US Army Corps
of Engineers
North Central Division

GREAT LAKES LEVELS

Update Letter No. 101 December 1, 1993

The Regulation of the Outflow from Lake Superior

The natural outflow from Lake Superior is through the St. Marys River (Figure 1) into Lake Huron. In the vicinity of the cities of Sault Ste. Marie, Michigan and Ontario the river drops about 20 feet in less than a mile. This reach is known as the St. Marys Rapids. Although the rapids represent a hindrance to navigation, the 20-foot drop also represents a source of potential energy.

In the last 200 years, the St. Marys River has undergone many physical changes intended to both harness its energy and to allow passage of vessels of evèr increasing tonnage. A combination of these changes made it possible to control the flow in the river and thus the outflow from Lake Superior.

History of the River

The natural regime of the St. Marys River was first disturbed by man in 1797, when the Northwest Fur Company built a 38-foot long lock in one of the small natural channels on the Canadian side of the rapids. The first use of water from the St. Marys River to produce mechanical power began in 1822, when a raceway and sawmill were built by the U.S. Army at Sault Ste. Marie, Michigan.

The International Railroad Bridge, built in 1887, was the first modification in the river that significantly affected the outflow from Lake Superior. The piers placed in the river to support the bridge restricted a critical section of the river, effectively decreasing the river's flow. Subsequent construction of larger navigation locks and development of hydroelectric power plants also altered the outflow capacity of the

