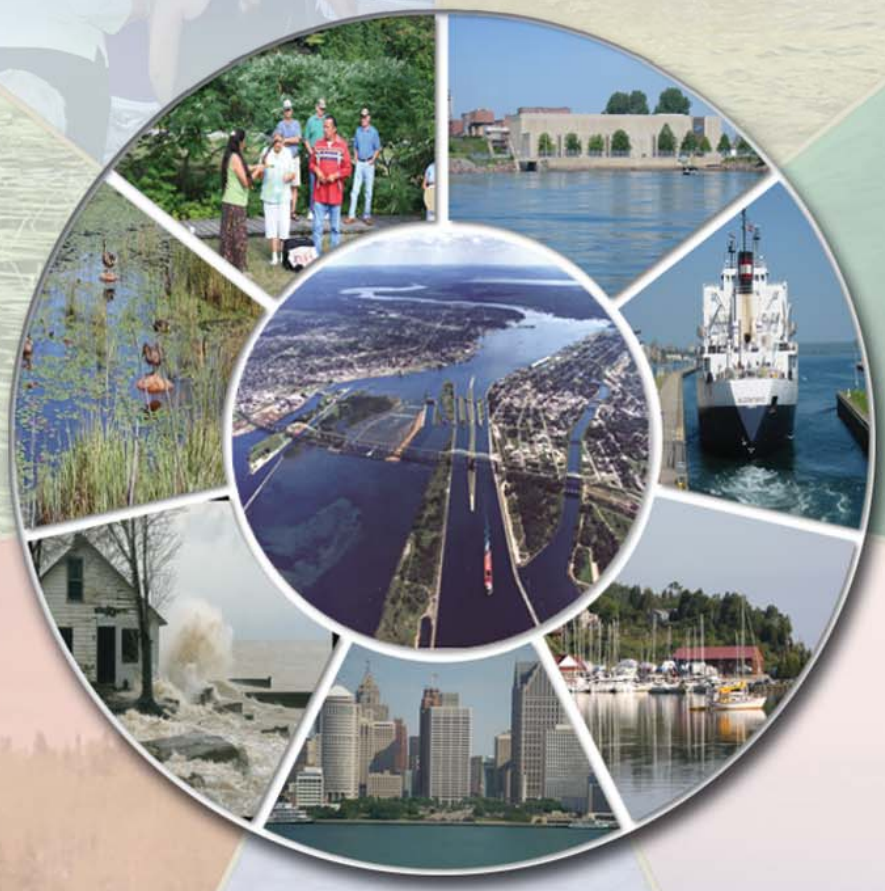
INTERNATIONAL
# Upper Great Lakes STUDY

## Lake Superior Regulation: Addressing Uncertainty in Upper Great Lakes Water Levels

# Summary of Findings and Recommendations



Final Report to the International Joint Commission
March 2012

### Report Cover

Changing water levels can have significant effects on the lives of the more than 25 million people who live and work in the upper Great Lakes region. The front cover shows an integrated view of the key interests served by these waters. In the centre of the image is a photograph of the control structures at the outlet of Lake Superior on the St. Marys River, the only location in the entire Great Lakes basin upstream from Niagara Falls where water levels can be affected by regulation.

Under the *Boundary Waters Treaty of 1909*, *domestic and sanitary water uses, navigation*, and *power and irrigation* are given order of precedence. These uses must be taken into account in the development of regulation plans. Today, it is recognized that other interests have rights under the Treaty, consistent with the International Joint Commission's balancing principle – providing benefits or relief to interests affected by water levels and flows without causing undue detriment to other interests. With this in mind, the International Upper Great Lakes Study added the interests of ecosystems, coastal zone uses and recreational boating and tourism to its analysis of Lake Superior regulation and uncertainty in future upper Great Lakes water levels.

In addition, the Study recognized that First Nations in Canada, Native Americans and Métis represent an important perspective in the upper Great Lakes. For thousands of years, and continuing into the present, many Native American communities and First Nations have relied on the natural resources of the Great Lakes to meet their economic, cultural and spiritual needs.

*Front cover graphic: Syed M. A. Moin*
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## For More Information on the Study

For more information on the International Upper Great Lakes Study, please visit the Study's website: www.iugls.org.

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This is the second and concluding report of the International Upper Great Lakes Study. The Study was launched by the International Joint Commission in 2007 to review the regulation of Lake Superior outflows and assess the need for improvements to address both the changing conditions of the upper Great Lakes and the evolving needs of the many interests served by the system.

This Summary Report provides a synthesis of the Study's approach, key findings and recommendations. More information on the Study, as well as the full scientific report and supporting planning, scientific and technical documents, are available at the Study's website: www.iulgs.org.

# Summary of Findings and Recommendations

## 1. The Challenge

The International Upper Great Lakes Study (the Study) was established to examine a recurring challenge in the upper Great Lakes system: *how to manage fluctuating lake levels in the face of uncertainty over future water supplies to the basin while seeking to balance the needs of those interests served by the system*.

Changing water levels can have significant effects on the lives of the more than 25 million people who live in the upper Great Lakes basin. The people around the Great Lakes depend on these waters for a myriad of uses: their livelihoods; drinking water; fishing; recreational boating; and spiritual needs. The economic importance of this region cannot be understated and industries such as navigation, hydroelectricity and thermal power are dependent on water levels. Water levels are also important for maintaining healthy wetlands, fisheries and other ecosystems across the basin.

In the entire upper Great Lakes basin, however, water levels are affected by regulation at only one location upstream from Niagara Falls: at the outlet of Lake Superior on the St. Marys River (Figure 1). The International Joint Commission (IJC) issued its first Orders of Approval in 1914 for hydropower development on the St. Marys River and the first Lake Superior regulation plan was implemented in 1921. Since then, the IJC has sought to incorporate new knowledge, data and modelling strategies to address the challenge of regulating water levels in the upper Great Lakes. In that sense, the existing Lake Superior regulation plan, **1977A**, in effect since 1990, represents the culmination of nearly 75 years of regulation experience responding to changing economic, environmental and social conditions.

