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Great Lakes Ice Cover, Winter 1973-74

R. A. ASSEL

BOULDER, COLO.
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CONTENTS

FIGURES

TABLES

GREAT LAKES ICE COVER, WINTER 1973-74

R. A. Assel

ABSTRACT

Twenty composite ice charts were produced from ice-cover data received at the Lake Survey Center[1] during the past winter. These charts illustrate estimated ice concentrations and distributions on the Great Lakes at weekly intervals from mid-December 1973 to the end of April 1974. In addition, 13 ice charts compiled from data collected by Lake Survey Center ice observers portray synoptic ice conditions on individual lakes and rivers.

Freezing degree-day accumulations indicate the 1973-74 winter was near normal over the Great Lakes. Accumulations were near their seasonal maximum the end of February on southern portions of the Great Lakes and the end of March on northern portions.

Extensive ice formation in protected shore areas and shallow parts of the Great Lakes was initiated by below normal temperatures the second half of December and first half of January. Above normal temperatures the second half of January retarded ice formation and caused significant loss of ice in some areas. Ice covers reached their maximum extent in February and were estimated to extend over 70 percent of Lake Superior, 20 percent of Lake Michigan, 65 percent of Lake Huron, 95 percent of Lake Erie, and 25 percent of Lake Ontario. Mild temperatures in early March resulted in rapid loss of ice on southern portions of the Great Lakes so that, by mid-March, they were virtually ice free. By mid-April, the bulk of the ice cover was gone on the northern portions of the Great Lakes as well. The only areas with extensive ice in mid-April were the west end of Lake Superior, various Lake Superior bays, and the North Channel in Lake Huron. Last reports of ice were made in late April.

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[1]In April 1974, the Limnology Division, Lake Survey Center, National Ocean Survey, was transferred to the Great Lakes Environmental Research Laboratory of the Environmental Research Laboratories. Several references to the Lake Survey Center appear since the work was being conducted under that organization at the time.

1. INTRODUCTION

The Great Lakes Environmental Research Laboratory has an ongoing project for the investigation of lake ice-cover distribution. Reports describing work carried out under this project for past winters, beginning with the 1962-63 winter season, are available from the Lake Survey Center, Detroit, Mich. In this report, data collected during the 1973-74 winter are described. As in previous reports in this series, this report contains a description of ice-cover formation, growth, and decay based on data collected the past winter. A brief summary of winter temperatures is also included.

2. DATA COLLECTION

Ice charts, satellite imagery, and surface ice reports made up the bulk of the ice-cover information collected. Ice charts were received from the Ice Navigation Center, Cleveland, Ohio, and Ice Forecasting Central, Ottawa, Canada, throughout the winter. Lake Survey Center personnel also produced ice charts from data collected on visual aerial ice reconnaissance flights. The primary information on ice charts is ice concentration, ice distribution, and age and size of ice floes. Surface reports of ice thickness and ice conditions were received from Lake Survey Center and U.S. Coast Guard ice observers. NOAA-2 VHRR satellite imagery was received from the National Environmental Satellite Service in Washington, D.C., from November 1973 through April 1974.

Lake Survey Center personnel completed 12 aerial ice reconnaissance flights between December 17, 1973, and March 21, 1974. Approximately 37 hours and 3660 miles (5860 km) were logged on these flights, the majority of which used chartered Cessna 172 and Cessna 182 aircraft. Three flights were made aboard U.S. Coast Guard aircraft during ice patrol flights. Flight dates and areas covered are given in table 1.

Data collected on aerial ice reconnaissance flights included observations of ice concentrations, ice distributions, ice floe size, ice age, and surface characteristics. This information was plotted on worksheets and redrafted on small-scale ice charts, which were sent to the Ice Navigation Center in Cleveland after each flight. Aerial photography of ice cover was also made on most flights over the St. Marys and St. Clair Rivers in support of the Demonstration Program to extend the navigation season. Four visual aerial ice reconnaissance flights were made to coincide with the time of estimated maximum ice cover on the Great Lakes as part of the ongoing lake ice-cover distribution project.

3. DATA PRESENTATION

3.1 Freezing Degree-Days

As in past winters, freezing degree-day accumulations, based on average weekly temperatures, were maintained for selected National Weather Service meteorological stations on the perimeter of the Great

Table 1. Ice Reconnaissance Flights - Winter 1973-74

Flight No.	Date	Area
1	Dec. 17	St. Marys River
2	Jan. 8	St. Marys River
3	Jan. 17	St. Clair River, Lake St. Clair
4	Jan. 24	St. Marys River
5	Feb. 5	St. Clair River, Lake St. Clair
6	Feb. 15	Lake Ontario
7	Feb. 25 (CG)	Lake Erie
8	Feb. 25	St. Clair River, Lake St. Clair, Southern Lake Huron
9	Feb. 26	St. Marys River
10	Feb. 27 (CG)	Northern Lakes Michigan and Huron
11	Mar. 4 (CG)	Northern Lakes Michigan and Huron, Lake Superior, and St. Marys River
12	Mar. 21	St. Marys River

(CG) = Coast Guard Flight Support

Lakes: Duluth, Minn.; Sault Ste. Marie, Mich.; Alpena, Mich.; Green Bay, Wis.; Milwaukee, Wis.; Detroit, Mich.; Cleveland, Ohio; and Rochester, N. Y. Freezing degree-days measure the cumulative temperature departure from 32° F (0° C). One freezing degree-day is accumulated when the mean daily temperature is 31° F. The mean daily temperature is defined as the mean of the daily maximum and minimum temperatures. Thus, for a mean daily temperature of 25° F, 7 freezing degree-days are accumulated. Graphs of freezing degree-days are given for each of the Great Lakes (fig. A.1 through A.5). The graphs show 1973-74 accumulations and a 10-year mean.

3.2 Composite Ice Charts

Twenty composite ice charts (fig. A.6 through A.25) illustrate the seasonal pattern of ice formation, growth, and decay on the Great Lakes from December 16, 1973, to April 28, 1974. These charts portray estimated ice conditions at weekly intervals, based on a subjective evaluation of available ice-cover information. Ice charts compiled by the Lake Survey Center, U.S. Coast Guard Ice Navigation Center, and Canadian Ice Forecasting Central provide the bulk of the ice-cover information used to compile composite charts. NOAA-2 VHRR satellite imagery was used to supplement these data.

Freezing degree-day accumulations at the eight locations noted earlier also are given on the composite ice charts. Weekly, seasonal, and normal seasonal accumulations are given to indicate the severity of each week and the relative severity of the seasonal accumulations.

3.3 Ice Charts

Thirteen ice charts, figures A.26 through A.38, compiled by the Lake Survey Center, illustrate synoptic ice conditions and provide greater detail than composite ice charts. Table 2 is a key to symbols and abbreviations used on these charts. Data for eight of the ice charts were collected on flights near the time when it was estimated the lakes would have their greatest ice cover. The remaining five ice charts were made during flights over the St. Clair and St. Marys Rivers in connection with the Lake Survey Center's participation in the Great Lakes-St. Lawrence Seaway Navigation Season Extension Demonstration Program.

4. DISCUSSION

4.1 Winter Characteristics

Two values of freezing degree-day accumulation can be used to characterize a winter season: (1) maximum accumulation and (2) date of maximum accumulation. The first value gives a measure of winter severity; and the second value, that is, the date, marks an inflection

Table 2. Key to Ice Chart Symbols

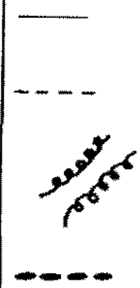
TOTAL CONCENTRATION

- OPEN WATER
- 1-3 TENTHS COVERAGE (VERY OPEN PACK)
- 4-6 TENTHS COVERAGE (OPEN PACK)
- 7-9 TENTHS COVERAGE (CLOSE PACK)
- 10 TENTHS COVERAGE (CONSOL PACK)

OPENINGS IN ICE

- CRACK OR BROKEN TRACK
- LEAD
- POOL OR POLYNYA (PLYA)
- RELATIVE MOVEMENT BETWEEN TWO FLOES

BOUNDARY



- OBSERVED VISUALLY
- ASSUMED
- UNDERCAST (LIMITS)
- LIMIT OF OBSERVED DATA

AGE AND SIZE OF FLOES
Station Model

$\frac{A}{\text{ACTUAL AGE}}$ $\frac{C_n}{(n_1)(n_2)(n_3)}$

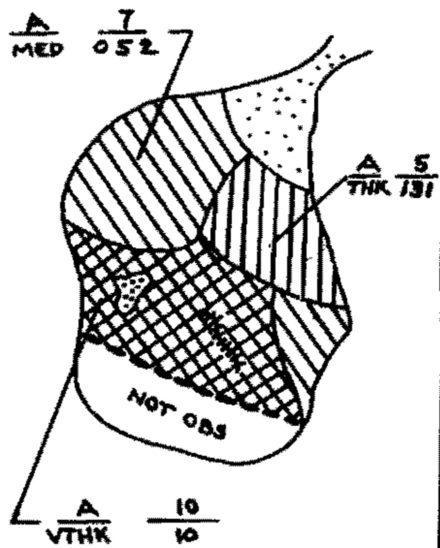
A -IND FOR ACTUAL AGE

ACTUAL AGE

SS -NEW ICE 2" or less
THIN -THIN ICE 2-6"
MED -MEDIUM ICE 6-12"
THK -THICK ICE 12-30"
VTHK -VERY THICK 30" or >

C_n - Total CONC of n_1n_2 and n_3 in 10ths
n_1 - CONC of brash and cakes in 10ths
n_2 - CONC of small and medium floes in 10ths
n_3 - CONC of big floes and ice fields in 10ths

EXAMPLE



SNOW COVER
Station Model

$\frac{S_n}{(n)}$

S_n - IND for Snow
(n) - Tenths on Ice

STAGE OF MELTING
Station Model

$\frac{Pd}{(n)+(n)TH+(n)F}$

Pd - IND for Melting
(n) - Tenths on Ice
(n)TH - Tenths Thaw Holes
(n)F - Tenths Frozen

TOPOGRAPHY

- RAFTED
- RIDGED
- HUMMOCKED

(n) - NUMBER OF TENTHS

ABBREVIATIONS

BSH = Brash
CK = Cake
NOT OBS = Not Observed
SLG = Sludge
RFZN = Refrozen

point separating a period of generally increasing ice formation potential from a period of decreasing ice formation potential. Using Rondy's[2] classification of winter severity, which is based on maximum freezing degree-day accumulations, the 1973-74 winter was in general normal. Dates of maximum freezing degree-day accumulation occurred in late March and early April on the northern half of the Great Lakes and in late February on southern portions, with accumulations at Cleveland occurring in mid-January to provide an exception to this trend. Average dates of maximum freezing degree-day accumulation given in the Great Lakes Ice Atlas indicate that the 1973-74 maximum accumulations were nearly normal on northern portions of the Great Lakes, that is, at Duluth, Sault Ste. Marie, Alpena, and Green Bay, while maximum accumulations were 2 to 4 weeks earlier than normal on the southern half of the Great Lakes, that is, at Milwaukee, Detroit, Cleveland, and Rochester.

4.2 General Seasonal Trends in Ice-Cover Distribution

Ice covers were in general confined to bays, harbors, and shallow protected areas of the Great Lakes through late January (fig. A.6 through A.12). In February (fig. A.13 through A.16), ice formed over deeper waters of the lakes and attained its greatest coverage. Mild spring-like weather the first half of March resulted in loss of ice cover so that by mid-month the southern half of the Great Lakes was virtually ice free (fig. A.17 through A.19). A cold period the last 2 weeks of March accounted for some new ice formation, especially on northern lakes (and Lake Superior in particular), as shown in figures A.20 and A.21. Ice covers were well into the decay period by mid-April (fig. A.22 and A.23), and by the end of April, the only ice of any significant coverage was located in the west end of Lake Superior, in the three large bays along the north shore of that lake, and in the North Channel of northern Lake Huron (fig. A.24 and A.25).

4.3 Lake Superior

Lake Survey Center ice observers made one flight over Lake Superior on March 4 and produced two ice charts from that flight, figures A.26 and A.27. The ice cycle of Lake Superior, based on available data, is described below.

Bays and harbors began to freeze over during the second week in December. By January 20, the southwest end of the lake from Duluth to Ashland and eastward to east of Ontonagon had extensive shore ice.

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[2]Rondy, D.R. (1971), Great Lakes Ice Atlas, NOAA Technical Memorandum NOS LSCR 1, Lake Survey Center, Detroit, Mich.

The three bays along the north shore were frozen, with the ice extending from the mainland to Isle Royale. Whitefish Bay at the east end of the lake was frozen over. Above normal temperatures the second half of January slowed the rate of ice formation and caused the loss of some ice cover. More seasonable temperatures through the first 3 weeks of February resulted in extensive ice formation over the lake. By the week ending February 17, freezing degree-day accumulations were within 75 percent of their seasonal maximum values, and the lake was estimated to be 70-percent ice cover and near its maximum ice cover for the 1973-74 season.

The following ice conditions were observed on an ice reconnaissance flight over Lake Superior on March 4. Whitefish Bay was completely frozen over, and the south end of the bay had only a little snow on the ice (see fig. A.27). The lake beyond the bay (fig. A.26) was ice free with the exception of scattered brash ice. Belts of brash, covering 10 to 20 percent of the area, were observed along the east shore. An open water area extending from Whitefish Point to Munising gradually became larger going west. Shore ice was located south of the open water and brash ice of various concentrations north of it, while the central part of the eastern half of the lake was virtually ice free. Going west, brash ice was once more observed approximately west of a line from Houghton to Marathon. A large pool of open water paralleled the south shore of Isle Royale and extended eastward from it, but ice covered 90 to 100 percent of the observed area west of Isle Royale; however, observation of the western half of the lake was severely limited by snow flurries. Rafting and ridging were evident in portions of the western lake ice cover and cracks and leads, predominately north-south oriented, were observed throughout that area. New ice was forming on the open water area.

A NOAA-2 satellite image taken February 20 illustrates the general distribution pattern of ice cover on Lake Superior near the time of estimated maximum ice cover (fig. A.39).

Mild spring-like weather the first part of March greatly reduced ice cover on the lake, as shown in figures A.18 and A.19. By March 17, the eastern half of the lake had only shore ice remaining and the western half had large areas of open water. Low temperatures the last half of March brought extensive new ice formation so that the lake was once more near maximum ice cover during the second half of March. Mild temperatures in April brought an end to significant ice formation. By mid-April, the lake was well into the decay period (fig. A.23). Bays and harbors were losing ice covers in the third and last week of April. By the end of the first week in May, all ice reports indicated that these areas were virtually ice free.

4.4 St. Marys River

Two ice charts were produced from visual aerial ice reconnaissance flights made over the St. Marys River, one on December 17, 1973, and the second on March 4, 1974. The following paragraphs describe the development of ice on the river.

Shore ice was reported forming on the southern end of the river on December 3 and on the northern part of the river above the locks on December 11. On the December 17 flight (fig. A.28), the river from just north of De Tour to Neebish Island and further north along the east side of Sugar Island contained an almost complete ice cover. Numerous cracks, leads, and a brash-filled ship track were observed south of Neebish Island. There were also scattered areas of snow on the ice. Along the west side of Sugar Island up to Sault Ste. Marie, the river contained shore ice and brash. Low concentration of brash was also observed from the mouth of the river to the southern tip of St. Joseph Island.

By the third week in January, the river was completely ice covered, with the exception of a few open water areas in the vicinity of the locks and in the river channel. The last ship passed through the locks at Sault Ste. Marie on February 6, 1974, ending a navigation season that had started on March 28, 1973.

The river remained ice covered through early March with little signs of decay. On March 4, it was observed to be still completely ice covered (fig. A.29), and a refrozen ship track could be seen its entire length. The first ship passed upbound through the locks on April 2, 1974. The ice cover on the northern part of the river started breaking up in early April, partially due to ship traffic and icebreaking activities. By mid-April, the ice cover on the southern half of the river was also showing signs of decay as icebreaking activity and mild weather took their toll. For all practical purposes, the river was ice free by May 1, 1974.

4.5 Lake Michigan

Visual aerial ice reconnaissance flights were made over the northern portions of Lake Michigan on February 27 (fig. A.30) and March 4 (fig. A.31). The general areal pattern of ice cover given below is based primarily on ice charts.

Ice began forming in the Straits of Mackinac and in Green Bay by mid-December, as shown in figure A.6. Much below normal temperatures the first 2 weeks in January, indicated by the upward slope of the freezing degree-days graphs on figure A.2, resulted in extensive ice cover formation in Green Bay, the Straits of Mackinac west to Beaver Island, and in the south end of the lake, as shown in figure A.10. Above normal temperatures the last half of January resulted in loss of ice cover on the southern lake area and little net change in lakeward extent of ice in the northern end of the lake as evidenced by figures

A.11 and A.12. Ice began forming in mid-lake areas of the northern end of the lake in the first half of February, resulting in maximum ice extent with ice covering an estimated 20 percent of the lake's surface (see fig. A.13 through A.15). By February 17, freezing degree-day accumulations for Green Bay and Milwaukee were over 85 percent of their maximum value for 1973-74.

During maximum ice cover, ice extended from the north entrance of Green Bay to Grand Traverse Bay. Green Bay and the Straits of Mackinac to Beaver Island were completely ice covered, while most of the open lake north of a line from Escanaba to Charlevoix was 70- to 90-percent ice covered. In the south end of the lake, shore ice of five- to seven-tenths concentration extended from Milwaukee southward.

On February 27, the following ice conditions were observed on a flight over the north end of the lake. Green Bay and the Straits of Mackinac had a snow-covered ice sheet. West of the solid ice in the Straits, brash ice of various concentrations lined the shore extending to the vicinity of Manistique, Mich. The lake to the east of Beaver Island contained brash of decreasing concentration southward.

Unseasonably mild weather in the first half of March, evidenced by the downward slope of the freezing degree-day graphs for Lake Michigan (fig. A.2), resulted in loss of ice in mid-lake areas at the north end of the lake. On March 17, the bulk of the ice was located in Green Bay and the Straits. Ice in these areas was gradually lost over the next month. By mid-April (fig. A.23), Lake Michigan was essentially ice free

4.6 Lake Huron

Visual aerial ice reconnaissance flights were made over Lake Huron on February 25, 27, and March 4. Observed ice conditions on these dates are portrayed in figures A.32 through A.34.

Bays and harbors had begun to freeze over by the third week of December. By the end of the first week of January, Saginaw Bay was ice covered, and the Straits east to Cheboygan, Mich., were 70- to 90-percent ice covered. Although ice cover continued to increase through the second week in January, mild temperatures retarded ice growth during the second half of January. In February, ice formed over the open areas of Lake Huron, and the lake was estimated to be near maximum ice cover between February 10 and 24. During that period, the lake was estimated to be 65-percent ice covered. On February 24, freezing degree-day accumulations at Alpena were 88 percent of the maximum season value. An intense winter storm moved over the Great Lakes on February 22 and 23, causing significant changes in ice-cover concentration and distribution. On February 27 (fig. A.34), the following ice conditions were observed: the Straits to Cheboygan had snow-covered ice, while a mixture of thin and thick ice covering 70 percent of the lake's surface extended east of Bois Blanc Island over much of the lake north of a line from Alpena to De Tour and along the north shore from De Tour eastward. Brash ice of lesser concentrations was located lakeward of the ice along the north shore. From Alpena southward, ice of six- to eight-tenths concentration was located along the shore beyond an open water area from Alpena to Harrisville. The north end of Saginaw Bay was ten-tenths ice covered and a lead was observed along the northeast shore. Beyond the solid ice in the bay, brash, covering 10 percent of the area, continued eastward many miles into the lake.

Ice cover, in general, decreased in March due to mile temperatures. Freezing degree-days at Alpena (fig. A.3) had a negative slope the week ending March 10, indicating a thaw period. By April 7, the only area with significant ice cover was the northeast part of the lake, including North Channel and Georgian Bay. By the fourth week of April, the ice in these northern areas was deteriorating rapidly.

4.7 St. Clair River and Lake St. Clair

Ice charts were produced for the February 5 and 25 flights over the St. Clair River and Lake St. Clair (fig. A.35 and A.36).

Ice was first reported on the St. Clair River on December 17. Above freezing temperatures during the last week of December, however, made the river virtually ice free by the end of that month. Another period of ice formation started in early January and continued through the second week of that month. A thaw period starting the third week of the month, reminiscent of the January 1973 thaw, resulted in ice-free conditions on the river by late January.

Low temperature returned during the first 2 weeks of February, causing rapid ice formation on both southern Lake Huron and the St. Clair River. An ice bridge was observed at Port Huron on February 5. On that date, the river was estimated to be seven- to nine-tenths ice covered and an ice jam was observed in the vicinity of Algonac. On February 25, the river was 30 to 40 percent covered with newly formed ice between Algonac and Stag Island. The upper river, north of Stag Island, had only shore ice, while southern Lake Huron was estimated to be 90-percent ice covered.

Unusually mild weather in early March brought an end to significant ice cover on the St. Clair River. The river was virtually ice free on March 3, although a cold spell March 24 to 26 brought widespread new ice formation of short duration. The last report of ice on the river was dated March 30.

Ice was first reported on Lake St. Clair on December 16. By January 6, the lake had a complete ice cover. As can be seen from figure A.4, above normal temperatures the last half of January, indicated by the freezing degree-day graphs for Detroit and Cleveland, caused deterioration of the ice cover. By the last week of the month (fig. A.12), Lake St. Clair had less ice than normal.

Ice covered the entire lake in early February; and on a flight on February 5 (fig. A.35) the lake had a medium-thick ice sheet with snow covering 20 to 30 percent of the ice in mid-lake.

The lake retained its complete ice cover until the last week of February (fig. A.36), when mild weather caused deterioration of the ice cover. Mild temperatures dominated the first half of March. The lake was for the most part ice free by March 10, as shown on figure A.18, although some new ice formed during the last half of March (fig. A.20). Last reports of ice came from the north end of the lake on March 25.

