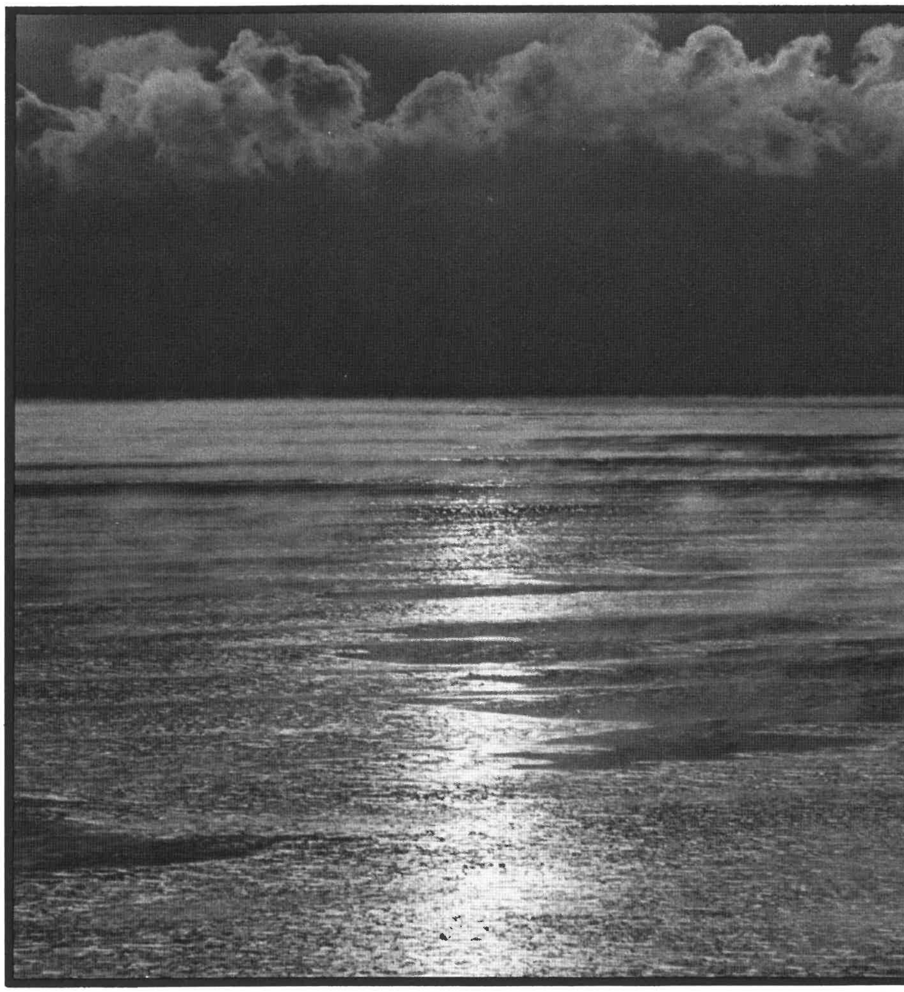

WATER LEVEL CHANGES

FACTORS INFLUENCING THE GREAT LAKES

Great Lakes Commission
2200 Bonisteel Boulevard
Ann Arbor, Michigan 48109

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PREFACE

Before any report is complete, the individuals and institutions contributing to its development and preparation must be recognized.

The Great Lakes Commission's Lake Levels, Flooding and Shoreline Erosion Task Force was created in October, 1985 at the Commission's Annual Meeting. The Task Force charge was to review Great Lakes flooding and water level problems and develop a document describing the numerous factors influencing lake levels. Task Force members were designated by member States and appointed by Great Lakes Commission Chairman James Ridenour, Director of the Indiana Department of Natural Resources. Member States were Illinois, Michigan, Minnesota, New York, Ohio and Wisconsin (see Appendix III).

Task Force members provided direction and advice to the Commission staff. Their input and recommendations during the writing and review process shaped the report. Figures and tables in this publication were secured from numerous sources. All have been adapted from the original to a common style.

The Commission extends its appreciation to Frank Quinn, Acting Director and Head, Lake Hydrology Group of the Great Lakes Environmental Research Laboratory. Dr. Quinn provided continual guidance and technical assistance to the Great Lakes Commission staff. His contributions to this report were invaluable.

The principal authors of this report, and the two people directly responsible for its completion, were Thomas Crane, Natural Resources Management Specialist, and Sylvie Stanish, Research Assistant.

The Executive Director was responsible for reviewing, editing and providing general support to the staff, but the preparation was a full Great Lakes Commission effort.

James Fish
Executive Director

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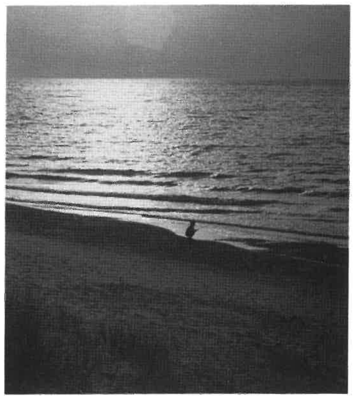
INTRODUCTION



The Great Lakes Commission prepared the following information to further public understanding of water levels and the causes of water level changes on the Great Lakes.

Fluctuations in Great Lakes water levels have occurred continually since the Great Lakes were formed some five to six thousand years ago with the retreat of the last glacier. There are yearly fluctuations which on the average account for changes of about 12 to 18 inches with lows normally occurring in January or February and highs in June through September. There are also long-term fluctuations in lake levels on the order of five to six feet from record lows to record highs. Since modern lake levels measurements began in 1860, the Great Lakes have experienced periods of high and low water levels. Such a short period of record (from a hydrologic/geologic standpoint) makes prediction of Great Lakes water levels extremely difficult.

Scientists are still learning about the hydrology, geology and climate of the Great Lakes region, especially patterns that occurred over the last 10,000 years. As they learn, they may be able to predict long-term lake level fluctuations more accurately.

Certainly, there are both positive and negative impacts associated with high and low lake levels. A better understanding of the causes of lake level changes won't ease the negative impacts of high or low water but may make it easier for communities and shoreline residents to plan future development.

THE GREAT LAKES SYSTEM

Essential to the understanding of lake levels in general is the comprehension of the vastness of the Great Lakes system. The Great Lakes contain approximately six quadrillion gallons of water. This is 20 percent of the world's supply of fresh surface water, 95 percent of the U.S. fresh surface water. Spread evenly over the contiguous U.S., the Great Lakes would flood the land with about eight to ten feet of water.

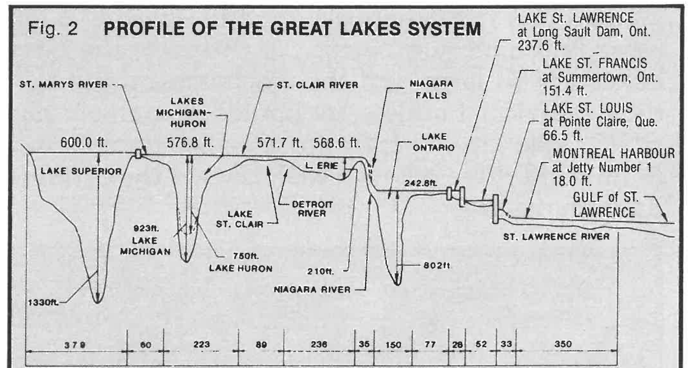
Fig. 1 GENERAL MAP OF THE GREAT LAKES

Source: Environment Canada

The five Great Lakes (Superior, Michigan, Huron, Erie and Ontario), their connecting channels and Lake St. Clair, make up the largest fresh water lake system in the world. The lakes have a total water surface area of 95,000 square miles.

