U.S. GREAT LAKES SHORELINE MAPPING PLAN

DEVELOPED BY THE

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

AND

U.S. GEOLOGICAL SURVEY

A COOPERATIVE UNDERTAKING BY THE USGS-NOAA JOINT OFFICE FOR

MAPPING AND RESEARCH

Open-File Report 90-97

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EXECUTIVE SUMMARY

Hundreds of millions of dollars have been lost during this century due to the fluctuating water levels of the Great Lakes. For the 40 million people and the many industries vital to our economy that are located in the Great Lakes basin, up-to-date large scale maps of the impacted coastal and nearshore regions are essential to establish setback limits, guide planning and safe development, and protect the environment.

Since the "dust bowl" period of the 1930's, lake levels have been increasing in a series of peaks, each higher than the last, that attained the most recent record level in 1986. During each high lake level, rates of bluff erosion increased, beachfront property was lost, and structures and beaches were submerged; during each intervening low lake level, navigation channels and harbors required extensive dredging often of polluted sediments, hydro-electric output decreased, the load on fresh-water pumping facilities increased, and sewage disposal problems became more complex.

To cope with these problems, the International Joint Commission (IJC) requested "updated and accurate large-scale maps of the shoreline and coastal zone." And subsequently, Congress, through PL 100-220, the Great Lakes Shoreline Mapping Act of 1987, instructed NOAA and USGS to-"submit to the Congress a plan for preparing maps of the shoreline of the Great Lakes-".

To meet this mandate, the recently formed USGS/NOAA Joint Office for Mapping and Research (JOMAR), will coordinate and integrate the efforts of the two agencies to focus on a systematic regional assessment of erosion, sedimentation, and flooding in the Great Lakes Basin. The two agencies will initially collate and compile the large volume of data that has already been acquired in and around the Lakes by Federal, State, Provincial and local agencies, universities, and private industry. Close cooperation with scientists and managers in Canada will be especially important in view of the extensive mapping and research that have been carried out on the Canadian side of the Great Lakes.

This plan contains a schedule to update existing maps, and to develop new ones, where needed, that depict the geographic and geologic framework of the Great Lakes shorelines, the areas of change, and some of the processes responsible for those changes. Within a 10-year period, we will obtain geodetically controlled shoreline photography to determine precise topographic and bathymetric information; these data will be combined with other hydrographic data, forming a continuous data set from onshore to offshore. Tentatively, the study will start in Lake Michigan followed by Lakes Huron, Erie, Ontario, and Superior. Priority

will be given to areas subject to a high risk of erosion (> 1 foot/year) or flooding.

Data will be maintained in a Geographic Information System (GIS) that will be available to the public. It will include the following suite of maps:

- Topography and geology of the onshore area for a distance of 1 km landward of the shoreline or to the 500-yr floodline.
- Classification of the shoreline as bluff, dune, plain, beach, bedrock, wetland, etc.
- Bathymetry and geology of the offshore area for a distance of 2 km or a water depth of 30 meters.
- Historic data depicting the migration of the shoreline.
- Wave, current, storm-surge, and climate history.
- Lake level history.
- Ice regime.
- Shore defense structures.
- Pertinent cultural, demographic, and transportation information.

From these basic-data maps, we will construct derivative maps depicting potential shoreline erosion, lake levels, flood limits, and wave climate that will enhance interagency efforts to develop models for predicting shoreline changes.

Principal Federal agencies involved in the execution of the studies will be the National Ocean Service (NOS) of the National Oceanic and Atmospheric Administration (NOAA), and the Geologic and National Mapping Divisions of the United States Geological Survey (USGS). Principal Federal users of the products generated during the study will be the International Joint commission (IJC), the U. S. Army Corps of Engineers (ACOE), the Federal Emergency Management Agency (FEMA), the Environmental Protection Agency (EPA), the Water Resources Division of the U. S. Geological Survey and the Great Lakes Environmental Research Laboratory (GLERL) of NOAA. In addition to these agencies NOAA and USGS will work closely with States, and regional and local agencies to ensure widest possible application of data and models to coastal hazard abatement.

The total cost of the plan is $9,950,000 per year over a 10-year period. The cost breakout is as follows:

ACTIVITY	AGENCY	COST
Shoreline and Hydrographic Surveys	NOAA	$3,950,000
Geologic and Topographic Mapping	USGS	$6,000,000
	Total Cost/year	$9,950,000

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Cover: Photograph courtesy of Philpott Associates Coastal Engineers, Ltd.
Port Bruce, Lake Erie
Storm, December 5, 1985
Photo by Milo Sturm

U.S. GREAT LAKES SHORELINE MAPPING PLAN

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INTRODUCTION

Background

"The Great Lakes encompass over 9000 miles of coastline, and the Great Lakes basin provides a home to 15 percent of the U.S. population and 50 percent of Canada's population. Of the entire Great Lakes shoreline, 83 percent is privately owned land, valued between $100 and $1000 per linear foot. Fluctuations in Great Lakes water levels have resulted in large losses along the Great Lakes shorelines. The high water period of 1951-52 caused an estimated loss of $61 million per year. A U.S. Army Corps of Engineers study indicated that, during the high water period of 1972-76, an estimated $170 million was spent on private shoreline protection structures, while $231 million of property (land and structures) loss occurred. The third, and most recent, occurrence of record-setting high lake levels during this century and the resultant severe storm damage throughout the Great Lakes region have once again pointed to the need for an increased understanding of coastal processes to minimize loss through better coastal resources management programs." [1]

Since the "dust bowl" period of the 1930's, lake levels have been increasing in a series of peaks, each higher than the last, that attained their most recent record high level in 1986. Each period of high lake level has been accompanied by increased storm damage and rates of erosion, loss of beachfront property, and submergence of structures and beaches. Intervening low level periods have been accompanied by commercial navigation problems associated with shoaling channels and harbors, requiring extensive dredging (often of polluted sediments), the need to modify docks and launching ramps, decreased hydro-electric output, increased load on fresh-water pumping facilities, and increasingly complex sewage disposal problems[2]. The impact of lake level fluctuations will increase in severity as the U.S. and Canadian populations continue to concentrate in lakefront areas.

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[1] Meadows, L.A., Editor, Great Lakes coastal erosion research needs, workshop summary, July 8-9, 1987 - Ann Arbor, Michigan, 63p.

[2] Modified from Grima, A.P. and Wilson-Hodges, C., 1977, Regulation of Great Lakes water levels: the public speaks out: J. Great Lakes Research, v. 3, p. 240-257.

This Study Plan responds to the need expressed by the International Joint Commission (IJC) for "updated and accurate large-scale maps of the shoreline and coastal zone", and to the language set forth in Public Law 100-220, the "Great Lakes Shoreline Mapping Act of 1987". PL 100-220 instructs the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Geological Survey (USGS) to -"submit to the Congress a plan for preparing maps of the shoreline of the Great Lakes-". The maps "shall include - bathymetry of the nearshore area - topography of the adjacent shoreline -, the geological conditions of the nearshore area and shoreline -, information concerning the recent geological past of the nearshore area - [all] to the extent that this area will directly affect or be affected by coastal erosion or flooding -, and appropriate information for use in predicting and preventing damage caused by erosion and flooding in the Great Lakes -".[3]

NOAA is responsible for mapping the coastal waters of the United States, including the Great Lakes shoreline, and the baseline from which marine boundaries are determined. The Agency is also responsible for measuring and reporting marine and nearshore bathymetry and topography. The Geologic Division of USGS offers state-of-the-art programs and techniques in land and marine geologic and geophysical mapping; the National Mapping Division of USGS has the responsibility for the topographic mapping of the Nation. All of these efforts can be integrated and systematized through the recently formed USGS/NOAA Joint Office for Mapping and Research (JOMAR) to focus on systematic regional assessments. At the same time, NOAA and USGS digital data bases can be expanded to accommodate the newly acquired coastal hazards data. The Joint Office thus can serve as a mechanism to collate and compile the large volume of data that has already been acquired in and around the Lakes by Federal, State, and local agencies, universities, and private industry.

In addition to ensuring that maps are compatible with those being assembled for Canadian waters, coordination and collaboration with the extensive work being carried on in Canada will be encouraged and supported. An excellent effort, for example, is now underway between the Michigan Department of Natural Resources and Environment Canada to develop and share data bases.

Representatives from the United States and Canadian Great Lakes shoreline erosion research communities will be invited to participate in an advisory committee to guide the compilation of existing data and acquisition of new data. Representatives from other areas of concern, such as environmental protection, natural resources, and recreation, will be included in the committee to ensure that maximum benefit is derived from the study. The committee also will be responsible for convening workshops at least once each year to monitor the progress of each phase of the study. In addition, a technical advisory group of Geographic Information System (GIS) and database specialists will be convened early in the program to establish standards for data storage and distribution. In concert with the advisory committee, this group will assist in determining the most appropriate hierarchal structure of the data assembly and collection.

[3]See Appendix 1 for the complete text of PL 100-220.

Although attempts to abate the effects of natural forces by construction of barriers and replenishment of sediment will continue in critical areas, modifying every threatened area along thousands of miles of shoreline will be too costly. In some cases, shoreline processes must be allowed to function and man-made facilities will have to retreat. To define the potential threat and determine the extent of necessary retreat or setback, information about the status and rates of change of coastal regions is required. We must improve our capability to predict lake-level changes and to evaluate the sensitivity for erosion of any particular stretch of coast. Both are imperative if we are to ameliorate the physical and economic effects of natural hazards.

Monitoring during periods of both high water and low water is essential. We are dealing with a system that is being primed during low lake levels for extensive shoreline erosion during high lake levels. The gun is loaded during low water and fired during high water. It will be impossible to solve the problems associated with high lake levels without fully understanding how they developed during periods of low lake level.

Decisions regarding the location/relocation and design of facilities within any coastal region must be based on valid data that define historical change, current geography, predicted erosion, and the long-term effects of subsidence or uplift.

STRATEGY

A series of maps will be developed that depict the geographic and geologic framework of the Great Lakes shoreline, the areas of change, and some of the processes responsible for those changes. These maps will be compatible with those being assembled for Canadian waters. Mapping will fill a need to assimilate basic information about the status and changeability of the coastal region: What is the location of the present shoreline and the configuration of nearby onshore and offshore features? What have been the historical changes in the shoreline? What is the geology of the area and what are the projected erosion rates? This information must be readily available before any decisions should be made concerning coastal development and definition of setback lines. Periodic measurement of geographic and geologic information in an integrated and systematic manner will also benefit the modelling of storm surge and sediment transport processes. Such data will provide information essential for the safety of life and property and wise management of the coastal region.

Studies of the most critical areas of erosion in the Great Lakes will be multifaceted and will require participation of scientists and engineers from various offices of both NOAA and the USGS, augmented by personnel from other Federal agencies, State agencies, universities, and private enterprise. The USGS and NOAA will integrate the activities, many of which will be occurring simultaneously.

The physiography and geology of the nearshore region on both the wet and dry sides of the shoreline must be accurately mapped to provide the essential framework with which to evaluate changes and to assess the processes responsible for those changes. For some areas, adequate information to construct the necessary maps already exists; for others, little or no information is currently available. New data will have to be collected to the degree necessary to characterize each area.

Within a 10-year period, geodetically controlled shoreline photography will be acquired to determine precise topographic information within selected regions that, combined with hydrographic data, will form a continuous data set from onshore to offshore based on the Great Lakes datum. Follow-on mapping will have a minimal 30-year cycle, with a 5-year cycle of photographic reobservation to monitor the interim status of regional change. Appendix 2 shows the status of existing hydrographic coverage. Appendix 3 provides details of the shoreline mapping effort. Appendices 4 and 5 provide depictions of flood-prone and erosion-prone areas along the shores of the Great Lakes.

The National Mapping Division's (NMD) cartographic and image mapping support will include updating the base map data where needed, compiling maps and digital data at 1:10,000 scale in areas of high shoreline mobility, and acquiring color infrared aerial photography at 1:40,000 scale. Contours will be in meters to be compatible with NOAA and the Canadian research community. All maps produced will be digitized to collect hypsographic, transportation, bathymetric, hydrographic, and boundary data categories. Appendix 6 shows the USGS Quadrangles most in need of revision, Appendix 7 shows the contour intervals available on the USGS Quadrangles, and Appendix 8 shows those areas where digital data are available.

The Geologic Division of the USGS will assemble existing data for each lake and will conduct onshore and offshore geologic and geophysical surveys where needed. This will require close collaboration with State Geological Surveys and with scientists mainly from research laboratories and universities surrounding the lakes.

For most stable areas, mapping will extend 1 km inland from the shoreline with a contour interval of 3 m. These mapping data will delineate the inland extensions of the 100- and 500-year flood plains.

For identified areas of high-priority coastal hazard, reobservations will be carried out from 6 months to 2 years. In such areas, low-altitude photography will be required to define precisely coastal topography (with a contour interval of 1-m, optionally 0.5-m) to the 500-year flood limit where possible. Intensive reobservation in specified study areas will be contracted locally.

Bathymetric profiles will be acquired from 2- to 30-m water depth or as far as 2 km from shore using a combination of techniques such as interferometric sidescan-sonar, photobathymetry, and laser bathymetry. Profiles will be spaced 1 km apart in areas where the shoreline is most stable and 500 m apart in areas where it is less stable. Both areas will be mapped with a depth contour interval of 3-m. In high priority areas, about 15 percent of the Great Lakes shoreline[4], line spacing will be reduced to 100 meters with a depth contour interval of 1.0-m where possible. USGS and NOAA data acquisition will be combined for efficiency of operation wherever possible, e.g., combined fathometer, sidescan-sonar, and 3.5-kHz bottom profiling. Shore-based field units using small boats will conduct much of the work. However, due to logistic requirements certain areas will require a ship with launches. Appendix 9 shows the areas that will require ship support. To update demographic impact in threatened high-priority areas, the USGS will review appropriate topographic and land use maps and possibly utilize orthophotomaps. Historic shoreline information will be compiled in digital form for each region as the surveys progress.

The sequence in which the various areas are to be studied will be based on the systematic expansion of the data base, with emphasis on areas of high erosion or flooding susceptibility and consideration for the value of the area being threatened or damaged. For each lake, the study will initially review all work previously conducted onshore and offshore. These data will be compiled into a Geographic Information System (GIS), and made available to the public. The GIS and a derivative Shoreline Atlas (to be published as a USGS Open-File Report) will serve two purposes: (1) ensure that the extensive available information is identified, correlated, and compiled; and (2) determine the need for and guide the direction and extent of new research.

Depending on the scope of available data, each Atlas will include maps of:

- Topography and geology of the onshore area for a distance of 1 km landward of the shoreline or to the 500-year floodline.
- Classification of the shoreline as bluff, dune, plain, beach, bedrock, wetland, etc.
- Bathymetry and geology of the offshore area for a distance of 2 km or to a water depth of 30 m.
- Historic data depicting migration of the shoreline.
- Wind, wave, current, storm-surge, and climate history.
- Lake level history.
- Ice regime.
- Shore-defense structures.
- Pertinent cultural, demographic, and transportation information.
- An outline of needed additional work.

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[4]Based on discussions during the NOAA-USGS workshop held in Ann Arbor, Michigan, 30-31 March 1989. The workshop was convened to review a draft of this Study Plan. The 70 participants included leaders in Great Lakes management and research from Federal, State, and the private sector of the United States and Canada. Their comments and suggestions have been incorporated in this document.

Subsequent studies will fill in the missing elements of the data base and provide for systematic monitoring of the shoreline region. Map scales will most often be 1:25,000 but may be from 1:1,000 to 1:12,000 in high priority areas. Horizontal positional accuracy will be 1-m where possible.

Fluctuation in the water level of the lakes is a major forcing mechanism for accelerating migration of the shoreline. Records are available of historic lake level variations back to the 1830's. Longer term records are essential to determine where the historic information fits into fluctuations over the past few thousand years. They will provide two critical elements needed to predict future shoreline changes: (1) a record of lake levels themselves and evidence of what controls them, and (2) a record of past shoreline response to those lake level changes.

New data will be acquired to supplement the background material in the GIS and to develop a series of overlay maps with which to depict the effects of the dynamic processes that control most shoreline erosion. These data will allow us to construct derivative maps that depict such phenomena as potential shoreline erosion, flood limits, and wave climate, and thereby enhance interagency efforts to develop models for predicting shoreline change.

Principal Federal agencies involved in the execution of the studies will be the National Ocean Service (NOS) of the National Oceanic and Atmospheric Administration (NOAA), and the Geologic and National Mapping Divisions of the U.S. Geological Survey (USGS). Principal Federal users of the products generated during the study will be the International Joint Commission (IJC), U.S. Army Corps of Engineers (ACOE), the Federal Emergency Management Agency (FEMA), the Environmental Protection Agency (EPA), the International Boundary Commission (IBC), the Water Resources Division of the U.S. Geological Survey, and the Great Lakes Environmental Research Laboratory (GLERL) of NOAA. In addition to these agencies, NOAA and USGS will work closely with State, regional, and local agencies to ensure the widest possible application of data and models to coastal hazard abatement.

Additionally, methods and predictive storm-surge models will be developed to aid regional response efforts. Such models will use the physiographic and geologic information in conjunction with real-time and forecast environmental information to define threat situations rapidly and thereby improve regional disaster response. USGS and NOAA will work with State, regional, and local agencies, as well as the private sector to ensure the widest possible application of data and models to coastal hazard abatement.

STUDY SEQUENCE

Assuming that the sequence of study follows a model like the one depicted below and that six years will be needed to complete the study of each lake, the level of effort will increase annually from Year 1, when work will start in Lake Michigan, to a maximum in Year 5 and Year 6, when work will be ongoing in all five lakes. It will then taper off until the last phase of work is completed in Lake Superior in Year 10. For each lake, existing data will be compiled during the first year (or year and a half depending on data volume) at the same time that map updates and data collection are initiated. During succeeding years, data acquisition will be carried on simultaneously in several lakes as follows: The first year's work in Lake Michigan will be carried into Lake Huron[5] the next year because the two lakes are part of the same hydrologic system. Studies of Lake Erie[6] and Lake Ontario[7] will be initiated in the succeeding two years. Work in Lake Superior[8] will be carried out last because the predominantly bedrock shoreline is least affected by erosion. In each lake areas with a high risk of erosion (> 1 foot/year) or flooding will be given highest priority. One year has been allowed for data compilation in each lake.

Six years have been assigned to each lake because, regardless of shoreline length, studies have to be carried out over a sufficiently long period of time to monitor changes and to identify the processes responsible for those changes. Thus the level of effort may vary between lakes but the time needed to carry out each study will be similar.

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[5]Includes St. Clair River and Lake St. Clair.

[6]Includes the Detroit and Niagara Rivers.

[7]Includes St. Lawrence River to Canadian border.

[8]Includes St. Mary's River.

Figure 1. Study Sequence

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LAKE

MICHIGAN  o+o+o++++++++++++++++++++c+c+c

          |    |    |    |    |    |    |    |    |    |    |

HURON          o+o+o++++++++++++++++++++c+c+c

          |    |    |    |    |    |    |    |    |    |    |

ERIE                o+o+o++++++++++++++++++++c+c+c

          |    |    |    |    |    |    |    |    |    |    |

ONTARIO                  o+o+o++++++++++++++++++++c+c+c

          |    |    |    |    |    |    |    |    |    |    |

SUPERIOR                      o+o+o++++++++++++++++++++c+c+c

   YEAR   1    2    3    4    5    6    7    8    9   10   11
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ooooo Data Assembly
+++++ Data Collection and Map Update
ccccc Data compilation
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PRODUCTS

Data for each lake will be compiled on a CD ROM with software that can be accessed from a variety of systems.

In addition to papers published after individual study elements are completed, an Atlas will be assembled as a USGS Bulletin or Professional Paper to integrate the new data into the already established data base. These documents will be published first as USGS Open-File Reports (approximately one year after studies are completed) and in more formal USGS and NOAA publications two to four years later as analyses and processing are completed.

The processed digital geographic and geologic data will be centralized in the USGS/Marine Geology and National Mapping Division and NOAA/NOS digital data bases. Observational data will be archived with the NOAA National Geophysical Data Center in Boulder, Colorado, for general public dissemination. Products that can be generated from the processed data include:

- Print-on-demand shoreline change maps.

- Digital topographic, bathymetric, and geophysical data sets, including historical shoreline data as available.

- More accurate nautical charts and bathymetric maps due to more frequent updates of shoreline detail and nearshore bathymetry.

- Improved models for predicting coastal hazards, such as shoreline change, storm surge, and sediment transport.

- Improved long-term record of lake-level fluctuations and shoreline responses to those fluctuations.

- Defined long-term rates of subsidence/uplift for use in the design of coastal engineering structures and for planning related to future shorelines.

- Photography to support ancillary studies of environmental conditions.

ESTIMATED COSTS

Estimated costs for the Great Lakes Shoreline Mapping Program are given below. The first year will include program start-up costs.

Table 1. Estimated Costs

AGENCY EFFORT	ESTIMATED COSTS ($1000)									
YEAR	1	2	3	4	5	6	7	8	9	10
NOAA Surveys										
General Shoreline	600						500			
Critical Shoreline	400									
Hydrographic Surveys	2,800									
Lake Levels	150									
USGS										
Assemble Existing Data	1,000									
Update Topographic & Geologic Maps	3,000			2,500						
Onshore & Offshore Geologic Surveys	2,000			2,500		3,000			2,000	
Integrate New Data						500			1,500	
Total/year	9,950						9,850			

APPENDICES

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APPENDIX 1

TEXT OF PL 100-220 "GREAT LAKES SHORELINE MAPPING ACT OF 1987"

ABSTRACTED FROM THE FEDERAL REGISTER

101 STAT. 1476 PUBLIC LAW 100-220 - DEC. 29, 1987

SUBTITLE B-GREAT LAKES MAPPING

SEC. 3201. SHORT TITLE

This subtitle may be cited as the "Great Lakes Shoreline Mapping Act of 1987".

SEC. 3202. GREAT LAKES SHORELINE MAPPING PLAN

(a) PREPARATION OF PLAN.-Not later than nine months after the date of the enactment of the subtitle, the Director, in consultation with the Director of the United States Geological Survey, shall submit to the Congress a plan for preparing maps of the shoreline of the Great Lakes under section 3203.

(b) CONTENT OF PLAN.-A plan prepared under paragraph (1) shall include-
- (1) a work proposal and a division of responsibilities between the National Oceanic and Atmospheric Administration and the United States Geological Survey:
- (2) a time schedule for completion of maps.
- (3) recommendation of funding needed for preparing the maps; and
- (4) an area mapping schedule, with first priority given to shoreline areas subject to a high risk of erosion or flooding.

SEC. 3203. PREPARATION OF GREAT LAKES SHORELINE MAPS.

(a) IN GENERAL.-The following completion of the a shoreline mapping plan under section 3202 and subject to authorization and appropriation of funds, the Director, in consultation with the Director of the United States Geological Survey, shall prepare maps of the shoreline areas of the Great Lakes.

