# A REPORT ON THE

# 1985 RECORD HIGH WATER LEVELS

# OF THE GREAT LAKES

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Note: The contents of this report do not necessarily reflect the views and policies of Environment Canada.

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## 1.0 PURPOSE AND SCOPE

This report summarizes the events leading to the extreme high water level conditions on the Great Lakes in calendar year 1985 and the resulting flood and erosion damages. It is planned that a subsequent edition of this report will be prepared covering Great Lake water level conditions in 1986. Federal, Provincial and Municipal Governments have closely monitored the high Great Lakes water level situation with all levels of government including the International Joint Commission responding to this extreme event and public concerns thereof. The purpose of this report is to place in one document much of the data and information pertaining to the record high lake levels for reference and use by all interested agencies and persons.

Although this report is written from the perspective of the programs and activities of the Water Planning and Management Branch (WP&MB), Inland Waters Directorate, Ontario Region, Environment Canada, an attempt has been made to present information on this event in a comprehensive manner rather than from the viewpoint of this one agency. It is recognized that information, or actions of other agencies may be inadvertently missing from this report. It is hoped that omissions of consequence will be brought to the attention of the authors.

All data in this report are in metric units unless stated otherwise. Lake water levels are measured in metres on the International Great Lakes Datum (1955).

## 2.0 CONDITIONS LEADING TO HIGH GREAT LAKES WATER LEVELS IN 1985

### 2.1 General

Since the late 1960's, water levels from Lake Superior to Lake Erie have been higher than average. This condition is a result of the persistent above-average precipitation that has occurred over the Great Lakes Basin since 1967. As of the end of 1984, water levels on these lakes were slightly below the record high water levels established in late 1972. The extreme hydrologic conditions that were to follow caused the lake water levels to rise to new monthly record high water levels (Table 1 and Figures 1 to 5). The following sections discuss the several major factors which caused the high lake water levels in 1985.

### 2.2 Precipitation

The recorded monthly mean precipitation over the Great Lakes are summarized by lake on Table 2.

Precipitation on the Lake Superior Basin was near average through the end of 1984 and the first three months of 1985. However, beginning in April 1985, monthly precipitation rates were well above average, especially in May, September, November, and December. Precipitation for the period November 1984 through March 1985 was near average; 18% above average for April to July; and 61% above average during the five month period of August to December 1985. This condition was responsible for the rise in Lake Superior's water level at the same time as water was being stored on Lake Superior by order of the International Joint Commission and International Lake Superior Board of Control (see Section 4.1).

Above average precipitation in September through December 1985 caused Lake Superior water levels to reach new record monthly high water levels.

On the Lakes Michigan and Huron Basins, precipitation was well above average from December 1984 to April 1985. While precipitation rates were near average in May and dropped to below average in June 1985, well above average precipitation was again experienced in August through December 1985.

Preliminary data show that the Lake Superior, Michigan and Huron basins received record high precipitation in 1985. The Lake Erie Basin also experienced well above average precipitation from November 1984 to March 1985, while precipitation on the Lake Ontario Basin was slightly above average. Precipitation in subsequent months was average to slightly below average on both lakes until November when record local water supplies in excess of double normal precipitation volumes were received.

Precipitation on the entire Great Lakes Basin from November 1984 to April 1985 was about 20% above average; and from May to December 1985 it was about 27% above average. Total precipitation for the year on the entire Great Lakes Basin in 1985 was about 1025 millimetres (26% above average) which was a new record high precipitation event for the record period of 1900 to 1985.

## 2.3 Runoff

Precipitation causes changes in the Great Lakes water levels as a function of the magnitude and timing of runoff entering the lakes. The Water Resources Branch (WRB) of Inland Waters Directorate, Ontario Region, Environment Canada examined the winter and spring streamflow data from a number of selected Canadian tributaries draining into the Great Lakes above the Niagara River.

Total discharges for the period January through April 1985 were compared with the long-term averages for the same four-month period. One representative tributary for each lake basin was selected for comparison purposes (Table 3).

Based on analysis of the data, WRB concluded that runoff into Lakes Superior, Huron, St. Clair and Erie from the Canadian Basin during January - April 1985 has been in the order of 20%, 40%, 65% and 45% respectively above normal for those lakes, and was the highest of any January - April period of the past 20 years of record.

The WRB review also identified that the 1985 peak tributary flows occurred about one week earlier than normal in the tributaries of Lakes Erie and St. Clair. Peak flows occurred at about the normal time in 1985 in tributaries of Lakes Superior and Huron.

## 2.4 Other Hydrometeorological Factors

a) Evaporation

Lake evaporation data (Table 4) from the Atmospheric Environment Service (AES), Environment Canada, were examined to assess the extent that this process affected lake water levels this year. On Lake Superior, evaporation in the first three months of 1985 was near average. Evaporation in April, May and June was low (net condensation occurred). On Lake Huron, evaporation in the first four months of 1985 was about 23% below average. New record low evaporation (net condensation) occurred in April. In May and June, evaporation was near average. On Lake Erie, evaporation was near average in the first three months of 1985, below average in April and above average in May and June.

In summary, although of much lesser significance than precipitation and runoff, the low evaporation in the early part of 1985 can be considered a factor leading to the high lake water levels.

b) Ice Jams

A severe ice jam occurred in the upper Niagara River in the last week of January and remained throughout much of February 1985. Ice retardation in the Niagara River is considered a normal event, and on the average amounts to flow reductions of about 110 and 130 cubic metres per second (cms) for January and February, respectively.

Ice retardation estimates for Niagara River streamflow during January and February 1985 caused by the unusual and severe ice jam were about 280 and 850 cms, respectively. Because the ice retardation effect lasted only a short time, the maximum raising effect due to Niagara River ice jams this year was about 0.06 metres on Lake Erie. The effect on Lakes St. Clair, Michigan and Huron was even smaller as the backwater effect diminishes on these upper lakes. A more detailed hydraulic study will be required to refine these estimates.

c) Welland Canal

On October 14, 1985, a small part of the wall at Lock No. 7 of the Welland Canal caved in rendering the lock unusable for about 24 days. The lock was put back into service on November 7 after emergency repairs were completed. During the period of this repair, navigation activities along the Welland Canal ceased, and thus reduced, very slightly, the amount of the diversion. As Lock 7 is downstream of the location in the canal where diversion water is taken off for the DeCew Falls Power plants, these power diversions were unaffected by this incident. Because of the small amount of the reduction in diversion and the short duration of this incident, the temporary impact on Lake Erie's water level

## 2.5 Lake Water Levels

Figures 1 to 5 are hydrographs of monthly water levels on the Great Lakes. Lake Superior water levels were slightly above average in the latter part of 1984 and the first three months in 1985. Beginning in April 1985, above average precipitation, together with the emergency actions to store water on Lake Superior beginning in May, caused the lake to rise rapidly.By October 1985 the lake set a new record high water level exceeding elevation 183.5 metres. Despite maximum possible outflows in the St. Mary's River from October 11 through to mid December these record high water levels continued with new monthly mean records of elevation 183.5 metres being set for November, and 183.4 metres for December.

Water levels on Lakes Michigan-Huron were near record maximum levels from November 1984 to February 1985. The subsequent above-average precipitation caused these lake water levels to increase rapidly. New record high water levels were set in April, May and June and again in October, November, and December 1985.

Lake St. Clair normally receives about 98 per cent of its water supply from Lake Huron. Hence, when Lake Huron is high producing high inflows into Lake St. Clair, the water levels on Lake St. Clair react accordingly. New record high water levels were set in February through May on Lake St. Clair, and again in September to December 1985.

