SAWDUST AND WOOD CHIP DEPOSITS IN NEAR-SHORE LAKE MICHIGAN WATERS NEAR MANISTIQUE, MICHIGAN

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ABSTRACT

This report summarizes efforts in 1979-80 to define the nature and origin of the problems associated with sawdust and other wood waste deposits which blanket Lake Michigan beaches near Manistique, Michigan. This survey is viewed as a necessary preliminary to any future efforts to facilitate a permanent solution to these problems.

The study included interviews with interested citizens, beach observations, collection of wind data for the study area, and most importantly, a SCUBA diving survey of the lake and river bottom in the study area.

Our results show no significant sawdust deposits in waters away from the Manistique River mouth. The area from Dutch Johns Point westward to Wiggins Point was surveyed. This indicated that if the river and the littoral areas near the river mouth can be freed of wood waste deposits, and if future additions of wood wastes are prevented, the sawdust problem near Manistique could be solved.

ACKNOWLEDGMENTS

Most of the work on this project was done by Stephen Wissler, the Research Assistant for the Project. He did all of the historical survey work, personal interviews, and mapping. With Robert Holmgren, he did all of the Fall 1979 SCUBA work. He, with the principal investigator, Robert Holmgren, David Tuck, and Mitchell Hubert, also participated in all of the 1980 SCUBA survey work. His efforts are primarily responsible for the results presented in this report. He also did part of the writing.

In addition to Michigan Sea Grant, support is acknowledged from the following sources. The Michigan Department of Natural Resources provided a boat and operator for one week. This support is gratefully acknowledged. The City of Manistique provided boat mooring facilities in the marina, plus gasoline for all boat operations. The project would not have been financially feasible without this support. Mr. John Weiss, owner of Miami Beach campground, is acknowledged for his gracious provision of fine camping facilities for our diving crew in June, 1980. Robert Holmgren provided able assistance in SCUBA diving and many other aspects of the project.

Northern Michigan University generously provided matching funds for the project, well over those required. We also express our thanks for the aid of Mitchell Hubert and David Tuck, who provided their time and diving skills free of charge. Finally, the aircraft use and pilot service rendered by Mr. Ronald Kauppila was a valuable part of our shoreline survey in the winter of 1980 and is gratefully acknowledged.

CONTENTS

BACKGROUND AND OBJECTIVES

Due to past lumber milling and logging operations and recent deposition of dredge spoils from the harbor at Manistique, Michigan, the waters of Lake Michigan near Manistique have contained large accumulations of sawdust, wood chips, and other forms of wood wastes.

These wood wastes have resulted in extensive deposits of sawdust and wood chips on the beaches near Manistique, creating esthetic problems which have been viewed as a significant detriment to the tourist industry in the area.

The objectives of this project were threefold. First, to determine the location and extent of sedimented wood waste deposits on the bottom of Lake Michigan near Manistique. Second, to develop a body of information related to prevailing winds and resulting water movements in the area which would enable prediction of the movement of these wood waste deposits. Finally, the project sought to assemble historical and geographical information about the nature and extent of the beach deposits.

HISTORICAL INTRODUCTION

It was the beginning of the 1850s, in Michigan's Upper Peninsula, when Thompson and Manistique - then just overgrown lumber camps - began to capitalize on the abundant white pine in the region. Their prime locations near the mouth of the Manistique River at Lake Michigan made processing and transportation of the lumber quite feasible. Logs as large as seven feet in diameter could be seen floating in the river. After the huge logs were sawn into lumber, schooners were loaded for markets in Chicago, New York, and France.

Peak lumbering years for white pine were between 1863 and 1912. During these years, five large lumber mills operated in the Manistique area. The Delta Lumber Company operated at Thompson. The Hall and Buell Lumber Company at Southtown, just east of Manistique, operated during the 1880s and 1890s.[1] From 1863 until 1871, the Chicago Lumber Company, located in Manistique, had an average yearly output of 70 million board feet.[1]

In 1871, the Weston Lumber Company was organized. It bought the Chicago Mill and opened two additional mills near Manistique. The three mills were in use until 1912 when they were purchased by the Consolidated Lumber Company. Most of the white pine was cut by 1915 when the Consolidated Corporation was sold to Stearns and Culver. They operated a hemlock and hardwood industry until 1922 when the Stack Lumber Company took over. By 1926 most lumbering had ceased.

From 1863 to 1912, while the white pine lumbering was at its peak, five large mills operated in the Manistique area, creating jobs, good times, and legends; but, part of the legacy of those times is the tons of sawdust which now wash onto shore and cause many problems for land owners and the City of Manistique.

It has been estimated that 786 board feet of lumber produces one ton of sawdust.[2] Between 1863 and 1871, 560 million board feet of lumber were cut by the Chicago mill alone, and an estimated 3.6 billion board feet were cut by the three Weston mills during their 40 years of operation.[1] Therefore, over 4 billion board feet of lumber were cut by three of the five large mills

[1] W. S. Crowe. 1977. Inside an era in the Manistique, Michigan region. Senger Publishing Company, Manistique, MI.
[2] Based on estimates from conversations with Marquette Timber Company personnel.

between 1863 and 1912. Using the above information, we can calculate that this sawing produced approximately 5.1 million tons of sawdust. This figure does not include waste from the Delta Mill in Thompson, the Southtown Mill owned by Hall and Buell, or small operations along the Manistique River and its tributaries.

General milling practice was to discharge unwanted sawdust into the Manistique River or transport it on barges and dump it in Lake Michigan (Crowe, op. cit. p. 2). There is speculation that not all of the sawdust was dumped into water. Some may have been used for heating the mills or other buildings; however, slabs and bark were usually the main source of fuel. Slabs were also used for dock construction. It has been mentioned that sawdust was also burned, not for heat, but as a means of disposal. Scrap burners, however, were not in use until after 1910.[3] By this time, white pine lumbering had been underway for 47 years. Another estimation is that 3% of all sawdust produced between 1863 and approximately 1920 was burned.[4] This leaves almost 5 million tons for the water around Manistique. The disposal of sawdust on land during the peak years is undocumented, but the lack of large piles of sawdust in the area indicates that land disposal was relatively unimportant.

Besides the discharge of sawdust and wood debris by lumber mills and logging operations of the White Pine era, another possible source of wood wastes in the Manistique River to be considered was the Manistique Pulp and Paper Company, which originated in 1918.

The Manistique Harbor and the Manistique River mouth were dredged periodically through the years to allow for vessel traffic. Records of dredging operations by the U.S. Army Corps of Engineers show activities between July,

[3] Les Boucher, Manistique, MI, personal communication December 5, 1979.
[4] Norman Wood, Manistique, MI, personal communication December 6, 1979.

1941, and November, 1967 (Table 1). Their log sheets give the percentages of rock, sand, clay, and sawdust removed. Table 1 lists the cubic yards and calculated tons of sawdust, slabs, and wood chips that were dredged from the harbor. The number of cubic yards of sawdust was obtained by multiplying the total cubic yards of dredged spoils by that percent known to be wood debris. The estimated number of tons of sawdust was calculated by multiplying the cubic yards of sawdust by the weight of wet sawdust and wood chip debris per cubic yard. A total of 66,751 cubic yards, or 47,000 tons of sawdust and wood waste, was dumped in Lake Michigan between July, 1941, and November, 1967.

The 47,000 tons of sawdust and wood waste were dumped in a stretch of Lake Michigan water located south 27° east from the eastern breakwater light (see

TABLE 1. Record of dredging operations of the U.S. Army Corps of Engineers between July, 1941, and November, 1967.

