PHASE I

REVISED REPORT ON GREAT LAKES OPEN-COAST FLOOD LEVELS

Prepared by the U.S. Army Corps of Engineers
for the Federal Emergency Management Agency

Detroit, Michigan
April 1988

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ON
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PHASE I

REVISED REPORT

ON

GREAT LAKES OPEN-COAST FLOOD LEVELS

INTRODUCTION

GENERAL

The Federal Emergency Management Agency (FEMA) has adopted the 100-year flood level as the standard for identification of flood hazard areas in conjunction with the National Flood Insurance Program. Often the 10, 50, and 500-year flood levels are also of concern in dealing with flood control and sound flood plain management strategies. A study was performed using water level information through 1974 to develop these flood levels for the Great Lakes. It was published in three booklets in 1977 and 1978; Phase I, Phase II, and Appendices A and B of the "Report on the Great Lakes Open-Coast Flood Levels". In 1987, due to the additional data collected since the original study was completed, and the extreme high water levels experienced in the Great Lakes since that time, FEMA requested an update of the previous study. The basic tenet of this update effort was to retain the approach utilized in the 1977 report. The original study methodology was followed, except where analysis of the data indicated variations were appropriate.

The results of the updated study have been published as three reports with the same format as used in the original Phase I, Phase II, and Appendices. The updated reports are entitled "Revised Report on Great Lakes Open-Coast Flood Levels". The Phase I report documents the statistical technique employed in determining the frequency curves, and details where the updated study methodology varies from the original report. The Phase I report also presents on Plates 1 through 5 the open-coast flood levels determined for each reach of the United States shoreline of the Great Lakes. Open-coast flood levels are defined in this report as the flood levels occurring along a lake shoreline which is unprotected by the presence of islands and which is uninterrupted by bays subject to additional wind setup. The areas excluded from the open-coast study are also indicated on Plates 1 through 5. Comparison of the results of the revised study from the 1977 study are also indicated on Table 2.

In the Phase II report, methods for determining the frequency of flood levels are presented for locations not included in the Phase I report. An analysis of the gage data on the connecting channels is given, along with general guidelines for the application and interpolation of the results. Methods are also included for simulating or deriving flood level data for gages with a short period of record, and for developing flood level frequencies at locations where records of water level data are not available.

Appendices A, B, C, D, and E contain documentation of the updated study which is too detailed to include in the Phase I or Phase II report. Appendix A includes tables of adjustment factors which were applied to recorded water levels to establish a common base which reflects a fixed regimen in the Great Lakes-St. Lawrence River system. The frequency curves from which the various return period flood levels were derived are included in Appendix B. Summary tables of the revised study results, in comparison to the 1977 report, and the water levels for the 10, 50, 100, and 500-year return period at each gage, are presented in Appendix C. Appendix D contains copies of all correspondence pertaining to the development and review of the various drafts of the Phase I and Phase II reports. Examples of flood level frequency determination using short period gage records for Phase II areas are contained in Appendix E.

The various State and Federal agencies concerned with flood insurance studies on the Great Lakes were provided copies of the Phase I and Phase II draft reports in mid-January, 1988 and the end of January, 1988, respectively. The comments that were received have been considered and where appropriate have been incorporated in the updated study.

DATA

RECORDED WATER LEVELS

Official monthly mean and hourly instantaneous water level data, published by the National Ocean Service of the U. S. Department of Commerce, and the Canadian Hydrographic Service of the Canadian Department of Environment, as recorded at 65 stations throughout the Great Lakes and their connecting channels, were used to derive the maximum annual flood levels. The stations and their periods of record are listed in Table 1. Recording gages were continuously operated at these stations for periods ranging from 22 to 86 years, as of 1986. Four additional gages, not included in the original report, were incorporated. They were Port Inland on Lake Michigan, Little Current and Point Edward on Lake Huron, and Port Lambton on the St. Clair River. The Black Rock Canal gage on the Niagara River is no longer functional and was excluded from the new study. The American Falls gage was also excluded from the new study. In 1976, the gage was relocated 400 feet upstream of the original site. Because of the steep slope of the Niagara River between these locations, the data from the two locations could not be used as

TABLE 1 - WATER LEVEL STATIONS

Water Level Gaging Station	Gage No.	Period of Record
Lake Superior		
Point Iroquois	9004	1933-1986
Marquette	9016	1903-1986
Ontonagon	9044	1960-1986
Duluth	9064	1950-1986
Two Harbors	9070	1942-1986
Thunder Bay (C)	02AB018	1915-1986
Michipicoten (C)	02BD004	1915-1986
Lake Huron		
Fort Gratiot	4098	1938-1986
Lakeport	5002	1956-1986
Harbor Beach	5014	1902-1986
Essexville	5035	1953-1986
Harrisville	5059	1963-1986
Detour	5098	1955-1986
Thessalon (C)	02CA006	1926-1986
Tobermory (C)	02FA003	1962-1986
Parrysound (C)	02EA014	1960-1986
Collingwood (C)	02ED012	1915-1986
Goderich (C)	02FE012	1915-1986
Little Current (C)	02CG002	1959-1986
Point Edward (C)	02GG010	1927-1986
Lake Michigan		
Ludington	7023	1951-1986
Holland	7031	1960-1986
Calumet Harbor	7044	1903-1986
Milwaukee	7057	1906-1986
Green Bay	7079	1954-1986
Sturgeon Bay	7072	1946-1986
Mackinaw City	5080	1900-1986
Port Inland	7096	1965-1986
Lake Ontario		
Oswego	2030	1935-1986
Rochester	2058	1956-1986
Cape Vincent	2000	1916-1986
Port Weller (C)	02HA018	1930-1986
Toronto (C)	02HC048	1915-1986
Cobourg (C)	02HD015	1956-1986
Kingston (C)	02HM008	1963-1986

(C) indicates a Canadian station

TABLE 1 - WATER LEVEL STATIONS (Cont'd)

Water Level Gaging Station	Gage No.	Period of Record
Lake Erie		
Buffalo	3020	1900-1986
Barcelona	3032	1961-1986
Erie	3038	1959-1986
Cleveland	3063	1904-1986
Marblehead	3079	1960-1986
Toledo	3085	1941-1986
Fermi	3090	1964-1986
Gibraltar	4020	1941-1986
Kingsville (C)	02GH070	1962-1986
Erieau (C)	02FG002	1957-1986
Port Stanley (C)	02GC027	1926-1986
Port Dover (C)	02GC028	1958-1986
Port Colborne (C)	02HA017	1911-1986
Lake St. Clair		
St. Clair Shores	4052	1953-1986
Belle River (C)	020M005	1961-1986
St. Marys River		
Southwest Pier	6070	1934-1986
U.S. Slip	6060	1934-1986
St. Clair River		
Dunn Paper	4096	1955-1986
Mouth of Black River	4090	1955-1986
Dry Dock	4087	1928-1986
Marysville	4084	1955-1986
St. Clair	4080	1953-1986
Port Lambton (C)	02GG011	1931-1986
Algonac	4070	1953-1986
Detroit River		
Windmill Point	4049	1952-1986
Fort Wayne	4036	1915-1986
Wyandotte	4030	1960-1986
Niagara River		
Niagara Intake	3012	1963-1986
Ashland Avenue	3007	1958-1986
St. Lawrence River		
Ogdensburg	1030	1935-1986

a continuous record. Ten years of record are available at the new location, however, this is too short of a period to develop a frequency curve. The American Falls gage can be included in future studies when the period of record is greater.