***Figure 1*** ***Lake Superior Regulation Control Structures***

*The first plan regulating outflows from Lake Superior at the St. Marys River came into effect in 1921. Today, the control structures consist of three hydropower plants and a gated dam at the head of the rapids, known as the compensating works.*

The rationale for reviewing the existing plan is based on several important factors that have emerged over the past 20 years since the current plan was implemented:

- First, there is considerable uncertainty about water supplies or net basin supplies[1] (NBS) and corresponding water levels in the Great Lakes basin in the future as a result of natural climate variability and human-induced climate change. Compounding uncertainty about NBS are the impacts of glacial isostatic adjustment (GIA), the differential adjustment of the earth's crust that has the effect of gradually "tilting" the Great Lakes basin over time.
- Second, there is better information available today than 20 years ago about the hydrology and hydraulics of the Great Lakes. Researchers have more confidence in the newer models that describe how the system performs under a variety of conditions. New knowledge has also been gained through recent investigations, such as the Study's own analysis of the changes in the conveyance of the St. Clair River.
- Finally, there is improved information about the different sectors and public interest concerns that any new regulation plan must address. Under the *Boundary Waters Treaty of 1909*, the interests of *domestic and sanitary water uses, navigation*, and *power[2] and irrigation* are given order of precedence. However, it is now recognized that in developing a new regulation plan, the needs of other interests, such as ecosystems, coastal zone uses, and recreational boating and tourism must be taken into account, as well.

### The International Joint Commission

In 1909, Canada and the United States signed the *Boundary Waters Treaty* establishing the International Joint Commission (IJC). The IJC seeks to prevent and resolve disputes regarding many of the lakes and rivers along the shared border of the two countries. This role includes approving the construction and management of works that affect levels and flows in boundary waters. The IJC also has a special role in helping the two countries restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes.

1 Net basin supply (NBS) is the net amount of water entering a lake, consisting of the precipitation onto the lake minus evaporation from the lake, plus groundwater and runoff from its local basin, but not including inflow from an upstream lake.

2 In interpreting the Treaty, "power" is taken to mean generation of hydroelectricity.

# 2. The International Upper Great Lakes Study

## Mandate of the Study Board

In February 2007, the IJC issued a Directive establishing the Study and appointing a 10-member bi-national Study Board to direct and manage the effort. Members were drawn from the two federal governments, state and provincial governments, universities and the public.

The IJC directed the Study Board to provide it with the information it needs to evaluate options for regulating levels and flows in the upper Great Lakes system in order to benefit affected interests and the system as a whole in a manner that conforms to the requirements of the *Boundary Waters Treaty of 1909*. The Directive further instructed the Study Board to provide options and recommendations for the IJC's consideration. Furthermore:

> *"… in carrying out this mandate, the Study Board is encouraged to integrate as many relevant considerations and perspectives into its work as possible, including those that have not been incorporated to date in assessments of the Upper Great Lakes system regulation, to assure that all significant issues are adequately addressed".*

The Study Board is only authorized to offer non-binding recommendations to the IJC that are consistent with its mandate established in the Directive. The Study Board is not empowered to implement any solutions. The IJC is responsible for making decisions on a new regulation plan and advising the governments of Canada and the United States.

The geographical scope of the Study was the upper Great Lakes basin, from the headwaters of Lake Superior downstream through lakes Michigan, Huron, St. Clair and Erie and the connecting channels (the St. Marys, St. Clair and Detroit rivers, the Straits of Mackinac and the upper Niagara River) (Figure 2).

The Study's first report, ***Impacts on Upper Great Lakes Water Levels: St. Clair River***, submitted to the IJC in December 2009, examined the physical processes and possible ongoing changes in the St. Clair River and the effects of such changes on the levels of Lake Michigan-Huron.[3]

This second and concluding report of the Study, Lake Superior Regulation: Addressing Uncertainty in Upper Great Lakes Water Levels, focuses on the formulation and evaluation of options for a new regulation plan. It also addresses restoration and multi-lake regulation as alternative

3 Available at: www.iugls.org
For the purposes of the Study, lakes Michigan and Huron were considered a single lake because they have the same surface water elevation due to their shared connection to the broad and deep Straits of Mackinac.

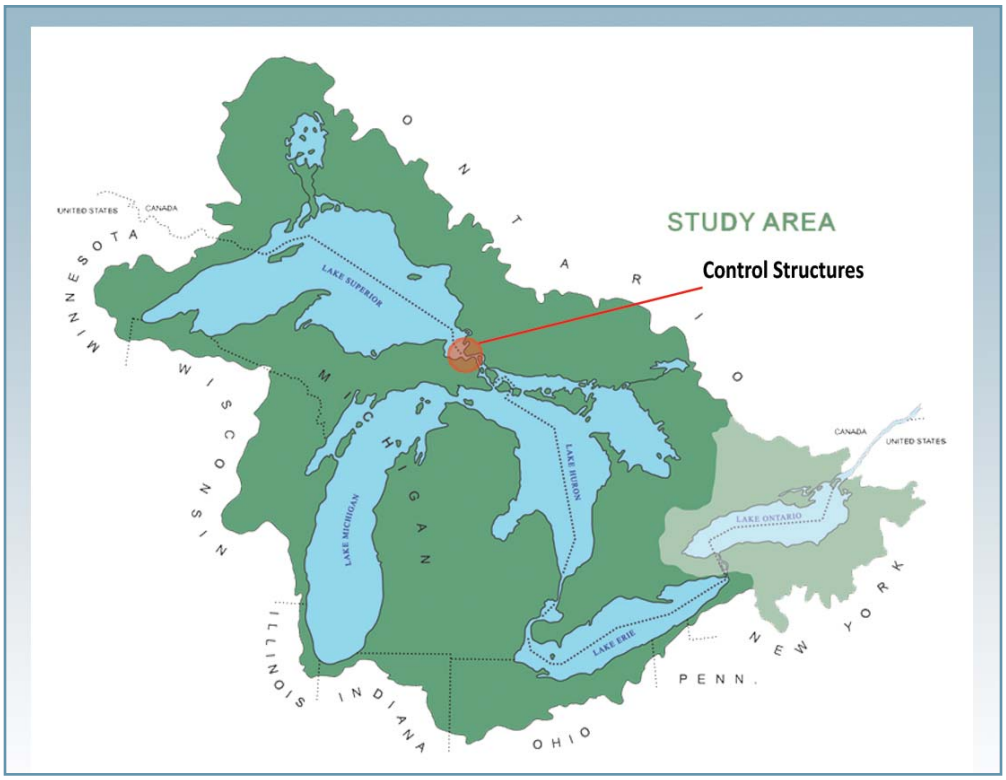


*Figure 2* ***Study Area***

approaches for dealing with extreme water levels beyond those addressed by Lake Superior regulation alone, and considers the important role that adaptive management can play to help the interests better anticipate and respond to extreme water levels in the future.