Date (Mo & Yr)	Cubic Yards of Sawdust Wood Debris
July 1941	4,772
August 1941	15,108
July 1954	14,933
August 1954	13,312
August 1962	3,025
November 1963	4,320
November 1964	1,818
July - November 1965	9,463
November 1967	0
Total	66,751*

* 66,751 cubic yards x 7.0×10^{-1} tons/cubic yard = 47,000 tons

Figure 1). Dumping in large quantities occurred 2 3/4 miles out in an area approximately 1,000 feet on side. Other dumpings occurred 1 1/2 and 2 1/2 miles out into the lake.

NATURE AND EXTENT OF RECENT BEACH DEPOSITS

To become familiar with the sawdust problem in Manistique, and as a means of becoming known in the area, radio announcements were made; newspaper articles were published stating achievements, setbacks, and tentative results; and interviews with residents were conducted both personally and through survey forms. Citizens interviewed included fishermen, real estate owners, bankers, an airplane pilot, and shoreline home owners (see Appendix A).

As a result of these interviews, a general body of information about the sawdust problem was formed. Feelings are that the sawdust and wood debris are an eyesore on beaches; however, the problem has not changed much through the years. Accumulations were evident on beaches and suspended in the lake as early as the 1890s. During the fall and early winter seasons, large quantities are said to build up. The sawdust may lie suspended in the water 50 to 100 feet from shore, or it may accumulate on land back as far as 30 feet from the water line and may be 1-2 feet thick.

A general theory put forth by local residents is that a circular, clockwise (west to east), longshore current moves sawdust along the shoreline, causing one area to be free of build-up one day and full of material the next. Weather conditions also affect movement. Residents feel that strong, southerly winds bring the sawdust in and that northerly (offshore) winds push the sawdust out. Large quantities accumulate on beaches within the city. Pockets of sawdust have

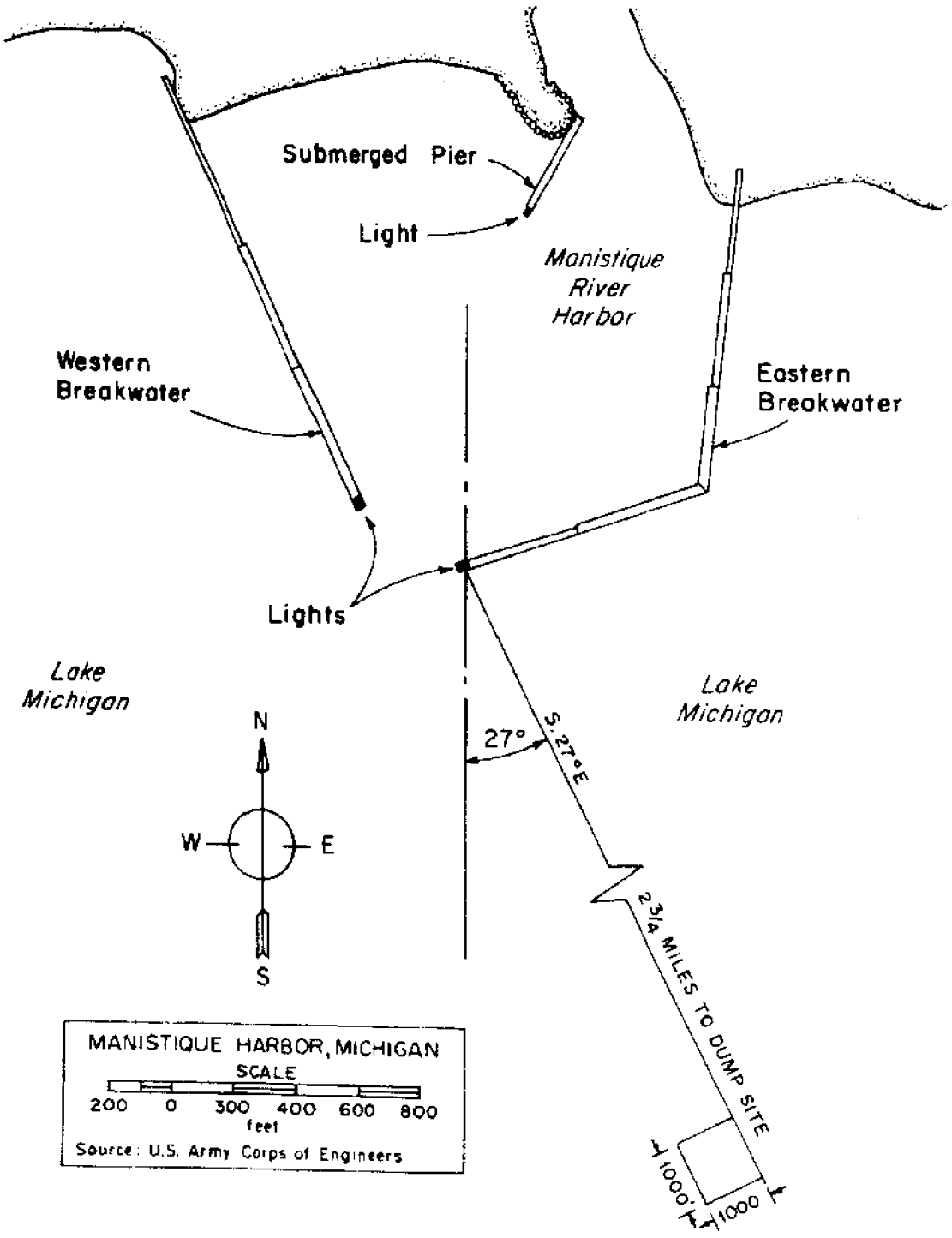


FIG. 1. Manistique Harbor, Michigan.

been seen regularly in the corners where the eastern and western breakwaters meet the shoreline. These corners are located out of the harbor (Figure 1). They collect the sawdust when waves sweep in toward shore. Sawdust, wood chips, and slabs have been observed as far east as Dutch Johns Point and as far southwest as Wiggins Point (Figure 2).

Our observations of the shoreline were made on an irregular basis from September 7, 1979, to June 26, 1980. Information drawn from resident interviews was compared with actual observations made by walking the shoreline, photography from a low-flying aircraft, or observing from a boat. The results have been recorded on three maps, one each for fall 1979, winter-spring 1980, and summer 1980 (see Figures 2, 3, and 4). The maps have been drawn to show common areas of accumulation during the three seasons. Each map represents a period of time because day-to-day sawdust movements could not be shown. The periods are: September through December, 1979, January through April, 1980, and May and June, 1980. The survey was made of the shoreline between Wiggins Point and Dutch Johns Point. Only sawdust accumulations that are 2 inches thick or greater are indicated with shaded areas on the three maps. Because of the map scales, accumulations within 20 feet of one another are shaded as one.

Pictures taken from a low-flying aircraft in January and April, 1980, were used to pinpoint wood waste accumulation. These are shown in Figure 3. Copies of color slides showing portions of the shoreline during these periods are available from the authors on request. During these overflights, attempts were also made to use color filtration and filter selection to achieve maximum water penetration to reveal underwater wood-waste deposits near shore. A yellow-colored filter and a Kodak E-4 process (Ektachrome) professional film seemed to produce results which show promise.