Lake Superior is the uppermost lake and the largest, containing 53 percent of the total water in the system. Water from Lake Superior flows through the St. Marys River to Lake Huron. Lake Michigan, located entirely in the United States, also drains to Lake Huron via the Straits of Mackinac. Water from Lake Huron flows to Lake Erie by way of the St. Clair River, Lake St. Clair and the Detroit River. Lake Erie flows into Lake Ontario by way of the Niagara River and the Welland Canal. Lake Ontario, the lowermost lake, drains into the St. Lawrence River which flows to the Gulf of St. Lawrence.

Fig. 2 PROFILE OF THE GREAT LAKES SYSTEM



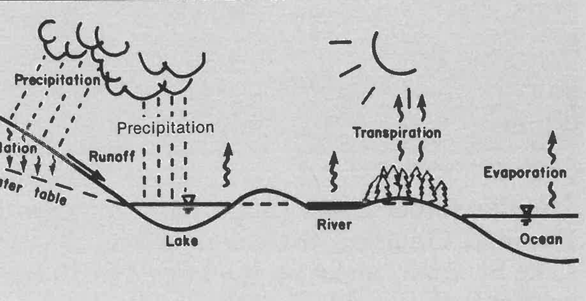
Elevations of the lake surface are given as Chart Datum (or Low Water Datum), expressed on International Great Lakes Datum, 1955. Chart Datum is a plane of reference on each lake to which navigation chart depths and Federal navigation improvement depths are referred. Horizontal and vertical scales have been distorted to convey visual impression.

Source: U.S. Army Corps of Engineers

NATURAL FACTORS AFFECTING GREAT LAKES WATER LEVELS

WATER LEVELS AND FLUCTUATIONS

Fig. 3



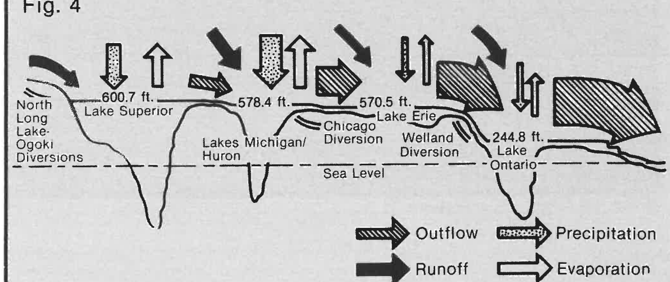
THE HYDROLOGIC CYCLE

Source: Environmental Pollution and Control by P. Aarne Vesilind

The water level in each of the Great Lakes rises or falls according to the amount of water entering the lake and the amount leaving it. The amount entering a lake includes precipitation falling on the lake, runoff including snowmelt from the surrounding area, inflow from connecting channels, diversions of water into the lake and groundwater inflow. The water leaving a lake consists of evaporation from the lake's surface, groundwater outflow, consumptive uses, diversions out of the lake and outflow at the lake outlet.

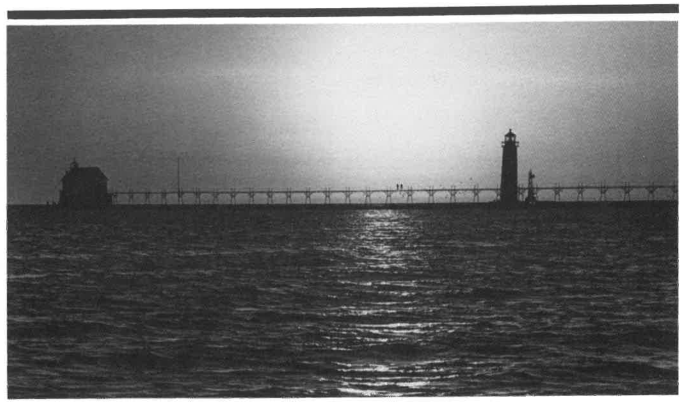
Water levels rise when the amount entering a lake exceeds the amount leaving it. Because the Great Lakes are so large and the discharge capacities of their individual outlets are limited, extremely high or low lake levels persist for a considerable length of time after the factors which caused the extremes have changed.

Fig. 4



GREAT LAKES INFLOWS AND OUTFLOWS

Source: Environment Canada



The hydrologic water balance determines lake levels in a drainage basin or watershed. Weather and climate are the principal factors affecting the hydrologic water balance of a system.

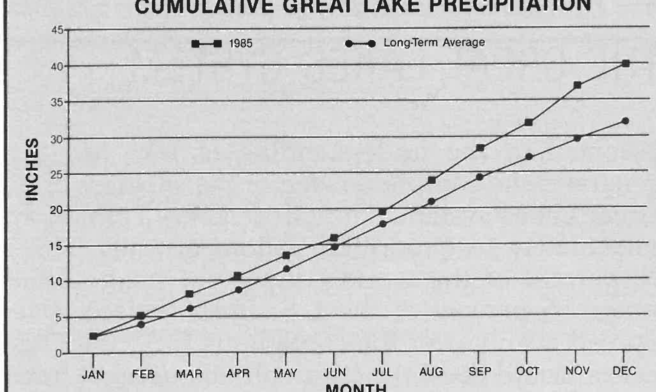
PRECIPITATION

The amount of precipitation is the main cause of long-term fluctuations in water levels on the Great Lakes. Analysis of Great Lakes water level records, kept since 1860, shows that the present high lake levels are the result of a long period of higher than normal precipitation. Figure 5 shows 1985 precipitation compared to the long term average. Average annual precipitation for the Great Lakes Basin is 31 to 32 inches.

From 1900 to present there have been two distinct precipitation patterns. Until 1940, the Great Lakes experienced below average precipitation. This was also

Fig. 5

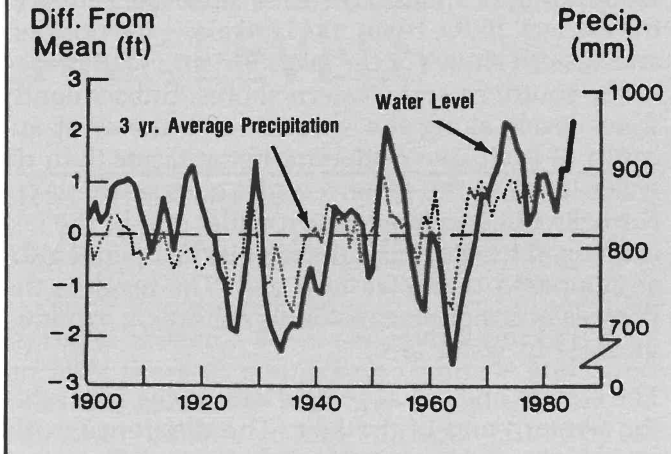
CUMULATIVE GREAT LAKE PRECIPITATION



Source: International Joint Commission

Fig. 6

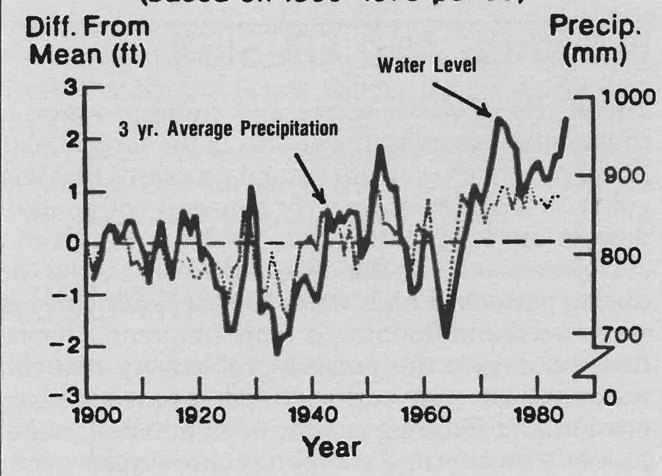
Lake Michigan-Huron Annual Water Levels (based on 1900–1979 period)



