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GREAT LAKES STORM SURGE PLANNING PROGRAM (SSPP)

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Table of Contents

List of Figures

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ABSTRACT. This report describes a computer program for estimating maximum and minimum storm surge water levels for the Great Lakes. Storm surge water levels for a given wind speed and wind direction can be calculated for Lake Ontario, Central and Eastern Lake Erie, Western lake Erie, Lake St. Clair, Lake Huron, Saginaw Bay, the eastern shore of Lake Michigan, the western shore of Lake Michigan, Green Bay, or Lake Superior. The program can be run on any PC-type computer.

1. BACKGROUND

The Great Lakes Storm Surge Planning Program (SSPP) is a computer program written in the BASIC computer language for the purpose of estimating maximum water levels due to storm surge in the five Great Lakes and Lake St. Clair. It was developed by the Great Lakes Environmental Research Laboratory (GLERL) in response to requests for such information from the Michigan Department of Natural Resources, the Ohio Department of Natural Resources, the U.S. Army Corps of Engineers, the Wisconsin Sea Grant Institute Advisory Service, the National Park Service, and the St. Lawrence - Eastern Ontario Commission. The program can be run on many types of personal computers. The user is asked to supply a mean lake water level, a wind speed, and a wind direction. The program then lists maximum and minimum expected water level elevations at several points on the shoreline of the selected area. A mean lake level value (IGLD - International Great Lakes Datum, MSL - Mean Sea Level, or chart datum) can be added to the maximum and minimum elevations by the program if desired. The program is intended to be used as a planning tool for disaster preparedness, not as a storm surge forecast method. (NOAA's National Weather Service has responsibility for Great Lakes storm surge forecasts.)

2. METHOD

The SSPP program is based on results from the numerical storm surge model developed by Schwab (1978) and Schwab et al. (1981). The numerical storm surge model is run on a 5-km grid for Lakes Ontario, Erie, Michigan, and Huron, a 1.2-km grid for Lake St. Clair, and a 15-km grid for Lake Superior, once with a uniform, impulsive wind stress from the west and once with a stress from the south. Since the model is based on linear dynamics, the response to an impulsive wind stress from any direction and of any magnitude can be synthesized from the eastward and northward results by linear superposition. This is the method used in SSPP. Water level responses for 15 points in each of ten areas are stored in DATA statements in the program. The responses are multiplied and superposed according to the input wind speed and direction. The maximum level for each of the 15 points during the 12 hours following the onset of the wind is then tabulated. The program can also list the hour of the maximum level. Water level responses have been stored for ten areas: (1) Lake Ontario, (2) Central and Eastern Lake Erie, (3) Western Lake Erie, (4) Lake St. Clair, (5) Lake Huron (except Saginaw Bay), (6) Saginaw Bay, (7) Eastern Shore of Lake Michigan, (8) Western Shore of Lake Michigan, (9) Green Bay, and (10) Lake Superior. The 15 points at which water level elevations are calculated for each area are shown in Figs. l-10.

3. RUNNING THE PROGRAM

A sample run of SSPP is shown in Appendix A. SSPP first asks for a file name for the listing it produces. SSPP then asks which area the program is to be run for. (In Append ix A, Western Lake Erie is selected by entering a “3”.) Next the program asks for the mean lake level in feet. This can be relative to IGLD or MSL, or it can be entered as 0 for relative elevations from an arbitrary mean level. (In Appendix A, a mean level of 571 feet is used.) The program then asks for wind speed in miles per hour. This should be a representative overwater wind speed for neutral stability conditions at 10 m above the water surface. If more details are required to convert overland to overwater wind speed or to adjust for atmospheric stability, see Schwab and Morton (1984) and Schwab (1978). (In the sample run, a wind speed of 30 mph is selected.) Finally, the program asks for the direction the wind is blowing from. An entry of 0 degrees corresponds to a wind blowing from the north, 90 corresponds to a wind from the east, 180 from the south, and 270 from the west. In the sample run, a wind direction of 45^{o} [NE] is used. The program then computes the water level response at each of the 15 points for the area selected (see Figs. l-10) and records the maximum and minimum hourly value from the 12 hours after the onset of the wind. The values are then added to mean level and listed in columns. (In the sample run, the maximum level obtained is 576.0 feet for point 8.)

