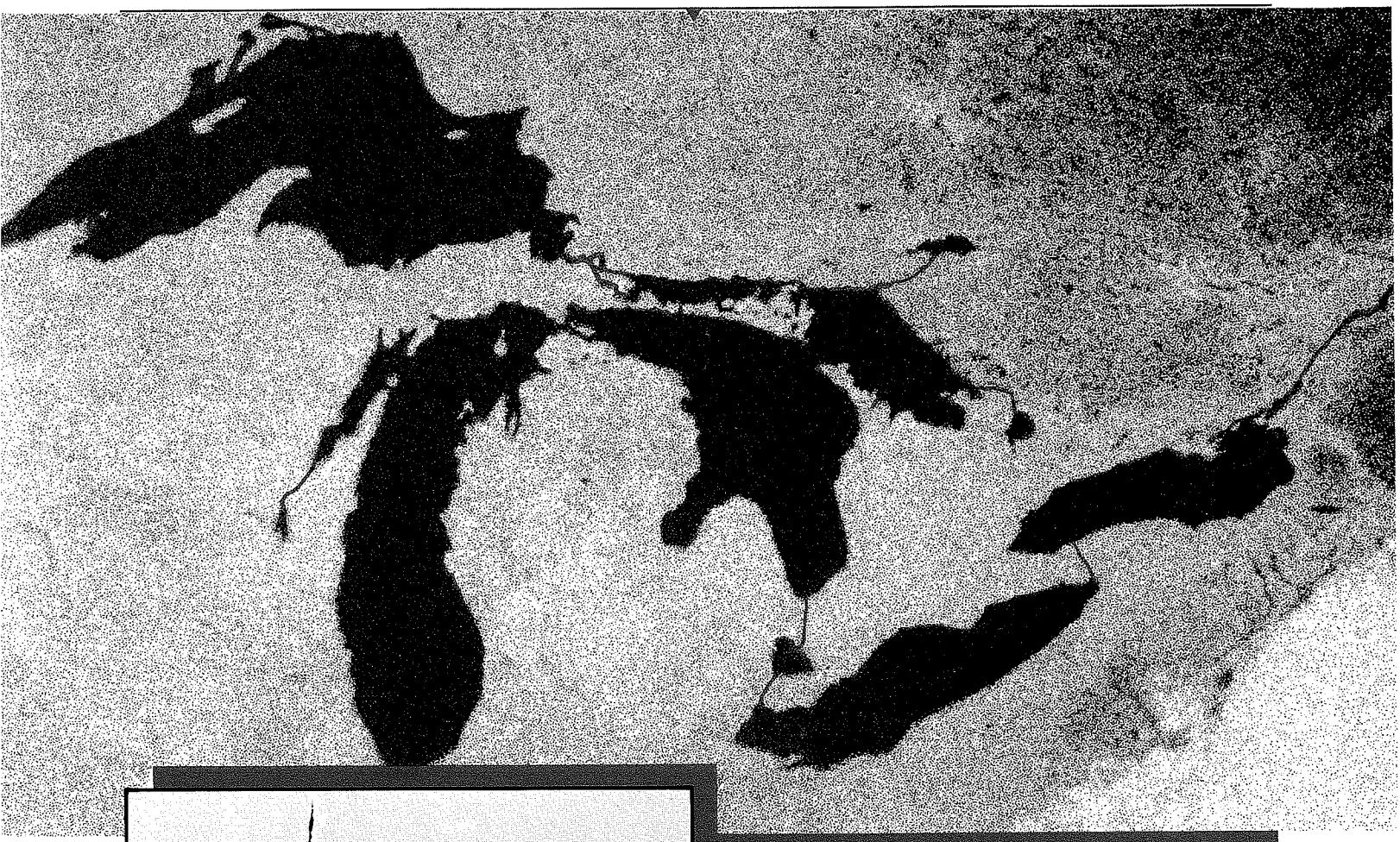
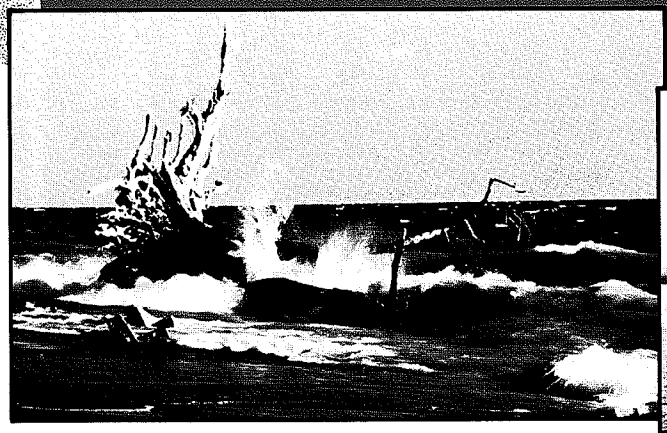
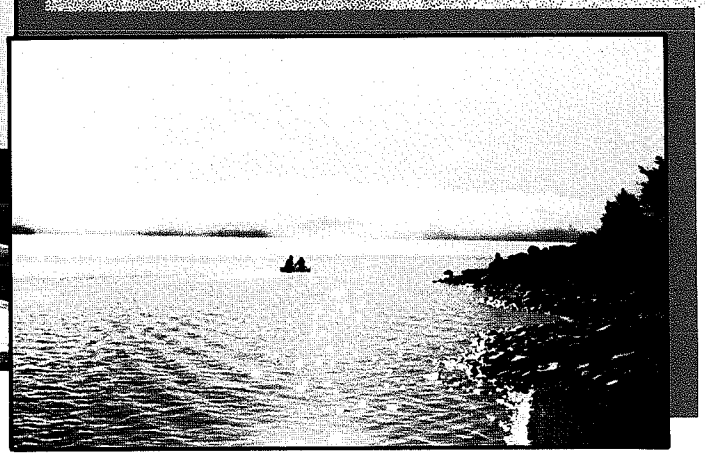
GREAT LAKES-ST. LAWRENCE RIVER REGULATION







What it Means and How it Works

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This printing is similar to the first edition with the exception that water level elevations are on the International Great Lakes Datum (1985). Canada and the United States began using the IGLD (1985) in January 1992. Readers can obtain the conversion factors between IGLD (1985) and IGLD (1955) by writing to the U.S. Army Corps of Engineers or Environment Canada listed at the back of this publication.

