GLAM GREAT LAKES – ST. LAWRENCE RIVER ADAPTIVE MANAGEMENT COMMITTEE

TRIENNIAL PROGRESS REPORT

First Report to the IJC

March 1 2015 through December 31 2016

First Report to the International Joint Commission on the progress of the Great Lakes-St. Lawrence River Adaptive Management Committee for the on-going review and evaluation of water level regulation plans.

April 12th, 2017

GLAM Committee 1st Triennial Progress Report to the International Joint Commission

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Blue text identifies other International Joint Commission Board and Committee affiliations

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NOTE: *The Great Lakes-St. Lawrence River Adaptive Management (GLAM) Committee was established by the International Joint Commission (IJC) and is comprised of an equal number of members from the United States and Canada. Members of the Committee serve at the pleasure of the IJC and are expected to be full participants in all activities of the Committee. As with all IJC Boards and Committees, the GLAM Committee members serve in their personal and professional capacity, not as a representative of their agencies or employers.*

Overview

Purpose

A Directive issued in January 2015 by the International Joint Commission (IJC) established the Great Lakes – St. Lawrence River Adaptive Management (GLAM) Committee to provide scientifically sound data, knowledge and technologically advanced tools to support management decisions by the Great Lakes Boards, the IJC, and the governments that may effectively adapt the implementation of water level and flow regulation plans to new or evolving ecological, economic and climate changes over time.

The directive outlines the requirements for the GLAM Committee and includes direction for the Committee to prepare a comprehensive progress report to be coordinated with the preparation of the IJC's "Triennial Assessment of Progress" (TAP) Report under the Great Lakes Water Quality Agreement, the first of which is due in early 2017. In order to synchronize these two reports, the GLAM Committee needed to produce its first progress report covering just the first 22 months of Committee activity (March 1, 2015 through December 31, 2016) to ensure future GLAM Committee triennial reports will coincide with the TAP report into the future. This first GLAM Committee progress report provides the background and context for why the Committee was established, summarizes the progress to date, identifies key communication and engagement initiatives, and outlines the Committee's strategic direction over the next three to five years including potential opportunities and challenges.

Towards the end of this reporting period in December 2016, the IJC signed an updated order of approval adopting Plan 2014 for the regulation of water levels and flows of Lake Ontario and the St. Lawrence River. The updated order includes an Adaptive Management component and will provide further direction for activities of the GLAM Committee in the months and years to come. Moving forward, the GLAM Committee will work to coordinate and support monitoring and assessments necessary to evaluate the effectiveness of Plan 2014 as well as the existing regulation plan for the outflows of Lake Superior, Plan 2012 adopted by the IJC in January 2015.

Contents *This Progress Report covers the following topics:*

1. Introduction

One thing is for sure: the future is uncertain. In the Great Lakes-St. Lawrence River, it is not clear how changing climate conditions will affect hydrology and what impact this might have on socio-economic and environmental indicators in the basin or how these indicators might evolve over time. That means it is impossible to design plans for regulating Great Lakes water levels and outflows (commonly referred to as regulation plans) that will be optimal for all stakeholders and for all possible future hydroclimate conditions, including climate change scenarios. In 2006, the International Joint Commission's (IJC's) International Lake Ontario – St. Lawrence River Study (LOSLRS) Board recommended adopting adaptive management as a means to review and refine its regulation plan recommendations which had been based on computer models representing the LOSLRS Board's best understanding of the system. The simulations provided an indication of how varying water levels might respond to a range of hydroclimate conditions and the impact this would have on several management objectives including wetland health and shore protection costs. The process recommended by that Board – plan, act, monitor, evaluate, learn, adjust, revisit the decision - is the essence of adaptive management.

The IJC's subsequent International Upper Great Lakes Study (IUGLS) Board agreed with the adaptive management approach and went further, making specific implementation suggestions after identifying the institutional challenges to adaptive management. The idea received important support from Great Lake organizations such as the Great Lakes Commission (GLC) and Conservation Ontario (CO). IJC Commissioners created an interim Great Lakes-St. Lawrence River Adaptive Management Task Team (Task Team) to explore the feasibility of the adaptive management strategy proposed by the IUGLS Board, and based on Task Team recommendations the IJC created the Great Lakes-St. Lawrence River Adaptive Management (GLAM) Committee in January 2015.

In establishing the GLAM Committee, the IJC has embraced the concept of adaptive management as an important tool to improve management of the outflows of Lake Superior and Lake Ontario and address potential questions raised by them and the Niagara Board as more knowledge about the system is gained and as conditions evolve. This greater emphasis reflects the understanding that adaptive management can be an effective way of coping with uncertainty and variability, including the uncertain impacts of climate change. As per the IJC Directive, the GLAM Committee reports to the three Great Lakes-St. Lawrence River Boards (Superior, Niagara and Lake Ontario-St. Lawrence (Boards)) as illustrated in Figure 1. The GLAM Committee will coordinate the required monitoring, modelling and assessment related to the on-going evaluation of the regulation plans and address other questions that may arise due to changing conditions in consultation with the Boards.

Figure 1: GLAM Committee reporting structure

The GLAM Committee membership (see list on Page ii) was confirmed by the IJC in February 2015 and the first meeting of the Committee took place in early March of the same year. Under the directive, the Committee was charged with preparing its first work plan along with an initial outreach and engagement strategy within the first six months, and these were delivered to the IJC in September 2015. The Committee commenced its first year work plan while also considering a longer-term strategy for moving forward.

The intent of this progress report is to provide background and context for why the GLAM Committee was established, report on the progress of the Committee in fulfilling its initial work plans and summarize the direction the Committee intends to head over the next three to five years.

1.1 Background and context

The overall objective of the GLAM Committee is to support and provide information to the International Great Lakes Boards, and advise them and the IJC regarding the effects of the implementation of the Orders of Approval and Directives issued by the IJC. This includes the on-going review and evaluation of regulation plans related to:

a) their effectiveness in managing water levels and flows in the Lake Ontario-St. Lawrence River system and the outflows of Lake Superior in the past and into the future;

b) examining how the system may be changing over time and whether any modifications to the plan(s) may be warranted to address any issues or changing conditions identified during the process; and
c) any other questions or concerns raised by the Boards and/or IJC that may affect the Boards' water management decisions over the long-term.

It is important to emphasize that the GLAM Committee is not a decision-making body, but rather a sub-committee of the Boards established to support and advise them in their responsibilities for the on-going review of their regulation plans and in addressing other questions that arise within their mandates.

1.2 GLAM Committee vision and scope

GLAM Vision 2020: *The Great Lakes-St. Lawrence River Adaptive Management (GLAM) Committee will serve the International Joint Commission's (IJC) International Great Lakes Boards by providing scientifically sound data, knowledge and technologically advanced tools for making management decisions that may effectively adapt the implementation of water flow/level regulation plans to new or evolving ecological, economic and climate induced changes within the system over time.*

The GLAM Committee's work covers the entire Great Lakes-St. Lawrence River system from Lake Superior through to Trois-Rivières on the St. Lawrence River with priority given to factors that drive regulation plan outcomes or are directly impacted by water levels and flows managed by the existing control structures. The directive to the GLAM Committee is to design a work plan that assists the Boards by addressing these questions:

1. How accurately are the impacts of levels and flows represented by current data and models used in the evaluation of the management of levels and flows?
2. Will future water supplies be different from those used to test the current management of levels and flows;
3. How are physical, chemical, biological, and/or socio-economic conditions of the system changing over time?
4. How can the management of levels and flows benefit physical, chemical, biological and/or socio-economic conditions?

While the work of the GLAM Committee is an on-going, long-term effort, there are timelines that must be adhered to as follows:

- Annually, the GLAM Committee will produce an updated work plan for approval by the Boards and the IJC.
- Semi-annually, the GLAM Committee will report on progress in fulfilling the work plan to the Boards and the IJC.

- Once every three years, the GLAM Committee, in consultation with the Boards, will prepare a comprehensive progress report timed to inform the IJC's Triennial Assessment of Progress (such as this first one in 2017).
- As directed by the IJC, and not more than 15 years after its establishment, the GLAM Committee will facilitate comprehensive reviews and evaluations of the regulation plans by the Boards, based on the available data and information garnered over the review period.

The GLAM Committee oversees, facilitates and integrates a body of work designed to continually review and improve the outcomes from the regulation of levels and flows in the Great Lakes-St. Lawrence River system. The Committee is supported by a number of agencies from both sides of the border, and the body of work includes all the systems and jurisdictions that make improved outcomes possible by directly linking water levels and flows to benefits and impacts. Where possible, this body of work builds on the efforts of collaborators. Collaboration is not an aspiration for the GLAM Committee, it is a necessity. The work described in this progress report is work done by its members, agencies and individuals across many disciplines. While the GLAM Committee is not a decision-maker, it ensures that the Boards, the IJC, and the United States and Canadian governments, have the best available data, scientific results, and knowledge in a format needed to support decisions about regulation plans.

Each year the GLAM Committee produces an annual work plan outlining the activities to be carried out in support of the directive. These work plans are designed to accommodate the short-term requirements of the Committee while building towards the longer-term commitments, including the 15-year review identified in the directive. The annual work planning cycle coincides with the U.S. fiscal year beginning in October and ending in September.

1.3 The adaptive management process

Collaborative, integrated, adaptive management offers an approach that helps address the uncertainties of an evolving future associated with climate change and the potential for extreme water levels and associated impacts. The definition used in a 2009 U.S. Department of the Interior guide is a simple one - "Adaptive management is a systematic approach for improving resource management by learning from management outcomes" (Williams et al., 2009, pg. 1 based on Sexton et al., 1999). The guide also reports that "Adaptive management as described here is infrequently implemented, even though many resource planning documents call for it and numerous resource managers refer to it." (Williams et al., 2009, pg. 1 based on Elliott et al., 2004)

Adaptive management is intended to improve management decisions over time as more is learned and as conditions evolve. Consider this, if decisions are made to take action to adapt to a condition, is it not important to know if the action is working and whether what was anticipated actually happened? And even more, is it not important to know if the actions taken will continue to work into the future? What if conditions change? Is it still the right action under future unknown conditions? Is it robust or flexible enough to adapt to future conditions such as unforeseen climate changes?

The GLAM Committee provides the important ingredients for effective adaptive management, based on these four components:

1) Good planning;
2) Collaboration;
3) Quantitative predictive modelling supported by monitoring; and
4) Decision Support which including the storing, integration, assessment, interpretation and presentation of information and knowledge.

GLAM Committee planning is focused not just on how well water level regulation rules performed under historically observed conditions, but also under potential future conditions. Many previous IJC studies were bound by short-term mandates and time limited funding. In contrast, the GLAM Committee, which emerged from these previous studies, is designed to evolve into a sustainable institution which builds on study findings and conclusions as part of an ongoing process to ensure water level regulation strategies continue to meet objectives under uncertain future conditions.

Collaboration is a key requirement for the GLAM Committee as it strives to work through international agencies and with experts, researchers, modellers, practitioners (including the Boards), and the various stakeholders who are affected by regulation decisions, as well as with the decision-makers consisting of the IJC and the U.S. and Canadian governments.

Monitoring and quantitative predictive modelling utilizes real world observations to both input good data to the models and to verify model results. It is impossible to monitor everything in such a geographically immense system as the Great Lakes-St. Lawrence River, so quantitative predictive models allow for assessments of potential actions based on model outcomes. They also allow for testing the performance of those potential alternative actions not only under observed water supply conditions, but also under a whole range of plausible future conditions.

A critical step in developing predictive models is to identify performance indicators that relate water levels and flows to impacts that people care about. These relationships must represent something of importance, and there must be a level of confidence in the data and science that support it. For example, one of the relationships identified to evaluate regulation rules on the Lake Ontario – St. Lawrence River system was coastal wetland biodiversity. This is directly linked to patterns of water level fluctuations (see text box). Monitoring changes in wetland plant vegetation distribution can be conducted and the results compared to model output to support validation.

Using available tools, water level regulation rulesets can be simulated with a quantitative predictive model to estimate how many acres of wetlands will be populated with meadow marsh plants under certain water level conditions. Quantification of outcomes in this way helps support trade-off and risk analysis, and help determine when and if a decision to take action, such as modifying a regulation plan, needs to be made in the future.

Decision support, the fourth component, ensures that not only is information and knowledge being gained, but it is being properly maintained, organized, interpreted, and visualized to support decision-making. It is not good enough just to monitor, model, and produce results. There must be a process for turning the data and information into meaningful assessments which can be understood and properly assessed by decision making bodies such as the IJC and its Boards. How binational information is collected, collated, integrated, stored, visualized, interpreted and disseminated to the Boards, the IJC and other stakeholders is critical to the success of adaptive management and a key focus of the GLAM Committee.

1.4 Preparing for the on-going review of regulation plans:

The context in which the GLAM Committee operates is based on the current operational strategies for regulating both Lake Ontario and Lake Superior outflows as well as the evolving understanding of how the regulation of water levels and flows in these systems impacts the various socio-economic stakeholders and ecological conditions as developed through the IJC's LOSLRS and IUGLS. Sections 1.4.1 and 1.4.2 provide further details on current and alternative regulation strategies in both systems as well as generalized descriptions of potential water level and flow impacts for various interest groups as developed during those studies.

The International Niagara Board of Control is also supported by the GLAM Committee although this board does not regulate Great Lakes water levels and flows. At the time of this initial progress report, there are no high priority issues that need to be examined on behalf of the Niagara Board. However, the efforts of the GLAM Committee, for instance in terms of the components of net basin supply, will improve understanding of the overall system that will also benefit the Niagara Board. Section 1.4.3.2 addresses some of the primary considerations in regard to the Board's role in regulating water levels in the Chippawa-Grass Island Pool on the Niagara River.

1.4.1 Baseline conditions – Lake Ontario and the St. Lawrence River

1.4.1.1 Lake Ontario – St. Lawrence River regulation

Regulation of outflows from Lake Ontario and the St. Lawrence River through control structures at Cornwall, Ontario and Massena, New York (see Figure 2) was managed in accordance with Plan 1958-D from 1963 through 2016. Plan 1958-D was designed to meet the criteria in the IJC's 1956 Order of Approval based on the supplies experienced from 1860 to 1954 for the benefit of hydropower, commercial navigation and shoreline property interests. The criteria did not explicitly recognize either the environment or recreational boating. Plan 1958-D was not designed for extreme water supplies and the International St. Lawrence River Board of Control had to deviate from the plan in accordance with "criterion k" of the 1956 Order to moderate lake levels when supplies were outside those experienced between 1860 and 1954. The Board also had discretionary authority to deviate from Plan 1958-D to provide benefits to one or more interests if it could do so without causing adverse effects to others. The Board exercised its discretionary authority as needed to try to address changing needs and

interests. As a result, the best expression of the operating regime in place from 1963 to 2016 was known as "Plan 1958-D with deviations," or Plan 1958-DD.

Figure 2: Moses-Saunders Dam at Cornwall, Ontario and Massena, New York (from Jacob Bruxer, Environment and Climate Change Canada)

In 1999, the IJC informed the governments that it was becoming increasingly urgent to review the regulation of Lake Ontario levels and outflows, initiating an effort spanning nearly sixteen years and culminating in a new regulation plan for Lake Ontario and the St. Lawrence River (Figure 3). The initial 1999 request to review the regulation plan was in response to potential climate change conditions, in view of dissatisfaction on the part of some interests, and in light of environmental concerns. The IJC appointed members to the International LOSLRS Board. Then, on December 11, 2000, the IJC issued a directive to the Study Board to review the impact of the regulation of levels and flows in the Lake Ontario–St. Lawrence River system on affected interests.

The governments of Canada and the United States each invested US$10 million to support the LOSLRS from 2000 to 2006. The LOSLRS provided an improved understanding of the impacts of water level regulation on a variety of interests, including the environment. It also helped lead to an improved understanding of the overall functioning of the Lake Ontario–St. Lawrence River system and the impacts of various climate scenarios. This entire process was supported by a Public Interest Advisory Group (PIAG).

The LOSLRS Board developed three candidate regulation plans. Each regulation plan was judged to perform better than the existing plan in terms of overall net economic and environmental benefits to various stakeholder interests throughout the system. During public consultation on the LOSLRS Board's Final Report in March 2006, the IJC found that no single plan sufficiently satisfied enough interests such

that any one of the plans could be chosen. The IJC reviewed the candidate regulation plans and developed Plan 2007, which attempted to provide improved benefits to all basin interests. However, Plan 2007 failed to win broad public support.

In December 2009, the IJC formed an internal working group with members from five jurisdictions in the Lake Ontario–St. Lawrence River basin (Canada, United States, Ontario, Quebec, and New York) to develop a proposal for an updated Order of Approval and regulation plan that would address the concerns of each jurisdiction. Based on the advice received from the jurisdictions, the IJC developed a new proposal for regulation of the Lake Ontario–St. Lawrence River system, which was a modified version of one of the proposed plans in the Study. In 2012, the IJC invited public comments on the proposed new approach. Unlike Plan 2007, the new plan was supported by many, but there were also many who voiced their opposition. These included property owners along the south shore of Lake Ontario in New York State who raised concerns about the increased risk they would face under the proposed approach. Commercial navigation interests also raised some concerns about potential impacts under the most extreme low water conditions.

The IJC and the ad hoc working group continued through the rest of 2012 to refine the new regulation plan in order to preserve the environmental benefits that had broad public support and reduce the negative impacts on the south shore of Lake Ontario. In May 2014, the IJC advanced Plan 2014 as the preferred option for regulating Lake Ontario-St. Lawrence River water levels and flows in a report titled *Lake Ontario-St. Lawrence River Plan 2014: Protecting Against Extreme Water Levels, Restoring Wetlands and Preparing for Climate Change*. After careful interagency review by Canadian and United States governments, both countries agreed by letter dated December 6, 2016 to replace Plan 1958-DD with Plan 2014 understanding that the new regulation plan will result in improved environmental conditions while maintaining benefits to navigation, hydro and recreational interests and minimizing potential impacts.

