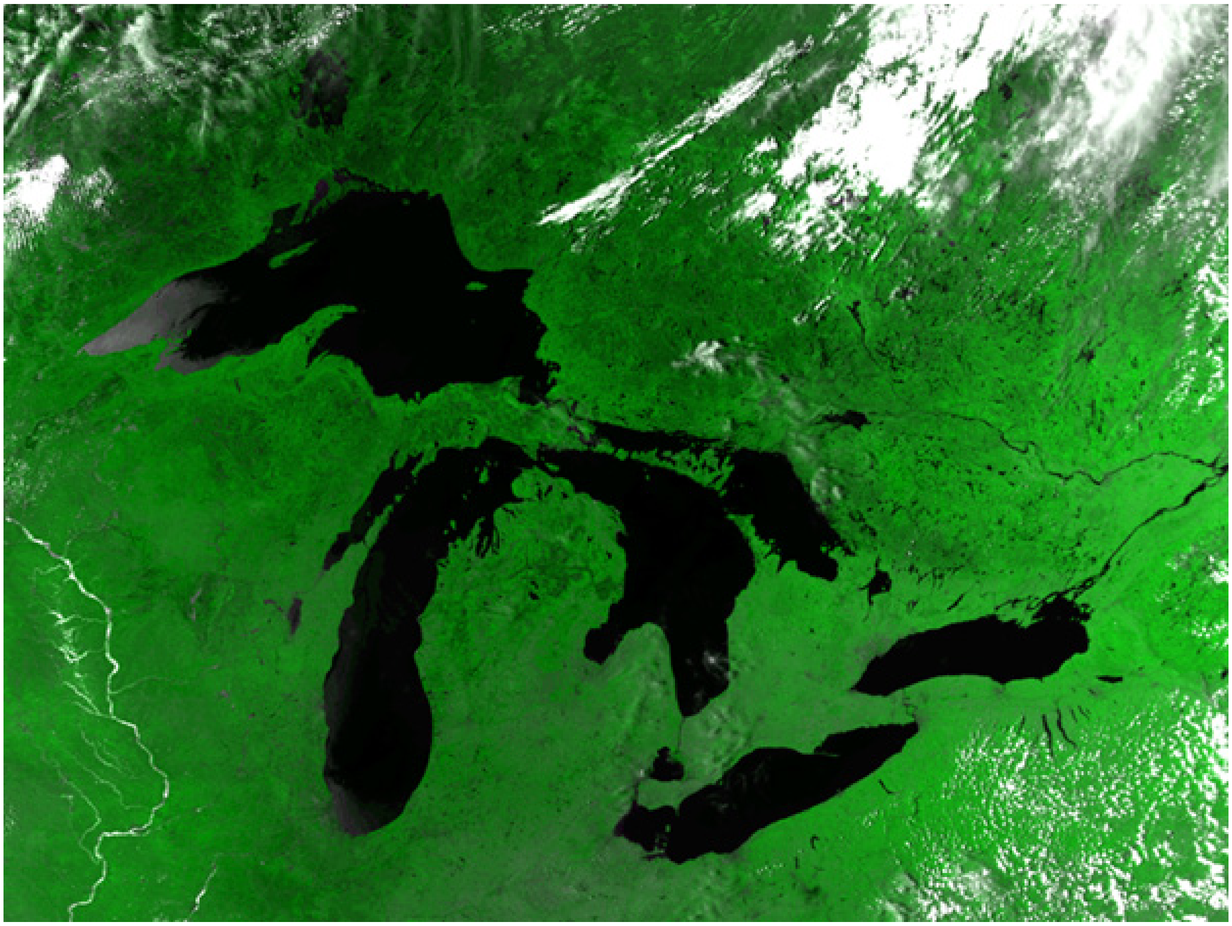
UPPER LAKES PLAN OF STUDY FOR THE REVIEW OF THE REGULATION OF OUTFLOWS FROM LAKE SUPERIOR



Prepared for the International Joint Commission
by the
Upper Lakes Plan of Study Revision Team

October 2005

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FOR THE REVIEW OF THE

REGULATION OF OUTFLOWS

FROM LAKE SUPERIOR

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Executive Summary

About This Document

This document describes the studies that are needed to investigate improvements to Lake Superior outflow regulation and to further our understanding of how changes in the St. Clair River affect regulation, as well as levels and flows in the upper Great Lakes.

Study Objectives and Scope

Lake Superior's outflows are regulated by structures on the St. Marys River. As the needs of the interests in the upper Great Lakes system continue to evolve and our concern with global climate change grows, questions arise as to whether the current methods to regulate the system could be improved to better meet the needs of the interests. Resources in this document are the people who live and work in the Great Lakes basin, the ecosystem which includes wetlands and other coincident uses.

The St. Clair River, Lake St. Clair and Detroit River connect Lake Huron with Lake Erie. The natural regime of this river system has been disturbed by human activities affecting the flow characteristics of the river. There is concern that further change may be ongoing in the relationship between the water levels of Lakes Michigan-Huron and Lake Erie. A change in the natural regime of the St. Clair River would affect the water levels of Lakes Michigan-Huron and would, in turn, impact Lake Superior outflow regulation.

The study tasks described in this document have been designed to examine these issues. The study area would include the upper Great Lakes system from Lake Superior downstream through Lake Erie including Lake Michigan and Lake Huron, their interconnecting channels and the Niagara River. These studies will be carried out in the context of Articles III and VIII of the 1909 Boundary Waters Treaty and the International Joint Commission's alerting responsibilities in the same manner as conducted for the IJC's Plan of Study for Criteria Review in the Orders of Approval for Regulation of Lake Ontario – St. Lawrence River Levels and Flows.

Study Approach

Investigating and evaluating water management options requires a good understanding of how water level changes affect the resources including the ecosystem. Also needed is knowledge of the hydrological and hydraulic processes of the Great Lakes system under the current climate regime and climate change. Computer models would be required to generate water levels and flows for various water management options, and methods would be developed to evaluate the effects that these options would have on resource groups including the ecosystem. The study and decision making processes would provide opportunity for public participation in all aspects of the study. The study will employ the most current science, and will engage relevant experts from governments, industries, academic community, First Nations/Native Americans and the public to conduct the study in an effective manner. Efforts will be made to ensure coordination and compatibility with related Great Lakes initiatives currently ongoing.

Public Participation

Public participation is a critical element in reviewing Lake Superior outflow regulation and examining the physical processes of the St. Clair – Detroit River system. The formation of a Public Interest Advisory Group is recommended. Periodic public meetings, issuing of newsletters and operation of an internet site would be part of the public participation process.

Understanding the St. Clair - Detroit River System

During the early part of the study, the factors affecting upper Great Lakes water levels and flows, including physical changes in the St. Clair River, would be investigated to provide a better insight into the cause of the recent and current water level changes. They include:

- Basin Water Supplies (which includes factors such as precipitation, evaporation and tributary flows)
- Diversions and Consumptive Uses
- Glacial Rebounding and Subsidence
- Flow Conveyance Capacity of the St. Clair – Detroit River System

Depending on the nature and extent of physical changes of the St. Clair River and their potential impacts on water levels and flows investigated during the course of the study, the study would explore potential remediation options.

Improving Lake Superior Outflow Regulation

The study to improve Lake Superior outflow regulation includes:

- Review of how Lake Superior outflow regulation and the operation of the control structures affect water levels and flows in the upper Great Lakes system
- Identification of potential updates and improvements to the criteria, requirements, operating rules and outflow limits as well as incorporating operating experience into the regulation plan
- Reviewing current institutional arrangements governing Lake Superior outflow regulation
- Testing of regulation plan performance under climate variability and climate change scenarios.

The Affected Resources

To determine whether the water management options to be explored in this study meet contemporary and emerging needs, and will manage the system in a sustainable manner, evaluations of their impacts on the various resources of the system are required. The evaluation of water management options would focus on the following resources:

- Ecosystem
- Recreational Boating and Tourism
- Hydropower
- Commercial Navigation
- Municipal, Industrial, and Domestic Water Use
- Coastal Zone

Study Organization

Given the multi-disciplinary nature of the study, it is proposed that a Study Board be set up to direct and manage the study. Within the Study Board, Study Directors are proposed to lead the study, with assistance from managers on financial, administrative matters and the day-to-day operations of the study. In addition, the Board would establish technical groups to generate water level and outflow information under the various water management options, and resource groups to evaluate the impacts of these options on the system's resources. A Public Interest Advisory Group is also proposed to advise the Study Board on issues and concerns as they relate to the resources.

Study Schedule and Cost

The tasks defined in this Plan of Study are designed to meet the study objectives and address the issues raised in the IJC Directive in one study. Consideration has been given to proper sequencing of tasks, currently available science and tools, and lessons learned from the International Lake Ontario – St. Lawrence River Study to ensure the study is conducted in an effective manner. The study is expected to take 5 years to complete at a cost of $14.6 million (U.S.) dollars, which is equivalent to $17.5 million (CDN) dollars assuming an exchange rate of 1.2. It is assumed that the cost would be split equally between the two Governments.

The Upper Lakes Plan of Study Revision Team is grateful for the considerable advice and many comments collected from members of the public, the study participants in the International Lake Ontario – St. Lawrence River Study, and other government and academic experts on the subject of Great Lakes water levels. Their input has helped toward making this document possible.

Respectfully submitted by the Upper Lakes Plan of Study Revision Team,

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1.0 Introduction

The water levels and outflows of the Great Lakes are continuously changing in response to the climate of the Great Lakes basin and, to some extent, are influenced by man-made factors. How the levels and outflows change can have significant impacts on the Great Lakes ecosystem and the people who live and work there.

Hydropower development on the St. Marys River, the outlet channel of Lake Superior, took place in the early part of the Twentieth Century following approval by the International Joint Commission (IJC). The operation of these structures is governed by the criteria and requirements specified by the IJC, and this led to the regulation of the outflows of Lake Superior. Supplementary orders have been issued and different regulation plans have been used to reflect changing conditions and requirements since the IJC first issued its Orders in 1914. However, as the needs of the interests continue to evolve and our concern with global climate change grows, questions arise whether the current method of operation could be improved to better meet their needs.

The St. Clair River, Lake St. Clair and Detroit River form the connecting channel between Lake Huron and Lake Erie. The natural regime of this river system has been disturbed by human activities which include sand and gravel mining, dredging for navigation, and shoreline infilling and hardening. These activities affect erosion and deposition of materials in the river and thereby, its ability to transport water from Lake Huron to Lake Erie. There is growing concern that these physical changes may have increased the flow carrying capacity of the St. Clair River. Both high and low water conditions greatly affect riparian communities, recreational boating and tourism, commercial navigation, a number of species and the ecosystems in which they live, and a number of other economic and social interests. A recent report has indicated that there may be on-going changes in the St. Clair River, primarily as a result of human activities, that may be significantly contributing to the lowering of the levels of Lakes Michigan and Huron. Other recent reports have suggested significant lowering of lake levels may result from climate change.

This document describes the studies that are needed to investigate improvements to the regulation of the outflow of Lake Superior given the impacts regulation may have on water levels, flows, and consequently affected resources throughout the upper Great Lakes system. It also describes the studies that are needed to closely examine the physical processes driving current Great Lakes water level conditions, and possible ongoing changes in the St. Clair River and their impacts on river flow and Lakes Michigan and Huron levels. These two issues are interrelated in that the outflow of Lakes Michigan-Huron, through the St. Clair River, plays a direct role in determining lake level, which in turn affects the regulated outflow from Lake Superior and the regulation objectives of the IJC Orders. Depending on the nature and extent of the possible St. Clair River changes and impacts reviewed during the course of the study, potential remediation measures would also be investigated. Remediation measures could include structural and non-structural approaches.

There are many related Great Lakes initiatives underway such as the Great Lakes Regional Collaboration, Annex 2001 and updates to the Great Lakes Water Quality Agreement. While they have their distinct and separate purposes, coordination will be required to share information and ensure compatibility. The possible consequences of climate change on water levels and flows will be examined as well.

The study will be carried out in the context of Articles III and VIII of the 1909 Boundary Waters Treaty and the IJC's alerting responsibilities in the same manner as conducted for the IJC's *Plan of Study for Criteria Review in the Orders of Approval for Regulation of Lake Ontario – St. Lawrence River Levels and Flows.* The review of the IJC's criteria and Lake Superior outflow regulation is a part of the IJC's on-going responsibility to ensure that the works authorized in boundary waters continue to be operated in a manner that best meet the needs of the resources in the Great Lakes system.

This document outlines the overall organization of the study, including a preliminary estimate of the cost and a schedule of major activities. Chapter 1 provides a general overview of the purposes and objectives of the study, its scope, and the general approach to managing and undertaking activities. Chapter 1 also contains background information on the hydrology of the upper Great Lakes basin, and Lake Superior outflow regulation. Chapter 2 describes the study tasks that are required to further our understanding of the past and possible on-going physical changes in the river system and how these changes affect water levels and outflows of the upper Great Lakes. Chapter 3 describes the tasks for evaluating possible improvements to Lake Superior outflow regulation to meet contemporary and emerging needs of the interests including conditions resulting from climate change. Chapter 4 describes the relationships between water levels and flows and the various resources, and the study tasks that are needed to evaluate the impacts of management options on those resources. Chapter 5 proposes an organizational structure to facilitate study management and organization of activities to carry out the study. Supporting and background information may be found in the annexes.

This revised Plan of Study (POS) has been prepared by the current Upper Lakes Plan of Study Revision Team and has built upon the work previously carried out in 2001-2002. This document supersedes that report entitled: "Upper Great Lakes Plan of Study for Review of the Regulation of the Outflows from Lake Superior" prepared for the IJC by the Upper Great Lakes Plan of Study Team, January 2002.

1.1 Background

1.1.1 Directive for Revised Plan of Study

In January 2002, a binational team established by the IJC prepared a plan of study to review the regulation of the outflows from Lake Superior. The purpose of the study was to determine whether changes to the IJC's Orders of Approval or Lake Superior outflow regulation plan were warranted to meet contemporary and emerging needs of the interests in the upper Great Lakes system from Lake Superior downstream through

Lake Erie, including the environment. This plan of study was forwarded to the two Governments in March 2002 and has not yet been funded.

In May 2005, the IJC established a new team (Upper Lakes Plan of Study Revision Team) to revise the 2002 Plan of Study, directing that three additional purposes be included. Annex 1 of this document contains the IJC's Directive to the Upper Great Lakes "Plan of Study" Revision Team. One added purpose is to examine, during the early part of the study, past and on-going physical changes in the St. Clair River and their impacts on the river flow and water levels of the upper Great Lakes. A second is to take into consideration the lessons learned from the five-year International Lake Ontario – St. Lawrence River Study, which was nearing its completion. Lastly, the IJC directed that the new team streamline the existing Plan of Study. The 2005 Directive retains the main purpose of the 2001 Directive concerning Lake Superior outflow regulation. The conduct of this study is dependent on the Canadian and United States governments providing funding.

1.1.2 Great Lakes Hydrology/Water Balance

The upper Great Lakes (Figure 1) form a system of large natural reservoirs connected by rather short channels, given the size of the basins. The total basin area (measured above Cornwall, Ontario and Massena, New York) is about 774,000 square kilometres (299,000 square miles). Table 1 provides information on the sizes of the Great Lakes and their drainage basins. Lake Superior, which is the most upstream of the Great Lakes, flows into Lake Huron through the St. Marys River. Lake Michigan also flows into Lake Huron through the Straits of Mackinac. The straits are wide and deep enabling both Lake Michigan's and Lake Huron's water levels to stand at the same elevation and respond hydraulically as one lake. Thus, the two lakes are also referred to as Lakes Michigan-Huron. From Lake Huron, water flows into Lake Erie via the St. Clair River, Lake St. Clair and the Detroit River. Lake Erie then flows into Lake Ontario through the Niagara River and the Welland Canal. Lake Ontario, in turn, flows into the St. Lawrence River which connects with the Gulf of St. Lawrence. Figure 2 shows the general water surface profile of the Great Lakes – St. Lawrence River System.

A rock ledge in the St. Marys Rapids of the St. Marys River acted as a natural submerged weir, controlling the outflows of Lake Superior. The hydropower development and construction of the St. Marys River Compensating Works in the early part of the Twentieth Century altered this part of the river, enabling humans to regulate the outflow from Lake Superior. The rate of water flow in the St. Clair – Detroit River system depends mainly on the level of Lakes Michigan-Huron and, to some extent, also Lake Erie's level. Other factors affecting this system's flow rate are aquatic growth in the river in summer and ice conditions in winter. Physical changes in the St. Clair and Detroit Rivers can have significant impacts on water flows of the river and Lakes Michigan-Huron water level. The flow of the Niagara River depends on Lake Erie's level at its outlet. Hydropower operations at Niagara Falls have considerable water level impacts in the immediate river stretches both upstream and downstream of these facilities but insignificant impacts on Lake Erie's level.

Lake Ontario's outflows are regulated by a hydropower dam and other control works in the international reach of the St. Lawrence River. Lake Ontario levels cannot affect the upstream Great Lakes water levels due to the almost 100-metre (328-foot) drop in elevation between Lake Erie and Lake Ontario, most of it located at Niagara Falls and cascades in the Niagara River.

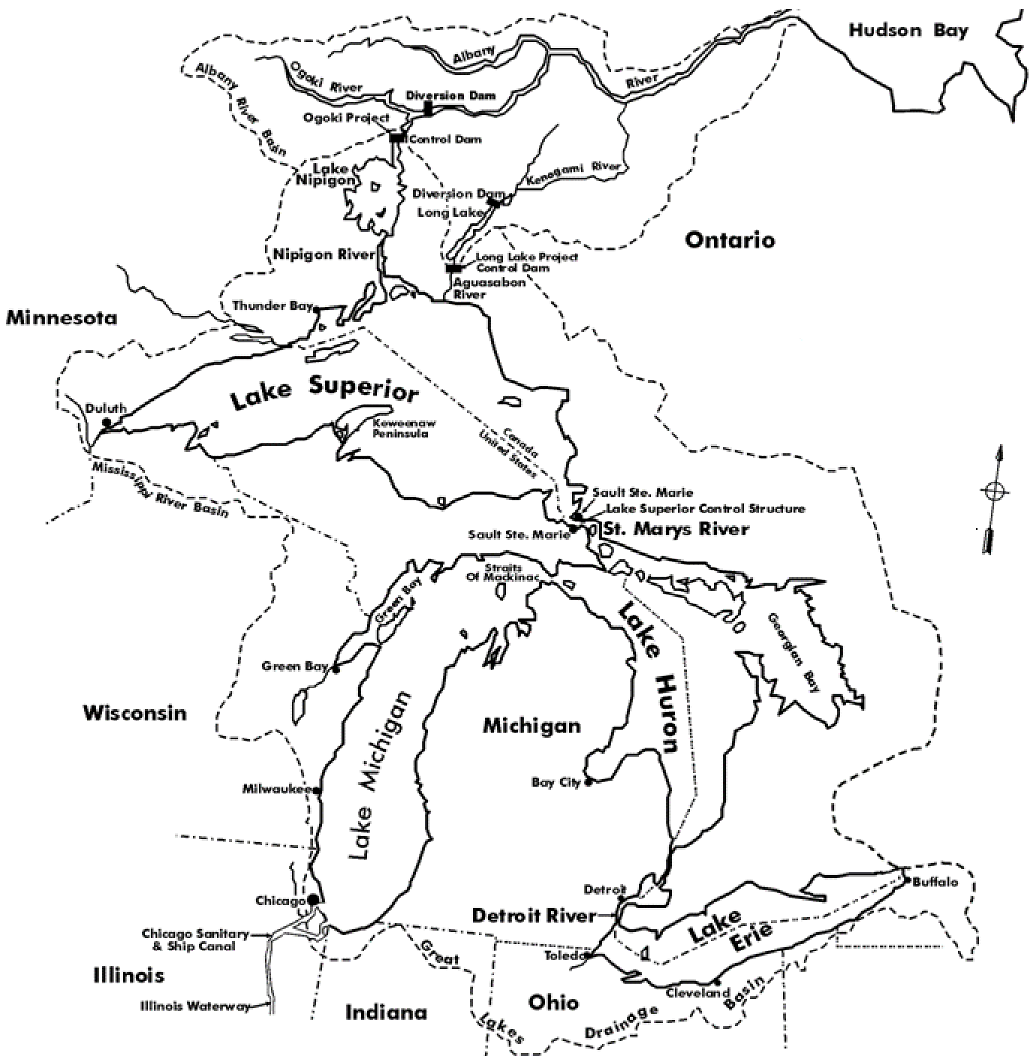


Figure 1 – Upper Great Lakes Basin

Table 1
Dimensions of the Great Lakes Basins

	Surface Area				Volume*		Max Depth*	
	Water		Land					
	km^2	miles^2	km^2	miles^2	km^3	miles^3	metres	feet
Lake Superior	82,100	31,700	127,700	49,300	12,100	2,900	405	1,330
St. Marys River	230	90	2,600	1,000				
Lake Michigan	57,800	22,300	118,000	45,600	4,920	1,180	281	923
Lake Huron	59,600	23,000	131,300	50,700	3,540	850	229	750
St. Clair River	55	21	3,300	1,270				
Lake St. Clair	1,110	430	12,430	4,800				
Detroit River	100	39	2,230	860				
Lake Erie	25,700	9,910	58,800	22,700	484	116	64	210
Niagara River	60	23	3,370	1,300				
Lake Ontario	18,960	7,340	60,600	23,400	1,640	393	244	802
St. Lawrence River To Cornwall/Massena	610	240	7,190	2,780				

*Measured when the lake's water level is at chart datum
Source: Coordinating Committee on Great Lakes Basin Hydraulic and Hydrologic Data, 1977

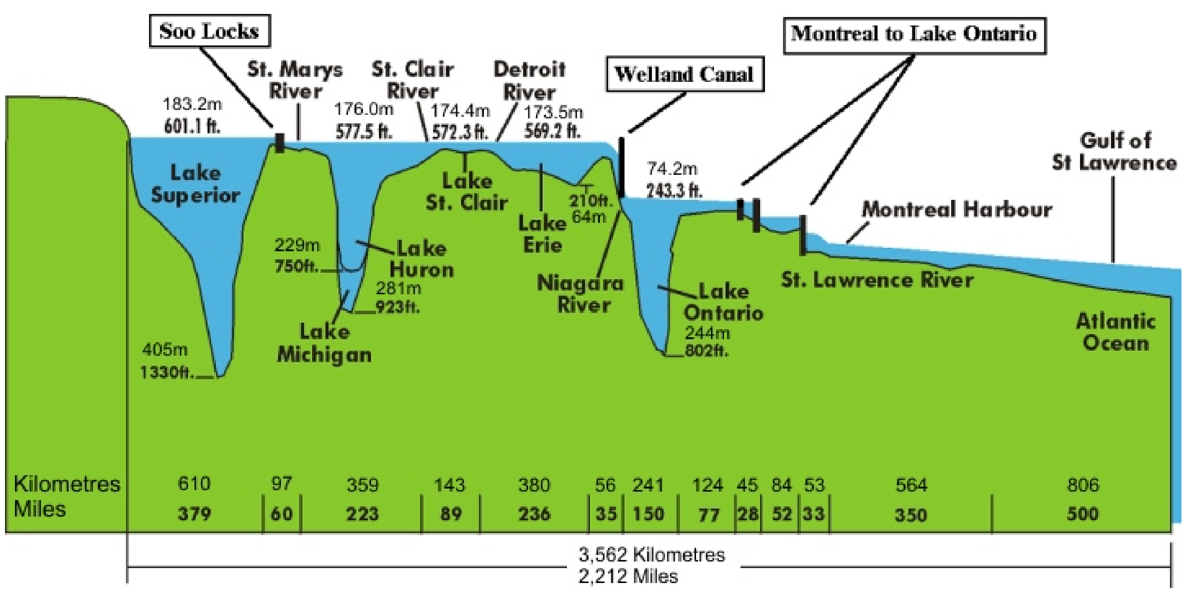


Figure 2 – Great Lakes St. Lawrence River Water Surface Profile

A lake's level rises and falls according to the amount of water entering and leaving the lake. Overlake precipitation, condensation at the lake's surface, surface runoff, inflows and groundwater flow provide water to the lake, while evaporation and outflow reduce the amount in storage. The term water supplies, calculated by analyzing water levels, outflows, other hydrological and meteorological data, comprise the net effect of these factors. Though not impacting on the quantity of the water in the system, ice and aquatic growth in the lake's outlet river generate flow resistance and thus affect the timing of the water flow from one lake to the next downstream. Human activities affecting levels and flows include dredging and infilling of rivers, water diversions, consumptive uses, and Lake Superior and Lake Ontario outflow regulation. Consumptive uses are water taken out and not returned to the lakes, such as water incorporated into manufactured products and exported out of the region, and the portion of water used for agricultural irrigation and other outdoor water consumption that is lost to evaporation.

Fluctuating water levels on the Great Lakes have been described as being of a long-term, seasonal, and short-term nature. Long-term fluctuations occur over periods of consecutive years as the result of climate variations affecting the region. Figure 3 shows plots of lake levels for the Great Lakes from 1918 through 2004. Prior to 1918, there were insufficient water level data and gauge stations to determine accurately the lake-wide average monthly mean lake levels. The plots show record low water levels occurred during sustained drought periods in the 1930s and 1960s. Record highs occurred during sustained wet periods in the early 1950s, in 1973, and in 1985-86. Water level trends can also reverse quickly, as demonstrated in the drop from very high to very low in a matter of about two years from 1986 to 1988 and again from 1997 to 1998.