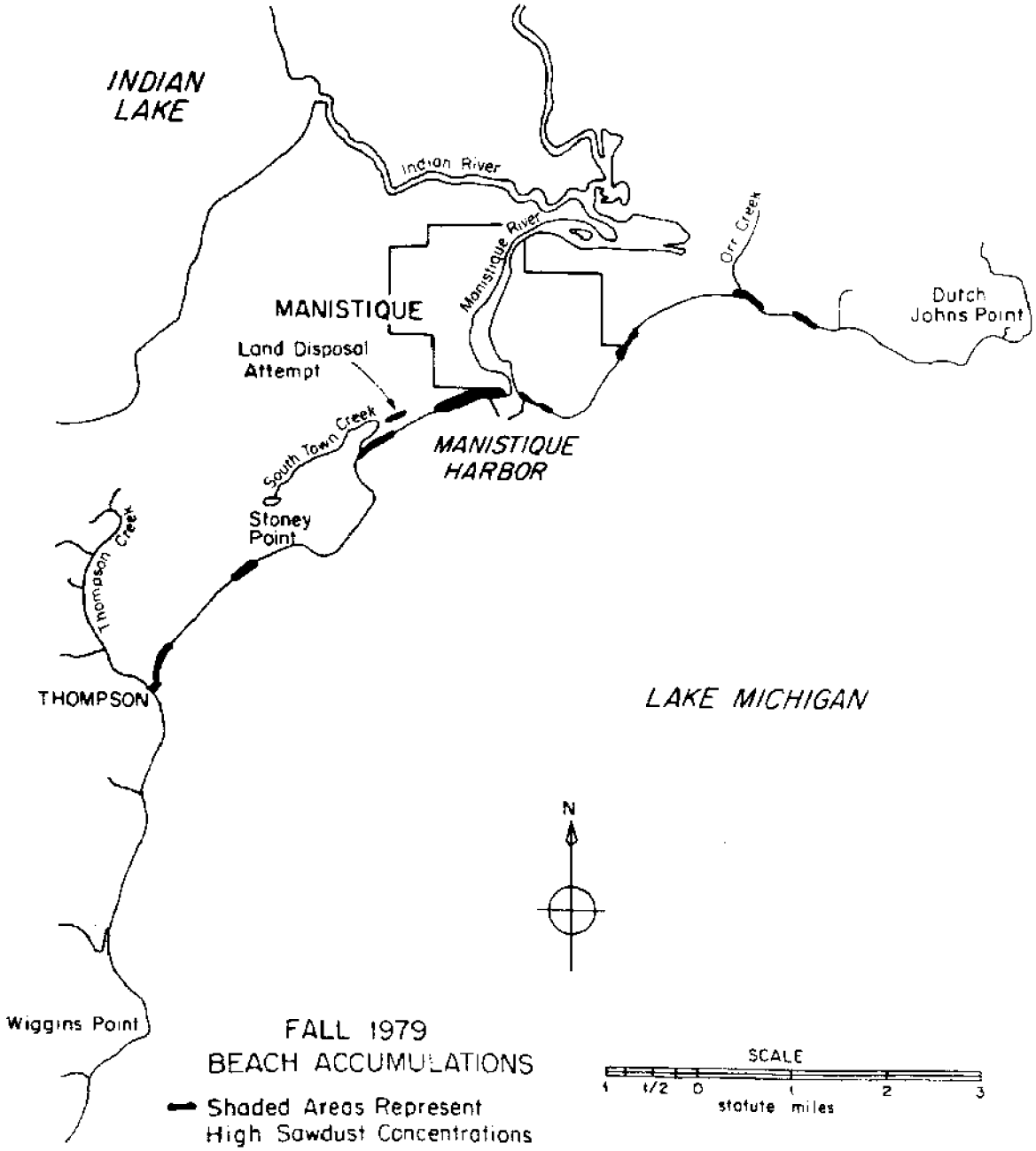


FIG. 2. Fall, 1979, beach accumulations.

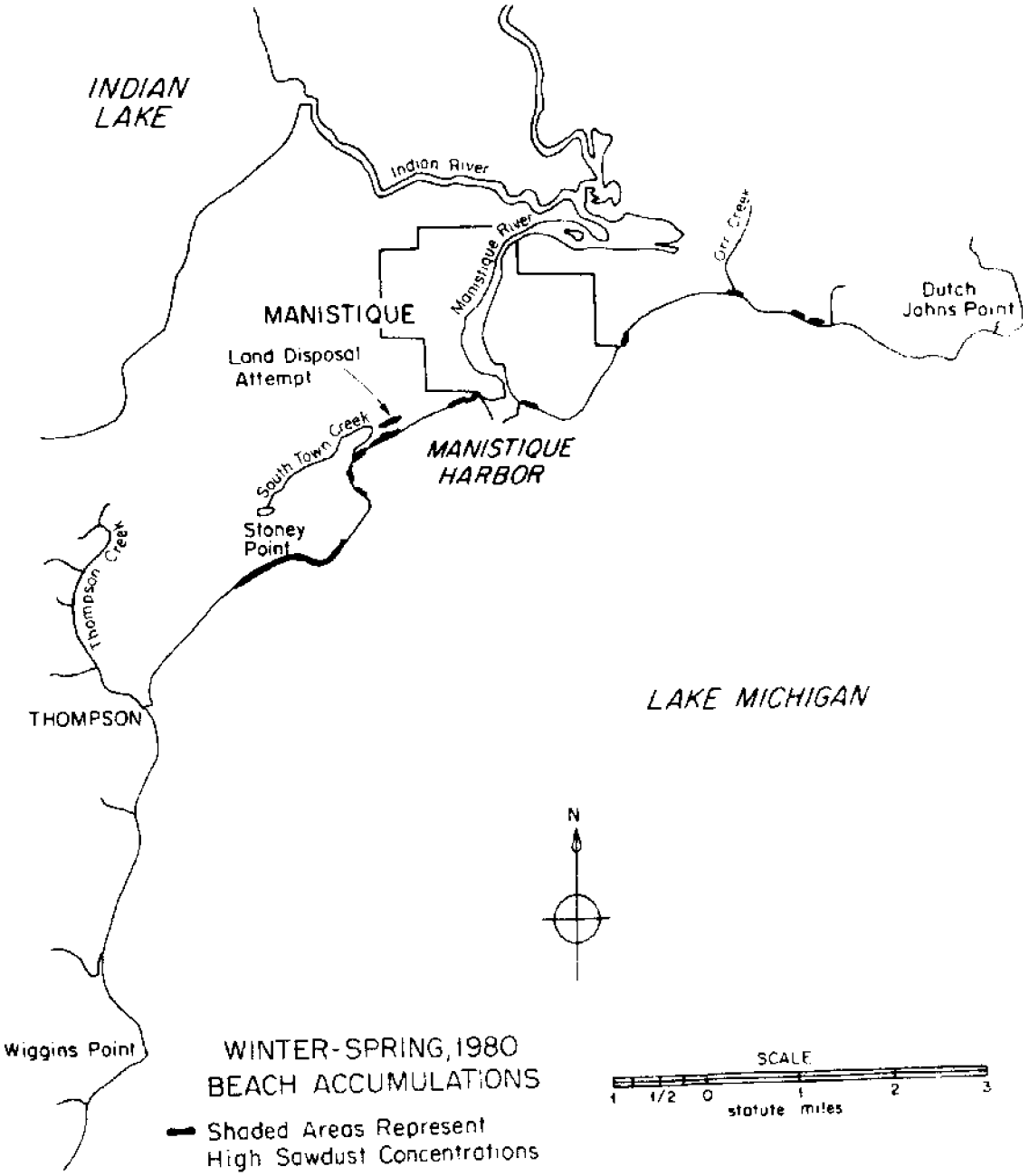


FIG. 3. Winter-spring, 1980, beach accumulations.