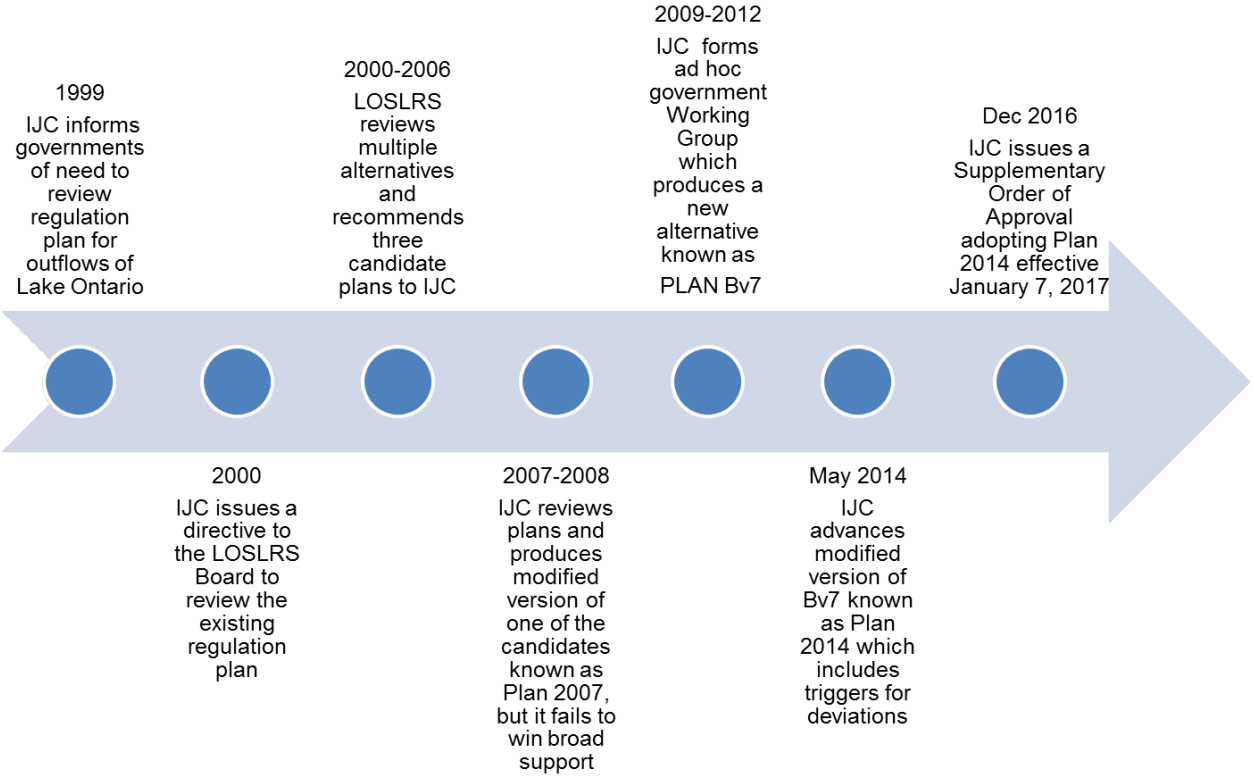

Figure 3: Plan evaluation timeline leading to implementation of Plan 2014

The expected outcomes of the new regulation plan are outlined in the IJC's May 2014 report to the Canadian and United States governments. The Executive Summary indicates that relative to 1958-DD, "*Plan 2014 will:*

- *provide essentially the same level of benefits to **domestic water uses**;*
- *provide essentially the same level of benefits for **navigation**;*
- *increasing by a small amount the generation of **hydropower** at the Moses-Saunders dam and the Hydro-Quebec facilities on the St. Lawrence River;*
- *provide **riparians** (owners of shoreline property) on the upper and lower river essentially the same level of protection;*
- *result in a small reduction of benefits to **riparians** on Lake Ontario, in the form of increased costs of maintaining shoreline protection structures;*
- *work to restore the natural **environment** of Lake Ontario and the upper St. Lawrence River that support wetlands, birds, amphibians, fish, and mammals;*
- *have a mixed effect on **recreational boaters**; and,*
- *provide essentially the same benefits **downstream** of the dam as does the previous regulation regime.*

Some of the benefits enjoyed by domestic water users, commercial navigation, hydropower producers and riparians on the St. Lawrence River are a result of ad hoc, discretionary decisions by the International St. Lawrence River Board of Control. Plan 2014 will make

> *these benefits more assured and predictable, by removing the discretionary aspect of many of these decisions and formally making them part of the Plan's regulation rules.*" (IJC, 2014, pg. viii)

On December 8, 2016, the IJC issued a Supplementary Order of Approval adopting Plan 2014 effective January 7, 2017.

Part of the GLAM Committee's role moving forward is to track Plan 2014's performance over time to verify whether observed outcomes are consistent with those predicted from the evaluation tools developed during the LOSLRS.

1.4.1.2 Existing socio-economic interests

The regulation of water levels and flows in the Lake Ontario – St. Lawrence River system (Figure 4) directly and indirectly impacts a range of users and stakeholders. During the IJC's LOSLRS, impacts were grouped within six general categories including Municipal and Industrial Water Uses, Commercial Navigation, Hydropower, Coastal Riparian property owners, Recreational Boating and the Ecosystem.

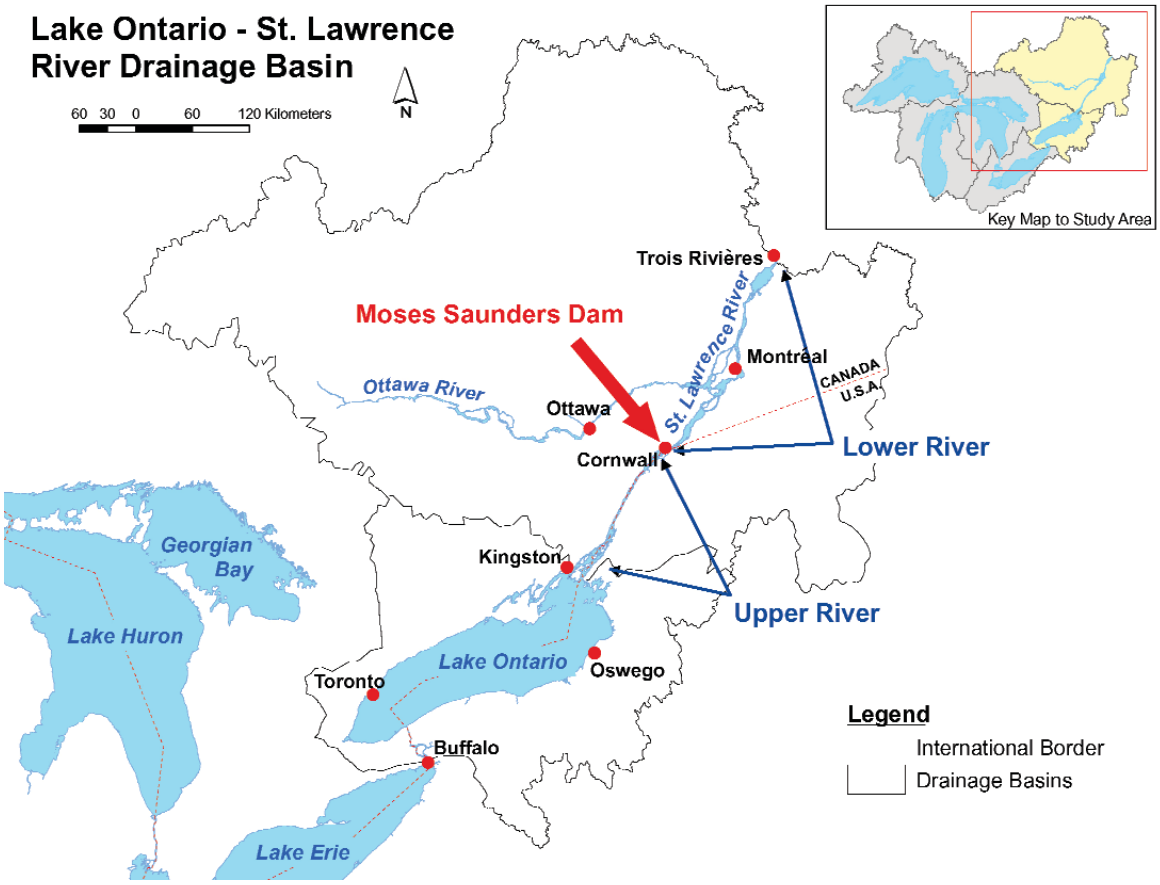

Figure 4: Lake Ontario - St. Lawrence River Discharge Basin (from IJC, 2014)

i. Municipal and Industrial Water Uses

The Municipal and Industrial water uses category captures "public and private sector organizations using water for domestic, municipal, and industrial purposes" (IJC, 2014, pg. 26). This includes both private and municipal water intakes as well as self-supplied industrial facilities. General municipal and industrial water use vulnerabilities associated with changing water levels are described in Appendix 2 and include the importance of having enough water to ensure adequate intake capacity while not having so much water that shoreline infrastructure facilities (e.g. treatment plants) suffer potential damages. In the context of the comparison of regulation plan outcomes during the LOSLRS and subsequent follow up work by the IJC, sensitivities were identified regarding prolonged drought conditions and the potential implications for municipal water supply systems, particularly on the St. Lawrence River (IJC, 2014). As well, some municipal water infrastructure facilities on Lake Ontario and in particular the south shore (e.g. Sodus Bay, Monroe County) were found to have experienced problems due to high water conditions in recent decades under Plan 1958-DD (IJC, 2014). From an impact evaluation perspective, municipal and industrial water use damages were found to be primarily driven by water supply conditions such as prolonged droughts and high supply periods with alternative regulation plans having limited relative differences in estimated impacts. In other words, there are potential water level and flow vulnerabilities related to municipal and industrial water uses on Lake Ontario and the St. Lawrence River but the many alternative regulation plans reviewed were not found to provide particular benefits or reduce potential impacts relative to Plan 1958-DD. However, it was also recognized during the LOSLRS that information associated with private shore wells was incomplete in some areas.

Municipal and Industrial Water Users Performance Indicators

- Water Quality infrastructure costs avoided on the lower St. Lawrence River
  - Based on costs of upgrading municipal drinking water treatment plants to treat test and odor compounds.
  - Based on costs required to adapt plants to lower than critical levels.

ii. Commercial Navigation

Commercial Navigation captures "domestic and international commercial ships transporting goods in the St. Lawrence and Lake Ontario system, including the St. Lawrence Seaway and the Port of Montreal" (IJC, 2014, pg. 27). This includes domestic and international vessels that transit the Great Lakes and the St. Lawrence Seaway as well as ocean-going vessels that call on the Port of Montreal (Figure 5).

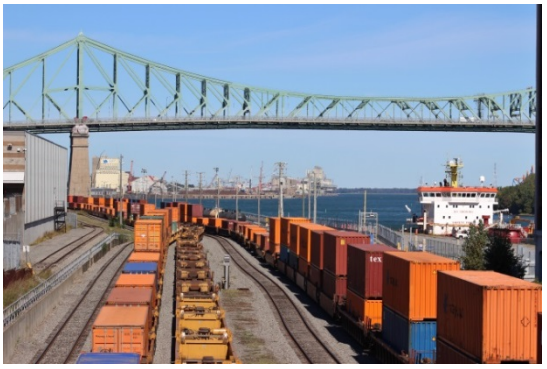

Figure 5: Port of Montreal (from Jacob Bruxer, Environment and Climate Change Canada)

The regulation of outflows affects water levels and

flows throughout the Lake Ontario and St. Lawrence Seaway which, in-turn, has impacts on commercial navigation throughout the system. Appendix 2 provides some general vulnerability characteristics related to water levels and flows for the various interests, including Commercial Navigation.

Critical commercial navigation priorities on the Lake Ontario – St. Lawrence River system include the need to reduce the risk of low water levels throughout the system and maintaining the continued ability of the Board to accommodate, as necessary and when conditions permit, transit of particular vessels through short-term minor deviations. High water level problems have also been observed related to velocity issues in portions of the Seaway.

The critical navigation performance indicators in the LOSLRS (see text box) were based on 1995-1999 shipping data and may not accurately represent current or future conditions. Containership traffic at the Port of Montreal has increased since the LOSLRS was conducted, and this has yet to be fully assessed. Finally, the navigation models used in LOSRLS were different and were disconnected from the upper Great Lakes models used during the IUGLS. A full system model recognizing the importance of lake-to-lake navigation could be pursued.

Commercial Navigation Performance Indicators:

- Transportation costs on Lake Ontario – based on tonne-km travel time
- Transportation costs on the Seaway – based on tonne-km travel time
- Transportation costs on below the Port of Montreal – based on tonne-km travel time

iii. Hydropower Production

Hydropower production on the International Section of the St. Lawrence River occurs at "the Robert-Moses station owned by the New York Power Authority and the Robert H Saunders station of Ontario Power Generation, which together form the Moses Saunders Dam" (IJC, 2014, pg. 29). These stations, shown in Figure 6, collectively produce approximately 13 million MWh of energy annually (IJC, 2014). In addition, there is approximately 12 million MWh of annual energy production at the Hydro Quebec facilities of Beauharnois and Les Cèdres stations at the outlet of Lake St. Francis (IJC, 2014). Generally speaking, hydropower production on the St. Lawrence River benefits from higher flows through the turbines as well as greater differences in water levels upstream and downstream of the turbines (see Appendix 2). However, excessively high flows that exceed turbine capacity require "spilling" of excess water which then cannot be used to produce electricity.

Figure 6: A downstream view of the Moses-Saunders hydropower facility (source - Environment and Climate Change Canada)

During times of lower water levels, outflows are typically reduced, which results in reduced water through the turbines and in general a reduction in the amount of energy produced.

The primary performance indicator developed during the LOSLRS was the value of hydropower produced (see text box). Hydropower prices directly impact estimates of the value of hydropower produced and there have been significant changes in the electricity market in the past decade. During the LOSLRS, the importance of week to week *stability* in flows was recognized as was the month to month *predictability* in flows over the longer term so that hydropower plant maintenance and operations could be maximized to reduce the need to spill water (IJC, 2014). Stability and predictability characteristics were captured in hydrologic metrics as opposed to economic performance indicators.

Hydropower Performance Indicators:

- Value of energy produced based on station head, flow, efficiency rate and price of electricity.
- Cost of foregone peaking opportunities (NYPA and OPG only) based on weekly averaged regulated release and value of peaking opportunity
- Predictability/stability of flows to maximize efficiency based on changes in flow and foregone energy production.
- Frequency and severity of spill at Long Sault Dam during spawning season.

iv. Coastal Property Interests

The LOSLRS estimated approximately 25,000 privately owned riparian properties along the Lake Ontario and upper St. Lawrence River shoreline and an additional 5,770 single family dwellings on the lower St. Lawrence River that may have some direct or indirect water level vulnerabilities (IJC, 2014). Figure 7 illustrates shoreline property in the Olcott, NY area of the Lake Ontario shoreline. On Lake Ontario and the upper St. Lawrence River, the combination of above average water levels and storm events leading to large waves and/or storm surge has led to observed shoreline damages, particularly along the south shore. Shoreline damages have been in the form of erosion and damage to existing infrastructure due to wave activity as well as short-term

Figure 7: Coastal riparian property - Olcott, NY (Source - U.S. Army Corps of Engineers)

inundation and flooding. While Lake Ontario typically reaches its annual maximum level in June, past shoreline damages have been much more commonly reported during the spring and fall periods when storm events tend to be more frequent and intense. Despite provisions in Plan 1958-D to provide some protection to Lake Ontario shoreline property owners, shore damages have been reported over the past several decades that Plan 1958-D was in place. Coastal riparians tend to prefer water level conditions closer to the long-term average, the objective of Plan 1958-D, and Board deviations attempting to reduce Lake Ontario water level variability was generally regarded as a benefit for this category.

There were three coastal performance indicators used during the LOSLRS including erosion to unprotected property, first floor flooding, and shore protection structure maintenance (see text box). Of the three, the shore protection maintenance performance indicator represented the greatest percentage of the coastal damages and the greatest differences between alternative regulation plans. Sensitivity testing conducted during the LOSLRS identified a number of model assumptions with the potential to impact results. Follow-up work has been initiated on a few of these items including assumptions regarding shore protection crest elevations. On the St. Lawrence River, flood inundation conditions have been periodically observed since the implementation of Plan 1958-D. These flood conditions tend to coincide with the Ottawa River freshet and efforts were made through deviations to manage Lake Ontario outflow during the freshet period to reduce the potential for downstream damages. Flood damages have occurred in the past and are expected to occur in the future particularly as some existing development remains in the flood hazard zone. Plan 2014 has internal rules that attempt to balance flood risks throughout the system, though these also require careful monitoring of conditions and may be modified through major deviations made by the Board under the high trigger levels outlined in Criterion H14 of the 2016 Supplementary Order.

Coastal Performance Indicators:

- Lake Ontario
  - Damages due to first-floor flooding
  - Erosion to developed, unprotected properties – cost of protection, not value of lost material
  - Shore protection maintenance costs
- Upper St. Lawrence River
  - Damages due to first-floor flooding
- Lower St. Lawrence River
  - Damages due to first-floor flooding
  - Shore protection maintenance costs

v. Recreational Boating

Recreational Boating represents pleasure boating, fishing, marinas, and the commercial cruise ship industry on the Lake Ontario – St. Lawrence River system (IJC, 2014). Recreational boating activities tend to be limited by both low and high water conditions with Appendix 2 providing a further description of general water level sensitivities. The primary performance indicator for recreational boating during the LOSLRS was the average annual economic value of boating relative to the regulation plan based on the net economic value or boaters' willingness-to-pay for boating over and above what they are already paying. Analysis done during the LOSLRS indicates that loss of recreational boating

opportunities on Lake Ontario and the St. Lawrence River are more severe during low water conditions when compared to high water conditions. Each geographic reach studied in the Lake Ontario-St. Lawrence River system had an ideal water level range. The size of the ideal water level range varied by reach and was a function of the vulnerability of marinas within those specific reaches. In terms of expected plan performance, the IJC notes in its Plan 2014 report that "compared to Plan 1958-DD, Plan 2014 would reduce average recreational boating benefits on Lake Ontario and the river upstream of Ogdensburg, NY and increase them on Lake St. Lawrence and the river below the dam" (IJC, 2014, pg. 47).

Recreational boating activity tends to be greatest during the June to September period; however regulation of water levels in the upper St. Lawrence River between Lake Ontario and the Moses-Saunders dam during the fall period has particular impact on the extension of the boating season during that period. The LOSLRS identified the potential for recreational boating benefits in the upper St. Lawrence by maintaining slightly higher water levels through the early fall period, although this benefit was not explicitly tracked through the recreational boating performance indicator. The Recreational Boating performance indicator has not be updated or modified since the end of the LOSLRS.

1.4.1.3 Existing ecosystem conditions

The ecosystem interest broadly captures "the biological components of the natural environment of Lake Ontario and the St. Lawrence River, together with the ecological services they provide to people who live and work in the region." (IJC, 2014, pg. 42) This includes habitat conditions influenced by water level and flow conditions, notably nearshore coastal wetland habitats, as well as the bird, fish, mammals, invertebrate, amphibian, and reptiles that are directly impacted by water level and flow conditions on Lake Ontario and the St. Lawrence River for some critical portion of their life cycle (see Figure 8). The quality of the Lake Ontario – St. Lawrence River system has become especially important as the surrounding communities transition to an increasing reliance on tourism and recreational opportunities. The magnitude of water level and flow changes as well as the timing and rate of change are all critical factors impacting ecosystem response. The IJC's 2014 report notes that regulation plan 1958-DD reduced some of the variability in lake levels that would have naturally occurred, and this in turn has had a negative impact on ecosystem response while providing a benefit to coastal riparian property owners. Adoption of Plan 2014 is expected to reduce such ecosystem impacts, albeit at a slight

Figure 8: Great Lakes coastal wetland (Source - Environment and Climate Change Canada)

reduction in benefits to riparians. This potential trade-off between ecosystem and coastal riparian water level preferences represented a primary conflict in the consideration of alternative regulation plans within the LOSLRS and subsequent IJC deliberations. There was no specific deviation guidance under Plan 1958-DD designed to improve ecosystem outcomes within the system. The coastal wetland meadow marsh indicator for Lake Ontario was established as a fundamental indicator of ecosystem response to water level changes as it provides diverse wetland vegetation reflecting observed flooding and dewatering history. Wetland habitat is also critical to various life stages of associated bird, mammal and fish species. The additional suite of key environmental performance indicators used during the LOSLRS is provided in Table 1. Some monitoring of wetland vegetation communities has been conducted in Lake Ontario coastal wetlands since the end of the LOSLRS to develop a baseline dataset that could be used to compare to model output for further validation.