(b) CONTENT OF THE MAPS.-Maps prepared under this section---
- (1) shall include-
  - (A) bathymetry of the nearshore area, to the extent that this area will affect coastal erosion and flooding;
  - (B) topography of the adjacent shoreline, to the extent that this area will directly affect of be affected by coastal erosion and flooding;
  - (C) the geological conditions of the nearshore area and shoreline to the extent that these areas will directly affect or be affected by coastal erosion or flooding;
  - (D) information on the recent geological past of the nearshore areas described in paragraph (3); and
  - (E) appropriate information for use in predicting and preventing damage caused by erosion and flooding in the Great Lakes;
- (2) shall be of appropriate scale and detail and take into account the greater informational needs of areas subject to a high risk of erosion or flooding; and

(3) to the maximum extent practicable, shall be consistent with similar shoreline maps prepared by, or for use of, the Government of Canada.

(c) CONSULTATION.-In preparing maps under this section, the Director shall consult with, and take into consideration, the informal needs of-

(1) the Army Corps of Engineers;
(2) the Federal Emergency Management Agency;
(3) other appropriate Federal agencies;
(4) the States of Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, and Wisconsin;
(5) appropriate local government units; and
(6) the general public.

(d) AVAILABILITY OF MAPS.-The Director shall make maps prepared under this section available to-

(1) Federal agencies;
(2) State governments;
(3) local governments units;
(4) the Government of Canada: and
(5) the general public.

(e) RECOVERY OF COSTS.- The cost of reproducing and distributing maps prepared under this section may be recovered under section 9701 of title 31, United States code, or another law.

SEC. 3204. CONTRACT AUTHORITY.

The Director may, subject to appropriations, enter into contracts and agreements on a reimbursable or cost-sharing basis with other Federal agencies, State government, local governments, and private entities, to carry out this subtitle.

SEC. 3205. DEFINITIONS

For purposes of this subtitle-

(1) The term "Director" means the Director of Charting and Geodetic Services of the National Ocean Service, within the National Oceanic and Atmospheric Administration.
(2) The term "Great Lakes" means Lake Erie, Lake Huron, Lake Michigan, Lake Ontario, Lake St. Clair, Lake Superior, the St. Mary's River, the St. Clair River, the Detroit River, the Niagara River, the St. Lawrence River to the Canadian border, to the extent such lake and rivers are subject to the jurisdiction of the United States.
(3) The term "high risk of erosion" means subject to erosion at a rate greater than 1 foot per year.

SEC. 3206. AUTHORIZATION OF APPROPRIATIONS.

There are authorized to be appropriated to carry out section 3202 not more than $100,000 for fiscal year 1988. Amounts appropriated pursuant to this section shall remain available until expended.

102 STAT. 3286 PUBLIC LAW 100-629. NOV. 7, 1988

PUBLIC LAW 100-629

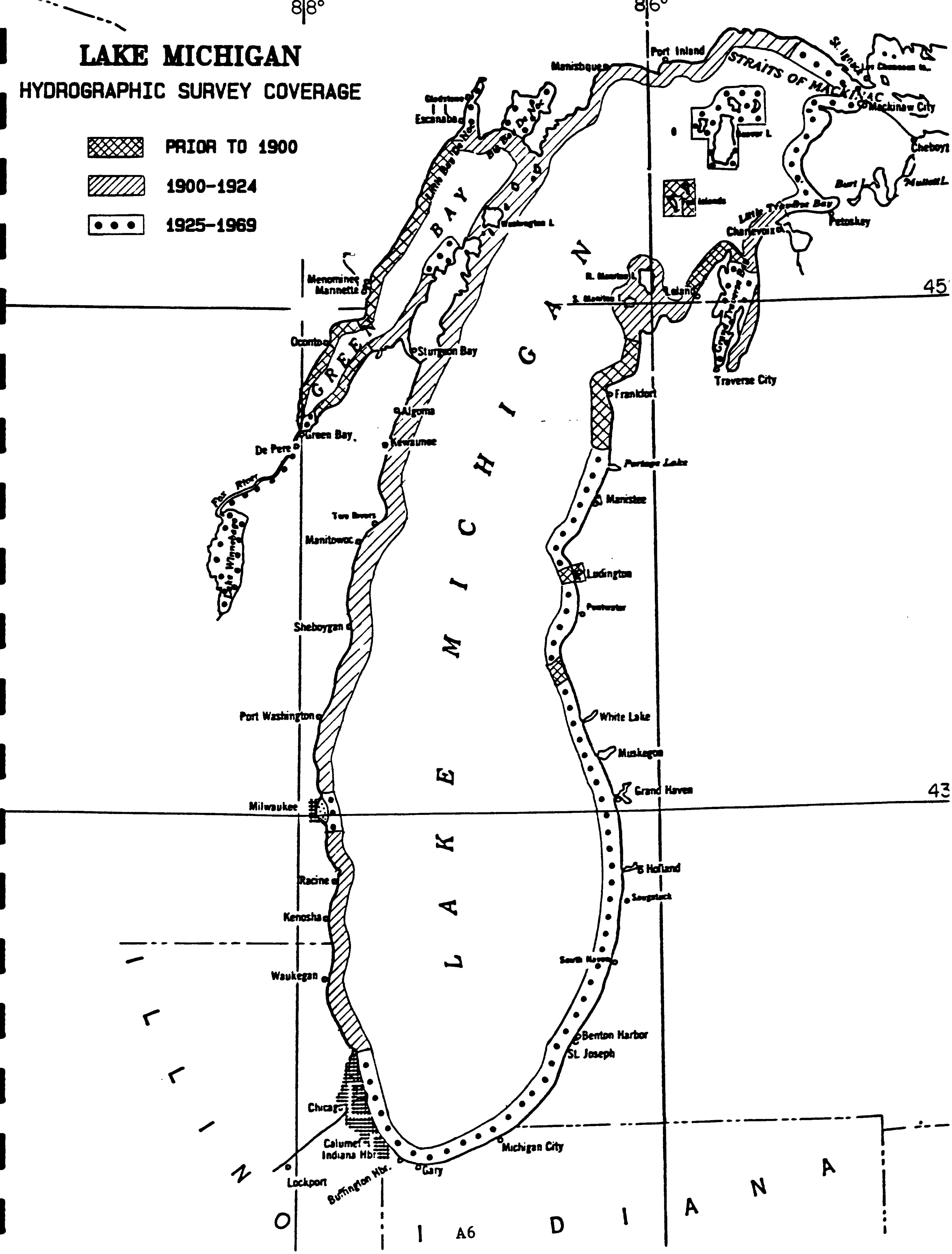
100th Congress

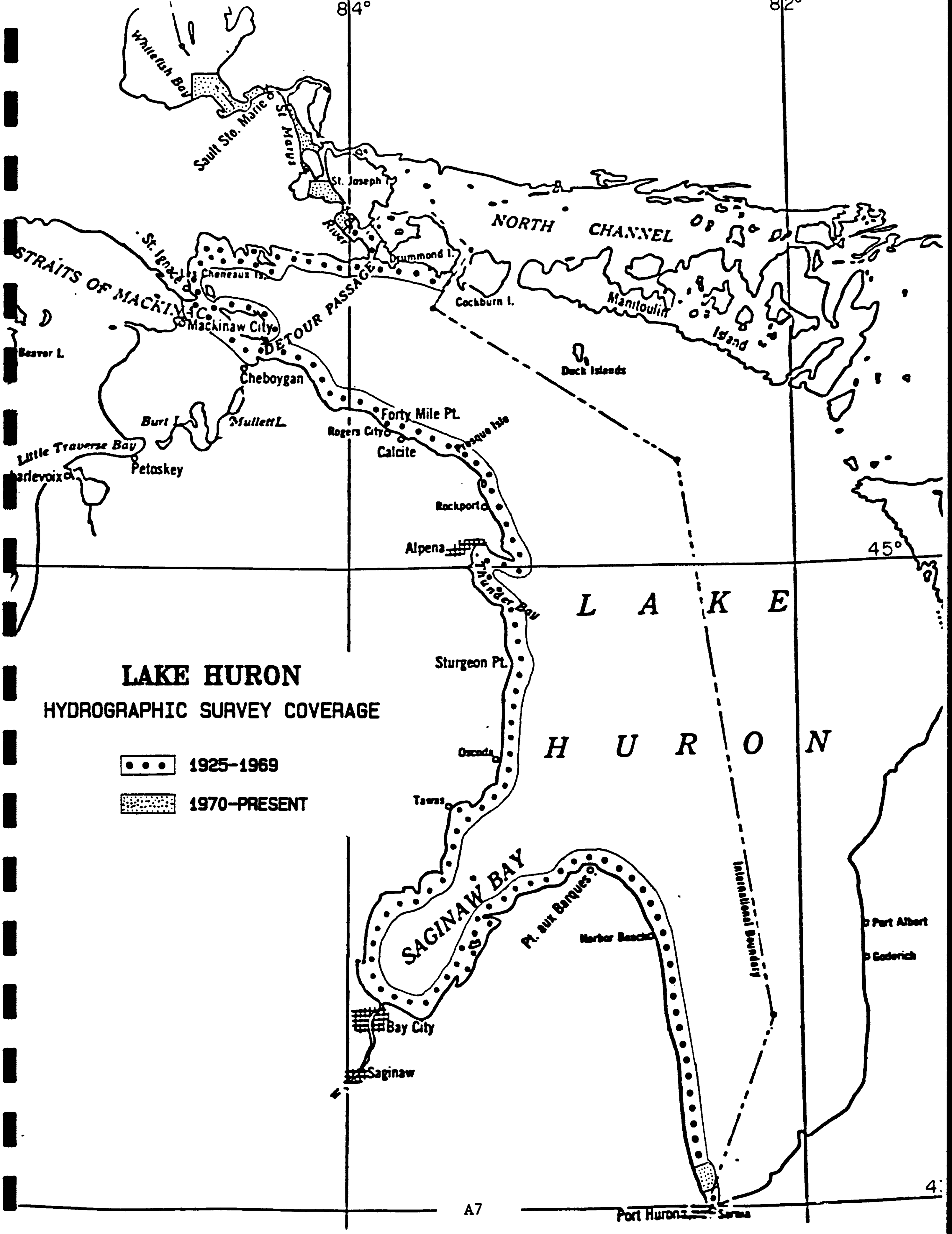
SEC. 3 GREAT LAKES MAPPING REAUTHORIZATION.

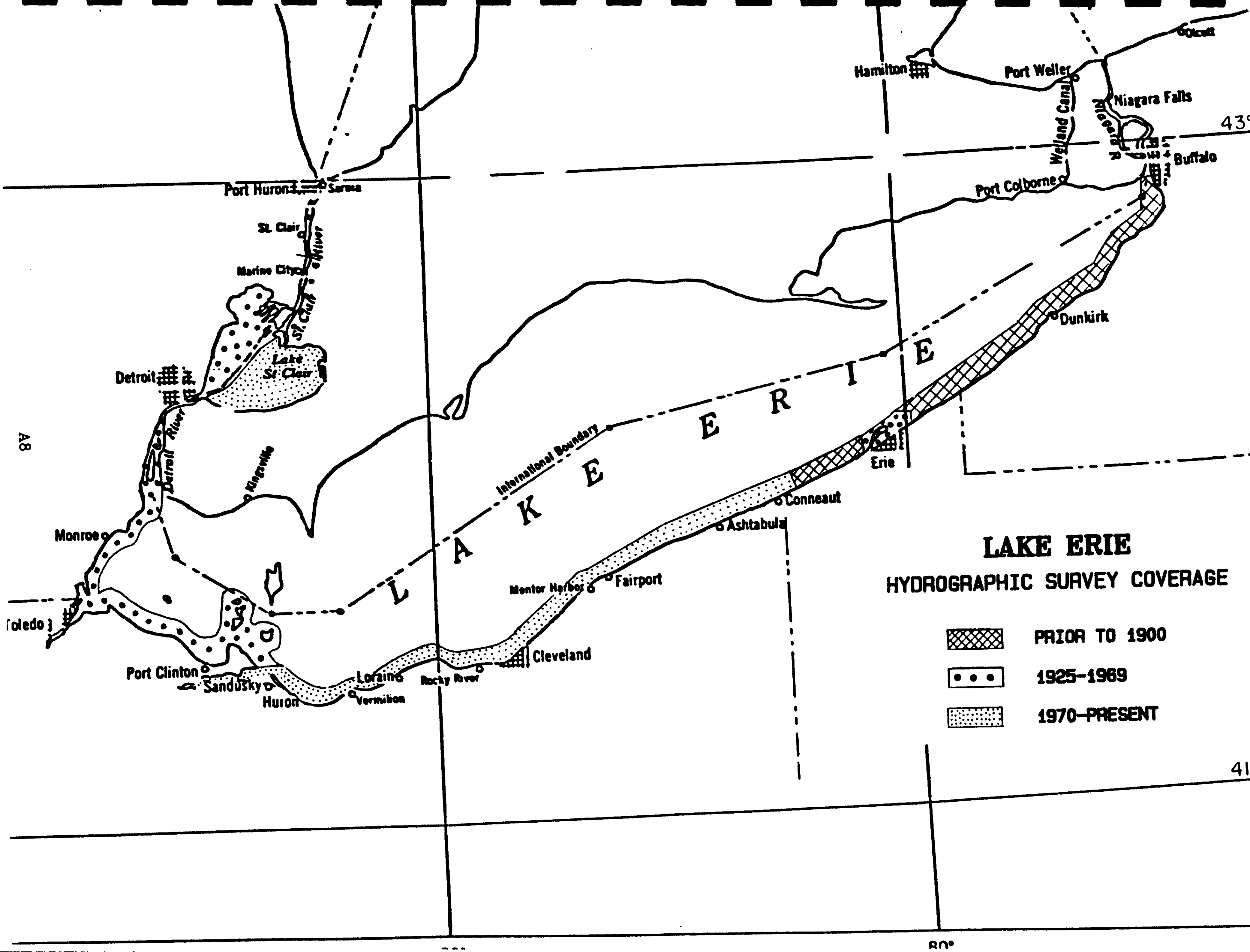
Section 3206 of Public Law 100-220 is amended by striking "1988", and inserting instead "1989"

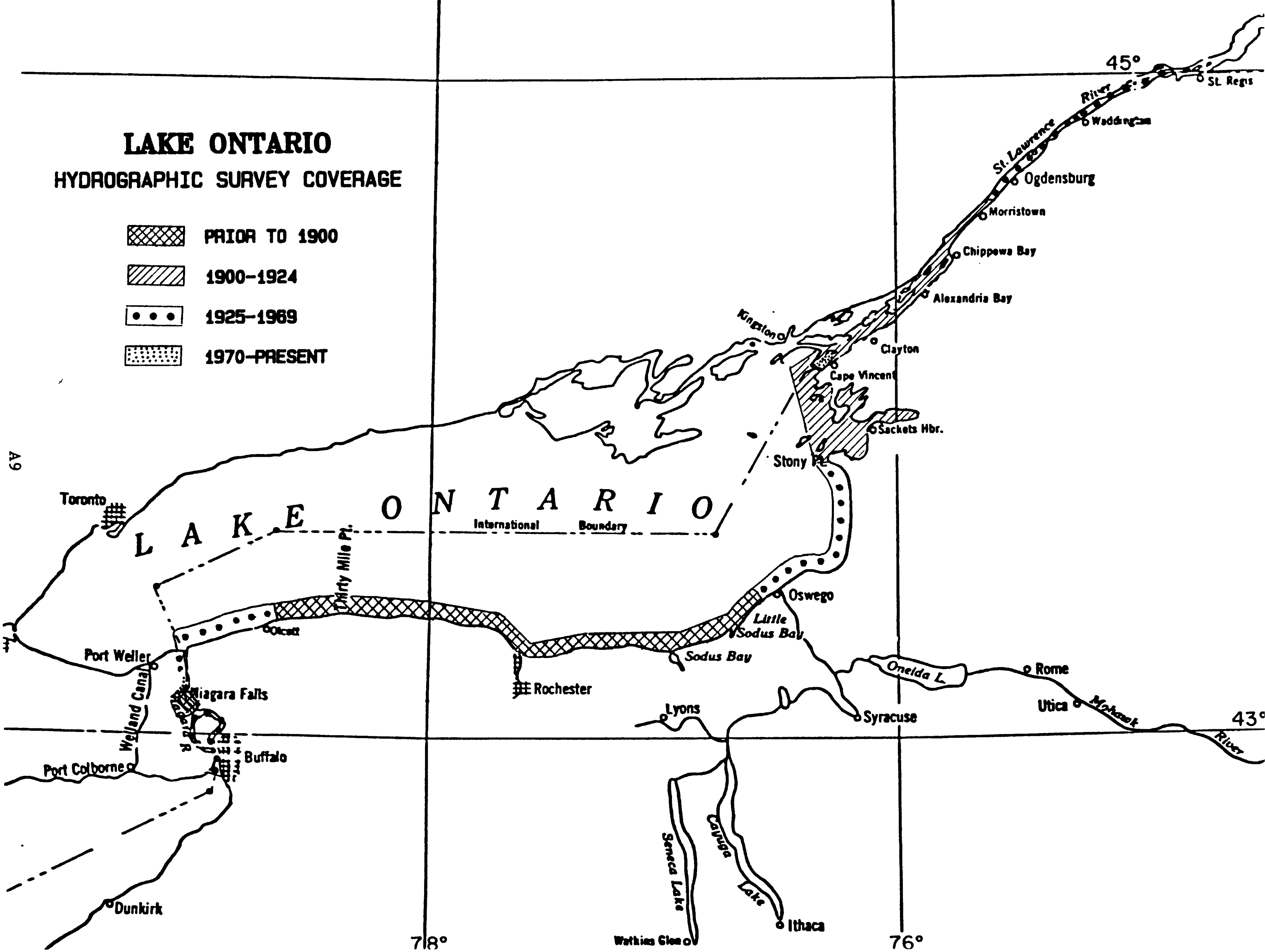
APPENDIX 2

STATUS OF ALONGSHORE HYDROGRAPHIC COVERAGE


LAKE MICHIGAN
HYDROGRAPHIC SURVEY COVERAGE
PRIOR TO 1900
1900-1924
1925-1969
88°
86°
45
43
LAKE MICHIGAN
GREEN BAY
STRAITS OF MACKINAC
ILLINOIS
INDIANA
Port Inland
Manistique
Mackinaw City
Escanaba
Menominee
Marinette
Oconto
Sturgeon Bay
Green Bay
De Pere
Fox River
Algoma
Kewaunee
Two Rivers
Manitowoc
Sheboygan
Port Washington
Milwaukee
Racine
Kenosha
Waukegan
Chicago
Calumet
Indiana Hbr.
Lockport
Buffington Hbr.
Gary
Michigan City
St. Joseph
Benton Harbor
South Haven
Saugatuck
Holland
Grand Haven
Muskegon
White Lake
Pentwater
Ludington
Manistee
Portage Lake
Frankfort
Traverse City
Leland
Charlevoix
Petoskey
Little Traverse Bay
Washington I.
Cheboygan
Burt L.
Mullett L.

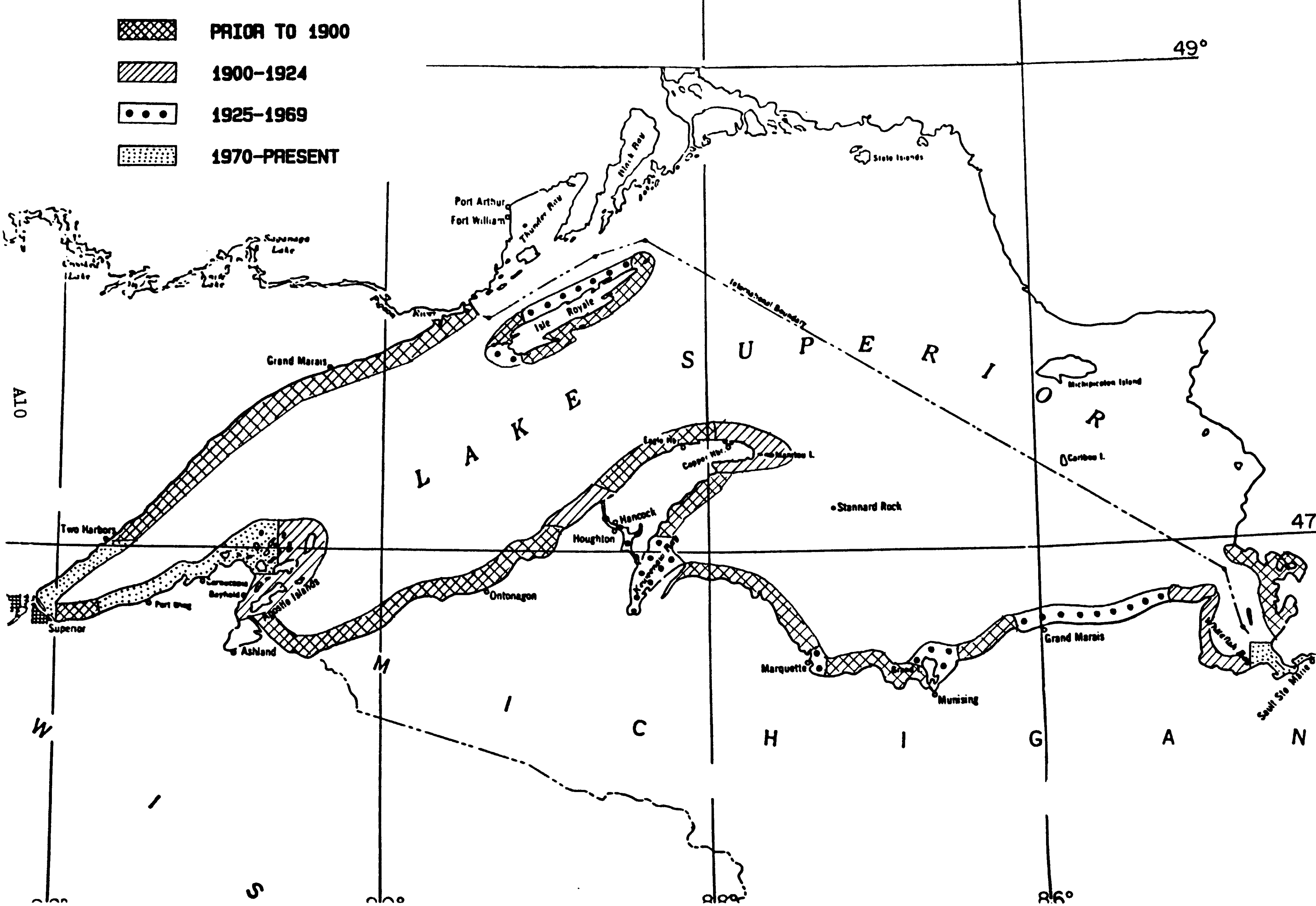

LAKE HURON
HYDROGRAPHIC SURVEY COVERAGE
1925-1969
1970-PRESENT
84°
82°
45°
Whitefish Bay
Sault Ste. Marie
St. Marys
St. Joseph I.
River
NORTH CHANNEL
St. Ignace
Les Cheneaux Is.
Drummond I.
STRAITS OF MACKINAC
DETOUR PASSAGE
Cockburn I.
Manitoulin Island
Mackinaw City
Beaver I.
Cheboygan
Duck Islands
Burt L.
Mullett L.
Forty Mile Pt.
Rogers City
Presque Isle
Calcite
Little Traverse Bay
Petoskey
Rockport
Alpena
Thunder Bay
LAKE HURON
Sturgeon Pt.
Oscoda
Tawas
SAGINAW BAY
Pt. aux Barques
Harbor Beach
International Boundary
Port Albert
Goderich
Bay City
Saginaw
Port Huron
Sarnia


LAKE ERIE
HYDROGRAPHIC SURVEY COVERAGE
PRIOR TO 1900
1925–1969
1970–PRESENT
43°
41°
80°
LAKE ERIE
International Boundary
Olcott
Hamilton
Port Weller
Niagara Falls
Niagara R
Welland Canal
Buffalo
Port Colborne
Dunkirk
Erie
Conneaut
Ashtabula
Fairport
Mentor Harbor
Cleveland
Rocky River
Lorain
Vermilion
Huron
Sandusky
Port Clinton
Toledo
Monroe
Detroit
Detroit River
Kingsville
Lake St Clair
St. Clair River
Marine City
St. Clair
Port Huron
Sarnia


LAKE ONTARIO
HYDROGRAPHIC SURVEY COVERAGE
PRIOR TO 1900
1900-1924
1925-1969
1970-PRESENT
LAKE ONTARIO
International Boundary
Toronto
Port Weller
Welland Canal
Niagara Falls
Buffalo
Port Colborne
Dunkirk
Olcott
Thirty Mile Pt.
Rochester
Sodus Bay
Little Sodus Bay
Oswego
Stony Pt.
Sackets Hbr.
Cape Vincent
Clayton
Kingston
Alexandria Bay
Chippewa Bay
Morristown
Ogdensburg
St. Lawrence River
St. Regis
Oneida L.
Rome
Utica
Mohawk River
Syracuse
Lyons
Seneca Lake
Cayuga Lake
Ithaca
Watkins Glen
45°
43°
78°
76°

LAKE SUPERIOR

HYDROGRAPHIC SURVEY COVERAGE



APPENDIX 3

STATUS OF SHORELINE MAPPING AND PROJECTED COSTS

Introduction

NOAA will develop the digital data base that will contain the shoreline data suitable to: (1) monitor the shoreline erosion and (2) define the topography of areas subject to severe erosion or flooding for additional detailed analysis. Photography and collection of field data will be done using a combination of government employees and private contractors. Field work will consist of the positioning of photo panels to Second-Order, Class II, or Third-Order, Class I, Horizontal Geodetic Specifications, depending on the available control. Second-Order and Third-Order Levels will extend vertical control throughout the project area where there is inadequate vertical control to support the topographic data collection. Office work will include aerotriangulation and digital compilation of the aerial photographs using first-order stereoplotters.

