and nature of all PIs and the extent to which the integrated tool will be needed for the impact assessment on resource response. Finally, research in support of the selection of indicators will be provided in a report to the Study Board and as input to resource response models.

Task RR3: Analysis of water uses and water intakes: In collaboration with the SPE AG, the RR TWG will (a) Complete an inventory of existing water uses, including industrial, municipal and domestic water intakes, as well as navigation and recreational boating within the first year of the study; (b) For water intakes, determine the characteristics of all water intakes (including domestic water intake lines) and shore wells. Collect information related to critical water levels, including extremely low water levels that could limit the availability of the resource, and impact water quality; (c) For recreational boating, estimate of both recreational loss (total possible boating days lost) and economic loss (net economic value lost) will be performed as water levels change. Create water level-impact relationships by collecting data on marinas and yacht clubs, boat ramps and private docks, as well as on fisheries (sport, commercial, and subsistence/native)

and fishing access areas; (d) Identify the degree of impact (e.g., physical, operational, environmental, and economic) as a function of water level and discharge, along with associated costs, and (e) Identify impacts associated with water level ranges and timing through the use of hydrographs and integrative response models.

Task RR4: Analysis of shoreline and floodplain built environment: Working closely with the SPE AG, the RR TWG will (a) Collect representative on-site data in order to develop stage-damage relationships for real estate property applicable on the LCRR system within the first year of the study. Calculate the primary economic flooding PI, dollar damage to buildings and contents of buildings as a result of a flood event, with the resulting stage-damage curves. In order to more fully describe the impacts of a flood on riverine communities, establish some societal PIs to complement and provide context for the economic PI, accounting for societal aspects of other direct damage. Such societal PIs could cover the area of flooded lands, and the length of flooded roads. Finally, on Lake Champlain and on some parts of the Richelieu River (Chambly Basin), impacts of flooding could not only result from inundation of structures, but also from the force of waves striking buildings. Develop the flooding PIs accordingly, (b) Compile an inventory of historical sites that are vulnerable to water level fluctuations, and (c) Assess shoreline erosion and the associated economic impacts for individual property parcels around the perimeter of the lake and on the river. For developed, unprotected properties, the economic value of land lost due to erosion will be assessed. For existing shoreline protection structures, assess the costs of maintenance or replacement (when the structure is overtopped and failure occurs).

Task RR5: Analysis of impacts on agriculture: Agricultural lands in low-lying areas are vulnerable to flooding, which can lead to soil erosion, nutrient and contaminant loss and lead to sediment deposits and associated geomorphological modifications (e.g., gully formation) of the landscape along with deposits of larger debris and additional sediments transported by river flows. The combined effects negatively impact cropping systems (soil fertility), surface drainage, preferential flows in riparian buffers, destruction of subsurface drain outlets, and livestock operations (e.g., destruction of retention ponds and streambank fencing). However, through effective water management, agricultural lands can also play a role in the mitigation of downstream flooding (e.g., see items below). In addition to the environmental impacts, farm operations can experience significant economic impacts from floods due to crop loss, loss of productive farm land and damages to structures.

The RR TWG will: (a) develop a basin data base within the first year of the study to support the evaluation of the effects of changes in water management on agricultural land in the LCRR based on high-resolution land use and land cover imagery and relevant geospatial data (e.g., LiDAR, hydrographic networks, soil characteristics, and road networks); (b) assessment of agricultural hillslopes included natural floodplains and in flooding zones of different return periods, (c) with the SPE AG, assess the value of existing agriculturally-developed land within the basin and quantify how it has been affected past floods and project how it will be affected by future floods, (d) identify potential areas for floodplain and wetland reclamation, land protection (e.g. water level control in ditches receiving agricultural drainage), and other flood risk mitigation measures, such as isolated wetlands and retention ponds and reduced tillage practices, and (e) determine optimal water levels needed to maintain agricultural lands and related rural communities in LCRR.

Task RR6: Analysis of the natural environment: The RR TWG will (a) Complete an inventory of existing wetland classification data and other biological data (e.g. wetland vegetation, fish, herpetofauna, birds etc.) in the basin (e.g. literature review, observational field surveys, past distribution maps, etc.). For the different species or group of species for which PIs would be needed according to the iterative process of task RR3 b) collect information related to critical water levels or flows, including extremely low water levels that could be detrimental to them or link the biological observations to the output produced by the hydraulic and hydrological models produced by HMMM. c) Develop wetland and faunal habitat models. Model output will be used to define PIs to be used in the CDST.

If appropriate, the development of environmental PIs, according to an iterative process, may include spawning and early stages of a sport fish (e.g. Northern pike), spawning and early stages of a threatened fish (e.g. Copper redhorse; running waters), reproduction of spiny softshell turtle (threatened terrestrial species), succession of wetlands, etc.

Task RR7: Integrative tool for the assessment of impacts on resources: Variation of the selected PIs to flood management and mitigation measures will be evaluated through an integrative tool to be determined during the iterative process explained in task RR2. It is envisioned that an Integrated Resource Response Model (IRRM)—based on Integrated Ecosystem Response Models (IERM) used in other transboundary studies on impacts of water level changes—will be used for many of the PIs. The IRRM would provide the PI values to be incorporated in the CDST. The CDST will include a baseline scenario and every mitigation measure will be evaluated compared to it. The percent of change in PIs' values will be the inputs in the CDST.

Task RR8: Resource baseline impact assessment: In the absence of any potential flood mitigation and management measures, impacts on resources in the system need to be characterized according to a set of baseline scenarios (i.e. the "status quo" according to current water supply conditions under stable and modified climate regimes and forecast socioeconomic changes). Measures proposed should improve upon one or more of the baseline scenarios according to PIs that represent the resources of the system. The PIs that will first be considered will reflect the immediate impacts of flooding, such as those related to state-damage curves, economic impacts and loss of shoreline due to erosion. Taking the full spectrum of hydraulic and hydrological variation into account, PI values will be expected to vary according to flood levels as well as periods of drought.

Task SPE6: Development of social, political, economic, and public health indicators: The SPE AG will develop social, political, economic, and public health PIs for assessing the many possible non-structural and structural measures to prevent, manage and respond to flooding: These PIs will contribute to construction of collaborative decision support tool (CDST), mostly through the integrated ecosystem response models. The development of these tools fall, respectively, under the responsibilities of the FMMM and RR TWGs.

The initial, broad PIs, based on outcomes from task SPE1 as well as SPE4, will be refined. Furthermore, the communities of the LCRR already monitor a broad array of PIs that will be considered.

Task FMMM1: **Development of a Collaborative Decision Support Tool (CDST):** The FMMM TWG will develop the CDST. That is, develop computer models that evaluate the various mitigation measures (non-structural and structural). The models will factor in social

(including human health, peoples' livelihoods, property, the communities in addition to other factors), political, economic and environmental perspectives.

Task FMMM2: **Development of metrics/performance indicators to evaluate the proposed measures:** Working closely with the other TWGs and other groups, the FMMM TWG will help develop the final metrics/PIs covering the broad range of perspectives that will be used to evaluate the proposed measures and options. This task builds on FMMM10. The FMMM TWG will hold workshops on an annual basis with all the TWGs and other groups in planning and implementation of the CDST and keep close tabs on the metrics/PIs collection that will be needed for evaluation purposes.

Task FMMM3: Finalization of metrics/performance indicators and familiarization with CDST's capabilities: Working with other TWGs, project developers, etc. the FMMM TWG will interact with the various groups to evaluate the utility of the broader set of metrics /PIs and finalize the suite of metrics/PIs that that will be used to analyze the proposed mitigation measures. The evaluation will assess the sensitivity of the various metrics/PIs against changing water levels and help assess whether they will provide meaningful results for prioritizing/ranking of options. Presentations of the collaborative decision support tool at various stages of development will demonstrate how the metrics and PIs will be used to evaluate and rank the various measures.

Budget and timeline are reflected in table 5.4 for Canada and the U.S.

Table 5.4 Timeline and budget estimates for the development of a collaborative decision support tool (CDST)

Development of a collaborative decision support tool (CDST) - Canadian Budget (Can K$)							
Id	Tasks	YR1	YR2	YR3	YR4	YR5	TOTAL
		17-18	18-19	19-20	20-21	21-22	CA k$
RR2	Iterative review and selection of indicators	20	0	0	0	0	**20**
RR3	Analysis of water uses and water intakes	20	55	50	15	0	**140**
RR4	Analysis of shoreline and floodplain built environment	55	120	100	75	10	**360**
RR5	Analysis of impacts on agriculture	40	45	45	45	20	**195**
RR6	Indicators for the natural environment analysis	10	95	95	75	20	**295**
RR7	Integrative tool for the assessment of impacts on resources	0	25	25	20	10	**80**
RR8	Resource baseline impact assessment	0	0	0	10	10	**20**
SPE6	Development of social, political, economic, and public health indicators	10	10	10	0	0	**30**
FMMM1	Develop collaborative decision support tool (and report)	0	75	0	0	0	**75**
FMMM2	Develop metrics/performance indicators to evaluate the proposed measures and options.	0	60	110	30	0	**200**
FMMM3	Working with TWGs, project developers, etc. finalize metrics/performance indicators and familiarize with model capabilities	0	0	30	30	0	**60**
TOTAL		**155**	**485**	**465**	**300**	**70**	**1475**