4. LIMITATIONS

The basic limitations of the hydrodynamic model are given in Schwab (1978). Briefly, the model is linear (water level displacements are assumed to be small compared with water depth), bottom friction is proportional to the square of the vertically averaged velocity, and baroclinic effects are ignored. In SSPP, the wind is assumed to be spatially uniform and constant in time. Time- or space- variable winds can have a significant effect on storm surge response (see Schwab, 1978). Also, results are computed only for 15 selected points for each area (Figs. l-10). SSPP uses a constant drag coefficient of 0.0032 to convert wind speed to wind stress at the water surface. This value is based on the work of Plateman (1963) and Schwab (1978) for storm surges on Lake Erie and Simons (1975) on Lake Ontario and may be somewhat high for the smaller fetches obtained in Lake St. Clair and Green Bay. There is also evidence that the drag coefficient increases in unstable marine boundary layers and decreases in stable conditions. These limitations should be considered when using the results of SSPD for planning.

5. REFERENCES

Platzman, G.W. 1963. The Dynamical Prediction of Wind Tides on Lake Erie. Meteorological Monographs, Vol. 4 No. 26, American Meteorological Society, Boston, 44 pp.

Schwab, D.J. 1978. Simulation and forecasting of Lake Erie storm surges. *Mon. Weather Rev*. 106(10):1476-1487.

Schwab, D.J., and J.A. Morton. 1984. Estimation of overlake wind speed from overland wind speed: a comparison of three methods. *J. Great Lakes Res*. 10(1):68-72.

Schwab, D.J., J.R. Bennett, and A.T. Jessup. 1981. A two-dimensional lake circulation modeling system. NOAA Tech. Memo. ERL-GLERL-38, 79 pp.

Simons, T.J. 1975. Effective wind stress over the Great Lakes derived from long-term numerical model simulations. *Atmosphere* 13(4):169-179.

Appendix A: Sample Run of SSPP

Great Lakes Storm Surge Planning Program
Version 1.4 - 313187

NOM - Great Lakes Environmental Research Laboratory
Ann Arbor, Michigan

Enter file name for listing ('LPTl:' for printer) or hit RETURN for screen output only: LPTl:

Area Selections:
[l] Lake Ontario
[2] Central and Eastern Lake Erie
[3] Western Lake Erie
[4] Lake St. Clair
[5] Lake Huron (except Saginaw Bay)
[6] Saginaw Bay
[7] Eastern Shore of Lake Michigan
[8] Western Shore of Lake Michigan
[9] Green Bay
[l0] Lake Superior
[0] End Program

Enter Area Selection: 3

Storm Surge Planning Program for Western Lake Erie

Enter mean lake level in feet (-999 to quit): 571

Enter wind speed in miles per hour: 30

Enter direction wind is coming from in degrees (0 = North): 45

Maximum and minimum water level elevation for Western Lake Erie with a mean lake level of 571 feet and wind speed of 30 mph from 45 degrees.

POINT NUMBER	MAXIMUM ELEVATION (feet)	MINIMUM ELEVATION (feet)
1	574.5	570.4
2	574.7	570.8
3	575.0	571.0
4	575.3	571.0
5	575.5	571.0
6	575.7	571.0
7	575.8	571.0
8	576.0	571.0
9	575.5	571.0
10	575.5	571.0
11	575.7	571.0
12	575.6	571.0
13	575.8	571.0
14	574.6	571.0
15	574.2	571.0

Figure 1. Locations of 15 grid squares corresponding to 15 water level elevation points for Lake Ontario (5 km grid).