Table 2 lists the long-term average and range of water level and outflow fluctuation for the period 1918-2004.

Seasonal fluctuations take place during the course of each year. Water levels rise in the spring in response to runoff from snowmelt and spring rainfall. The levels decline during late summer through the fall and winter due to reduced runoff from tributaries and increased evaporation from the lake. Owing to the timing of the water supply to Lake Superior, the level of that lake usually peaks in August or September, about a month or so later than the other downstream lakes.

One cause of short-term fluctuation is sustained high winds blowing over a lake producing a wind set-up or storm surge on the downwind shore of the lake. This results in lower water levels at the opposite shore of the lake. Superimposed on water level fluctuations are wind-induced waves. When the wind subsides, the water on the lake oscillates or sloshes (also called seiche) until it stabilizes again.

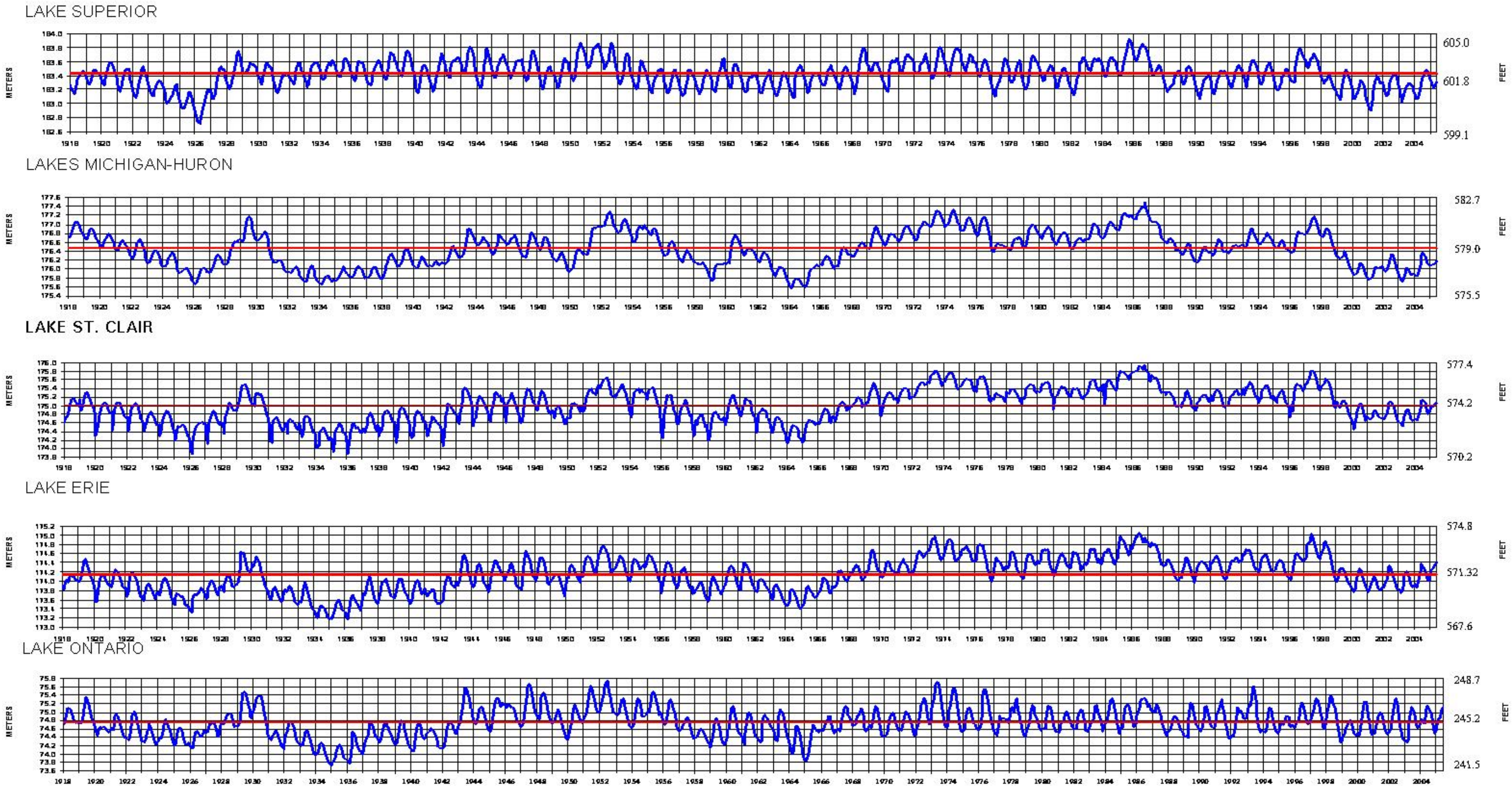
High or low lake levels and flows can persist for a considerable time after a change in the system, because of the large size of the Great Lakes and the limited flow capacities of their outlet rivers.

Table 2
Summary of Monthly Mean Water Levels and Outflows

	Water Levels, IGLD 1985		Outflows	
	metres	feet	m^3/s	ft^3/s
Lake Superior				
Average	183.42	601.77	2130	75,200
Maximum	183.91	603.38	3600	127,100
Minimum	182.72	599.48	1160	41,000
Range	1.19	3.90	2440	86,200
Lakes Michigan-Huron				
Average	176.46	578.94	5170	182,600
Maximum	177.50	582.35	6740	238,000
Minimum	175.58	576.05	3000	105,900
Range	1.92	6.30	3740	132,100
Lake St. Clair				
Average	175.01	574.18	5330	188,200
Maximum	175.96	577.30	7080	250,000
Minimum	173.88	570.47	3170	111,900
Range	2.08	6.82	3910	138,100
Lake Erie				
Average	174.14	571.33	5930	209,400
Maximum	175.04	574.28	7820	276,200
Minimum	173.18	568.18	3340	118,000
Range	1.86	6.10	4480	158,200
Lake Ontario				
Average	74.75	245.24	6980	246,500
Maximum	75.76	248.56	10,010	353,500
Minimum	73.74	241.93	4360	154,000
Range	2.02	6.63	5650	199,500

(1) Water levels for each lake are calculated using recorded monthly values from a network of gauges on the lake for the period 1918-2004. Daily and instantaneous water levels at a location on the lake are significantly more extreme than the values shown.
(2) Source: Environment Canada, Great Lakes – St. Lawrence Regulation Office

Figure 3 - Great Lakes Hydrographs



Lake Superior's outflow channel has a limited ability to make rapid and significant changes to its level or to that of the downstream receiving lakes. This can be demonstrated in the following example. If the Lake Superior outflow as specified by the regulation plan for the month of August 2005 was increased by 20 percent, the maximum impact due to this deviation from the regulation plan would be about one centimetre (0.4 inch) lowering on Lake Superior, and about one centimetre (0.4 inch) raising on Lakes Michigan-Huron. The impact of this one-month outflow increase would be moderated by the storage capacity of Lakes Michigan-Huron resulting in lesser impact on Lake St. Clair, Lake Erie's level and its outflow to Lake Ontario. As a second example, if the monthly mean outflows were set at 10 percent more than those specified by the regulation plan for a period of twelve months, at the end of this period, the maximum lowering impact on Lake Superior would be about nine centimetres (3.5 inches). The maximum raising impacts under this scenario would be about four centimetres (1.6 inches) on Lakes Michigan-Huron, three centimetres (1.2 inches) on Lake St. Clair and two centimetres (0.8 inch) on Lake Erie. Whereas consistent Lake Superior outflow increases (or decreases) from the regulation plan over a period of time have a cumulated impact on that lake's level, the impacts of these same deviations on Lakes Michigan-Huron are not linear or completely cumulative. The open-channel flow characteristics of the St. Clair River respond to the rise (or fall) in the Lakes Michigan-Huron levels thus moderating the impacts of the changes in the outflow from Lake Superior. These responses are markedly different from that for Lake Ontario outflow regulation where the lake surface is much smaller. The long-term average Lake Ontario outflow is about 7,000 m^3/s (247,000 ft^3/s) and a change of 700 m^3/s (24,700 ft^3/s) or 10 percent for one month is equivalent to 9 centimetres (3.5 inches) of water depth on Lake Ontario.

Some insight into patterns of lake level change from decades to millennia have been offered by recent research of hindcasting water levels using shorelines on Lake Michigan (Baedke and Thompson, 2000) and Lake Superior (Johnston and others 2004). They suggest that there are natural long-term lake-level fluctuations that have persistently reoccurred during the last 3,500 years. Two patterns of lake-level change that are important for historical record interpretation have periods of around three decades and a century and-a-half.

There is a growing concern about climate change and the effects it may have on the water levels of the Great Lakes. Current research points to an increase in regional temperatures, and possibly increased frequencies of severe weather events. Results from most global modelling studies show a decrease in water supplies to the lakes, resulting in lower water levels and decreased outflows.

Although we tend to think of our land masses and their relative elevations as being stable over time, this is not the case in the Great Lakes region. The present system of Great Lakes was formed about 10,000 years ago when the last glaciers retreated. Glaciologists believe that during the last ice age the region beneath the glacier was depressed while the regions on the periphery bulged upward. After the glacier melted, the crust underneath the glacier started to rebound upward while the forebuldge began to subside to achieve its former equilibrium prior to the ice age. This view is supported by current satellite-based Global Positioning System (GPS) measurements which clearly show that the areas formerly beneath the glacier are rising and the forebuldge is subsiding in an absolute sense (relative to the geocentre); however, studies of historical beach ridges on Lakes Superior, Michigan, and Huron (for example, Baedke and Thompson, 2000) suggest that the dissipating forebuldge may be a more recent phenomenon. Although further work is required to resolve this difference, key to this effort is the fact that that the earth's crust in the Great Lakes region continues to move today, but at varying rates, affecting land-to-water relationships around individual lakes as well as the elevation differences and hydraulic relationships between lakes. Section 2.4.3 provides more detailed discussion on this phenomenon, formally referred to as glacial isostatic adjustment (or GIA), and describes study tasks to examine this issue, which increases the complexity in both understanding what change is ongoing within the basin and in estimating what impact this may have on the ability of the lakes to store water and for the channels to convey water from lake to lake.

1.1.3 Orders of Approval and Supplementary Orders

In 1914, the IJC issued Orders of Approval permitting Algoma Steel Corporation in Canada and the Michigan Northern Power Company in the United States to divert St. Marys River water for hydropower generation and to complete the construction of a 16-gate control structure (St. Marys River compensating works) above the St. Marys Rapids. The Orders specified a list of conditions to be met in the construction and operation of these works, and established the International Lake Superior Board of Control to oversee their operation. This led to the regulation of the outflows of Lake Superior.

The 1914 regulation criteria recognized three major interests, namely, riparian on Lake Superior, hydropower and commercial navigation. The criteria supplemented the simple order of precedence listing from among the various interests already laid out in Article VIII of the Boundary Waters Treaty of 1909, namely (1) uses for domestic and sanitary purposes, (2) uses for navigation, including the service of canals for the purpose of navigation, and (3) uses for hydropower and irrigation purposes.

Since 1914, the IJC has issued supplementary orders to meet the changing conditions and requirements in the upper Great Lakes system. The 1978 supplementary order permitted the redevelopment of the Canadian hydropower facilities at Sault Ste. Marie, Ontario. Environmental concerns were taken into consideration when the IJC issued supplementary orders in 1978 and 1985 focusing on the hydropower redevelopment and fishery in the St. Marys Rapids area.

An important part of the 1979 supplementary order, which is built into the current regulation plan, requires that the water levels of both Lake Superior and Lakes Michigan-Huron be taken into account in determining Lake Superior outflows. The objective of this more system-wide consideration when regulating is to provide benefits throughout the upper Great Lakes system.

1.1.4 Current Regulation Plan

Since 1916, seven different regulation plans have been used to determine Lake Superior outflows. The early generation of regulation plans considered only the level of Lake Superior in determining the outflow because they were designed to comply with the 1914 Order. During the study by the IJC's International Great Lakes Levels Board, which occurred from 1964 to 1973, an experimental plan was developed that used the concept of balancing of Lake Superior and Lakes Michigan-Huron levels. That plan, known as Plan SO-901, was used as a guide for Lake Superior outflow regulation during the mid-1970s.

In May 1977, the IJC requested that the International Lake Superior Board of Control prepare a revised regulation plan that provides benefits to interests throughout the Great Lakes system without undue detriment to Lake Superior interests. In September of that year, the Board submitted a report on the development and evaluation of Plan 1977, which was a refinement of Plan SO-901. Plan 1977 was officially adopted in October 1979. Further improvements led to the development of Plan 1977-A, which took effect in June 1990. Plan 1977-A is the regulation plan used currently.

Plan 1977-A specifies monthly average outflows with the objective of balancing the levels of Lakes Superior and Michigan-Huron taking into consideration their historical ranges. The plan has a number of outflow limitations to meet the regulation criteria and requirements of the IJC Orders. For example, one outflow limit serves to prevent excessive lowering of the levels of Lake Superior, while another prevents high water level conditions in the lower St. Marys River at Sault Ste. Marie. The regulation plan also has a limit on maximum allowable outflow in the winter to reduce the risk of ice jam and associated flooding in the lower St. Marys River.

The monthly Lake Superior outflow, as specified by Plan 1977-A, is first allocated to meet the needs of municipal - industrial water uses, operate the navigation locks and provide sufficient flow to maintain the aquatic habitat of the St Marys Rapids. The remainder of the flow, which is the majority, is allocated equally to the US and Canadian hydropower facilities to generate electricity. If the amount of water available for hydropower generation exceeds the capacities of the hydropower plants, the excess is released by opening gates at the 16-gate Compensating Works. To maintain aquatic habitiat, a minimum gate setting of one-half gate open, or its equivalent, is required at all times for the main rapids. In addition, Gate 1, at the north end of the structure, is set partially open to provide a continuous water flow for the fishery remedial works in accordance with the IJC requirement.

The International Lake Superior Board of Control constantly monitors the hydrological conditions of the upper Great Lakes basin. Each month, the Board determines Lake Superior's outflow according to Regulation Plan 1977-A. Under certain conditions, the IJC approves deviations from the regulation plan or changes to gate settings at the compensating works on the advice of the Board. These deviations may include flow changes to accommodate repairs at hydro facilities or the compensating works, support flow measurements, sea lamprey trapping that typically takes place in the summer, surveys or environmental studies of the rapids, or to deal with unusual water supply conditions.

To meet energy demand which fluctuates over the course of the day and week, hydropower plants typically conduct peaking and ponding operations. In peaking and ponding operations, higher flows pass through the plants during the daytime on weekdays when energy demand is high, which is then offset by lesser flows during the night and on weekends. These flow variations cause water levels to fluctuate downstream of the plants and in the lower St. Marys River. Peaking and ponding operations are carried out with the approval of the IJC.

1.1.5 Public Involvement

Extensive public involvement activities were carried out in the preparation of the 2002 Plan of Study and in the preparation of this revised POS. Annex 2 lists the activities carried out during the two exercises and a summary of these activities is presented below.

In May 2001, the IJC informed the governments and the public of its intention to develop a plan of study, and invited comments on the draft directive setting up the POS team. The IJC held public meetings during June and July 2001 in the upper Great Lakes basin to hear views and concerns, and solicit opinions on the proposed study. The draft plan of study was made available for peer review by a panel of experts in Canada and the United States, and for public review during October 2001. Another round of public meetings was held in October and November 2001 to receive public comments on the draft plan of study. The former team also conducted targeted consultation with First Nations and Native Americans, and with interest groups that included: ecosystem, hydropower, navigation, residential property owner associations and recreational boating.

To supplement the input collected during the 2001 public consultation process, the plan of study revision team sent letters in July 2005 to citizens and interest groups, First Nations and Native Americans, government agencies, industries and elected officials in both countries inviting them to provide comments and advice on the proposed study and to attend the public consultation meetings. Four public consultation meetings were held in September 2005, two in Canada and two in the United States. The team's efforts were posted on an internet web site to inform the public on progress of work, and to solicit public inputs and advice on the draft revised plan of study. Team members consulted with experts in governments and the academic community on current science and tools that could be of value for the study.

In both the 2001 and 2005 public consultations, there were overwhelming public support for a review of the Lake Superior outflow regulation. Numerous feedbacks from the public also support inclusion of the study of the St. Clair River. Many expressed concerns about the adverse effects of extreme low water levels on wetlands. Some raised concern that governments might rush into unwise actions, and urged that sufficient scientific investigations be conducted to understand the factors that are driving current low water levels prior to undertaking activities regarding their potential remediation.

1.1.6 Related Studies

1986 IJC Reference Study

The most recent major international study of Great Lakes water levels was conducted under the 1986 IJC reference and completed in 1993. That study identified some potential changes to the Lake Superior outflow regulation, for example modifying some of the outflow limits and exploring other techniques to balance water level conditions of Lake Superior with those of Lakes Michigan-Huron. Following the completion of the study, the Study Board recommended that the current IJC's Orders of Approval be reviewed to determine if the current regulation criteria are consistent with the current uses and needs of the users and interests of the upper Great Lakes system.

International Lake Ontario – St. Lawrence River Study

Another study that is of similar nature to the proposed Upper Lakes Study is the 5-year study to investigate improvements to Lake Ontario outflow regulation. This study was essentially completed by the Fall of 2005. During June and July 2005, the Plan of Study Revision Team consulted with the participants of the International Lake Ontario – St. Lawrence River Study on lessons learned from that study. The findings from these consultations that are applicable to the Upper Lakes Study are as follows:

Plan of Study

A well-thought-out plan of study is prerequisite to an effective and successful study. The plan must make clear its mandate, identify the issues and objectives, and next select requisite studies that help to answer the critical questions. In other words, how will the study results help society select an outflow regulation plan that is better than the one currently in use?

The plan of study should provide a description of how the Great Lakes system works, and what the impacts and limitations are of current or proposed Lake Superior outflow regulation. It should have a realistic definition of what the potential is for water level changes so as not to cause undue expectations.

Investigating improvements to Great Lakes water management takes time and resources. Too long a study however, risks high staff turnover.

Study Participants and Organization

It is important for all participants to clearly understand the purpose of the study and for the study board to provide clear and focused direction. It is strongly advised that all study participants be educated on Great Lakes hydrology and outflow regulation at an early stage in the overall process. The duties and responsibilities of all participants should be clearly defined. When scheduling and approving work tasks, study management should include a monitoring provision to ensure timely completion of the work and submission of written reports. Procedures should be in place to enable effective communications among the technical work groups and the study board.

The study organization of the International Lake Ontario – St. Lawrence River Study Board has worked well. Advisors on economic evaluations and basin-wide ecosystem planning are recommended at the early stage to help the study board decide on the focus and direction of the study.

Public Participation

Public participation is vital for the success of the study. The study must be proactive, searching out and engaging the public early, to provide opportunity for the public to participate in all aspects of the study. Public meetings, newsletters and a web site are essential elements of the study to maintain dialogue with the public and update the public on work progress. The Public Interest Advisory Group has proven to be valuable, providing not only direct inputs to the study but serving as a liaison between the study and stakeholders.

Establish an outreach team from the beginning of the study to map out a communication strategy template for the entire length of the study.

First Nations and Native Americans Participation

Efforts should be made to involve the First Nations and Native Americans in preparing the plan of study and the conduct of the study from the beginning. Their participation brings expertise to the study, and ensures that the water level issues and concerns of the native community are taken into consideration.

Study Approach

Given the complexity of the issues to be addressed in the proposed Upper Lakes Study, a proper sequencing of study tasks would be required. The initial work would scope out the physical limitations of the existing Lake Superior outflow regulation plan and potential changes, and would include a scoping exercise to identify priority and anticipated level of detail for evaluation. A team similar to the Plan Formulation and Evaluation Team is advised at the early stage to establish evaluation methods and guidelines on integrating study results for decision making. Also needed at an early stage are experts on economic and ecosystem evaluations. Early tasks would also define a study organization and expertise required for the study. This strategy aims to maintain the study focus and avoid needless costly scientific research and data collection.

Data, Science and Tools

Wherever possible, the data, science and tools used in the International Lake Ontario - St. Lawrence River Study and other studies would be adopted for analysis in the Upper Lakes Study. Additional data would be collected if they are determined to be essential to fill data gaps.

For example, vessel transit and cargo forecast data and evaluation methods are available from the International Lake Ontario – St. Lawrence River Study and other seaway studies. The methods for evaluating impacts of levels and flows on hydropower generation in the St. Lawrence River are also expected to be applicable, although changes would be required in the assumptions due to differences in energy marketing systems. The study of climate change has generated data for the Great Lakes basin. As the sciences in these issues continue to improve, some updating may be required for the Upper Lakes Study.

The general nature of the relationships between water levels and most interest groups such as coastal zone processes, hydropower, navigation and water uses are similar throughout much of the Great Lakes system, while some areas do have unique qualities. On the Great Lakes, there are many types of wetlands which, as a result of water level changes over the years and local settings, have evolved into what we see today. The water level requirements of wetlands are relatively more complex compared to other interest groups. Methods have been developed in the International Lake Ontario - St. Lawrence River Study to evaluate the impacts of alternative Lake Ontario regulation plans, and these would be considered for the Upper Lakes Study.

It is also recommended that peer review be conducted during the course of the study to ensure the credibility of the science. Some follow-up monitoring strategies may be advisable to verify whether the projected evaluation of impacts on the interest groups had been correctly reflected within the decision model.

In major studies of this scope and nature, new science, techniques and knowledge may be uncovered during the course of the study. Consideration should be given to developing mechanisms to ensure that governments are aware of these when making water management decisions for the Great Lakes.

Information Technology

The Upper Lakes Study should make appropriate use of information technology in public communication, the handling and storage of information, data and knowledge generated during the study.

1.2 Objectives

This plan of study is designed to fulfill the IJC's 2005 Directive. The two primary objectives are:

- To improve the operation of the structures controlling the outflows from Lake Superior, and to improve Lake Superior outflow regulation to meet contemporary and emerging needs of the interests including the environment in the upper Great Lakes system.
- To improve our knowledge of the physical process of the St. Clair River and use this knowledge for Great Lakes water management.

1.3 Scope

The geographic area of the Upper Lakes Study would encompass the upper Great Lakes basin from Lake Superior downstream through Lake Erie including Lake Michigan and Lake Huron, their interconnecting channels and the Niagara River.

The early part of the study will focus on the hydraulic, physical changes and sedimentation processes of the St. Clair - Detroit River system, and how past and possibly on-going physical changes affect river flows and water levels in the upper lakes system. If the impacts due to these changes are found to be significant and warrant remediation measures, the study would identify the nature of the remediation measures and their costs. In addition to analyzing existing data, new data to be collected includes bathymetry, water level and flow measurements to determine the present hydraulic regime, and sediment transport and core bed data for application of simulation models to study sedimentation processes. The study area includes the St. Clair River, Lake St. Clair and the Detroit River, as these water bodies form the connecting channel between Lake Huron and Lake Erie. The focus is the St. Clair River, with less detailed work needed on Lake St. Clair and the Detroit River. The study would also examine lower Lake Huron sedimentation processes and how they affect sedimentation processes in the St. Clair – Detroit River system.

The early part of the study would also include components of the Lake Superior regulation study which do not require additional data collection, and are not contingent upon decisions concerning evaluation methods and assumptions. These include reviewing existing outflow regulation criteria and technical aspects of the current regulation plan, and outflow capability of the control structures.

No structural modifications to the St. Marys River would be considered when investigating potential improvements to Lake Superior outflow regulation. The evaluation of existing and potential Lake Superior regulation plans may need to consider scenarios of potential structural modifications to the St. Clair River, should physical remediation works in that river be warranted. The testing of alternative Lake Superior outflow regulation plans will take into consideration climate variability and climate change as well.

No changes would be considered to the existing treaties or agreements between Canada and the United States concerning Great Lakes water levels. The review of the Orders of Approval governing Lake Superior outflow regulation will be carried out in the context of Articles III and VIII of the Boundary Waters Treaty and the Commission's alerting responsibilities in the same manner as conducted in the study to review the IJC Orders of Approval for hydropower developments in the St. Lawrence River and the regulation of the outflows of Lake Ontario.

1.4 Approach

The evaluation of options to improve Great Lakes water management requires an understanding of the wide range of water level and outflow issues. This study requires focused guiding principles, best available science and experts, and public participation. For an effective study, tasks must be conducted in proper sequence.

1.4.1 Guiding Principles

1. The investigation of water management options, including Lake Superior outflow regulation and St. Clair River investigations, will consider the needs of all the interests including ecosystem in the upper Great Lakes system and, in doing so, will balance benefits without undue detriment to any interest, region or lake.

2. All tasks proposed for the study must be compatible with the study objectives. The level of detail for evaluating alternative Lake Superior outflow regulation plans and other water management options would be dependent on the degree of impacts on water levels and flows.

3. Decision-making with respect to the development of water management options and evaluation methods will be transparent. Opportunity will be provided for meaningful participation of First Nations, Native Americans and the public in all aspects of the study to ensure their advice and concerns are considered and that all have the opportunity to contribute to the success of the study.