RECYCLED PAPER HAS BEEN USED TO PRODUCE THIS PUBLICATION

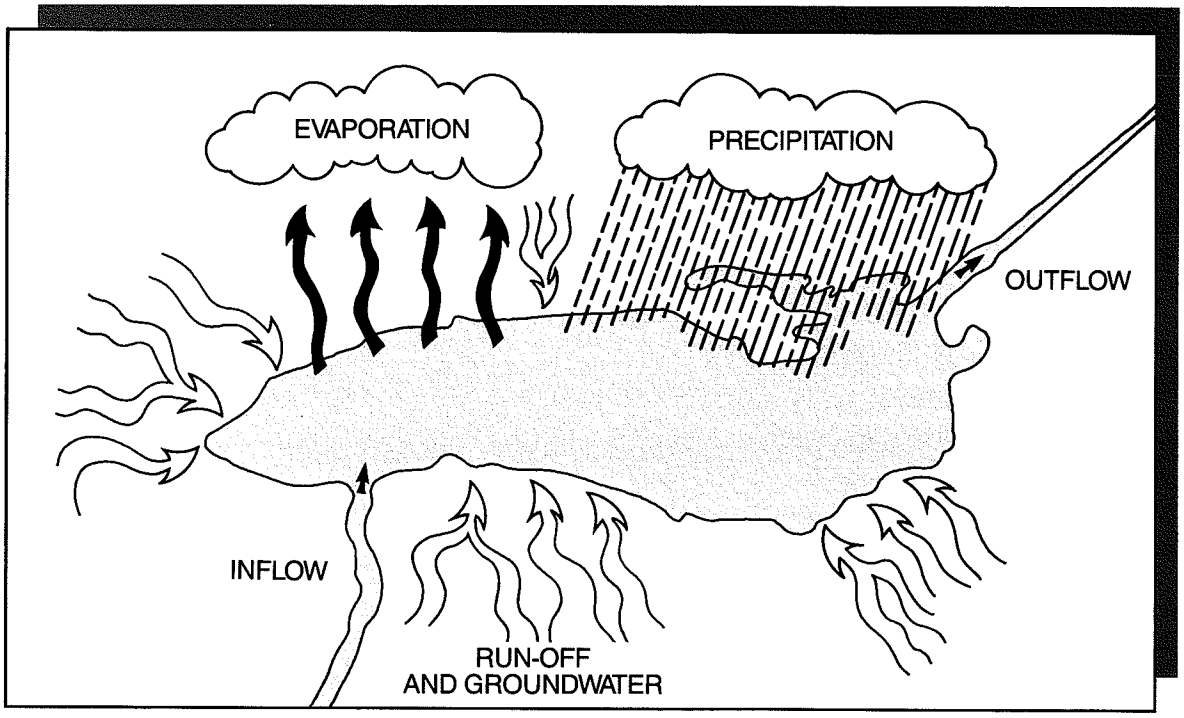
1. INTRODUCTION

The Great Lakes-St. Lawrence River System is one of North America's most important natural resources. The lakes and rivers provide countless benefits to the region, including a source of electricity. As hydroelectric power developed in the system, dams were built to artificially regulate the outflows from two of the five Great Lakes: Lake Superior and Lake Ontario. This booklet explains when and why this regulation came about, how it works, and its benefits and limitations.

the St. Marys and St. Lawrence Rivers.

The six-member IJC is supported by staff at its offices in Washington, D.C. and in Ottawa and Windsor, Ontario. The IJC also relies on the services of government and public experts from both countries to conduct its studies on such issues as regulation of the Great Lakes-St. Lawrence River.

The process that leads to the IJC approving obstructions or diversions of Great Lakes water consists of several major steps. First, the entity interested in constructing and operating a diversion facility on the Great Lakes must apply to the IJC for approval.



Natural Factors Affecting Lake Levels

2. THE INTERNATIONAL JOINT COMMISSION

With the signing of the Boundary Waters Treaty of 1909, Canada and the United States established the International Joint Commission (IJC) to oversee issues concerning boundary and transboundary waters shared by the two countries, including the Great Lakes. The Treaty requires the IJC approve certain uses, obstructions or diversions of boundary waters if these operations affect the natural level or flow of the boundary waters in the other country. In addition, under the Treaty, Canada and the United States can ask the IJC to conduct studies and make recommendations on specific problems along the common frontier. Two examples of the IJC authority have been to approve the development of hydropower projects in

The IJC then conducts studies, and in many cases, appoints a study board or a panel of experts to carry out any detailed technical investigations. Public hearings are also held to receive comments on the application from the public and various levels of governments. Through this process, the IJC identifies what impacts these facilities could have on the levels and flows of the Great Lakes, and thus considers the merit of each application based on a variety of viewpoints and technical information.

If the IJC approves the application, its consent (called Orders of Approval) may include conditions and criteria governing the construction and operation of the facilities. In some cases, the IJC also requires that a board be established to develop regulation plans and to supervise the operation of these facilities in order to ensure that the conditions and criteria in the Orders are met.

Review of IJC authorized projects and the Orders has continued over the years, and changing conditions have required periodic revisions to the Orders and the regulation plans. When reviewing its Orders, the IJC again considers the views of the public, the advice of its boards and the views and comments of governments.

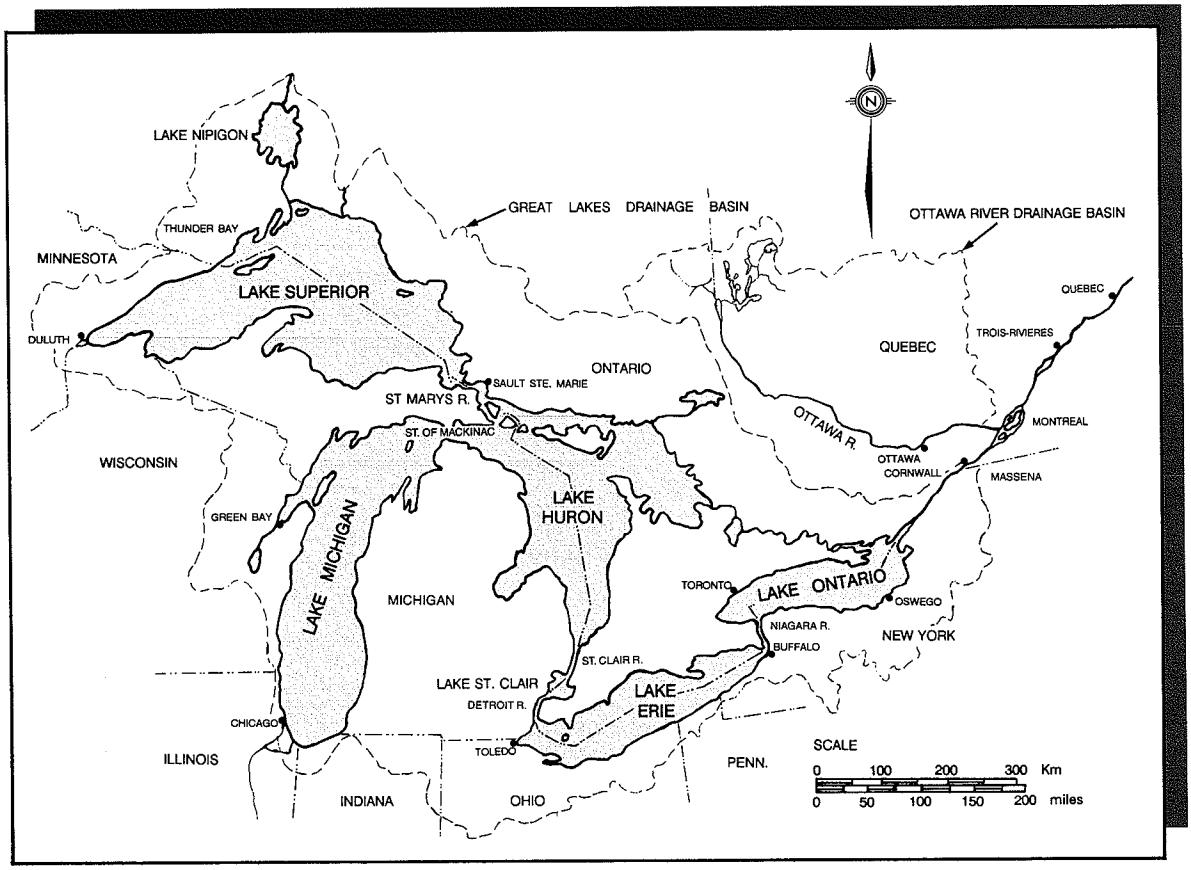
3. THE GREAT LAKES-ST. LAWRENCE RIVER SYSTEM

The Great Lakes is a system of natural reservoirs. Lake Superior, at the top of this chain, flows into Lake Huron through the St. Marys River. Water also flows out of Lake Michigan to Lake Huron through the broad and deep Straits of Mackinac. Since Lake Michigan and Lake Huron stand at the same elevation, they are often referred to as one lake hydrologically, or Lakes Michigan-Huron.