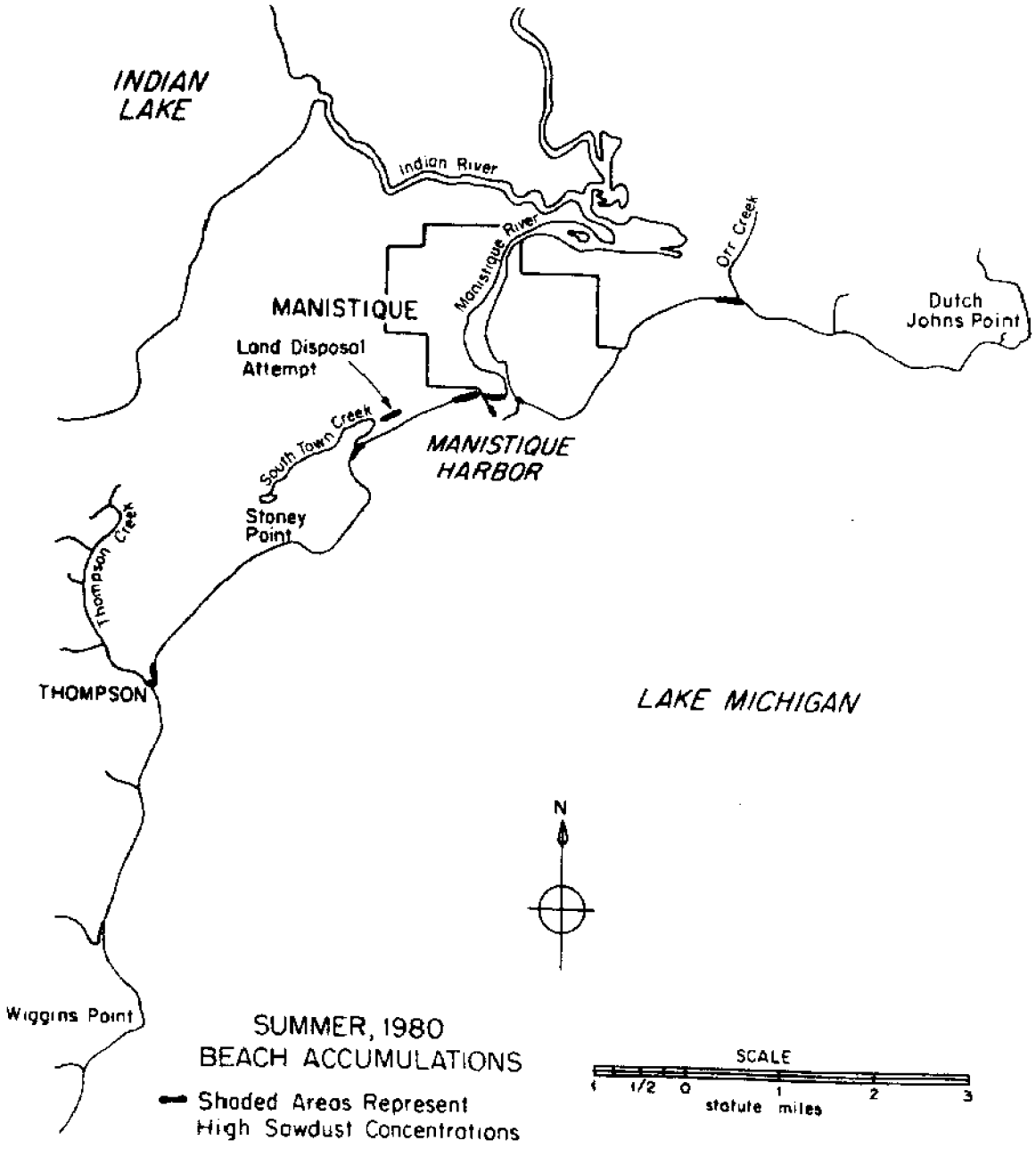


FIG. 4. Summer, 1980, beach accumulations.

When the sawdust accumulations of each season are compared, one concludes that there are five areas that consistently have deposits from September through June. The mouths of Thompson Creek, Southtown Creek, and Orr Creek are major collecting areas for wood debris. Immediately east and west of Manistique Harbor are two other prime locations. The locations of these five areas compare well with those mentioned by Manistique residents.

The site of highest concentration is located immediately west of Manistique Harbor. Here, the breakwater and shoreline create a funneling effect by catching waves and channeling suspended wood debris into the corner formed by the shoreline and breakwater. Quantities 2 feet thick that spread 25-30 yards up from the waterline were observed during the fall months. The mouths of Thompson, Southtown, and Orr creeks are often altered by sawdust mounds. The opening of Southtown Creek into Lake Michigan has been observed 40 yards west of its usual location, quite likely due to accumulation of the waste material.

The largest accumulations of sawdust waste occur during the fall months because of the strong, predominantly southerly winds which prevail during the late summer and fall. Suspended wood waste in the Manistique River plume and near-shore waters is, therefore, pushed directly into the shore locations that are mentioned above. Beach deposits that have become resuspended are also pushed into these locations. Manistique receives extreme wave action because of its location on the northern shore of Lake Michigan. Strong southerly late summer and fall winds increase the likelihood of sawdust and wood chips being washed ashore on the Manistique shoreline.

WEATHER AND CURRENT INFORMATION

Wind data for recent years were compiled from these sources:

a) The Manistique Airport: Weekly wind speed and direction information from December, 1978, through December, 1979.

b) Inland Lime and Stone Company: Wind direction only, from April through October, 1978.

c) Our observations: Wind direction and estimated speeds, October-November, 1979, and June, 1980.

The wind directions can be summarized as follows:

April, 1978 - Almost all winds had a northerly component. Only 1 day with southerly winds was recorded. Average wind direction, 0°, N.

May, 1978 - Again, most winds were northerly, with a larger than usual number of observations (10) with easterly (NE, E, or SE) winds. Average direction, 40°, NE.

June, 1978 - Winds were highly variable, with 11 wind observations from the N to E (0° to 90°) quadrant, 2 from the E to S (91° to 180°) quadrant, 6 from the S to W (181° to 270°) quadrant, and 8 from the W to N (271° to 359°) quadrant. Average direction, NNW, 350°.

July, 1978 -

0° - 90°	9 observations
91° - 180°	3 observations
181° - 270°	10 observations
271° - 359°	5 observations

Average direction, 170°, SSE

August, 1978 - 0° - 90° 4 observations

91° - 180° 5 observations

181° - 270° 8 observations

271° - 359° 5 observations

Average direction, 225°, SW

September, 1978 - 0° - 90° 8 observations

91° - 180° 5 observations

181° - 270° 8 observations

271° - 359° 5 observations

Average direction, 180°, S

October, 1978 - 0° - 90° 5 observations

91° - 180° 4 observations

181° - 270° 12 observations

271° - 359° 5 observations

Average direction, 245°, WSW

January, 1979 - 5 observations, all from 300° - 350°, average direction, 330°, NNW, average speed, 6 knots.

February, 1979 - 7 observations, all had northerly component, average direction, 25°, NNE, average speed, 7 knots.

March, 1979 - 4 observations, all had northerly component, average direction, 290°, ENE, average speed, 5 knots.

April, 1979 - 1 observation, 80°, 8 knots.

May, 1979 - 1 observation, 350°, 8 knots.

June, 1979 - 2 observations, 270° and 350°, average speed, 7 knots.

July, 1979 - 2 observations, 140° and 340°, average speed, 11 knots.

August, 1979 - 4 observations, average direction 270°, W, average speed, 10 knots.

September, 1979 - 1 observation, 140°, 13 knots.

October, 1979 - 9 observations, all but 2 had a western component. Average direction, 280°, WNW, average speed, 10 knots.

November, 1979 - 6 observations, all but one between 165° and 280°, average direction, 215°, average speed, 12 knots.

December, 1979 - 2 observations, 30° and 240°. Average speed, 15 knots.

June, 1980 - 16 observations. Winds were strong and variable during the first half of the month, but northerly directions were predominant. The last half of the month showed reduced wind speeds, with all winds from southerly directions.

In summary, these observations showed winds predominantly from northerly directions during the winter and spring months, with southerly winds predominant in the summer and fall months. In general, as expected, southwesterly winds were predominant in these warmer months.

Older weather data, for the period 1921 to 1933 inclusive, were obtained from the U.S. Army Corps of Engineers for Escanaba, Michigan, which is about 60 miles west of Manistique. They are summarized by average duration and velocity for eight directions in Table 2.

These data clearly show that northerly winds tended to be stronger in this area and that winds with a westerly component were predominant. This is consistent with our more recent wind data.