Lake Erie's water level began to rise in the latter part of February, much earlier than normal. The extreme high inflows from the upper Great Lakes and record precipitation over the Erie Basin in February and March plus the severe ice jam that occurred in the east channel of the upper Niagara River all acted to sharply increase Lake Erie's water level in the spring of 1985.

While only one record high monthly water level was set (April) in the spring and summer, the lake's water levels remained very close to record high water levels throughout the year. The extreme wet fall conditions on top of these water levels and record Detroit River inflows caused new record water levels to be set in November and December.

Lake Ontario's water levels were near normal to slightly above normal from the end of 1984 through to the fall months of 1985. It should be noted that Lake Ontario's outflows have been regulated since 1958. The present regulation plan, Plan 1958-D, was able to cope with the high water supplies received from Lake Erie by way of the Niagara River through release of maximum or close to maximum outflows down the St. Lawrence River. A point that should be made here is that the enlarged capacity of the St. Lawrence River resulting from construction of the St. Lawrence Seaway and Power Project makes it possible to discharge flows greater than those that would have occurred under natural pre-project conditions. Despite a continuation of maximum outflows, Lake Ontario water levels rose in November and December and was almost 30 cm above average by the end of 1985 as a result of high rainfall over the basin and continued record high inflows from Lake Erie.

Because the Niagara River and Niagara Falls separate Lake Ontario from the rest of the Great Lakes, water level conditions on Lake Ontario have no hydraulic impact on the upstream lakes. The vast amount of excess water now stored on the upper lakes will, however, ensure high supplies to Lake Ontario and potential high Lake Ontario water levels for several years.

## 3.0 EFFECTS OF HIGH LAKE WATER LEVELS

Record high water levels on the Great Lakes in 1985 in combination with spring and fall storms caused millions of dollars in shore property damage.

### 3.1 Storms of March 31 and April 6, 1985

On the weekend of March 31, 1985, a spring storm blowing from out of the east struck Lake Erie. Hardest hit by this storm was Point Pelee. One week later on April 6, 1985, a storm out of the south-west passed over Lakes St. Clair and Erie. Both Point Pelee and Long Point were badly battered by this storm. Surveys of the affected areas were carried out by WP&MB staff in April following these storms and a report entitled, "Lake Erie-Lake St. Clair Shore Damage Survey Resulting From Storms of March 31 and April 6, 1985", was prepared. The report contains several maps and photos of the areas of major damage. A number of cottages were severely damaged or totally destroyed, access roads washed out, beach sand eroded, trees uprooted and dykes battered and breached. While no field surveys of total damages were made by Federal or Provincial Government Agencies, several conservation authorities provided dollar estimates of the damages in their specific jurisdictions. For example, estimates of lakeshore property damages totalling $5 and $12 million for Kent and Essex counties respectively were quoted.

### 3.2 Storm of December 2, 1985

A major storm occurred over the Great Lakes Basin on December 2, 1985 causing extensive flood and erosion damage along some of the lake shorelines with western exposures. The eastern end of Lake Erie was severely effected. Shore erosion was experienced on Lake Huron in the Bayfield/Goderich/Kincardine area and minor flooding was reported along the north shore of Lake St. Clair.

The storm started at about 10:00 p.m. on December 1, with winds from the southwest gusting up to 100 kilometres per hour by the early hours of December 2. Flood levels peaked in the mid-morning of December 2. The water level in the eastern end of Lake Erie rose approximately 2.4 metres above its pre-storm calm water level which in itself was 0.9 metres above the average water level for this time of year. This established a new water level record of elevation 177.0 metres at the Buffalo Harbour gauge and set a new maximum instantaneous outflow record of about 12,500 cms in the Niagara River. Local flooding along the U.S. shoreline of the Niagara River was experienced.

On Long Point many cottages on Hastings Drive were demolished with several being swept into the Big Creek Marsh. Much of Turkey Point was flooded during the storm as were shoreline property and structures in Ports Ryerse and Dover. In the Lowbanks - Long Beach - Belleview Beach areas, considerable damages were inflicted on shore protection, cottages and cottage property. Port Colborne experienced water back-up through its storm drain network and general shoreline damage was reported through to Fort Erie.

In summary the shoreline flood and erosion damage for the December 2 storm on the Great Lakes was concentrated in the eastern end of Lake Erie with total Canadian property damage running in the order of several million dollars. Much of this damage was inflicted on seasonal residences in the Long Point to Port Colborne area. In the Port Colborne to Fort Erie area, a number of permanent homes were affected. Severe erosion occurred at the toe of shoreline bluffs on Lakes Erie and Huron during this storm which will lead to increased sloughing of the bluffs and further property losses during future storms. Detailed assessment of storm damages are being undertaken by some conservation authorities.

## 4.0 WATER MANAGEMENT ACTIONS TAKEN RELATED TO HIGH LAKE WATER LEVELS

### 4.1 Lake Superior Regulation

In 1979, the IJC issued a supplementary order and approved the use of Regulation Plan 1977 in the regulation of Lake Superior. The plan takes into consideration the water levels of both Lake Superior and Lakes Michigan-Huron in determining Lake Superior's outflow. The plan was tested using recorded historical supplies. However, extreme high and at times record high supplies to the Lakes in 1985 prompted the IJC to make departures from the regulation plan during the year.

In early 1985, water levels on Lakes Michigan-Huron, St. Clair and Erie rose sharply and were approaching record high water levels. In anticipation of further deterioration of the situation, the International Lake Superior Board of Control developed several options to reduce Lake Superior's outflow in an effort to relieve the extreme high water level condition downstream. These options were submitted to the International Joint Commission for consideration on March 21, 1985.

The emergency Lake Superior outflow reduction commenced on May 2, 1985. In the subsequent several months, outflows were reduced by about one-third when compared with the flow called for by Regulation Plan 1977. However, continued high supplies to the Great Lakes necessitated a moderation of these emergency actions and commencing in mid-August 1985 outflow reductions were minimized to protect Lake Superior interests.

By September, the Lake Superior water level was approaching its upper limit of 183.5 metres and the flows out of Lake Superior were equivalent to that called for by Plan 1977. In October and November, Lake Superior not only exceeded the elevation of 183.5 metres, IGLD (1955), but also set new maximum records for those months, despite the release of maximum possible outflows through the St. Mary's River.

The emergency outflow reduction action described above caused about 0.1 metre of water to be stored on Lake Superior by the end of August 1985. This action also lowered the water level of Lakes Michigan-Huron by about 0.07 metre when compared with the water level that would have occurred if Plan 1977 was followed. Similar but smaller lowering effects were felt on Lakes St. Clair and Erie. Table 5 summarizes the effects on lake water levels of this emergency action. A point to note is that the previous record Lake Superior levels of 183.41 metres and 183.32 metres for November and December respectively would have been broken without the additional surcharge of water on the Lake due to this outflow reduction action. In essence, the original objective to provide a measure of relief to the downstream lakes was met. However, this action and the higher-than-average precipitation over the Lake Superior Basin during the late spring, summer and fall months raised Lake Superior water levels much higher than anticipated.

## 4.2 Ogoki Diversion

Commencing June 28, 1985, Ontario Hydro, at the request of the Province of Ontario, took action to store Ogoki Diversion waters on Lake Nipigon. The diversion of Ogoki waters to Lake Nipigon was also gradually reduced.