From Lake Huron, water flows through the St. Clair River, Lake St. Clair and Detroit River to Lake Erie. Lake Erie flows into Lake Ontario via the Niagara River. Lake Ontario, the lowest lake in the chain, flows into the Atlantic Ocean via the St. Lawrence River.

The water levels of the Great Lakes change in response to many factors. Over-lake precipitation and water runoff from the land both provide water to the system, while evaporation lowers water quantities in the lakes. Persistently high or low precipitation over several years is the main natural factor causing extreme high or low lake levels. Other natural factors which impact lake levels and outflows include flow restrictions due to ice or aquatic weed growth in the outlet rivers. Several human activities also affect levels and flows, including dredging of channels, water diversions, consumptive uses (water taken out and not returned to the system; for example, water used for drinking or industrial uses) and flow regulation.

Lake Superior's water level fluctuates somewhat less than those of the downstream lakes. Since 1900, the total range of fluctuation – the difference between the maximum monthly average and the minimum monthly average – has been about four feet (1.2 metres). The Lake Superior drainage basin is about two and one-half times the size of the lake's surface area, and thus land runoff contributes significant supplies of water to the lake. In fact, monthly water supplies to the lake have been estimated to be as high as 4.7 times the lake's average outflow. Supply of this magnitude would raise the lake's level one foot (0.3 metre) in one month alone



Great Lakes-St. Lawrence River Basin

unless it is offset by the lake's outflow.

Lake Ontario is quite different from Lake Superior. The Lake Ontario drainage basin, which includes all of the land and water of the upper lakes as well as land surrounding the lake, is about 40 times the size of the lake itself. Hence, water supplies – and changes in these supplies – are also much larger than those for Lake Superior. For example, the highest recorded monthly water supplies to Lake Ontario are equivalent to 4.8 feet (1.5 metres) of water on the lake. These statistics, along with the limited storage capacity of the lake and the diversified interests located on Lake Ontario and in the St. Lawrence River, make the regulation of Lake Ontario complex. Lake Ontario's total range of fluctuation is about 6.6 feet (2.0 metres).

Several sectors of society, or interests, are affected by the inevitable variations in the levels and outflows of the Great Lakes. Generally, they fall into four categories: shore property owners, fish and wildlife enthusiasts, navigation interests and those people involved in the hydropower industry.

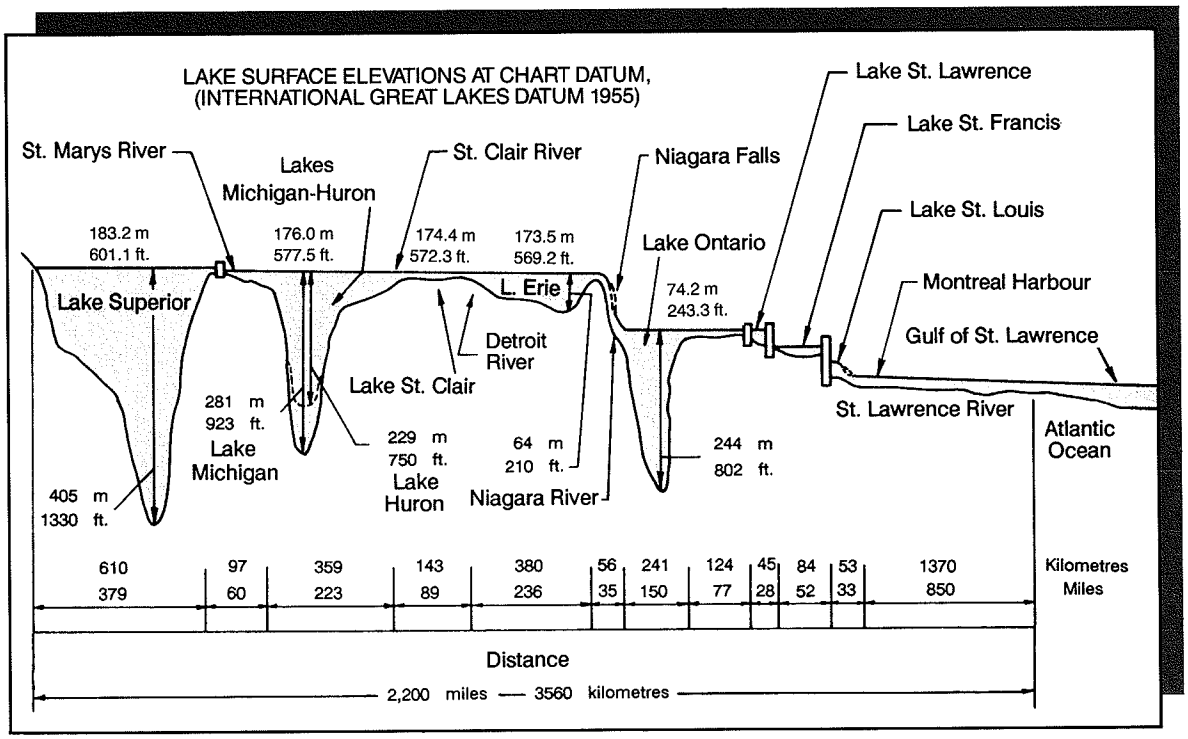
Each of these interests have unique concerns and preferences when it comes to Great Lakes levels and outflows. Most shore property owners, for example, benefit from stable water levels and a reduction of the extremes in high or low lake levels. Up to a limit, navigation is best served by high lake levels. High flows also increase hydropower generation. Fish and wildlife interests, however, tend to be divided as to

Table 1 Dimensions of the Great Lakes-St. Lawrence River

			Shoreline Length		Water Depth	
	Area Sq Mi (Sq Km)	Volume Cu Mi (Cu Km)	Mainland Miles (Km)	Island Miles (Km)	Average Feet (Metres)	Maximum Feet (Metres)
Lake Superior	31,700 (82,100)	2,900 (12,100)	1,730 (2,780)	997 (1,600)	483 (147)	1,330 (405)
St. Marys River	89 (230)		95 (153)	152 (244)		
Lake Michigan	22,300 (57,800)	1,180 (4,920)	1,400 (2,250)	238 (383)	279 (85)	923 (281)
Lake Huron	23,000 (59,600)	850 (3540)	1,850 (2,970)	1,980 (3,180)	195 (59)	750 (229)
St. Clair River	21 (55)		58 (93)	5 (8)		
Lake St. Clair	430 (1,110)		130 (210)	127 (204)		21 (6)
Detroit River	39 (100)		60 (96)	72 (116)		
Lake Erie	9,910 (25,700)	116 (484)	799 (1,290)	72 (116)	62 (19)	210 (64)
Niagara River	23 (60)		69 (110)	37 (60)		
Lake Ontario	7,340 (19,000)	393 (1640)	634 (1,020)	78 (125)	283 (87)	802 (244)
St. Lawrence						
*	235		301	352		
*	(610)		(484)	(567)		
**	960		705	466		
**	(1,540)		(1,130)	(750)		

* From Lake Ontario to Cornwall/Massena.

** From Cornwall/Massena to Ile d'Orleans near Quebec City



Profile of the Great Lakes-St. Lawrence River System at Chart Datum IGLD 1985

whether high, low or stable lake levels are beneficial. Fish and wildlife tend to live in wetlands, which past studies have identified as vital to the ecological health of the Great Lakes. Fluctuations in lake levels also tend to encourage and support a wide diversity of plant and animal life.