The questions of the predominant lake currents in the Manistique area and the effects of winds on changes in these currents are pertinent to our

TABLE 2. Average winds at Escanaba, Michigan, 1927-1933.

Direction	Average Duration (% of winds)	Average Velocity (mph)
N	18%	11.9
NE	10%	10.4
E	4%	8.1
SE	4%	7.9
S	23%	9.2
SW	14%	8.1
W	9%	7.5
NW	18.7%	10.1

investigation of possible movements of wood waste deposits by water currents. Interviews with Manistique area residents indicate a predominance of west to east (clockwise) longshore currents in the area. Our limited observations in September-December, 1979, and June, 1980, support this contention. The Manistique River plume, which is generally quite visible, curves to the east as it enters Lake Michigan. However, there are exceptions to this. During one period of strong south to southeast winds, in the spring of 1980, the plume curved sharply to the west at the end of the breakwater, and was visible for about one-half mile west of the river mouth.

As will become obvious in later sections of this report, the need for extensive current data is obviated to a great extent by the observed distributions in wood-waste deposits. For this reason, in part, we did not conduct drift bottle studies of currents. Other reasons included severe time

constraints imposed by boat problems and our observations of the variability in the longshore currents revealed by the river plume.

However, should future workers find a need for more detailed current data, we suggest that the current modeling computer program (Appendix B) developed by Dr. Guy A. Meadows of the University of Michigan's Department of Atmospheric and Oceanic Science be explored.

SCUBA SURVEY RESULTS

Our program of SCUBA investigation of the bottom of Lake Michigan, near Manistique, was somewhat limited compared to our original plan. This was caused by extreme weather conditions during much of the fall of 1979 and by weather and boat problems in the spring of 1980. Nevertheless, our survey was extensive and the overwhelming feature of our observations is the lack of any evidence of wood waste deposits outside of the shallow waters very close to the mouth of the Manistique River and in the river itself. Our observations are summarized below.

Six fall survey dives were made in 1979. Only three of these dives extended out of Manistique Harbor. Every survey within the harbor found sawdust (Figure 5). The dives indicate that large concentrations of sawdust cover approximately 75 to 80% of the harbor bottom. Sawdust was found close to shore, along the two breakwaters, and within the harbor channel. We have made a conservative estimate of the sawdust thickness to be 3 feet. Only sawdust was observed in the harbor; no slabs or large logs were seen. Harbor channel concentrations indicate that the sawdust is either moving down the river or it is washing in from peripheral areas of the harbor.

Two survey dives were also completed around Stoney Point, located west of

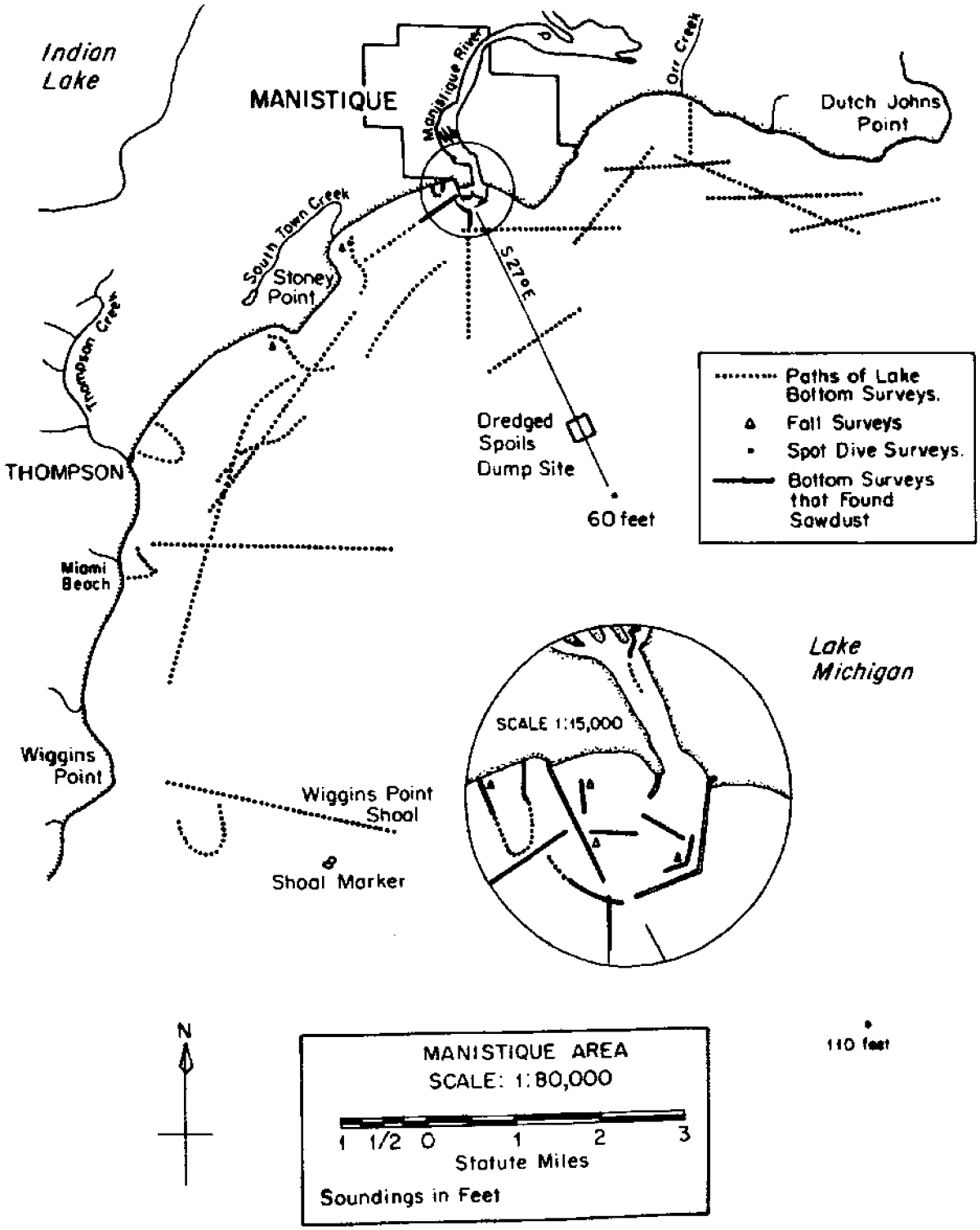


FIG. 5. Manistique area.

the Manistique Harbor. This area was clear; only limestone and sand were observed.

May and June dives were more extensive, covering an area west as far as Wiggins Point and east to Dutch Johns Point. Twenty-six dives were made. Large areas of the Lake Michigan bottom were observed by towing two SCUBA divers by boat. The dive locations included the most likely collectors of wood waste: distinct drop-offs and holes. The entire length of shoreline from Wiggins Point to Dutch Johns Point was observed at average depths from 10 to 30 feet (Figure 5). Dives were also made at the mouths of Thompson, Southtown, and Orr creeks. Additional surveys to a depth of 110 feet were made as far as 10 miles from Manistique Harbor. The Wiggins Point Shoal area, the U.S. Army Corps of Engineers' dredged spoils dump site, and sections located around the harbor mouth were of major interest. One dive was made in the eastern channel of the Manistique River, beginning at a point 1,500 feet from the mouth of the river and covering a 600 feet section downstream to a point opposite the commercial fisheries.

No sawdust was observed in Lake Michigan beyond 1 mile from Manistique Harbor. Figure 5 shows all sawdust observed during SCUBA surveys. Surveys found that only the harbor mouth and to 1,000 feet west of the harbor contained any sawdust concentrations. Sawdust in these areas was up to 2 feet deep in small patches. The Manistique River dive, from the eastern channel to the commercial fisheries, showed logs, wood chips, and sawdust in slow water areas. All other areas contained limestone rock slabs, boulders, clay, sand, and large concentrations of silt.

