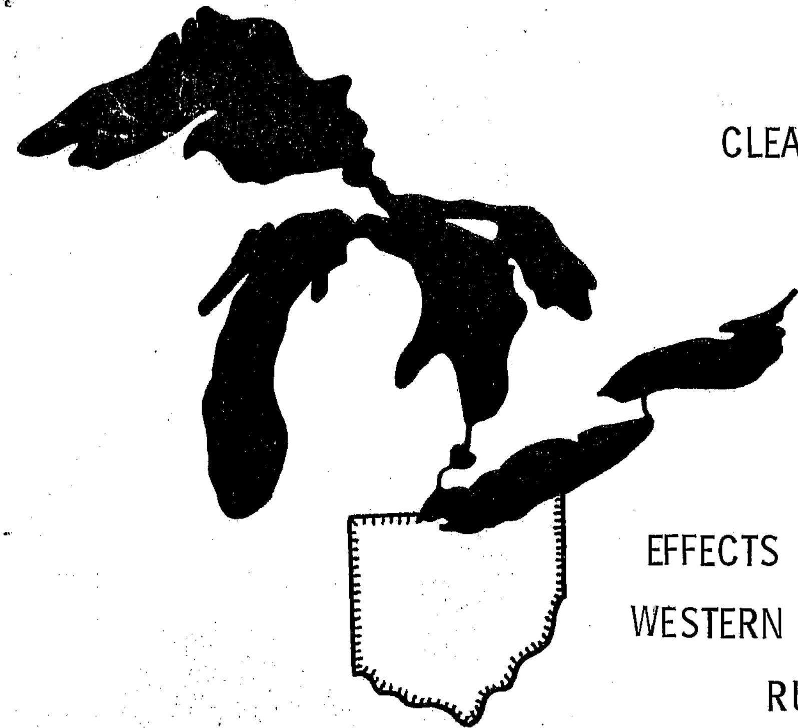

CLEAR TECHNICAL REPORT NO. 65

EFFECTS OF TRIBUTARY LOADING TO WESTERN LAKE ERIE DURING SPRING RUNOFF EVENTS

by

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TABLE OF CONTENTS

INTRODUCTION

Suspended sediments and associated chemical contaminants in western Lake Erie originate from at least four sources: (1) land runoff and channel erosion via tributaries, (2) resuspension of bottom sediments and erosion of shore material by wave action, (3) vessel operation, including dredging and (4) atmospheric contributions. Because the Maumee River is one of the major contributors of sediment and chemical contaminants the high level of these materials has been suspected of having a profound effect on the western basin of Lake Erie.

The results of the 1975 pilot study in Maumee Bay (NASA, 1975 and Herdendorf, 1975) demonstrated the advantages of coordinated shipboard/aircraft surveys in obtaining information on the effects of river loadings and dispersal of tributary-derived pollutants. Information on the resuspension of sediments by wave action was also obtained during the pilot study. Based on the experience gained in 1975, the project was continued and expanded in the spring of 1976. This report deals with the preliminary results of the second year of this project.

The 1976 study was also undertaken in close coordination with the NASA/Lewis Research Center. The objective of the second year was to conduct comprehensive surveys of the Maumee River and Detroit River mouths, and adjacent areas of western Lake Erie immediately after ice "break-up" and to continue these surveys during the major tributary runoff events which affect the western basin. Following the major effects, cruises and overflights were planned to sample: (1) areas of tributary plumes, (2) areas of major sediment resuspension, (3) offshore areas of the western basin, (4) island areas of the western basin and (5) interface of the western and central basins of the lake.

These surveys were intended to establish: (1) the areas of direct tributary impact, (2) the areas and amount of sediment resuspension and (3) a chronology of western basin transport patterns including the long-term transport of tributary inflow throughout the basin. A combination of aircraft and shipboard data has been utilized to interpret the processes in western Lake Erie and respond to the project objectives.

METHODS

The field aspects of the project covered the period February 18, 1976 to June 10, 1976. During this period a total of 10 cruises (Table 1) resulting in 36 ship-days, were undertaken. Three vessels (R/V Hydra - 65 ft., Sea Ray - 24 ft. and Boston Whaler - 21 ft.) were used to visit 172 stations (Fig. 1); at times they were operated simultaneously to obtain synoptic inshore and offshore data. During the same period aircraft overflights were made on 16 days and Landsat coverage on four days. Concurrent aircraft/ship coverage occurred on 8 days (Fig. 2). The NASA/Lewis Research Center aircraft was equipped with a 10-channel, ocean-color scanner (OCS) and was operated at an altitude of 12.5 km. Details of the aircraft operation and image processing are contained in a companion report prepared by NASA.

The geographic coordinates of the 172 stations are listed in Table 2. The stations visited during each cruise date are presented in Table 3. The sampling program at the Maumee River mouth was initiated on February 18, 1976, the first day the harbor area was free of ice. During the following week cruises in the western basin were limited by the margin of the ice front which precluded sampling east of West Sister Island. By early March, the western basin was free of ice and the entire basin could be sampled.

The chemical and physical parameters measured during the cruises are listed in Table 4. Surface and bottom water samples were taken at most stations with a submersible pump system or a 5-liter Niskin sampler. Filtered samples (Whatman GF/C filter pads) were analyzed for soluble reactive phosphorus, ammonia, nitrate + nitrite and dissolved silica;and unfiltered samples for total phosphorus on board ship with a Technicon Auto Analyzer II. Alkalinity was determined at selected stations by HCl-titration. Calcium, magnesium, chloride and sulfate were measured with Orion specific-ion probes fitted to an Orion model 407 pH meter. Cadmium, chromium, copper, lead and nickel, and zinc were determined using standard atomic absorption procedures prescribed for a Perkin-Elmer model 303AA. Mercury was analyzed using cold vapor flameless atomic absorption procedures with a PE-303 AA. Determinations of particulate carbon and nitrogen were performed according to standard procedures for a Perkin-Elmer model 240 elemental analyzer. Chlorophyll was determined with a Varian spectrophotometer, programmed for a, b, and c wave lengths and linked to a computer for calculating pheopigment corrections. Chlorophyll was analyzed according to procedures outlined by Strickland and Parsons (1968). Concentrations of chlorophyll were calculated using equations of SCOR/UNESCO (1966). Pheopigments were determined according to Lorenzen (1967). A Martek Mark II model A monitor system (an integrated multi-parameter instrument for simultaneous measurements) was utilized for measures of temperature, conductivity, pH, depth, and dissolved oxygen. Transparency was measured with a 30-cm Secchi disk, transmissibility with a Martek transmissometer, light penetration with Kahl submarine photometer and turbidity with a Hach model 2100 turbidometer. Suspended solids were determined using standard muffle furnace techniques. Phytoplankton samples were taken with a Niskin sampler, zooplankton samples with a 50-cm diameter, no. 20 net (80 micron mesh) and benthic invertebrates with a Ponar sampler using a no. 40 sieve (0.425 mm mesh).

CHRONOLOGY OF EVENTS IN THE WESTERN BASIN OF LAKE ERIE

This section of the report traces the sediment-related events in western Lake Erie from mid-February to early June 1976. A chronology has been developed by analyzing Landsat and Ocean-color scanner images of the basin. Inferred water flow patterns have been constructed for each scanner image. These depictions are presented in a figure following each image. The interpretations of the events illustrated were aided by reference to Toledo wind data (Table 5) and discharge records for the Maumee River (Fig. 2) and Detroit River (Fig. 3) as well as water quality information from ship surveys.

February 13, 1976

Landsat image (Fig. 4) shows that most of the western basin is ice covered. The Maumee River is icebound and no discharge plume is discernible.

February 23, 1976

Scanner image (Fig. 5) shows that the water is open in the western part of the basin and that the ice margin is in the vicinity of West Sister Island. Westerly winds of moderate velocity (Table 5) on the preceding day contributed to this movement. The turbid flow of the Maumee River can be seen in Maumee Bay and along the Ohio shoreline as far east as Catawba. Figure 6 is an interpretation of the water flow patterns on this data. The Detroit River flow is clear because Lake St. Clair is still frozen and not subject to sediment resuspension. The turbidity observed along the south shore is suspected to be the result of tributary loading rather than resuspension because of the calm lake conditions and the shielding by the ice. The Maumee River flow, 70,000 cfs, was at peak discharge on this date (Fig. 2).

February 25, 1976

Scanner image (Fig. 7) and water flow interpretation (Fig. 8) show that the Maumee River continues to be very turbid while the Detroit River flow is clear. The Maumee flow appears to have moved northward along the Michigan shore while wedges of clear Detroit flow have reached the Ohio shore near Little Cedar Point and Locust Point. Detroit River flow at this time, 230,000 cfs, was also high (Fig. 3). The turbid water along the Ohio shore between these wedges may represent both Maumee River flow and offshore resuspension due to a moderate southerly wind (Table 5.)

March 8, 1976

Scanner image (Fig. 9) shows the second major discharge event of the Maumee River at 52,000 cfs (Fig. 2). Tributary discharge and resuspended sediment has spread along the south shore and north through the Bass Islands area (Fig. 10). The Detroit River also experienced a peak discharge at 240,000 cfs (Fig. 3) which can be seen as a series of turbid bands near the river mouth. These bands may be the result of seiche activity on Lake St. Clair which produced alternating clear and turbid water in the Detroit River.

March 11, 1976

Landsat image (Fig. 11) shows a major input of turbid water into the western basin from both the Detroit and Maumee Rivers. It is interesting to note that the eastern half of Lake St. Clair is significantly more turbid than the western half. This division persists in the Detroit River and in the discharge plume in western Lake Erie. The scanner image (Fig. 12) and the water flow interpretation (Fig. 13) show the clearer flow leaving the west side of the Detroit River mouth and encountering the Ohio shore near Locust Point. The Maumee River appears to be contributing material to the north along the Michigan shore and to the east along the Ohio shore. Resuspension has taken place along the Ohio shoreline and this material has flowed north into the islands area and east into the central basin via the South Passage. A moderate northeast wind (Table 5) has driven a clearer wedge of central basin water into Sandusky Bay.

March 15, 1976

Scanner image (Fig. 14) and flow pattern interpretation (Fig. 15) show the influence of an east wind (Table 5) which has shifted the Detroit River sediment plume toward the Michigan shore. Resuspension continues to be evident along the Ohio shoreline.

March 22-25, 1976

Scanner images (Figs. 16, 18 and 20) and flow pattern interpretation (Figs. 17, 19 and 21) show the results of low flow in the Maumee River and light southwesterly winds. Lake St. Clair has cleared, diminishing the sediment plume at the mouth of the Detroit River. This series of images shows the accumulated effect of several days of southwest wind. Resuspended sediment from west of the Bass Islands is seen to drift through the islands area and out into the central basin. The clockwise gyre of flow from the Maumee River, then northward along the Michigan shore, then southeastward into the western basin near the Detroit River mouth is also well illustrated in this series of images. The main portion of the western basin remained clear during this period.

April 3-7, 1976

Scanner images (Figs. 22 and 24), flow pattern interpretations (Figs. 23 and 25) and Landsat image (Fig. 26) show the Michigan shore gyre. This series of illustrations depicts the increasing influence of westerly winds as the turbid water from the east side of the gyre is driven progressively eastward. The same situation is illustrated in the island area as resuspended sediment is progressively transported into the central basin. Peculiar counter-currents formed tight gyres along the Ohio shore of the central basin. By the end of this period, westerly winds and associated wave action had resuspended sediment in the eastern half of Lake St. Clair resulting in a plume on the east side of the Detroit River mouth.

April 12-13, 1976

Scanner images (Figs. 27 and 29) and flow pattern interpretations (Figs. 28 and 30) show that strong northerly winds preceding this period produced sediment resuspension along the Ohio shore while retarding the gyre along the western shore. Possibly the western nearshore area had been depleted of recent sediment by the westerly movement described for April 3-7, 1976. A moderate sediment plume was present on the east side of the Detroit River mouth, but the predominant clear flow from this river formed a wedge between sediment-laden water near Locust Point. This wedge of Detroit River water appears to have forced the displaced turbid water northward and eastward into the islands area. Both the Detroit and Maumee Rivers were near their minimum spring flows during this period.

April 29, 1976

Scanner image (Fig. 31) and inferred flow patterns (Fig. 32) illustrate the movement of sediment-ladened water along the western side of the Bass Islands under the driving force of Detroit River flow. The turbid water appears to not only move eastward through the islands area but northeastward toward Pelee Passage. A moderate plume from the east side of the Detroit River persists and extends to the central portion of the western basin.

May 12, 1976

Scanner image (Fig. 33) shows little evidence of suspended material in the western basin. The inferred flow patterns (Fig. 34) indicate that clear Detroit River water is influencing most of the basin. Although the winds on the preceding day were moderately brisk from the northwest (Table 5), wave resuspension does not appear to have occurred along the Ohio shore.

May 22, 1976

Landsat image (Fig. 35) shows a similar condition to the scanner image of ten days earlier. The western basin appears to have been cleared of the highly-turbid water of early spring. Maumee Bay and Sandusky Bay are remarkably clear in this image.

June 5-7, 1976

Scanner images (Figs. 36 and 38) and inferred flow patterns (Figs. 37 and 39) show the results of a minor runoff event of the Maumee River (Fig.2) and the rapid cleansing of the western basin. The northern flow of Maumee River water appears to have been diverted to the east by the Detroit River flow which removed any trace of the event within two days.

RESULTS OF SHIP SURVEYS

The preliminary results of the ship surveys are reviewed in this section of the report. The following parameters have been found to provide information on tributary discharge patterns, areas of water quality impairment and sediment resuspension. Selected parameters measured on shipboard during overflights are presented in Table 6 and trace metal data are given in Table 7.

Water Temperature

Cruise 2 (February 24-25, 1976) temperatures show Maumee Bay water at 5°C warmer than Detroit River flow (Fig. 40). The Maumee River appears to be influencing the Michigan and Ohio nearshore areas. By March 8-10, 1976 (Fig. 41) the warming trend had spread westward to the islands area but the northern portion of the Michigan shore remained at a minimum temperature. April and May temperature contours (Figs. 42, 43 and 44) show the classical pattern of cooler Detroit River flow penetrating deeply into the western basin and the small area of warmer water influenced by the Maumee River.

Conductivity

Conductivity is a reliable indicator of dissolved contaminants in tributary discharge and it is useful in tracing flow patterns within the lake. In late February (Fig. 45) Maumee River flow was about 33% more mineralized than mid-basin water and appeared to be flowing northward along the Michigan shore and southeastward along the Ohio shore. In early March (Fig. 46) this trend continued with the mid-basin being influenced by the Detroit River. The conductivity patterns for mid-April (Fig. 47) show the sweep of Ohio shore water masses northeastward through the islands area. The low-conductance water of the Detroit River was three times lower in mineralization than the Maumee River.

Suspended Solids

The February 24-25, 1976 survey of suspended solids (Fig. 48) shows the effect of peak Maumee River discharge with highly turbid conditions in Maumee Bay and adjacent portions of western Lake Erie. The early March survey (Fig. 49) shows the moderately high concentrations of solids in the Ohio and Michigan nearshore areas. The mid-April survey (Fig. 50) indicates sediment resuspension along the Ohio shore and west of the Bass Islands. The northern portion of the Michigan shore shows the influence of the less turbid Detroit River flow. By the later part of April (Fig. 51) the turbid water had moved progressively eastward into the islands area. The mid-May survey (Fig. 52) indicates a significant clearing of the western basin water. The suspended solids patterns are consistant with the scanner images discussed in the previous section.

Figures 53 and 54 are illustrations of the volatile, largely organic, fraction of the suspended solids. In February the highest concentrations were found in Maumee Bay and the adjacent shorelines indicating a high discharge of organic debris. In mid-April an additional high concentration occurred west of the Bass Islands possibly indicating a high algae (diatoms) populations.

Phosphorus

The early March (Fig. 55) survey illustrates the typical phosphorus pattern in the western basin of Lake Erie. The Maumee River was discharging water containing over 900 ppb of total phosphorus (TP) while the Detroit River concentration was less than 50 ppb. The Detroit River flow penetrated deeply into the basin, encountering the Ohio shore near Locust Point. The area of sediment resuspension appears to be confined to the areas of greater than 100 ppb of TP.

Chlorophyll

Chlorophyll a contour patterns for late February (Fig. 56) and mid-April (Fig. 57) are similar to the patterns for volatile suspended solids (Figs. 53 and 54). This is particularly the case along the Michigan shore and west of the Bass Islands where concentrations are high indicating a high rate of primary productivity. These areas are also supplied with high nutrient concentrations from the Maumee River which further fosters algal growth.

Trace Metals

Trace metals surveys for cadmium (Fig. 58), chromium (Fig. 59), copper (Fig. 61), lead (Fig. 61), mercury (Fig. 62), nickel (Fig. 63) and zinc (Fig. 64) were conducted during peak runoff in late February and early March. All of the metals, except cadmium, show a definite gradient from high concentration in the Maumee River to low concentration in the middle portion of the western basin. Mercury and zinc concentrations decreased rapidly in a lakeward direction from Maumee Bay in February during peak flow (Figs 65 and 66). However, in early March this is less discernible as the flow of the Maumee decreased and the flow of the Detroit River reached its peak (Fig. 67). Metals contamination of the western basin by these two tributaries appears to be significant.

SEDIMENT RESUSPENSION IN THE WESTERN BASIN OF LAKE ERIE

Recent multispectral scanner images of the western basin of Lake Erie indicate large masses of turbid water along the south shore and in the islands area (NASA, 1975). Several of the images were taken during periods of relatively low tributary flows, when the introduction of sediment to the basin from these sources was at a minimum. The turbid masses have been correlated with wind storms and associated waves which have resuspended bottom sediments in the shallow water areas of the basin. Data gathered by the Ohio Department of Natural Resources, Division of Geological Survey (Herdendorf, 1968; Herdendorf and Braidech, 1972) have been reanalyzed in an attempt to quantify the magnitude of sediment resuspension in the western basin during the spring, summer and early fall months.

Premise and Methods

Annual sedimentation can be expressed by the simple equation:

$$S = D - R,$$

where S is net sedimentation, D is the total material deposited and R is the material lost through sediment resuspension or erosion. Data obtained from sediment collection devices placed on several bedrock reefs and shoals in the western basin of Lake Erie (Fig. 68) indicated that a considerable amount of material (over 200 mm annually) was deposited during the spring, summer and fall of 1967, 1968, and 1969. However, information gathered during SCUBA diver surveys of the reefs shows that the sediment veneer over the bedrock is seldom greater than a few millimeters and is commonly absent. Therefore, if sedimentation in the above formula is considered to be zero, then sediment resuspension would be equal to the sediment deposited (material retained in the collection devices). Based on this premise the quantity of sediment resuspension in the western basin has been calculated.

The sediment collection devices (Fig. 69) used to measure deposition resuspension consisted of 2-liter wide-mouth Nalgene jars fitted with 40 cm-long drop tubes. The drop tubes were constructed of 54 mm-diameter PVC plastic tubing. To insure stability of the collectors while underwater, they were placed in a frame constructed of steel rods which were welded to a base plate. The plate, in turn, was secured to a 150 kg steel platform. Each platform held two collectors. On station, the collectors were filled with water and the platform was fitted with a marker buoy and lowered to the bottom. The collectors were normally retrieved bimonthly (April-October) and the platforms reset with fresh collection jars.

Collected sediment was measured and analyzed for grain size by sieve and hydrometer methods. Selected samples were analyzed for percent volatile solids on ignition as an indicator of organic content. Analytical procedures are more fully described by Herdendorf and Braidech (1972).

Deposition and Resuspension

Data from sediment collectors on six reefs indicate that a considerable amount of material was deposited during the spring, summer, and fall of 1967, 1968, and 1969. A summary of the amounts of sediment obtained from 16 periods of collection on Starve Island Reef, 11 on Crib, Toussaint, and West Reef, 10 on Kelleys Island Shoal, and 9 on Gull Island Shoal is given in Tables 8-10. Information from collectors set in deep water half a mile southwest of Gull Island Shoal for 3 periods of collection and another set in deep water 1 mile southwest of Gull Island Shoal for 6 periods is also contained in Table 10. During the approximately 102-day study in 1967, an average thickness of 1.0 mm/day of material was deposited. In 1968 the 173-day study yielded an average of 1.4 mm/day. A 175-day study in 1969 indicated an average rate of 1.0 mm/day for the reefs and 1.4 mm/day at the deepwater stations. Data from the deepwater collectors appear to be more indicative of permanent sedimentation.

Considerable variation was noted in the amounts of sediment collected on the individual reefs. Toussaint Reef, which is only 3.5 miles from the shoreline and is near the mouth of the Toussaint River, received the most sediment, over twice the amount that was collected on West Reef, Gull Island Shoal, or Kelleys Island Shoal, the reefs located the farthest from the mainland. Starve Island Reef, located in South Passage, received the second highest amount of sediment. This is probably due to its proximity to the Portage River flow and to the fact that high velocity currents in the constricted passage are capable of carrying more and larger particles. Crib Reef, only 1.3 miles lakeward of Toussaint Reef, received considerably less sediment than Tousssaint, indicating a shoreward source area for the sediment.

Seasonal variations in the deposition rates are also conspicuous. The spring deposition rate on Toussaint Reef was over 2 mm/day, but the summer rate was only 1 mm/day (Figs. 70 and 71). In 1967 and 1968 the other reefs showed similar patterns, with a progressive decrease in the amount of sediment collected from May to August (Figs. 70 and 71). In 1968, a sharp rise in the rates was noted in the fall (Fig. 71). Data from 1969 do not show as distinct a pattern but in general the trends are the same except for a high peak in early July at two of the stations (Fig. 72). This peak correlates with a severe storm that occurred on July 4, 1969, which may have caused significant resuspension of bottom sediment.

The results of grain size analyses of material obtained from the sediment collectors are given in Tables 11-13. In 1967, over 50 percent of the collected sediment on each reef fell between 20 and 45 microns in diameter, the medium and coarse grades of silt (Table 14). The highest percentages of sand were deposited in the spring. The high-velocity currents in South Passage may explain the 11.2 percent sand, the highest recorded, found in the spring collections at Starve Island Reef. Only small percentages of clay-sized particles were found in the spring samples; however, both Starve Island Reef and Toussaint Reef yielded fairly high percentages of clay during the summer. The trend of coarser sediment in the spring and finer material in the summer and fall was common to all the reefs. Similar patterns were observed for 1968 and 1969 samples.

Volatile-solids determinations (Table 15) indicate that contemporary sediments average about 10 percent organic matter. The highest concentration occurred on West Reef, the reef farthest from the mainland. The next highest concentration occurred on Crib Reef, the shallowest reef and the one with the most noticeable growth of filamentous green algae. An interesting peak in the percentage of volatile solids on both Starve Island and West Reef was noted for the period June 2-26, 1967. The increase in organic content corresponds to the period immediately following the spring plankton bloom when the remains would settle and become incorporated in the bottom sediments. A similar peak occurred for Crib Reef, but not until the following collection period, June 26 to July 10, 1967. Toussaint Reef showed a general increase in organic content throughout the 1967 period of collection.

Based on the observations that virtually all of the material deposited on the reefs was eventually resuspended, it is possible to estimate the rate and amount of resuspension in western Lake Erie. Considering the portion of the basin most susceptible to this process (Maumee Bay eastward through the island area to the central basin at water depths less than 25 feet), approximately 600 Km^2 or a water volume of 2.7×10^9 m^3 are affected. Also considering a mean deposition rate of 1.0 mm per day, a mean water depth of 4 meters, and assumming that resuspension occurs at least as fast as deposition (this is probably a minimum rate assumption), this would produce a resuspension concentration of 250 mg/l or a quantity of 6.75×10^5 metric tons of sediment within a single day.

DISCUSSION

The Maumee River is formed in Fort Wayne, Indiana by the merger of the St. Joseph River and the St. Marys River. The St. Joseph River originates in Hillsdale County, Michigan and flows southwest to Indiana. The St. Marys River originates in Shelby County, Ohio and flows northwest to Indiana. The Maumee flows from Fort Wayne through Defiance to Toledo and Lake Erie. The entire drainage basin is 6,586 square miles, 1,260 are in Indiana, 470 in Michigan and 4,856 in Ohio (Ohio Division of Water, 1960). The basin has a circular shape with a diameter of roughly 100 miles. The average gradient of the Maumee River is 1.3 ft/mile. The St. Marys averages 2.8 ft/mile and the St. Joseph 1.6 ft/mile. Some of the headwater tributaries have gradients as high as 10 ft/mile.

The main stem flows generally northeast from Ft. Wayne to Toledo, Ohio, about 135 miles distance. The Maumee River empties into Maumee Bay, a shallow basin at the southwestern tip of Lake Erie. The relatively flat basin yields a low gradient and a correspondingly sluggish flow. With a mean discharge of approximately 4,700 cfs (ranges from a high of 94,000 cfs to a low of 32 cfs), it is not a large river, but it is the largest tributary to the Great Lakes (Great Lakes Basin Commission, 1975). The maximum 1976 flow occurred in February when discharge reached 72,000 cfs. The Maumee River accounts for only 3 percent of the flow into Lake Erie, but included in this discharge is 1.2 million tons of suspended solids annually, representing 37 percent of the total sediment load to the lake (Table 16). Low relief, gentle gradient and fine-grained soils account for many of the river's traits: its low velocity, muddiness and sediment-clogged bed (Horowitz, et al., 1975). Floods occur annually during the early part of the year usually in Febraury, March or April. The floods are caused by rainfall, frozen ground and melting snow. These factors are accentuated by the inability of the slow, sluggish Maumee to accept the increased load.

The lower 15 miles of the Maumee River can be considered a freshwater estuary. The formation of this estuary on Lake Erie is the result of a series of geologic events related to Pleistocene glaciation. The flow of the Maumee River was reversed from its southwest direction when the glacial lakes drained from the Erie Basin as the ice sheet melted exposing the Niagara River outlet. Base-level lowering accelerated river velocities and the Maumee valley was cut deeply into lacustrine deposits, glacial tills and bedrock. With the weight of the ice removed, the outlet eventually rebounded and produced a rise in water level. The lake encroached upon the valley forming the present drowned stream mouth which is analogous in many ways to a marine estuary. Virtually all of the tributaries entering Lake Erie on the Ohio shore have estuarine-type lower reaches where lake water masses affect water level and quality for several miles upstream from traditional mouths (Brant and Herdendorf, 1972).

The estuary of the river begins just above the Maumee-Perrysburg Bridge where the bedrock riffles end. As the water enters the estuary, its velocity abruptly diminishes except during major runoff events, causing sedimentation of suspended particles. Within the estuary, currents are extremely unstable. Reversals of flow due to fluctuations in Lake Erie water levels have been measured by Herdendorf (1970). The estuary is approximately a mile wide at Eagle Point and nearly 30 feet deep in the dredged navigation channel. Early maps and charts show that the estuary was frequently 25 feet deep even before the Corps of Engineers began to improve the harbor. Horowitz, et al., (1975) considered the estuary a reservoir, a sloshing dilution basin where the river is progressively mixed with backflow from the lake, and a large settling basin where solids from upriver are sedimented and occasionally scoured during periods of major flushing. They also reported that the river water can be relatively stagnant for long intervals.

Miller (1968) observed that currents in Toledo Harbor exhibit some of the properties of tidal currents, in that they reverse when the water level changes from "flood" to "ebb" during wind tide and seiche activity. During the period May to November 1966 he found that 90 percent of the time the currents were less than 15 cm/sec (0.5 ft/sec), and that the maximum speeds, about 45 cm/sec (1.5 ft/sec), occurred during the greatest rate of change in water level, whereas the minimums are at times of high and low water. A comparison of simultaneous data obtained from current meters and drogues showed that current speeds in the mid-channel were up to 2.5 times greater than near the channel edge. Miller also made estimates of river discharge magnitude in relation to its effect on the currents during seiching. Below 7,000 cfs current maintains its reversing characteristics and the effect of river discharge on current speed is not easily recognized. Above this discharge value the current reverses from its down-channel direction only during periods of rapid rises in lake level. For discharge rates greater than 20,000 cfs, the up-channel current component usually disappears even with 40 cm (1.3 ft) seiche amplitudes. Periods with this rate of flow are infrequent and of short duration. Horowitz, et al. (1975) also studied the hydraulic complexities of the estuary. In May and September 1974 they demonstrated periods of stagnation, river flushing and reverse flow with stage recorders and drogues; as the water level rose, lake water was pushed into the estuary, as it fell, river water flowed into the bay. They estimated that each one-foot change in water level causes the volume of water in the estuary to adjust by approximately 120 million cubic feet.

Walters and Herdendorf (1975) demonstrated that the Maumee River has produced a sediment plume that extends from Maumee Bay into western Lake Erie by measuring the concentration and distribution of mercury in the surficial sediments. This technique indicates that recent sedimentation in Maumee Bay ranges from 0.5 to 1.0 cm/year.

The primary driving forces that produce current in the Maumee River estuary are wind tides, seiches and river discharge. The estuary and harbor area of Maumee Bay are not greatly affected by longshore currents because of the sheltering effect of man-made fills (Miller, 1968). The outer parts of the bay, in the vicinity of Cedar Point spit and North Cape, are more strongly effected by longshore currents. Wind tides are a direct result of wind stress which pushes water toward the leeward shore, increasing the water level at that shore while it is depressed on the windward shore. As the wind force diminishes, the stress cannot maintain the gradient, resulting in a free oscillation of the lake surface or seiche. The period for a longitudinal seiche (NE - SW) on Lake Erie is approximately 14 hours (Verber, 1960). Wind-produced fluctuation occurring in conjunction with prevailing low or high water have resulted in water levels ranging from 7.5 feet below (U.S. Army, Corps of Engineers, 1945) to 7.4 above (Carter, 1973) LWD.

The Maumee Bay shore is exposed to storm waves mainly from the east to northeast to north. The maximum fetch distance for the Maumee Bay shoreline is approximately 50 miles which restricts the development of large waves. The shallow nature of the bay causes "deep water" open lake waves to break, reform, and break again several times before they reach the shore, thus dissipating much of their energy (Benson, 1975). The maximum annual "deep water" wave height which could be developed in the western basin of Lake Erie had been calculated by the U.S. Army, Corps of Engineers (1953) to be approximately 8.1 feet at Monroe, Michigan during the ice free period of the year. The depth of water at which a wave breaks is approximately 1.3 times the wave height (U.S. Army, Corps of Engineers, 1961). No detailed analysis of wave characteristics is available for Maumee Bay but Benson (1975) stated the generalization that wave heights are lower in the bay than for the open lake due to: (1) predominately offshore winds which do not generate large nearshore waves in the bay, (2) low fetch distances when compared to other portions of the Lake Erie shoreline and (3) shallowness of the bay which precludes the formation or translation of large waves. In particular he concluded that the spoil islands adjacent to the navigation channel exert a "tremendous influence" on the wave characteristics of the bay. Waves crossing the spoil mounds interact with the bottom and break, thus acting as an offshore breakwater offering protection to the west shore of Maumee Bay when waves are from the east or northeast and for the south shore when waves are from the north or northwest. Benson also stated that the subaqueous portion of the Cedar Point spit can influence wave activity within the bay by buffering large open lake waves from the north and northeast.

The Maumee River estuary, for much of its 15-mile length is polluted. Despite its "gross" pollution designation, few of the numerical water quality standards are violated (Horowitz, et al., 1975). Dissolved oxygen and fecal coliform bacteria, particularly downstream from the Anthony Wayne Bridge, are the principal parameters which exceed the standards. Over one million tons of sediment flow down the river to the estuary annually. This produces continually turbid conditions in the lower reaches of the river. Also carried by the river are substantial quantities of fertilizers and pesticides. Approximately 160,000 tons of nitrogen, phosphorus and potassium and 16,000 tons of herbicides, fungicides, and insecticides are applied to farm lands within the basin annually. Turbidity in Maumee Bay decreases 130 percent from the river mouth to navigation light No. 30 (five miles offshore) and reaches background concentrations approximately 15 miles into Lake Erie (Pinsak and Meyer, 1975). The general trend is for high concentrations of nutrients, chloride, silica, calcium, sodium, magnesium and potassium in the river to decrease northeastwardly across the bay. The Toledo Lucas County Port Authority (Fraleigh, et al., 1975) conducted a comprehensive investigation in 1974 of water quality and biota of Maumee Bay with particular emphasis on the proposed diked disposal area adjacent to Harbor View. This study found that Lake Erie has a pronounced effect on the water quality of the bay; the dilution effect of the lake in summer tends to improve water quality in the bay. In general, good quality lake water enters the bay from the east and poor quality water enters from the south and west via the Maumee and Ottawa Rivers.

Processing of multispectral scanner data from the 1976 overflights by NASA/Lewis Research Center combined with shipboard meaurements obtained by the Center for Lake Erie Area Research (CLEAR) can provide quantitative information about water quality parameters over large areas. NASA has been able to construct a water quality map of the entire western basin of Lake Erie by correlating shipboard measurements with aircraft measurements of upwelling radiation intensity (Fig. 73).

Total suspended solids (TSS) appears to provide the best direct correlation between a water quality parameter and the measurement of upwelling radiation (Fig. 74). However, other physicochemical parameters such as total phosphorus, secchi transparency, turbidity and non-volatile (inorganic) suspended solids also provide a reasonably high indirect correlation with Channel 8 (714 nm) radiance by virtue of their relationship to TSS (Table 17). Table 18 shows the distribution of indirect or secondary parameters relative to TSS in western Lake Erie on 8 March 1976.

The general trend that has emerged from analyzing the shipboard and aircraft data in conjunction with meteorological and hydrological data is that the vast majority (over 90%) of the sediment loading to western Lake Erie via the Maumee River occurred during February and March in 1976. Much of this material, including associated nutrients and metals, is deposited in Maumee Bay and adjacent areas of western Lake Erie. Following this initial sedimentation, spring storms resuspended most of this material and currents carried it either north along the Michigan shore or east along the Ohio shore. The Ohio shore material eventually passes into the central basin via one of three routes, (1) South Passage, (2) the inter-island area or (3) Pelee Passage. The net result is that by early summer the western basin nearshore area (the area most susceptible to resuspension) has been cleansed of the sediments deposited during spring runoff events. This is evidenced by the fact that late spring and early summer storms of intensity equal to those of the early spring do not produce highly turbid conditions in the western basin. This fact suggests that there is an absence of resuspendable material in the nearshore area during the late spring and early summer.

CONCLUSIONS

1. The Maumee and Detroit Rivers are the major and nearly equal contributors of sediment loading to western Lake Erie.

2. Sediment loading is the greatest during spring runoff events.

3. Turbidity plumes from the Detroit River are associated with resuspension of sediments in Lake St. Clair; resuspension in Lake St. Clair is greatest in the spring immediately following the melt of the winter ice cover.

4. Approximately 70% of the annual sediment loading from the Maumee River occurred in February and an additional 20% in March 1976 which underscores the importance of late winter and early spring runoff events in delivering sediment to western Lake Erie.