General Shoreline

Approximately 60 percent of the Great Lakes shoreline has been mapped by NOAA, National Ocean Survey (NOS), since 1970. The location and scale of these contemporary planimetric shoreline surveys are shown in Figures la through le. Unfortunately, surveys prior to 1970 are unreliable. However, under this proposal, NOS will complete the planimetric mapping of the Great Lakes in 5 years at a scale of 1:20,000. This general mapping will provide the base for measuring shoreline changes.

The photography will be aerial, flown at 25,000 feet above ground level for a nominal photo-scale of 1:50,000. The actual shoreline will be delineated by mapping the water-land interface. No other contours will be compiled. All roads, structures, and other significant features along the shoreline will be mapped.

The total cost for general shoreline mapping is estimated to be $2,555,000. Table 1 tabulates for each lake: (1) the total shoreline length, (2) the shoreline requiring new mapping, and (3) the estimated cost for completion.

After all the Great Lakes shoreline has been surveyed at least once, NOS will begin a resurvey to provide quantitative information on the rate of shoreline movement. The time between the original and second survey will vary from 10 to 20 years. The resurveys will cost $4,216,000. Table 3 shows the cost data.

Critical Shoreline

Approximately 30 percent of the shoreline of the Great Lakes is subject to some erosion or flooding and 15 percent is subject to severe erosion or flooding. See Appendix 4, page A22 for areas subject to flooding, and see Appendix 5, page A28 for areas subject to erosion.

Only the most critical 15 percent of the shoreline along the Great Lakes will be mapped at a scale of 1:5,000 with 1-m contours. These detailed surveys will cover the area from the shoreline up to the first contour interval above the 500-year flood line. In general, this will be 3 to 4 m. In most cases the limit of mapping will be either (1) one kilometer landward from the shoreline or (2) the 3- to 5-m contour landward from the annual average lake level. In other cases, the first major road may define the upper limit of the topographic mapping. This detailed mapping will be similar to the Canadian effort along their Great Lakes shoreline.

To maintain accuracy in data acquisition, the C-Factor of the stereoscopic instrumentation will control the flying height of the surveying aircraft. The highly accurate stereo-analytical plotter of the Integrated Digital Photogrammetric Facility (IDPF) system and NOS procedures have a capable working C-Factor of 2,000. A flying height of 6,500 feet (2000 meters) is suitable to develop 1 meter contours, using this system. The nominal photo scale will be 1:13,000.

The total cost for this detailed shoreline mapping is estimated to be $3,914,000. Table 2 tabulates for each lake: (1) the length of the shoreline with severe erosion, (2) the length of the shoreline subject to flooding, (3) the length of shoreline where severe erosion and flooding overlap, (4) the length of detailed mapping, and (5) the estimated cost for detailed mapping. These figures were obtained by combining data from two reports:

(1) Status report, Development of data bases of land use of the U.S. Great Lakes shoreline: International Joint Commission, Great Lakes Water Level Reference of 1986, Coastal Zone and Environment Functional Study Group, U.S. Territorial Subgroup, March 6, 1989.

(2) Horvath, Frank J., Jannereth, M. R., and Shafer, C. A., 1989, Impacts of water level fluctuations in Great Lakes water levels: shoreline dilemmas: Water Science and Technology Board, Natural Research Council, National Academy Press, Washington, DC, p. 27-44.

Table 1- Standard Planimetric Shoreline Mapping[1]

Lake	Total Length (Miles)	New Mapping (Miles)	Estimated Cost ($1,000)
Michigan	1,640	980	833
Huron	840	830	706
Erie	470	400	340
Ontario	330	0	0
Superior	1,250	625	532
St. Mary's River	120	0	0
St. Clair River & Lake St. Clair	170	170	144
Detroit River	70	0	0
Niagara River	70	0	0
Total	4,960	3,005	2,555

[1]Note: St. Lawrence River not included

Table 2- Detailed Shoreline Mapping[1]

Lake	Severe (Miles)	Flooding (Miles)	Overlapping (Miles)	Detailed (Miles)	Cost ($1,000)
Michigan	509	345	60	794	1,588
Huron	135	244	10	369	738
Erie	47	291	20	318	636
Ontario	43	125	5	163	326
Superior	275	38	0	313	626
Total	1,009	1,043	95	1,957	3,914

[1]Note: If the detailed mapping is done at one-half meter contour interval, the total cost will be $8,810K.

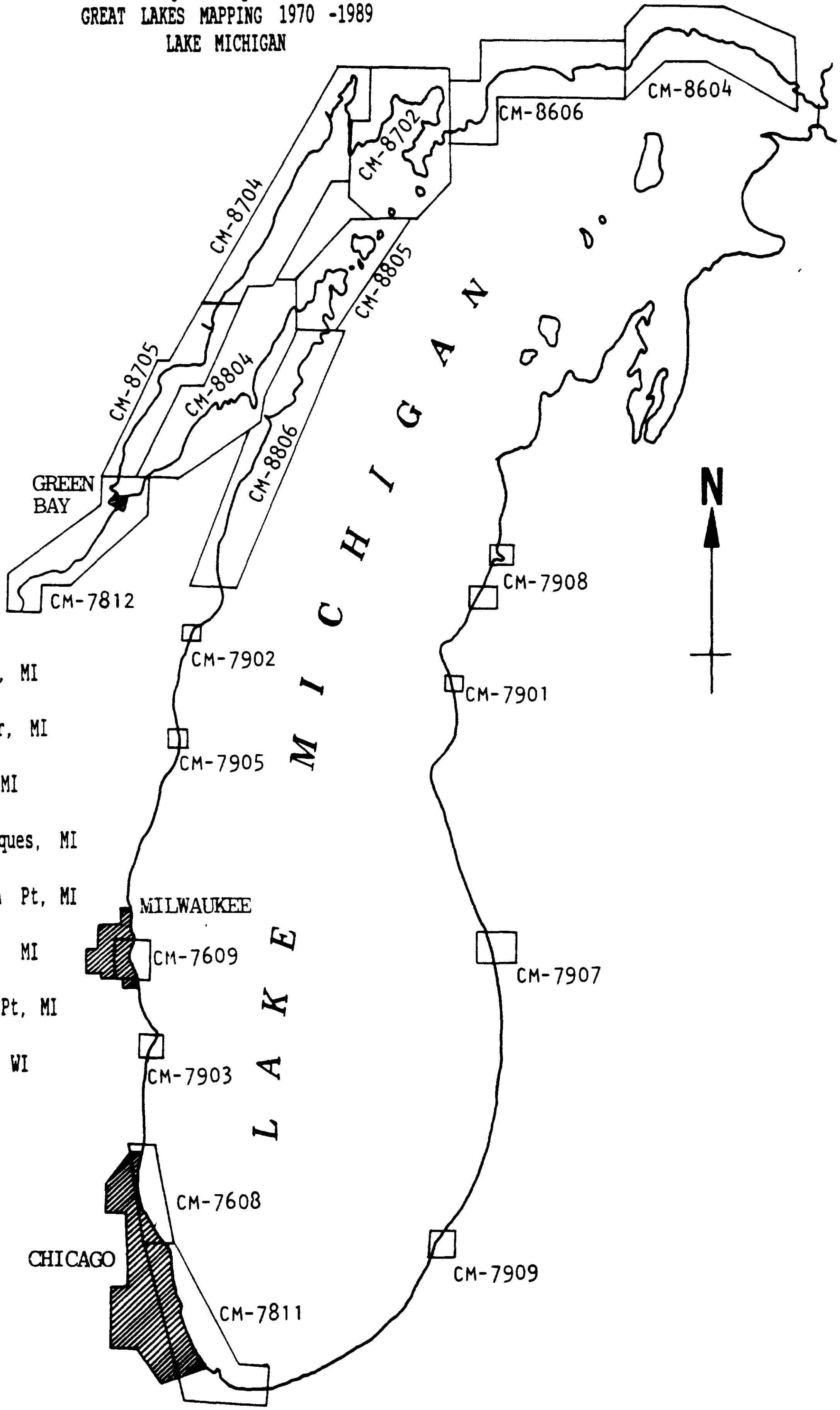
Table 3- Standard Shoreline ReMapping[1]

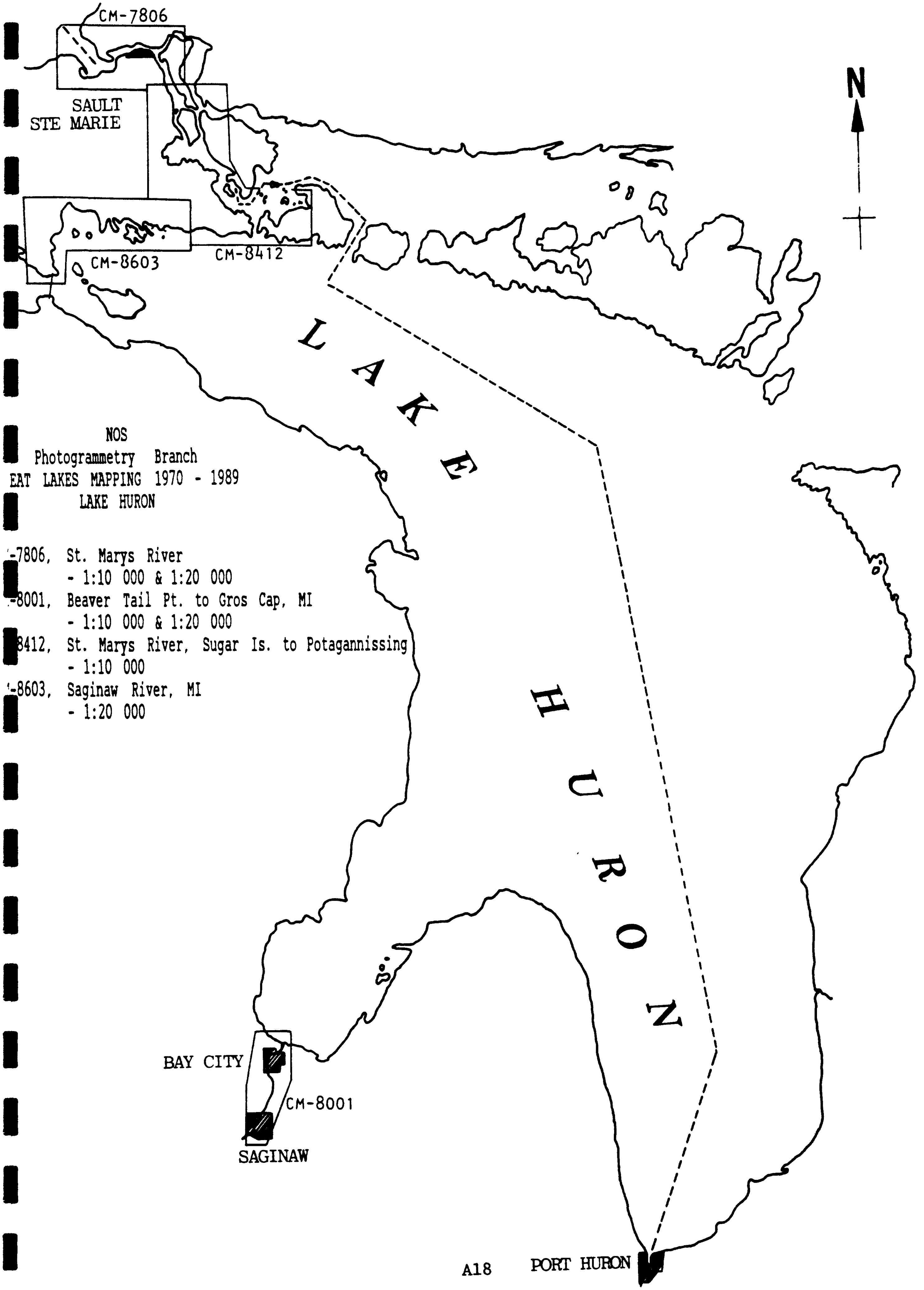
Lake	Total Length (Miles)	Estimated Cost ($1,000)
Michigan	1,640	1,394
Huron	840	714
Erie	470	400
Ontario	330	280
Superior	1,250	1,062
St. Marys River	120	102
St. Clair River & Lake St. Clair	170	144
Detroit River	70	60
Niagara River	70	60
Total	4,960	4,216

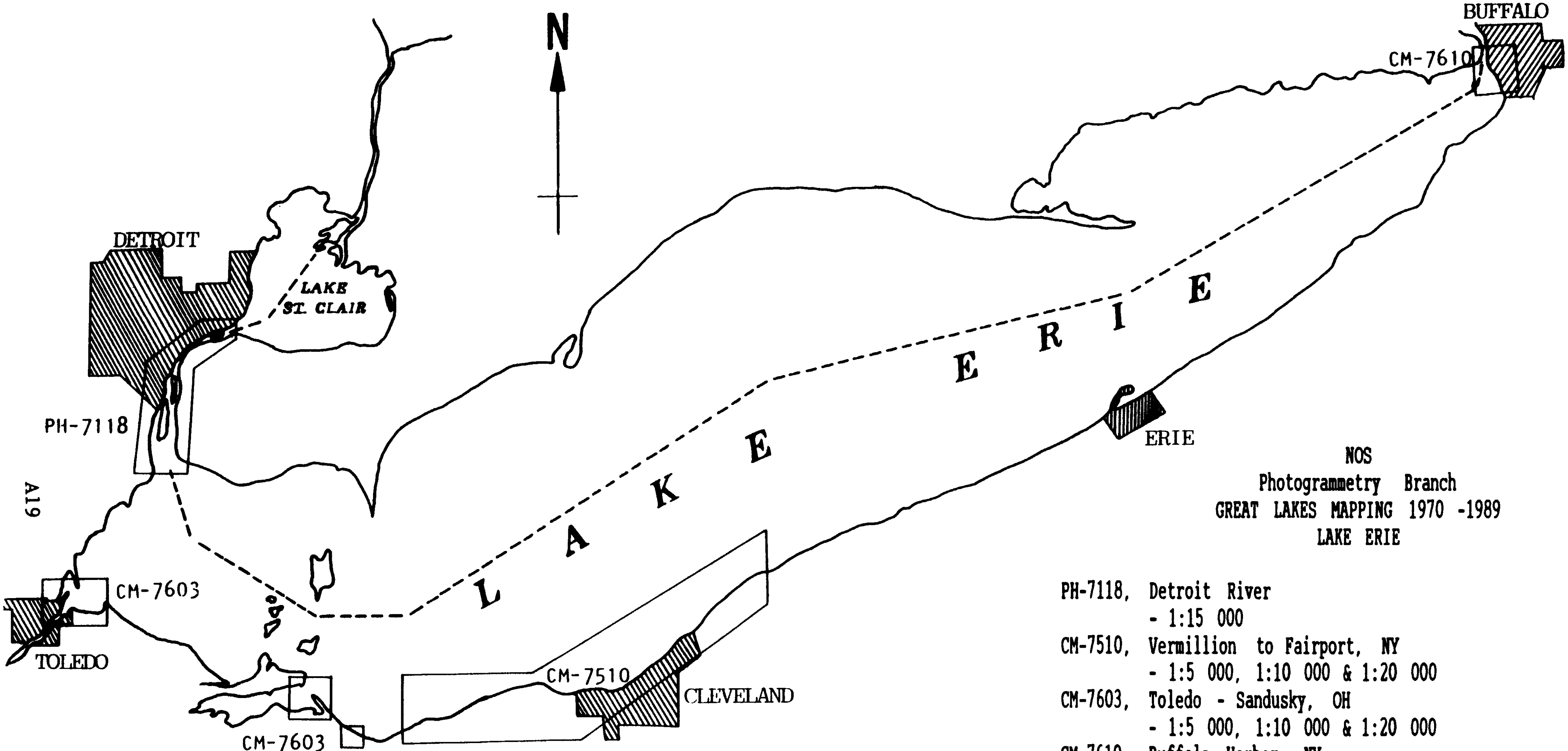
[1]Note: St. Lawrence River not included

NOS
Photogrammetry Branch
GREAT LAKES MAPPING 1970 -1989
LAKE MICHIGAN

CM-7608, Evanston to Waukegan, IL
- 1:10 000
CM-7609, Milwaukee Harbor, WI
- 1:10 000
CM-7811, Chicago Lake Front
- 1:10 000
CM-7812, Fox River, WI
- 1:15 000
CM-7901, Ludington Harbor, MI
- 1:15 000
CM-7902, Manitowoc, WI
- 1:10 000
CM-7903, Racine Harbor, WI
- 1:10 000
CM-7905, Sheboygan Harbor, WI
- 1:10 000
CM-7907, Grand Haven, MI
- 1:15 000
CM-7908, Mannistee and Portage Lake, MI
- 1:10 000
CM-7909, St Joseph and Benton Harbor, MI
- 1:10 000
CM-8604, Gros Cap to Pt Patterson, MI
- 1:20 000
CM-8606, Pt Patterson to Pt Aux Barques, MI
- 1:10 000 & 1:20 000
CM-8702, Pt Aux Barques to Peninsula Pt, MI
- 1:20 000
CM-8704, Peninsula Pt to Ingallston, MI
- 1:20 000
CM-8705, Ingallston to Little Tail Pt, MI
- 1:15 000 & 1:20 000
CM-8804, Dykesville to Chambers Is, WI
- 1:20 000
CM-8805, Ephraim to Cave Pt, WI
- 1:20 000
CM-8806, Cave Pt to Two Creeks, WI
1:20 000




CM-7806
SAULT
STE MARIE
CM-8603
CM-8412
N
LAKE HURON
NOS
Photogrammetry Branch
EAT LAKES MAPPING 1970 - 1989
LAKE HURON
-7806, St. Marys River
- 1:10 000 & 1:20 000
-8001, Beaver Tail Pt. to Gros Cap, MI
- 1:10 000 & 1:20 000
8412, St. Marys River, Sugar Is. to Potagannissing
- 1:10 000
-8603, Saginaw River, MI
- 1:20 000
BAY CITY
CM-8001
SAGINAW
PORT HURON