4. Credible and generally accepted science, current knowledge and state-of-the-art technologies for hydrological, hydraulic, economic and environmental evaluations are to be used in the study. New and innovative techniques are encouraged if they result in the provision of critical information for the decision making process that would have otherwise not been available. Peer review by independent experts would be conducted prior to adopting study methods and techniques, including major assumptions and overall approaches to be undertaken.

5. All technical reports funded through the study should be placed on the web site for public access and scrutiny.

6. Information technology will be used for public communications, while at the same time making provisions for providing information in conventional ways (for example,

paper format for reports) for the public who do not have access to computers or internet.

1.4.2 Organizational Period

The experience from the current International Lake Ontario - St. Lawrence River Study has shown it is important to lay the proper groundwork prior to initiating a full-blown study. An organization period spanning about six months is recommended. During this period, a small team would scope out the nature and extent of the hydrological, economic and environmental studies, including deciding on evaluation methods and assumptions. The team would also consider potential study participants from the public, government agencies and the academic community, and design a study organization with terms of references for study groups. It is recommended that this team consist of IJC staff, advisors and people who have the expertise and experience in setting up and conducting multi-disciplinary studies. Members of the Plan of Study Revision Team and the International Lake Ontario – St. Lawrence River Study could also provide valuable insight.

1.4.3 Evaluation Methodologies

To ensure a cost-effective study and the credibility of the science in the study, the organization team would consult with experts in governments and academia on appropriate scientific and engineering approaches to consider within the study. It is expected that some of the work from the International Lake Ontario - St Lawrence River Study will be useful for the Upper Lakes Study. These may include the data and methods used for commercial navigation and hydropower studies, hydrological studies including impacts of climate change, and techniques used for environmental evaluation. However, care should be exercised in adopting these methods as they reflect the state-of-knowledge at the time. Some updating of these methods and the data used to generate results are expected to be required for the Upper Lakes Study.

As discussed earlier, Lake Ontario outflow regulation has relatively much larger impacts on water levels and flows in the Lake Ontario and St. Lawrence River system than Lake Superior outflow regulation has on the upper Great Lakes system. This makes a scoping exercise essential to determine whether qualitative or detailed quantitative evaluations are sufficient. A hydrological and hydraulic team will be required throughout the study to determine the water levels and flows resulting from various water management options. It is expected that evaluation of the impacts of water management options will follow the general sequence as that in the International Lake Ontario - St. Lawrence River study, which are:

- identify the needs of the interest groups
- consider outcome of St. Clair River analyses and possible remediation options
- investigate changes to Lake Superior regulation plan
- generate water levels and flows under (1) existing regulation plan, (2) assuming pre-project St. Marys River hydraulic conditions, and (3) alternative regulation plans, assuming current climate and climate change scenarios
- evaluate impacts on the interest groups

- compile the evaluation results
- consider water management options and make recommendations

1.4.4 Timeline

The identification and evaluation of water management options that consider the complexity of the upper Great Lakes system and the relationships between water levels and interests requires a study that would span several years. Proper sequencing of study tasks having well-defined objectives is essential to conduct the study effectively in order to provide information for decision making. This study is envisioned to take five years and incorporates all necessary tasks to address the IJC's Directive.

Year 1 would initially focus on study organization and beginning work to study the physical aspects of the St. Clair – Detroit River system. It is expected that considerable effort will be required for analyzing historical data, detailed planning of the collection of new data and technical studies and selection and set-up of complex computer simulation models. In subsequent years, if the results from these studies show changes have occurred in the river and are continuing thus significantly impacting lake levels and flows, the work would include investigating remediation measures such as structural works in the river and non-structural measures.

Concurrent with beginning the St. Clair Study in Year 1 would be a review of the capabilities and limitations of Lake Superior outflow regulation considering climate variability and climate change, along with a preliminary review of the relationships between water levels and the interest groups. The results from these studies, along with the results from the St. Clair River study, will determine the level of detail in later years. Another essential task for Year 1 would be selection of the evaluation methodologies. Decisions on evaluation methods at an early stage are critical in guiding the direction of the scientific and economic studies thereby making the study focused and cost-effective. Detailed evaluation of the impacts on the various interest groups would be carried out in later years.

Throughout the entire study, public participation is a key element.

2.0 Physical Processes and Possible Ongoing Changes in the St. Clair River

2.1 Background

Following almost three decades of generally above average water levels, Lakes Michigan and Huron are now experiencing levels that are well below their long-term average for the 1918-2004 period-of-record. Although lower and more extensive periods of below average water levels have occurred in the past, questions have been raised about what may be the driving forces behind today's lower levels.

Such interest is not new to the waters of Lakes Michigan and Huron. In 1927, Horton and Grunsky published their major work on evaluating what they established to be the more important causes of changes in lake levels. Beyond “variations in annual rainfall, runoff and evaporation”, they noted that “there have been important geographic changes in the Lakes region in recent times” (Horton and Grunsky, 1927, p. 3). These included impacts resulting from the deformation or tilting of the earth’s surface as a result of the last glaciation, changes in land-use (for example, deforestation and agriculture), artificial diversions from the basin, and alterations to the natural river channels over time. They concluded that the factors that cause significant changes to water levels include variations in rainfall, diversions and alterations to the natural channels.

Over the years, various alterations to the natural channel conditions have occurred. The IJC’s Great Lakes Water Level Task Force (IJC, 1987) documented a history of significant alterations to the natural regime and estimated their physical effect on the levels of Lakes Huron and St. Clair, based on an analysis of existing studies. With present day concerns over lowering water level conditions, investigative work was recently undertaken, at the request of the Georgian Bay Association by Baird & Associates (2005). The report concluded that “the steady and ongoing decline [in the water levels of Lakes Michigan-Huron] observed since 1970 implies ongoing river bed erosion.” Their associated “alarming observation is that all other head drops (i.e. other than the condition since 1970) could be linked to dredging events or operations” (ibid, p. 72). This report has raised concerns that recent lower levels on Lakes Michigan-Huron may not be entirely due to natural hydrological factors, but rather to ongoing physical changes in the upper portion of the St. Clair River.

The IJC decided to expand the 2002 Upper Great Lakes Plan of Study to thoroughly investigate the St. Clair River issue. The Directive (see Annex 1) required that the revised plan of study incorporate a new first phase to examine physical processes and possible ongoing changes in the St. Clair River channel and impacts on levels of Lakes Michigan and Huron”. The Revision Team was further directed, depending on the nature and extent of St. Clair River changes and impacts uncovered under the course of the study, to include within the revised POS consideration of potential remediation options and their evaluation.

The Directive also dictates that the revision is to retain the principal purpose of the study pertaining to the regulation plan of Lake Superior, including an assessment if changes are warranted and the evaluation of any identified options to improve the existing plan. Prior to performing these aspects of the Directive, it is imperative that physical processes be examined and possible ongoing change be verified with respect to the St. Clair River. Should change in the St. Clair River be on-going and be such that it affects the outflow characteristics of Lake Huron, the review of the Lake Superior regulation plan (Chapter 3) would need to take this and any possible remediation options into account. This underlines the importance of first establishing an investigation of the physical processes and possible ongoing changes within the system, which is the goal of the work outlined within this chapter.

2.2 History of St. Clair River Channel Changes

In its natural state, the St. Clair River had navigation depths of about 6 metres (20 feet) or more throughout most of its length, excluding some isolated shoals. Improvements for commercial navigation began in 1855 mostly in the delta area, where the lower river meets Lake St. Clair. In addition, commercial interests mined sand and gravel from 1908-1925, mostly in the upper river, but this practice was later halted by the governments of both countries.

The U.S. Rivers and Harbors Act of July 27, 1916 authorized dredging of the "Port Huron West Channel" and construction of a compensating weir. The original documents included only customary units, so the metric equivalents have been added in this section as a reference. The channel was constructed to provide for down bound traffic along the water front of Port Huron, 21 feet [6.4 metres] deep at low water and 400 feet [122 metres] wide, including a submerged weir below the channel". The International Joint Commission issued an Order of Approval, dated May 18, 1917. This order notes "… and for the construction of a submerged weir or compensating work, about 8 feet [2.4 metres] high, extending across the river from high water on the United States shore to the same elevation on the Canadian shore, to be located at a point about 3,000 feet [910 metres] downstream from the International Tunnel; and whereas careful calculations indicate that the dredging of the proposed channel will cause a lowering of Lake Huron about one-eight inch [0.3 centimetre] unless compensated for; and it appears to the satisfaction of the commission that a submerged weir not exceeding 3 feet [0.9 metre] in height will give sufficient contraction to the river to compensate for the excavation …". The order further notes that "…consent of the Province of Ontario to the construction of the said submerged weir on the Canadian side of the international boundary be obtained before the said weir is constructed." The order also required that the U.S. "… maintain automatic gages at suitable points above and below the proposed works for a period sufficient to determine the effects of these works upon the levels of Lake Huron; and the height of the said submerged weir be modified if necessary so as to make the compensation full and complete".

The dredging of the Port Huron West Channel was carried out between August 1920 and July 1921. Subsequent reports indicated, "The foundation for the submerged weir was formed by the deposit of selected dredge material, but the placing of stone thereon will be deferred until the effect of the improvement upon water levels has been determined." (Report to Chief of Engineers, 1922, p. 1611). Chief of Engineers reports, as late as 1928, indicate that water gauges were being maintained "for the purpose of determining any change in slope that might have resulted from the removal of the middle ground shoal or from other causes." Information from these gauges has not been found, nor any report that might discuss the analyses of the gauge data and the corresponding effect of the dredging.

No records have been located by agencies of both governments and the IJC which refer to any consent of the Province of Ontario to the construction. Shortly after, in 1930, the 25-foot [7.6 metre] navigation channel was authorized. It is thought that the actual construction of the weir was superseded by the authorization of the 25 foot [7.6 metre] navigation channel. This authorization also called for compensating works, thereby potentially addressing all previous dredging activities.

The U.S. Congress authorized a project depth of 25 feet [7.6 metres] throughout the system in the Rivers and Harbors Act, dated July 3, 1930. This authorization notes "The special board agrees with the joint international board that compensating works should be constructed in Niagara and St. Clair Rivers to compensate for diversions and for enlargement of the lake outlets. The works proposed in the St. Clair River are a series of submerged rock sills, the exact number to be determined as the work progresses, estimated to cost $2,700,000." The act further notes "As the construction of compensating works involves questions requiring a formal international agreement, their construction may be delayed." "The proposed works in the St. Clair River are a series of submerged rock sills, with crests 31 feet [9.4 metres] below datum. The approximate locations of the sills which were computed as necessary to effect a rise of 1 foot [0.3 metre] in the levels of Lakes Michigan and Huron …" "The construction of the sills should be prosecuted consecutively, their effectiveness determined by slope and discharge observations as the work proceeds, and the work stopped when the desired results are secured." There was another statement in the economics section that noted "Should the international or political aspects of construction of compensating works result in a protracted delay in their execution …" Again it is noted "The construction of the compensating works proposed in this report will require the assent of the Canadian Government and the approval of the International Joint Commission."

The actual dredging of the 25-foot [7.6 metre] channel started in June 1933 and was completed in October 1936. There were model studies done in 1932-33 and surveys done in 1934 for the submerged weirs. There are no records to show that an application for approval by the IJC was ever presented for this dredging or compensation. This could be due to an agreement between the two governments, which would then not need IJC approval. To the Team's knowledge, no documents have yet been located by agencies of both governments or the IJC to ascertain any decisions made.

Subsequently, the U.S. Congress authorized a project depth of 27 feet [8.2 metres] throughout the system in the Rivers and Harbors Act, dated March 21, 1956. This authorization notes "With regard to the effect of the project on the water levels of the Great Lakes, detailed hydraulic studies have been undertaken and compensating works are included in the plan of improvement which will assure that the lakes will not be adversely affected. In St. Clair River, accomplishment of the presently authorized compensating works would offset the lowering effect on Lakes Michigan and Huron of both the proposed improvement and previous dredging. The existing project for deep-draft navigation in the St. Clair River is complete except for construction of compensating works in the St. Clair River at an estimated cost (1954) of $10,600,000. Total compensation which would offset the present proposed deepening and restore Lakes Michigan and Huron levels can be accomplished by construction of all or part of the presently authorized compensation sills, none of which have been constructed to date."

The actual dredging was started in April 1960 and completed in 1962. There was a report issued by the Interdepartmental Engineering Committee on Compensating Sills in the St. Clair River on February 21, 1962. This committee was established by the Government of Canada as a result of a request of the United States Government for permission to construct sills along the International Boundary in the St. Clair River in order to compensate Lake Huron water levels for the lowering which had occurred as a result of past dredging and which would occur under the authorized dredging for a 27-foot [8.2 metres] controlling channel depth. The report noted that sufficient time was not available to adequately determine all the issues, but that approval in principle can be given to the United States Government proposal subject to the approval of detailed plans. There are no records to show that an application for approval by the IJC was ever presented for this dredging or compensation.

There are various reports of hydraulic studies for compensating works being carried out from 1963-1969. There were minor design studies for the compensating works done in 1970. A report was issued by the Waterways Experiment Station in 1972 concluding that submerged sills could be used and making recommendations on their design. The completion of these studies to determine submerged sill locations and numbers came at a time where Lakes Michigan-Huron were approaching record high water levels (the 1973-1974 records were later surpassed in 1985-1986). There was no real interest in placing submerged sills which would then raise water levels even higher. During the period 1969 through about 1999, water levels on Lakes Michigan-Huron remained above average for the most part. The above discussion demonstrates the need to conduct a review of past physical changes, in particular the major dredging projects in the St. Clair River, and how governments have addressed them. It also points out the need to consider both ends of the spectrum when considering remediation works in the river.

2.3 Required Studies and Causal Analyses

Components of the hydrological cycle, their relative magnitudes and their feedback with one another dictate whether an area will be an arid desert, a tropical rain forest, or something in between. The upper Great Lakes are blessed with a seemingly boundless supply of freshwater to the lakes through overlake precipitation and local drainage basin runoff, be it from groundwater or surface streams. Another important component of the cycle is evaporation of water from the lake's surface. These components of the cycle can be combined to provide an estimate of the water available or "supplied" by a lake's local drainage basin, often referred to as a lake's net basin supply (NBS).The net total supply (NTS), or more simply the total supply to a lake, consists of the net basin supply for the lake plus its inflow from the upper lakes, as applicable. (See Figure 4)

The water level of each of the Great Lakes depends on the balance between the total water supplies received by a lake and its outflow (or discharge). If the water supplies received by the lake are greater than those discharged, its level will rise. Conversely, if the water supplies are less than the discharge, the lake's level will fall.

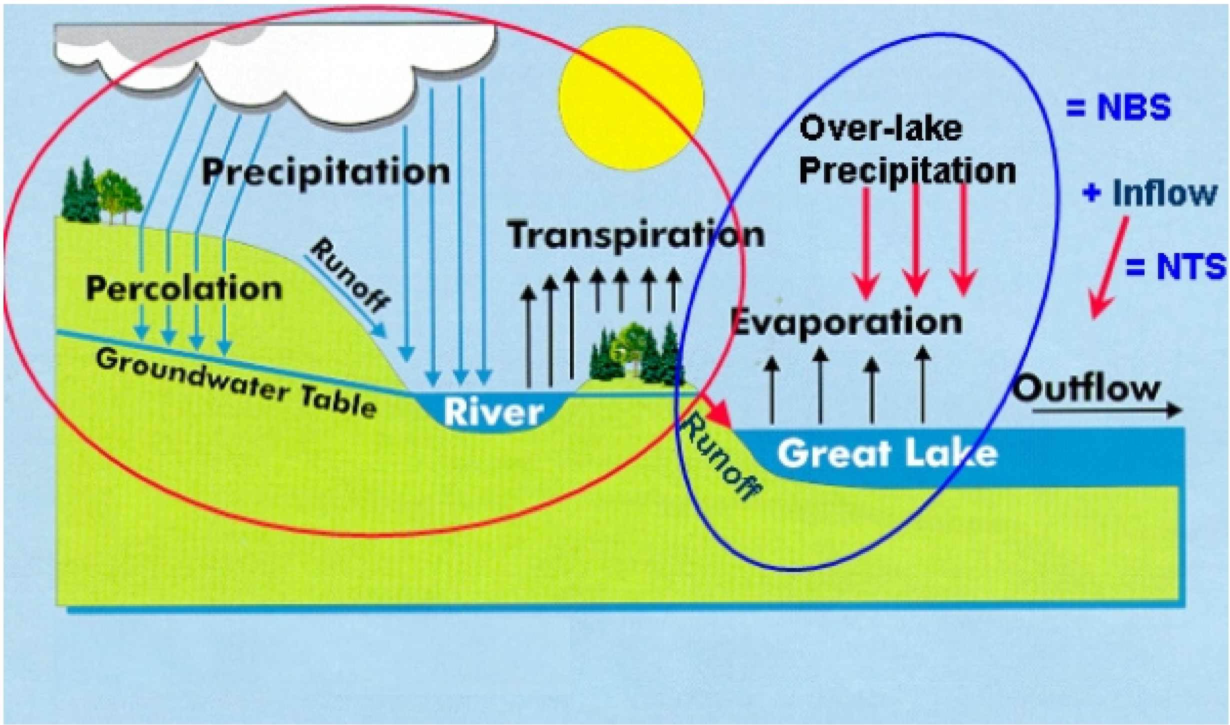


Figure 4 – The Hydrologic Cycle and Estimation of NBS and NTS

Water moves from a lake to the next one below it in the chain by rivers termed "connecting channels". Natural factors such as ice cover, aquatic vegetation, and channel erosion and deposition can affect the flow characteristics in a connecting channel seasonally and from one year to the next. As well, human intervention in the connecting channels have affected their ability to transport water, either through the construction of control works, infilling or the construction of obstructions such as bridge piers, or dredging for navigational purposes. It is also a possibility that changes due to sedimentation processes are on-going. Water is also leaving the basin via artificial diversions and consumptive use losses (the portion of water withdrawn for use that does not reenter the natural water system of the basin). Water budget and related hydrological and hydraulic analyses can be used to explore the relative magnitudes of the various components of the cycle and the amounts of water that are potentially being diverted or lost, and the relative amounts of water that are leaving through the outlet channel. Variations in any one or more aspects in combination will result in alterations to the amount of water being transported in channels and the water level of the local lake. Hydrological and hydraulic analyses can establish the relative impact of the modification of any aspect on lake levels and discharges.

Within the Lakes Michigan and Huron system, such factors are at play, resulting in its past and current water levels. Various factors can be categorized and described under four broad headings: 1) hydrological cycle or basin supply – NBS and NTS; 2) diversions and consumptive use; 3) glacial rebounding and subsidence (glacial isostatic adjustment or GIA); and 4) conveyance capacity of the St. Clair River-Lake St. Clair-Detroit River-Lake Erie system. These factors are very similar to those studied by Horton and Grunsky (1927) and Baird and Associates (2005), with some modifications incorporated and described in the proceeding sections.

An outline is provided of proposed monitoring, modelling and analytical activities. It is proposed that a conceptual linking of these major factors be performed to provide a causal model, leading to an increased understanding of what is driving Lakes Michigan-Huron level fluctuations and the sensitivity of the system to changes in certain factors. Proposed monitoring, modelling and analyses would be undertaken to allow the determination of the magnitude of the response to past interventions on lake levels and flows and would further allow a description of the sensitivity of the system to such interventions. The proposed activities include: quantification of the impact over time of the major factors influencing Lakes Michigan-Huron levels (Section 2.4); the modelling environment and data analyses required to establish the impacts of the factors upon the system (Section 2.5); and the monitoring and field work required to support investigative and interpretive analyses (Section 2.6).

The above described activities would also provide the necessary tools and information to evaluate the impacts of potential remediation options for the St. Clair River. Potential options and their evaluation are further addressed in Section 2.7.

2.4 Overview of Factors

2.4.1 Basin Supplies

There are two approaches commonly used to estimate NBS. The first approach, which is called the component method, derives NBS using a water balance of the components of the hydrological cycle. The second method, called the residual method, is more indirect and is based on change in storage of the lake.

With the component method, NBS is computed as the precipitation occurring over the lake plus runoff to the lake from the surrounding basin, plus groundwater, plus condensation on the lake surface minus evaporation from the lake surface. Runoff to the lake by the surrounding watershed is a composite of flow from measured tributaries and estimated, ungauged tributaries. It is important to note that the runoff when measured by conventional stream gauges would reflect all upstream impacts on the available water supply including any upstream diversions, consumptive use or changes due to land use. Estimation of contribution of water from ungauged tributaries within the local basin should also take into account upstream diversions and consumptive use. The groundwater component is not quantitatively included in most analyses of balance within the Great Lakes basin (GLC, 2003). Computing NBS by the component method requires an estimation of overlake precipitation, evaporation and condensation, which are not directly measured but can be derived using various models. For example, precipitation over the Great Lakes is typically estimated based on interpolated point measurement data from inland stations. The uncertainty associated with the estimation of overlake precipitation and evaporation has been estimated to range from 15 to 60% (GLC, 2003).

An alternative approach for estimating NBS is through what is termed “reverse routing” or the residual method. Reverse routing is a mass balance of streamflows entering and leaving the system plus or minus any changes in storage on the local lake. Recorded amounts of the diversions into and out of the lake, and estimates of consumptive use can be factored in when calculating the net basin supply. For Lakes Michigan-Huron, NBS by this method is computed as the change in volume of water in storage on Lakes Michigan-Huron plus the outflow through the St. Clair River, plus out-going diversions and consumptive use, minus the outflow from Lake Superior. Outflow from Lakes Michigan-Huron is derived using hydraulic ratings which correlate water levels and river flow. The inflow from Lake Superior, through the St. Mary’s River is determined as the summation of recorded flows through each of the different structures at Sault Ste Marie

Ideally, the change in water storage in a lake is determined by knowing the surface area at various elevations; however in the case of Lakes Michigan-Huron a constant lake surface area is used. Rating equations are subject to error usually less than 5% of the flow value, while the stage or elevation of the lake is an average reading of a number of representative water level gauges within the combined lake system. Determining the lake-wide average level is subject to measurement error, and readings over a period of two days from a network of gauges are used to determine lake-wide end-of-month levels.

Care must be taken when comparing estimates of NBS derived using the component or residual method due to the different way diversions and consumptive use may be handled in the computation. Any analysis or comparison of NBS values must take these differences or limitations into account. For example, the interpretation of trend analysis of NBS series needs to reflect upon the possible shifting patterns of consumptive uses and land use within the entire basin and the quality/quantity of available source data over time. A water balance over the local basin would be required to accurately account for components of the system, namely precipitation, runoff, groundwater, diversions, consumptive use and evaporation, recalling that either measured or model-derived estimates of runoff should represent human-impacted runoff for the tributary basins. A separate analysis of each component is also required to better understand what may be changing and why within the hydrological cycle.

The net total supply (NTS) to Lakes Michigan-Huron is the amount of water over unit time that is being supplied to the lake from the local basin, basically its NBS, and outflow from Lake Superior. NTS could be derived using both the residual and component methods. Once again, care must be taken when dealing with diversions into or out of the basin, namely the Long Lac, Ogoki and Chicago Diversions. When performing water balance study, one can either include the diversions as tributary inflow and outflow, or as separate components in the derivation of their values for NBS and NTS. Consistency is critical in the determination of NBS and NTS taking into consideration their intended use.

Outflows from Lake Superior are included in the estimate of the Lakes Michigan-Huron NTS which has influence on their levels. The outflows from Lake Superior have been fully regulated since 1921, with changes in the regulation policy being implemented over time. An adjustment for the variation in regulation policy is required to create series that facilitate analysis for patterns and trends.

Should NTS to Lakes Michigan-Huron be increasing or decreasing over recent time, there would have been a corresponding change in water levels. Changes to the characteristics of the outlet could also influence the lake's response to changes in NTS. Outflow from Lakes Michigan-Huron is governed by the lake level at the outlet. The NTS and the amount of water taken from the lake by diversions and consumptive use over the time period impact upon the levels of Lakes Michigan-Huron, and consequently influence the downstream river conditions and flows of the St. Clair River.

2.4.2 Diversions and Consumptive Uses

Diversions and consumptive use have impacts on Great Lakes water levels. There are a number of large water diversions. Some bring water to the Great Lakes basin from outside, while some take water out. These are described below.

The Long Lac and Ogoki diversions started in 1939 and 1943, respectively. These two diversions bring an average of 148 m^3/s (5,200 ft^3/s) of flow into Lake Superior from outside the Great Lakes basin, with some variation over the years depending on the hydrological conditions of their watersheds. The Chicago diversion, which was started in the mid-1800s, is currently removing approximately 91 m^3/s (3,200 ft^3/s) from Lake Michigan (IJC, 2000, p.13). The amount of the Chicago Diversion is currently limited by a U.S. Supreme Court decree. The Welland Canal system has been in operation since 1829 and has seen several major modifications since its inception with the current alignment existing since 1973. The average Welland Canal diversion for the period 1973 through 2004 was 238 m^3/s (8,400 ft^3/s) based on data of the International Niagara Committee.

The city of London diverts about 3 m^3/s (105 ft^3/s) from Lake Huron and returns it to Lake St. Clair via the Thames River (IJC, 2000, p. 13). The city also withdraws some water from Lake Erie which is also returned to Lake St. Clair. A number of other smaller inter- and intra-basin diversions exist within the Great Lakes system.

The Welland Canal and Chicago diversions decrease the water levels in Lake Erie and Lakes Michigan-Huron, while Long Lac and Ogoki diversions increase their levels. The magnitude and timing of outflow via diversions plays a significant role in understanding the impacts of these specific human activities on the water levels and flows within the Great Lakes system.