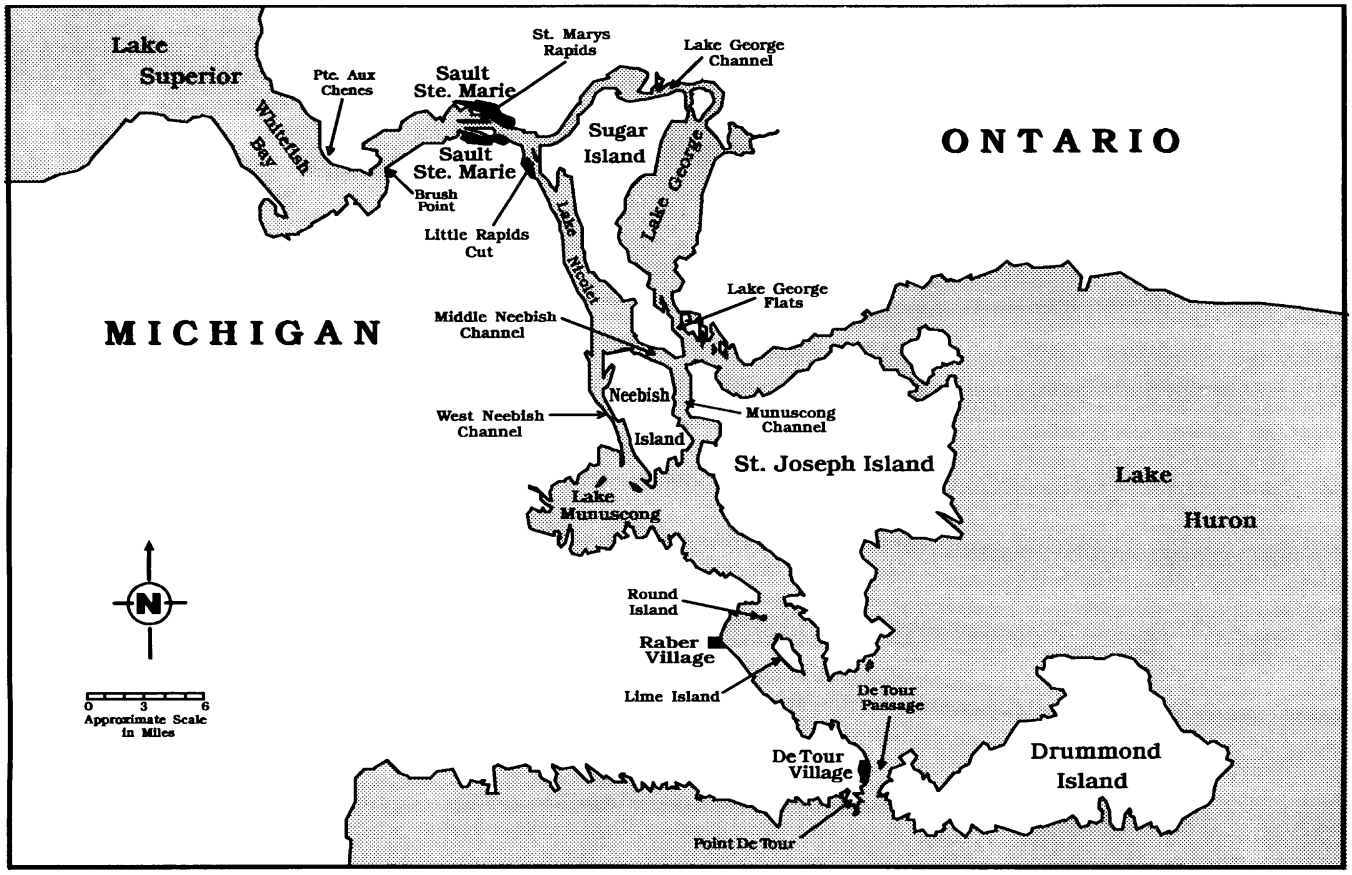

Figure 1. The St. Marys River

river.

To adjust for these changes in channel capacity, work began in 1901 on a gated dam at the head of the rapids. The outflow from Lake Superior has been completely controlled since the completion of this structure, known as the Compensating Works, in 1921. Crossing the international boundary, it controls the flow over the rapids, and therefore, the flow out of Lake Superior. It is almost 1,000 feet long and contains 16 vertical-lift gates. The first eight gates are owned by Great Lakes Power Limited (Canada), and the remaining eight gates are owned by the U.S. Government.

Figure 2 shows the present channel configuration in the vicinity of the St. Marys Rapids and contrasts this with a depiction of the area as it existed in 1825. Today, the water flowing from Lake Superior passes through a series of structures located adjacent to the St. Marys Rapids, which are identified in Figure 3. The structures located on the U.S. side of the river are the Edison Sault Electric Company hydroelectric plant, the U.S. Government power plant and four navigation locks. On the Canadian side of the river are the Canadian Ship Canal and Navigation Lock (now closed) and the Great Lakes Power Limited hydroelectric plant.

In 1985, in response to fishery interests, remedial works were placed in the rapids along the Canadian shore to enhance and protect the sports fishery in the river. The Fishery Remedial Works include a 2,800-foot long dike. This dike is designed to retain a sufficient flow of water along the south flank of Whitefish Island to approximate the previous natural conditions in this area of the rapids. Water is provided to the remedial works through the first gate on the Canadian side of the Compensating Works (Gate No. 1).