Source: National Oceanic & Atmospheric Administration

Fig. 7

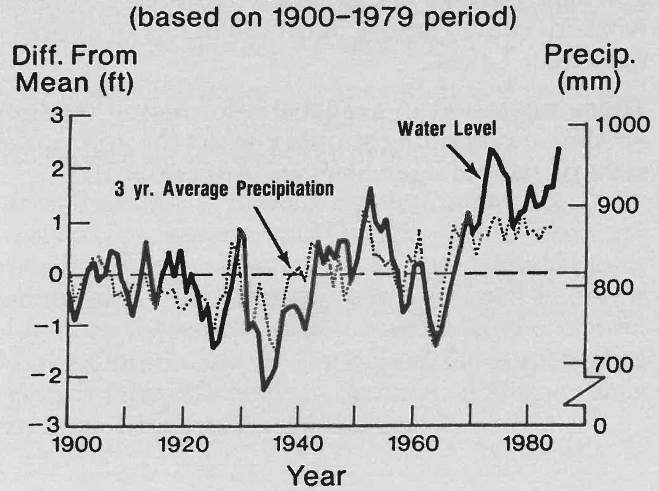
Lake St. Clair Annual Water Levels (based on 1900–1979 period)



Source: National Oceanic & Atmospheric Administration

Fig. 8

Lake Erie Annual Water Levels (based on 1900–1979 period)



Source: National Oceanic & Atmospheric Administration

a period of increased shoreline development. Thus, low water levels and atypical conditions were considered as normal by most people. Hence, many homes were built closer to the shoreline than they may have been during periods of higher precipitation and higher water levels.

After 1940, precipitation, with the exception of a few dry years, has been above average. Above average precipitation was recorded for 13 of the 16 years since 1970. Basin-wide average annual precipitation for the period 1900-1939 was 30.77 inches compared to average annual precipitation of 32.77 inches for the period 1940-1984. This extra two inches per year, a six percent increase, is a tremendous amount of water being added to the system. Figures 6, 7 and 8 show the high precipitation over the last 20 years and also indicate the high correlation between precipitation and lake levels for Lakes Michigan-Huron, St. Clair and Erie. Precipitation usually leads lake levels by about one year, but the cause and effect relationship is clearly shown.

RUNOFF

Great Lakes water levels are influenced significantly by the amount and timing of runoff. Runoff refers to all of the water flowing through streams that eventually empties into the lakes. With reference to runoff, the Great Lakes Basin can be compared to a sponge. Normally, if you take a sponge and pour water on it much of the water will be absorbed. If the sponge is saturated the water will run off.

Under current conditions the Great Lakes Basin is nearly saturated. Most of the precipitation that falls onto the basin will run off into the system. When extended periods of above average precipitation occur throughout the drainage basin, the problems associated with high lake levels will be exacerbated by increased runoff.

Since 1940 the Great Lakes Basin has experienced a six percent increase in precipitation resulting in a 14 percent increase in runoff.

TEMPERATURE AND EVAPOTRANSPIRATION

The Great Lakes Basin is colder than it used to be. Since 1960, the basin has averaged about two degrees Fahrenheit cooler than the period from 1930 to 1960, the warmest period in the last 2,000 years in the Great Lakes region.

Evapotranspiration refers to evaporation from land areas and transpiration from plants. For the Great

Lakes Basin it is less significant than precipitation in determining lake levels, but is still a factor. The cooler climate has meant less evapotranspiration from the Great Lakes area. Lower temperatures since 1960 have caused a five percent increase in runoff by reducing evapotranspiration throughout the region. Evaporation from the lake surfaces, however, has increased with the cooler temperatures. On a seasonal basis, evaporation is least in the spring when the lakes are cold relative to the air and is greatest in the fall and early winter when water is warm relative to the air.

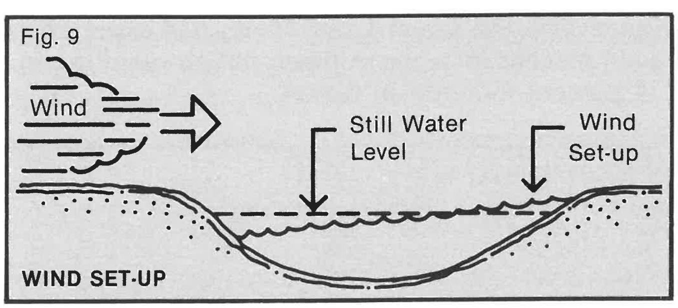
The cool falls and winters since 1960 have contributed to the increase in evaporation from the lake surfaces.

The combined effect of the increase in precipitation (both on the land and over the lake) with the decreased basin-wide temperatures and lower evapotranspiration gives a 12 percent increase in combined precipitation and runoff.

METEOROLOGICAL EVENTS

Another important factor contributing to lake level changes is wind. At high levels, still water can cause damage especially to water distribution system intake structures and wastewater treatment facility outfalls. However, high water levels combined with intense storms have caused extensive severe flooding and related property damage.

When strong winds blow in one direction for a prolonged period they produce a surface tilt or wind setup (see Figure 9). Extreme examples of this occur when winds blow along the axis of a lake. For instance, during the storm of December 2, 1985 there was a 16-foot difference in water levels on Lake Erie between Toledo and Buffalo. While the water levels at Toledo dropped eight feet, Buffalo experienced an eight foot rise in water levels. This caused extensive



Source: Environment Canada

shoreline erosion and millions of dollars in property damage. The winds were out of the southwest which coincides with the axis of Lake Erie. If sustained winds had predominated from the northeast, the effects would have been reversed.

CRUSTAL MOVEMENT

Crustal movement is the continued uplifting or rebounding of the earth's crust since the retreat of the glaciers. In the basin, the land along the northern and eastern shores of the lakes is rising with respect to the southern and western shores. Subsequently, water levels along the shorelines to the west and south of each lake outlet are rising faster than the water levels at the eastern outlet ends of the lakes. For Lake Ontario, the eastern outlet end of the lake is rising at a rate of about seven inches per century as compared to the western end. The result is that the western shoreline residents are seeing a gradual increase in water level.

The eastern end of Lake Superior is rising faster than the western end of the lake. The difference in the rate of rebound is approximately ten inches per century. Since 1900, shoreline residents at Duluth, Minnesota have experienced a rise in lake levels of about eight inches due strictly to crustal movement.

FLOODING AND EROSION

The effects of wind, waves and running water are constantly reshaping the shores of the Great Lakes. Flooding and erosion are natural processes that were going on long before we were here and will continue despite our best efforts after we are gone. Even at average water levels flooding and erosion occur. But during periods of high water levels erosion rates are accelerated and flooding is more frequent. This fact does not lessen the present problem for shoreline residents, but may add some perspective. Because erosion and flooding cannot be eliminated, at best property owners and shoreline communities can try to ease the impacts.

If structural protection is being considered, federal and state permits are generally required before any work in, under, across or on the banks or shores of the Great Lakes.