4.8 Lake Erie

Lake Survey Center personnel made one flight over Lake Erie in late February (fig. A.37).

The bays and harbors in western Lake Erie began to freeze over in mid-December, as shown on figure A.6, with the last ship passing through the Welland Canal on December 31. The perimeter and western end of the lake were the main areas of ice formation in January. A thaw the second half of that month caused reduction of ice cover so that by January 27 (fig. A.12) the main body of ice was located along the north shore of the western end of the lake. Ice began forming over the entire lake the first week in February, and by February 10 (fig. A.14) the lake was near maximum ice cover. Ice cover neared the maximum extent intermittently during the last 3 weeks of February in response to changing weather conditions. Freezing degree-day accumulation at Cleveland was approximately 80 percent of its maximum value on February 17 (fig. A.4). On February 25, the lake was estimated to be 95-percent ice covered. A zone of thin and new ice was observed along the northern shore on that date. Medium-thick ice with a 30- to 40-percent snow cover was observed lakeward of the thin ice. The rest of the lake's perimeter was observed to have medium-thick ice of nine- to ten-tenths concentration with variable snow cover.

The ice cover decreased in extent in early March, and by mid-month (fig. A 19), there was very little ice left. An area of ice persisted in the eastern end of the lake through the end of March. The Welland Canal opened on March 29, 1974, and the last report of ice came from Buffalo, N. Y., on April 4.

4.9 Lake Ontario

Figure A.38 portrays observed ice conditions on eastern Lake Ontario for February 15 and is based on a Lake Survey Center ice reconnaissance flight made over that area.

Low temperatures the second and third weeks of December brought ice formation to the bays in Lake Ontario with the St. Lawrence Seaway closing on December 20, 1973. The last week in December was mild with temperatures for the week averaging above freezing at Rochester, N. Y., as evidenced by the downward slope of the freezing degree-day graph in figure A.5. December's temperature pattern was repeated in January as the first half of that month had low temperatures followed by milder weather the last half. As a result, the ice cover, which was most prominent in the northeast area of the lake, advanced and retreated in January as shown in figures A.10 and A.11. Low temperatures the second and third weeks of February coincided with the period of maximum ice cover on Lake Ontario. On February 17, freezing degree-day accumulation at Rochester was at 98 percent of its seasonal maximum. Two days earlier, February 15, the lake was estimated to be 25-percent ice covered.

The ice conditions illustrated in figure A.39 were observed on a flight over the lake on February 15. Thin ice of four- to five-tenths concentration was observed from Rochester to Oswego, N. Y., ranging 3 to 8 miles (5 to 13 km) into the lake from shore. A semi-circular shaped zone of complete ice cover paralleled the shore from the southeast end of the lake to the northeast shore. Lakeward, a mixture of thin and medium ice of nine-tenths concentration and a zone of brash ice beyond that extended many miles into the lake. Thick snow-covered ice extended from bays and harbors to the islands in the northeast end of the lake, while a light dusting of snow covered much of the ice surface along the southeast shore.

Much of the ice in the open lake was gone by early March as mild weather, evidenced by the sharp drop in freezing degree-day accumulation in figure A.5, caused deterioration of the existing ice cover. By early March (fig. A.17), the bulk of the open lake ice was gone. Lower temperatures the last half of the month helped preserve existing ice cover. The last report of ice came from Cape Vincent, N. Y., and was dated March 29.

The St. Lawrence Seaway opened on March 26, recording the earliest opening date in its 15-year history.

5. ACKNOWLEDGMENTS

Lake Survey Center visual aerial ice reconnaissance activities were carried out under the general guidance of Dr. L. Bajorunas, Chief of Limnology Division, and Dr. F. H. Quinn, Chief of the Lake Hydrology Group, and were under the supervision of C. Adams of the Lake Hydrology Group. Ice observers included C. Adams, G. Leshkevich, and M. Eisenstat.

Flight support was provided by the U.S. Coast Guard, Ninth District (U.S.C.G. Air Stations, Detroit, Mich., and Traverse City, Mich.).

Climatological data used in this report were taken from the U.S. Department of Commerce publication Weekly Weather and Crop Bulletin.

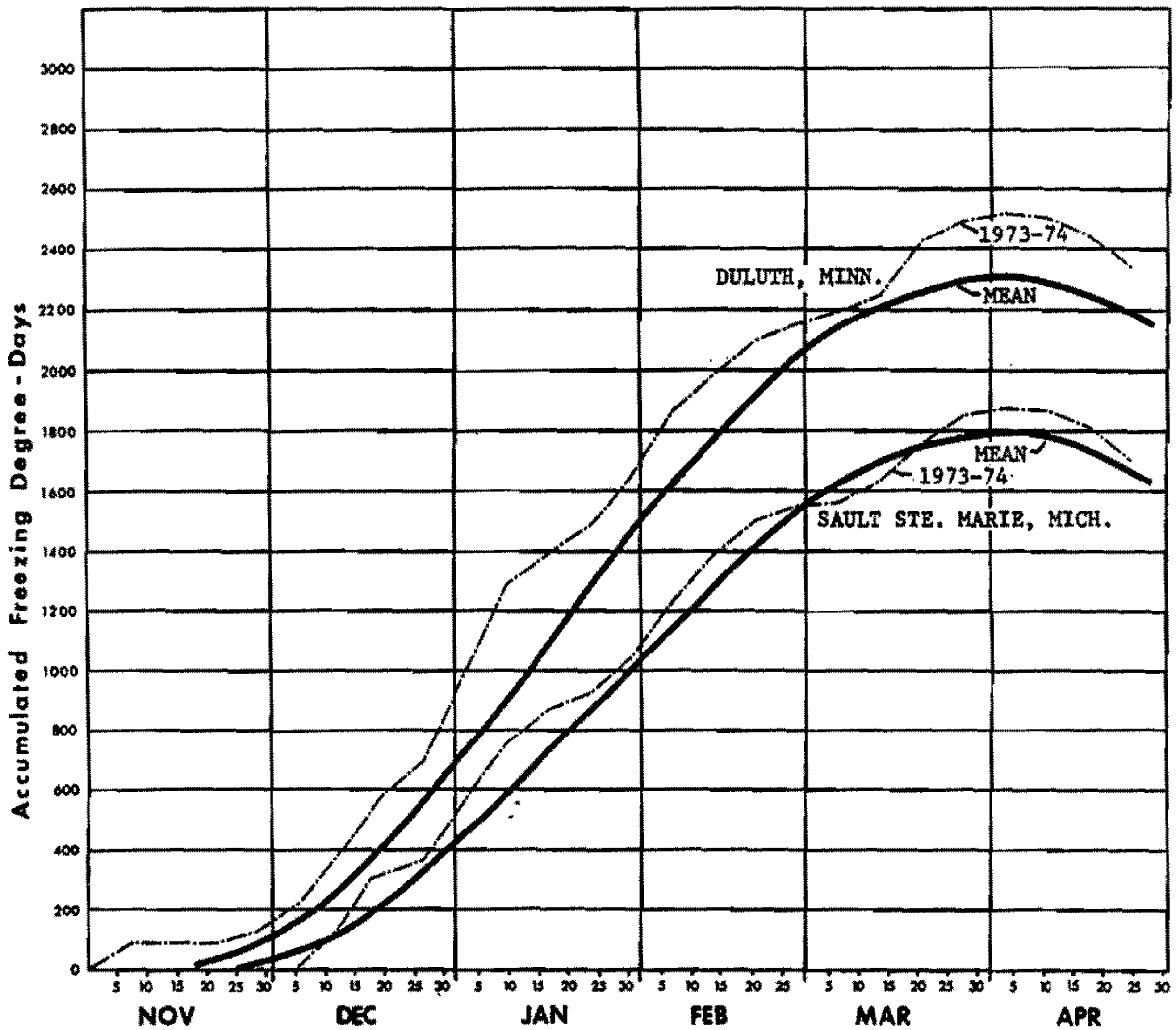


Figure A.1. Accumulated freezing degree-days - Lake Superior at Sault Ste. Marie, Mich., and Duluth, Minn.

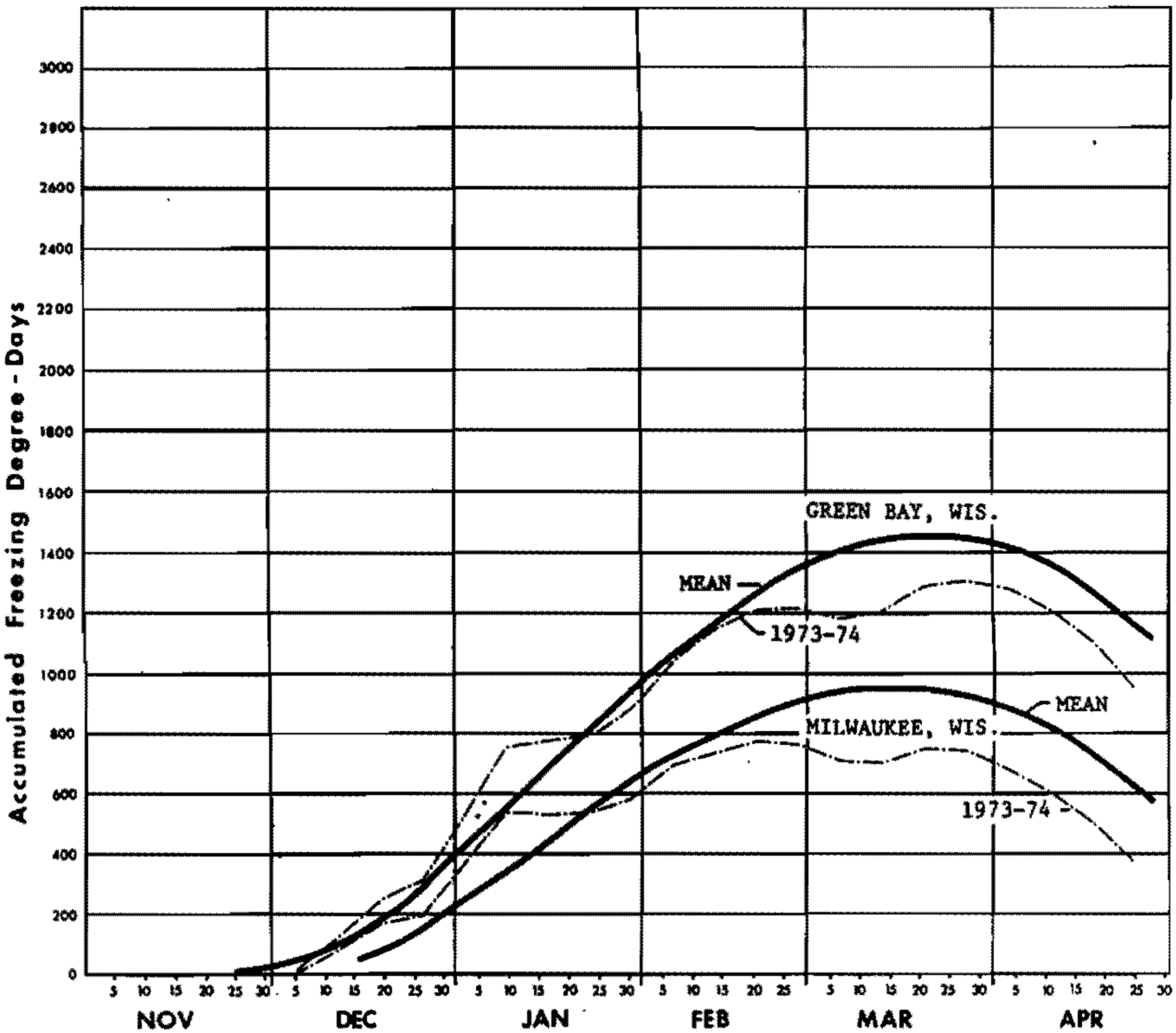


Figure A.2. Accumulated freezing degree-days - Lake Michigan at Green Bay and Milwaukee, Wis.

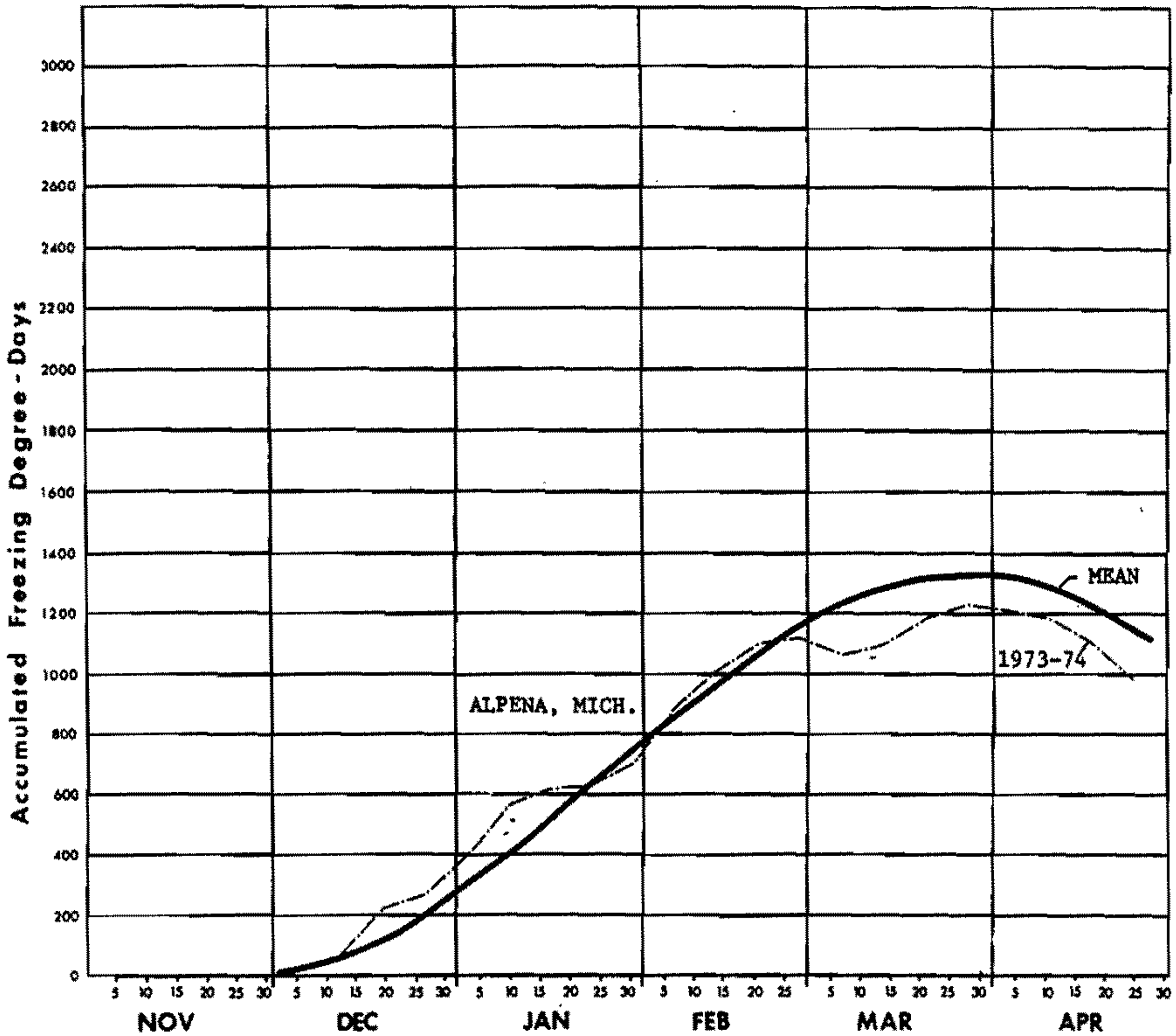


Figure A.3. Accumulated freezing degree-days - Lake Huron at Alpena, Mich.

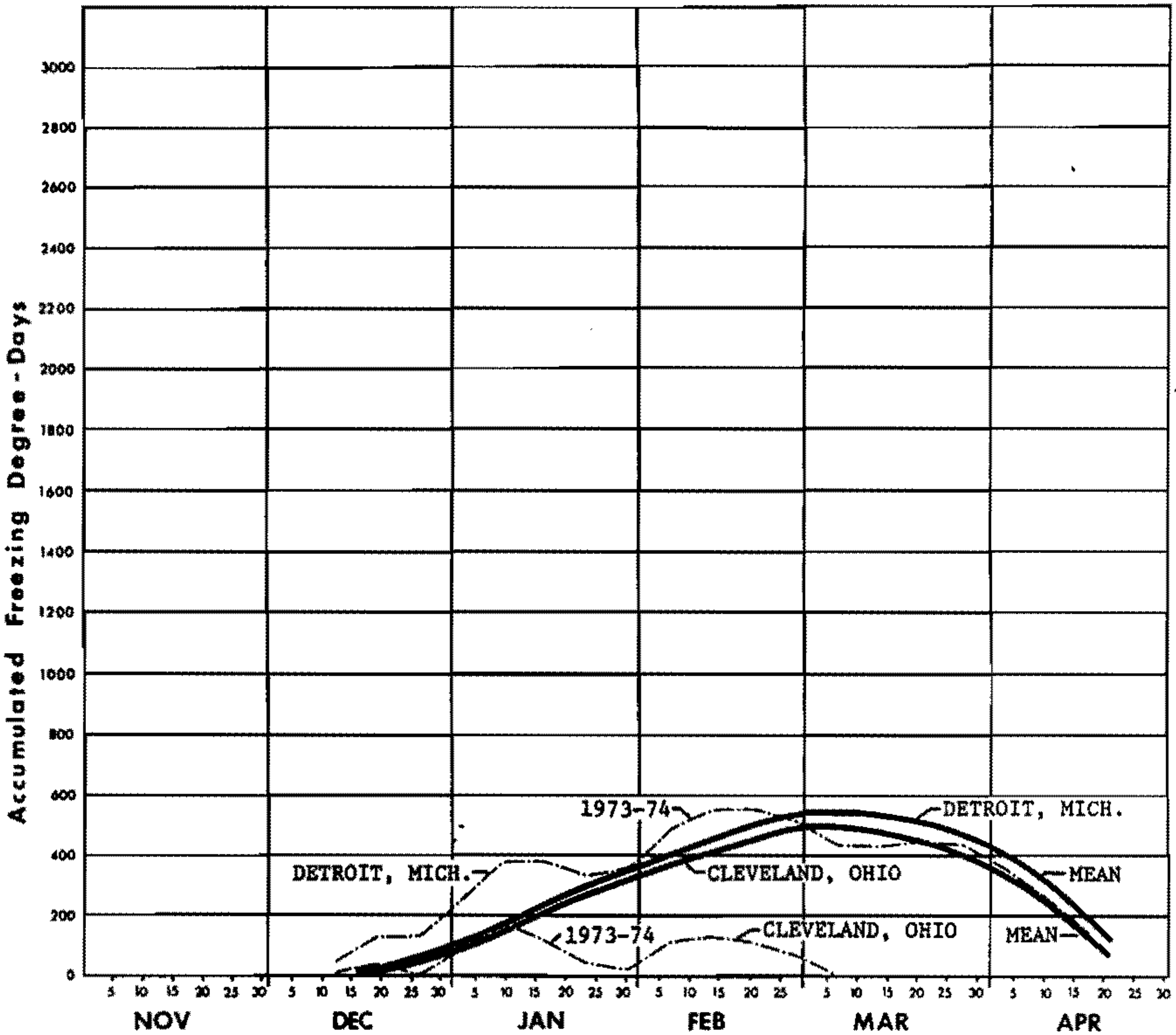


Figure A.4. Accumulated freezing degree-days - Lakes Erie and St. Clair at Cleveland, Ohio, and Detroit, Mich.

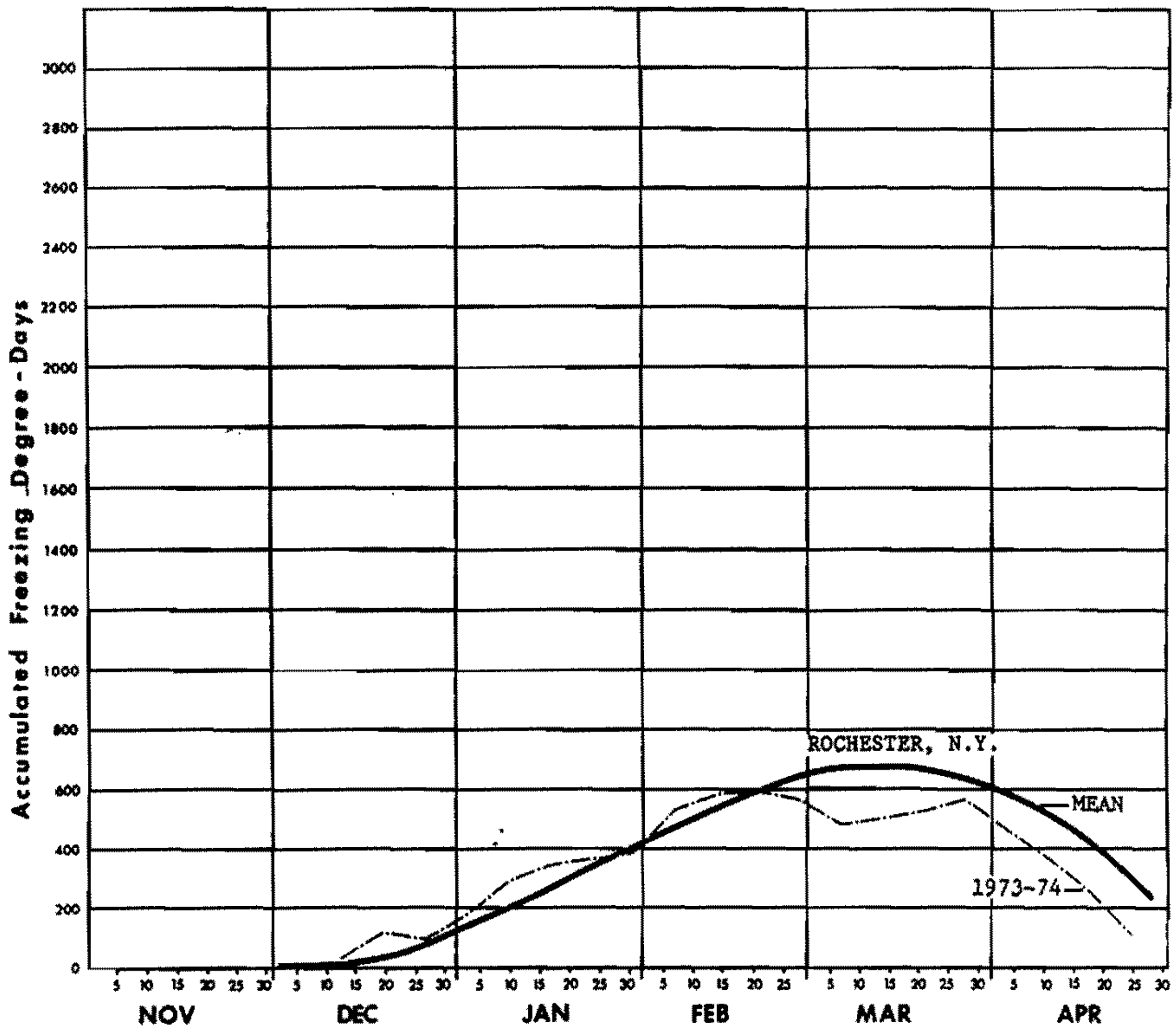


Figure A.5. Accumulated freezing degree-days - Lake Ontario at Rochester, N. Y.