By the end of August 1985, above normal precipitation in the Ogoki/Nipigon watersheds and flood level conditions on Lake Nipigon forced the complete closure of the diversion (except for control dam leakages) and the resultant spill of Ogoki water to James Bay via the Albany River. This action continued through mid-December. On December 20, Ontario Hydro established winter operation settings for the Ogoki control dams so that approximately 60 percent of Ogoki diversion waters were redirected back into Lake Nipigon and eventually to Lake Superior. The remaining 40 percent of the Ogoki diversion continued to flow northward during the winter to the Albany River and James Bay.

Table 6 gives an account of the action to store or re-divert the Ogoki water for the period June through December 1985 and Table 7 draws a comparison with the effects of similar actions taken during the high water period of 1972-73.

Because of the relatively small amount of water involved and the short duration of the Province's actions, the effect of withholding Ogoki and local inflows water on Lake Nipigon was very minor on the Great Lakes' water levels. The storing of Ogoki water on Lake Nipigon during July and August had the ultimate effect of raising the Lake Nipigon water level by about 0.16 metre and lowering Lake Superior water level by about 0.01 metre. The redirection of the Ogoki water northward during the months of September through December 1985 resulted in an additional 0.02 metres decrease in Lake Superior water levels.

## 4.3 Lake Ontario Regulation

Throughout 1985, outflows from Lake Ontario were in accordance with the Regulation Plan 1958-D. There were some minor deviations due to either winter operations or unit outage at the Moses-Saunders Power Plants. These deviations were minor and had no measurable impact on Lake Ontario water levels.

High water supplies to Lake Ontario in 1985 did not cause any significant water level related problems on that lake. When Lake Ontario reached its annual peak in May 1985, the lake water level was still some 0.5 metre lower than the pre-project water level which is the water level that would have occurred had the St. Lawrence Seaway Power Project not been built.

Lake Ontario's water level was slightly above average from March to July and in August through October was near average. Record water supplies to the lake in November and December due to record November precipitation and inflows from Lake Erie caused an increase in Lake Ontario's water level at year end to about 0.3 metre above average for that time of year. Above average water levels on the lake were predicted for 1986.

On December 17, the IJC directed its International St. Lawrence River Board of Control to implement Criteria (k) at the closing of the 1985 navigation season. Criterion (k) is one of the requirements in the IJC's Order of Approval for regulation of Lake Ontario. A more detailed discussion of this action will be presented in the subsequent 1986 edition of this report.

4.4 Public Information

The 1985 high water level conditions on the Great Lakes caused considerable attention to be focussed on the issue by government agencies, the public and elected representatives. The following is a list of public information activities undertakén during the year by Water Planning and Management Branch in response to the high water levels problem, and often in cooperation with other agencies.

1. Completed the publication in June 1985 of a new brochure on Great Lakes Water Levels and distributed about 10,000 copies.

2. Inclusion of a high water level advisory in the monthly Great Lakes Water Level Bulletin.

3. Preparation of a set of answers to address most often asked questions concerning lake water levels.

4. Briefings of Federal Members of Parliament.

5. Presentations on water levels at IJC Seminars.

6. Attendance at public meetings and as invited guest speakers at private meetings to discuss the subject of lake water levels.

7. Handling of numerous telephone inquiries concerning lake water levels from the general public, radio stations and major newspapers in Ontario.

8. Appearance on television to explain the causes of high lake water levels and related shoreline damage.

9. Recommendations to the Ontario Ministry of Natural Resources (OMNR) suggesting the issuing of flood warnings or advisories to affected conservation authorities, shoreline residents and OPP detachments.

10. Surveys of the Lake Erie and Lake St. Clair shoreline to assess damages due to high lake water levels and storms.

11. Provision of information to Provincial Government Agencies for the purpose of briefing Provincial Ministers and MPP's.

12. Initiation of a joint Canada/Ontario project to acquire up to date aerial photography of the Lakes Erie, St. Clair and Huron shorelines under the Flood Damage Reduction Program.

13. Provision of technical assistance and support to the International Joint Commission and its International Lake Superior and St. Lawrence River Boards of Control in carrying out their Great Lakes water level regulation responsibilities.

14. Preparation of ministerial correspondence and direct responses to the public and shore property owner concerns about high lake water levels.

15. Preparation of ministerial briefing documents.

Other activities by branch staff include discussions with Atmospheric Environment Service, Ontario Ministry of Natural Resources and the Conservation Authorities to determine at what water levels storm warnings should be issued to shore property residents.

# 5.0 ASSESSMENT OF ACTIONS TAKEN

## 5.1 General

The problems created by fluctuating Great Lakes water levels have been examined in a number of major studies. Following a period of low water in 1964 the International Joint Commission initiated the International Great Lakes Levels Board Study to determine the feasibility of further regulation of the Great Lakes.This ten year study concluded that significant further regulation of the system was not practical. Subsequent to the high water levels of the early 1970's, two IJC reference studies were also carried out to determine:

(1) Whether the existing major Great Lakes diversions could be manipulated for the purpose of Great Lakes water level management; and

(2) If Lake Erie regulation would be practical.

These studies concluded that it was not feasible to further control lake water levels through either diversion manipulation or the regulation of Lake Erie.

From 1973 to 1976 Canada and Ontario conducted a joint assessment of the serious flood and erosion problems along the Great Lake shores. The Canada-Ontario Shore Damage Survey concluded that the costs of providing long term protection to shoreline properties would be prohibitive and that better shoreline management was the best way of dealing with the problem.

The following sections provide an assessment of government actions taken in 1985, compares these actions to similar measures taken in the early 1970's and points out whether other actions could have been taken that could further help to alleviate the high Great Lakes water level problems.

## 5.2 Lake Superior Regulation

A comparison of the Lake Superior emergency outflow reductions in 1972-73 and 1985, as summarized in Table 7, shows that they started in February 1973 and May 1985, respectively.Had the 1985 action been initiated earlier, for example on February 1, 1985, another 2,270 cms-months of water could have been stored on Lake Superior by the end of April 1985, thus raising it another 0.07 metre. This action may have lowered Lake Michigan-Huron water levels to the extent that they may have marginally avoided setting new record high water levels in the spring. However, such action would have resulted in critically high water levels on Lake Superior earlier than actually occurred thus requiring an earlier termination of the emergency action. The above-average precipitation over the Lake Superior Basin in 1985, combined with the emergency actions that started in May, raised Lake Superior's water level to 183.48 metres in September, and above the water level of 183.5 metres in October and November, despite outflows being increased to maximum allowable limits during the late fall.

New record high water levels were also set on Lake Huron in October through December, and on Lake St. Clair in September through December. Hence, in retrospect, if the 1985 emergency action had occurred any earlier, any potential incremental improvement to Lakes Michigan-Huron and downstream lake water levels would have been offset by worse conditions on Lake Superior in the late fall months.

### 5.3 Ogoki Diversion

A review of the Ogoki diversion data for 1985 (see Table 6) shows that for the period July through September, the average Ogoki diversion into Lake Nipigon was 109 cms, compared to the long term average of 133 cms. The result of Ontario Hydro's action to store the diverted Ogoki water on Lake Nipigon commencing June 28, was a maximum raising effect on Lake Nipigon of about 0.17 metre.The corresponding lowering effect on Lake Superior was about 0.01 metre.

The subsequent action by Ontario Hydro to redirect the Ogoki Diversion northward to Hudson Bay during the latter part of 1985 caused an additional and approximate 0.02 metrepotential lowering effect on Lake Superior. This incremental effect on Lake Superior level is small and difficult to quantify as the action to redirect Ogoki water northward would have been necessary, to some degree, in any case due to the extremely high local runoff conditions in the Ogoki and Nipigon watersheds.