MAXIMUM ANNUAL FLOOD LEVELS

The maximum annual flood level at a station is considered to be the highest instantaneous level recorded by a gage during the year at that station. This level is comparable to the storm water level which results from a wind setup superimposed on the undisturbed water level of the lake. Figure 1 illustrates wind effects on lake levels. Short-period fluctuations of water levels, such as created by wave action, are almost completely dampened by the stilling wells in which the gage floats operate. Consequently, flood levels in this report do not include wave runup caused by the waves rushing up a beach or a structure.

There are two types of gages, digital and analog. An analog gage makes a continuous graph of water levels over time. The maximum instantaneous level is readily discernible on analog gage records. A digital gage records water levels at prescribed time intervals, for example, the water level may be measured every hour. Since a maximum instantaneous level cannot be measured by a digital gage, the maximum hourly water level is used. This is usually acceptable, as maximum hourly data published from

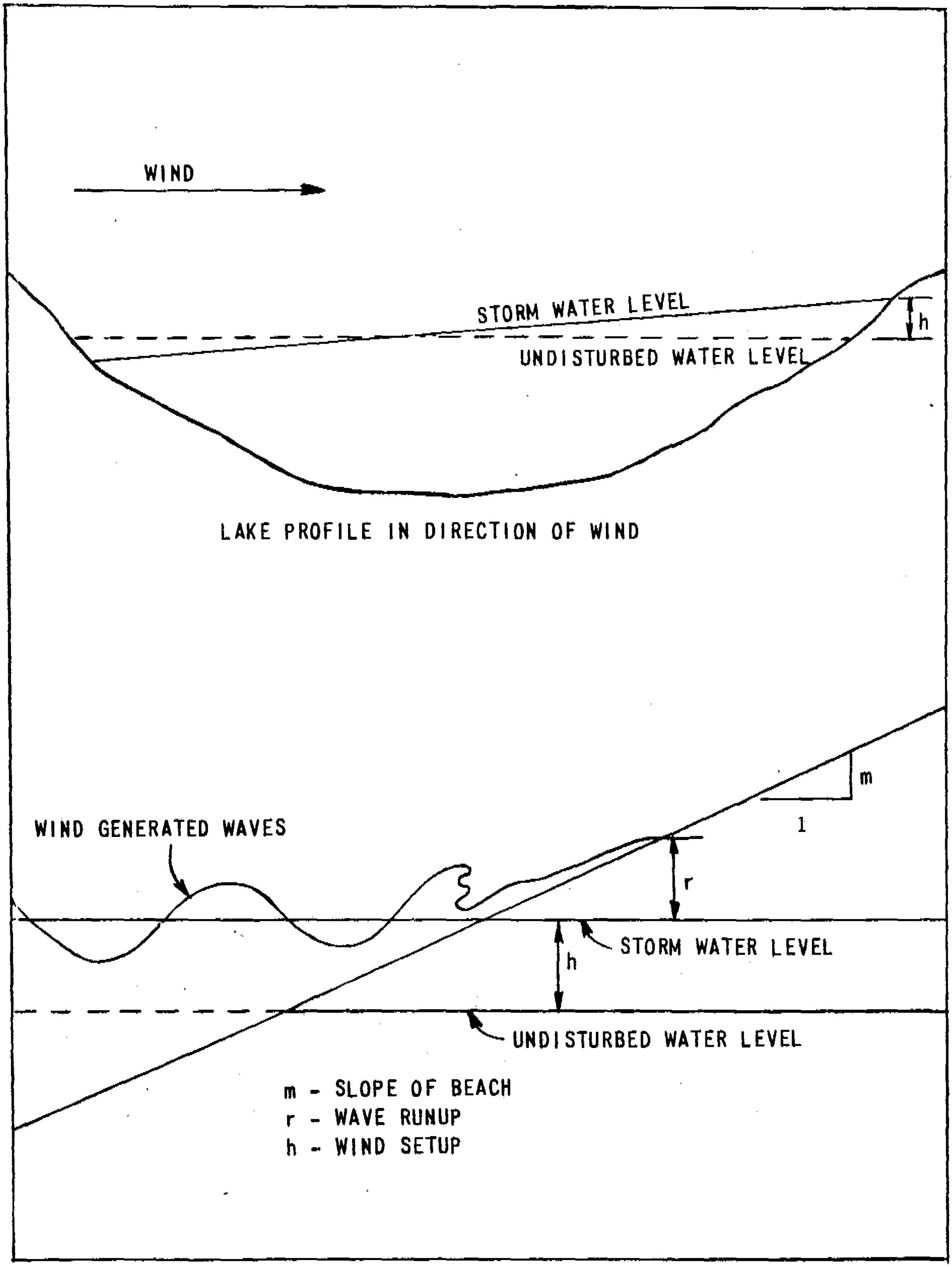


FIGURE 1. WIND EFFECTS ON LAKE LEVELS

digital gages are not significantly different from the maximum instantaneous levels derived from analog gages. However, there are exceptions, as for example at Buffalo, New York, where the water level during storms may rise or fall more than five feet in an hour. In such cases, instantaneous water levels are derived from the recorder of a second analog gage operating in the same well along with the digital gage.

ADJUSTMENT FACTORS

Over the period of record, the levels of the lakes have been significantly affected by changes in the amount of diversions into and out of the Great Lakes Basin, changes in the outflow conditions resulting from regulation of Lakes Superior and Ontario, and dredging within the connecting channels. To account for the effects of these changes on historical levels, the recorded levels were adjusted to present conditions. Adjustments were derived from monthly mean lake levels obtained by routing the 1900-1986 net basin supplies through the Great Lakes under present diversion and outlet conditions. Since the previous study, a revised Lake Erie outlet rating equation has been incorporated, the Long Lac and Ogoki Diversions have been increased from 5,000 cubic feet per second (cfs) to 5,600 cfs, and the Welland Canal Diversion increased from 7,000 cfs to 9,200 cfs. The regulation of Lake Superior has also changed from the 1955 Modified Rule of 1949 to the current plan of operation, known as Plan 1977. The differences each month between the derived levels and the recorded monthly mean levels at the Master Gage sites (Marquette, Harbor Beach, St. Clair Shores, Cleveland and Oswego) were mathematically smoothed and tables of monthly adjustments were generated for 1900 to 1986. These tables are included in Appendix A. The adjustments to be applied to the annual maximum recorded levels at all sites on each lake were obtained from these tables.