Development of a collaborative decision support tool (CDST) - US Budget (US K$)							
Id	Tasks	YR1	YR2	YR3	YR4	YR5	TOTAL
		17-18	18-19	19-20	20-21	21-22	U.S. k$
RR2	Iterative review and selection of indicators	15	75	75	60	20	**245**
RR3	Analysis of water uses and water intakes	15	45	40	10	0	**110**
RR4	Analysis of shoreline and floodplain built environment	35	60	50	35	0	**180**
RR5	Analysis of impacts on agriculture	35	35	35	35	15	**155**
RR6	Indicators for the natural environment analysis	10	75	75	60	20	**240**
RR7	Integrative tool for the assessment of impacts on resources	0	20	15	15	15	**65**
RR8	Resource baseline impact assessment	0	0	0	10	10	**20**
SPE6	Development of social, political, economic, and public health indicators	10	10	10	0	0	**30**
FMMM1	Develop collaborative decision support tool (and report)	0	50	0	0	0	**50**
FMMM2	Develop metrics/performance indicators to evaluate the proposed measures and options.	0	40	80	20	0	**140**
FMMM3	Working with TWGs, project developers, etc. finalize metrics/performance indicators and familiarize with model capabilities	0	0	25	25	0	**50**
TOTAL		**120**	**410**	**405**	**270**	**80**	**1285**

5.5 Performing a quantitative and qualitative assessment of structural and non-structural potential flood management and mitigation measures

This study objective addresses the governments' reference item 2: *Assessing the possibilities offered by floodplain best management practices* and the governments' reference item 6: *Performing a quantitative and qualitative assessment of potential flood management and mitigation measures (non-structural and/or moderate structural works) and their impacts on important resources of the system: the wetland and fauna, recreational, domestic, industrial and municipal uses of water, shoreline and floodplain built environment and agriculture.* Best management practices for floodplains include, but are not limited to, measures such as: emergency response plans, land-use regulation, detention of water, culvert sizing, tile drainage usage, routing of high flows to wetlands, etc. Best floodplain management practices are a form of mitigation measures,

Lead: FMMM TWG

This component of the study will identify and document the possible non-structural and structural flood management and mitigation measures, in collaboration with the HHM TWG, the RR TWG and with the SPE AG, and the PAG. The evaluation and ranking of the potential candidate measures for flood management and mitigation will be supported by a CDST to be developed as an integral part of the study (section 5.4).

Scope of work:

Task FMMM4: Preliminary assessment of possible in-stream structural or channel modification solutions: Working closely with the HHM TWG, undertake a preliminary analysis of hydraulic impacts for several known probable structural or channel modification solutions such as: excavation the St. Jean shoal, increasing flows through the Chambly canal, removal of man-made in-stream flow obstructions, water retention schemes (e.g., wetland creation, water storage reservoirs), etc. Use this knowledge to educate and engage the public and decision-

makers in the discussions of potential in-stream mitigation measures and their potential impacts on flows.

Task FMMM5: Engagement of decision-makers/stakeholders in mitigation solutions: The FMMM TWG will need to work closely with the SPE AG and the PAG in identifying and approaching decision-makers and key stakeholders and determining their support as per the various potential mitigation measures.Timeline: Multiple engagements will be required as the study progresses from early consultation to review of results and proposed mitigation solutions.

Task FMMM6: Survey of basin jurisdictions' approaches to flooding: This task will involve conducting a survey of the jurisdictions in the basin to identify a comprehensive list of the various strategies and approaches currently being employed for flood management practices and their perceived effectiveness. This will be based on what is currently considered the flood elevation on a floodplain for a prescribed flood event. This work will be done in close collaboration with the SPE group to identify practical alternatives. Work Groups (SPE AG and RR TWG) will also combine their efforts to develop impact functions and PIs.

Task SPE7: Develop a LCRR outreach plan: The LCRR flood resilience initiative is a large complex effort. It is binational, and involves many layers of federal, regional, and local level governance organizations. Establishing trust, encouraging local stakeholders to participate, developing commitment and support for the effort requires a coordinated, unified and multifaceted outreach effort alongside the work of the TWG's .Furthermore, many stakeholders in Quebec, New York, and Vermont do not share a unified vision of the impacts of floods and need for flood resilience/mitigation. Completing the study effort, developing recommendations for future flood management, and building support to make the recommended adaptations necessary to improve flood management requires significant involvement from stakeholders throughout the LCRR basin. For example, at different stages of the planning effort stakeholders throughout the basin will need to:

- Share stories about social, political and economic impacts from flooding;
- Participate in data sharing and collection efforts;
- Assist in data analysis;
- Learn about the various flood mitigation and management techniques that can be used to forecast, prevent, plan, manage and respond to flooding-- and the implications of these measures on life in the region;
- Build trust in the various decision-making tools, models and informational resources produced and recommended by TWGs;
- Participate in decision-making activities that use the resources developed by TWGs; and
- Support and enact adaptations to flood management regimes in the region, among other things.

This study cannot expect stakeholders to participate in these activities without knowledge and trust in the overall purposes and objectives of these efforts, or awareness of the shared working approach adopted by TWGs/AG on this study.

In this task, SPE will work with all other TWGs, PAG, the Communication WG and SB to develop an outreach plan to guide outreach efforts associated with the LCRR study. This plan will clarify different types of outreach occurring within the study, the purposes of these initiatives, timelines and performance responsibilities, and metrics for assessing outreach efforts.

The plan will also include protocols to prevent overlap and redundancies in outreach activities that threaten to confuse stakeholders and/or compete for stakeholders' time. A plan for structured engagement around outreach topics with TWGs, PAG, Communication WG and SB will be included.

Task SPE8: **Governance analysis on flood preparedness and response:** This task consists of an analysis of governance, networks, communication, collaboration, inter-relationship related to preparedness and response, including forecasting and communications, logistics, emergency and medical responders, disaster declarations, media, clean-up and post-flood management.

A survey and network analysis will be conducted to identify and understand the sum of mechanisms, processes, relationships, and institutions that the population has put in place to assert their interests, rights, and obligations in regard to flooding. All LCRR institutions and organizations with a relationship to flooding will be invited to participate in the survey. Results will be obtained through surveys, interviews, focus groups and other methods of selected participants and synthesized into a report.

The network map and analysis constructed from this work will be multi-scalar including local, regional, state/provincial, and federal organizations from the public, private and third-sectors.

Participation bias will be limited in three ways:

- by collecting data using multiple, mixed-methods to reveal a diversity of information types;
- by triangulating the findings by seeking multiple data points for each node of the study network map;
- by purposely seeking counter-examples and exceptions to the study's findings.

Task SPE9: **Development of multi-agent governance model:** The management of floods typically involves a mix of structural and non-structural measures, which are often designed and managed by various autonomous institutions (river basin authority, municipalities, etc.). To assess the effectiveness of those measures, they can be integrated into a single, coherent, modelling framework usually organized around a hydro-economic model. Such models are most commonly framed as economic optimization problems that maximize region-wide net benefits (or minimize costs) subject to physical, institutional and economic constraints. Since traditional hydro-economic models largely ignore institutional complexity, the management decisions are divorced from political reality – in particular, the fact that water policies stem from a multiplicity of institutions that have different objectives. This observation has led to the development of a new class of hydro-economic models based on a multi-agent simulation (MAS) framework where the agents are autonomous decision makers interacting at different hierarchical levels.

This tasks thus involves the development of a multi-agent (agent viewed as a stakeholder) decision-making model for flood management: The model aims at simulating the decision processes within the basin, each agent representing an institution or a group. The model will make use of the sociological, economic and political information gathered from task SPE8 and others, and allow the evaluation of possible alternative institutional arrangements. The outcome from this task will be portfolio and SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis of alternative governance models.

Task FMMM7: Literature review on structural options: A literature review of previous LCRR studies will be done and a comprehensive list of practical structural or channel

modification options that could be applied in the basin will be compiled. Input from the public and decision makers on other possible options will be incorporated.

Task FMMM8: Literature review of non-structural options: A literature review focusing on knowledge and lessons learned by North American jurisdictions (i.e., provinces, conservation authorities, states, etc.) and globally on flood management and mitigation measures will be done. A comprehensive list of the different strategies and approaches that have been employed by the various agencies will be gathered. Input from the public and decision makers on other possible measures will be incorporated. A compendium of solutions will be developed.

Task FMMM9: Expert workshop on options for LCRR basin: A workshop of external experts, TWG representatives and decision makers will be held to develop the list of the more promising options (structural and non-structural) for consideration in the LCRR basin. This work will involve prioritizing the list of options that will be compiled from the basin survey, literature review and discussions with other jurisdictions that have developed strategies for reducing the impacts of flooding in other basins.

Task FMMM10: Initial assessment and prioritization of proposed metrics/performance indicators to use to evaluate mitigation measures: A list of planning objectives and metrics will be developed. Metrics and indicators will be proposed that will be used to quantify progress towards those objectives. Flood damage reduction is clearly a prime objective, but there are others, such as the protection or improvement of environmental health. This work will be coordinated with input from all the groups.

Task FMMM11: Stakeholders shortlist of mitigation measures (non- structural and structural): A list of possible flood damage reduction measures has already been assembled based on information from within and outside the basin. This task will identify those specific mitigation measures that decision makers in the basin support for further detailed analyses. The focus will be on identifying those specific measures that have a good chance of being implemented.

Task FMMM12: Engineering feasibility assessment: An engineering feasibility assessment of the promising structural measures will be conducted. This will be accompanied with an approximate cost of implementation and a description of the expected benefits. It will also identify any potential issues or limitations related to that specific structural solution being implemented.

