GREAT LAKES SYSTEM

FLOOD LEVELS

AND WATER RELATED HAZARDS

Conservation Authorities and Water Management Branch

Ontario Ministry of Natural Resources

February 1989

Foreword

This report contains updated information on flood levels and water related hazards for the Ontario portion of the Great Lakes shoreline and connecting channels, excluding the St. Lawrence River. The information was prepared primarily to aid in identifying shoreline hazard areas, but may also be of use in designing shore protection and navigation structures.

The information contained in this report is largely derived from the Great Lakes Hazard Lands Technical Committee report of November 1988. That report was reviewed by staff of the Conservation Authorities and Water Management Branch, Ministry of Natural Resources regional engineers and select Environment Canada staff. Based upon the comments received, the flood hazard information was revised and this report was prepared.

The flood hazard information contained in this report will be incorporated into the background Technical Guidelines to accompany the Draft Shoreline Hazard Management Policy Statement. Rather than await the release of the policy statement and accompanying guidelines, the Branch is circulating the updated 100 year flood information to assist in the preparation of shoreline hazard mapping.

A. GREAT LAKES FLOOD LEVELS

A.1 100 Year Flood Level

The 100 year flood level is defined as the peak instantaneous water level having a total probability of being equalled or exceeded during any year of 1%. This means that on average, during a 100 year period, the 100 year flood level is expected to be equalled or exceeded once: during a 1000 year period, the 100 year flood level would be equalled or exceeded 10 times on average.

For each of the Great Lakes there are many separate combinations of stillwater levels and wind setups which could result in the same local water level. Therefore, 100 year flood levels for the Great Lakes are determined by calculating the probability of all possible combinations of the entire range of monthly mean lake levels and wind setups which could combine to result in a peak instantaneous water level having a total probability of being equalled or exceeded of 1% in any year.

For the connecting channels of the Great Lakes, the 100 year flood level, defined as the peak instantaneous water level having a 1% probability of being equalled or exceeded in any year, is based on a frequency analysis of recorded data adjusted to "Basis of Comparison" conditions as defined in Appendix 1.

Information on water levels for the Great Lakes is provided as follows:

- Figures A.1 to A.5
  - 100 year flood levels (G.S.C) and the sectors of Great Lakes shoreline to which they apply
- Table A.1
  - list of 100 year flood levels (G.S.C) by lake and sector

- Table A.2
  - peak instantaneous water levels (I.G.L.D.) for recurrence intervals from 2 to 200 years
- Table A.3
  - highest annual monthly mean lake levels (I.G.L.D.) for recurrence intervals from 2 to 200 years
- Table A.4
  - wind setup values for recurrence intervals from 2 to 200 years

A.1.1 Method of Calculation

The following steps were taken to calculate the flood levels:

a) A frequency distribution of highest annual monthly mean lake levels was derived for each lake based on recorded water level data adjusted to 1988 "Basis of Comparison" conditions (see Appendix 1).

b) Surge or wind setup values were obtained from recorded surges at gauging stations and by modelled surges between gauges using the SURGE model obtained from Environment Canada. At gauging stations, the highest annual surges were calculated by subtracting static levels from recorded peak instantaneous levels. A frequency distribution of highest annual recorded surges was then obtained using the HYDSTAT model.

c) Average wind speed data for use in the SURGE model were obtained from the Atmospheric Environment Service of Environment Canada. The data included 1, 2, 3, 6 and 12 hour duration average wind speeds for 8 wind directions (N,NE,E,SE,S,SW,W,NW) at selected stations in the Great Lakes Basin. The highest annual average wind speed for each duration and direction was compiled.

d) The SURGE model was then calibrated by iteration. First, the annual maximum wind series for the period of record, made up of winds of various durations and directions, which produced the highest surge at the gauge site of interest was determined. Once this governing annual maximum measured wind speed series was determined, it was multiplied by a selected constant and input to the model to produce a series of modelled annual surge values at the gauge site. Various constants were selected until the maximum annual surge population produced by the model at a gauge site did not differ significantly from the recorded highest annual surge population at the site. Differences between 100 year modelled surges and 100 year recorded surges at a gauge site were generally less than 0.1 m.

The wind speed calibration constants were assumed to apply to adjacent sectors. Surges were modelled for the highest annual 1, 2, 3, 6 and 12 hour duration winds for each applicable wind direction for the period of record of the wind data. From this data the highest annual surge population for the sector (ie. SURGE model grid location) was selected. This represents for a particular year the highest surge that would occur from a 1, 2, 3, 6 or 12 hour duration wind speed from any wind direction relevant to a particular segment of shoreline.

e) A combined probability analysis1 was then completed of the highest annual monthly mean water levels and the best-fitting frequency distribution of surge values at each grid point was selected to obtain 100 year peak instantaneous water levels. Those grid points with 100 year levels within 0.1 m and common physiographic features and shore alignments were then grouped together into a common sector. The resulting 100 year flood level is assumed to be applicable throughout the sector.

f) For the connecting channels of the Great Lakes system, 100 year peak instantaneous levels were calculated using recorded data adjusted to "Basis of Comparison" conditions. Sectors are based on changes of 0.1 m using changes in slope based on known flow profiles. Environment Canada's Consolidated Frequency Analysis computer program was used to calculate the stage frequency relationships at Canadian gauge locations. The results obtained by the U.S. Army Corps of Engineers (F.E.M.A. 1988) for U.S. gauges in the connecting channels were also taken into consideration in determining the 100 year flood levels.

A.1.2 Serial Correlation

An underlying assumption of computing frequencies of extreme annual events is that the recorded extreme in each year is an independent event. For the Great Lakes, annual extreme events are not truly independent because the large storage capacity of the lakes in relation to the outflow capacities of the channels results in persistence in the system. This persistence is evident in the serial correlation or autocorrelation that exists between successive highest annual levels.

The U.S. Army Corps of Engineers (U.S.A.C.E. 1984) found that, of all of the Great Lakes, the series of annual maximum monthly mean levels for Lake Michigan-Huron had the highest degree of autocorrelation. To test the significance of this autocorrelation, two separate sample population series were constructed based on even year and odd year data to eliminate the yearly dependence present. The study concluded that the overall impact of reducing the dependence and re-introducing it in the form of a complete annual series did not appear to significantly alter the frequency relationships.

Both U.S. and Canadian agencies analyze Great Lakes data assuming highest annual events are independent and that serial correlation does not significantly alter results.

A.1.3 Climate Change

An inherent assumption of the preceding water level frequency analyses is that the regional climate of the Great Lakes Basin has and will not change appreciably over the long term.

It is generally accepted that the earth is undergoing a global warming trend, attributed to an increase in carbon dioxide and certain other gases in the atmosphere (ie. greenhouse effect). However, the impacts of this warming on precipitation and evaporation in the Great Lakes Basin is less certain.

For the purpose of planning coastal facilities over the next 50 years, Bishop (1987) carried out a review of studies undertaken to evaluate the predicted climate change in the Great Lakes Basin and of studies of the impacts of the predicted climate changes on water levels. Under a scenario of doubled atmospheric concentrations of carbon dioxide, some climate models predict likely decreases in net basin water supplies and consequently lower mean annual lake levels. However, the high level of uncertainty in predicting changes in precipitation, wind patterns and relative humidity under the scenario is such that water supplies to the basin could also increase. The review concludes that over the next 50 years, water levels are unlikely to appreciably exceed the modern records.

A.2 Wave Action and other Water Related Hazards

A.2.1 Wave Action Limits

In areas susceptible to wave action, hazard areas extend landward beyond the 100 year flood level to the limit of wave action. All shorelines in the Great Lakes system should be considered to be susceptible to wave action unless site specific study demonstrate that wave action is not significant.

Wave action includes wave runup, wave setup, wave spray and/or wave overtopping. Wave setup is the mean increase in water level caused by the onshore transport of water due to waves breaking at the shoreline, while wave runup is the time varying height above the mean water level that the water runs up the shore face. For straight, uniform reaches without structures, the landward limit of wave action can be represented by the maximum sum of wave setup and wave runup. In areas where waves act on shore protection and other structures, and in areas with irregular shorelines, the wave action may include spray and overtopping which are more difficult to determine and may require detailed study.

A.2.1.1 Wave Runup

Combined wave setup and wave runup levels have been calculated for a number of sites using accepted procedures as outlined in the U.S. Army Corps of Engineers Shore Protection Manual (1984). For convenience, the combined level resulting from wave setup and wave runup is referred to as the wave runup level.