METHOD

STATISTICAL ANALYSIS

The statistical analyses of the data addressed the concerns of appropriate frequency distribution, autocorrelation of the data, and regional skew values. The Hydrologic Engineering Center (HEC), and the Waterways Experiment Station (WES) were consulted, and provided comments to the Detroit District's analysis. HEC's report and WES's summary of conclusions are provided in Appendix D.

In the 1977 study, a log-Pearson Type III frequency distribution was used to analyze the data. For this study update, both the log-Pearson Type III and the Pearson Type III distributions were investigated. Comparison of the two methods, when applied to the adjusted data, showed that the skew coefficients were almost identical. HEC concluded that the long record gages gave the same flood levels for given return periods using either method. Therefore, the logarithmic transformation was deemed unnecessary, and the Pearson Type III frequency distribution was adopted for this analysis.

In this study, as well as in the previous study, coincident frequency analysis had been suggested by HEC as the procedure to use. Coincident frequency analysis involves generating two separate frequency curves, one for short duration water level rises (wind induced setup), and one for the maximum undisturbed lake levels. These curves are then statistically combined to produce the final frequency curve. The maximum undisturbed lake levels are not directly measured, but estimated by maximum monthly mean lake levels. The short duration water level rises are calculated by subtracting the monthly mean water levels from the recorded instantaneous maximum water levels. However, since the basic tenet of this update was to retain the approach utilized in the 1977 report, the more complex procedure of coincident frequency analysis was not used.

Two other significant concerns had to be addressed during the course of the statistical analysis of the data. These concerns were the autocorrelation of lake levels, and the different skew values exhibited by frequency distributions among gage sites.

Autocorrelation, as related to lake levels, measures the tendency of a lake level to be similar to the previous year's (or following year's) level. Skew measures the distribution of the magnitude of water levels. Skew gives an indication if high levels occur more frequently than low levels, or vice versa. A zero skew indicates that on the average, high levels occur as often as low levels.

Lakes Michigan-Huron showed the greatest autocorrelation in the yearly data. The other Great Lakes exhibited autocorrelation to a lesser degree. The question of whether autocorrelation was significant was answered by constructing two separate frequencies, based on even year data and odd year data from the Harbor Beach gage. This eliminated the strong yearly dependence present in the data. The overall impact of reducing the dependence and re-introducing it in the form of total data did not significantly alter the frequency relationship. Since Lakes Michigan-Huron exhibited the strongest autocorrelation and this dependence did not create significant differences, the effect of autocorrelation on the other lakes was considered insignificant.

The second concern involved different skew values among gages on the same lake and from lake to lake, and required study to arrive at a satisfactory solution. The Hydrologic Engineering

Center (HEC) performed an extensive analysis on the regional skew characteristics of the data and recommended the following:

	Skew
Lake Superior	0.2
Lake Michigan-Huron	0.2
Lake Erie	0.2
Lake Ontario	0.4

The Waterways Experiment Station (WES) was also consulted and their general findings supported the analysis of HEC. Both reports found that the length of the data record consistently influences computed skews. Gages with longer records gave skews which were less variable and closer to zero. Both reports found regional skew variations between the Lakes, with Lake Ontario being significantly different from the rest. To determine the effect on the frequency curves of using a zero skew or a regional skew, a comparison was made. With the use of HEC's regional skew values, the generated water levels were 0.1 foot to 0.2 foot higher for all of the Lakes, in comparison to the use of zero skew. Based on HEC's extensive review, and WES's recommendation for using a regional skew for Lake Ontario, the regional skew values provided by the Hydrologic Engineering Center were adopted.

RESULTS

OPEN-COAST LEVELS

The open-coast flood levels were derived from the 10, 50, 100, and 500-year flood levels computed for each station taking into consideration such factors as the number of years of record, physical environment of the gage, levels at other gages on the lake and the configuration of the adjoining shoreline. The open-coast levels between gaging stations were interpolated, taking all these factors into consideration, for a smooth transition to avoid showing sudden rises and falls in the levels. The derivation of open-coast levels at the stations and between stations in some cases is judgmental rather than mathematical in nature. Although the flood levels at all current Canadian and U. S. stations were considered in determining the open-coast flood levels, more weight was given to the levels at the stations with the longer periods of record. However, where a gage exists within a reach, the derived open-coast level for that reach is within the 5% and 95% confidence limit interval for the gage's frequency curve.

The updated open-coast flood levels are shown on Plates 1-5. These plates are produced from navigation charts, and show the U.S. shoreline divided into reaches. The delineation of the reaches is unchanged from the 1977 report. The updated 10, 50, 100, and 500-year open-coast flood levels which apply to the reaches are shown in tables located on the Plates, with elevations in feet on both International Great Lakes Datum (1955) and Mean Sea Level Datum (Mean Sea Level Datum is equivalent to the National Geodetic Vertical Datum of 1929).

COMPARISON OF RESULTS

A comparison between the findings of the 1977 report and the updated study generally shows higher expected flood elevations for each of the reported reaches. The higher elevations are mainly due to the fact that extreme high water levels occurred during the added period (1975-1986). A portion of the difference in elevation (0.1 to 0.2 foot) can be attributed to the use of regional skew values as discussed earlier in this report. The average and maximum differences between water levels from each study for each Lake and return period, are listed in Table 2. A detailed comparison of the 1977 study to the revised study, in tabular form, is included in Appendix C. This table compares the 1977 study's 10, 50, 100, and 500-year flood levels for each reach to the results of the updated study.

FUTURE UPDATES

Because the period of record of some stations used in this report is so short, the flood levels reported herein should be

TABLE 2 - COMPARISON OF RESULTS

The Average and Maximum Differences Found in Comparing the Revised Study to the 1977 Study, (Feet)

	Return Period							
	10-Year		50-Year		100-Year		500-Year	
Lake	Ave.	Max.	Ave.	Max.	Ave.	Max.	Ave.	Max.
Lake Superior	0.0	0.2 (C)	0.1	0.3 (C)	0.1	0.3 (C)	0.2	0.4 (C)
Lake Huron	0.0	0.0	0.2	0.2	0.3	0.3	0.6	0.6
Lake Michigan	0.5	0.9 (K)	0.7	1.1 (K)	0.8	1.2 (K)	1.1	1.5 (K)
Lake St. Clair	0.7	0.7 (AA)	1.0	1.0 (AA)	1.1	1.1 (AA)	1.5	1.5 (AA)
Lake Erie	0.2	0.6 (Z)	0.3	0.7 (A,Z)	0.4	0.9 (A)	0.7	1.1 (A,Z)
Lake Ontario	0.0	0.0	0.3	0.3	0.3	0.3	0.6	0.6

The average difference was calculated by (1) subtracting the 1977 study results from the revised study results for each reach in a lake, and then (2) averaging the differences on each lake.