Task HHM6: Hydraulic modeling of potential mitigation measures: Hydraulic and hydrologic analysis and 2D hydraulic modeling suite developed by HHM TWG will be used to analyze the flood mitigation measures identified by the FMMM TWG. This will likely include structure changes in the Richelieu River and increased storage of flood waters in the tributaries of Lake Champlain. Analyses will also evaluate whether restoration of floodplains of Lake Champlain tributaries will attenuate flood levels in the Richelieu River. The NBS to the LCRR will be varied in a number of realistic ways, and the model will be adjusted to incorporate the proposed measure. The effectiveness of mitigation measures will be considered under ta number of scenarios, including: the previously identified flood levels used to generate flood inundation maps; the 2011 flood event; historical NBS; and climate-driven NBS scenarios. Furthermore, the ecosystem response under these conditions will be evaluated based upon the model outputs generated here.

Tasks include:

- Simulation of flood mitigation measures under multiple flood scenarios. Analysis and 2D hydrodynamic modeling of LCRR system will be used to analyze flood mitigation measures. This includes the use of LC tributary floodplains to attenuate inflows and resulting flooding in the Richelieu. The NBS will be varied under a number of scenarios to examine the effectiveness of measures, including: flood levels used for flood maps; 2011 flood event; historical NBS; and extreme hydroclimate scenarios. Modification of the DEM according to the proposed mitigation measures would also be done.

Task SPE10: Cost-benefit analysis of potential mitigation measures: An economic analysis of possible mitigation measures will be realized: This task consists of conducting cost-benefit analysis (CBA) of the mitigation measures retained and identified by the FMMM TWG. The economic analysis will compare the discounted costs and benefits of each mitigation measures to the costs of the reference scenario (without mitigation)

More specifically, the cost-benefit framework will build on the work done in task SPE1, where the economic assessment of the 2011 flooding events will have produced information, data and methodologies enabling the quantification of the impacts of a reference scenario (without mitigation) on economic, social, environmental and policy issues. Stage-damage curves built by the RR TWG will be used to quantify and project future damages to private residential properties in the basin. This quantification will be supported by the use of future climate scenarios as well as socioeconomic and land use scenarios and subsequent effects on flooding. The impacts quantified for the reference scenario will include but won't be limited to: increase in flooding damages, losses of economic activity, increase in security expenditures, costs of policy adaptations, additional costs in healthcare, emergency response, loss of tourism activity, loss of employment and economic activities. Moreover, building on the work done by the RR group, the economic analysis will quantify ecosystem services (supporting, provisioning, regulating and cultural services) and there variation in response to flood events and to the implementation of mitigation measures.

The CBA will evaluate the costs related to implementing the mitigation measures identified previously. For structural measures, these costs will include: Cost of design (including the feasibility study and impact assessment), the cost of construction (including cost of material, transportation and surveillance) and the cost of maintenance of the structure or reconstruction. For policies, regulatory, land use and environmental restoration measures, direct costs of implementation will include any additional study or analysis necessary to implement the measures.

Taking into account that mitigation measures are implemented in a specific social and economic context, these interventions will have positive or negative social and economic impacts. Therefore, based on the identification of obstacles, costs and benefits, the impacts of the implementation of the mitigation measures will be monetized. These impacts will be monetized using output produced by other groups (primarily by the RR using the IRRM) and different economic methods in consideration to the availability of the data and the object to be monetized.

The CBA will be conducted by comparing the situation without intervention (reference scenario) to the mitigation measures retained for the analysis using standard economic indicators such as the net present value (NPR), cost-benefit ratio (CBR), and internal rate of return (IRR).

Task RR9: Indicator Calibration: Indicators will be calibrated and responses will be forecasted based on historical flood events, including the event of 2011, using existing data to the extent possible.

Task SPE11: Vulnerability and impacts analysis of potential mitigation measures: Scenarios analysis will be used to improve understanding of the social, political and economic consequences of different strategies for preparing for, planning and preventing flood damages- as well as management of resources and hazards during and after flood events. Several facilitated discussions will be hosted among a variety of targeted stakeholder groups at which a series of different future scenarios that describe possible outcomes of flood management will be provided to participants. Scenario descriptions may include narrative descriptions, audio and video elements, and other types of mapping and data visualizations. The scenario descriptions will align with the indicators and cost benefit analysis developed in tasks SPE6 and SPE10, respectively. It will also largely draw from information gathered and developed by all the other TWGs. As the scenarios are presented to stakeholders, we will ask a set of structured questions designed to understand the changes that need to occur in the LCRR in order to make these scenarios reality. Input will also be sought on the accuracy of the predictions for social, political, and economic outcomes, as well as stakeholders' preferences for these scenarios. Example questions are:

- What economic, social and political structures within and beyond LCRR need to change in order to make each scenario a reality?
- How will the changes that need to occur improve LCRR preparedness for future flood events?
- What unintended consequences may arise from the changes you foresee in each scenario?
- What obstacles stand in the way of making each scenario a reality?

This information will be used to inform progress and decision-making among all TWGs, including development of the CDST and other decision support tools produced throughout the LCRR flood resilience effort.

Task RR10: Assessment of cumulative impacts of anthropogenic modifications to the system: Over the decades, the system has undergone substantial change due to successive anthropogenic modifications. These modifications range from the establishment of eel cribs and rail and road transportation piers to widening of piles and the Chambly Canal, among others. The purpose of this task is to quantify the relative impacts of these alterations of the system, thereby enabling a common understanding of what anthropogenic factors have led to the current hydraulic regime. Therefore, this task involves a) listing and dating the various anthropogenic modifications; b) integrating the changes in the DEM; c) evaluating the changes in the hydraulic regime. There is a possibility that the results from this task may lead to the quantification of the impacts on wetlands and other resources of the changes in the hydraulic regime linked to the anthropogenic modifications.

Budget and timeline are reflected in table 5.5 both for Canada and the U.S.

Table 5.5 Timeline and budget estimates for performing a quantitative and qualitative assessment of structural and non-structural potential flood management and mitigation measures

Performing a quantitative and qualitative assessment of structural and non-structural potential flood management and mitigation measures - Canadian Budget (Can K$)							
Id	**Tasks**	**YR1**	**YR2**	**YR3**	**YR4**	**YR5**	**TOTAL**
		17-18	**18-19**	**19-20**	**20-21**	**21-22**	**CA k$**
FMMM4	Preliminary assessment of probable in-stream structural or channel modification solutions	0	30	0	0	0	**30**
FMMM5	Engagement of decision-makers/stakeholders in mitigation solutions	15	25	10	10	10	**70**
FMMM6	Survey of basin jurisdictions' approaches to flooding	25	0	0	0	0	**25**
FMMM7	Literature review on structural options	25	0	0	0	0	**25**
FMMM8	Literature review of non-structural options	25	0	0	0	0	**25**
SPE7	Develop a IJC LCRR outreach plan	10	0	0	0	0	**10**
SPE8	Governance analysis on flood preparedness and response	20	40	10	0	0	**70**
FMMM9	Expert workshop on options for LCRR basin	0	25	0	0	0	**25**
FMMM10	Initial assessment and prioritization of proposed metrics/performance indicators to use to evaluate mitigation measures	0	40	0	0	0	**40**
SPE9	Development of multi-agent governance model	0	35	55	35	0	**125**
SPE10	Cost-Benefit Analysis of Potential Mitigation Measures	0	30	35	50	10	**125**
FMMM11	Stakeholders shortlist of mitigation measures (non-structural and structural)	0	30	0	0	0	**30**
SPE11	Vulnerability and impact assessment	0	0	35	65	10	**110**
RR9	Indicator Calibration	0	0	0	10	10	**20**
HHM6	Analysis of mitigation plans	0	0	45	120	15	**180**
RR10	Assessment of Cumulative impacts of anthropogenic modifications to the system	0	10	15	0	0	**25**
TOTAL		**120**	**265**	**205**	**290**	**55**	**935**

Performing a quantitative and qualitative assessment of structural and non-structural potential flood management and mitigation measures - US Budget (US K$)							
Id	**Tasks**	**YR1**	**YR2**	**YR3**	**YR4**	**YR5**	**TOTAL**
		17-18	**18-19**	**19-20**	**20-21**	**21-22**	**U.S. k$**
FMMM4	Preliminary assessment of probable in-stream structural or channel modification solutions	0	25	0	0	0	**25**
FMMM5	Engagement of decision-makers/stakeholders in mitigation solutions	10	15	10	10	10	**55**
FMMM6	Survey of basin jurisdictions' approaches to flooding	25	0	0	0	0	**25**
FMMM7	Literature review on structural options	25	0	0	0	0	**25**
FMMM8	Literature review of non-structural options	25	0	0	0	0	**25**
SPE7	Develop a IJC LCRR outreach plan	3	0	0	0	0	**3**
SPE8	Governance analysis on flood preparedness and response	23	25	5	0	0	**53**
FMMM9	Expert workshop on options for LCRR basin	0	60	0	0	0	**60**
FMMM10	Initial assessment and prioritization of proposed metrics/performance indicators to use to evaluate mitigation measures	0	30	0	0	0	**30**
SPE9	Development of multi-agent governance model	0	40	55	30	0	**125**
SPE10	Cost-Benefit Analysis of Potential Mitigation Measures	0	0	10	25	5	**40**
FMMM11	Stakeholders shortlist of mitigation measures (non-structural and structural)	0	30	0	0	0	**30**
SPE11	Vulnerability and impact assessment	0	0	35	50	5	**90**
RR9	Indicator Calibration	0	0	0	8	8	**16**
HHM6	Analysis of mitigation plans	10	50	50	0	0	**110**
RR10	Assessment of Cumulative impacts of anthropogenic modifications to the system	0	10	20	0	0	**30**
TOTAL		**121**	**285**	**185**	**123**	**28**	**742**

5.6 Development of a binational flood forecasting and real-time flood plain mapping system for operational implementation

This study objective directly addresses the governments' reference item 4: *Developing and making recommendations for implementing, as appropriate, an operational real-time flood forecasting and flood inundation mapping system for the Lake Champlain-Richelieu River basin.*

Lead: HHM and FMMM TWGs

This component of the study will define the components of the lake level and river flow forecasting system to be implemented operationally, including the modeling of wind set-up and wave action. It will also define the governance of the system and address the delivery of forecasts and real-time maps to the end users. The term 'governance' in regard to the binational flood forecasting and real-time floodplain mapping system refers to: (1) the governmental process and decisions necessary to allow the flood forecasting tool to provide the greatest benefit to tactical flood response plans and actions by emergency response bureaucracies on a municipal and local level and (2) the proposed design of institutional organizations that will operate and maintain a binational forecast system such that it will continue to support flood preparedness and response plans after the study is completed. These governance issues will require federal agency budget design and a binational agreement to support and apply the forecasting tool collaboratively. The recommendations for governance of the operation of the flood forecasting tool will evolve over the course of the study.