Wiggins Point Shoal has a varied topography and was thought to be a likely location for sawdust deposits; however, no sawdust was located. The U.S. Army

Corps of Engineers' dredged spoils dump site and a straight line transect from the site to the harbor (S 27°E bearing) was observed. Only sites of dredged rocks were seen; no sawdust or wood debris were observed. One dive made approximately 5 miles south (S 27°E) from the harbor in 110 feet of water showed no sawdust, slabs, or other wood debris. An important feature of the lake bottom at this depth is the presence of ripples, 4-5 inches deep and spaced 2-2.5 feet apart, in the sand. The presence of ripples at 110 feet indicates that the Lake Michigan bottom in the Manistique area is a high-energy environment. Because of this energy and the fact that the topography is basically flat, the lack of sawdust in these areas is not surprising. Figure 6 shows the depths of the water around Manistique.

CONCLUSIONS AND RECOMMENDATIONS

The inescapable conclusion of our SCUBA study is that there is little or no evidence to support the notion that a large body of sedimented wood waste products exists in the waters surrounding Manistique. This means either that the deposits which litter the beaches originate from some faraway location on the Lake Michigan bottom or that they are the result of deposition, washout and re-suspension, and re-deposition of near-shore accumulations. The latter seems to us to be the more likely explanation, since the wind and weather patterns in the area indicate that material near the shore would most likely be held in the nearshore zone by wind and wave action.

The extremely thick layers of wood-wastes in the Manistique River and harbor indicate that this continues to be a major source of wood-wastes added to the lake. The majority of the sawdust in the river is probably old. If these

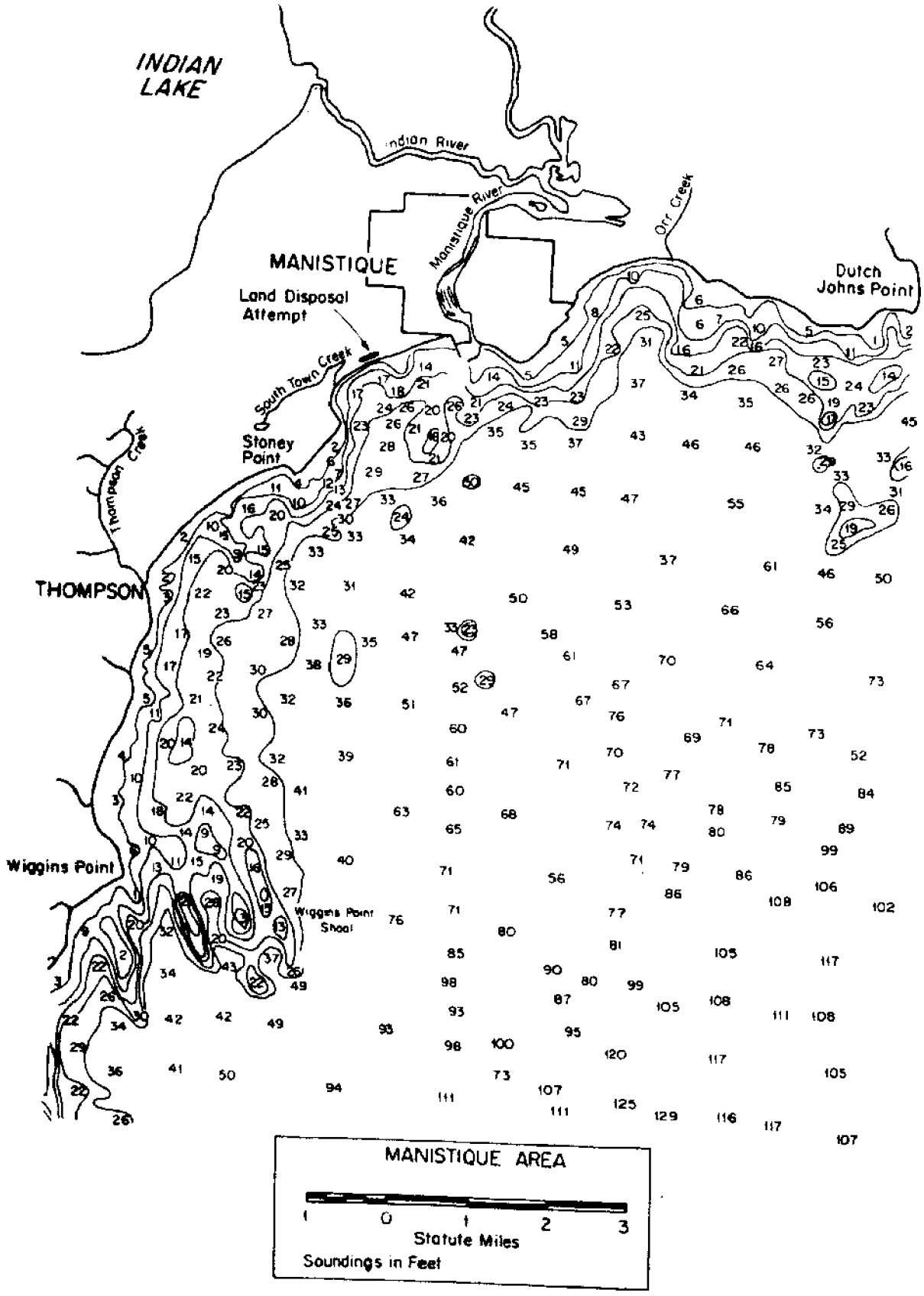


FIG. 6. Soundings in the Manistique area.

conclusions represent the situation correctly, as we feel they do, then the implications for any attempted long-term solution to the problem are relatively straightforward.

If the existing bottom deposits of sawdust and wood wastes in the river and around its mouth can be removed, future additions of sawdust to the lake will be minimal. Annual early spring or late fall cleanups of deposits along the shoreline near Manistique for the next few years would remove most of the remaining wood-waste accumulations.

This dredging and shoreline cleanup would, of course, be an undertaking of considerable effort and expense, but our study reveals that the problem appears to be localized in the river and in the area around its mouth.

APPENDIX A

Citizens Who Responded to Interviews, and Sample Questionnaire

Mr. and Mrs. Vern Bernard, managers, Schoolcraft County Airport

Mr. Les Bouschor, local citizen

Mr. Casey, local commercial fisherman

Mr. Leif Christensen, Plant Manager, Manistique Pulp and Paper Company

Mr. Loyd Christensen, driftwood collector and gift shop owner, Manistique

Mr. George Danko, County Commissioner, Schoolcraft County

Mr. and Mrs. Joseph A. DeWinter, shoreline residents

Mr. Al Hepker, county extension agent

Mr. Ron Howell, City Manager, Manistique

Mr. Oscar Jasmin, local citizen

Mr. Robert Knoph, real estate owner

Mr. Earl H. LeBrasseur, Manistique resident historian

Mr. Fred Lesica, local citizen

Mr. Ada Livermore, local citizen

Mr. Mike Lyundberg, local citizen

Ms. Helen McNally, local citizen

Mayor Mary Moffat, Mayor, Manistique

Mr. and Mrs. Muligan, shoreline residents

Mrs. Hasell Osterhout, Thompson resident historian

Mr. Keith Perry, local fisherman

Mr. and Mrs. Paul Sablak, shoreline residents

Mr. Clarence Sellman, local commercial fisherman

Mr. St. Pierre, local citizen

Mr. and Mrs. Tyler, shoreline residents

Mrs. Sherry Varnum, shoreline resident

Mr. Henry Weber, local citizen

Mr. and Mrs. John Weiss, Thompson Trailer Park owners

Mr. Ralph Williams, past owner of the Breakers Motel, Manistique

Mr. Normal Wood, local citizen

APPENDIX A

Sawdust Research Survey for Manistique and Schoolcraft County Residents

With the help of the Michigan Sea Grant Program, Northern Michigan University, Schoolcraft County, and the City of Manistique, research is being conducted concerning sawdust build-up along near shore areas in Manistique. This survey has been devised to determine sawdust location and extent along the Lake Michigan beaches. We hope, with your help, to better understand the sawdust problem. If you have any questions, or wish to help us in our project in any way, please write or call.