Lake Ontario	
Vegetation	▪ Wetland meadow marsh community – total area, supply-based
Fish	▪ Fish guild (low vegetation, 18C) – spawning habitat supply ▪ Fish guild (high vegetation, 24C) – spawning habitat supply ▪ Fish guild (low vegetation, 24C) – spawning habitat supply ▪ Northern Pike – Young-of-Year recruitment ▪ Largemouth Bass – Young-of-Year recruitment
Birds	▪ Virginia Rail – median reproductive index ▪ Least Bittern – median reproductive index (species at risk (SAR)) ▪ Black Tern – median reproductive index (SAR) ▪ Yellow Rail – preferred breeding habitat coverage (SAR) ▪ King Rail – preferred breeding habitat coverage (SAR)
Upper St. Lawrence River	
Fish	▪ Fish guild (low vegetation, 18C) – spawning habitat supply, Thousand Islands to Lake St. Lawrence ▪ Fish guild (high vegetation, 24C) – spawning habitat supply, Thousand Islands to Lake St. Lawrence ▪ Fish guild (low vegetation, 24C) - spawning habitat supply, Thousand Islands to Lake St. Lawrence ▪ Northern Pike – Young-of-Year recruitment, Thousand Islands to Lake St. Lawrence ▪ Largemouth Bass – Young-of-Year recruitment, Thousand Islands to Lake St. Lawrence ▪ Northern Pike – Young-of-Year net productivity in Thousand Islands area
Birds	▪ Virginia Rail – median reproductive index on Lake St. Lawrence
Mammals	▪ Muskrat – House density in drowned river mouth wetlands in Thousand Islands area
Lower St. Lawrence River	
Fish	▪ Golden Shiner – suitable feeding habitat surface area from Lake St. Louis to Trois-Rivières ▪ Wetland Fish – abundance index in lower St. Lawrence River ▪ Northern Pike – suitable reproductive habitat surface area from Lake St. Louis to Trois-Rivières ▪ Eastern Sand Darter – reproductive habitat surface area from Lake St. Louis to Trois-Rivières ▪ Bridle Shiner - reproductive habitat surface area from Lake St. Louis to Trois-Rivières (SAR)
Birds	▪ Migratory waterfowl – floodplain habitat surface area from Lake St. Louis to Trois-Rivières ▪ Least Bittern – reproductive index from Lake St. Louis to Trois-Rivières ▪ Virginia Rail – reproductive index from Lake St. Louis to Trois-Rivières ▪ Migratory waterfowl – productivity from Lake St. Louis to Trois-Rivières ▪ Black Tern - reproductive index from Lake St. Louis to Trois-Rivières
Herptiles	▪ Frog species – reproductive habitat surface area from Lake St. Louis to Trois-Rivières ▪ Spiny Softshell Turtle – reproductive habitat surface area from Lake St. Louis to Trois-Rivières (SAR)
Mammals	▪ Muskrat – surviving houses from Lake St. Louis to Trois-Rivieres

Table 1: Key environmental performance indicators from the LOSLRS (from LOSLRS, 2006, pg. 17)

1.4.2 Baseline conditions – Lake Superior outflows

1.4.2.1 St. Marys River regulation

Regulation of outflows through the St. Marys River occurs through a series of structures at Sault Ste. Marie, Ontario and Sault Ste. Marie, Michigan. Figure 9 illustrates the various structures and channels. Water is routed through a series of control structures, including three hydropower plants, a series of navigation canals and locks, and a gated dam known as the Compensating Works. The total flow and allocation to each of these structures is currently determined based on rules outlined in the IJC's 2014 Supplementary Order of Approval and in regulation Plan 2012, which was approved by the IJC and officially implemented by the International Lake Superior Board of Control (ILSBC) in January 2015 as a replacement for Plan 1977-A which had been in place since 1990. Plan 2012 was the recommended plan identified during the IUGLS and was designed to maintain or slightly improve existing benefits to stakeholders throughout the upper Great Lakes system, balance Lake Superior and Lake Michigan-Huron water levels, and follow more natural month-to-month outflow patterns in the St. Marys River.

In May 2014, the International Lake Superior Board of Control requested approval and was authorized by the IJC to deviate from Plan 1977-A, using Plan 2012 as a guide to address rising water levels and outflows from Lake Superior. Subsequently, starting in May 2015, the Board again requested and received authority from the IJC to deviate from the regulation, this time deviating from Plan 2012 in order to reduce month-to-month flow changes in the St. Marys Rapids related to continued above-average outflows from Lake Superior combined with short-term changes in flow capacity at some of the hydropower facilities, resulting from necessary maintenance activities. The requests to deviate were made in recognition of the potential impacts on stakeholders and with the desire to support the intent of the plan to provide natural month-to-month flow patterns in the St. Marys River and reduce potential ecosystem impacts in the rapids area specifically. The Board continues to work with support from the GLAM Committee on reviewing deviation approaches, recently required due to above average Lake Superior outflows, and impacts of variations in the capacity of the hydropower facilities to pass flows outlined in the regulation plan.

Figure 9: Looking downstream at the St. Marys River (from International Lake Superior Board of Control)

1.4.2.2 Existing socio-economic conditions

The IUGLS identified six broad interest categories to capture existing conditions within the Lake Superior, Lakes Michigan-Huron, and St. Marys River geographic area (Figure 10). These interest categories are consistent with the ones used during the LOSLRS.

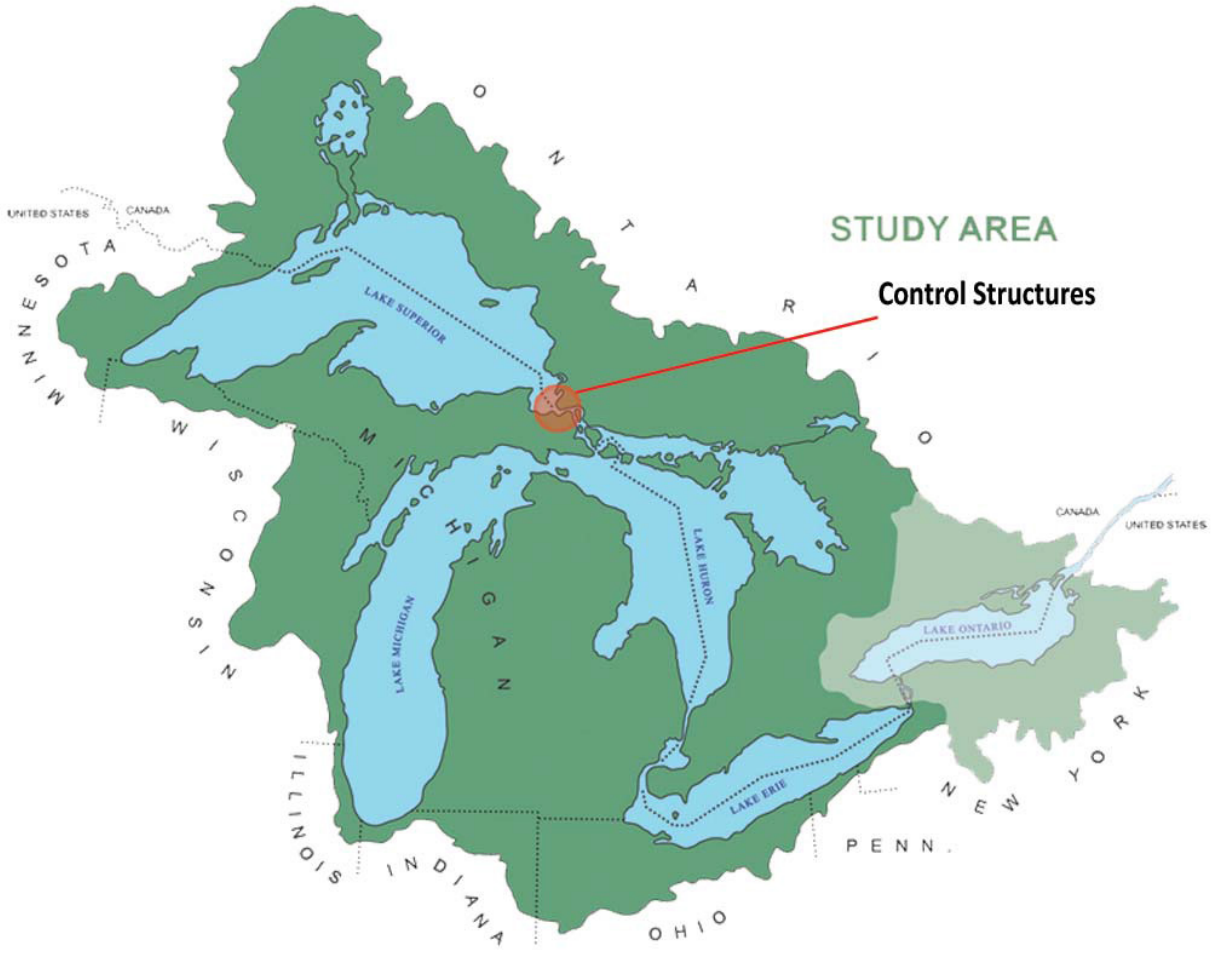

Figure 10: Study area for the IUGLS (from IUGLS, 2012, pg. 2)

The evaluation of alternative regulation plans during the IUGLS was framed by the expected impacts of Lake Superior outflow regulation on both Lake Superior and Lakes Michigan-Huron water levels, which tend to be fairly limited due to a combination of physical and operational constraints on the system. This is particularly the case for Lakes Michigan-Huron where Lake Superior outflow regulation can do little to reduce the risk associated with long-term water level fluctuations without resulting in a disproportionate risk of extreme water level fluctuations on Lake Superior. Performance indicators and more broadly defined coping zones were used to identify potential water level and flow impacts on the key interest groups. Rather than ranking based on some specific measure of overall performance, regulation plan alternatives were instead tested for robustness, defined as their capacity to meet particular regulation objectives under a broad range of plausible future hydrological scenarios, including those related to climate change. A challenge common to the development of all performance indicators in the IUGLS was capturing the broad geographic scale of the interests across the upper Great Lakes at a resolution appropriate for the relatively small water level differences between regulation plan options. The challenge was approached differently by the various technical working groups with some

conducting a detailed study site analysis that was extrapolated to the broader system and others gathering more general information throughout the system.

The final IUGLS report of March 2012 (IUGLS, 2012) provides a good general overview of the interest categories and the sensitivity to water level changes identified during the study. The results of the study provide useful context for consideration by the GLAM Committee in guiding current and future activities, and a brief summary is provided for each interest group in the following sections. Appendix 3 identifies a few general highlights related to how the various interest groups of the upper Great Lakes are impacted by changing water levels and flows. The key economic performance indicators as reported in the IUGLS report (IUGLS, 2012) are provided in Table 2 and the eight primary ecological performance indicators in Table 3.

Key Interest	Primary PI	Other PIs
Domestic, Municipal and Industrial Water Uses	None used; all plans had very similar impacts in this interest, so a primary PI was not useful in plan selection	- Frequency and duration of affected services and the population affected
Commercial Navigation	Net average annual change in the costs of shipping	- Frequency and magnitude of navigation benefits by month
Hydroelectric Generation	Net average annual change in the value of energy at St. Marys River hydropower plants	- Net average annual change in power produced at the St. Marys River plants - Frequency and magnitude of hydropower benefits by month - Robustness of plan benefits with various price assumptions - Minimum power produced in a month - Minimum value produced in a month - Month-to-month and annual flow stability
Coastal Zone	Net average annual change in the costs of maintaining shoreline protection	- Flooding: high water levels statistics - Low water impacts: low water level statistics - Erosion: rates of erosion on lakes Superior and Michigan-Huron (but there are no significant plan differences in the erosion rates)
Recreational Boating and Tourism	None used; although plans could change the number of slips available on Lake Superior, there was no evidence that showed an unusable slip actually hindered boating	- Number of slips each month that were unavailable for use - Boat ramp utility score

Table 2: Summary table of IUGLS economic performance indicators (taken directly from IUGLS, 2012, pg. 68)

PI Code	Zone C Condition	Performance Indicators	Goal is to Avoid Zone C
SUP-01	SUP-01 measures the degree to which natural **peak water level** events on Lake Superior, which occur roughly on a 30-year cycle, are lowered by regulation		Prevent/minimize range compression for Lake Superior
SUP-02	SUP-02 measures the degree to which there is a **drawdown** of Lake Superior following a peak water level 'event'. SUP-01 and SUP-02 scores closer to pre-project (and larger than 1977A) are better		Prevent/minimize range compression for Lake Superior
SUP-04	Peak summertime water level rises above 184.0 m (603.7 ft) for **3 or more** consecutive years	Wild rice abundance in Kakagon Slough, near Duluth, MN	Maintain viability of wild rice population
SUP-05	Mean spring (Apr-May) water level is more than 0.67 m (2.2 ft) below the mean level for the preceding 10-year period for **7 or more** consecutive years	Northern pike habitat and population in Black Bay on the north shore of Lake Superior	Prevent significant decline in northern pike abundance
SMQ-01	Mean flow rate during June maintained below 1,700 m3/s (60,035.5 ft3/s) for **5 or more** consecutive years	Lake sturgeon spawning habitat	Provide suitable spawning area for lake sturgeon
SMQ-02	Mean flow rate during May-June maintained below 2,000 m3/s (70,600 ft3/s) for **7 or more** consecutive years	Maintenance of flushing flows in the channel into Lake George (A small lake near Sault Ste. Marie, ON)	Maintain substrate in Lake George channel
LMH-07	Mean growing season (Apr-Oct) water level is less than 176.00 m (577.4 ft) for a period of **4 or more consecutive years**	Fish and wildlife community eastern Georgian Bay wetlands	Maintain fish access to eastern Georgian Bay wetlands (current conditions)
LMH-08	Mean growing season (Apr-Oct) water level is less than 176.12 m (577.8 ft) for a period of **4 or more consecutive years**	Fish and wildlife community eastern Georgian Bay wetlands	Maintain fish access to eastern Georgian Bay wetlands (+100 yr conditions)

Table 3: Summary table of the eight primary IUGLS ecological performance indicators (taken directly from IUGLS, 2012, pg. 70)

i. Domestic, Municipal and Industrial Water Uses

The Domestic, Municipal and Industrial Water Uses interest group represents "public and private sector organizations using water for domestic, municipal and industrial purposes." (IUGLS, 2012, pg. 24). Vulnerabilities in this sector are similar to those identified as part of the LOSLRS. The Technical Working Group conducted a survey of facilities along the upper Great Lakes shoreline with regard to vulnerabilities related to high and low water levels. In the end, no specific performance indicator was developed related to this interest group because the survey response sample size was not large enough

on the various lakes and in some cases the survey responses were too vague to develop quantitative relationships to water levels. The Technical Working Group identified particular gaps in the analysis as:

- Limited survey response due to facility security concerns and the short response time of the survey.
- Lack of available costs estimates related to the mitigation of high and low water impacts.

The Technical Working Group did develop general coping zones guidance (Bartz and Inch, 2011) related to 1) the population served by public water systems that are affected at high and low water levels and 2) the number of water withdrawal facilities where problems are expected to occur and/or where operations may cease along with the optimal operating range and levels where modifications are necessary for intakes and outfalls.

ii. Commercial Navigation

The Commercial Navigation interest "represents owners/operators of the United States and Canadian fleets of bulk carriers, tankers, barges and other commercial ships transporting goods in the Great Lakes-St. Lawrence Seaway system, as well as ocean-going cargo vessels that use the system" (IUGLS, 2012, pg. 26). Figure 11 shows a freighter transiting the locks at Sault Ste. Marie. Commercial Navigation benefits for the upper lakes were estimated in the Shared Vision Model based on shipping costs between destinations given available navigation water depths. Generally speaking, a regulation plan that provides slightly greater water depths across the full route will allow for a greater amount of cargo per load to be carried, thus reducing costs. "The maximum tonnage of cargo that can be carried, however, is limited by the design capacity of vessels. Higher water levels also can damage and disable loading/unloading facilities, and impact safe operation of navigation locks if levels reach the top of approach walls or lock gates" (IUGLS, 2012, pg. 27). The differences between alternatives could then be compared using an economic metric. The Study

Figure 11: Freighter transiting the locks at Sault Ste. Marie (source - Jacob Bruxer, Environment and Climate Change Canada)

Board preferred plans that reduced shipping costs, or at least kept costs comparable to what they would have been under Plan 1977-A (IUGLS, 2012). The Commercial Navigation Technical Working Group noted that the transportation cost model is based on 2005 vessel traffic information (Moulton et al., 2011). While comparison of regulation plan options was possible on a relative basis, future use of the model will need to consider how vessel traffic and transportation costs may be changing over time and whether it will be necessary to update the performance indicator to capture some of those changes (e.g. modal shifts from boat to rail or changes in seasonality of vessel traffic). Furthermore, acknowledging that commercial navigation extends throughout the Great Lakes system, including Lake Ontario and the St. Lawrence River, development of a model to capture water level and flow impacts throughout the system has been suggested.

iii. Hydropower Production

The IUGLS report defines the hydropower generation interest as representing "owners/operators of the three hydroelectric generating stations on the St. Marys River as well as the stations on the Niagara River and the Welland Canal." (IUGLS, 2012, pg. 28) Appendix 3 outlines some of the broad hydropower sensitivities to water level changes on the upper Great Lakes. As part of the plan review, the Study Board primarily considered changes to production at the St. Marys River sites when considering regulation plan alternatives and quantified these changes based on the value of hydropower produced. There is a good understanding of hydropower production capabilities at the St. Marys River, however, estimates of future hydropower prices are highly variable and ultimately influence estimates of hydropower value. During the IUGLS, Synapse Energy Economics, Inc. prepared a hydropower price forecast report (White and Napoleon, 2011) and assumptions in that report may need to be re-evaluated as electricity markets continue to evolve. As well, the ILSBC through its implementation of Plan 2012 has identified that hydropower plant maintenance activities can result in large, frequent fluctuations in St. Marys Rapids flow and water level conditions, in particular during relatively high Lake Superior outflow periods, and this is expected to have some unintended outcomes in the rapids unless strategies can be developed to address them.

iv. Coastal Zone

The Coastal Zone TWG focused primarily on private shoreline property owners (riparians) on the upper Great Lakes. A series of white papers were prepared identifying critical shoreline vulnerabilities related to flooding, erosion, shore protection, and low water conditions as driven by fluctuating water levels. Some of the highlights are provided in Appendix 3. As with many of the other interest groups, changes in water levels over time can impact coastal riparians although it can be difficult to differentiate impacts between alternative water level regulation plans that produce similar water levels in the upper Great Lakes. The primary economic metric used within the IUGLS Shared Vision Model (SVM) to differentiate coastal zone impacts was the cost of maintaining shore protection structures. These costs were estimated using a model developed by Coldwater Consulting Ltd. (MacDonald, Wiebe, Davies, 2011). Additional tools were developed related to flooding, erosion, and low water impacts although they were only applied in site specific areas and not to the broader regulation plan evaluation in part

because of the significant funding that would be required to gather data at a resolution necessary to apply the tools to broad geographic areas and the fact that the value of doing so would be reduced given the small differences in performance that would be expected from the different regulation plan options reviewed. The Coastal Zone TWG identified a number of follow up items that could be considered in the context of adaptive management implementation (Coastal Zone Technical Working Group, 2011), although the prioritization should be reconsidered in the context of GLAM Committee priorities. As well, the implementation of Plan 2012 has led to the identification of specific riparian issues not directly addressed during the study that are likely of greater immediate priority, notably, flooding of recently developed areas of Whitefish Island in the St. Marys River.

v. Recreational Boating, Marinas and Tourism

The IUGLS looked at water level benefits and impacts to recreational boating activity, marinas, and coastal tourism including cruise ship traffic (IUGLS, 2012). Appendix 3 describes some of the associated benefits and impacts, particularly related to recreational boating and marina operations. Marina operations tend to be more dramatically impacted by low water levels when compared to high water levels (IUGLS, 2012). There was one recreational boating and tourism performance indicator used to evaluate regulation plans during the IUGLS. The indicator was the change in availability of boat slips across the study area and was represented as a Pass/Fail score based on whether changes were considered disproportionate for a particular lake or region. The coastal tourism and cruise ship sectors were not represented by a performance indicator. Data on boating activities and trends is fairly limited and may represent an area that requires further investigation through adaptive management.