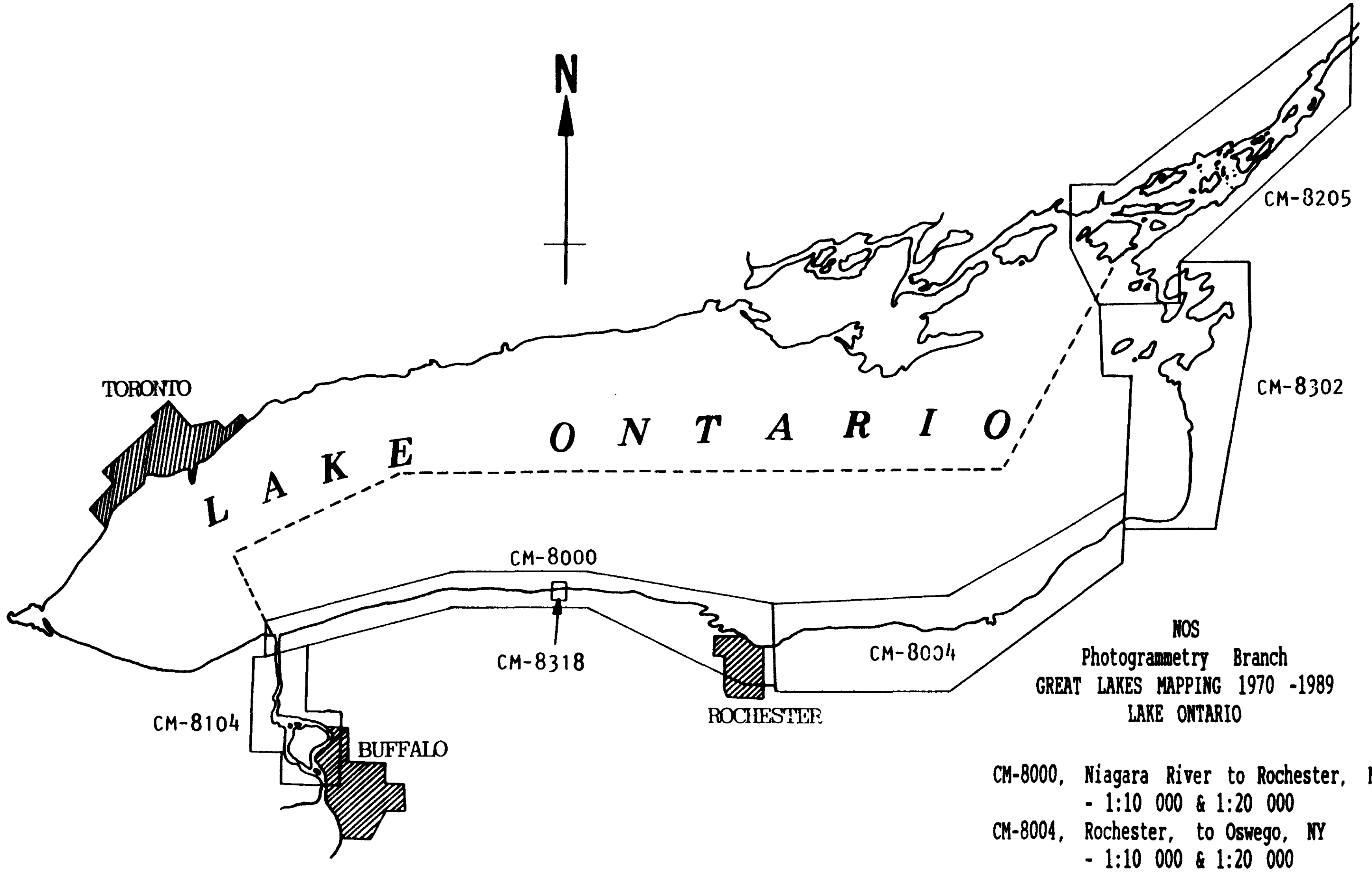
NOS
Photogrammetry Branch
GREAT LAKES MAPPING 1970 -1989
LAKE ERIE

PH-7118, Detroit River
- 1:15 000

CM-7510, Vermillion to Fairport, NY
- 1:5 000, 1:10 000 & 1:20 000

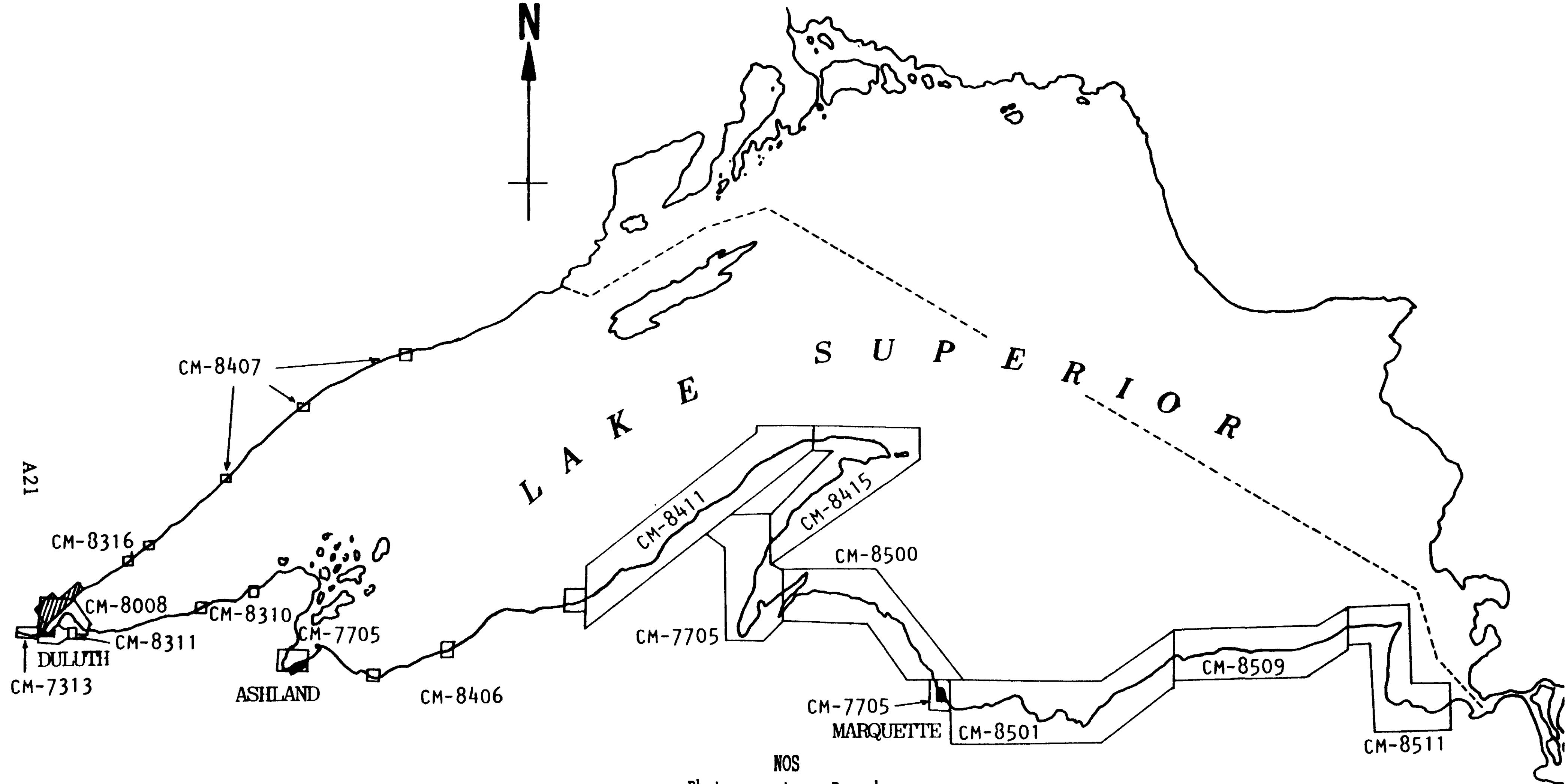
CM-7603, Toledo - Sandusky, OH
- 1:5 000, 1:10 000 & 1:20 000

CM-7610, Buffalo Harbor, NY
- 1:15 000



NOS
Photogrammetry Branch
GREAT LAKES MAPPING 1970 -1989
LAKE ONTARIO

CM-8000, Niagara River to Rochester, NY
- 1:10 000 & 1:20 000
CM-8004, Rochester, to Oswego, NY
- 1:10 000 & 1:20 000
CM-8104, Niagara River, NY
- 1:20 000
CM-8205, St Lawrence River to Brockville, NY
- 1:20 000
CM-8302, Chaumont to Nine Mile Pt, NY
- 1:10 000 & 1:20 000
CM-8318, Oak Orchard Harbor, NY
- 1:5 000



NOS
Photogrammetry Branch
GREAT LAKES MAPPING 1970 -1989
LAKE SUPERIOR

CM-7313, Duluth, MN
- 1:15 000 & 1:30 000

CM-7705, Keweenaw Waterway, Marquette, MI, Ashland, WI
- 1:15 000 & 1:30 000

CM-8008, Duluth - Superior, MN - WI
- 1:5 000

CM-8310, Cornucopia and Port Wing, WI
- 1:5 000

CM-8311, Nemadji River, WI
- 1:5 000

CM-8316, Two Harbors and Knife Harbor, MN
- 1:5 000 & 1:10 000

CM-8406, Ontonagon, MI, Saxon, Black Rv, WI

CM-8407, Silver Bay, Taconite, Grand Marais, MN
- 1:10 000

CM-8411, Fourteen Mile Pt to Eagle Pt, MN
- 1:10 000 & 1:20 000

CM-8415, Eagle Harbor to Traverse Pt, MN
- 1:5 000, 1:10 000 & 1:20 000

CM-8500, Pt Abbaye to Thorney Pt, MI
- 1:5 000 & 1:20 000

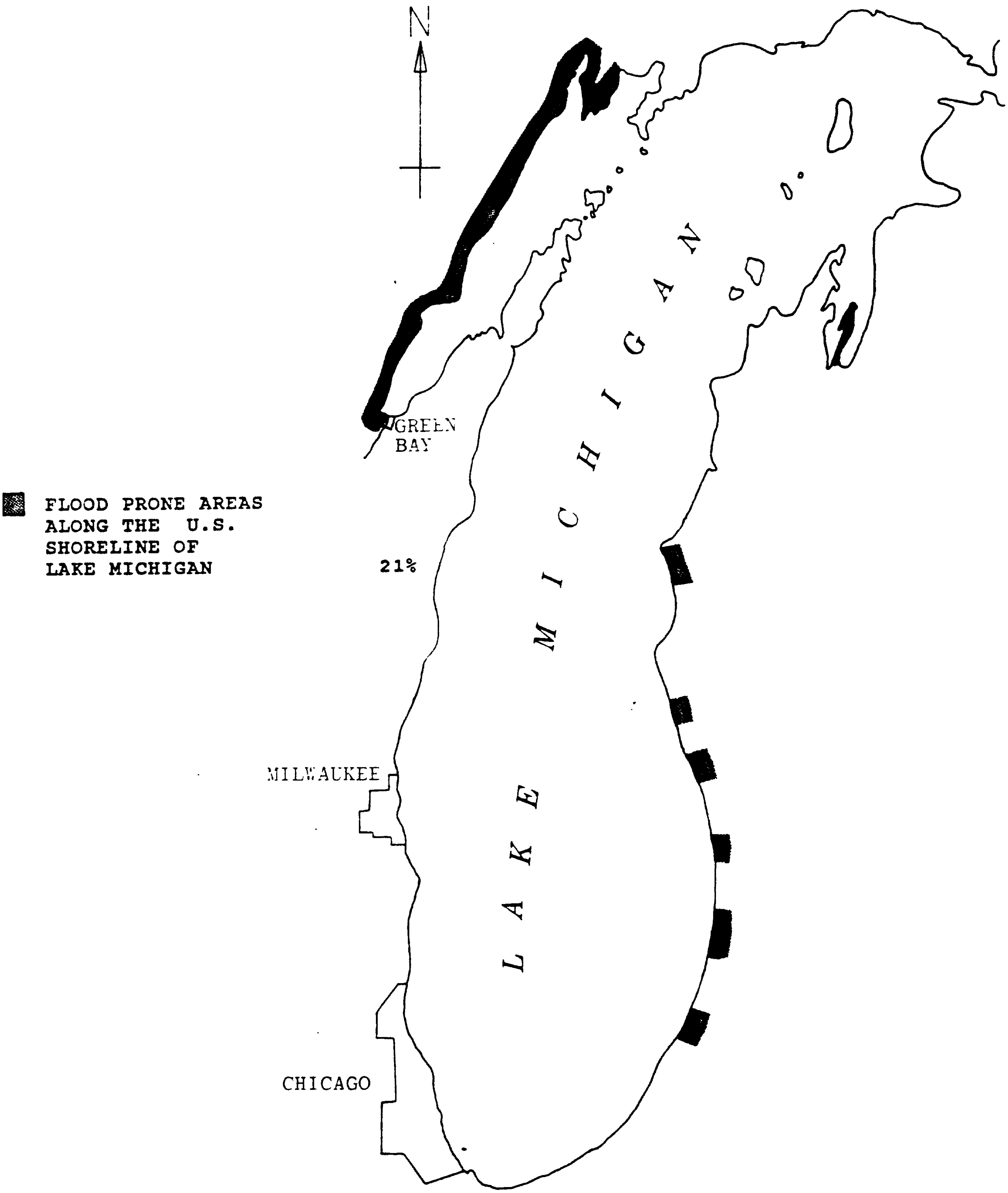
CM-8501, Marquette to Au Sable Pt, MI
- 1:10 000 & 1:20 000

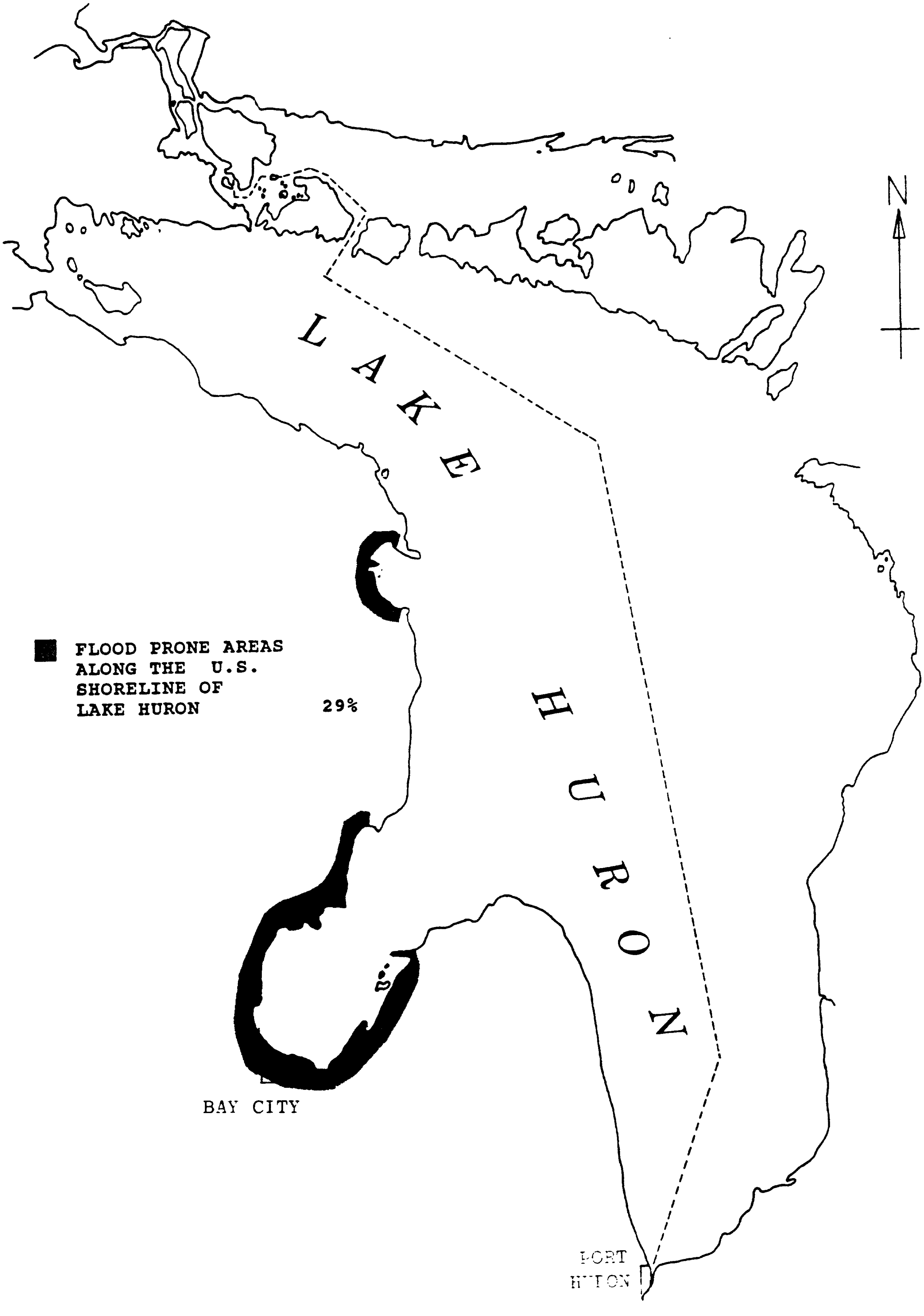
CM-8509, Au Sable Pt to Crisp Pt, MI
- 1:5 000, 1:10 000 & 1:20 000

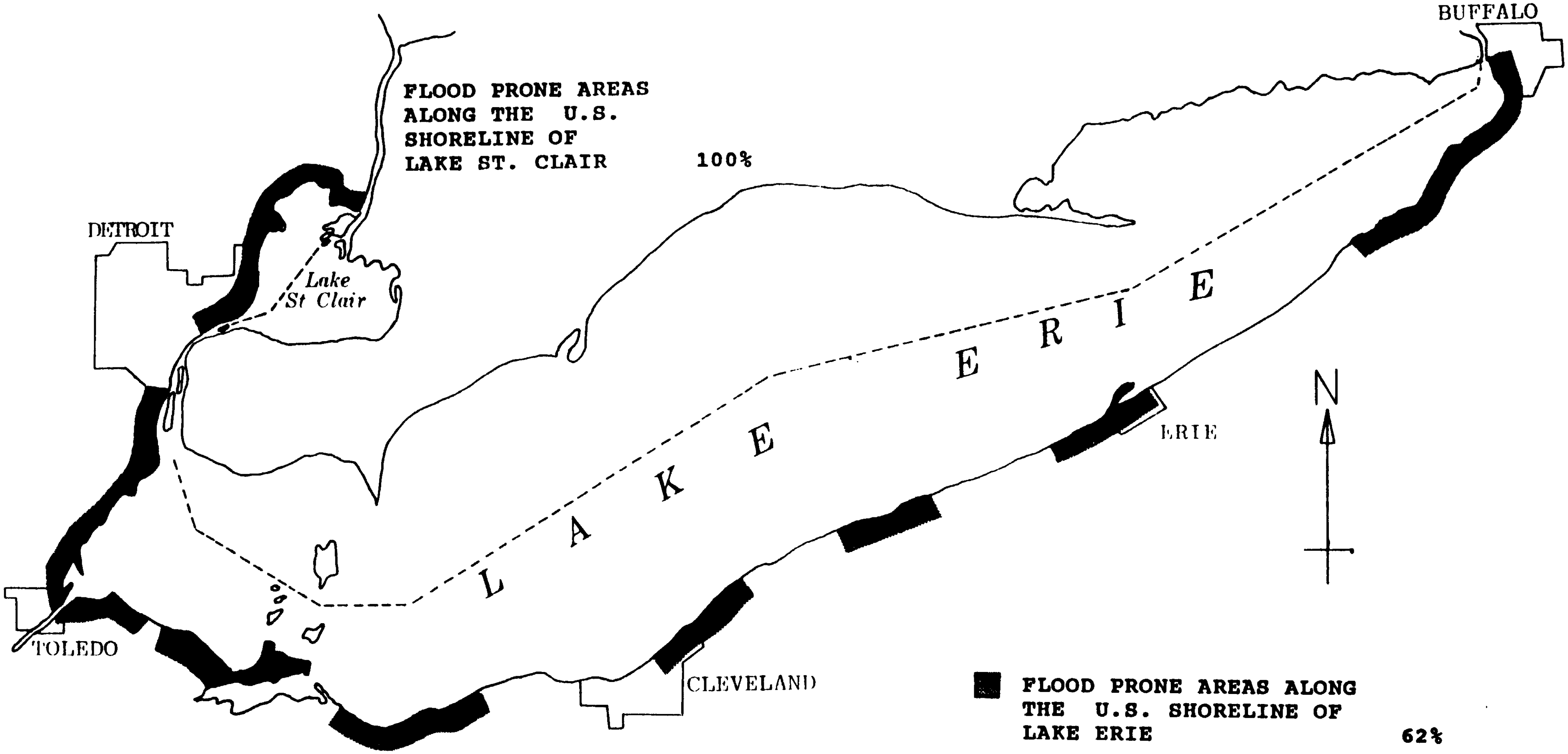
CM-8511, Crisp Pt to Nadoway Pt, MI
- 1:5 000 & 1:20 000