Consumptive uses also represent an extraction of water from the natural system, resulting in impacts on water levels, whether water is taken directly from the lake or from the basin's tributaries. Losses of water through consumptive uses for the entire system has been estimated to be approximately 106 to 121 m^3/s (3,740 ft^3/s to 4,270 ft^3/s), with the latter number estimated in 1993 (IJC, 2000, p. 9). Consumptive uses of water within the local basins of the Great Lakes system represent significant losses of water to the natural system and have subsequent impact on levels and flows within the system. Sensitivity analyses using existing and any updated data are needed to determine how increases in consumptive uses affect water supplies to the lakes and ultimately, their water levels and outflows. An assessment would also be made of the impacts on Great Lakes water levels and flows due to changes in land use, such as urban development and de-forestation, should historical data be available suitable for analytical purposes.

Effort is required to obtain improved estimates of outflow and inflow via diversions and consumptive use over the basins. These estimates will be of use to improve estimates of NBS and NTS for the system and to enhance knowledge of the water budget within the system. These data would also be used to assess their impacts on upper Great Lakes water levels and outflows. Changes in the amount and timing of these diversions and consumptive uses need to be analyzed as well to look for trends over time and to ensure that they have been appropriately reflected in the estimate of supplies to the lakes during the last 100 years.

2.4.3 Glacial Rebounding and Subsidence

As noted in Chapter 1, the earth's crust in the Great Lakes region continues to move today as it recovers from its deformation during the last ice age. This phenomenon is formally referred to as glacial isostatic adjustment (or GIA), but is also called post-glacial rebound or crustal movement. An analysis of recent data (Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data, 2001; Mainville and Craymer 2005) shows that the northeastern part of the Great Lakes basin has been rising faster than the southwestern part. Because rates of movement vary across the region, land-to-water relationships around individual lakes are affected as are the elevation differences and hydraulic relationships between lakes. GIA needs to be well understood when analyzing water level data and hydraulic characteristics of lake and river systems.

On an individual lake, how water depths change over time along the shoreline due to differential crustal movement depends on the direction and rate that a particular shoreline location moves relative to the lake's outlet. The lake's outlet is important because it helps regulate water levels in the lake. The results of an analysis (Coordinating Committee, 2001) using historical water level data show that Parry Sound, Ontario, on the northeastern shoreline of Lake Huron is rising about 24 cm (9.4 inches) per century relative to Lake Huron's outlet near Sarnia-Port Huron. As a result, during the 41 years that passed from the period-of-record lows experienced on Lakes Michigan-Huron in 1964 to 2005, the Parry Sound area has risen about 10 cm (4 inches) relative to the lake's outlet, and the lake's surface. Since the entire Georgian

Bay area continues to rise relative to the outlet, depths along its shoreline will continue to decrease for any given lake level as time goes by. At the same time, residents at Holland, Michigan on the southeast shore of Lake Michigan are observing an apparent rise in water levels over time as the land there falls 8 cm (3.1 inches) per century relative to the outlet near Sarnia-Port Huron. Similar circumstances are occurring on each of the Great Lakes as land-to-water relationships around the lakes change as a result of GIA.

Although the current rates of apparent movement around each of the lakes relative to their individual outlets are reasonably well known, absolute rates of movement over the region, that is, how locations in the basin are moving relative to the geocentre, are not yet well know, particularly in the southern portion of the basin. Gradient changes due to GIA between Sarnia-Port Huron at the head of the St. Clair River and Bar Point on Lake Erie seem to be negligible according to the Coordinating Committee's 2001 report. However, the contours are estimates only, established by combining the results of a global postglacial rebound model and lake gauge-derived velocities, and as such are not definitive. Currently, we do not yet know for certain the relative movement rate between sites on two different lakes, for example, between Harbor Beach, Michigan on Lake Huron and Cleveland, Ohio on Lake Erie. The use of satellite-based Global Positioning System (GPS) techniques is seen as the emerging technology which will allow us, after a few years, to determine absolute rates of vertical movement at points throughout the region and to accurately link the relative rates of all five Great Lakes and Lake St-Clair. Few data points and short records have also limited our knowledge around the outlets. The analysis of ancient shorelines may assist in relating basins, adding extra control points, and exploring long-term trends.

In relative terms, the Cleveland area is falling at a rate of around 10 cm (4 inches) per century relative to Lake Erie's outlet at Buffalo. We do not know with absolute certainty whether the Lake Erie outlet is rising, the west end is subsiding, or some combination of the two, but as a result of GIA Lake Erie is increasingly storing water over time. We also know that GIA affects water levels recorded at points around a lake. The changes in recorded levels at local points over time may represent a real or apparent change in water levels with respect to a common datum.

Crustal movement can also influence the conveyance characteristics of the river system due to differential shifting of the bed and through a reduction or an increase in the system's energy gradient depending on the relative movement between Sarnia-Port Huron at the head of the St. Clair River and Bar Point on Lake Erie. This phenomenon needs to be well understood, and it is important that the study reflect the most recent advances in estimating GIA. Furthermore, GIA should be taken into account in estimating flows and impacts, such as head differences between lakes based on recorded water level data, within the system. Again, the use of GPS should help quantify current movement rates between points on different lakes. A longer-term perspective of rates of rebound can be attained from ancient shorelines that rim the lakes. Many of these shorelines are hundreds and even thousands of years old and provide a context for the relatively short historical rates measured using GPS and water level data. These shorelines also help clarify whether the rate is linear versus exponential, which is important in developing predictions. GPS, water level, and shoreline data need to be analyzed together, while taking advantage of available technologies such as Geographic Information Systems (GIS).

2.4.4 Conveyance Capacity Downstream of Lake Michigan-Huron

Erosion and sedimentation are continuous and dynamic natural processes that have occurred since the formation of the present Great Lakes system. However, the natural relationship between water levels and water flows in these channels has been disturbed by various human activities such as sand and gravel mining, dredging for navigation, and shoreline infilling and hardening. The stream bed characteristics and profile of the system have also been affected by these activities. In turn, human activities may have exacerbated erosion and deposition of materials within the system, resulting in changes to the shape of the cross-sections along the channel, the slope of the river bed and the roughness, material size and composition of the bed material. Ongoing fluvial processes may have altered the channel characteristics since the last human intervention, and these processes may be continuing to occur, resulting in changes in the ability of the channel to convey water.

The assessment of the ability of the system to convey water is further complicated by considering the impacts of GIA on an individual lake and between different lakes. For example, analyses would need to consider the real or apparent impacts that stem from the rebounding sill at the outlet of Lake Erie, subsidence at the western end of Lake Erie, or a combination of the two.

Natural processes can also result in an increase or decrease in the conveyance capacity or characteristics of the channel, leading to an increase or decrease in discharge capacity. Water level conditions in Lake Erie can fluctuate quasi-independently from those of Lakes Michigan-Huron, as climatological forces may vary from basin to basin over time. For a given level of Lakes Michigan-Huron, decreasing water levels downstream in Lake Erie due to its response from local input would result in increases in the conveyance characteristics of the river-lake system. Conversely, an increase in downstream water level for the same upstream water level will result in a decrease in conveyance. Rising water levels in Lake Erie resulting from its rebounding outlet relative to the rest of the lake would tend to decrease the conveyance capacity of the St. Clair-Detroit system. The formation of ice and weed growth in the channel can also impact on conveyance. The magnitude and timing of such factors is dependent on a number of conditions, including water temperatures and local climatology.

In essence, some factors may increase conveyance, while others may impede the conveyance of the system. All factors must be appropriately reflected within the mathematical modelling of the system. Such models are useful for illustrating the magnitude of impact for various conditions at certain locations within the overall system. However, limitations on the ability to replicate specific factors in mathematical modelling, both spatially and/or temporally, can limit the scope and utility of possible analyses.

“Rating curve” models are commonly used to estimate the discharge in a river based on the observed water level or stage at one or more locations. It is known that under certain riverine conditions, a relationship exists between the river’s stage and its discharge that is sufficiently accurate to allow for an estimation of discharge or flow by observing stage or water level. A number of field measurements of stage and discharge are taken covering various water level and flow conditions over time to establish the relationship and to ascertain its stability over time. Should the conveyance of a river be increasing or decreasing over time and should the stage-discharge relationship not be altered to reflect the changing conditions, the resultant estimates of discharge would be in error. Typically, field measurement programs are systematically undertaken so that data are periodically available to examine the on-going stability of the relationship and to develop new relationships, should they be necessary. It is important that work be undertaken in this study to ensure rating curves and composite flow estimates are accurate for any particular time period.

Should the increase in the earth’s greenhouse gases result in an overall warming trend for the Great Lakes basin, the historical patterns of weed growth and ice formation and its longevity may be altered. In winter time, the ice in the system acts as a retardant to flow from Lakes Michigan-Huron to Lake Erie by increasing the resistance for water to flow through the system. When there is less ice or no ice present in the winter, the conveyance capacity through the system will increase from its historical levels for those months. With normal climate variability, there are already naturally varying cooling or warming periods, resulting in longer or shorter durations of ice cover to possibly no ice cover forming in the St. Clair-Detroit River system for a particular year or number of years. Ice processes are of importance in the connecting channels as well as in coverage of the lakes. Variations in lake ice coverage directly impacts on the amount of water leaving the system through evaporative losses during the cold season. Another consideration is the impact of variability and change during the warm season on weed formation and growth within the interconnecting channels. Longer weed growth seasons could result in an overall decrease in channel conveyance during this period of the year. On an annual basis, increased conveyance capacity through the system due to a decreasing influence of ice may be all or partially offset by an increasing impact of weed formation and growth. It is important to understand the impact of the formation and longevity of ice and weeds on the conveyance of the system and the water levels on Lakes Michigan-Huron. Work is required in this study to establish the relative degree of impact of these processes on the conveyance capacity of the system, and if there have been any changes over time.

2.5 Modelling Environment and Data Analyses

A modelling environment that mathematically depicts water balance, the hydrological cycle, lake response and hydraulic routing is required to describe the causal relationship amongst the physical conditions of the system, as well as hydrometeorological factors and their feedback effects. A water balance or hydrological model is required for the Lakes Michigan-Huron and Lake Erie basins to establish net input to the lakes that reflect impacts of diversions, consumptive uses, overlake precipitation and evaporation, gauged and ungauged tributary runoff to estimate NBS and NTS. Lakes must be connected via hydrodynamic models that can adequately reflect historical as well as current conditions.

One modelling effort of particular interest is the on-going activities in support of the Coordinated Great Lakes Regulation and Routing Model (CGLRRM) (CCBGLHHD, 2004). The model was designed to test the performance of various Lake Superior regulation plans and was not designed to recreate historical water levels. This model computes average monthly levels and outflows for the upper Great Lakes system through Lake Erie, given historical or simulated water supplies and using existing or modified regulation plans. A limitation of the utility of the existing model for the proposed study of the St. Clair River is that a constant physical Lakes Michigan-Huron water level to outflow relationship is assumed to apply for the entire simulation period, although the effects of ice and aquatic weed-growth resistance on flow can vary with time. The model can not progressively reflect channel modifications or changes to diversions and consumptive use losses that have occurred discretely or continuously over time. As well, computational methods are not able to “reflect short-term hydrodynamic effects such as wind setup, ice jams, etc.” (*ibid*, p.5). An assessment should be performed to establish if shorter computational time periods are required and what modifications to the model are required to enhance its capabilities for analytical purposes of the study.

The CGLRRM is a rather simple hydrological “routing” model and is useful for generating water levels and flow data for the upper lakes under various assumptions such as Lake Superior’s pre-project outlet conditions, the present or other outflow regulation plans, or the addition of Lakes Michigan-Huron and/or Lake Erie outflow regulation. Since it is a water-balance model, it can evaluate the impacts on lake levels due to diversions and consumptive uses given net basin supply.

The eventual modelling environment should be designed to allow a simulation that accurately reflects historical and potential future physical and climatic conditions as well as scenario playing to establish response sensitivity to existing or hypothetical conditions. An important limitation may lie in the lack of historical data that may be available upon which to condition models.

The adoption of more advanced hydrodynamic models should be considered, particularly should rating curves be found not to provide sufficiently accurate estimates of outflow. There is also the need for 3-D (three-dimensional) hydrodynamic and sediment transport modelling to more effectively understand and describe hydraulic forces driving erosion and deposition within critical sections of the St. Clair River from the outlet of Lakes Michigan-Huron downstream to approximately the confluence of the St. Clair River with the Black River. This would complement analyses performed from the outlet of Lakes Michigan-Huron to the outlet of the Detroit River into Lake Erie at the 2- and 1-D level. An accurate and representative modelling system and models are required to assess the sensitivity of various factors on water level conditions and conveyance capacities**.** Such models may also be able to describe future channel conditions, based on simulation experiments. The modelling environment includes adopting and adapting models and obtaining data that are fundamental for representing physical conditions for model set-up. Data are also required for calibration and validation of the models. More details on monitoring requirements are provided in Section 2.6.

A number of modelling activities are required. Some of these include:

- Investigate abilities and suitability of the CGLRRM or other available models for this overall effort. Define modifications or approaches that should be undertaken to develop a modelling environment/system that suitably represents the physical system using appropriate time domains. Undertake modifications to the CGLRRM or other available models that would be suitable to achieve the desired system. This system would be used to facilitate modelling within the study.
- Improve upon the estimation of ungauged tributary inflows, overlake precipitation and lake evaporation, subsequently revising estimates, as required, to improve their accuracy and reliability.
- Take existing 1- and 2-D hydrodynamic models of St. Clair-Detroit River system and create additional 2-D mesh(es) using historical and new bathymetric data. Compute the anticipated changes in water levels and discharges using 1- and 2-D models with appropriate mesh(es) under a variety of hydrological conditions to ascertain the impacts of physical changes of the river and flow regimes on water levels.
- Calibrate and validate 1- and 2-D model application for complete, recent partial surveys of 2005 and new surveys proposed for the study from Lakes Michigan-Huron through Lake Erie. Apply models using partial survey data to obtain impacts of change on the hydrological regime.
- Adopt and adapt open source 3-D hydrodynamic and sediment transport models for the critical reach from the outlet of Lakes Michigan-Huron to approximately the confluence of the St. Clair River with the Black River. Apply 1-D and 2-D hydraulic and sediment transport models to enhance understanding of the bed morphology within the St. Clair River system. Results of this analysis may indicate the need to broaden the application of the 3-D model within the system.
- Establish optimal model configuration, including nesting of models, and boundary conditions for various hydraulic and sediment transport analyses.
- Apply stage-discharge, stage-fall, regression analysis based stage-fall, 1-D and 2-D hydrodynamic models to various reaches of St. Clair River to establish discharge from stage and to calibrate and verify suitability of rating models over various time periods. This may lead to the development of alternate outflow estimation techniques yielding more accurate and reliable values.

A number of activities associated with data and their analyses should be considered. These include:

- Review and verify rating equations used in the computation of Great Lakes outflows to ensure accurate estimates of discharge are determined over time. This would include rating equations for the current and historical hydraulic regimes of the St. Clair River. A review and verification of composite flow estimates used in the computation of Great Lakes outflows (e.g., St. Marys River) needs to be performed. The uncertainty of the discharge estimate and its stability over time should also be estimated. Efforts should consider the existing databases containing measurement data since 1962 to present, and there may be a requirement to extend the databases to earlier periods to assess changes in relationships.

- The verification of the homogeneity of data prior to 1900 and post 1900 should be performed for two aspects, namely the method of transference to correct for differential crustal movement and the impact of moving from water levels observed 3 times daily from staff gauges (pre-1900) to continuous recording (post-1900) using stilling wells.
- Obtain the most recent estimation of absolute and relative rates of movement due to glacial isostatic adjustment within the upper Great Lakes system.
- The establishment and application of appropriate datum corrections to water level and bed data.
- Obtain updated consumptive use data for upper Great Lakes including tributary basins so that such data can be used in estimating basin supply to the lakes and in establishing their impacts on water levels and outflows using sensitivity analysis.
- Analyze bathymetric data using GIS for complete surveys for target period to ascertain patterns of change and volume of change in bed (erosion, deposition) (The application of consistent approaches to establishing contours is important in this step.)
- The development of cross-sectional profiles for comparative purposes, including an estimate of their uncertainty.
- Review for accuracy and consistency and update, if required, water level and flow data used in computation of NBS and NTS. Review the approaches to computing NBS for each major basin to ensure factors such as diversions and consumptive use are consistently reflected in the estimates. Develop consistent NBS and NTS series as input to the modelling system and for analytical purposes.
- Review of historical NBS and NTS and their component and residual parts for patterns over time.
- Trend and shift analyses of water levels, NBS, water cycle components, etc. should be performed if visible patterns are discernable.

2.6 Monitoring and Field Work

A variety of data are required for the modelling system, model development and application, and analyses of results. These include: water levels throughout the system (with appropriate crustal movement adjustments); bathymetry (all complete surveys for target periods, including five new surveys covering spring and fall for 2.5 years to assess transient nature of bed); crustal movement rates; overlake precipitation for Lake Superior, Lakes Michigan-Huron and Lake Erie; other climatological data necessary for estimation of lake evaporation and sufficient to drive models estimating ungauged tributary inflows; gauged local tributary inflow; outflow from Lake Superior and Lake Erie. Field discharge measurement data (i.e., conventional hydrometric and Acoustic Doppler Current Profiler (ADCP) data) should also be acquired for ratings within the system and model calibration and verification purposes. Three additional in-situ and one roving ADCP should be installed and operated for the duration of the study to provide continuous data for assessment and modelling purposes. Data on tributary flows, diversions and consumptive uses by basin are also required.

In order to assess the geomorphologic changes in the St. Clair River's regime, additional data are required to assist in calibrating and validating the multidimensional hydraulic and sediment transport models. These activities include core sediment samples across approximately five cross-sections in the critical reach, with bed material sampling and size analysis performed coincident with the core sampling sections. Suspended sediment analysis and loadings would be estimated from the proposed operation of one sediment monitoring station within the St. Clair River.

2.7 Remediation Options and Their Evaluation

The IJC Directive to the Revision Team was to consider potential remediation options and their evaluation, depending on the nature and extent of St. Clair River changes and impacts investigated during the course of the study. This section outlines the type of options that could be considered and a process for their evaluation.

There are two general categories of remediation measures, and these are normally termed structural and non-structural approaches. Structural measures imply the undertaking of the construction of civil works geared to providing the desired physical outcome. Should erosion, exacerbated by human intervention, be causing an on-going impact on water levels in Lakes Michigan-Huron, then structural measures could be considered that may reverse or counter the effects. Structural measures can be either of a static or dynamic nature, where the latter implies ability to affect flows and levels by mechanical adjustment of the structure (e.g., control gates). Static structural approaches include a variety of options that tend to focus on stream channel modifications. These could include options of providing in-fill in one or more locations, covering eroding areas in sensitive reaches with rock substrate to reduce the rate of erosion and the creation of a system of weirs or a series of submerged berms. Various structural options can be selected for consideration based on knowledge of the processes and physical conditions of the site.

Nonstructural measures can also be considered as being part of the "toolbox". These comprise non-physically oriented activities such as implementation of regulations on shoreline land-use planning. Although land use planning and regulations are under the jurisdiction of local authorities, the study could conduct a general review of this subject to provide possible recommendations as to their ability to reduce the adverse effects of water level fluctuations. Nonstructural measures could also consider increased public awareness of variability and change (e.g., impacts of glacial isostatic adjustment) within the system. Adaptation activities could be explored to deal with variability and change.

Both nonstructural and structural approaches can be considered in isolation or in combination, as adopting more than one measure may lead to a preferred outcome.

If structural measures are being considered that return the conveyance characteristics of the St. Clair River to be similar to that of a previous time period, the question will be one of what level of adjustment to consider. This may require an evaluation of remediation measures that reflect a selection of alternative target conditions. This could be expressed as target conveyance levels associated with earlier time periods, such as circa 1940, 1965, 1980 and 2005 conditions. Note that these dates are given only for example purposes. Should remediation measures of a dynamic nature be considered, a regulation plan and operating rules for such measure would need to be developed in concert with Lake Superior outflow regulation. Any plan would also need to be able to respond to unusual hydrological conditions, including the potential for changes in water supply as a result of climate change and variability affecting the upper Great Lakes system. Modelled future conditions may also be considered within this context to help illustrate impacts within the system on stakeholders should erosion be on-going. Resource evaluations, which are described in Chapter 4, would be required to adequately evaluate the impact of each option. Outcomes would be evaluated based on an analysis of benefits and losses from economic, social and environmental perspectives.

Within the International Lake Ontario-St. Lawrence River Study, a “shared vision” computer model was constructed to facilitate the assessment of potential options (IJC, 2005). For the Upper Lakes Study, a similar model would be helpful in assessing the effects of various remediation options on aspects of importance to stakeholders. The intent of such a model is to combine key information from various “resources evaluations” in such a way that various scenarios or options can be assessed to estimate the potential positive or negative impacts on various interests. These results can lead to the development of additional remediation options that can further limit damages or increase benefits, resulting in the development of potentially “acceptable” remediation plans for consideration by the IJC.

The costs for the St. Clair River evaluation of the study are estimated as follows:

	Year 1	Year 2	Year 3	Year 4	Year 5
Total Cost (U.S. dollars)	$500K	$1,250K	$1,250K	$500K	$0K
or					
Total Cost (Canadian dollars)	$600K	$1,500K	$1,500K	$600K	$0K

The total cost for the St. Clair River evaluation would be about $3,500K (U.S. dollars). This is equivalent to about $4,200K in Canadian dollars.

3.0 Regulation Plan Review

The principal purpose of this Plan of Study is to create a framework for three major items related to the regulation of Lake Superior: (i) review the operation of the structures controlling the outflows from Lake Superior in the light of the impacts of those operations on water levels, flows, and consequently affected interests in the Upper Great Lakes system from Lake Superior downstream through Lake Erie, including the environment; (ii) assess whether changes to the Orders or regulation plan are warranted to meet contemporary and emerging needs, interests and preferences for managing the system in a sustainable manner, including climate change scenarios; and (iii) evaluate any options identified to improve the operating rules and criteria governing Lake Superior outflow regulation.

To accomplish these goals, the study will begin by reviewing the Orders of Approval (including all Supplementary Orders), the operating rules and criteria currently in use and any past deviations from the regulation plan. Options will be developed as to what items may be adjustable. Additionally, climate change/variability scenarios will be generated to ensure any new regulation plans have the ability to operate over a future range of conditions. Any significant items investigated in the St. Clair river portion of the study will be incorporated in new regulation plans also. Lakes Michigan-Huron outflow changes will impact any alternative regulation plans and subsequent Orders of Approval. These analyses will then be used as input to the design process for alternative regulation scenarios. Extreme high and low ranges of these possible changes can then be analyzed to determine the maximum effect that is achievable on water levels and flows in the system. Based on the magnitude of these potential water level and flow changes, due to alternative regulation scenarios, an estimate of the degree of impact on various resources will be known. This will help guide the creation and evaluation of candidate alternative regulation plans.

The findings from the consultations with the International Lake Ontario – St. Lawrence River Study staff that are directly applicable to this study are highlighted as “Lessons Learned” in the following sections.

3.1 Orders of Approval, Operating Rules and Criteria

3.1.1 Current Orders, Rules and Criteria

The following is a listing of the pertinent conditions and criteria currently in effect as noted in the original Orders of Approval and any Supplementary Orders. The original Orders of Approval were issued in May 1914 in response to applications of the Algoma Steel Corporation, Limited and the Michigan Northern Power Company for approval of the obstruction, diversion and use of the waters of the St. Marys River on the Canadian and United States side of the international boundary at Sault Ste. Marie, Michigan and Ontario. They authorized the construction of the Compensating Works and the regulation of Lake Superior outflows. They also created “The board of control” to oversee the operation of all the said works, canals, headgates and by-passes. The major items listed below refer to the conditions dealing with control and operation. Any items that were deleted by subsequent supplementary orders have not been listed. Any items that have been amended are only listed as the currently amended wording in effect as of the most recent supplementary order. These are the items to be reviewed for possible update and their subsequent effect on alternative regulation plans.

The Supplementary Order of Approval, dated 27 September 1978, includes the following provisions:

- Condition 2:
  - Upon completion of the remedial works to maintain the sport fishery in the St. Marys Rapids , the outflows of water from Lake Superior shall be distributed according to the following order of priority:
  - a) the requirements of navigation will be met;
  - b) a flow sufficient to protect the sport fishery in the St. Marys Rapids shall be maintained;
  - c) the use and diversion of water as approved in the 1914 Orders of Approval shall be maintained, without prejudice to any determination by Governments of the ownership and distribution of waters diverted into Lake Superior from Long Lac and Ogoki.