1.4.2.3 Existing ecosystem conditions

The IUGLS broadly captured the ecosystem interest as "the biological components of the natural environment of the upper Great Lakes basin, together with the ecological services that the natural environment provides to the people who live and work in the region." (IUGLS, 2012, pg. 29) The Ecosystem Technical Working Group (TWG) covered a large geographic area across the upper Great Lakes and considered a range of indicators that could be used to represent potential regulation plan impacts and benefits. While water level fluctuations affect varying habitats and species differently, the Ecosystem TWG identified some general characteristics and expected responses associated with water level changes on the upper Great Lakes as well as flows in the St. Marys River that are captured in Appendix 3. Through the development of the Integrated Ecological Response Model 2 (IERM2) and associated coping zones, the Ecosystem TWG was able to characterize potential vulnerabilities and benefits from changing water levels and broadly compare regulation plan alternatives. As part of its study summary, the Ecosystem TWG identified a number of priority items and the GLAM Committee may consider following up on these items to validate assumptions. These items are described in detail in the Ecosystem TWG summary document (Mackey, 2012). Three of these priorities were related to the St. Marys River and included:

- Following up on proposed operational flow adjustments in the months of June and July to improve sea lamprey control efforts.

- Verifying the potential benefits of slowing the speed of gate setting changes at the Compensating Works to reduce the risk of fish and other aquatic animals from being flushed out of or stranded in the St. Marys Rapids.
- Determining whether additional environmental benefits could be achieved by increasing the minimum gate setting to increase the wetted surface area and provide additional habitat in the St. Marys Rapids.

In addition, Mackey (2012) identifies a number of broader adaptive management items of particular interest to the Ecosystem TWG including:

- Develop a robust long-term environmental monitoring and analysis program to collect and analyse data necessary to develop and implement effective adaptive management strategies.
- Use IERM2 modelling results to focus limited monitoring resources on the most sensitive sites.
- Identify "sentinel" monitoring sites to track systemic environmental responses to changes in water level regime, either from natural variability or from variability resulting from regulation and/or climate trends.

1.4.3 Baseline conditions - The Niagara River

1.4.3.1 The International Niagara Board of Control

The International Niagara Board of Control was established by the IJC in 1953 to provide advice on matters related to the IJC's responsibilities for water levels and flows in the Niagara River. The Board's main duties are to oversee water level regulation in the Chippawa-Grass Island Pool on the Niagara River and installation of the Lake Erie-Niagara River Ice Boom. The Board also collaborates with the International Niagara Committee, a body created by the 1950 Niagara Treaty to determine and verify the amount of water passed over Niagara Falls and the amount available for hydropower generation.

The Board meets at least twice a year and provides semi-annual progress reports to the IJC. The Board also produces an annual report on the operation of the Lake Erie-Niagara River Ice Boom and holds an annual public meeting to provide information and receive input from all interested persons.

1.4.3.2 Regulation of the Chippawa-Grass Island pool

Various international studies have examined factors affecting the scenic beauty of Niagara Falls and the Niagara River. Remedial works, first suggested in 1929, were constructed in the 1950s to enhance the scenic beauty, provide for the most beneficial use of the river's waters and maintain the minimum flows over the Falls required by the 1950 Niagara Treaty. The remedial works consist of the International Niagara Control Works, which controls water levels in the Chippawa-Grass Island Pool, and excavation and fill on both flanks of Horseshoe Falls. The excavation and fill provide for a more even and unbroken flow across the Horseshoe Falls.

The International Niagara Control Works is a structure extending about 0.8 kilometre (0.5 mile) into the river from the Canadian shore at the downstream end of the Chippawa-Grass Island Pool (Figure 12). Its

18 sluice gates allow for precise changes in the flow over the Falls and adjustments to the water level in the Chippawa-Grass Island Pool, where water is diverted for hydroelectric power production.

Figure 12: International Niagara Control Works (source - Frank Seglenieks, Environment and Climate Change Canada)

The Board, under its directive from the IJC, monitors the effects of the operation of the control works by the power entities, Ontario Power Generation and the New York Power Authority, on the Chippawa-Grass Island Pool. The Board maintains an additional directive with the power entities for this purpose and monitors compliance. To lessen the adverse effects from high or low water levels, the power entities are required to maintain the long-term average level of the Chippawa-Grass Island Pool within certain tolerances. Under abnormal flow or ice conditions, these tolerances may be suspended and a somewhat wider range of levels is permitted. Operation of this structure does not change the total flow of the Niagara River and has no measurable effect on Lake Erie water levels.

The ability to change water levels near Niagara Falls by adjusting gate settings and altering plant diversions has, on numerous occasions, assisted in river rescue operations to save people from going over the Falls.

1.4.3.3 Lake Erie-Niagara River ice boom

In 1964 the IJC approved an application by the power entities to install a floating ice boom in Lake Erie near the entrance to the Niagara River. The purpose of the ice boom is to reduce the frequency and duration of heavy ice runs into the river. Ice runs may cause ice jams that can damage shoreline property and significantly reduce power diversions. The ice boom speeds formation of and stabilizes the natural ice arch near the head of the Niagara River every winter. The boom is owned, operated and maintained by the power entities.

When in position, the 2,700-metre (8,000-foot) ice boom is located approximately three kilometres (two miles) upstream of the Peace Bridge and spans the outlet of Lake Erie (see Figure 13). Installation of the floating sections of the boom may begin on December 16th, or when the water temperature at the Buffalo water intake reaches four degrees Celsius (39 degrees Fahrenheit), whichever occurs first. All floating sections of the ice boom are opened by the first of April, unless ice cover surveys on or about that date show there is more than 650 square kilometres (250 square miles) of ice remaining in the eastern end of the lake. If that is the case, the ice boom opening may be delayed.

Figure 13: Lake Erie-Niagara River ice boom (source - Peter Kowalski, Ontario Power Generation)

2. What Has the GLAM Committee Been Working On?

The GLAM Committee has had two work plans endorsed by the Great Lakes Boards and the IJC. The Committee's first work plan covered the period from October 1st, 2015 to September 30th, 2016 (the FY16 work plan) and the second work plan covers the period from October 1st, 2016 through September 30th, 2017 (the FY17 work plan). The projects undertaken to date represent initial activities of the GLAM Committee and include follow up to questions raised during the previous LOSLRS and IUGLS as well as new and emerging items that support needs of the various boards. There is a lot of ground to cover, both in terms of the range of stakeholders and broad geographic extent, and the GLAM Committee has had to be realistic in what was tackled first given available resources. Many of the work plan tasks have been and continue to be supported primarily through in-kind contributions provided by members of the GLAM Committee and their associates. Where resources could not be fully applied or the task ended up being more work than originally anticipated, certain FY16 work plan tasks were carried over as part of the FY17 work plan. It is also important to note that the GLAM Committee will seek to incorporate a variety of other sound scientific contributions by non-GLAM associates or partners where deemed appropriate. The following sections categorize the range of tasks being pursued by the GLAM Committee as part of the FY16 and FY17 work plans in four areas, including: 1) Impact Assessment Activities[1], 2) Hydroclimate Science Activities, 3) Plan Review and Evaluation Activities, and 4) GLAM

[1] Formerly referenced as "Stakeholder Assessment" activities this language has been updated to more accurately capture the Committee's efforts in this category.

Committee Oversight and Administration Activities. General updates within these broad categories are provided below. While the GLAM Committee has made excellent progress since its inception in January 2015, it is not to the point yet with its work products to report on any key findings. As a result, this 2017progress report to the IJC is focused on outlining some of the key initiatives pursued by the GLAM Committee, while in future reports, it is expected that further emphasis will be placed on reporting key findings and outcomes of specific GLAM Committee projects. It is important to emphasize that the activities to date represent a summary of the initial work of the GLAM Committee. As the GLAM Committee moves forward, efforts will be made within the context of available resources to expand activities to cover the full range of stakeholders that may benefit or be impacted by water level regulation.

2.1 Initial impact assessment activities

The GLAM Committee has made progress on a number of Impact Assessment activities designed to ensure outcomes of water level and flow scenarios can be measured and assessed for the various interests. Impact Assessment activities help address key questions identified in the IJC directive to the GLAM Committee, including whether existing performance indicators are appropriate and adequate for the on-going review of the regulation plans, whether impact assessment models can be verified by real data, and whether socio-economic and ecosystem conditions as they relate to Great Lakes water level regulation are changing over time.

Some of the initial priorities identified by the GLAM Committee as part of the FY16 work plan relate to follow up on a number of questions which emerged from the development of impact assessment tools during the LOSLRS and were utilized post study in the evaluation and selection of Plan 2014. In some cases, work on these initial tasks has carried over to the FY17 work plan. In addition, the GLAM Committee has initiated Stakeholder Assessment activities designed to review and track the need for potential new performance indicators to assess regulation plan performance. The categories only serve to organize the work that has been planned and conducted so far by the GLAM Committee and do not represent the limits of impact assessment activities that can and will be prioritized in the future.

2.1.1 Lake Ontario coastal wetland response to changing water levels

2.1.1.1 Rationale

The LOSLRS and the IJC's Plan 2014 Report both emphasized coastal wetland plant diversity as a critical measure of ecosystem response to water level management on Lake Ontario. The water supply based meadow marsh performance indicator was the primary wetland metric used to evaluate performance of regulation plans in terms of ecosystem response and the overall wetlands model also represents a baseline component required to evaluate ecosystem outcomes for a number of other key ecosystem performance indicators used in the LOSLRS (e.g. some of the bird, fish and species at risk performance indicators). The expected meadow marsh response was a fundamental driver in the decision to support Plan 2014. Recognizing the importance of the wetlands indicator and related ecosystem indicators in driving the decision to adopt Plan 2014, the GLAM Committee has initiated a number of tasks to gather

on-site observational wetland vegetation data in order to establish baseline conditions and to help verify and validate the wetlands performance indicators and modelling tools developed during the LOSLRS.

2.1.1.2 Progress

The GLAM Committee coordinated wetland field data collection at eight Canadian wetland sites on the shore of Lake Ontario in August/September 2015. The data collection was supported through the International Watersheds Initiative (IWI) and in-kind contributions of the Canadian Wildlife Service (CWS), Environment and Climate Change Canada. The field data collection protocol has been developed by staff from the CWS over the past number of years specifically to look at the impact of water level fluctuations on Lake Ontario wetland vegetation (Grabas and Rokitnicki-Wojcik, 2015). The protocol is designed to track vegetation for a range of elevations within each wetland geomorphic type. Figure 14 shows a temporary Global Positioning System (GPS) base station used to support the field survey at one of the sample wetland sites in 2015. Figure 15 illustrates how the field sampling points were distributed at the Presqu'ile Bay Marsh during 2015 sampling.

Figure 14: Temporary Global Positioning System (GPS) base station at wetland sample site (Canadian Wildlife Service, 2016)

The GLAM Committee has been using the 2015 data, along with previously collected data from the CWS (2009-2014) and State University of New York – Environmental Science and Forestry (SUNY-ESF) (2012, 2014), to initiate a project to compare observations from the wetland field monitoring to model output from the meadow marsh performance indicator.

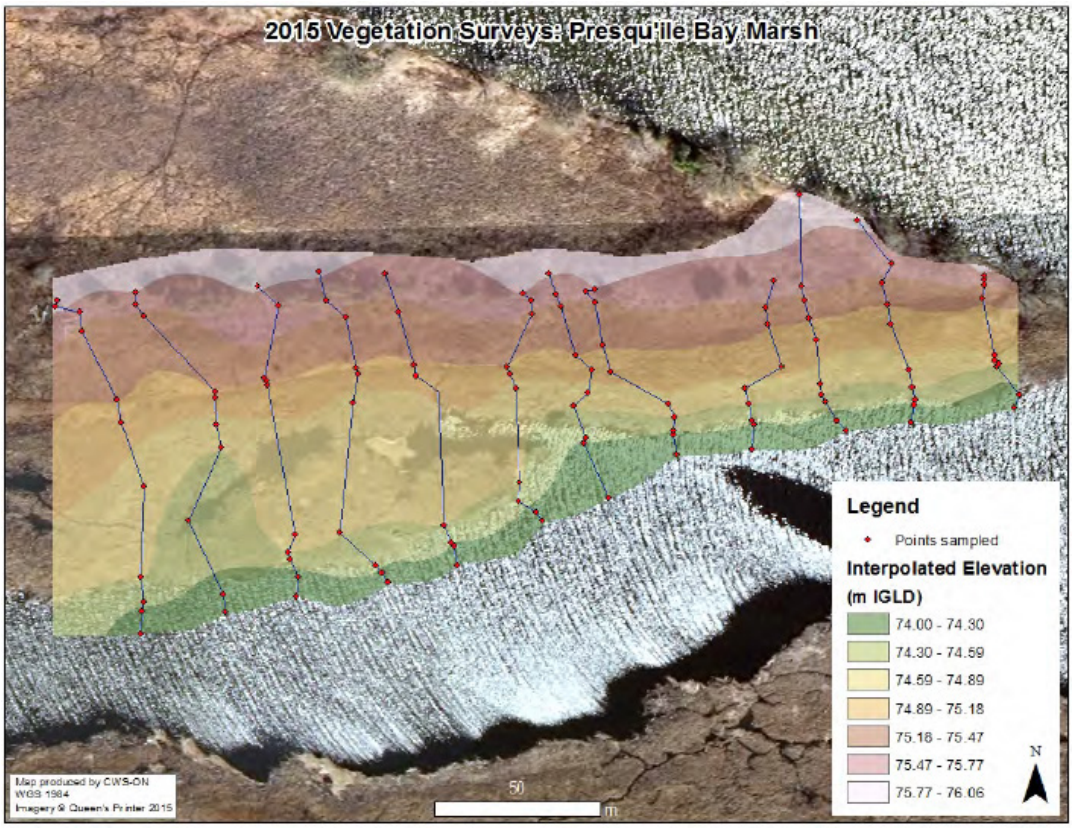

Figure 15: Example of field transects at the Presqu'ile Bay marsh along with an interpolated elevation surface based on 2015 sampling (CWS, 2016)

A workshop was held in Burlington, Ontario in March 2016 with wetland experts and individuals involved in the original performance indicator development to discuss appropriate procedures. Since that time, the available field data has been processed using an ordination analysis and an Excel-based dashboard has been developed to compare simulated changes in wetland vegetation zones to those observed based on the field data. The GLAM Committee and associated wetlands experts are in the process of reviewing the results and identifying critical findings. The work will enable the GLAM Committee to establish procedures to validate the algorithm used to predict the dynamics of wetland meadow marsh extent across Lake Ontario and upper St. Lawrence River wetlands during the LOSLRS. The wetlands algorithm is based on flooding and dewatering and was therefore not likely to show a great difference under Plan 1958-DD with the recent water supplies during which wetland data was gathered (2009-2015). Nevertheless, the data may be used to help establish a baseline of expected outcomes under recent water level conditions. Further data will be required in the future under Plan 2014.

Additional wetland monitoring is planned for sites on the U.S. and Canadian shores of Lake Ontario in 2017 to supplement the available data and feed back in to the validation process. In addition, the GLAM Committee will benefit from high resolution (8 cm GSD) ortho-imagery and land elevation data collected at 17 Canadian wetland sites on Lake Ontario by the Ontario Ministry of Natural Resources and Forestry (MNRF) in 2016 and a related EPA GLRI funded project using aerial imagery to look at vegetation distribution in a series of U.S. wetland sites. These projects initiated by MNRF and the EPA will benefit the GLAM Committee in future verification of the wetland algorithm, while also illustrating the importance of collaborative efforts to support long-term GLAM Committee objectives. The GLAM Committee will also benefit from New York State funding to SUNY-College of Environmental Science and Forestry to monitor various ecological performance indicators including Northern Pike spawning and Muskrat dens.

The GLAM Committee has also included two wetland imagery related projects in the FY17 work plan. The first project is designed to estimate the spatial extent of certain wetland vegetation communities using air photo interpretation across a series of U.S. Lake Ontario coastal wetlands. The bulk of the work is expected to take place in the summer of 2017 and the results will support comparisons to similar efforts based on earlier aerial photos to track changes in distribution over time. The project will also complement a wetland vegetation classification project currently being supported through the Lake Ontario Lakewide Action and Management Plan (LAMP). The GLAM Committee also supported a project in its FY17 work plan comparing Common Reed (*Phragmites*) extent in a series of coastal wetlands along the Lake Ontario shoreline in the Province of Ontario. The project was designed to test whether there is any relationship between *Phragmites* distribution on Lake Ontario and water level regulation. During the fall of 2016, the distribution of *Phragmites* within the sample wetlands was estimated through aerial and oblique photograph interpretation. Figure 16 identifies a *Phragmites* patch in Frenchman's Bay wetland. A draft report was prepared and will be submitted to the GLAM Committee in 2017 for review. All Lake Ontario coastal wetland tasks identified in the GLAM Committee's FY16 and FY17 work plans have been supported in part through the IWI.