5. Sediment discharged by the tributaries in the spring is initially deposited in the western basin but progressively moves eastward by a series of resuspension events associated with wind-generated wave action.

6. By late spring most of the sediment which entered the western basin earlier in the year has been transported to deeper portions of the western basin or more likely carried eastward into the central basin.

7. A high correlation has been found between upwelling radiance and total suspended ~~di~~ssolved solids; likewise, total phosphorus and water clarity parameters correlate well with TSS.

8. Indirect correlations, therefore, provide a mechanism for estimating the concentrations and quantities of several lake contaminants and their distribution over a large area.

9. The fact that the western basin receives the bulk of its sediment and nutrient loading within a relatively short period of time (2 months) and that this basin is cleansed of most of this contamination by resuspension and transport out of the basin in an equally short period of time, present possibilities for rapid improvement of lake water quality.

10. Control of sediment loading in the late winter and early spring could effect a 90% decrease in total suspended solds and total phosphorus inputs to the western basin via the Maumee River.

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TABLES

TABLE 1

WESTERN LAKE ERIE CRUISE SCHEDULE FOR 1976

Cruise No.	Date	Julian No.	Total No. Stations
1	February 18	49	8
2	February 24, 25	55, 56	26
3	March 8-12	68 - 72	84
4	March 23-30	83 - 89	6
5	April 12-16	103 - 107	89
6	April 21 - 24	112 - 115	23
7	April 28 - May 1	119 - 122	77
8	May 8-13	129 - 134	80
9	May 20-23	141 - 144	74
10	June 2 - 10	154 - 162	24

TABLE 2

GEOGRAPHIC COORDINATES FOR SAMPLING STATIONS

STATION NO.	LATITUDE N.	LONGITUDE W.	STATION NO.	LATITUDE N.	LONGITUDE W.
47	41° 50' 18"	82° 12' 48"	113	41° 48' 18"	83° 13' 36"
50	41° 48' 48"	82° 30' 06"	116	41° 41' 48"	83° 08' 30"
51	41° 38' 30"	82° 24' 12"	118	41° 51' 48"	83° 20' 18"
52	41° 31' 54"	82° 27' 12"	119	41° 49' 36"	83° 18' 12"
53	41° 25' 12"	82° 30' 12"	120	41° 47' 12"	83° 16' 30"
54	41° 34' 00"	82° 38' 06"	123	41° 40' 30"	83° 11' 00"
55	41° 44' 18"	82° 44' 00"	125	41° 50' 12"	83° 23' 12"
56	41° 54' 42"	82° 50' 24"	126	41° 47' 00"	83° 21' 30"
57	41° 49' 54"	83° 01' 06"	127	41° 43' 18"	83° 17' 48"
58	41° 41' 06"	82° 56' 00"	128	41° 40' 12"	83° 15' 48"
59	41° 43' 36"	83° 09' 00"	129	41° 39' 54"	83° 14' 00"
60	41° 53' 30"	83° 11' 48"	131	41° 46' 36"	83° 24' 24"
61	41° 56' 48"	83° 02' 42"	132	41° 44' 18"	83° 22' 36"
65	41° 39' 00"	82° 44' 00"	133	41° 42' 06"	83° 20' 54"
66	41° 58' 00"	82° 40' 00"	135	41° 42' 48"	83° 25' 36"
67	41° 40' 00"	82° 52' 00"	136	41° 41' 30"	83° 24' 30"
68	41° 45' 00"	82° 51' 00"	138	41° 41' 36"	83° 25' 54"
69	41° 33' 00"	82° 55' 00"	139	41° 41' 48"	83° 27' 48"
70	41° 46' 00"	83° 20' 00"	148	41° 42' 36"	83° 23' 06"
74	41° 40' 00"	82° 35' 00"	150	41° 45' 12"	83° 25' 24"
75	41° 54' 00"	83° 18' 00"	151	41° 41' 42"	83° 26' 30"
76	41° 36' 30"	83° 04' 00"	157	41° 52' 00"	82° 59' 36"
77	41° 39' 00"	82° 49' 00"	160	41° 52' 36"	83° 10' 42"
81	41° 36' 36"	82° 50' 40"	163	41° 54' 30"	83° 00' 48"
101	41° 51' 12"	83° 07' 48"	166	41° 55' 00"	83° 11' 36"
102	41° 55' 54"	83° 15' 36"	167	41° 55' 36"	83° 07' 24"
103	41° 54' 30"	83° 14' 30"	168	41° 56' 24"	83° 05' 00"
105	41° 49' 54"	83° 10' 36"	169	41° 56' 54"	83° 01' 42"
107	41° 45' 30"	83° 06' 48"	170	41° 57' 36"	82° 58' 24"
109	41° 41' 12"	83° 03' 30"	172	41° 57' 42"	83° 15' 00"
110	41° 55' 12"	83° 19' 12"	173	41° 57' 54"	83° 12' 48"
111	41° 53' 00"	83° 17' 12"	174	41° 58' 30"	83° 09' 30"
112	41° 50' 48"	83° 15' 30"	175	41° 59' 00"	83° 06' 18"

TABLE 2 CON'T.

GEOGRAPHIC COORDINATES FOR SAMPLING STATIONS

STATION NO.	LATITUDE N.	LONGITUDE W.	STATION NO.	LATITUDE N.	LONGITUDE W.
176	41° 59' 42"	83° 02' 48"	269D	41° 59' 24"	83° 04' 24"
177	42° 00' 12"	82° 59' 30"	270D	41° 58' 24"	83° 10' 54"
178	42° 01' 36"	83° 10' 30"	271D	41° 57' 48"	83° 14' 00"
179	42° 01' 54"	83° 07' 18"	272M	41° 43' 08"	83° 25' 42"
180	42° 00' 24"	83° 08' 24"	272D	41° 55' 36"	83° 10' 00"
181	41° 58' 48"	83° 09' 00"	273M	41° 02' 42"	83° 25' 24"
182	41° 58' 42"	83° 08' 00"	273D	41° 54' 52"	83° 12' 48"
183	41° 58' 42"	83° 07' 48"	274	41° 56' 42"	83° 03' 30"
184	41° 59' 48"	83° 07' 30"	275	41° 57' 12"	83° 00' 00"
185	41° 57' 30"	83° 07' 24"	276	41° 57' 54"	82° 56' 48"
186	41° 55' 54"	83° 07' 00"	302	41° 52' 48"	82° 30' 54"
187	41° 56' 00"	83° 06' 48"	304	41° 51' 42"	82° 34' 12"
188	41° 56' 06"	83° 06' 30"	306	41° 50' 24"	82° 36' 30"
189	41° 54' 48"	83° 06' 12"	315	41° 33' 48"	82° 41' 48"
191	41° 52' 18"	83° 05' 18"	316	41° 32' 48"	82° 42' 24"
202	41° 46' 48"	83° 04' 00"	400	41° 43' 00"	83° 15' 06"
204	41° 49' 24"	82° 58' 24"	401	42° 04' 00"	83° 08' 00"
206	41° 52' 24"	82° 52' 12"	402	42° 03' 00"	83° 08' 00"
208	41° 55' 06"	82° 46' 30"	L2	41° 40' 30"	83° 29' 30"
225	41° 43' 48"	82° 57' 36"	L5	41° 43' 42"	83° 25' 42"
227	41° 46' 36"	82° 51' 30"	L6	41° 45' 00"	83° 22' 48"
229	41° 49' 30"	82° 45' 54"	L7	41° 46' 18"	83° 20' 12"
231	41° 52' 00"	82° 39' 48"	L8	41° 42' 12"	83° 24' 36"
232	41° 53' 24"	82° 36' 54"	L10	41° 43' 30"	83° 21' 48"
244	41° 38' 06"	82° 56' 48"	L11	41° 43' 06"	83° 20' 48"
248	41° 43' 36"	82° 45' 00"	L12	41° 42' 24"	83° 18' 30"
251	41° 34' 30"	82° 57' 54"	L13	41° 43' 24"	83° 17' 24"
252	41° 35' 48"	82° 55' 00"	L14	41° 44' 24"	83° 12' 42"
253	41° 37' 36"	82° 51' 18"	L15	41° 44' 42"	83° 05' 54"
259	41° 36' 12"	82° 47' 18"	L17	41° 45' 00"	82° 51' 48"
261	41° 39' 00"	82° 41' 24"	L18	41° 39' 06"	83° 14' 00"
264	41° 57' 06"	83° 09' 30"	L19	41° 40' 00"	83° 11' 42"
267	41° 58' 39"	83° 08' 36"	L20	41° 41' 30"	83° 08' 42"
268D	41° 59' 36"	83° 01' 06"	L21	41° 37' 48"	83° 07' 24"

TABLE 2 CON'T.

GEOGRAPHIC COORDINATES FOR SAMPLING STATIONS

STATION NO.	LATITUDE N.	LONGITUDE W.	STATION NO.	LATITUDE N.	LONGITUDE W.
L24	41° 36' 24"	83° 02' 12"	L44	41° 32' 30"	82° 46' 42"
L25	41° 41' 30"	83° 02' 06"	L45	41° 33' 24"	82° 47' 18"
L26	41° 37' 54"	83° 00' 54"	L46	41° 36' 00"	82° 45' 36"
L27	41° 39' 48"	82° 58' 24"	L47	41° 38' 42"	82° 42' 54"
L28	41° 38' 48"	82° 56' 30"	L48	41° 40' 42"	82° 41' 36"
L29	41° 35' 42"	82° 54' 24"	L49	41° 39' 48"	82° 40' 54"
L30	41° 32' 12"	82° 57' 42"	L50	41° 33' 36"	82° 43' 42"
L31	41° 31' 36"	82° 53' 00"	L51	41° 35' 12"	82° 40' 54"
L32	41° 33' 12"	82° 53' 12"	L52	41° 38' 18"	82° 38' 48"
L33	41° 42' 00"	82° 52' 54"	L54	41° 31' 06"	82° 41' 30"
L34	41° 42' 48"	82° 51' 18"	L55	41° 34' 48"	82° 39' 36"
L35	41° 43' 30"	82° 50' 12"	L56	41° 49' 12"	82° 59' 00"
L36	41° 39' 42"	82° 51' 24"	L57	41° 47' 12"	82° 50' 00"
L37	41° 34' 30"	82° 49' 12"	L58	41° 45' 18"	82° 49' 30"
L38	41° 35' 06"	82° 49' 30"	L59	41° 46' 12"	82° 49' 06"
L39	41° 37' 36"	82° 49' 06"	L60	41° 45' 24"	82° 41' 42"
L40	41° 39' 36"	82° 49' 24"	L61	41° 42' 36"	82° 41' 12"
L41	41° 41' 18"	82° 47' 48"	L62	41° 36' 36"	82° 48' 00"
L42	41° 39' 18"	82° 47' 12"	L63	41° 35' 00"	82° 45' 36"
L43	41° 41' 12"	82° 44' 36"			

TABLE 3

STATIONS VISITED DURING 1976 CRUISES IN WESTERN LAKE ERIE

Cruise No.	1	2		3				4		5					6			7				8						9				10				
Julian Date	49	55	56	68	69	70	72	83	89	103	104	105	106	107	112	114	115	119	120	121	122	129	130	131	132	133	134	141	142	143	144	154	158	159	161	162
Station No.																																				
47								X																								X	X			
50							X						X																	X					X	
51								X																					X					X		
52									X																									X		
53									X																									X		
54									X				X																X					X		
55							X																							X					X	
56						X																								X					X	
57				X		X																						X							X	
58						X																						X								X
59				X						X								X							X			X								X
60				X																								X							X	
61				X								X																	X						X	
65							X																											X		
66						X						X								X							X			X					X	
67				X						X						X		X							X			X								X
68						X																								X						X
69				X												X												X								X
70		X		X		X				X	X							X							X			X								X
74								X					X																X			X			X	
75					X																							X							X	
76				X																										X						
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109										X								X							X											
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113		X		X		X				X									X							X										
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133		X																																		
135	X	X	X	X		X				X	X							X	X						X											
136	X																																			

TABLE 3 CON'T.

STATIONS VISITED DURING 1976 CRUISES IN WESTERN LAKE ERIE

Cruise No.	1	2		3				4		5					6			7				8						9				10				
Julian Date	49	55	56	68	69	70	72	83	89	103	104	105	106	107	112	114	115	119	120	121	122	129	130	131	132	133	134	141	142	143	144	154	158	159	161	162
Station No.																																				
138	X																																			
139	X	X	X	X		X				X								X							X											
148		X																																		
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244										X								X							X											
248													X							X							X									
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253																X																				
259													X					X							X											
261													X																							

TABLE 3 CON'T.

STATIONS VISITED DURING 1976 CRUISES IN WESTERN LAKE ERIE

Cruise No.		2		3				4		5					6			7				8						9				10				
Julian Date	49	55	56	68	69	70	72	83	89	103	104	105	106	107	112	114	115	119	120	121	122	129	130	131	132	133	134	141	142	143	144	154	158	159	161	162
Station No.																																				
264				X		X																														
267					X																															
268D					X																															
269D					X																															
270D					X																															
271D					X																															
272M	X																																			
272D					X	X																														
273M	X																																			
273D				X	X																															
274					X																															
275					X																															
276					X						X								X								X									
302													X																							
304													X																							
306													X																							
315													X																							
316																													X							
400		X																																		
401						X																														
402						X																														
L2	X																																			
L5											X				X					X				X						X						
L6											X									X				X						X						
L7											X									X				X						X						
L8															X					X				X						X						
L10											X				X					X				X						X						
L11											X									X				X						X						
L12											X									X				X						X						
L13											X									X				X						X						
L14																				X				X						X						
L15											X									X				X						X						
L17												X							X				X						X							
L18											X									X				X						X						
L19											X									X				X						X						
L20											X									X				X						X						
L21																				X				X						X						
L24																X			X					X					X							
L25																X				X				X					X							
L26												X				X			X					X					X							
L27												X				X			X					X					X							
L28										X						X			X					X					X							
L29										X						X			X					X					X							
L30										X						X			X					X					X							
L31										X						X			X					X					X							
L32										X						X			X					X					X							
L33												X					X		X			X							X							
L34												X							X			X							X							

TABLE 3 CON'T.

STATIONS VISITED DURING 1976 CRUISES IN WESTERN LAKE ERIE

Cruise No.	1	2		3				4		5					6			7				8						9				10				
Julian Date	49	55	56	68	69	70	72	83	89	103	104	105	106	107	112	114	115	119	120	121	122	129	130	131	132	133	134	141	142	143	144	154	158	159	161	162
Station No.																																				
L35												X							X			X							X							
L36										X						X		X				X							X							
L37													X					X				X						X								
L38													X					X				X						X								
L39													X			X		X				X						X								
L40												X				X				X		X							X							
L41												X				X		X				X							X							
L42												X				X		X				X						X								
L43												X						X				X							X							
L44													X					X				X						X								
L45													X					X				X						X								
L46													X									X									X					
L47												X						X				X							X							
L48												X						X				X							X							
L49												X						X				X							X							
L50													X					X				X						X								
L51													X					X				X						X								
L52												X						X				X							X							
L54													X								X					X					X					
L55													X					X				X						X								
L56											X									X					X					X						
L57												X							X					X					X							
L58																								X					X							
L59												X							X					X					X							
L60												X												X					X							
L61												X												X				X								
L62													X					X				X						X								
L63													X									X						X								

TABLE 4

WATER QUALITY METHODS

PARAMETER	METHOD
1. Temperature	Meter
2. Conductivity	Meter
3. Dissolved Oxygen	Meter
4. pH	Meter
5. Transparency	Secchi
6. Turbidity	Turbidometer
7. Suspended and Volatile Solids	Muffle Furnace
8. Light	Photometer
9. Transmissibility	Transmissometer
10. Current	Meter
11. Total Phosphorus	Auto-Analyzer
12. Soluble Reactive Phosphorus	Auto-Analyzer
13. Nitrate plus Nitrite	Auto-Analyzer
14. Ammonia Nitrogen	Auto-Analyzer
15. Dissolved Silica	Auto-Analyzer
16. Chloride	Auto-Analyzer
17. Calcium plus Magnesium	Atomic Absorption
18. Cadmium	Atomic Absorption
19. Chromium	Atomic Absorption
20. Copper	Atomic Absorption
21. Mercury	Atomic Absorption
22. Zinc	Atomic Absorption
23. Lead	Atomic Absorption
24. Nickel	Atomic Absorption
25. Chlorophyll _a_, _b_, and _c_ plus Pheopigments	Spectrophotometer
26. Particulate Carbon and Nitrogen	Elemental Analyzer
27. Alkalinity	HCl-titration

TABLE 5

WIND OBSERVATIONS FOR TOLEDO, OHIO[1]
FEBRUARY 1976

Date	Resultant Direction	Resultant Speed (mph)	Average Speed (mph)
1	270	6.9	14.7
2	260	10.7	11.7
3	190	6.3	6.5
4	280	7.4	10.8
5	050	11.7	12.1
6	290	9.9	11.8
7	230	13.8	14.2
8	280	13.9	15.4
9	180	7.9	9.2
10	210	12.9	14.4
11	270	13.3	13.8
12	200	11.5	11.9
13	300	6.0	11.8
14	100	5.1	7.9
15	210	11.6	13.4
16	100	4.7	8.2
17	250	2.5	12.5
18	260	6.8	15.7
19	260	9.7	10.5
20	180	3.7	7.6
21	110	2.6	12.4
22	320	13.7	14.5
23	240	6.7	10.9
24	210	13.9	14.1
25	210	12.2	12.7
26	240	10.0	11.8
27	220	10.3	10.9
28	290	2.7	9.8
29	260	5.8	11.2

1 Data Source: U.S. Weather Service

TABLE 5

WIND OBSERVATIONS FOR TOLEDO, OHIO[1]

MARCH 1976

Date	Resultant Direction	Resultant Speed (mph)	Average Speed (mph)
1	060	15.6	16.0
2	070	11.3	11.4
3	280	1.9	8.9
4	100	6.6	10.5
5	260	18.5	20.7
6	260	16.9	17.5
7	280	15.1	15.7
8	360	1.9	6.3
9	080	6.9	7.9
10	250	5.9	9.6
11	070	5.8	10.5
12	180	8.8	15.0
13	270	16.8	18.0
14	240	10.9	12.2
15	040	3.7	9.2
16	320	11.0	12.9
17	280	12.8	13.8
18	190	8.4	8.9
19	210	13.8	14.2
20	200	16.8	17.1
21	280	16.7	17.5
22	230	2.9	4.5
23	220	8.6	9.5
24	210	12.7	13.8
25	240	9.7	11.4
26	180	13.5	14.0
27	230	11.3	16.7
28	090	2.5	7.3
29	090	9.4	9.9
30	200	11.8	17.4
31	250	8.8	9.1

1 Data Source: U.S. Weather Service

TABLE 5

WIND OBSERVATIONS FOR TOLEDO, OHIO[1]

APRIL 1976

Date	Resultant Direction	Resultant Speed (mph)	Average Speed (mph)
1	260	11.1	11.7
2	300	8.8	9.8
3	100	8.2	9.8
4	010	11.5	11.9
5	260	9.3	10.4
6	290	7.7	8.9
7	350	6.6	8.8
8	010	8.6	9.8
9	310	2.5	5.2
10	240	9.2	9.9
11	360	12.6	13.8
12	290	4.3	6.2
13	260	6.1	6.5
14	210	7.5	8.2
15	220	11.5	11.7
16	220	11.3	12.2
17	190	9.3	9.9
18	210	10.4	11.2
19	270	8.4	9.6
20	060	9.2	11.4
21	170	6.7	9.5
22	270	11.6	13.2
23	080	4.6	7.8
24	070	14.3	14.5
25	030	14.8	16.4
26	340	11.2	11.4
27	310	10.5	10.6
28	280	8.3	8.6
29	300	8.7	8.8
30	230	4.4	5.2

1 Data Source: U.S. Weather Service

TABLE 5

WIND OBSERVATIONS FOR TOLEDO, OHIO[1]

MAY 1976

Date	Resultant Direction	Resultant Speed (mph)	Average Speed (mph)
1	210	4.9	6.0
2	230	11.6	14.4
3	270	15.1	15.2
4	230	10.3	10.8
5	220	17.1	17.4
6	050	4.5	11.5
7	340	12.3	13.1
8	270	6.4	7.3
9	240	11.7	12.4
10	230	10.2	10.5
11	310	8.0	12.4
12	300	2.6	5.6
13	130	5.8	7.2
14	210	6.4	7.1
15	070	9.2	9.5
16	170	3.8	5.2
17	300	5.2	11.4
18	330	12.7	14.0
19	300	12.6	12.9
20	260	10.7	11.5
21	310	9.5	10.5
22	360	5.8	7.9
23	050	6.4	6.5
24	020	7.2	8.6
25	030	5.7	6.6
26	010	4.0	6.0
27	070	5.2	5.9
28	140	5.9	6.8
29	090	8.4	9.6
30	110	1.5	6.5
31	270	2.9	6.5

[1] Data Source: U.S. Weather Service

TABLE 5

WIND OBSERVATIONS FOR TOLEDO, OHIO[1]
JUNE 1976

Date	Resultant Direction	Resultant Speed (mph)	Average Speed (mph)
1	050	7.3	8.5
2	060	8.6	9.9
3	050	10.7	11.1
4	080	9.4	9.8
5	060	5.2	5.3
6	040	2.2	3.2
7	300	6.4	6.9
8	290	6.3	6.8
9	240	4.4	4.6
10	240	7.7	7.9
11	280	9.3	10.1
12	070	8.7	10.5
13	210	6.2	7.5
14	220	8.6	9.6
15	210	13.1	13.2
16	250	9.4	10.4
17	050	2.2	3.7
18	170	7.1	8.6
19	310	5.3	11.1
20	040	6.3	8.5
21	350	3.7	5.3
22	170	5.9	7.1
23	160	3.7	5.3
24	180	9.0	12.4
25	260	10.1	10.8
26	230	7.7	7.9
27	230	6.6	7.1
28	230	6.5	7.5
29	300	4.4	9.8
30	270	11.0	12.8

1 Data Source: U.S. Weather Service

TABLE 6

WESTERN LAKE ERIE WATER QUALITY VALUES FOR SURFACE SAMPLES ON DAYS OF NASA/LEWIS RESEARCH CENTER OVERFLIGHTS

Station	Total P	Chl. a	Total Solids	Volatile Solids	Turb.	Temp.	Trans.	Cond.	Transp	D.O.
	ppb	µg/l	mg/l	mg/l	JTU	°C	%	µmhos	m	ppm
DATE: 25 February 1976 (056) - Cruise 2										
111	137	41.42	20.6	4.05	79	1.3	-	338	0.10	14.3
112	71	7.16	4.55	1.6	2	0.5	-	332	1.20	14.0
118	102	97.37	19.1	6.1	48	1.7	-	361	0.12	16.0
119	61	25.65	6.1	2.3	12	0.4	-	299	1.00	15.3
125	94	90.56	15.65	4.55	44	2.0	-	359	0.30	15.7
126	261	40.44	46.8	6.7	200	2.2	-	396	0.12	14.0
131(a)	228	57.64	52.4	8.95	180	2.0	-	386	0.10	15.2
131(b)	81	74.44	12.45	4.35	29	1.6	-	329	0.60	15.8
135	383	0.82	-	-	340	3.9	-	375	0.05	12.7
139	400	1.26	131.75	14.95	345	3.9	-	375	0.04	12.7
150	436	3.24	300.5	33.3	425	3.8	-	384	0.05	14.2
DATE: 8 March 1976 (068) - Cruise 3										
57	55.0		19.76	2.5	20	1.25	24.5	269	0.52	13.3
59	79.0		22.33	3.3	-	3.0	25.0	283	0.60	12.6
60	42.2		19.4	5.3	15	0.8	83.0	259	0.65	13.6
61	16.0		6.93	1.2	8	2.0	64.5	213	1.10	13.3
67	121.0		51.75	9.65	-	2.75	-	253	0.47	12.6
69	172.0		90.3	11.55	-	3.0	0.0	309	0.20	12.5
70	106.0		20.5	2.5	34	2.5	66.0	336	0.30	12.8
76	41.8		84.3	11.5	-	3.5	25.0	344	0.15	12.2
105	41.6		15.3	5.0	-	0.5	80.0	280	0.70	13.4
113	40.1		9.2	2.9	15	1.0	85.0	302	0.60	13.3
120	40.4		8.3	6.0	15	1.0	85.0	294	0.60	13.2
132	235		4.5	-0.2	115	4.0	82.0	374	0.18	12.1
135	980		282.6	42.7	260	5.2	66.0	362	0.06	11.0
139	925		200.1	24.6	285	5.0	65.0	364	0.05	11.4
178	84.0		5.4	0.4	12	1.0	98.0	331	0.60	12.2
179	32.2		8.8	1.0	15	1.0	84.0	276	0.55	14.0
180	32.5		14.47	5.87	18	1.0	78.0	258	0.45	13.8
181	30.0		6.2	1.8	12	1.0	86.0	294	0.65	13.4
183	32.0		17.27	-	18	1.75	26.0	234	0.56	13.1
185	20.0		4.1	3.5	10	2.0	48.0	212	1.00	13.2
189	121.0		26.43	7.13	20	2.0	17.0	319	0.52	12.6
191	59.5		21.13	4.37	18	1.5	24.0	223	0.50	13.1
264	73.0		12.6	3.1	18	1.0	84.0	350	0.55	13.0
273	60.7		31.6	4.55	15	1.0	80.0	294	0.60	13.4

TABLE 6 CON'T.

WESTERN LAKE ERIE WATER QUALITY VALUES FOR SURFACE SAMPLES ON DAYS OF NASA/LEWIS RESEARCH CENTER OVERFLIGHTS

Station	Total P ppb	Chl. a µg/l	Total Solids mg/l	Volatile Solids mg/l	Turb. JTU	Temp. °C	Trans. %	Cond. µmhos	Transp. m	D.O. ppm
DATE: 23 March 1976 (083) - Cruise 4										
74	149.5	-	69.63	9.0	57.0	3.25	0.0	303	0.28	12.5
51	16.3	-	2.92	1.26	3.8	2.25	83.0	281	2.9	13.2
47	14.0	-	2.1	0.56	3.4	2.0	80.0	287	2.4	13.4
DATE: 12 April 1976 (103) - Cruise 5										
L31	127				52	9.0		350		
L30	114				52	8.0		325		
L32	128				53	6.0		330		
L29	76.1				32	7.5		305		
L28	42.6				14	10.0		325		
L36	42.4				16	9.0		335		14.2
59	72.4	16.63	48.83	3.9						
67	64.2	22.10	24.95	4.0						
70	77.5	23.68	29.15	5.7						
77	100.1	26.24	44.75	6.0						
109	75.5	13.88	3.95	6.7						
113	20.1	5.82	6.44	1.72						
135		38.47	67.2	9.2						
139	200	30.35	69.95	12.75						
202	74.5	7.78	25.47	4.4						
225	42.2	13.49	16.86	3.267						
244	89.6	27.32								
DATE: 13 April 1976 (104) - Cruise 5										
L5	173				46	8		360		
L6	130				34	8		380		
L11	lost				31	12.5		530		
L10	122				32	11		450		
L12	99.6				20	11.8		450		
L7	65.6				22	7.5		265		
L13	96.7				19	11		475		
L15	527				17	8		295		
L56	61.3				20	8.5		300		
L18	130				40	9		410		
L19	92.5				31	10		360		
L20	67.6				25	10		320		

TABLE 6 CON'T.

WESTERN LAKE ERIE WATER QUALITY VALUES
FOR SURFACE SAMPLES ON DAYS OF
NASA/LEWIS RESEARCH CENTER OVERFLIGHTS

Station	Total P	Chl. a	Total Solids	Volatile Solids	Turb.	Temp.	Trans.	Cond.	Transp.	D.O.
	ppb	µg/l	mg/l	mg/l	JTU	^oC	%	µmhos	m	ppm
70	89.9	-	33.15	9.15						
101	18.4	6.34	3.88	1.54						
112	22.7	8.90	-	-						
126	67.2	15.29	11.04	3.18						
135	2.10	40.78	85.5	11.5						
163	25.8	5.61	10.68	1.42						
166	18.9	3.06	4.58	1.26						
175	33.9	4.38	25.7	3.47						
180	18.8	2.95	10.9	1.63						
276	45.1	10.74	14.8	2.53						
DATE: 29 April 1976 (120) - Cruise 7										
101	23.1		10.525	1.25	9.9	9.0	53.0	269	1.16	10.8
111	22.2		5.38	0.86	6.5	7.5	67.0	233	1.41	10.9
113	25.7		10.25	1.475	8.9	8.5	53.0	286	1.07	10.2
135	133.		37.95	5.35	30.0	10.0	6.0	564	0.34	9.0
163	28.1		10.975	1.925	10.5	9.5	47.0	296	1.00	11.3
166	29.8		17.37	1.87	17.5	8.0	25.0	243	0.70	10.6
175	25.6		22.27	2.53	21.0	9.25	16.0	297	0.44	10.8
180	19.2		12.76	1.7	11.0	7.0	46.0	244	0.79	10.9
204	30.6		12.125	1.425	12.0	9.25	42.0	257	0.84	10.9
276	23.8		8.7	2.8	7.6	9.25	58.0	294	1.10	11.3
L57	56.1				25	9.8	40.0	255		
L33	78.0				36	10.0	30.0	260		
L35	52.7				21	9.8	40.0	260		
L34	66.9				25	9.8	35.0	285		
L28	48.2				17	10.5	40.0	250		
L29	79.4				32	12.0	30.0	275		
L24	59.6				20	11.0	40.0	300		
L32	101.4				50	12.0	25.0	340		
L30	119.				50	11.5	20.0	365		
L17	62.2				29	10.0	40.0	260		
L26	54.5				19	10.5	40.0	300		
L27	47.0				18	10.4	40.0	270		
L31	127.				67	14.0	20.0	390		
L59	51.9									

TABLE 6 CON'T.

WESTERN LAKE ERIE WATER QUALITY VALUES FOR SURFACE SAMPLES ON DAYS OF NASA/LEWIS RESEARCH CENTER OVERFLIGHTS

Station	Total P ppb	Chl. a µg/l	Total Solids mg/l	Volatile Solids mg/l	Turb. JTU	Temp. °C	Trans. %	Cond. µmhos	Transp. m	D.O. ppm
DATE: 12 May 1976 (133) - Cruise 8										
101	30.8	-	8.50	2.62	6.4	10.0	64.0	260	1.0	11.2
111	33.7	-	5.60	2.10	3.6	11.0	84.0	282	1.4	11.5
113	57.2	-	8.18	3.00	5.0	10.75	67.0	263	1.4	11.5
157	26.6	-	3.40	1.24	3.2	11.5	78.0	278	1.7	10.9
163	21.3	-	4.48	1.36	4.0	11.5	73.0	268	1.6	11.4
166	31.0	-	9.10	3.48	5.6	12.0	69.0	295	1.0	10.9
180	22.9	-	9.60	2.26	6.4	9.25	61.0	229	1.0	11.3
204	17.0	-	5.00	1.98	3.5	11.25	83.0	287	1.7	11.0
DATE: 22 May 1976 (143) - Cruise 9										
50	25.0		2.16	1.90	1.9	13.0	82.0	293	2.5	10.8
55	23.6		5.26	2.98	3.7	16.0	81.0	271	1.7	11.3
56	16.1		12.50	4.64	2.3	13.5	84.0	280	2.8	11.1
66	25.0		2.66	1.20	2.2	13.25	82.0	276	2.5	10.7
68	26.1		5.28	2.48	3.6	13.0	76.0	269	1.5	10.4
76	46.4		11.70	3.74	7.2	14.25	54.0	299	1.0	10.3
DATE: 7 June 1976 (159) - Cruise 10										
51	9.3	-	-	-	2.0	17.75	-	282	4.8	9.4
52	19.2	-	1.12	0.64	2.5	18.50	-	268	3.6	9.3
53	39.6	-	3.52	2.00	4.0	20.00	77.0	216	2.2	9.9
54	22.7	-	1.28	0.88	4.0	18.00	77.5	282	2.0	9.0
65	18.0	-	1.82	2.82	-	20.00	82.0	252	3.0	9.4

Notes:
- Total P - total phosphorus
- Chl a - chlorophyll a (corrected)
- Total Solids - total suspended solids
- Turb - turbidity
- Temp - water temperature
- Trans - transmissibility
- Cond. - specific conductance
- Transp - secchi disk transparency
- D.O. - dissolved oxygen

25 February 1976: Station 131 at contact of turbid (a) and clear (b) water masses.

TABLE 7

TRACE METALS IN WESTERN LAKE ERIE

DATE: 18 February 1976 (049) - Cruise 1

STATION	ZINC Zn (ppb)	LEAD Pb (ppb)	CADMIUM Cd (ppb)	COPPER Cu (ppb)	CHROMIUM Cr (ppb)	NICKEL Ni (ppb)	MERCURY Hg (ppb)
S L2	210	34	6.7	46	31	25	0.071
B	210	28	3.2	60	37	38	0.064
S 135	190	45	5.9	72	45	55	0.048
B	510	29	3.5	220	55	46	0.24
S 139	460	33	1.6	65	48	39	0.059
B	260	80	3.2	110	34	58	0.056
S 151	240	47	6.4	130	24	18	0.035
B	120	<2	8.8	29	3.3	27	0.022
S 138	140	22	6.7	74	9.1	11	0.030
B	-	-	-	-	-	-	-
S 272	140	<2	2.2	27	16	20	0.024
B	-	-	-	-	-	-	-
S 273	-	-	-	-	-	-	-
B	250	<2	1.8	62	<2	5.8	0.024
Blank Values	10	23	4.4	5.0	17	15	0.014

TABLE 7 CON'T.

TRACE METALS IN WESTERN LAKE ERIE

DATE: 24 February 1976 (055) - Cruise 2

STATION	ZINC Zn (ppb)	LEAD Pb (ppb)	CADMIUM Cd (ppb)	COPPER Cu (ppb)	CHROMIUM Cr (ppb)	NICKEL Ni (ppb)	MERCURY Hg (ppb)
S 70	73	<2	5.4	17	27	12	0.006
B	79	<2	3.2	45	<2	35	0.016
S 105	68	<2	4.2	5.6	<2	9.7	0.002
B	42	17	2.7	57	<2	<2	0.004
S 107	33	8.8	5.5	44	<2	<2	0.017
B	27	<2	3.4	13	15	8.6	0.004
S 112	21	<2	4.9	17	<2	7.7	0.007
B	-	-	-	-	-	-	-
S 113	58	<2	1.3	30	15	3.2	<0.001
B	59	15	6.3	21	11	15	0.047
S 116	-	-	-	-	-	-	-
B	19	28	7.0	20	<2	5.6	<0.001
S 118	65	3.3	6.0	27	15	<2	0.004
B	-	-	-	-	-	-	-
S 120	36	14	4.2	20	19	5.5	<0.001
B	32	12	5.3	33	<2	<2	0.008
S 123	47	<2	16	23	<2	17	<0.001
B	41	3.8	2.6	47	<2	<2	0.002
S 127	58	<2	3.7	17	11	2.8	<0.001
B	21	<2	5.7	15	<2	5.6	<0.001
S 128	49	<2	4.8	33	6.6	4.0	0.056
B	99	<2	1.5	31	9.8	20	0.026
S 129	85	19	4.6	38	19	21	0.024
B	-	-	-	-	-	-	-
S 132	200	39	5.1	31	18	19	0.029
B	100	23	6.8	44	22	19	0.021
S 133	88	26	2.4	38	18	8.9	0.033
B	-	-	-	-	-	-	-
S 135	160	29	4.3	51	13	22	0.032
B	400	7.6	4.4	52	9.7	<2	0.022
S 139	170	19	1.4	120	18	16	0.035
B	120	6.3	0.8	29	25	24	0.026
S 148	83	<2	1.1	49	28	13	0.019
B	-	-	-	-	-	-	-
S 400	51	16	<.4	9.8	<2	3.6	0.008
B	340	70	5.6	180	100	39	0.24
Blank Values	10	23	4.4	5.0	17	15	0.014

TABLE 7 CON'T.