The Supplementary Order of Approval, dated 3 October 1979, includes the following provisions:

- Condition 1:
  - maintain the monthly level of Lake Superior as nearly as may be within its recorded range of stage below elevation 183.86 metres (602.0 feet)(IGLD 1985);
  - provide no greater probability of exceeding elevation 183.86 metres (602.0 feet) (IGLD 1985) than would have occurred using the 1955 Modification of the Rule of 1949;
  - maintain the levels of Lake Superior and Lakes Michigan-Huron at the same relative position within their recorded ranges of stage and with respect to their mean monthly levels, assuming supplies of the past as adjusted; and in such a manner as not to interfere with navigation. Supplies of the past as adjusted are defined as the monthly water supplies for the period 1900-1976 adjusted to a condition assuming a continuous diversion out of the Great Lakes Basin of 90 m^3/s (3100 ft^3/s) at Chicago and a continuous diversion into the Great Lakes Basin of 140 m^3/s (5000 ft^3/s) from the Albany River Basin.
  - ***Criterion a:*** The level of Lake Superior shall be maintained within its recorded range of stage when tested with supplies of the past as adjusted. The regulated monthly mean level of Lake Superior shall not exceed elevation 183.86 metres (602.0 feet) (IGLD 1985) or fall below elevation 182.76 metres (598.4 feet) (IGLD 1985) under these conditions.
  - ***Criterion b:*** To guard against unduly high stages of water in the lower St. Marys River, the excess discharge at any time over and above that which would have occurred at a like stage of Lake Superior prior to 1887, shall be restricted so that the elevation of the water surface immediately below the locks shall not be greater than 177.94 metres (582.9 feet) (IGLD 1985).
  - ***Criterion c:*** To guard against unduly low levels in Lake Superior, the outflow from Lake Superior shall be reduced whenever, in the opinion of

the Board, such reductions are necessary in order to prevent unduly low stages of water in Lake Superior, and shall fix the amounts of such reductions; provided, that whenever the monthly mean level of the Lake is less than 183.40 metres (600.5 feet) (IGLD 1985), the total discharge permitted shall be no greater than that which it would have been at the prevailing stage and under the discharge conditions which would have been obtained prior to 1887.

- Condition 2:
  - The mean elevation of Lakes Superior, Michigan and Huron shall be ascertained by taking the mean of the readings of automatic gauges on each lake. The gauges shall be so located that the combined readings on each lake provide a representative mean level on that lake. At least four gauges shall be utilized on Lake Superior, two of which are maintained by Canada and two by the United States; at least six gauges shall be utilized on Lakes Michigan-Huron, two of which are maintained by Canada and four by the United States.

- Condition 3:
  - A Board of Control to be known as the International Lake Superior Board of Control, consisting of an equal number of members from Canada and the United States, is hereby established. The members of the Board of Control shall be appointed by the Commission.

- Condition 5:
  - The amount of water available in each country for power purposes, under the 1914 Order, as amended, shall be one-half of the total amount available for power purposes as determined by the approved regulation plan and the requirements regarding flow allocation of the said Order, as amended, without prejudice to any determination by Governments of the ownership and distribution of water diverted into Lake Superior from Long Lac and Ogoki.

The Supplementary Order of Approval, dated 11 December 1985, includes the following provisions:

- Condition 2:
  - The outflows of water from Lake Superior shall be distributed in accordance with Condition 2 of the Supplementary Order dated 27 September 1978.

- Condition 3:
  - a) flows through the section of the Compensating Works which is between the dike and St. Marys Island will achieve a minimum water level between the dike and Whitefish Island equal to that provided by opening four (4) gates in the Compensating Works prior to construction of the dike;

- flows sufficient for fisheries habitat management to a maximum of 0.8 m^3/s (30 ft^3/s) will be maintained in the Whitefish Channel between Whitefish Island and St. Marys Island; and
- the water level in the main St. Marys Rapids to the south of the dike will be at least equal to that which occurred with one half (1/2) gate open in the Compensating Works before the dike was constructed, and will reach the bottom toe of the dike.

There are a number of additional operational rules, guidelines and limitations, not specifically noted in the Orders of Approval that merit review as well. These are:

- The maximum winter outflow is 2,410 m^3/s (85,000 ft^3/s)
- The minimum winter outflow is 1,560 m^3/s (55,000 ft^3/s)
- The maximum change in outflow, from month to month, can not exceed 850 m^3/s (30,000 ft^3/s)
- The minimum gate setting in the Compensating Works shall not be less than ½ gate open
- The balancing routine and its parameters
- The outflow forecasting routines and trigger levels
- Each remaining Plan 1977-A parameter
- U.S. Slip water level relationships
- S.W. Pier water level relationships

3.1.2 Improvement Opportunities for Orders, Criteria and Regulation Plans

There are a variety of work items that have been studied in the past, specifically the recent Levels Reference Study and issues that have recently come to light that need review to make the regulation plan as robust as possible.

- The specified upper and lower water level limits for Lake Superior, while being sufficient for data of the recorded past, may not be appropriate under a climate change scenario or under conditions reflecting normal climate variability. These should be reviewed for their relevance and the necessity of having the elevations specifically noted, rather than optimal ranges noted.
- Review the supply forecast method used in the plan and consider if there are more useful approaches.
- The balancing equation for Lake Superior and Lakes Michigan-Huron should be reviewed and the possibility of incorporating water supply forecasts into the balancing routine considered. In addition, the parameters that define the state of balance between the lakes should be reviewed and updated if necessary.
- Consider other means of systemic regulation as alternatives to the balancing equation approach of Plan 1977-A. An example would be a regulation plan using a multi-objective, multi-lake optimization approach.
- The outflow limits in the plan should be reviewed for their appropriateness. There are limits specified for maximum outflows, minimum outflows, winter outflows, maximum changes from month to month, as well as the pre-project criteria to prevent flooding in Soo Harbor and unduly low Lake Superior levels. Modifying the outflow limits could improve the balancing of the levels and would allow greater flexibility in responding to extremes.

- The outflow forecasting procedures should be evaluated to determine if improvements can be made to smooth the transition of flows from month to month while maintaining the responsiveness of the plan. Issues to be addressed may include incorporation of trigger levels for introducing high or low water supplies, changing the length of the forecast period used, using seasonal trigger levels, and better linkage between outflow forecasting and balancing.
- Update the Niagara River stage-fall-discharge equation and St. Clair – Detroit River stage-fall-discharge equations used in the hydraulic routing as well as varying ice and weed retardation impacts.
- The split of water for power production is currently 50/50. Recent developments show that the generation capacity of the U.S. side is slightly more. This results in either a non-50/50 split or spilled water.
- Peaking and ponding is not specifically mentioned in the Orders of Approval or the Supplementary Orders. The power companies currently engage in this practice, under the auspices of the Board. Should this issue be definitively addressed in updated Orders?
- Some criteria, guidelines and limitations can cause large flow changes from month to month, resulting in excess water discharges which are not available for power generation. These larger releases cause fishery and environmental concerns as well. New plans could be more flexible in spreading the release of water.
- Fishery interests note that the ½ gate open minimum setting is not sufficient to water the entire bed of the Rapids. Investigations into providing a greater permanently watered surface area should be conducted, taking other parameters such as velocity, depth and habitat into consideration as well.
- Sea lamprey trapping personnel have noted that high flows in the rapids during the months of June and July decrease the effectiveness of the trapping program.
- Investigate the need for the International Lake Superior Board of Control (ILSBC) to have discretionary authority to deal with deviations from the regulation plan. This may take on more importance in dealing with climate variability and possible St. Clair River remediation options.
- Review the membership of the ILSBC to determine if additional members are necessary to reflect the diversity of interests in the basin and to meet emerging needs.
- Review any other aspects of the ILSBC to see if changes are warranted based on past deficiencies or future needs, including public communications.

These items should be reviewed as to their compliance with the Boundary Waters Treaty, and how they meet the contemporary and emerging needs and interests and preferences for managing the system in a sustainable manner. The items that are deemed acceptable for change/update should become part of alternative regulation plans. Several of these options may have a range of increments with which they can be implemented. Sensitivity analyses would be beneficial here to see the magnitude of the impacts of each option.

3.2 Response to Climate Change and Variability

The climate of the upper Great Lakes basin has a great impact on the requirements and effectiveness of the Lake Superior outflow regulation plan. Net basin supply is a function of climate. Over the long term, the net basin supply received limits the amount of water that can be stored in or released from a lake. The net basin supply has had historical variations on many timescales. Periods of higher and lower water supplies will undoubtedly occur in the future due to the natural variation in climate, with and without the effects of anthropogenic increases of greenhouse gases in the atmosphere. To design a regulation plan that would be more useful under a wider range of supplies, consideration would be given to generating hydrological sequences based on the statistical properties of existing historical supply using, for example, a stochastic approach as was done in the International Lake Ontario – St. Lawrence River Study.

A qualitative assessment of changes due to demographic and other possible factors, such as consumptive uses, would be made to illustrate how such changes may affect water supplies and related hydrological factors. Alternative basin supplies could then be routed through the hydraulic model to determine the impacts on levels and flows using the modelling environment described in Section 2.5.

Lake Superior Regulation Plan 1977-A was developed and tested using 1900-1986 historical water supplies to Lake Superior and the downstream lakes, adjusted to certain assumptions concerning water diversions and outlet conditions of the downstream lakes. Since 1986, more extreme supplies have been recorded. These include the rapid decline in the water supplies in 1987-1988, the very high supplies of the mid 1990s, and the very low supplies that began in the late 1990s and have continued through current times. Among the first steps in this study would be the review and updating of the historical water supplies through to the most recent available year and defining other basic parameters in the modelling environment such as diversions, outlet conditions, and ice and aquatic growth impacts on flows. Some of this work may have to be revisited if it is found that significant changes in the St. Clair River flow capacity have occurred in recent decades.

Climatic factors contribute to the variability in the levels of the Upper Great Lakes. The utility of observed time series of lake levels has been enhanced by the use of a 50,000-year stochastically generated time series of net basin supply having statistical characteristics similar to those of the observed time series (Fagherazzi et. al. 2005. Lee, et al. 1994). This is a useful method for synthesizing time series of net basin supply to test the robustness and performance of a regulation plan under a wide array of plausible supply conditions. These series can also be applied for calculating the frequency of exceedence of various lake levels under scenarios corresponding to experimental outflow regulation plans. Work done for the International Lake Ontario – St. Lawrence River Study would be directly applicable here. In that study the equivalent of 50,000 years of NBS sequences for each of the upper lakes were generated and routed to create the NTS series for Lake Ontario. These data could be used directly in the Upper Lakes Study.

Additional analyses would also be undertaken making use of, and possibly extending, the application of climate change general circulation models (GCM) to estimate future supplies to the Great Lakes. The future supply scenarios that were generated for the upper lakes as part of the International Lake Ontario – St. Lawrence River Study (Croley 2003) could be directly applied for this study, but consideration should also be given to generating new scenarios based on more current GCM and Regional Circulation Model (RCM) results should they be available. RCMs provide potentially higher resolution output, which may be more physically representative of the Great Lakes geography, leading to more accurate results, however at the time of the Lake Ontario – St. Lawrence River Study, even these models did not account for lake-atmosphere interactions.

Rather than assessing variability as depicted by general circulation models (GCM), it might be more fruitful to attempt to gain greater understanding of the long-term variability of the past, whose modes might be extended into the future. This includes the relationship between climatic variables and lake levels at time scales from a few years to a few decades and an understanding of the manifestations and causes of common variability of climate and lake levels at timescales of a few years to several decades. The long-term modes of variability involve regimes of wet-cold, wet-warm, dry-cold, and dry-warm conditions, which are connected to large-scale, persistent atmospheric circulation patterns. These circulation anomalies have been characterized by teleconnection indices, such as El Niño Southern Oscillation (ENSO), the North Atlantic Oscillation (NAO), the Pacific Decadal Oscillation (PDO), and others. Empirical matching of combinations of the magnitudes and phases of these indices with the precipitation-temperature regime of the Great Lakes region could be carried out, leading to enhanced physical understanding of the causes of teleconnections between the climate of the Great Lakes region and foci of oceanic forcing.

Scenarios of net basin supply can be generated by extension of observed net basin supply through stochastic synthesis of a long time series, and also through reconstruction of paleo-levels. Baedke and Thompson (2000) reconstructed high stand levels of Lake Michigan over the past 4700 years, which may be useful in assessing historical net basin supply, and input into a hydraulic routing model. They have demonstrated that a 150- to 160-year cycle in lake levels exists concurrently with a 30- to 33-year cycle, both of which they believe to be related to climatic factors. A similar reconstruction is pending for Lake Superior levels.

These various methods will be investigated to provide the best scenario to model future climate variability and change, and therefore not all of these approaches will be adopted in the study. The selected climate-related studies would be coordinated with hydraulic and hydrological studies, with the outputs from the climate studies being used as input to hydrological models, as well as channel routing and lake regulation models. The water levels and flows resulting from the various regulation plans and climate scenarios will be evaluated using the approach developed in the study to assess impacts on the resource groups.

LESSON LEARNED: When running the coordinated routing model with stochastic scenarios during the International Lake Ontario – St. Lawrence River Study, Plan 1977-A did not do well under extreme high supply conditions, suggesting changes are necessary to make the regulation plan more robust for future climate.

3.3 Maximum Impact Achievable on Levels and Flows

During Phase II of the IJC's Levels Reference Study, Task Group 1 of Working Committee 3 developed several alternative regulation scenarios. They were specifically designed to better balance the levels of Lakes Superior and Michigan-Huron and provide benefits to the middle Great Lakes in the form of decreased frequency of extreme levels. The most promising plan was designated PL2 by the Working Committee and when combined with a Lake Ontario regulation plan, was designated Plan 1.21 by the Study Board. This plan included: changes to the outflow forecasting routines; an increase in the winter maximum outflow limit; and modifications to the balancing equation and its parameters.

This experimental plan was run for the 1900-1989 time period along with the basis of comparison plan. Comparison of lake levels during this 90 year period, including mean, maximum and minimum, is shown in Table 3.

The frequency of occurrence of extreme levels on Lakes Michigan-Huron and Erie were decreased, while they were increased on Lake Superior. As shown in Table 3, the range of levels were reduced by 13.1 centimetres (0.43 feet) and 5.8 centimetres (0.19 feet) on Lakes Michigan-Huron and Erie, respectively, and increased by 12.5 centimetres (0.41 feet) on Lake Superior. It was found that the experimental plan balanced the levels of Lakes Superior and Michigan-Huron better, while decreasing the frequency of large changes in outflow from month to month. The plan decreased the number of months when the Lake Superior outflows were below the capacity of the hydropower plants.

Table 3
Summary Statistics for Levels Reference Study Plan 1.21
(Relative to Plan 1977-A)

• Lake Superior mean water level	-3.4 centimetres (-0.11 feet)
• Lake Superior max water level	+7.6 centimetres (+0.25 feet)
• Lake Superior min water level	-4.9 centimetres (-0.16 feet)
• Lakes Michigan-Huron mean water level	0.0 centimetres (0.00 feet)
• Lakes Michigan-Huron max water level	-5.2 centimetres (-0.17 feet)
• Lakes Michigan-Huron min water level	+7.9 centimetres (+0.26 feet)
• Lake Erie mean water level	+0.3 centimetres (+0.01 feet)
• Lake Erie max water level	- 1.2 centimetres (-0.04 feet)
• Lake Erie min water level	+ 4.6 centimetres (+0.15 feet)

The plans evaluated in Phase II of the Levels Reference Study did not include all the options which may be reviewed in this Plan of Study. This past work shows that there are additional potential benefits to be obtained from the consideration of alternative regulation plans. It is recommended that early in the study, some preliminary work be done to establish the maximum achievable impacts on levels and flows from regulation. This could include all possible changes to the regulation plan at one time, without final determination as to their applicability. These ranges of level and flow changes will then give the resource evaluation groups an estimate of the outer extremes of impacts possible by changing the regulation plan. This information can guide decisions on how detailed any resource evaluations will need to be.

3.4 Formulation and Evaluation of Alternate Regulation Plans

The evaluation of Lake Superior regulation plans, the practicality of proposed criteria, and the hydrological impacts on the resource groups, require computer simulation of water levels and flows. Computer models currently exist, including the CGLRRM, which can be used for these evaluations. This model incorporates the existing Lake Superior regulation plan and hydraulic outlet conditions of the St. Clair, Detroit, and Niagara Rivers and Great Lakes diversions. The model computes water levels and flows of the upper Great Lakes and their connecting channels through Lake Erie and the Niagara River, given historical water supplies or other supply scenarios. In addition to outflow regulation study, the model may be a useful tool in assessing the impacts of dredging, diversions, and climate variability. There are also other hydrological models, such as the hydrological prediction and basin runoff models developed and operated by GLERL or the coupled weather and WATFLOOD hydrological models of Environment Canada that could be used in these analyses. Model environments developed for the St. Clair River investigations would possibly be used here as well.

Due to the size and response time of the upper Great Lakes to water supplies, the Lake Superior outflows are regulated on a monthly basis. Most historical water supply data are also developed on a monthly basis. Studying the implications of a change to more frequent regulation, such as weekly, would be very time intensive and costly. For example, data including net basin supplies and river flows would need to be calculated from 1900 to the present time on a quarter monthly basis. Daily data necessary for these analyses may not be available. Assessing the potential gain or loss from more frequent regulation may not be economically feasible due to the expense of generating the necessary data sets. Thus, for the testing and hydrological evaluation of regulation plans, and for climate change studies, levels and flows would likely be computed on a monthly basis using the regulation plan and supply routing model discussed above. With this time step, it is possible to ignore short-term non-regulation effects such as those caused by winds and transients set-up by flow changes.

To examine short-term water level effects, for example, daily or weekly flow changes at Sault Ste. Marie, detailed hydraulic models would be needed to simulate changing water levels and flows of the St. Marys River. 1- and 2-D hydrodynamic models of the St. Marys River exist. There may be sufficient daily and hourly water level and flow data available for recent years to study short-term effects, however additional detailed data may be required to properly calibrate these models. The study team should investigate the availability of these models and data at study inception to determine if they would be feasible tools. Such models would be required to investigate impacts of dredging and other factors in the St. Marys River.

3.4.1 Basis of comparison supply scenario

In order to compare alternative regulation plans, the Study Team needs to develop a basis of comparison (BOC) scenario of levels and flows to compare against. It is recommended that the BOC be developed from Lake Superior through Lake Erie. This BOC would assume Plan 1977-A as the plan of regulation, along with current hydraulics and hydrology, including diversions and channel hydraulics and outlet conditions. This data set should encompass the period from 1900 to the date of study inception and include statistics such as maximum, minimum and average values as well as frequency of occurrence information.

LESSON LEARNED: There is a need to review the water supplies for Lake Erie for the past 30 years, as there appears to be a shift in their magnitude.

3.4.2 Climate change supply scenarios

As noted in Section 3.2, any alternative regulation plans must be able to manage the system in a sustainable manner, not only for the historical range of levels and flows, but also for future levels and flows that might result due to climate change and variability. Using some of the methods noted in Section 3.2, the Study should develop a series of level and flow scenarios to cover the possibilities of potential climate variability and future climate change including use of scenarios such as wet-cold, wet-warm, dry-cold and dry-warm.

3.4.3 Lake Superior Pre-Project Outlet Conditions

To compare water level and flow conditions under regulation to those that would have occurred without regulation, a model using the pre-project or unregulated Lake Superior outlet hydraulic relationship would be applied. This can be done with the CGLRRM. Levels and flows under pre-project conditions are essential, particularly for assessing impacts on resources throughout the basin. The results obtained would also facilitate the consideration of options consistent with systemic regulation, but which would result in mean levels and variability closer to those in the state of nature. This state of nature regime of water levels and flows is also essential for all the resource committees to assess the impacts of a regulation scenario that simulates pre-regulation or pre-project outflow conditions.

The routing of water supplies would assume existing downstream hydraulic outlet conditions in the St. Clair and Detroit River system. If necessary, the routing of supplies could include assumed St. Clair – Detroit River outlet conditions for previous time periods, such as prior to the major dredging projects of the 1930s and 1960s. A fairly comprehensive hydraulic analysis would be needed to accurately determine the stage-fall-outflow relationships for the St. Clair – Detroit River system for different channel regimes. This will likely be carried out as part of the St. Clair River investigations noted in Chapter 2.

This pre-project scenario will be created in an effort to help estimate the impacts of historical human activities on levels and flows within the system. It is intended to show what water levels and flows would have been like without any past regulation. It will be evaluated as another possible plan, along with alternative regulation plans. It will not be used as an additional basis of comparison to evaluate alternative regulation plans. Alternative plans will only be compared to the Basis of Comparison when evaluating new options.

3.4.4 Diversions, Consumptive Uses, Groundwater and Land Use

The impacts on Great Lakes water levels and outflows due to existing major water diversions would be updated using the CGLRRM. The most recent estimate of consumptive uses would be updated if applicable. The impacts on Great Lakes water levels and flows due to current and projected consumptive uses would be determined. A qualitative assessment of the relationship between Great Lakes water levels and groundwater flows would be made. An assessment would also be made of the impacts on Great Lakes water levels and flows due to changes in land use, such as urban development and de-forestation, should historical data be available that are suitable for analytical purposes. Diversions, consumptive uses, groundwater and land use changes, and their subsequent impacts are not regularly monitored or recorded. Therefore reliable data will be difficult to obtain. Sensitivity analysis will be conducted to bound the uncertainties associated with these data and provide a range of what may be occurring and its system-wide impacts.

3.4.5 Alternative Regulation Plans

A range of alternative regulation plans will be developed to address the Directive's purposes of reviewing the operation of the structures controlling the outflows from Lake Superior and the examination of physical processes and possible ongoing changes in the St. Clair River. These will address the issues noted in Section 3.1.2.

This review will also need to address the response of the alternative regulation plans to possible remediation measures that could be proposed for the St. Clair River. This will likely be dealt with by creating new hydraulic relationships for the St. Clair River to simulate remediation over an incremental range of levels and flows.

Levels and flows will be generated using all alternative regulation plans, as well as with the BOC conditions, climate variability/climate change supply scenarios and various remediation options. It is recommended that any alternative plans developed for evaluation and consideration by the Study Board not be given names. Use of some generic identifier, such as a letter or number, may be better so that study members and the public do not seem to prefer certain plans based on conceptual ideas of what a specific name might imply.

Tasks would include the following:

- Assess the impacts on water levels of the St. Marys River due to peaking and ponding operations by hydropower plants at Sault Ste. Marie, develop guidelines governing peaking, taking into consideration the needs and concerns of other resources; work with the Superior Board to coordinate efforts based on what has already been done.
- Investigate all issues related to improvement opportunities for Orders, criteria, operational rules, guidelines and limitations.
- Update historical water supply sequence through the current year.
- Establish pre-project Lake Superior outlet conditions (utilizing the historical supply sequence), and determine resulting water levels and outflows in all lakes and connecting channels, assess water level impacts of existing outflow regulation.
- Qualitatively assess impacts of future basin water needs and land use changes on water levels and flows.
- Investigate relationship between groundwater and levels and flows.
- Incorporate any relevant findings from the St. Clair River investigations.
- Summarize the impacts of man-made changes in the Niagara River (e.g., installation of hydropower works and fills in the river) on Lake Erie water levels.
- Investigate and incorporate technical changes to Plan 1977-A, as listed in Section 3.1.2.
- Generate levels and flows under the base case, using Plan 1977-A.
- Generate levels and flows under pre-project conditions.
- Develop regulation scenarios to address user needs/preferences of water level/flow ranges and frequencies; generate levels and flows for these scenarios.
- Generate water levels and flows for alternative regulation plan(s) under potential climate change/variability scenarios; recommend regulation plan improvements to enhance their robustness in response to climate variability and their ability to cope under changing climatic conditions.

LESSONS LEARNED: Net basin supplies were computed for all the lakes during the Lake Ontario Study and may be useable for the Upper Lakes Study. The 50,000 years of stochastic supplies may be useful too. The climate change study results may still be applicable for the Upper Lakes Study, as well.

The costs for the hydraulics and hydrological evaluation (including climate variability) of the study are estimated as follows:

	Year 1	Year 2	Year 3	Year 4	Year 5
Total Cost (U.S. dollars)	$350K	$650K	$650K	$530K	$200K
or					
Total Cost (Canadian dollars)	$420K	$780K	$780K	$636K	$240K

The total cost for the hydraulic and hydrological evaluation would be about $2,380K (U.S. dollars). This is equivalent to about $2,856K in Canadian dollars.

4.0 Resource Evaluations

In order to determine if alternative regulation plans meet contemporary and emerging needs, as well as interests and preferences for managing the system in a sustainable manner, evaluations need to be performed to assess the impacts of changes in levels and flows on various resource groups. The following sections list the studies that are recommended to provide the information necessary to make sound decisions on possible alternative regulation plans.

Resource evaluations will be conducted to address the entire study area, including Lakes Superior, Michigan, Huron and Erie, as well as the connecting channels (St. Marys River, St. Clair River, Lake St. Clair, Detroit River and Niagara River). The level of detail in the evaluation will depend on the degree of impacts of alternative water management options. Evaluations will be conducted to include all alternative regulation plans and St. Clair River investigations.

> LESSON LEARNED: It is very important to define clearly the objective of the study and the questions to be answered. Studies should then be funded that will provide information to answer those questions, and not just interesting research projects. The subjects studied must clearly be impacted significantly by water levels and flows.

4.1 Ecosystem

The ecosystem resource area covers a broad spectrum of valuable individual resources on the upper Great Lakes from Lake Superior through Lake Erie that could potentially be affected by changes in regulation of Lake Superior outflows. Ecosystem is defined for purposes of this document as a community or assemblage of living things, together with their environment. The community of living things that will be addressed under the ecosystem evaluation area will include wildlife, fish, and supporting habitats and food web organisms. Ecosystems of particular interest are coastal habitats including wetlands, where water levels changes on the order of centimetres (inches) could shift or alter them significantly.