The maximum difference was the maximum value found on a lake at a specific reach when the 1977 study results were subtracted from the revised study results. The letter in parentheses indicates the reach at which the maximum difference occurred. If no letter follows the maximum value, this indicates that the difference was the same for all reaches on a lake.

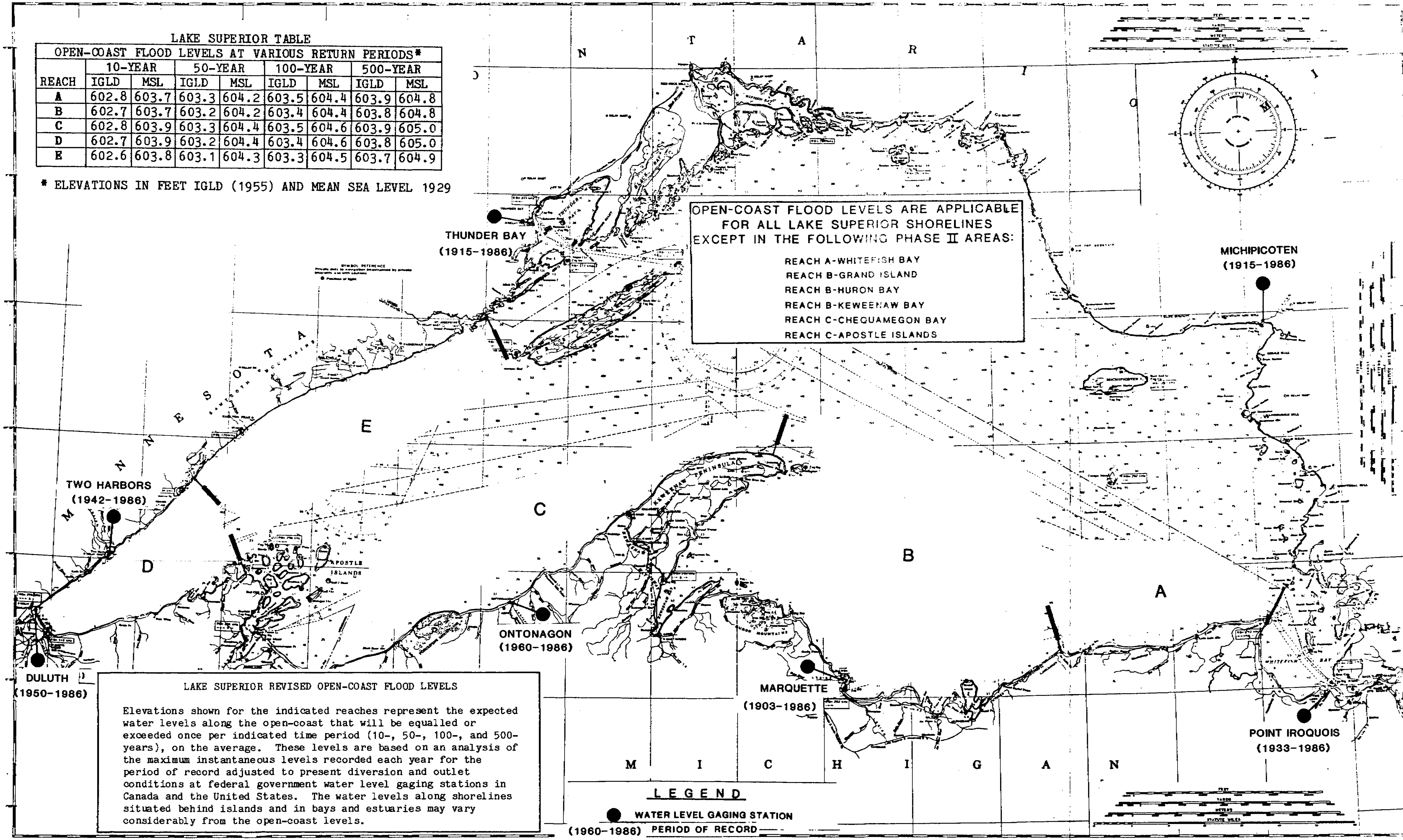
reviewed in about 15 years (2000-2005). At that time, the longer record will provide data of greater statistical significance.

Note: See the Phase II report of the Revised Report on Great Lakes Open-Coast Flood Levels for those areas not covered in this Phase I report.

LAKE SUPERIOR TABLE

OPEN-COAST FLOOD LEVELS AT VARIOUS RETURN PERIODS*								
	10-YEAR		50-YEAR		100-YEAR		500-YEAR	
REACH	IGLD	MSL	IGLD	MSL	IGLD	MSL	IGLD	MSL
A	602.8	603.7	603.3	604.2	603.5	604.4	603.9	604.8
B	602.7	603.7	603.2	604.2	603.4	604.4	603.8	604.8
C	602.8	603.9	603.3	604.4	603.5	604.6	603.9	605.0
D	602.7	603.9	603.2	604.4	603.4	604.6	603.8	605.0
E	602.6	603.8	603.1	604.3	603.3	604.5	603.7	604.9

* ELEVATIONS IN FEET IGLD (1955) AND MEAN SEA LEVEL 1929



OPEN-COAST FLOOD LEVELS ARE APPLICABLE FOR ALL LAKE SUPERIOR SHORELINES EXCEPT IN THE FOLLOWING PHASE II AREAS:

- REACH A-WHITEFISH BAY
- REACH B-GRAND ISLAND
- REACH B-HURON BAY
- REACH B-KEWEENAW BAY
- REACH C-CHEQUAMEGON BAY
- REACH C-APOSTLE ISLANDS

