US Army Corps
of Engineers
North Central Division

GREAT LAKES LEVELS

UPDATE LETTER NO. 77 2 DECEMBER 1991

LAKE ONTARIO REGULATION PLAN IMPROVEMENTS

Background

As mentioned in the October 1, 1991 issue of "Great Lakes Levels, Update Letter No. 74," Lake Ontario outflows have been regulated since April 1960. The current regulation plan, Plan 1958-D, has been used by the International St. Lawrence River Board of Control since 1963. It was developed in order to provide deep-draft navigation throughout the St. Lawrence-Lake Ontario system, provide hydroelectric power generation, reduce the levels range for riparians (shoreline property owners), and provide improved Montreal Harbor levels. It also requires that the downstream St. Lawrence River be provided the same protection it had prior to construction of the project.

During the last 30 years, Lake Ontario has been subjected to extreme hydrologic conditions to which interest groups have adapted. New interest groups have developed as a result of these extremes, most notably the recreational boating interest (Figure 1).

Historically, the plan with discretionary deviations has performed well, resulting in lower levels during wet periods and higher levels during dry periods. However, there have been numerous occasions when the plan has been criticized. During extended wet periods, there is a perception by riparians that regulation keeps the

Figure 1. Recreational Boats

levels too high. Many riparians have seen their property become inundated or substantially eroded away when subjected to high levels and storm-induced waves. During extended dry periods, there is a perception that regulation keeps levels too low. Many boaters have lost propellers or grounded during the season or had difficulty pulling their boats out at the end of the season due to lower than expected levels.

Any regulation plan has a limited ability to affect water levels, since it can only specify an outflow. If it were possible to control the inflow as well, a particular level could be assured. However, the inflow to the lake comes from upstream lakes and streams which flow into the lake's drainage basin and from the net sum of hydrologic factors. These factors include precipitation which falls directly on and evaporation which is extracted from the lake surface.

The Great Lakes basin consists of 298,500 square miles of land and water surface area. Lake Ontario receives the natural drainage of all of the other lakes, in addition to its own net basin supply. An additional 1,800 cubic feet per second (cfs) enters the system, which is the net diversion of 5,000 cfs from the Albany River basin to Lake Superior (Long Lac-Ogoki diversion) and about 3,200 cfs from Lake Michigan through the Chicago Sanitary and Ship canal (Chicago diversion). The vast majority of upper lakes' supplies enter Lake Ontario via the Niagara River at an average rate of 202,000 cfs. The Welland Canal also provides about 9,400 cfs from Lake Erie.

Previous Studies to Update Lake Ontario Regulation

In 1973, the board requested that its working committee review actual operations since regulation began, "with the objective of possible incorporation of some of the operational experience and techniques employed over the years into the regulation plan." Four plans were developed. However, after reviewing the results of these plans in 1975, the board concluded that none provided significant improvement over Plan 1958-D with discretionary authority.

Subsequent to completion of the 1975 review, the International Joint Commission requested the board to update the report to include data for the period from 1900 to 1978 to examine how each alternative plan compared to the present plan in terms of reducing the range of stage and meeting the criteria. In January 1980, the board recommended that Plan 1958-D, with operational discretion, be continued. This was because none of the plans investigated showed a marked improvement over the present plan. Also, any modifications to the plan's limits or criteria would redistribute benefits among the interests and vary the extent to which the criteria are satisfied.

As a result of conditions which occurred during the summer of 1987 on the lake and the St. Lawrence River, further studies to improve Lake Ontario regulation have been undertaken.

Regulation Plan 1958-D

The current plan consists of a supply indicator, two basic relationships, seasonal adjustments, and a number of maximum and minimum outflow limits. The basic regulated outflow is derived from the basic relationships which show outflow as a function of lake level and adjusted supply indicator. The basic regulated outflow is modified by applying seasonal adjustments. Seasonal adjustments are applied in order to store water in the winter, spring, and early summer months by reducing the outflow below the basic relationship outflow and to increase outflow above the basic relationship outflow in the late summer and fall months. The resultant seasonal adjusted outflow is then compared to maximum and minimum outflow limits which vary throughout the year. If the seasonal adjusted outflow is between minimum and maximum limits for the period, it is adopted as the regulated outflow. Otherwise, the applicable outflow limit is adopted as the regulated outflow.