TRACE METALS IN WESTERN LAKE ERIE

DATE: 10 March 1976 (070) - Cruise 3

STATION	ZINC Zn (ppb)	LEAD Pb (ppb)	CADMIUM Cd (ppb)	COPPER Cu (ppb)	CHROMIUM Cr (ppb)	NICKEL Ni (ppb)	MERCURY Hg (ppb)
S 70	170	<2	4.8	33	<2	<2	0.063
S 105	73	34	4.9	2.0	2.4	11	0.045
S 113	150	<2	2.3	35	9.0	<2	0.032
S 120	90	38	5.9	53	<2	<2	0.032
S 132	170	38	6.6	39	5.1	28	0.046
S 135	110	37	0.6	41	12	21	0.041
S 139	570	34	18	140	44	93	0.041
S 150	70	14	7.6	26	26	20	0.018
S 160	43	15	3.1	13	<2	<2	0.028
S 180	140	55	5.0	13	18	15	0.035
S 264	190	<2	4.7	35	11	<2	0.030
S 272	120	39	7.2	45	<2	6.9	0.037
S 401	160	<2	6.2	39	<2	16	0.031
S 402	170	17	3.7	61	<2	4.4	0.042
Blank Values	10	23	4.4	5.0	17	15	0.014

Note:

S - Surface sample
B - Bottom sample

Determinations by Dr. Lester J. Walter, Geochemistry Laboratory, Department of Geology, Bowling Green State University

TABLE 8

1967 SEDIMENT COLLECTOR DATA - WESTERN LAKE ERIE REEF AREA

Collector Number	Station Location	Water Depth (feet)	Date & Time Set	Date & Time Retrieved	Time Down (days)	Height (mm)	Rate (mm/day)	Volume (ml)
SET NO. 1								
1-A	Starve Is. Reef	8.0	5/13/67 1810	5/24/67 0940	10.7	18.7	1.8	42.8
2-A	Starve Is. Reef	8.0	5/13/67 1810	5/24/67 0940	10.7	18.2	1.7	41.7
3-A	West Reef	5.0	5/13/67 0810	5/24/67 0945	11.2	10.5	0.9	24.0
4-A	West Reef	5.0	5/13/67 0810	5/24/67 0945	11.2	11.3	1.0	25.9
5-A	Crib Reef	5.3	5/11/67 1245	5/24/67 1250	13.0	22.0	1.7	50.4
6-A	Crib Reef	5.3	5/11/67 1245	5/24/67 1250	13.0	17.4	1.3	39.8
7-A	Toussaint Reef	7.5	5/11/67 1205	5/24/67 1325	13.1	28.5	2.2	65.3
8-A	Toussaint Reef	7.5	5/11/67 1205	5/24/67 1325	13.1	29.3	2.2	67.1
SET NO. 2								
1-B	Starve Is. Reef	8.0	5/24/67 1000	6/2/67 1605	9.3	16.9	1.8	38.7
2-B	Starve Is. Reef	8.0	5/24/67 1000	6/2/67 1605	9.3	15.2	1.6	34.8
3-B	West Reef	5.0	5/24/67 1205	6/2/67 1450	9.1	6.5	0.7	14.9
4-B	West Reef	5.0	5/24/67 1205	6/2/67 1450	9.1	6.8	0.7	15.6
5-B	Crib Reef	5.3	5/24/67 1305	6/5/67 1245	12.0	16.9	1.4	38.7
6-B	Crib Reef	5.3	5/24/67 1305	6/5/67 1245	12.0	9.5	0.8	21.8

TABLE 8 CON'T.

SET NO. 2
(continued)

Collector Number	Station Location	Water Depth (feet)	Date & Time Set	Date & Time Retrieved	Time Down (days)	Height (mm)	Rate (mm/day)	Volume (ml)
7-B	Toussaint Reef	7.5	5/24/67 1335	6/5/67 1230	12.0	27.1	2.3	62.1
8-B	Toussaint Reef	7.5	5/24/67 1335	6/5/67 1230	12.0	26.2	2.2	60.0
				SET NO. 3				
1-C	Starve Is. Reef	8.0	6/2/67 1610	6/26/67 1515	24.0	25.8	1.1	59.1
2-C	Starve Is. Reef	8.0	6/2/67 1610	6/26/67 1515	24.0	22.0	0.9	50.4
3-C	West Reef	5.0	6/2/67 1500	6/26/67 1610	24.0	13.3	0.6	30.5
4-C	West Reef	5.0	6/2/67 1500	6/26/67 1610	24.0	14.2	0.6	32.5
5-C	Crib Reef	5.3	6/5/67 1305	6/26/67 1710	21.2	23.4	1.1	53.6
6-C	Crib Reef	5.3	6/5/67 1305	6/26/67 1710	21.2	20.4	1.0	46.7
7-C	Toussaint Reef	7.5	6/5/67 1245	6/26/67 1735	21.2	28.1	1.3	64.3
8-C	Toussaint Reef	7.5	6/5/67 1245	6/26/67 1735	21.2	25.8	1.2	59.1
				SET NO. 4				
1-D	Starve Is. Reef	8.0	6/26/67 1530	7/10/67 1050	13.8	12.9	0.9	29.5
2-D	Starve Is. Reef	8.0	6/26/67 1530	7/10/67 1050	13.8	12.6	0.9	28.9
3-D	West Reef	5.0	6/26/67 1625	7/10/67 1210	13.8	6.3	0.5	14.4
4-D	West Reef	5.0	6/26/67 1625	7/10/67 1210	13.8	9.4	0.7	21.5
5-D	Crib Reef	5.3	6/26/67 1725	7/10/67 1315	13.8	13.2	1.0	30.2
6-D	Crib Reef	5.3	6/26/67 1725	7/10/67 1315	13.8	11.0	0.8	25.2

TABLE 8 CON'T.

SET NO. 4
(continued)

Collector Number	Station Location	Water Depth (feet)	Date & Time Set	Date & Time Retrieved	Time Down (days)	Height (mm)	Rate (mm/day)	Volume (ml)
7-D	Toussaint Reef	7.5	6/26/67 1750	7/10/67 1345	13.8	15.9	1.2	36.4
8-D	Toussaint Reef	7.5	6/26/67 1750	7/10/67 1345	13.8	17.6	1.3	40.3

SET NO. 5

Collector Number	Station Location	Water Depth (feet)	Date & Time Set	Date & Time Retrieved	Time Down (days)	Height (mm)	Rate (mm/day)	Volume (ml)
1-E	Starve Is. Reef	8.0	7/10/67 1055	8/22/67 0935	42.9	38.5	0.9	88.2
2-E	Starve Is. Reef	8.0	7/10/67 1055	8/22/67 0935	42.9	49.1	1.1	112.4
3-E	West Reef	5.0	7/10/67 1215	8/22/67 1015	42.9	26.2	0.6	60.0
4-E	West Reef	5.0	7/10/67 1215	8/22/67 1015	42.9	23.0	0.5	52.7
5-E	Crib Reef	5.3	7/10/67 1320	8/22/67 1100	42.9	24.3	0.6	55.6
6-E	Crib Reef	5.3	7/10/67 1320	8/22/67 1100	42.9	19.7	0.5	45.1
7-E	Toussaint Reef	7.5	7/10/67 1350	8/22/67 1115	42.9	45.5	1.1	104.2
8-E	Toussaint Reef	7.5	7/10/67 1350	8/22/67 1115	42.9	42.7	1.0	97.8

TABLE 8 CON'T.

1967 SUMMARY

Collector Number	Station Location	Period of Record	Days	Total Height (mm)	Average Rate (mm/day)	Total Volume (ml)
1	Starve Is. Reef	5/13/67 - 8/22/67	100.6	112.6	1.1	257.9
2	Starve Is. Reef	5/13/67 - 8/22/67	100.6	117.1	1.2	268.2
3	West Reef	5/13/67 - 8/22/67	101.5	62.8	0.6	143.8
4	West Reef	5/13/67 - 8/22/67	101.5	64.7	0.6	148.2
5	Crib Reef	5/11/67 - 8/22/67	102.9	99.8	1.0	228.5
6	Crib Reef	5/11/67 - 8/22/67	102.9	78.0	0.8	178.6
7	Toussaint Reef	5/11/67 - 8/22/67	102.9	145.1	1.4	332.3
8	Toussaint Reef	5/11/67 - 8/22/67	102.9	141.6	1.4	324.3
		Total Average	102.0	102.7	1.0	235.2

TABLE 9

1968 SEDIMENT COLLECTOR DATA - WESTERN LAKE ERIE REEF AREA

SET NO. 1

Collector Number	Station Location	Water Depth (feet)	Date & Time Set	Date & Time Retrieved	Time Down (days)	Height (mm)	Rate (mm/day)	Volume (ml)
1-A	Starve Is. Reef	8.0	4/26/68 1415	6/4/68 1015	38.8	72.5	1.9	166.0
2-A	Starve Is. Reef	8.0	4/26/68 1415	6/4/68 1015	38.8	61.0	1.6	139.6
3-A	West Reef	5.0	4/26/68 1305	6/5/68 1040	39.9	25.0	0.6	57.3
4-A	West Reef	5.0	4/26/68 1305	6/5/68 1040	39.9	46.8	1.2	107.2
5-A	Crib Reef	5.5	4/26/68 0935	6/5/68 0920	40.0	76.7	1.9	175.6
6-A	Crib Reef	5.5	4/26/68 0935	6/5/68 0920	40.0	76.0	1.9	174.0
7-A	Toussaint Reef	7.5	4/26/68 0830	6/5/68 0850	40.0	75.3	1.9	172.4
8-A	Toussaint Reef	7.5	4/26/68 0830	6/5/68 0850	40.0	69.2	1.7	158.5
	SET NO. 2							
1-B	Starve Is. Reef	8.0	6/4/68 1035	6/19/68 1800	15.4	23.7	1.5	54.2
2-B	Starve Is. Reef	8.0	6/4/68 1035	6/19/68 1800	15.4	33.4	2.2	76.5
3-B	West Reef	5.0	6/5/68 1055	6/19/68 1655	14.3	9.2	0.6	21.0
4-B	West Reef	5.0	6/5/68 1055	6/19/68 1655	14.3	8.3	0.6	19.0
5-B	Crib Reef	5.5	6/5/68 0930	6/20/68 0915	15.0	32.0	2.1	73.3
6-B	Crib Reef	5.5	6/5/68 0930	6/20/68 0915	15.0	33.5	2.2	76.7

TABLE 9 CON'T.

SET NO. 2
(continued)

Collector Number	Station Location	Water Depth (feet)	Date & Time Set	Date & Time Retrieved	Time Down (days)	Height (mm)	Rate (mm/day)	Volume (ml)
7-B	Toussaint Reef	7.5	6/5/68 0905	6/20/68 0955	15.0	31.5	2.1	72.1
8-B	Toussaint Reef	7.5	6/5/68 0905	6/20/68 0955	15.0	32.5	2.2	74.4
				SET NO. 3				
1-C	Starve Is. Reef	8.0	6/19/68 1825	7/26/68 1330	36.8	40.2	1.1	92.1
2-C	Starve Is. Reef	8.0	6/19/68 1825	7/26/68 1330	36.8	42.1	1.1	96.4
3-C	West Reef	5.0	6/19/68 1710	7/22/68 1615	33.0	23.0	0.7	52.7
4-C	West Reef	5.0	6/19/68 1710	7/22/68 1615	33.0	22.5	0.7	51.5
5-C	Crib Reef	5.5	6/20/68 0925	7/26/68 1130	36.1	42.8	1.2	98.0
6-C	Crib Reef	5.5	6/20/68 0925	7/26/68 1130	36.1	41.0	1.1	93.9
7-C	Toussaint Reef	7.5	6/20/68 1005	7/26/68 1015	36.0	55.8	1.5	127.8
8-C	Toussaint Reef	7.5	6/20/68 1005	7/26/68 1015	36.0	51.2	1.4	117.2
				SET NO. 4				
1-D	Starve Is. Reef	8.0	7/26/68 1345	8/19/68 1700	24.1	25.4	1.1	58.2
2-D	Starve Is. Reef	8.0	7/26/68 1345	8/19/68 1700	24.1	28.6	1.2	65.5
3-D	West Reef	5.0	7/22/68 1640	8/8/68 1150	16.8	8.5	0.5	19.5
4-D	West Reef	5.0	7/22/68 1640	8/8/68 1150	16.8	9.0	0.5	20.6

TABLE 9 CON'T.

SET NO. 4
(continued)

Collector Number	Station Location	Water Depth (feet)	Date & Time Set	Date & Time Retrieved	Time Down (days)	Height (mm)	Rate (mm/day)	Volume (ml)
5-D	Crib Reef	5.5	7/26/68 1200	8/21/68 1030	25.9	20.3	0.8	46.5
6-D	Crib Reef	5.5	7/26/68 1200	8/21/68 1030	25.9	21.0	0.8	48.1
7-D	Toussaint Reef	7.5	7/26/68 1035	8/21/68 1100	26.0	27.5	1.1	63.0
8-D	Toussaint Reef	7.5	7/26/68 1035	8/21/68 1100	26.0	25.9	1.0	59.3
			SET NO. 5					
1-E	Starve Is. Reef	8.0	8/19/68 1715	9/26/68 0930	37.7	65.8	1.7	150.7
2-E	Starve Is. Reef	8.0	8/19/68 1715	9/26/68 0930	37.7	56.0	1.5	128.2
3-E	West Reef	5.0	8/8/68 1210	9/26/68 1045	48.9	42.7	0.9	97.8
4-E	West Reef	5.0	8/8/68 1210	9/26/68 1045	48.9	35.0	0.7	80.2
5-E	Crib Reef	5.5	8/21/68 1045	9/26/68 1330	36.1	45.6	1.3	104.4
6-E	Crib Reef	5.5	8/21/68 1045	9/26/68 1330	36.1	36.4	1.0	83.4
7-E	Toussaint Reef	7.5	8/21/68 1115	9/26/68 1440	36.2	57.5	1.6	131.7
8-E	Toussaint Reef	7.5	8/21/68 1115	9/26/68 1440	36.2	56.7	1.6	129.8
			SET NO. 6					
1-F	Starve Is. Reef	8.0	9/26/68 0945	10/17/68 1330	21.1	53.4	2.5	122.3
2-F	Starve Is. Reef	8.0	9/26/68 0945	10/17/68 1330	21.1	58.2	2.8	133.3

TABLE 9 CON'T.

SET NO. 6
(continued)

Collector Number	Station Location	Water Depth (feet)	Date & Time Set	Date & Time Retrieved	Time Down (days)	Height (mm)	Rate (mm/day)	Volume (ml)
3-F	West Reef	5.0	9/26/68 1100	10/18/68 1100	22.0	22.6	1.0	51.8
4-F	West Reef	5.0	9/26/68 1100	10/18/68 1100	22.0	23.4	1.1	53.6
5-F	Crib Reef	5.5	9/26/68 1350	10/16/68 1000	19.8	32.0	1.6	73.3
6-F	Crib Reef	5.5	(Collector lost on station)		----	----	---	-----
7-F	Toussaint Reef	7.5	9/26/68 1430	10/16/68 1030	19.8	46.1	2.3	105.6
8-F	Toussaint Reef	7.5	9/26/68 1430	10/16/68 1030	19.8	45.9	2.3	105.1

TABLE 9 CON'T.

1968 SUMMARY

Collector Number	Station Location	Period of Record	Days	Total Height (mm)	Average Rate (mm/day)	Total Volume (ml)
1	Starve Is. Reef	4/26/68 - 10/17/68	173.9	281.0	1.6	643.5
2	Starve Is. Reef	4/26/68 - 10/17/68	173.9	279.3	1.6	639.6
3	West Reef	4/26/68 - 10/18/68	174.9	131.0	0.7	300.0
4	West Reef	4/26/68 - 10/18/68	174.9	145.0	0.8	332.1
5	Crib Reef	4/26/68 - 10/16/68	172.9	249.4	1.4	571.1
6	Crib Reef	4/26/68 - 9/26/68	153.1	207.9	1.4	476.1
7	Toussaint Reef	4/26/68 - 10/16/68	173.0	293.7	1.7	672.6
8	Toussaint Reef	4/26/68 - 10/16/68	173.0	281.4	1.6	644.3
		Total Average	171.2	233.6	1.4	534.9

TABLE 10 CON'T.

SET NO. 2
(continued)

Collector Number	Station Location	Water Depth (feet)	Date & Time Set	Date & Time Retrieved	Time Down (days)	Height (mm)	Rate (mm/day)	Volume (ml)
7-B	Gull Is. Deep #1	38.5	5/29/69 1500	6/17/69 1645	19.1	13.7	0.7	31.4
8-B	Gull Is. Deep #1	38.5	5/29/69 1500	6/17/69 1645	19.1	13.7	0.7	31.4
			SET NO. 3					
1-C	Starve Is. Reef	8.0	4/25/69 1155	5/13/69 0945	17.9	27.0	1.5	61.8
2-C	Starve Is. Reef	8.0	4/25/69 1155	5/13/69 0945	17.9	25.0	1.4	57.3
3-C	Kelleys Is. Shoal	7.0	5/7/69 1040	5/21/69 1050	14.0	10.5	0.8	24.0
4-C	Kelleys Is. Shoal	7.0	5/7/69 1040	5/21/69 1050	14.0	10.3	0.7	23.6
5-C	Gull Is. Shoal	16.0	6/17/69 1715	7/2/69 1030	14.7	9.2	0.6	21.1
6-C	Gull Is. Shoal	16.0	6/17/69 1715	7/2/69 1030	14.7	5.1	0.4	11.7
7-C	Gull Is. Deep #1	38.5	6/17/69 1700	7/2/69 1100	14.7	14.8	1.0	33.9
8-C	Gull Is. Deep #1	38.5	6/17/69 1700	7/2/69 1100	14.7	14.9	1.0	34.1
			SET NO. 4					
1-D	Starve Is. Reef	8.0	5/13/69 1000	5/29/69 1000	16.0	14.0	0.9	32.1
2-D	Starve Is. Reef	8.0	5/13/69 1000	5/29/69 1000	16.0	14.0	0.9	32.1
3-D	Kelleys Is. Shoal	7.0	5/21/69 1120	6/3/69 1200	14.0	6.5	0.5	14.9
4-D	Kelleys Is. Shoal	7.0	5/21/69 1120	6/3/69 1200	14.0	4.7	0.3	10.8

TABLE 10

1969 SEDIMENT COLLECTOR DATA - WESTERN LAKE ERIE REEF AREA

Collector Number	Station Location	Water Depth (feet)	Date & Time Set	Date & Time Retrieved	Time Down (days)	Height (mm)	Rate (mm/day)	Volume (ml)
SET NO. 1								
1-A	Starve Is. Reef	8.0	4/3/69 1200	4/14/69 1130	11.0	6.0	0.6	13.7
2-A	Starve Is. Reef	8.0	4/3/69 1200	4/14/69 1130	11.0	5.0	0.5	11.5
3-A	Kelleys Is. Shoal	7.0	4/7/69 1500	4/24/69 1445	17.0	17.0	1.0	38.9
4-A	Kelleys Is. Shoal	7.0	4/7/69 1500	4/24/69 1445	17.0	16.0	0.9	36.6
5-A	Gull Is. Shoal	16.0	5/15/69 1000	5/29/69 1430	14.2	8.2	0.6	18.8
6-A	Gull Is. Shoal	16.0	5/15/69 1000	5/29/69 1430	14.2	8.0	0.6	18.3
7-A	Gull Is. Deep #1	38.5	5/15/69 1015	5/29/69 1445	14.2	11.0	0.8	25.2
8-A	Gull Is. Deep #1	38.5	5/15/69 1015	5/29/69 1445	14.2	11.0	0.8	25.2
SET NO. 2								
1-B	Starve Is. Reef	8.0	4/14/69 1140	4/25/69 1140	11.0	35.0	3.2	80.2
2-B	Starve Is. Reef	8.0	4/14/69 1140	4/25/69 1140	11.0	37.0	3.4	84.7
3-B	Kelleys Is. Shoal	7.0	4/24/69 1500	5/7/69 1020	12.8	3.0	0.2	6.9
4-B	Kelleys Is. Shoal	7.0	4/24/69 1500	5/7/69 1020	12.8	3.0	0.2	6.9
5-B	Gull Is. Shoal	16.0	5/29/69 1440	6/17/69 1700	19.1	9.2	0.5	21.1
6-B	Gull Is. Shoal	16.0	5/29/69 1440	6/17/69 1700	19.1	10.0	0.5	22.9

TABLE 10 CON'T.

SET NO. 4
(continued)

Collector Number	Station Location	Water Depth (feet)	Date & Time Set	Date & Time Retrieved	Time Down (days)	Height (mm)	Rate (mm/day)	Volume (ml)
5-D	Gull Is. Shoal	16.0	7/2/69 1035	7/11/69 1345	9.1	25.0	2.8	57.3
6-D	Gull Is. Shoal	16.0	7/2/69 1035	7/11/69 1345	9.1	25.2	2.8	57.7
7-D	Gull Is. Deep #1	38.5	7/2/69 1115	7/11/69 1330	9.1	41.5	4.6	95.0
8-D	Gull Is. Deep #1	38.5	7/2/69 1115	7/11/69 1330	9.1	44.8	4.9	102.6
			SET NO. 5					
1-E	Starve Is. Reef	8.0	5/29/69 1015	6/27/69 0900	29.0	29.0	1.0	66.4
2-E	Starve Is. Reef	8.0	5/29/69 1015	6/27/69 0900	29.0	26.5	0.9	60.7
3-E	Kelleys Is. Shoal	7.0	6/3/69 1220	6/17/69 1200	13.0	7.7	0.6	17.6
4-E	Kelleys Is. Shoal	7.0	6/3/69 1220	6/17/69 1200	13.0	5.4	0.4	12.4
5-E	Gull Is. Shoal	16.0	7/11/69 1350	7/30/69 1415	19.0	4.2	0.2	9.6
6-E	Gull Is. Shoal	16.0	7/11/69 1350	7/30/69 1415	19.0	4.7	0.3	10.8
7-E	Gull Is. Deep #2	39.5	7/11/69 1400	7/30/69 1345	19.0	9.7	0.5	22.2
8-E	Gull Is. Deep #2	39.5	7/11/69 1400	7/30/69 1345	19.0	8.2	0.4	18.8
			SET NO. 6					
3-F	Kelleys Is. Shoal	7.0	6/17/69 1210	7/11/69 1300	24.0	17.0	0.7	38.9
4-F	Kelleys Is. Shoal	7.0	6/17/69 1210	7/11/69 1300	24.0	18.2	0.8	41.7

TABLE 10 CON'T.

Collector Number	Station Location	Water Depth (feet)	Date & Time Set	Date & Time Retrived	Time Down (days)	Height (mm)	Rate (mm/day)	Volume (ml)
SET NO. 6 (continued)								
5-F	Gull Is. Shoal	16.0	7/30/69 1420	8/15/69 1040	15.8	3.6	0.2	8.2
6-F	Gull Is. Shoal	16.0	7/30/69 1420	8/15/69 1040	15.8	4.8	0.3	10.9
7-F	Gull Is. Deep #2	39.5	7/30/69 1350	8/15/69 1015	15.8	8.5	0.5	19.5
8-F	Gull Is. Deep #2	39.5	7/30/69 1350	8/15/69 1015	15.8	7.1	0.5	16.3
SET NO. 7								
3-G	Kelleys Is. Shoal	7.0	7/11/69 1315	7/30/69 1315	19.0	4.2	0.2	9.6
4-G	Kelleys Is. Shoal	7.0	7/11/69 1315	7/30/69 1315	19.0	5.0	0.3	11.5
5-G	Gull Is. Shoal	16.0	8/15/69 1045	9/11/69 1300	27.1	22.0	0.8	50.4
6-G	Gull Is. Shoal	16.0	8/15/69 1045	9/11/69 1300	27.1	22.5	0.8	51.5
7-G	Gull Is. Deep #2	39.5	8/15/69 1020	9/11/69 1130	27.1	33.2	1.2	76.0
8-G	Gull Is. Deep #2	39.5	8/15/69 1020	9/11/69 1130	27.1	35.2	1.3	80.6
SET NO. 8								
3-H	Kelleys Is. Shoal	7.0	7/30/69 1325	8/15/69 0930	15.8	4.0	0.3	9.2
4-H	Kelleys Is. Shoal	7.0	7/30/69 1325	8/15/69 0930	15.8	3.0	0.2	6.9
5-H	Gull Is. Shoal	16.0	9/11/69 1305	9/29/69 1145	17.9	28.0	1.6	64.1
6-H	Gull Is. Shoal	16.0	9/11/69 1305	9/29/69 1145	17.9	37.7	2.1	86.3
7-H	Gull Is. Deep #2	39.5	9/11/69 1135	9/29/69 1100	18.0	38.7	2.2	88.6
8-H	Gull Is. Deep #2	39.5	9/11/69 1135	9/29/69 1100	18.0	41.0	2.3	93.9

TABLE 10 CON'T.

SET NO. 9

Collector Number	Station Location	Water Depth (feet)	Date & Time Set	Date & Time Retrieved	Time Down (days)	Height (mm)	Rate (mm/day)	Volume (ml)
3-I	Kelleys Is. Shoal	7.0	8/15/69 0945	9/11/69 1100	27.1	15.0	0.6	34.4
4-I	Kelleys Is. Shoal	7.0	8/15/69 1045	9/11/69 1100	27.1	15.0	0.6	34.4
5-I	Gull Is. Shoal	16.0	9/29/69 1200	10/28/69 1030	28.9	46.5	1.6	106.5
6-I	Gull Is. Shoal	16.0	9/29/69 1200	10/28/69 1030	28.9	47.3	1.6	108.3
7-I	Gull Is. Deep #2	39.5	9/29/69 1115	10/28/69 1100	29.0	57.8	2.0	132.4
8-I	Gull Is. Deep #2	39.5	9/29/69 1115	10/28/69 1100	29.0	60.0	2.1	137.4

SET NO. 10

Collector Number	Station Location	Water Depth (feet)	Date & Time Set	Date & Time Retrieved	Time Down (days)	Height (mm)	Rate (mm/day)	Volume (ml)
3-J	Kelleys Is. Shoal	7.0	9/11/69 1115	9/29/69 1030	18.0	20.2	1.1	46.3
4-J	Kelleys Is. Shoal	7.0	9/11/69 1115	9/29/69 1030	18.0	20.2	1.1	46.3

TABLE 10 CON'T.

1969 SUMMARY

Collector Number	Station Location	Period of Record	Days	Total Height (mm)	Average Rate (mm/day)	Total Volume (ml)
1	Starve Is. Reef	4/2/69 - 6/27/69	84.9	111.0	1.3	254.2
2	Starve Is. Reef	4/3/69 - 6/27/69	84.9	107.5	1.3	246.3
3	Kelleys Is. Shoal	4/7/69 - 9/29/69	174.7	105.1	0.6	240.7
4	Kelleys Is. Shoal	4/7/69 - 9/29/69	174.7	100.8	0.6	231.1
5	Gull Is. Shoal	5/15/69 - 10/28/69	165.8	155.9	0.9	357.1
6	Gull Is. Shoal	5/15/69 - 10/28/69	165.8	165.3	1.0	378.3
7	Gull Is. Deep #1	5/15/69 - 7/11/69	57.1	81.0	1.4	170.6
8	Gull Is. Deep #1	5/15/69 - 7/11/69	57.1	84.4	1.5	178.4
7	Gull Is. Deep #2	7/11/69 - 10/28/69	108.9	147.9	1.4	338.7
8	Gull Is. Deep #2	7/11/69 - 10/28/69	108.9	151.5	1.4	347.0
		Total Average	118.3	121.0	1.1	247.2

TABLE 11 CON'T.

1967 DATA
(continued)

Percent of Particle Diameters (mm)

Collector Number	SAND >.061	SILT .061 to .045	.045 to .032	.032 to .020	.020 to .015	.015 to .009	.009 to .006	CLAY .006 to .004	.004 to .003	.003 to .002	<.002
6-D 6-E	2.94	8.82	30.89	22.06	0.00	23.53	11.76				
7-A 7-B 7-C	3.03	0.00	0.00	51.08	33.77	6.06	2.60	3.46			
7-D 7-E	2.06	2.58	1.03	63.40	8.25	7.22	1.55	1.55	5.15	3.09	4.12
1968 DATA											
1-A	1.85	12.96	12.04	22.22	15.75	12.96	13.89	8.33			
3-A	2.17	6.52	70.66	20.65							
5-A	4.88	7.31	50.00	11.59	1.21	11.59	3.05	2.44	7.93		
7-A	5.20	8.44	56.49	8.44	3.25	18.18					
1-B	2.25	14.61	61.80	8.99	12.35						
3,4-B	0.00	28.21	20.51	51.28							
5,6-B	1.32	5.27	64.47	3.29	1.97	7.89	7.24	8.55			
7,8-B	1.59	4.76	40.21	37.57	5.82	3.17	6.88				

TABLE 11

GRAIN SIZE ANALYSES OF SEDIMENT COLLECTOR SAMPLES

1967 DATA

Percent of Particle Diameters (mm)

Collector Number	SAND				SILT				CLAY		
	>.061	.061 to .045	.045 to .032	.032 to 0.20	.020 to .015	.015 to .009	.009 to .006	.006 to .004	.004 to .003	.003 to .002	<.002
2-A 2-B 2-C	11.22	0.00	6.34	49.28	21.46	7.80	3.90				
2-D 2-E	1.38	0.00	12.39	37.15	0.46	5.96	12.84	11.93	1.83	0.92	15.14
4-A 4-B 4-C	4.05	0.00	37.84	45.95	1.35	10.81					
4-D 4-E	3.39	2.54	31.36	44.07	2.54	6.78	2.54	6.78			
6-A 6-B 6-C	1.96	1.31	29.41	51.63	0.00	6.54	3.92	5.23			

TABLE 11 CON'T.

1968 DATA
(continued)

Percent of Particle Diameters (mm)

Collector Number	SAND				SILT				CLAY		
	>.061	.061 to .045	.045 to .032	.032 to .020	.020 to .015	.015 to .009	.009 to .006	.006 to .004	.004 to .003	.003 to .002	<.002
1-C	0.81	7.25	75.81	2.42	2.42	11.29					
3-C	2.08	6.25	62.50	29.17							
5-C	2.25	3.37	42.70	7.87	6.74	1.12	5.62	7.86	4.49	2.25	15.73
7-C	1.28	3.85	24.36	20.52	14.10	14.10	21.79				
1-D	1.59	7.94	73.01	17.46							
3,4-D	3.45	3.45	55.17	37.93							
5-D	2.27	29.55	36.36	31.82							
7-D	2.22	6.67	60.00	6.67	4.44	20.00					
1-E	0.00	5.43	64.13	16.30	4.35	9.79					
3-E	1.79	7.14	14.29	37.50	19.64	19.64					
5-E	5.45	10.91	58.18	1.82	3.64	20.00					
7-E	3.33	11.67	63.33	21.67							
1-F	0.93	7.41	49.07	29.63	2.78	10.18					
3-F	1.79	19.64	62.50	16.07							
5-F	1.79	0.00	44.64	10.71	3.57	39.29					
7-F	2.22	13.33	36.67	4.44	6.67	10.00	2.23	3.33	0.00	3.33	17.78

TABLE 11 CON'T.