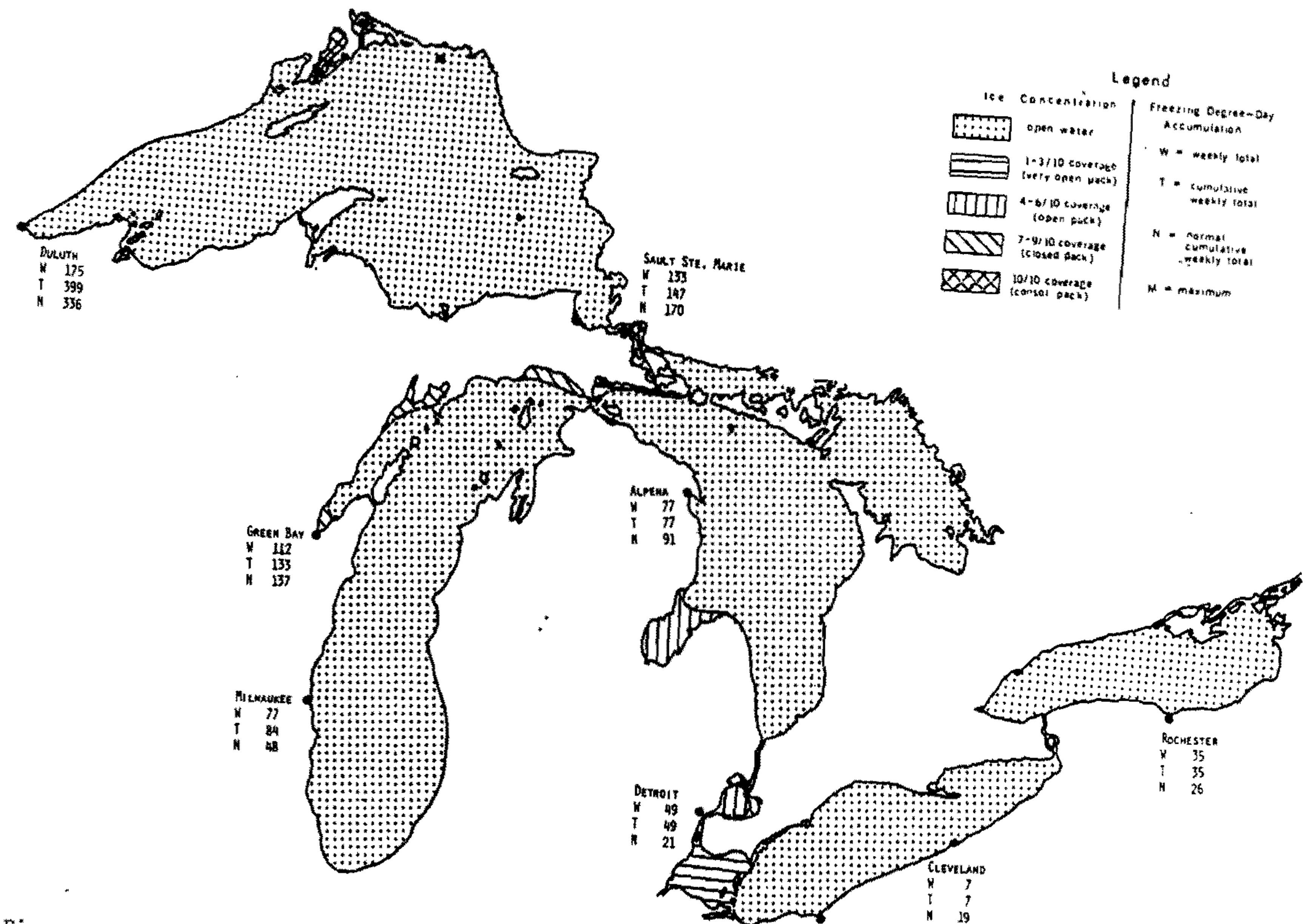


Figure A.6 Composite ice chart - week ending December 16, 1973.

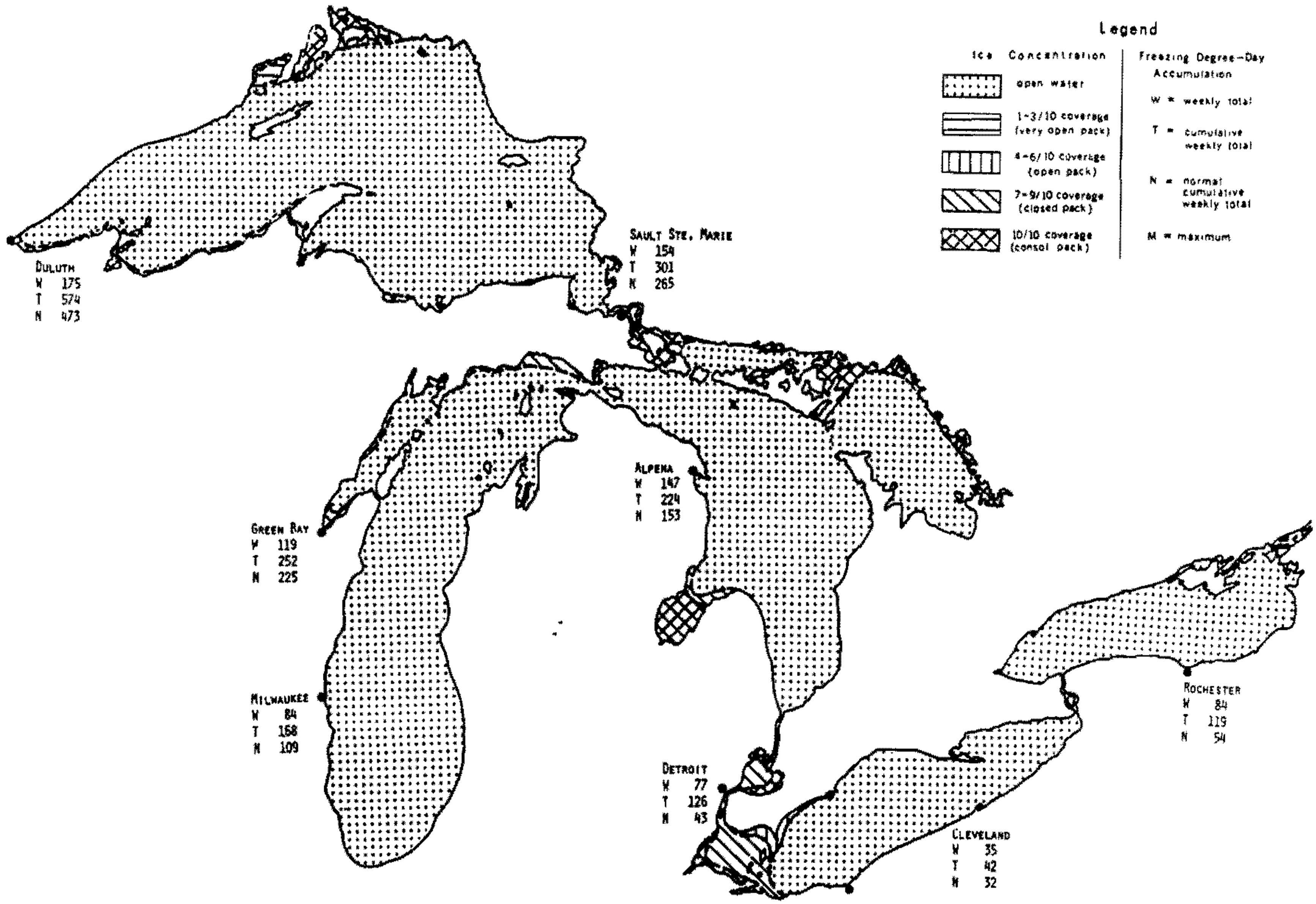


Figure A.7. Composite ice chart - week ending December 23, 1973.

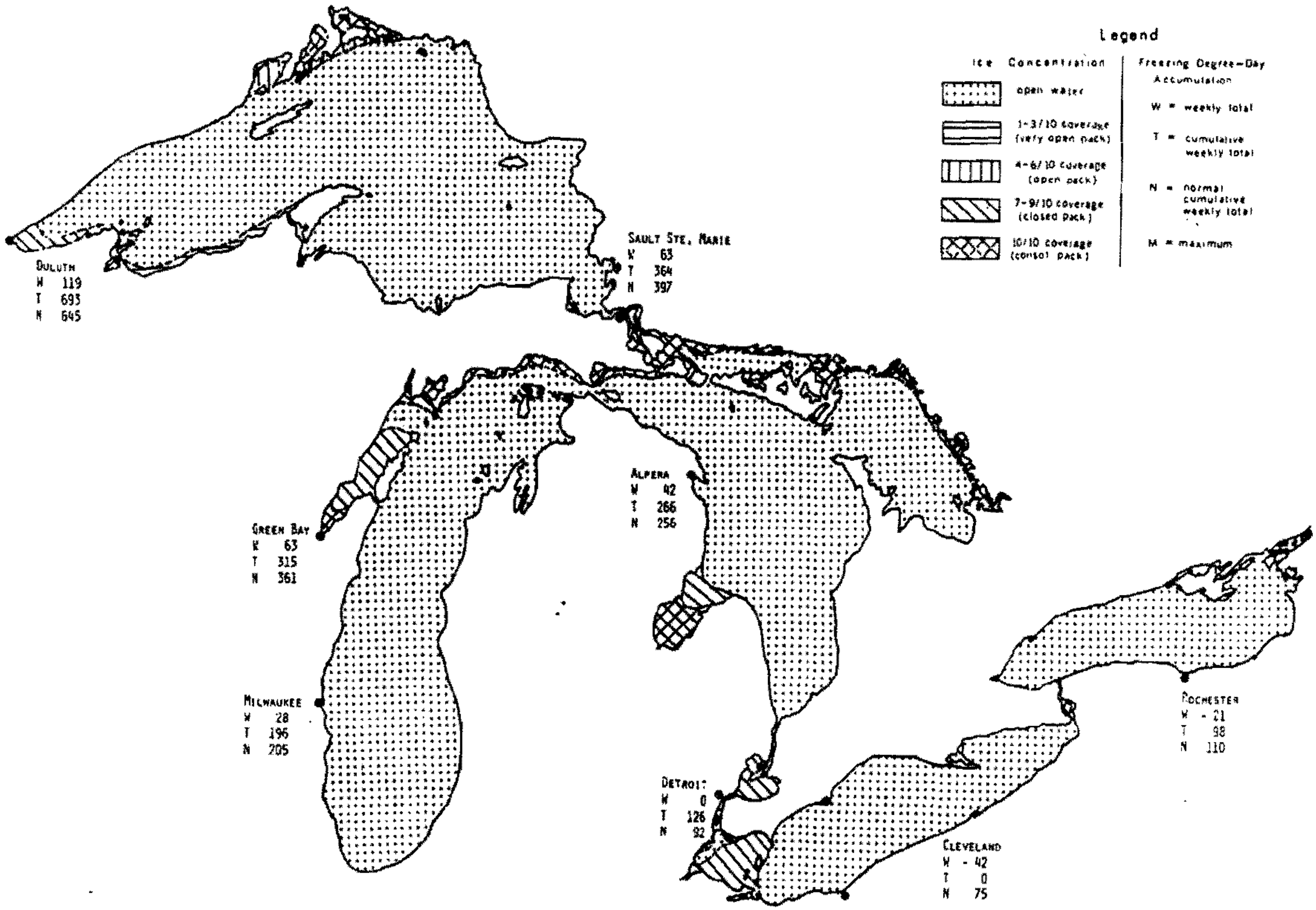


Figure A.8. Composite ice chart - week ending December 30, 1973.

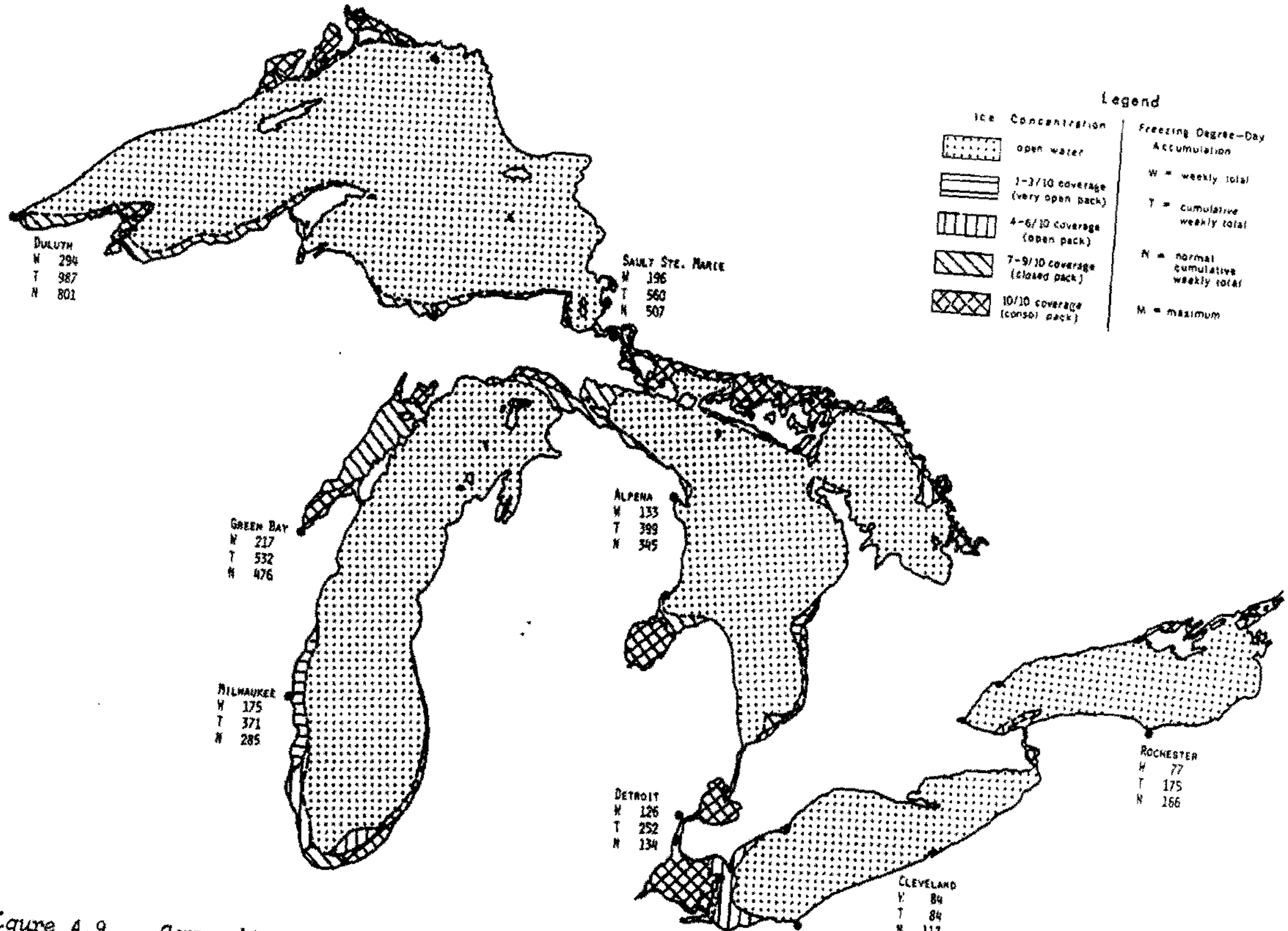


Figure A.9. Composite ice chart - week ending January 6, 1974.

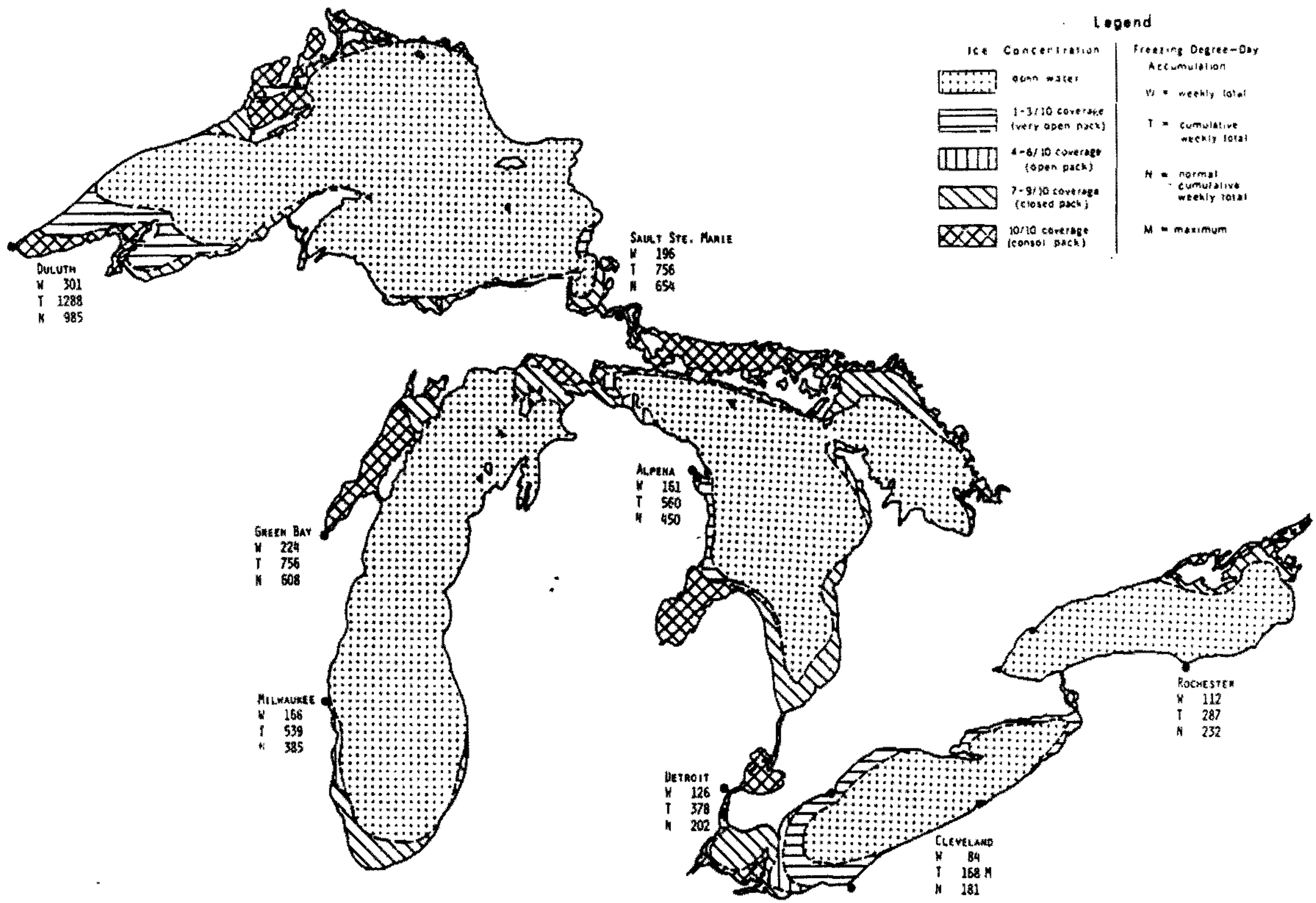


Figure A.10. Composite ice chart - week ending January 13, 1974.