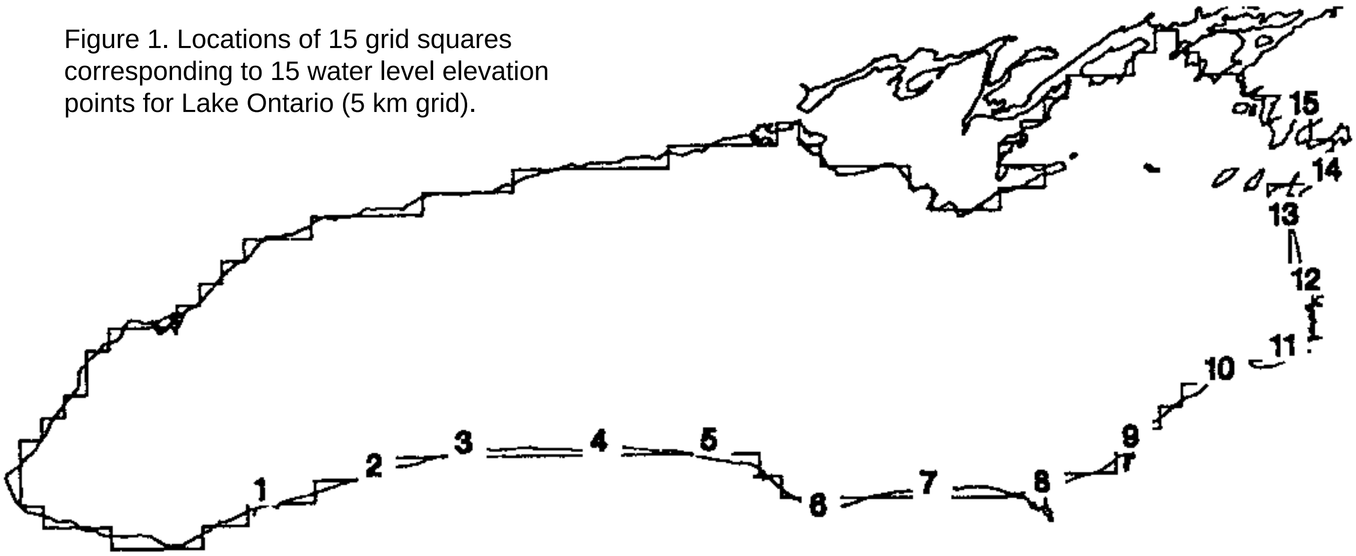
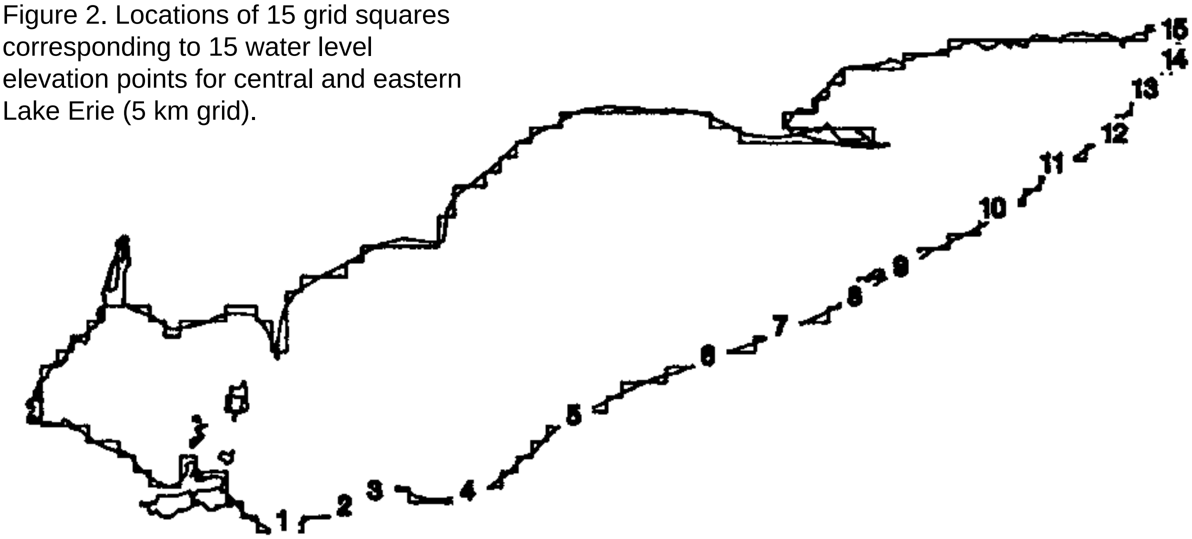