Those interested in available information on shore erosion and flooding should contact the appropriate state or federal agencies (see Appendix I).

OTHER FACTORS INFLUENCING LAKE LEVELS

DREDGING FOR NAVIGATION IMPROVEMENTS

Dredging is done primarily to maintain adequate depths in shipping lanes for navigation. Dredging can alter flows in connecting channels and affect mean lake levels. For instance, dredging in the St. Clair River has lowered Lake Michigan-Huron by ten inches since the early 1900's.

DIVERSION

Diversion is a man-made transfer of water into or out of a drainage basin. Currently there are five operating diversions on the Great Lakes: Ogoki, Long Lac, Chicago, Welland Canal and the New York State Barge Canal. These diversions are regulated by control structures and change the natural water supply to the lakes or bypass a natural outlet.

REGULATION

Scientists, planners and managers often talk about regulating water levels when they describe the various features and controls, which include locks, canals, dams and compensating works on the Great Lakes. The term regulation is misleading in that it implies that lake levels can be completely controlled by humans. For the most part, the Great Lakes act as a natural system and water will flow through the system only as quickly as nature will allow.

Water levels on the Great Lakes can, however, be partially regulated through the use of outlet control structures for the retention or release of water.

Currently there is limited regulation of two of the Great Lakes—Superior and Ontario—under plans approved and implemented by the International Joint Commission (IJC). The regulation of Lake Superior influences the whole system, while the regulation of Lake Ontario has no impact on the upper lakes because of the difference in elevation at Niagara Falls (326 feet) which acts as a control.

Regulation affects mean lake levels only to a minimal extent. Current regulation cannot alter long-term lake level trends and cannot influence lake levels significantly in the short term. Regulation can only partially alter or alleviate lake level extremes.

Nevertheless, changes in the regulation plans for the Great Lakes have been suggested to help alleviate the problems caused by high water levels. Such could come in the form of changing regulation at existing regulatory sites or new structures to reduce the water levels. Regulatory changes, in most cases, have to be approved by the IJC which has the responsibility to decide if the application for the use, obstruction or diversion of boundary waters is harmful to either Canada or the United States. Except for Lake Michigan, all of the Great Lakes and their connecting channels are boundary waters.

PRESENT CONTROL STRUCTURES

There are five diversions of Great Lakes water (see Figure 10), and additional regulatory structures at Sault Ste. Marie and Lake Ontario. These structures have varying capacities to modify water levels.

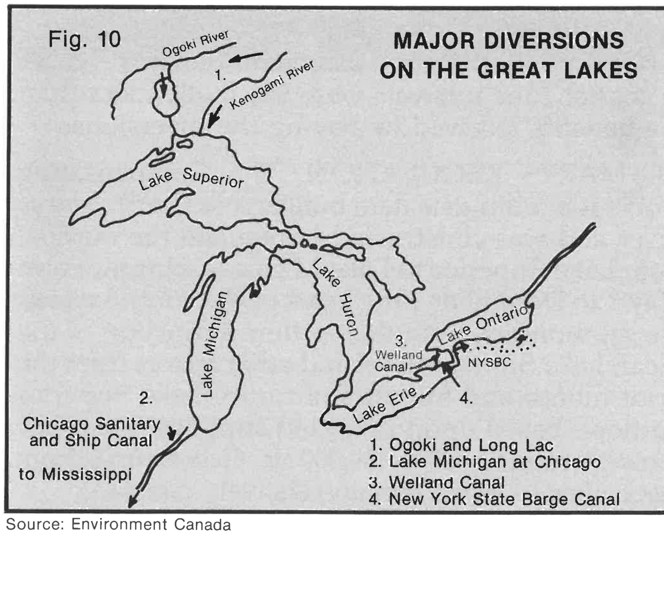
Changes in water levels of the Great Lakes from diversions and control works require a great deal of

Table 1. Effect of Existing Diversions on Mean Great Lakes Water Levels (in inches)

Diversion	Rate	Superior	Michigan-Huron	Erie	Ontario
Long Lac/Ogoki	5,600	+2.5	+4.5	+3.0	+2.6
Lake Michigan at Chicago	3,200	−0.8	−2.5	−1.7	−1.2
Welland Canal	9,400	−0.7	−2.2	−5.3	0
TOTAL		−1.0	−0.2	−4.0	+1.4

Source: International Joint Commission

Fig. 10 MAJOR DIVERSIONS ON THE GREAT LAKES



Source: Environment Canada

time to take effect. This is due to the tremendous surface area of the Great Lakes. On the upper lakes, it takes approximately 3½ years to realize one-half of the anticipated effect of increasing or decreasing the amount of water to the lakes. For a diversion into or out of Lake Michigan-Huron, for instance, it would take 3½ years for about one-half of the expected change in water levels on Lake Michigan-Huron, St. Clair and Erie to occur. The full effect of change would take about 12 to 15 years. Table 1 shows the effect that existing diversions have had on Great Lakes water levels versus what they would be under strictly natural conditions.

LONG LAC AND OGOKI DIVERSIONS. Actually two separate diversions, Long Lac and Ogoki are often considered together because they both divert James Bay water into Lake Superior. The Long Lac diversion connects the headwaters of the Kenogami River with the Aguasabon River, which naturally discharges into Lake Superior. The Ogoki diversion connects the upper portion of the Ogoki River to Lake Nipigon and from there flows into Lake Superior. Together, both diversions bring an annual average flow of 5,600 cubic feet per second (cfs) with a range of 2,500 to 8,000 cfs over the years. One cfs equals 646,316 gallons per day. These diversions were developed to generate hydro-electric power and to transport pulpwood logs southward.

Ogoki and Long Lac can be altered so that less water is being brought into the Great Lakes system. In 1985, Ontario took action to store Ogoki waters on Lake Nipigon and after Lake Nipigon developed critically high water levels, Ogoki water was redirected to the Albany River and Hudson Bay. This action continued until December, 1985 and its ultimate effect was the lowering of Lake Superior by about 0.4 inches.

Totally stopping these diversions was found to be very costly. An IJC study board found that the losses to coastal zone interests were $53 million less than the benefits received by having the diversions.

ST. MARYS REGULATION. The Compensating Works is a multi-gate dam built across the St. Marys River and was constructed to regulate the outflow from Lake Superior to Lake Michigan-Huron. From May 1 to December 1 the gates of the control works are set monthly, with the outflow a function of the mean Lake Superior level and other factors from the prior month and forecasts of future Lake Superior outflows based upon projected supplies. This flow can vary from 55,000 to 134,000 cfs. Gate settings from December to April remain relatively constant.

The regulatory plan used at this site, Regulation Plan 1977, is based on the principle of balancing the levels of Lakes Superior and Michigan-Huron for the benefit of the total Great Lakes system. Extreme levels on these lakes are reduced because the lake which has a less extreme situation is used to relieve conditions on the other lake. The plan requires that Lake Superior not be allowed to rise beyond 602 feet above sea level, under normal conditions.

Changes in the Superior outflow to lower downstream water levels have occurred in the past. The most recent action was initiated in May 1985. Outflows were reduced by one-third of the flow called for by Plan 1977. This action had to be ended in August, 1985 when Lake Superior's water supply began to increase rapidly. The action ultimately raised Lake Superior's level by about 4.4 inches and reduced the water levels of Lake Michigan-Huron by about 3.0 inches, Lake St. Clair by about 1.8 inches and Lake Erie by 1.3 inches when compared to the water level that would have occurred if no changes had been made. The maximum effect for the upper lakes occurred in August. The maximum effect for Lake Erie occurred in October.