Scope of work:

Task FMMM13: Recommend a governance mechanism for the on-going operation of the binational forecasting system and its interactions with key agencies and the public. The FMMM TWG will work with HHM, SPE and RR to integrate the binational flood forecasting and real-time flood plain mapping system with flood response plans. The FMMM TWG will also evaluate the reduction in the level of risk in terms of exposure and vulnerability and community preparedness using advanced flow and water level forecasting.

Task HHM7: Development of a real-time flood forecasting system: The HHM team will assemble all components of a predictive flood forecasting and real-time flood plain mapping system that uses ensemble predictive meteorology-hydrology (HHM4) and 2D/3D hydrodynamic models (HHM3). Also, the U.S. will develop, test and implement a 3D hydrodynamic model for flood prediction on Lake Champlain in conjunction with a 2D hydrodynamic model for the upper Richelieu River which will be driven by hydrologic predictions and meteorological forecast models. The U.S. will also develop wind wave for the lake to be used in this predictive system. Canada will be using the same 2D model presented in section 5.2 The predictive system will combine U.S. and Canadian meteorology and three hydrological models (ECCC, NCRR and MDDELCC) that will be transferred to a single U.S.-Canada hydrodynamic model to map expected flooding extent. An ensemble approach for predicting lake and river levels and flooding potential will provide probabilistic forecast guidance that will be used to select flood maps which reflect forecast conditions. This system will assimilate recent observations to produce reliable solutions. The HHM team will use an approach that involve, in a first step, the rapid implementation and use of current forecasting tools & early development of new tools. These would be used as soon as the spring 2018. These tools will evolve and will be updated as soon as new products become available in order to learn from potential public outreach and real-time use. HHM will test this flood forecasting system and make recommendations on future operational implementation.

The 3D modelling proposed for Lake Champlain will use NOAA's enterprise forecasting model system. Being linked to the enterprise program will facilitate use of the model for an operational forecasting system in the future. The 3D model could help address many of the questions the public had on addressing water quality and sedimentation concerns for the Lake should future other studies address these concerns.

Tasks include:

- Improvement of the current forecasting system in Quebec (Quebec-Hydrotel): Fully functional and expanded hydrotel system.
- Proof of concept and best practice for automated predictive Meteorology-Hydrology-Hydrodynamic-Mapping system: Implementation of several versions of the forecasting system. This task requires the participation of all HHM-Canadian members and their teams in a collaborative effort for producing the most relevant system combining meteorology, hydrology and 2D/3D hydrodynamic modelling for mapping the forecasted state of the LCRR system.
- Develop 3D hydrodynamic model for forecasting Lake Champlain water levels: Develop and test a hydrodynamic model for forecasting LC and the upper Richelieu River driven by meteorological models and hydrological predictions.

- Evaluate hydrodynamic models for transition to operations: Forecast predictive system will be validated via skill assessment against historical observational data in preparation for transition to operations.
- Develop a wave model for Lake Champlain. Development of unstructured wind wave model for LC that will be coupled to hydrodynamic forecast model.
- Develop flood forecasting and mapping service: Create a flood forecasting and mapping service driven by probabilities of exceeding flood levels for given time/location and make recommendations for operational implementation.

Budget and timeline are reflected in table 5.6 for Canada and U.S.

Table 5.6 Timeline and budget estimates for the development of a flood forecasting and real-time flood plain mapping system for operational implementation

Development of flood forecasting and real-time floodplain mapping system for operational implementation - Canadian Budget (Can K$)							
Id	**Tasks**	**YR1 17-18**	**YR2 18-19**	**YR3 19-20**	**YR4 20-21**	**YR5 21-22**	**TOTAL CA k$**
HHM7	Development of real-time flood forecasting system	10	75	85	105	55	**330**
FMMM13	Recommend a governance mechanism for the operation of flood forecasting system	0	0	20	50	0	**70**
TOTAL		**10**	**75**	**105**	**155**	**55**	**400**

Development of flood forecasting and real-time floodplain mapping system for operational implementation - US Budget (US K$)							
Id	**Tasks**	**YR1 17-18**	**YR2 18-19**	**YR3 19-20**	**YR4 20-21**	**YR5 21-22**	**TOTAL U.S. k$**
HHM7	Development of real-time flood forecasting system	195	270	215	80	60	**820**
FMMM13	Recommend a governance mechanism for the operation of flood forecasting system	0	0	0	0	0	**0**
TOTAL		**195**	**270**	**215**	**80**	**60**	**820**

6 Public engagement

6.1 Introduction

The IJC is committed to the requirement in the Boundary Water Treaty that all interested parties shall be given convenient opportunity to be heard. Therefore, the IJC promotes policies and programs that enable community input in the decision-making process. The IJC emphasizes the importance of public outreach, consultation and participation. In the conduct of its activities, the Study Board will carry out its public participation and outreach activities in accordance with the principles contained in the Directive and in the *Guidance to the Study Board on Communication and Public Participation - November 2016* document.

The IJC and LCRR Study Board will strive to collaborate with existing regional organizations in developing and carrying out its communication and public outreach activities.

6.2 Objectives

Public participation in the study will be objectives-driven. The principal objectives are to:

- Ensure that the study process is open, inclusive and fair;
- Make the public aware of the study and provide opportunities to participate;
- Explain the decision-making process of the study;
- Identify and utilize local expertise and information;
- Identify and consider the public's views of the principal issues and questions of the study;
- Identify and consider the public's priorities and preferences;
- Enhance public understanding of the causes and effects of flooding and potential solutions;
- Broadly disseminate study findings as they become available; and
- Encourage the public to assist in disseminating study findings.

The public refers to any person, association, organization or group that is affected, likely to be affected by, or has an interest in the study and any decisions that may ultimately be taken by the IJC in response to the findings or recommendations of the study. The public includes, but is not limited to, the following individuals and organizations from the following: Environmental work, Navigation including recreational boating, Industry, Agriculture, Water supply and stormwater/sewage treatment, Riparian interests and Municipalities.

6.3 Communication Plan

A Communication Plan is an important tool for any complex study and it is being developed for the LCRR study. The main elements of the Communication Plan will be:

- Identification of key contacts;
- Development of a stakeholder list (municipalities, elected officials, First Nations/Tribes, local media, interest groups, riparian associations, etc.);
- Determination of key deliverables from the Study Board and work group work plans (public meetings, workshops, reports, comment periods, public outreach products, etc.);
- Development of a specific communication plan for each key deliverable. It will include details such as notice time, translation needs and time, production time, costs, approvals or room bookings; and
- Development of key messaging for both the overall study and each key deliverable or announcement.

The Communication Plan is provided in ***Annex 3***. It is a living document and as such it will be revised as necessary throughout the study.

The Study Board will use three important means for public participation and outreach: public meetings, the LCRR website for public outreach products and the Public Advisory Group (PAG).

6.4 Public meetings

The Study Board will conduct public participation meetings, as appropriate, holding at least one in each country for any specific topic or periodic update. During these meetings, the Study Board

Co-Chairs will invite comments from the public on specific or general issues associated with the study as well as provide opportunities for the public to express its views.

In order to inform and provide context for the technical investigations associated with the study, the public was consulted at the beginning of the Study to identify the public's views on the principal issues, questions and study objectives, acquire any available knowledge in the form of historical data, anecdotal information indigenous knowledge as well as existing or future plans, activities and initiatives. Public meetings were held in Burlington, VT, Saint-Jean-sur-Richelieu, QC and Plattsburgh, NY from July 11-13, 2017 and an online public comment period was open from June 27, 2017 to July 28, 2017 to provide the public with the opportunity to learn more about the study and comment on the Study Board's draft work plan.

More information on the past public meetings and the public comment period can be found here: http://www.participateijc.org/Champlain-Richelieu.

Other public participation activities or meetings will be conducted at strategic junctures throughout the study.

6.5 Public Advisory Group (PAG)

The IJC is committed to engaging with the public during the study on an ongoing basis through the Public Advisory Group (PAG). The PAG will be binational and members should represent multiple areas of interest and various geographic locations across the LCRR basin. PAG members will have the opportunity to provide advice on the Study Board's public participation activities laid out in its directive. More specifically, the PAG will be asked to:

- Advise the Study Board on public consultation, involvement and information exchange;
- Serve as a conduit for public input to the study process, and for public dissemination of study outcomes;
- Review and provide feedback on Study Board approaches, reports, products, findings and conclusions as requested; and
- Advise the Study Board on the responsiveness of the study process to public concerns.

As such, PAG members will be asked to draw upon their knowledge, contacts and experience to provide informed input to the study.