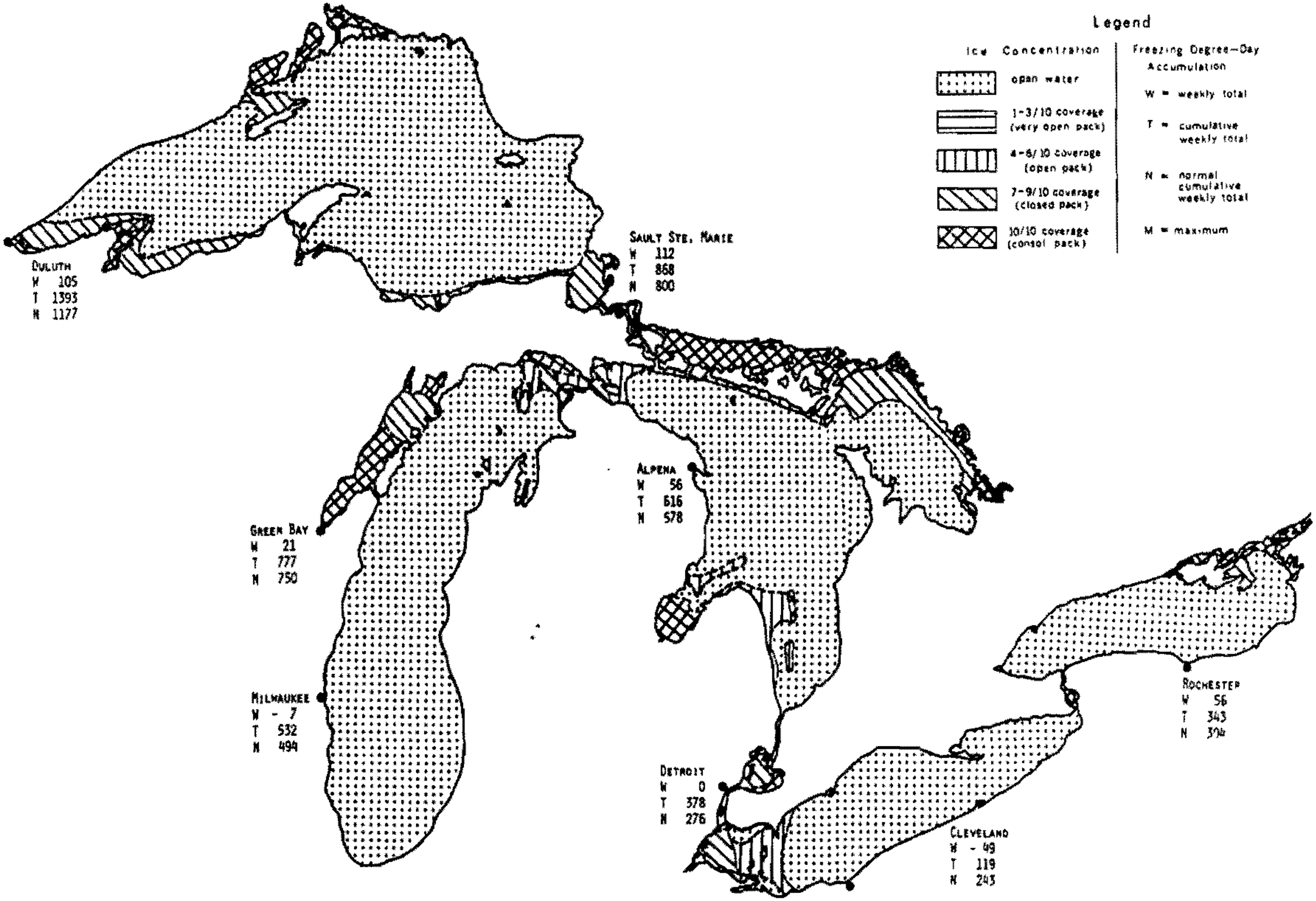


Figure A.11. Composite ice chart - week ending January 20, 1974.

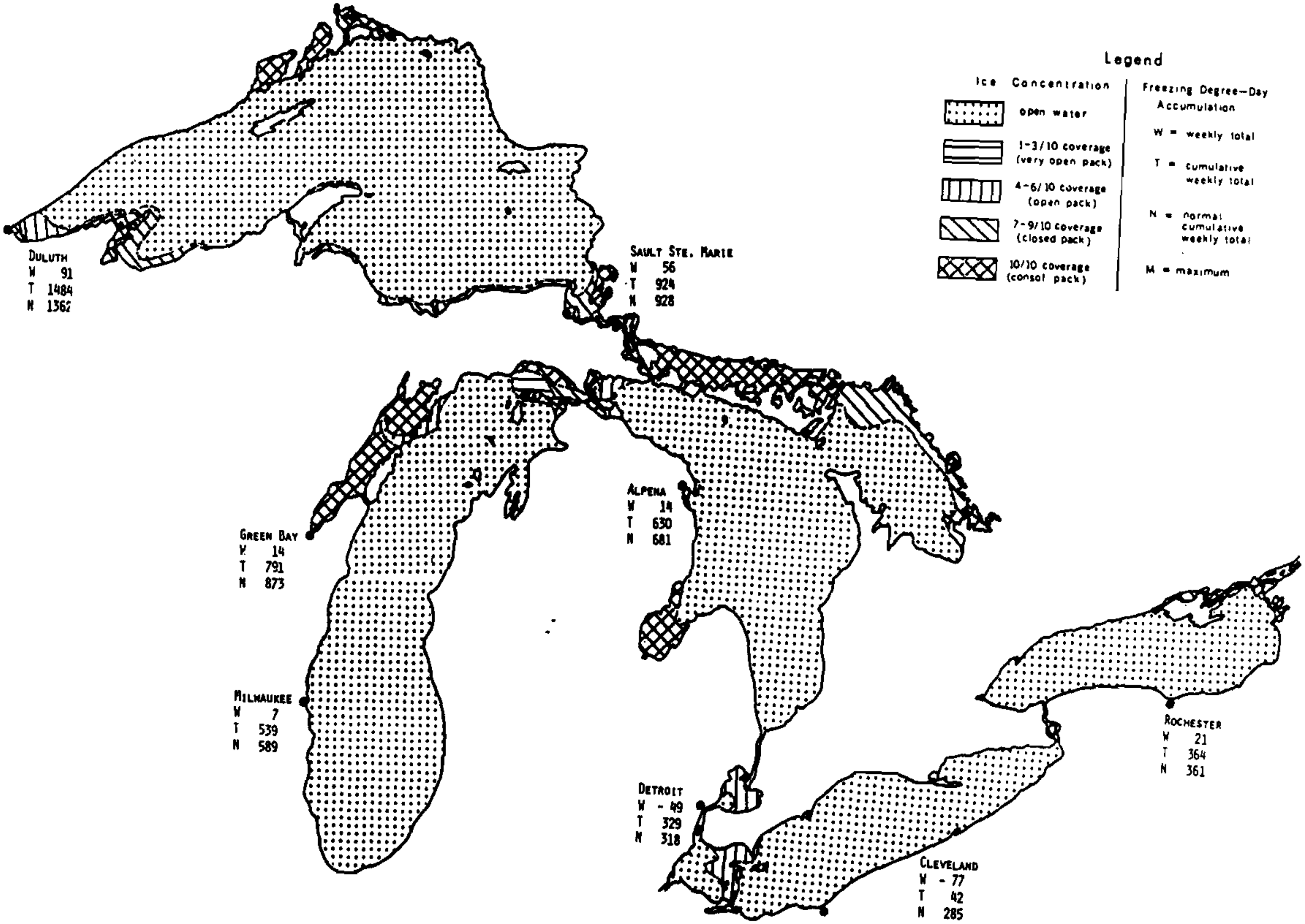


Figure A.12. Composite ice chart - week ending January 27, 1974.

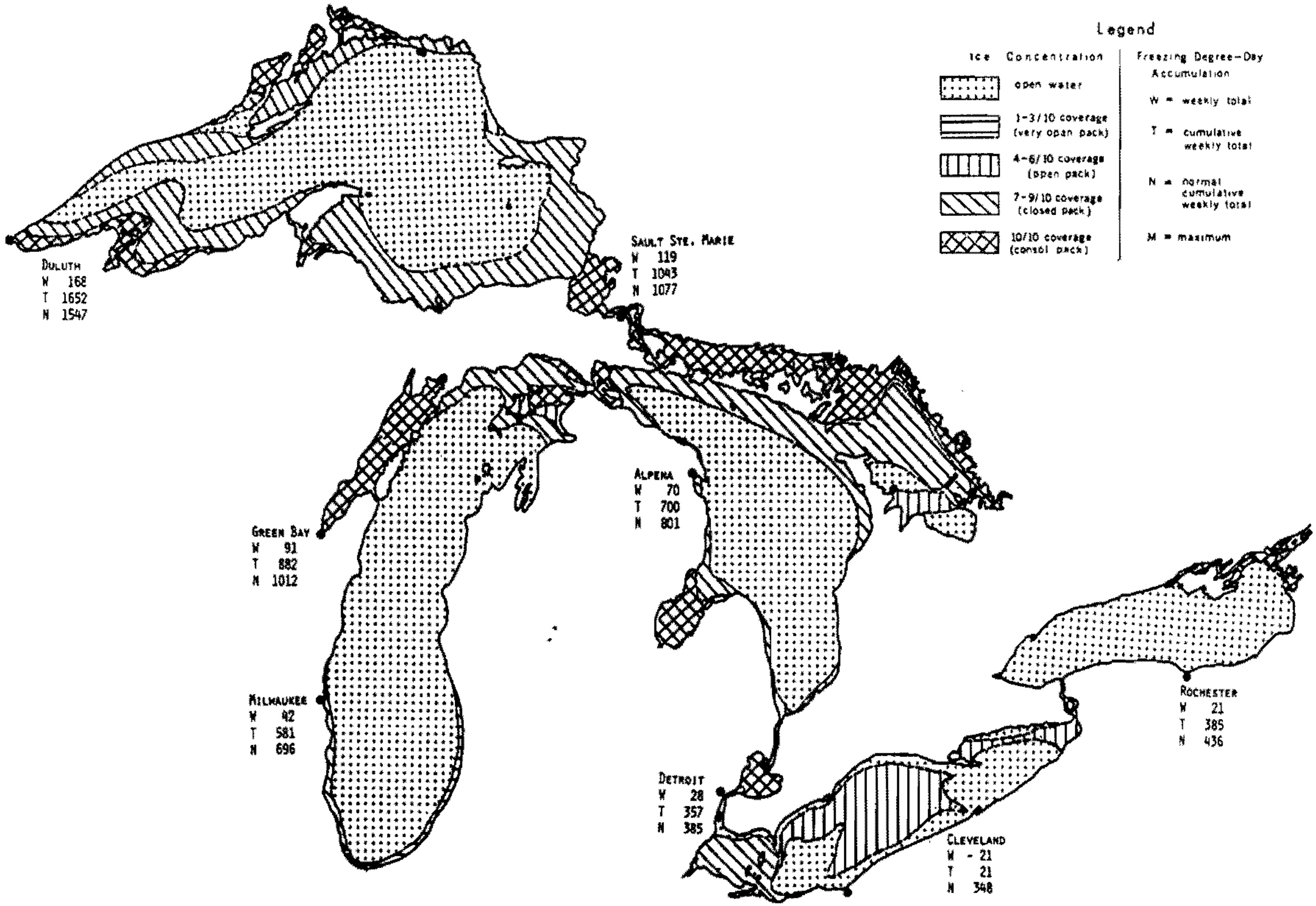


Figure A.13. Composite ice chart - week ending February 3, 1974.

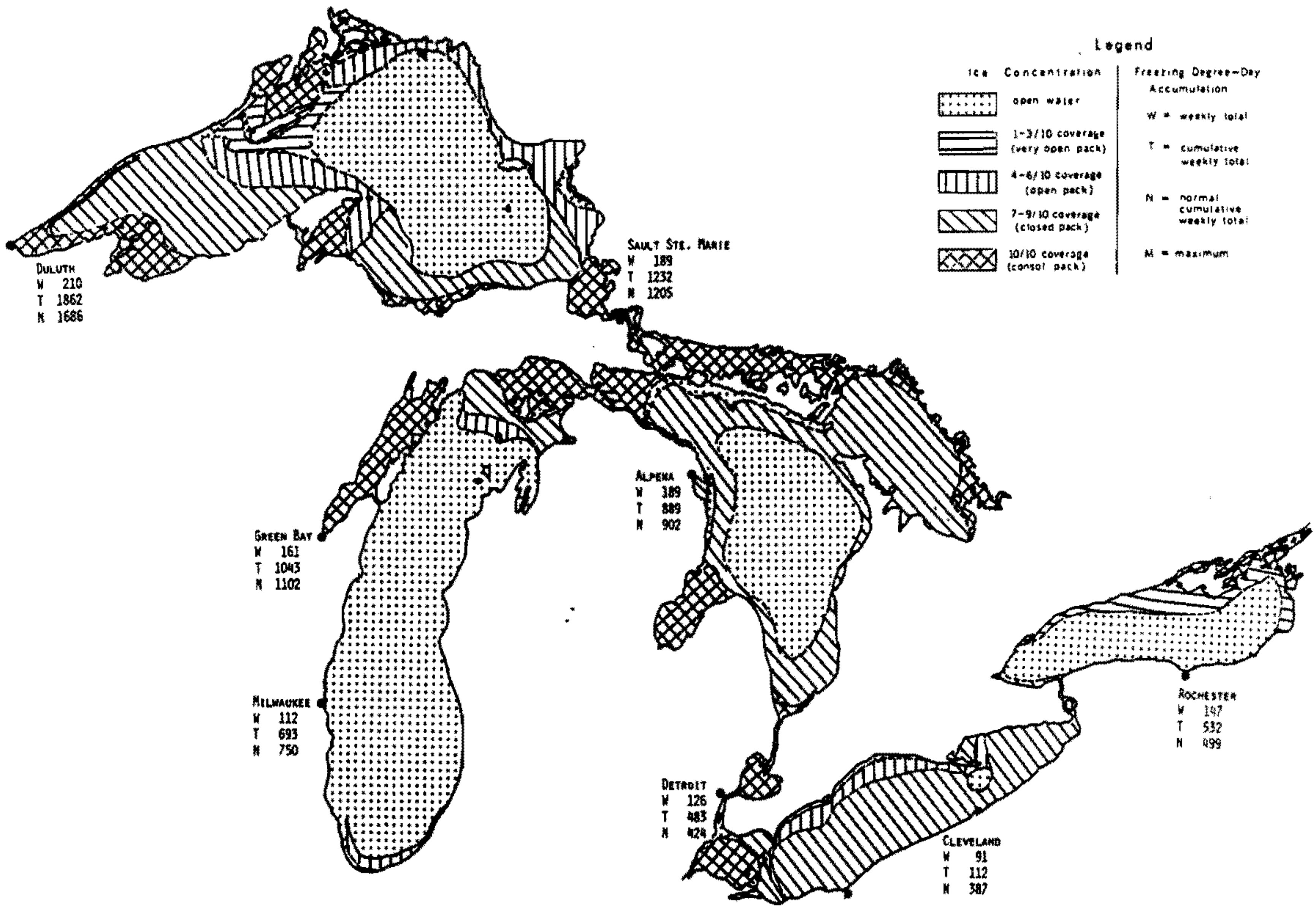


Figure A.14. Composite ice chart - week ending February 10, 1974.

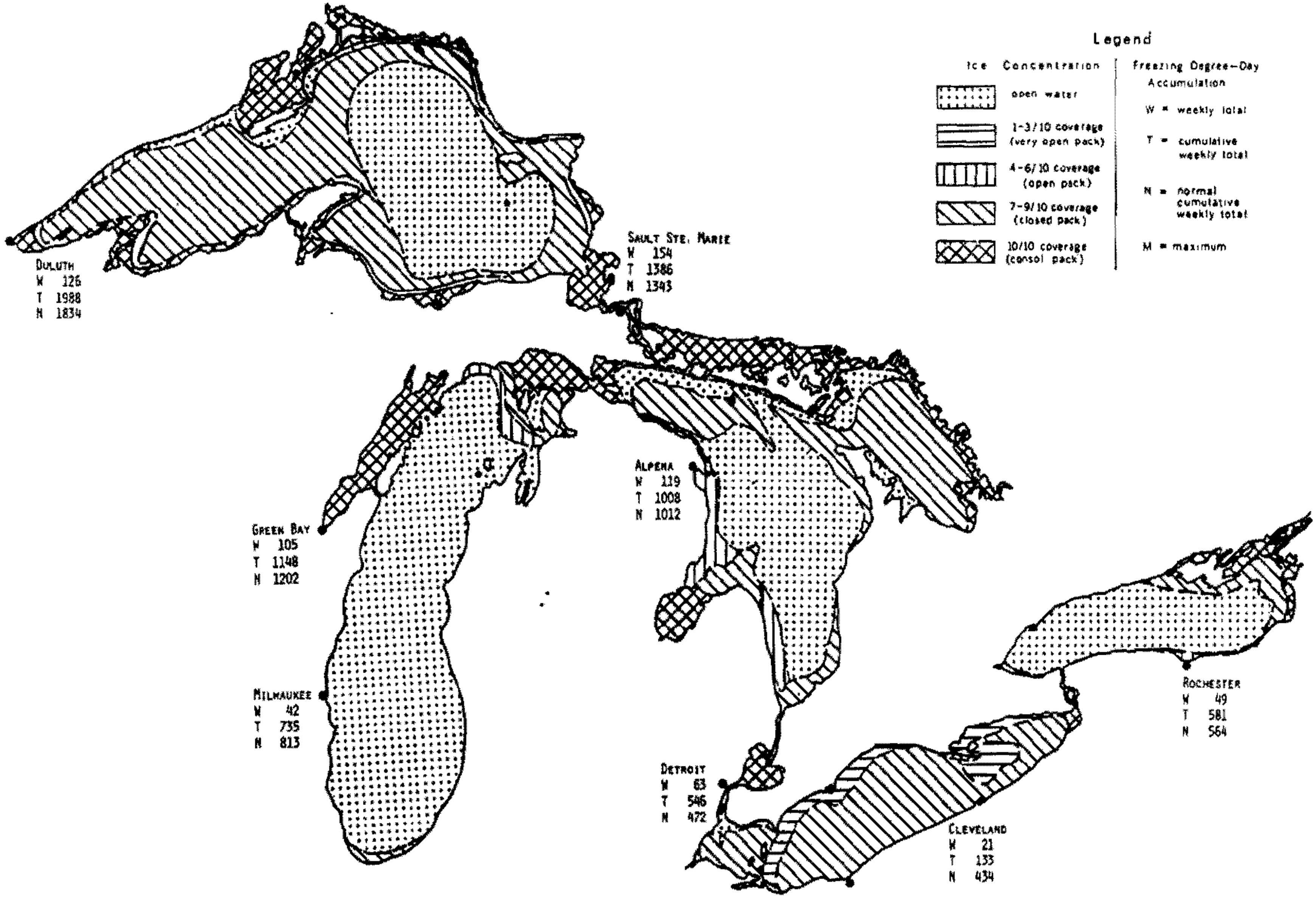


Figure A.15. Composite ice chart - week ending February 17, 1974.

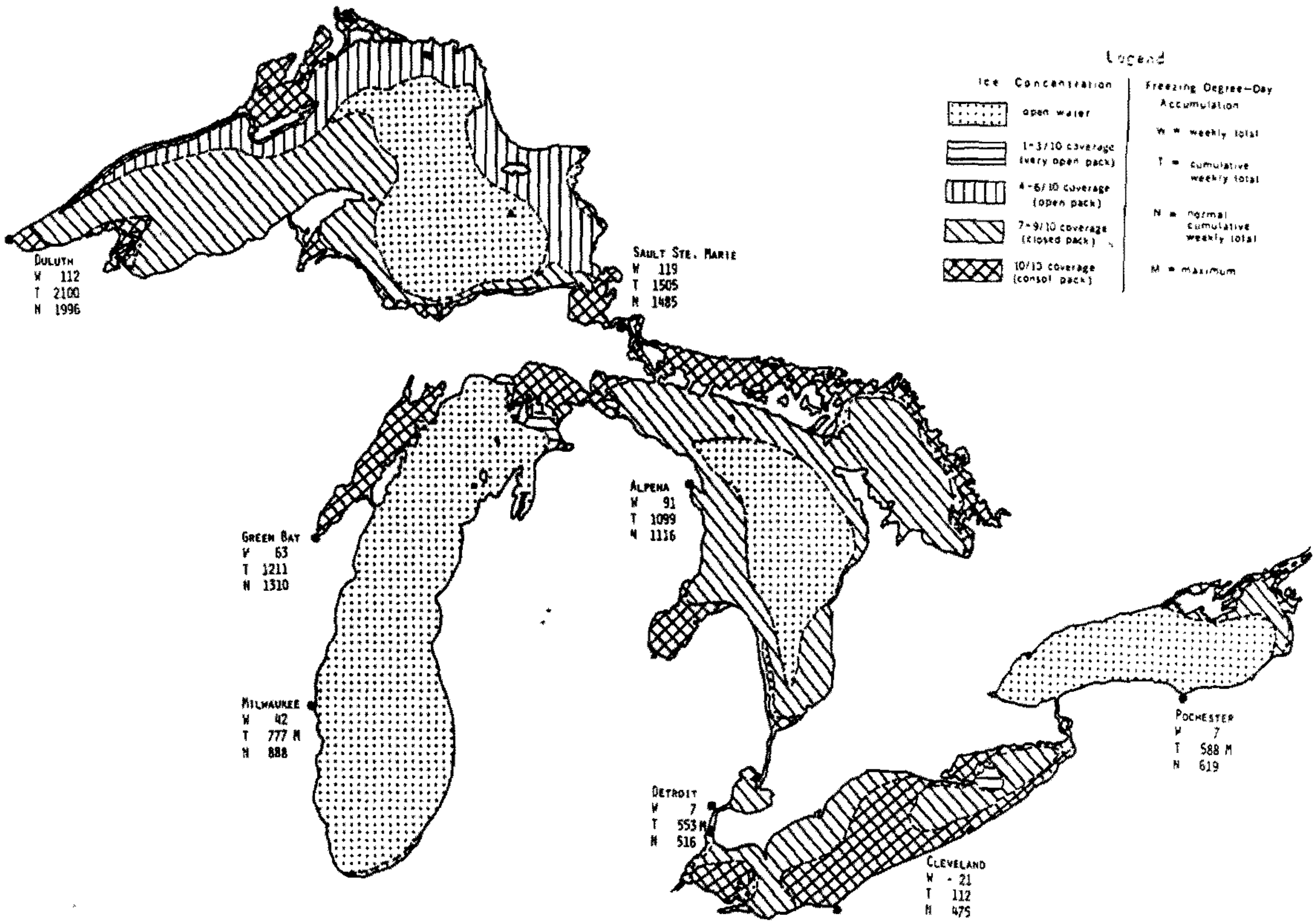


Figure A.16. Composite ice chart - week ending February 24, 1974.