1969 DATA

Percent of Particle Diameters (mm)

Collector Number	SAND >.061	SILT .061 to .045	.045 to .032	.032 to .020	.020 to .015	.015 to .009	.009 to .006	CLAY .006 to .004	.004 to .003	.003 to .002	<.002
3,4-B		27.27	72.73								
3,4-C	2.38	33.33	42.86	2.38	19.05						
3,4-D,E		7.41	70.37	22.22							
3,4-F	2.32	12.79	77.91	6.98							
3,4-G,H		30.77	69.23								
3,4-I	4.35	1.45	14.49	60.87	18.84						
3,4-J	2.44	4.06	31.71	55.29	6.50						
5,6-A,B	11.76	38.24	35.30	14.70							
5,6-C		51.85	37.04	11.11							
5,6-D	3.52	8.45	49.31	19.72		3.52	5.63	5.63	4.22		
5,6-E,F	5.56	16.67	16.67	16.67	44.43						
5,6-G	3.16	11.58	73.69	2.10	7.37	2.10					
5,6-H	2.63	5.26	25.79	46.32	4.21	3.16	2.10	6.32	4.21		
5,6-I	3.32	1.02	2.30	27.89	30.70	13.04	3.07	6.90	11.76		
7,8-A	5.71	68.58	25.71								
7,8-B	2.94	13.24	70.59	4.41	1.47	7.35					
7,8-C,D	2.00	5.50	25.50	38.00	4.50	9.50	5.50	2.50	7.00		
7,8-E,F	1.78	35.71	38.28	3.58		16.07	3.58				
7,8-G	1.44	0.48	1.44	54.81	23.56	11.54	2.40	0.48	3.85		
7,8-H	1.53	3.82	12.60	54.97	0.76	5.72	5.72	5.34	9.54		
7,8-I	1.89	2.32	3.59	14.10	36.84	22.95	1.68	5.05	11.58		

TABLE 12

PERCENT VOLATILE SOLIDS AND PARTICLE SIZES IN SEDIMENT COLLECTOR SAMPLES - 1967

Location	Volatile Solids	Sand	Silt Course	Silt Medium	Silt Fine	Clay
Toussaint Reef						
May - June	9.2	3.0	0.0	84.8	8.7	3.5
July - August	10.1	2.1	3.6	71.7	8.8	13.9
Starve Island Reef						
May - June	9.5	11.2	6.3	70.8	11.7	0.0
July - August	9.3	1.4	12.4	37.6	18.8	29.8
Crib Reef						
May - June	9.5	2.0	30.7	51.6	10.5	5.2
July - August	12.4	2.9	39.7	22.1	35.3	0.0
West Reef						
May - June	11.4	4.1	37.8	47.3	10.8	0.0
July - August	10.6	3.4	33.9	46.6	9.3	6.8
Mean						
May - June	9.9	5.1		92.7		2.2
July - August	10.6	2.5		84.9		12.6

TABLE 13

PERCENT PARTICLE SIZES IN SEDIMENT
COLLECTOR SAMPLES - 1968

Location	Collector No.	Percent Sand (>0.061mm)	Percent Silt (0.061-0.004mm)	Percent Clay (<0.004mm)
Starve Is. Reef	1,2-A	1.85	98.15	0.00
	1,2-B	2.25	97.75	0.00
	1,2-C	0.81	99.19	0.00
	1,2-D	1.59	98.41	0.00
	1,2-E	0.00	100.00	0.00
	1,2-F	0.93	99.07	0.00
		mean 1.24		
West Reef	3,4-A	2.17	97.83	0.00
	3,4-B	0.00	100.00	0.00
	3,4-C	2.08	97.92	0.00
	3,4-D	3.45	96.55	0.00
	3,4-E	1.79	98.21	0.00
	3,4-F	1.79	98.21	0.00
		mean 1.48		
Crib Reef	5,6-A	4.88	87.19	7.93
	5,6-B	1.32	98.68	0.00
	5,6-C	2.25	75.29	22.46
	5,6-D	2.27	97.73	0.00
	5,6-E	5.45	94.55	0.00
	5,6-F	1.79	98.21	0.00
		mean 2.99		
Toussaint Reef	7,8-A	5.20	94.80	0.00
	7,8-B	1.59	98.41	0.00
	7,8-C	1.28	98.72	0.00
	7,8-D	2.22	97.78	0.00
	7,8-E	3.33	96.67	0.00
	7,8-F	2.22	76.67	21.11
		mean 2.64		

TABLE 14

WENTWORTH SEDIMENT GRADE SCALE

Class	Grade limits: microns (approx.)	Grade limits: mm	Grade limits: in	Grade name	ϕ units ($-\log_2$ diameters in mm)	U.S. Sieve series
GRAVEL		4096	160		-12	
				Very large boulders		
		2048	80		-11	
				Large boulders		
		1024	40		-10	
				Medium boulders		
		512	20		-9	
				Small boulders		
		256	10		-8	
				Large cobbles		
		128	5		-7	
				Small cobbles		
		64	2.5		-6	
				Very coarse pebbles		
		32	1.3		-5	
				Coarse pebbles		
		16	0.6		-4	
				Medium pebbles		
		8	0.3		-3	
				Fine pebbles		
		4	0.16		-2	5
				Very fine pebbles		7
SAND		2	0.08		-1	10
				Very coarse sand		14
	1000	1			0	18
				Coarse sand		25
	500	½			+1	35
				Medium sand		45
	250	¼			+2	60
				Fine sand		80
	125	⅛			+3	120
				Very fine sand		170
MUD	62	1/16			+4	230
				Coarse silt		
	31	1/32			+5	
				Medium silt		
	16	1/64			+6	
				Fine silt		
	8	1/128			+7	
				Very fine silt		
	4	1/256			+8	
				Coarse clay		
	2	1/512			+9	
				Medium clay		
	1	1/1024			+10	
				Fine clay		
	½	1/2048			+11	
				Very fine clay		
	¼	1/4096			+12	

Modified from Dunbar and Rodgers (1957).

TABLE 15

VOLATILE SOLIDS ANALYSES OF SEDIMENT COLLECTOR SAMPLES

1967 DATA

Collector Number	Station Location	Period of Collection	Percent Volatile Solids
1-A	Starve Island Reef	5/13/67-- 5/24/67	9.48
1-B	Starve Island Reef	5/24/67 - 6/2/67	9.22
1-C	Starve Island Reef	6/2/67 - 6/26/67	9.89
1-D	Starve Island Reef	6/26/67 - 7/10/67	9.25
1-E	Starve Island Reef	7/10/67 - 8/22/67	9.32
3-A	West Reef	5/13/67 - 5/24/67	10.82
3-B	West Reef	5/24/67 - 6/2/67	10.91
3-C	West Reef	6/2/67 - 6/26/67	12.55
3-D	West Reef	6/26/67 - 7/10/67	10.77
3-E	West Reef	7/10/67 - 8/22/67	10.41
5-A	Crib Reef	5/11/67 - 5/24/67	8.89
5-B	Crib Reef	5/24/67 - 6/5/67	8.99
5-C	Crib Reef	6/5/67 - 6/26/67	10.49
5-D	Crib Reef	6/26/67 - 7/10/67	13.24
5-E	Crib Reef	7/10/67 0 8/22/67	11.61
8-A	Toussaint Reef	5/11/67 - 5/24/67	9.21
8-B	Toussaint Reef	5/24/67 - 6/5/67	8.61
8-C	Toussaint Reef	6/5/67 - 6/26/67	9.68
8-D	Toussaint Reef	6/26/67 - 7/10/67	9.92
8-E	Toussaint Reef	7/10/67 - 8/22/67	10.25

TABLE 15
(continued)
1968 DATA

Collector Number	Station Location	Period of Collection	Percent Volatile Solids
2-A	Starve Island Reef	4/26/68 - 6/4/68	8.89
2-B	Starve Island Reef	6/4/68 - 6/19/68	8.98
2-C	Starve Island Reef	6/19/68 - 7/26/68	9.27
2-D	Starve Island Reef	7/26/68 - 8/19/68	10.21
2-E	Starve Island Reef	8/19/68 - 9/26/68	9.65
2-F	Starve Island Reef	9/26/68 - 10/17/68	9.30
4-A	West Reef	4/26/68 - 6/5/68	9.66
3, 4-B	West Reef	6/5/68 - 6/19/68	10.48
4-C	West Reef	6/19/68 - 7/22/68	11.60
3, 4-D	West Reef	7/22/68 - 8/8/68	11.01
4-E	West Reef	8/8/68 - 9/26/68	14.05
4-F	West Reef	9/26/68 - 10/18/68	10.01
6-A	Crib Reef	4/26/68 - 6/5/68	9.30
5, 6-B	Crib Reef	6/5/68 - 6/20/68	8.95
6-C	Crib Reef	6/20/68 - 7/26/68	10.80
6-D	Crib Reef	7/26/68 - 8/21/68	11.76
6-E	Crib Reef	8/21/68 - 9/26/68	10.96
5-F	Crib Reef	9/26/68 - 10/16/68	10.41
8-A	Toussaint Reef	4/26/68 - 6/5/68	8.43
7, 8-B	Toussiant Reef	6/5/68 - 6/20/68	9.57
8-C	Toussaint Reef	6/20/68 - 7/26/68	9.94
8-D	Toussaint Reef	7/26/68 - 8/21/68	11.93
8-E	Toussaint Reef	8/21/68 - 9/26/68	10.56

TABLE 16

TRIBUTARY LOADING TO LAKE ERIE FROM NORTHWESTERN OHIO STREAMS[1]

River	Year	Runoff (cm)	Soluble Reactive Phosphorus			Total Phosphorus			Nitrite & Nitrate (N)			Total Suspended Solids		
			Total Load (m tons)	Conc. (mg/l)	Unit Area Load (kg/ha/yr)	Total Load (m tons)	Conc. (mg/l)	Unit Area Load (kg/ha/yr)	Total Load (m tons)	Conc. (mg/l)	Unit Area Load (kg/ha/yr)	Total Load (m tons)	Conc. (mg/l)	Unit Area Load (kg/ha/yr)
Maumee	1975	32	604.0	.116	.37	3190.0	.608	1.95	33,600.0	6.28	20.5	1,590,000.0	304.0	970.0
	1976	26	412.0	.096	.25	2240.0	.523	1.64	13,600.0	3.16	8.30	1,220,000.0	301.0	744.0
Portaga	1975	29	39.5	.127	.36	153.0	.476	1.38	2,380.0	7.42	21.5	79,400.0	248.0	716.0
	1976	24	31.2	.116	.28	106.0	.396	.95	944.0	3.51	8.52	44,700.0	166.0	403.0
Sandusky	1975	32	63.3	.068	.20	476.0	.514	1.47	4,060.0	4.35	12.5	273,000.0	293.0	842.0
	1976	21	57.7	.083	.18	316.0	.455	.98	2,400.0	3.45	7.41	156,000.0	225.0	481.0
Huron	1975	28	25.3	.091	.26	117.0	.417	1.22	923.0	3.31	9.61	71,700.0	257.0	746.0
	1976	25	36.6	.154	.38	70.3	.295	.73	530.0	2.23	5.52	44,000.0	184.7	458.0

1. Data Source: Heidelberg College, River Studies Laboratory

TABLE 17

CORRELATION OF TOTAL SUSPENDED SOLIDS TO UPWELLING RADIANCE AND OTHER WATER QUALITY PARAMETERS IN WESTERN LAKE ERIE

DATE	VARIABLES		EQUATION	MEASURED RANGE (DEPEND)	CORRELATION RANGE	CORRELATION COEFFICIENT	STANDARD ERROR OF ESTIMATE
	DEPENDENT	INDEPENDENT					
3-8-76	Suspended Solids, mg/l	Channel 8, counts	$S.S.=-15.41+1.75x+.0058x^2$	4.1-286	0 to 200	1.00	4.4
	Dissolved Oxygen, ppm	Suspended Solids, mg/l	$D.O.=13.38-.01S.S.$	11-14	11 - 14	.92	.25
	Secchi Depth,	Suspended Solids, mg/l	$S.D.=.70-.0038S.S.$	.05-1.1	0 - .7	.77	.18
	Total Phosphorus ppb	Suspended Solids, mg/l	$T.P.=27.13+1.60S.S.$	15-980	0 - 237	.96	17.6
	Total Phosphorus ppb	Suspended Solids, mg/l	$T.P.=-708+7.0S.S.$	15-980	237 - 980	-	-
	Turbidity, JTU	Suspended Solids, mg/l	$Turb=6.9+.66S.S.+.00078(S.S.)^2$	0-286	0 - 286	.99	5.5
	Inorganic Solids, mg/l	Suspended Solids, mg/l	$I.S.=-2.155+.886S.S.$	0-240	0 - 240	1.00	1.5
3-23-76	Suspended Solids, mg/l	Channel 8, counts	$S.S.=-9.48+.321x+.0019x^2$	3-70	0 - 100	.99	5.3
4-12-76	Suspended Solids, mg/l	Channel 8, counts	$S.S.=-7.20+.185x-.00054x^2$	6-70	0 - 100	.99	5.3
4-13-76	Suspended Solids, mg/l	Channel 8, counts	$S.S.=-15.5+.222x+.00422x^2$	3-40	0 - 100	.99	5.3
5-12-76	Suspended Solids, mg/l	Channel 8, counts	$S.S.=-4.25+.143x+.00027x^2$	3-9.6	0 - 50	.99	5.3

Data Source: NASA/Lewis Research Center

TABLE 18

DISTRIBUTION OF SECONDARY PARAMETERS RELATIVE TO TOTAL SUSPENDED SOLIDS IN WESTERN LAKE ERIE ON 8 MARCH 1976

TOTAL SUSPENDED SOLIDS (mg/l)	TOTAL PHOSPHORUS (ppb)	DISSOLVED OXYGEN (ppm)	SECCHI TRANSPARENCY (m)	TURBIDITY (JTU)	INORGANIC SUSPENDED SOLIDS (mg/l)
10	43	13.3	.66	13.6	6.7
20	59	13.2	.62	20.4	15.6
30	75	13.1	.59	27.4	24.4
50	107	12.9	.51	41.9	42.1
75	147	12.6	.42	60.8	64.3
100	187	12.4	.32	80.7	86.4
125	227	13.1	.23	101.6	108.6
150	342	11.9	.13	123.5	130.7
175	517	11.6	.04	146.3	152.9
200	692	11.4		170.1	175.0

FIGURES

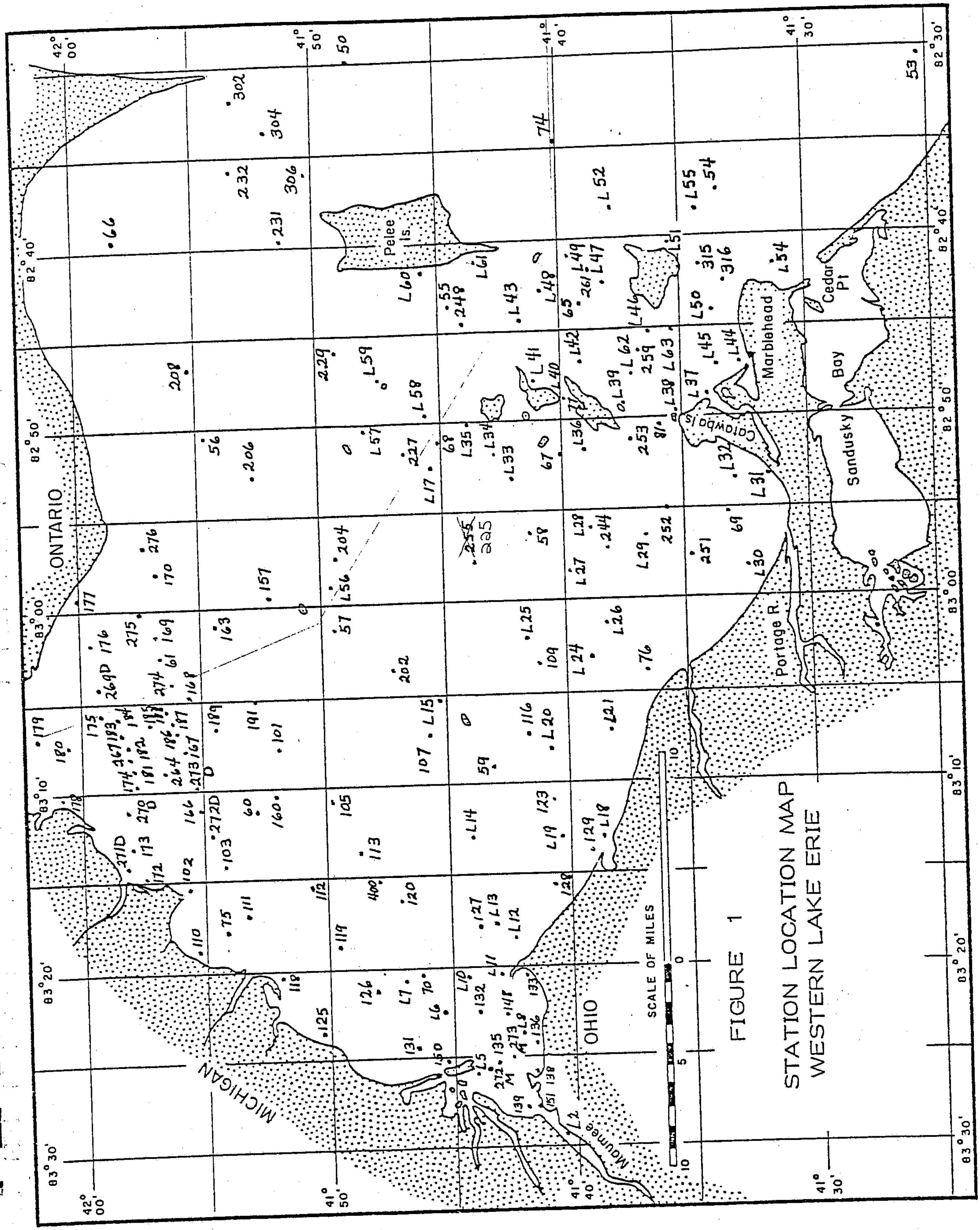
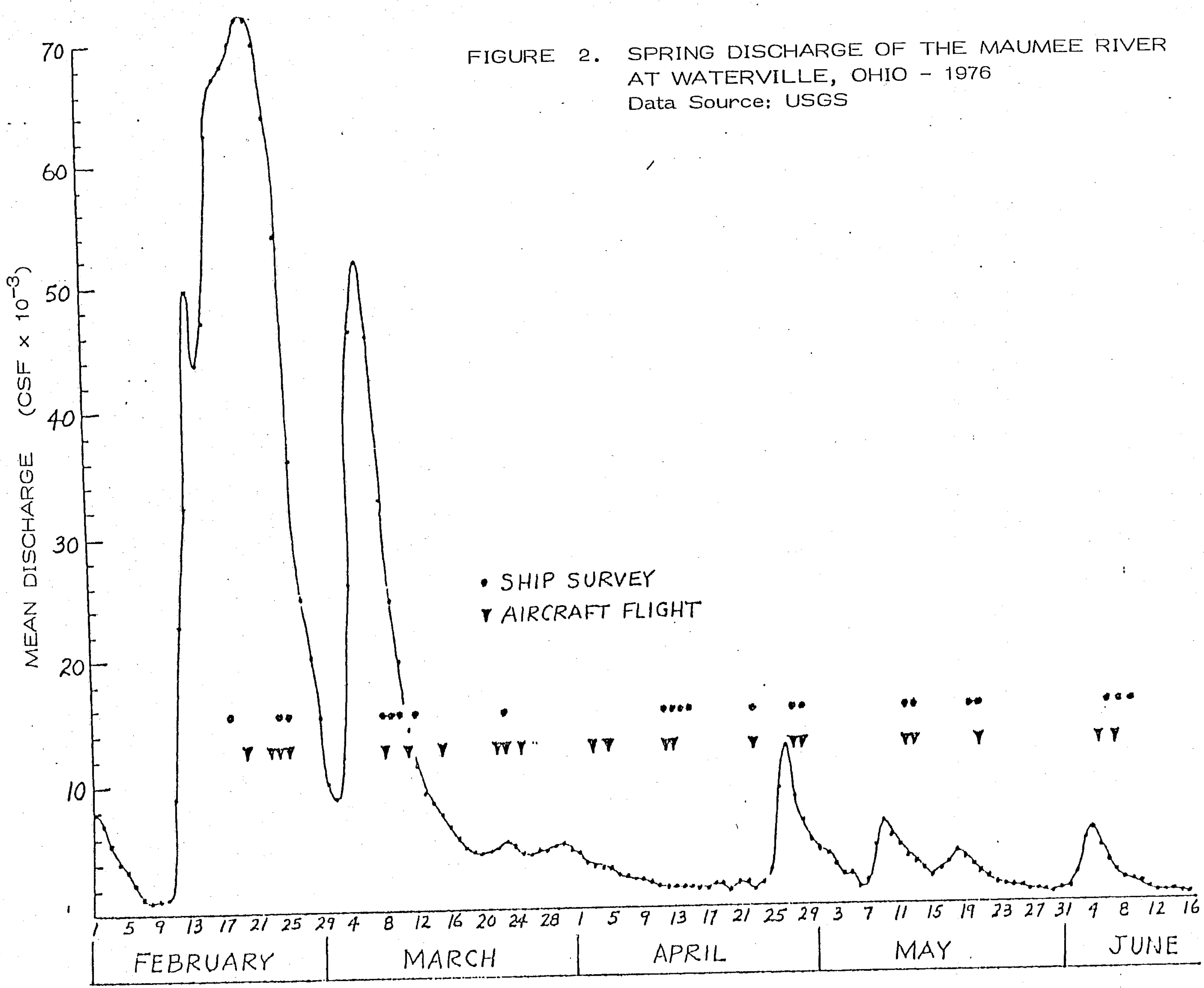


FIGURE 1

STATION LOCATION MAP
WESTERN LAKE ERIE

FIGURE 2. SPRING DISCHARGE OF THE MAUMEE RIVER AT WATERVILLE, OHIO - 1976
Data Source: USGS



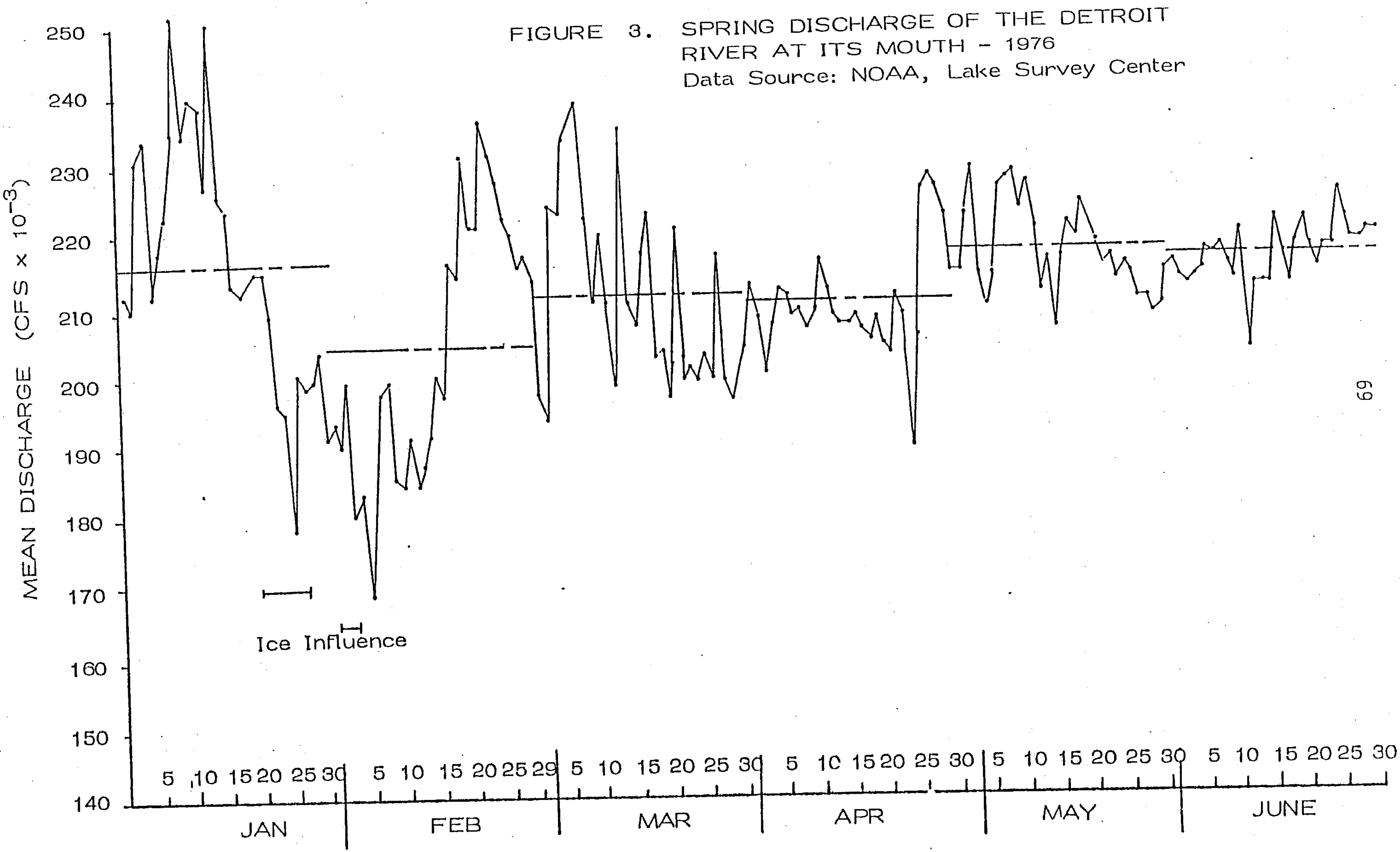


FIGURE 3. SPRING DISCHARGE OF THE DETROIT RIVER AT ITS MOUTH - 1976
Data Source: NOAA, Lake Survey Center

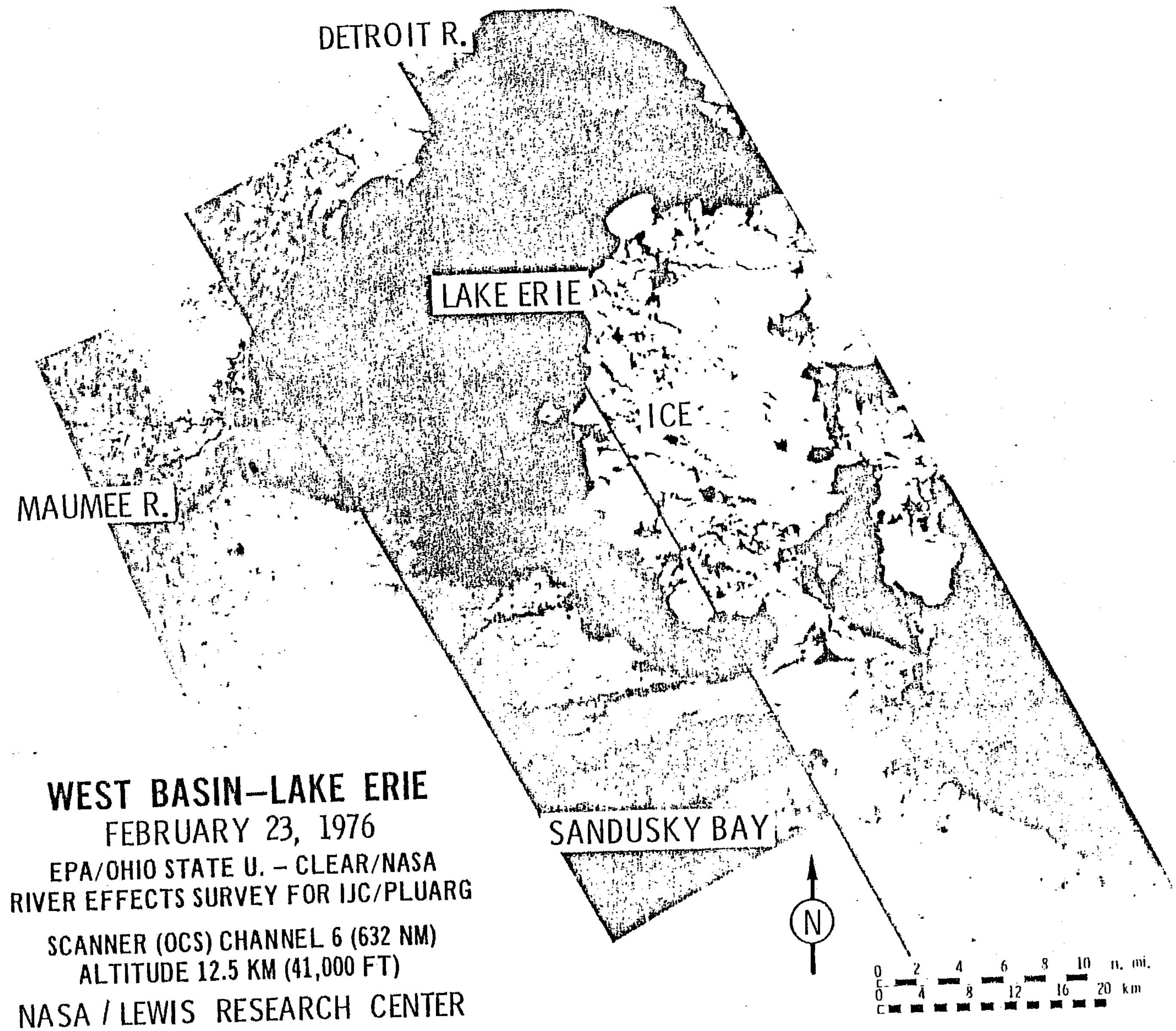

DETROIT R.
LAKE ERIE
ICE
MAUMEE R.
SANDUSKY BAY
N
0 2 4 6 8 10 n. mi.
0 4 8 12 16 20 km
WEST BASIN–LAKE ERIE
FEBRUARY 23, 1976
EPA/OHIO STATE U. – CLEAR/NASA
RIVER EFFECTS SURVEY FOR IJC/PLUARG
SCANNER (OCS) CHANNEL 6 (632 NM)
ALTITUDE 12.5 KM (41,000 FT)
NASA / LEWIS RESEARCH CENTER

FIGURE 5

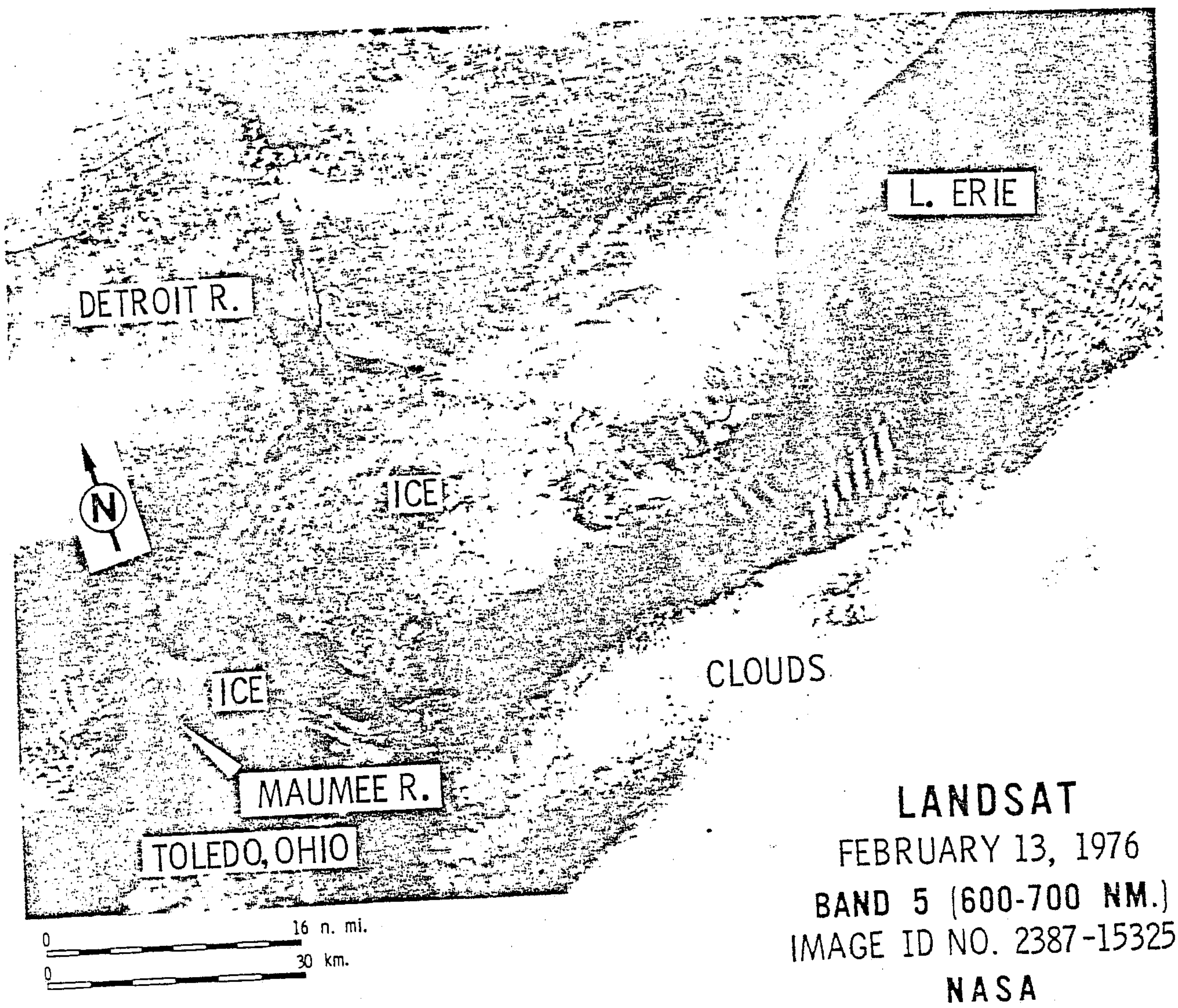

L. ERIE
DETROIT R.
N
ICE
CLOUDS
ICE
MAUMEE R.
TOLEDO, OHIO
0
16 n. mi.
0
30 km.
LANDSAT
FEBRUARY 13, 1976
BAND 5 (600-700 NM.)
IMAGE ID NO. 2387-15325
NASA

FIGURE 4

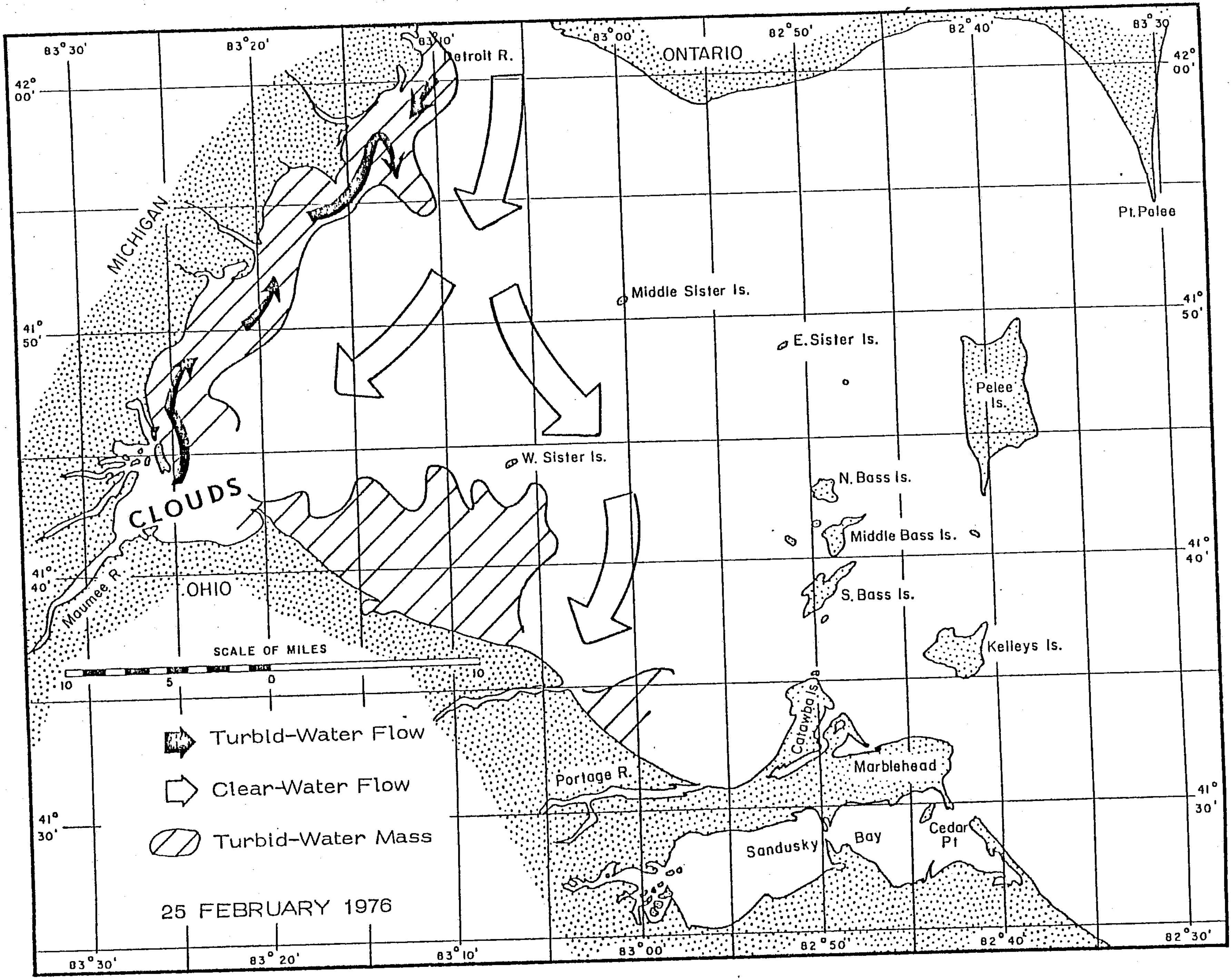


FIGURE 8. WATER FLOW PATTERNS IN WESTERN LAKE ERIE INFERRED FROM NASA OCEAN-COLOR SCANNER IMAGERY - WQ 51.