The wave runup levels provided for the Great Lakes shorelines were calculated as follows:

a) Onshore and offshore nearshore bottom profile data were obtained for the 163 Great Lakes erosion monitoring stations established in 1973. The calculation of wave runup levels were limited to those stations having a bluff height of less than 3 metres above lake datum. In total, 88 stations between Wasaga Beach on Lake Huron to Outlet Beach on Lake Ontario were selected.

   For each profile, a beach slope, on which the wave runup occurs, and a nearshore slope were characterized. Breaking wave heights were estimated at the points of intersection of beach and nearshore slopes. For the 88 profile stations examined, it was determined that the calculated maximum breaking wave heights were limited by the water depth and not by the magnitude of the offshore waves. This allowed a determination of maximum wave runup levels due to depth-limited breaking wave heights.

b) Wave runup values were estimated using the design charts provided in the Shore Protection Manual (U.S.A.C.E. 1984) and were subsequently corrected for scale effect. In cases where the runup level exceeded the beach berm elevation, a composite beach slope was used (see Shore Protection Manual).

   At some of the profile locations, the measured onshore elevations did not extend high enough to contain the predicted runup. Of the 88 profiles selected for wave runup analysis, only 43 profiles provided sufficient information to determine the extent of wave runup.

c) For the 43 sites examined, the calculated horizontal offset due to runup and setup ranged as far as 16 metres with the average being 10.3 metres.

On the Lake Superior shoreline, almost 70% of existing (1987) residential properties have either highly or medium erodible soils. Only 2% of existing properties have a high wave susceptibility. It would appear that most existing development is located along shorelines that are similar to the other Great Lakes (ie. most development is not located on exposed bedrock shoreline with steep nearshore depths that might allow fetch-limited wave conditions to govern wave runup). As such, the standard guideline of a 15 metre wave runup offset would be suitable for general application across the Great Lakes. In cases where development is planned for irregular or bedrock shoreline, wave runup calculations should be undertaken using site-specific information.

For the connecting channels, wave runup levels are normally the result of ship-generated waves. A wave runup offset allowance of about 3 metres would appear to be suitable for most sites away from the influence of lake waves. For shoreline reaches with significant fetch areas, wind generated waves should be calculated, or depth-limited wave conditions assumed, to determine the wave runup offset allowance.

It should be kept in mind that these criteria are intended to be general enough to satisfy wide areas of applicability and flexible enough for adaption to site-specific conditions. They should be used as guidelines and, in the absence of more specific data and detailed analysis, as a reasonable estimate of areas subject to wave action.

A.2.1.2 Wave Spray

Wave spray has been observed to go over and past many shoreline houses, cottages and other such structures. The landward extent and quantity of wave spray depends on the type of shore, nearshore bathymetry, type of protection structure, size of the incident waves and wind conditions. Generally, during storms a significant amount of spray will occur behind the structures that are near vertical and subjected to large breaking waves (ie. in deeper water).

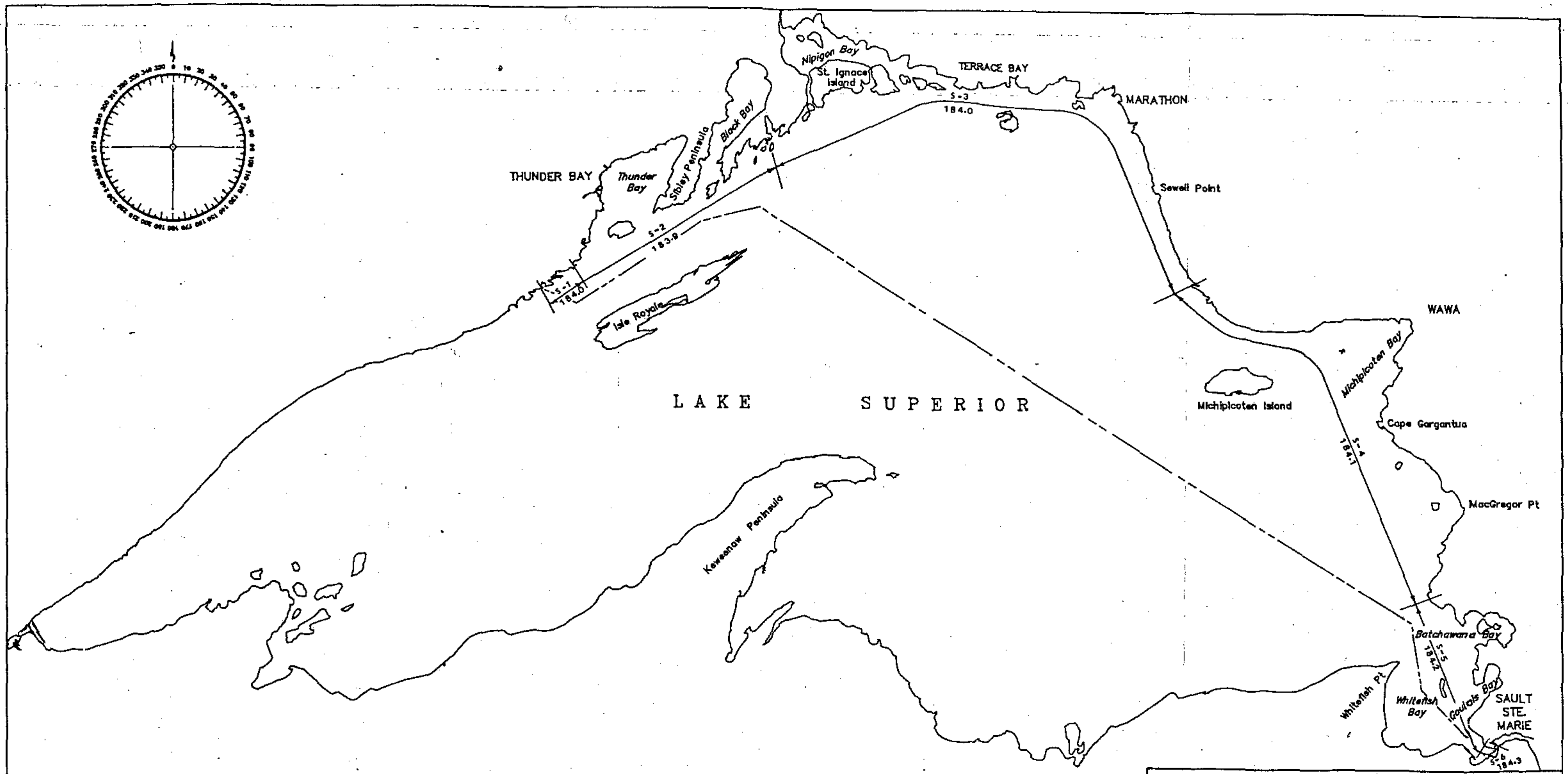
An allowance for wave spray has not been included in the wave action offset because the extent of spray cannot be readily calculated. However, for riparian sites wave spray should be considered. Local experience is usually the best guideline.

A.2.2 Ice Piling

Ice piling occurs when wind driven currents and waves carry ice floes onto shore. Occasionally ice pileups can occur at river mouths when flood flows carrying river ice meet a frozen lake and spread onto adjacent lands. Under certain meteorological conditions, ice piling on lake shores can extend up to 45 metres landward of the prevailing waterline.

During the months of January to April, when ice piling occurs, the lake levels are usually about 0.3 metres lower than the maximum annual monthly mean level. The presence of ice limits wave runup and may reduce wind setup so that the lake level at the shoreline during an ice piling event would usually be less than the 100 year flood level.

On most natural shorelines, the landward extent of ice piling will be generally less than that due to the 100 year flood level and wave runup. However, at riparian sites with shore protection structures, ice piling may extend further than the 100 year flood level and wave runup. At these locations, site-specific studies based on local conditions are normally required. Local experience with the impacts of ice piling is the best guide to help in defining the extent of hazard land.



NOTES:

ALL ELEVATIONS SHOWN ARE REFERENCED TO GEODETIC SURVEY OF CANADA DATUM (G.S.C.).