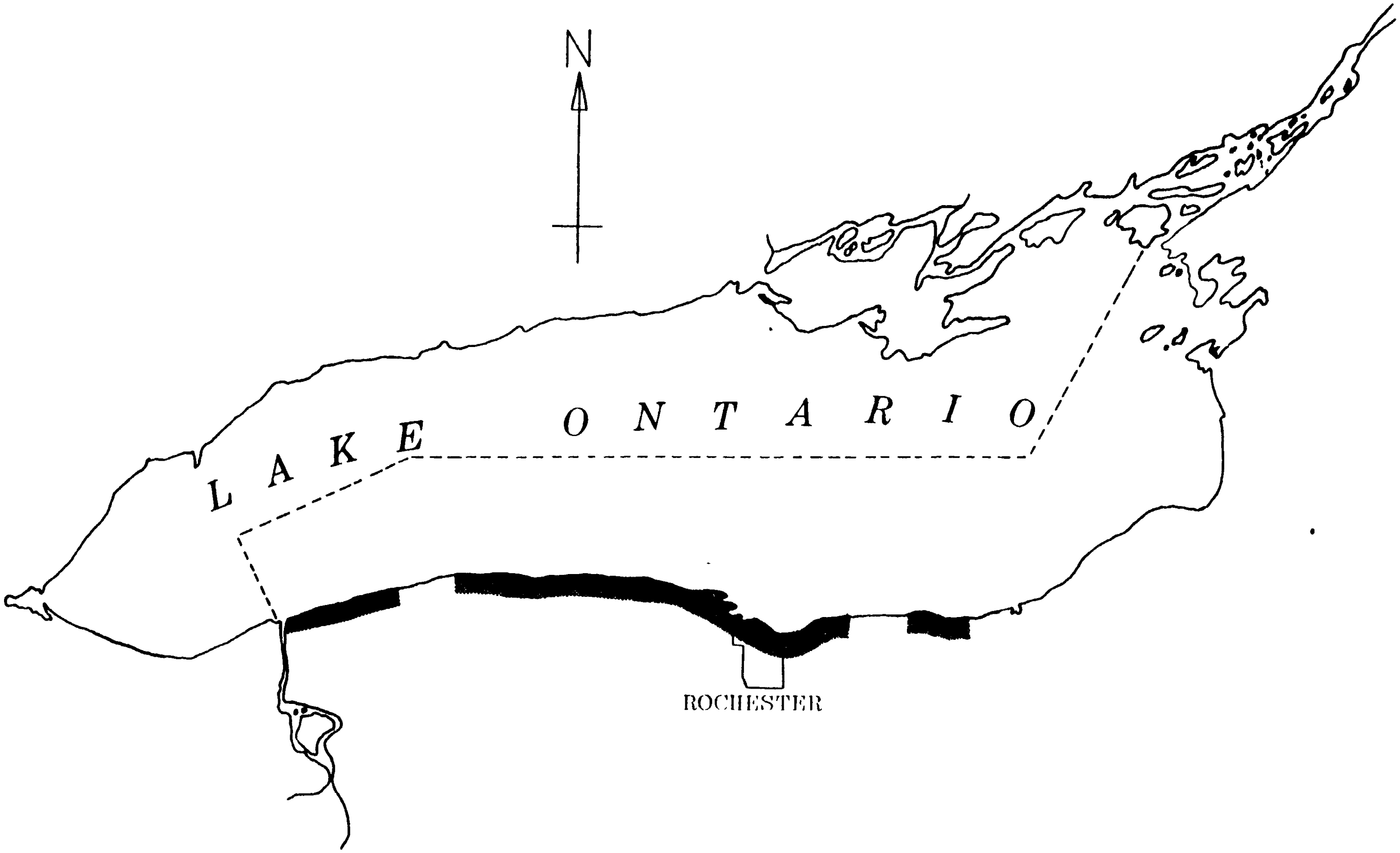
APPENDIX 4

FLOOD PRONE AREAS ALONG THE U.S. SHORELINE OF THE GREAT LAKES

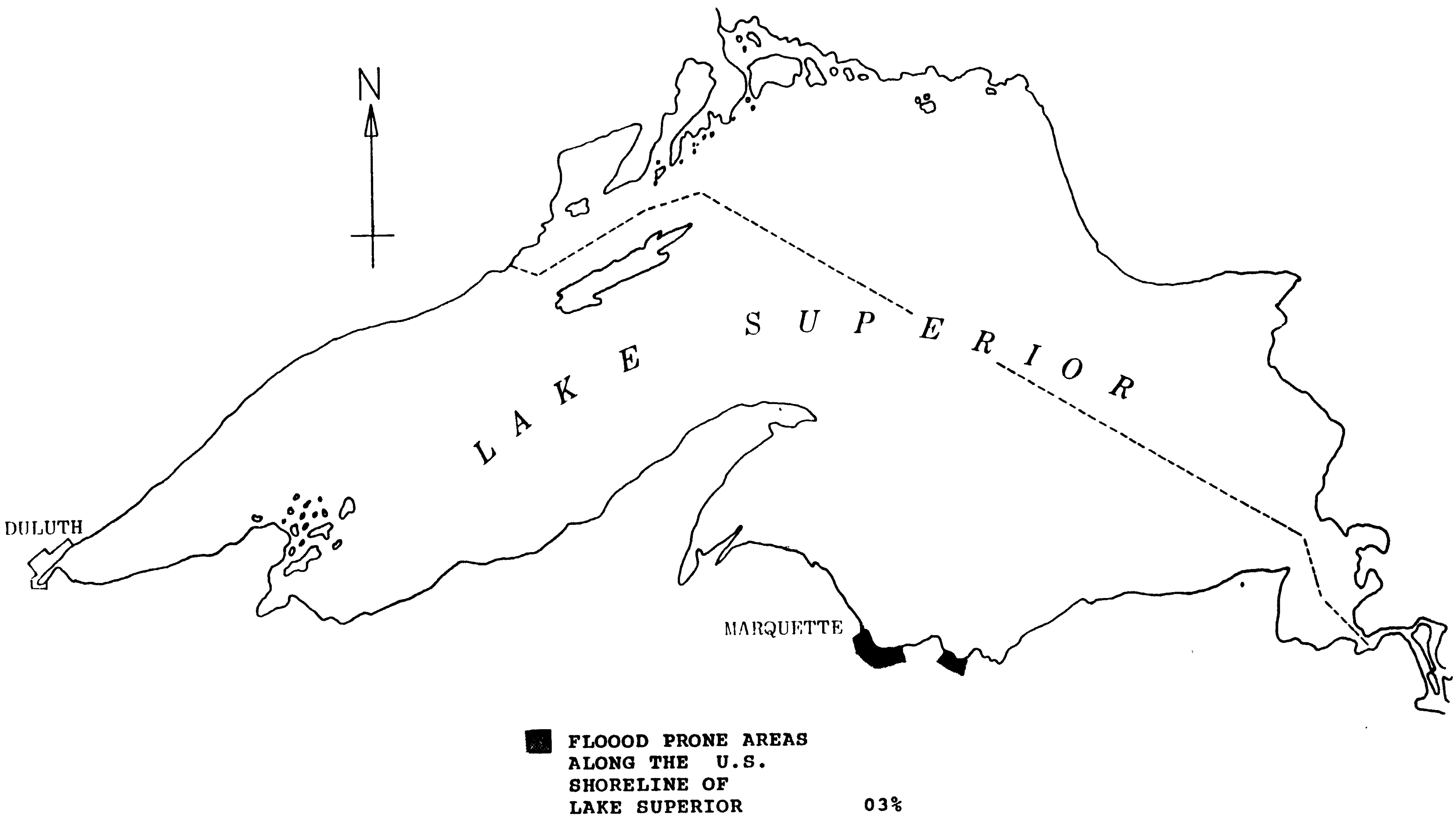

N
GREEN BAY
LAKE MICHIGAN
FLOOD PRONE AREAS ALONG THE U.S. SHORELINE OF LAKE MICHIGAN
21%
MILWAUKEE
CHICAGO


N
LAKE HURON
FLOOD PRONE AREAS
ALONG THE U.S.
SHORELINE OF
LAKE HURON
29%
BAY CITY


FLOOD PRONE AREAS
ALONG THE U.S.
SHORELINE OF
LAKE ST. CLAIR 100%
BUFFALO
DETROIT
Lake
St Clair
LAKE ERIE
ERIE
N
TOLEDO
CLEVELAND
FLOOD PRONE AREAS ALONG
THE U.S. SHORELINE OF
LAKE ERIE 62%

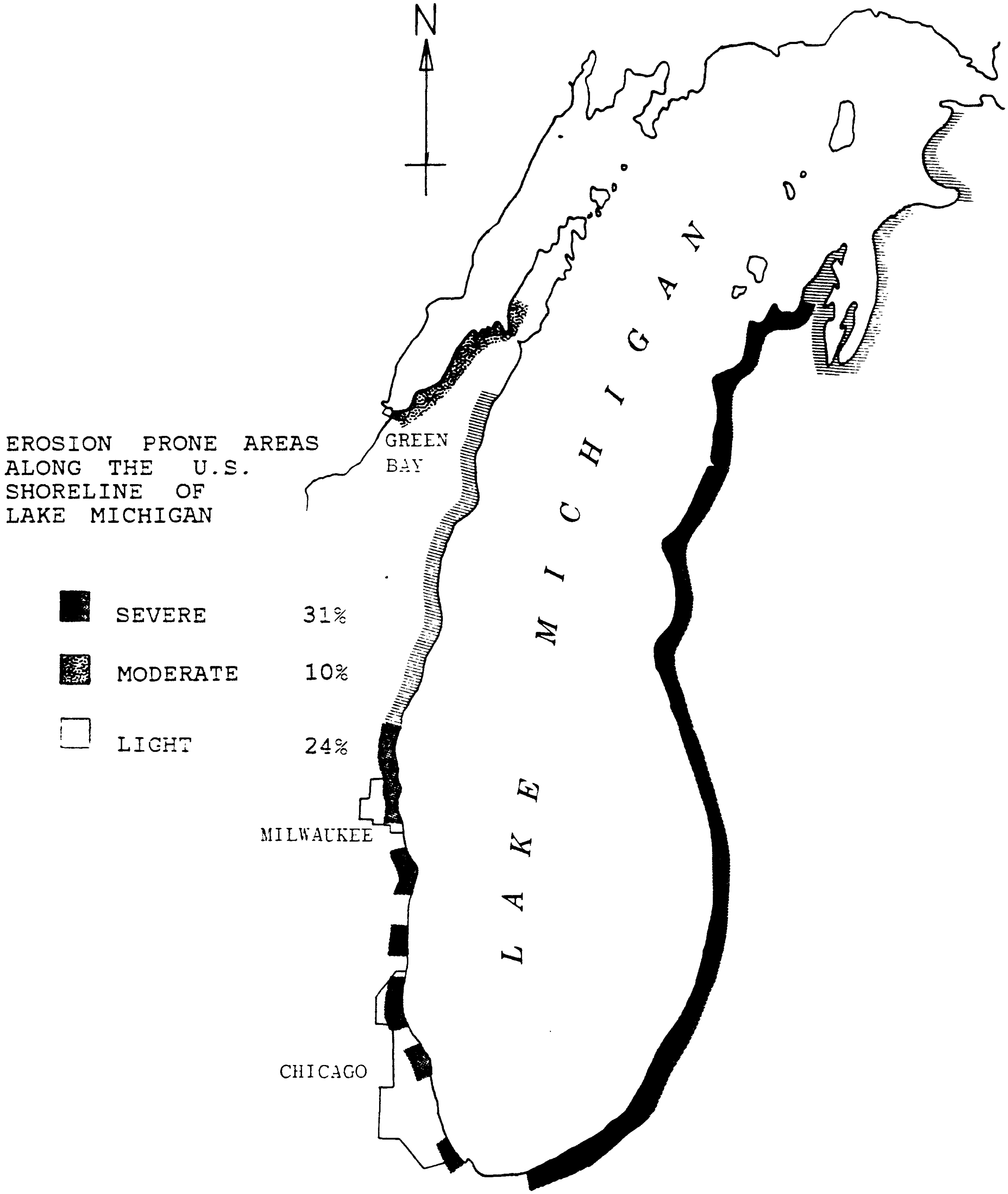


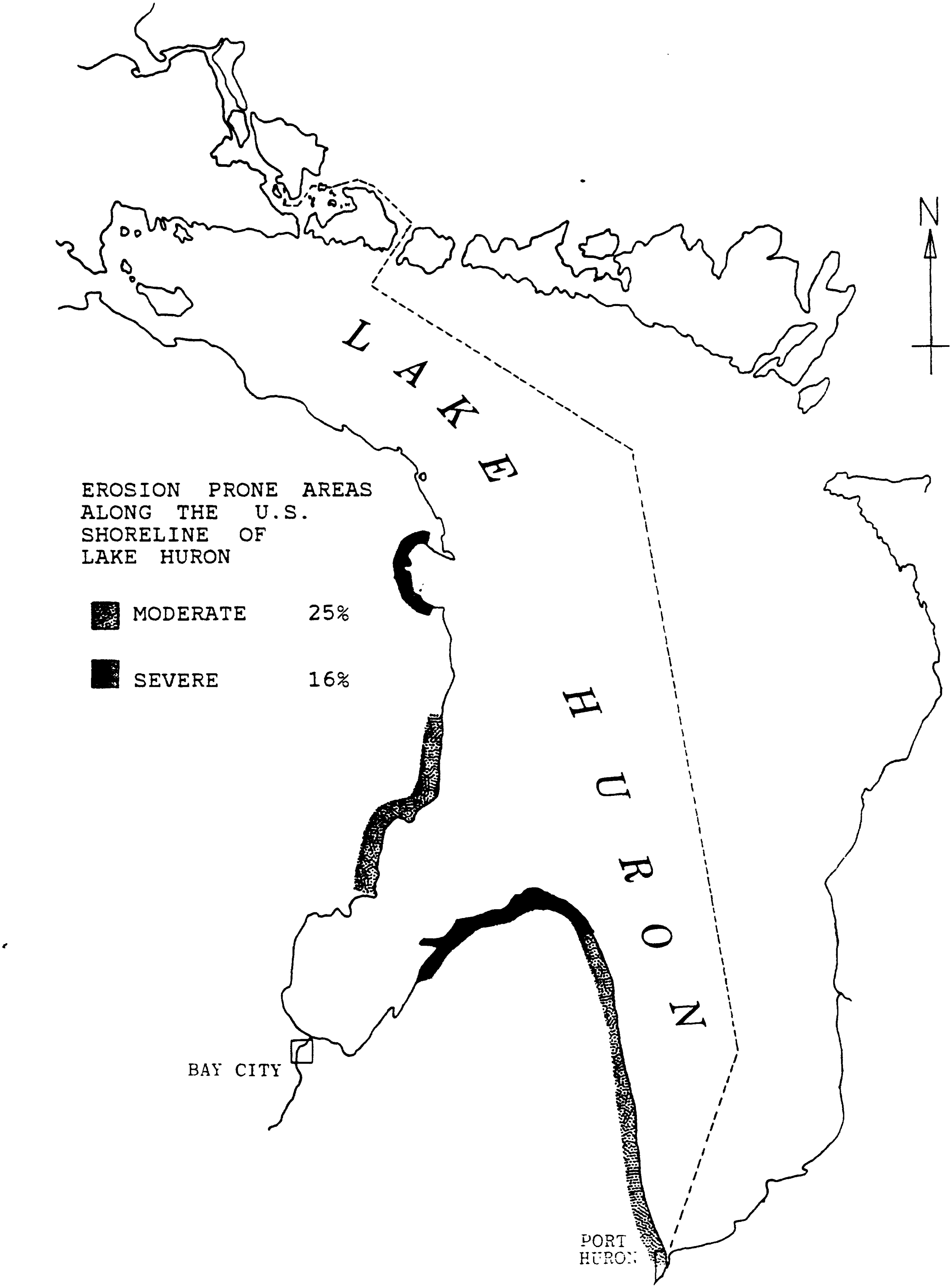
FLOOD PRONE AREAS ALONG THE U.S. SHORELINE OF LAKE ONTARIO 38%

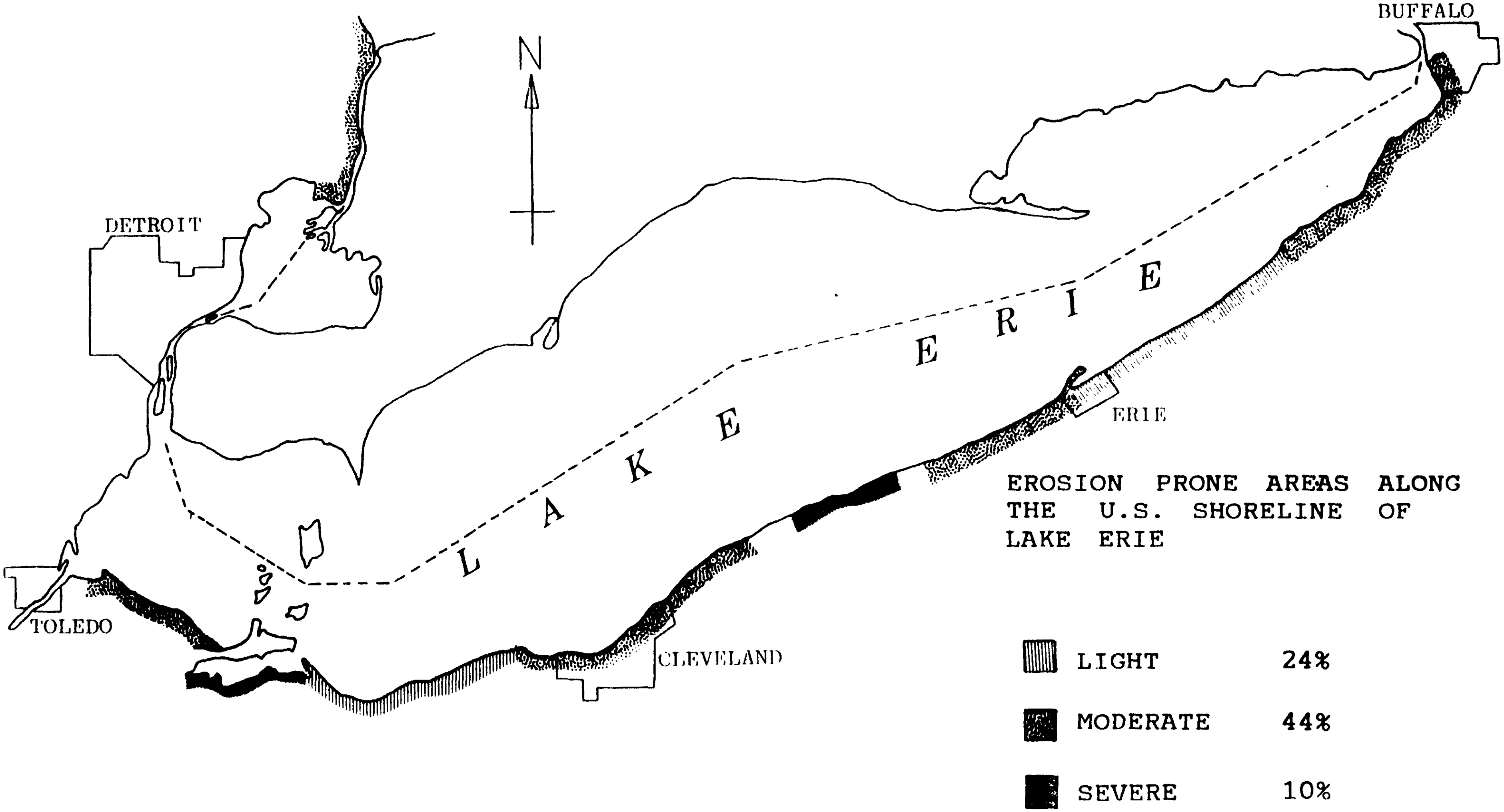

N
LAKE SUPERIOR
DULUTH
MARQUETTE
FLOOOD PRONE AREAS ALONG THE U.S. SHORELINE OF LAKE SUPERIOR
03%

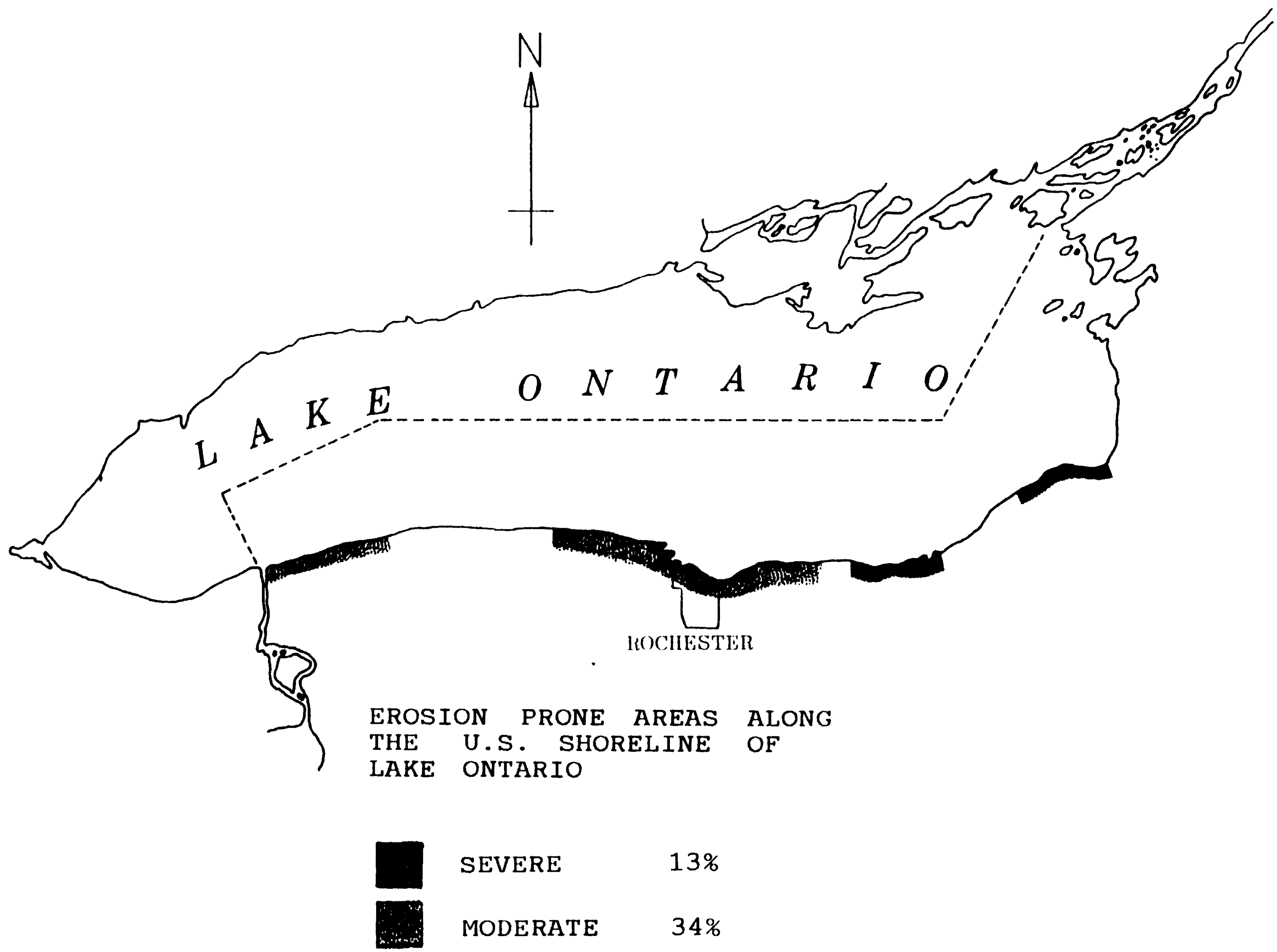
APPENDIX 5

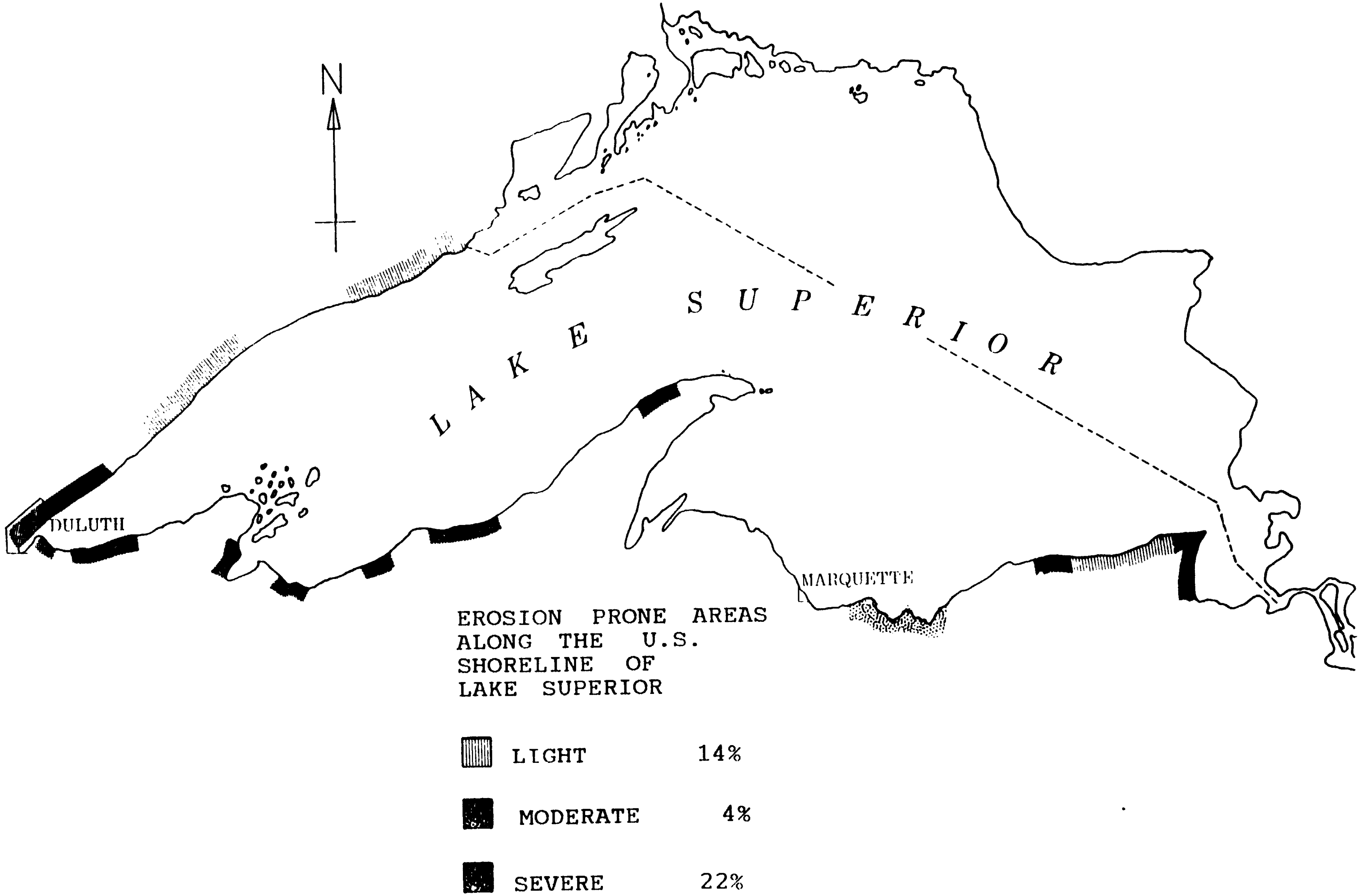
EROSION PRONE AREAS ALONG THE U.S. SHORELINE OF THE GREAT LAKES


EROSION PRONE AREAS
ALONG THE U.S.
SHORELINE OF
LAKE MICHIGAN
SEVERE 31%
MODERATE 10%
LIGHT 24%
N
GREEN
BAY
MILWAUKEE
CHICAGO
LAKE MICHIGAN