4. LAKE SUPERIOR REGULATION

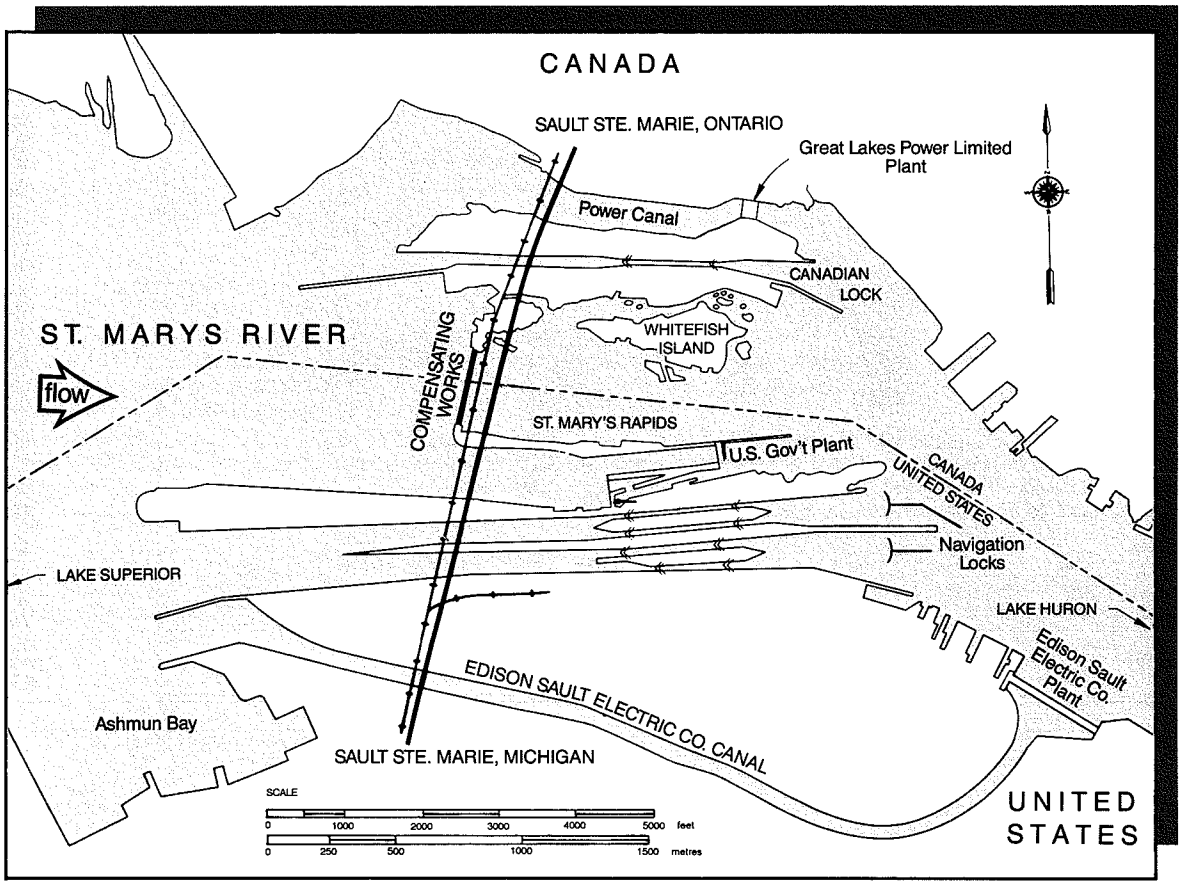
4.1 IJC Orders of Approval

In 1913, Algoma Steel Corporation in Canada and the Michigan Northern Power Company in the United States applied to the IJC for approval, as required by the 1909 Boundary Waters Treaty, to divert some of the water of the St. Marys River for hydropower generation. After a series of public hearings and a technical study, the IJC approved the request and issued an Order of Approval in 1914, which specified a list of conditions that were to be met in the construction and operation of the hydropower facilities. The IJC Order also established the International Lake Superior Board of Control to oversee the operations of the facilities in the St. Marys River. The Lake Superior Board has two members: one representing the United States from the Army Corps of Engineers and one representing Canada from Environment Canada.

The 1914 Order established the basic objectives for, and limits to, regulation. One condition states that, "All compensating works . . . shall be operated as to maintain the level of Lake Superior as nearly as may be between the levels 601.7 and 603.2 feet (183.40 and 183.86 metres) and in such manner as not to interfere with navigation." This target range was smaller than the historical range prior to 1914 and was considered possible under regulation.

The 1914 IJC consent order has been updated over the years to meet the changing conditions and requirements in the Great Lakes-St. Lawrence River System. For example, supplementary orders were issued in 1978, 1979 and again in 1985 to protect the sport fishery in the rapids section of the St. Marys River. A 1978 supplementary order also permitted the redevelopment of the Canadian hydropower company facilities at Sault Ste. Marie, Ontario.

In 1979, the IJC further amended its Order of Approval following an extensive study by its International Great Lakes Levels Board, a series of IJC public meetings and consultation with Governments. While all previous orders required that only the levels of Lake Superior be considered in determining the outflows, the 1979 amendment requires that the levels of Lakes Michigan-Huron also be taken into account in determining Lake Superior's outflows, also known as systemic regulation. The objective of systemic regulation is to provide benefits throughout the Great Lakes System. The 1979 order also specified that adequate flows must be ensured for fish habitat in the rapids section of the St. Marys River.



Regulatory Works at Sault Ste. Marie

A provision for extreme water supply conditions was also contained in the 1979 order. Thus, during extreme water supply conditions, the IJC will indicate the appropriate outflows from Lake Superior, taking into account upstream and downstream interests.

4.2 Regulatory Facilities

Hydropower plants and navigation locks have all been built and operate using the waters of the St. Marys River. The hydropower plant in Canada is operated by Great Lakes Power Limited, while in the United States, one hydropower plant is operated by the Edison Sault Electric Company and another one by the U.S. Army Corps of Engineers. The navigation locks, four in the United States and one in Canada, also use a small portion of the flows in the river. Navigation lock operations are directly under federal authorities in either country, however, and are not under the supervision of the IJC or its Lake Superior Board.

The construction of the 16-gate Lake Superior Compensating Works was a key requirement in the IJC's 1914 order. As its name suggests, the Compensating Works was built to offset, or compensate for, the increased outflow capacity of the St. Marys River that resulted from hydropower developments. Gate openings are adjusted to achieve, along with the flows through the other facilities, the total monthly flow specified by the regulation plan.

When the regulation plan calls for low flows, reductions in the diversion of water for hydropower generation will usually occur. At times of extreme high flows, all gates at the Compensating Works can be opened. In an emergency, the navigation locks in the United States have been used temporarily to increase the river flow.

4.3 Lake Superior Regulation Plans and Their Operations

Just as the IJC Orders are modified in response to the changing conditions on the Great Lakes, the regulation plan for Lake Superior is also updated and improved to meet the changing conditions specified in the Orders. The development and testing of regulation plans, using historical water supplies to the Great Lakes, is a key requirement in the IJC Orders.

Four different regulation plans were used to regulate Lake Superior from 1928 to 1979. All these plans were developed to meet the conditions and criteria specified in the IJC's 1914 Order. The water

level of Lake Superior was the main factor considered in determining the outflows of Lake Superior.

The IJC, in its 1976 report to the U.S. and Canadian Governments, noted that regulating the levels of Lake Superior would provide benefits throughout the Great Lakes system if the regulation took the levels of Lakes Michigan-Huron into account. The first plan to incorporate this new concept of systemic regulation was Plan SO-901, which was later improved and given the name Plan 1977. Plan 1977 came into effect following the issuing of the IJC 1979 Order of Approval.