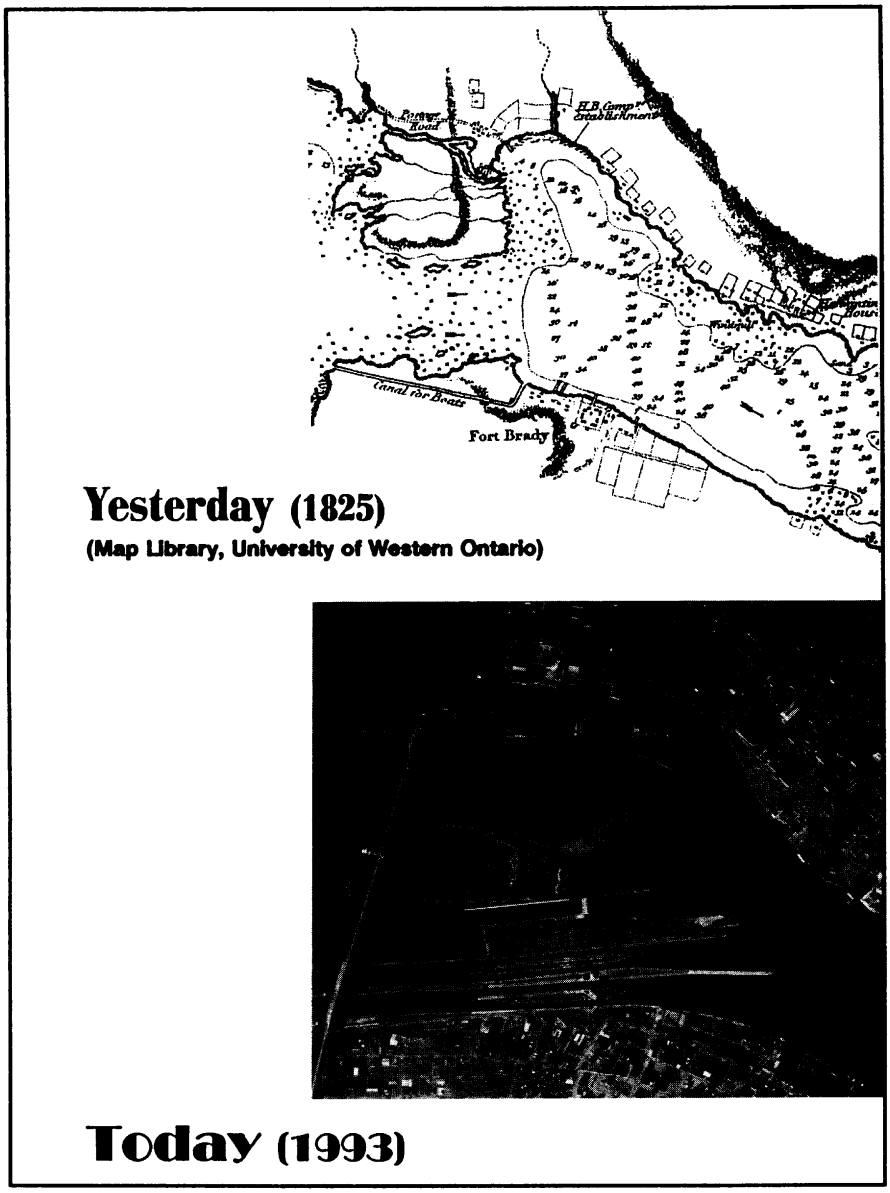

Figure 2. St. Marys River, vicinity of St. Marys Rapids

History of Regulation

The outflow from Lake Superior was first subject to some degree of artificial control as the result of the Rivers and Harbors Act of 1902. This act required the U.S. Secretary of War to approve operation of the early U.S. power canal diversions. The approval included restrictions on power diversions when the level of Lake Superior rose or fell outside specified limits.

By the terms of the International Boundary Waters Treaty of 1909, the regulation of the outflow from Lake Superior fell under the jurisdiction of the International Joint Commission (IJC). In its original Order of Approval (Order) for the Regulation of Lake Superior, dated May 26 and 27, 1914, the IJC set forth the conditions for the control and operation of the regulatory structures on the St. Marys River. The Order provides that the works be operated so as to maintain the level of Lake Superior, as near as possible, within a specified range, and in such a manner so as not to interfere with navigation. Further, it provides safeguards against extremely high levels in the harbor below the control works. The Order has been amended several times over the years to keep up with physical changes to the system, and to reflect changing philosophies on outflow regulation.

The Order calls for a plan of regulation to determine the outflow from Lake Superior consistent with certain conditions and criteria. Since 1916, seven different plans have been