Figure 2. Locations of 15 grid squares corresponding to 15 water level elevation points for central and eastern Lake Erie (5 km grid).



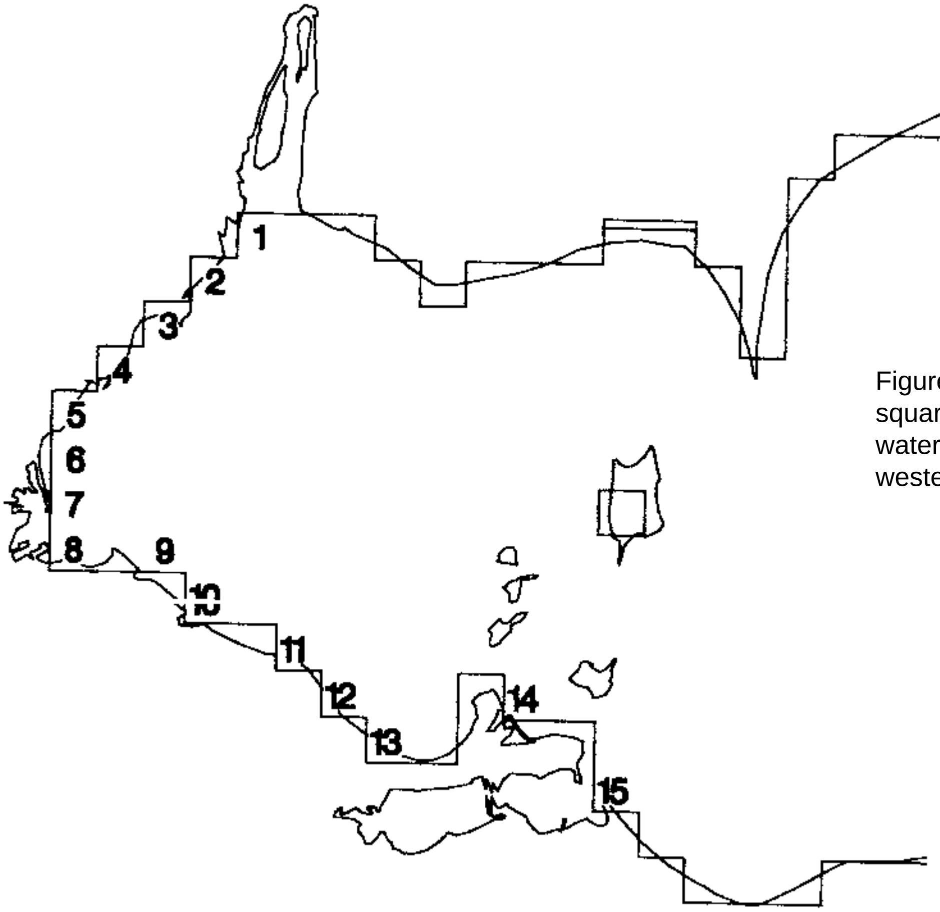


Figure 3. Locations of 15 grid squares corresponding to 15 water level elevation points for western Lake Erie (5 km grid).