## The Study's Strategy

The IJC's Directive to the Study Board called for an understanding of the key interests served by the upper Great Lakes system, an examination of the changing conditions in the water levels of that system, and the identification and evaluation of options to regulate water levels while balancing the needs of the interests. Addressing these closely related issues required a thorough analysis of past, present and projected future hydroclimatic conditions in the system and an effective approach to testing regulation options in relation to impacts on water levels and flows on the key water interests.

### The Key Interests

Future changes in water levels in the upper Great Lakes basin will affect a complex and interrelated network of individual, institutional and commercial interests (Figure 3). With this in mind, the Study commissioned detailed analyses of the current and emerging conditions and perspectives of six key interests likely to be affected by possible future changes in water levels in the upper Great Lakes basin.

1. Domestic, municipal and industrial water uses;
2. Commercial navigation;
3. Hydroelectric generation;
4. Ecosystems;
5. Coastal zone; and,
6. Recreational boating and tourism.

These analyses summarized the socio-economic context for the interest, including important values and perceptions, and identified the likely consequences, if any, for the interest of changing water levels, together with the prospects for the interest to address these risks through adaptive behavior and response.

***Figure 3*** ***An Integrated View of the Interests Served by the Waters of the Upper Great Lakes***

The Study also recognized that indigenous First Nations in Canada, Native American tribes in the United States, and Métis represent a unique perspective in the upper Great Lakes. With respect to changing water levels, their concerns cut across the Domestic Water Users, Coastal Zone and, in particular, Ecosystems interests investigated in detail. Study Board members engaged a number of First Nations and Native American tribes through workshops and other outreach activities to identify their issues and concerns with respect to Great Lakes water levels. In addition, a member of a Native American tribe with extensive experience in Great Lakes water issues was a member of the Public Interest Advisory Group (PIAG).

### *Hydroclimatic Analysis*

A key task of the Study was to improve understanding of hydroclimatic conditions in the upper Great Lakes system, focusing on the possible impacts of climate variability and climate change on future water levels. The Study addressed two primary science questions:

- *What are the historical estimates of the NBS in the upper lakes and how have any potential changes to the water balance components affected the level of the lakes?*
- *What potential impact could variations in the climate system have on any future regulations of the upper Great Lakes?*

Three themes were central to the Study's approach to the hydroclimatic analysis:

1. understanding the water balance (precipitation, evaporation and runoff) of the Great Lakes;
2. assessing the reliability of historical recorded and estimated data, and increasing understanding of potential NBS conditions through the use of paleo-information[4] and stochastic[5] analysis; and,
3. addressing the plausibility and scope of climate change impacts on water supplies through new modelling work.

### *Regulation Plan Formulation and Evaluation*

A primary objective of the Study was to develop and evaluate possible new Lake Superior regulation plans to determine if a new plan could improve on the performance of **1977A** – particularly in the context of the considerable uncertainty about future climate conditions and corresponding water levels on the upper Great Lakes.

The Study Board established clear objectives for a new Lake Superior regulation plan – and for the upper Great Lakes basin as a whole – based on the IJC's Directive and feedback received at public meetings:

- To maintain or improve the health of coastal ecosystems;
- To reduce flooding, erosion and shore protection damages;
- To reduce the impact of low water levels on the value of coastal property;
- To reduce or maintain shipping costs;
- To maintain or increase hydropower value;
- To maintain or increase the value of recreational boating and tourism opportunities; and,
- To maintain or enhance municipal-industrial water supply withdrawal and wastewater discharge capacity.

4 *Paleo* – a combining form meaning "old" or "ancient," especially in reference to former geologic time periods, used in the formation of compound words, as in *paleo-hydrology*.

5 *Stochastic* –Statistics involving or showing random behaviour. In a stochastic simulation, a model is used to create a new 'synthetic' series of plausible flows and lake levels, based on historical data. The synthetic series will, on average, preserve important properties of the historical record, such as the mean and standard deviation, while generating new combinations of high and low flow conditions that could represent more severe conditions than those seen in the past.

Of the hundreds of NBS sequences generated by the Study's hydroclimatic analysis, 13 were chosen as representative of the range of plausible future conditions that could be used to test the limits of any new proposed regulation plan. This suite of NBS sequences allowed the Study Board to test plans for *robustness* – the capacity to meet particular regulation objectives under a broad range of possible future NBS conditions.

In formulating, evaluating and ranking regulation plans, the Study applied shared vision planning, an iterative and collaborative process through which participants can better understand the implications of any regulatory decision. The Study Board used a shared vision model to undertake practice decisions, allowing experts, stakeholders and decision makers a series of opportunities to weigh the results as information developed.

Study plan formulators generated more than 100 alternative regulation plans, using a variety of scientific approaches, so as to ensure a comprehensive search for regulation plan options. The Study Board reduced the list of plans to four. One of the final four plans performed better than or as well as any other regulation plan considered, regardless of the NBS sequence or the decision criterion applied. As a final step in the selection process, plan formulators developed three variations of the preferred plan as part of an optimization analysis. One of the variations was selected as the recommended plan.

### *The Limits of Lake Superior Regulation*

The Study Board recognized that Lake Superior regulation on its own has limited ability to affect the levels of Lake Michigan-Huron or address risks of extreme lake levels downstream of Lake Superior. In addition, the Study Board concluded that the impacts of climate change and climate variability on future water levels would introduce uncertainty to any regulation effort. As a result, the Study Board concluded that to more fully address changing water levels in the upper Great Lakes basin, there was a need to look beyond the existing system of Great Lakes regulation and consider alternative approaches for managing and responding to uncertain future water level conditions.[6] These alternative approaches were: restoration of Lake Michigan-Huron water levels; multi-lake regulation of the Great Lakes-St. Lawrence River system as a whole; and, adaptive management.