LAKE MICHIGAN DIVERSION AT CHICAGO. The Chicago Diversion passes water out of Lake Michigan through the Illinois Waterway and on to the Mississippi River. This diversion is not under the jurisdiction of the IJC because Lake Michigan is not a boundary water. Flow through the Chicago diversion is currently limited by U.S. Supreme Court decree (388 U.S. 426) and increases in flows out of Lake Michigan must be approved by the Court or legislated by the U.S. Congress. The flow in the present system is set at 3,200 cfs which is a long-term average, based on a 40-year period.

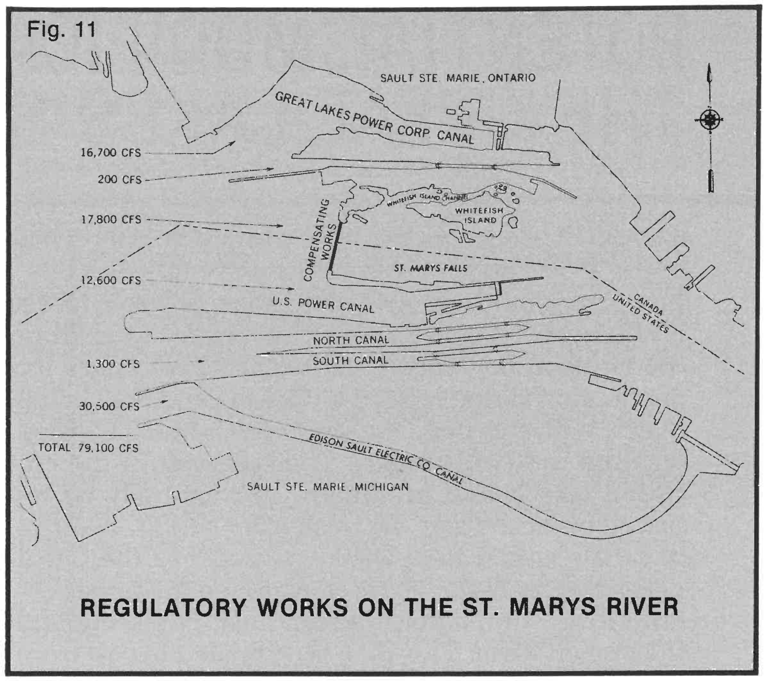
WELLAND CANAL DIVERSION. The Welland Diversion takes water from Lake Erie at Port Colborne and diverts it across the Niagara Peninsula to Lake Ontario, bypassing the Niagara River and Falls. The diversion is used primarily for navigation and hydropower, and also supplies water for industrial and municipal use. The current flow rate of Great Lakes water through the canal is about 9,400 cfs and is monitored by the International Niagara Committee. The International Niagara Committee is not a committee of the IJC. The Welland Diversion increased the outflow capacity of Lake Erie and has lowered the upstream lake levels. The mean level of Lake Erie has been lowered by around 5.3 inches, while Lake Michigan-Huron and Lake Superior were reduced by about 2.2 and 0.7 inches, respectively. No regulatory structures exist that would significantly increase water flow through the canal.

NEW YORK STATE BARGE CANAL. This canal takes water primarily for navigation purposes from the Niagara River and returns all of it to Lake Ontario through several tributaries and the Oswego Canal. The average flow of water through the New York State Barge Canal is about 700 cfs with a maximum flow during the navigation season (April to November) of 1,100 cfs. This diversion has little hydrologic impact on any of the Great Lakes. All of the flow is returned to Lake Ontario, with no loss of water to the system.

REGULATION OF LAKE ONTARIO OUTFLOW. The outlet of Lake Ontario is regulated by a series of structures and channel enlargements. The Iroquois Dam, Moses-Saunders Power Dam, Long Sault Dam and the Eisenhower and Snell Navigation Locks control the levels of Lake Ontario so that navigational as well as property owners' needs are met. The main control structure is the Moses-Saunders Powerhouse which has the capacity to discharge 330,000 cfs of Lake Ontario water into the St. Lawrence. The long-term average outflow of Lake Ontario is about 240,000 cfs. The objectives of the IJC's Regulation Plan 1958-D are to select outflows from Lake Ontario such that enough water is available for navigation and hydropower without hurting riparians or littoral property owners on Lake Ontario and the St. Lawrence River.

Lake Ontario is regulated under Criterion (k) of Plan 1958-D which says:

> "In the event of supplies in excess of the supplies of the past as adjusted, the works in the International Rapids section shall be operated to provide all possible relief to riparian owners upstream and downstream. In the event of supplies less than the supplies of the past as adjusted, the works in the International Rapids section shall be operated to provide all possible relief to navigation and power interests."



REGULATORY WORKS ON THE ST. MARYS RIVER

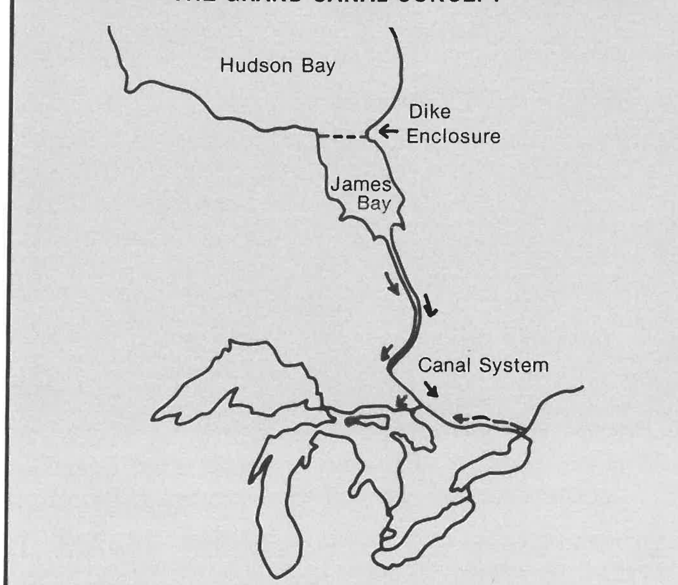
Source: International Great Lakes Levels Board

POTENTIAL MODIFICATIONS TO THE GREAT LAKES SYSTEM

GRAND CANAL CONCEPT. Originally conceived in the 1930's and revived in the early 60's and 80's, this plan would constrict the range of water levels on the upper Great Lakes by diverting water from the Hudson Bay watershed to the Great Lakes for distribution to arid regions of Canada and the United States. With this plan, the James Bay would be sealed off from the Hudson Bay. The saltwater in the enclosed lake would eventually and naturally be replaced by freshwater, via freshwater runoff. A series of canals would then transport water to the Great Lakes by way of the Harricanaw River, the upper Ottawa River, the Mattawa River, Lake Nipissing and the French River. This plan is estimated to cost from $79-$100 billion Canadian (see Figure 12).

NORTH AMERICAN WATER AND POWER ALLIANCE (NAWAPA). First presented in 1963 when water levels were at record lows, NAWAPA would divert water southward to the Great Lakes from rivers in Alaska, Yukon and British Columbia by means of a massive reservoir canal river system. A potential inflow of 40,000 cfs from the reservoir to Lake Superior was envisioned as a means to control lake level fluctuations. The 1963 cost estimates were about $100 billion. NAWAPA has never been and is not now being considered by the federal government or other proponents.