Ministry of Natural Resources
Ontario

GREAT LAKES 100 YEAR PEAK INSTANTANEOUS WATER LEVELS

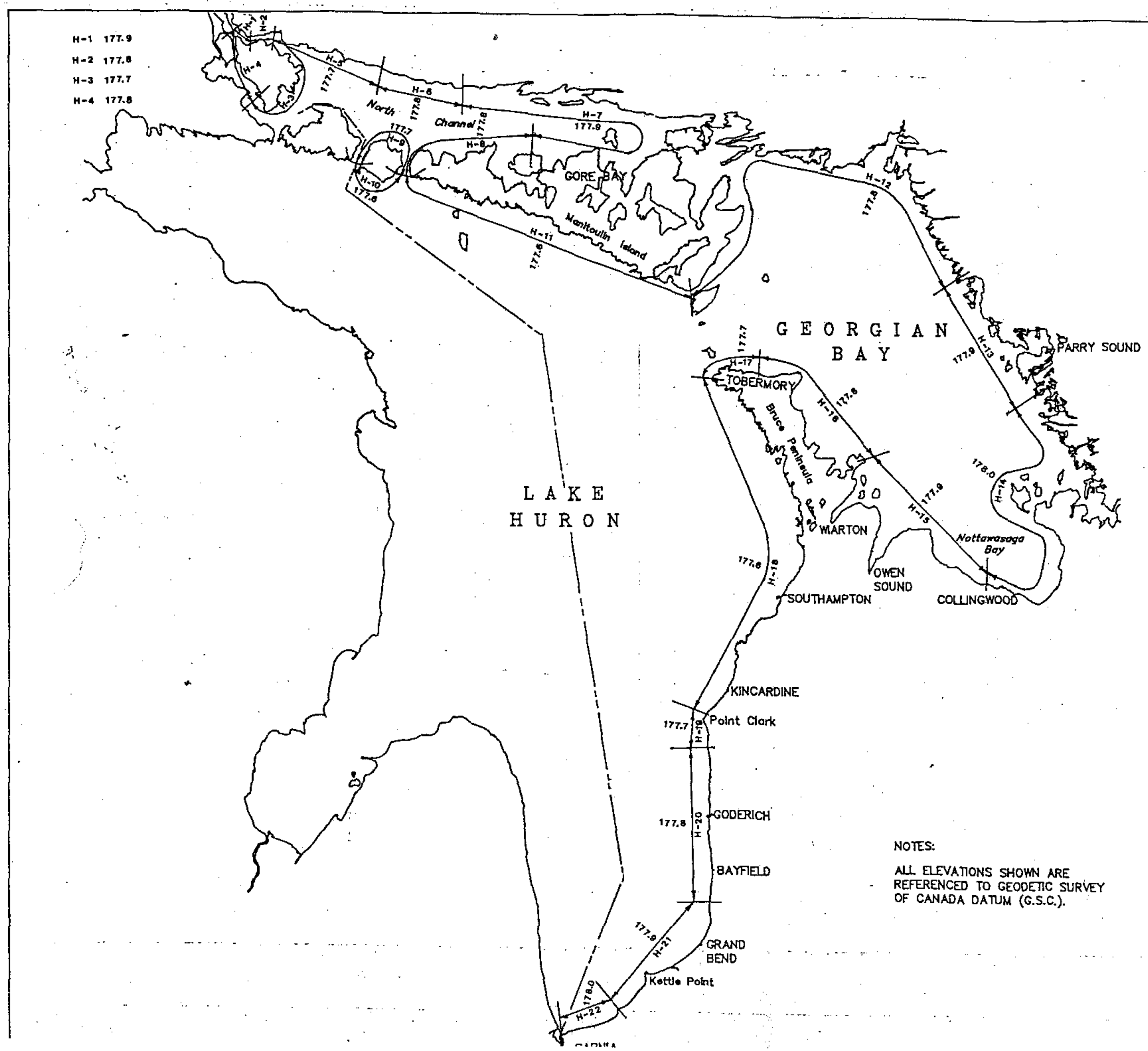
LAKE SUPERIOR

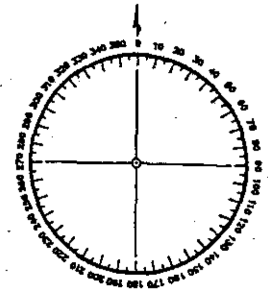
SCALE 1:1,500,000

10 5 0 10 20 30 40 50 km

1988

FIGURE N°. A.1





NOTES:

ALL ELEVATIONS SHOWN ARE REFERENCED TO GEODETIC SURVEY OF CANADA DATUM (G.S.C.).

Ministry of Natural Resources
Ontario

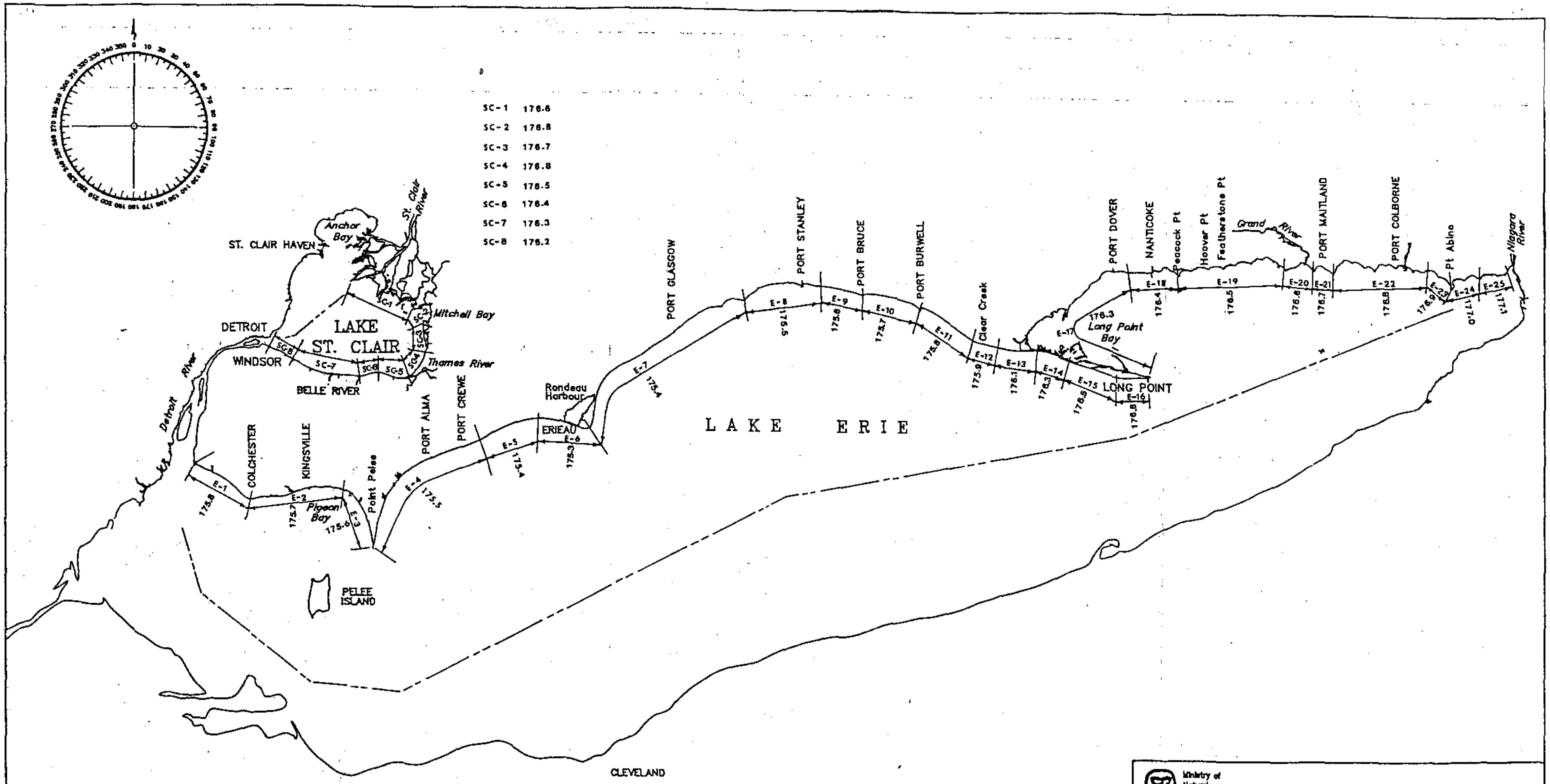
GREAT LAKES 100 YEAR PEAK INSTANTANEOUS WATER LEVELS

LAKE HURON AND GEORGIAN BAY

SCALE 1:1,500,000

10 5 0 10 20 30 40 50 km

FIGURE N° A.2



NOTES:

ALL ELEVATIONS SHOWN ARE REFERENCED TO GEODETIC SURVEY OF CANADA DATUM (G.S.C.).