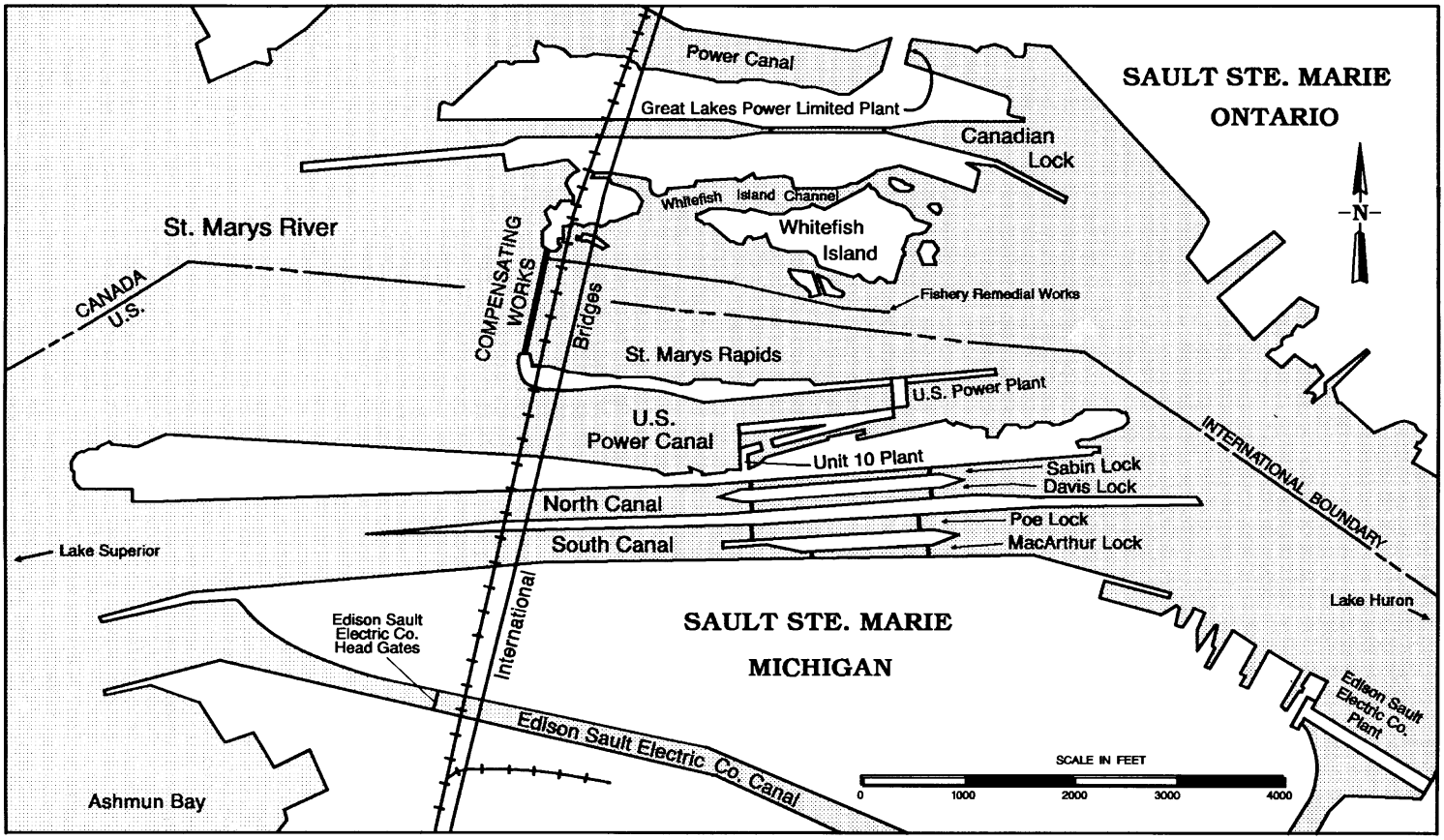

Figure 3. Present Configuration of the St. Marys River Rapids Area.

used to regulate Lake Superior outflows. These are listed, along with a short description, in Table 1. The regulation plans utilized up until 1973 determined outflows which considered only the levels of Lake Superior and the St. Marys River, and certain maximum and minimum flow limits. The last of this type of plan was known as the 1955 Modified Rule of 1949.

In a 1972 report entitled, "Special Interim Report on the Regulation of Lake Superior Outflows to Provide Relief from High Water Levels on the Great Lakes," the IJC stated that by taking into account the level of Lakes Michigan-Huron when regulating the outflow from Lake Superior, benefits would be provided throughout the Great Lakes system. (Since Lakes Huron and Michigan are at the same level and connected by the broad and deep Straits of Mackinac, they are hydraulically considered one lake.)

In 1973, at a time of record high water on the Great Lakes, an experimental plan was introduced. This plan, known as SO-901, incorporated the concept of trying to balance the levels of Lake Superior and Lakes Michigan-Huron. It was used as a guide in conjunction with the 1955 Modified Rule of 1949 to determine Lake Superior outflow until 1979.