Variation in water levels over cycles of hours, days, seasons, years, decades, and beyond is a feature of the Great Lakes that sets them apart from other aquatic systems in North America. Existing ecosystems have evolved under conditions of water level variation since Holocene glaciation. Natural variation in annual levels of the Great Lakes is caused by climate-driven precipitation and evaporation patterns in the watershed and over the lakes. Glacial isostatic adjustment, causing some parts of the basin to slowly sink and others to slowly rise, also affects natural variation in lake levels over decades.

In the 20^{th} Century, water levels of Lakes Superior and Ontario were affected by human structures that regulate outflows for purposes of hydroelectric power generation, flood control, and commercial navigation. The effect has been to reduce long-term variation especially in these lakes, but has also influenced lake levels for all of the Great Lakes.

Differences in shoreline topography, geomorphology, and geology among the upper lakes affect the manner in which the physical environment and biological communities respond to water level variations. For example, much of the Lake Superior Canadian shoreline is composed of a rugged bedrock shoreline, with beaches and wetlands occurring within some embayments, near river mouths, and in areas of lower topography. In other areas of the basin, the coastal zones may be comprised of active beaches or bluffs of less consolidated material. In these areas, erosional and depositional processes vary with storm events, water levels and flows.

Owing to the great variability of the upper Great Lakes shorelines, there is a complex array of response mechanisms of both the physical and biological environment to water levels changes. This response would be expected to differ in relation to the vertical range of variability (i.e., depth), the spatial extent of the area affected, and the duration of flooding or exposure (e.g., daily versus seasonal versus long term).

Shallow habitats of the nearshore and coast are disproportionately more influenced by lake levels than are deep waters. Small (centimetre) shifts in lake levels can alter the extent, structure, and functions of coastal habitats, and alter the extent of interaction between coastal and nearshore habitats. Most habitats and fish and wildlife populations occur in nearshore and coastal sites, and these zones are high in biodiversity. Human uses of natural habitats are highest in coastal and nearshore areas. Coastal habitats are maintained in states of arrested succession owing to annual and greater cycles of variation in Great Lakes water levels.

Daily flow variations due to hydropower peaking operations and releases from control structures have the potential for affecting local ecosystems. For example, in the St. Marys River, changes in flows may affect spawning fish, fish substrate, and other aquatic organisms. Monthly flow variations due to regulation plan gate changes can also impact fishery resources. Dispersing the effects of discharge changes in the Rapids over a longer period of time may be more beneficial. These resources should be evaluated. The Ecosystems Group will conduct any necessary studies to determine impact associated with hydropower peaking and ponding and participate with the Hydropower, Commercial Navigation and Lake Superior Outflow Regulation Groups to determine system-wide benefits and disbenefits.

Seasonal water-level variation is caused by watershed drainage of snowmelt and precipitation minus evaporation, which influences the growing season processes of habitats and fish and wildlife populations. Aquatic and wetland habitats, such as submerged vegetation, coastal marsh, beaches, mud bottoms and flats, and forested wetlands, form complexes and arrays supported by lake-level variation. Such ecosystem complexes serve many functions that are important to humans, such as reducing erosion; filtering nutrients, contaminants, and sediment; supporting populations of fish, wildlife and other aquatic biota, and commercial products such as wild rice and marsh hay; maintaining native biodiversity; and providing aesthetic and inspiring sites for tourism.

Ongoing studies of the wetlands in Georgian Bay will provide valuable information on the identification and assessment of these wetlands. Specifically, determinations are being made as to which wetlands will be able to migrate towards or away from the shore in response to persistently high or low water levels.

A large scale study was recently completed by The Nature Conservancy and Nature Conservancy of Canada to identify lands and waters critical to the biodiversity in the Great Lakes region. The “Binational Conservation Blueprint for the Great Lakes” scientifically and systematically identifies native species, natural communities and ecological system characteristics and determines where they need to be protected to ensure their long-term survival. These studies will be valuable to the Upper Lakes Study.

Part of an assessment for the ecosystem needs to include the examination of issues related to future basin land use changes. Demographic and land use changes and shifts will likely continue to occur in the basin, along with corresponding water needs. Increased population can result in construction of new highways near the lakeshore or across floodplains. Where these highways cross riverine wetlands adjacent to the lake, flow restrictions under bridges or though culverts also disrupt sediment transport processes and can result in excessive siltation in wetlands or alter hydrological processes. Encroachment can result in direct loss of nearshore environment and chemical contamination of that environment.

The Ecosystem Group should address the issues of climate change/variability and how the ecosystem may need to adapt in the future to respond to more extreme conditions than have been experienced in the past. While water levels and flows will be generated by the Lake Superior Outflow Regulation Group, the impact on ecosystems will be assessed here.

Fundamental to understanding the relationship between management of Lake Superior outflows and the coastal ecosystems of Lakes Superior, Michigan, Huron, St. Clair, and Erie is development of various shoreline mapping and modelling tools. Decision-support tools allow us to synthesize information about relationships and to simulate conditions based on alternative regulation scenarios. In the International Lake Ontario – St. Lawrence River Study an “Integrated Ecological Response Model” (Limno-Tech, 2005) was developed to simulate the interactions of various ecosystem performance indicators and their response to various water level regimes.

Resource-specific analyses are needed to relate the landscape-scale patterns to ecosystem functions and biological populations and communities. Endpoints for analysis include resources such as species at risk, key fisheries, wildlife, wetlands, and other shoreline habitats important to ecosystem sustainability. Resource-specific analyses can fill important gaps in decision-support tools to aid us in understanding and predicting responses of ecosystems to changes in Lake Superior outflow regulation vs.

natural variation and climate. Ecosystem study aspects would include the following tasks:

- Assess impacts of water level variations, such as from peaking and ponding, on the St. Marys River ecosystem, in particular, habitat for fish species, and provide input on guidelines governing flow variations in the St. Marys River at Sault Ste. Marie
- Should a structural solution having dynamic capability be proposed as an option to remediate conditions resulting from modifications to the St. Clair River, a similar analysis needs to be undertaken.
- Acquire and synthesize, for purposes of analysis of lake level scenarios, existing data and expert opinion on the following ecosystem functions of coastal and nearshore habitats: wetlands and other coastal habitats for fish and wildlife, species at risk, fisheries, colonial nesting birds, amphibians and reptiles, submerged aquatic vegetation, exotic/invasive species, wild rice, toxic contaminants, and eutrophying nutrients.
- Develop decision-support models to link water levels and flows with ecosystem information to have predictive capabilities to assess effects of various alternative regulation plans on ecosystems. Methods for model validation should be included. Incorporate existing bathymetry and topography for coastal ecosystems where data are available, and make decision-support tools available to stakeholders.
- Enhance platforms for status and trend reporting and ways to incorporate status and trend information into decision support tools.
- Evaluate effects of alternative regulation scenarios on the ecosystem.
- Develop a risk assessment framework for use in evaluation of lake level responses by key features of ecosystems, as the scope of effects emerges.

While water quantity does have an impact on water quality, it is not within the mandate of this study to investigate water quality in detail. Qualitative discussions will be included where appropriate. It is noted that water quality is being addressed by other avenues such as the Great Lakes Water Quality Agreement and portions of the Great Lakes Regional Collaboration.

LESSON LEARNED: The International Lake Ontario – St. Lawrence River Study started with many environmental performance indicators. Of 400 performance indicators initially simulated, 32 were deemed to have sufficient sensitivity, significance and confidence in their relationship to water levels to be used in evaluations. The same exercise may be needed for the Upper Lakes Study, but the Lake Ontario experience should expedite the process.

The costs for the ecosystem evaluation, including salaries and travel, are estimated as follows:

	Year 1	Year 2	Year 3	Year 4	Year 5
Total Cost (U.S. dollars)	$200K	$550K	$550K	$350K	$100K
or					

Total Cost (Canadian dollars)	$240K	$660K	$660K	$420K	$120K

The total cost for Ecosystems would be about $1,750K (U.S. dollars). This is equivalent to about $2,100K in Canadian dollars.

4.2 Recreational Boating and Tourism

Recreational boating and tourism are important economic industries in the Great Lakes states and in Ontario. The Great Lake Commission estimates that there are over a million recreational boats registered in U.S. counties that border the Great Lakes and nearly 800,000 in Ontario that are used on the Great Lakes (GLC, 2000). The recreational boating industry is greatly affected by water levels. Low water may adversely affect recreational boating in several ways. Direct effects include damages to boats, docks, and seawalls, and reduced accessibility as water levels drop. Accessibility is particularly a problem to properties that have water-only access, such as on eastern and northern Georgian Bay. Damage to boats may occur when boats run aground or hit submerged objects. Docks and seawalls exposed to air as water levels drop may start to decay, leading to accelerated deterioration and failure. Even high water levels can cause occasional problems, preventing passage under bridges, for example.

Although effects due to high and low water would both be addressed, most of the effects to recreational boating occur due to low water, so those would be a primary focus of the recreational boating effort. Indirect effects of low water on recreational boating include the loss of boat use and the resulting reduction in related spending. Marinas, boat launches, and related boater support services suffer when boating days are reduced either due to low or high water. Costs for dredging increase during low water periods as many marinas are forced to dredge to stay in business. Facilities often have to be renovated or upgraded. Boat sales also suffer during periods of low water, as the perception of low water affects overall user interest in the industry.

Outdoor recreation and water-related tourism is likewise greatly affected by variations in water levels. Extreme high and low water levels can reduce business at marinas, waterfront restaurants, and other commercial establishments and increase costs of doing business. Beaches are a very popular tourist destination in the Great Lakes, and the vacation dollars they bring to the local economies are significant. The commercial and sport fishing industry is also a growing economic force. When extreme high or low water levels occur, tourism in the coastal communities throughout the upper Great Lakes suffers.

In order to assess the effects of alternative regulation plans on recreational boating and tourism in the upper Great Lakes, a detailed description of current recreational boating use and tourism would be developed. A detailed recreational boating study was recently completed for Lake Michigan (PZ&C et. al., 2001). The recreational boating study on Lake Michigan assessed the economic effects of extreme low and high water levels on the recreational boating, sports fishery, marinas, and boat launching facilities.

A similar study could be performed on Lakes Superior, Huron, St. Clair, and Erie. In addition, the implications of changes to the Lake Superior regulation plan on tourism throughout the upper Great Lakes would be assessed.

The study approach may entail the use of site visits, mail and phone surveys, focus groups, interviews, and mapping to collect and analyze data. A crucial element of any survey task is to develop and test the surveys that would be given to the recreational boaters, marinas, dealerships, charter fishing boats and other related tourism sectors. The end result would include a wealth of never-before-gathered information about how Great Lakes water levels affect the tourism and recreation economic sectors and how the Lake Superior regulation plan can be modified to help the recreation and tourism industry on the upper Great Lakes. It would provide a tremendous amount of information that would also be useful to natural resource and recreation administrators at all levels.

The study would assess the current state of recreational boating and tourism on the upper Great Lakes and then project potential impacts due to alternative operating plans and climate conditions. The study would be designed similar to the study recently completed on Lake Michigan so that the Lake Michigan results can be used directly in this study. The low water level period that began in the late 1990s provides a useful basis of comparison when conducting the surveys.

Once an assessment of the recreational boating on the lakes is complete, the results of the survey can be used to develop a relationship between water levels and boater days. The economic information collected through the surveys would also be used to develop an average cost expended per day. Using these relationships, the relative impacts of alternative regulation scenarios on recreational boating can be evaluated. Although this approach does not develop a computerized “model” to predict economic impacts of different water levels, it is appropriate for determining relative impacts between alternative regulation scenarios and has been used successfully for the same purpose on Lake Michigan.

Many areas in the upper Great Lakes are prime fishing locations. Extreme high and low water levels impact the quality and availability of fishing resources, including such issues as the ability to launch boats as well as to wade in the rivers, lakes and rapids areas.

Impacts on tourism would also be addressed in this study. Impacts would be limited to those directly related to fluctuating water levels, such as effects on waterfront commercial districts that are inaccessible during high water levels. Conversely, effects could also include impacts on businesses in small waterfront communities during low water periods that make their marinas inaccessible or reduce the attractiveness of waterfront facilities, such as beaches, for visitors and customers. Sport and commercial fishing will also be addressed.

The Recreational Boating and Tourism Group should address the issues of climate change/variability and how these resources may need to adapt in the future to respond to more extreme conditions then have been experienced in the past. While water levels and flows will be generated by the Lake Superior Outflow Regulation Group, the impact on recreational boating and tourism will be addressed here.

The study on recreational boating and tourism would include tasks as follows:

- Refine study method in consultation with U.S. and Canadian agency representatives, industry organizations, First Nations/Native Americans leaders.
- Analyze tourism, boating, and commercial fishing businesses and the relationship of their infrastructure to water levels on Lakes Superior, Huron, Michigan, St. Clair, and Erie.
- Integrate all data to report on the size and economic importance of coastal tourism, commercial and charter fishing, and recreational boating and the relationship of these resources to water level fluctuations.
- Conduct mail and telephone surveys of marinas, charter boats, boat dealers, boat repair and reconditioning facilities, boaters, and Great Lakes-dependent tourism businesses in Ontario and the states bordering the upper Great Lakes. Representative samples of registered boat owners would be developed to ensure the survey sample represents all sizes and types of boats and marinas.
- Integrate economic analysis on industries and Great Lakes economy to estimate the economic impacts of fluctuating water levels on recreational boating and tourism industry.
- Assess relative impacts of alternative regulation plans and make recommendations for any improvements to regulation plans specifically for the recreational boating and tourism industry.

LESSON LEARNED: The magnitude of water level changes due to Lake Superior outflow regulation is relatively small and the upper lakes recreational boaters might not be as sensitive to these small changes. If recreational boating has problems, they may not be as a result of Lake Superior regulation, but other factors.

The costs for the recreational boating and tourism evaluation, including salaries and travel, are estimated as follows:

	Year 1	Year 2	Year 3	Year 4	Year 5
Total Cost (U.S. dollars)	$50K	$125K	$125K	$100K	$50K
or					
Total Cost (Canadian dollars)	$60K	$150K	$150K	$120K	$60K

The total cost would be about $450K (U.S. dollars). This is equivalent to about $540K in Canadian dollars.

4.3 Hydropower

There are two hydroelectric power plants located on the United States side of the St. Marys River. The U.S. Government Hydropower Plant consists of a plant completed in 1951 together with a smaller unit that is the remnant of a larger plant originally built in 1888. The other U.S. plant, which was built in 1902, is operated by Edison Sault Electric Company. In Canada, Great Lakes Power Limited retired its older station and constructed a new plant in 1982. In accordance with IJC Orders, after the requirements for domestic use, navigation, and St. Marys Rapids including the fishery remedial works are met, the remaining outflow from Lake Superior is shared equally between Canada and the United States for hydropower purposes. Any remaining flow allotment that exceeds the discharge capacity of the hydropower plants is normally released through the compensating works.

Since the redevelopment of the Canadian facilities in 1982, the total installed hydropower capacity on the St. Marys River has been increased. It is doubtful that there will be any significant hydropower expansion in the future. However, given the age of the Edison Sault facilities, their eventual redevelopment should be considered in the review of the regulation criteria. Equipment upgrades in the future are expected to marginally improve the efficiencies of these plants.

There are no hydropower facilities on the St. Clair and Detroit Rivers. Several hydropower plants are located at Niagara Falls, New York and Ontario. These plants divert water from the Chippawa-Grass Island Pool above Niagara Falls, and return the water to the Niagara River below Niagara Falls. The amount of water available for hydropower purposes at these plants depends on the Niagara River flow which, in turn, depends on the water level of Lake Erie. The initial work efforts of the study would be focused more on the hydropower generation on the St. Marys River, where changes to Lake Superior regulation would have the greatest impact on hydropower operations. If, however, potential changes to Lake Superior criteria and regulation plan were expected to have measurable impacts on Lake Erie and its outflows, study tasks to include impacts on hydropower facilities at Niagara would be initiated.

The amount of hydropower generation on the St. Marys River depends on several factors, the key ones being head, flow, efficiency, tailwater level, river ice and aquatic growth, and meteorological disturbances. Apart from these physical factors, there are other elements that affect hydropower operations. The first element is timing. In some years, the water available for hydropower production in June may not generate as much monetary return as the same water in January when electrical demand is typically higher. On the other hand, hydropower would be a premium during a heat wave in June. When the flows are too low, the electricity generated may not meet the demands of the customers and the utilities may have to purchase power from other sources at relatively higher prices. The purchased power may be generated by coal, oil, or nuclear. Therefore, the purchasing power would involve transfer of monetary benefits and may have environmental implications. The move to an open market system means that reliability of water is essential for both long- and short-term planning purposes.

Relatively high water levels on Lake Superior means relatively higher flows, as directed by the regulation plan. This translates into more electricity generated. Relatively low water levels on Lake Superior would bring about the opposite condition. When the amount of water available for hydropower purposes exceeds the capacities of the plants, the excess is typically discharged into the St. Marys Rapids via the compensating works. This represents a potential loss to hydropower generation. Extended periods of equipment shutdown at the plant could also lead to additional water released at the compensating works.

To meet energy demand, which varies within the day and within the week, the hydropower plants in the St. Marys River carry out peaking and ponding operations. In peaking and ponding operations, the plants pass high flows during the daylight hours when energy demand is high, which they offset by using less water during the night and on weekends. Such adjustments are made, while ensuring plan flows are met on a monthly basis. These operations take place when the water allocated for hydropower purposes is less than the flow capacity of the hydropower plants, and thus typically take place when Lake Superior's water levels and outflows are below average. While beneficial to the hydropower interests, these flow variations have given rise to concerns by navigation, fisheries, and other interests in the St. Marys River. The concerns become more pronounced during low water level and flow conditions in the river. It is recommended that priority be given to address this issue. The impacts of peaking and ponding operations would be assessed early in the study, which would provide input to development of guidelines governing these operations, subject to confirmation at the completion of the study. The issue of peaking and ponding affects other resources as well. It is recommended that the Hydropower Group lead the effort to examine peaking and ponding impacts. A small subgroup may be required which would include participation from the Ecosystems and Commercial Navigation Groups as well as the Lake Superior Outflow Regulation Group.

The Hydropower Group should address the issues of climate change/variability and how hydropower may need to adapt in the future to respond to more extreme conditions than have been experienced in the past. While water levels and flows will be generated by the Lake Superior Outflow Regulation Group, the impact on hydropower will be addressed here.

Tasks would include the following:

- Evaluate in energy and monetary terms the impacts of peaking and ponding operations; provide inputs in developing guidelines governing peaking and ponding operations.
- Project hydropower facilities for the study period; determine their flow capacities and generating efficiencies.
- Update, and develop as required, evaluation methods that determine the relationships between energy production and flows.
- Investigate, and adapt wherever suitable, other evaluation techniques including those used in the International Lake Ontario - St. Lawrence River Study.
- Assist in identifying changes to regulation plans to improve operation.

- Evaluate the impacts of Lake Superior outflow regulation under a range of alternative regulation and supply scenarios, including those generated by climate variability and change.

Fairly sufficient information is available to evaluate the hydropower effects due to alternative regulation plans. Therefore, no extensive data collection efforts are required. The costs for the hydropower evaluation of the study, including salaries and travel, are estimated as follows:

	Year 1	Year 2	Year 3	Year 4	Year 5
Total Cost (U.S. dollars)	$20K	$100K	$100K	$20K	$20K
or					
Total Cost (Canadian dollars)	$24K	$120K	$120K	$24K	$24K

The total cost for the study would be about $260K (U.S. dollars). This is equivalent to about $312K in Canadian dollars.

4.4 Commercial Navigation

Using the Great Lakes – St. Lawrence River navigation system, waterborne freight is transported both within the Great Lakes and between much of North America and overseas. The present system of locks and channel deepening was completed by the early 1960s. At that time, channels provided an available depth of 8.2 metres (27 feet) over the entire route from Montreal in the St. Lawrence River to Lake Superior. A series of locks enables vessels to bypass rapids and other barriers in the St. Lawrence River between Montreal and Lake Ontario. Likewise, locks in the Welland Canal enable vessels to transit between Lake Ontario and Lake Erie, bypassing Niagara Falls. In the St. Marys River, there are four navigation locks in the United States, and one lock in Canada enabling vessels to transit between Lake Superior and Lakes Michigan and Huron.

The focus of this study would be on the water levels and flows of the upper Great Lakes from Lake Superior through Lake Erie. However, it should be recognized that vessels affected by water levels on the upper lakes (for example vessels carrying lighter loads to compensate for low levels in connecting channels) could be affected on their trans-Atlantic and other global trade routes. In addition, there are other factors that could have impacts on water levels and flows, and Lake Superior regulation, and vice versa. A recent study prepared for the St. Lawrence Seaway Development Corporation titled *Economic Impact Study of the Great Lakes St. Lawrence Seaway System* would provide useful information on economics related to the commercial navigation industry.

Generally, higher water levels allow for deeper draft vessels carrying heavier loads. At lower water levels, shallower drafts, and consequently, lighter loads, are necessary. More trips are needed to carry the same tonnage of cargo, and some per ton operating expenses rise accordingly, to the disadvantage of the shipping industry. Excessively high water levels would not bring additional benefits since vessel sizes are limited by existing lock dimensions. Very high water levels could flood some dock facilities, and generate undesirable and hazardous water currents in the connecting channels.

Ice on the Great Lakes and in the connecting channels can severely hamper navigation transits. It is not uncommon to see severe ice jams in the St. Clair and Detroit Rivers that last for days or even weeks. The ice problem is much less frequent or pronounced on the St. Marys River, due to the use of an ice boom. A severe and prolonged winter can cause significant problems at times of opening or closing of the navigation season.

One factor that affects navigation interests is flow variations at the hydropower plants at Sault Ste. Marie. The high flows during daytime and weekdays at the hydropower facilities cause higher levels in the vicinity of the Soo locks and channels immediately downstream of Sault Ste. Marie, which could be beneficial. However, the offsetting lower flows at night and on weekends cause lower levels and could delay ship transit and affect cargo capacity. This problem is more pronounced during low water level periods. Shippers also need to know in advance accurate forecast of water levels to plan their short-term and long-term routes. Accurate advance water level information helps planning and increases operating efficiency. The Commercial Navigation Group will conduct any necessary studies to determine impact associated with hydropower peaking and ponding and participate with the Hydropower, Ecosystems and Lake Superior Outflow Regulation Groups to determine system-wide benefits and detriments.

Much of the study can take advantage of the data, forecasts and evaluation methods currently generated in the International Lake Ontario - St. Lawrence River Study. These would be reviewed to determine whether they are applicable to this study. Because of the many inherent economic assumptions made in the forecast and evaluation calculations, particularly regarding monetary values which are subject to change, the evaluation of impacts of water level fluctuations should not be conducted in terms of purely economic values.

The Commercial Navigation Group should address the issues of climate change/variability and how commercial navigation may need to adapt in the future to respond to more extreme conditions than have been experienced in the past. While water levels and flows will be generated by the Lake Superior Outflow Regulation Group, the impact on commercial navigation will be addressed here.

Tasks would include the following. The POS team assumes that some of this information may already be available from commercial navigation resources and agencies:

- Project Great Lakes–St. Lawrence navigation facilities for the study period, including planned dredging projects and capital investments that have a high likelihood of occurring.
- Project cargoes and routes and make an assessment of the relationship between navigation service and other means of transportation (air, rail, pipeline, and truck).
- Determine applicability of existing transportation and evaluation models.

- Formulate assumptions concerning fuel costs and other operating costs.
- Update, and develop as required, the relationships between transportation costs and water levels and flows.
- Investigate, and adapt wherever suitable, other evaluation techniques.
- Identify changes to regulation plans or criteria to improve operations for navigation and navigation interests.
- Identify the impacts on navigation due to level and flow variations in the St. Marys River, identify critical water level locations in the St. Marys River, provide input in developing guidelines governing hydropower operations; identify remedial measures including improvements in communication and scheduling of ship transits.
- Evaluate the effects of alternative regulation and supply scenarios on navigation and navigation interests, including flooding under high level conditions and deterioration of timber crib/pile under low level conditions.

LESSONS LEARNED: Future traffic projections may be obtainable from current studies for a new navigation lock at Sault Ste. Marie. Be careful with issues related to commodity growth – that gets tricky. The model used in the Lake Ontario Study may be useable for the Upper Lakes Study.

The costs for the commercial navigation evaluation of the study, including salaries and travel, are estimated as follows:

	Year 1	Year 2	Year 3	Year 4	Year 5
Total Cost (U.S. dollars)	$20K	$100K	$100K	$20K	$20K
or					
Total Cost (Canadian dollars)	$24K	$120K	$120K	$24K	$24K

The total cost of the study would be about $260K (U.S. dollars). This is equivalent to about $312K in Canadian dollars.

4.5 Municipal, Industrial, and Domestic Water Use

In general, municipal and industrial water intakes are not greatly affected by fluctuating water levels on the upper Great Lakes system. Most, if not all, intakes are located at depths well below the historical range of water levels recorded in the previous century. Record low water levels occurred in the mid-1920s on Lake Superior and in the mid-1960s on Lakes Michigan-Huron. All major municipal and industrial water intakes built subsequent to these low water levels are most likely designed to accommodate at least these record lows; further investigations would verify whether this is the case.