The L-limit is based on the channel excavations in the International Rapids Section which were "designed to provide stipulated limiting depths and velocities for navigation and stipulated maximum velocities for formation of an ice cover." During April through December, outflows are limited by permissible navigation velocities and depths. During January through March, outflows are limited by permissible ice-forming velocities or winter operating conditions.

The I-limit controls the maximum allowable flows for ice formation requirements near Montreal. It restricts the outflows from Lake Ontario to an amount such that the outflow from Lake St. Louis does not exceed 280,000 cfs during the third and fourth quarters of December.

During certain periods of the year, the deviation of regulated outflows from pre-project outflows is moderated. Pre-project refers to the time before the seaway was built. The P-limit was included for this purpose and pertains to maximum and minimum values.

The M-limit pertains to the "absolute" minimum outflows for each period of the year. The load requirements of the power entities in the International Rapids Section were the chief factor for determining winter minimum outflows, while the minimum summer outflows were based on the requirements of the navigation and riparian interests in the Canadian reach of the river. The limit varies from 188,000 cfs in April and May to 210,000 cfs in December and January.

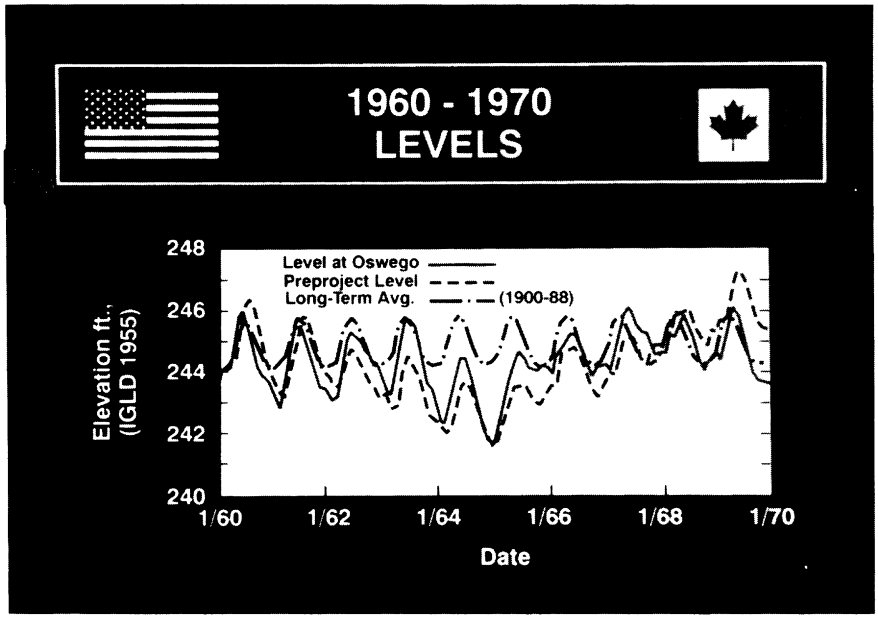
The final outflow limit, the J-limit, specifies that the variation in outflow between quarter-months is limited to 20,000 cfs except when other outflow limits require a greater variation.

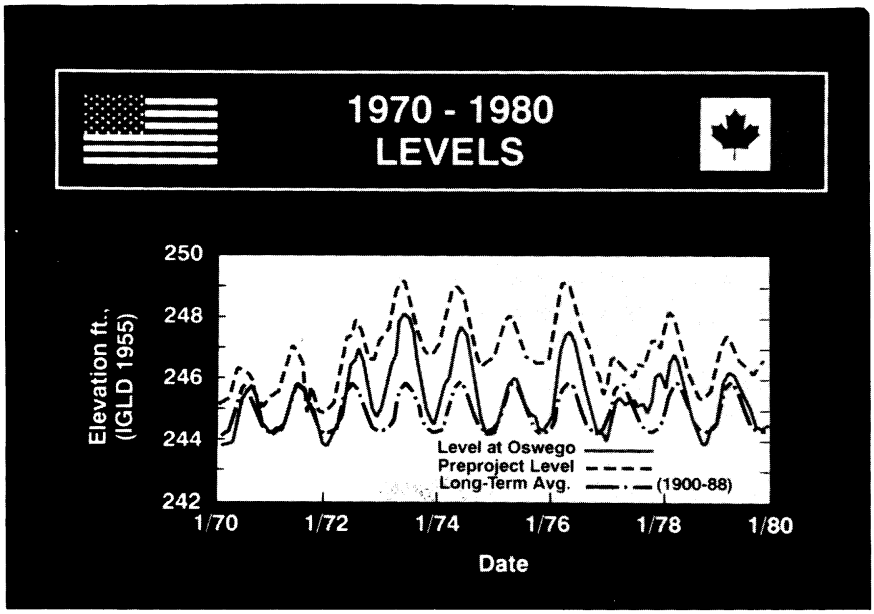
The adoption of Plan 1958-D was based on its successful performance in meeting the requirements of established criteria as compared to pre-project conditions. The following briefly summarizes the criteria of the plan:

a. Minimum regulated outflows to protect navigation interests in Montreal Harbor.