LAKE SUPERIOR REVISED OPEN-COAST FLOOD LEVELS

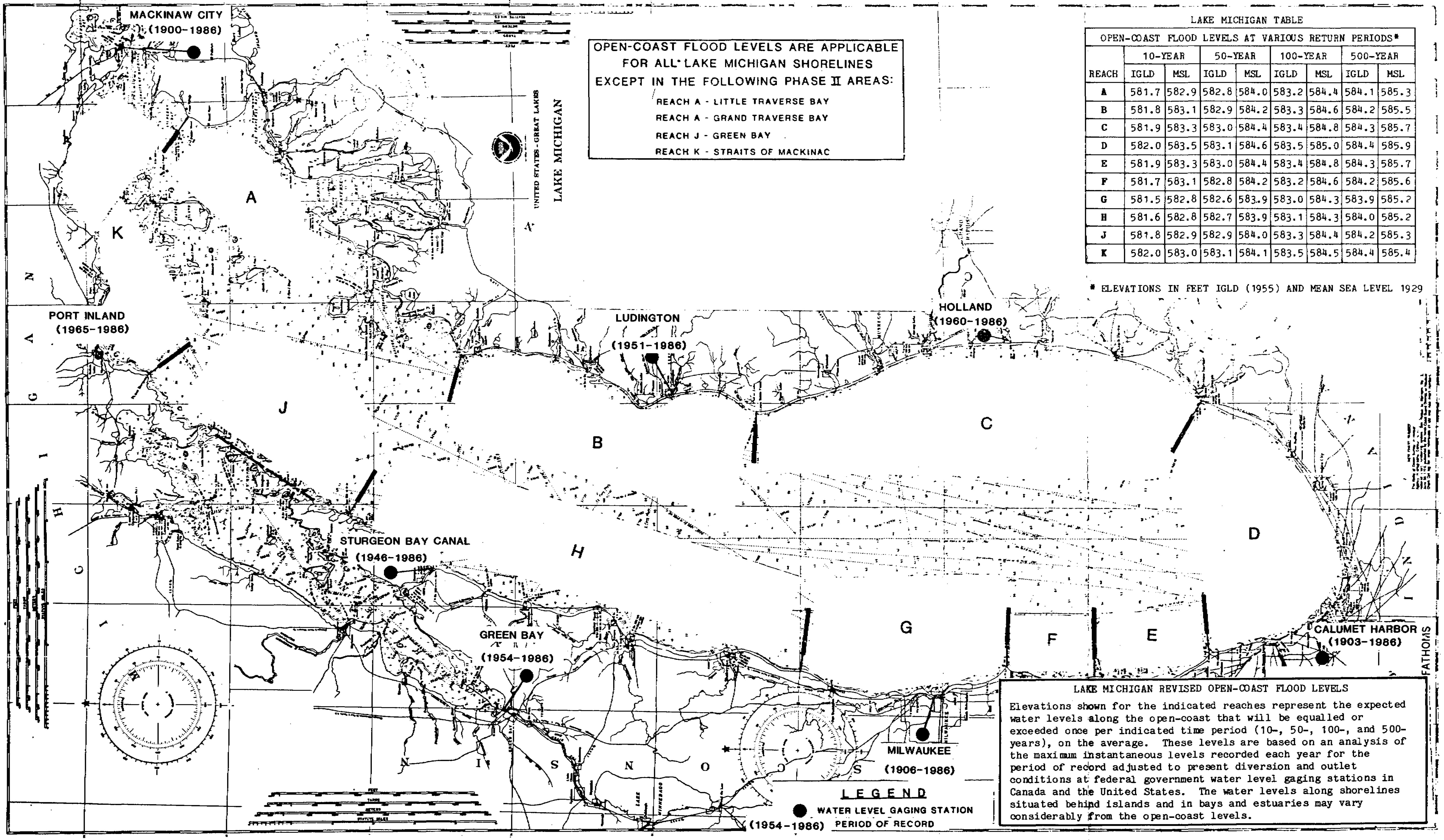
Elevations shown for the indicated reaches represent the expected water levels along the open-coast that will be equalled or exceeded once per indicated time period (10-, 50-, 100-, and 500-years), on the average. These levels are based on an analysis of the maximum instantaneous levels recorded each year for the period of record adjusted to present diversion and outlet conditions at federal government water level gaging stations in Canada and the United States. The water levels along shorelines situated behind islands and in bays and estuaries may vary considerably from the open-coast levels.

LEGEND

● WATER LEVEL GAGING STATION

(1960-1986) PERIOD OF RECORD

PLATE 1



OPEN-COAST FLOOD LEVELS ARE APPLICABLE FOR ALL LAKE MICHIGAN SHORELINES EXCEPT IN THE FOLLOWING PHASE II AREAS:

REACH A - LITTLE TRAVERSE BAY
REACH A - GRAND TRAVERSE BAY
REACH J - GREEN BAY
REACH K - STRAITS OF MACKINAC

LAKE MICHIGAN TABLE

OPEN-COAST FLOOD LEVELS AT VARIOUS RETURN PERIODS*								
	10-YEAR		50-YEAR		100-YEAR		500-YEAR	
REACH	IGLD	MSL	IGLD	MSL	IGLD	MSL	IGLD	MSL
A	581.7	582.9	582.8	584.0	583.2	584.4	584.1	585.3
B	581.8	583.1	582.9	584.2	583.3	584.6	584.2	585.5
C	581.9	583.3	583.0	584.4	583.4	584.8	584.3	585.7
D	582.0	583.5	583.1	584.6	583.5	585.0	584.4	585.9
E	581.9	583.3	583.0	584.4	583.4	584.8	584.3	585.7
F	581.7	583.1	582.8	584.2	583.2	584.6	584.2	585.6
G	581.5	582.8	582.6	583.9	583.0	584.3	583.9	585.2
H	581.6	582.8	582.7	583.9	583.1	584.3	584.0	585.2
J	581.8	582.9	582.9	584.0	583.3	584.4	584.2	585.3
K	582.0	583.0	583.1	584.1	583.5	584.5	584.4	585.4