## 6.0 CONCLUSIONS AND RECOMMENDATIONS

### 6.1 Conclusions

The record high water levels on Lakes Michigan-Huron, St. Clair and Erie in the spring and fall months of 1985 were caused by a combination of above average to record level precipitation, low evaporation and antecedent above average Great Lakes water level conditions.

The action to store Ogoki water on Lake Nipigon during the summer months in 1985 had an extremely small impact on the Great Lakes in light of the magnitude and duration of the effects of this action.

Emergency actions to reduce Lake Superior's outflow during the spring and summer months met the objective of providing a small measure of relief to downstream interests during the summer. However, these actions combined with continued above average precipitation raised Lake Superior water levels to new record high water levels in October, November and December. In retrospect, earlier actions in this regard or even a larger reduction in Lake Superior's outflows would not have brought any additional overall relief to the entire Great Lake system.

Public information on the high water level situation, its causes, effects and future impacts was provided by many agencies via many channels and to a range of interest groups. As a result, the general public have been reasonably well informed of the potential for impending shore property damages and have had lead time to prepare accordingly.

Hopefully shoreline damages this year and in future months were and will be minimized by these actions although no quantitative measure of the effectiveness of the public information program is possible.

Despite the desire to look for and act on expedient solutions during times of crisis following severe storm induced damages, the reliance on lake level regulation and expensive shore protection works is invariabley overemphasized in an attempt to deal with the biophysical rather than the human nature root of the hazard problem. Similarly the natural reaction to initiate a study of the problem and possible physical solutions, e.g. in the form of regulatory works for Lake Erie, may be an avoidance of the real problem.

The conclusions of all government studies, academic reviews and evaluations of the recurring problem of shoreline damages on the Great Lakes is that occupancy and construction of damage prone buildings in hazardous shore areas must be discouraged. Policies that will reduce shoreline damages by modifying the existing potential for losses have considerable potential. These policies include hazard land use regulation, public acquisition, relocation and hazard-sensitive building design. In this regard all levels of government must be aggressive in the regulation of land use in hazardous shore areas.

## 6.2 Recommendations

1. Manipulation of existing Great Lakes diversions is not recommended nor practical as a Great Lakes water level management solution.

2. For the long term Lake Superior's Regulation Plan 1977 should be evaluated in light of the record high supply conditions of 1985 and any apparent deficiencies in the Plan should be examined. The current efforts by the IJC and its Superior Board to investigate the possibility and merits of incorporating improved water supply forecasts into Plan 1977 should be continued.

3. Efforts should be continued by all government agencies to provide information to the public on the causes and effects of Great Lakes water level fluctuations, current and forecasted water level conditions, and the dangers of building too close to the shoreline.

4. The provision of government financial assistance to shoreline property owners to repair damaged buildings to their pre-disaster condition and location should be carefully assessed. This practice serves to perpetuate the problem and is in effect a levy on the general public for the continued benefit of a few.

## 7. FORECAST OF FUTURE WATER LEVEL CONDITIONS

The December 1985 issue of the Great Lakes water level bulletin shows that new record high water levels will most likely be set on Lakes Superior, Michigan-Huron, St. Clair and Erie in the winter and spring months of 1986 (Figures 1 to 4).

While Lake Ontario's December 1985 water level is slightly above normal,the water levels of this lake are expected to rise sharply over the next six months (Figure 5) in response to the record inflows from the upper lakes.

In view of these forecasted record high Great Lake water levels, severe flood and erosion damages can be expected to continue along the Great Lakes shores during 1986, particularly during periods of severe wind storms in the spring and fall months.

**Table 1**

**Great Lakes Water Levels: 1985 and Previous Record Maximums**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Superior(at Thunder Bay)** | | | | | | | | | | | | |
| 1985 | 183.07 | 183.02 | 183.03 | 183.07 | 183.20 | 183.29 | 183.36 | 183.43 | 183.48 | 183.53* | 183.50* | 183.40* |
| Previous Record | 183.25 | 183.18 | 183.16 | 183.22 | 183.35 | 183.44 | 183.53 | 183.52 | 183.54 | 183.47 | 183.41 | 183.32 |
| (year) | (1952) | (1952) | (1951) | (1951) | (1951) | (1916) | (1916) | (1916) | (1916) | (1916) | (1916) | (1951) |
| **Michigan-Huron(at Goderich)** | | | | | | | | | | | | |
| 1985 | 176.73 | 176.67 | 176.76 | 176.92* | 177.03* | 177.05* | 177.02 | 176.98 | 176.99 | 176.95* | 176.97* | 177.06* |
| Previous Record | 176.77 | 176.77 | 176.76 | 176.88 | 176.96 | 177.05 | 177.07 | 177.07 | 177.03 | 176.92 | 176.84 | 176.77 |
| (year) | (1973) | (1952) | (1973) | (1952) | (1973) | (1973) | (1973) | (1973) | (1952) | (1973) | (1973) | (1972) |
| **St. Clair(at Belle River)** | | | | | | | | | | | | |
| 1985 | 175.26 | 175.35* | 175.51* | 175.59* | 175.58* | 175.57 | 175.55 | 175.50 | 175.47* | 175.38* | 175.51* | 175.54* |
| Previous Record | 175.34 | 175.32 | 175.47 | 175.51 | 175.55 | 175.60 | 175.60 | 175.54 | 175.45 | 175.34 | 175.29 | 175.30 |
| (year) | (1974) | (1973) | (1973) | (1973) | (1974) | (1973) | (1973) | (1973) | (1973) | (1973) | (1972) | (1972) |
| **Erie(at Port Colborne)** | | | | | | | | | | | | |
| 1985 | 174.41 | 174.29 | 174.58 | 174.82* | 174.72 | 174.70 | 174.64 | 174.53 | 174.46 | 174.36 | 174.48* | 174.73* |
| Previous Record | 174.56 | 174.45 | 174.61 | 174.72 | 174.73 | 174.79 | 174.76 | 174.66 | 174.50 | 174.38 | 174.39 | 174.51 |
| (year) | (1973) | (1973) | (1974) | (1973) | (1974) | (1973) | (1973) | (1973) | (1973) | (1973) | (1972) | (1972) |
| **Ontario(at Kingston)** | | | | | | | | | | | | |
| 1985 | 74.49 | 74.45 | 74.68 | 74.92 | 74.99 | 75.00 | 74.94 | 74.75 | 74.60 | 74.46 | 74.47 | 74.62 |
| Previous Record | 75.03 | 75.12 | 75.22 | 75.47 | 75.58 | 75.61 | 75.52 | 75.44 | 75.27 | 75.09 | 75.04 | 75.06 |
| (year) | (1946) | (1952) | (1952) | (1952) | (1952) | (1952) | (1947) | (1947) | (1947) | (1945) | (1945) | (1945) |

All elevations are in metres above sea level on the International Great Lakes Datum (1955) as recorded at one Canadian location on each lake. These data are slightly different from those used in lake regulation purposes, where data are used from a number of Canadian and United States stations on each lake.