Ministry of Natural Resources
Ontario

GREAT LAKES 100 YEAR PEAK INSTANTANEOUS WATER LEVELS

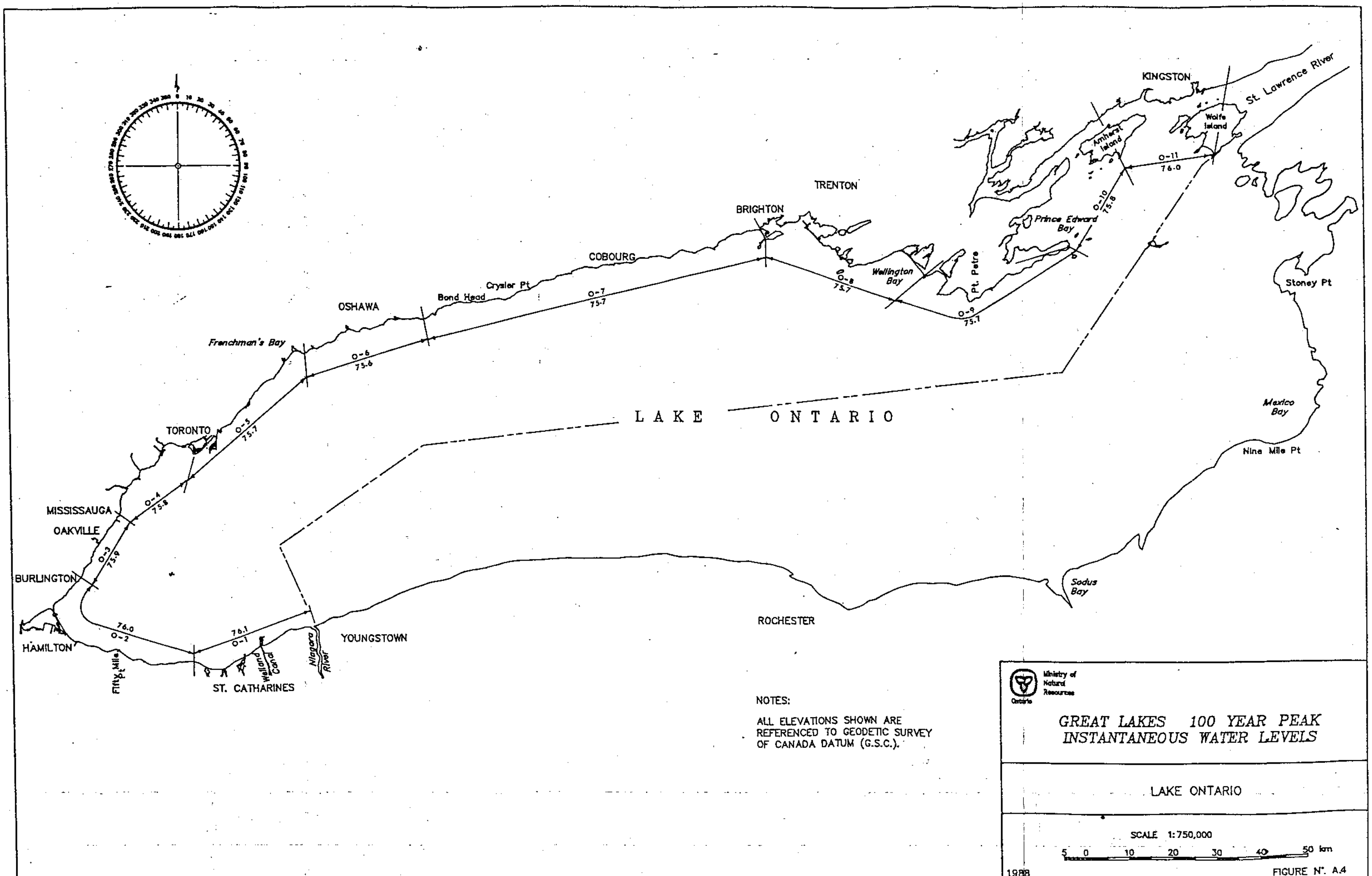
LAKE ERIE AND LAKE ST. CLAIR

SCALE 1:1,000,000

10 5 0 10 20 30 40 50 Kilometres

1988

FIGURE N°. A3



GREAT LAKES 100 YEAR PEAK INSTANTANEOUS WATER LEVELS

LAKE ONTARIO

FIGURE N°. A.4

Figure A.5 Connecting Channels 100 Year Water Levels

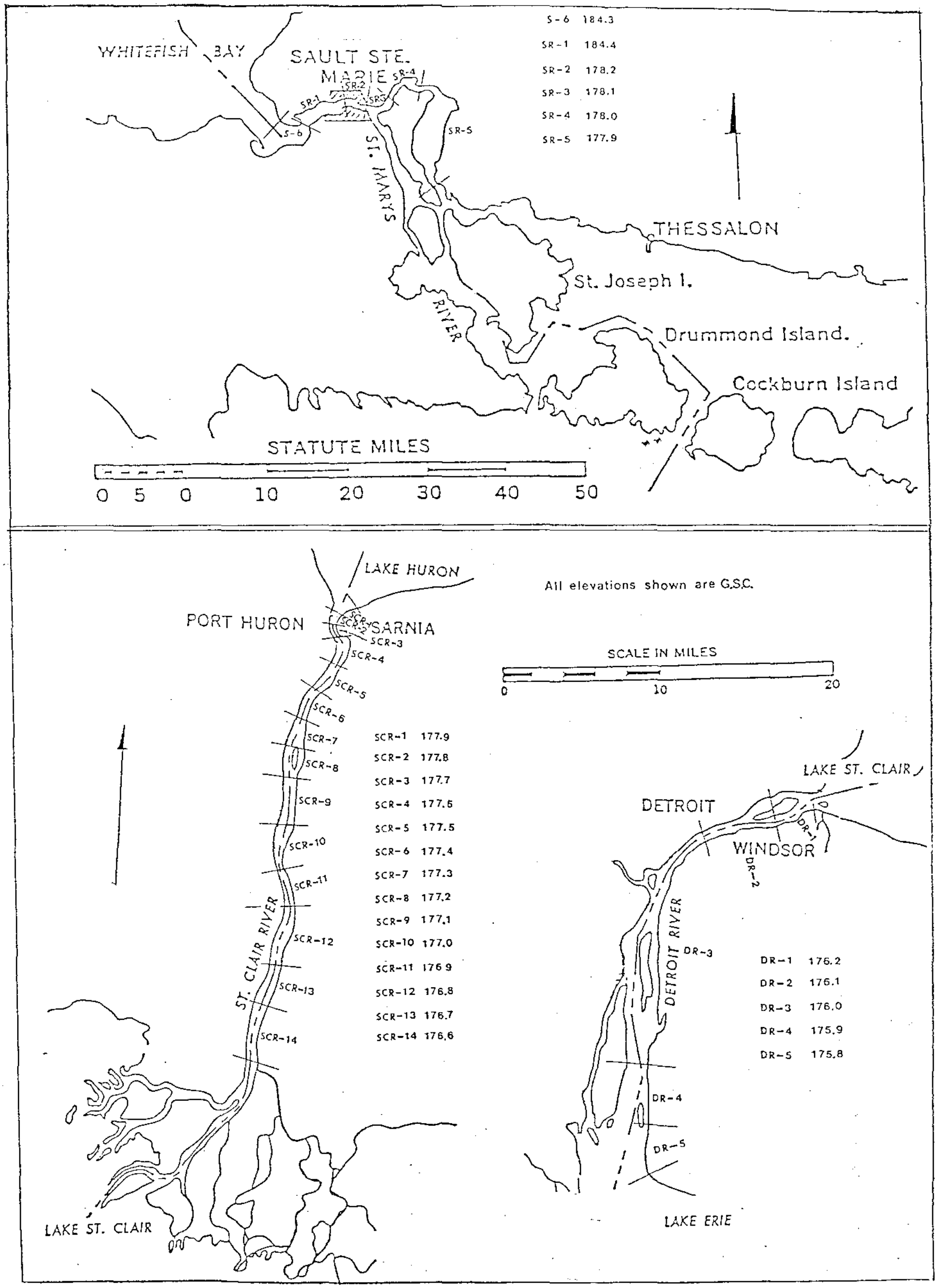


TABLE A.1

100 YEAR PEAK INSTANTANEOUS WATER LEVELS

Sector	100 Year Peak Instantaneous Water Level (m) G.S.C.
LAKE SUPERIOR	
S-1 Pine Point	184.0
S-2 Thunder Bay	183.9
S-3 Rossport	184.0
S-4 Michipicoten	184.1
S-5 Gros Cap	184.2
S-6 Pointe Louise	184.3
ST. MARY'S RIVER	
SR-1	184.4
SR-2	178.2
SR-3	178.1
SR-4	178.0
SR-5	177.9
LAKE HURON	
H-1 Neebish	177.9
H-2 Richards	177.8
H-3 Hilton	177.7
H-4 St Joseph	177.8
H-5 Thessalon	177.7
H-6 Mississagi Bay	177.8
H-7 Little Current	177.9
H-8 Cape Robert	177.8
H-9 N. Cockburn Is.	177.7
H-10,H-11 S. Shore	177.6
H-12 N Georgian Bay	177.8
H-13 Parry Sound	177.9
H-14 Collingwood	178.0
H-15 Meaford	177.9
H-16 Dyer's Bay	177.8
H-17 Tobermory	177.7
H-18 Southampton	177.6
H-19 Point Clark	177.7
H-20 Goderich	177.8
H-21 Kettle Point	177.9
H-22 Bright's Grove	178.0
ST. CLAIR RIVER	
SCR-1	177.9
SCR-2	177.8
SCR-3	177.7
SCR-4	177.6
SCR-5	177.5