Simply put, Plan 1977 works like this: If Lake Superior's level is much higher than its average and Lakes Michigan-Huron are slightly above average, the outflow from Lake Superior will be increased to ease its high water level condition. If Lake Superior is very much below average and Lakes Michigan-Huron are slightly below average, the outflow from Lake Superior will be reduced in order to raise its level. Similarly, if more extreme water level conditions exist on Lakes Michigan-Huron when compared with Lake Superior, the flows will be adjusted accordingly to ease the conditions on the downstream lakes. This water level balancing technique is the principal tool of systemic regulation.

Plan 1977 also specifies a minimum allowable flow in the St. Marys River. This requirement was designed to prevent excessively low river levels downstream. It also ensures water for power production, and maintains adequate flows in the St. Marys Rapids for fish habitat. In addition, winter flows are limited to a specified maximum to help prevent ice jams in the river.

Each month, the Lake Superior Board assesses the factors that affect lake levels on Lake Superior and Lakes Michigan-Huron before setting outflows according to Regulation Plan 1977. Water available for hydropower generation is shared equally between Canada and the United States.

During winter operations, ice management becomes an important factor in regulating the outflows. Under the present operational procedure in Plan 1977, the flow is held constant over the five winter months (December through April). This is due, in part, to the difficulty of moving gates in the Compensating Works during the winter and the need to keep flows as uniform as possible for ice management. Each winter, the U.S. Army Corps of Engineers installs an ice boom in the lower St. Marys River to maintain ferry service between Sugar Island and the U.S. mainland. The boom also serves to reduce ice

Lake Superior Compensating Works

jams, which could be detrimental to Soo Harbor and the hydropower facilities.

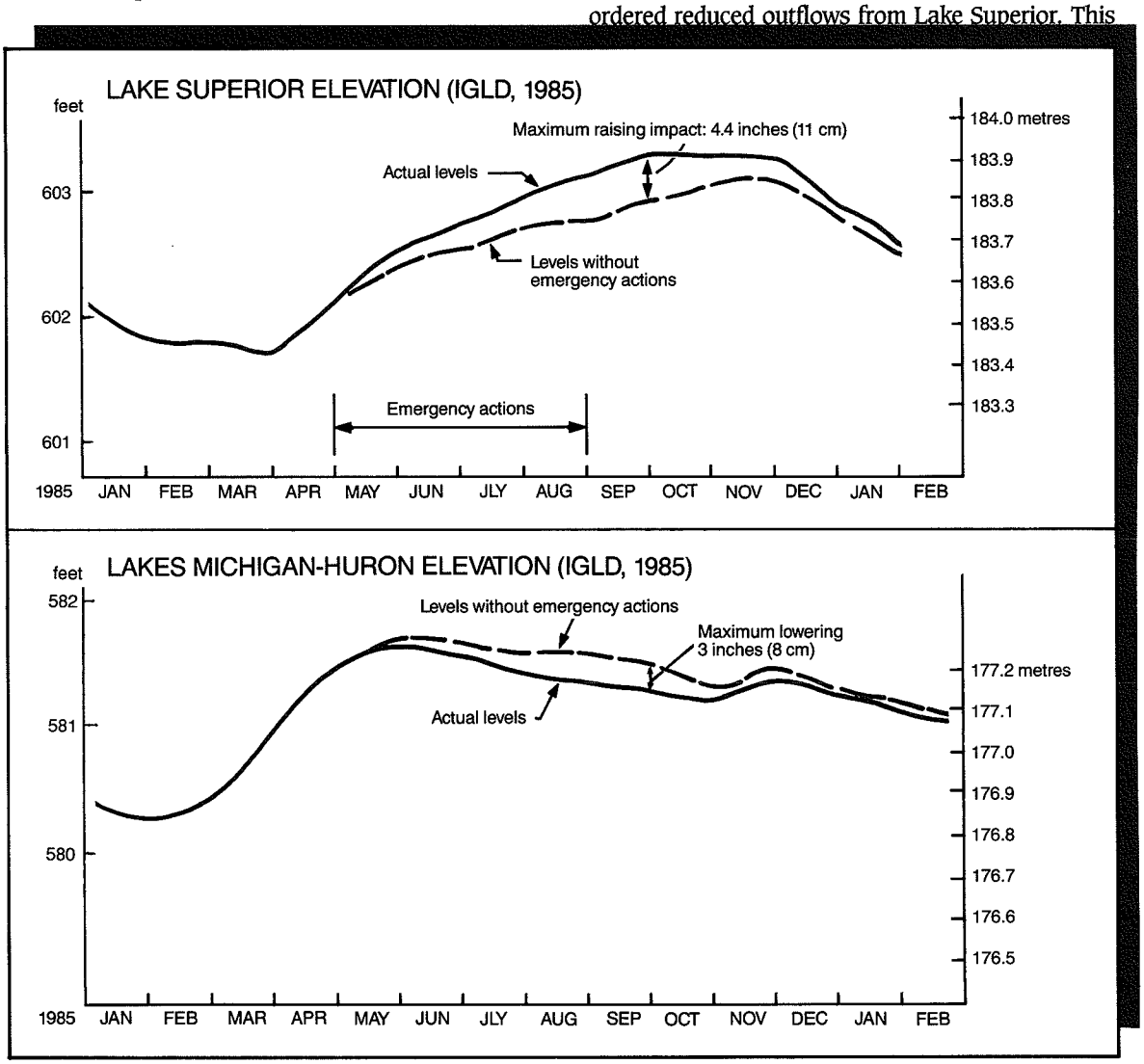
4.4 Experience in Lake Superior Regulation

The presence of Lake Superior regulation facilities does not mean that full control of lake levels is possible. This is because the major factors affecting the water supply to the Great Lakes – over-lake precipitation, evaporation and runoff – cannot be controlled; neither can they be accurately predicted over the long term. With the advent of Lake Superior regulation in 1921, humans have altered somewhat the amount of water that flows in the St. Marys River from that which would have occurred under natural channel conditions. But, it is important to note that the impact of regulation is small compared to the natural factors which affect lake levels.

While one objective of the 1914 order was to maintain Lake Superior levels within a more narrow range than the historical range, this proved to be impossible when record high and low water supplies occurred in later years. During the early 1950s, the maximum level as prescribed in the 1914 Order (603.2 feet or 183.86 metres) was exceeded. From the mid-1950s through the late 1960s, water levels were on many occasions below the minimum level called for in the 1914 Order (601.7 feet or 183.40 metres).

In the mid-1960s, low water levels were even more severe on Lakes Michigan-Huron. To help alleviate the situation on these lakes, outflows from Lake Superior in excess of those called for by the regulation plan were discharged. Due to extremely low water supplies, however, only minimal assistance could be provided.

In the early 1970s high water supplies again occurred. Because of critically high water levels on Lakes Michigan-Huron, St. Clair and Erie, the IJC ordered reduced outflows from Lake Superior. This



Impact of the 1985 Emergency Actions on Lake Superior and Lakes Michigan-Huron.

emergency action provided nominal relief to the lower lakes while still maintaining Lake Superior below the level of 603.2 feet (183.86 metres).