- Work on the development of state-of-the-art public involvement techniques to engage a wide range of implementation mechanisms for facilitating outreach to and the participation of First Nations and Tribes in public participation and outreach
- Use of geospatial technologies (including geodatabases for archiving and analysis; GPS for geotagged imagery) to create a participatory mapping framework that captures stories, observations and other geospatial data across the basin.

6.6 LCRR Web site

The web is an important communication tool. It is one of the primary means of providing information to a large public. As such, the Study Board will maintain and promote the Study Board LCRR Website (http://ijc.org/en_/LCRR) which provides information on the progress and achievements of the Study under the IJC's Rules of Procedure, and other information relevant to

the study. The Study Board will also use the IJC's public engagement platform www.ParticipateIJC.org to seek public comments and encourage public discussion on the study.

The Study Board will also encourage public discussion by inviting comments from the public on specific or general issues associated with the study, and providing opportunities for the public to express its views by, among other means: publicizing a mailing address in each country for correspondence and submissions; establishing and promoting the use of a dedicated e-mail address; and hosting a web-based dialogue.

The Study Board will develop the necessary communication tools and materials, ranging from posters to videos to interactive maps, to educate the public on flooding and a flood mitigation aspect considered in the study, for use during and after the study is complete.

Timeline and budgets for public engagement is reflected in table 6.1 for Canada and the U.S.

Table 6.1 Budget estimates for Public engagement

Public engagement - Canadian Budget (Can K$)							
Id	**Tasks**	**YR1**	**YR2**	**YR3**	**YR4**	**YR5**	**TOTAL**
		17-18	**18-19**	**19-20**	**20-21**	**21-22**	**CA k$**
-	Public meetings	22	22	22	22	0	**88**
-	PAG	34	34	34	34	0	**136**
-	PP&O	10	10	10	10	0	**40**
-	Translation/Edition	20	10	10	10	20	**70**
-	Communication officer	25	55	55	55	55	**245**
TOTAL		**111**	**131**	**131**	**131**	**75**	**579**

Public engagement - US Budget (US K$)							
Id	**Tasks**	**YR1**	**YR2**	**YR3**	**YR4**	**YR5**	**TOTAL**
		17-18	**18-19**	**19-20**	**20-21**	**21-22**	**U.S. k$**
-	Public meetings	15	15	15	15	0	**60**
-	PAG	68	65	65	65	32	**295**
-	PP&O	5	5	5	5	5	**25**
-	Translation/Edition	0	0	0	0	0	**0**
-	Communication officer						
TOTAL		**88**	**85**	**85**	**85**	**37**	**380**

7 Independent Review

The Independent Review Group (IRG), appointed by the IJC, will provide independent technical review and documentation of appropriate Study components and documents during the Study process. Anticipated involvement of the IRG will occur at strategic milestones such as review of selected products, draft work plan, and the final review of the study. IRG members can provide advice on the Study as a whole, as well as in regard to their respective subject-matter expertise. The IRG provides its reports through IJC staff for consideration by the Study Board and the IJC.

Budget and timeline are reflected in table 7.1 for Canada and the U.S.

Table 7.1 Timeline and budget estimates for the independent review

Independent Review - Canadian Budget (Can K$)							
Id	Tasks	YR1 17-18	YR2 18-19	YR3 19-20	YR4 20-21	YR5 21-22	TOTAL CA k$
-	4 Reviewers	10	10	10	10	10	**50**
TOTAL		**10**	**10**	**10**	**10**	**10**	**50**

Independent Review - US Budget (US K$)							
Id	Tasks	YR1 17-18	YR2 18-19	YR3 19-20	YR4 20-21	YR5 21-22	TOTAL U.S. k$
-	4 Reviewers	12	12	24	24	12	**84**
TOTAL		**12**	**12**	**24**	**24**	**12**	**84**

8 Information and Data Management

Implementing an information management (IM) framework is critical to ensuring the transparency of the study progress and process, and to protect the investments made by the LCRR SB, the IJC as well as both governments and participating agencies.

The role of the IM/IT Support Group will be to provide support to the LCRR Study Board and TWGs activities with respect to:

- Data management;
- Content management and sharing;
- Cataloguing modeling software needs
- Providing IT support
- Generation of visualization and other data products;
- Communication and collaboration;
- Coordination with IJC IM/IT staff and management on all aspects of IM/IT requirements.

Scope of Work

Task IMIT1: Survey of IM/IT Requirements:

- A register of data and model requirements will be developed and use as basis for building inventory of existing and proposed datasets. The output of the first phase of this activity will be a comprehensive list of data and model required for the LCRR Study. Survey from each TWG, information on how datasets will flow from various sources (organizations) to the various study components and contributors and, further, how the

data are then used and/or modified for use within the individual projects that together constitute the study.

- A detailed documentation of the software and hardware requirements for the study data management framework and infrastructure that will support modeling, data analysis and other science-based investigative activities will be developed.
- Efforts will be made to raise awareness of existing IJC policies so that the modeling activities take into consideration the IJC's model selection criteria.

Task IMIT2: Metadata protocols for the LCRR study: This task will be accomplished while taking into account the different the metadata specifications of contributing agencies such as the USGS, ECCC, NOAA, USACE, States of Vermont and New York and the Province of Québec. The output of this activity will be metadata specifications that will facilitate data sharing between study contributors and will enable discovery of and access to study data through public portals.

Task IMIT3: Data management system: A data management system based will be developed, implemented and operated. The output from this activity will be a turnkey database management system that will help optimize data flow within and across study projects and will lessen potential risks to data integrity that could result from improper processing (system) or transactions (individuals).

Task IMIT4: Communication and collaboration tools: The output will be online applications deployed for access to designated TWG and Study Board members, supported by documentation of acceptable usage rules and protocols. For the sake of minimizing complexity of use and administration, preferred solutions will be part of Microsoft Office and Office 365 suites of products.

Task IMIT5: Support to the Collaborative Decision Support Tool development: in collaboration with all the TWGs and AG, the IM/IT support team will work with the FMMM for the development of the Collaboration Decision Tool to provide the necessary tools and data to support the assessment of the benefits and impacts of the proposed flood mitigation and management measures.

Budget and timeline are reflected in table 8.1 for Canada and the U.S.

Table 8.1 Timeline and budget estimates for information and data management (IM/IT)

IM/IT - Canadian Budget (Can K$)							
Id	Tasks	YR1 17-18	YR2 18-19	YR3 19-20	YR4 20-21	YR5 21-22	TOTAL CA k$
IMIT1	Survey of IM/IT requirements	15	5	5	5	5	**35**
IMIT2	Metadata protocols for the LCRR Study	10	5	5	5	5	**30**
IMIT3	Data management system	5	5	5	5	5	**25**
IMIT4	Communication and collaboration tools	12	12	12	13	13	**62**
IMIT5	Support to the CDST development	15	20	20	25	15	**95**
TOTAL		**57**	**47**	**47**	**53**	**43**	**247**

IM/IT - US Budget (US K$)							
Id	Tasks	YR1	YR2	YR3	YR4	YR5	TOTAL
		17-18	18-19	19-20	20-21	21-22	U.S. k$
IMIT1	Survey of IM/IT requirements	11	4	4	4	4	**26**
IMIT2	Metadata protocols for the LCRR Study	7	4	4	4	4	**22**
IMIT3	Data management system	4	4	4	4	4	**18**
IMIT4	Communication and collaboration tools	9	9	9	10	10	**46**
IMIT5	Support to the CDST development	10	15	15	15	10	**64**
TOTAL		**41**	**35**	**35**	**36**	**31**	**176**

9 Secretariat

Watershed organisations have been contracted by the IJC to provide secretariat support to the study, to take advantage of already established networks of interested and competent participants. In Canada, the Organisme de bassin versant de la baie Missisquoi (http://obvbm.org/) has been selected, and, in the U.S., the Lake Champlain Basin Program (http://www.lcbp.org/) in Vermont has been selected.

Budget and timeline are reflected in table 9.1 for Canada and the U.S.

Table 9.1 Timeline and budget estimates for the Secretariat

Secretariat - Canadian Budget (Can K$)							
Id	Tasks	YR1	YR2	YR3	YR4	YR5	TOTAL
		17-18	18-19	19-20	20-21	21-22	CA k$
-	Secretary	30	30	30	30	30	**150**
TOTAL		**30**	**30**	**30**	**30**	**30**	**150**

Secretariat - US budget (US K$)							
Id	Tasks	YR1	YR2	YR3	YR4	YR5	TOTAL
		17-18	18-19	19-20	20-21	21-22	U.S. k$
-	Secretary	89	89	89	89	45	**401**
TOTAL		**89**	**89**	**89**	**89**	**45**	**401**

10 Study Management

Effective study management is necessary so that the study is conducted efficiently, within fiscal limits, is coordinated, and that proper oversight and study decisions are being made. This study management is provided by the Study Board, study co-chairs, study managers and IJC liaisons and other IJC support staff. Other study management activities include hosting workshops, manager travel, and facilitator or other support.

Budget and timeline are reflected in table 10.1 for Canada and the U.S.