Thank you very much for your time and support.

Sincerely,

Stephen Wissler
Research Associate
Chemistry Department 1-227-2911
Northern Michigan University
Marquette, MI 49855

1. How long do you think the dust has been present?

2. At what times during the year does sawdust build up?

3. Where does it build up?

4. How much builds up? Please give rough dimensions of sawdust deposits.

5. Does the sawdust come and go?

6. Are weather conditions involved with the sawdust movement?

7. Do you have any suggestions concerning the sawdust problem in Manistique?

APPENDIX B

GREAT LAKES ENVIRONMENTAL RESEARCH LABORATORY OIL SPILL MODEL
FOR INFORMATION CALL R.L. PICKETT FTS 378-2282

ENTER SUB-GRID ORGIN(LATITUDE,LONGITUDE) SEPERATED BY A COMMA(E.G. 44.2,82.0)

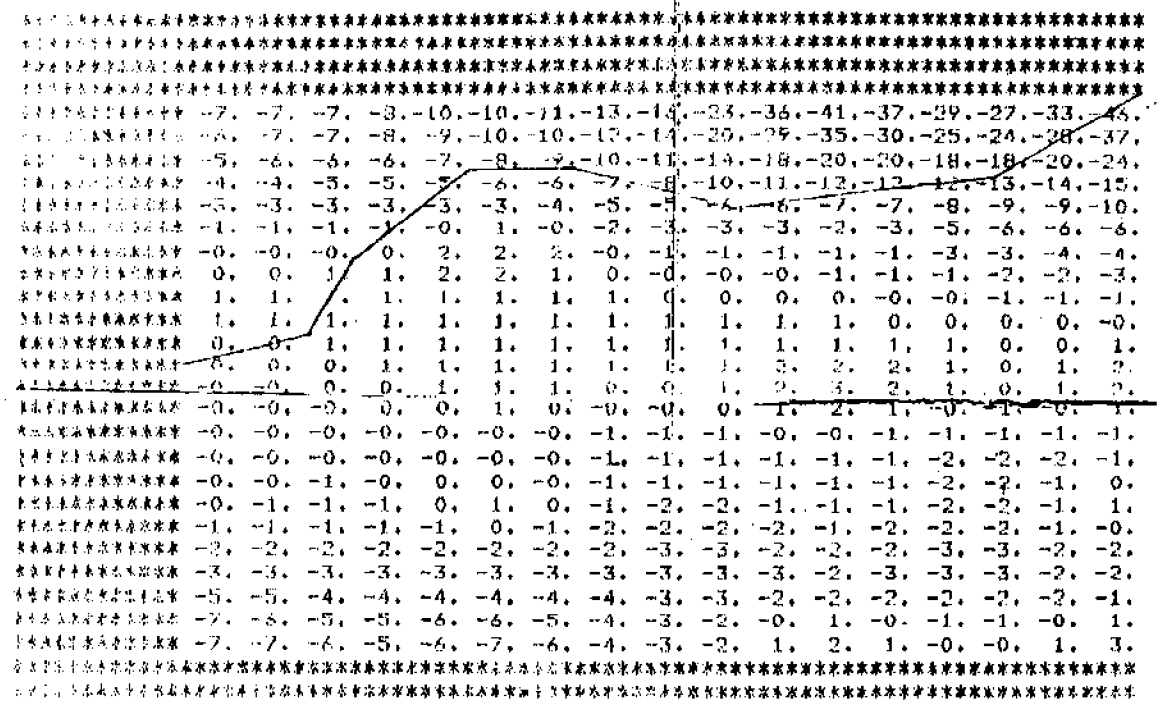
[illegible]

SUB-GRID ORIGIN ON LAND

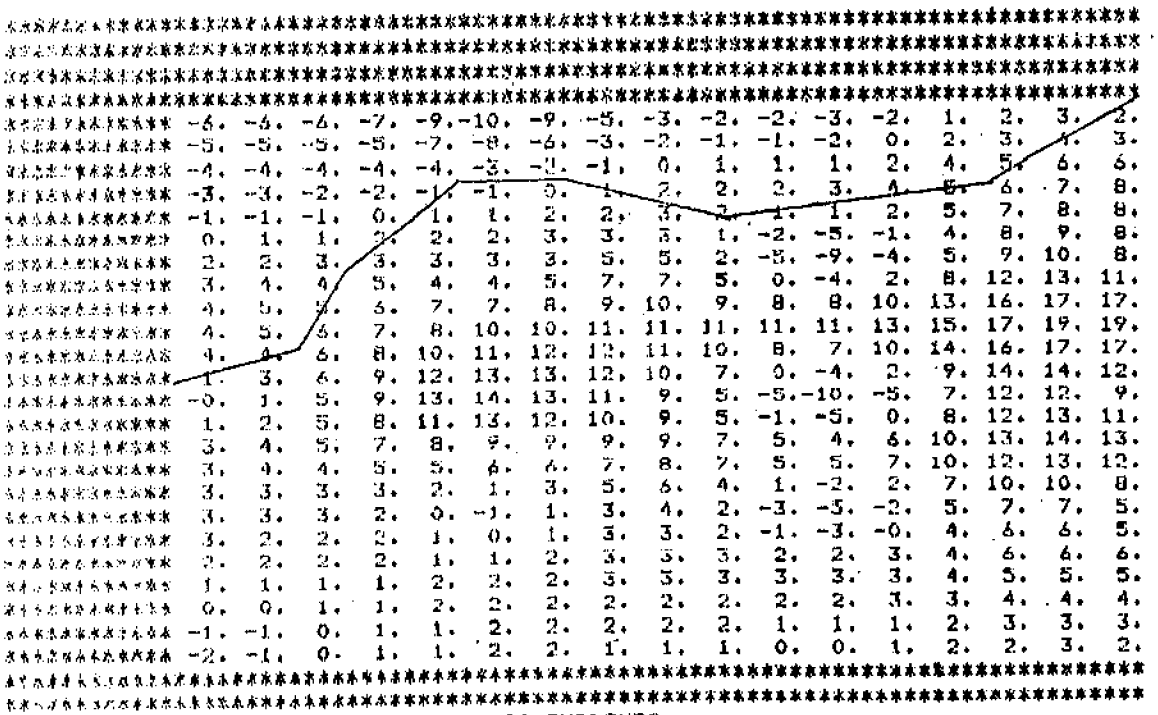
DO YOU WANT TO SEE PRESENT SUB-GRID CURRENTS
YES

EAST COMPONENT OF CURRENT (CM/SEC)

Line indicates approximate shoreline.