* ELEVATIONS IN FEET IGLD (1955) AND MEAN SEA LEVEL 1929

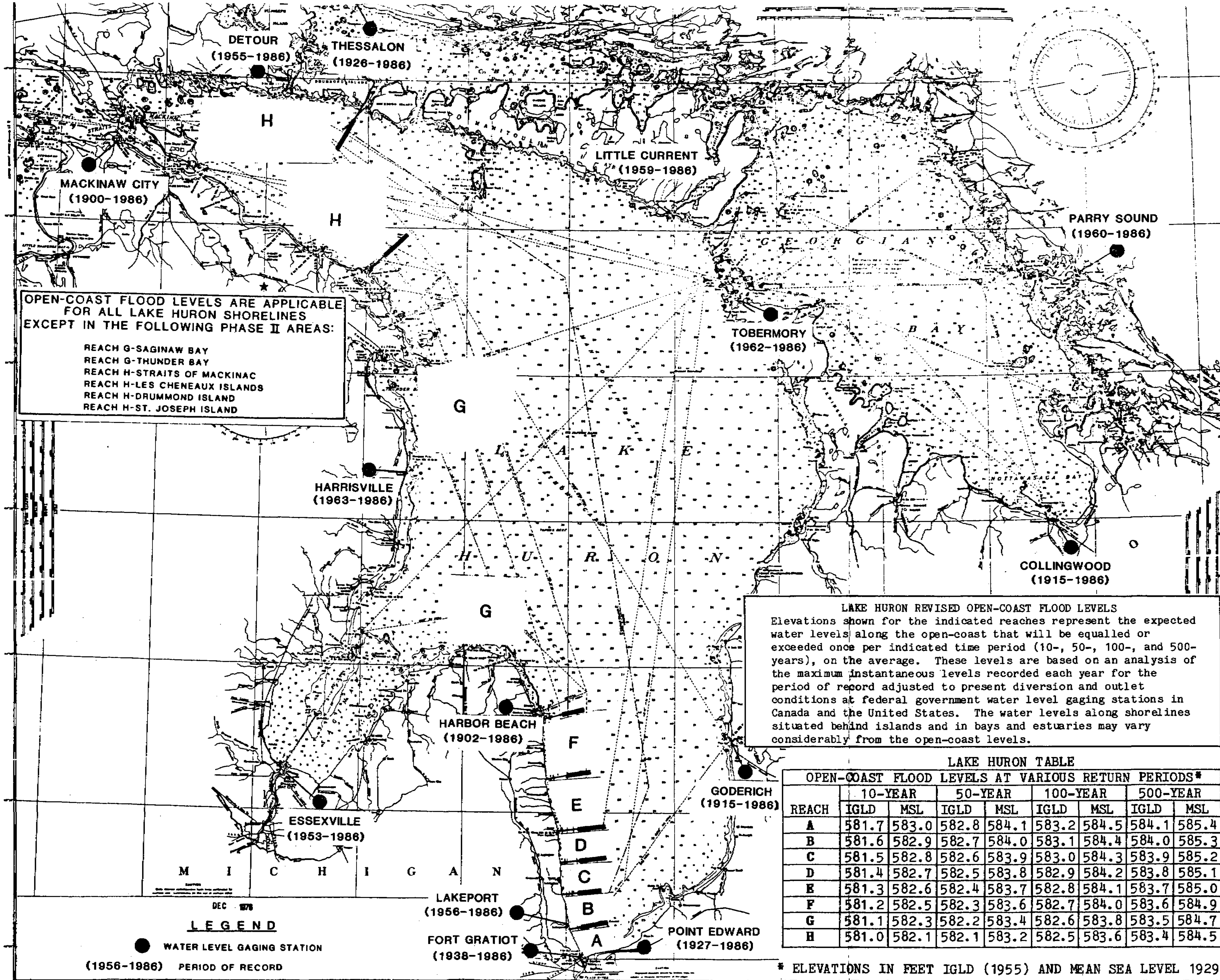
LAKE MICHIGAN REVISED OPEN-COAST FLOOD LEVELS

Elevations shown for the indicated reaches represent the expected water levels along the open-coast that will be equalled or exceeded once per indicated time period (10-, 50-, 100-, and 500-years), on the average. These levels are based on an analysis of the maximum instantaneous levels recorded each year for the period of record adjusted to present diversion and outlet conditions at federal government water level gaging stations in Canada and the United States. The water levels along shorelines situated behind islands and in bays and estuaries may vary considerably from the open-coast levels.

LEGEND

● WATER LEVEL GAGING STATION
(1954-1986) PERIOD OF RECORD

PLATE 2



LAKE HURON REVISED OPEN-COAST FLOOD LEVELS

Elevations shown for the indicated reaches represent the expected water levels along the open-coast that will be equalled or exceeded once per indicated time period (10-, 50-, 100-, and 500-years), on the average. These levels are based on an analysis of the maximum instantaneous levels recorded each year for the period of record adjusted to present diversion and outlet conditions at federal government water level gaging stations in Canada and the United States. The water levels along shorelines situated behind islands and in bays and estuaries may vary considerably from the open-coast levels.