In the spring of 1985, the IJC again reduced the outflows of Lake Superior below those specified by Regulation Plan 1977 to help alleviate high water level problems on Lakes Michigan-Huron and downstream. However, after four months it was necessary to reverse this procedure and increase Lake Superior's outflows when high precipitation on the Lake Superior basin caused that lake to climb to a record high level. By mid-October, the IJC had increased the flow to 133,000 cubic feet (3,770 cubic metres) per second, the largest outflow on record. Nevertheless, continued heavy rains over the Lake Superior basin made it impossible to prevent Lake Superior from slightly exceeding the level of 603.2 feet (183.86 metres) for the months of October and November 1985.

The maximum effect of the 1985 emergency action was realized on Lake Superior in late August of that year when that lake was raised 4.4 inches (11.2 cm). Levels of Lakes Michigan-Huron, also by the end of August, were reduced 3.0 inches (7.6 cm). Lakes St. Clair and Erie realized their maximum benefit at the end of August and October, respectively. The maximum reduction was 1.8 inches (4.6 cm) for Lake St. Clair and 1.3 inches (3.3 cm) for Lake Erie.

5. LAKE ONTARIO REGULATION

5.1 IJC Orders of Approval

In 1952, the IJC issued an Order of Approval to the applications from Canada and the United States to construct hydropower facilities in the international reach of the St. Lawrence River, which extends from Lake Ontario to Cornwall, Ontario and Massena, New York. The order gave Ontario Hydro the responsibility to construct and operate the Canadian portion of the hydropower facilities, while the New York Power Authority was made responsible for the hydropower facilities in the United States. In 1956, during construction of the project, the IJC amended its order to include regulation criteria designed to reduce the range of levels experienced on Lake Ontario, facilitate navigation in the St. Lawrence River, and provide protection for riparian and other interests downstream in the Province of Quebec.

In addition, the order established the International St. Lawrence River Board of Control to ensure compliance with the provisions of the Orders by the operators of these works. Upon completion of the project in 1960, the St. Lawrence River Board took on its duties and is presently the operating board in the regulation of Lake Ontario outflows. Its present eight members are from the Corps of Engineers, Transport Canada, Environment Canada, and five other state, provincial and local agencies and representatives.

One of the primary conditions in the IJC order was that Lake Ontario be regulated within a target range of 243.29 and 247.29 feet (74.15 and 75.37 metres), respectively. Recognizing that future water supplies to Lake Ontario would at times be higher or lower than those experienced in the past, the IJC included an emergency provision. Criterion (k) of the order specifies that, in the event that supplies exceed supplies of the past, the works in the international rapids section should be operated to provide all possible relief to the riparian owners upstream and downstream. In the event that supplies less than the supplies of the past occur, the works should be operated to provide all possible relief to navigation and power interests. This criterion has been followed on several occasions to deal with extreme water supplies to Lake Ontario.

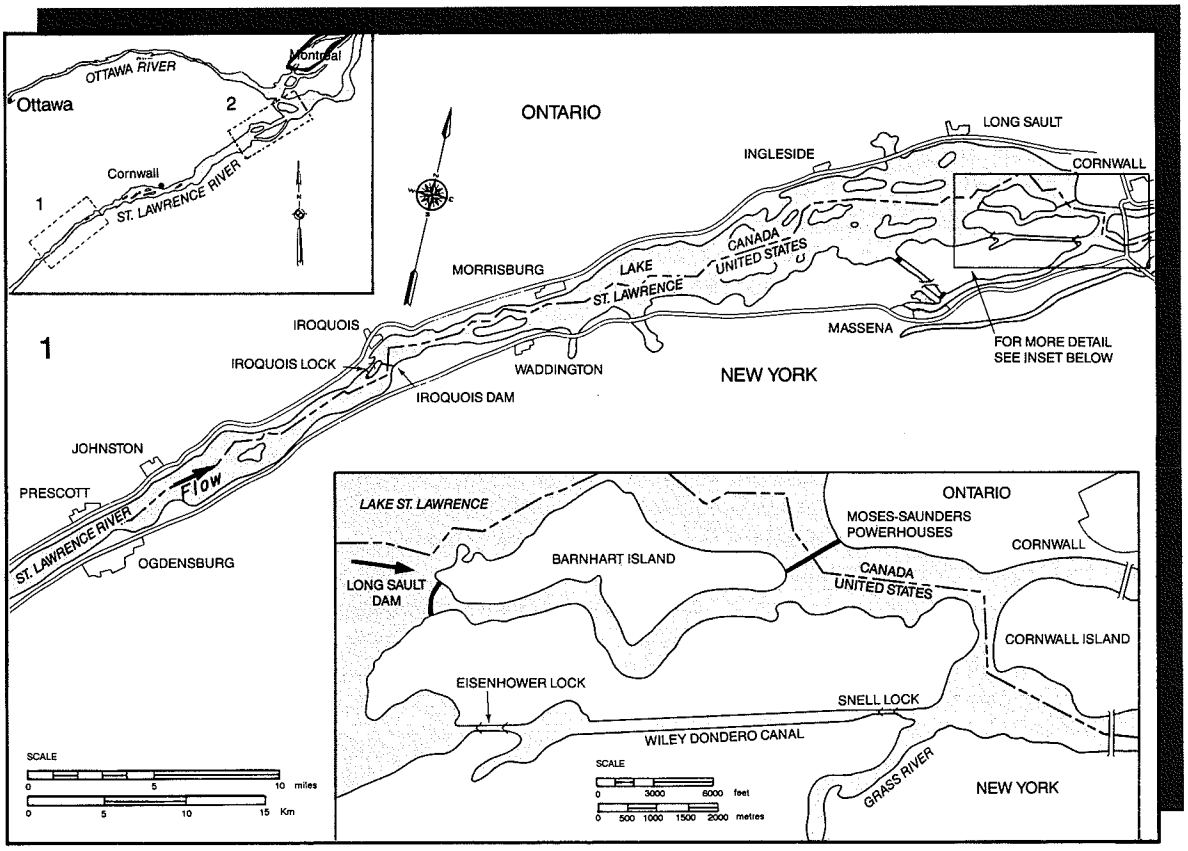
5.2 Regulatory Facilities

The outflows of Lake Ontario have been regulated since 1960, following completion of the St. Lawrence Seaway and Power Project. The project required extensive river deepening and construction of navigation locks. The Moses-Saunders power dam that crosses the St. Lawrence River between Cornwall, Ontario and Massena, New York is the principal regulatory structure. A second dam, located near Long Sault, Ontario, acts as a spillway when outflows from Lake Ontario are larger than the capacity of the power dam. A third structure at Iroquois, Ontario, can also be used to regulate the flow of water, but is used principally to assist in the formation of a stable ice cover in the winter as well as to prevent water levels from rising too high in Lake St. Lawrence which is upstream of the power dam.