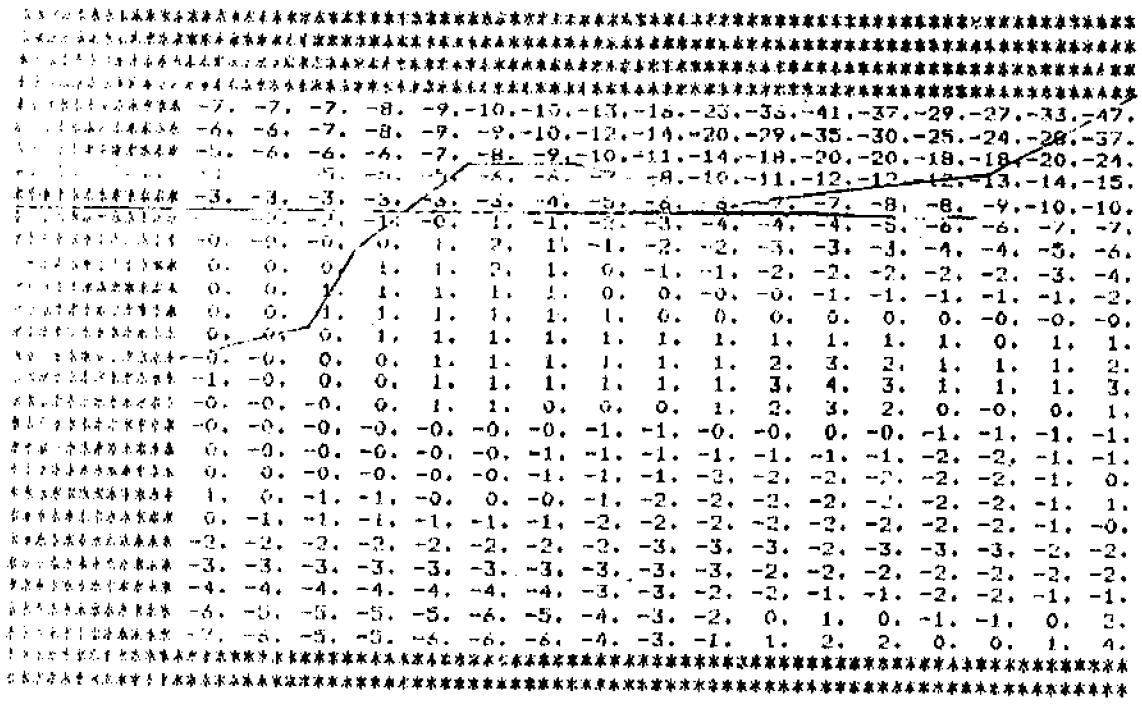
NORTH COMPONENT OF CURRENT (CM/SEC)



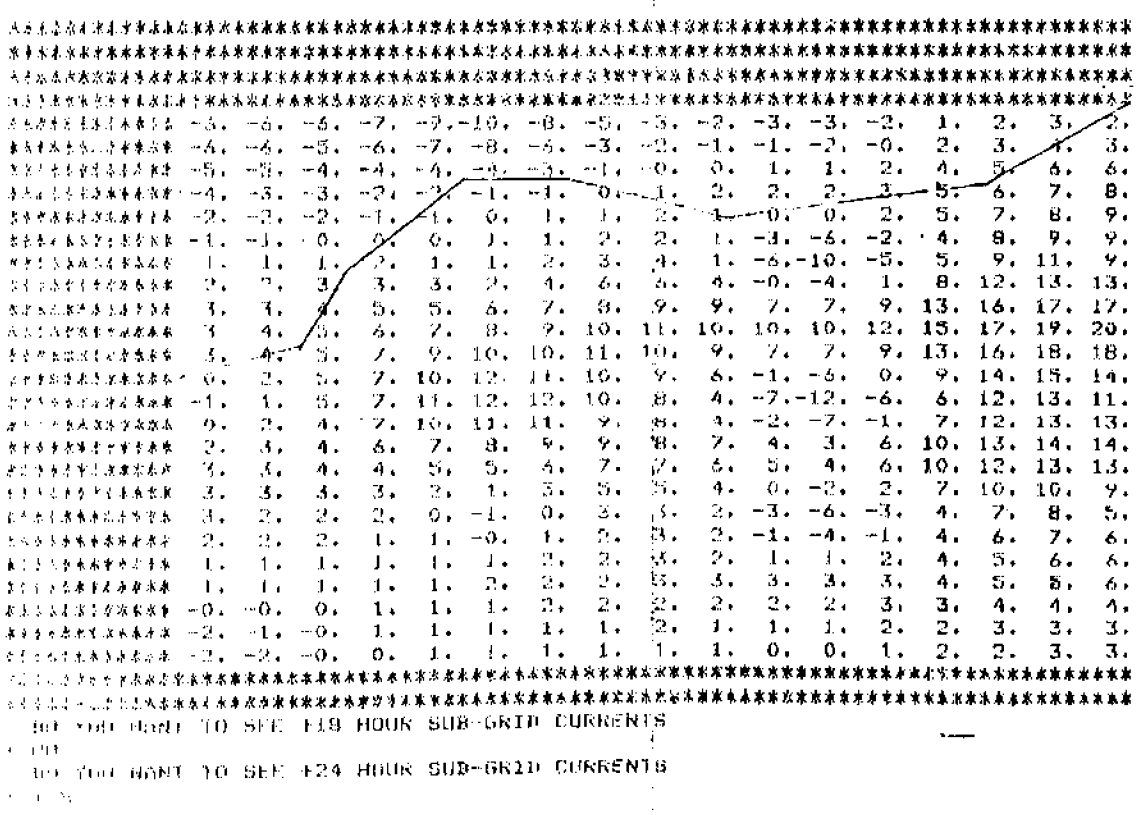
DO YOU WANT TO SEE +6 HOUR SUB-GRID CURRENTS
? NO

DO YOU WANT TO SEE +12 HOUR SUB-GRID CURRENTS
? YES

EAST COMPONENT OF CURRENT (CM/SEC)



NORTH COMPONENT OF CURRENT (CM/SEC)



DO YOU WANT TO SEE 119 HOUR SUB-GRID CURRENTS

DO YOU WANT TO SEE 124 HOUR SUB-GRID CURRENTS

BIBLIOGRAPHY

Bagnold, R.A. 1946. Motions of waves in shallow water; interactions between waves and sand bottom. Proc. Roy. Soc. (London), Series A. 187:1-15.

Bajournas, L., and D.B. Duane. 1969. Shifting offshore bars and harbor shoaling: J. Geophys. Res. 72: 6195-6205.

Crowe, W.S. 1977. Lumberjack - Inside an Era in the Manistique, Michigan Region. Senger Publishing Company, Manistique, Michigan.

Garland, H. 1947. Inventory of Wood Using Industries of the Upper Peninsula of Michigan. Lansing, Michigan, pp. 97-98.

Hoyt, J.H. 1971. Field Guide to Beaches. ESCP pamphlet series PS-7. Boston: Houghton Mifflin Co.

King, C.A.M. 1961. Beaches and Coasts. London: Edward Arnold Ltd.

_____, and W.W. Williams. 1959. The formation and movement of sand bars by wave action. Geog. Jour. 113: 70-85.

Komar, P.D. 1976. Beach Processes and Sedimentation. Englewood Cliffs, New Jersey: Prentice-Hall, Inc.

Miller, R.L., and J.M. Zeigler. 1958. A model relating sediment patterns in the region of shoaling waves, breaker zone and foreshore. J. Geol. 66: 417-441.

_____, and _____. 1964. A study of sediment distribution in the zone of shoaling waves over complicated bottom topography, pp. 135-153. In Papers in Marine Geology, ed. R.L. Miller. New York: Macmillan.

Manohar, M. 1955. Mechanics of Bottom Sediment Movement Due to Wave Action. U.S. Army Corps of Engineers, Beach Erosion Board Tech. Memo No. 75.

Ore, Jack. 1979. Lumberjacks and River Pearls. Manistique, Michigan: The Pioneer-Tribune.

Sawyer, Alvah. 1911. A History of the Northern Peninsula of Michigan and Its People. Vol. 1, pp. 350-361. Chicago: The Lewis Publishing Co.

Scott, T. 1954. Sand Movement by Waves. U.S. Army Corps of Engineers, Beach Erosion Board Tech. Memo No. 38.

Standing, Linda J. 1970. Longshore sediment transport near Glenn, Michigan. In Studies in Geology, No. 1. Dept. of Geology, Western Michigan University, Kalamazoo, Michigan. Reprinted in Richard A. Davis (ed.), Coastal Sedimentation of Southeastern Lake Michigan: Field Trip Guidebook. Dept. of Geology, Western Michigan University, Kalamazoo, Michigan.