The philosophy of systemic regulation was incorporated when the Order of Approval was amended on October 3, 1979. At that time a new regulation plan was activated -- Plan 1977. Plan 1977 incorporated many of the concepts of Plan SO-901, and added an outflow forecast component to smooth the operation of the plan.

Plan 1977 was revised in June 1990. The changes made were not dramatic, but were meant to bring the plan up to date and to improve its operational efficiency. The revised plan, known as Plan 1977-A, is the current operating plan. Plan 1977-A, like its predecessor, is designed to meet the conditions and criteria set forth in the Order of Approval, while operating within certain restrictions of the existing structures and the river system.

It should be noted that during periods of extreme high or low levels on the Great Lakes, the IJC has occasionally applied its discretionary authority and has set outflows which deviate from the prescribed regulation plan.

Conditions and Criteria for the Regulation of Lake Superior

The Order of Approval, as amended by Supplementary Order dated October 3, 1979, and updated to reflect International Great Lakes Datum, 1985 (IGLD, 1985), gives the following conditions for Lake Superior outflow regulation:

> "...maintain the monthly mean level of Lake Superior as nearly as may be within its recorded range of stage below elevation [603.22 feet (IGLD 1985)]; provide no greater probability of exceeding elevation [603.22 feet] than would have occurred using the 1955 Modified Rule of 1949; and ... maintain the levels of Lakes Superior and Michigan-Huron at the same relative position within their recorded ranges of stage and with respect to their mean monthly levels, ... in such a

Table 1
Lake Superior Regulation Plans

Name	Period of Operation	Description
Sabin Rule	1916-1941	Used a rule curve and monthly mean level of Lake Superior to determine the outflow. Minimum flow of 51,000 cfs, maximum of 126,000 cfs. Ensured about 48,000 cfs primary water for power. Not closely adhered to. Allowed a minimum of zero gates open.
Rule P-5	1941-1951	New rule curve, to increase flow allotted for power. Minimum flow of 54,000 cfs in winter, 57,000 cfs for the rest of the year. Maximum outflow 125,000 cfs. Followed closely.
Rule of 1949	1951-1955	Followed principles established in Rule P-5. Recognized increased supplies from Long Lac/ Ogoki diversions. Summer minimum flow 58,000 cfs, maximum 130,000 cfs. Winter minimum 55,000 cfs, maximum 85,000 cfs.
1955 Modified Rule of 1949	1955-1979	Same as Rule of 1949 with addition of minimum setting of 1/2 gate open.
Plan SO-901	1973-1979	First plan to incorporate the concept of systemic regulation. Used as a guide to deal with high water levels on the Great Lakes. Balance storage of Lakes Superior and Michigan-Huron -- linear relationship between beginning of month levels of the two lakes. Maximum outflow limited to 65,000 cfs side channel plus 16-gates open in the Compensating Works. Minimum outflow 55,000 cfs all months. No flows between 65,000 and 55,000 cfs. No flow changes in winter. Change in outflow from month to month limited to 30,000 cfs.
Plan 1977	1979-1990	Followed principles established in Plan SO-901. Added outflow forecast to smooth monthly flow changes.
Plan 1977-A	1990-present	Updated plan parameters and maximum outflow capacity. Modified outflow forecast. Allowed flow changes in winter with flows up to 85,000 cfs, and allowed flows between 65,000 and 55,000 cfs.

manner as not to interfere with navigation."

It is the condition related to the balancing of the levels of Lakes Superior and Michigan-Huron, which is the essence of the present regulation plan, Plan 1977-A, and its predecessors Plan SO-901 and Plan 1977.

In addition to the conditions, the Order states that the operation of the control structures shall be in accordance with a plan of regulation consistent with three criteria:

(a) maintain the level of Lake Superior between 603.2 and 599.6 feet (IGLD, 1985) when tested with water supplies of the past (1900-1976);

(b) maintain the water level below the locks at or below 583.8 feet (IGLD, 1985), when outflows are greater than those that would have occurred under the discharge conditions which prevailed prior to 1887; and,

(c) when Lake Superior's level is below 601.7 feet (IGLD, 1985), maintain the outflow at or below that which would have occurred under the discharge conditions which prevailed prior to 1887.