Figure 16: Example of Common Reed (*Phragmites*) patch in Frenchman's Bay, Lake Ontario (photo provided by Greg Grabas, Canadian Wildlife Service)

2.1.2 Lake Ontario coastal riparian vulnerabilities to changing water levels

2.1.2.1 Rationale

Vulnerabilities of shoreline property owners to fluctuating Lake Ontario water levels has been well documented, particularly during past high water periods including 1973, 1974, 1976, and 1993. During the LOSLRS, considerable effort was placed on developing the Flood and Erosion Prediction System (FEPS) to allow for a relative assessment of how alternative water level conditions might impact shoreline property owners around the lake. The FEPS model results were designed around performance indicators related to costs associated with first floor flooding, erosion of unprotected properties, and maintenance of existing shore protection. Specific aspects and assumptions of the FEPS model and the individual performance indicators were identified during the LOSLRS as priorities for post study follow-up. To-date, there has been particular interest related to the shore protection maintenance performance indicator because it typically represents the most significant costs of the three Lake Ontario coastal performance indicators and was most sensitive to the differences in various regulation plan alternatives, particularly on the south shore of Lake Ontario. In particular, it was determined through sensitivity analyses during and after the LOSLRS that crest elevation assumptions used in the shore protection performance indicator could influence plan evaluation outcomes. In anticipation of an adaptive management effort, considerable investment was made by the agencies prior to the initiation of the GLAM Committee to acquire information on shore protection heights that could be used to compare to the model assumptions. This information was not otherwise being collected which had been a limiting factor in verifying that aspect of the model during the earlier IJC studies.

The GLAM Committee recognizes that there are other aspects of the FEPS model beyond the shore protection height assumption that require revisiting. As well, a common requirement for all interest

categories will be a need to monitor plan outcomes to see how they compare with model results. These requirements and priorities will be revisited annually as part of the GLAM Committee's work planning process with additional tasks identified as resources permit. As with the GLAM Committee's first two work plans, the Boards and the IJC will continue to review and provide input to the work plans.

2.1.2.2 Progress

The GLAM Committee initiated an activity to review the shore protection maintenance indicator in the FY16 work plan and work continues as part of the FY17 work plan. This project examines assumptions in the FEPS model regarding crest elevations for shore protection structures. The project relies on aerial and oblique photography, permit file reviews, and shore protection structure elevation data previously collected for the New York State Department of Environmental Conservation (NYDEC), sampled in 2012, and the U.S. Army Corps of Engineers, sampled in 2014 and 2015, prior to the formation of the GLAM Committee. Considerable resources were invested in acquiring this information. Without this data collection, the GLAM Committee would not have been in a position to initiate this review. The data collection involved site visits to various shore protection structures in Jefferson, Wayne, Monroe, Orleans, and Niagara counties (see Figure 17 for example site visit photo). For each shore protection structure visited, field technicians conducted a classification of the structure and measured elevations. 140 structures were visited for the NYDEC survey and another 212 for the U.S. Army Corps of Engineers. The GLAM Committee has integrated the field data into the FEPS database and is conducting sensitivity testing to determine how the shore protection maintenance cost estimates may change based on this new information.

Figure 17: Example of shoreline protection in Wilson, NY (source - U.S. Army Corps of Engineers)

2.1.3 Maintain existing impact assessment tools

2.1.3.1 Rationale

Both the LOSLRS and the IUGLS relied on impact assessment tools and related performance indicators to evaluate how particular interests would respond to specific changes in water levels and flows. Many of these existing tools and performance indicators will be useful as the GLAM Committee initiates a long-term process to evaluate existing regulation plan performance, validate available tools, and develop new tools to meet emerging needs. Ongoing effort is needed for baseline maintenance and upgrading (e.g. software and coding upgrades) of these tools to ensure they remain functional moving forward.

2.1.3.2 Progress

The GLAM Committee has prioritized the re-coding of the lower St. Lawrence River Integrated Ecological Response Model – 2 Dimensions (IERM2D) model in the FY17 work plan to ensure the ability to assess

ecosystem impacts on the Lower St. Lawrence River due to changes in water level regulation strategies is maintained. The IERM2D for the lower St. Lawrence River models 40 performance indicators representing 14 different components of the ecosystem and are used to quantify the effect of discharge/water level modifications for several flora and fauna resources. Figure 18 illustrates the geographic extent and provides an example of the model node density for a portion of Lake Saint-Louis. The programming language initially used to model the performance indicators (vb.Net 2008) is no longer supported and consequently, these performance indicator models will rapidly become obsolete unless the program code is updated. This task was initiated in the fall of 2016 and is being supported through the IJC's IWI. Staff from Environment and Climate Change Canada 's Hydrology and Ecohydraulics office in Quebec City are conducting the code modifications.

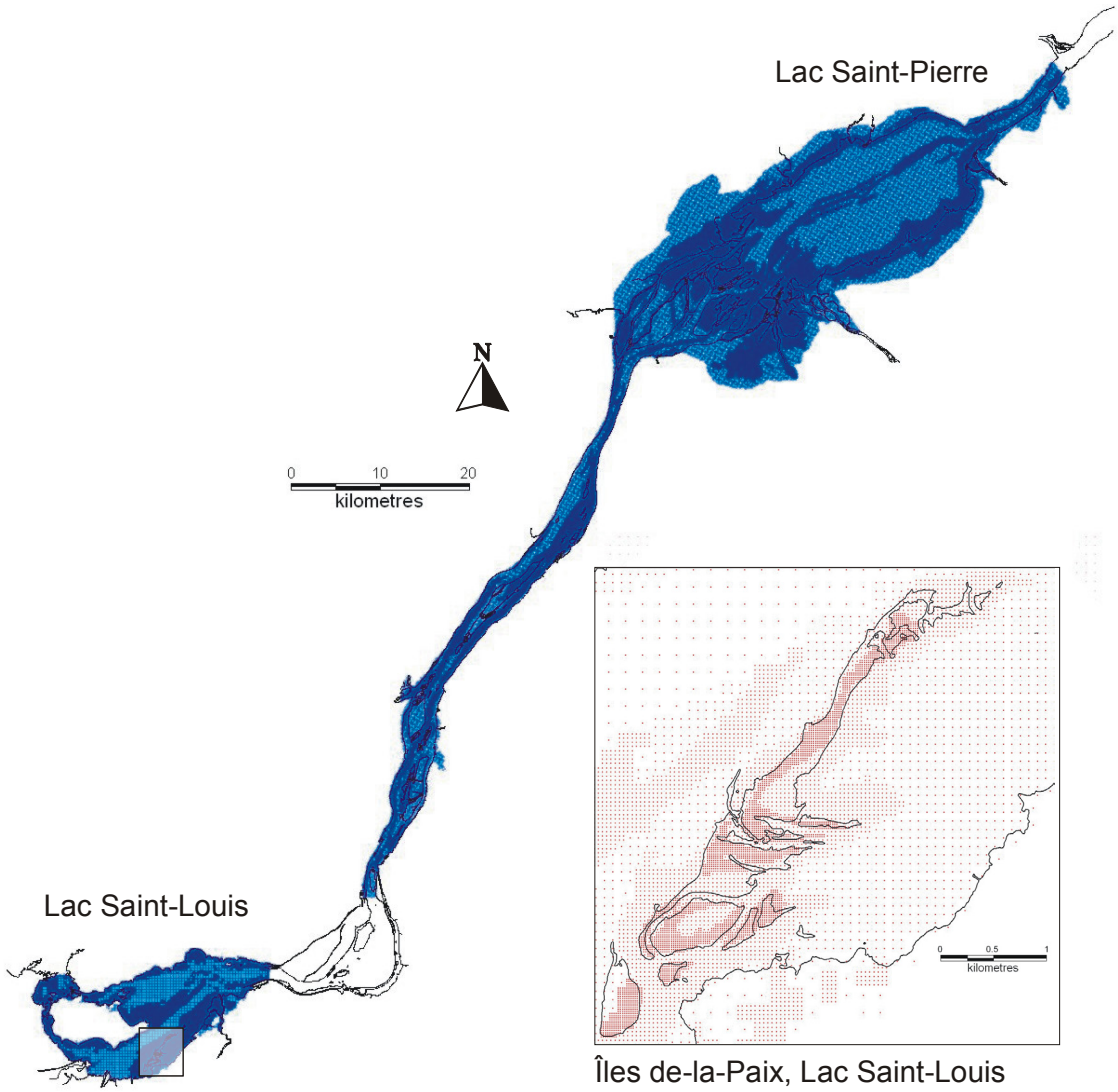

Figure 18: Geographic extent of the IERM2D model for the St. Lawrence River (inset map illustrates node density of the model for a portion of Lac Saint-Louis) (image courtesy of Jean Morin, Environment and Climate Change Canada)

2.1.4 New impact issues and performance indicators

2.1.4.1 Rationale

The GLAM Committee plans to conduct on-going surveillance activities to stay aware of new and emerging issues that may be partially impacted by Great Lakes water level regulation. The GLAM Committee uses the term "monitoring" to refer to a focused act of making observations linked explicitly to performance indicators through the performance indicator algorithm, and "surveillance" to refer to *the act of identifying and synthesizing information that could help improve regulation outcomes.* The objective of surveillance is to find useful information the GLAM Committee is not currently aware of. This work supports the GLAM Committee in meeting its Directive requirement to assess how well the impacts of levels and flows are represented by current data and models and also to determine whether the biological and socio-economic conditions of the system are changing over time.

2.1.4.2 Progress

As part of the FY16 work plan, the GLAM Committee oversaw contracts related to ecosystem and socio-economic surveillance. The contracts identified some of the issues and themes that have emerged since the end of the LOSLRS and the IUGLS related to Great Lakes water levels and flows. The ecosystem surveillance contract was conducted by Limno-Tech and the socio-economic surveillance by Dr. Frank Lupi from the University of Michigan. This ecosystem surveillance identified continued support amongst wetland researchers for naturally variable water levels over time in support of dynamic coastal ecosystems. However the importance of human factors limiting upslope and downslope vegetation transitions was highlighted as a factor that might limit natural wetland response to changing water levels. In addition, a variety of recent studies have looked at *Phragmites* expansion in some portions of the upper Great Lakes shorelines following the recent rise in water levels after a prolonged period of low water levels. While final publications have not been produced yet, there is evidence that *Phragmites* were able to expand considerably under the low water conditions on the upper lakes and that the recent rebound in water levels has not directly contributed to an immediate reduction in *Phragmites* extent. The GLAM Committee will be integrating new information from the surveillance items into future work planning activities including the development of the FY18 work plan. Moving forward, the GLAM Committee will be developing routine procedures to continue impact assessment surveillance activities into the future and strategies to support prioritization of new performance indicator development.

The GLAM Committee has already identified the need to develop new ecosystem performance indicators and modelling tools in the St. Marys River (Sault Ste. Marie). The need for ecosystem indicators in this area has emerged through the operation of Plan 2012, decisions and deviations that have recently been made regarding operational issues related to gate operations at the Compensating Works, and the effects of reduced side channel capacity that impact water level and flow conditions in the St. Marys rapids. This includes potential alternative gate operating procedures that may be possible in the future as a result of a current Great Lakes Restoration Initiative (GLRI) project, funded through the U.S. Army Corps of Engineers, that will automate a number of the gates at the compensating works and allow more flexibility in terms of potential gate operations. This also includes preliminary work

related to improving St. Marys River ecosystem modelling, which will be initiated early in 2017 with support from the IWI. The project is being led by staff from Environment and Climate Change Canada's Hydrology and Ecohydraulics office in Quebec City in collaboration with the Lake Superior Board's regulation representative staff from the U.S. Army Corps of Engineers in Detroit and Environment and Climate Change Canada in Cornwall. The U.S. Army Corps of Engineers in Detroit has been leading the development of a hydraulic model for the St. Marys River that will form the basis for the ecohydraulic model. An example of the hydraulic model output flow velocities under two different gate settings is provided in Figure 19.

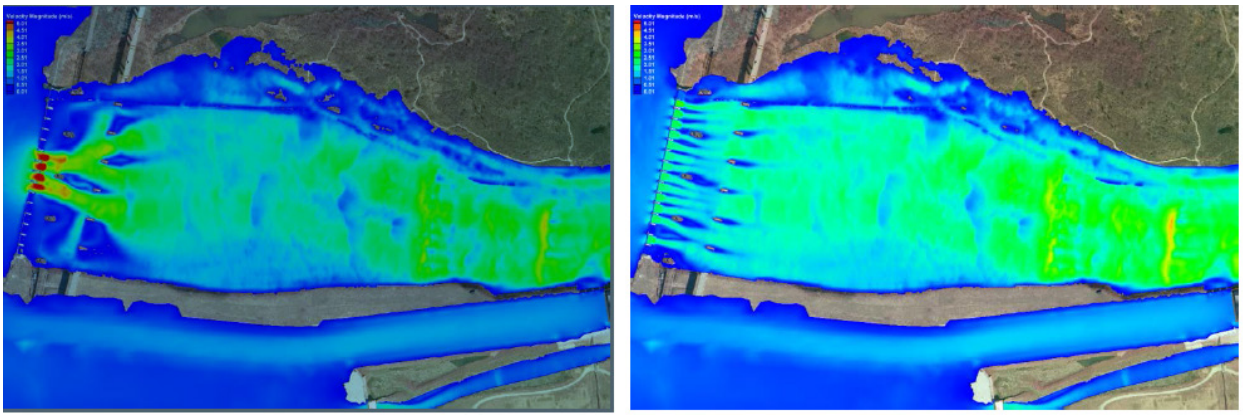

Figure 19: Examples of hydraulic output for St. Marys River rapids under four full gates open (left) and four gate equivalent over 13 partially open gates (right) (images provided by the U.S. Army Corps of Engineers, Detroit District)

2.2 Initial hydroclimate science activities

The GLAM Committee's Hydroclimate Science activities are designed to improve understanding of hydroclimate drivers, including climate change projections, in the Great Lakes basin as they relate to the regulation of water levels and flows. In the context of GLAM Committee activities, initial priorities include improving the net basin supply (NBS) information that is required to drive water level and flow simulations and evaluate robustness of water level regulation plans, as well as improving information related to other secondary hydroclimate factors (e.g. winds, waves, ice, etc.) that are important components of simulating performance indicator outcomes and understanding climate variability and trends. The GLAM Committee is also tasked with looking at how hydroclimate conditions may be changing over time, the implications of climate changes and the potential impacts on regulation plan implementation. To date, the work has been focused on improving understanding of NBS conditions.

2.2.1 Improving understanding of net basin supply conditions

2.2.1.1 Rationale

There is currently a large amount of uncertainty regarding the components that drive NBS in the Great Lakes basin, including over-lake precipitation, runoff to the lakes, and evaporation from the lake surface. Improving understanding of NBS components is critical to support the detection of changes over time and the hydroclimate tasks included in the FY16 and FY17 work plans were primarily designed to help reduce uncertainty related to NBS components. The GLAM Committee recognizes that there is a

broad range of hydroclimate science activities being led by federal and state/provincial agencies as well as academic researchers. Part of the GLAM Committee's role is to keep track of the broad range of work being conducted and synthesize the critical information necessary to support the review and evaluation of water level regulation strategies for Lake Superior and Lake Ontario outflows. Moving forward, the GLAM Committee will be looking to prioritize tasks that directly contribute to improving regulation plan outcomes.

2.2.1.2 Progress

One of the initial activities identified by the GLAM Committee within the FY16 and FY17 work plans was the need to improve and/or formalize processes to share information between some of the key groups working in this area, particularly the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data (CCGLBHHD). This included a joint project with the CCGLBHHD summarizing available NBS data sources within the Great Lakes basin. The summary of NBS data sources has been completed and is now being used by the Hydrology Subcommittee of the CCGLBHHD as well as GLAM Committee members. The GLAM Committee also supported a physical changes surveillance effort led by Linda Mortsch from the University of Waterloo to look at some of the emerging research themes related to hydroclimate science as it may impact water level regulation or performance indicator analysis. For example, the surveillance document highlights an emerging trend of increasing winds over the Great Lakes, and a clockwise rotation in the wind direction which can impact wave energy and possibly have implications on the coastal performance indicator algorithms used in assessing regulation plans. The GLAM Committee is seeking input on the specific portions of that review, which fall within the mandate of the CCGLBHHD, and will also be looking at developing routine strategies to maintain hydroclimate surveillance activities into the future. This will be an important baseline activity to support on-going GLAM Committee work plan development and prioritization efforts.

The GLAM Committee is also supporting specific projects designed to reduce uncertainty in the NBS components. Through the IWI, the Environmental Numerical Weather Prediction Research section at Environment and Climate Change Canada is using hindcasting of precipitation, runoff, and evaporation to improve historical estimates of NBS components (Fortin et al, 2015). For precipitation specifically, the available records of over-lake precipitation are really extrapolations from land-based stations which can vary significantly with what is occurring over the lakes. High resolution short term precipitation forecasts can provide more consistently accurate estimates of rainfall on the lakes (see Figure 20 as an example spatial estimate from the Canadian Precipitation Analysis system). When the drivers used in these forecasts are available as historical datasets, the models can use them to produce "hindcasts" – predictions of things that have already happened. But this hindcast also gives values for the other NBS components, namely runoff and evaporation. These components are difficult to calculate over each lake so this project has given the GLAM Committee insight into some of the longer term trends in these components. A five year hindcast run during the Upper Great Lakes Study provided convincing evidence that this would produce a better historical precipitation record, but it required substantial computing power. The research team have been able to optimize the data and computing requirements necessary to make the hindcast simulations feasible on Environment and Climate Change Canada's supercomputer (Gasset and Fortin, 2016).

In a separate but related project, the Great Lakes Environmental Research Laboratory (GLERL) is applying a novel statistical model that uses a time-series analysis of water supply information from both the component and residual NBS approaches in an attempt to close the water balance. As it does so, it can use the information generated as cues to find errors and assess uncertainty in the different components of the water balance (Gronewold et al., 2016). An initial experiment using a small dataset was successful in describing the driving factors of the recent rise in water levels on Lake Superior and Lake Michigan-Huron. Now GLERL will attempt to apply the method to a much longer dataset and across all the Great Lakes supported through the IWI.