* denotes new record maximum set in 1985

Table 2

**Precipitation Data for the Great Lakes (in millimetres)**

| | 1984 | | 1985 | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | | Comparison by Year |
| **Superior** | | | | | | | | | | | | | | | | |
| Mean | 62.6 | 50.5 | 49.0 | 37.4 | 44.5 | 50.4 | 68.6 | 83.9 | 81.3 | 80.3 | 88.6 | 67.8 | 62.6 | 50.5 | Mean | 764.9 |
| 1984-85 | 35.8 | 72.7 | 46.5 | 40.2 | 47.4 | 57.1 | 99.4 | 83.6 | 95.8 | 108.7 | 167.9 | 77.2 | 114.6 | 94.0 | 1985 | 1032.4 |
| % of Mean | 57 | 144 | 95 | 107 | 107 | 113 | 145 | 100 | 118 | 135 | 190 | 114 | 183 | 186 | % of Mean | 135 |
| **Huron** | 73.2 | 67.5 | 61.2 | 49.5 | 55.6 | 61.1 | 70.4 | 73.0 | 71.2 | 73.0 | 85.0 | 72.5 | 73.2 | 67.5 | Mean | 813.2 |
| 1984-85 | 82.2 | 97.8 | 81.0 | 89.7 | 90.0 | 81.9 | 75.2 | 47.6 | 91.2 | 99.1 | 116.8 | 88.6 | 111.5 | 86.1 | 1985 | 1058.7 |
| % of Mean | 112 | 145 | 132 | 181 | 162 | 134 | 107 | 65 | 128 | 136 | 137 | 122 | 152 | 128 | % of Mean | 130 |
| **Michigan** | | | | | | | | | | | | | | | | |
| Mean | 61.8 | 49.2 | 43.6 | 37.8 | 53.3 | 69.5 | 81.8 | 86.2 | 78.5 | 80.2 | 87.3 | 66.9 | 61.8 | 49.2 | Mean | 796.1 |
| 1984-85 | 62.3 | 67.0 | 44.1 | 62.6 | 77.9 | 70.5 | 71.5 | 57.2 | 84.1 | 126.2 | 106.4 | 81.0 | 141.7 | 58.7 | 1985 | 981.9 |
| % of Mean | 101 | 136 | 101 | 166 | 146 | 101 | 87 | 66 | 107 | 157 | 122 | 121 | 229 | 119 | % of Mean | 123 |
| **Erie** | | | | | | | | | | | | | | | | |
| Mean | 69.3 | 65.9 | 62.4 | 52.6 | 71.1 | 79.8 | 83.2 | 86.9 | 82.9 | 79.2 | 78.6 | 67.7 | 69.3 | 65.9 | Mean | 879.6 |
| 1984-85 | 78.2 | 84.1 | 61.7 | 87.3 | 115.0 | 46.8 | 76.6 | 72.7 | 89.7 | 119.6 | 59.2 | 101.1 | 180.1 | 65.8 | 1985 | 1075.6 |
| % of Mean | 113 | 128 | 99 | 166 | 162 | 59 | 92 | 84 | 108 | 151 | 75 | 149 | 260 | 100 | % of Mean | 122 |
| **Ontario** | | | | | | | | | | | | | | | | |
| Mean | 76.2 | 73.5 | 68.0 | 60.3 | 67.6 | 72.1 | 77.1 | 77.3 | 78.8 | 77.7 | 78.7 | 75.4 | 76.2 | 73.5 | Mean | 882.7 |
| 1984-85 | 66.5 | 84.9 | 72.1 | 86.6 | 78.3 | 49.3 | 74.0 | 75.6 | 62.5 | 83.1 | 74.7 | 80.3 | 155.7 | 61.7 | 1985 | 953.9 |
| of Mean | 87 | 116 | 106 | 144 | 116 | 68 | 96 | 98 | 79 | 107 | 95 | 107 | 204 | 84 | % of Mean | 108 |
| **Great Lakes** | | | | | | | | | | | | | | | | |
| Mean | 67.4 | 59.0 | 54.6 | 45.0 | 55.3 | 63.7 | 74.9 | 81.3 | 78.0 | 78.0 | 84.9 | 69.5 | 67.4 | 59.0 | Mean | 811.6 |
| 1984-85 | 62.6 | 80.5 | 59.4 | 69.1 | 77.4 | 64.1 | 81.1 | 66.2 | 87.6 | 109.1 | 116.2 | 84.6 | 133.5 | 76.6 | 1985 | 1024.9 |
| % of Mean | 93 | 136 | 109 | 154 | 140 | 101 | 108 | 81 | 112 | 140 | 137 | 122 | 198 | 130 | % of Mean | 126 |

Source: National Oceanic and Atmospheric Administration, all figures are in millimetres and are computed using data from United States and Canadian stations.
Mean data are calculated for the period 1900-1984 inclusive
Data for June to December 1985 are provisional
Total Great Lakes Basin figures are computed using individual lake date weighted according to basin area as a fraction of the total Great Lakes Basin area.

Table 3

**Comparison of Canadian Tributary Discharges**
**for the Period January through April**

| | Long Term Average (period of record) | 1985 | Percent Above Average |
|---|---|---|---|
| a) Lake Superior (Pic River) | 3 766 (1974-1984) | 4 778 | 27 |
| b) Lake Huron (Saugeen River) | 12 159 (1966-1984) | 18 872 | 55 |
| c) Lake St. Clair (Thames River) | 11 910 (1966-1984) | 19 393 | 63 |
| d) Lake Erie (Big Creek) | 1 203 (1966-1984) | 1 817 | 51 |

All figures are in cubic metres per second-days.

Source: Water Resources Branch, Environment Canada

TABLE 4

Comparison of Evaporation Records for the Great Lakes(millimetres)

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **a) Lake Superior** | | | | | | | | | | | | |
| Minimum | 85.3 | 39.4 | 22.1 | 6.3 | -23.6 | -56.9 | -105.2 | - 52.6 | - 9.1 | 35.3 | 69.8 | 89.4 |
| Maximum | 156.0 | 132.3 | 92.5 | 49.8 | 54.6 | -7.6 | -34.0 | 28.2 | 116.6 | 124.0 | 143.5 | 195.3 |
| Mean | 123.6 | 81.1 | 61.6 | 22.8 | 16.2 | -36.4 | -67.5 | -15.4 | 49.2 | 78.5 | 115.6 | 119.5 |
| 1985 | 123.4 | 83.8 | 61.0 | 6.1 | -1.5 | -20.3 | n/a | n/a | n/a | n/a | n/a | n/a |
| **b) Lake Huron** | | | | | | | | | | | | |
| Minimum | 62.2 | 27.7 | -10.7 | -19.0 | -25.4 | -48.0 | -36.3 | 10.4 | 29.7 | 53.3 | 63.5 | 32.5 |
| Maximum | 145.5 | 101.9 | 68.3 | 36.6 | 48.5 | 5.6 | 68.8 | 85.1 | 142.7 | 140.7 | 152.7 | 158.7 |
| Mean | 106.6 | 68.8 | 38.7 | 4.1 | 12.0 | -14.4 | 1.8 | 46.6 | 78.1 | 99.2 | 103.2 | 97.7 |
| 1985 | 93.0 | 59.4 | 39.4 | -23.4 | -1.3 | 7.9 | n/a | n/a | n/a | n/a | n/a | n/a |
| **c) Lake Erie** | | | | | | | | | | | | |
| Minimum | 30.7 | -2.8 | -19.3 | -32.0 | 20.6 | 45.0 | 30.5 | 48.8 | 102.4 | 68.1 | 68.6 | 31.2 |
| Maximum | 123.7 | 83.6 | 65.3 | 28.4 | 97.5 | 114.0 | 127.5 | 152.9 | 294.6 | 215.1 | 182.6 | 159.3 |
| Mean | 74.9 | 51.2 | 18.7 | 0.6 | 58.8 | 68.3 | 73.2 | 108.9 | 155.7 | 153.9 | 116.6 | 84.7 |
| 1985 | 99.1 | 46.7 | 16.5 | -19.0 | 74.7 | 95.8 | n/a | n/a | n/a | n/a | n/a | n/a |