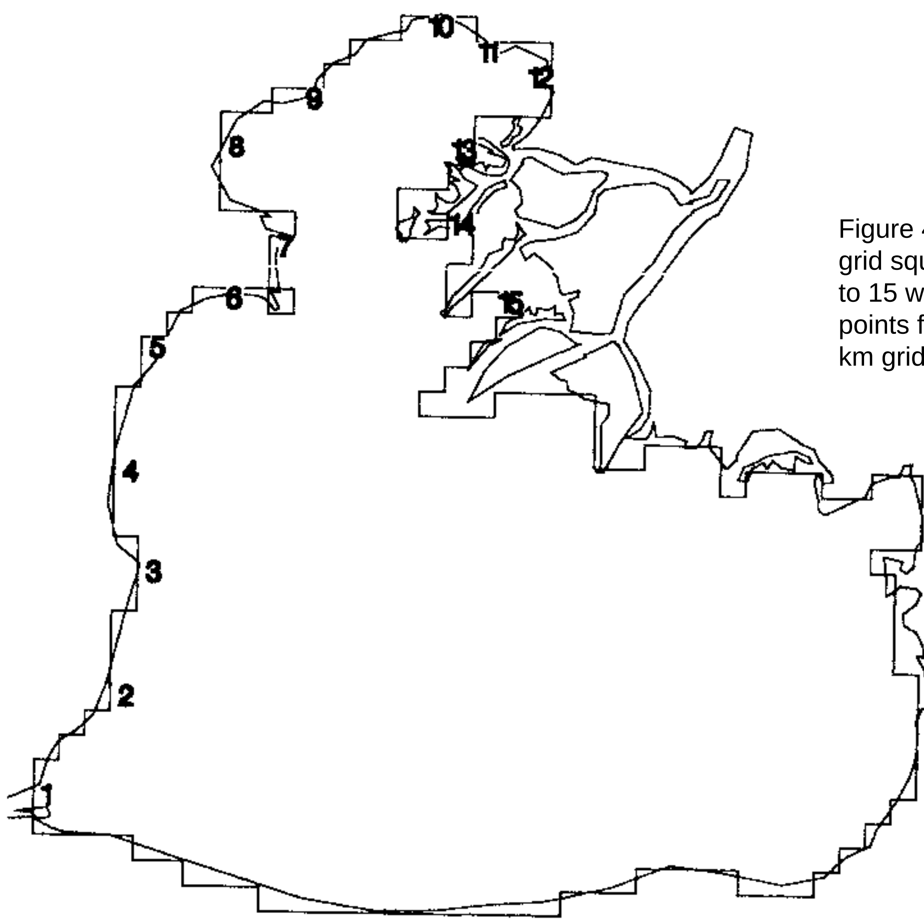


Figure 4. Locations of 15 grid squares corresponding to 15 water level elevation points for Lake St. Clair (1.2 km grid).

Figure 5. Locations of 15 grid squares corresponding to 15 water level elevation points for Lake Huron (except Saginaw Bay) (5 km grid).