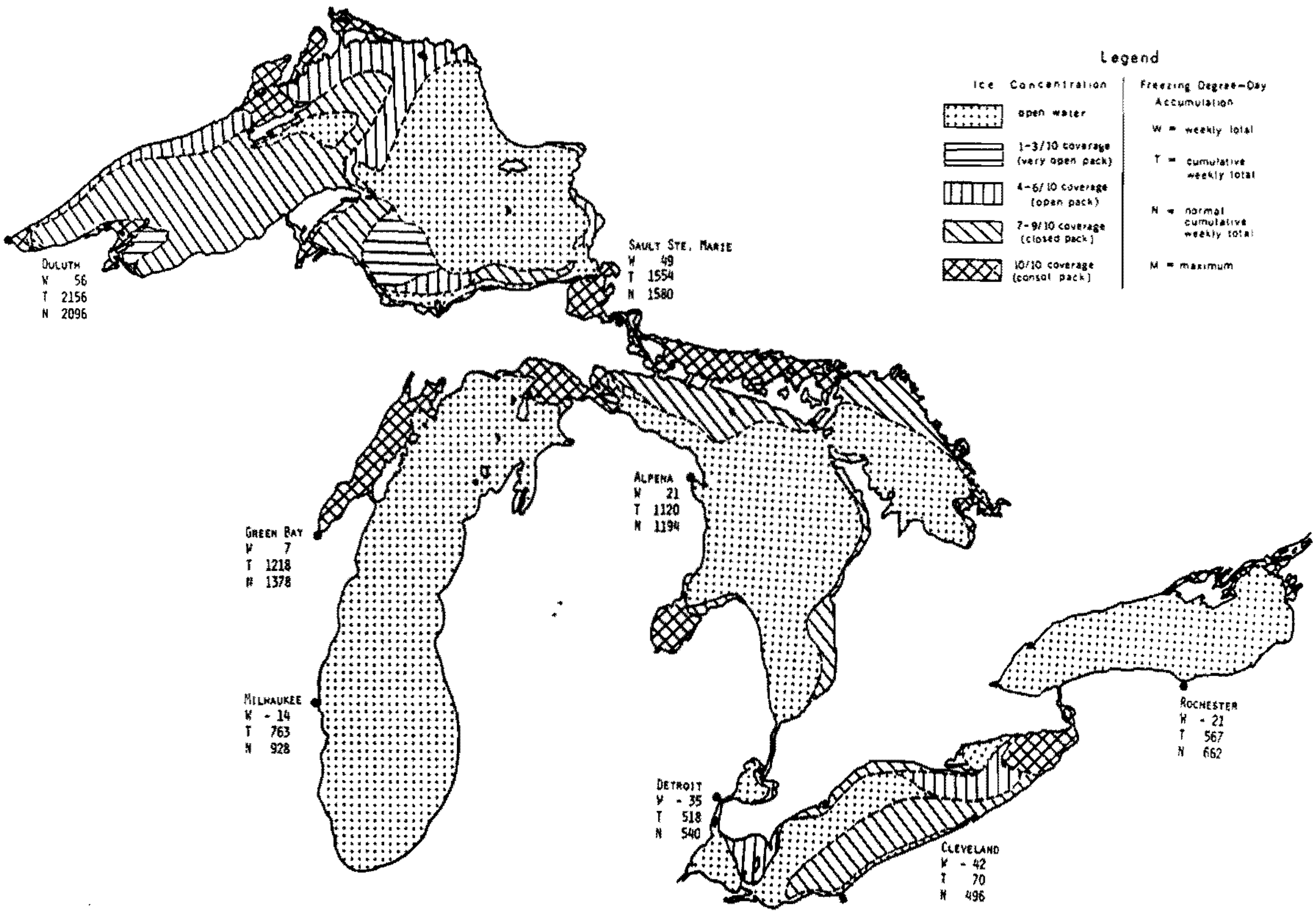


Figure A.17. Composite ice chart - week ending March 3, 1974.

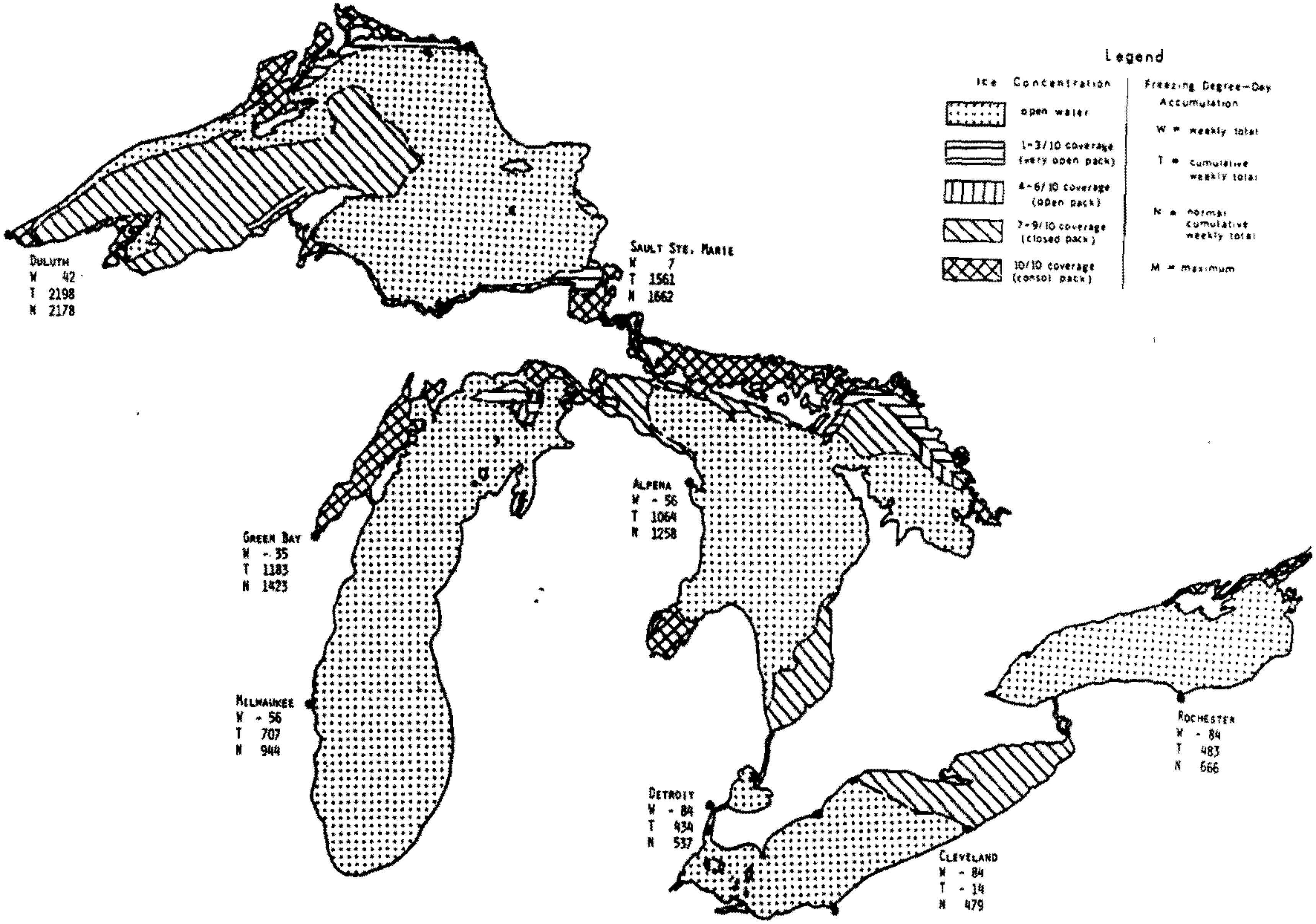


Figure A.18. Composite ice chart - week ending March 10, 1974.

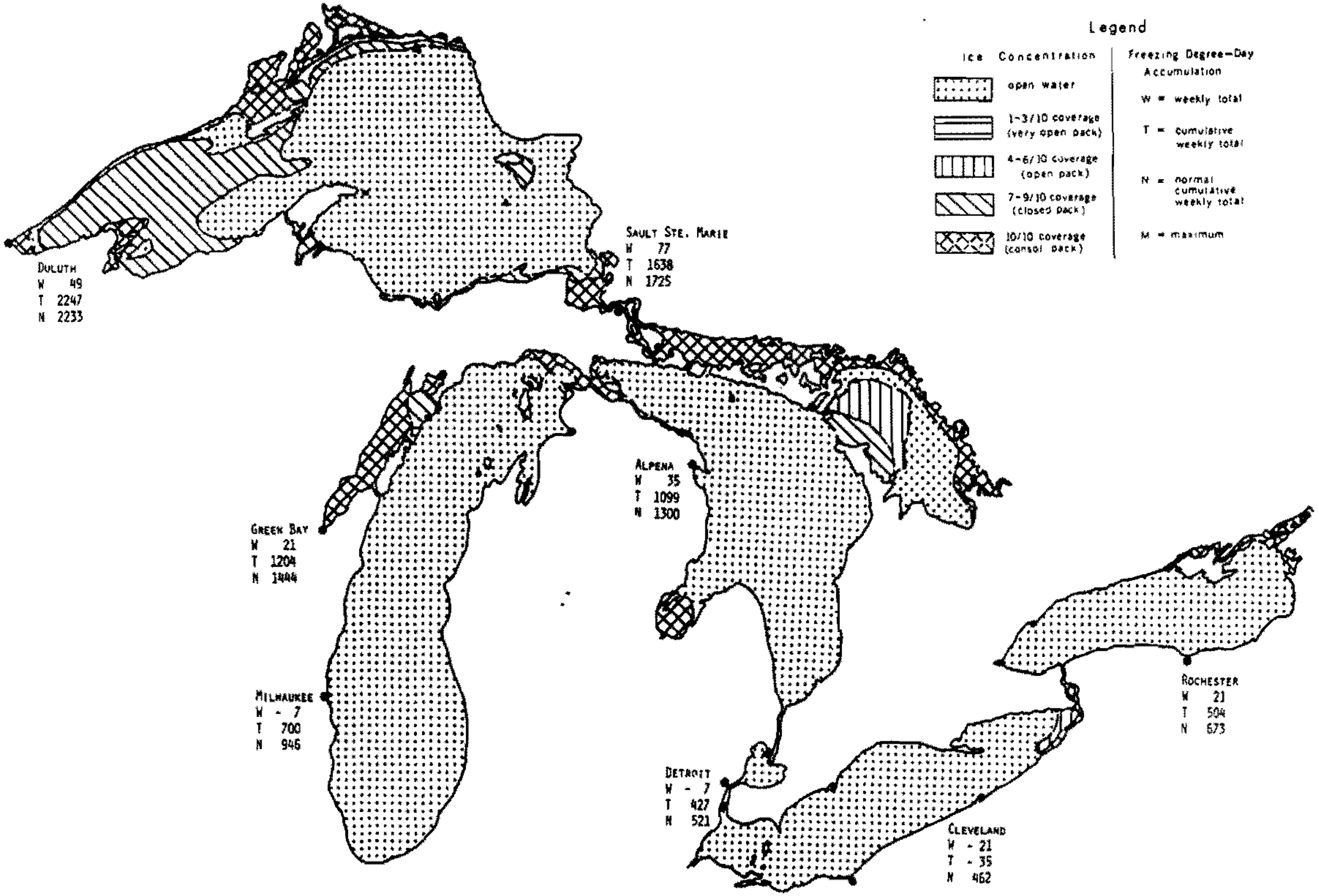


Figure A.19. Composite ice chart - week ending March 17, 1974.

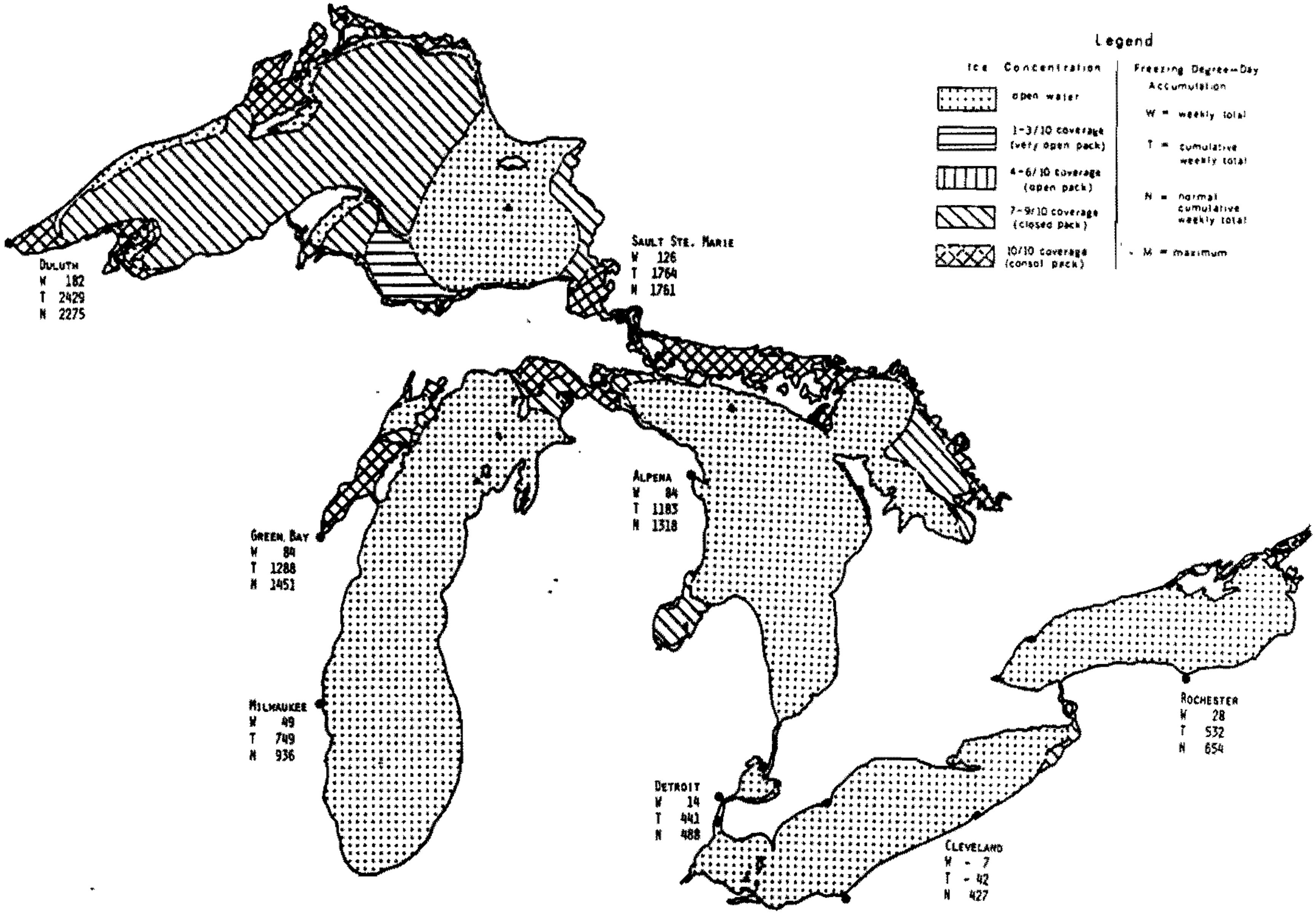


Figure A.20. Composite ice chart - week ending March 24, 1974.

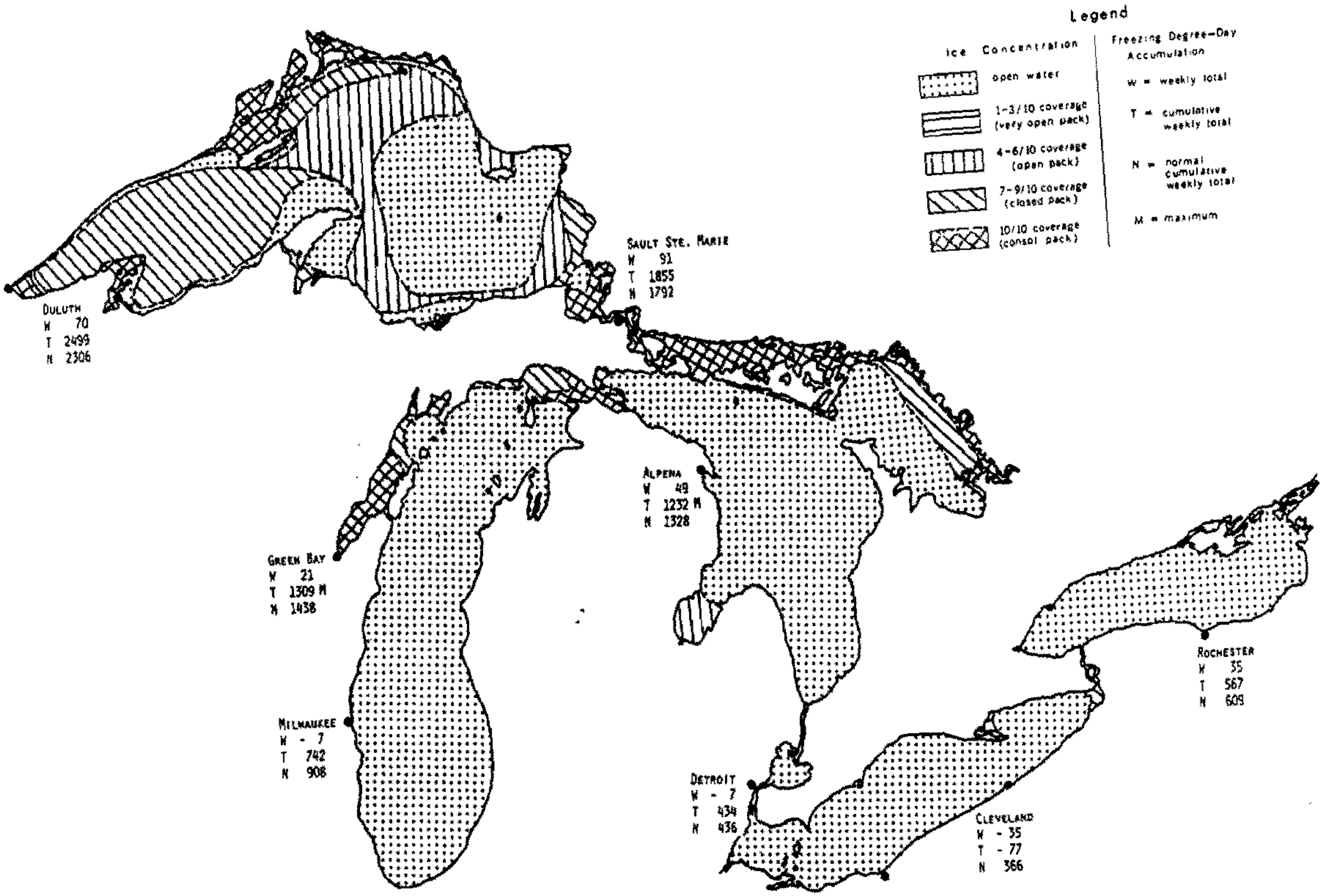
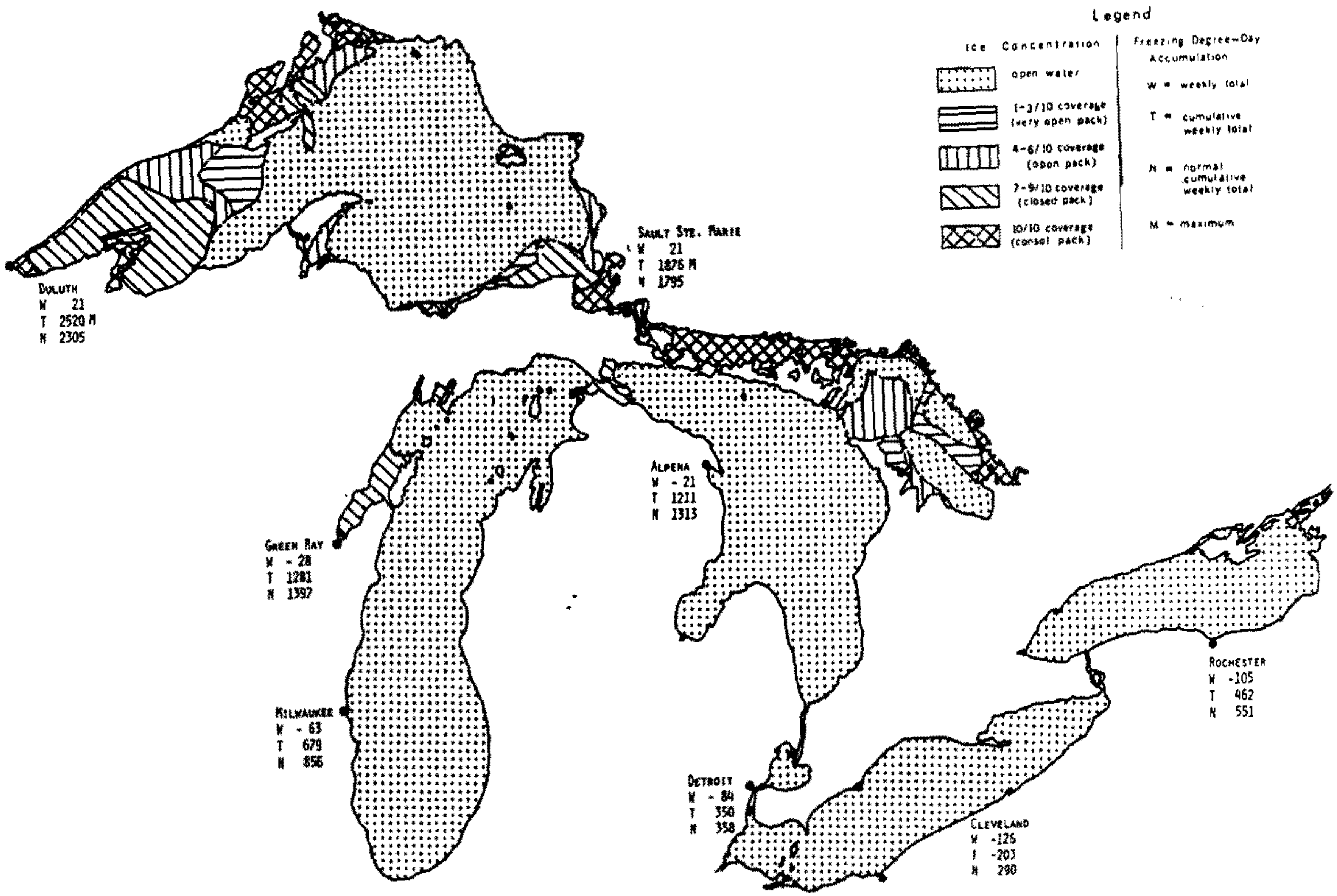


Figure A.21. Composite ice chart - week ending March 31, 1974.