Fig. 12 THE GRAND CANAL CONCEPT



Source: Potential Impacts of Great Lakes Diversions by E. Kluitneberg

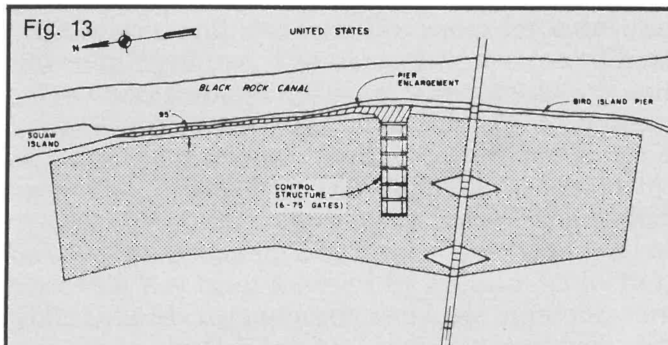
LAKE MANAGEMENT PLANS

The following plans were analyzed by the International Lake Erie Regulation Study Board (IJC, 1983). In addition to the specifics of each of the three plans, all call for dredging in the St. Lawrence River to accomodate increased flows from Lake Erie. These plans were found to be not economically justified.

NIAGARA PLAN 25N. This plan would excavate a narrow section of the Niagara River to increase the outflow from Lake Erie by 25,000 cfs. A channel about 3,400 feet long, 700 feet wide and up to 17 feet in depth would be excavated. Shore protection would be needed to offset high velocity waters. Control structures would be built to restrict water flows through the new channel when increased outflows were not needed. This structure would extend about 600 feet into the river and would contain six submersible tainter gates. Damages to wetland areas from this plan would be serious. Estimated decreases in maximum Lake Erie water levels due to this plan would be around 13 inches with changes in lake levels for Lake Superior and Lake Michigan-Huron estimated to be 0.8 and 4.8 inches, respectively. The estimated cost for this project is $134.2 million (1979 dollars). Estimated benefits were about $51.3 million (see Figure 13).

BLACK ROCK CANAL-SQUAW ISLAND PLAN 15S. Plan 15S would also increase the outflow of Lake Erie. A controlled diversion adjacent to the Black Rock Canal (which runs parallel to the upper Niagara

Fig. 13



NIAGARA RIVER PLAN 25N

Source: International Joint Commission

River) would be built in an attempt to alleviate high lake levels. Existing control structures and flow regulations for Lakes Superior and Ontario would be modified to work in conjunction with the new structure. With the operation of the nearby Black Rock Lock for navigation, average annual Lake Erie outflows would be increased by about 9,600 cfs. It is estimated that this plan would decrease maximum Lake Erie water levels by about 5.0 inches. Estimated costs for this project are $22.5 million with benefits estimated to be around $11.1 million in 1979 dollars (see Figure 14).

BLACK ROCK LOCK PLAN 6L. This plan utilizes the existing lock at the Black Rock Canal as a channel but would require a new gated control structure at the upstream end of the lock. Lake Erie outflows would be increased by about 3,700 cfs. The estimated costs were $13.8 million and benefits were about $4.2 million in 1979 dollars. Estimated decreases in the maximum Lake Erie water level would be 1.8 inches (see Figure 15).

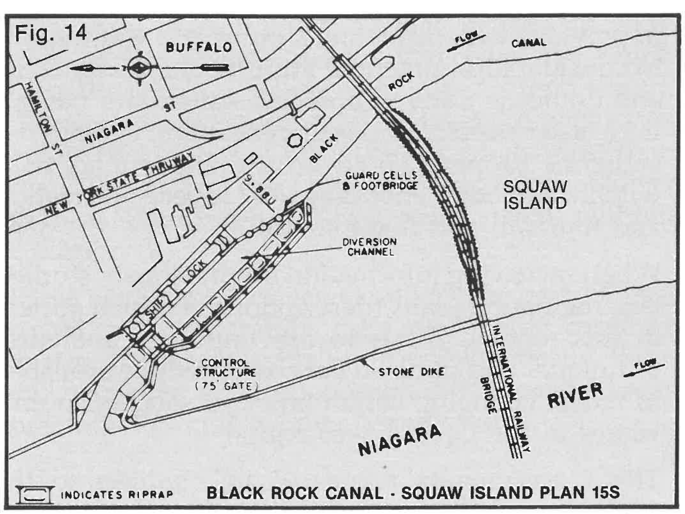
In 1964, the Canadian and American governments requested that the IJC investigate the possibilities of regulating the Great Lakes system for the benefit of navigation, power, flood control, agriculture, wildlife, recreation and other public purposes. In response, the International Great Lakes Levels Board was formed. The following plans were investigated and analyzed by the Board and were presented to the IJC in 1973.

PLAN SO-901. With Plan SO-901 and minor modifications of the St. Marys control works, the levels of Lakes Superior and Huron would remain at relatively the same position with respect to their mean levels. Outflow from Lake Ontario would need to be adjusted to account for the new outflow regime of Lake Superior, which could not exceed the discharge capacity of the Compensating Works plus 85,000 cfs during May through November.

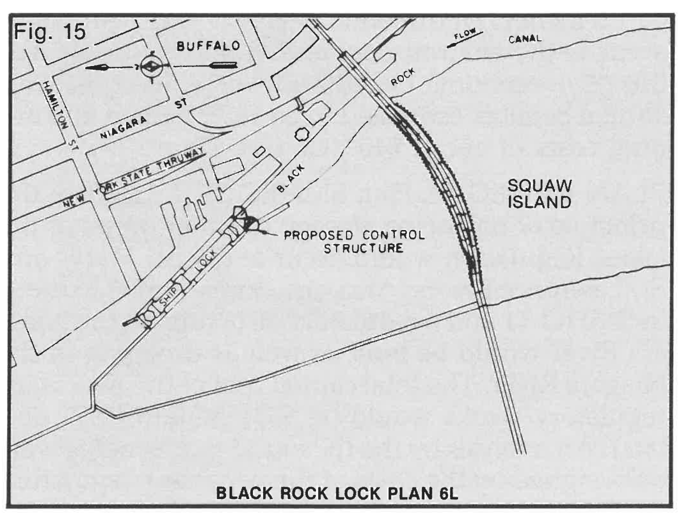
Plan SO-901 is the forerunner of the current regulation plan for Lake Superior, Plan 1977. Plan SO-901 is the same as Plan 1977 except that Plan 1977 employs forecasts of Lake Superior outflows based on projected supplies. This addition was made to minimize the possibility of Lake Superior exceeding its maximum level of 602 feet which is based on a monthly mean. This Plan also minimizes the number of gate movements needed in the St. Marys River, providing a uniform outflow from Lake Superior.

PLAN SMHO-11. This plan calls for the coordinated regulation of the four lakes, Superior, Michigan, Huron and Ontario. Regulation would occur through the use of existing structures for Lakes Superior and Ontario and new structures in the St. Clair and Detroit Rivers. With plan SMHO-11, an 11,000 cfs increase in the channel capacity of the St. Clair and Detroit Rivers would be required. Nine new structures would be built to reduce flows when necessary: Four in the St. Clair River, and five in the Detroit River. Total costs of this project would be $239.7 million. Average annual costs of this project would be $18 million; total benefits were estimated to be around $2 million (1971 dollars). Because costs of this project would be so much greater than its benefits, no attempt was made to refine and utilize this project.