EROSION PRONE AREAS ALONG THE U.S. SHORELINE OF LAKE HURON
MODERATE 25%
SEVERE 16%
LAKE HURON
BAY CITY
PORT HURON
N


EROSION PRONE AREAS ALONG THE U.S. SHORELINE OF LAKE ERIE
LIGHT 24%
MODERATE 44%
SEVERE 10%
BUFFALO
DETROIT
TOLEDO
CLEVELAND
ERIE
LAKE ERIE
N

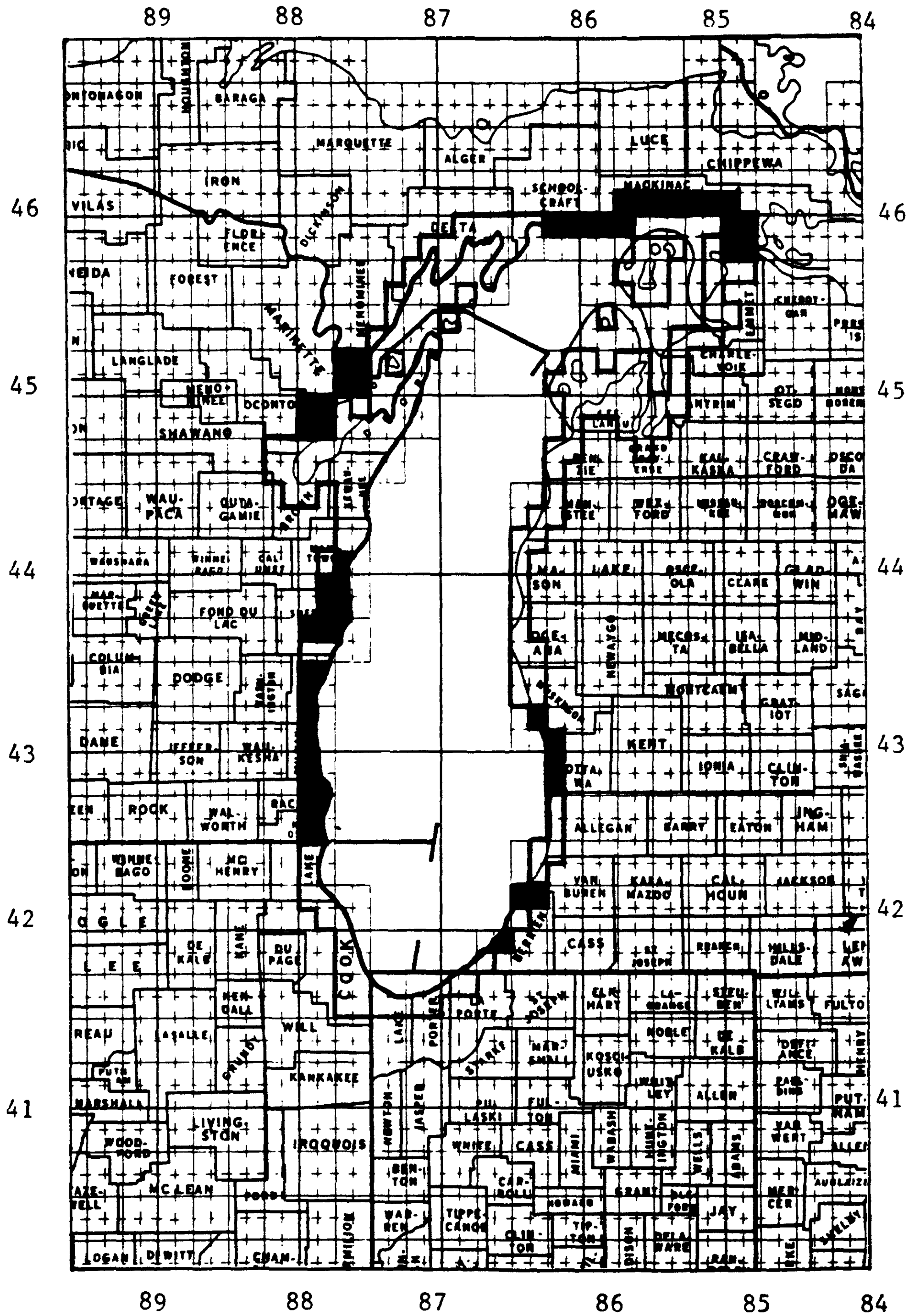

N
LAKE ONTARIO
ROCHESTER
EROSION PRONE AREAS ALONG
THE U.S. SHORELINE OF
LAKE ONTARIO
SEVERE 13%
MODERATE 34%


N
LAKE SUPERIOR
DULUTH
MARQUETTE
EROSION PRONE AREAS
ALONG THE U.S.
SHORELINE OF
LAKE SUPERIOR
LIGHT 14%
MODERATE 4%
SEVERE 22%

APPENDIX 6

U.S. GEOLOGICAL SURVEY QUADRANGLES MOST IN NEED OF REVISION

LAKE MICHIGAN

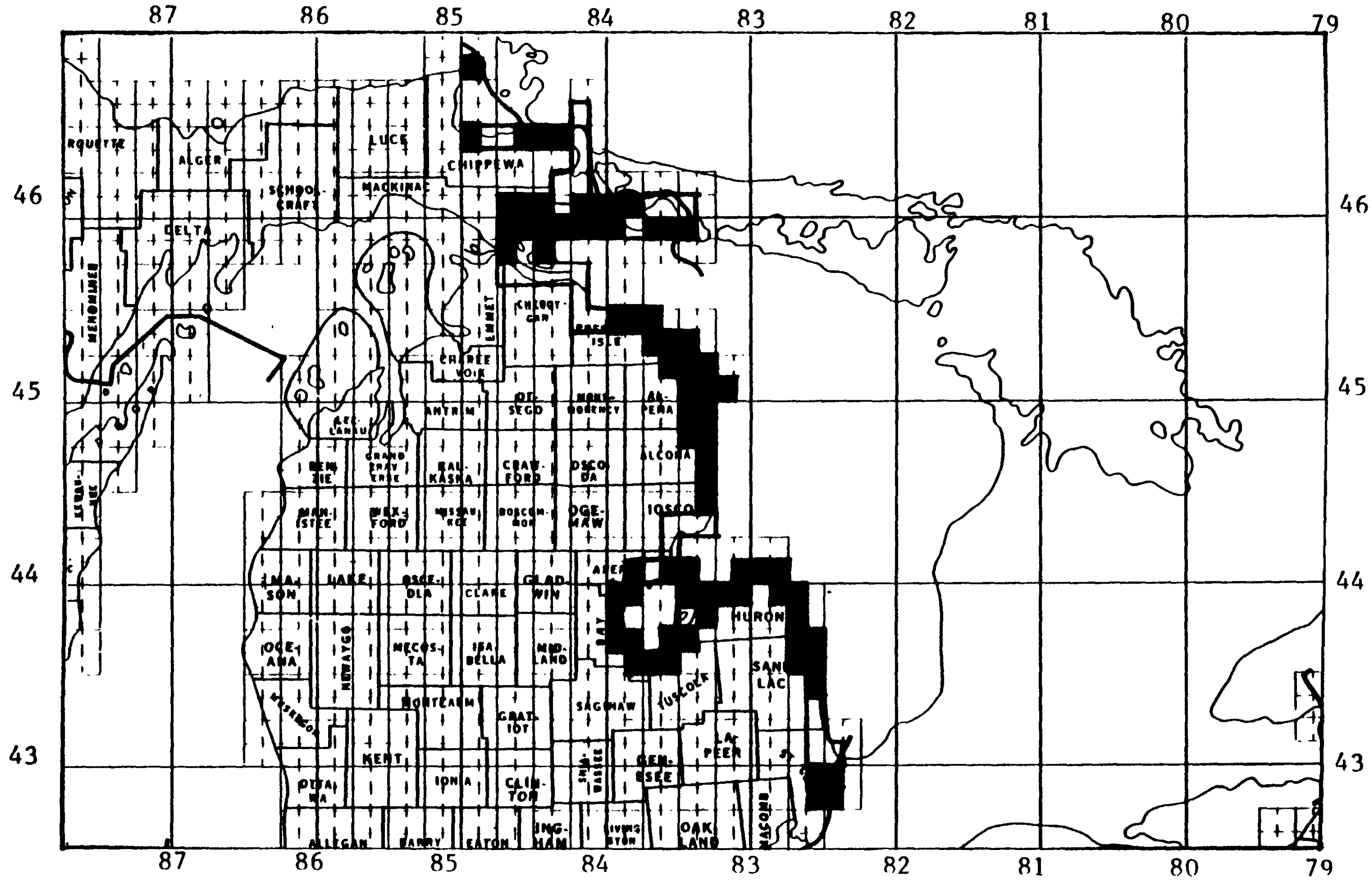


Study Area Boundary

Maps Most in Need of Revision

LAKE MICHIGAN

LAKE HURON

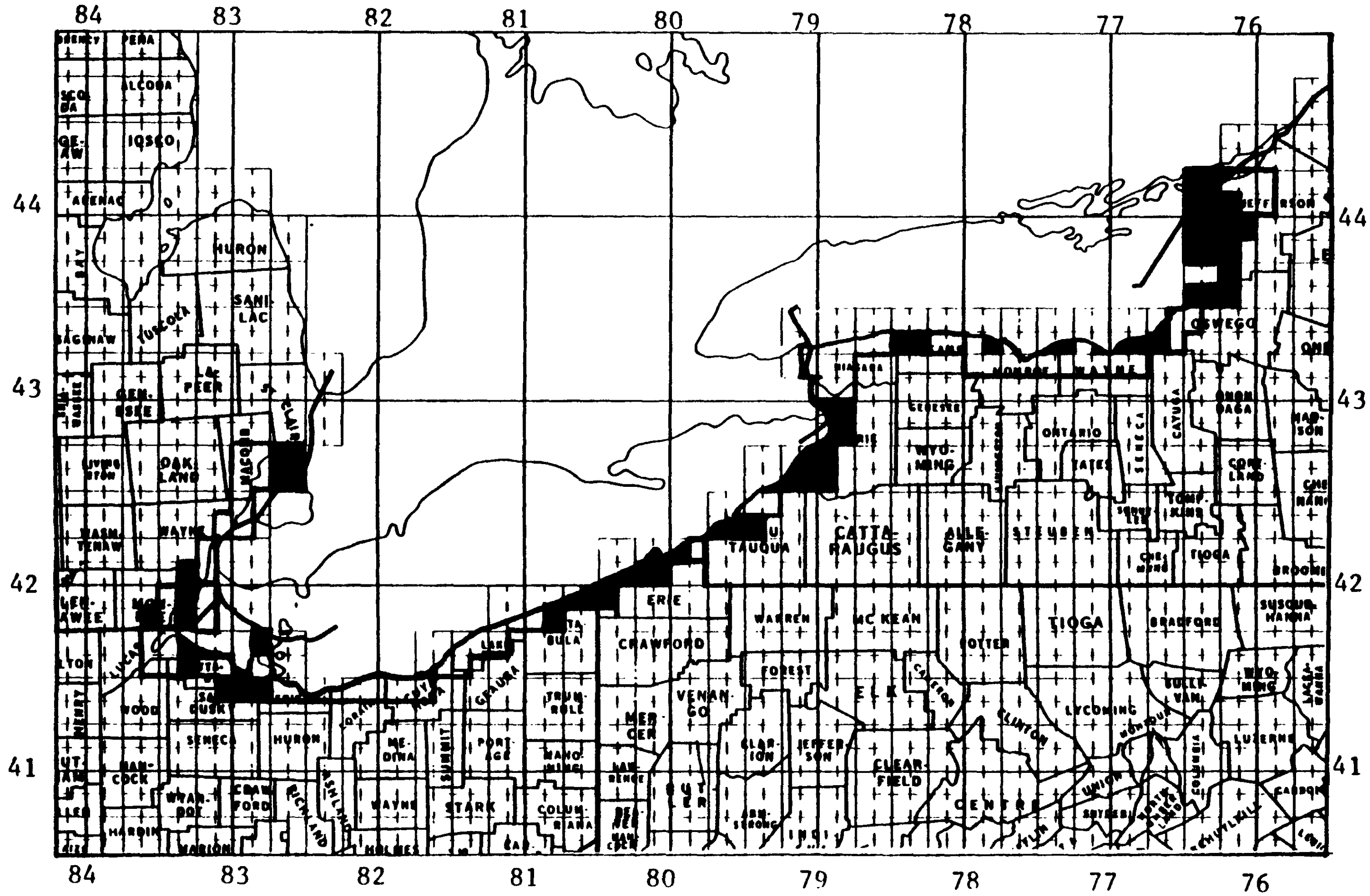


Study Area Boundary

Maps Most in Need of Revision

LAKE HURON

LAKES ERIE AND ONTARIO

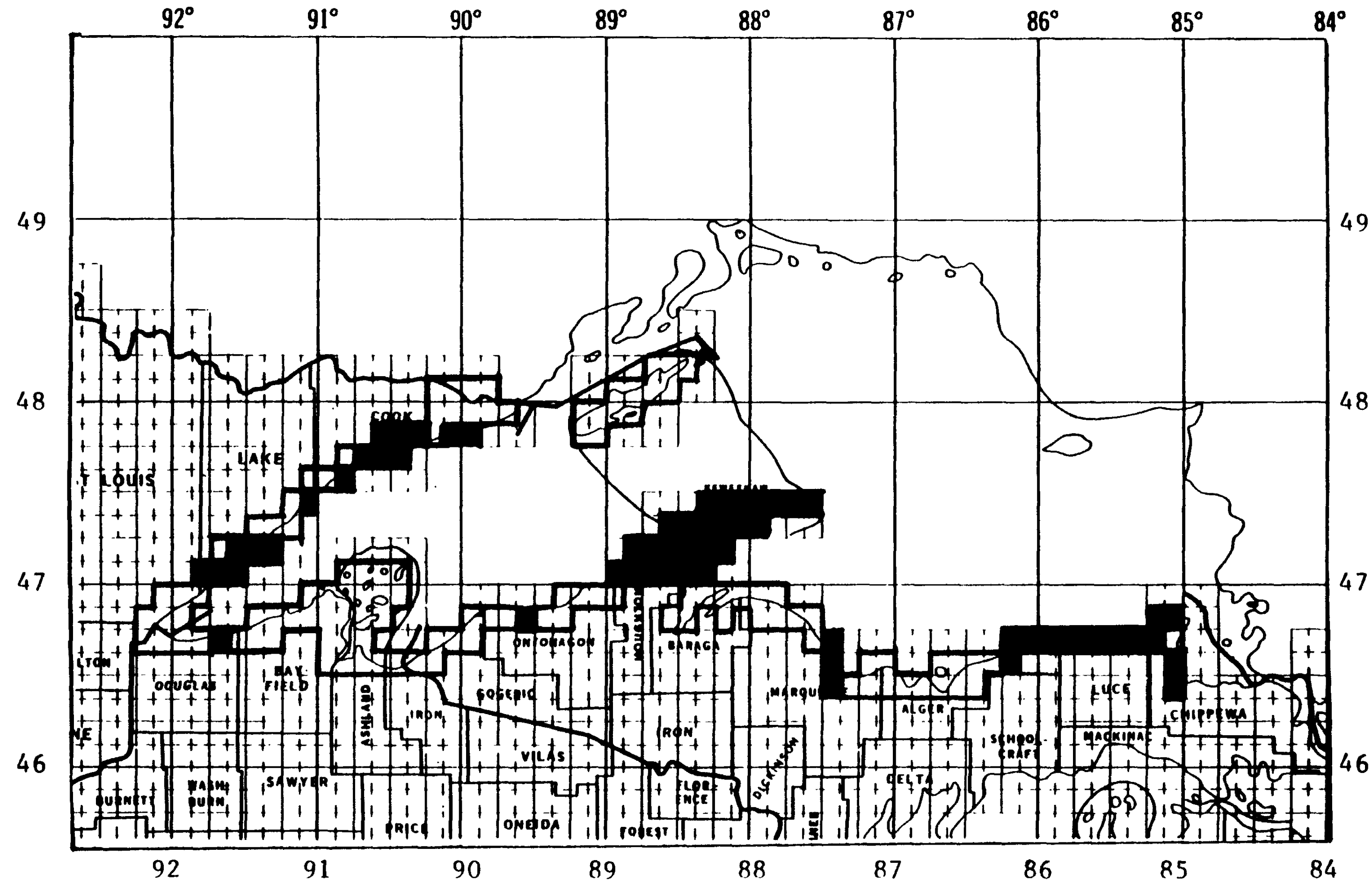


Study Area Boundary

Maps Most in Need of Revision

LAKES ERIE AND ONTARIO

LAKE SUPERIOR



Study Area Boundary

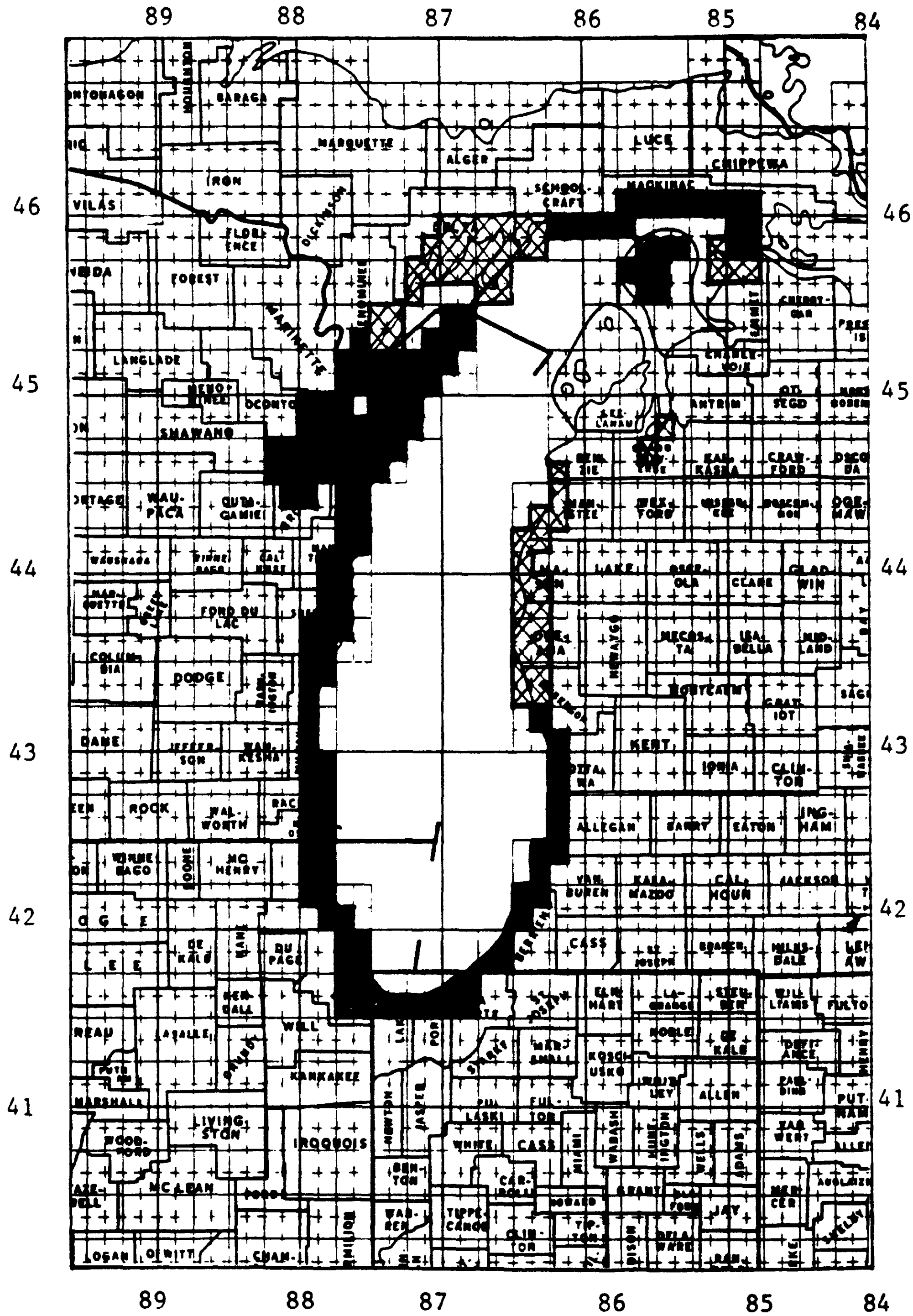
Maps Most in Need of Revision

LAKE SUPERIOR

APPENDIX 7

AVAILABLE CONTOUR INTERVALS ON U.S. GEOLOGICAL SURVEY QUADRANGLES

LAKE MICHIGAN



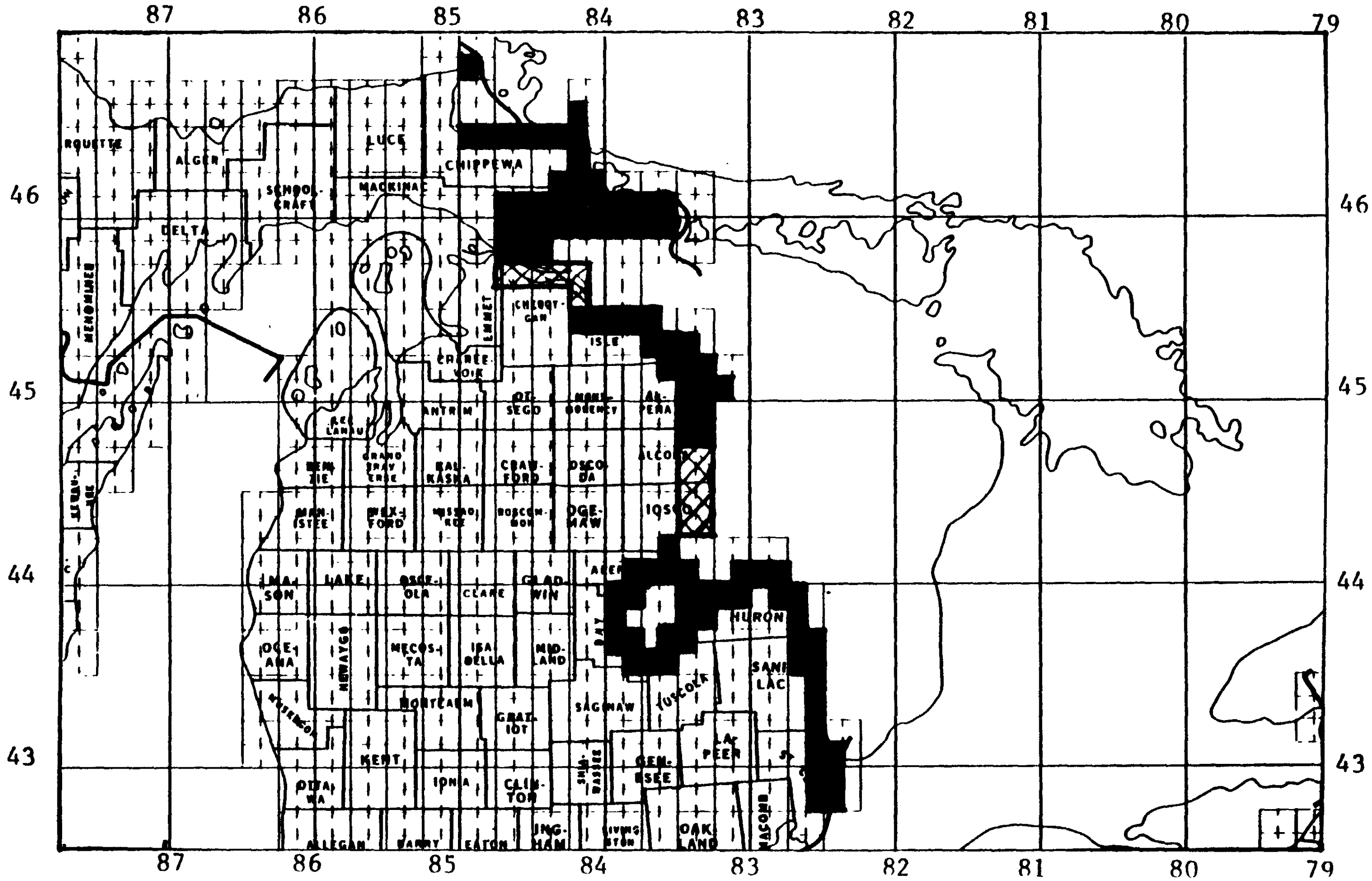
Contour Intervals

5ft and 10ft

LAKE MICHIGAN

1.5 m. and 3 m.