The criteria only address conditions on Lake Superior and on the St. Marys River immediately below the rapids. No limits or requirements are stipulated for levels on Lakes Michigan-Huron.

Outflow Limitations

Plan 1977-A takes into account certain outflow limitations not specified in the Order of Approval. These limitations reflect the realities of the physical system and the local interests on the St. Marys River. The outflow limitations incorporated into Plan 1977-A are as follows.

- The maximum Lake Superior outflow is limited to the discharge capacity of the 16-gate Compensating Works, plus 82,000 cubic feet per second (cfs), diversion through the remainder of the structures (the locks and hydropower plants).
- The maximum winter outflow (December through April) is 85,000 cfs.
- The minimum outflow (all months) is 55,000 cfs.
- The maximum change in outflow from month to month is limited to 30,000 cfs.

The first limitation reflects the physical limits of the control structures. The 82,000 cfs is based on the combined capacities of the hydropower plants and the typical flow needed to maintain ship traffic through the navigation locks.

The next limitation is considered the "safe" winter maximum, based on past experience with flooding due to ice jamming in the harbor below the structures and in the lower St. Marys River. It is possible to discharge higher flows in some winters, but the severity of ice conditions is not predictable. During a demonstration test in the late 1960s and early 1970s, winter flows as high as 95,000 cfs were attempted. Ice cover and water level conditions in the harbor must be closely monitored, with winter flows of this magnitude.

The minimum outflow limitation of 55,000 cfs arose from the need to maintain a minimum outflow for power and the fishery interests in the lower river. Past regulation plans had minimum outflows ranging from 51,000 cfs to 58,000 cfs.

The restriction on the change in flow from month to month (30,000 cfs maximum monthly change) relates to limiting extreme fluctuations of water levels in the river downstream of the structures. Large changes in outflow can have adverse effects on navigation and the environment in Soo Harbor and the lower river.

Balancing the Lakes

Central to Plan 1977-A is a relationship which determines the monthly Lake Superior outflow necessary to balance the water levels of Lake Superior and Lakes Michigan-Huron, taking into consideration their historic range of fluctuation and the differing sizes of the lakes and their drainage basins. The fundamental goal of the balancing relationship is to make the water stored in the two lakes (represented by the water levels) proportionally the same. If the level of Lake Superior at the beginning of the month is proportionally greater than that of Lakes Michigan-Huron, the relationship will call for a Lake Superior outflow greater than average. Conversely, if the beginning of month level of Lakes Michigan-Huron is in a relatively higher position than that of Lake Superior, the resulting outflow will be lower than average.

Plan 1977-A uses a forecast of future outflows to smooth the transition of flow from month to month. For each determination of a monthly regulated outflow release, the outflow from Lake Superior is estimated five months into the future, using the balancing relationship and checking against the outflow limits. The five forecasted outflows are averaged. The average is checked against the outflow limits and for compliance with the regulation criteria. If necessary it is adjusted and a final outflow is determined.

Distribution of Flow

The releases from Lake Superior, once they are determined by the regulation plan, are made through the various structures on the St. Marys River. To fulfill the requirements of the Order of Approval, the flows allocated to these facilities adhere to the following order of priority: 1) navigation; 2) fisheries; and, 3) hydropower.

The navigation requirements relate to the water necessary to operate the navigation locks. To meet the minimum needs of the fishery interests, a minimum of one-half gate open is maintained in the Compensating Works (Figure 4), to maintain a flow in the main portion of the rapids. Additionally, about 500 cfs of flow is released through Gate No. 1 of the Compensating Works, providing water to the Fishery Remedial Works. The remaining water can be used for power production, up to the capacity of the hydroelectric power plants. Any remaining water is released through the Compensating Works by opening additional gates, up to the maximum of 16.

The amount of water available in each country for power production is one-half of the total amount available for power purposes. Great Lakes

Power Limited is the sole Canadian user. On the U.S. side, the needs of the U.S. Government plant are satisfied first. (The energy is used to operate the locks complex, with the surplus energy sold to the local utility.) The remainder of the U.S. share of water is allocated to Edison Sault Electric under a contract with the Department of the Army.