6 Currently, the Great Lakes-St. Lawrence River system is regulated at two locations: at the outlet of Lake Superior on the St. Marys River, and at the outlet of Lake Ontario on the St. Lawrence River. These two structures are operated to regulate water levels for the upper Great Lakes and Lake Ontario/upper St. Lawrence River, respectively.

### *Public Engagement and Peer Review*

Public involvement was a core element of the Study from the outset. Recognizing the many interests concerned with the future of water levels in the upper Great Lakes, the IJC appointed a bi-national PIAG to provide advice to the Study Board on issues related to the Study and advice and support in the development and implementation of the Study Board's public information and engagement activities. These activities included a series of 12 public meetings around the Great Lakes basin, attended by more than 1,200 people, to present preliminary findings, respond to questions and receive public comments.

Finally, given the diverse public and private interests concerned about Great Lakes water levels and the uncertainty and debate around some of the scientific issues, the IJC and Study Board recognized the need to ensure that the Study was scientifically credible and open. As a result, much of the Study's work was subject to a high level of independent scientific scrutiny by external peer reviewers as well as extensive review by internal experts. The peer reviewers operated independently of the Study Board and provided their views directly to the IJC. They reviewed drafts and background studies of several of the Study's scientific and technical chapters. The Study's final report also was reviewed by the co-leads of the independent expert reviewers group. The Study Team considered and responded to each comment from the expert reviewers.

# 3. Summary of Study Findings

This section summarizes the key findings of the Study in seven major areas.

## The Key Interests Served by the Upper Great Lakes System

***Key Finding 1:***

*Most of the key interests have demonstrated their capacity to adapt to changes in water level conditions that have been within historical upper or lower ranges. However, future water levels that are outside these ranges would require some interests to carry out more comprehensive and costly adaptive responses than any undertaken to date.*

The Study undertook a comprehensive analysis of the current and emerging conditions and perspectives of six key interests likely to be affected by possible future changes in water levels in the upper Great Lakes basin. Based on this analysis, the Study Board concluded that:

- Under the *Boundary Waters Treaty of 1909*, *domestic and sanitary water uses, navigation*, and *power and irrigation* are given order of precedence. These uses must be taken into account in the development of regulation plans. Today, it is recognized that other interests, such as ecosystems, coastal zone uses, and recreational boating tourism have rights under the Treaty, consistent with the IJC's balancing principle, which provides for benefits or relief to interests affected by water levels and flows without causing undue detriment to other interests.
- All six interests are experiencing major change as a result of broad, underlying economic, social and environmental forces. The decline in heavy industry and manufacturing in the region has put into motion changes such as declines in income, population, and municipal taxes, which in turn affect demand for shipping, energy and recreation. At the same time, the region's economic transition could see the rise of new, more water-intensive industries, such as irrigated agriculture, biofuels, oilsands refining and electricity production.
- All the interests have a long-established presence in the upper Great Lakes basin, and all represent significant economic value to the region. There are expectations across all the interests that water levels will be maintained in the future to support their needs.
- All six interests can be adversely affected by both high and low water conditions. Most of the interests have demonstrated their capacity to adapt to changes in water level conditions that have been within historical upper or lower ranges (Figure 4). However, future water levels that are outside these historical ranges would require some interests to carry out more comprehensive and costly adaptive responses than any undertaken to date.
- For thousands of years, and continuing into the present, many Native American communities and First Nations have relied on the natural resources of the Great Lakes to meet their economic, cultural and spiritual needs. A fundamental ongoing concern of indigenous peoples is the extent to which they are involved in the decisions of governments in the United States and Canada with regard to the Great Lakes.

***Figure 4*** ***Shoreline Protection Structure, 2004 – Near Michigan City, IN on Lake Michigan***

## Uncertainty in Future Upper Great Lakes Water Levels

> ***Key Finding 2:***
>
> *Changes in the levels of the upper Great Lakes may not be as extreme in the near future as previous studies have predicted. Lake levels are likely to continue to fluctuate, but still remain within the relatively narrow historical range – while lower levels are likely, the possibility of higher levels cannot be dismissed. Both possibilities must be considered in the development of a new regulation plan.*

The Study undertook extensive analysis to improve understanding of the hydroclimatic forces at work in the upper Great Lakes basin and their likely impacts on future water levels. It also considered how the uncertainties in the hydroclimatic analysis could influence the evaluation and decision-making framework. Based on this analysis, the Study Board concluded that:

- Perhaps most striking from the perspective of effective lake regulation is how little the lake dynamics on inter-annual and decadal timescales are understood. Despite best efforts, the lake levels remain almost entirely unpredictable more than a month ahead. In terms of understanding the lakes system relative to lake levels, the unavoidable conclusion is that the Great Lakes basin is a complex system whose dynamics are only partially understood.
- Without substantially increased confidence in historical NBS estimates and an understanding of the uncertainty associated with these estimates, choosing plausible futures in the context of past events is highly problematical.
- In general, information from global change models (GCMs) introduced more uncertainties that are very difficult to reconcile with historical data.
- Determination of climate change impacts on NBS using regional climate model (RCM) tools provided insights into the dynamics of the hydroclimatic systems that are not possible through statistical down-scaling. Features such as local feedback and recycled evaporation are not captured in any of the GCMs. This work advanced scientific knowledge in this area. Due to the limited number of RCM runs, however, the full range of impacts was not assessed.
- Despite these uncertainties, it is clear that lake evaporation is increasing and likely will increase for the foreseeable future, likely due to the lack of ice cover, increasing surface water temperatures and wind speeds. Analysis indicates that in the Lake Michigan-Huron basin this increased evaporation is being largely offset by increases in local precipitation.
- In the Lake Superior basin, however, increasing evaporation over the past 60 years has not been compensated for by increased precipitation. As a result, NBS have been declining in general in the basin. This trend is consistent with the current understanding of climate change. Unless changes in the precipitation regime occur, which is possible, NBS in Lake Superior will continue to decline, on average, despite the possibility of higher supplies at times. It will be important to ensure that further climate analysis be undertaken to explore these dynamics and provide more certainty of future NBS estimates.
- The very short record of measured evaporation initiated by the Study suggests that earlier evaporation amounts may be over-estimated. However, regardless of differences in absolute evaporation measurements, the trends in increased evaporation rates, inferred from the earlier estimates, are thought to be reasonably reliable.
- As a result, changes in lake levels in the near-term future may not be as extreme as previous studies have predicted. Lake levels are likely to continue to fluctuate, but still remain within the relatively narrow historical range. While lower levels are likely, the possibility of higher levels at times cannot be dismissed (Figure 5). Both possibilities must be considered in the development of a new regulation plan.
- Beyond the next 30 years, some projections by GCMs and RCMs of more extreme water levels in the upper Great Lakes may have more validity. However, due to the limitations of these models for this region, there is, at present, no completely satisfying representation of the future water balance.
- Therefore, in terms of water management and lake regulation, the best approach is to make decisions in such a way as to not overly rely on assumptions of particular future climatic and lake level conditions or specific model projections. *Robustness* – the capacity to meet regulation objectives under a broad range of possible future water level conditions – must be a primary attribute of any new regulation plan.