LAKE HURON



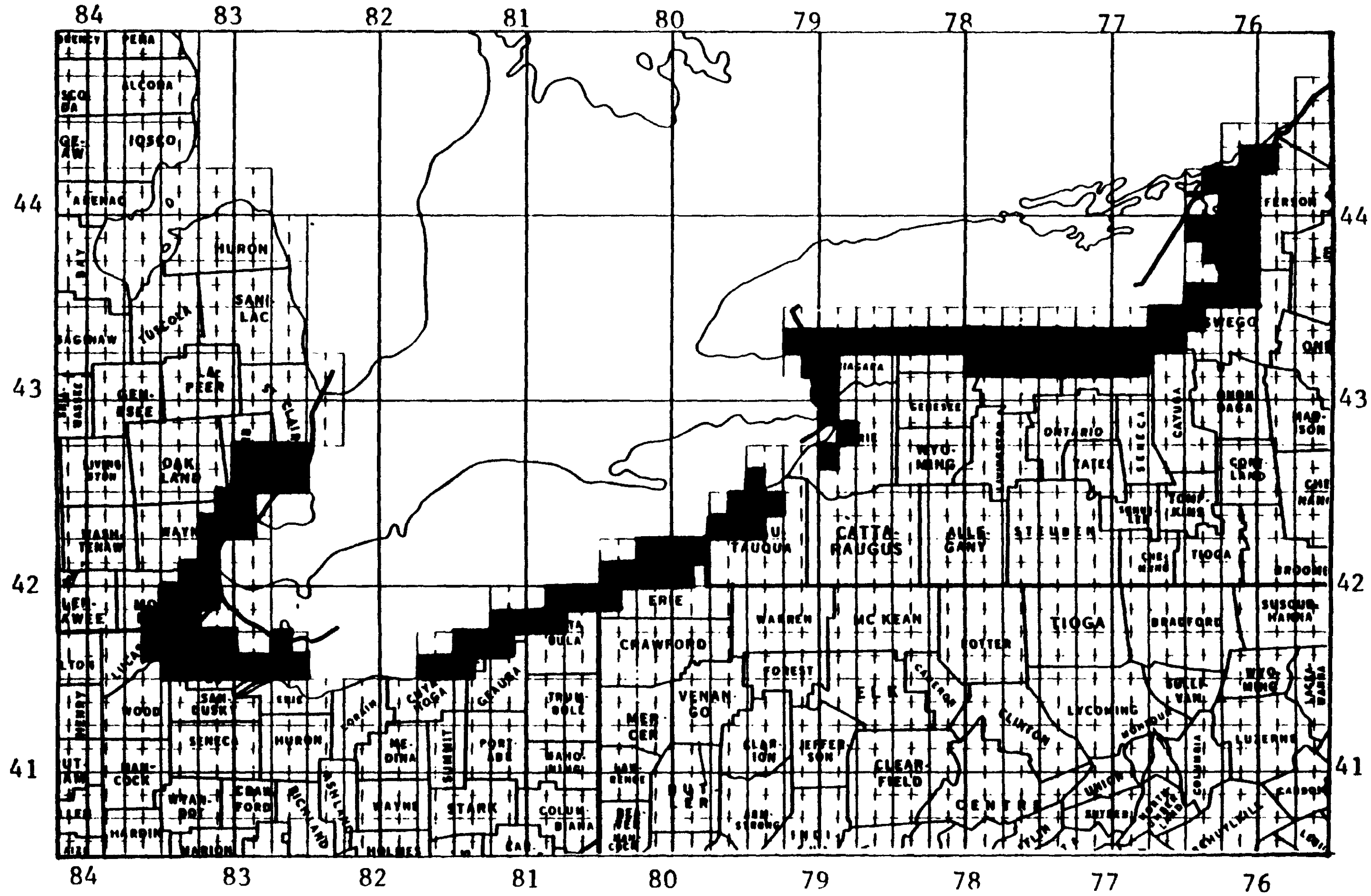
LAKE HURON

Contour Intervals

■ 5ft and 10ft

⊠ 1.5 m. and 3 m.

LAKES ERIE AND ONTARIO



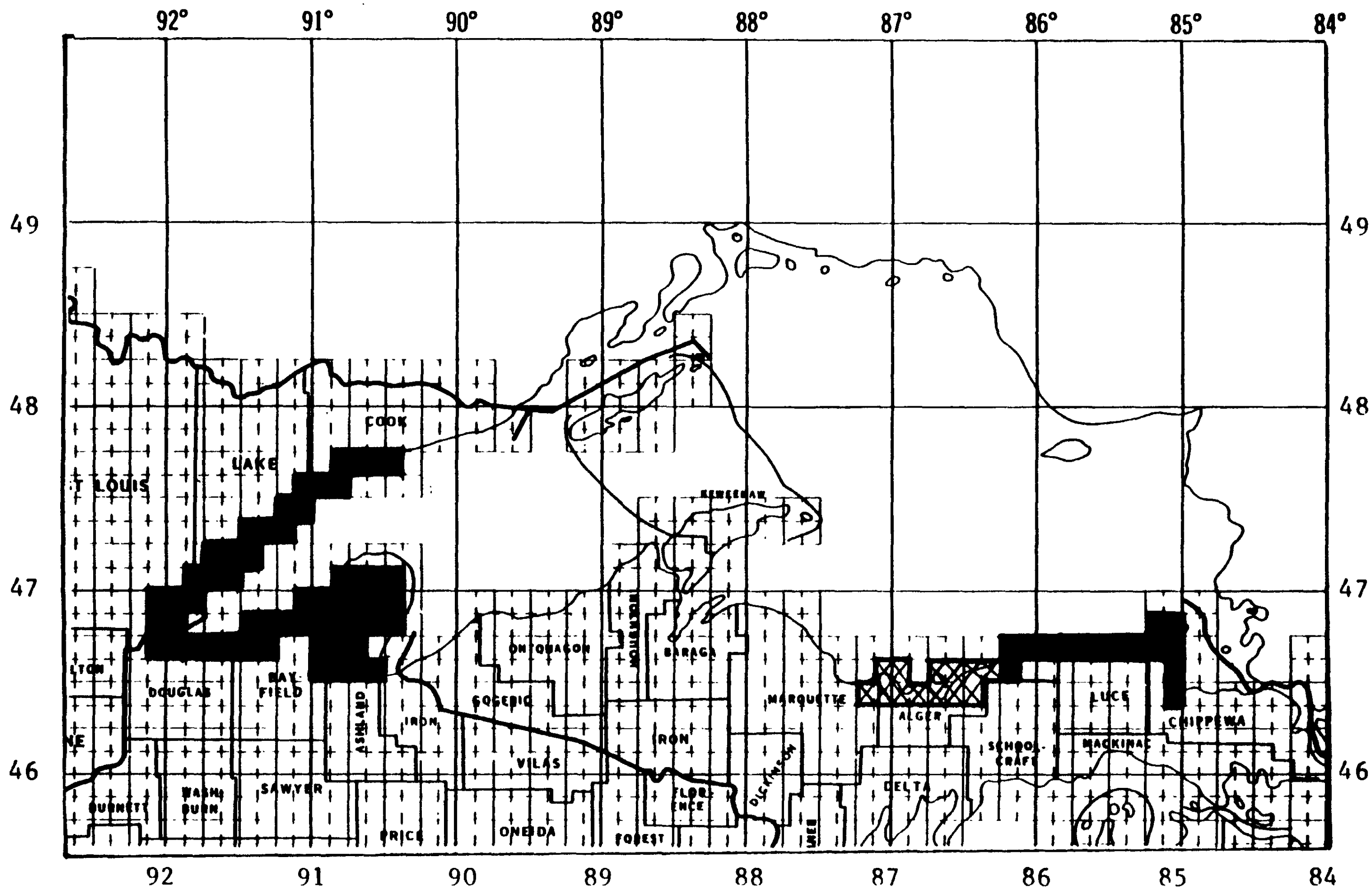
Contour Intervals

5ft and 10ft

1.5 m and 3 m.

LAKES ERIE AND ONTARIO

LAKE SUPERIOR



Contour Intervals

■ 5ft and 10ft

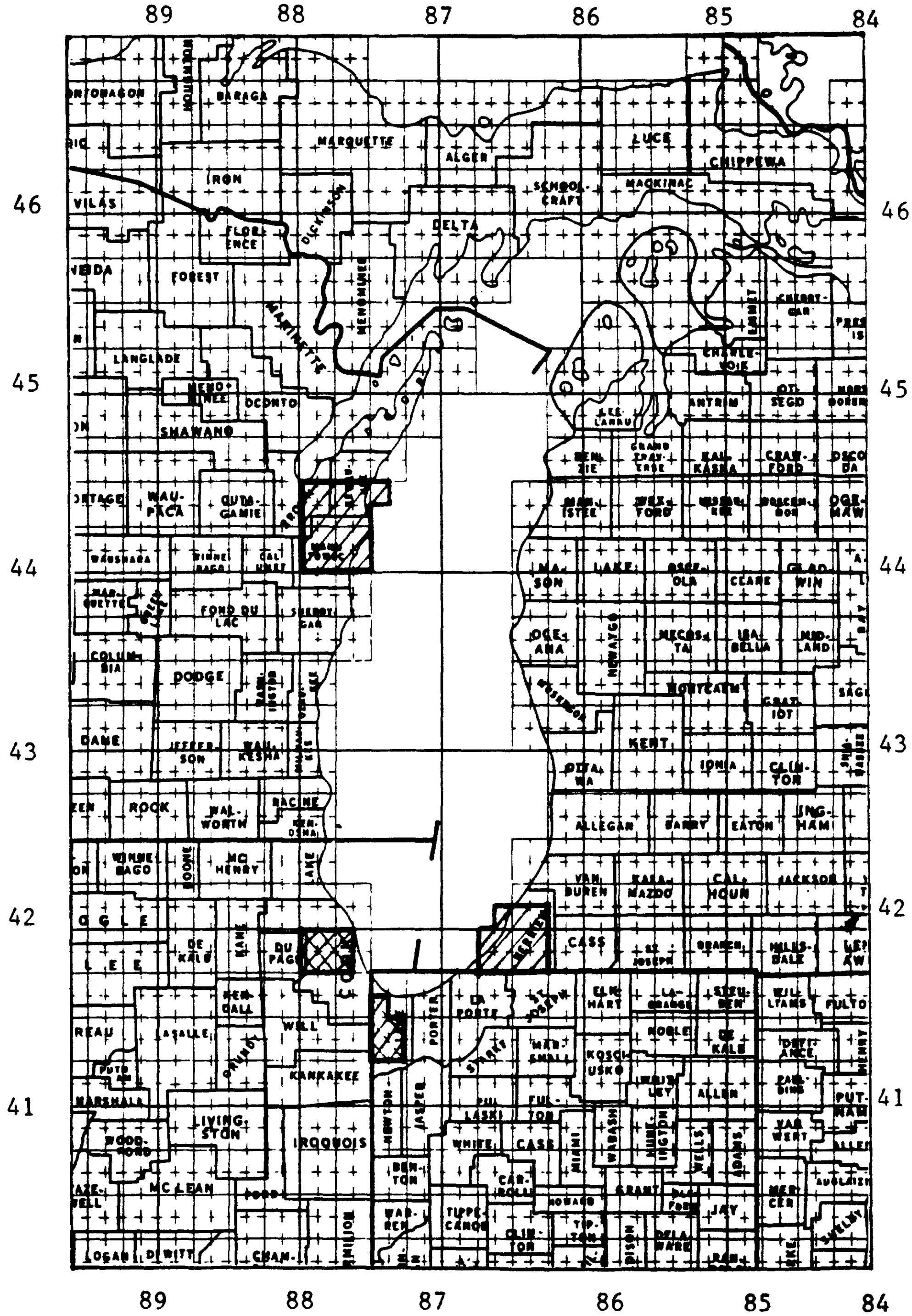
⊠ 1.5 m. and 3 m.