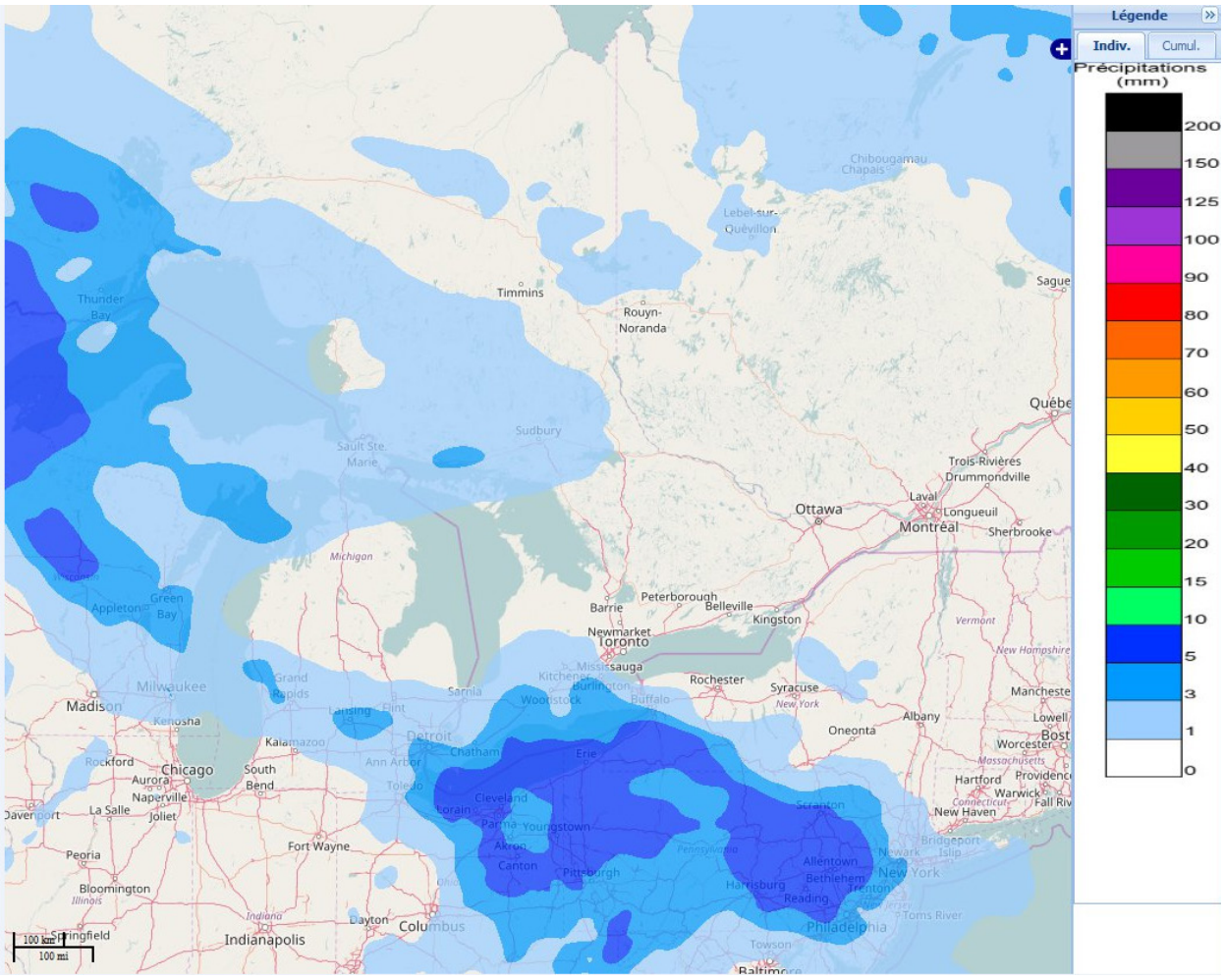

Figure 20: Example output from the Canadian Precipitation Analysis (CaPA) system. Model output can be used to improve historical estimates of over-lake precipitation.

Finally, the GLAM Committee has been undertaking tasks necessary to support the simulation of water levels and flows under alternative regulation strategies. In particular, this has involved work initiated in the FY16 work plan and continued in the FY17 work plan to update data sets for hydrologic and hydraulic parameters in the St. Lawrence River downstream of Cornwall/Massena. These data sets include parameters such as tributary inflows, ice and weed conditions that drive hydrologic and

hydraulic conditions in the river. The work supports the ability of the GLAM Committee to simulate water levels and flows caused by alternative Lake Ontario water level regulation strategies.

2.3 Initial plan review and evaluation activities

Plan review and evaluation activities include running the models and tools used in reviewing and evaluating regulation plan performance. These activities integrate all of the data and science to allow the assessment of regulation plan performance. Collectively, these activities are needed to understand whether the management of levels and flows can provide benefits to various physical, chemical, biological, and/or socio-economic conditions. The plan review and evaluation process integrates the findings and information generated by both the Impact Assessment and Hydroclimate Science activities from all components of the work plan. Activities within the GLAM Committee's FY16 and FY17 work plans have been broadly categorized into three areas including managing St. Marys River flows, establishing baseline plan review and evaluation procedures, and maintaining capacity to conduct baseline plan review and evaluation activities.

2.3.1 Managing St. Marys River flows

2.3.1.1 Rationale

Plan 2012, the regulation strategy for managing Lake Superior outflows, was developed and tested during the IUGLS assuming a maximum side-channel capacity of 2320 m^3/s. This value primarily represents a physical capacity limitation – it is essentially the combined flow capacity of all structures other than the Compensating Works at the head of the main portion of the St. Marys Rapids, the majority of which is the flow through the three hydropower plants. When side-channel capacity is exceeded, additional gates are opened to pass the required Lake Superior outflow. The maximum side-channel capacity of 2320 m^3/s was used to evaluate and rank all plans generated as part of that study and this assumption has carried through to the operational implementation as well. However, this constant value does not reflect actual operational conditions related to hydropower outages and hydrometeorologic conditions, including those related to long-term water level variations and winter ice conditions. In spring 2015, the ILSBC requested deviation authority from the IJC to address these conditions under Plan 2012. The GLAM Committee has prioritized tasks to help develop and evaluate alternative deviation strategies.

Figure 21: Compensating gates at the St. Marys rapids (from IUGLS, 2012, pg. 66)

Another priority related to managing Lake Superior outflows is the gate setting of the Compensating Works and the implications of different gate configurations on hydraulic conditions in the St. Marys Rapids. The ILSBC has recently been employing multiple partially open gates, in lieu of the more traditional use of fully open gates, in order to more evenly distribute water across the rapids and provide potential benefits, including more natural flow and water level conditions. The GLAM Committee is also interested in learning how alternative gate settings impact conditions in the rapids and how this might be better applied to achieve beneficial outcomes related to outflow management. Other means of operating the gates such as opening different gate configurations and reducing the rate that gate settings are changed, as previously mentioned, have also been suggested as a means to improve ecological conditions in the rapids, but these options were not fully evaluated during the IUGLS nor previous studies.

2.3.1.2 Progress

Side-channel capacity and gate settings are strongly linked. The GLAM Committee has made progress on the regulation and routing modelling and the hydraulic modelling components necessary to simulate flow conditions under varying side-channel capacity and gate setting scenarios in the St. Marys River and St. Marys Rapids. This included redeveloping model code to simulate different regulation strategies, collection of additional flow measurements at the Compensating Works to develop flow rating equations under partially open gate settings and evaluation of this new operational approach. A new hydraulic model in the St. Marys River and St. Marys Rapids was also developed. As discussed in Section 2.1.4.2, the hydraulic model will support the development of an ecohydraulic model that will be used to

assess the impact of changes in the timing and amount of flow through the rapids on fish habitats. GLAM Committee work in relation to the St. Marys River is being conducted in close coordination with the ILSBC and the regulation offices.

2.3.2 Establishing baseline plan review procedures

2.3.2.1 Rationale

A fundamental GLAM Committee requirement is to develop baseline plan review procedures. These procedures will establish ongoing approaches that the GLAM Committee will use to track regulation plan outcomes and guide future work plan priorities.

2.3.2.2 Progress

The GLAM Committee spent a lot of time in FY16 discussing and debating various approaches as part of its initial planning efforts. There was considerable debate and deliberation within the Committee regarding the role of the plan evaluation approaches used during the LOSLRS and the IUGLS and their potential applicability to longer-term plan review procedures. The primary product from this debate and discussion was the development of the mid-term strategy which outlined the broad planning and organizational framework envisioned for the Committee over the next 3-5 years. That mid-term strategy is discussed further in Section 4 of this document. Moving into FY17, the GLAM Committee has initiated efforts to test the implementation of the mid-term strategy framework and, in particular, aspects related to the baseline and routine plan review activities that are expected on an on-going basis.

2.3.3 Maintaining baseline plan review and evaluation capacity

2.3.3.1 Rationale

The GLAM Committee recognizes the importance of maintaining the capacity to use evaluation tools previously developed as part of the LOSLRS and the IUGLS. While it is not expected that all previously developed tools will be used as part of future GLAM Committee activities, it is important to ensure some capacity to operate the tools until such time as updated baseline plan review and evaluation procedures have been prepared and appropriate tools have been developed.

2.3.3.2 Progress

As part of the GLAM Committee's FY16 work plan, a preliminary strategy was put together to help newer agency staff who were not involved in the previous IJC studies become familiar with some of the LOSLRS and IUGLS tools. This included a planning workshop in March 2016 in Burlington, Ontario as well as a webinar to conduct training related specifically to the FEPS model. However, implementation of the learning phase was found to be difficult to work through in the abstract because there is a lot of material to cover and GLAM Committee priorities were still being developed. Moving into the FY17 work plan, more emphasis is being placed on learning how to use the available tools through application as part of specific GLAM Committee tasks. For example, the GLAM Committee will continue learning phase activities in FY17 by developing and testing the baseline plan review and evaluation procedures (Sections 2.3.2 and 2.3.3), through the FEPS and meadow marsh performance indicator

evaluation tasks (Sections 2.1.2 and 2.1.1), and the St. Marys River tasks (Sections 2.1.4 and 2.3.1). From an evaluation tool perspective, the long-term goal of the GLAM Committee is to ensure redundant agency capacity to operate the existing (or any newly developed) plan evaluation models and tools.

The GLAM Committee has also been working with the CCGLBHHD to initiate a project to update the Coordinated Great Lakes Regulation and Routing Model. This routing model is used to simulate water levels and flows in the upper Great Lakes and the GLAM Committee is seeking improvements which support more efficient testing of alternative flow management scenarios in the St. Marys River.

2.4 GLAM Committee oversight and administration

The GLAM Committee has identified a series of oversight and administrative activities needed to manage the overall direction of the Committee and support all work projects. These oversight and administration activities are overarching items that broadly apply to Impact Assessment, Hydroclimate Science, and Plan Review and Evaluation activities and are expected to lead to long-term efficiencies in the work of the Committee.

2.4.1 Coordination, strategic planning, and reporting

The GLAM Committee has carried out a number of coordination, strategic planning, and reporting tasks as part of the FY16 and FY17 work plans. Some of these are routine activities developing FY16 and FY17 annual work plans as required in the directive, monitoring progress in delivering on work plan tasks, and conducting semi-annual progress reporting for the Boards and the IJC in April 2016 and October 2016.

Since the FY16 and FY17 work plans represent the first two work plans of the Committee, there were a number of start-up activities required to lay the groundwork for on-going GLAM Committee activities. The most critical planning item carried out by the Committee was the development of the mid-term strategic plan. The mid-term strategic plan was drafted in FY16 and was reviewed by the Boards early in FY17. The draft document will be submitted for IJC review in 2017. A more detailed description of the mid-term strategic plan is provided in Section 4.

2.4.2 Information management

Information Management (IM) will be an on-going requirement of the GLAM Committee. There are a wide range of IM needs including ensuring access to impact assessment models and tools, maintaining baseline datasets, storing reports and other documents, and making all of these items available to users across the variety of agencies that contribute to GLAM Committee operations. The GLAM Committee has already leveraged available IJC support to establish a high level website along with making use of SharePoint and File Transfer Protocol (FTP) resources to communicate internally and manage products and information as part of these initial activities. While it is possible to broadly speculate on longer-term IM needs for the Committee, the details are likely to only be evident once the GLAM Committee

begins its baseline assessment activities and has products to work with. Additional IM planning is expected to take place later in FY17 in consultation with IJC IM staff to further scope out these requirements and implementation approaches.

3. Communications, Outreach and Engagement

The GLAM Committee's directive notes that "transparency, awareness and engagement of relevant organizations and institutions, as well as members of the public are key operating principles of the Boards and the GLAM Committee." The directive goes on to say "Among other things, this includes keeping these organizations, institutions and the public informed and engaged on progress of the GLAM Committee's work and, when appropriate, involving them in any sub-committees or task teams that may be established and/or establishing a separate public engagement committee." The GLAM Committee initiated the development of a Communication, Outreach, and Engagement strategy as part of the FY16 work plan and is building on a number of aspects of the strategy in FY17 including further developing and articulating an engagement plan for a series of advisory networks.

To this end, the GLAM Committee requires communication and engagement with a range of stakeholders including the IJC and its Boards, agencies, academia and interest groups in order to maintain awareness of the diverse and potentially changing needs of the various interests, and to ensure an open and transparent science-based adaptive management process. The GLAM Committee understands the critical nature of communication and stakeholder engagement to ensure the adaptive management process truly adapts to changing conditions and the priorities of the various interests on and around the Great Lakes. In short, adaptive management is ineffective, if not impossible, when attempted in a bubble. It is essential to have solid two-way communication with the various interests and the GLAM Committee recognises this as an area of focus for FY17 and over the coming years. With the expected conclusion of several of the on-going research initiatives, the GLAM Committee anticipates that there will be data and results to communicate with the Boards and stakeholders in the near future and that it will be conducting much more outreach and engagement in FY17. In future work plans, specific communication strategies will be defined for each work plan item. This should clarify for the Boards how the GLAM Committee anticipates the results of that particular work plan item will inform potential modifications in adaptive management strategy.

The recent approval of Lake Ontario – St. Lawrence River Plan 2014 will likely serve to heighten awareness of GLAM Committee activities for the public and many other stakeholders. The emphasis on adaptive management in Plan 2014 provides an opportunity for the GLAM Committee to reach out to those who have been most engaged in both the support and opposition of Plan 2014 to include them in the on-going review and evaluation of the regulation plan. This will incorporate active dialogue and involvement in the on-going assessment as part of the adaptive management approach. While the GLAM Committee certainly understands and appreciates the importance of this two-way communication and will strive to meet these needs, the Committee also recognizes that it is simply impossible to engage and maintain relationships with everyone, so it must be strategic in terms of

ensuring active participation and collaboration with those engaged. To that end, the GLAM Committee will pursue a "circles of influence" philosophy whereby it targets those individuals who are trusted representatives of a broader constituency who can actively reach out to a large group of people and effectively represent their views and opinions. In this way, connections with just a few individuals can assist the GLAM Committee with reaching as broad a community as possible.

3.1 Communication and engagement with the Boards and IJC

The GLAM Committee is regularly engaged with the Boards. It has presented its annual work plans for comment and engaged with the Boards at all of their meetings since inception of the Committee. The GLAM Committee has also presented to the IJC on its activities four times since its creation. The GLAM Committee seeks endorsement of its annual work plans and caters its efforts to the Boards requirements and mandates. It has communicated its desire to engage with stakeholders to the Boards and has agreed to inform the Boards of stakeholder engagement while adhering to the following principles:

Communication Principles

1. The GLAM Committee's external communications will be effectively coordinated with the Lake Superior, Niagara and St. Lawrence River Boards and IJC Communications. GLAM Committee public announcements and interactions will typically be made through the Boards or IJC and/or with full endorsement of the Boards and IJC.
2. However, the GLAM Committee may engage in external communication directly with specific audiences to facilitate research, seek stakeholder input, provide information regarding general adaptive management principles, and identify funding opportunities.
3. The GLAM Committee's internal and external communications will adhere to the IJC communication principles.
4. While the focus of GLAM Committee communications will be to maintain the on-going evaluation and assessment of lake level regulation plans, communications activities will also generally support the principle of adaptive management. These activities will inform those who are more interested in adaptive management than lake regulation.

3.2 Communication procedure

The GLAM Committee will require communication, outreach, and engagement to fulfil its diverse objectives. First, "communication" will be used to report on activities and convey key messages to the Boards and the IJC, as well as for public consumption. Second, the GLAM Committee will use "outreach" to maintain awareness of outside efforts from government and non-government agencies, organizations, researchers/academia, and stakeholders that may support adaptive management efforts. Lastly, the GLAM Committee will use "engagement" to facilitate collaboration and coordination among relevant parties that may support adaptive management activities.

Application of the communications procedure produced a number of tactics that the Committee considers best practices and intends to concentrate its efforts on:

1. GLAM Committee web site content
2. Media lines
3. Attend and participate in stakeholder meetings, conferences, conventions,
4. Stakeholder circles of influence meetings, webinars and teleconferences
5. An agency advisory committee/network of key agencies and organizations committed to adaptive management with whom the GLAM Committee can regularly engage
6. Use existing Great Lakes research networks to communicate research opportunities that would support adaptive management
7. Use existing Great Lakes communications networks (e.g. Sea Grants and Conservation Authorities) to distribute key messages

3.3 Outreach and engagement to date

Committee members took advantage of a number of conferences and proceedings to promote the activities of the committee with technical experts in the fields of adaptation planning, water level impact analysis, and coastal management. Consistent with the communication principles and at the request of the IJC, the GLAM Committee engaged in an outreach effort with RUSL (Regroupement des usagers du Saint-Laurent) on January 12, 2016. A background presentation introducing the committee and its role was prepared with support from IJC communications staff and presented to RUSL. The presentation was well received and the group was supportive of potential future engagement on relevant issues. The Committee also prepared a brief fact sheet that may be used for future stakeholder communication. A presentation similar to the one given for RUSL was also made to the Comité de Concertation Navigation in March 2016.

In separate events in April 2016 presentations were given to the Adaptation 2016 conference in Ottawa, Ontario and the Initiatives pour l'Avenir des Grands Fleuves workshop in Montreal, Quebec; committee members were also invited to give a presentation on Lake Superior regulation and the GLAM Committee at a meeting of the Lake Superior Partnership Work Group. In May 2016, the Canadian co-chair presented at a University of Michigan workshop and live-streamed event regarding water level integrated assessment (see Figure 22). Presentations were also made at the International Association of Great Lakes Researchers as well as the Coastal Zone Canada conference in June 2016 and at the Great Lakes Adaptation Forum in October 2016.

Figure 22: GLAM Committee members presenting at the University of Michigan water levels integrated assessment forum

3.4 Long-term engagement plan

Over the next 3-5 years, the GLAM Committee will be working to implement the strategy. To this end, the committee is in the process of adopting a long-term engagement strategy that is currently being reviewed and finalized. In order to facilitate the long-term engagement strategy the Committee has proposed developing an Impact Assessment Working Group to spear-head the outreach and engagement efforts. This Working Group would be comprised of three sub groups covering:

- Commercial navigation, hydropower, and municipal and industrial water uses (operational economic interests)
- Coastal and recreational boating (non-operational economic interests)
- Ecosystem interests

Committee members tasked with serving on these sub-groups would be entrusted with engaging with their respective groups of stakeholders while following the Communication Principles and Procedures defined above to ensure that no proprietary or confidential information is released without prior review and approval of the Boards and /or the IJC.

The GLAM Committee also intends to set-up advisory groups consisting of researchers and technical experts in various fields of interest. These groups will serve to provide input to GLAM Committee efforts when called upon about a specific approach or area of interest as the GLAM Committee identifies potential changes to the system or a shift in stakeholder interests.