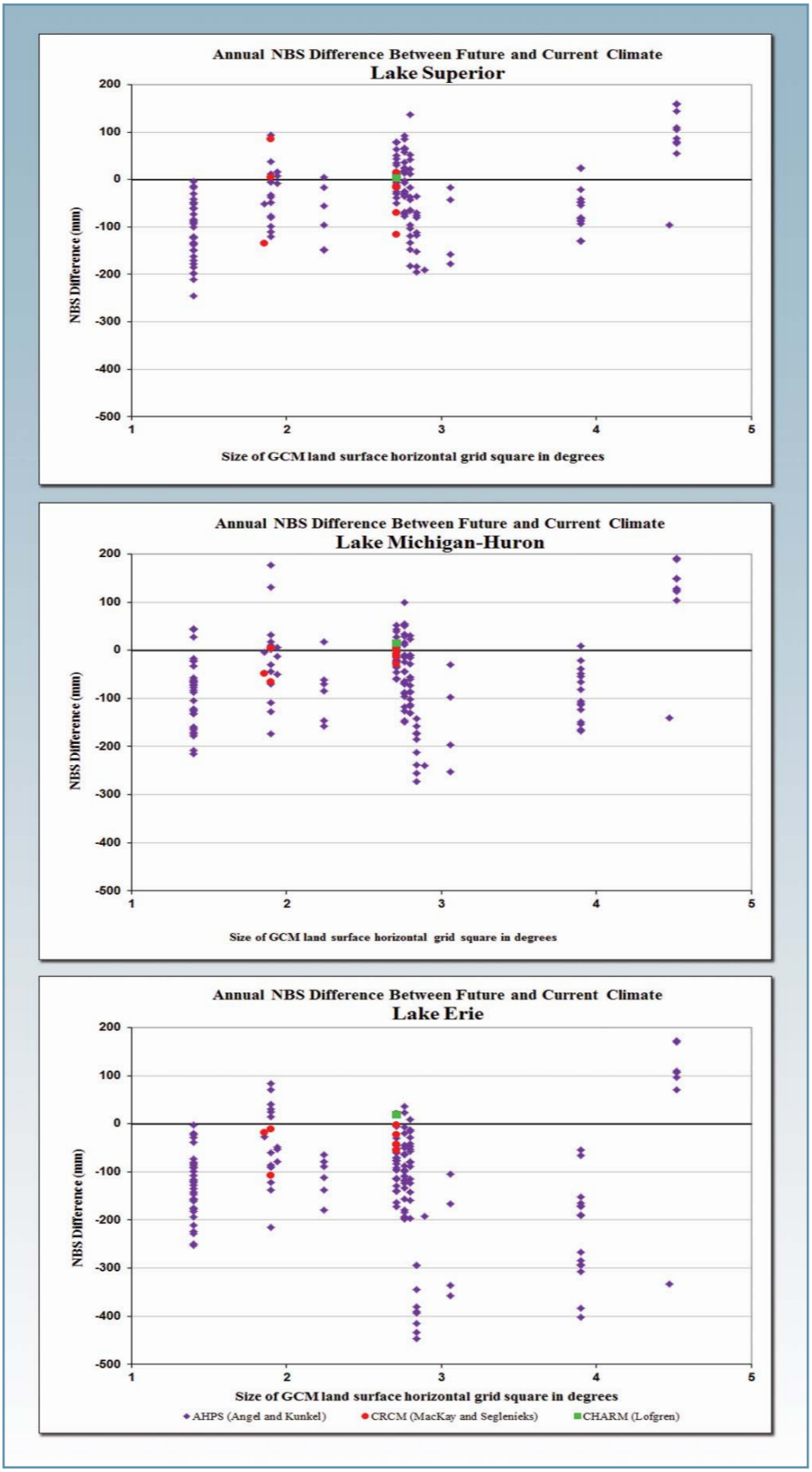


***Figure 5* Integration of Results of the Study's Hydroclimatic Analysis**

*This figure shows the ranges in NBS conditions estimated for 2040 above and below long-term averages for lakes Superior, Michigan-Huron and Erie, as projected by several different climate models. The projections suggest that lake levels are likely to continue to fluctuate, but still remain within a relatively narrow range. Lower levels appear to be likely, but there is also the possibility of higher levels at times.*

## Lake Superior Regulation Plan 2012

> ***Key Finding 3:***
>
> *The Study Board identified a regulation plan that will be more robust than the existing plan and that will provide important benefits related to the maintenance of Lake Superior levels, environmental impacts, economic benefits and ease of regulation.*

Through the shared vision planning process, the Study developed and evaluated numerous Lake Superior regulation plan options to determine if a new plan could improve on the performance of **1977A**. Based on this work:

- Reviewing more than 100 alternative regulation plans, the Study Board identified one plan, named **Lake Superior Regulation Plan 2012**, that, on the basis of the evaluations, performed better than or as well as any other plan considered regardless of the NBS sequence or the decision criterion applied. This performance satisfied the objective of *robustness* in a new plan. Table 1 summarizes the evaluation findings of the final four plan options.
- **Lake Superior Regulation Plan 2012** will bring several benefits compared to the existing plan:
  - The recommended plan will perform in a similar manner as the existing plan if future NBS are similar to those that have been experienced since 1900. However, if future NBS become significantly drier under climate change, then the new plan will do a better job preserving water levels on Lake Superior, while taking into account the downstream lakes.
  - If future NBS are much drier than historical conditions, then **Lake Superior Regulation Plan 2012** will still be able to avoid infrequent but serious adverse effects on the spawning habitat of lake sturgeon, an endangered species, in the St. Marys River. Under **1977A**, adverse effects on fish habitat would be more frequent under drier NBS conditions.
  - **Lake Superior Regulation Plan 2012** will provide modest benefits compared to the existing plan for commercial navigation, hydroelectric generation and coastal zone interests, under both wetter and drier NBS conditions. Importantly, under very dry future NBS conditions, commercial navigation through the Sault Ste. Marie locks, as well as hydroelectric generation at the St. Marys River power plants, would be threatened with closure under **1977A**, but not under **Lake Superior Regulation Plan 2012**.
  - Month-to-month changes in flow on the St. Marys River with **Lake Superior Regulation Plan 2012** will generally be smaller than with **1977A**, which will give the St. Marys River a more natural flow relationship to Lake Superior levels. Natural river flow frequencies have been identified as an important factor in sustaining riverine ecosystem health. The smaller changes will also help hydroelectric power producers.
  - The rules for operating **Lake Superior Regulation Plan 2012** will be much less complex than rules for **1977A**, making the new plan easier to manage.

**Table 1:** Summary Evaluations of Robustness of Plans

| Plan | Strengths | Limitations | Study Board Decision |
|---|---|---|---|
| 129 | Provides small net economic benefits under historical NBS | Like **1977A**, allows Lake Superior levels to drop too low in severe dry NBS sequences | **Eliminated** because of poor performance in severely dry NBS sequences |
| PFN3 | Compressed the range of Lake Superior levels<br>Maintained Lake Superior levels in a "severely dry" NBS sequence | Compression often caused slightly worse economic and ecological scores | **Eliminated** because of mixed performance and because it compressed Lake Superior levels at the expense of levels on Lake Michigan-Huron |
| Bal26 | Scores on all nine criteria were good and very close to those of Nat64D | Not clearly better than Nat64D and not balanced in extremely dry sequences | **Eliminated** because of limitations under dry NBS sequences |
| Nat64D (the basis for **Lake Superior Regulation Plan 2012**) | Better than **1977A** for most of the criteria and historical NBS<br>Among the best plans for all NBS | Does not outperform **1977A** for all criteria and every NBS | **Preferred** because of the gained benefits and robustness |

- In reviewing the IJC's Orders of Approval governing how Lake Superior outflows are regulated, the Study Board concluded that there was no need for major revisions to the Orders. However, the Study Board concluded that there is a risk of confusion in having the conditions that are still in force spread between the original 1914 Orders and several much more recent Supplementary Orders, amid many superseded conditions. Implementing a new regulation plan would provide an opportunity for the IJC to integrate various existing Orders and Supplementary Orders and recognize some existing policies or practices within new Orders of Approval.

## Restoration of Lake Michigan-Huron Levels

> ***Key Finding 4:***
>
> *Restoration structures designed to raise Lake Michigan-Huron water levels would result in adverse effects on certain key interests served by the upper Great Lakes system.*

At the direction of the IJC, the Study Board considered the feasibility and implications of raising water levels of Lake Michigan-Huron by means of restoration structures in the St. Clair River to compensate for past natural and human-induced changes. The IJC did not request that the Study Board make any recommendation as to implementing a particular restoration option. Based on this analysis, the Study Board concluded that:

- Several of the restoration options reviewed are technically feasible. Construction cost estimates ranged from about $30 million to about $170 million, depending on the technology and level of restoration provided.
- Restoration would reduce the occurrences of extreme low water levels on Lake Michigan-Huron, but also increase the number of occurrences of extreme high lake levels.
- Commercial navigation and recreational boating and tourism interests would benefit, while coastal zone interests, hydroelectric generation and indigenous peoples would be adversely affected.
- Positive environmental effects would be concentrated in the wetlands of the Georgian Bay region, which have suffered significantly during low water levels in the past and would benefit from higher Lake Michigan-Huron levels. In contrast, restoration structures in the St. Clair River would adversely affect important spawning habitat of the lake sturgeon, an endangered species, and would have adverse effects on the Lake St. Clair fishery (Figure 6).
- Restoration of Lake Michigan-Huron levels would temporarily help to counteract the effects of GIA on lowering water levels in Georgian Bay. However, restoration would compound the effects of GIA in much of the densely populated southern portion of the upper Great Lakes, resulting in more high water impacts.
- Climate change could magnify the impacts of restoring Lake Michigan-Huron water levels. If water levels become generally lower in the future as a result of climate change, then the commercial navigation sector and Georgian Bay wetlands would be adversely affected, and restoration could help mitigate these adverse effects. Conversely, if water levels become higher at times in the future, flood damages would increase, and restoration would exacerbate these adverse effects.
- Restoration structures would require the ongoing commitment and financing of the governments of Canada and the United States, a process that could take 20 years or more for the full range of planning, environmental reviews, regulatory approvals and design steps.

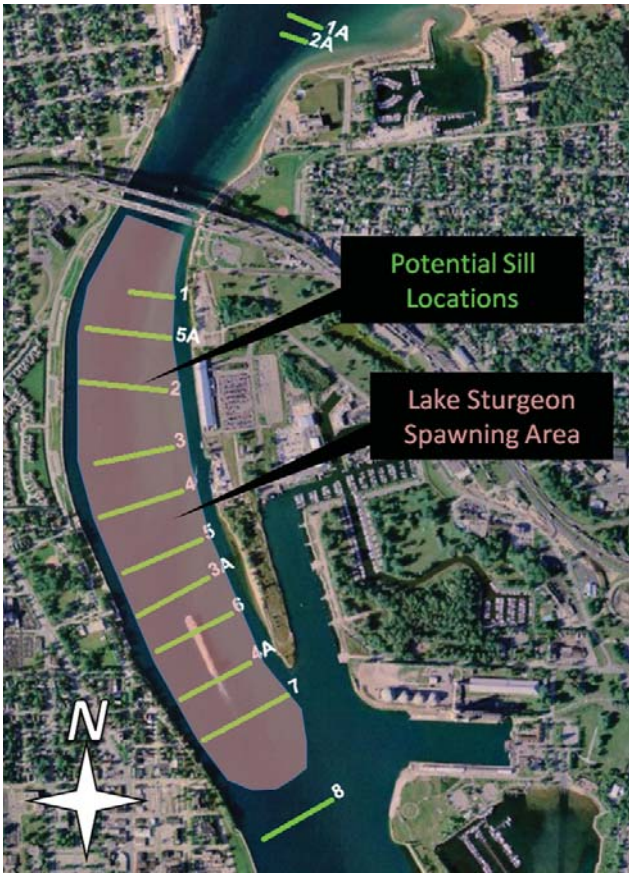


***Figure 6 Overlapping Zone of Potential Sill Locations and Lake Sturgeon Spawning Habitat in the Upper St. Clair River***