PLAN SEO-33. Plan SEO-33 would raise the maximum and minimum monthly levels of Lake Superior but would lower the maximum and minimum monthly levels on Lake Michigan-Huron and Lake Erie. Dredging the upper part of the Niagara River plus building an eight gate regulatory structure at the head of the river would be needed with this plan. Capital costs for the Lake Erie regulatory works would be $107.7 million with annual costs of $8.1 million (1971 dollars). These costs would be approx-



Source: International Joint Commission



Source: International Joint Commission

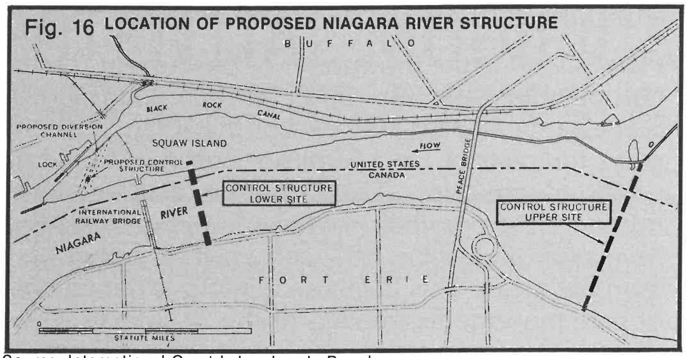


Fig. 16 LOCATION OF PROPOSED NIAGARA RIVER STRUCTURE

Source: International Great Lakes Levels Board

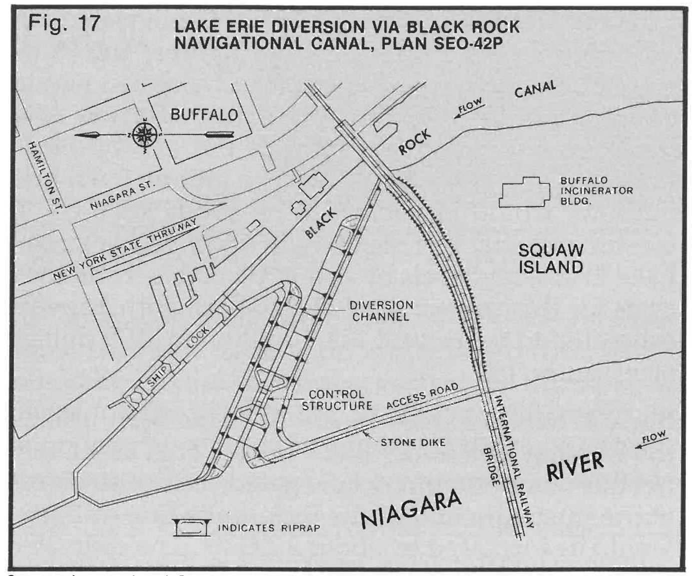


Fig. 17 LAKE ERIE DIVERSION VIA BLACK ROCK NAVIGATIONAL CANAL, PLAN SEO-42P

Source: International Great Lakes Levels Board

imately equalled by the corresponding average annual benefits of around $8 million (see Figure 16).

PLAN SEO-901. No new structure is required for this plan, but dredging of the Niagara River to provide a channel capacity increase of 4,000 cfs would be necessary. The dredging would occur just below the Peace Bridge and would result in a permanent general lowering of about 2.2 inches on Lake Erie and 0.7 inches on Lake Michigan-Huron. This lowering of lake levels is dependent on further regulation (similar to SO-901) at the St. Marys River and Lake Ontario. Lake Superior's mean monthly level would rise as a result of this activity. Capital costs of this plan would be $1.9 million with annual costs of $169,000 (1971 dollars). There are more economic benefits than costs. Benefits averaged around $6.36 million. However, environmental effects could be high. Also, there is no regulatory structure, so water couldn't be held back during periods of low levels.

PLAN SEO-42P. This is the same plan as Plan SO-901 except a controlled diversion through Squaw Island in the Niagara River would also be included. This channel would divert up to 8,000 cfs during times of normal supply. Total capital costs for this plan would be $4.9 million (1971 dollars). The plan would lower the levels of Lake Michigan-Huron and Lake Erie by an estimated 4.0 inches, and Lake Ontario by 1.0 inches. Detrimental effects of this plan might occur to the environment and to power supply. For this plan, economic benefits outweigh the costs, with annual benefits estimated to be $8.79 million and annual costs of about $400,000 (see Figure 17).

PLAN SMHEO-38. Plan SMHEO-38 is based on the principle of balancing storage of water on all of the lakes. Regulation would occur at the St. Marys and St. Lawrence Rivers. Also, structures similar to those in SMHO-11 and a regulatory structure on the Niagara River would be built as well as dredging in the Niagara River. The total capital cost of the necessary regulatory works would be $321 million (1971 dollars). An analysis by the IJC found that benefits were outweighed by the costs of the necessary regulatory works with annual benefits being about $10 million.

NEW IJC REFERENCE

On August 1, 1986 the Governments of the United States and Canada requested the International Joint Commission (IJC) investigate and examine methods of alleviating the adverse impacts of water level changes in the Great Lakes/St. Lawrence River Basin. This new reference calls for a comprehensive, multi-year study and will involve a substantial commitment of resources.

In making the new request, the Governments recognized that previous reports were based on recorded water supplies which are now being exceeded, that economic conditions have changed and that improved analytical techniques may now be available.

The IJC report will build on information accumulated in previous lake regulation studies and will take into consideration potential impacts on: Commercial and domestic water supply and sanitation; navigation; water supply for power generation; agriculture; shoreline property, both private and public; fish, wildlife and other environmental aspects; recreation and tourism; and flood control.

When reviewing information on previously studied lake regulation plans (descriptions of which appear in this report), IJC is to use improved analytical techniques and updated data bases, where available, to reflect changing conditions and socio-economic values in the Great Lakes region.

The Governments requested IJC, subject to the availability of adequate appropriations, to present its final report May 1, 1989. An interim report, focusing on measures to alleviate the present "crises" is to be submitted one year after the IJC study board begins its work.

Copies of the complete request from the U.S. and Canadian Governments are available from the International Joint Commission office in Washington, D.C.

FUTURE WATER LEVELS

The forecast of future water levels is extremely difficult and requires accurate information on the many factors described here. Generally, during the first 40 years of this century, Great Lakes water levels were low. During the next 30 years, lake levels were higher. For the past 15 years, lake levels have been higher yet.

Table 2. Conversion Table

1 acre-foot:	43,560 cubic feet (an acre-foot covers one acre of land with one foot of water)
1 acre-foot:	325,851 U.S. gallons
1 cubic foot:	7.48 U.S. gallons
1 cubic foot per second (cfs):	646,316 U.S. gallons per day 724 acre-feet per year 448.8 U.S. gallons per minute

It was in 1964 that record low levels were set on most of the Great Lakes. People were displeased about this and were wondering if the Lakes were being kept artificially low. Now, just over 20 years later, the Great Lakes are experiencing very high levels.

Most of the record high water levels on the Great Lakes that were set in 1973 were topped in 1985, with the exception of Lake Ontario. The Lake Ontario basin did not experience the extreme above average precipitation received by the rest of the Great Lakes basin in 1985. Lake Ontario precipitation was, however, eight percent above average in 1985. In addition, as the lowermost lake, it receives the runoff from the whole upper system. Lake Ontario would, therefore, be exceeding its all time record high levels except that Criterion (k) allows for greater flow than Plan 1958-D. So Lake Ontario is over two feet lower than if Plan 1958-D were being used without Criterion (k).

If one were to project water levels for the next 40 years based on recent trends, the Lakes would continue to rise. For water levels to drop dramatically, there will have to be a correspondingly long period of lower precipitation and warmer temperatures. Even if water supplies return to normal, as we now define normal, it will take six to ten years for the Lakes to return to average levels. With no indication of a change in temperatures and precipitation, it is likely that serious flooding and erosion problems will continue along the shorelines of the Great Lakes for several years to come.