Source: Atmospheric Environment Service

Negative figure indicates condensation

Maximum, Minimum and Mean figures are based on period 1965-83

n/a = not available

Table 5
Computed Effects of Emergency Actions Regarding
Lake Superior Regulation on Great Lakes Water Levels

| | Lake Superior Outflow | | End of Month | Lowering Effects | | |
|---|---|---|---|---|---|---|
| | Computed Plan 1977 | Actual | Cumulative Storage on Lake Superior | Mich-Huron | St.Clair | Erie |
| | (cubic metres per second) | | (metres) | | (metres) | |
| May 1985 | 2 780 | 1 950 | 0.024 | 0.018 | 0.006 | 0 |
| June | 2 890 | 2 040 | 0.055 | 0.040 | 0.018 | 0.003 |
| July | 2 750 | 1 930 | 0.082 | 0.055 | 0.030 | 0.009 |
| August | 3 060 | 2 290 | 0.107 | 0.070 | 0.040 | 0.018 |
| September | 2 860 | 2 660 | 0.107 | 0.067 | 0.043 | 0.027 |
| October | 2 350 | 3 540 | 0.070 | 0.043 | 0.034 | 0.030 |
| November | 3 170 | 3 770 | 0.052 | 0.027 | 0.027 | 0.030 |
| December | 2 380 | 2 920 | 0.037 | 0.015 | 0.021 | 0.027 |

Note: No impact on Lake Ontario due to the operation of Lake Ontario's regulation plan.

All flows are in cubic metres per second, water levels are in metres to three decimal places.

TABLE 6

Effects of Storing Water on Lake Nipigon**

| | Ogoki Water Discharged Northward (cms) | Ogoki Diversion Into Lake Nipigon (cms) | Ogoki Average Diversion 1944-1984 (cms) | End of Month Accumulated Storage on Lake Nipigon Ogoki*** (m) | Local Inflow (m) | Total (m) |
|---|---|---|---|---|---|---|
| June 1985 | 20 | 325 | 201 | 0.017 | 0.028 | 0.045 |
| July | 0 | 210 | 157 | 0.135 | 0.102 | 0.237 |
| August | 18 | 96 | 127 | 0.160 | 0.091 | 0.251 |
| September | 137 | 20* | 116 | 0.164 | 0.113 | 0.277 |
| October | 244 | 20* | 109 | 0.168 | 0.082 | 0.250 |
| November | 221 | 20* | 115 | 0.171 | 0.018 | 0.188 |
| December | 126 | 44 | 108 | 0.171 | -0.138 | 0.033 |

End of Month Accumulated Lowering Effect on Lake Superior**

| | Due to storage of Ogoki and Local Inflow on Lake Nipigon (m) | Due to direction of Ogoki Water to James Bay (m) |
|---|---|---|
| June 1985 | 0.002 | nil |
| July | 0.013 | nil |
| August | 0.014 | nil |
| September | 0.015 | 0.004 |
| October | 0.014 | 0.012 |
| November | 0.010 | 0.019 |
| December | 0.002 | 0.023 |

* Leakages at Summit Control Dam
** Based on storage constant 1 730 cms-months = 1 metre on Lake Nipigon and 31 400 cms-months = 1 metre on Lake Superior
*** All Ogoki waters stored on Lake Nipigon are assumed to be released beginning in January 1986.
All effects are in metres rounded to three decimal places

TABLE 7

Comparison of Emergency Actions
in 1972-73 and in 1985 and their
Impacts* on Lake Water Levels

| | 1972-73 | 1985 |
|---|---|---|
| Storing Ogoki Water on Lake Nipigon | Commencing Dec. 1, '72 | Commencing June 28 |
| Reducing Lake Superior's Outflow from Plan Flow | Commencing Feb 1, '73 | Commencing May 2 |
| Ultimate Raising Effect* on Lake Superior | 20 cm | 11 cm |
| Ultimate Lowering Effect* on Lake Huron | 13 cm | 7 cm |
| Actual Highest Monthly Lake Superior Level | | |
| at Marquette | 183.46 m (601.91 ft) | 183.53 m (602.12 ft) |
| at Thunder Bay | 183.42 m (601.77 ft) | 183.53 m (602.13 ft) |

*Impacts do not include the effect of storing Ogoki waters on Lake Nipigon.
All elevation figures are rounded to two decimal places.