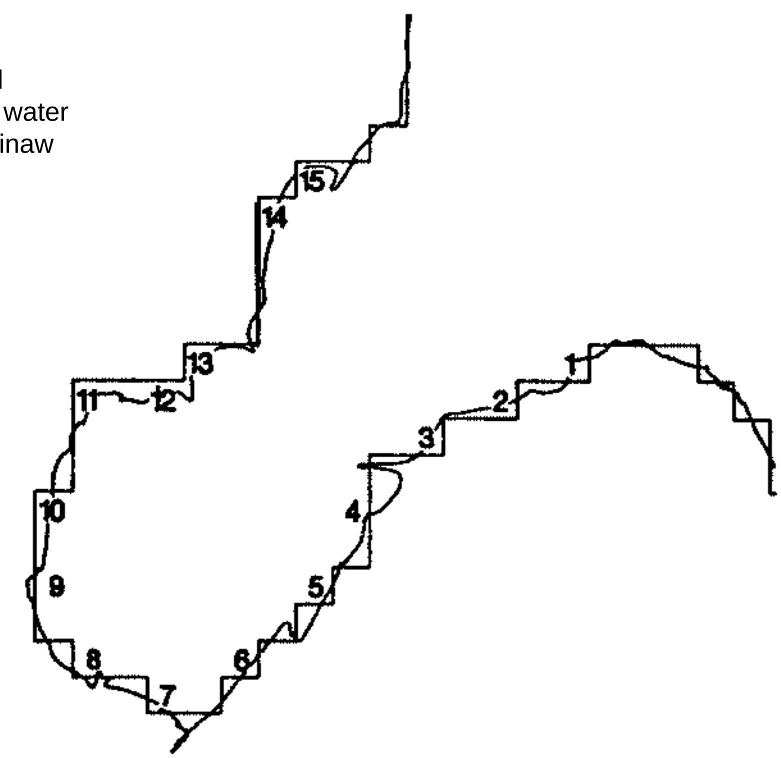


Figure 6. Locations of 15 grid squares corresponding to 15 water level elevation points for Saginaw Bay (5 km grid).

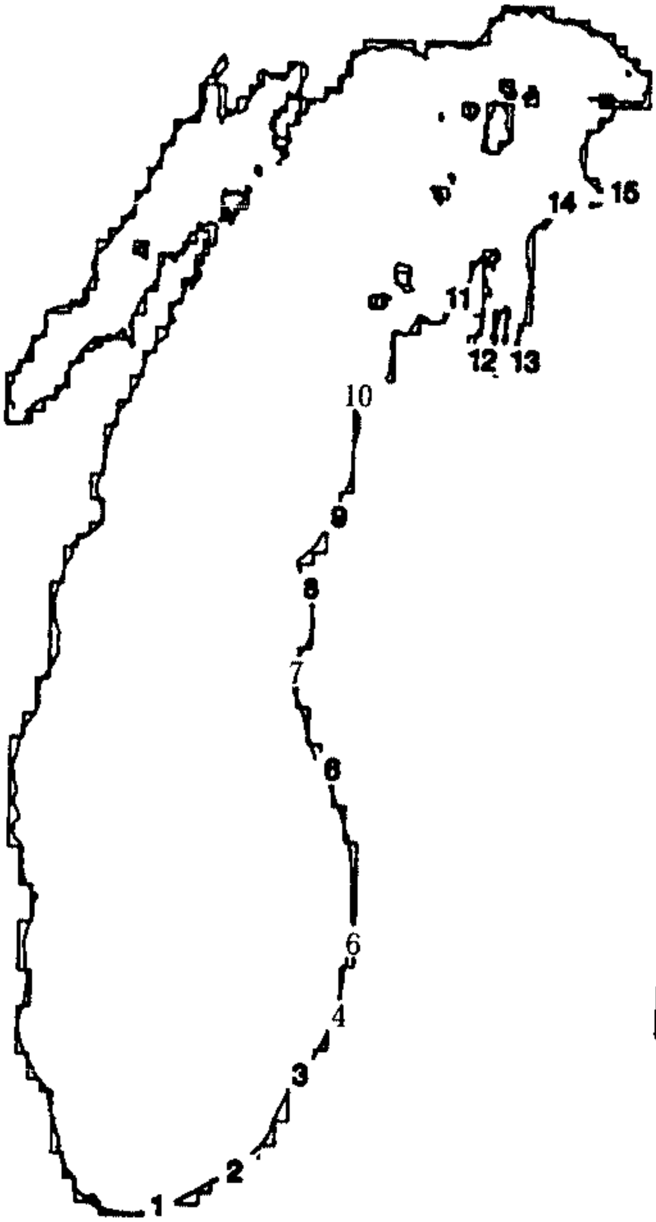


Figure 7. Locations of 15 grid squares corresponding to 15 water level elevation points for eastern shore of Lake Michigan (5 km grid).