b. Regulated winter outflows to permit formation of a stable ice cover in the International Rapids Section for power generation. The maximum mean velocity which will permit ice formation in this section of the river is 2.25 feet per second.

c. Regulated outflows during the annual spring ice breakup (in





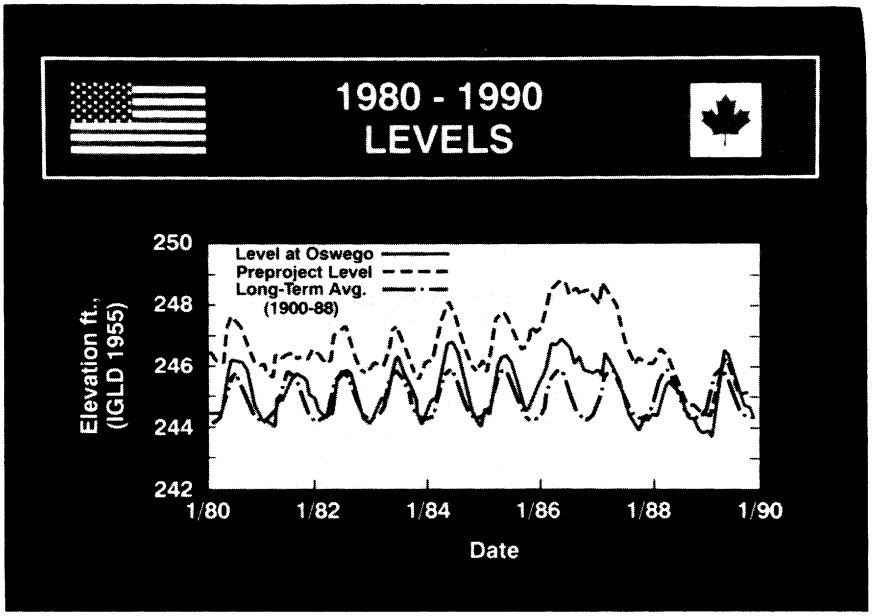


Figure 2. Lake Ontario Levels (1960-1990).

Great Lakes Basin Hydrology

The precipitation, water supplies, and outflows for the lakes are provided in Table 1. For the precipitation, this includes the provisional for the past month, the year-to-date and the long-term average. Both the provisional and long-term average water supplies and outflows are also shown.

Table 1
Great Lakes Hydrology[1]

PRECIPITATION								
BASIN	NOVEMBER				YEAR-TO-DATE			
	1991*	AVG.**	DIFF.	% OF AVG.	1991*	AVG.**	DIFF.	% OF AVG.
Superior	4.4	2.5	1.9	176	33.3	28.2	5.1	118
Michigan-Huron	3.1	2.7	0.4	115	33.7	29.6	4.1	114
Erie	3.0	2.8	0.2	107	29.8	32.2	-2.4	93
Ontario	2.4	3.1	-0.7	77	30.5	32.1	-1.6	95
Great Lakes	3.4	2.7	0.7	126	32.7	29.8	2.9	110

LAKE	NOVEMBER WATER SUPPLIES***		NOVEMBER OUTFLOW[3]	
	CFS[2]	AVG.[4]	CFS[2]	AVG.[4]
Superior	109,000	18,000	70,000	80,000
Michigan-Huron	73,000	36,000	188,000[5]	190,000
Erie	-15,000***	-5,000***	195,000[5]	199,000
Ontario	6,000	20,000	223,000	236,000

*Estimated (inches) **1900-89 Average (inches)
***Negative water supply denotes evaporation from lake exceeded runoff from local basin.

[1]Values (excluding averages) are based on preliminary computations.
[2]Cubic Feet Per Second [3]Does not include diversions [4]1900-89 Average (cfs)
[5]Reflects effects of ice/weed retardation in the connecting channels.