3.5 Connections with the Great Lakes Water Quality Agreement

The IJC is responsible under the *International Boundary Waters Treaty of 1909* for managing water levels/flows in the binational Great Lakes waters and for assisting or advising the Canadian and United States governments with implementation of the binational Great Lakes Water Quality Agreement (GLWQA), first signed in 1972 and amended most recently in the 2012 Protocol. Management actions taken under both of these high profile accords require adaptive decision-making within the context of highly dynamic ecological and climatic factors. The adaptive management approach of the GLAM Committee grew out of the LOSLRS due to the inherent uncertainties of ecologic and economic models and climate change risks. Likewise, the 2012 GLWQA includes adaptive management as a guiding principle in order to systematically assess the effectiveness of actions and adjust future actions to achieve the ecological integrity goals and objectives for the waters of the basin. The IJC, recognizing the importance of these two adaptive management efforts, directed the GLAM Committee to better link water levels and flow regulation with water quality considerations under the GLWQA. The GLWQA's Great Lakes Executive Committee (GLEC) is in the early stages of considering how to apply adaptive management processes to assess the effectiveness of actions and adjust future actions. However, the two IJC water level/flows studies already developed provide significant metrics and guidelines for the GLAM Committee to build upon. Since hydrology and ecology are so strongly linked, the GLAM Committee is working to optimize its existing resources and networks to help bridge adaptive

management efforts between these two closely related binational programs spanning the Great Lakes basin.

In addition, the Emerging Issues Work Group of the IJC's Water Quality Board has recently submitted a report entitled *Climate Change and Adaptation in the Great Lakes,* and has noted the need for a coordinated regional perspective approach or strategy related to adaptation planning and implementation. This also provides a link for the GLAM Committee.

3.5.1 Topics that involve water levels and water quality

Governments tend to separate water quality and quantity management responsibilities into separate laws, agencies and funding streams, but in some cases they are physically connected. There are a few known areas of overlap on the Great Lakes and more may surface after more cross-objective collaboration. Areas for strong connections include the GLWQA's requirement for the development of a Nearshore Framework under Annex 2 - Lakewide Action Management Plans. Work related to water levels necessitates a good understanding of the nearshore and shoreline processes and dynamics, and there is much to be shared and learned as both water quantity and quality initiatives promote an adaptive management approach to address nearshore issues. There is also a GLWQA requirement for a Habitat Baseline Survey under Annex 7 – Habitat and Species, which could provide important connections, particularly related to work on wetlands and the spread of *Phragmites*. There are important connections as well to be made with Annex 10, the Science Annex, particularly related to adaptive management and the requirements for information and data management. The Cooperative Science and Monitoring Initiative (CSMI), which has a five-year rotation between lakes, also has the potential for overlap with GLAM Committee performance indicators. As an example, harmful algal blooms (HABs) may be the most important water quality issue on the Great Lakes. The HAB conceptual model is that rainfall washes phosphorus and nitrogen off land into streams that flow into lakes, providing nutrients that allow algae to grow in nearshore areas of those lakes. The runoff is aggravated by extreme precipitation events. Growth in the lakes is affected by water temperature and sunlight on the lake bottom, which is in part a function of water depth in the nearshore. The GLAM Committee's experience in the application of climate change research for water level management could inform the pertinent Annex subcommittee's efforts to determine how climate change will affect HABs. Nearshore bathymetry would be useful both for modelling HABs and erosion/deposition for beaches and shore damages, issues that fall under water level/flow management. Further, many of the agencies and experts participating in the GLWQA Annex sub-committees are also represented on the GLAM Committee. By working collaboratively, the GLAM Committee and the GLWQA Annex sub-committees for climate change (Annex 9) and nutrients (Annex 4) could more efficiently develop models and monitoring programs, and achieve greater efficiency from funding opportunities.

3.5.2 How will the GLAM Committee connect on water quality?

The goal of working together would be to improve evaluation and decision-making outcomes from both water level and water quality management in the Great Lakes. The GLAM Committee will engage on water quality in two ways. First, the Committee will collaborate with IJC advisory boards established to support the IJC in its role under the GLWQA, including the Great Lakes Water Quality Board – GLWQB, the Great Lakes Science Advisory Board – GLSAB, the Research Coordination Committee (RCC),the Science Priority Committee (SPC), and the Health Professionals Advisory Board. Secondly, the GLAM Committee will engage directly with the GLWQA Annex sub-committees. Connections between the GLAM Committee and the GLEC would be indirect, through the IJC.

The connection with IJC advisory boards has already been established through the IJC Advisory Board Co-Chairs group that includes GLAM Committee co-chairs and meets during the IJC Semi-Annual Meetings. The Co-Chairs will work with the IJC's Great Lakes Regional Office to explore important water quantity and quality linkages, such as connecting on the work of the GLWQB Emerging Issues Work Group related to Climate Change and Adaptation in the Great Lakes. This connection directly supports the GLAM Committee directive and ensures the groups are communicating, sharing information and making connections when practicable.

The link between the GLAM Committee and the GLWQA Annexes has not yet been formalized, but wherever possible the connection to the GLWQA Annex sub-committees would be through people working with the Annex as well as with the GLAM Committee. Collaboration between the GLAM Committee and the GLWQA Annex sub-committees would have two primary objectives:

1. The GLAM Committee could share its experience with adaptive management to help the GLWQA Annex sub-committees implement adaptive management as a framework for science-based management options; and
2. The GLAM Committee and the GLWQA Annex sub-committees could share information and expertise on topics that touch on both water quality and quantity. For example, the information developed by water level researchers about climate change could help in assessing and managing the chemical, physical and biological quality of the ecosystem's waters.

4. GLAM Committee Mid-term Strategy

The activities conducted to date by the GLAM Committee represent start-up efforts that were identified as initial priorities by the GLAM Committee to ignite the adaptive management process. Moving forward, the GLAM Committee wants a more established road map of how and when GLAM Committee objectives can be achieved over the coming years to meet the IJC directive. This road map represents a snap shot in time of what is an evolving process and therefore, this strategy is expected to be dynamic and updated regularly to reflect changing priorities, challenges and opportunities. The purpose of this mid-term strategy is to be forward looking so the GLAM Committee, the Boards (to whom the

Committee reports), the IJC, stakeholders and the public all understand the direction the GLAM Committee is heading. The current strategy is outlined below with further explanation provided in the more detailed mid-term strategy document (GLAM, 2017).

The GLAM Committee's goal over the next three to five years is to move the adaptive management process from its start-up, conceptual phase through to implementation. That means that the networks of people and processes the GLAM Committee currently has will have matured into well-defined and sustainable institutions. In those areas where the GLAM Committee is now determining what should be done and how, there will be well established procedures and regularly published results and recommendations. This includes a systematic assessment of existing and potential future performance indicators (PIs), model validation and improvements, enhancement of plan evaluation tools and decision support processes, and several aspects of water balance science to help better understand water levels and flows, future conditions and extremes. The GLAM Committee will prioritize activities in these areas to address identified gaps and to ensure that the information and tools reflect the needs of water level regulation decision makers.

The GLAM Committee will strive to have nascent surveillance, information management, communication, and outreach and engagement efforts will be transformed into functioning, peopled networks which inform the on-going review of regulation plans, help track system changes and bring information to those who can use it to improve outcomes. The committee's flexibility will be derived from its ability to reach out and include individuals or organizations having the specialized knowledge or tools needed, the capacity of participating agencies and organizations to fund and complete initiatives or projects as needs arise, and a work plan that is reviewed and updated on an annual basis. The focus will be on ensuring important linkages with complimentary programs and in particular with the IJC's IWI as well as the binational GLWQA and its LaMPs, Nearshore Framework, Baseline Assessment, Climate Change impact assessments and other science and data management initiatives. The GLAM Committee will strive to be a leader in binational adaptive management and will actively share information, tools and lessons learned with others who may also be pursuing adaptive management efforts.

To be successful, this adaptive management effort requires on-going commitment. The GLAM Committee has a long-term, 15-year time horizon within which to gather data and information, improve tools and work towards perfecting the evaluation process to allow for an effective review of the existing regulation plans. While this strategy focuses on the next 3 to 5 years, the GLAM Committee must ensure that the mid-term strategy supports the longer-term commitment of the committee. It also requires extensive collaboration, since no one agency has either the responsibility or resources to conduct all components of an effective adaptive management process. The GLAM Committee relies on the direct contribution of agencies that make up its current membership, along with the support of other agencies, non-governmental organizations (NGOs), broader research communities, and stakeholders that help contribute to the adaptive management process. The committee operates within the IJC governance framework, and focuses on coordination and networking, as well as leveraging and

building on existing networks and initiatives. This openness allows it to collaborate with others on work that may have multiple objectives.

The primary objective of GLAM is to review and evaluate, on an on-going basis, the performance of the regulation plans. The ability to evaluate regulation plans begins with the calculation of water levels and flows resulting from a given regulation plan. Water levels and flows are then used as the primary inputs to predictive models which use performance indicators to assess the potential benefits and impacts to various stakeholders. Model outputs represent potential trade-offs, which must be assessed by a set of decision criteria to evaluate what is considered acceptable plan performance, based on regulation plan objectives established by the IJC. Assessments of plan performance will be used to support decisions, ultimately made by the IJC, on the best balance for regulating water levels and flows. Regulation plan assessments may also yield sufficient information to suggest that changes to the regulation plan need to be made. Figure 23 below provides a general flow chart of the plan review and evaluation process. Efforts to update and improve each step of the evaluation process are part of the GLAM mandate. Monitoring and model validation is a critical component of the process to ensure the reliability of the models and that the assessment of the performance indicators is credible, re-producible and communicable to stakeholders. The GLAM Committee will coordinate the monitoring and assessment efforts to validate and update models and assess changing conditions over time.

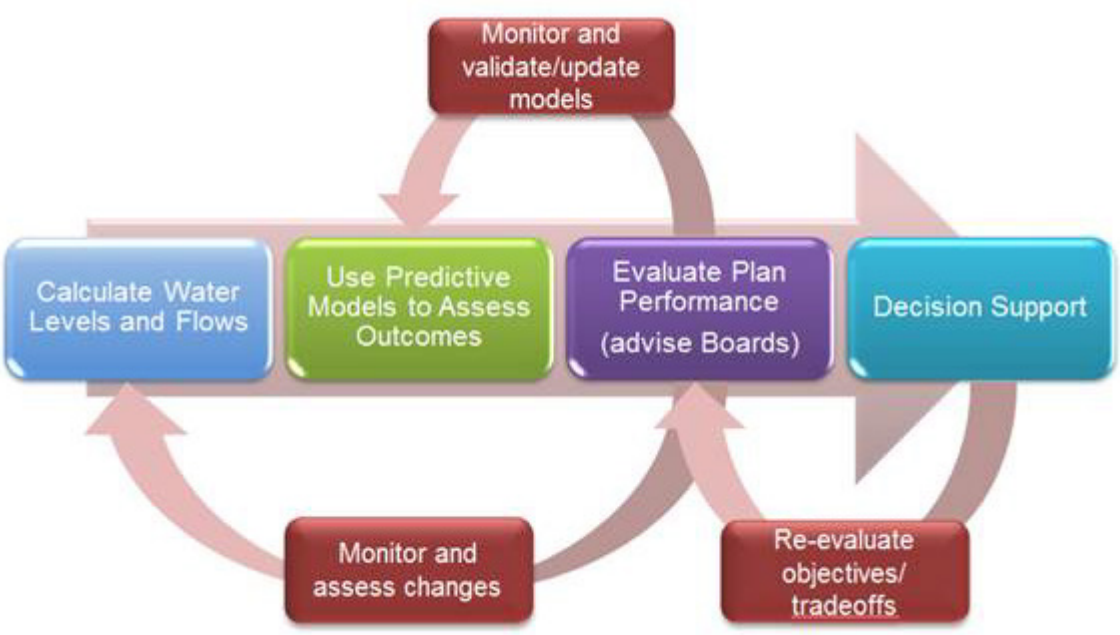

Figure 23: General overview of plan evaluation under an adaptive management approach

To undertake this plan review and evaluation process, the GLAM Committee has developed a three tiered approach discussed starting in section 4.1.

4.1 Three tiered approach

To fulfil its directive, the GLAM Committee is charged with two primary responsibilities: first, to consider the on-going performance of existing regulation plans and whether they are meeting intended objectives; and second, to consider how the Great Lakes – St. Lawrence River system may be changing and how that might alter the outcomes of regulation and the decisions made on how best to regulate flows. To help the GLAM Committee address both of these requirements, a three-tiered framework has been proposed as a means to organize the core technical work necessary to meet the requirements of the directive into a comprehensive, well-defined, and structured process. Figure 24 shows the three-tiered approach working from the bottom-up. The core technical work involves all tasks that the GLAM Committee will conduct to allow it to provide information to the Boards. This includes how existing regulation plans have performed in the past, how they can be expected to perform in the future, and whether that performance can be improved to better adapt to changing conditions in the system. The three-tiered framework links information generated to the prioritization and decisions of tasks that the GLAM Committee will conduct. It is also consistent with how the agencies currently operate (work planning, resourcing, staffing, etc.).

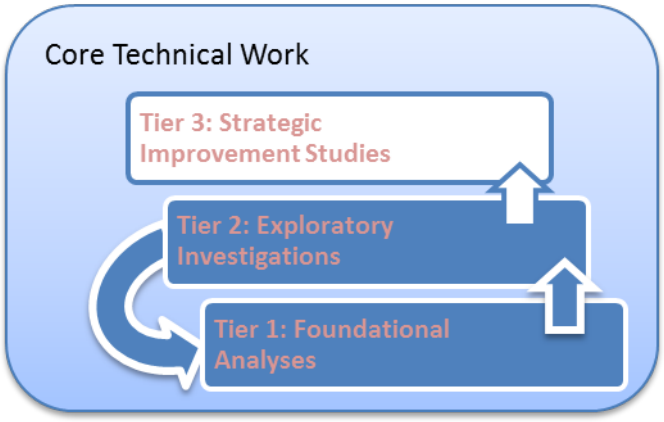

Figure 24: Proposed tier framework for the GLAM Committee

Tier 1: Foundational Analyses: *An annual review of foundational requirements for the on-going review of the regulation plans and an assessment of priorities for the coming year.*

The Foundational Analyses cover all of the ongoing, routine tasks, assessments and basic requirements for plan reviews and performance evaluations. The objective of Tier 1 is to ensure a regular check-up of what has been happening in recent years in terms of water levels and flows, and the effects these have on various interests. It will also generate a stream of information that will be used by the GLAM Committee in its planning processes to identify and assess priorities for future study.

The GLAM Committee cannot possibly track each and every interest on an annual, on-going basis, nor update every tool utilized in the evaluation process at this level of frequency. It is nevertheless important for the GLAM Committee to continually stay abreast of the critical aspects required to evaluate regulation plans so that proper maintenance and updating of the data and tools can occur when necessary, and can be done systematically and efficiently. Over the next 3 to 5 years, the focus of the foundational analyses tier will be on developing an annual cycle of tasks to review and update impacts and benefits related to the performance of the existing regulation plans under observed hydroclimate conditions and trends and in relation to real world outcomes.

Tier 2: Exploratory Investigations: *Targeted studies to investigate specific aspects of a regulation plan and improve the Performance Indicators, tools, and processes to support Strategic Improvement Studies (Tier 3), and provide feedback into the Foundational Analysis (Tier 1).*

This tier focuses on special investigations targeting improved understanding of current regulation plan performance through exploration of alternative strategies under observed and potential future hydrologic conditions, including extremes and climate changes. This tier includes conducting analyses of the sensitivity, certainty and significance of the various PIs and an assessment of gaps. These exploratory analyses will help to identify work that needs to be conducted to improve the PIs, models, tools and assessments to compare alternative regulation plans and reduce uncertainty. This tier supports a systematic, but flexible process to analyse alternative processes for plan comparison and assess areas for future work. The results may be fed back into the Foundational Analysis, but will primarily be directed towards improving the PIs, tools and processes for the longer-term comparison of alternative regulation strategies and identifying opportunities to improve regulation outcomes. The exploratory investigations conducted under this tier will be decided by the Committee and the Boards based on their importance, feasibility, and available resources and opportunities. Attention will be given to improvements to the hydroclimate science to assess historical and future water level conditions and extremes, including potential climate change projections, and on validating performance indicator algorithms linking water levels and effects with real world observations. Additionally, gaps in PIs identified by surveillance of emerging trends will be assessed, as well as feedback from circles of influence to ensure the performance indicators are an adequate reflection of what people care most about. Focus will also be placed on the models and tools used to assess performance indicator results and improvements; updates as required to these tools, based on monitoring data and technological advances; and improvements to the evaluation process.

Tier 3: Strategic Improvement Studies: *Comprehensive assessment of the relative performance of a set of alternative regulation strategies to achieve improved outcomes.*

This tier is focussed on using improved understanding of the system and what has been learned through Tiers 1 and 2 to develop alternative strategies for potential future conditions and to assess the performance of these alternatives in a comprehensive way. This tier is triggered after a longer-term assessment, when sufficient evidence has been accumulated through the Committee's collective works. It will include results of Tier 1 and Tier 2 studies which may suggest that significant changes in the system have occurred, are occurring, or are likely to occur, and whether the potential for improvement to regulation outcomes is possible. The GLAM Committee directive requires the Committee to produce a comprehensive review, at a minimum of every 15 years, of its collective works and a synthesis of what has been learned, as well as recommendations to the Board on whether changes to regulation plans may be warranted. While this is the formal reporting period, Tier 3 will be triggered any time extensive evidence exists that an improvement to the plan may be warranted. A Tier 3 plan formulation and evaluation process would incorporate all that is learned about the system and the datasets, tools and models that have been developed and improved upon through work conducted in Tiers 1 and 2. Tier 3 studies would also require that plan objectives be clearly articulated and properly aligned with appropriate metrics for evaluation established through the performance indicators.

Each tier requires stakeholder outreach and engagement to ensure that the information and scientific data gathered and the tools and processes that are developed are accessible, transparent and trusted. Therefore, the 3-5 year strategy must not only focus on the activities and products required to support the three tiered plan review and evaluation process, but also the activities and products necessary to ensure implementation of an effective adaptive management process which includes long-term operating procedures, outreach and engagement.

4.2 GLAM Committee organization, roles, and responsibilities

In developing its mid-term strategy, the GLAM Committee has established three integrated working groups to deliver on the activities required to meet the 2015 Directive and the specific activities within the three tiers. Figure 25 outlines the general organizational structure. The main working groups include the following:

1. Hydroclimate Working Group: Focusses on understanding and reducing uncertainty in the primary "driver", that being the dynamics of the hydroclimate system. This includes potential climate change, the impacts on water supplies and other secondary factors (i.e., winds, waves, etc.), and the resulting water level and flow response. This WG will focus on building and improving historical and future water supply scenarios for use in assessing regulation plans under past and plausible future conditions. The Hydroclimate WG will ensure that the GLAM

Committee is looking at whether future water supplies will be different from those used to test the current management of levels and flows, and whether key hydroclimate conditions in the system are changing over time.

2. Impact Assessment Working Group: Made up of three sub-groups covering: i) Commercial navigation, hydropower, and municipal and industrial water uses; ii) Coastal and recreational boating and iii) Ecosystem interests. These sub-groups work to ensure that the outcomes of water level and flow scenarios affecting the various interests are measurable and assessable. More specifically, they support the GLAM Committee in helping to understand how accurately the impacts on these groups are represented by current data and models used in evaluating the management of levels and flows. The Impact Assessment Working Group will also look at whether conditions of the system are changing over time.