APPENDICES

APPENDIX I

FEDERAL AND STATE AGENCIES INVOLVED WITH SHORELINE EROSION AND FLOOD ASSISTANCE PROGRAMS

U.S. ARMY CORPS OF ENGINEERS

NEW YORK, PENNSYLVANIA AND OHIO
U.S. Army Engineer District
1776 Niagara Street
Buffalo, NY 14207-3199
(716) 876-5454

ILLINOIS
U.S. Army Engineer District
219 South Dearborn
Chicago, IL 60604-1797
(312) 353-6428

MICHIGAN AND INDIANA
U.S. Army Engineer District
P.O. Box 1027
Detroit, MI 48231-1027
(313) 226-6440

WISCONSIN AND MINNESOTA
U.S. Army Engineer District
1135 U.S. Post Office & Customhouse
St. Paul, MN 55101
(612) 725-7712

STATE AGENCIES

ILLINOIS
Department of Transportation
Division of Water Resources
310 S. Michigan Ave., Room 1606
Chicago, IL 60604
(312) 793-3123

INDIANA
Department of Natural Resources
Division of Water
2475 Director's Row
Indianapolis, IN 46241
(317) 232-4160

MICHIGAN
Department of Natural Resources
Division of Land Resource Programs
P.O. Box 30028
Lansing, MI 48909
(517) 373-1950
or
Department of Natural Resources
Michigan Office for the Great Lakes
P.O. Box 30028
Lansing, MI 48909
(517) 373-3588

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Appendix I continued

MINNESOTA
Department of Natural Resources
Division of Water
500 Lafayette Road, Box 32
St. Paul, MN 55146
(612) 296-4810

NEW YORK
Department of State Coastal Zone
Management Program
162 Washington, 4th Floor
Albany, NY 12231
(518) 474-3643

OHIO
Department of Natural Resources
Division of Water
Building E, Fountain Square Court
Columbus, OH 43224
(614) 265-6717

PENNSYLVANIA
Department of Environmental Resources
Office of Resource Management
P.O. Box 1467
Harrisburg, PA 17120
(717) 783-5338

WISCONSIN
Department of Natural Resources
Bureau of Water Regulation and Zoning
P.O. Box 7921
Madison, WI 53707
(608) 266-8030
or
Department of Administration
Wisconsin Coastal Management Program
P.O. Box 7868
Madison, WI 53707
(608) 266-8234

APPENDIX II

OTHER AGENCIES

Great Lakes Environmental Research Laboratory
National Oceanic and Atmospheric Administration
U.S. Department of Commerce
2300 Washtenaw Ave.
Ann Arbor, MI 48104
(313) 668-2235

International Joint Commission
2001 S. Street, NW
Washington, DC 20440
(202) 673-6222

APPENDIX III

GREAT LAKES COMMISSION LAKE LEVELS, FLOODING AND SHORELINE EROSION TASK FORCE

Jerry Bartnik (Task Force Chairman)
GLC Commissioner
State Representative, Michigan

Richard Bartz
Special Assistant for Lake Erie
Division of Water
Ohio Dept. of Natural Resources

Kenneth DeBeaussaert
GLC Vice-Chairman, Michigan

Neil Dieterich
GLC Commissioner
State Senator, Minnesota

Joan Gipp
GLC Commissioner, New York

Scott Hausmann
Section Chief
Bureau of Water Regulation and Zoning
Wisconsin Dept. of Natural Resources

Daniel Injerd
Chief
Lake Michigan Management Section
Division of Water Resources
Illinois Dept. of Transportation

APPENDIX IV

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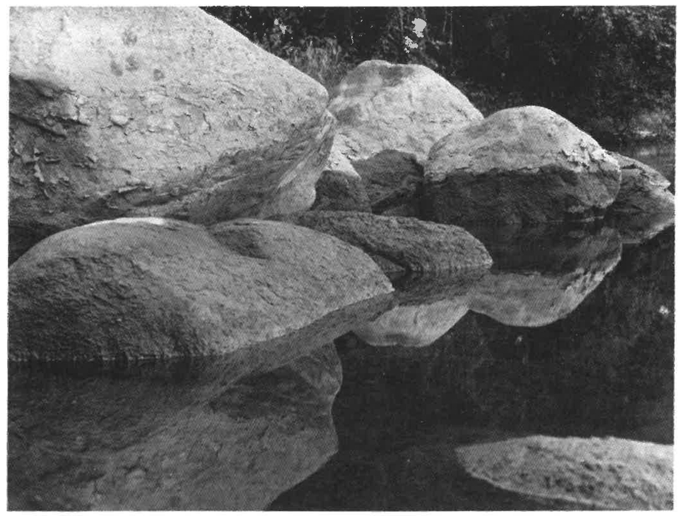
APPENDIX V

LIST OF FIGURES

LIST OF TABLES



For additional copies:

Great Lakes Commission
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Ann Arbor, Michigan 48109
(313) 665-9135

THE GREAT LAKES COMMISSION

was created by legislation of the eight Great Lakes States in 1955. It was authorized as an interstate compact commission by the U.S. Congress in 1968. It is unique in the United States and a reflection of the deeply felt need of the states to have an organization fully recognized by law that reflects common concerns about a shared resource, the Great Lakes, the largest body of fresh water in the world.

The Commission has no regulatory authority and it doesn't build projects. It deals with resource and economic issues of the eight states:

- Developing and sharing information
- Assisting in coordination of state positions on regional matters
- Advocating those positions on which there is agreement

The Commission provides a common regional voice for the States on Great Lakes issues, primarily to the U.S. Congress and the Federal government. It serves the States as a forum in which common solutions to common problems can be found.

MEETINGS OF THE COMMISSION

are held twice yearly, in spring and fall. An Executive Committee guides the work of the Commission between meetings.

When the Commission identifies common issues requiring detailed examination, specific task forces are appointed, drawing on Commissioners, experts from the States, private industry and educational institutions. When a Task Force completes its work, it is disbanded.

Meetings of the Commission and its Task Forces are fully open.

COMMISSIONERS INCLUDE

three to five persons from each State, determined by the State's own legislation. Some are designated because of their position in state government and some are legislators. At least one Commissioner per state is appointed by the governor.

The Commission invites Federal agencies to provide information and comments. The Federal and Provincial governments of Canada also designate observers to the Commission.

STAFFING

The Commission staff is small—a director, three staff professionals, a financial officer, two secretaries and part-time research assistants. The staff is located on the campus of University of Michigan.

COMMISSION ISSUES ARE DIVERSE

but can be generally divided into two areas—natural resources and economic:

NATURAL RESOURCES

- water pollution
- commercial and sport fishing
- planning
- coastal zone management
- recreational boating
- water policy
- hazardous waste management
- erosion and conservation
- wetlands
- acid rain
- wildlife
- lake levels
- Great Lakes diversion
- water use
- federal programs and legislation

ECONOMIC

- Seaway funding
- dredging
- port development
- maritime user fees
- project cost sharing
- intermodal transportation
- shipbuilding
- energy
- commodity shipment
- economic development and promotion
- export promotion
- federal preference cargoes
- federal actions affecting Great Lakes economy
- federal budget impacts
- regional economic analysis

FUNDING

The Commission is funded by the eight states on an equal share basis.

PUBLICATIONS

A publications list is available; write the Commission staff.