Low water levels, however, could lead to problems including increased pumping costs, poor water quality in some areas, increased turbidity which can be worsened by passing boats and commercial vessels, algae growth and decay, and higher water treatment costs. Very low water levels predicted by some of the global climate models may render some of these intakes ineffective or completely inoperable. High water levels, on the other hand, may flood water treatment facilities that are located on flood prone coastlines.

Outside the urban centres, shore-wells are the source of water for many cottages, campers, and permanent homes along the shores of the upper Great Lakes. Shore-wells are generally not built to accommodate the total historical range of water level fluctuations due to lack of regulatory oversight and excessive costs. Again, if the low water levels predicted by some of the global climate models actually occur, many shore-wells would be affected to the point of complete shutdown.

This study can make use of the data and evaluation methods being generated in the International Lake Ontario - St. Lawrence River Study. A fairly comprehensive inventory of the major urban and industrial intakes, especially those relatively more vulnerable to water level fluctuations, should be made. Much of this inventory data is already available from state or provincial agencies. For example, the U.S. Environmental Protection Agency is conducting a source water assessment in all Great Lake states. All major water intakes have been documented. Invert elevations for many of these intakes are also available through this effort. Any additional information that is needed can be obtained by letter and telephone communications and if needed, followed by visits to the critical sites. During this data collection effort, information on future basin needs for municipal and industrial water supply can also be obtained, if available. This information would be closely related to future land use changes in the basin. As population continues to grow and shift, water demand will also. Analyses should include identification of areas where additional water use may occur in the future as well as relative magnitude of these potential increases.

The Municipal, Industrial and Domestic Water Use Group should address the issues of climate change/variability and how the water use as a whole may need to adapt in the future to respond to more extreme conditions than have been experienced in the past. While water levels and flows will be generated by the Lake Superior Outflow Regulation Group, the impact on all water uses will be addressed here.

Tasks would include the following:

- Use existing state and provincial agency inventories to identify major municipal and industrial intakes, including those vulnerable to extreme water level fluctuations.
- Compile current municipal and domestic uses; estimate future expected water demands, in terms of quantity and quality.
- Assess the effects of the current regulation plan on these water uses, assuming present and future use projections.
- Conduct pilot studies designed to provide more detailed assessment, if necessary, using selected urban and rural areas.
- Visit selected sites to collect data, if necessary.
- Investigate, and adapt wherever suitable, evaluation techniques.
- Assist in identifying any changes to regulation plans to improve operations to benefit municipal, industrial, and domestic water uses.

- Evaluate the effects of alternative regulation and supply scenarios on municipal, industrial, and domestic water interests.

While water quantity does have an impact on water quality, it is not within the mandate of this study to investigate water quality in detail. Qualitative discussions will be included where appropriate. It is noted that water quality is being addressed by other avenues such as the Great Lakes Water Quality Agreement and portions of the Great Lakes Regional Collaboration.

The costs for the municipal, industrial, and domestic water use evaluation of the study, including salaries and travel, are estimated as follows:

	Year 1	Year 2	Year 3	Year 4	Year 5
Total Cost (U.S. dollars)	$50K	$150K	$150K	$100K	$50K
or					
Total Cost (Canadian dollars)	$60K	$180K	$180K	$120K	$60K

The total cost for the municipal, industrial, and domestic water use evaluation of the study would be about $500K (U.S. dollars). This is equivalent to about $600K in Canadian dollars.

4.6 Coastal Zone

Coastal Zone in this plan of study includes the shore zone and lands adjacent to the water that are either under private or public ownership. Fluctuating water levels affect the coastal zone in all of the lakes under consideration in this study. Coastal impacts include erosion and flooding along the coast and impacts due to low water levels. Near shore littoral sand movement can also be impacted by fluctuating water levels. These impacts affect shore property values and thus result in economic gains or losses. The occurrence of long-term maximum and minimum water levels, when combined with short-term seiche or surge/drawdown impacts, can cause substantial damage to coastal resources.

Fluctuating water levels affect most coastal zone interests either directly or indirectly. High water levels can combine with storm waves or ship wakes to cause serious flood and erosion damage. Low levels increase the shore area, but can also affect water intakes, ramp and docking facilities, and water quality, and can lead to the undercutting of shore protective works.

Due to its geological setting and the relatively sparse urban development, flood and erosion damage on the Canadian shores of Lake Superior is relatively minor compared to that on the U.S shores or on the other Great Lakes. On the Canadian shores, the major urban centres affected by both high and low water levels are Thunder Bay and Sault Ste. Marie, Ontario. Numerous campsites, marinas and boat docks, cottages (some year-round) are located along the shores of Lake Superior, Lake Huron including Georgian Bay, and the St. Clair – Detroit River system. The Canadian shores of Lake Erie consist of mainly low-lying farmland in the western portion, and a combination of farms, cottages and small urban and industrial centres further to the east. Studies during the Levels Reference Study found that, in Canada, the highest incidence of erosion has occurred on Lake Erie.

The eastern coast of Georgian Bay is unique in its features. By size alone, it could be considered a lake in itself. However, unlike other bays on the Great Lakes, it is geologically, hydrologically, geomorphologically, and limnologically unique. Because of the shallow waters around the 30,000 islands, Georgian Bay is greatly affected by changes in water levels. There are extensive wetlands among the shallow waters in the steep granite shoreline island areas. When water levels change, these wetlands have difficulty migrating due to the steep nearshore environment.

The U.S. side of the upper Great Lakes differs from the Canadian coastal zone in several key areas. Population on the U.S. side is much greater than on the Canadian side. The potential for coastal damages is much higher. The U.S. portion of the upper Great Lakes coastal zone also contains more shoreline area and more areas that are subject to active erosion and flooding. Coastal erosion and flooding are a particular concern in the high bluff environment of Lake Michigan, the far western shores of Lake Superior, and select areas on Lake Erie. Previous studies have identified shore type and recession rates along all the Great Lakes.

Investigations on Lake Michigan should take advantage of the detailed analyses conducted during the Lake Michigan Potential Damages Study (LMPDS). The coastal processes model established for five coastal counties on Lake Michigan under the LMPDS could be used for this study. The models were developed using detailed bathymetric and topographic data, historical bluff line analysis, and coastal feature collection. The coastal processes model for these five counties could be run with water level scenarios from alternative regulation plans to assess the relative effects of the alternative plans on coastal erosion in these representative regions on Lake Michigan. If there is little relative difference in coastal erosion predicted under various alternative regulation plans for these five counties, or if the predicted differences in erosion rates is within the margin of error of the models, further intensive data collection to support detailed coastal modelling would not be recommended.

Coastal zone analyses must include investigations into the potential impacts of future basin land use changes. Demographic and land use changes and shifts will likely continue to occur in the basin. Demographic changes may result in increased shoreline development that may affect the nearshore environment. When shoreline protection is constructed, natural sediment transport processes are altered, and erosion of barrier beaches and coastal wetlands increases. A review should be made of the existing land use management practices, including zoning, designed to minimize flood and erosion damage. What can not be “managed” through water level regulation, may be able to be mitigated by appropriate land use management practices. An inventory of current practices may help to educate the users of the system as to what can be done to make developments along the coasts more sustainable.

The Coastal Zone Group should address the issues of climate change/variability and how the coastal zone may need to adapt in the future to respond to more extreme conditions than have been experienced in the past. While water levels and flows will be generated by the Lake Superior Outflow Regulation Group, the impact on the coastal zone will be addressed here.

Tasks would include the following:

- Conduct a literature review of past flood and erosion concerns, as well as riparian risk land use trends.
- Conduct site-specific visits to gather additional information.
- Gather master plans and zoning ordinances of upper Great Lakes waterfront communities, including existing land use maps, air photos, and other sources of information on land use.
- Consult riparian representatives, experts, and land-use planners on desirable ranges of water levels.
- Assess the impacts on coastal zone of the lower St. Marys River due to flow variations at Sault Ste. Marie, provide input to developing guidelines governing hydropower operations.
- Develop water level – impact relationships or other alternatives such as stage-damage curves, erosion sensitivity versus water level or flooded buildings versus water level curves to compare regulation plans.
- Review and assess effectiveness of existing land use regulations at protecting coastal zone interests from water level related damages, now and into the future.
- Conduct pilot studies for detailed assessment of impacts of water levels [note—pilot study could consist of using the detailed modelling results developed on Lakes Michigan and Ontario and develop a strategy to apply the results to similar shore environments, thus maximizing use of previous work and reducing amount of detailed modelling necessary; consider modelling five Lake Michigan counties under alternative regulations plans].
- Develop new stage-damage curves and other evaluation techniques.
- Identify any changes to regulation plans that could minimize coastal resource impacts.

The costs for the coastal zone evaluation of the study, including salaries and travel, are estimated as follows:

	Year 1	Year 2	Year 3	Year 4	Year 5
Total Cost (U.S. dollars)	$200K	$300K	$300K	$200K	$100K
or					
Total Cost (Canadian dollars)	$240K	$360K	$360K	$240K	$120K

The total cost for the coastal zone evaluation would be about $1,100K (U.S. dollars). This is equivalent to about $1,320K in Canadian dollars.

5.0 Study Organization

The study is envisioned to be completed through study management as described in Section 5.1, along with additional working groups. The overarching groups described in Section 5.2 are integral portions of the study which provide resources and support to all. The technical study groups described in Section 5.3 will complete all the detailed hydraulic and hydrological work necessary for the Lake Superior outflow regulation and St. Clair River studies. The data generated by these two groups will then be used by the Resource Groups described in Section 5.4. The resource groups will use the water levels, flows, and other hydraulic and hydrological information to determine impacts on their particular resource area. These impacts will show how the various resource groups respond to the alternative regulation plans.

5.1 Study Management

Given the multi-disciplinary nature of the study, it is proposed that a Study Board be set-up to direct the work of the study teams. The Study Board would be responsible for the conduct of the study; the Board would ensure that study objectives are met, that work is focused on meeting study objectives, that schedules are maintained, and that funds are allocated in a timely and logical manner. The Board would be composed of an equal number of members from Canada and the United States who would be appointed by the IJC to serve in their personal and professional capacities. The POS team recommends that the Study Board consist of 6 to 10 people, as a Study Board that is too large can become unwieldy, which reduces effectiveness. The Board members should be experts in the fields related to this study with the experience and ability to understand and take an objective approach to scientific/technical information.

LESSON LEARNED: A smaller and more engaged study board is desirable.

The IJC should consider the appointment of study director(s) to provide leadership to the study and to chair the study board, and study manager(s) to manage day-to-day financial and administrative operations of the study. The addition of administrative assistant(s) may also help in the process, depending on the time commitments of any director(s) and manager(s). Clear objectives for these positions would need to be established at the outset to ensure the leadership of the study is clear and duplication of effort is not occurring.

The Study Board would then establish specific binational committees as needed. They would be responsible for conducting the individual studies for their particular resource area. They would be composed of an equal (as nearly as possible) number of members from Canada and the United States who would serve the Commission in their personal and professional capacities. Potential agencies that have the necessary expertise for these individual studies are listed in Annex 3.

LESSON LEARNED: The study board needs to be careful to ensure that team members are not advising the board to fund work tasks that benefit their specific agency and personal research project.

Prior to the conduct of the study and expenditure of funds, the roles and responsibilities of the Board, the study director(s), study manager(s) and all committees would be clearly defined. It is expected that, like the International Lake Ontario – St. Lawrence River Study, the IJC would seek government funding for the study. The funding obtained by the IJC would be used to help fund Board operations - for example travel, communication, and contract work. Government agencies in Canada and the United States may provide some in-kind support of their expert staff.

LESSON LEARNED: Terms of Reference for the Study Board, Study Directors and other groups need to explicitly outline their respective roles, responsibilities and expectations.

LESSON LEARNED: There are increasing pressures from within agencies to limit in-kind support to various projects. The study should budget for and pay for most services. Increased start-up time is required to bring additional staff and resources to bear on the study.

The IJC should take care to ensure that First Nations / Native American peoples are considered for membership throughout the study. They should have representation in the appropriate areas, such as the Study Board, the Public Interest Advisory Group, the technical study groups and the resource evaluation groups. Members should be considered to reflect the geographic diversity as well as interests such as ecosystems, water use, coastal processes, navigation, hydropower, recreational boating and tourism, riparians and any others as appropriate.

The Study Board will take on the charge to ensure adaptive management is considered throughout the conduct of the study. A recent review of adaptive management policies for the U.S. Army Corps of Engineers noted the following elements that the Study Board may wish to consider:

- Management objectives that are regularly revisited and accordingly revised.
- A model(s) of the system being managed.
- A range of management choices.
- Monitoring and evaluation of outcomes.
- A mechanism(s) for incorporating learning into future decisions.
- A collaborative structure for stakeholder participation and learning.

Many of these items are already designed into this POS. The Study Board should then ensure the other aspects are addressed consistently across the study and make any overarching recommendations on adaptive management in their report to the IJC.

All committees will be expected to communicate routinely with each other and to share efforts (for instance GIS data, hydrological scenarios, climate forecasts, etc). Since the end result is to balance and optimize the benefits to all resources, good coordination and cooperation between the study committees is critical. The IJC appointed study director(s)/study manager(s) will ensure cooperation and communication among the study committees and seek efficiency where resources can be shared.

It is proposed that the Study Board would meet a minimum of twice a year, or more often as required. The purpose of the meetings may vary, but important objectives would be to evaluate progress and provide additional direction to the committees. Each of the committees would meet more frequently and provide quarterly status reports to the Study Director(s)/Manager(s), who, in turn, would provide updates and status reports to the Study Board. Progress reports would be provided to the IJC on a semi-annual basis. The Study Director(s)/Manager(s) would also be available to brief the IJC at their semi-annual hearings in Washington and Ottawa.

The costs for study management for the study include salaries and travel. Costs are also included for administrative support of the study by the IJC each year as there are many additional tasks required in conducting a study of this magnitude. Costs are estimated as follows:

	Year 1	Year 2	Year 3	Year 4	Year 5
Total Cost (U.S. dollars)	$440K	$440K	$440K	$440K	$440K
or					
Total Cost (Canadian dollars)	$528K	$528K	$528K	$528K	$528K

The total cost for study management of the study would be about $2,200K (U.S. dollars). This is equivalent to about $2,640K in Canadian dollars.

5.2 Overarching Groups

There are several groups necessary for this study which are essential to provide critical support to the study. They will have broad involvement and impact on the study as a whole. They are required to ensure a successful completion of the study and are noted below.

5.2.1 Communications Group

Ongoing communications during the execution of the study are extremely important. A separate group would be established for handling all the communication efforts, both within the study itself, as well as externally. Communications would be accomplished through a variety of means, including public meetings, workshops, conference presentations, newsletters, email, and the Internet.

The POS revision team utilized an IJC web page during development of the POS to provide information to interested parties regarding the POS development. Once the study is initiated, a detailed study web page needs to be created to provide a means of ongoing public communication. The web page could contain, at a minimum:

- Objectives/Goals of Study
- Study Board members and Director(s)/Manager(s)
- Working Group members
- Descriptions on ongoing studies
- Searchable metadata system, describing distributed data that reside on users' systems
- Periodic updates on study progress
- Individual committee reports on methods and results
- Any graphics or PowerPoint presentations developed to help explain study objectives/goals
- An area that allows public to provide feedback and to add their name to a mailing list for notification of public meetings and events
- Basic educational information on Great Lakes hydraulics and hydrology and the limited influence of Lake Superior regulation.

Another communication tool would be a study newsletter that would be sent to all interested members of the public on a semi-annual basis. The newsletter would serve to update the public on studies underway, any results available, and other current events related to the study. The newsletter would be sent to members of the public, agencies, and groups that participated in the POS consultation as well as names added to the mailing list through the web page. This newsletter would also go to media outlets with news releases highlighting any interesting developments. In addition, conference calls could be used to communicate study progress to interests around the basin.

LESSONS LEARNED: The Lake Ontario Study web site was a success in that it got more than a million hits. However, improvements are possible to provide the information designed to meet the needs of the readers. The newsletter, Ripple Effects, was excellent, and a similar product should be considered when conducting the Upper Lakes Study.

LESSON LEARNED: It may be advantageous to have a seasoned, dedicated communications person leading this aspect on a part-time basis, possibly one of the officers of the IJC.

Public meetings would be planned on an annual basis to communicate with the public in a more formal manner. The meetings could be coordinated to coincide with the International Lake Superior Board of Control's annual meetings or other related events. In addition to mailouts and internet notices, the team should also use newspapers and radio to publicize public meetings. Presentations for regional conferences are another good means of communicating the study goals and early results with the technical community.

LESSON LEARNED: The turn out at some public meetings have been very low for the Lake Ontario Study, even though they were held in large cities. Additional effort is needed to advertise events.

An issue of public involvement that would be addressed during the study is recommendations for ensuring appropriate communication with interested parties following completion of the study. Many interested parties could benefit from easier access to water levels and flow data. The Communications Group would tackle this issue, ensuring that a wide range of communication enhancements are investigated and recommendations are made on the most feasible options.

It is recommended that the Communications Group also address the issues of public education. K-12 educational materials may be appropriate as well. Issues to be included would be lake level variability, climate change, human-induced changes and others. Educational opportunities may help to ensure the success of the study by educating people on the natural system and how little influence man really has.

The costs for a Communications Group for the study, including salaries and travel, are estimated as follows:

	Year 1	Year 2	Year 3	Year 4	Year 5
Total Cost (U.S. dollars)	$75K	$100K	$75K	$100K	$100K
or					
Total Cost (Canadian dollars)	$90K	$120K	$90K	$120K	$120K

The total cost for Communications for the study would be about $450K (U.S. dollars). This is equivalent to about $540K in Canadian dollars.

5.2.2 Public Interest Advisory Group

A Public Interest Advisory Group (PIAG) is a critical element in reviewing the regulation of outflows and potentially recommending improved criteria and regulation plans. This group differs from the Communications Group discussed above in that the PIAG would act as more of an avenue for public input to the study, rather than study presentations to the public. It is critical that the public involvement process begin early and continue throughout the study. The PIAG should be established at the study initiation and should meet twice a year, as a minimum. PIAG members will be appointed by the IJC. A size of 10-12 members is recommended. It should be noted that PIAG members are volunteers, with only their travel paid. The expectations of time commitments should be clearly communicated to potential members at the start of the study.

In addition to obtaining views and opinions from the public, it is equally important that the public and interested parties are informed on the limitations of regulation of Lake Superior outflows and its effects on downstream levels and flows. The public information program must convey the understanding of the relationship of natural vs. anthropogenic effects on water levels and flows.

To achieve this understanding, it is recommended that the major user groups and a select number of the public be involved directly in the study. The PIAG should be an advisory arm of the Study Board. The POS team recommends that the PIAG be assembled to ensure that the interests and issues of major affected groups and parties are represented in a formal way during the study. The PIAG would have members that would act as liaisons to each of the committees, and thereby have significant knowledge of the direction of the study and the work of the various committees. Given its unique role, PIAG would be a forum for evaluating and ground-truthing the direction of the study. Through the PIAG, the public would help meet the goals and objectives of the study, provide input to the development of evaluation methodologies, identify possible regulation scenarios and remediation options, and provide advice and guidance to other critical components of the study.

The PIAG would include members representing a variety of interests, with representatives chosen through their affiliation. These could include riparians, commercial navigation, hydropower, recreational boating and tourism, ecosystems, fisheries, municipal and industrial water users, and others as appropriate. The PIAG would include representatives from Canada and the U.S., from Lake Superior down through Lake Erie.

Members of the PIAG are expected to assist with other public involvement efforts using their own local contacts. For example, a representative of a shoreline property owners group that participates on the PIAG would be expected to keep its members up to date on the activities and efforts of the PIAG and the study itself. This would help facilitate communication to all interested parties and the general public. The team recognizes that many resources and interests are keenly concerned about variations in water levels and flows. Many of these interests have competing recommendations for water level changes. The success of the study would be dependent in part on conveying the complex issues regarding competing uses of the waters to the public and furthering the understanding that most proposed solutions that benefit one resource would have some negative consequences for others.

The costs for a Public Interest Advisory Group for the study are estimated as follows:

	Year 1	Year 2	Year 3	Year 4	Year 5
Total Cost (U.S. dollars)	$50K	$100K	$100K	$100K	$100K
or					
Total Cost (Canadian dollars)	$60K	$120K	$120K	$120K	$120K

The total cost for Public Interest Advisory Group of the study would be about $450K (U.S. dollars). This is equivalent to about $540K in Canadian dollars.

LESSON LEARNED: A public interest advisory group is essential.

5.2.3 Information Technology

The Team recommends the development of an Information Management Strategy (IMS) for the study. This should be developed early in the process so that all study groups are following consistent guidelines related to information collected and generated by the study. The IMS should include an assessment of available information resources, likely future additional resources and alternative approaches for integrated information management. A distributed approach toward information management is recommended, rather than central repositories of information.

A web site should be used for public information exchange while an FTP site might be better suited for the exchange of more detailed information between the study groups. The Information Technology Group would be tasked with running the FTP site and ensuring that information posted to the site is properly documented, follows standardized naming conventions, and that only recent versions of files remain on the site. Appropriate security measures should be in place to ensure only approved people can add, delete or modify files.

The Information Technology Group should also work toward early identification of model integration and data exchange standards. This will help with seamless integration of several models during the evaluation phase. A protocol could be quite simple, such as flat file exchange of data as long as basic standards are set early on.

All study data should include the production of compliant metadata. Metadata are records about the quality, lineage, appropriate uses and other characteristics of the information compiled for, or used by, the study. The Information Technology Group should ensure metadata templates are produced early in the study and distributed to all working groups for use.

The Information Technology Group also needs to address management of all study web sites, FTP sites, document management systems, etc. This is important, not only throughout the life of the study, but into the future as well.

The costs for the Information Technology implementation in the study, including salaries and travel, are estimated as follows:

	Year 1	Year 2	Year 3	Year 4	Year 5
Total Cost (U.S. dollars)	$50K	$50K	$50K	$50K	$50K
or					
Total Cost (Canadian dollars)	$60K	$60K	$60K	$60K	$60K

The total cost for Information Technology would be about $250K (U.S. dollars). This is equivalent to about $300K in Canadian dollars.

5.2.4 Independent Technical Review Group

An important lesson learned from the International Lake Ontario – St. Lawrence River Study was that independent technical review is a critical part of ensuring study success. This was noted by several of the individual task groups. It is recommended that a process to ensure independent technical review be instituted at the beginning of the study. Two options for independent technical review are possible. The first being a single group, comprised of diverse members, who would handle the technical review for all aspects of the study. The second being an oversight group who would ensure the individual groups conducted their own appropriate independent technical reviews.

In the first case, the Independent Technical Review Group could involve members with backgrounds in economics, hydraulics and hydrology, ecosystems, coastal processes, hydropower, commercial navigation, recreational boating and tourism, water use, plan formulation and plan evaluation. Members should be selected from both the U.S. and Canada, though not necessarily needing one for each category from both countries, in an effort to keep the group a manageable size. These members should not have participated in the development of the Plan of Study or be members of any of the Working Groups associated with the execution of the study, so as to avoid any potential or real conflicts of interest that could arise regarding review of work. This group would review the working group products as they are generated to be sure they meet accepted scientific standards and support the study goals. Having one consolidated Independent Technical Review Group could help to ensure studies are coordinated among the working groups and that each group's work is complimentary with the others.

In the second case, the Independent Technical Review Group would consist of one member from each country with a background in the concept of independent technical review. They would be responsible to coordinate this process for the whole study for consistency and credibility, and advise the committees on whether certain work should be reviewed through the external arms-length mechanism. Each group would then be responsible for conducting necessary independent technical review of their technical products and reports, as appropriate. The group would be responsible for liaising with independent bodies contracted by the IJC to oversee the independent peer review process, such as the Royal Society of Canada and the National Academy of Sciences. This would ensure the independent technical reviews are being accomplished in a coordinated fashion, but would place the work tasks within each technical study group, overarching group and resource evaluation group.

> LESSON LEARNED: The studies and their assumptions should be reviewed by organizations such as the National Academy of Sciences.

The costs for Independent Technical Review of the study, including salaries and travel, are estimated as follows:

	Year 1	Year 2	Year 3	Year 4	Year 5
Total Cost (U.S. dollars)	$0K	$25K	$100K	$100K	$25K
or					
Total Cost (Canadian dollars)	$0K	$30K	$120K	$120K	$30K

The total cost for Independent Technical Review would be about $250K (U.S. dollars). This is equivalent to about $300K in Canadian dollars.

5.2.5 Plan Evaluation Group

A sound evaluation methodology identified early in the process and used to guide decisions on study design is critical to the success of the overall study. The evaluation methodology would be used to characterize and assess impacts associated with various water level and flow scenarios. The methodology must be able to measure effects on non-economic resources such as ecosystems so that evaluations can consider effects on all resources. The committee may consider developing a set of performance indicators to assist in evaluating effects of alternative regulation plans on each of the resource areas. The indicators should address for each resource, common parameters associated with Lake Superior outflow regulation and remediation options put forward regarding the St. Clair River. Such parameters could include timing of water level/flow changes, annual and seasonal level and flow averages and variations, recovery potential, and adaptability of the resource to various temporal scales of water level fluctuations. Trade-offs must be made, considering basin-wide and cumulative effects on hydropower, navigation, recreational boating and tourism, ecosystems, and water use. Trade-offs and balancing even within one resource area must be considered when evaluating regulation changes on such a large geographic area. Using the parameters suggested above, the study team could determine which short-term impacts may be reasonably acceptable if they occurred at a certain time or if the affected resource could adapt to the changes, thus minimizing impacts.