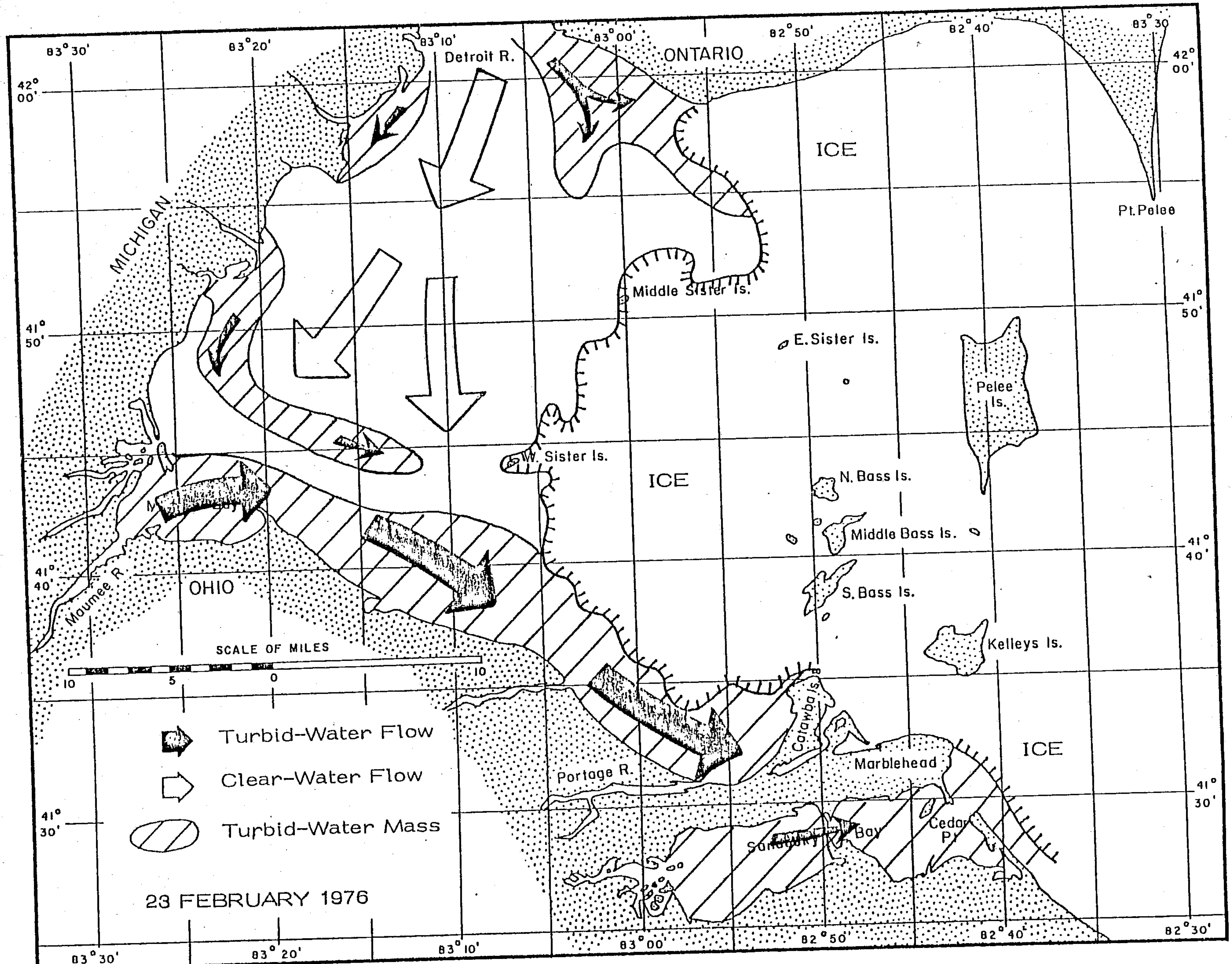


FIGURE 6. WATER FLOW PATTERNS IN WESTERN LAKE ERIE FROM NASA OCEAN-COLOR SCANNER IMAGERY - WQ 48.

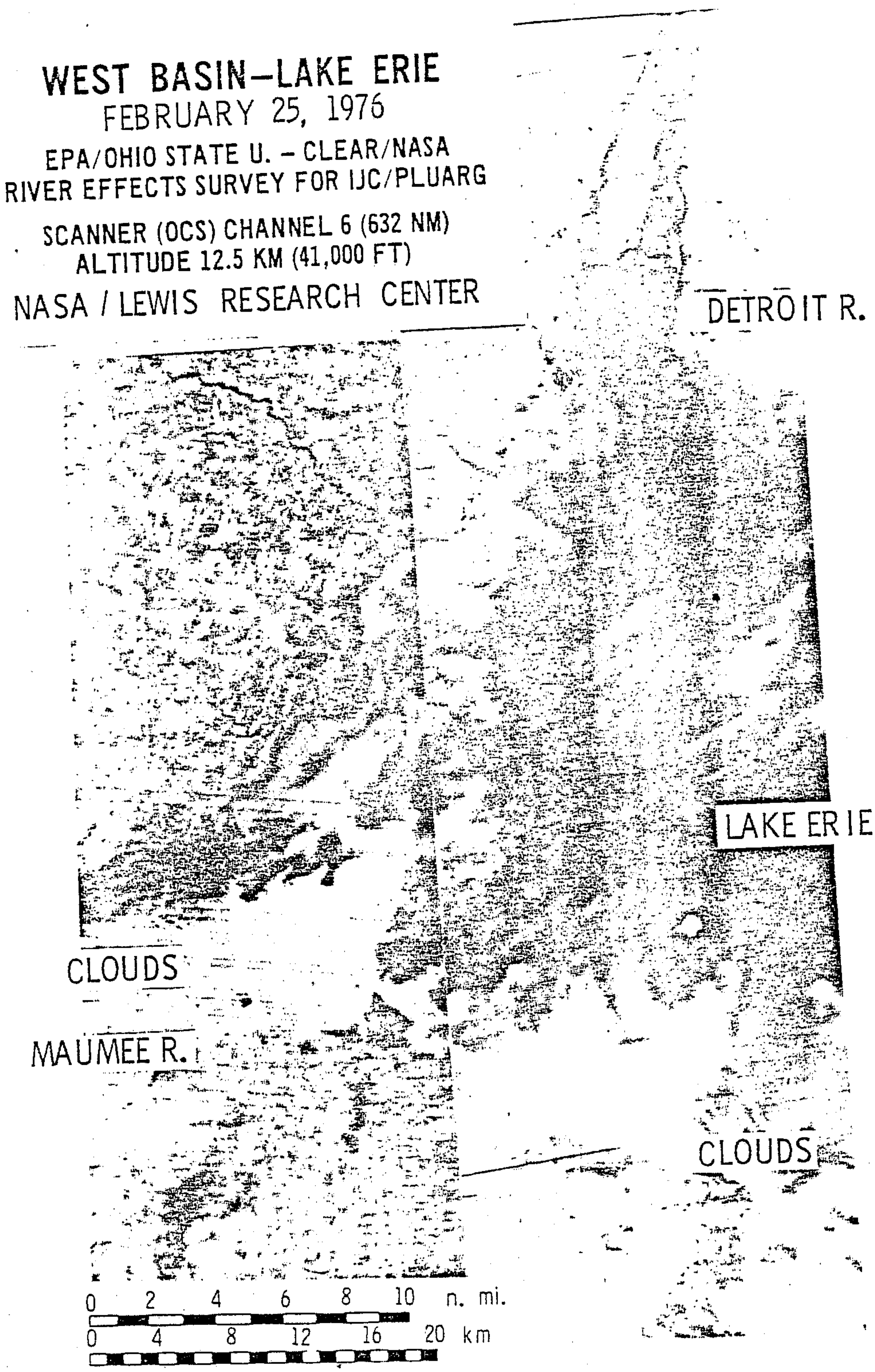

WEST BASIN—LAKE ERIE
FEBRUARY 25, 1976
EPA/OHIO STATE U. – CLEAR/NASA
RIVER EFFECTS SURVEY FOR IJC/PLUARG
SCANNER (OCS) CHANNEL 6 (632 NM)
ALTITUDE 12.5 KM (41,000 FT)
NASA / LEWIS RESEARCH CENTER
DETROIT R.
LAKE ERIE
CLOUDS
MAUMEE R.
CLOUDS
0 2 4 6 8 10 n. mi.
0 4 8 12 16 20 km

FIGURE 7

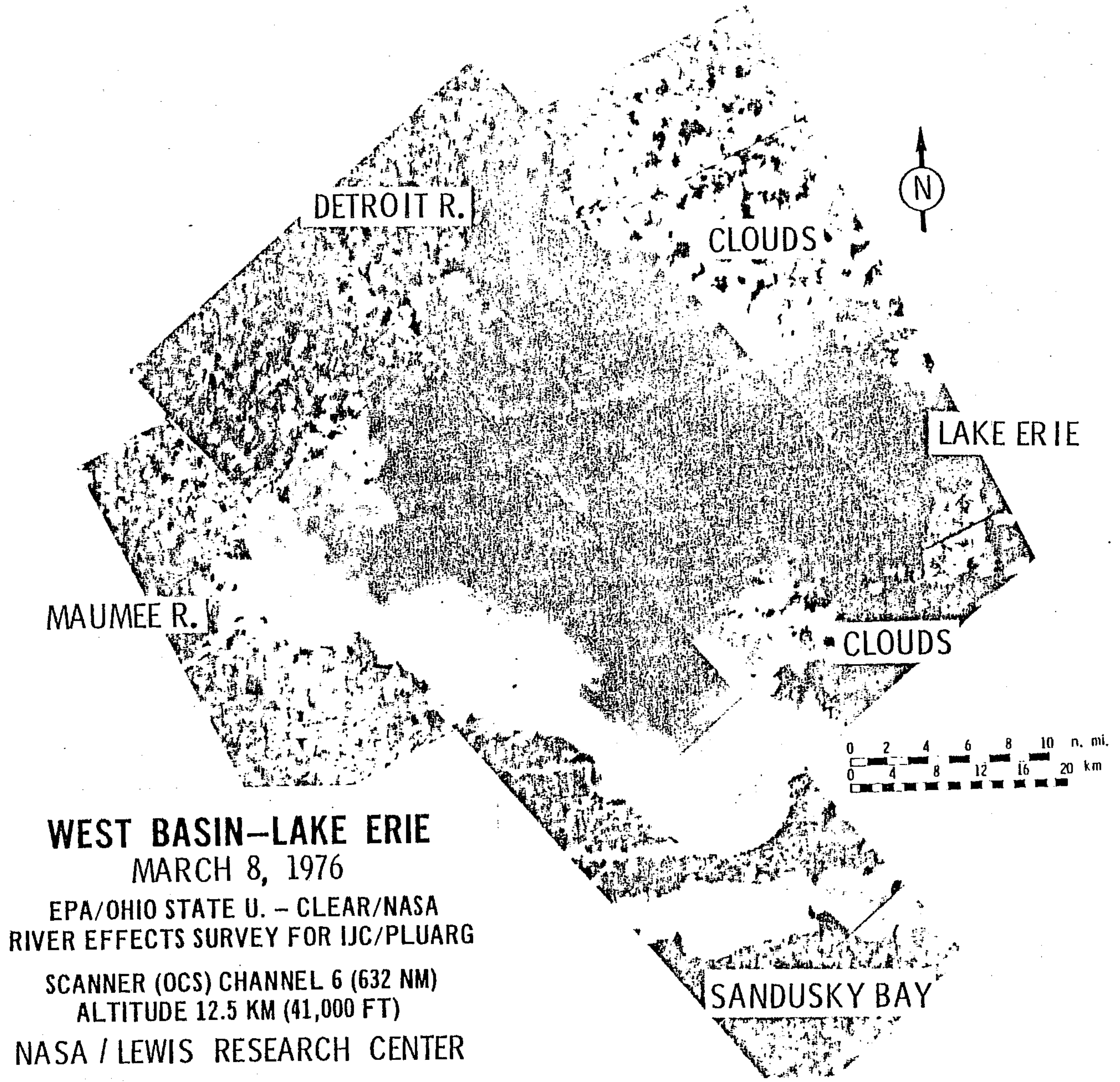

DETROIT R.
CLOUDS
LAKE ERIE
MAUMEE R.
CLOUDS
SANDUSKY BAY
0 2 4 6 8 10 n. mi.
0 4 8 12 16 20 km
WEST BASIN—LAKE ERIE
MARCH 8, 1976
EPA/OHIO STATE U. – CLEAR/NASA
RIVER EFFECTS SURVEY FOR IJC/PLUARG
SCANNER (OCS) CHANNEL 6 (632 NM)
ALTITUDE 12.5 KM (41,000 FT)
NASA / LEWIS RESEARCH CENTER

FIGURE 9

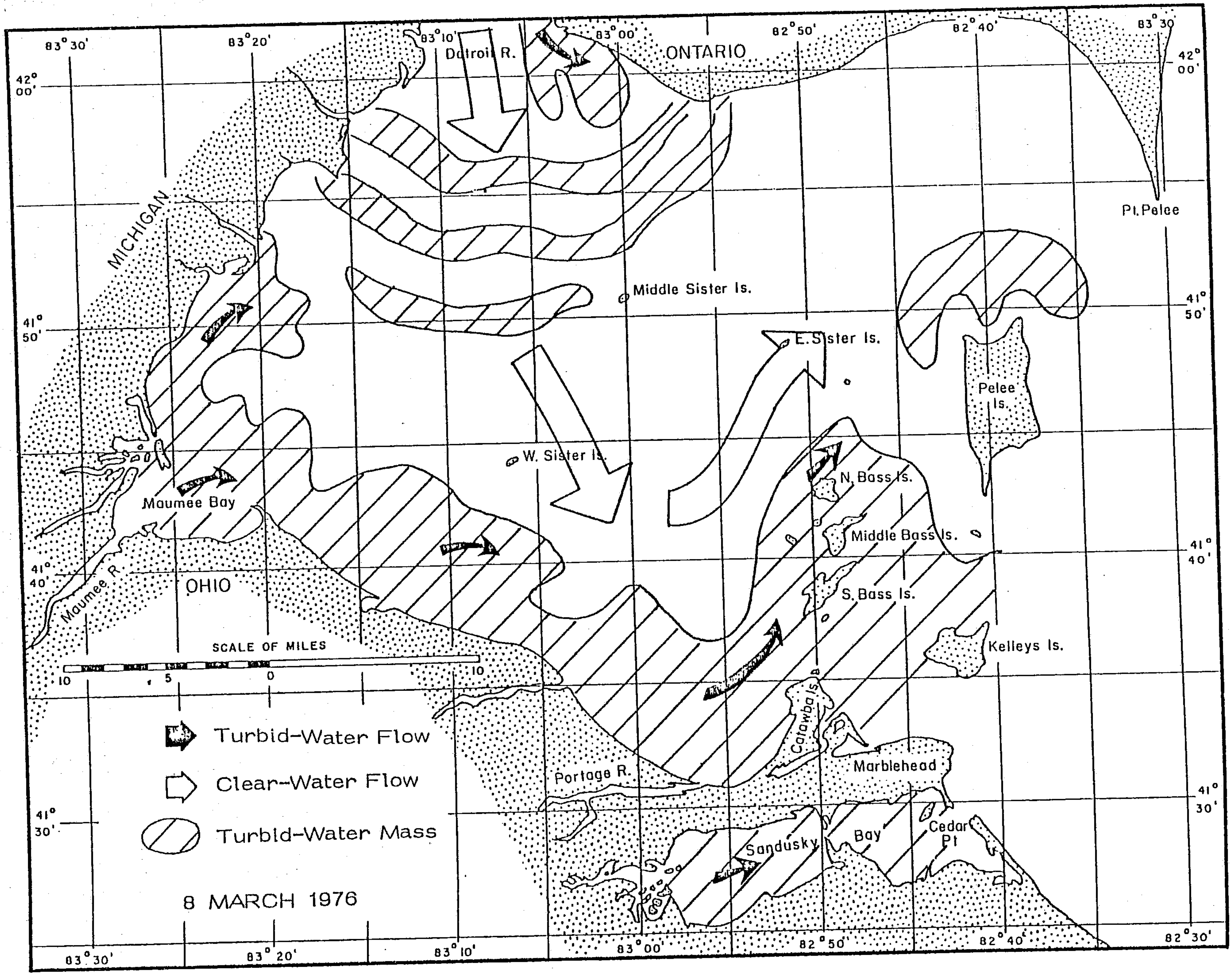


FIGURE 10. WATER FLOW PATTERNS IN WESTERN LAKE ERIE FROM NASA OCEAN-COLOR SCANNER IMAGERY - WQ 52.

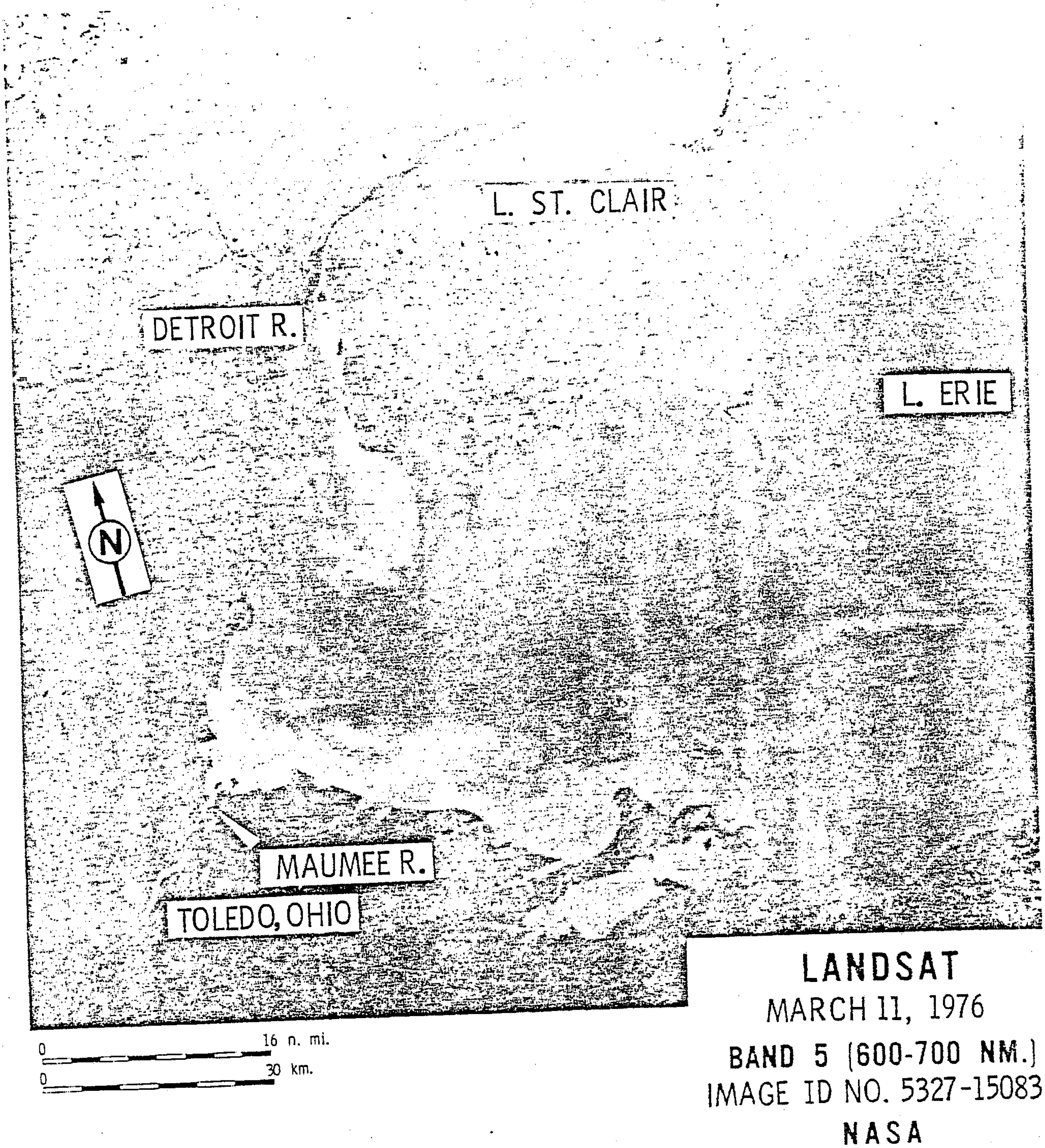
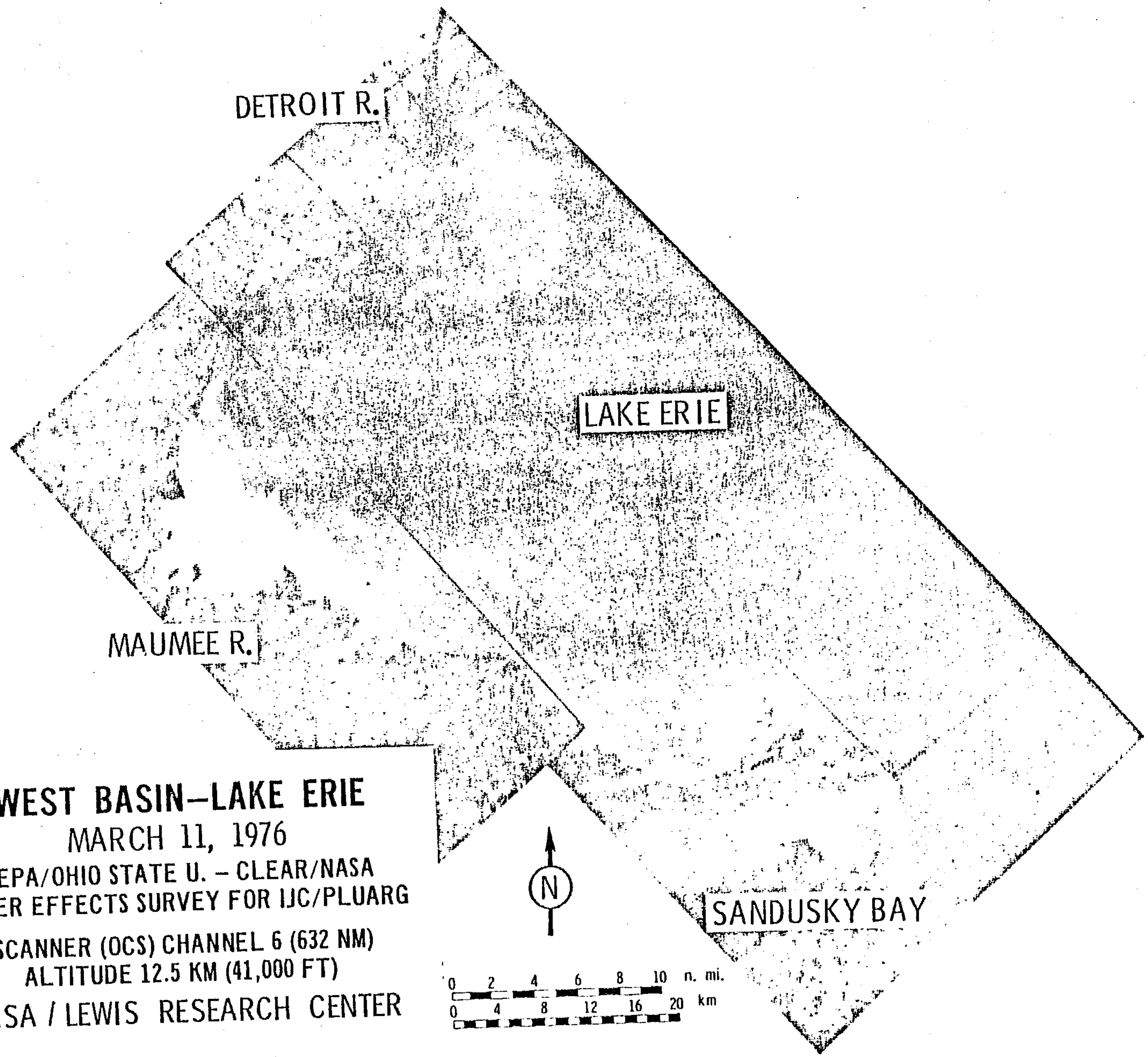

L. ST. CLAIR
DETROIT R.
L. ERIE
N
MAUMEE R.
TOLEDO, OHIO
0
16 n. mi.
0
30 km.
LANDSAT
MARCH 11, 1976
BAND 5 (600-700 NM.)
IMAGE ID NO. 5327-15083
NASA

FIGURE 11



WEST BASIN–LAKE ERIE
MARCH 11, 1976
EPA/OHIO STATE U. – CLEAR/NASA
RIVER EFFECTS SURVEY FOR IJC/PLUARG
SCANNER (OCS) CHANNEL 6 (632 NM)
ALTITUDE 12.5 KM (41,000 FT)
NASA / LEWIS RESEARCH CENTER

FIGURE 12

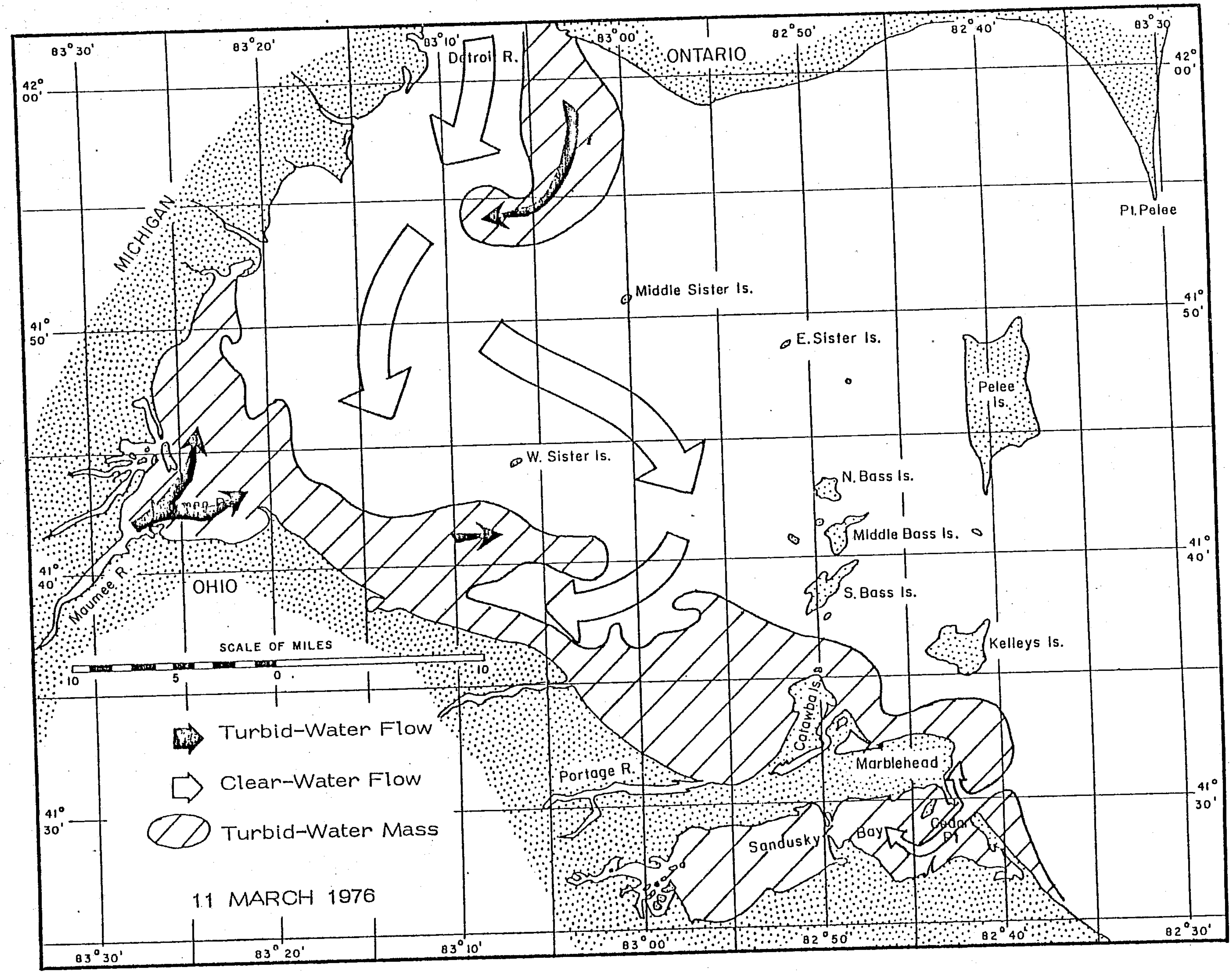


FIGURE 13. WATER FLOW PATTERNS IN WESTERN LAKE ERIE INFERRED FROM NASA OCEAN-COLOR SCANNER IMAGERY - WQ 53.

WEST BASIN–LAKE ERIE
MARCH 15, 1976
EPA/OHIO STATE U. – CLEAR/NASA
RIVER EFFECTS SURVEY FOR IJC/PLUARG
SCANNER (OCS) CHANNEL 6 (632 NM)
ALTITUDE 12.5 KM (41,000 FT)
NASA / LEWIS RESEARCH CENTER

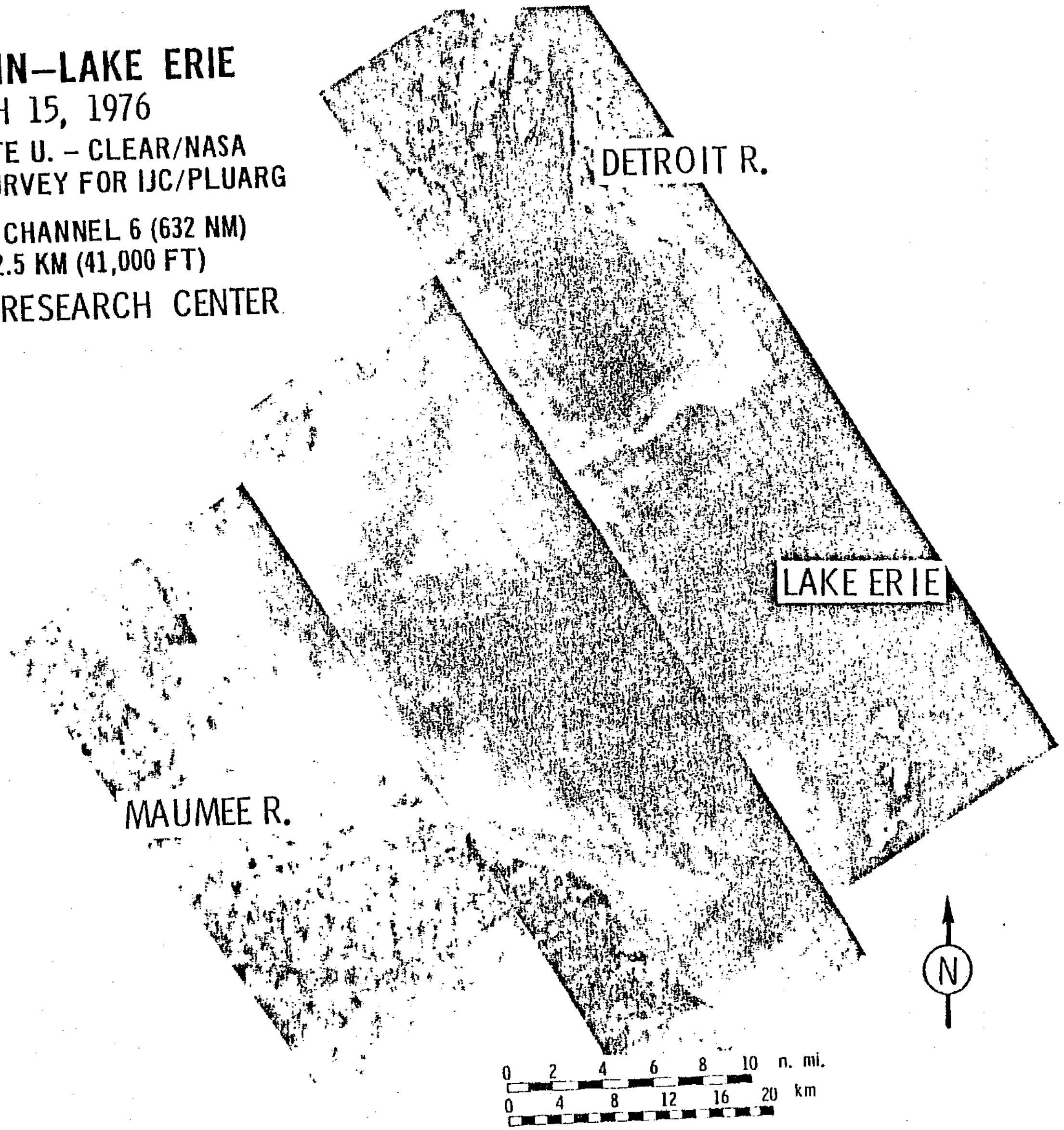


FIGURE 14

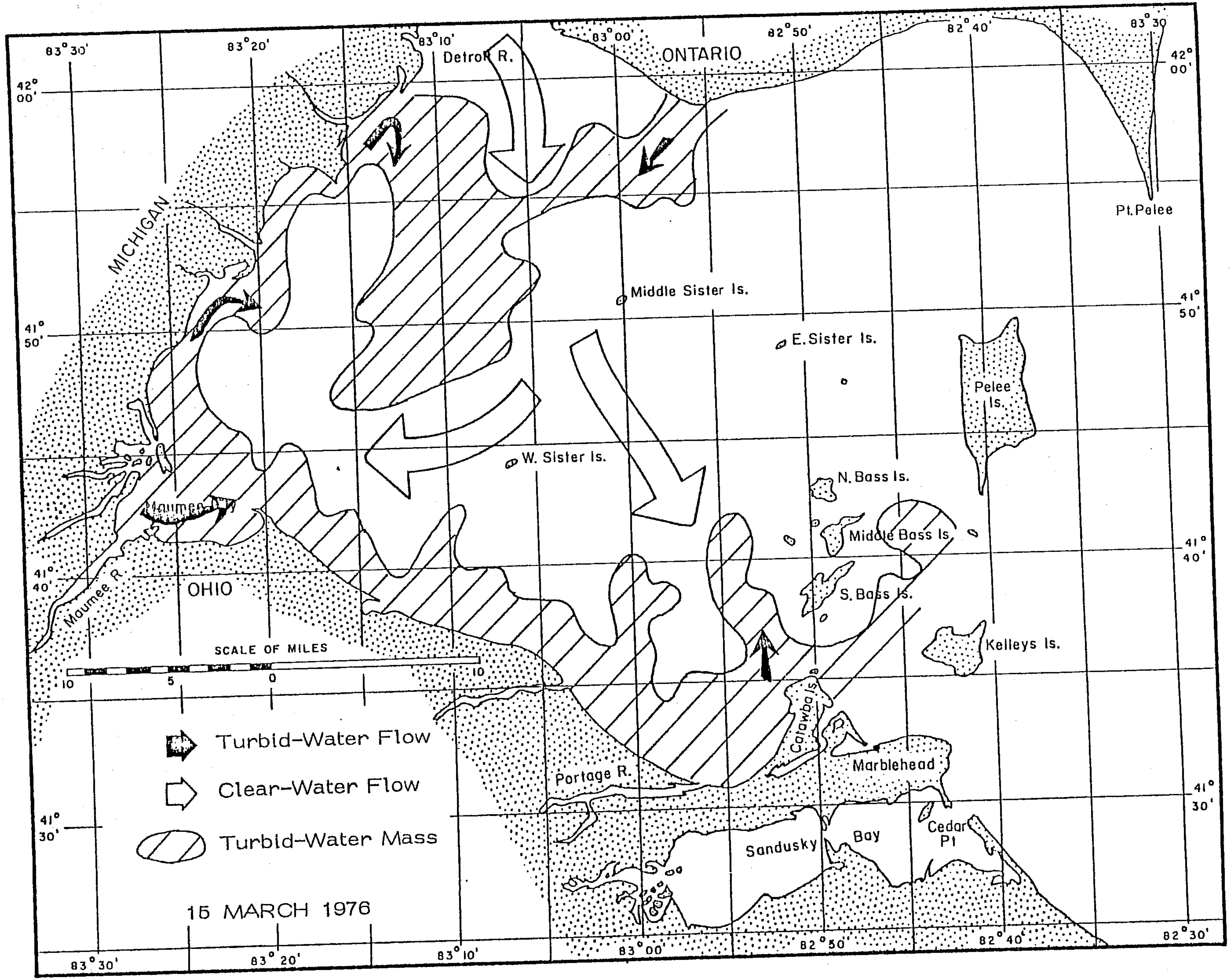


FIGURE 15. WATER FLOW PATTERNS IN WESTERN LAKE ERIE INFERRED FROM NASA OCEAN-COLOR SCANNER IMAGERY - WQ 54.