For Great Lakes basin technical assistance or information, please contact one of the following Corps of Engineers District Offices:

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Montreal Harbor and in the river downstream) no greater than would have occurred assuming the project had not been built.

d. Regulated outflows to protect riparian interests on Lake St. Louis, in Montreal Harbor, and on the river downstream.

e. Minimum regulated outflows to secure the maximum dependable flow for power.

f. Ensure that maximum regulated Lake Ontario outflows shall not produce dangerous navigation conditions.

g. Regulated outflows for the benefit of shore property owners by reducing extremes of stage which have been experienced.

h. Regulated monthly mean level of Lake Ontario shall not exceed elevation 246.77 feet with the supplies of the past as adjusted.

i. Regulated outflows to reduce the frequency of high levels.

j. The regulated monthly mean level of the lake from 1 April to 30 November shall be maintained at or above elevation 242.77 feet. The pre-project minimum water level is 241.61 feet.

k. For high level conditions all possible relief is provided to the riparian owners upstream and downstream. When low levels occur, all possible relief is provided to navigation and power interests.

This last criterion (Criterion (k)) was included to allow outflows to be specified in response to conditions outside the range on which the plan was developed. Since regulation began, discretionary deviations occurred during the 1960s in response to low supplies and during the 1970s and 1980s in response to high supplies. The most recent invocation of Criterion (k) by the IJC was in December 1985.

Plan Performance

As mentioned previously, since the initiation of Lake Ontario regulation, the Great Lakes have been subject to periods of both low and high supply periods. Precipitation on the Great Lakes basin was generally below average during the early 1960s, most notably 1963, which was 17 percent below average. Between 1965 and 1988, above-average precipitation prevailed. Only 5 of these 24 years had below average precipitation, and only 1974 was more than slightly below.

Throughout the dry and wet periods, Lake Ontario regulation has performed as intended. While record low levels were being recorded on Lakes Michigan-Huron in 1964 and 1965, the levels on Lake Ontario were higher than would have occurred with pre-project conditions. Similarly, levels were maintained below pre-project levels during high supply periods in the mid-1970s and late 1980 (Figure 2). Strict application of the procedural plan would not have mitigated these extreme situations, but for the discretionary actions under Criterion (k).

The sequence of high supplies which occurred in 1985 and 1986 exceeded all records on the Great Lakes. Record high levels were established on each of the upper Great Lakes. In December 1985, the IJC invoked Criterion (k) in light of these records levels. However, lower net basin supplies on Lake Ontario and extraordinarily high outflows prevented new record levels on the Lake. During January 1987, outflows of 360,000 cfs were possible due to the relatively mild winter and ice-free conditions on the St. Lawrence River. By this time, Criterion (k) operations had reduced Lake Ontario levels by about 3.5 feet.

November 1986 to July 1987 was the driest 9-month period on the Great Lakes during this century. The strategy to discharge the greater of plan or pre-project during the prevailing high supply period (December 1985 invocation of Criterion (k)), resulted in levels dropping rapidly during the sudden unexpected shift in supply situations. The levels which resulted during the summer of 1987 were below average; a condition which, although not intrinsic to the plan, had not been experienced during that time of year for decades. The "low" (actually slightly below average) levels resulted in a great deal of criticism regarding the plan's ability to respond to changing supply conditions. The recreational boating industry which had increased significantly within the 1000 Islands area of the St. Lawrence River during the high water years was particularly vocal.

Present Efforts to Improve Lake Ontario Regulation

Improvements to Lake Ontario regulation are being investigated by several parallel efforts. The following is a summary of the efforts and progress which has been made to date:

a. Studies Being Undertaken by the Levels Reference Study Board.

The IJC's Levels Reference Study Board is investigating changes to the plan and new procedures. Interests not previously considered may be factored in, such as recreational boating and environmental concerns. The board is working with individuals associated with the St. Lawrence River Working Committee drawing from the investigations that have already been undertaken. Recent investigations identified procedures within the plan which can be updated or modified. Specific factors considered were updating the database, supply factors, and seasonal adjustments.

The original plan is based on data from 1860 to 1954. Although this data includes periods of low and high supplies, it was decided that including the low supplies of the early 1960s and extremely high supplies of the 1980s, would result in improved supply indicator factors in the plan; the revised database is for the period 1900-1986. Historic data are used in the plan development as a means of testing the plan against conditions that have at one time occurred. It should be noted, however, that what has happened during the last 100 years may not reflect what may have happened in centuries past. As such, any plan may perform poorly when subjected to a sequence of supplies not experienced since record keeping began prior to 1860.