Table 10.1 Timeline and budget estimates for study management

Study management- Canadian Budget (Can K$)							
Id	Tasks	YR1	YR2	YR3	YR4	YR5	TOTAL
		17-18	18-19	19-20	20-21	21-22	CA k$
-	Study manager	130	136	142	149	78	**635**
-	Workshops	25	25	25	25	25	**125**
-	IJC support staff	30	30	30	30	30	**150**
-	*travel fees	30	30	30	30	30	**150**
TOTAL		**215**	**221**	**227**	**234**	**163**	**1060**
*Estimated admissible travel fees							

Study management - US Budget (US K$)							
Id	Tasks	YR1	YR2	YR3	YR4	YR5	TOTAL
		17-18	18-19	19-20	20-21	21-22	U.S. k$
-	Study manager	105	105	100	100	75	**485**
-	Study co-chair	45	45	50	50	25	**215**
-	Workshops	20	20	20	20	20	**100**
-	IJC support staff	0	0	0	0	0	**0**
	*travel fees	15	15	15	15	10	**70**
TOTAL		**185**	**185**	**185**	**185**	**130**	**870**
*Estimated admissible travel fees							

11 Study Products, Timeline and Budget

This section summarizes the major products to be produced from this study, timelines of study activities and a summary of study costs by major task. As previously mentioned, this Work Plan is considered a living document and will be revised on a regular basis, as the Study progresses, work scope is modified, funding levels change, results become available and stakeholders and public inputs are provided.

Table 11.1 outlines the key reports that are currently envisioned to answer the joint References' objectives. Reports will be jointly written with all TWGs and AG, reviewed by the IRG, approved by the Study Board and presented to public.

Table 11.1 Key reports from the LCRR Study Board

Study's main reports	Leader	Completion date
Numerical modelling of the LCRR system in the context of past and future flooding events	HHM TWG	2019-04
Evaluating the causes and impacts of past floods, especially the event of 2011	RR TWG	2019-01
Development of a collaborative decision support tool (CDST)	FMMM TWG	2019-01
Conducting an in-depth study of current social and political perception on flood mitigation measures	SPE AG	2020-12
Performing a quantitative and qualitative assessment of structural and non-structural potential flood management and mitigation measures	FMMM TWG	2021-04
Development of a binational flood forecasting and real-time flood plain mapping system for operational implementation	HMM and FMMM TWGs	2021-04

Work flow description will be pursued to better define tasks and their integration to insure that this study will meet the joint Reference's objectives.

Table 11.2 summaries proposed costs for the Study's main objectives over the course of the entire study. The budget totals for the US portions of the study are currently $368,000 above the target of $5.5 million; reductions in the projected budgets are needed to meet the targeted total funds. These reductions will be identified in the Fall 2017. Adjustments to all the budgeted line items will occur throughout the study, as needed.

Table 11.2 Summary of Study Costs

Study - Canadian Budget (Can K$)						
Sections	**YR1**	**YR2**	**YR3**	**YR4**	**YR5**	**TOTAL**
	17-18	**18-19**	**19-20**	**20-21**	**21-22**	**CA k$**
Numerical modeling of the LCRR system	280	330	330	70	0	**1010**
Evaluating the causes and impacts of past floods, especially the	80	65	0	0	0	**145**
In-depth study of current social and political perception on flood	40	75	35	30	0	**180**
Development of a collaborative decision support tool (CDST)	155	485	465	300	70	**1475**
Performing a quantitative and qualitative assessment of structural and non-structural potential flood management and mitigation	120	265	205	290	55	**935**
Development of flood forecasting and real-time floodplain	10	75	105	155	55	**400**
Public participation and outreach	111	131	131	131	75	**579**
IM/IT	57	47	47	53	43	**247**
Independant Review	10	10	10	10	10	**50**
Secretariat	30	30	30	30	30	**150**
Study Management	215	221	227	234	163	**1060**
Total	**1108**	**1734**	**1585**	**1303**	**501**	**6231**
Contingency						**842**

Study - US Budget (US K$)						
Sections	**YR1**	**YR2**	**YR3**	**YR4**	**YR5**	**TOTAL**
	17-18	**18-19**	**19-20**	**20-21**	**21-22**	**U.S. k$**
Numerical modeling of the LCRR system	505	265	60	0	0	**830**
Evaluating the causes and impacts of past floods, especially the	40	85	0	0	0	**125**
In-depth study of current social and political perception on flood	20	100	30	5	0	**155**
Development of a collaborative decision support tool (CDST)	120	410	405	270	80	**1285**
Performing a quantitative and qualitative assessment of structural and non-structural potential flood management and mitigation	121	285	185	123	28	**742**
Development of flood forecasting and real-time floodplain	195	270	215	80	60	**820**
Public participation and outreach	88	85	85	85	37	**380**
IM/IT	41	35	35	36	31	**176**
Independant Review	12	12	24	24	12	**84**
Secretariat	89	89	89	89	45	**401**
Study Management	185	185	185	185	130	**870**
Total	**1416**	**1821**	**1313**	**897**	**423**	**5868**

ANNEXES

Annex 1 Governance of the study

Study Board

The Study Board is comprised of 10 members with composition reflecting the various governments and publics involved and striving for a balanced set of professional capacities. The purpose of the Study Board is to provide oversight to study activities and to help ensure that study activities will meet the goals of the references and directives of the IJC International LCRR Study.

Composition of the LCRR Study Board

Study Board			
Canada		***U.S.***	
Jean-François Cantin, *Canadian Co-Chair*	National Hydrological Service Meteorological Service of Canada Environment and Climate Change Canada	Keith Robinson, *U.S. Co-Chair*	U.S. Geological Survey New England Water Science Center
Daniel Leblanc	Direction régionale de l'analyse et de l'expertise de l'Estrie et de la Montérégie - Ministère du Développement durable, de l'Environnement et de la Lutte contre les changements climatiques	Deborah Lee	National Oceanic and Atmospheric Administration Great Lakes Environmental Research Laboratory
Michel Jean	Canadian Centre for Meteorological and Environmental Prediction Environment and Climate Change Canada	Eric Day	Clinton County Office of the Emergency Services
Richard Turcotte	Direction de l'expertise hydrique Ministère du Développement durable, de l'Environnement et de la Lutte contre les changements climatiques	Louis Porter	Commissioner for Fish & Wildlife Vermont Agency of Natural Resources
Madeleine Papineau	*Canadian Co-Chair of the Public Advisory Group*	Lesley-Ann Dupigny-Giroux	*U.S. Co-Chair of the Public Advisory Group* Professor, Department of Geography University of Vermont

Commission Staff Liaisons

The Commission Staff Liaisons are designated by the IJC shall keep the IJC informed of its progress and direction and will maintain awareness of basin-wide activities and conditions and shall inform the IJC of any such activities or conditions that might affect its work. These Commission Staff Liaisons will provide regular contact between the IJC and the Study Board.

U.S. IJC Liaison: Michael Latta

Canadian IJC Liaison : Pierre-Yves Caux

Study Core Oversight Group

A Study Core Oversight Group (called the Core Group) weekly reviews study activities and provides overall decision making on routine study issues. The Core Group is made up of the two study chairs, the two study managers and the two IJC liaisons. At periodic intervals these weekly discussions include the Study Board, TWG co-leads and others as issues need discussion and resolution. Study managers maintain notes and actions taken during the Core Group meetings.

Composition of the Study Core Oversight Group

Study Core Oversight Group				
	Canada		***U.S.***	
Co-Chairs	Jean-François Cantin	ECCC	Keith Robinson	USGS
IJC Liaisons	Pierre-Yves Caux	IJC	Michael Laitta	IJC
Study Managers	Maryse Sohier	IJC	Robert Flynn	USGS

Social Political and Economic Analysis Group

The Social, Political and Economic Analysis Group (SPE AG) is responsible for the execution of an in-depth study of current social and political perception on structural and other flood mitigation measures to support and confirm the desirability of potential mitigation measures, including consultations with the public, stakeholders and decision-makers of relevant political jurisdictions and in collaboration with the PAG. This group is responsible for addressing the social dimension of the causes and impacts of flooding in the LCRR basin, and adaptations to future climates (once hydrological water supplies and associated water levels under selected climate change scenarios are be available). The group, in collaboration with the Resource Response TWG (RR TWG), will also assess the economic aspects related to the impacts of

flooding and benefit/costs analysis as related to the potential flood management and mitigation measures.

In addressing socio-political considerations, this group will seek the input of elected officials and decision-makers to obtain their perspective on the proposed flood mitigation measures. All other communications with elected or governmental officials pertaining to the overall Study should be directed to the IJC.

The Co-Leads of this group, with the assistance of the Study Board and the PAG will determine the required approach.

Main Tasks from the 2013 PoS (Option B)

Here are the tasks attributed to the SPE AG; some will be carried out in collaboration with other TWGs:

a) Historical analysis of flooding in the LCRR
b) Impacts Analysis of the selected flooding events
c) Historical profile of the evolution of the land use, its exposure and sensitivity to flooding and solutions put forward
d) List of indicators of social and territorial sensitivity and adaptive capacity
e) Vulnerability mapping (sensitivity, social, territorial, adaptability)
f) In-Depth Study of Current Social and Political Perception on Structural Mitigation Measures

Composition of the Social, Political and Economic Analysis Group

Social Political Economic Analysis Group				
	Canada		***U.S.***	
Co-Leads	François Anctil	U. Laval	Curt Gervich	SUNY Plattsburgh
Members	Dominique Morin	U. Laval	Christopher Koliba	University of VT (UVM)
	Isabelle Thomas	U. Montréal	Heather Darby	VT extension
	Laurent Da Silva	Ouranos	Caitlin Lecker	NY Empire State Development
	Claudine Beaudoin	MAMOT, Qc government	Robert Paquin	Retired, USDA Farm Service Agency (VT) Director

Hydrology, Hydraulics and Mapping TWG

This TWG is responsible for the application of the hydrological models, the identification of data needs (historical, near-future and climatic weather scenarios), the creation of the hydraulic models, real-time floodplain mapping and the development and demonstration of a real-time operational flood forecasting and flood mapping system. Once calibrated, the models will be used to determine the effectiveness and acceptability of the various flood management and mitigation measures developed by the Flood Management and Mitigation Measures TWG.