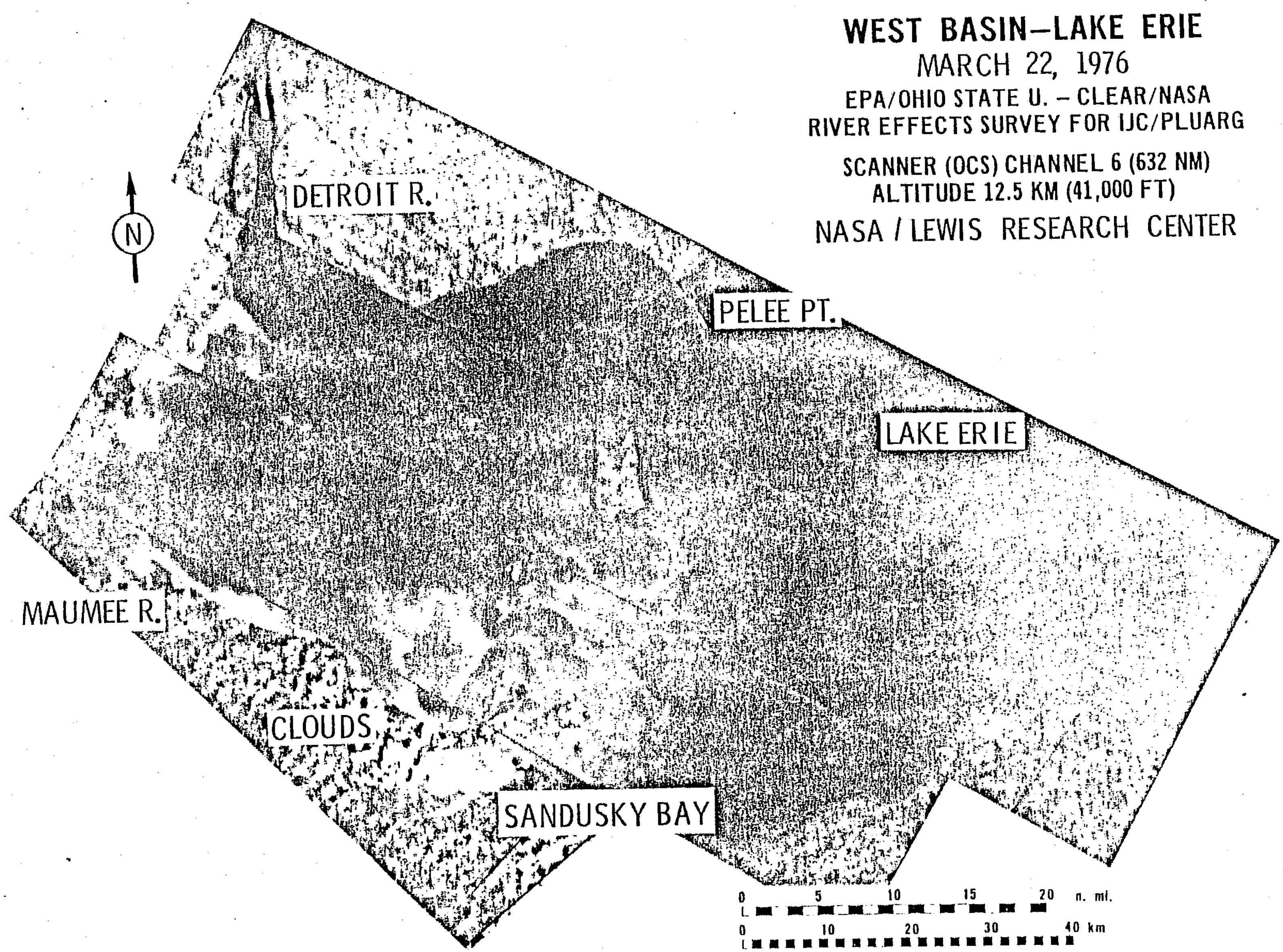

WEST BASIN–LAKE ERIE
MARCH 22, 1976
EPA/OHIO STATE U. – CLEAR/NASA
RIVER EFFECTS SURVEY FOR IJC/PLUARG
SCANNER (OCS) CHANNEL 6 (632 NM)
ALTITUDE 12.5 KM (41,000 FT)
NASA / LEWIS RESEARCH CENTER
N
DETROIT R.
PELEE PT.
LAKE ERIE
MAUMEE R.
CLOUDS
SANDUSKY BAY
0 5 10 15 20 n. mi.
0 10 20 30 40 km

FIGURE 16

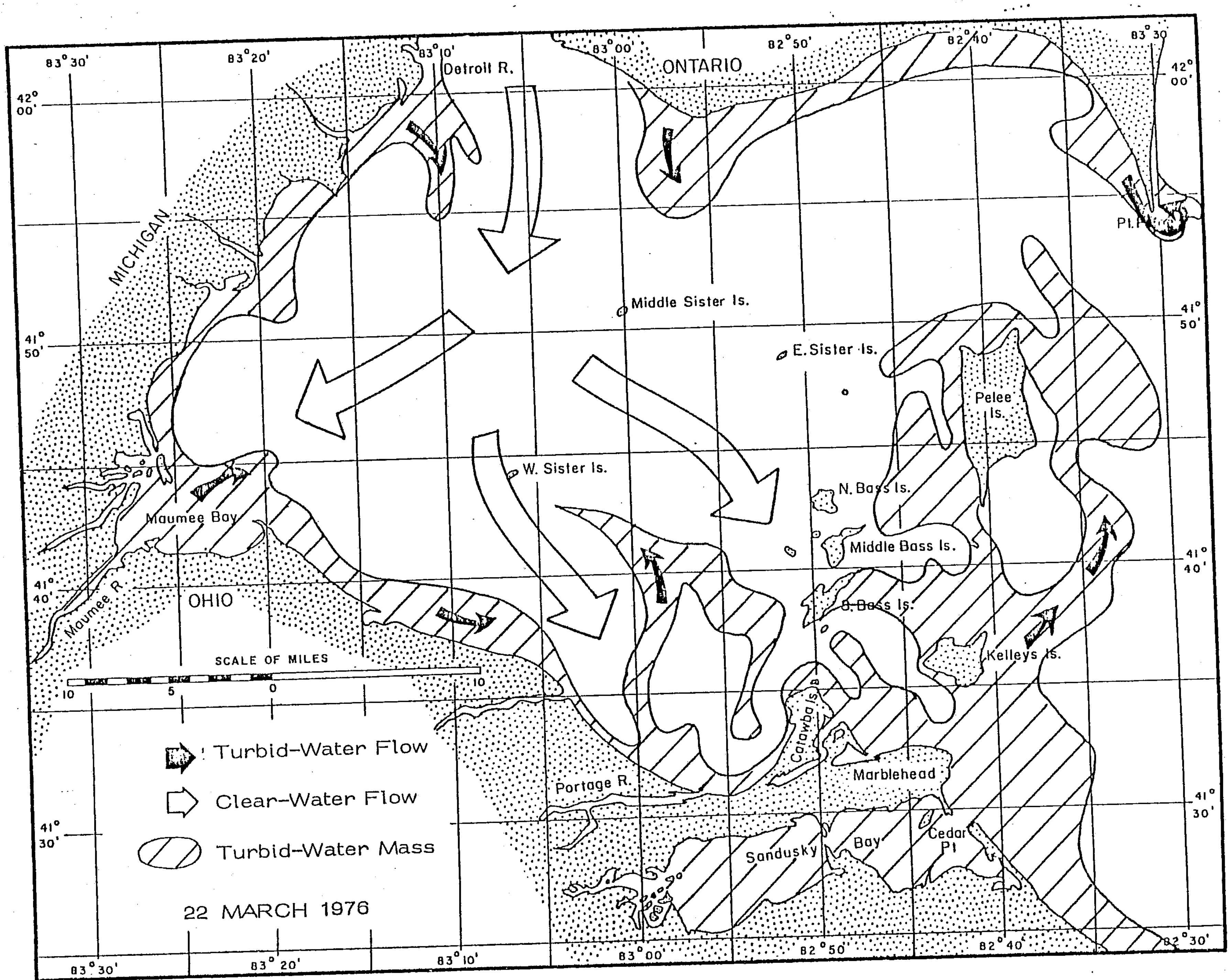


FIGURE 17. WATER FLOW PATTERNS IN WESTERN LAKE ERIE FROM NASA OCEAN-COLOR SCANNER IMAGERY - WQ 57.

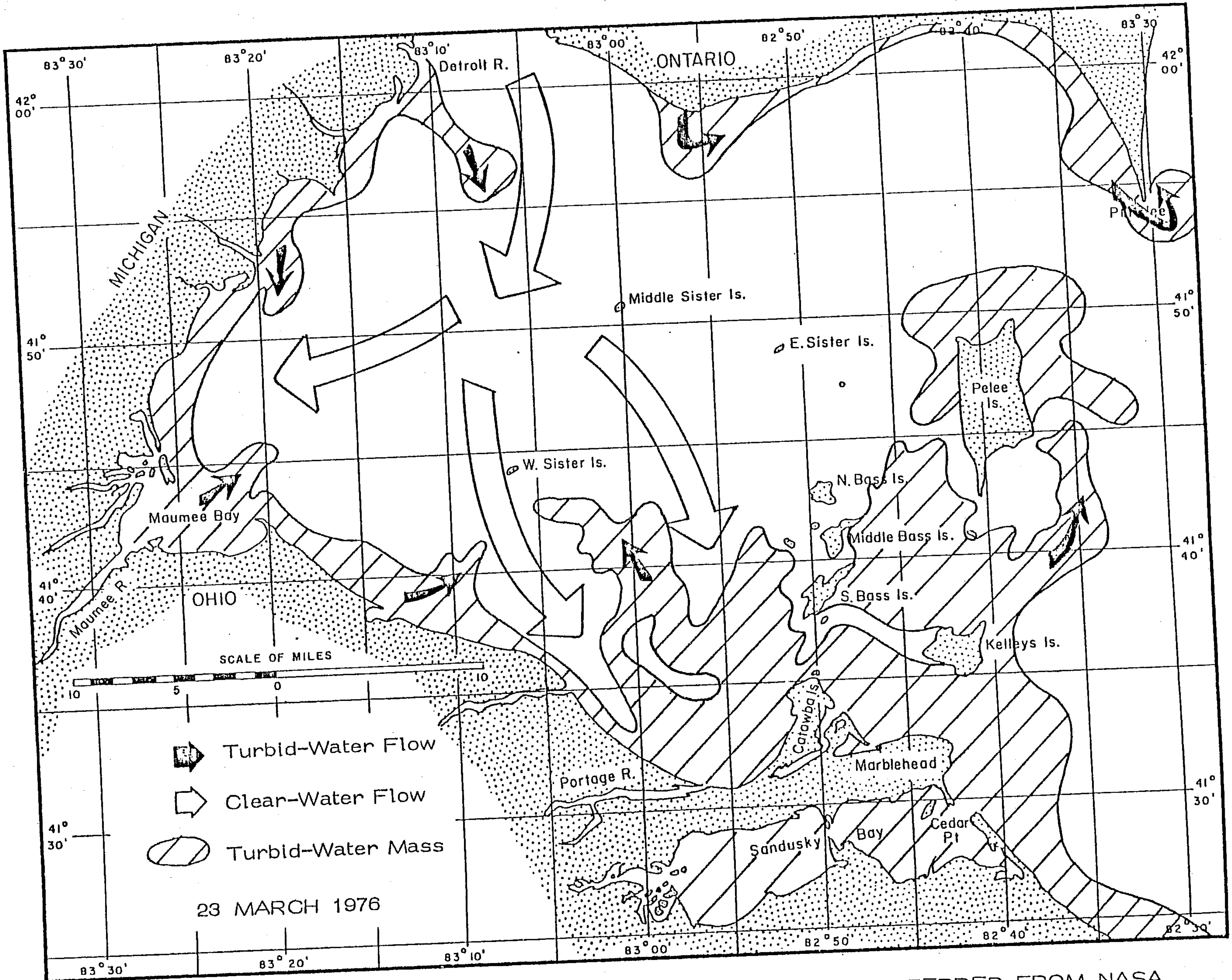


FIGURE 19. WATER FLOW PATTERNS IN WESTERN LAKE ERIE INFERRED FROM NASA OCEAN-COLOR SCANNER IMAGERY - WQ 58.

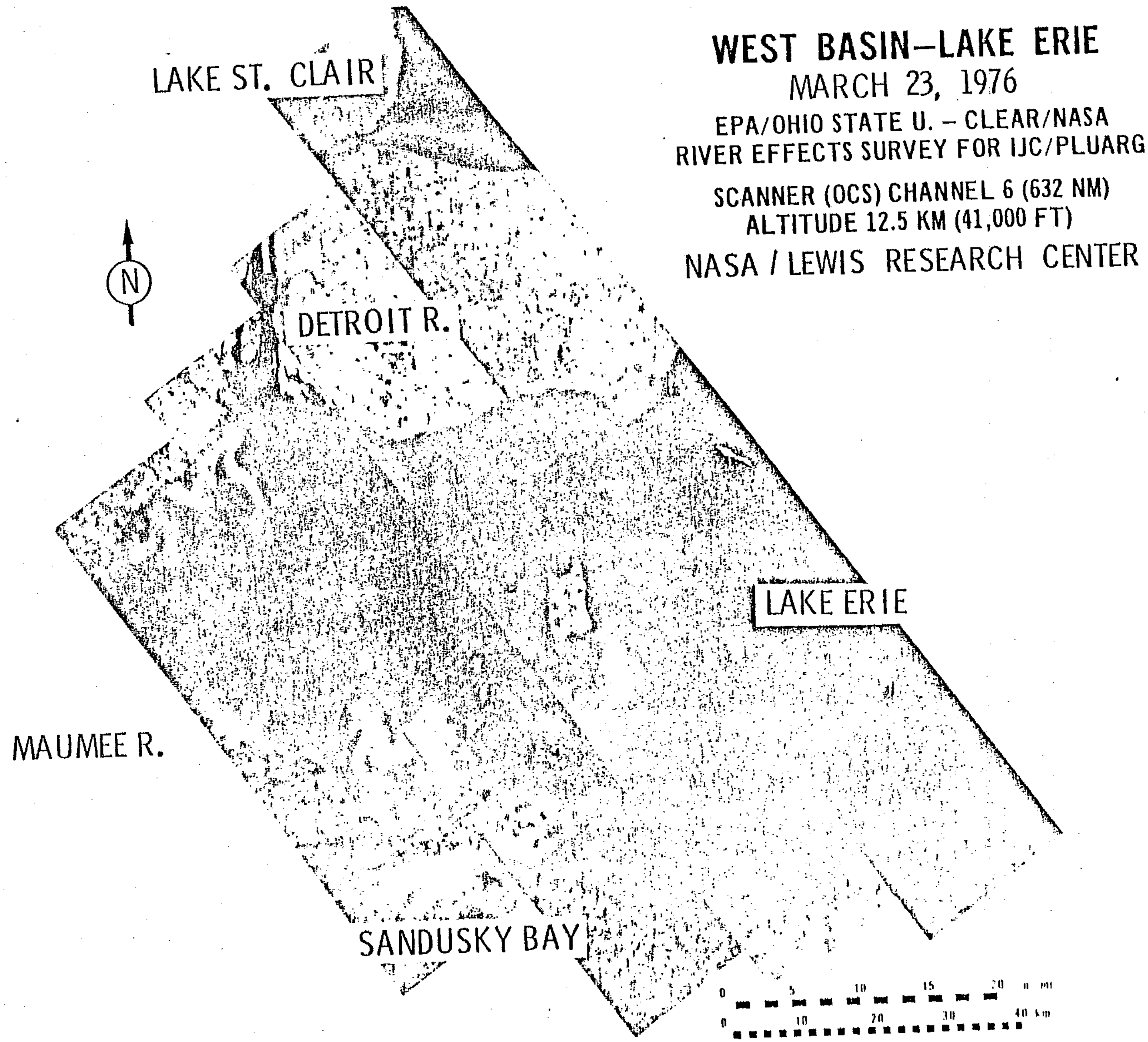

WEST BASIN–LAKE ERIE
MARCH 23, 1976
EPA/OHIO STATE U. – CLEAR/NASA
RIVER EFFECTS SURVEY FOR IJC/PLUARG
SCANNER (OCS) CHANNEL 6 (632 NM)
ALTITUDE 12.5 KM (41,000 FT)
NASA / LEWIS RESEARCH CENTER
LAKE ST. CLAIR
N
DETROIT R.
LAKE ERIE
MAUMEE R.
SANDUSKY BAY

FIGURE 18

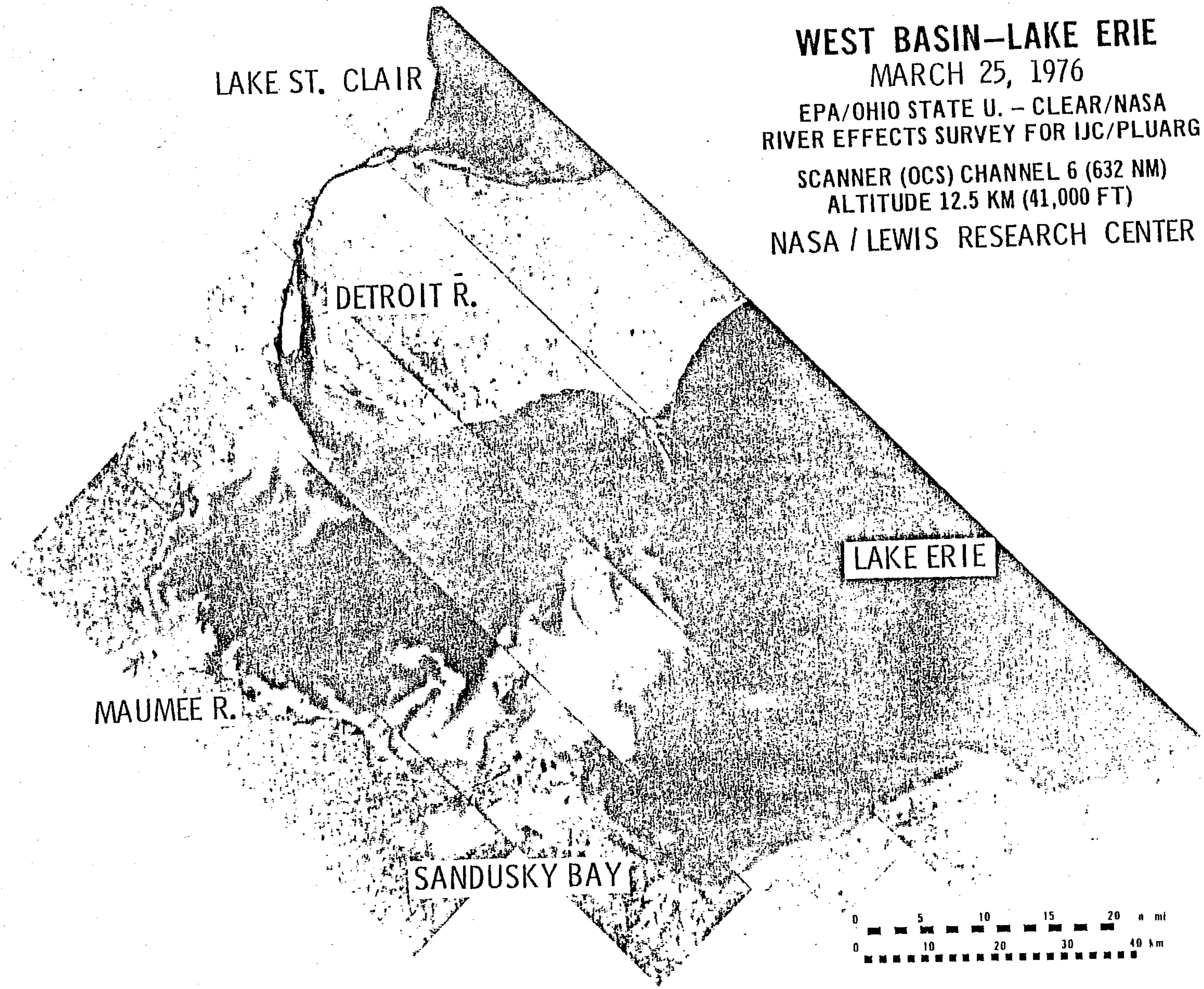

WEST BASIN–LAKE ERIE
MARCH 25, 1976
EPA/OHIO STATE U. – CLEAR/NASA
RIVER EFFECTS SURVEY FOR IJC/PLUARG
SCANNER (OCS) CHANNEL 6 (632 NM)
ALTITUDE 12.5 KM (41,000 FT)
NASA / LEWIS RESEARCH CENTER
LAKE ST. CLAIR
DETROIT R.
LAKE ERIE
MAUMEE R.
SANDUSKY BAY
0 5 10 15 20 n mi
0 10 20 30 40 km

FIGURE 20

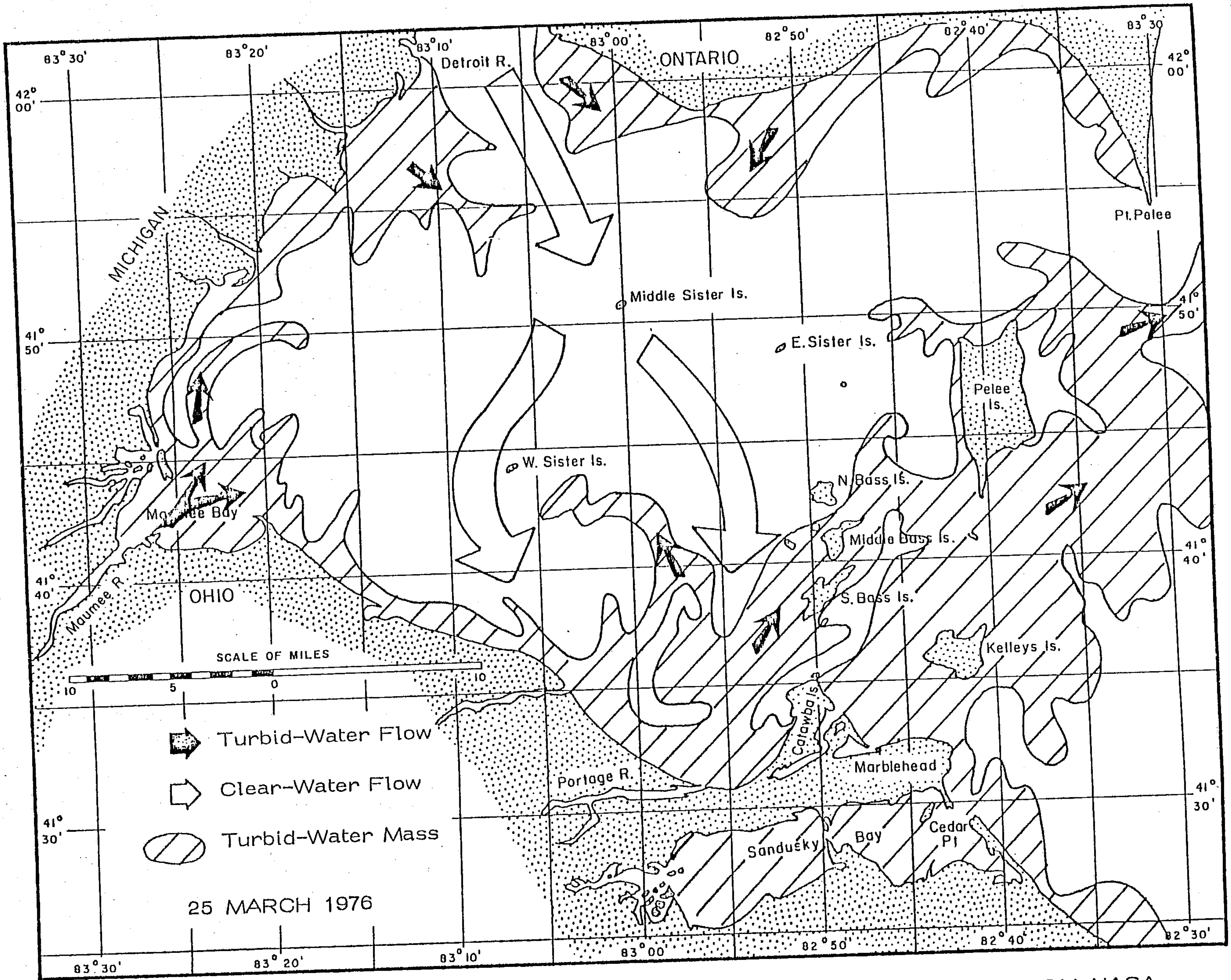


FIGURE 21. WATER FLOW PATTERNS IN WESTERN LAKE ERIE INFERRED FROM NASA OCEAN-COLOR SCANNER IMAGERY - WQ 60.

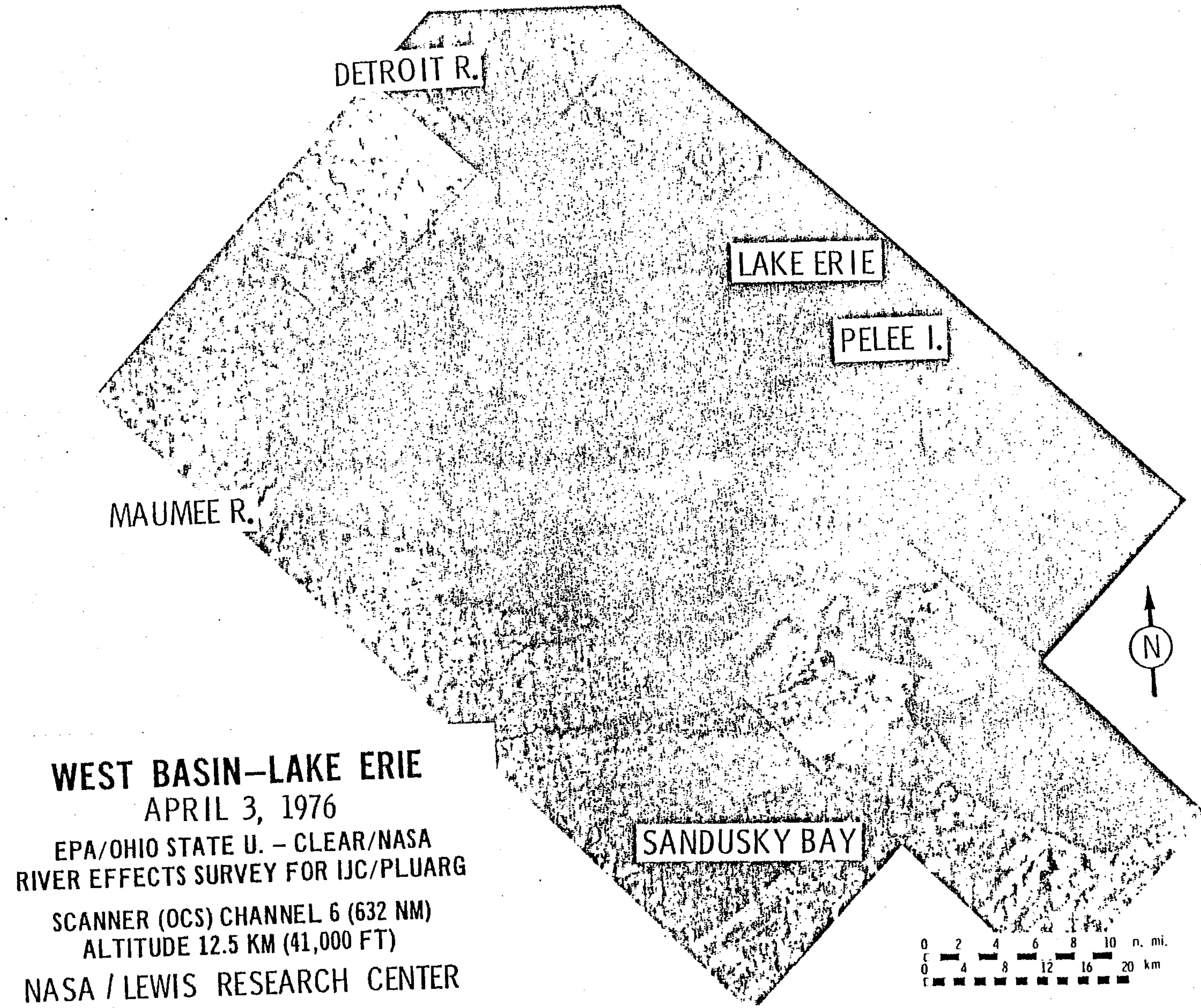

DETROIT R.
LAKE ERIE
PELEE I.
MAUMEE R.
SANDUSKY BAY
N
0 2 4 6 8 10 n. mi.
0 4 8 12 16 20 km
WEST BASIN–LAKE ERIE
APRIL 3, 1976
EPA/OHIO STATE U. – CLEAR/NASA
RIVER EFFECTS SURVEY FOR IJC/PLUARG
SCANNER (OCS) CHANNEL 6 (632 NM)
ALTITUDE 12.5 KM (41,000 FT)
NASA / LEWIS RESEARCH CENTER

FIGURE 22

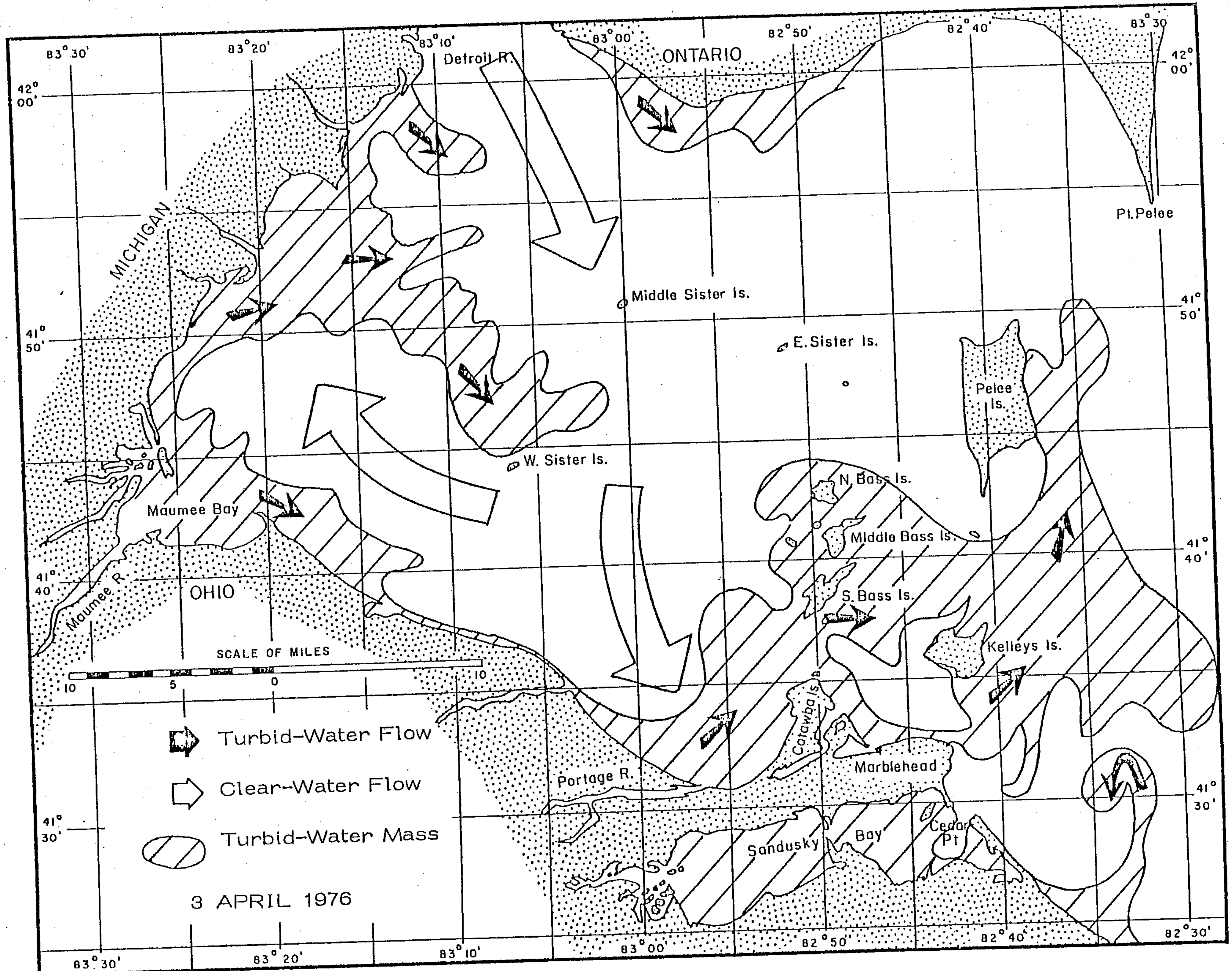


FIGURE 23. WATER FLOW PATTERNS IN WESTERN LAKE ERIE INFERRED FROM NASA OCEAN-COLOR SCANNER IMAGERY - WQ 62.