LAKE SUPERIOR (Thunder Bay) LAC SUPÉRIEUR

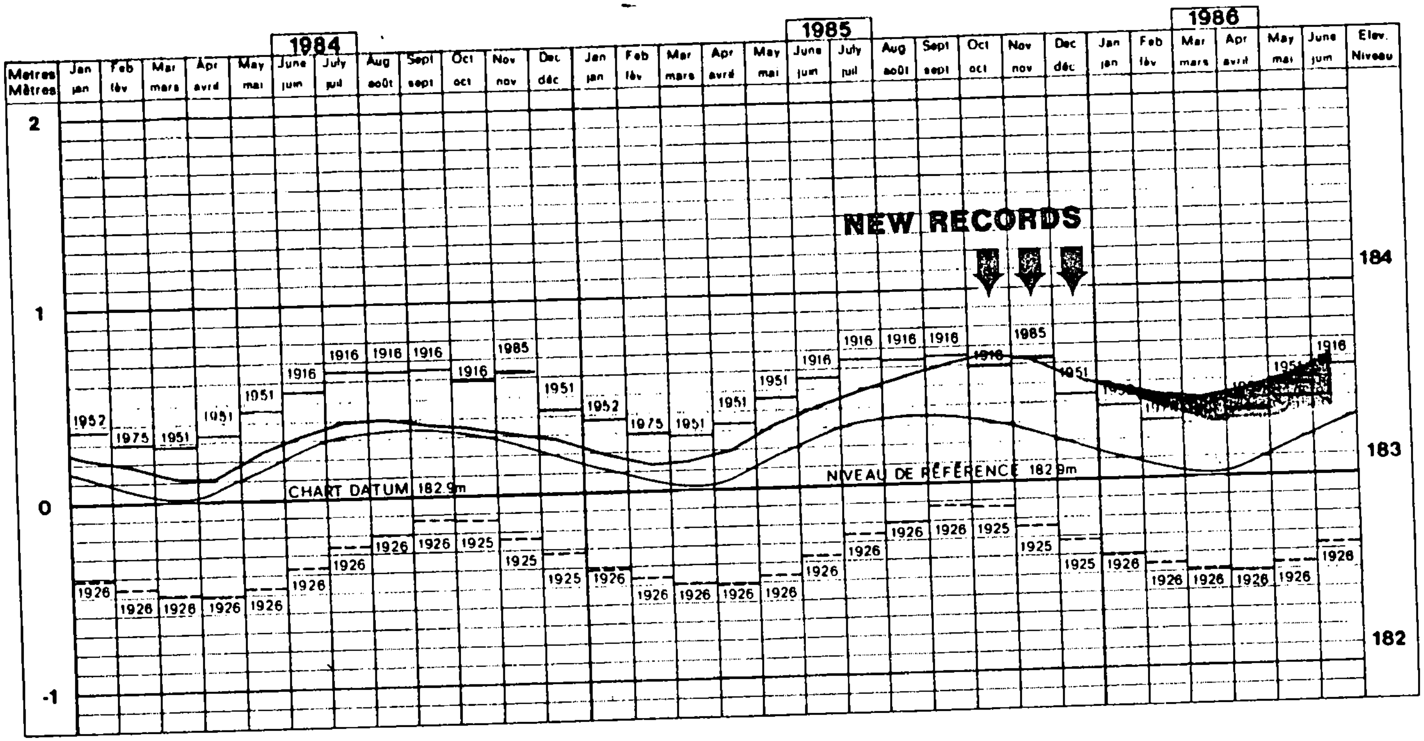


**FIGURE 1 WATER LEVEL HYDROGRAPH OF LAKE SUPERIOR**

METRIC - MÉTRIQUE

LAKE HURON (Goderich) LAC HURON

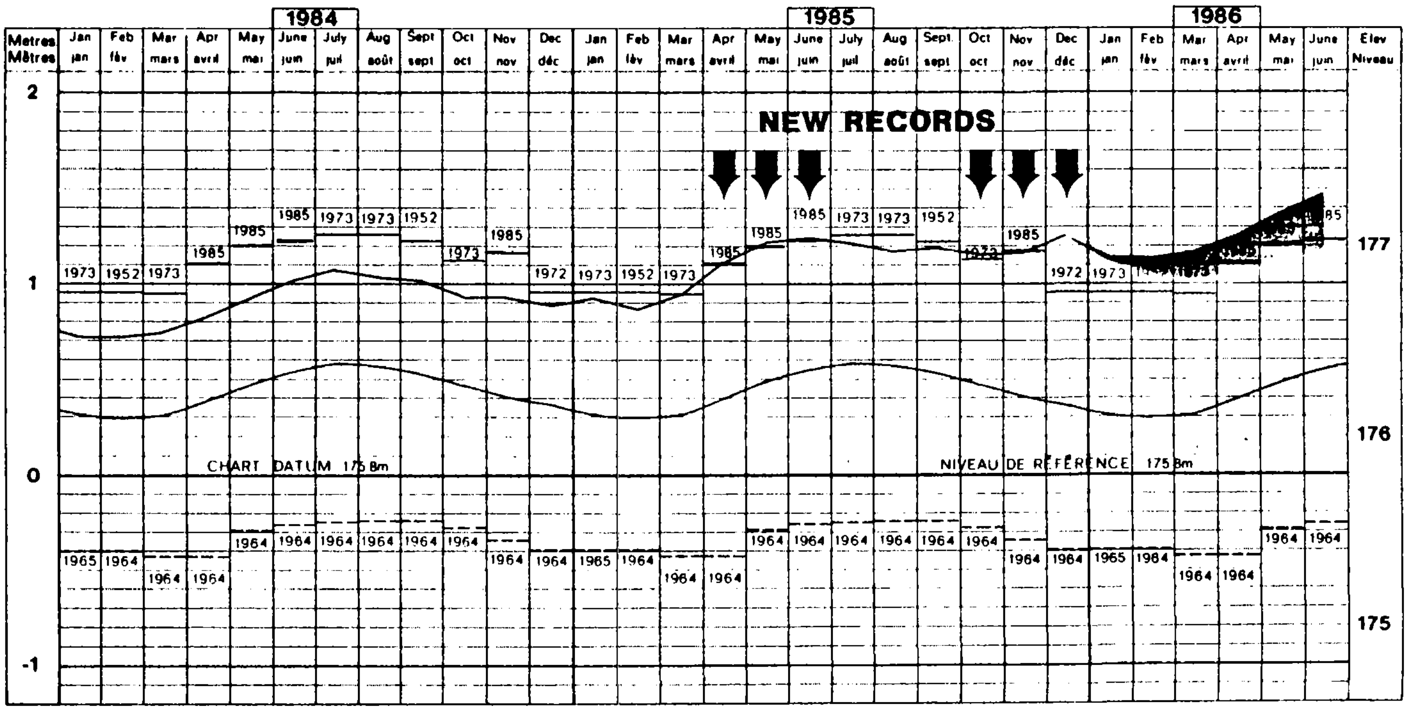


**FIGURE 2 WATER LEVEL HYDROGRAPH OF LAKES MICHIGAN-HURON**

DECEMBER 1985 DÉCEMBRE 1985