International Lake Superior Board of Control

The International Lake Superior Board of Control (Board) was established by the IJC in its 1914 Order of Approval. The Board is charged with overseeing the supervision of operation and maintenance of the Compensating Works, power canals and all appurtenances on the St. Marys River at Sault Ste. Marie, Michigan and Ontario with a view to controlling the outflow from Lake Superior in accordance with the provisions of the IJC's Order of Approval. These are continuing responsibilities of the Board.

The Board has two members, one each from Canada and the United States. To assist them in carrying out their directives, each section has a Secretary, a Regulation Representative, and an On-Site Representative.

The Regulation Representatives make monthly Lake Superior outflow recommendations to the Board, and ensure that the outflow decisions of the Board are carried out. The Regulation Representatives also monitor the hydrologic conditions on the Lake Superior and Lakes Michigan-Huron basins; generate monthly probability forecasts of levels and outflows for these lakes; and, in general, provide technical support to the Board.

The On-Site Representatives oversee the gate movements and power and navigation operations; monitor the river levels; and, maintain liaison with the public for flow changes.

The Levels Reference Study Board, which was set up by the IJC to respond to a 1986 Reference to study fluctuating Great Lakes water levels, recently made several related recommendations to the IJC in March 1993. One of these concerned increasing the size of the Board. The purpose would be to increase state province, and citizen participation i Board decisions. This may become a future development if the IJC concurs.

Related Update Letters

No. 96, June 1, 1993: Water Levels Reference Study Board Recommendations.

No. 93, April 1, 1993: Soo Locks at Sault Ste. Marie, Michigan.

No. 76, November 4, 1991: International Great Lakes Datum, 1985.

No. 71, June 6, 1991: The Binational Approach of the International Joint Commission.

for **RICHARD W. CRAIG**
Colonel, EN
Commanding

Figure 4. Compensating Works in St. Marys River

Great Lakes Basin Hydrology

During the month of November precipitation on the Lakes Michigan-Huron and Erie basins was near average, while Lake Superior was below average and Lake Ontario above. For the year to date, precipitation is about 7% above average for the entire Great Lakes basin. With the exception of Lake Superior, the net supply of water to each of the Great Lakes in November was above average. Table 2 lists November precipitation and water supply information for all of the Great Lakes.

In comparison to their long-term (1900-1992) averages, the November monthly mean water levels of Lakes Superior, Michigan-Huron, St. Clair and Erie were 2, 10, 13 and 12 inches, respectively, above average, while Lake Ontario was about 2 inches below its average level. Shoreline residents on Lakes St. Clair and Erie, and to a lesser extent Lakes Michigan-Huron, are cautioned to continue to be alert to possible adverse weather conditions, as these could compound an already high lake level situation. Further information and advice will be provided by the Corps of Engineers should conditions worsen.

Table 2
Great Lakes Hydrology[1]

PRECIPITATION (INCHES)

BASIN	NOVEMBER				YEAR-TO-DATE			
	1993[2]	Average (1900-1991)	Diff.	% of Average	1993[2]	Average (1900-1991)	Diff.	% of Average
Superior	2.1	2.5	-0.4	84	29.3	28.3	1.0	104
Michigan-Huron	2.5	2.7	-0.2	93	32.6	29.7	2.9	110
Erie	3.0	2.8	0.2	107	33.5	32.2	1.3	104
Ontario	3.6	3.1	0.5	116	33.5	32.2	1.3	104
Great Lakes	2.6	2.7	-0.1	96	31.9	29.9	2.0	107

LAKE	NOVEMBER WATER SUPPLIES[3] (CFS)		NOVEMBER OUTFLOW[4] (CFS)	
	1993[2]	Average (1900-1989)	1993[2]	Average (1900-1989)
Superior	9,000	18,000	75,000	80,000
Michigan-Huron	50,000	36,000	204,000[5]	190,000
Erie	23,000	-5,000	217,000[5]	199,000
Ontario	33,000	20,000	257,000	236,000

[1]Values (excluding averages) are based on preliminary computations.
[2]Estimated.
[3]Negative water supply denotes evaporation from lake exceeded runoff from local basin.
[4]Does not include diversions.
[5]Reflects effects of ice/weed retardation in the connecting channels.

CFS = cubic feet per second.

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