Composite ice chart - week ending April 7, 1974.

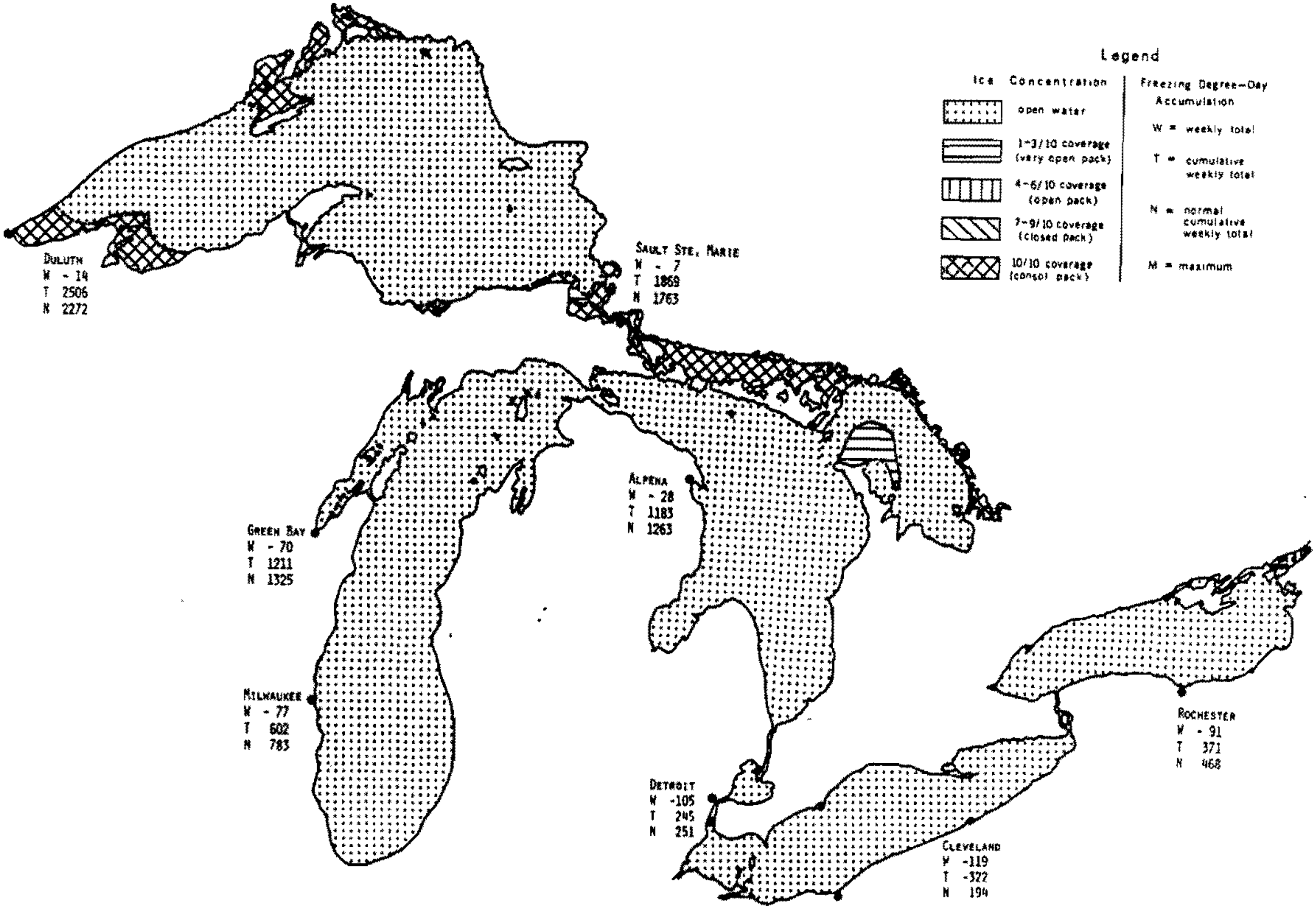


Figure A.23. Composite ice chart - week ending April 14, 1974.

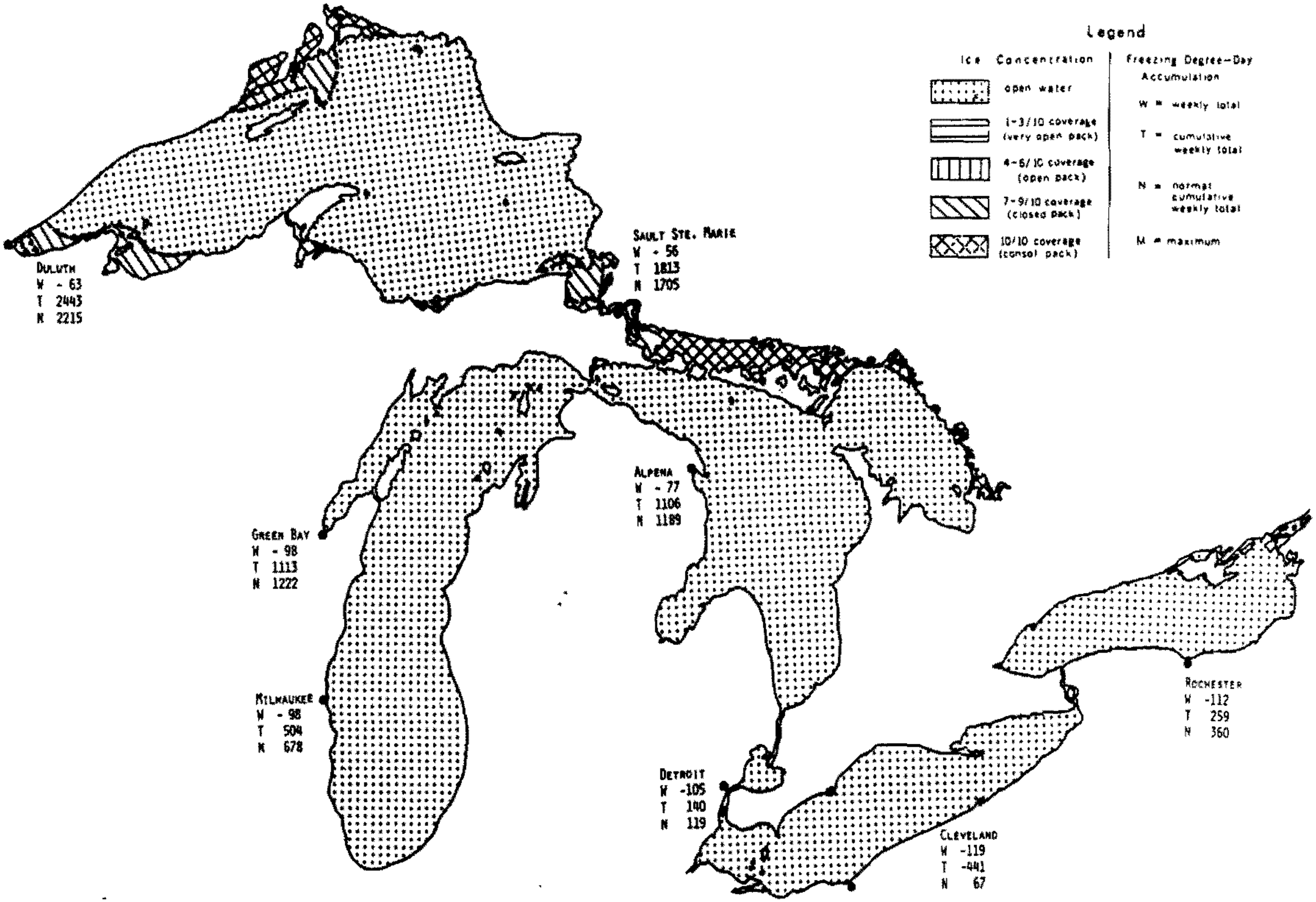


Figure A.24. Composite ice chart - week ending April 21, 1974.

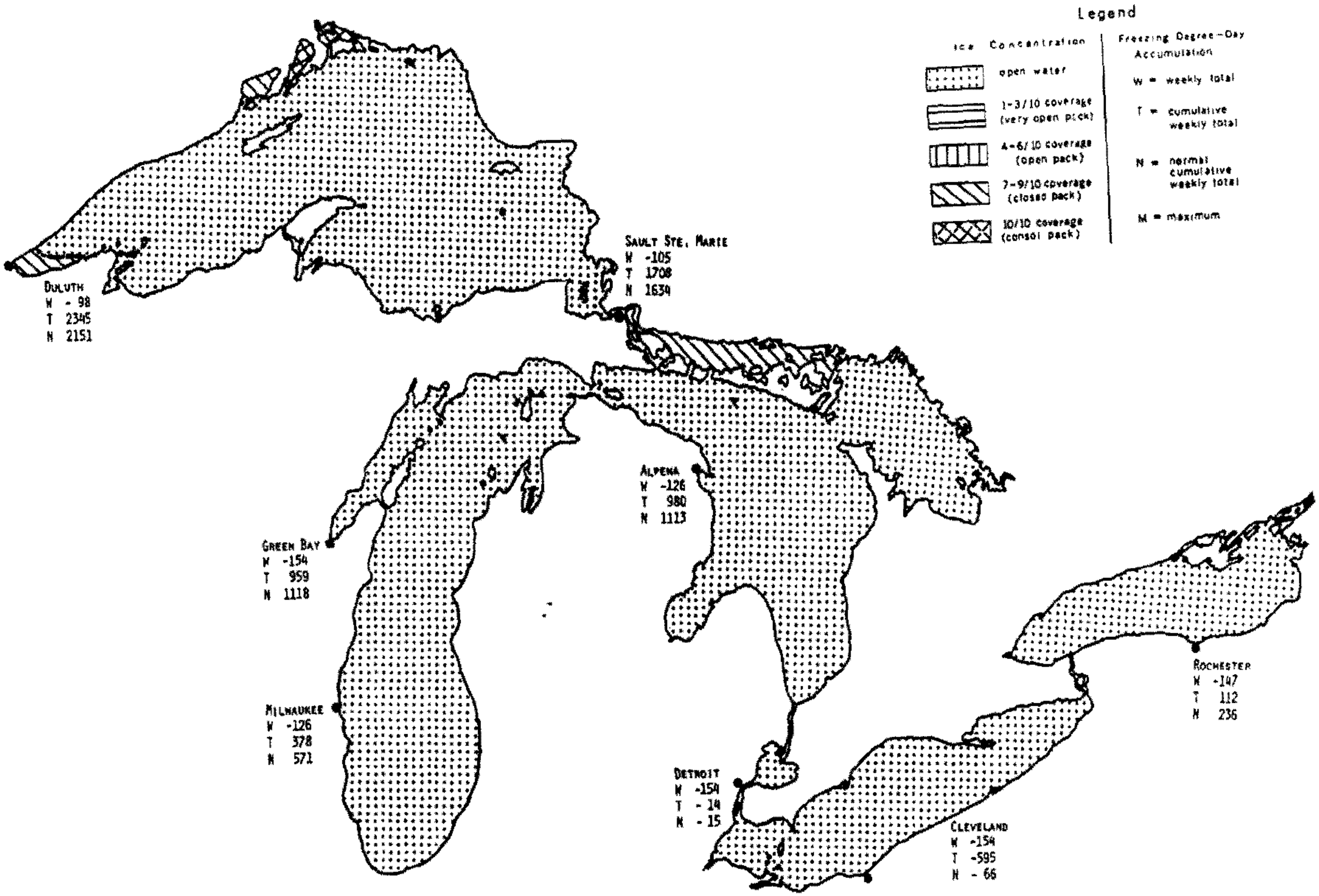


Figure A.25. Composite ice chart - week ending April 28, 1974.

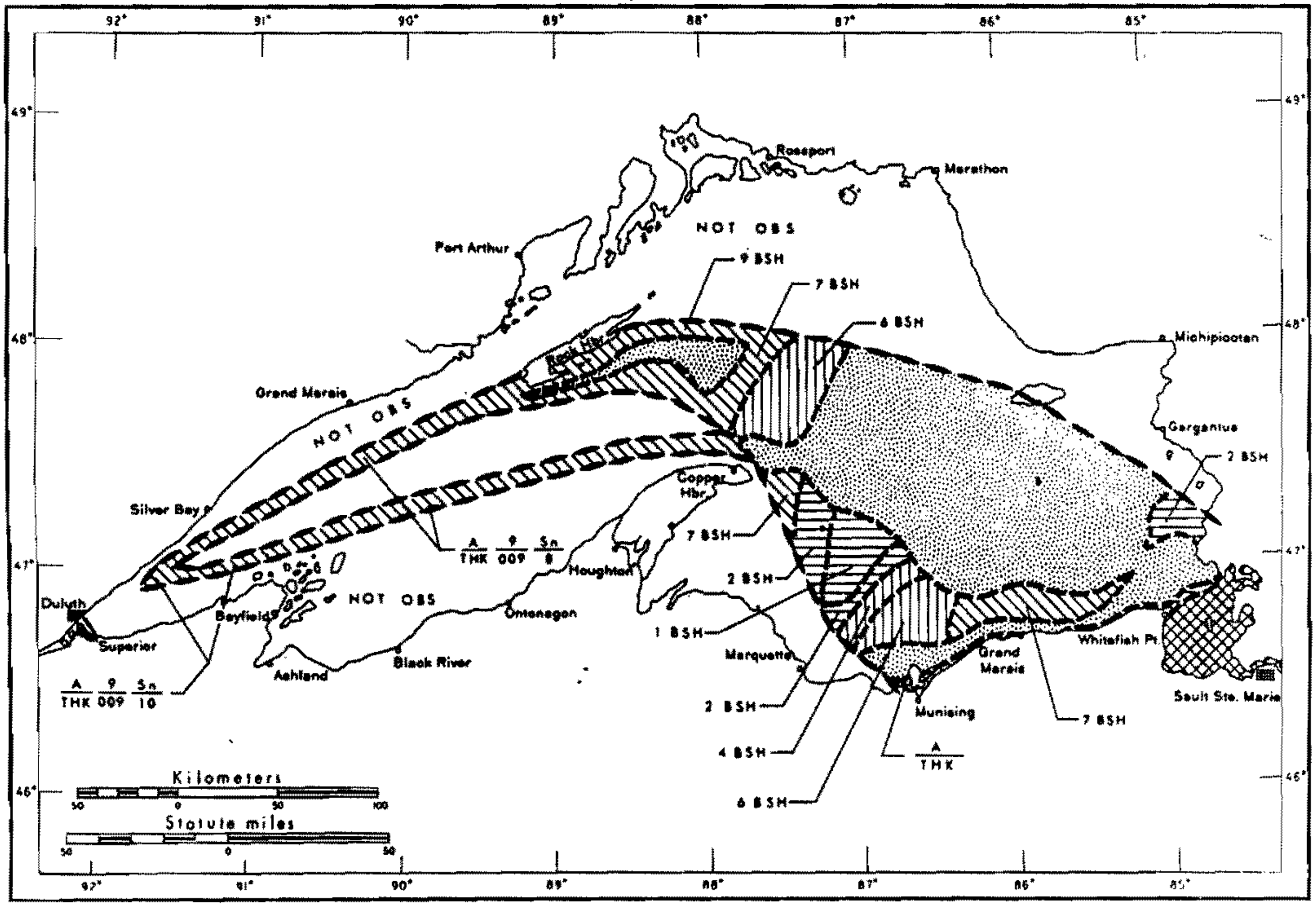


Figure A.26. Lake Superior ice chart - March 4, 1974.

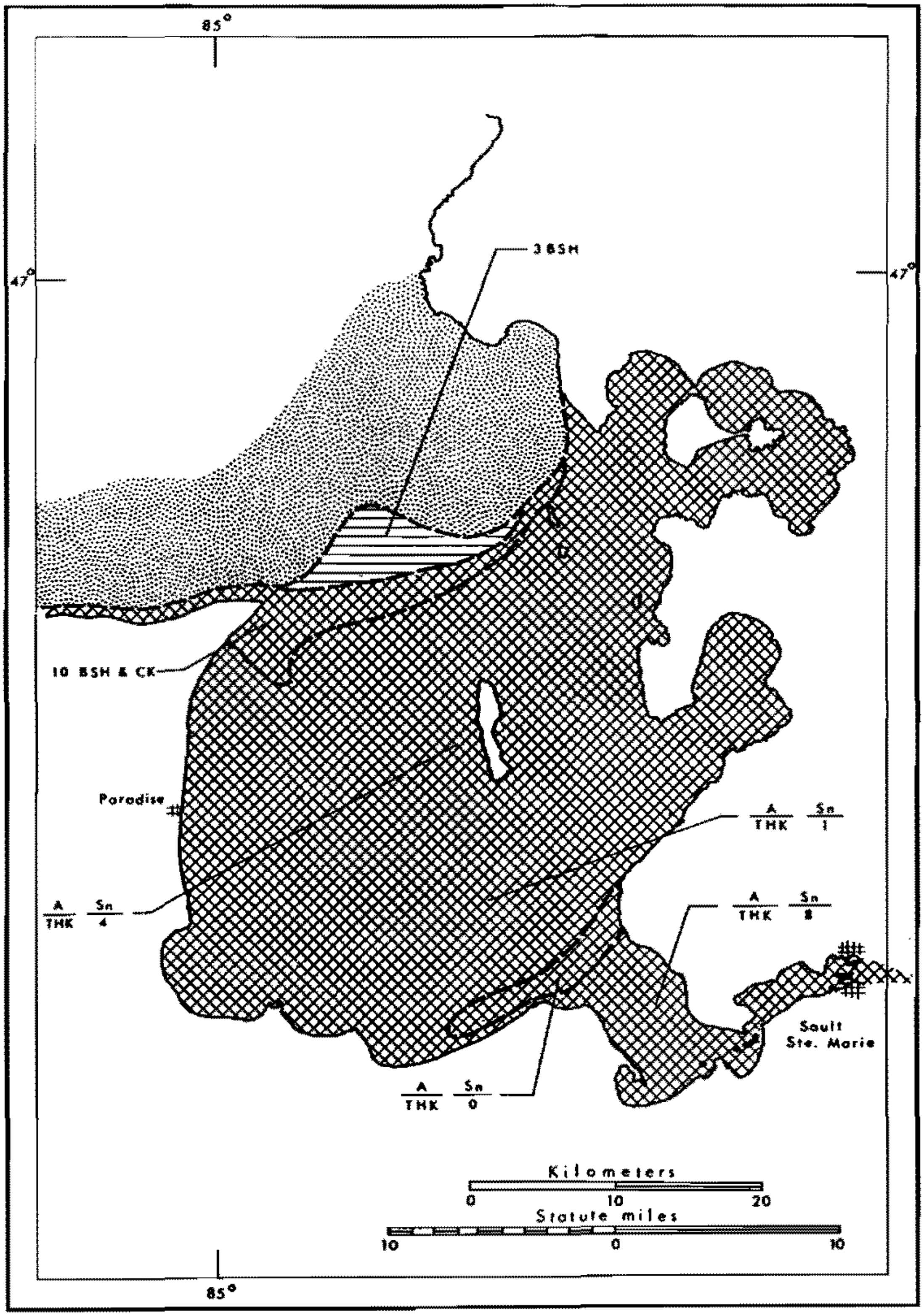


Figure A.27. Whitefish Bay ice chart - March 4, 1974.

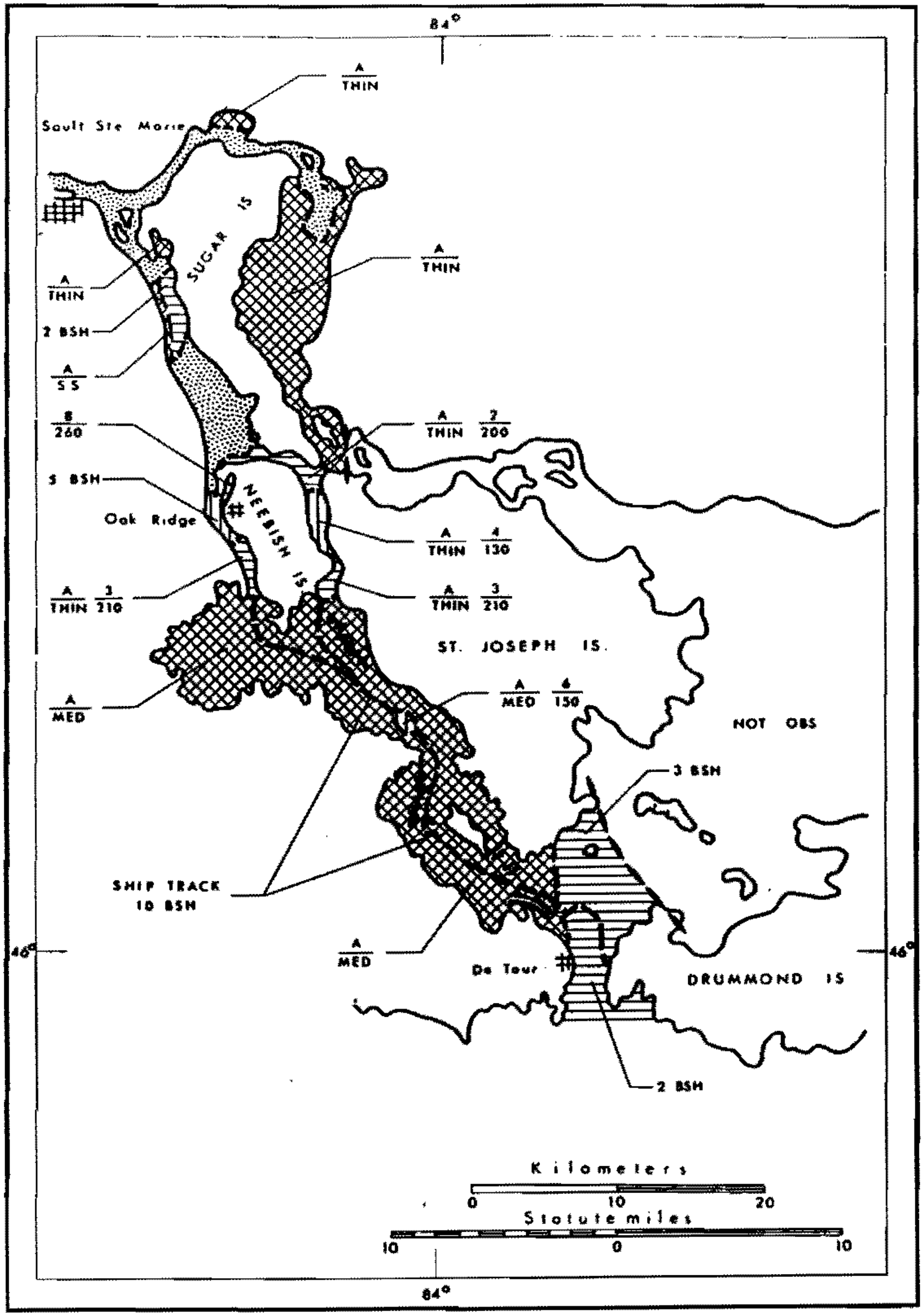


Figure A.28. St. Marys River ice chart - December 17, 1973.