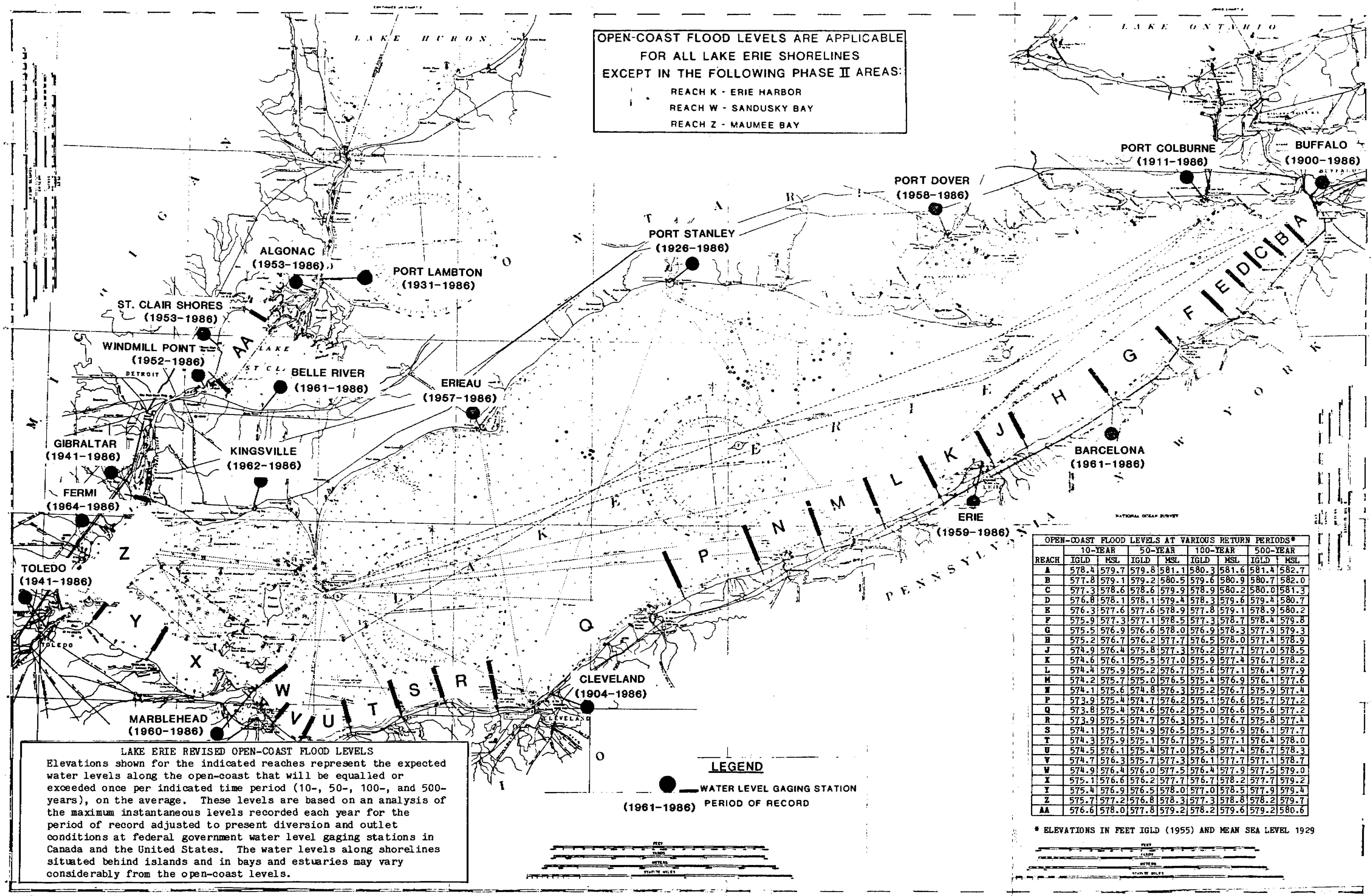
LAKE HURON TABLE

OPEN-COAST FLOOD LEVELS AT VARIOUS RETURN PERIODS*

REACH	10-YEAR		50-YEAR		100-YEAR		500-YEAR	
	IGLD	MSL	IGLD	MSL	IGLD	MSL	IGLD	MSL
A	581.7	583.0	582.8	584.1	583.2	584.5	584.1	585.4
B	581.6	582.9	582.7	584.0	583.1	584.4	584.0	585.3
C	581.5	582.8	582.6	583.9	583.0	584.3	583.9	585.2
D	581.4	582.7	582.5	583.8	582.9	584.2	583.8	585.1
E	581.3	582.6	582.4	583.7	582.8	584.1	583.7	585.0
F	581.2	582.5	582.3	583.6	582.7	584.0	583.6	584.9
G	581.1	582.3	582.2	583.4	582.6	583.8	583.5	584.7
H	581.0	582.1	582.1	583.2	582.5	583.6	583.4	584.5

* ELEVATIONS IN FEET IGLD (1955) AND MEAN SEA LEVEL 1929

PLATE 3



OPEN-COAST FLOOD LEVELS ARE APPLICABLE FOR ALL LAKE ERIE SHORELINES EXCEPT IN THE FOLLOWING PHASE II AREAS:

REACH K - ERIE HARBOR
REACH W - SANDUSKY BAY
REACH Z - MAUMEE BAY

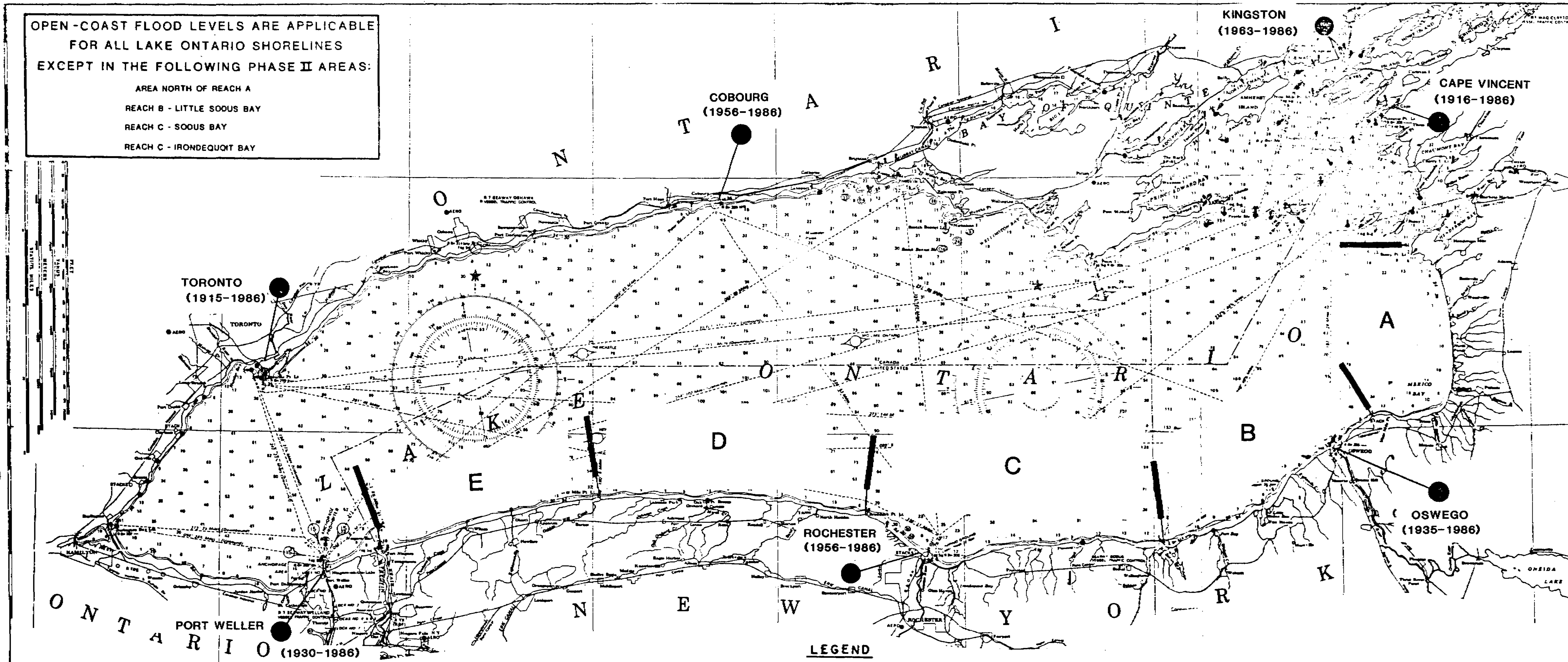
LAKE ERIE REVISED OPEN-COAST FLOOD LEVELS

Elevations shown for the indicated reaches represent the expected water levels along the open-coast that will be equalled or exceeded once per indicated time period (10-, 50-, 100-, and 500-years), on the average. These levels are based on an analysis of the maximum instantaneous levels recorded each year for the period of record adjusted to present diversion and outlet conditions at federal government water level gaging stations in Canada and the United States. The water levels along shorelines situated behind islands and in bays and estuaries may vary considerably from the open-coast levels.