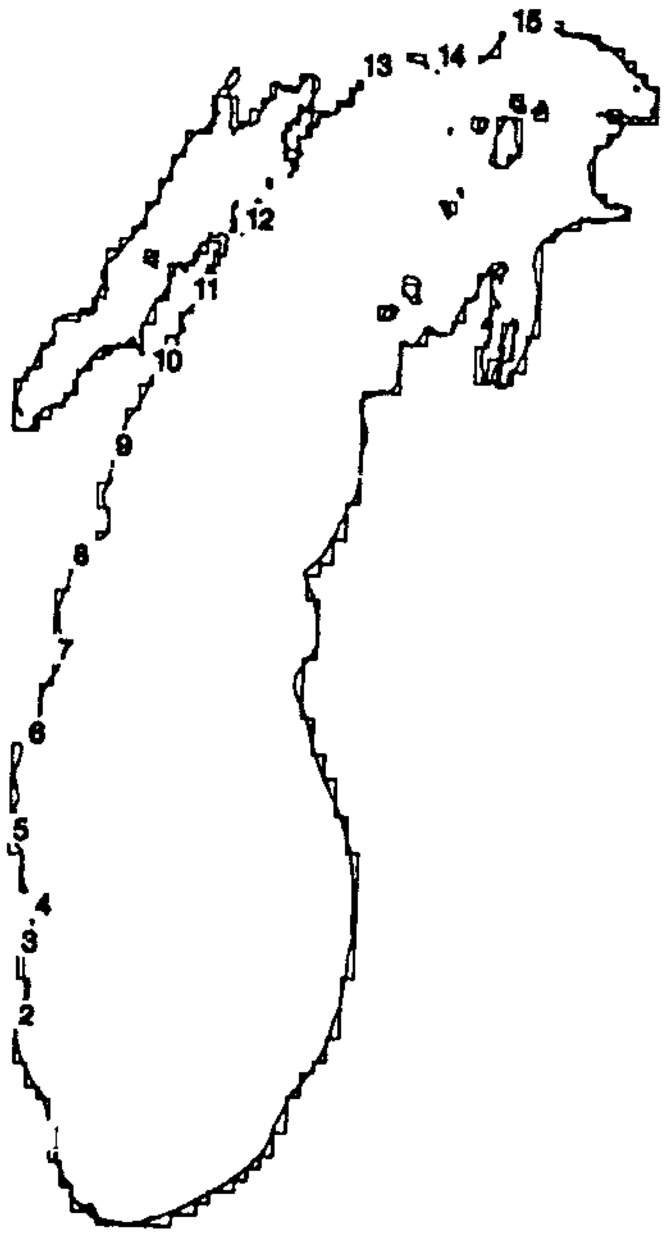
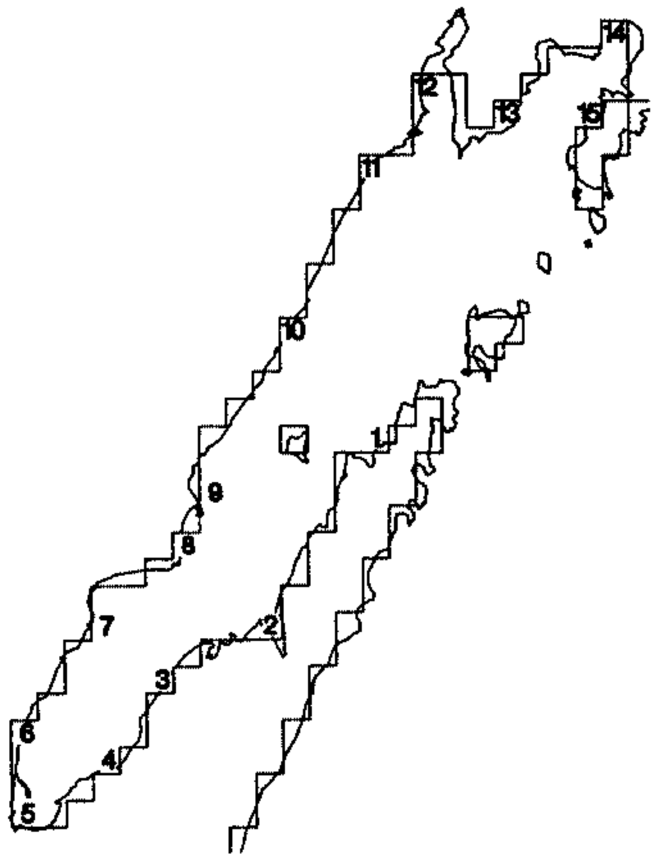