Sector	100 Year Peak Instantaneous Water Level (m) G.S.C.
ST. CLAIR RIVER (continued)	
SCR-6	177.4
SCR-7	177.3
SCR-8	177.2
SCR-9	177.1
SCR-10	177.0
SCR-11	176.9
SCR-12	176.8
SCR-13	176.7
SCR-14	176.6
LAKE ST. CLAIR	
SC-1 Walpole	176.6
SC-2 Mitchell	176.8
SC-3 Dover	176.7
SC-4 Thames	176.8
SC-5 Tremblay	176.5
SC-6 Stoney Point	176.4
SC-7 Belle River	176.3
SC-8 Tecumseh	176.2
DETROIT RIVER	
DR-1	176.2
DR-2	176.1
DR-3	176.0
DR-4	175.9
DR-5	175.8
LAKE ERIE	
E-1 Bar Point	175.8
E-2 Kingsville	175.7
E-3 Pelee West	175.6
E-4 Wheatley	175.5
E-5 Port Crewe	175.4
E-6 Erieau	175.3
E-7 Port Glasgow	175.4
E-8 Port Stanley	175.5
E-9 Port Bruce	175.6
E-10 Port Burwell	175.7
E-11 Hemlock	175.8
E-12 Clear Creek	175.9
E-13 Erie View	176.1
E-14 Long Point Park	176.3

TABLE A.1

100 YEAR PEAK INSTANTANEOUS WATER LEVELS

Sector	100 Year Peak Instantaneous Water Level (m) G.S.C.
LAKE ERIE (continued)	
E-15 Long Point Central	176.5
E-16 Long Point East	176.6
E-17 Long Point Bay	176.3
E-18 Nanticoke	176.4
E-19 Selkirk	176.5
E-20 Port Maitland	176.6
E-21 Mohawk Point	176.7
E-22 Port Colborne	176.8
E-23 Point Abino	176.9
E-24 Crystal Beach	177.0
E-25 Fort Erie	177.1

Sector	100 Year Peak Instantaneous Water Level (m) G.S.C.
LAKE ONTARIO	
O-1 Port Weller	76.1
O-2 Burlington	76.0
O-3 Oakville	75.9
O-4 Mississauga	75.8
O-5 Toronto	75.7
O-6 Oshawa	75.6
O-7 Cobourg	75.7
O-8 Wellington	75.7
O-9 Point Petre	75.7
O-10 Prince Edward	75.8
O-11 Kingston	76.0

TABLE A.2

Peak Instantaneous Water Level Frequencies (m) (I.G.L.D.)

Sector	Recurrence Interval (yrs)							HYDSTAT Parameters (Log Pearson III)		
	2	5	10	25	50	100	200	Location	Scale	Shape
LAKE SUPERIOR										
S-1 Pine Point	183.42	183.58	183.67	183.77	183.85	183.91	183.97	5.52075	0.00022036	19.734
S-2 Thunder Bay*	183.43	183.56	183.62	183.69	183.74	183.77	183.81	5.2280	-0.000042826	377.020
S-3 Rossport*	183.46	183.62	183.71	183.81	183.97	183.94	183.99	5.2067	0.000178480	29.803
S-4 Michipicoten*	183.60	183.77	183.87	183.97	184.04	184.10	184.16	5.2004	0.000096459	128.880
S-5 Gros Cap*	183.61	183.76	183.84	183.92	183.98	184.03	184.08	5.1714	0.000023506	1760.400
S-6 Pointe Louise	-	-	-	-	-	184.20	-	-	-	-
ST. MARY'S RIVER										
SR-1*	183.74	183.93	184.03	184.15	184.23	184.30	184.37	5.2063	0.000187230	38.819
SR-2*	177.12	177.50	177.69	-	178.01	178.12	178.22	A=0.1051	B=10.43	M=3.370
SR-3	-	-	-	-	-	178.0	-	-	-	-
SR-4	-	-	-	-	-	177.9	-	-	-	-
SR-5	-	-	-	-	-	177.8	-	-	-	-
LAKE HURON										
H-1 Neebish	-	-	-	-	-	177.7	-	-	-	-
H-2 Richards	-	-	-	-	-	177.6	-	-	-	-
H-3 Hilton	-	-	-	-	-	177.5	-	-	-	-
H-4 St. Joseph	-	-	-	-	-	177.6	-	-	-	-
H-5 Thessalon*	176.76	177.04	177.19	177.34	177.44	177.52	177.60	5.2071	-0.000117500	275.670
H-6 Mississagi Bay	176.84	177.13	177.28	177.43	177.53	177.62	177.69	5.2104	-0.00011001	319.63
H-7 Little Current*	176.89	177.20	177.35	177.52	177.63	177.73	177.82	5.2796	-0.000041126	2531.500
H-8 Cape Robert	176.82	177.11	177.25	177.41	177.50	177.59	177.67	5.2087	-0.00011402	294.67
H-9 N Cockburn Is	176.78	177.06	177.21	177.36	177.46	177.54	177.62	5.2076	-0.00011631	281.82
H-10,H-11 S Shore	177.63	176.91	177.05	177.20	177.30	177.38	177.46	5.2045	-0.00012259	248.81
H-12 North Georgian Bay	176.81	177.10	177.25	177.41	177.50	177.60	177.67	5.21	-0.00011341	305.24
H-13 Parry Sound*	176.91	177.22	177.37	177.54	177.64	177.74	177.82	5.2446	-0.000060426	1142.000
H-14 Collingwood*	176.99	177.29	177.45	177.61	177.71	177.80	177.89	5.2267	-0.000081248	623.440
H-15 Meaford	176.87	177.17	177.32	177.48	177.58	177.67	177.75	5.22	-0.000097832	422.14
H-16 Dyer's Bay	176.80	177.09	177.24	177.40	177.50	177.58	177.66	5.21	-0.00010662	345.41
H-17 Tobermory*	176.74	177.03	177.18	177.33	177.43	177.52	177.60	5.2107	-0.000107530	335.330
H-18 Southampton	176.66	176.95	177.09	177.25	177.34	177.43	177.51	5.2097	-0.000106960	331.800
H-19 Point Clark	-	-	-	-	-	177.50	-	-	-	-
H-20 Goderich*	176.83	177.12	177.27	177.42	177.52	177.61	177.69	5.2100	-0.000110790	314.080
H-21 Kettle Point	176.93	177.22	177.37	177.53	177.63	177.72	177.80	5.2161	-0.000098794	408.560
H-22 Brights Grove	177.01	177.32	177.48	177.65	177.75	177.84	177.94	5.2097	-0.000106960	331.800

NOTES:

1. The frequencies of peak instantaneous LAKE levels are calculated by combining the individual frequency distributions of monthly mean lake levels and surge values (wind setup) using the MNR HYDSTAT computer program

2. The frequencies of peak instantaneous RIVER levels are calculated with recorded peak instantaneous levels using the computer program CFA88; this program does not list a 25 year value

3. Levels for sectors marked with an * are based on recorded surges; surges at other sections are calculated using the computer model SURGE from AES

4. Conversions from I.G.L.D. to G.S.C. are given in Appendix I

TABLE A.2

Peak Instantaneous Water Level Frequencies (m) (I.G.L.D.)