OPEN-COAST FLOOD LEVELS AT VARIOUS RETURN PERIODS*

REACH	10-YEAR		50-YEAR		100-YEAR		500-YEAR	
	IGLD	MSL	IGLD	MSL	IGLD	MSL	IGLD	MSL
A	578.4	579.7	579.8	581.1	580.3	581.6	581.4	582.7
B	577.8	579.1	579.2	580.5	579.6	580.9	580.7	582.0
C	577.3	578.6	578.6	579.9	578.9	580.2	580.0	581.3
D	576.8	578.1	578.1	579.4	578.3	579.6	579.4	580.7
E	576.3	577.6	577.6	578.9	577.8	579.1	578.9	580.2
F	575.9	577.3	577.1	578.5	577.3	578.7	578.4	579.8
G	575.5	576.9	576.6	578.0	576.9	578.3	577.9	579.3
H	575.2	576.7	576.2	577.7	576.5	578.0	577.4	578.9
J	574.9	576.4	575.8	577.3	576.2	577.7	577.0	578.5
K	574.6	576.1	575.5	577.0	575.9	577.4	576.7	578.2
L	574.4	575.9	575.2	576.7	575.6	577.1	576.4	577.9
M	574.2	575.7	575.0	576.5	575.4	576.9	576.1	577.6
N	574.1	575.6	574.8	576.3	575.2	576.7	575.9	577.4
P	573.9	575.4	574.7	576.2	575.1	576.6	575.7	577.2
Q	573.8	575.4	574.6	576.2	575.0	576.6	575.6	577.2
R	573.9	575.5	574.7	576.3	575.1	576.7	575.8	577.4
S	574.1	575.7	574.9	576.5	575.3	576.9	576.1	577.7
T	574.3	575.9	575.1	576.7	575.5	577.1	576.4	578.0
U	574.5	576.1	575.4	577.0	575.8	577.4	576.7	578.3
V	574.7	576.3	575.7	577.3	576.1	577.7	577.1	578.7
W	574.9	576.4	576.0	577.5	576.4	577.9	577.5	579.0
X	575.1	576.6	576.2	577.7	576.7	578.2	577.7	579.2
Y	575.4	576.9	576.5	578.0	577.0	578.5	577.9	579.4
Z	575.7	577.2	576.8	578.3	577.3	578.8	578.2	579.7
AA	576.6	578.0	577.8	579.2	578.2	579.6	579.2	580.6

* ELEVATIONS IN FEET IGLD (1955) AND MEAN SEA LEVEL 1929



LEGEND

● Water level gaging station

(1935-1986) PERIOD OF RECORD

LAKE ONTARIO TABLE

OPEN-COAST FLOOD LEVELS AT VARIOUS RETURN PERIODS*								
	10-YEAR		50-YEAR		100-YEAR		500-YEAR	
REACH	IGLD	MSL	IGLD	MSL	IGLD	MSL	IGLD	MSL
A	247.5	248.7	248.3	249.5	248.5	249.7	249.2	250.4
B	247.4	248.6	248.2	249.4	248.4	249.6	249.1	250.3
C	247.3	248.5	248.1	249.3	248.3	249.5	249.0	250.2
D	247.2	248.4	248.0	249.2	248.2	249.4	248.9	250.1
E	247.1	248.2	247.9	249.0	248.1	249.2	248.8	249.9

* ELEVATIONS IN FEET IGLD (1955) AND MEAN SEA LEVEL 1929

LAKE ONTARIO REVISED OPEN-COAST FLOOD LEVELS

Elevations shown for the indicated reaches represent the expected water levels along the open-coast that will be equalled or exceeded once per indicated time period (10-, 50-, 100-, and 500-years), on the average. These levels are based on an analysis of the maximum instantaneous levels recorded each year for the period of record adjusted to present diversion and outlet conditions at federal government water level gaging stations in Canada and the United States. The water levels along shorelines situated behind islands and in bays and estuaries may vary considerably from the open-coast levels.

GLOSSARY

Analog Gage: A recording device where a pen scribes on a continuous graph the water levels obtained at a certain location.

Annual Maximum Instantaneous Water Level: The highest water level that was recorded during a year by a gage with a sampling frequency of an hour or less.

Annual Maximum Monthly Mean Water Level: The highest monthly average water level that occurred at a gage during a year.

Autocorrelation: Tests the tendency of certain numbers to be related to other numbers.

Confidence Limits: Computed values on both sides of an estimate of a parameter that show for a specified probability the range in which the true value of the parameter lies.

Digital Gage: A recording device that registers water levels on punch tape at a certain prescribed interval at a certain location.

Diversion: The transfer of water from one drainage basin to another.

Fetch: The unobstructed distance over water in which waves are generated by a wind of relatively constant direction and speed.

Flood Frequency Curve: A graph relating flood water elevation and the probability of occurrence in any year.

Frequency Distribution: A function describing the relative frequency with which events of various magnitudes occur.

International Great Lakes Datum (IGLD): Common reference datum for the Great Lakes area based on mean water level in the St. Lawrence River at Father Point, Quebec and established in 1955.

International Joint Commission: A single unit commission between the U.S. and Canada, created by the Boundary Waters Treaty of 1909, seeking solutions to the common problems in the joint interest of both countries.

Master Gage: A lake level gage situated as to give an overall representative level of a lake, and usually having a long period of record.

Mean Sea Level (MSL): The datum referenced to the average height of the surface of the sea, found by averaging all stages of the tide over a 19-year period, at 26 stations along the Atlantic and Pacific Oceans, and the Gulf of Mexico. The establishment of the National Geodetic Vertical Datum included the 26 stations, thus referencing NGVD to MSL (See National Geodetic Vertical Datum.)

National Geodetic Vertical Datum of 1929 (NGVD): The nationwide reference surface for elevations throughout the United States. It was established by the National Geodetic Survey in 1929. Mean Sea Level datum is equivalent to NGVD of 1929 (See Mean Sea Level).

One Hundred Year Flood: A flood level that would be equalled or exceeded once in 100 years on average.

Open-Coast: Shoreline which is unprotected by the presence of islands and which is uninterrupted by bays.

Period of Record: The time interval in which data have been collected.

Reach: A section of a lake's shoreline with similar physical characteristics.

Regional Skew: A geographic area which displays similar skewing characteristics (see skew).

Runup: The rush of water up a beach or structure, associated with the breaking of a wave. The amount of runup is measured according to the vertical height above still water level that the rush of water reaches.

Skew Coefficient A numerical measure or index of the lack of symmetry in a frequency distribution. A negative skew indicates that values less than the mean occur more frequently in the sample distribution. A positive skew indicates that values greater than the mean occur more frequently in the sample distribution.

Still Water Level: The elevation that the surface of the water would assume if all wave action were absent.

Storm Water Level: A rise above normal water level on the open-coast due to the action of wind stress on the water surface (see Wind Setup).

GLOSSARY (Cont'd.)

Wave Height: The vertical distance between a crest and the preceeding trough.

Wave Setup: Superelevation of the water surface over normal surge elevation due to onshore mass transport of the water by wave action alone.

Wind Setup: Vertical rise in the stillwater level on a body of water caused by piling up of water on the shore due to wind action.

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