The supply indicators and seasonal adjustment factors in Plan 1958-D were examined by the working committee, and these studies will be continued by the reference study,

which also is in a posture to examine completely new techniques.

b. Information Gathering by Environment Canada and the Buffalo District.

In March 1990, Environment Canada, Burlington, Ontario, sent out 25,000 questionnaires to property owners on the Canadian shores of the Great Lakes. The purpose of the survey was to collect information on flooding and erosion, owner's attitudes towards water-level fluctuations, and other socioeconomic data. Response to the questionnaire was excellent with over 58 percent returned. Analysis showed a strong preference for levels which are near the long-term average.

Also, in 1990, Environment Canada wrote to Ontario's conservation authorities, located on Lake Ontario and the St. Lawrence River, asking for input to the Plan 1958-D study. The majority of those who replied indicated that they prefer the present regime of water-level fluctuations and suggested that no changes be made to the plan or the IJC Orders of Approval until a thorough study is completed.

The Buffalo District carried out an extensive survey of recreational boating facilities along the U.S. shoreline of Lake Ontario between Massena and Youngstown, New York. The data is presently being compiled into a reference document, which includes descriptions of marinas, photos, and sketches. A database is being formulated for ready access and updating. The information will be directly tied to a computerized water-level data collection system, which is linked to the district by satellite.

These recent efforts to acquire data supplement the information provided by the working committee to identify the range of levels which would be preferred by interests.

c. Bulletin of St. Lawrence River Levels.

The Buffalo District is presently developing a monthly bulletin, which will provide forecasts of St. Lawrence River levels between Cape Vincent and Massena, New York. This work is being performed for the St. Lawrence Board as part of its public information program. During the boating season, the Cornwall Office of Environment Canada issues a news release on the water level conditions on Lake Ontario and in the St. Lawrence River as far downstream as Montreal Harbor, about once every 3 weeks. The U.S. Army Corps of Engineers and Environment Canada are currently in the process of combining the two products for publishing it as an international bulletin starting in spring 1992. Hence, information on river levels will be available for seven locations, from Lake Ontario to Lake St. Francis in Quebec.

d. Assessment of Levels Forecasting Techniques.

One of the most important aspects of improving lake-level regulation is developing more reliable forecasting techniques of water supplies. In the weekly operations that are performed to determine the plan outflow, an assessment is made of supply conditions that have occurred in prior weeks and that could occur in the near future. The probability of exceeding supplies of the past for 5, 50, and 95 percent of the time is considered. Based on weather data and outlooks supplied by the U.S. National Weather Service and the Canadian Atmospheric Environment Service, a strategy for future outflow releases is adopted. However, weather predictions change drastically in a very short time. This is particularly true in this part of the world, due to the many factors which can influence the weather, such as arctic air troughs and the proximity to large bodies of water.

Many agencies and universities around the Great Lakes are investigating new and improved forecasting techniques, which can be used in conjunction with improved regulation procedures.

e. Other Work Being Performed

The U.S. Army Corps' Cold Regions Research and Engineering Laboratory has completed its development of an ice-forecasting model for the St. Lawrence River. The model will be installed on Buffalo District computers. The objective of model development is to provide a method to assist in determining required outflows for ice management. The model will be evaluated, tested, and used to assist in the regulation of Lake Ontario.

The Great Lakes Environmental Research Laboratory (GLERL) Large Basin Runoff Model is being installed on Buffalo District computers. This model can be used to help estimate the net basin supply to Lake Ontario and help in forecasting conditions.

Closing Remarks

Regulation of Lake Ontario outflows has provided benefits to Lake Ontario and St. Lawrence River riparians, by decreasing the range of level fluctuations which had occurred under preproject conditions. It has also provided a source of abundant hydropower and a route from the lake to the ocean. New interests that have developed along the shores and new sensitivities to the environment since the initial development of the plan make a plan modification necessary. The final outcome of this effort will most likely be a dynamic regulation procedure, i.e., a combination of a regulation plan guided by hydrologic-based forecasting models. The procedure will be flexible to incorporate future regulation improvements and operational experience. Discretionary actions may be formalized to some degree; however, they cannot be eliminated, since future supply conditions will remain unknown.

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