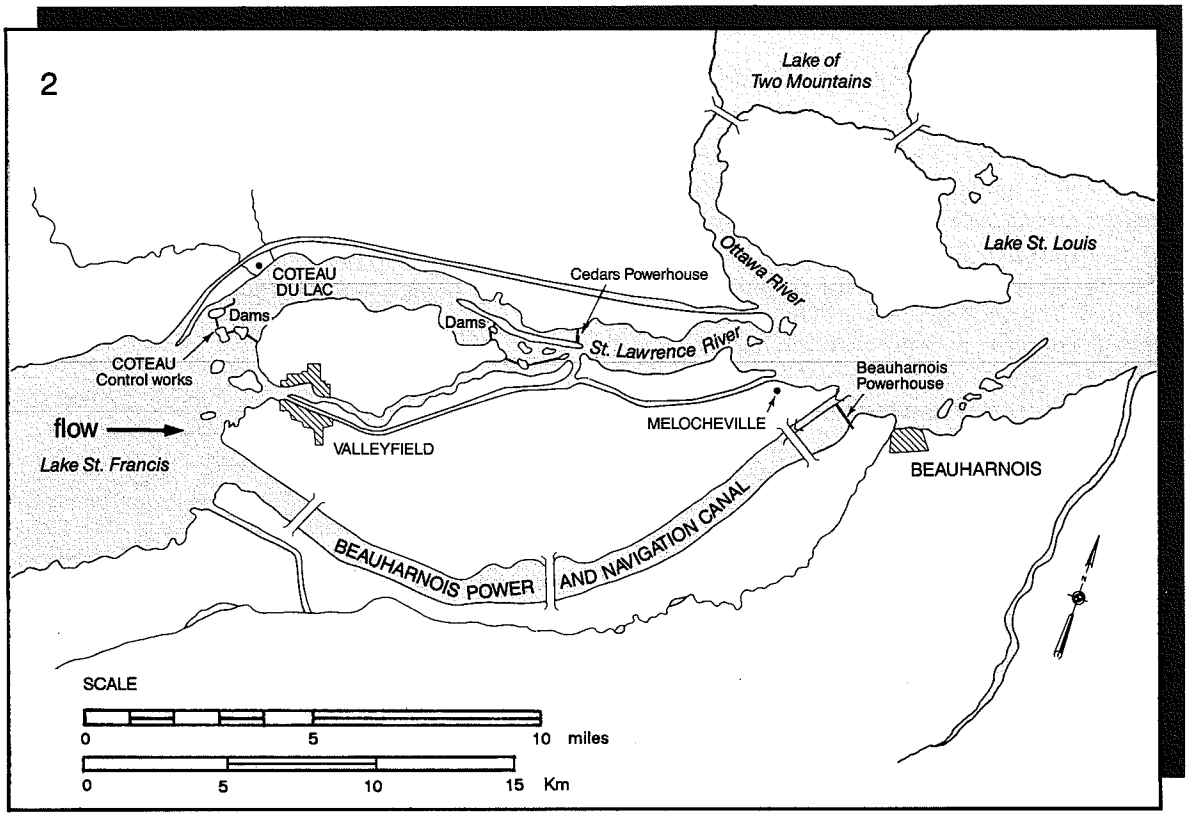
The navigation locks in the Canadian portion of the St. Lawrence Seaway are operated by the St. Lawrence Seaway Authority. Locks in the United States are operated by the St. Lawrence Seaway Development Corporation. Similar to the lock facilities on the St. Marys River, operations of these facilities are federally controlled and not under the supervision of the IJC. Other hydropower and navigation facilities exist downstream of the power dam, in the Province of Quebec.

5.3 Lake Ontario Regulation Plans and Their Operations

Three plans have been used to regulate the outflows of Lake Ontario. All of these plans were designed to



Lake Ontario Regulatory Works



Power and Navigation Facilities in the Province of Quebec

meet the objectives specified in the 1952 Order and the 1956 Supplementary Order of Approval. Plan 1958-D, the present regulation plan, has a family of operating curves for different trends in the water supply conditions for Lake Ontario. If the water supplies to the lake are high, for example, the curve with a higher supply indicator will be used to determine the outflows, and vice versa. This was designed to maintain the levels on Lake Ontario within the target range of 243.29 and 247.29 feet (74.15 and 75.37 metres), respectively.

Plan 1958-D also specifies a number of flow limitations. For example, monthly minimum permissible flows are specified to ensure adequate flows for hydropower production. However, another limitation restricts the flows in the river when Lake Ontario's water level is low. The latter restriction is designed to ensure adequate depth in the St. Lawrence River.

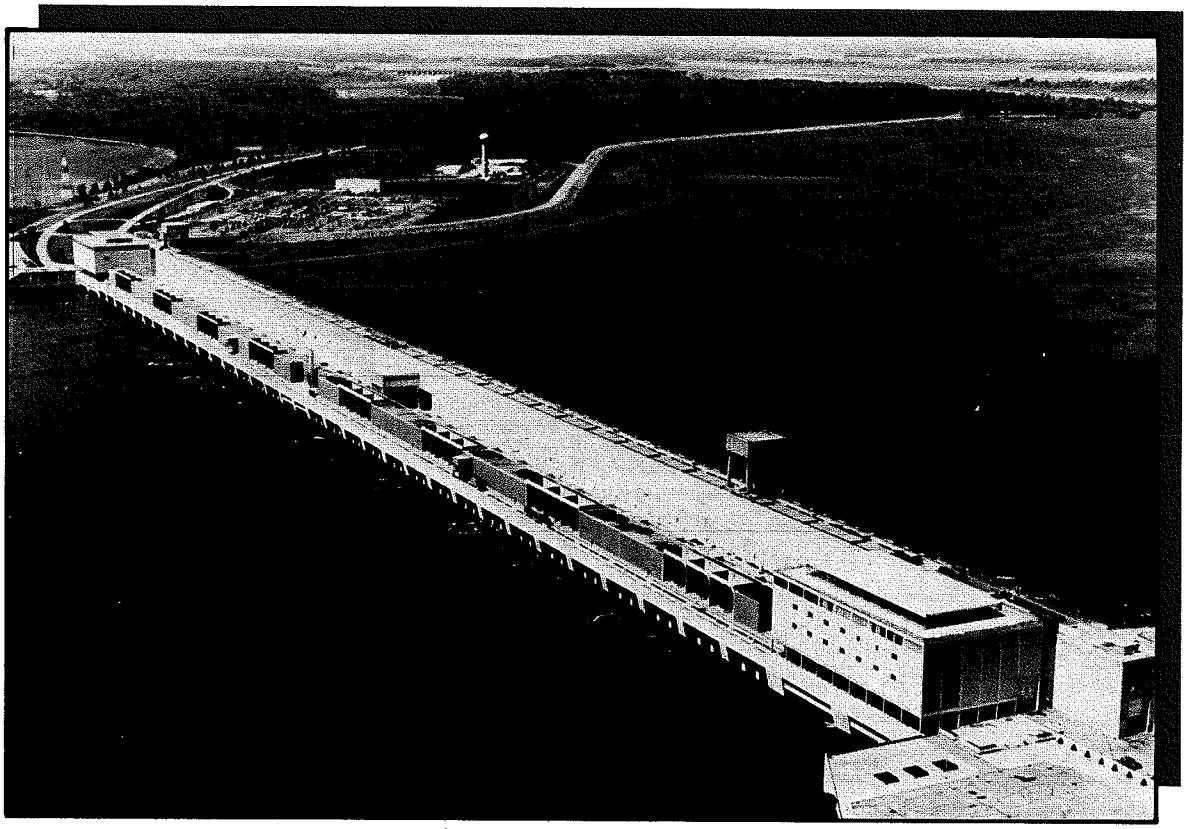
While Lake Superior's outflow is adjusted monthly, Lake Ontario's outflow is adjusted weekly by the St. Lawrence River Board according to Regulation Plan 1958-D. This is done for two reasons. First, Lake Ontario is much smaller than Lake Superior, and thus its levels respond more quickly to changes in water supplies to the lake. Secondly, inflows to Lake Ontario, made up mainly by outflows from Lake Erie, are much higher than the inflows to Lake Superior.

During winter operations, ice becomes an important factor in regulating Lake Ontario outflows. For a short period at the beginning of the winter, outflows from Lake Ontario are often temporarily reduced to assist in the formation of a stable ice cover at the outlet of Lake St. Francis (at the Beauharnois-Des Cedres hydropower complex upstream of Montreal) and in the international rapids section of the St. Lawrence River upstream of Cornwall, Ontario and Massena, New York. Ice booms are also located at several sites in the river to help this process. A breakup of the ice cover can cause an ice jam and result in severe difficulties in flow regulation and hydropower production. After a stable ice cover is formed, flows in the river are gradually increased to offset any temporary flow reductions.