Sector	Recurrence Interval (yrs)							HYDSTAT Parameters (Log Pearson III)		
	2	5	10	25	50	100	200	Location	Scale	Shape
ST CLAIR RIVER										
SCR-1	-	-	-	-	-	177.7	-	-	-	-
SCR-2	-	-	-	-	-	177.6	-	-	-	-
SCR-3	-	-	-	-	-	177.5	-	-	-	-
SCR-4	-	-	-	-	-	177.4	-	-	-	-
SCR-5	-	-	-	-	-	177.3	-	-	-	-
SCR-6	-	-	-	-	-	177.2	-	-	-	-
SCR-7	-	-	-	-	-	177.1	-	-	-	-
SCR-8	-	-	-	-	-	177.0	-	-	-	-
SCR-9	-	-	-	-	-	176.9	-	-	-	-
SCR-10	-	-	-	-	-	176.8	-	-	-	-
SCR-11	-	-	-	-	-	176.7	-	-	-	-
SCR-12	-	-	-	-	-	176.6	-	-	-	-
SCR-13	-	-	-	-	-	176.5	-	-	-	-
SCR-14 Port Lambton*	175.64	175.93	176.07	na	176.29	176.37	176.43	A=-.01785	B=13.78	M=7.165
LAKE ST. CLAIR										
SC-1 Walpole	175.61	175.90	176.05	176.21	176.31	176.40	176.49	5.2916	-0.000030566	4033.4
SC-2 Mitchell	175.74	176.04	176.20	176.38	176.48	176.58	176.67	34.708	-1.4289E-07	206730000
SC-3 Dover	175.65	175.95	176.10	176.26	176.37	176.46	176.55	5.2932	-0.000032085	3887
SC-4 Thames	175.71	176.01	176.17	176.34	176.45	176.55	176.64	3.9675	-3.5236E-06	34093
SC-5 Tremblay	175.41	175.68	175.83	175.98	176.07	176.16	176.24	5.2506	-0.000040971	2038.3
SC-6 Stoney Point	175.38	175.65	175.78	175.93	176.02	176.10	176.14	5.2083	-0.000079299	521.77
SC-7 Belle River*	175.38	175.66	175.80	175.96	176.05	176.14	176.22	5.2601	-0.000038259	2434.7
SC-8 Tecumseh*	175.33	175.59	175.71	175.85	175.93	176.01	176.08	5.193	-0.00011537	228.68
DETROIT RIVER										
DR-1	-	-	-	-	-	176.0	-	-	-	-
DR-2	-	-	-	-	-	175.9	-	-	-	-
DR-3	-	-	-	-	-	175.8	-	-	-	-
DR-4	-	-	-	-	-	175.7	-	-	-	-
DR-5	-	-	-	-	-	175.6	-	-	-	-
LAKE ERIE										
E-1 Bar Point*	174.79	175.08	175.23	175.39	175.50	175.59	175.67	5.2298	-0.000061375	1079.100
E-2 Kingsville*	174.77	175.03	175.17	175.32	175.41	175.49	175.57	5.2020	-0.000087765	439.640
E-3 Pelee West	174.63	174.90	175.04	175.20	175.30	175.38	175.47	4.7283	7.8498E-06	55332

NOTES:

1. The frequencies of peak instantaneous LAKE levels are calculated by combining the individual frequency distributions of monthly mean lake levels and surge values (wind setup) using the MNR HYDSTAT computer program

2. The frequencies of peak instantaneous RIVER levels are calculated with recorded peak instantaneous levels using the computer program CFA88; this program does not list a 25 year value

3. Levels for sectors marked with an * are based on recorded surges; surges at other sections are calculated using the computer model SURGE from AES

4. Conversions from I.G.L.D. to G.S.C. are given in Appendix I

TABLE A.2

Peak Instantaneous Water Level Frequencies (m) (I.G.L.D.)

Sector	Recurrence Interval (yrs)							HYDSTAT Parameters (Log Pearson III)		
	2	5	10	25	50	100	200	Location	Scale	Shape
LAKE ERIE (cont)										
E-4 Wheatley	174.58	174.84	174.97	175.12	175.21	175.29	175.36	5.2157	-0.000059296	899.47
E-5 Port Crewe	174.49	174.87	174.87	175.01	175.09	175.17	175.24	5.1964	-0.000086291	400.05
E-6 Erieau*	174.47	174.71	174.83	174.96	175.05	175.12	175.19	5.1901	-0.000099727	284.66
E-7 Port Glasgow	174.49	174.75	174.89	175.03	175.12	175.20	175.28	5.2474	-0.000036678	2332.3
E-8 Port Stanley*	174.60	174.87	175.01	175.17	175.26	175.35	175.44	5.1625	0.000010770	29641
E-9 Port Bruce	174.71	174.98	175.11	175.26	175.35	175.43	175.50	5.1805	-0.00014416	142.36
E-10 Port Burwell	174.78	175.04	175.18	175.32	175.41	175.49	175.56	5.1876	-0.00014413	167.14
E-11 Hemlock	174.88	175.17	175.31	175.46	175.56	175.64	175.72	5.1873	-0.00017496	133.18
E-12 Clear Creek	174.97	175.27	175.42	175.58	175.68	175.77	175.85	5.1875	-0.00019372	118.56
E-13 Erie View	175.08	175.40	175.56	175.73	175.83	175.93	176.01	5.1904	-0.00051904	127.63
E-14 Long Point Park	175.14	175.49	175.68	175.88	176.00	176.12	176.23	5.0173	-0.000038103	3891.1
E-15 Long Point Central	175.23	175.60	175.80	176.02	176.16	176.29	176.40	5.1073	-0.00010708	548.88
E-16 Long Point East	175.29	175.68	175.89	176.11	176.26	176.40	176.53	5.124	-0.00015867	267.61
E-17 Long Point Bay	175.33	175.62	175.77	175.93	176.03	176.13	176.21	5.2673	-0.000038677	2601.5
E-18 Nanticoke	175.42	175.72	175.87	176.03	176.14	176.23	176.32	5.2832	-0.00003476	3338.9
E-19 Selkirk	175.46	175.76	175.92	176.08	176.19	176.29	176.38	5.3279	-0.000026185	6130.3
E-20 Port Maitland	175.57	175.88	176.05	176.21	176.32	176.42	176.50	5.2358	-0.000066124	1024.7
E-21 Mohawk Point	175.62	175.94	176.10	176.28	176.39	176.49	176.58	5.2412	-0.000063822	1141.9
E-22 Port Colborne*	175.51	175.88	176.09	176.32	176.47	176.61	176.74	5.1453	0.00027407	81.874
E-23 Point Abino	175.78	176.12	176.30	176.49	176.62	176.73	176.83	5.0396	0.000040564	3196.2
E-24 Crystal Beach	175.87	176.21	176.39	176.58	176.70	176.81	176.91	5.2696	-0.000054835	1821.2
E-25 Fort Erie	175.97	176.33	176.52	176.71	176.84	176.95	177.05	5.2841	-0.000051535	2208
LAKE ONTARIO										
O-1 Port Weller*	75.09	75.33	75.50	75.72	75.88	76.04	76.20	4.3147	0.0026394	1.7856
O-2 Burlington*	75.28	75.49	75.61	75.75	75.84	75.93	76.02	4.3111	0.00088175	11.79
O-3 Oakville	-	-	-	-	-	75.83	-	-	-	-
O-4 Mississauga	-	-	-	-	-	75.73	-	-	-	-
O-5 Toronto*	75.10	75.27	75.36	75.47	75.54	75.61	75.67	4.3039	0.00043745	34.351
O-6 Oshawa	75.05	75.22	75.31	75.42	75.49	75.55	75.61	4.304	0.00044283	32.256
O-7 Cobourg*	75.15	75.32	75.42	75.53	75.60	75.67	75.73	4.3035	0.00043239	37.111
O-8 Wellington	75.07	75.24	75.33	75.44	75.51	75.58	75.64	4.3042	0.00045958	31.209
O-9 Point Petre	75.04	75.21	75.30	75.41	75.48	75.54	75.61	1.43041	0.00045106	31.301
O-10 Prince Edward	75.09	75.27	75.36	75.48	75.55	75.62	75.69	1.43042	0.00048204	30.474
O-11 Kingston*	75.25	75.44	75.54	75.66	75.73	75.81	75.87	4.3041	0.00046649	36.177

NOTES:

1. The frequencies of peak instantaneous LAKE levels are calculated by combining the individual frequency distributions of monthly mean lake levels and surge values (wind setup) using the MNR HYDSTAT computer program

2. The frequencies of peak instantaneous RIVER levels are calculated with recorded peak instantaneous levels using the computer program CFA88; this program does not list a 25 year value

3. Levels for sectors marked with an * are based on recorded surges; surges at other sections are calculated using the computer model SURGE from AES

4. Conversions from I.G.L.D. to G.S.C. are given in Appendix I

TABLE A. 3

Highest Annual Monthly Mean Lake Level Frequencies

Lake	Water Level (m IGLD) Return Period (years)							HYDSTAT Parameters (Log Pearson Type III)		
	2	5	10	25	50	100	200	Location	Scale	Shape
Superior	183.17	183.29	183.35	183.41	183.45	183.48	183.51	5.2183	-0.0000815	96.86
Huron	176.47	176.76	176.91	177.06	177.16	177.24	177.32	5.1976	-0.0001639	149.42
St. Clair	175.05	175.31	175.44	175.57	175.65	175.73	175.8	5.1847	-0.0001628	120.71
Erie	174.18	174.42	174.55	174.67	174.76	174.83	174.89	5.1805	-0.0001442	142.36
Ontario	74.92	75.1	75.2	75.31	75.39	75.46	75.53	4.3057	0.0006083	18.03

NOTES:

1. "Basis of Comparison" water levels for the period 1900 to 1987 were used in the analysis.