Main Tasks from the 2013 PoS

Here are the Tasks attributed to the HHM TWG; some will be carried out in collaboration with other TWGs and the AG:

a) Description of the Lake Champlain- Richelieu River basin (morphology, dimension, topography, main tributaries, relative contribution and response times, main hydraulic structures (dams, dykes, roads, etc.) and human interventions, land use, climatology;
b) Past hydrometric records analysis on Lake Champlain and the Richelieu River to identify a subset of extreme flood events in the basin for further analysis;
c) recommendations for additional hydrometric or atmospheric monitoring that may be required to properly characterize flood events in the basin;
d) Scientific report on the causes and impacts of flooding events in the LCRR;
e) Acquisition of LIDAR data to achieve complete coverage of the LCRR floodplain;
f) High resolution bathymetry of the St-Jean Shoal & between Chambly and Fryers Dam
g) Aquatic Vegetation Mapping in the upper RR and Northern portion of LC, substrum sampling;
h) Common database of observed climate and hydrometric characteristics;
i) Common database of geophysical data;
j) Land Use Data;
k) Setup of a Seamless Digital Terrain Model;
l) Basin Physiographic Characteristics Changes Over Time;
m) Preliminary flood ferquency analysis based on inflow data;
n) Set-up and calibrate high-resolution hydrological models;
o) Measurement of overlake evaporation;
p) Climatic projection of the temporal horizon 2050-2100;
q) Ensemble generation of daily water supplies time series scenarios from climate and stochastic analysis;
r) Analysis and quantification of the benefits of Real-Time Flood Inundation Mapping
s) Definition and construction of the appropriate ensemble forecasts and analysis required for the operation of the models
t) Implementation of the water levels forecast system in U.S. and Canada operational agencies - need refinement
u) 2D Hydrodynamic Model of the entire domain
v) Surveys of water velocities and longitudinal surface profiles
w) 3D Hydrodynamic Model of Lake Champlain
x) Wind Wave Model for the Lake Champlain
y) Ice Model on the LCRR
z) Deployment of a stage/height stations on the Inland Sea portion of the lake

Composition of the Hydrology, Hydraulics and Mapping Technical Working Group

Hydrology, Hydraulics and Mapping				
Canada			***U.S.***	
Co-Leads	Jean Morin	ECCC	Jesse Feyen	NOAA
Members	Vincent Fortin	ECCC	Bill Saunders	NOAA, NWS NERFC
	Olivier Champoux	ECCC	Bill Coon	USGS
	Simon Ricard	MDDELCC	Tim Calappi	USACE
	Dominic Roussel	MDDELCC	Blaine Hastings	VT ANR DEC, Watershed Management Division

Flood Management and Mitigation Measures TWG

This TWG is responsible for the design and assessment of the flood management and mitigation scenarios (non-structural and moderate structural) and will work to plan, evaluate and rank the potential candidate measures for flood management and mitigation.

Main Tasks from the 2013 PoS

Here are the Tasks attributed to the FMMM TWG; some will be carried out in collaboration with other TWGs and the AG:

a) Flood Plain Management Practices Literature Review
b) Analysis of the effectiveness of Flood Plain Management Practives
c) Formulation of Best Practices in Flood Plain Management Applicable to the LCRR
d) Inventory of adaptation options with list of advantages and disavantages
e) Identification of opportunities for floodplain reclemation
f) Early identification of problems, decisions criteria, coordination
g) Build shared vision approach
h) Objectives and Metrics Development for Evaluation (with SPE AG)
i) Potential non-structural and flood mitigations measures
j) Evaluation and ranking alternatives
k) Solutions Recommendations

Composition of the Flood Management and Mitigation Measures Technical Working Group

Flood Management and Mitigation Measures				
	Canada		*U.S.*	
Co-Leads	Ted Yuzyk	IJC	Bill Werick	Retired from US Army Corps of Engineers
Members	Jan Adamowski	U. McGill	Ben Rose	VT Division of Emergency Management and Homeland Security
	Syed Moin	IJC	Michael Kline	VT DEC, Watershed Management Division
	Brian Morse	U. Laval	Fletcher Potter	Natural Resources Conservation Service
	Pascal Marceau	Ministère de la Sécurité publique – Qc government	Jason Shea	US Army Corps of Engineers

Resource Response TWG

This TWG is responsible for the development of the indicators required for the assessment of the various flood management and mitigation measures on wetland and fauna, recreational, domestic, industrial and municipal uses, shoreline and floodplain built environment and agriculture.

Main Tasks from the 2013 PoS

Here are the Tasks attributed to the RR TWG; some will be carried out in collaboration with other TWGs and the AG:

a) Wetlands study (with wild rice and hard stem bulrushed)
b) Wetland fish reproduction (northern pike)
c) Turtle (spiny softshell)
d) Riparian birds (least bittern, blue wing teal, black tern, Virginia rail)
e) Hairy necked tiger beetle
f) Copper redhorse
g) Muskrat overwintering
h) Integrated modeling
i) Inventory/update of recreational, domestic, industrial and municipal water uses

j) Survey to obtain from all water uses information on the preferred regime of water level fluctuations
k) Assessment of the impacts of moderate water level fluctuations on the uses
l) Flood vulnerability assessment
m) Flood hazards maps
n) Qualitative assessment of the shoreline erosion and loss of real estate property and public infrastructures
o) Agricultural flood hazard mapping
p) Quantification of current and historical agricultural practices on flooding
q) Assessment of agricultural land in the basin that is protected by dikes
r) Evaluation of the soil quality following flood deposits
s) Analyse the impacts of stream alteration, tillage and animal densities
t) Baseline Impact Assessment for FMMM
u) Cumulative Impact of selected past anthropogenic

Composition of the Resource Response Technical Working Group

Resource Response				
	Canada		***U.S.***	
Co-Leads	Glenn Benoy	IJC	Perry Thomas	Vermont Agency of Natural Resources
Members	Marianne Bachand	ECCC	Rose Paul	The Nature Conservancy (TNC) of Vermont
	Marc Mingelbier	MFFP - Qc Government	Donna Rizzo	University of Vermont's Gund Institute for the Environment
	Alain Rousseau	INRS-ETE	Phil Von Bargen	Town of Plattsburgh, NY Planning Department
	Bernard Doyon	Canadian Coast Guard	Tim Mihuc	State University of NY (SUNY) Plattsburgh

Public Advisory Group

The Public Advisory Group (PAG) will serve as a conduit for public input to the study process, and for public dissemination of study outcomes. It will assist in developing the Communications Plan, provide comment on Study Board approaches, reports, products and findings as requested, and advise the Study Board on public consultation, involvement and information exchange. As such, PAG members can promote public participation in Study Board meetings. They can also help work groups identify and utilize local expertise, data and information for their work.

The PAG will also gather information from public comments and concerns made through various means and analyze the responsiveness of study process to public concerns. The PAG will report regularly to the IJC through the Study Board and recommend improvements as appropriate.

The PAG will work with all WGs throughout the study and will have a direct voice on the Study Board through its Co-Leads.

The PAG will help the Study Board to develop and propose the best possible flood management and mitigation measures, likely to be deemed acceptable by both the concerned public, as well by the political and administrative organizations responsible for the execution of the measures.

PAG membership will be posted on the LCRR website.

Composition of the Public Advisory Group

Public Advisory Group				
Canada			***U.S.***	
Co-Leads	Madeleine Papineau	Water and Ecosystem Management	Lesley-Ann Dupigny-Giroux	University of Vermont Vermont State Climatologist/Professor Burlington, Vermont
Members	Harm Sloterdijk	COVABAR administrateur Beloeil, Qc	Philip Von Bargen	Municipal planning expert Morrisonville, NY
	Pierre Leduc	Organisme de bassin versant Baie Missisquoi, Bedford, Qc	Marla Emery	USDA Forest Service Research geographer Burlington, Vermont
	Josée Julien	Tourisme Montérégie Directrice générale Sabrevois, Qc	Mark Malchoff	Lake Champlain Sea Grant Program Aquatic Research Specialist Plattsburgh, New York
	Jérémie Letellier	Union des producteurs agricoles (UPA) – Montérégie Napierville, Qc	Eric Howe *Pending approval*	Lake Champlain Basin Program Program Director Grand Isle, Vermont

Independent Review Group

The Independent Review Group (IRG) is an independent group that will comment and review study activities and products for the IJC, and provide advice to the Study Board with objectivity on the direction and work to be produced in this study. Anticipated involvement of the IRG will occur at strategic milestones such as review of selected products and the final review of the Study.

Composition: Selected reviewers that can provide advice on the Study as a whole, as well as in regard to their respective subject-matter expertise, to reflect the Study's different areas of work to be performed.

Composition of the Independent Review Group

Independent Review *Group*				
	Canada		***U.S.***	
Co-Leads	André St-Hilaire	INRS	William Howland	Retired Director Lake Champlain Basin Program
Members	Pascale Biron	Concordia University	David Mears	Vermont Law School, former Director VT Department of Environmental Conservation
	Diane Dupont	Brock University	Todd Redder	Limnotech – Water Science and Engineering Firm
	Pierre Aubé	Retired Director General of the Centre d'expertise hydrique du Québec	Lisa Bourget	U.S. Army Corps of Engineers, former U.S. IJC section Secretary

Communications Working Group

The establishment of a Communications Working Group is viewed as essential to prepare communication products, such as news releases, banners, media statements, develop communication plans for individual events such as the upcoming summer meetings, and to provide guidance and direction to communications staff in the production of draft communication products. Such a Communications Working Group will bring together the various individuals from the Study Board, the Analytical Group, and the IJC staff involved in communications activities to provide timely and through review and development of communication plans and products and ensure coordination of activities and continuity of communications across the Study Board. This committee would not approve final communications products, as similar to the TWGs this would be a Study Board activity.