The evaluation methodology is so critical that the POS team recommends that an evaluation committee be established at the outset of the project. The evaluation committee would include, as a minimum, one member from each of the resource committees. Another option would be to select members based on their experience with Great Lakes modelling and evaluation processes. Each of these members could then be assigned to a particular resource group throughout the study to act as a liaison between the resource group and the evaluation group. In addition, the chairs of the evaluation committee should have access to expertise in decision support technology, which would be very helpful in establishing the methodology for making regulation decisions and recommendations regarding remediation options. The evaluation committee would be formed at the start of the study and would define its evaluation methods, as well as the data and informational needs at the outset of the study, which would help focus the work of the individual resource committees.

LESSON LEARNED: Be aware that there are uncertainties when evaluating small changes among the regulation plans.

The costs for the evaluation methodology committee for the study, including salaries and travel, are estimated as follows:

	Year 1	Year 2	Year 3	Year 4	Year 5
Total Cost (U.S. dollars)	$100K	$200K	$150K	$150K	$200K
or					
Total Cost (Canadian dollars)	$120K	$240K	$180K	$180K	$240K

The total cost for the evaluation methodology in the study would be about $800K (U.S. dollars). This is equivalent to about $960K in Canadian dollars.

5.3 Technical Study Groups

It is anticipated that one of the first actions of the Study Board would be to establish specific technical work groups that would be responsible for study design using the scope, methods, and tasks discussed previously. The technical work groups would use the available expertise of the two nations and allocate resources accordingly, utilizing the various agencies with potential participation of the groups listed in Annex 3. Scheduling of their work would need to be coordinated through the Study Board.

A technical study group would be required for the work tasks related to the St. Clair River portions of the directive. These tasks and costs are described in Chapter 2. A second technical study group would be required for the work tasks related to the evaluation of Lake Superior's regulation plan, which may also reflect remediation options, and would include all associated hydrological and hydraulic studies as noted in Chapter 3. Advances made regarding system modelling (e.g., modelling environment, rating curves, etc.) would be incorporated into the efforts associated with the evaluation of Lake Superior's regulation plan and criteria. The tasks and costs are described in Chapter 3.

Through the evaluation and study process, it is likely that a number of trial regulation plans would need to be developed and considered by the Study Board to allow the effects of any new or revised criteria or other regulation plan changes to be described in a manner that the general public and the IJC can fully appreciate. While criteria may be stated in a number of ways, including upper and lower limits of levels or flows or restrictions on the frequency of exceeding certain conditions, their impacts and impacts of regulation plan improvements can only be appreciated once they are used to frame a new regulation plan. The outcome can then be tested using historical data so as to allow comparisons against previous experience.

5.4 Resource Evaluation Groups

The Study Board would also establish specific resource evaluation groups that would be responsible for study design using the scope, methods, and tasks previously discussed. The resource evaluation groups would also use the available expertise of the two nations and allocate resources accordingly, using the various agencies with potential participation of the groups listed in Annex 3. Development and schedules of their work would need to be coordinated through the Study Board.

Resource evaluation groups would be necessary for the following interests: ecosystems, recreational boating and tourism, hydropower, commercial navigation, municipal, industrial and domestic water use, and coastal zone. The tasks and costs are described fully in Chapter 4.

It would be the task of the overall Study Board, with input from each technical study group and resource evaluation group, as well as the Public Interest Advisory Group, to then consider the recommendations from the resource evaluation groups and bring these forward for public discussion of the impacts and benefits of various regulation plans and criteria. The Board, with assistance from the various study groups, should also assess how the current Orders, or any recommended changes to them, are carried out.

It is important that all interested parties understand that the study is not expected to be simply one of adding one or two regulation criteria. Since the needs of the users are different and divergent, conflicts among the criteria will invariably surface. As well, there is the potential that remediation measures for the St. Clair River may further complicate the review of and potential improvements to the regulation plan and criteria. As noted earlier, the challenge of the study will be to promote understanding and acceptance of what is feasible given current institutional arrangements and control facilities. The process leading to new criteria and/or improvements to the regulation plan would include iterations in defining possible changes, meeting with user groups, and meetings with the IJC, which may itself result in consultations with governments.

5.5 Schedule and Cost

The proposed study for the review of regulation of outflows from Lake Superior and the investigation into the potential regime change of the St. Clair River has been designed to obtain the optimal amount of benefit versus cost. The study would be conducted such that the information deemed necessary to make decisions on alternative regulation plans would be available at the conclusion of the study. It would require 5 years to complete, assuming a 6-month organizational spin up time, approximately 4 years of technical studies, and a 6-month period for study summation and public presentation. The study would be conducted by, and these funds allocated to, a series of binational teams. The teams would be composed of subject matter specialists serving in their personal and professional capacities from various federal, state and provincial agencies; academia and private consultants; and the stakeholders impacted by Lake Superior regulation and St. Clair River issues. The binational Study Board would conduct overall coordination and provide leadership necessary to bring the study to a successful conclusion.

The study is estimated to cost a total of $14.6 million in U.S. dollars, which is equivalent to $17.5 million in Canadian dollars. This represents the total cost of the study; it is assumed that the cost would be split roughly equally between the two Governments. A cost summary, based on the five-year implementation period is presented in Tables 4 and 5. Costs in Canadian dollars were estimated as 1.2 times U.S. dollar costs.

Table 4. Total Cost Summary (Thousand U.S. dollars)

Study Components	YR1	YR2	YR3	YR4	YR5	Total
St. Clair River	500	1,250	1,250	500	0	3,500
Lake Superior Regulation	350	650	650	530	200	2,380
Ecosystem	200	550	550	350	100	1,750
Recreational Boating and Tourism	50	125	125	100	50	450
Hydropower	20	100	100	20	20	260
Commercial Navigation	20	100	100	20	20	260
Municipal, Industrial, and Domestic Uses	50	150	150	100	50	500
Coastal Zone	200	300	300	200	100	1,100
Study Management	440	440	440	440	440	2,200
Communication	75	100	75	100	100	450
Public Interest Advisory Group	50	100	100	100	100	450
Information Technology	50	50	50	50	50	250
Independent Technical Review	0	25	100	100	25	250
Plan Evaluation	100	200	150	150	200	800
Grand Total	**2,105**	**4,140**	**4,140**	**2,760**	**1,455**	**14,600**

Table 5. Total Cost Summary (Thousand Canadian dollars)

Study Components	YR1	YR2	YR3	YR4	YR5	Total
St. Clair River	600	1,500	1,500	600	0	4,200
Lake Superior Regulation	420	780	780	636	240	2,856
Ecosystem	240	660	660	420	120	2,100
Recreational Boating and Tourism	60	150	150	120	60	540
Hydropower	24	120	120	24	24	312
Commercial Navigation	24	120	120	24	24	312
Municipal, Industrial, and Domestic Uses	60	180	180	120	60	600
Coastal Zone	240	360	360	240	120	1,320
Study Management	528	528	528	528	528	2,640
Communication	90	120	90	120	120	540
Public Interest Advisory Group	60	120	120	120	120	540
Information Technology	60	60	60	60	60	300
Independent Technical Review	0	30	120	120	30	300
Plan Evaluation	120	240	180	180	240	960
Grand Total	**2,526**	**4,968**	**4,968**	**3,312**	**1,746**	**17,520**

Annex 1

DIRECTIVE
To The
UPPER GREAT LAKES "PLAN OF STUDY" REVISION TEAM

The purpose of this directive is to establish and direct the Upper Great Lakes "Plan of Study Revision" Team (Team) to:

- incorporate a new first phase to examine physical processes and possible ongoing changes in the St. Clair River channel and impacts on levels of Lakes Michigan and Huron
- incorporate lessons learned from the Lake Ontario – St. Lawrence River Study
- further streamline the existing Plan of Study (POS) which will now be known as the Upper Lakes Plan of Study (ULPOS)

The Upper Great Lakes Plan of Study of January 2002 was sent to Governments in March 2002 with a request for funding. The Governments have not, to this date, funded the proposed study. In the past year, evidence pointing to possibly important water level changes in Lakes Michigan and Huron due to ongoing physical changes in the upper St. Clair River has come to light in the Georgian Bay Association funded Baird Report. The Commission decided to revise its ULPOS to thoroughly investigate this issue after consulting with its Great Lakes Control Boards, and following a March 30 binational multi-agency meeting on the subject hosted by Environment Canada.

This work of revision is to retain the principal purpose of the study which is to (i) review the operation of structures controlling the outflows from Lake Superior in the light of the impacts of those operations on water levels, flows, and consequently affected interests in the upper Great Lakes system from Lake Superior downstream through Lake Erie, including the environment; (ii) assess whether changes to the Orders or regulation plan are warranted to meet contemporary and emerging needs, interests and preferences for managing the system in a sustainable manner, including under climate change scenarios; and (iii) evaluate any options identified to improve the operating rules and criteria governing Lake Superior outflow regulation. The POS revision work will be conducted in the context of Articles III and VIII of the Boundary Waters Treaty and the Commission's alerting responsibilities in the same manner as conducted for the IJC's *Plan of Study for Criteria Review in the Orders of Approval for Regulation of Lake Ontario – St. Lawrence River Levels and Flows.*

This revised POS shall include:

a. the definition of the studies to be performed, including possible development of a 3-dimensional hydrodynamic model for the St. Clair River and the level of detail anticipated for each study,
b. recommendations as to the agencies or organizations capable of carrying out each study, recognizing that studies are to be conducted binationally,

c. sources of, or means of obtaining, needed information,
d. recommendations on the order and duration of the study and its phases,
e. depending on the nature and extent of St. Clair River changes and impacts – recommendations for mitigation, and
f. estimates of the time, dollar and personnel resources required for the conduct of each unit of the study.

In the course of streamlining the 2002 POS, the team shall retain the essential work related to the following studies or activities:

a. Review of available data and research that will inform and prioritize studies and activities to be completed through the POS
b. System flow and level modeling using compiled historical flow records, available post-glacial levels information, extended supply variability data, and considering current diversions into and out of the Great Lakes system
c. Climate change impacts on levels and flows
d. Effects of past and current dredging on levels and flows
e. Groundwater impacts on levels and flows
f. Defining the amount of anthropogenic regulation effects compared to natural levels and flows in the system
g. Development of alternative control approaches that as nearly as possible meet the needs of all interests (including the integrity of the ecosystem), appropriately balance effects between Lakes Superior and Michigan-Huron while considering impacts on the St. Marys River and downstream of Lakes Michigan-Huron (including on Lake Erie), make provision for emergency conditions, and respect the requirements of the Boundary Waters Treaty and in particular Article VIII
h. Ongoing public involvement in executing the study, including institutional arrangements to ensure appropriate communication with and among all interests, as well as a means of testing and demonstrating the effects of possible scenarios with the public
i. Development of recommendations concerning appropriate communications on Lake Superior outflow regulation with and among all interests following completion of the study
j. Development and implementation of an evaluation methodology for characterizing and assessing impacts associated with various water level and flow scenarios
k. Qualitative assessment of how demographic and other possible future changes may affect user needs, water supplies, and regulation impacts

The Commission shall appoint an equal number of members from Canada and the United States to the Team. Members act in their personal and professional capacities and not as representatives of their countries, agencies, organizations, or other affiliations. Team members shall be responsible for their own expenses unless otherwise arranged by the Commission.

The Team shall consult with others as necessary, and especially the International Lake Superior Board of Control, to complete its work. It shall take note of work of all other agencies and organizations in both countries in order to make the most effective use of resources and efforts in both countries. It shall consult with the Lake Ontario - St. Lawrence River Study Board, currently conducting studies for the St. Lawrence River basin, to determine how best to leverage progress from that study applicable to the upper Great Lakes.

The Team shall keep the Commission informed of its progress and direction. The Team shall submit to the Commission:

1. Within one month of its formation, a document framing the general nature of the anticipated POS, and a public consultation plan;
2. By August 25, a draft revised POS; and
3. By October 15, 2005, a final POS (an electronic copy and two printed copies provided to each section of the Commission.)

The Team shall make use of public input received prior to and during the development of the POS. To the extent possible, the POS revision shall be an open and transparent process. The Team shall conduct at least one meeting with the public in Canada and one in the United States to obtain input directly from the public. The Team shall provide other opportunities for the public to provide input during the revision of the POS. The Team shall coordinate its public involvement plans with the Commission.

Documents, letters, memoranda, and communications of every kind in the official records of the Commission are privileged and become available for public information only after release by the Commission. The Commission considers all documents in any official files that the team may establish to be similarly privileged. Accordingly, all such documents shall be so identified and maintained as separate files. The Commission will work with the Team to assure that relevant information is available for public review in a timely manner.

To assist in carrying out this assignment, attached are copies of the following:

a. 1909 Boundary Waters Treaty
b. Commission Orders of Approval
d. March 19, 1996, Scope of Work, developed by the International Lake Superior Board of Control
e. Membership of the International Lake Superior Board of Control
f. Upper Great Lakes Plan of Study of January 2002

signed: May 12, 2005

Elizabeth C. Bourget
Secretary
U.S. Section

Murray Clamen
Secretary
Canadian Section

Annex 2

Public Consultation in the Preparation of the 2002 Plan of Study and 2005 Revised Plan of Study

This annex contains two parts. Part A is a summary of the public consultation activities conducted in preparing the January 2002 Upper Great Lakes Plan of Study (POS). Part B describes the activities carried out in 2005 for the revision of the plan of study.

Part A: January 2002 Plan of Study

In May 2001, the International Joint Commission (IJC) informed the governments of its intention to develop a plan of study with the purpose of reviewing the IJC Orders and the regulation of the outflows from Lake Superior. Concurrently, the IJC informed the public and invited comments on the draft directive setting up a team to prepare the plan of study. The IJC held public meetings to hear views and concerns, and solicit opinions from the public on the proposed study in the following cities:

June 25, 2001, Sault Ste. Marie, Ontario
June 26, 2001, Sarnia, Ontario
June 27, 2001, Port Severn, Ontario
July 9, 2001, Duluth, Minnesota
July 10, 2001, Thunder Bay, Ontario

About 70 members of the public attended the five public meetings. There was overwhelming agreement and support for the study.

In addition to comments provided by citizens, the IJC received comments from the following groups in the spring and early summer of 2001 prior to forming the Plan of Study team:

Great Lakes Commission
U.S. Congressional members of Great Lakes States and staff
Lake Superior Binational Forum
Great Lakes Fishery Commission
Great Lakes Mayors
Great Lakes United
Edison Sault Electric Company
Chippewa Ottawa Resource Authority
International Great Lakes Coalition
WayWahTaysee Association
Ohio Department of Natural Resources
New York State Department of Environmental Conservation
Michigan Department of Environmental Quality
Pennsylvania Department of Environmental Protection

Illinois Division of Water Resources Management
The Nature Conservancy
Minnesota Department of Natural Resources
U.S. Geological Survey
U.S. Department of State
Great Lakes Boating

The team consulted with or received comments from the following during preparation of the draft Plan of Study:

International Great Lakes Coalition
Whitefish Bay Shoreline Association
Georgian Bay Association
Edison Sault Electric Company
U.S. Coast Guard
Great Lakes Shipping
Shipping Federation of Canada
Great Lakes Power Limited
Lake Carriers Association
USS Great Lakes Fleet
Western Great Lakes Pilots Association
Environment North, Thunder Bay
National Marine Conservation Area
Northwest Region Advisory Committee
Union of Ontario Indians (1850 First Nations)

In October 2001, the team invited a panel of experts in Canada and the United States to conduct a peer review of the draft POS. The peer reviewers were selected as representative of a broad range of interests, expertise and geography. Later in the same month, the team finalized the draft POS and mailed close to 400 copies to the public, interest groups, elected officials, and First Nations / Native Americans, requesting comments on the document. Next, another round of public meetings was held in the following cities:

October 31, 2001, Duluth, Minnesota
November 1, 2001, Thunder Bay, Ontario
November 5, 2001, Sault Ste. Marie, Ontario
November 6, 2001, Muskegon, Michigan
November 7, 2001, Milwaukee, Wisconsin
November 13, 2001, Parry Sound, Ontario
November 14, 2001, St. Clair Shores, Michigan
November 15, 2001, Cleveland, Ohio

A toll-free call-in number was also made available at the Milwaukee and Parry Sound meetings to accommodate members of the public who could not travel to meeting locations. About 80 members of the public attended this second series of public meetings. The vast majority of participants represented some 20 different non-governmental organizations, several of which have memberships numbering in the thousands. Broad support was expressed for both the study and the proposed approach. Specific comments for additions or improvements to the document were made in all the meetings.

In preparing the 2002 POS, the team also conducted targeted consultations with interest groups. Interest groups included in these formal and informal consultations included:

Hydropower
Commercial Navigation
Residential property owner associations
Recreational boating
Ecosystem
First Nations/Native Americans

The team received written comments from the following organizations:

Sierra Club
The Nature Conservancy
Georgian Bay Association
Lake Superior Binational Forum
Michigan Department of Natural Resources, Parks and Recreation Bureau
U.S. Army Corps of Engineers, Great Lakes and Ohio River Division, Water Management Team
Ohio Lakefront Group
National Wildlife Federation
Indiana Geological Survey
New York Department of Environmental Conservation
Ojibways of the Pic River First Nation
Michigan Department of Natural Resources, Alpena Great Lakes Fisheries Research Station
U.S. Department of Transportation, Maritime Administration
Michigan Boating Industries Association

All comments received were reviewed by the POS team. Many comments contributed towards improving the draft document and they were incorporated when preparing the January 2002 POS.

Part B October 2005 Revised Plan of Study

In May 2005, the IJC informed the governments by letters and the public through a media release of its plan to expand the 2002 Plan of Study to include a study of the St. Clair River and its impacts on water levels. Two other purposes were also added, one to incorporate lessons learned from the International Lake Ontario – St. Lawrence River

Study and the other to streamline the existing plan of study. Later in the month, the IJC appointed members of the Upper Great Lakes Plan of Study Revision Team and informed the public through its June 2 media release.

Extensive efforts were made to publicize the work of the Team, and to invite the public: to comment on the proposed study; to attend public consultation meetings; and to comment on the draft revised plan of study. Public notices were placed in Environment Canada's newsletter (Level*news*) and in the Corps of Engineers' newsletter (Great Lakes Update) informing on the work of the POS Revision Team and announcing the public consultation meetings. On July 28, about 320 letters were sent in Canada and 450 in the United States, to the public, elected officials, Federal, State, Provincial, local and non-government agencies inviting them to provide advice and comments on revising the plan of study, and to invite them to attend the following public meetings:

September 1, 2005 Parry Sound, Ontario
September 13, 2005 Sault Ste. Marie, Ontario
September 14, 2005 Port Huron, Michigan
September 15, 2005 St. Joseph, Michigan

The meeting announcement was also sent out on some internet listservices as well as posted on additional web sites. Prior to the public meetings, public notices were placed in local newspapers, radio stations and community television stations. A total of about 110 members of the public attended the four consultation meetings.

Beginning in August 2005, the IJC hosted a POS Revision Team internet web site to inform the public of the revision of the plan of study, work progress, and to solicit public inputs. On the web site, a template was made operational during the period August 24 – October 6, whereby the public could send in their comments on the proposed study and on the draft revised Plan of Study which was placed on the web site on August 25. A media release was issued on August 26 inviting public comments. The Team received about 205 public comments via this web site. The Team also invited the public to provide comments by either e-mail or written letters. Close to another 100 individuals responded by e-mails, letters and fax.

In addition to making it possible for the public to download the draft Plan of Study from the Internet, the Team provided hard and CD copies of the draft Plan of Study at the public meetings, and mailed material to those who did not have internet access.

Similar to the results of the 2001 public consultation, the public response in 2005 shows overwhelming support for the study, and for the addition of the St. Clair River to the plan of study.

All comments received were reviewed by the POS team. Many comments contributed towards improving the draft document and they were incorporated when preparing the October 2005 POS.

Annex 3

Responsibilities of Study Participants and Suggested Source for Expertise

The Plan of Study proposes a study organization consisting of a study board, study directors, panels of advisors and technical/resource groups responsible for studies. While experts in government agencies are expected to be appointed to the study organization, private citizens, companies and industries, and the academic community who have good knowledge of Great Lakes water level issues and experience in multi-disciplinary studies should be considered. All study participants serve in their personal and professional capacity and do not represent their employer, company or institution. The list below is not meant to be all inclusive. There are many agencies that may provide expertise to the study, such as local governments, universities and non-governmental organizations, which are too numerous to mention.

On joining the study organization, the study participant should be advised of the time expected to be spent on the study, including travel to attend meetings.

Experts from the following organizations could assist the study.

1. Study Board and Study Management

Appointments to the Study Board and study management are to be made by the International Joint Commission.

2. Communications

This group would have individuals who are well versed in the public affairs and public communications.

United States:
U. S. Army Corps of Engineers
NOAA SeaGrant Program
Canada:
Environment Canada
International:
International Joint Commission
Great Lakes Commission
Non-Governmental Organizations

3. Public Interest Advisory Group

This group would have individuals who are very knowledgeable of water level issues. Their responsibilities would include advising the study board and work groups on issues of concern, advising on the technical nature of the study, and acting as liaison between the study board and their constituents.

4. Information Technology

This group would be responsible for developing long-term information strategy for the study board, and its implementation. The group would also operate and maintain the study board's web site to facilitate data exchange and storage among the work groups, and to communicate with the public.

5. Independent Technical Review

Experts will be invited from time to time to advise and comment on the science used in the study. The Study Board or its work groups would invite peer review when warranted, of the science and evaluation techniques prior to their adoption for use. Panels of experts on various Great Lakes disciplines especially economic and environmental evaluation would be essential at the early phase of the study to assist the Study Board on deciding study methods and major study assumptions.

6. Plan Evaluation

This group would advise the study board on selection of evaluation methods and study assumptions, and would be responsible for developing and implementing procedures and schedule for timely synthesis of study results for the Board's consideration.

7. Resource Evaluation Groups

Resources evaluation groups for various disciplines are proposed. The resource evaluation groups are responsible for: evaluating, in accordance with method and level of detail approved by the Board, various water management options and provide information essential for decision making; timely submission of work progress reports and final report in suitable formats for use by the Study Board; providing timely information to support for the study board web site to inform the public on the study progress.

Listed below are the potential sources for expertise when making up the study organization.

Ecosystem

United States:
U. S. Fish & Wildlife Service
U.S. Geological Survey
U.S. Environmental Protection Agency
U.S. Army Corps of Engineers
Great Lakes Environmental Research Laboratory
Various State Departments of Environmental Quality and Natural Resources
State Geological Surveys
Native American / Tribal Organizations
NOAA SeaGrant Program

The Nature Conservancy
Canada:
Environment Canada
Fisheries and Oceans Canada
Ontario Ministry of Natural Resources
Conservation Authorities
Ontario Ministry of Environment
First Nations
International:
Non-Governmental Organizations
Universities

Recreational Boating and Tourism

United States:
U.S. Army Corps of Engineers
U.S. Coast Guard
Michigan State University
NOAA Sea Grant Program
Canada:
Ontario Ministry of Natural Resources
Environment Canada
Canadian Coast Guard
Canadian Hydrographic Service
Ontario Marina Operators Association
International:
Great Lakes Commission
Non-Governmental Organizations

Hydroelectric Power

United States:
Edison Sault Electric Company
U.S. Army Corps of Engineers
New York Power Authority
Canada:
Great Lakes Power Company
Ontario Ministry of Natural Resources
Ontario Power Generation

Commercial Navigation

United States:
U.S. Army Corps of Engineers
U.S. Coast Guard
Lake Carriers Association
U.S. Great Lakes Shipping Association
Western Great Lakes Pilots Association

St. Lawrence Seaway Development Corporation
Canada:
Canadian Coast Guard
Shipping Federation of Canada
Canadian Ship Owners Association
FedNav Limited
Transport Canada
Canadian Pilotage Authority
St. Lawrence Seaway Management Corporation
International:
Great Lakes Commission
Non-Governmental Organizations

Municipal, Industrial, Domestic Water Uses

United States:
State Departments of Environmental Quality
Public Works/ Municipality Representatives
U. S. Environmental Protection Agency
U.S. Geologic Survey
State Departments of Public Health
Canada:
Ontario Ministry of Environment
Environment Canada
Public Works/Municipality Representatives

Coastal Zone

United States:
U.S. Army Corps of Engineers
State Departments of Environmental Quality and Natural Resources
U.S. Geological Survey
State Geological Surveys
NOAA SeaGrant Program
Canada:
Environment Canada
Ontario Ministry of Natural Resources
Conservation Authorities
Ontario Ministry of Municipal Affairs and Housing

8. Technical Study Groups

Lake Superior Outflow Regulation

United States:
U.S. Army Corps of Engineers
Great Lakes Environmental Research Laboratory
U.S. Geological Survey

NOAA CO-OPS
Canada:
Environment Canada
International:
Non-Governmental Organizations
Universities

St. Clair – Detroit River Systems

United States:
U.S. Army Corps of Engineers
Great Lakes Environmental Research Laboratory
U.S. Geological Survey
NOAA CO-OPS
Canada:
Environment Canada
International:
Non-Governmental Organizations
Universities

Annex 4

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