*The Study's analysis of restoration structures concluded that underwater sills in the St. Clair River would adversely affect important spawning habitat of the lake sturgeon, an endangered species.*

## Multi-lake Regulation

> ***Key Finding 5:***
>
> *The potential for multi-lake regulation to address extreme water levels is limited by the uncertainty regarding future climatic conditions and NBS, very high costs, environmental concerns and institutional requirements.*

The Study Board considered the feasibility of multi-lake regulation – operating existing and new regulation structures to benefit the Great Lakes-St. Lawrence River system as a whole. The Study analyzed multi-lake regulation plans that used both the existing structures on the St. Marys and St. Lawrence rivers and hypothetical structures on the St. Clair and Niagara rivers to reduce the frequency of occurrence of extreme water levels under possible extreme future NBS scenarios. Based on this analysis, the Study Board concluded that:

- Multi-lake regulation plans, involving the existing structures as well as new control points on the St. Clair and Niagara rivers, or on the Niagara River alone, could be designed to reduce the frequency of occurrence of extreme water levels across multiple extreme NBS scenarios relative to the existing system of regulation. However, system-wide multi-lake regulation could not eliminate extreme water level events entirely. Extreme water levels in the future may be unavoidable, even with additional regulation capabilities.
- New water level control points are extremely costly, requiring the construction of adjustable control structures, such as a gated dam, to restrict flows during dry conditions, as well as excavation to increase channel conveyance and increase flows during wet conditions. The cost of excavation is normally much greater than the cost of the control structures themselves.
- Many of the environmental impacts and institutional considerations that would arise with restoration structures apply equally to multi-lake regulation.
- Multi-lake regulation plans must be developed with consideration given to the impacts on water levels throughout the system, including the lower St. Lawrence River. Though not assessed directly in the Study's analysis, extensive mitigative measures costing several billion dollars and involving both control structures and excavation, would be necessary in the lower St. Lawrence for any multi-lake regulation plan developed.


***Figure 7*** ***Elements of an Adaptive Management Strategy***

## Adaptive Management

> ***Key Finding 6:***
>
> *Adaptive management has an important role to play in addressing the risks of future extremes in water levels in the upper Great Lakes, though it requires leadership and strengthened coordination among institutions on both sides of the international border.*

With the concurrence of the IJC, the Study Board expanded the scope of the Study's work to include a more comprehensive consideration of the role of adaptive management in helping interests in the upper Great Lakes basin better anticipate and respond to future extreme water levels. Based on this analysis, the Study Board concluded that:

- Adaptive management has an important role to play in addressing the risks of future changes in water levels in the upper Great Lakes. Lake Superior regulation on its own can do little to address risks of extreme lake levels downstream of Lake Superior. New structures in various parts of the Great Lakes Basin could take decades to implement and cost billions of dollars. Nor can multi-lake regulation fully eliminate the risk of extreme lake levels outside the historical range. Therefore, regardless of the Lake Superior regulation plan adopted by the IJC, ongoing monitoring and modelling efforts will be required to continue to assess risks and address uncertainties and changing conditions.
- Information and education are powerful components of adaptive management. They contribute to both anticipating and preventing lake level-induced damage, particularly when focused on understanding risk, the limits of regulation, inherent uncertainties and system vulnerability.
- An effective adaptive management strategy must include six core elements (Figure 7):
  - bi-national hydroclimatic monitoring and modelling;
  - ongoing risk assessment;

- information management and outreach;
- tools and processes for decision makers to evaluate their actions;
- a collaborative regional adaptive management study for addressing water level extremes; and,
- the integration of water quality and quantity modelling and activities.

- Application of a comprehensive adaptive management strategy requires a new approach to institutional involvement and coordination. Existing legal, regulatory and programmatic efforts related to adaptive management vary considerably from one jurisdiction to the next. Federal, state and provincial governments generally provide the policy and regulatory framework, while site-specific selection and application of adaptive risk management measures is largely a local government responsibility.
- Furthermore, no bi-national organization currently is responsible for coordinating data and information on an ongoing basis for adaptive management efforts in the Great Lakes basin. Efforts to coordinate approaches and promote consistency across jurisdictions have been limited and generally have focused on accommodating seasonal lake level fluctuations and the occasional extreme high and low water events. Little focus has been placed on long-term implications of climate change-induced impacts and the need for new adaptive risk management measures.
- Adaptive management to address future levels in the upper Great Lakes basin has direct relevance to several important initiatives in the Great Lakes-St. Lawrence River system, including:
  - adaptive management efforts in the Lake Ontario-St. Lawrence River part of the system;
  - the Great Lakes Water Quality Agreement; and,
  - the Great Lakes-St. Lawrence River Basin Sustainable Water Resource Agreement.