Figure 8. Locations of 15 grid squares corresponding to 15 water level elevation points for western shore of Lake Michigan (5 km grid).

Figure 9. Locations of 15 grid squares corresponding to 15 water level elevation points for Green Bay (5 km grid).



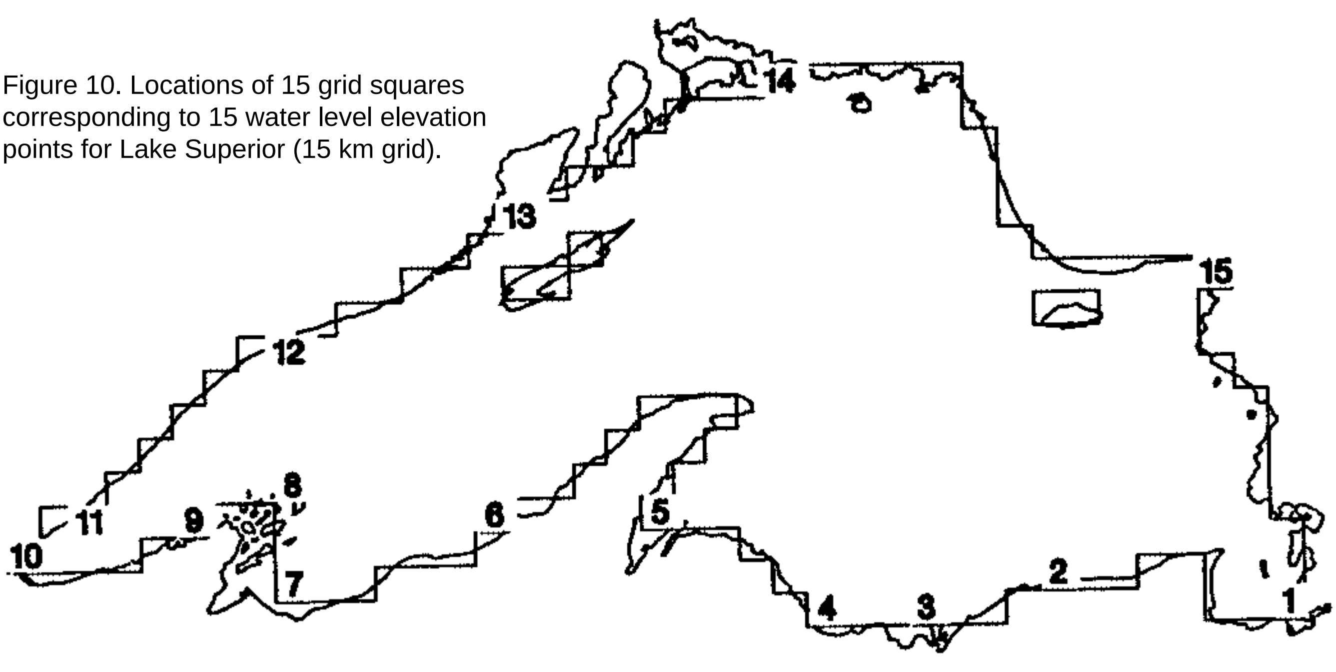


Figure 10. Locations of 15 grid squares corresponding to 15 water level elevation points for Lake Superior (15 km grid).