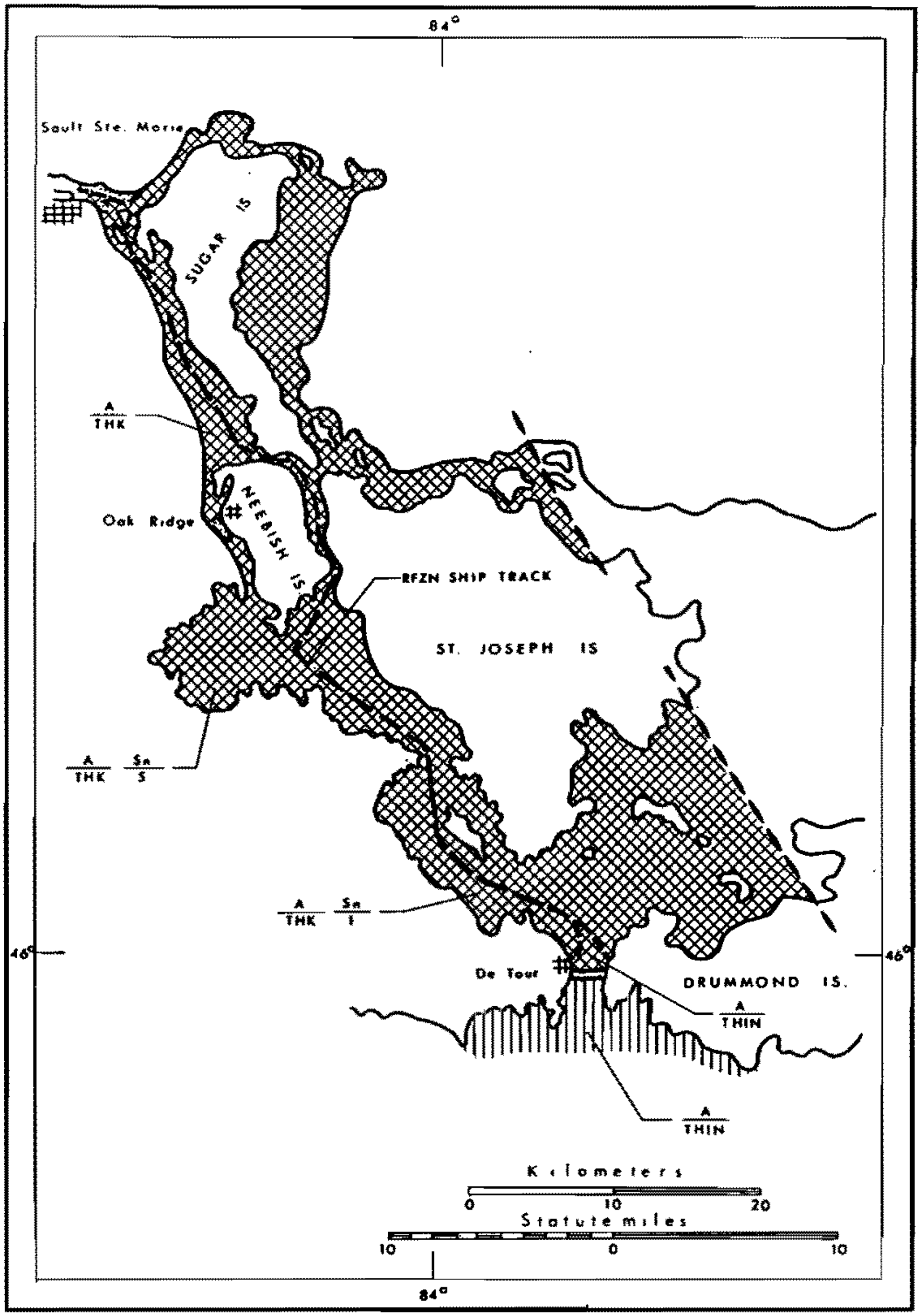


Figure A.29. St. Marys River ice chart - March 4, 1974.

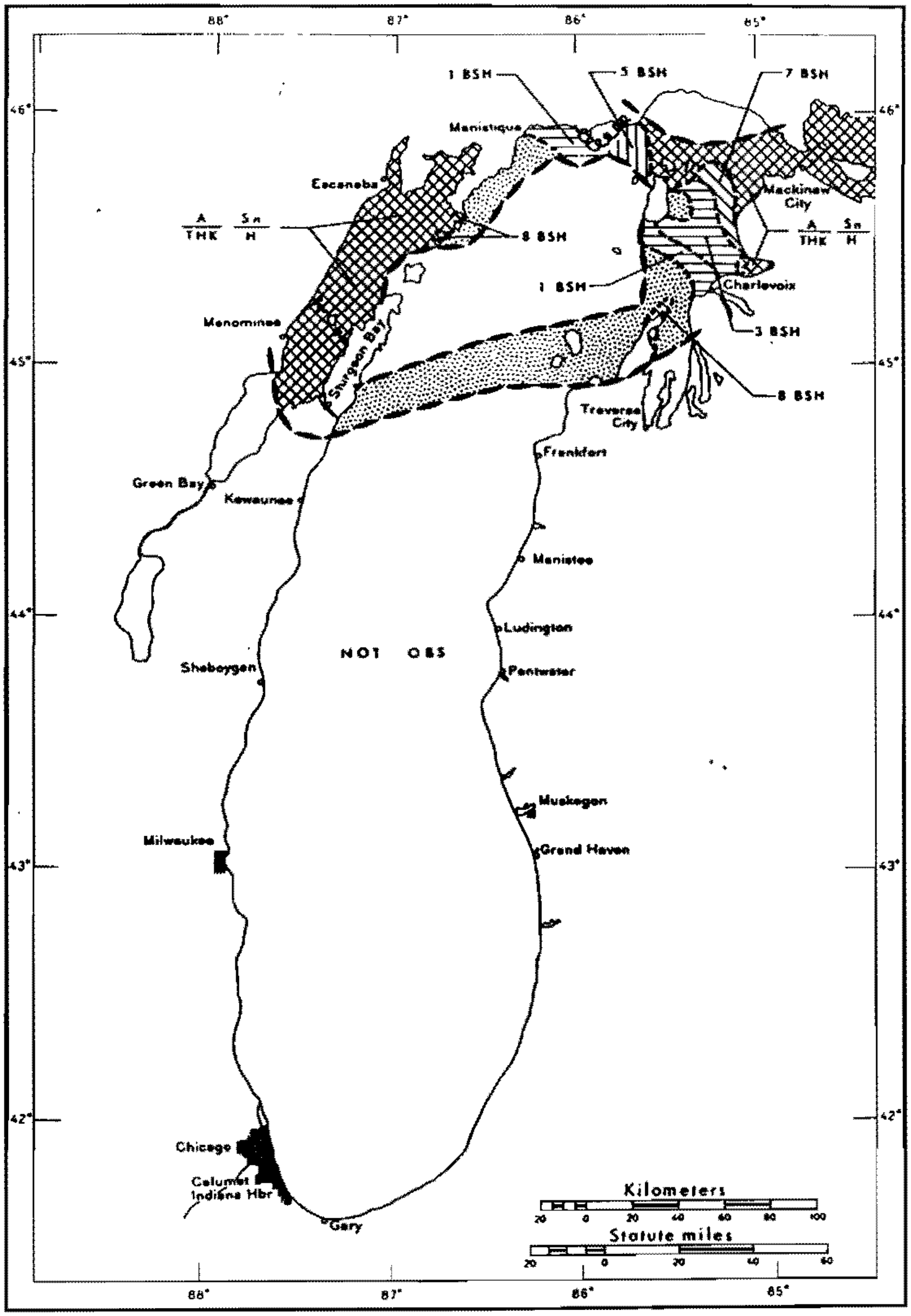


Figure A.30. Lake Michigan ice chart - February 27, 1974.

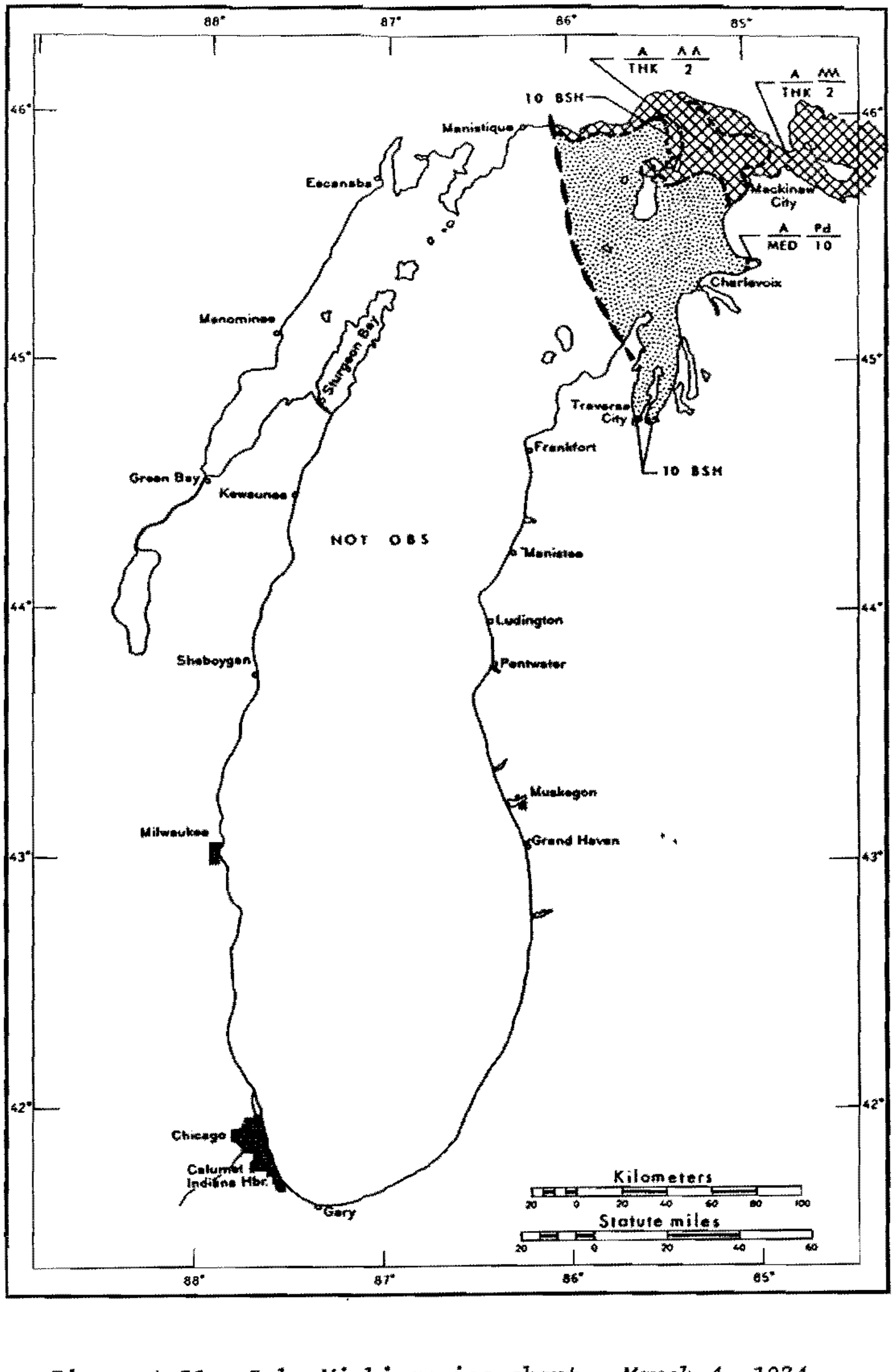


Figure A.31. Lake Michigan ice chart - March 4, 1974.

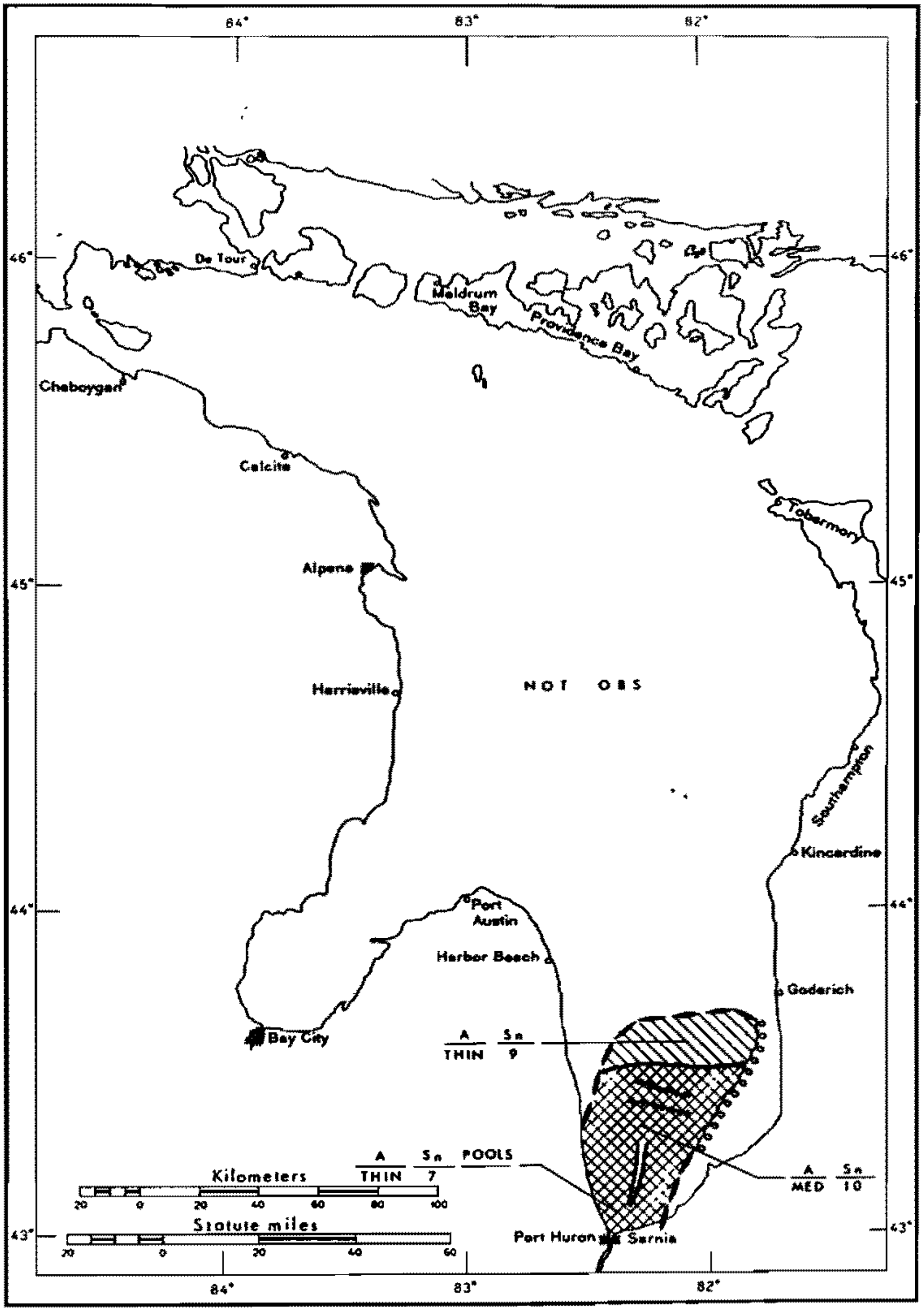


Figure A.32. Lake Huron ice chart - February 25, 1974.

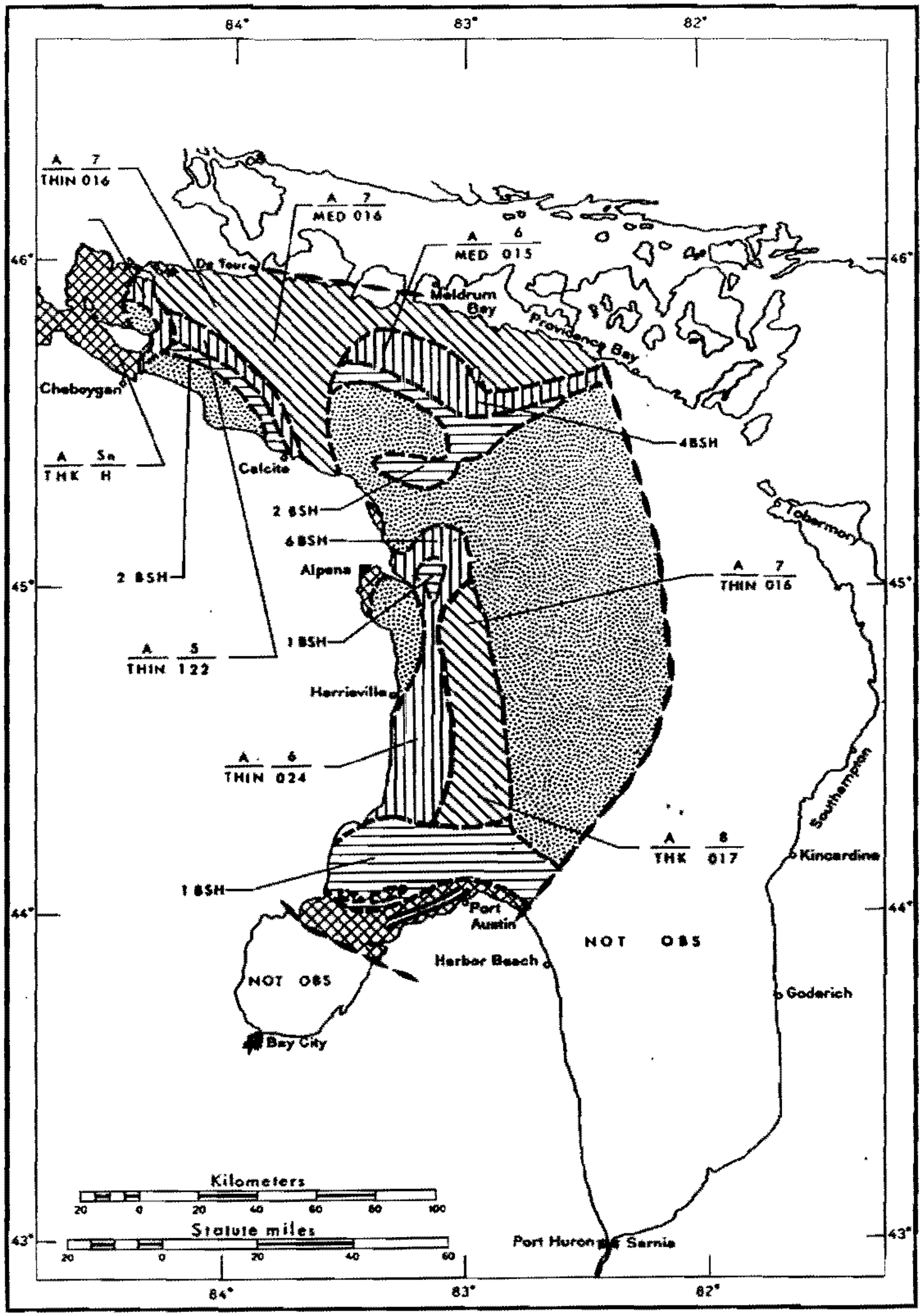


Figure A.33. Lake Huron ice chart - February 27, 1974.