The Committee consists of:

- PAG Co-Chairs – Study Board Members
- A US and Canadian member of SPE AG

- Study Board communications staff (or until such time as those people are appointed IJC communications staff)
- One Representative of the each of the three Watershed Organizations

As with all Study Board Committees the Study Chairs, Study Managers and IJC Liaisons would be ex-officio members, and invited to all meetings.

Annex 2 Cited Organizations and Programs Acronyms

AG	Analysis Group
AHPS	Advanced Hydrologic Prediction System
CD	Canada
CDSA	Collaborative Decision Support Approach
CDST	Collaborative Decision Support Tool
CGVD2013	Canadian Vertical Datum of 2013
DBM	Database Management
ECCC	Environment and Climate Change Canada
ECCC-HES	ECCC Hydrology and Ecohydraulic section
ECCC-CMC	ECCC Canadian Meteorological Center
Eng	English
Fr	French
DEM	Digital Elevation Model
FEMA	Federal Emergency Management Agency
FMMM	Flood Management and Mitigation Measures
FVCOM	Finite Volume Community Ocean Model (Hydrodynamic model)
HHM	Hydrology, Hydraulics and Mapping
IERM	Integrated Ecosystem Response Model
IRRM	Integrated Resource Response Model
ILCRRSB	International Lake Champlain Richelieu River Study Board
IJC	International Joint Commission
IM/IT	Information Management / Information Technology

INRS	Institut national de la Recherche Scientifique
IRG	Independent Review Group
LCBP	Lake Champlain Basin Program
LCRR	Lake Champlain-Richelieu River
LiDAR	Light Detection And Ranging (Laser Altimetry Remote Sensing Data)
NAVD88	North American Vertical Datum of 1988
NGVD29	National Geodetic Vertical Datum of 1929
MDDELCC	Ministry of Sustainable Development, Environment, and Action against Climate Change
MSP	Ministère de la Sécurité Publique
NBS	Net Basin Supply
NOAA	National Oceanic and Atmospheric Administration
NY	New York
PAG	Public Advisory Group
Pi	Performance Indicator
PoS	Plan of Study
PPO	Public Participation and Outreach
RR	Resource Response
SPE	Social, Political, Economic
SUNY	State University of New York
TNC	The Nature Conservancy
TWG	Technical Work Group
US	United States

USDA	United States Department of Agriculture
USGS	United States Geological Survey
UVM	University of Vermont
VMC	Vermont Monitoring Cooperative
VT	Vermont
VT DEC	Vermont Department of Environmental Conservation
QC	Quebec
USACE	United States Army Corps of Engineers
2D	Two-Dimensional
2011 event	Major flood event in LCRR basin that occurred in Spring and Summer of 2011
3D	Three-Dimensional

Annex 3 Communication Plan - DRAFT

Introduction

This draft Communication Plan is effervescent and will be better defined as the study progresses and is reviewed by study participants.

This strategic communication plan for the International Lake Champlain-Richelieu River Study Board (ILCRRSB) is intended to describe a simple, systematic approach that the International Lake Champlain-Richelieu River Study Board (ILCRRSB), its technical working group and advisory groups will use as a pathway for enhancing the study board's communication and outreach activities over the next five years. The plan is based on the parts of the Directive and the Guidance on Communication and Public Participation to the ILCRRSB.

Strategic Communication Goals

1. **an informed public** that knows the Study Board's mandate, and the role of the IJC, the extent of what the ILCRRSB Is able to do
2. **people willing to engage** with the International Joint Commission, the Watershed Board, its committees and advisory groups

1) Informational and educational goals:

- Make the public aware of the Study and provide opportunities to participate;
- Enhance public understanding of the causes and effects of flooding and potential solutions;
- Increase understanding among researchers, municipal officials, stakeholders, indigenous peoples, students, and the general public of the role of the IJC, the ILCRRSB, the Technical Working Groups and advisory groups of the Board, in all facets of what they do
- Communicate accurately to the public about the actions and the decision-making process of the Study Board and the reasons for those actions and decision, with particular awareness on the Technical Working Groups
- Broadly disseminate Study findings as they become available; ensure that basin policy makers are aware of the Study Board's public meetings, reports and actions.
- Encourage the public to assist in disseminating Study findings.

2) Engagement goals:

- Provide for an open exchange of information which
  - insures that the Study process is open, inclusive and fair;
  - identifies and considers the public's views of the principal issues and questions of the Study;
  - arranges opportunities to understand experiences and concerns of the persons in the basin;

        - *increases awareness of the IJC and the Study Board's roles and activities in the basin until 2021*
        - *creates a better understanding by the public of the physical limitations that the geography and hydrology place*
    - *Develop awareness of* the role others could play in assisting with board activities and identify and utilize local expertise and information;
        - General public
        - Municipal officials
        - Communities and community associations - i.e., cottage owner and lake associations
        - Students in elementary, high schools, and colleges
        - Indigenous peoples – i.e., members First Nations, and American Tribes who are more directly affected by water management issues

3) Internal communication goals:

- Full utilization of the Office 365 site to support collaboration on work products among the Study Board, its technical working group and advisory groups
- Use of Office 365 site as a resource for previous work, minutes and background information

Key Messages

The Study's purpose is to identify measures to mitigate flooding and the impacts of flooding of Lake Champlain and the Richelieu River.

The Study's main objectives are to:

- Develop and recommend the implementation of a bi-national, real-time flood forecasting and flood inundation mapping system to prepare for and mitigate the impacts of floods.
- Recommend measures – structural and non-structural - to mitigate flooding and the impact of flooding throughout the basin,
- Determine public, community and stakeholder desirability of the proposed measures to mitigate flooding and the impact of flooding throughout the basin

The Study's Recommendations will be based on scientific investigations of water levels, flows and the impacts of flooding in the Lake Champlain-Richelieu River basin, as well as the social and political perceptions of stakeholders of the desirability of structural and non-structural flood mitigation measures.

Public and stakeholder engagement is an essential and ongoing component of the study, and includes both direct engagement by the Study Board and working with the Public Advisory Group. Science, outreach and public participation are expected to foster a shared understanding of the relationship between the various basin communities and their environment in the context of flooding.

Rivers and lakes by their very nature flood and no measures can completely eliminate flooding. The study will recommend measures for reducing the impact of flooding. Potential measures could include structural modifications such as storm water retention, weirs and channel enhancements, as well as non-structural approaches, such as land use regulations and enhanced use of flood plains and wetlands.

Tag Line:

Using the best science available and with ongoing consultation with the public and stakeholders, the International Lake Champlain-Richelieu River Study (ILCRRS) will recommend to the International Joint Commission flood mitigation measures (and advise of their desirability), as well as approaches for flood forecasting and preparedness.

The ILCRRS will develop shared understanding of how the human/built environment, and natural ecology of the system, interact to form a social-ecological system of which flooding is a natural and integral component, as well as how humans have modified and exacerbated flood regime.

Target Audiences and Partners (identification of key contacts)

- First Nations and Tribes: The Study Board will directly engage early with Aboriginal peoples including First Nations and Native American Tribes historically in the basin to seek their input in the Study and their involvement in the PAG as described in the directive. Neither the Commission, nor the Study has any role in fulfilling the Canadian Crown's duty to consult with Métis or First Nations.
- Municipalities
- Elected Officials
- Riparians
- Industry
- Navigation, including recreational boating
- Environment
- Agriculture

Communications Program Overview

Program Component	Audiences	Activities/Products	Resources and Roles
Information & Education	Stakeholders Civically- Engaged Community Members Indigenous peoples Elected officials Media	1. First-rate website 2. Interactive and standard material about water flows, hydrology in the basin – TWGs (ex. brochures, flyers, FAQs, reports, summaries) 3. Interactive maps and story maps 4. Newsletter 5. Videos and Presentations 6. Media releases re Board activities; reports 7. Notices of public meetings 8. Database of contact lists	Communication Committee members set direction and content for products. IJC advisors provide advice IJC public affairs advisors provide advice, use of social media, and web support. TWGs provide content and comms activities to Comms Committee. IJC advisors provide advice. IJC Communications Officer to maintain contact lists.

Consultation and Outreach	Stakeholders Civically-Engaged Community Members Indigenous peoples Elected officials	1. Public Meetings 2. Public Open Houses 3. Elected Officials Open Houses 4. Online consultations 5. Non traditional engagement 6. Presentations to stakeholders/bas in organizations 7. Record Efforts: database tracking involvement, including contacts for each in database (presentations, interviews, meetings with elected officials, etc.)	Study Board organizes public meetings and open houses with assistance from the Communication Committee and input from PAG Communication Committee set direction and content for products with input from PAG. IJC public affairs advisors provide advice and web support. Engineering advisors and/or Board Secretaries coordinate presentations. IJC Communication Officer maintain database.
Media Relations	Regional and Local media	1. Board spokespersons	Study Board Co-Chairs are spokespersons

		2. Protocols for timely responses 3. News releases 4. Emergency communications	IJC communication officer prepare press releases re news releases and emergency communications.
Internal Communications	Core Study Board meetings; Communication Committee meetings; PAG meetings; Technical Working Group meetings	1. Efficient meetings 2. Timely meeting notes with assignments and action items 3. Clear reporting and briefings 4. Notification protocols 5. Emergency contacts 6. Effective Office 365 site	Study Board Managers, Technical Working Group chairs and IJC Communications Officer organize well-run meetings with meeting notes. Engineering advisors maintain notification protocols and emergency contacts. IJC provides Office 365 support. Study Board Managers and Communications Officer update Office 365 as needed

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