3. Plan Review and Evaluation Working Group: This group will augment, enhance, update and run the models and tools used to review and evaluate regulation plan performance. This group integrates all of the data and science necessary for the assessment of regulation plan performance. Collectively, this WG supports the activities needed to understand whether the management of levels and flows can benefit other physical, chemical, biological, and/or socio-economic conditions.

4. Decision Support**:** This is not a separate working group, but is carried out by the GLAM Committee members and IJC advisors working with the Boards to determine how to best visualize and present information in a meaningful way. Another goal is to articulate regulation plan objectives and decision criteria to determine when and how the Boards should decide to recommend changing a regulation plan to the IJC.

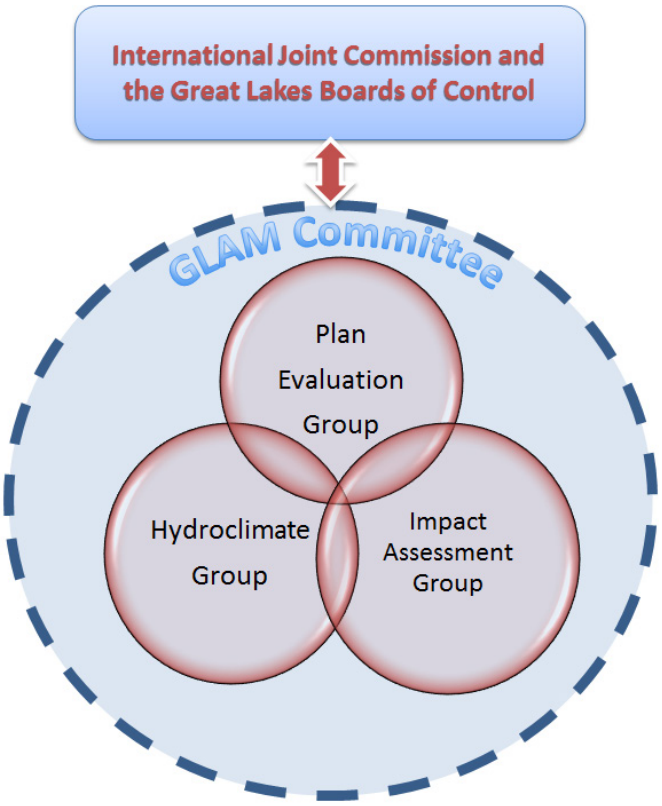

Figure 25: Proposed GLAM Committee organizational and reporting structure

5. Budget and Resourcing Context

It is important to note that, to date, the GLAM Committee has operated without formal U.S. or Canadian budgets. GLAM Committee success in meeting its Directive and carrying out the mid-term strategy outlined in this document relies primarily on the annual in-kind support of the agencies represented on the Committee along with additional staff support, as identified by those agencies. In addition, the GLAM Committee is eligible, as a Committee under the IJC, to apply for support through the IJC's International Watershed Initiative (IWI). This allows for potential access to funds, provided they can be used to leverage Board responsibilities and are in line with the IJC's strategic initiatives, and IWI requirements. From the time the GLAM Committee was formed in January 2015, it has successfully applied for and received IJC support for eleven IWI endorsed projects that were included in the GLAM Committee annual work plans. Table 4 provides a complete list through December 2016.

IJC Reference Code	Project Title	IWI Source	IWI Support
AM-01-2015	Monitoring of Lake Ontario coastal Wetland Habitat in Support of Adaptive Management	Can	$31,500
AM-02-2015	Comparison of Modelled and Monitored Outcomes of Lake Ontario Wetland Habitat in Support of Adaptive Management	US	$40,000
AM-03-2015	Extended CaPA and GEM Hindcasts of Water Supply Components in the Great Lakes Basin	Can	$50,000
AM-04-2015	Closing the water balance of the Great Lakes: Developing a new historical record reconciling bias and uncertainty	US	$53,000
AM-05-2015	Programming Support for update of Coordinated Great Lakes Regulation and Routing Model	US	$23,219
AM-06-2015	Monitoring of Lake Ontario - St. Lawrence River Coastal Wetland Habitat in Support of Adaptive Management (Field Monitoring)	US	$60,947
AM-07-2015	Monitoring of Lake Ontario - St. Lawrence River Coastal Wetland Habitat in Support of Adaptive Management (Imagery)	US	$50,148
AM-08-2015	Update the computing code of the Lower St. Lawrence Environmental Performance Indicators (IERM2D)	Can	$30,000
AM-01-2016	Extended hindcast of water supply components over Canada/US transboundary watersheds based on the CaPA, CaLDAS and GEM systems	Can	$55,000
AM-02-2016	Baseline common reed extent in selected Lake Ontario coastal wetlands	Can	$32,900
AM-03-2016	Detailed scope of requirements for developing an ecohydraulics model of the St. Marys River and prototype application to the St. Marys Rapids area	Can	$62,700
		CAN	$262,100
		US	$227,314
		Total	**$489,414**

Table 4: IJC support of GLAM Committee projects endorsed through the IWI

The GLAM Committee also plans to develop partnerships and collaborations that reach beyond its existing membership and available resources. These relationships must be developed and nurtured to leverage potential contributions from agencies and organizations with related authorities and goals. The GLAM Committee is still working to establish and define these collaborative relationships with potential partners.

As this is an on-going effort, the priorities set in annual work plans are estimates based on what the committee understands to be the resources available within each fiscal year. The expertise available through potential partner agencies and collaborators is also assessed annually and throughout each fiscal year as the work plan progresses. In some cases, capacity to complete specific work plan tasks can change throughout the year due to shifts in priorities from contributing agencies. This can result in

specific work plan tasks being carried over into the following fiscal year. The boards are kept notified of progress through GLAM Committee semi-annual reports and ad-hoc project specific updates when necessary.

The GLAM Committee recognizes the need for long-term planning, but it is difficult without formal long-term budgets and the need to rely on opportunistic contributions beyond its existing resources. To-date the GLAM Committee has not compiled forward looking cost estimates beyond its annual assessments. However, the GLAM Committee and the Boards see value in establishing a long-term costing model that outlines potential requirements in the near future and building towards a potential 15 year review of the regulation plans. The GLAM Committee hopes to work with the boards to prepare such a model, and anticipates including those estimates in the next Triennial Report, expected in 2020.

6. Opportunities and Challenges Going Forward

On December 8, 2016, after 16 years of study and consultation, the IJC announced it was moving forward with the implementation of Plan 2014 for Lake Ontario and the St. Lawrence River, as a modern plan replacing a nearly 60 year old regulation plan. Likewise, in January 2015 the IJC implemented Plan 2012, an updated plan for the outflows of Lake Superior. For the IJC, Canadian and U.S. governments, and for many stakeholders these new plans represent a new era of balanced water management, where the environment, other interests such as recreational boating, and other driving factors such as climate change are recognized and considered as part of the equation. With these new regulation plans comes the expectation of improved overall outcomes over-time, without undue harm to any one interest. There is much at stake and much to learn as the IJC Boards work to implement operational versions of the regulation plans. This will happen under real world conditions; with real world freshets and ice conditions;, and considering operational requirements such as hydropower dam maintenance, commercial navigation traffic, and wind and weather events, all in an ever changing and dynamic system that includes climate changes that could only be modelled through simulations prior to their implementation.

Many, including governments and the IJC itself, will want to know if the expected outcomes of these new regulation plans are being realized, how and when the system is changing, and how that might influence regulation over time. To that end, the IJC and governments have made a bold commitment to adaptive management, a concept well supported in theory, but rarely implemented in practice because of the long term commitment to monitoring and scientific assessment required, and the inherent need for collaboration. Yet the IJC has set the stage for adaptive management in a binational context, on a scale not seen before. In many ways, this will be a true real world test of concept. The creation of the binational GLAM Committee is the first step in this collaborative process. Working together, the GLAM Committee has the opportunity to provide the necessary coordinated follow-up to allow an on-going assessment of regulation plans and to test how those plans are performing. The Committee has the opportunity now to assess how well the models, tools and assumptions used to choose the plans actually reflect reality using real world observations so that improvements and updates to those models

and tools can be made, as more is learned and advancements are realized. It also provides the opportunity for reflection and to make adjustments if further improvements are found to be possible.

While the GLAM Committee is a newly established committee of the IJC, it is not starting from scratch. The GLAM Committee has the benefit of the two major IJC studies on the regulation plans – the IUGLS and the LOSLRS – which both concluded that adaptive management is the best way to address the uncertainties associated with climate change, the potential for extreme water levels and their associated impacts. These studies provide the backbone from which the adaptive management effort can be built, including the development of multiple water supply sequences, performance indicators, evaluation tools and models, along with a process to evaluate and rank regulation plans. In essence, the adaptive management effort begins where the studies left off and recognizes these studies as an important contribution to the first phase of implementation.

As there are opportunities, there will also be many challenges. Adaptive management has its stumbling blocks and requires a steadfast commitment that is often hard for governments with short-term mandates to support. Expectations for the new regulation plans will be high, and yet it could take years to accurately assess how these regulation plans are performing under a range of conditions. It will be a challenge over the years to maintain the commitment of supporting agencies. As such, the GLAM Committee has its work cut-out for it to show progress on a regular basis. It must also build and maintain relationships with experts and stakeholders alike, and engage them regularly in an open and transparent adaptive management process. It must be able to manage information gathered over time and convey that information in a meaningful way to the Boards, stakeholders and the IJC in order to support future decisions. There is no doubt that resources will be an on-going issue as supporting agencies attempt to maintain a level of commitment and as other budget pressures compete for those resources. The GLAM Committee has the added challenge of how to manage limited and often short-term resourcing commitments and still provide the necessary information to support on-going decision making. The Committee will need to learn to be nimble and flexible and ready to take advantage of funds when they become available to support long-term commitments. It must also be ready to conduct monitoring on short notice, when conditions are conducive and/or events drive it, even when resources may not be readily available.

Prerequisites required to ensure the success of adaptive management include the on-going annual support of the agencies represented on the GLAM Committee along with additional staff support as identified by those agencies. It also assumes that funding will continue to be available through sources such as the International Watershed Initiative and the Great Lakes Restoration Initiative, and that the mechanisms for ensuring the transfer of funds to the supporting agencies are in place. It requires collaboration and recognizes that the GLAM Committee is in many ways a facilitator and integrator of the work of many beyond the Committee itself. There must also be vision and clear understanding among all involved of the purpose and direction of the adaptive management effort. It will be impossible to study all impacts at all times and strategic planning will be key to having the right information needed at the right times to assist decision-making.

The GLAM Committee was established and functions with the support of the agencies represented. There is a formal commitment to the on-going assessment of the regulation plan in the updated Order of Approval for the regulation of Lake Ontario outflows and all the Great Lakes Boards have been given the new mandate of adaptive management by the IJC. The stage is set for effective adaptive management and as the years unfold, the hope of the GLAM Committee is to effectively deliver and provide a show case for a working example of adaptive management in practice on a binational scale.

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APPENDIX 1: List of Acronyms

CCGLBHHD – Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data
CO – Conservation Ontario
CSMI - Cooperative Science and Monitoring Initiative
CWS – Canadian Wildlife Service
FEPS - Flood and Erosion Prediction System
GLAM – Great Lakes – St. Lawrence River Adaptive Management
GLC – Great Lakes Commission
GLEC - Great Lakes Executive Committee
GLERL – Great Lakes Environmental Research Laboratory
GLRI – Great Lakes Restoration Initiative
GLSAB – Great Lakes Science Advisory Board
GLWQB - Great Lakes Water Quality Board
GLWQA - Great Lakes Water Quality Agreement
HAB – Harmful Algal Bloom
IERM2D – Integrated Ecological Response Model – 2 Dimensions
IJC – International Joint Commission
ILSBC - International Lake Superior Board of Control
IWI - International Watersheds Initiative
IUGLS – International Upper Great Lakes Study
LAMPs – Lakewide Action and Management Plans
LOSLRS – Lake Ontario - St. Lawrence River Study
NYDEC - New York Department of Environmental Conservation
NBS – Net Basin Supply
NGOs – Non-Governmental Organizations
PIAG – Public Interest Advisory Group
PI – Performance Indicators
RCC – Research Coordination Committee
RUSL - Regroupement des usagers du Saint-Laurent
SPC – Science Priority Committee
SUNY-ESF – State University of New York – Environmental Science and Forestry
TAP – Triennial Assessment of Progress

APPENDIX 2: General Response of Lake Ontario – St. Lawrence River Interest Categories to Water Level and Flow Conditions

Interest	Vulnerability to Water Level and Flow Conditions
Municipal and Industrial Water Uses	- Sensitive to extreme water levels due to potential to limit intake capacity (on the low end) or increase vulnerabilities to inundation or storm damage (on the high end). - Robustness to changing water levels varies based on site specific characteristics and infrastructure design.
Commercial Navigation	- Particularly sensitive to low water conditions which can require reduced draft and a reduction in cargo carried. - The stability and predictability of water levels can be a critical factor, particularly in the St. Lawrence River, as loading decisions are sometimes made weeks in advance for international vessel arrivals in the Port of Montreal and those transiting the seaway. - Extreme high water levels can also be a concern in some parts of the St. Lawrence River and the Seaway due to issues around safe transit velocities.
Hydropower	- Hydropower production is a function of the outflows and the operating head which is the difference between the waters levels just upstream and just downstream of the facility. - Higher outflows and/or higher operating head results in a greater amount of hydropower production, up to the peak unit efficiency after which there is no additional benefit to higher flows or greater operating head.
Coastal	- On Lake Ontario, <u>erosion</u> is driven by storms and significant wave events and can occur under a range of water levels, although the manifestation as bluff recession tends to be more pronounced under high water conditions or when water levels rise quickly after a period of below normal water levels. - <u>Shore protection</u> damages can occur under a range of water levels based on storm conditions but as with erosion tend to be more acute during periods of high water levels. - <u>Flooding</u> damages are primarily a concern during periods of high water levels, particularly in association with storm events. Vulnerabilities vary spatially around the lake based on patterns and age of development as well as soil conditions, topography, and exposure to dominant wave conditions.
Ecosystem	- "The biological communities of Lake Ontario and the St. Lawrence River have, by necessity, evolved to adapt to the natural range of water levels and water level changes that occur on time scales ranging from wind-driven seiches that can occur several times daily, to the seasonal cycle, to changes that occur over decades and longer" (IJC, 2014, pg. 42) - "The biological effects of water level fluctuations are greatest in shallow water, where even small changes in water levels can result in conversion of a standing water environment to an environment in which sediments are exposed to the air, or *vice versa*." (IJC, 2014, pg. 42)
Recreational Boating	- Recreational boating damages can occur during both low and high water level conditions although damages tend to be greater during low water conditions. - Recreational boating activities in the upper St. Lawrence River were also sensitive to water levels during the fall draw-down period. A slower decline in water levels during this period was found to contribute to an extension of the boating season in that area.

APPENDIX 3: General Response of Upper Great Lakes Interest Categories to Water Level and Flow Conditions

Interest	Vulnerability to Water Level and Flow Conditions
Domestic, Municipal and Industrial Water Uses	- "Changing lake levels may impact each water withdrawal facility differently, depending, among other factors, on the location of the facility, the infrastructure of the intake, and the amount of water withdrawn." (IUGLS, 2012, pg. 25) - High water has typically been less problematic than low water. High water leads to flooding of certain shore facilities, while low water can lead to intake capacity issues. (IUGLS, 2012, pg. 25)
Commercial Navigation	- "In general, low water levels will adversely impact the interests more than higher levels." (IUGLS, 2012, pg. 27) - "Reductions in water depths will force vessels to operate with reduced under keel clearance, thus increasing risk of environmental incident such as grounding in controlled Draft area of Seaway Jurisdiction." (SLSMC, 2012, JAM) - "Reductions in water depths will force vessels to operate with reduced maneuverability in shallow and confined channel waters, thus increasing risk of navigational incident such as collision and loss of direction." (SLSMC, 2012, JAM) - "Reductions in water depths will force vessels to operate with reduced loads, thus increasing the number of trips and the total cost of moving a given amount of cargo." (IUGLS, 2012, pg. 27) - "High Water flows will force vessels to operate with reduced maneuverability in up current direction in confined canal waters, thus increasing risk of navigational incident such as collision and loss of direction." (SLSMC, 2012, JAM) - "Higher water levels may allow increased vessel loads, reducing the costs of moving given quantities of cargo. The maximum tonnage of cargo that can be carried, however, is limited by the design capacity of vessels." (IUGLS, 2012, pg. 27)
Hydroelectric Generation	- "…the amount of electricity that the hydropower stations produce depends on available head (*i.e.*, the difference in water levels upstream and downstream of the plants) and the amount of flow allocated to the stations. In some cases, high water conditions enable hydropower operators to increase power generation. However, very high levels and flows can have adverse impacts on their operations. For example, very high lake outflows can result in "surplus" water spilled through the spillway and thus missed opportunity to generate additional power due to lack of diversion capacity." (IUGLS, 2012, pg. 29) - "Low water conditions have more of an impact on hydroelectric generation, forcing stations to operate below capacity and reducing revenues." (IUGLS, 2012, pg. 29)
Ecosystem	- "Natural fluctuations in water levels (over both the short and long-term) are essential to maintaining habitat diversity and critical ecological functions in the Great Lakes. Under natural conditions, coastal biological communities adapt to high and low water conditions by migrating upslope, downslope, or laterally, while maintaining biodiversity, ecological functions and benefits. Even though the Great Lakes ecosystem is dynamic and requires fluctuating water level regimes to maintain functional biodiversity, many policies and regulations are designed to maintain an ecological "status quo" (*i.e.*, a narrow range of water level and ecological conditions defined by short-term historical conditions) irrespective of changing environmental conditions." (IUGLS, 2012, pg. 30)
Coastal	- "Historically, the most serious impacts to riparian interests on the upper Great Lakes have occurred when water levels were extremely high." (IUGLS, 2012, pg. 32) - "By far the most common negative impacts during these periods have been related to flood and erosion damage during storm activity, loss of land and structures from accelerated bluff or beach erosion, damage to shore protection structures, loss of beach access, and the related social and economic impacts associated with these." (IUGLS, 2012, pg. 32) - "For some riparian property owners, low water levels can mean wider beaches in front of coastal bluffs and sandy beach areas, and significantly reduced threats of flooding in lower lying environments" (IUGLS, 2012, pg. 32) - "low water levels can negatively affect use of, or access to, property where boats are the primary means of access." (IUGLS, 2012, pg. 32)
Recreational Boating and Tourism	- "Marinas typically are more adversely affected by low water level conditions, while high water levels are more of a nuisance than a serious problem." (IUGLS, 2012, pg. 36) - "Potential impacts of changing water levels on the cruise ship sector are not clear, as there has been only limited experience with the industry in the basin." (IUGLS, 2012, pg. 36) - "To date, there has been little evidence linking water levels and coastal tourism." (IUGLS, 2012, pg. 35)