LAKE ST. CLAIR (Belle River) LAC ST. CLAIR

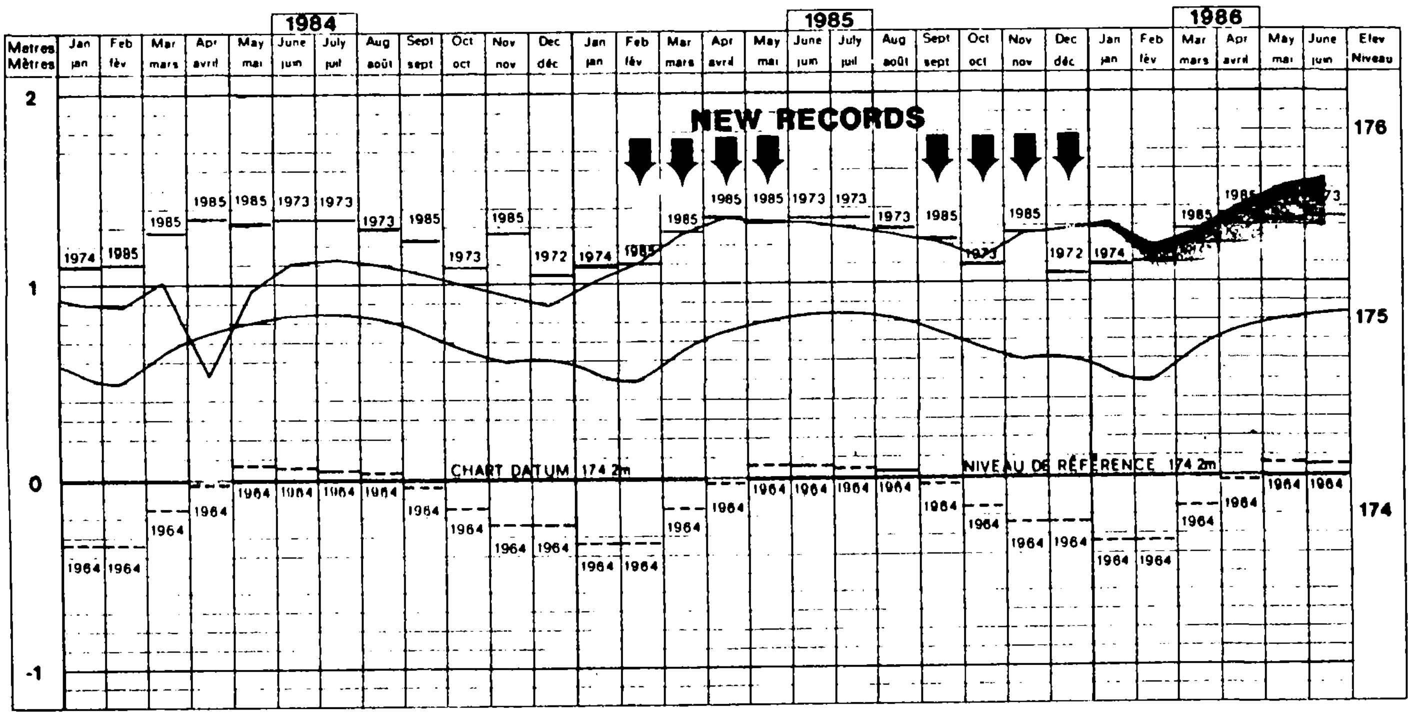


**FIGURE 3 WATER LEVEL HYDROGRAPH OF LAKE ST. CLAIR**

LAKE ERIE (Port Colborne) LAC ÉRIÉ

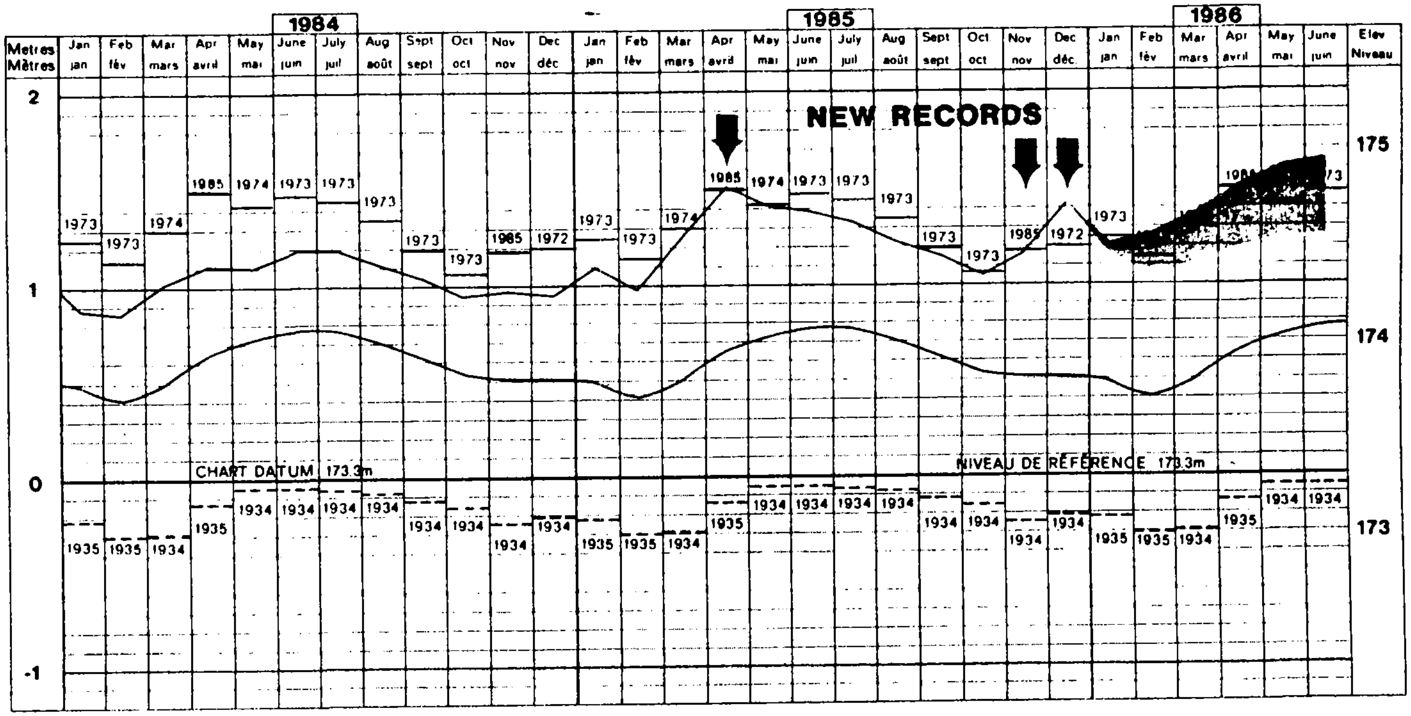


**FIGURE 4 WATER LEVEL HYDROGRAPH OF LAKE ERIE**

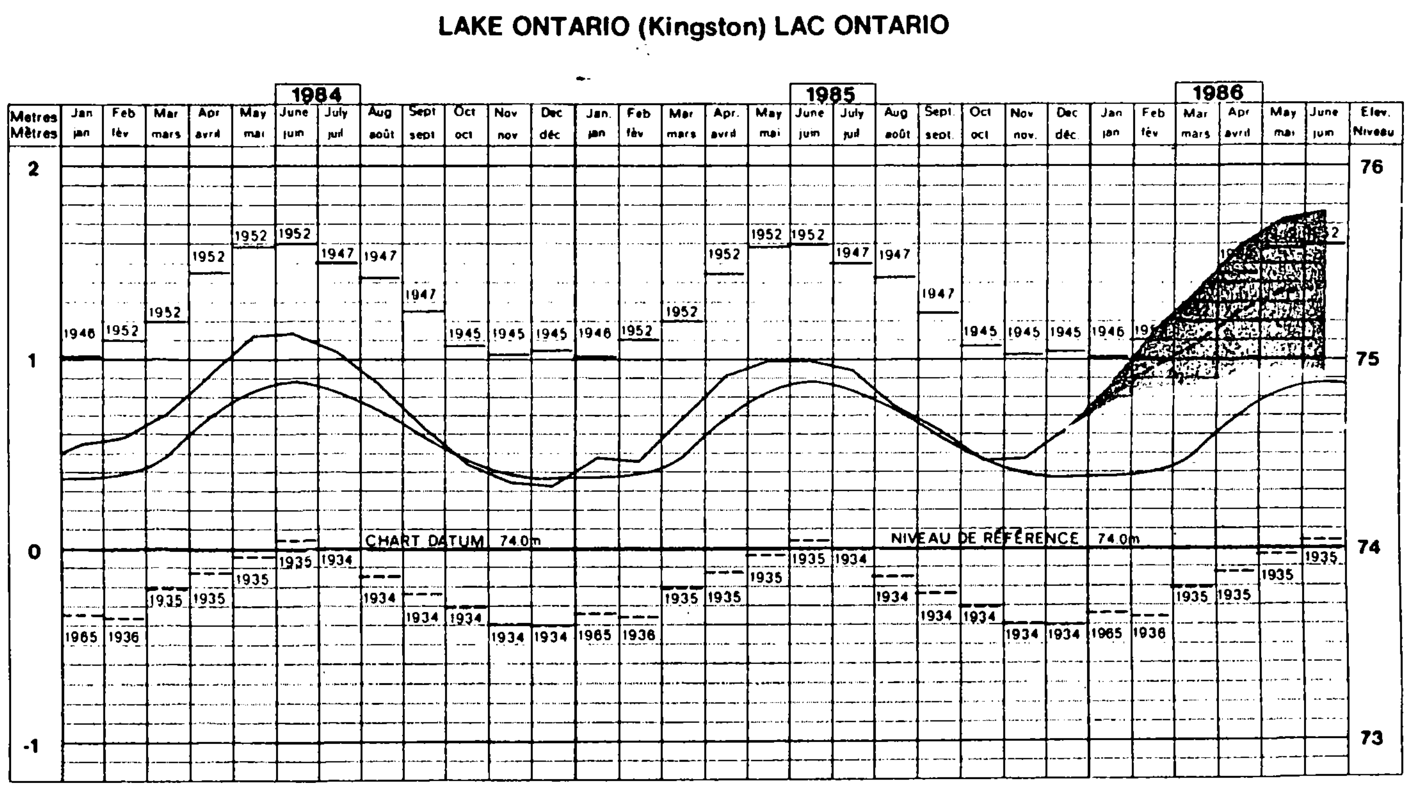


**FIGURE 5 WATER LEVEL HYDROGRAPH OF LAKE ONTARIO**