2. For all lakes, the "best fitting" distribution was the Log Pearson Type III according to the least squares criterion in HYDSTAT.

TABLE A. 4

WIND SETUP/SURGE FREQUENCIES

Sector	Wind Setup (m)							HYDSTAT Parameters			
	2	5	10	25	50	100	200	Type	Location	Scale	Shape
LAKE SUPERIOR											
S-1 Pine Point	0.24	0.33	0.40	0.52	0.62	0.75	0.91	LG	-1.529958	0.271399	-
S-2 Thunder Bay*	0.26	0.31	0.35	0.38	0.41	0.43	0.45	LP III	4.342	-0.008635	658.88
S-3 Rossport*	0.28	0.37	0.45	0.56	0.66	0.76	0.88	3 LN	-2.19325	0.72085	-
S-4 Michipicoten*	0.42	0.56	0.64	0.74	0.80	0.86	0.93	P III	0.061455	0.056367	6.7672
S-5 Gros Cap*	0.43	0.53	0.60	0.67	0.71	0.76	0.80	P III	0.061235	0.03567	10.598
S-6 Pointe Louise	-	-	-	-	-	0.96	-	-	-	-	-
LAKE HURON											
H-1 Neebish	-	-	-	-	-	0.48	-	-	-	-	-
H-2 Richards	-	-	-	-	-	0.48	-	-	-	-	-
H-3 Hilton	-	-	-	-	-	0.48	-	-	-	-	-
H-4 St. Joseph	-	-	-	-	-	0.48	-	-	-	-	-
H-5 Thessalon*	0.28	0.33	0.37	0.41	0.45	0.48	0.51	LP III	-2.34430	-0.03746	28.971
H-6 Mississagi Bay	0.35	0.42	0.47	0.53	0.58	0.63	0.68	LP III	-1.51300	0.07458	6.656
H-7 Little Current*	0.40	0.51	0.59	0.69	0.78	0.87	0.96	LP III	-1.96870	-0.74045	14.373
H-8 Cape Roberts	0.34	0.40	0.44	0.49	0.54	0.58	0.63	LP III	-1.51580	-0.72405	6.191
H-9 N. Cockburn Is	0.29	0.35	0.39	0.44	0.48	0.53	0.58	LP III	-1.58060	0.09059	4.201
H-10,H-11 S. Shore	0.15	0.18	0.20	0.22	0.24	0.25	0.27	LP III	-4.77250	0.01553	185.110
H-12 N. Georgian Bay	0.34	0.41	0.46	0.50	0.53	0.56	0.59	LP III	0.15276	-0.05508	22.914
H-13 Parry Sound*	0.42	0.53	0.61	0.72	0.82	0.92	1.03	LP III	-1.35750	0.11729	4.498
H-14 Collingwood*	0.50	0.61	0.68	0.78	0.85	0.93	1.01	LP III	-1.35360	0.06756	10.116
H-15 Meaford	0.39	0.49	0.55	0.62	0.68	0.73	0.78	LP III	-5.08660	-0.01602	259.070
H-16 Dyer's Bay	0.32	0.39	0.45	0.51	0.56	0.61	0.67	LP III	-2.49740	0.04603	29.558
H-17 Tobermory*	0.25	0.32	0.36	0.43	0.48	0.54	0.60	LP III	-1.82390	0.11297	4.346
H-18 Southampton	0.19	0.23	0.25	0.27	0.28	0.30	0.31	LP III	-0.71061	-0.06452	15.412
H-19 Point Clark	-	-	-	-	-	0.49	-	-	-	-	
H-20 Goderich*	0.36	0.43	0.48	0.55	0.61	0.67	0.74	LP III	-1.45400	0.09080	5.005
H-21 Kettle Point	0.44	0.53	0.59	0.66	0.72	0.78	0.84	LP III	-1.60450	0.05311	15.038
H-22 Brights Grove	0.52	0.64	0.72	0.83	0.91	1.00	1.10	LP III	-1.39380	0.07053	10.736
LAKE ST. CLAIR											
SC-1 Walpole	0.55	0.70	0.79	0.91	0.99	1.07	1.14	LN	-0.59216	0.28193	-
SC-2 Mitchell	0.68	0.86	0.97	1.10	1.18	1.27	1.34	LP III	1.973	-0.0372	63.797
SC-3 Dover	0.59	0.76	0.86	0.97	1.04	1.11	1.17	LP III	1.1464	-0.0059	28.666
SC-4 Thames	0.65	0.83	0.94	1.07	1.16	1.24	1.32	P III	0.026512	0.06853	9.7852
SC-5 Tremblay	0.34	0.45	0.53	0.64	0.74	0.85	0.96	LP III	-1.18036	0.11994	6.3629
SC-6 Stoney Point	0.32	0.41	0.47	0.56	0.63	0.71	0.79	LP III	-1.22	0.076521	14.066
SC-7 Belle River*	0.31	0.44	0.53	0.64	0.72	0.81	0.90	LN	-1.1648	0.40826	-
SC-8 Tecumseh*	0.28	0.33	0.36	0.40	0.42	0.45	0.47	LN	-1.27839	0.20194	-

NOTES:

* based on recorded surges: surges at other sectors are calculated using the computer model SURGE from AES.

Where frequency relationships have not been calculated, the 100 year wind setup has been interpolated from adjacent sites.

TABLE A. 4

WIND SETUP/SURGE FREQUENCIES

Sector	Wind Setup (m)							HYDSTAT Parameters			
	2	5	10	25	50	100	200	Type	Location	Scale	Shape
LAKE ERIE											
E-1 Bar Point*	0.61	0.80	0.89	0.98	1.03	1.07	1.11	LP III	0.23225	-0.18941	4.1496
E-2 Kingsville*	0.60	0.72	0.79	0.85	0.90	0.94	0.97	P III	12.7366	-0.001771	6855.88
E-3 Pelee West	0.43	0.56	0.66	0.78	0.88	0.99	1.10	LP III	-2.0266	0.073952	16.374
E-4 Wheatley	0.51	0.65	0.73	0.84	0.91	0.98	1.05	3 LN	-0.68838	0.28436	-
E-5 Port Crewe	0.31	0.39	0.44	0.51	0.55	0.60	0.64	3 LN	-1.23364	0.29466	-
E-6 Erieau*	0.28	0.34	0.37	0.42	0.46	0.49	0.53	LP III	-1.8176	0.06283	9.1582
E-7 Port Glasgow	0.30	0.40	0.47	0.58	0.67	0.77	0.87	3 LN	-1.9131	0.61814	-
E-8 Port Stanley*	0.40	0.53	0.63	0.75	0.85	0.96	1.07	LP III	-2.7365	0.059921	30.625
E-9 Port Bruce	0.56	0.67	0.72	0.77	0.79	0.81	0.83	LP III	0.97221	-0.053782	8.057
E-10 Port Burwell	0.63	0.74	0.78	0.81	0.81	0.82	0.83	LP III	-0.19712	-0.2959	1.121129
E-11 Hemlock	0.72	0.88	0.94	0.98	1.00	1.01	1.02	LP III	0.02158	-0.29084	1.14995
E-12 Clear Creek	0.81	0.99	1.07	1.15	1.19	1.23	1.26	P III	1.15583	-0.072874	10.558
E-13 Erie View	0.92	1.13	1.23	1.32	1.38	1.43	1.47	P III	2.0139	-0.065833	16.945
E-14 Long Point Park	0.96	1.23	1.37	1.54	1.64	1.74	1.84	3 LN	1.31776	0.0818	-
E-15 Long Point Central	1.05	1.34	1.51	1.70	1.82	1.94	2.05	P III	-0.91089	0.05821	33.954
E-16 Long Point East	1.11	1.42	1.60	1.81	1.94	2.07	2.19	P III	-0.63955	0.073059	24.221
E-17 Long Point Bay	1.15	1.32	1.42	1.52	1.59	1.66	1.72	P III	-0.027084	0.026833	53.406
E-18 Nanticoke	1.24	1.42	1.52	1.63	1.71	1.77	1.84	P III	-0.45576	0.043159	67.591
E-19 Selkirk	1.28	1.47	1.58	1.69	1.77	1.84	1.91	P III	-0.5325	0.026695	68.229
E-20 Port Maitland	1.40	1.60	1.71	1.82	1.90	1.96	2.02	N	1.4027	0.24019	-
E-21 Mohawk Point	1.45	1.66	1.77	1.89	1.97	2.04	2.10	N	1.45111	0.25151	-
E-22 Port Colborne*	1.32	1.61	1.80	2.01	2.17	2.32	2.46	LN	0.27407	0.24342	-
E-23 Point Abino	1.60	1.85	1.99	2.14	2.25	2.34	2.43	LP III	1.9755	-0.02167	69.884
E-24 Crystal Beach	1.70	1.95	2.08	2.22	2.31	2.39	2.47	N	1.6961	0.30026	-
E-25 Fort Erie	1.80	2.07	2.21	2.36	2.46	2.55	2.63	N	1.8028	0.3206	-
LAKE ONTARIO											
O-1 Port Weller*	0.16	0.27	0.39	0.59	0.79	1.06	1.41	LG	-2.05023	0.478792	-
O-2 Burlington*	0.33	0.44	0.53	0.67	0.79	0.94	1.12	LG	-1.19962	0.248271	-
O-3 Oakville	-	-	-	-	-	0.81	-	-	-	-	-
O-4 Mississauga	-	-	-	-	-	0.72	-	-	-	-	-
O-5 Toronto*	0.16	0.21	0.24	0.28	0.31	0.34	0.37	3 LN	-2.07162	0.38076	-
O-6 Oshawa	0.12	0.15	0.17	0.20	0.21	0.23	0.25	LN	0.125	0.03411	-
O-7 Cobourg*	0.21	0.27	0.31	0.36	0.40	0.44	0.47	LN	0.22	0.06826	-
O-8 Wellington	0.13	0.17	0.21	0.27	0.32	0.39	0.47	LP III	-1.24069	0.24073	1.7135
O-9 Point Petre	0.10	0.13	0.16	0.20	0.23	0.27	0.32	LG	-2.347132	0.227774	-
O-10 Prince Edward	0.14	0.21	0.26	0.34	0.40	0.47	0.55	3 LN	-2.45682	0.67569	-
O-11 Kingston*	0.31	0.40	0.46	0.54	0.60	0.66	0.72	LP III	-4.9361	0.025067	150.16