LAKE SUPERIOR

APPENDIX 8

DIGITAL DATA AVAILABLE ON U.S. GEOLOGICAL SURVEY QUADRANGLES

LAKE MICHIGAN



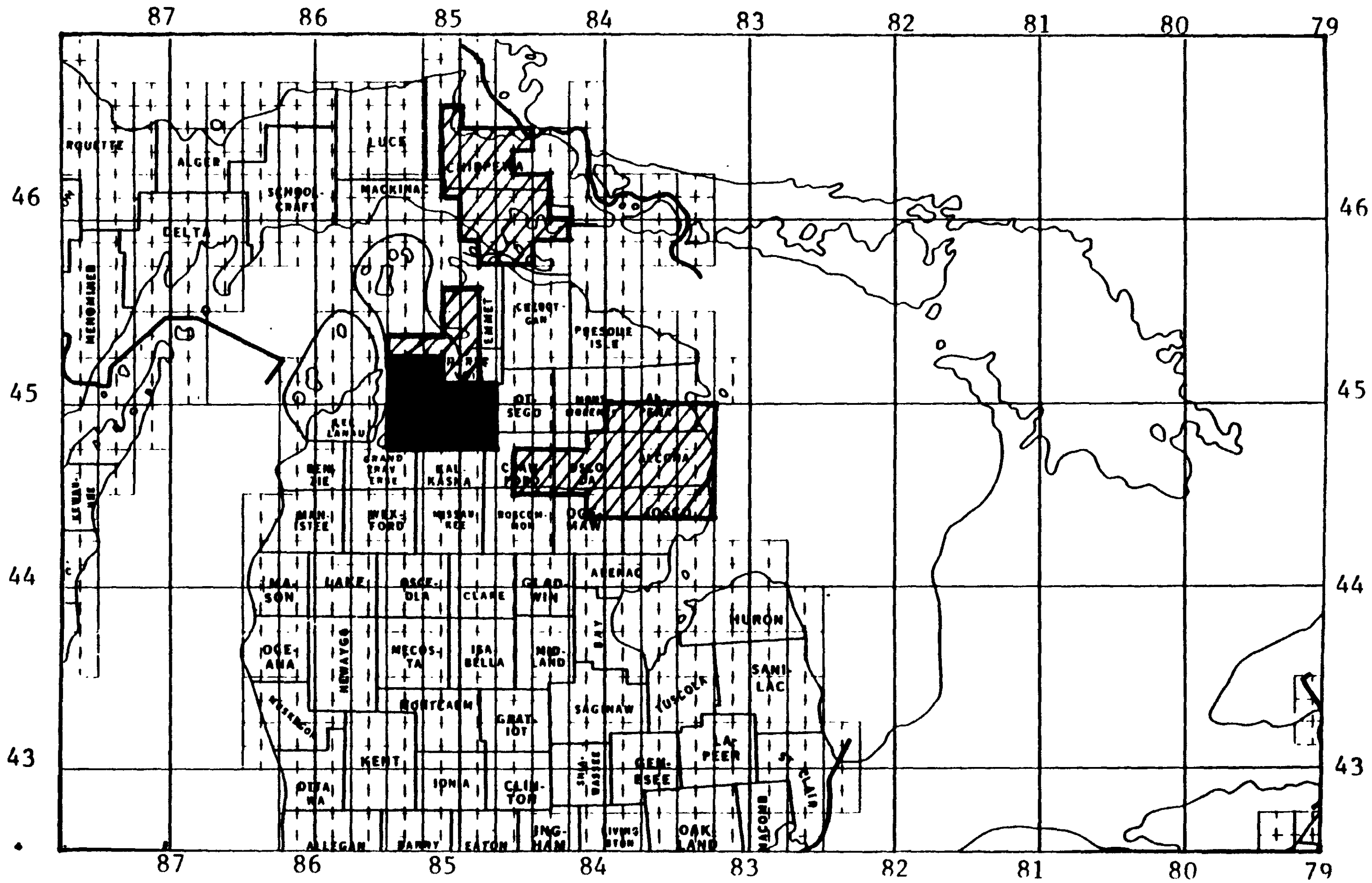
Digital Data Available

Elevation Models (DEM) LAKE MICHIGAN

Line Graphs (DLG) Only

Both DEM And DLG

LAKE HURON



Digital Data Available

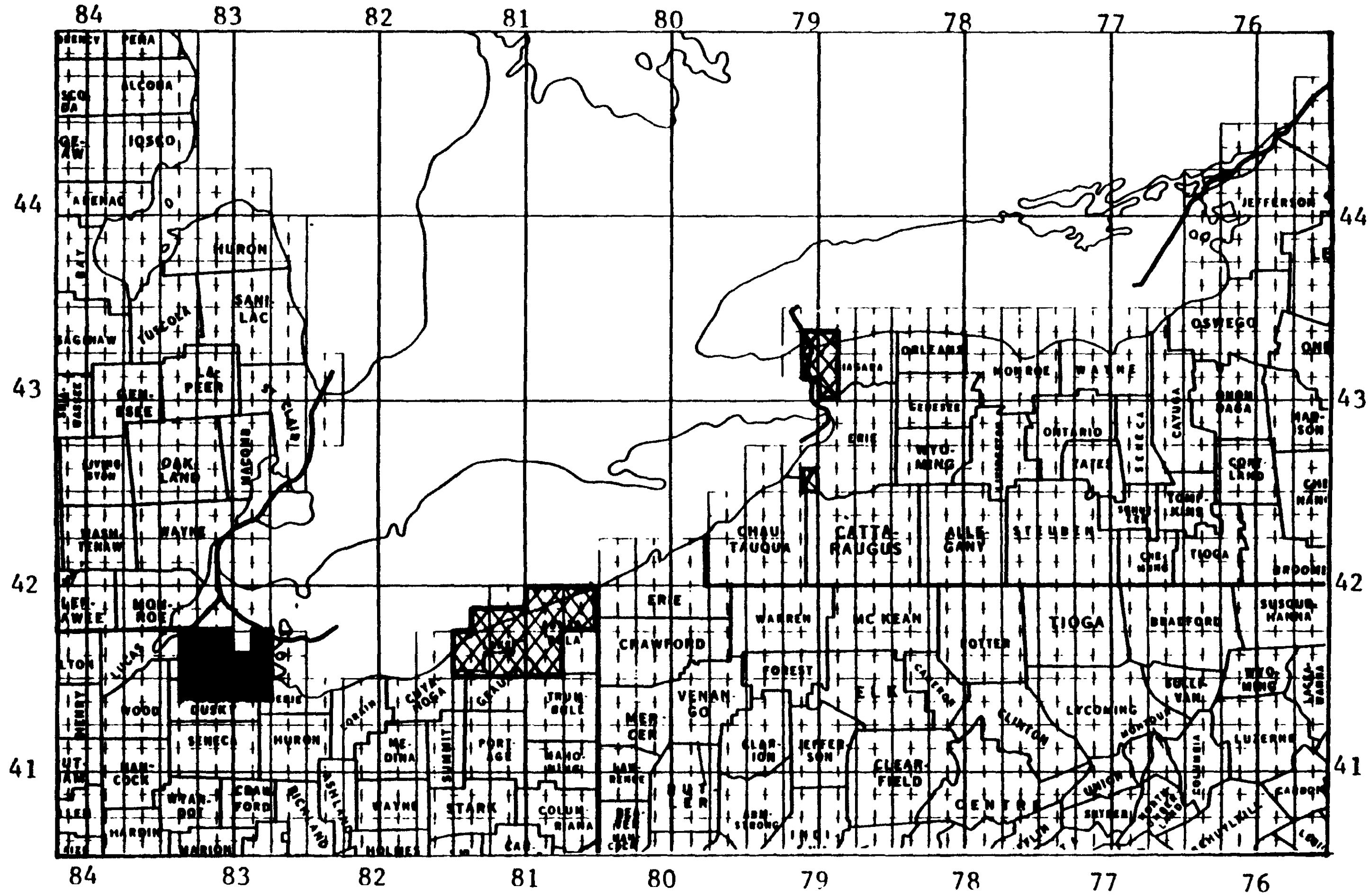
Elevation Models (DEM) Only

Line Graphs (DLG) Only

Both DEM And DLG

LAKE HURON

LAKES ERIE AND ONTARIO



Digital Data Available

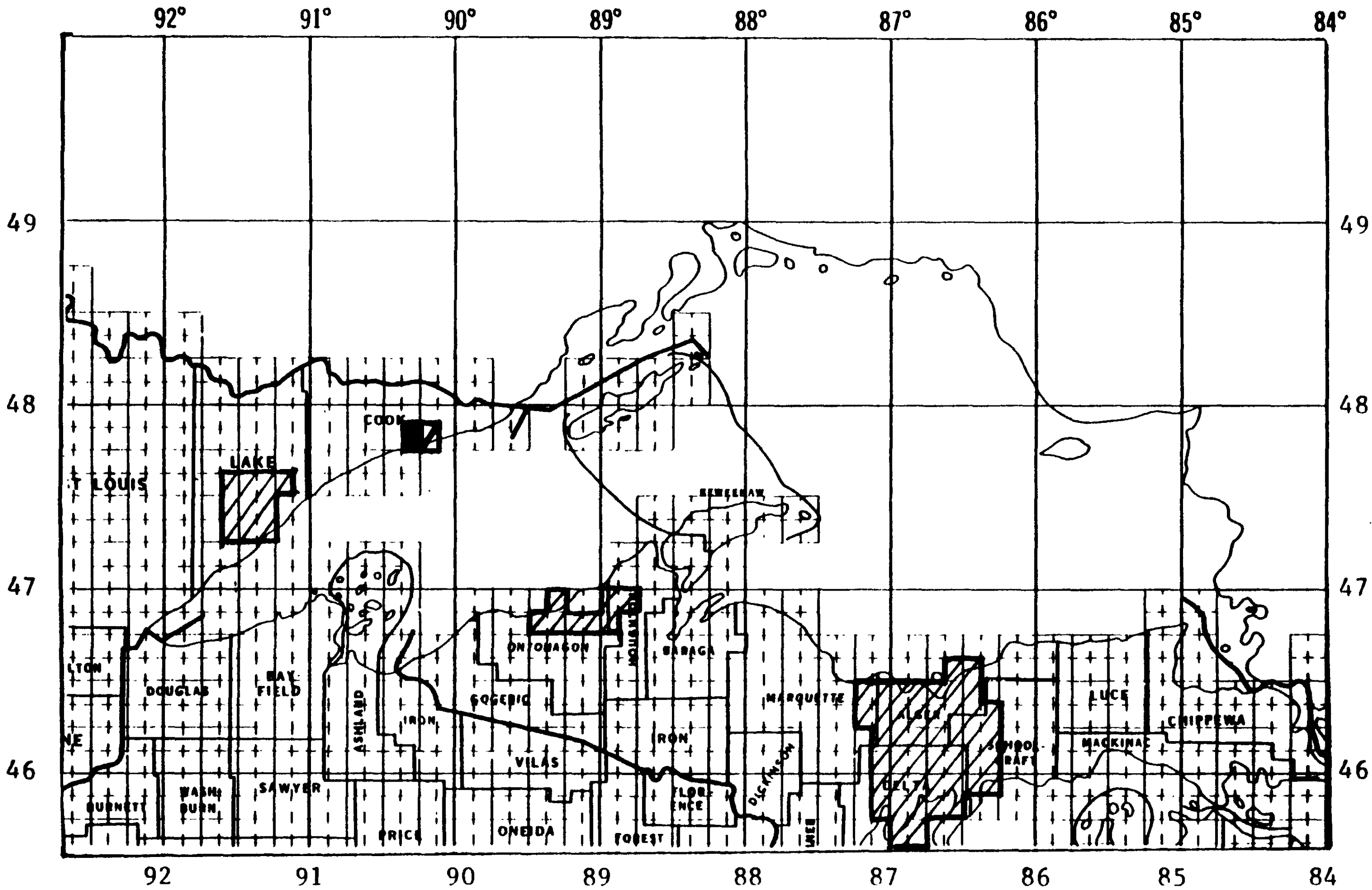
Elevation Models (DEM) Only

Line Graphs (DLG) Only

Both DEM And DLG

LAKES ERIE AND ONTARIO

LAKE SUPERIOR



Digital Data Available

Elevation Models (DEM) Only

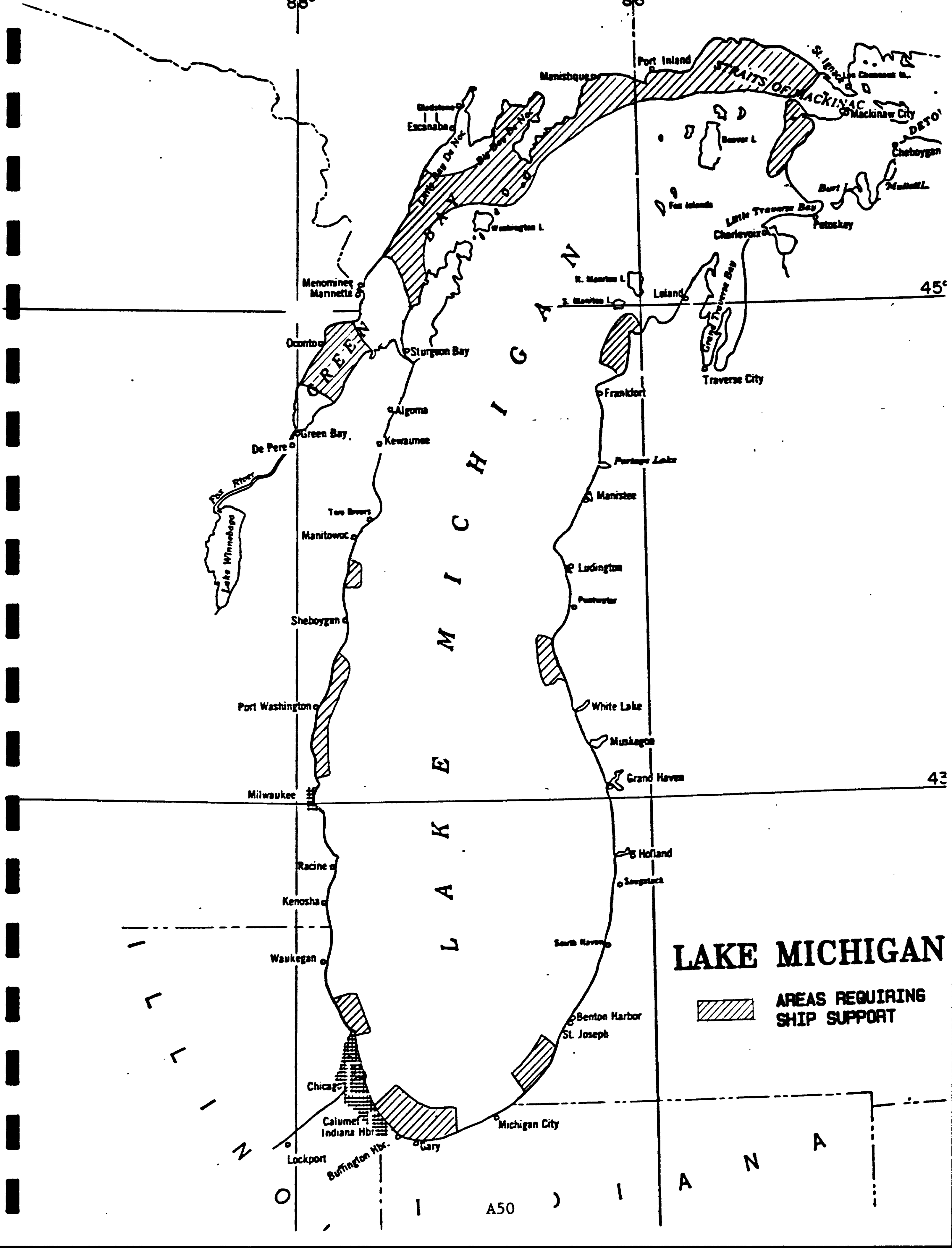
Line Graphs (DLG) Only

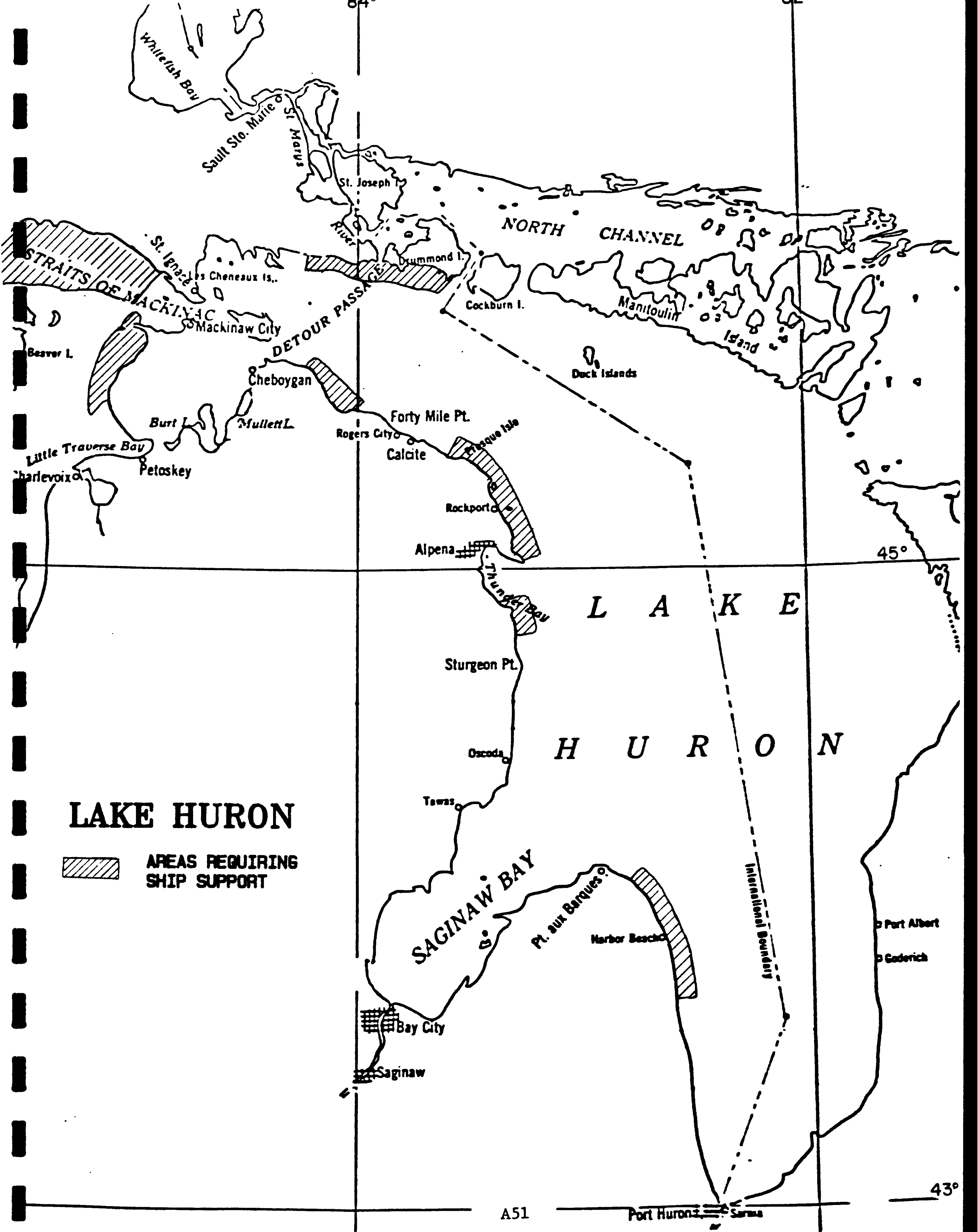
Both DEM And DLG

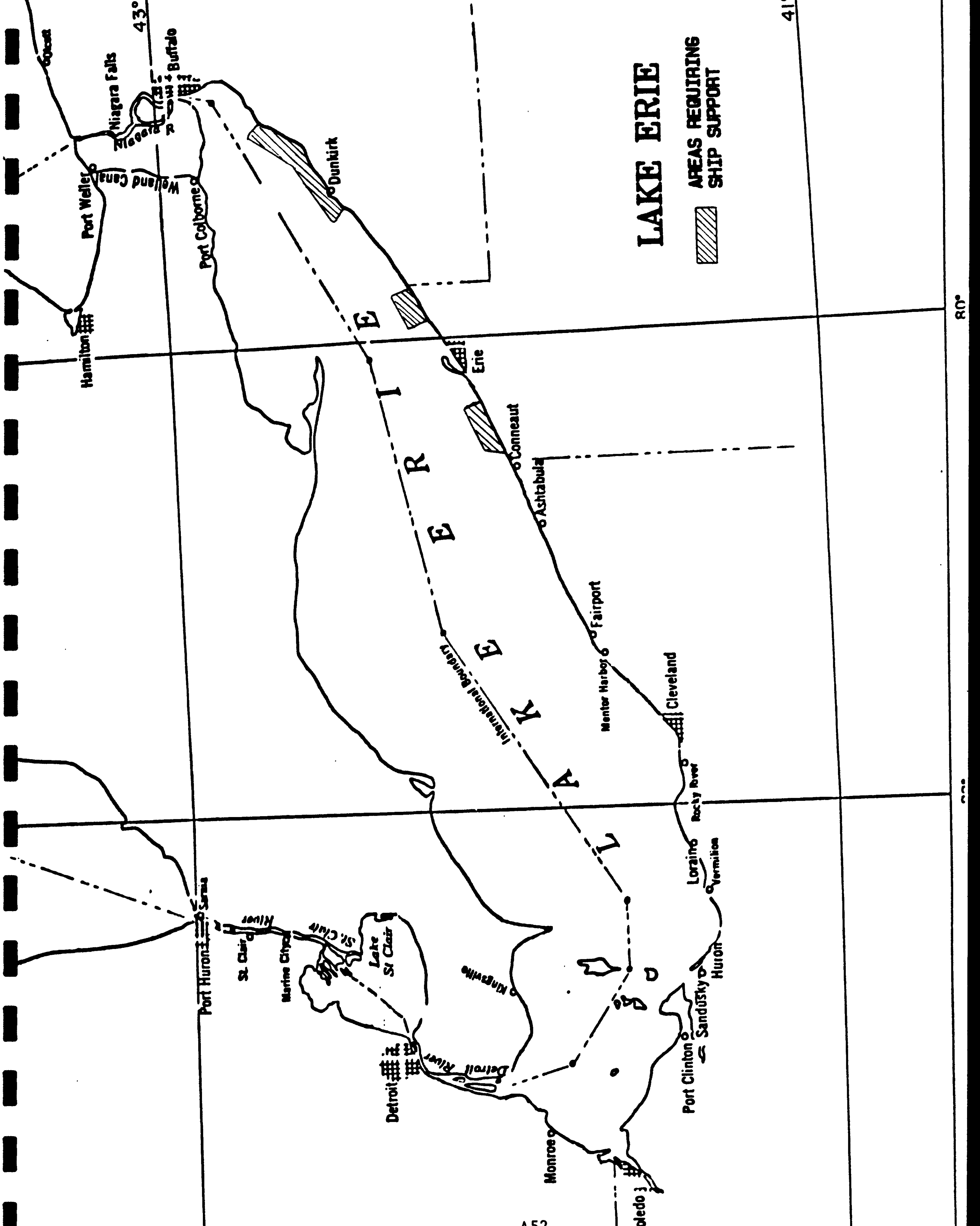
LAKE SUPERIOR

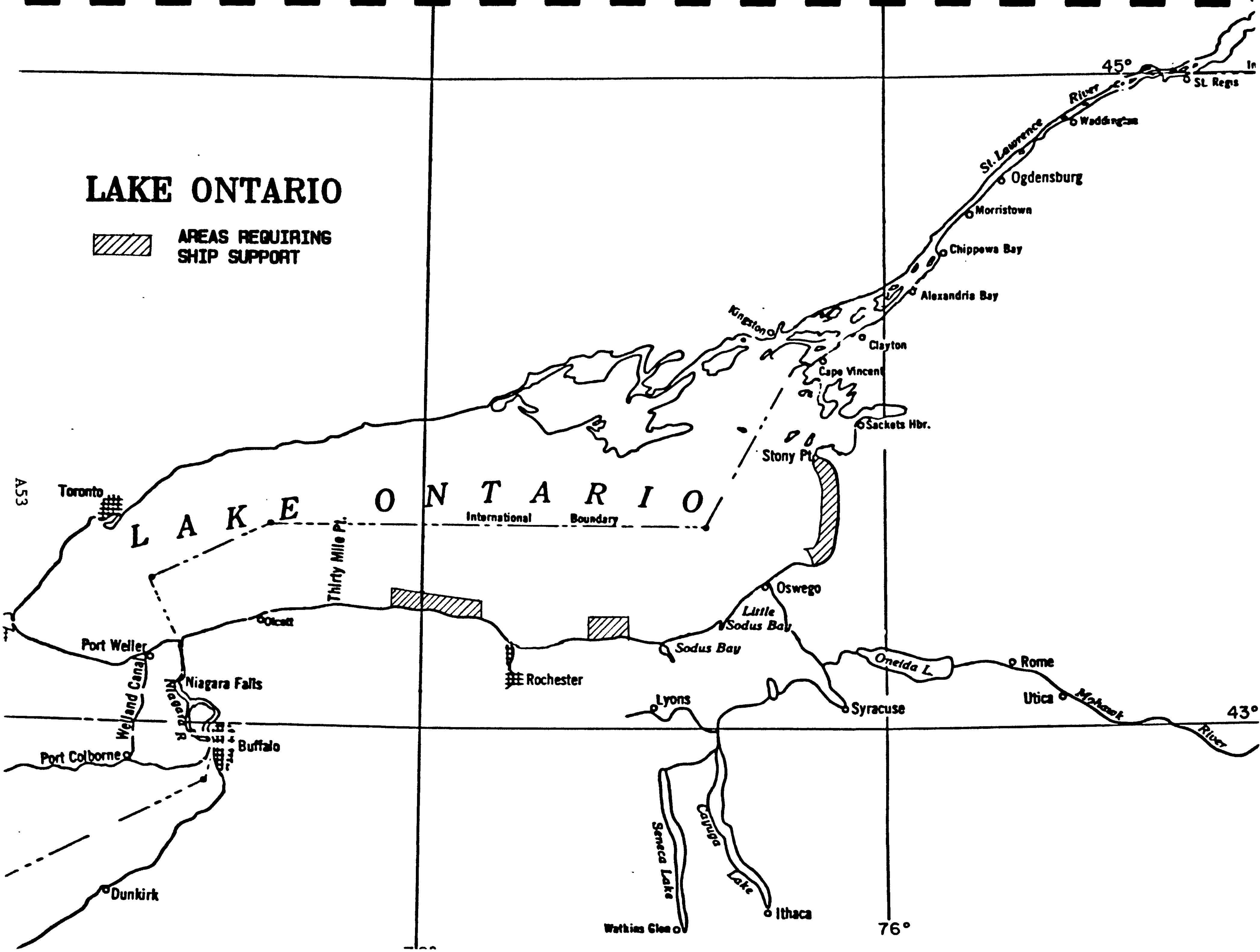
APPENDIX 9

AREAS REQUIRING SHIP SUPPORT


LAKE MICHIGAN
AREAS REQUIRING SHIP SUPPORT
LAKE MICHIGAN
GREEN BAY
STRAITS OF MACKINAC
Port Inland
Manistique
Gladstone
Escanaba
Mackinaw City
Cheboygan
Beaver I.
Fox Islands
Washington I.
Little Traverse Bay
Charlevoix
Petoskey
N. Manitou I.
S. Manitou I.
Leland
Grand Traverse Bay
Traverse City
Menominee
Marinette
Oconto
Sturgeon Bay
Frankfort
Algoma
Green Bay
De Pere
Kewaunee
Portage Lake
Fox River
Lake Winnebago
Manistee
Two Rivers
Manitowoc
Ludington
Pentwater
Sheboygan
White Lake
Port Washington
Muskegon
Grand Haven
Milwaukee
Holland
Racine
Saugatuck
Kenosha
South Haven
Waukegan
Benton Harbor
St. Joseph
Chicago
Calumet
Indiana Hbr
Michigan City
Lockport
Buffington Hbr.
Gary
45°
43
ILLINO
INDIANA


LAKE HURON
AREAS REQUIRING SHIP SUPPORT
Whitefish Bay
Sault Ste. Marie
St Marys River
St. Joseph I.
NORTH CHANNEL
Drummond I.
Cockburn I.
Manitoulin Island
Duck Islands
St. Ignace
Les Cheneaux Is.
STRAITS OF MACKINAC
DETOUR PASSAGE
Mackinaw City
Beaver I.
Cheboygan
Burt L.
Mullett L.
Forty Mile Pt.
Rogers City
Calcite
Presque Isle
Little Traverse Bay
Petoskey
Charlevoix
Rockport
Alpena
45°
Thunder Bay
L A K E
H U R O N
Sturgeon Pt.
Oscoda
Tawas
SAGINAW BAY
Pt. aux Barques
Harbor Beach
International Boundary
Port Albert
Goderich
Bay City
Saginaw
43°
Port Huron
Sarnia


LAKE ERIE
AREAS REQUIRING SHIP SUPPORT
LAKE ERIE
International Boundary
Buffalo
Niagara Falls
Niagara R
Welland Canal
Port Weller
Port Colborne
Hamilton
Dunkirk
Erie
Conneaut
Ashtabula
Fairport
Mentor Harbor
Cleveland
Rocky River
Lorain
Vermilion
Huron
Sandusky
Port Clinton
Toledo
Monroe
Detroit
Detroit River
Kingsville
Lake St Clair
St. Clair River
Marine City
St. Clair
Port Huron
Sarnia
43°
41°
80°


LAKE ONTARIO
AREAS REQUIRING
SHIP SUPPORT
45°
43°
76°
St. Regis
Waddington
St. Lawrence River
Ogdensburg
Morristown
Chippewa Bay
Alexandria Bay
Kingston
Clayton
Cape Vincent
Sackets Hbr.
Stony Pt.
LAKE ONTARIO
International Boundary
Toronto
Thirty Mile Pt.
Oswego
Little Sodus Bay
Sodus Bay
Oneida L.
Rome
Utica
Mohawk River
Syracuse
Lyons
Rochester
Olcott
Port Weller
Welland Canal
Niagara Falls
Niagara R.
Buffalo
Port Colborne
Dunkirk
Seneca Lake
Cayuga Lake
Ithaca
Watkins Glen

LAKE SUPERIOR