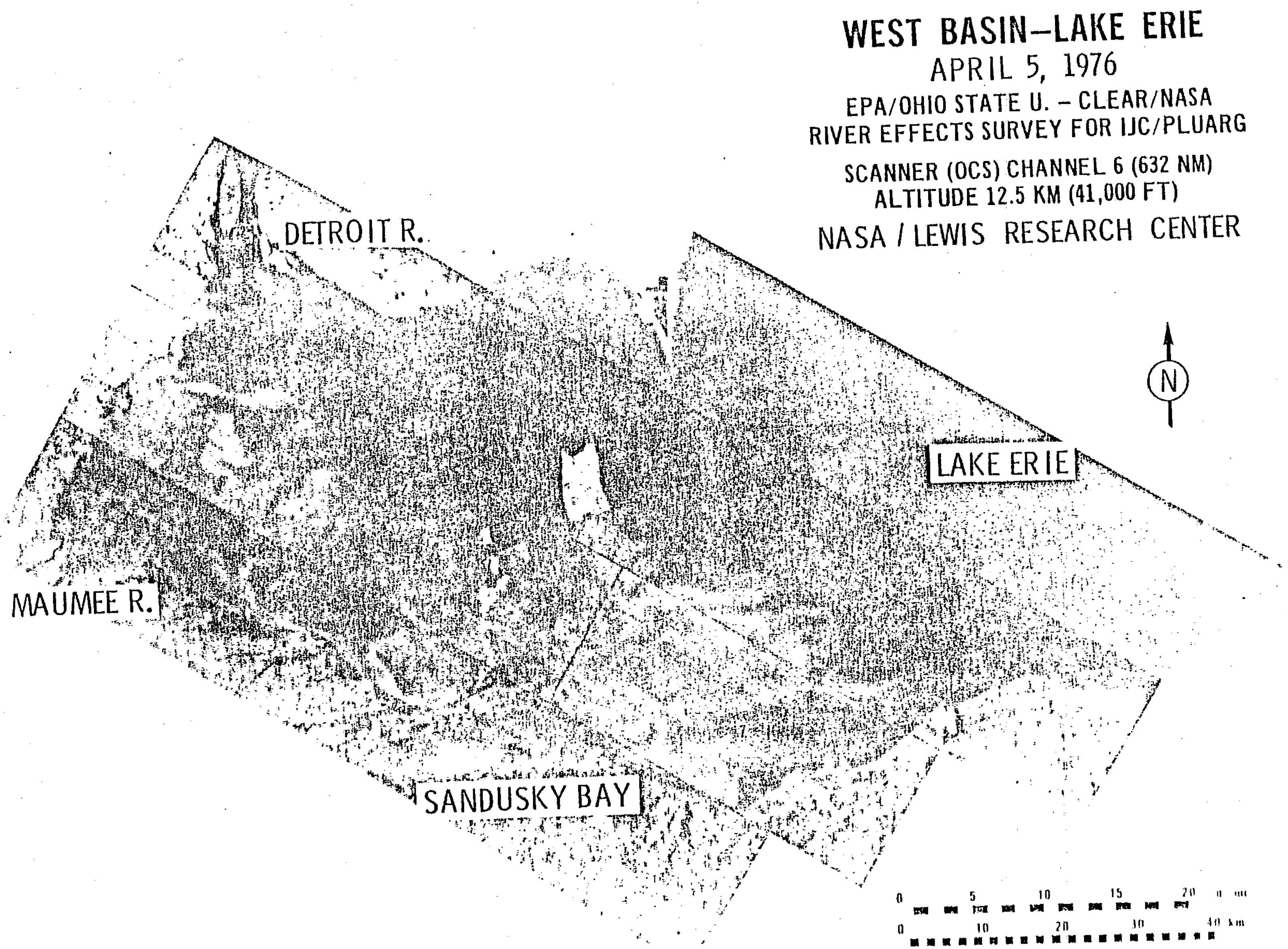

WEST BASIN—LAKE ERIE
APRIL 5, 1976
EPA/OHIO STATE U. – CLEAR/NASA
RIVER EFFECTS SURVEY FOR IJC/PLUARG
SCANNER (OCS) CHANNEL 6 (632 NM)
ALTITUDE 12.5 KM (41,000 FT)
NASA / LEWIS RESEARCH CENTER
N
DETROIT R.
LAKE ERIE
MAUMEE R.
SANDUSKY BAY
0 5 10 15 20
0 10 20 30 40 km

FIGURE 24

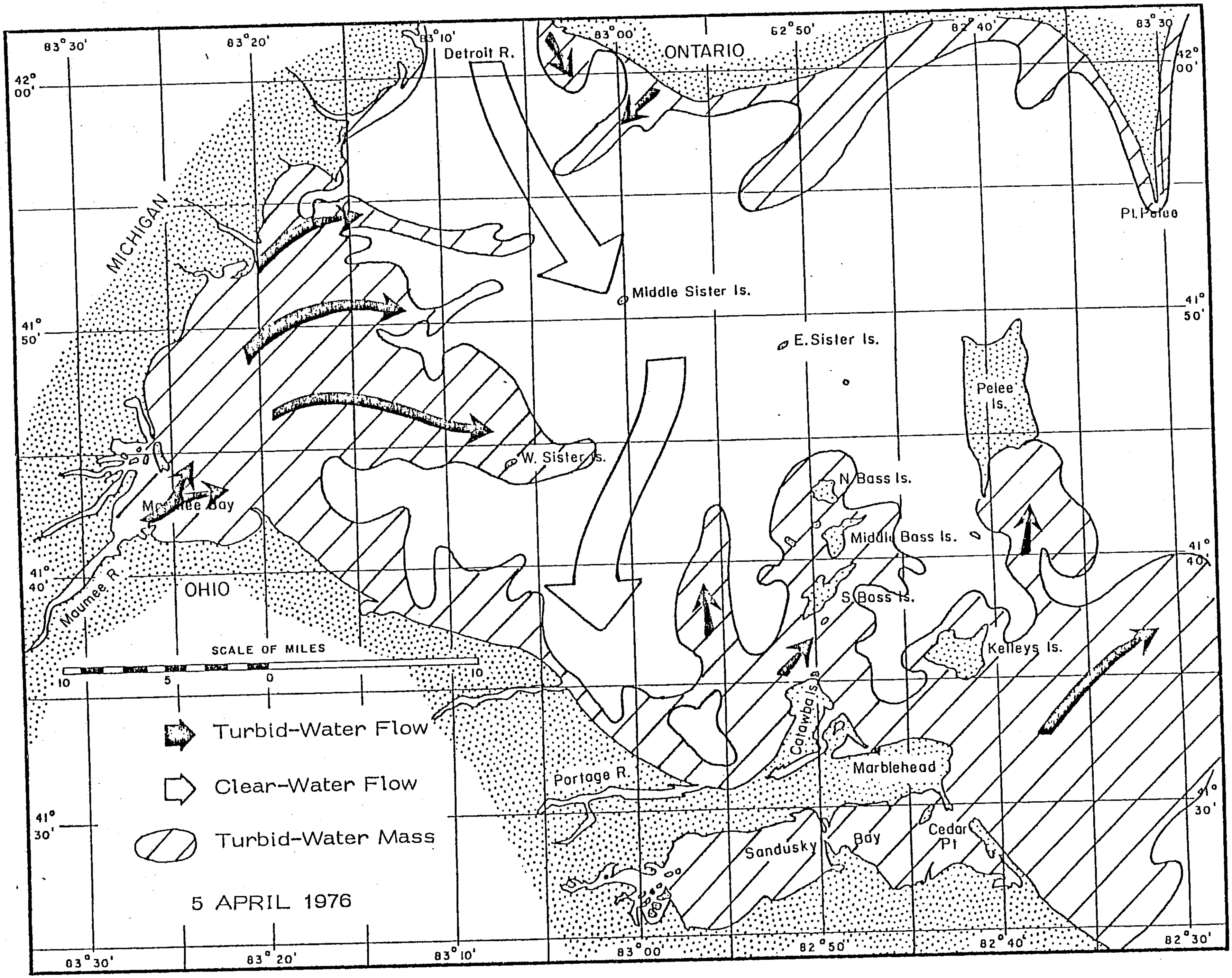
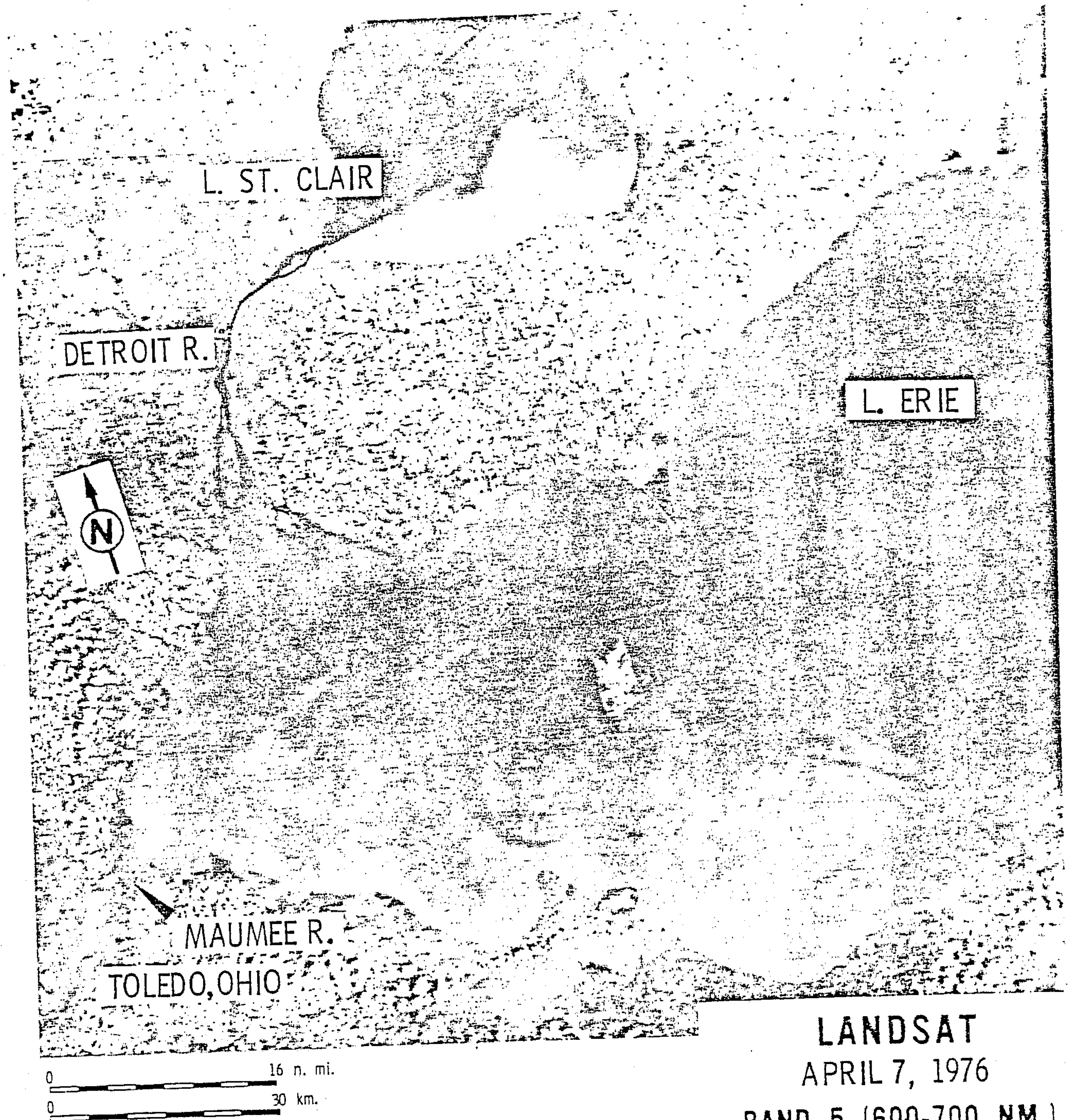


FIGURE 25. WATER FLOW PATTERNS IN WESTERN LAKE ERIE INFERRED FROM NASA OCEAN-COLOR SCANNER IMAGERY - WQ 64.



LANDSAT
APRIL 7, 1976
BAND 5 (600-700 NM.)
IMAGE ID NO. 2441-15311
NASA

FIGURE 26

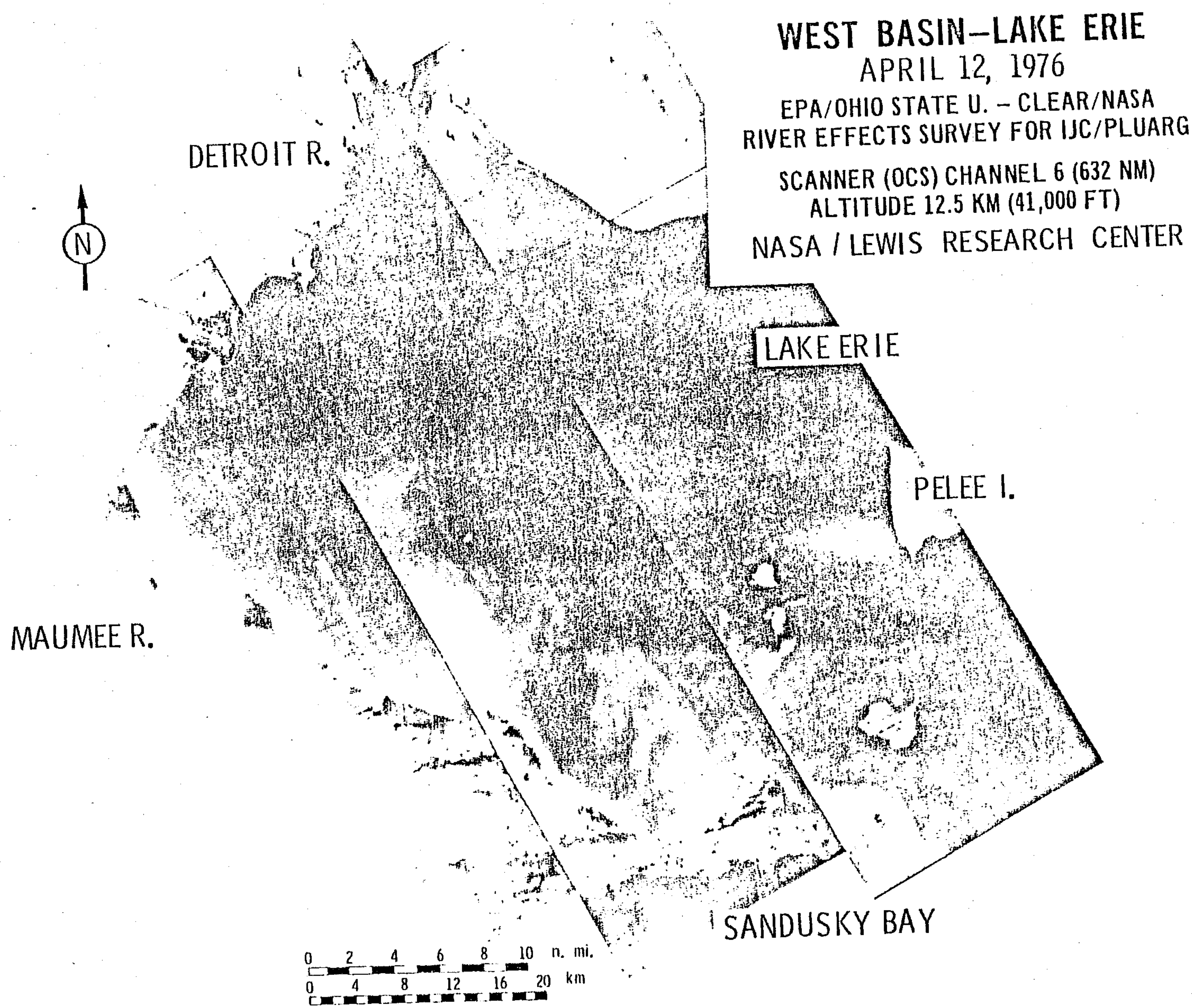

WEST BASIN—LAKE ERIE
APRIL 12, 1976
EPA/OHIO STATE U. – CLEAR/NASA
RIVER EFFECTS SURVEY FOR IJC/PLUARG
SCANNER (OCS) CHANNEL 6 (632 NM)
ALTITUDE 12.5 KM (41,000 FT)
NASA / LEWIS RESEARCH CENTER
DETROIT R.
N
MAUMEE R.
LAKE ERIE
PELEE I.
SANDUSKY BAY
0 2 4 6 8 10 n. mi.
0 4 8 12 16 20 km

FIGURE 27

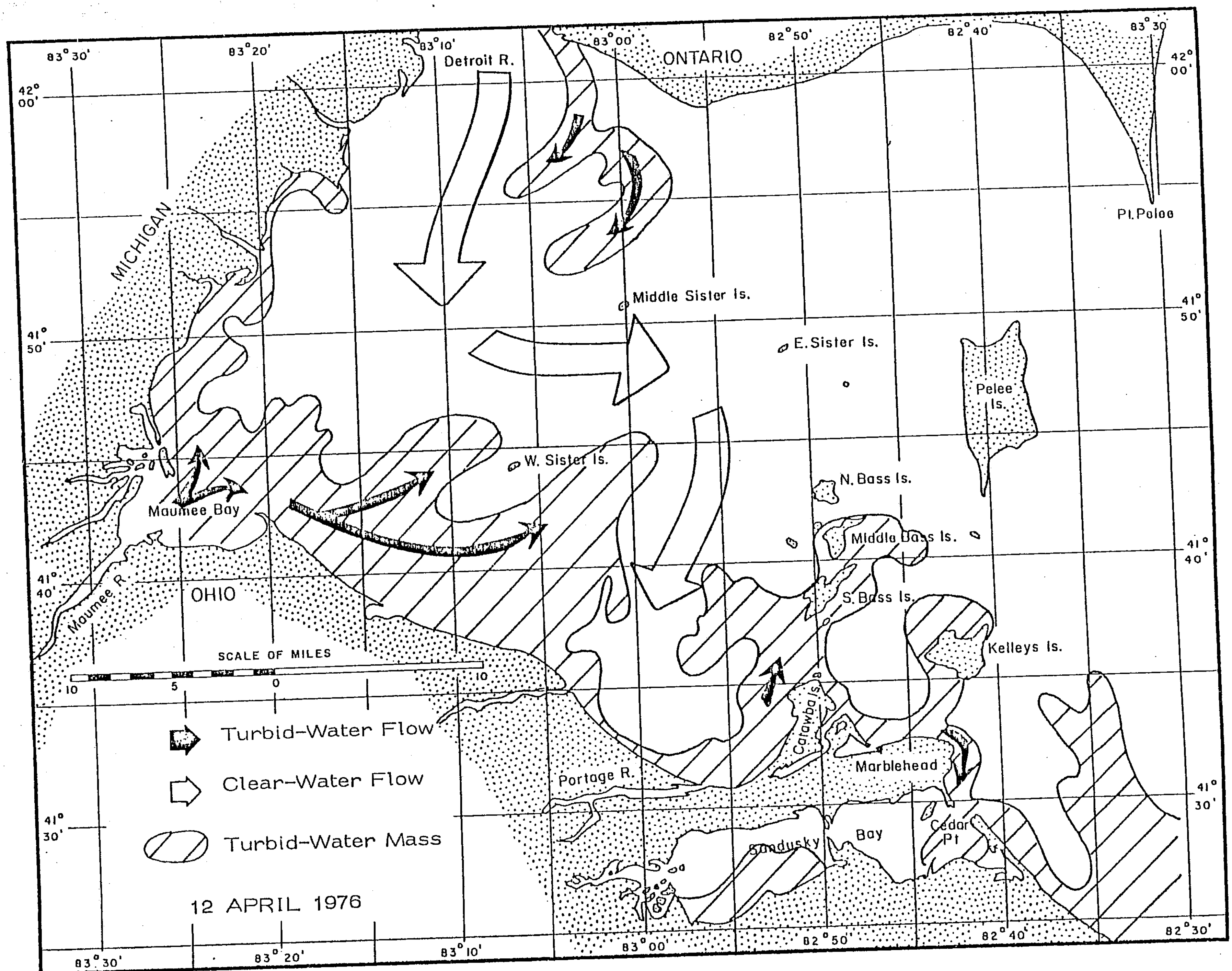
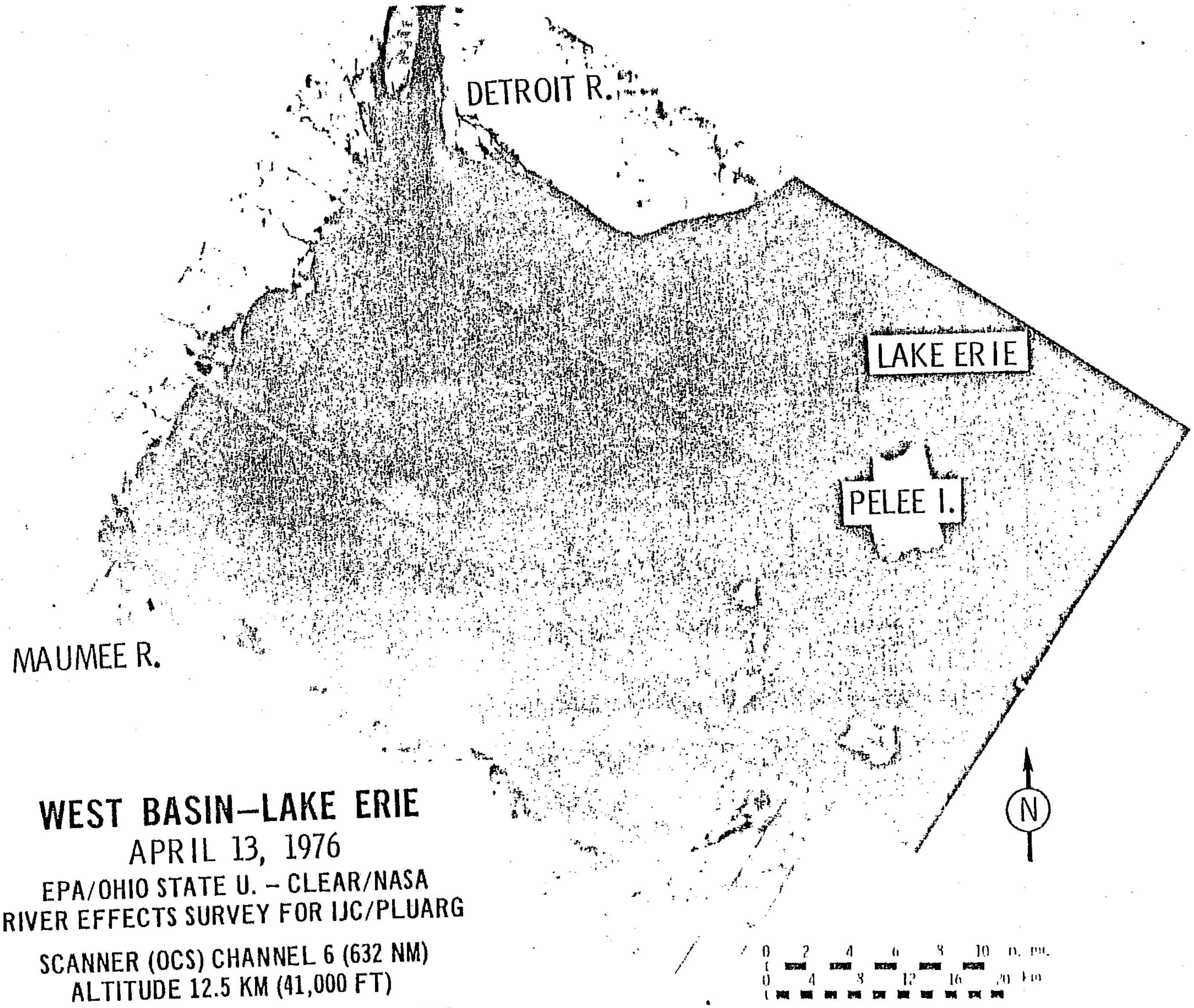


FIGURE 28. WATER FLOW PATTERNS IN WESTERN LAKE ERIE INFERRED FROM NASA OCEAN-COLOR SCANNER IMAGERY - WQ 68.



WEST BASIN–LAKE ERIE
APRIL 13, 1976
EPA/OHIO STATE U. – CLEAR/NASA
RIVER EFFECTS SURVEY FOR IJC/PLUARG
SCANNER (OCS) CHANNEL 6 (632 NM)
ALTITUDE 12.5 KM (41,000 FT)
NASA / LEWIS RESEARCH CENTER

FIGURE 29

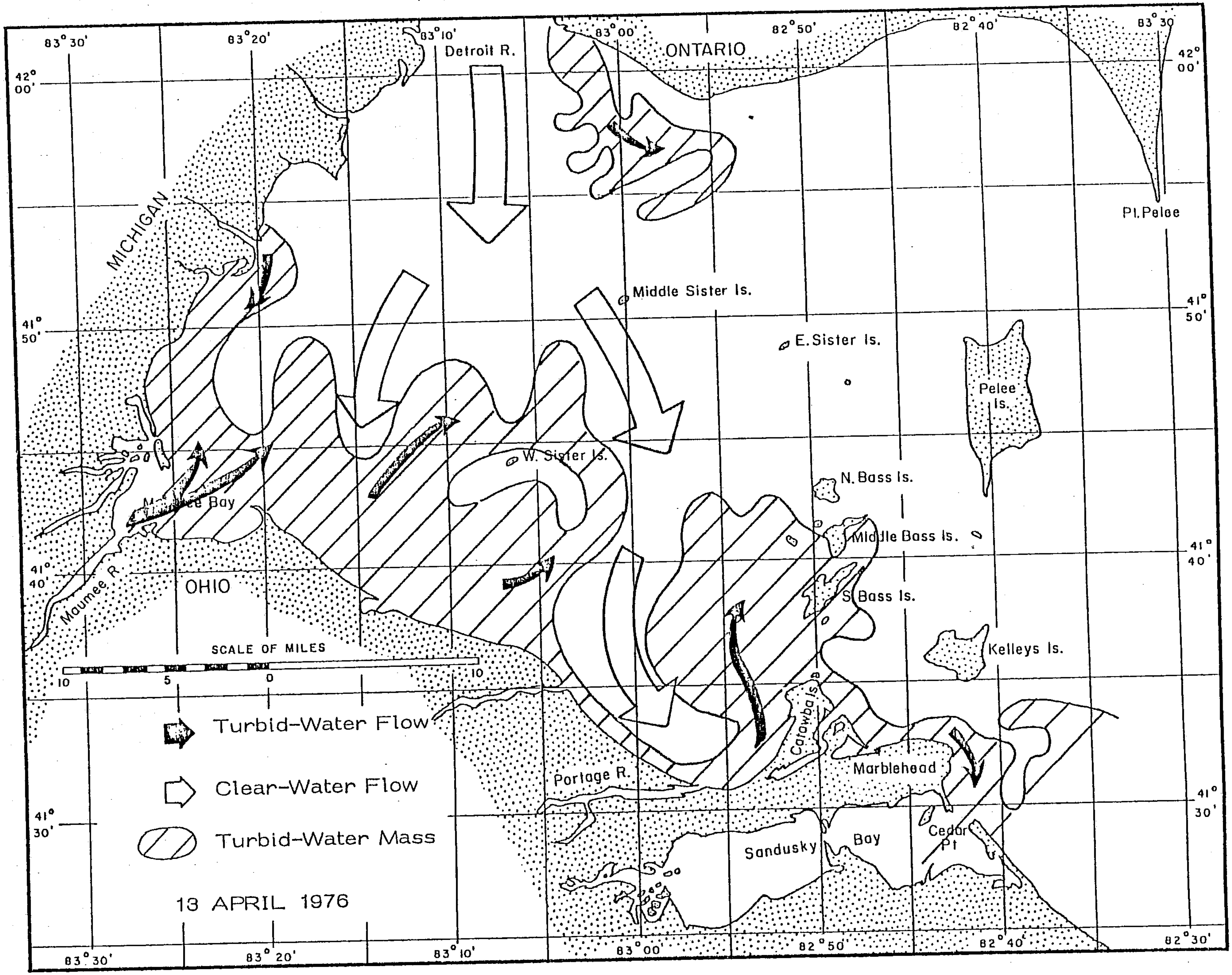


FIGURE 30. WATER FLOW PATTERNS IN WESTERN LAKE ERIE FROM NASA OCEAN-COLOR SCANNER IMAGERY - WQ 69.

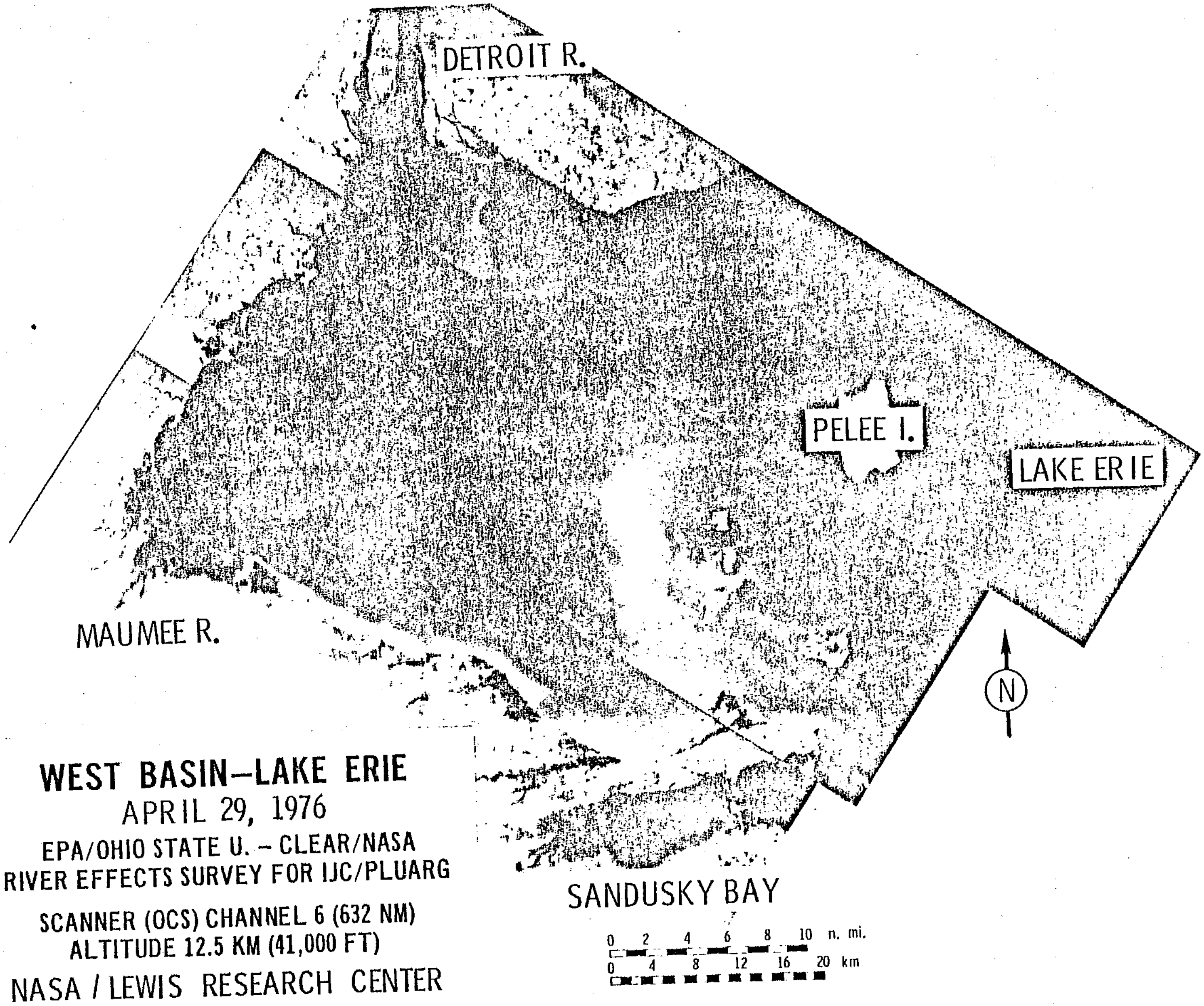

DETROIT R.
PELEE I.
LAKE ERIE
N
MAUMEE R.
SANDUSKY BAY
0 2 4 6 8 10 n. mi.
0 4 8 12 16 20 km
WEST BASIN–LAKE ERIE
APRIL 29, 1976
EPA/OHIO STATE U. – CLEAR/NASA
RIVER EFFECTS SURVEY FOR IJC/PLUARG
SCANNER (OCS) CHANNEL 6 (632 NM)
ALTITUDE 12.5 KM (41,000 FT)
NASA / LEWIS RESEARCH CENTER

FIGURE 31

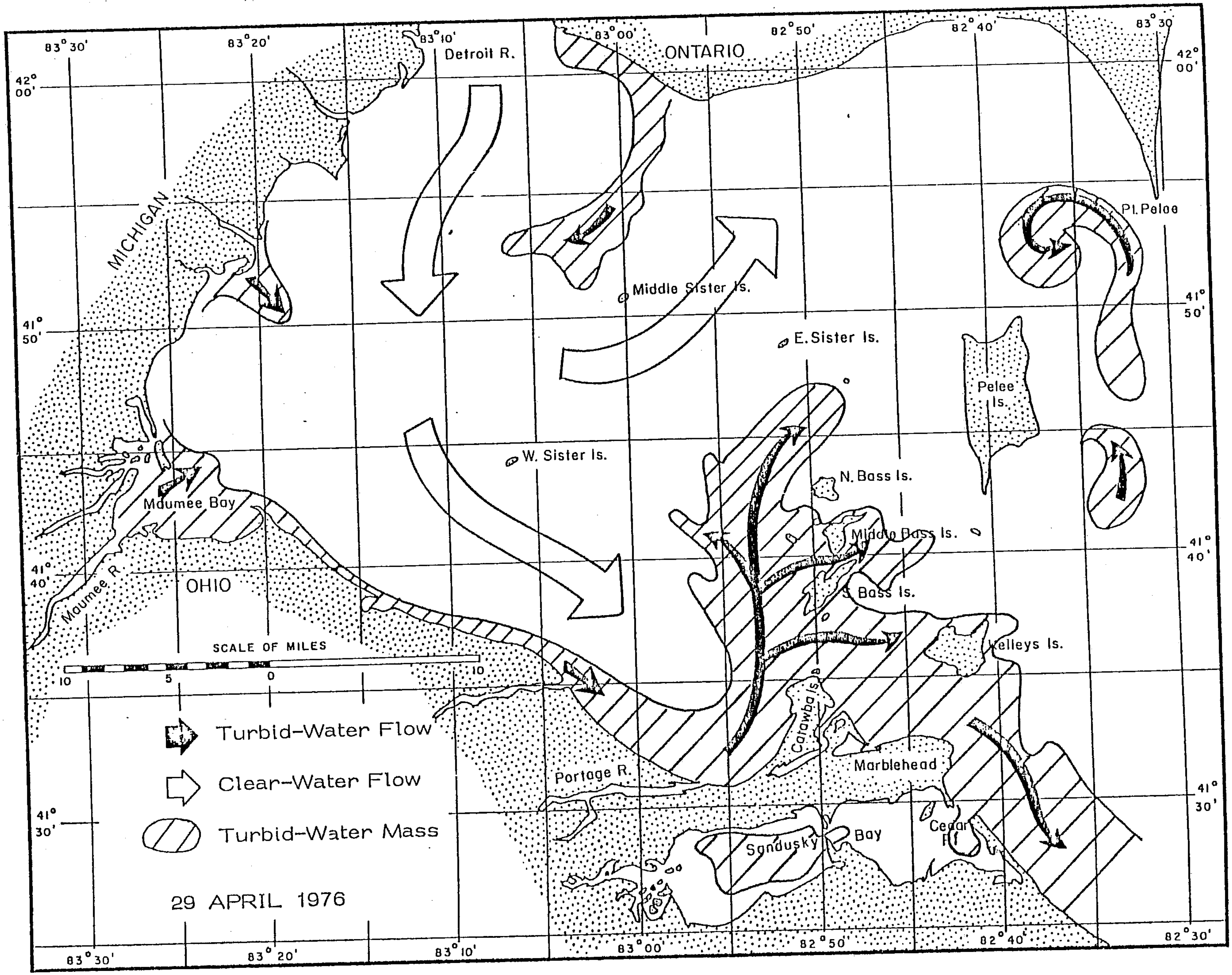


FIGURE 32. WATER FLOW PATTERNS IN WESTERN LAKE ERIE FROM NASA OCEAN-COLOR SCANNER IMAGERY - WQ 72.