## Public Concerns about Upper Great Lakes Water Levels

***Key Finding 7:***

*Public concerns about water levels in the upper Great Lakes differ strongly depending on geographical location.*

With the advice and support of the PIAG, the Study undertook a comprehensive public information and engagement program to communicate information about the Study's approach and findings and to gain a better understanding of public attitudes regarding Lake Superior regulation and, more generally, issues related to water levels in the upper Great Lakes (Figure 8). Based on the results of these activities, the Study Board concluded that:

***Figure 8 Understanding Public Concerns about Upper Great Lakes Water Levels***

*More than 1,200 people attended the 2011 summer public meetings to hear progress on the Study and provide feedback. Here, residents attend a meeting in Midland, ON.*

- There was general support among participating individuals and organizations for an improved regulation plan for Lake Superior outflows. However, the issue did not generate extensive comment, as there was general agreement that any new plan would mean only marginal changes from the existing plan.
- Public views on other key water level issues within the Study's mandate differed strongly depending on geographical location:
  - Many residents in the Georgian Bay region of Ontario, as well as several other communities upstream from the St. Clair River, supported the construction of new structures in the St. Clair River to restore Lake Michigan-Huron levels or to provide for multi-lake regulation. They expressed concern that important coastal wetlands in Georgian Bay will be lost unless some form of water level restoration is achieved for that area. Some residents also expressed doubts about the seriousness of negative environmental impacts at or downstream of new structures in the upper St. Clair River.
  - In contrast, many individuals residing along the shorelines of much of Lake Michigan and the western and southern shorelines of Lake Huron expressed concerns about the negative shoreline effects of higher water levels resulting from restoration structures or multi-lake regulation. Those living downstream of the upper St. Clair River, including along Lake St. Clair and Lake Erie as well as some First Nations and Native American communities, expressed concerns about the environmental impacts of lower water levels even for a few years in their areas. Others opposed to multi-lake regulation said the approach was impractical given its high cost.

# 4. Summary of Study Recommendations

On the basis of the Study's analysis and findings, and in accordance with its mandate under the IJC Directive, the Study Board makes the following recommendations to the IJC.

## A New Lake Superior Regulation Plan

In developing, evaluating and ranking a set of new Lake Superior regulation plans, the Study Board identified a regulation plan that would be more robust than the existing plan, **1977A** and provide important additional benefits. The new plan would perform similarly under historical NBS conditions, but much better if future climatic conditions are either drier or wetter than in the period of historical record (1900-2008).

In considering the need to revise the existing IJC's Orders of Approval governing how Lake Superior outflows are regulated, the Study Board also concluded that the implementation of a new regulation plan provides the IJC with an opportunity to establish new integrated Orders to bring greater clarity and efficiency to the suite of new and existing requirements.

Therefore, the Study Board recommends that:

1. *The IJC should approve **Lake Superior Regulation Plan 2012** as the new plan for regulating Lake Superior outflow and advise governments that the **1977A** plan will be replaced with the new plan.*
2. *The IJC should prepare and issue new integrated Orders of Approval that consolidate all of the applicable conditions and requirements of the original and Supplementary Orders, as well as the additional considerations required to implement the recommended new plan, **Lake Superior Regulation Plan 2012**.*

## Hydroclimatic Science

The Study's hydroclimatic analysis has established a new standard that should be used as the starting point for Great Lakes planning and related research conducted in the future. However, considerable work remains – the Study's comprehensive hydroclimatic analyses using a range of approaches showed that assessing the uncertain impacts of climate variability and change on upper Great Lakes water levels will continue to be a challenging task. The Study identified important avenues to be pursued in the near- and medium-term to improve understanding of these impacts and their implications for regulation. To better link this work to planning and decision making across the Great Lakes basin, these scientific initiatives would be most effectively undertaken in a coordinated, bi-national manner as part of the recommended adaptive management measures, led by the proposed new water levels advisory board (see below).

In its first report to the IJC, ***Impacts on Upper Great Lakes Water Levels: St. Clair River***, the Study Board identified a number of specific "legacy" recommendations regarding strengthening data collection, scientific knowledge and institutional capacity. In this final report, the Study Board reaffirms those recommendations and in particular, notes the need for support and expansion of key data collection programs (*e.g.*, evaporation gauges, International Gauging Stations). Long-term data collection continues to be essential for improving scientific understanding of how the Great Lakes system functions and how it is – and is likely to be – affected by both natural forces and human activities.

Therefore, the Study Board recommends that:

3. *The IJC should seek to improve scientific understanding of hydroclimatic processes occurring in the Great Lakes basin and the impacts on future water levels as part of a continuous, coordinated bi-national effort. In particular, the IJC should endorse the following initiatives as priorities and strongly recommend ongoing government support:*
   - *strengthening climate change modelling capacity in the Great Lakes basin in light of the promising preliminary results identified in the Study; and,*
   - *enhancing hydroclimatic data collection in the upper Great Lakes basin.*

## Adaptive Management

The Study's analysis concluded that adaptive management has an important role to play in addressing the risks of future extremes in water levels in the upper Great Lakes, particularly given the limits of Lake Superior regulation and the high costs and impacts associated with restoration structures and additional multi-lake regulation.

Therefore, the Study Board recommends that:

4. *An adaptive management strategy should be applied to address future extreme water levels in the Great Lakes-St. Lawrence River basin through six core initiatives:*
   - *strengthening hydroclimatic monitoring and modelling;*
   - *ongoing risk assessment;*
   - *ensuring more comprehensive information management and outreach;*
   - *improving tools and processes for decision makers to evaluate their actions;*
   - *establishing a collaborative regional adaptive management study for addressing water level extremes; and,*
   - *promoting the integration of water quality and quantity modelling and activities.*
5. *The IJC should seek to establish a Great Lakes-St. Lawrence River Levels Advisory Board to champion and help administer the proposed adaptive management strategy for the entire Great Lakes-St. Lawrence River system.*
6. *The IJC should work with governments to pursue funding options and coordinate adaptive management efforts with the Lake Ontario-St. Lawrence River Working Group, the renewal of the Great Lakes Water Quality Agreement, and the implementation of the Great Lakes-St. Lawrence River Basin Sustainable Water Resource Agreement.*

## Multi-lake Regulation

Past studies of the potential for multi-lake regulation to address water level conditions in the Great Lakes system have consistently dismissed the concept on the basis of historical water supplies. The Study's exploratory analysis considered more severe NBS conditions, and concluded that multi-lake regulation may have potential to address (though not eliminate) extreme water levels in the upper Great Lakes basin. However, considerable uncertainty remains regarding the future climate and its impact on Great Lakes hydrology. This uncertainty, along with environmental concerns, institutional requirements and the high costs pose significant challenges for moving forward with multi-lake regulation. Furthermore, there may be adaptive measures that could more effectively address risks related to extreme water level conditions.

Therefore, the Study Board recommends that:

7. *Further study of multi-lake regulation in the Great Lakes-St. Lawrence River system should not be pursued at this time.*


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