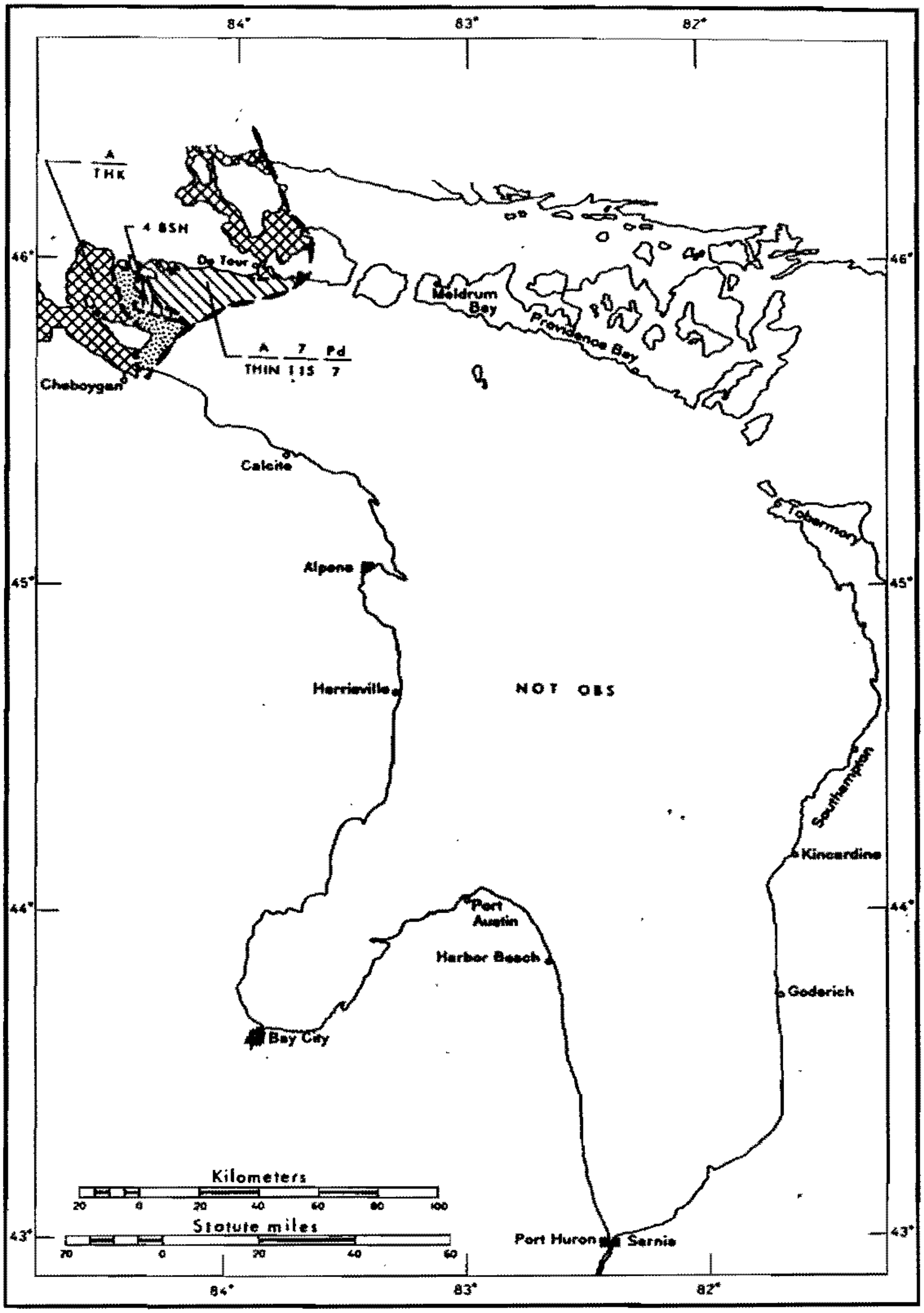


Figure A.34. Lake Huron ice chart - March 4, 1974.

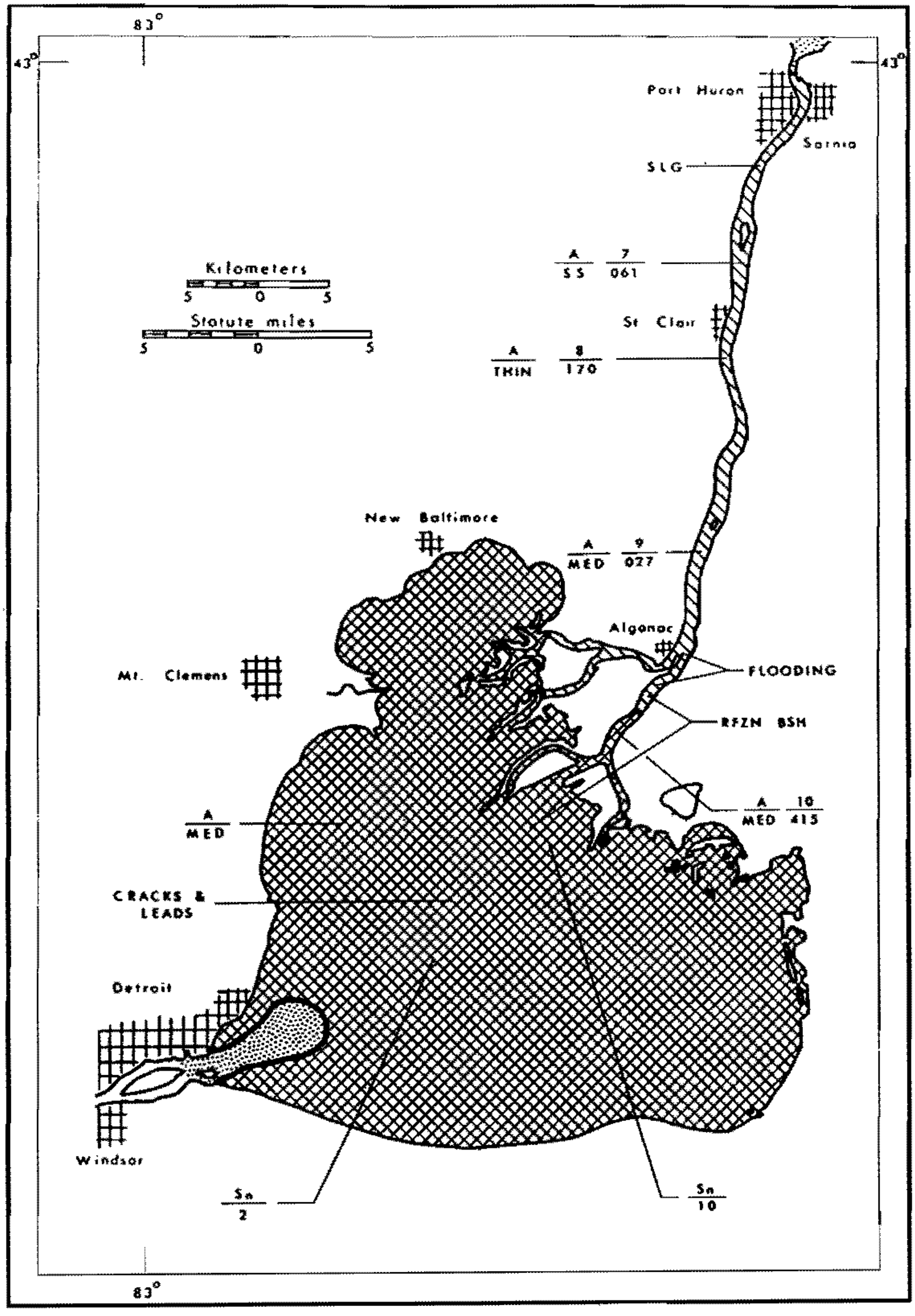


Figure A.35. Lake St. Clair ice chart - February 5, 1974.

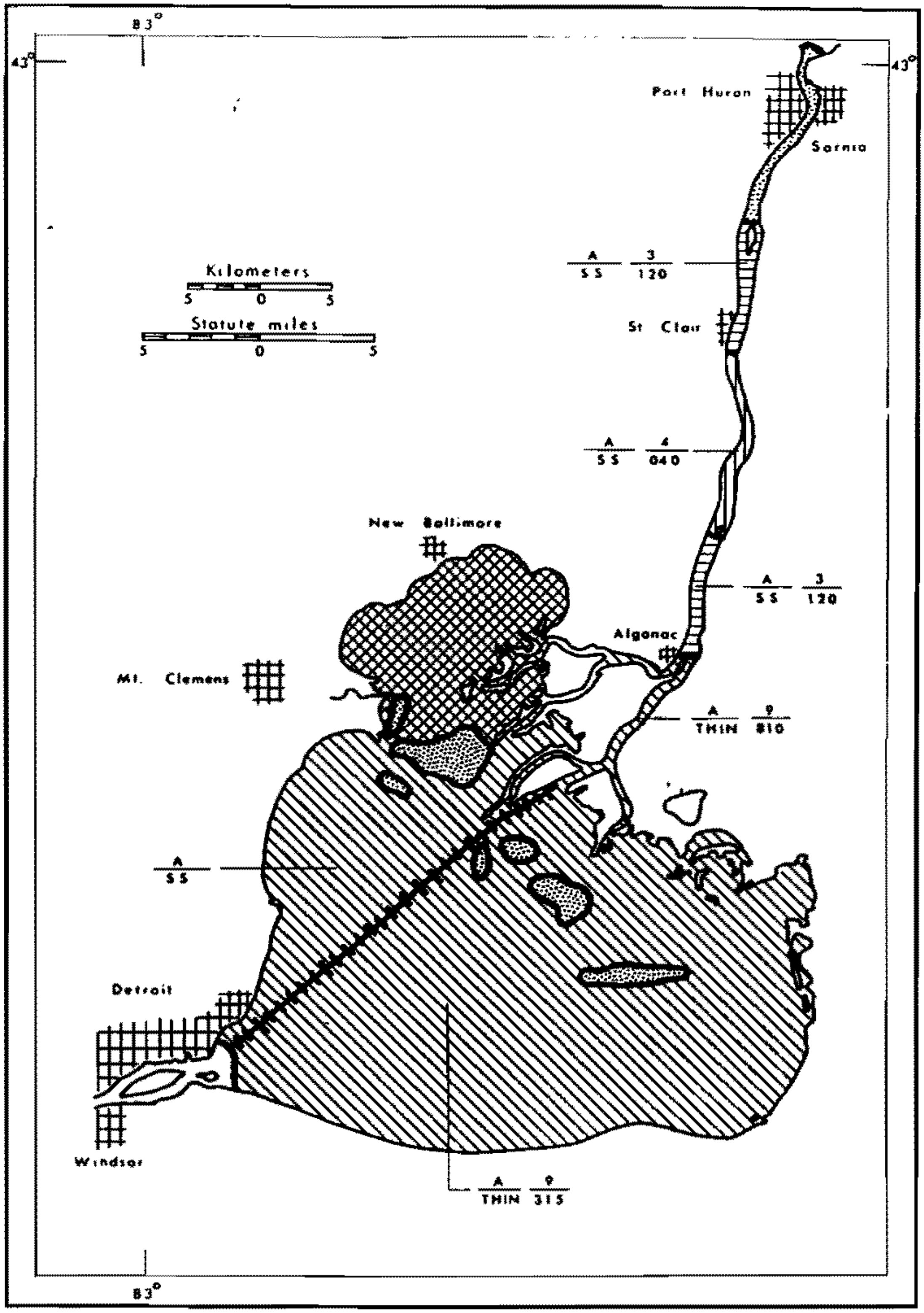


Figure A.36. Lake St. Clair ice chart - February 25, 1974.

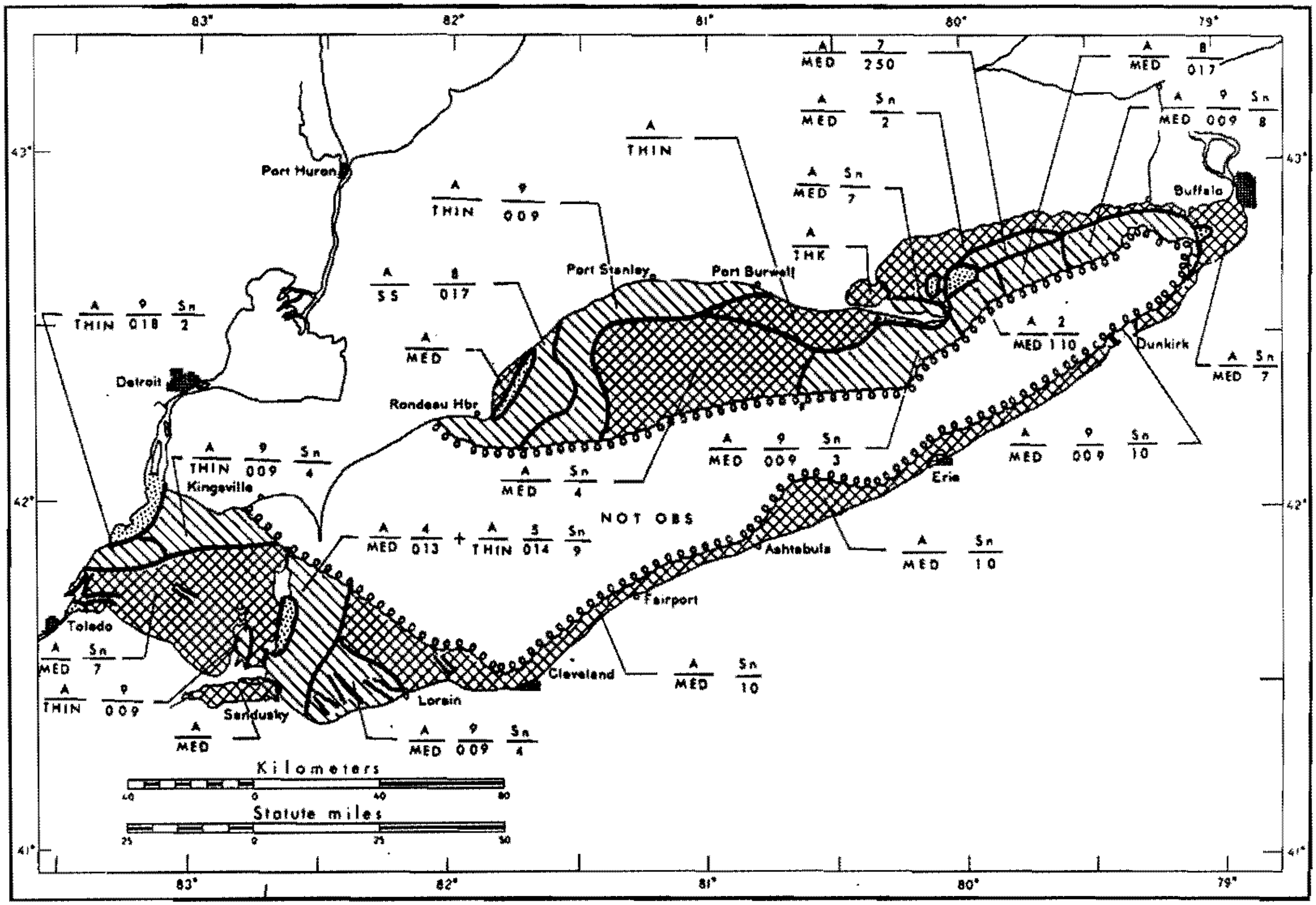


Figure A.37. Lake Erie ice chart - February 25, 1974.

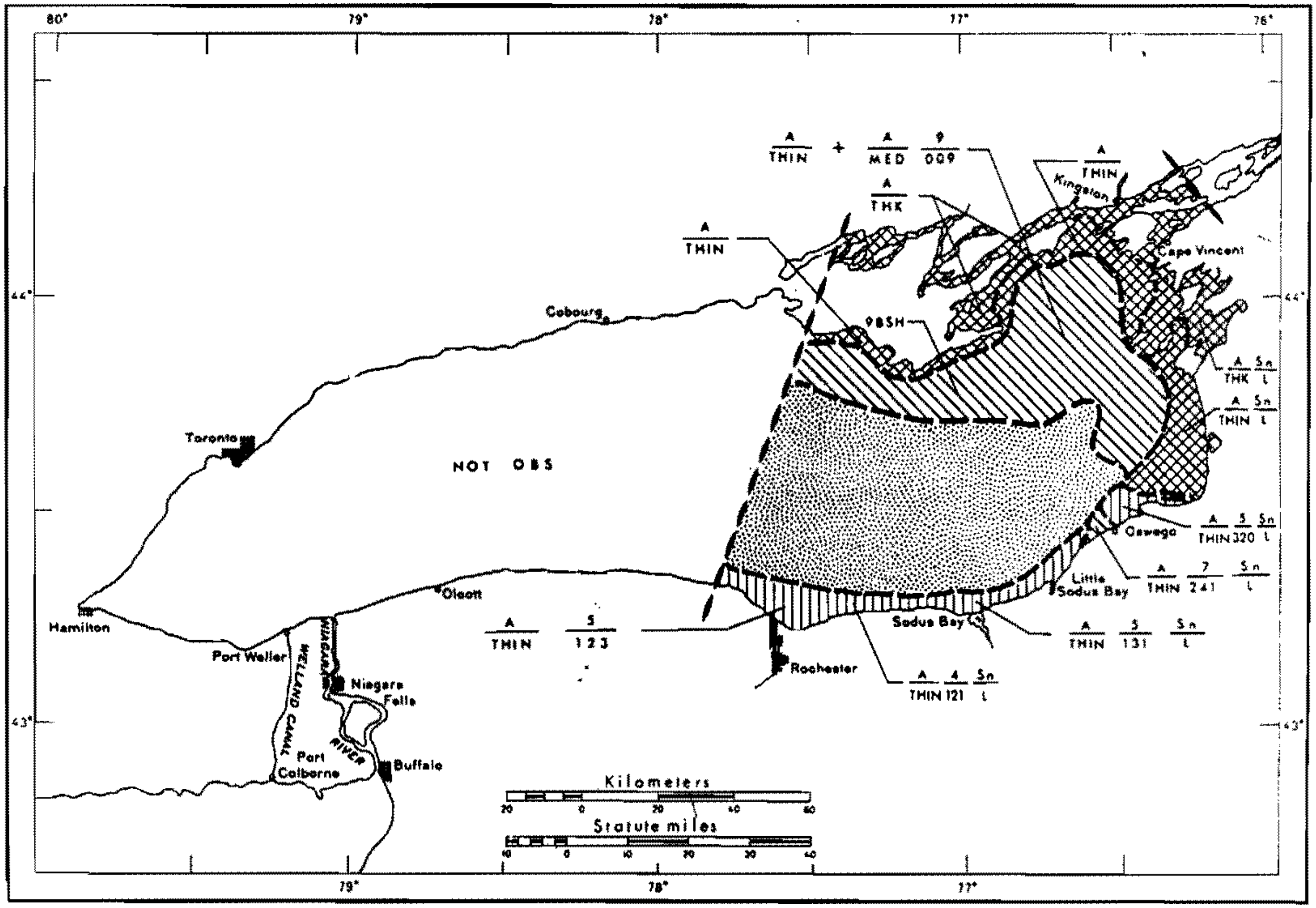
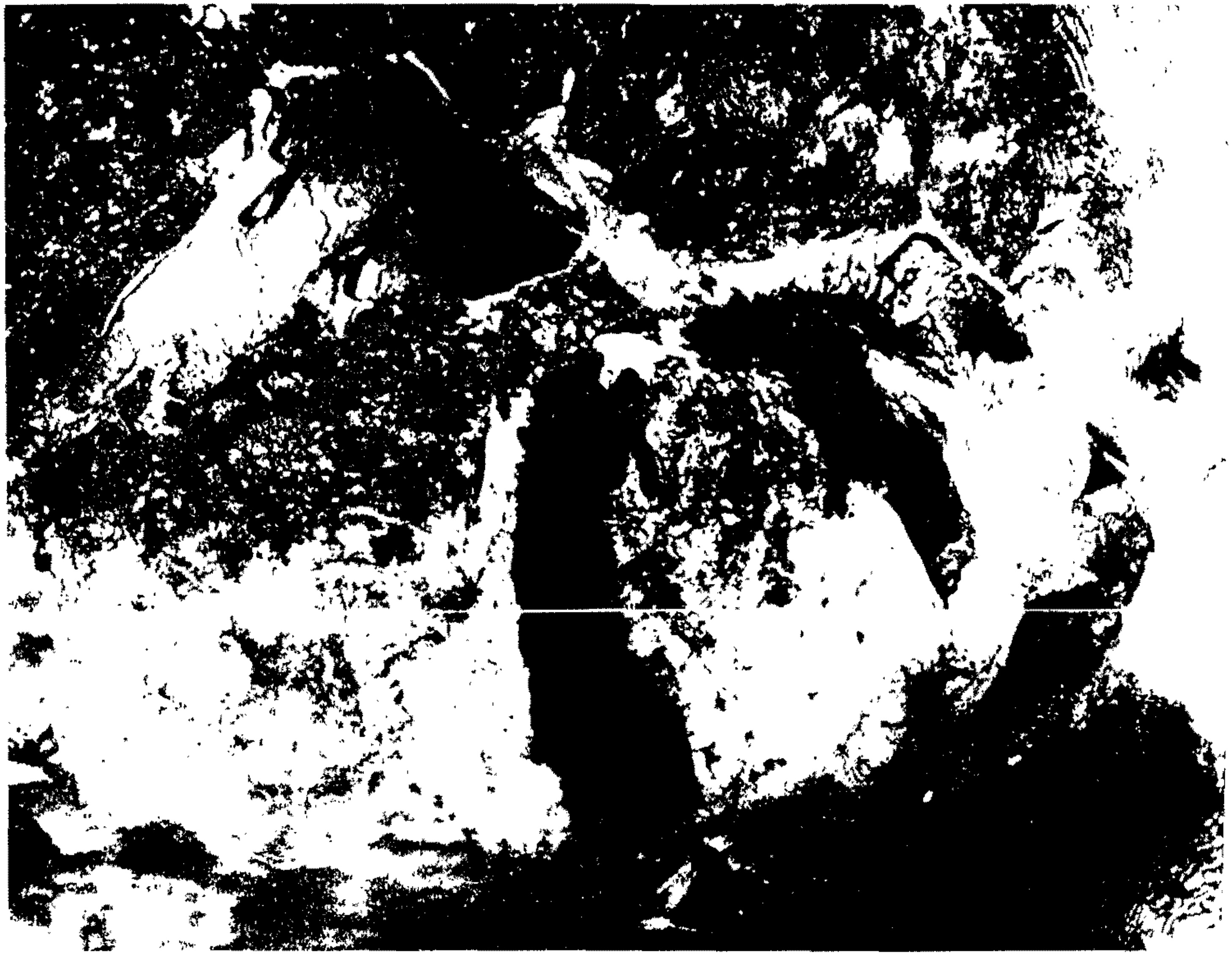


Figure A.38. Lake Ontario ice chart - February 15, 1974.



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