NOTES:

* based on recorded surges: surges at other sectors are calculated using the computer model SURGE from AES

Where frequency relationships have not been calculated, the 100 year wind setup has been interpolated from adjacent sites.

REFERENCES

1. Federal Emergency Management Agency 1988. *Revised Report on Great Lakes Open Coast Flood Levels*. U.S. Army Corps of Engineers. Detroit, Michigan.

2. Bishop, C.T. 1987. *Great Lakes Water Levels: A Review for Coastal Engineering Design*. National Water Research Institute, NWRI Contribution 87-18. Burlington, Ontario.

3. U.S. Army Corps of Engineers 1984. *Shore Protection Manual Coastal Engineering Research Centre, Corps of Engineers*. U.S. Government Printing Office. Washington, D.C.

APPENDIX 1

Basis of Comparison (June, 1988)

APPENDIX 1

BASIS OF COMPARISON (June, 1988)

Over the years a number of changes in the regulation of the Great Lakes - St. Lawrence system (eg. St. Lawrence River dams) and changes in diversions into and out of the lakes have taken place which have had measurable effects on flows and levels in the system. In order to estimate water level frequencies in the Great Lakes - St.Lawrence system from measured flow and level records, the observed data must first be adjusted to a constant set of conditions of regulation and diversions.

The general conditions are as follows:

1. A constant diversion of 5,600 cfs into Lake Superior by way of the Long Lac and Ogoki diversions. This diversion was authorized under the exchange of notes, dated October 14 and 31 and November 7, 1940, between the United States and Canada and has averaged approximately this amount since that date.

2. Lake Superior regulated in accordance with Plan 1977, which is the currently authorized plan being used by the International Lake Superior Board of Control for determining releases from Lake Superior.

3. A constant diversion of 3,200 cfs out of Lake Michigan at Chicago. This is the maximum allowable diversion at Chicago by decree of the U.S. Supreme Court, dated June 12, 1967.

4. 1962 outlet conditions for Lake Huron. This represents the current conditions, which have existed since the completion of the 27-foot navigation channel dredging in 1962.

5. A constant diversion, by way of the Welland Canal, of 9,200 cfs out of Lake Erie and into Lake Ontario. This is the current average diversion.

6. 1953 outlet conditions for Lake Erie. In its 1953 report on the Preservation and Enhancement of Niagara Falls, the International Joint Commission considered it essential that the relationship existing

at that time between the Niagara River flow and the Chippewa-Grass Island Pool level be maintained following the commencement of operation of the Chippewa-Grass Island Pool Control Structure and power diversions as permitted by the 1950 Niagara Treaty. The rating curve for the outlet conditions was updated in 1987.

7. Lake Ontario regulated during the period 1900-April 1960 in accordance with Plan 1958-D without discretionary deviation. For the period from April 1960 to the present, Lake Ontario was regulated in accordance with Plan 1958-D with discretionary deviations as they occurred. Minor adjustments to the discretionary deviation values were required during high water periods to preclude violation of the St. Lawrence River low water profiles.

8. Recorded conditions for the Ottawa River and local inflow to the St. Lawrence River.

The levels and outflows to be used as a basis-of-comparison for each lake were obtained by routing through the system the coordinated net basin supplies employing the constant conditions previously listed.

For Lake Superior, the basis-of-comparison levels and outflows were obtained by routing through the lake the coordinated net basin supplies (adjusted for a constant 5,600 cfs diversion into the lake by way of the Long Lac and Ogoki diversions) in accordance with the present regulation plan known as Plan 1977.

Because of the nature of the control in the St. Clair and Detroit Rivers, the problem of routing supplies through Lakes Michigan-Huron, St. Clair and Erie was fairly complex. The St. Clair River and Detroit River flows are dependent not only on Lake Huron levels, but also on the water levels in the lower river and Lake Erie. Therefore, a method of successive approximations of supply routing was used.

APPENDIX 2

Differences Between Geodetic Survey of Canada Datum and International Great Lakes Datum

APPENDIX 2

DIFFERENCES BETWEEN GEODETIC DATUM AND INTERNATIONAL GREAT LAKES DATUM FOR HOLDING BENCH MARKS AT PERMANENT GAUGING STATIONS OPERATED BY THE CANADIAN HYDROGRAPHIC SERVICE

The following differences have been calculated using elevations on Geodetic Datum received from Geodetic Survey of Canada to April 1985 and the originally established elevation on International Great Lakes Datum (IGLD) 1955. Differences marked ** have been calculated using an IGLD (1955) elevation which is different from the originally established elevation. The differences presented below may change as a result of the redefinition of the Geodetic elevation by the Geodetic Survey of Canada.

PLACE	HOLDING B.M.	DIFFERENCE (METRES)
Thunder Bay (Port Arthur)	346-E	.07
Rossport	70-U-652	.06
Michipicoten Harbour	698 G.S.C.	.04
Gros Cap	GROS 3-1963	.13
Sault Ste. Marie (above)	MIDDLE SOO	.11
Sault Ste.Marie (below)	MIDDLE SOO	.11
Thessalon	THES 2-1959	.19
Little Current	LICU 9-1965	.21
Parry Sound	420-A-3	.22
Collingwood	DCLXIX	.20
Tobermory	101-R2	.14
Goderich	72-U-108	.19
Point Edward	PTED 1-1959	.15**
Port Lambton St. Clair River Mouth	POLA 1-1959	.17
Belle River	BELL 1-1961	.21
Tecumseh	TECU 2-1959	.19
La Salle Detroit River	MMMDXLVIII	.19
Amherstburg	71-U-117	.21
Bar Point	3016	.21
Kingsville	3031	.20**
Erieau	H.S. 1-1957	.20
Port Stanley	JW-1975	.17
Port Dover	MMDCCXXX	.20**
Port Colborne	71-U-032	.16
Port Weller	H.S. 3	.11
Burlington, Institute Site	60-U-3327	.08**
Toronto	579-F	.08
Cobourg	67-U-057	.07
Kingston	75-U-502	.14
Brockville	68-U-339	.13
Iroquois Lock (above)	H.S. 2	.12
Iroquois Lock (below)	H.S. 1	.12
Cornwall	CORN-11	.10
Summerstown	2616	.10

Note: G.S.C. Elevation - Difference = I.G.L.D. Elevation