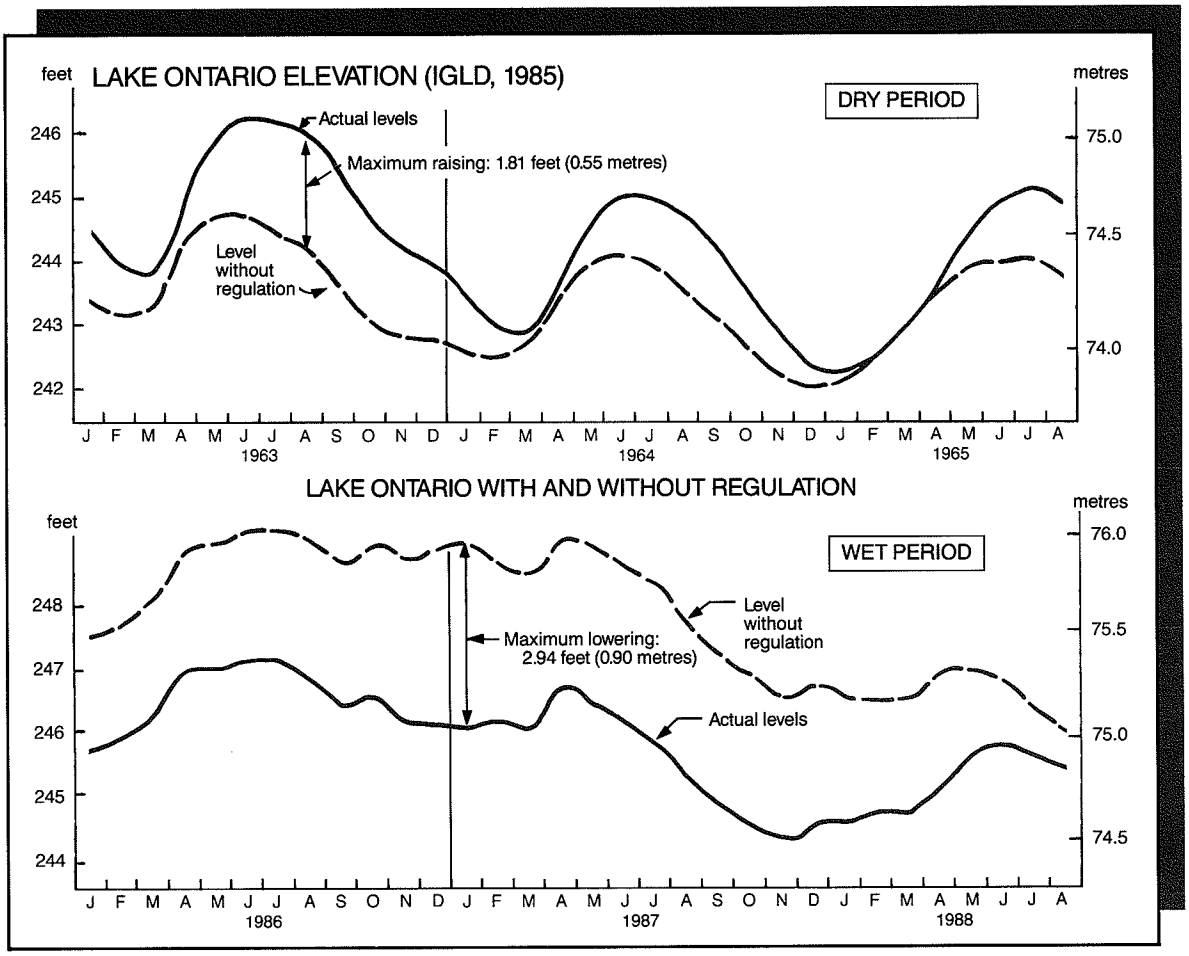
Operational experience has shown that flooding in Montreal area by spring runoff from the Ottawa River (a major tributary to the St. Lawrence River) can be reduced by temporary reductions in Lake Ontario outflows. These reductions are later offset following the freshet.

5.4 Experience in Lake Ontario Regulation

As with Lake Superior, regulation of Lake Ontario does not ensure full control of the levels of the lake, because the major factors affecting the water supply



Moses/Saunders Powerhouse, Cornwall, Ontario/Massena, New York



Impact of Lake Ontario Regulation

to the Great Lakes – over-lake precipitation, evaporation and runoff – can not be controlled, nor can they be accurately predicted over the long term. Further, the fluctuation of Lake Ontario levels cannot affect the upstream lakes due to the presence of Niagara Falls. Nonetheless, Lake Ontario regulation since 1960 has had some impacts.

During the extreme low water period of the mid-1960s, Lake Ontario levels were maintained slightly higher than they otherwise would have been without regulation. In the early and mid-1970s, when water supplies were critically high, water levels were held to more than a foot (0.3 metre) below pre-project levels. Despite this action, and because of unusually high water supplies, Lake Ontario water levels reached 248.43 feet (75.72 metres), well above the range prescribed in the IJC's Order of Approval.

In the winter of 1986-87, the IJC increased Lake Ontario's outflows above those prescribed by Plan 1958-D. This action prevented Lake Ontario from rising to extreme high levels due to continued extreme high inflows to the lake from the upper Great Lakes. The very mild weather and favourable ice conditions in the St. Lawrence River that winter helped to make these high flows possible. During that time, water level conditions in the Montreal area and downstream were monitored closely so as to not aggravate the existing high water conditions.

High flows in the St. Lawrence River have been made possible with the completion of the Seaway and Power Project. But high flows increase cross currents and water velocity, which in turn can make navigation difficult. At times, these conditions temporarily halt ship traffic.

In the Spring of 1989, the Board reduced Lake Ontario's outflows because of a concern that its levels had fallen significantly below its seasonal long-term average. There was also the concern about low levels in the international section of the river. The flow reduction was carried out during the Ottawa River spring runoff, so as to not adversely affect downstream interests. An unexpected heavy spring rainfall, combined with the reduced outflows, caused the level of Lake Ontario to rise sharply, and thus enabled a return to plan flows earlier than anticipated.

6. WHO YOU CAN CONTACT ABOUT LAKE REGULATION

Several organizations focus some or all of their work on Great Lakes levels and outflow regulation. If you have comments or questions about the regulation of Lake Ontario or Lake Superior, contact the following offices.

In Canada

Secretary, Canadian Section
International Lake Superior Board of Control
Environment Canada
111 Water Street, East
Cornwall, Ontario K6H 6S2
Telephone: (613) 938 5725

Secretary, Canadian Section
International St. Lawrence River Board of Control
Transport Canada
6th floor, Canada Building
344 Slater Street
Ottawa, Ontario K1A 0N7 Telephone: (613) 990 5617

Great Lakes Water Level Communications Centre
Environment Canada
P.O. Box 5050
867 Lakeshore Road
Burlington, Ontario L7R 4A6
Telephone: (416) 336 4581

Ministere de l'Environnement du Quebec
Direction de l'hydraulique
2360 chemin Sainte-Foy
Sainte-Foy, Quebec G1X 4H2
Telephone: (418) 644 3430

International Joint Commission
Canadian Section
100 Metcalfe Street, 18th floor
Ottawa, Ontario K1P 5M1
Telephone: (613) 995 2984

In United States

Secretary, United States Section
International Lake Superior Board of Control, and
Secretary, United States Section
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