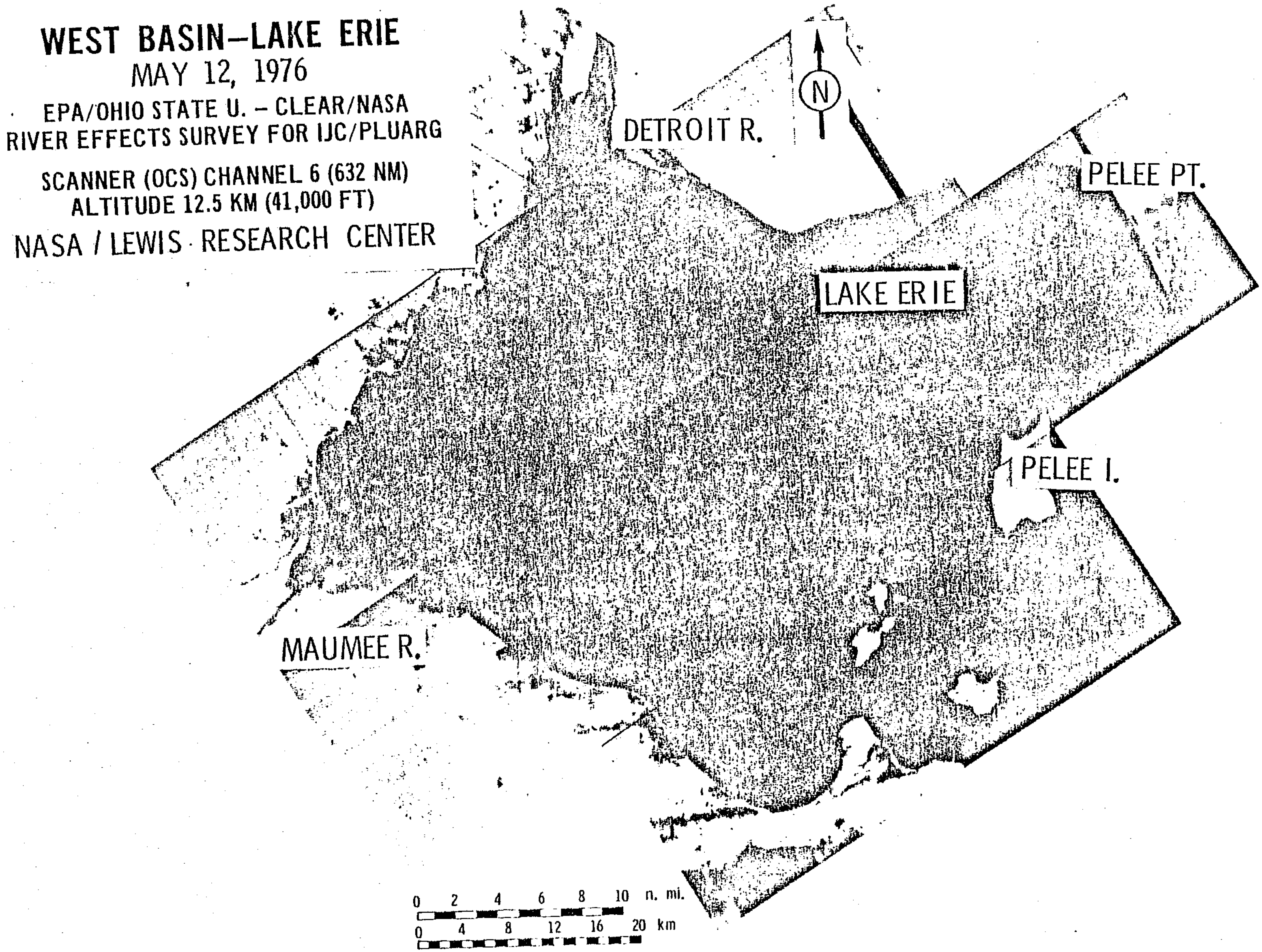

WEST BASIN–LAKE ERIE
MAY 12, 1976
EPA/OHIO STATE U. – CLEAR/NASA
RIVER EFFECTS SURVEY FOR IJC/PLUARG
SCANNER (OCS) CHANNEL 6 (632 NM)
ALTITUDE 12.5 KM (41,000 FT)
NASA / LEWIS RESEARCH CENTER
DETROIT R.
N
PELEE PT.
LAKE ERIE
PELEE I.
MAUMEE R.
0 2 4 6 8 10 n. mi.
0 4 8 12 16 20 km

FIGURE 33

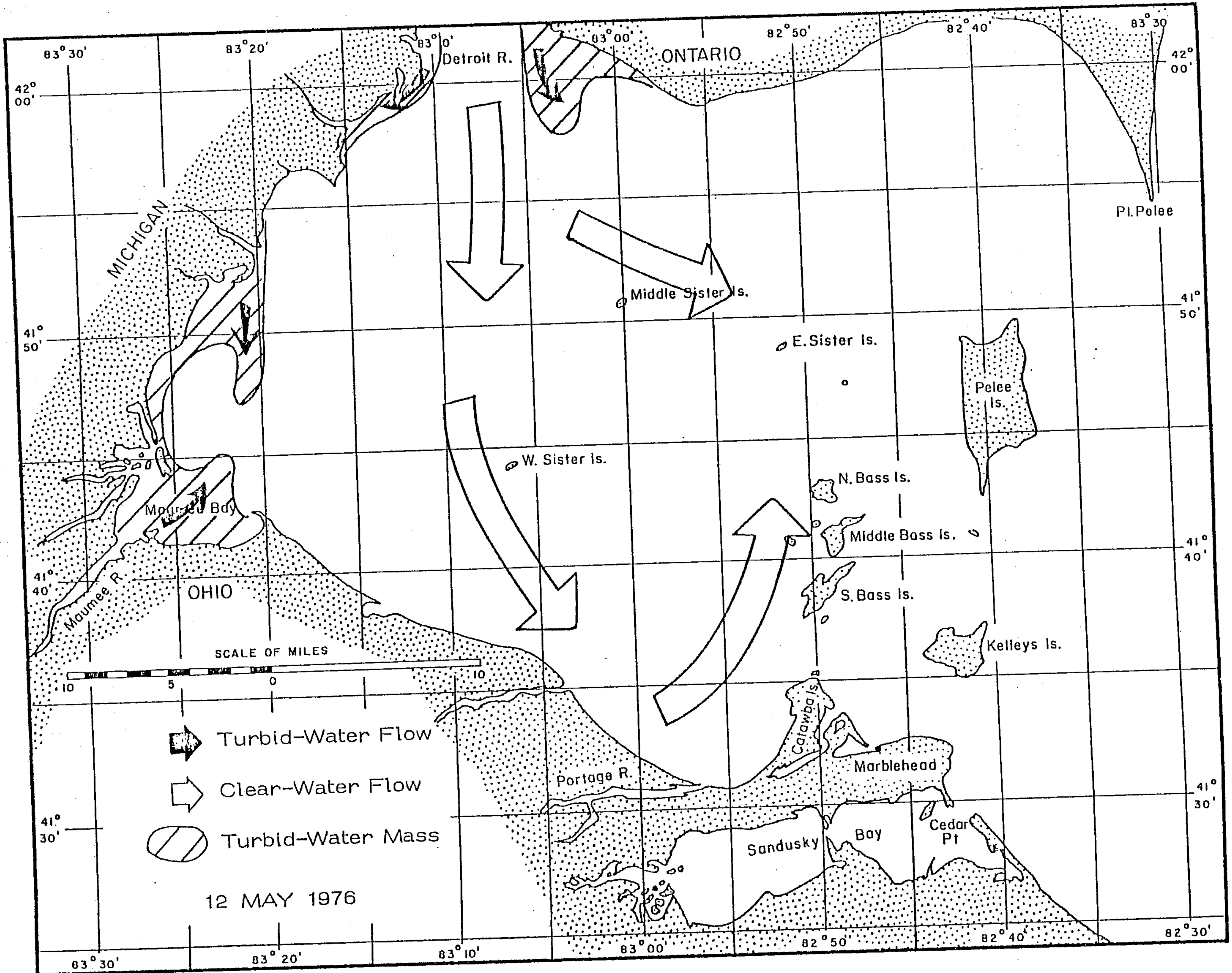


FIGURE 34. WATER FLOW PATTERNS IN WESTERN LAKE ERIE FROM NASA OCEAN-COLOR SCANNER IMAGERY - WQ 74.

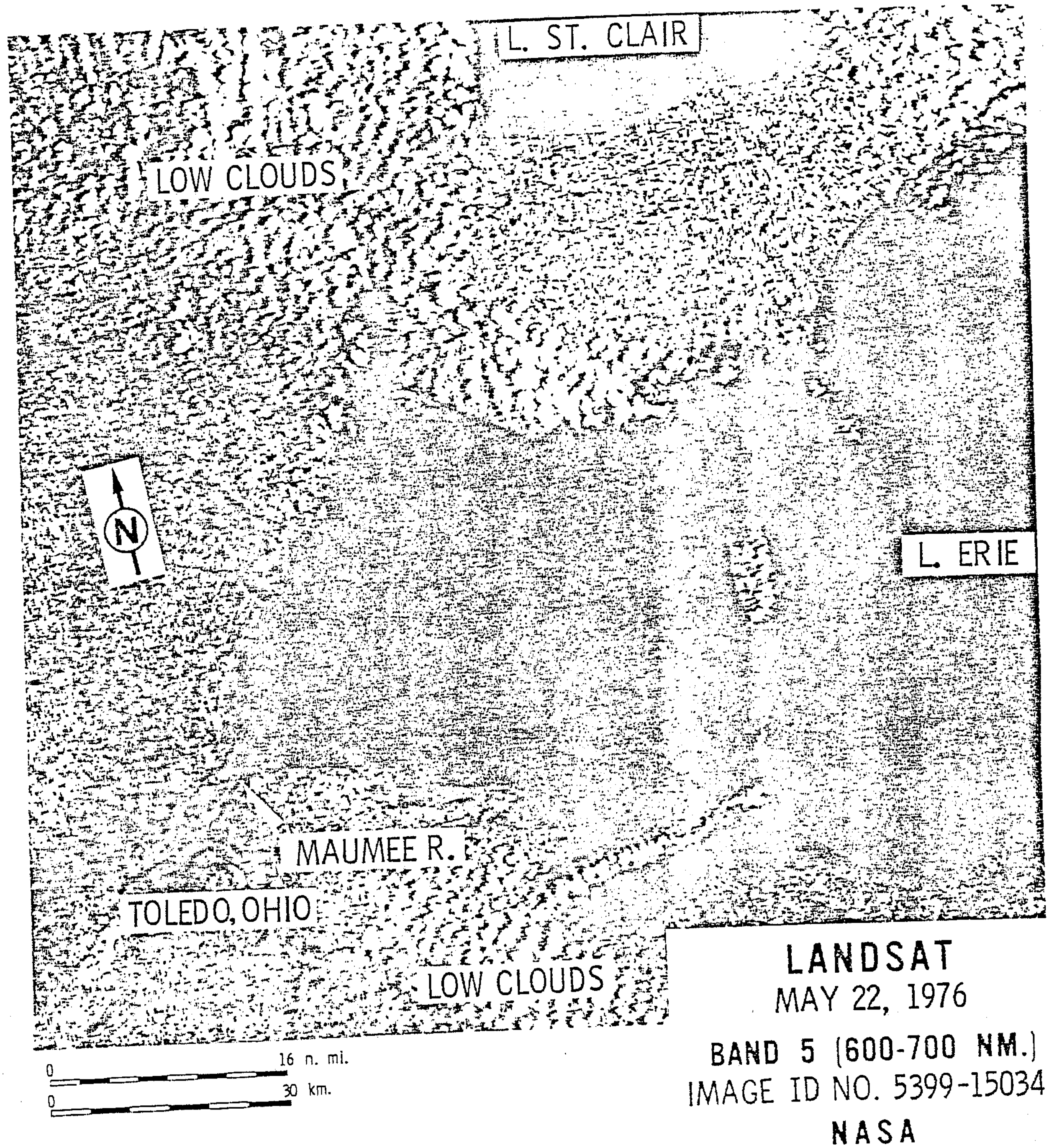

L. ST. CLAIR
LOW CLOUDS
N
L. ERIE
MAUMEE R.
TOLEDO, OHIO
LOW CLOUDS
0
16 n. mi.
0
30 km.
LANDSAT
MAY 22, 1976
BAND 5 (600-700 NM.)
IMAGE ID NO. 5399-15034
NASA

FIGURE 35

WEST BASIN–LAKE ERIE
JUNE 5, 1976
EPA/OHIO STATE U. – CLEAR/NASA
RIVER EFFECTS SURVEY FOR IJC/PLUARG
SCANNER (OCS) CHANNEL 6 (632 NM)
ALTITUDE 12.5 KM (41,000 FT)
NASA / LEWIS RESEARCH CENTER

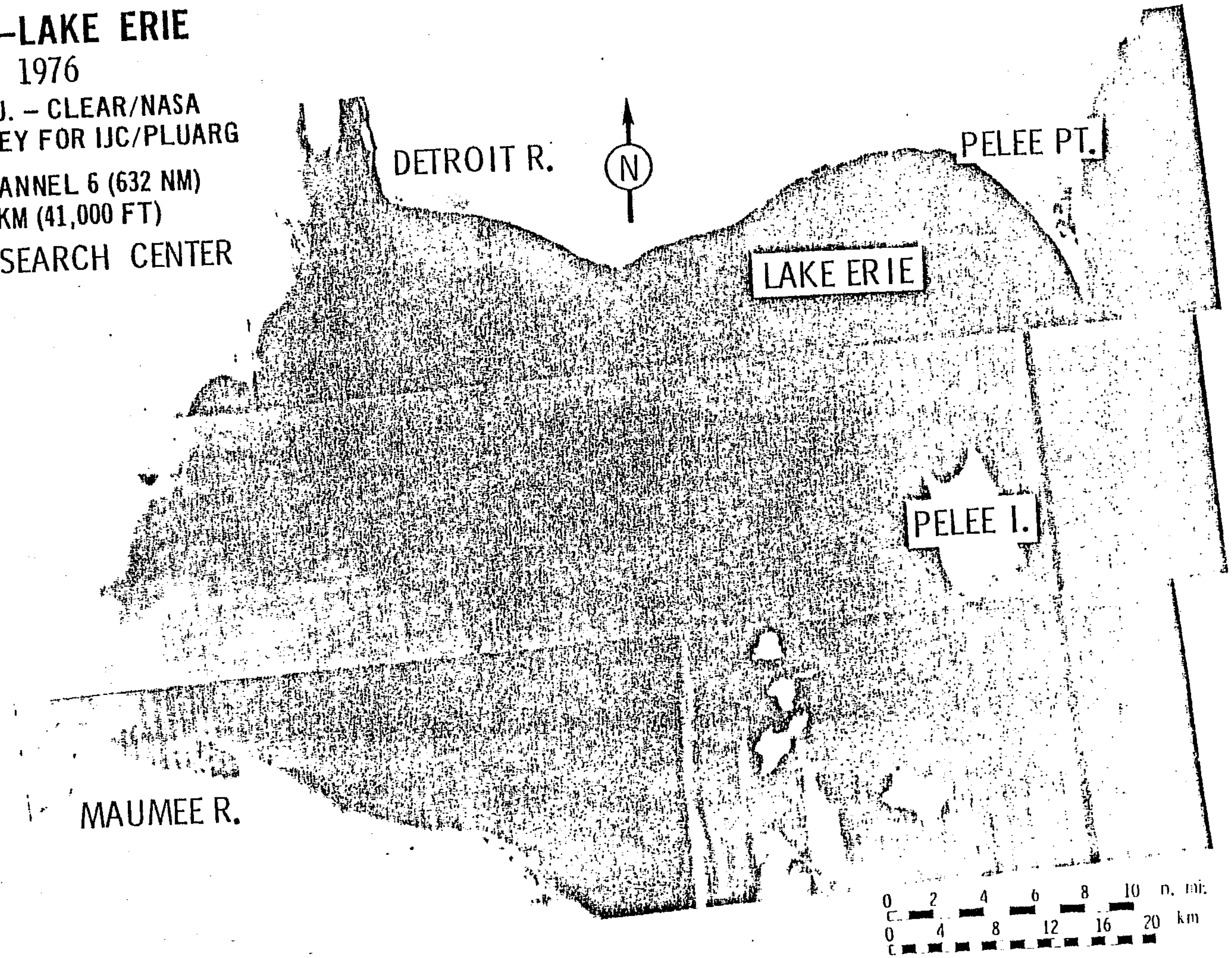


FIGURE 36

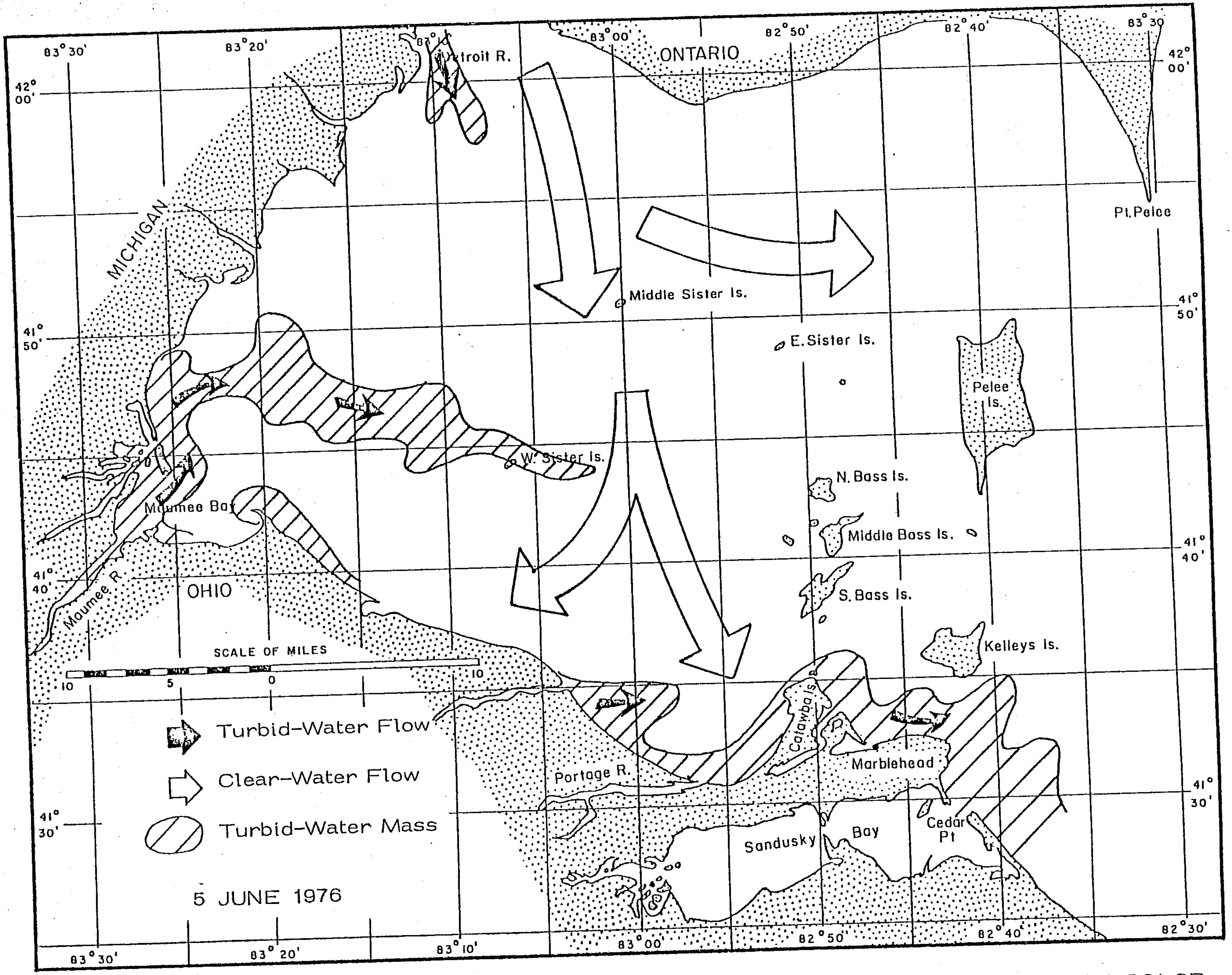


FIGURE 37. WATER FLOW PATTERNS IN WESTERN LAKE ERIE FROM NASA OCEAN-COLOR SCANNER IMAGERY - WQ 84.

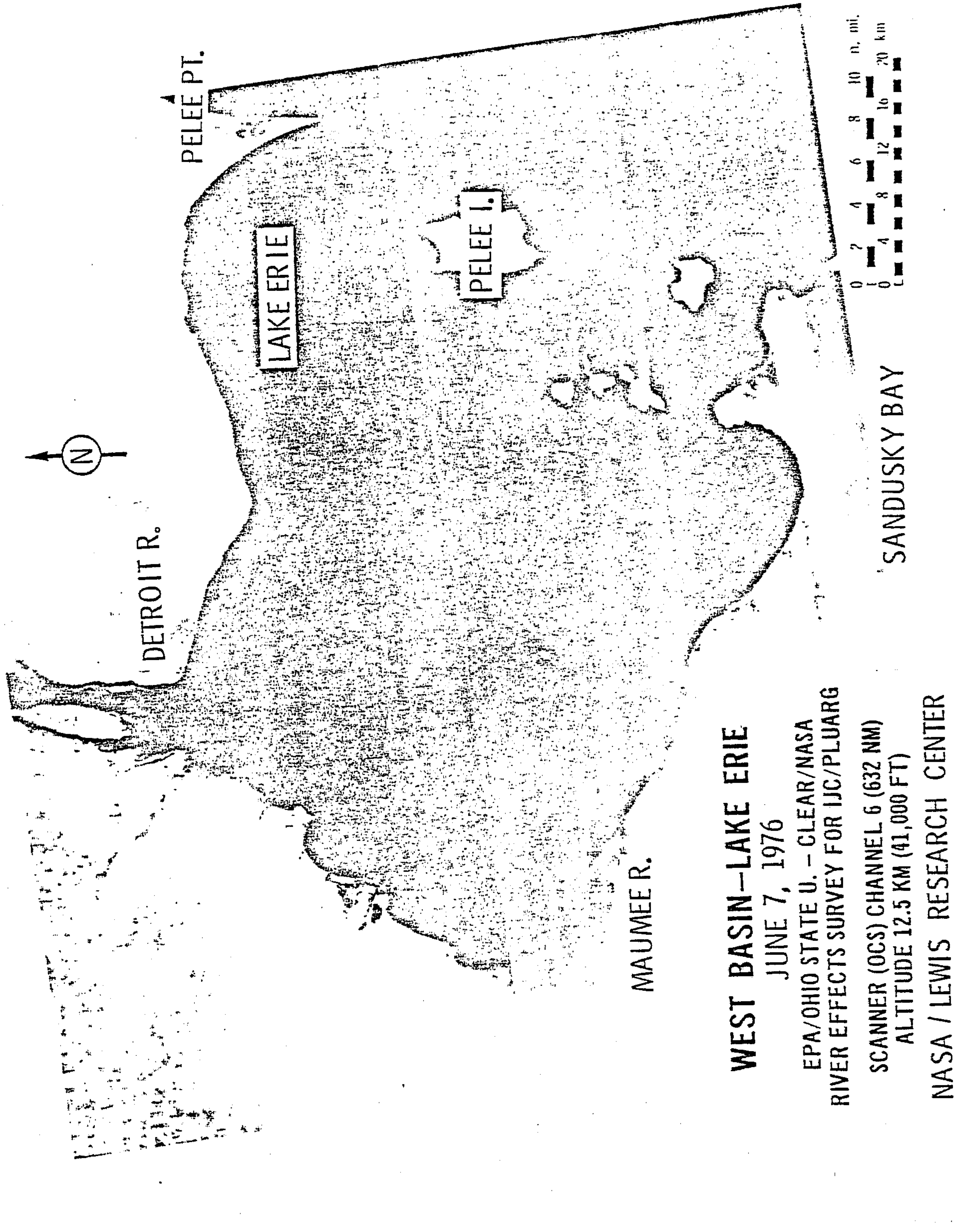

PELEE PT.
LAKE ERIE
PELEE I.
DETROIT R.
N
SANDUSKY BAY
MAUMEE R.
0 2 4 6 8 10 n. mi.
0 4 8 12 16 20 km
WEST BASIN—LAKE ERIE
JUNE 7, 1976
EPA/OHIO STATE U. – CLEAR/NASA
RIVER EFFECTS SURVEY FOR IJC/PLUARG
SCANNER (OCS) CHANNEL 6 (632 NM)
ALTITUDE 12.5 KM (41,000 FT)
NASA / LEWIS RESEARCH CENTER

FIGURE 38

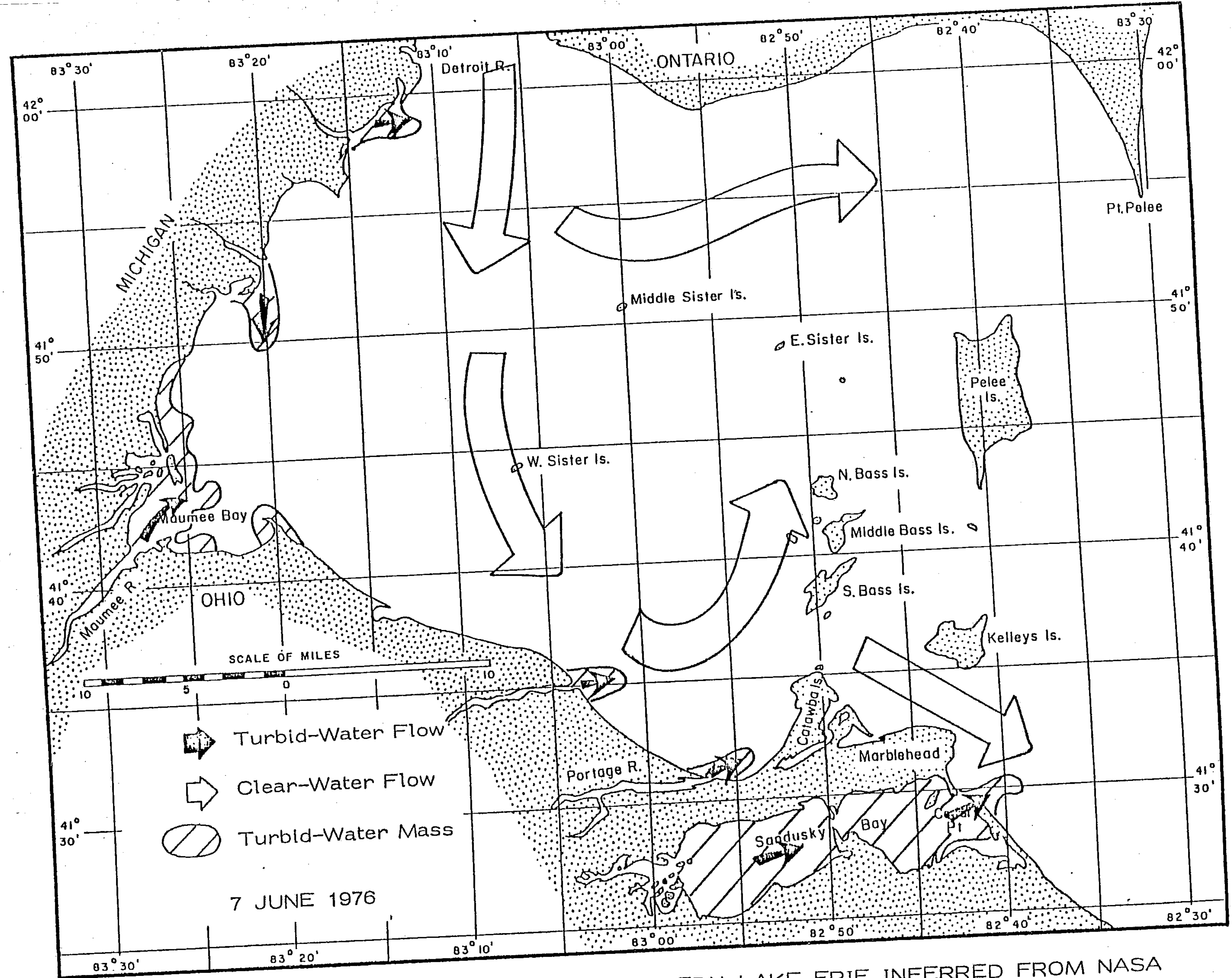


FIGURE 39. WATER FLOW PATTERNS IN WESTERN LAKE ERIE INFERRED FROM NASA OCEAN-COLOR SCANNER IMAGERY - WQ 88.

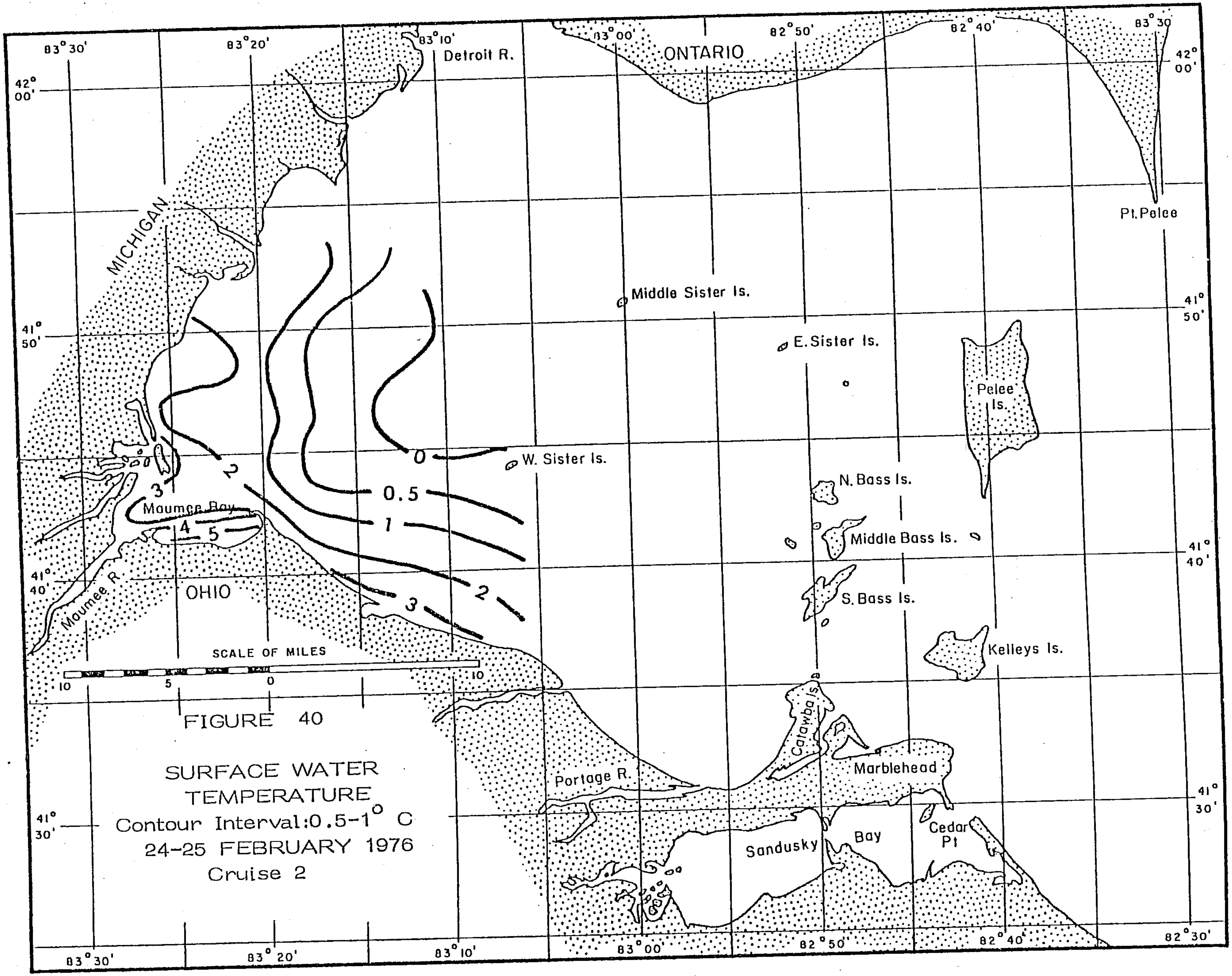


FIGURE 40

SURFACE WATER TEMPERATURE
Contour Interval: 0.5–1° C
24–25 FEBRUARY 1976
Cruise 2

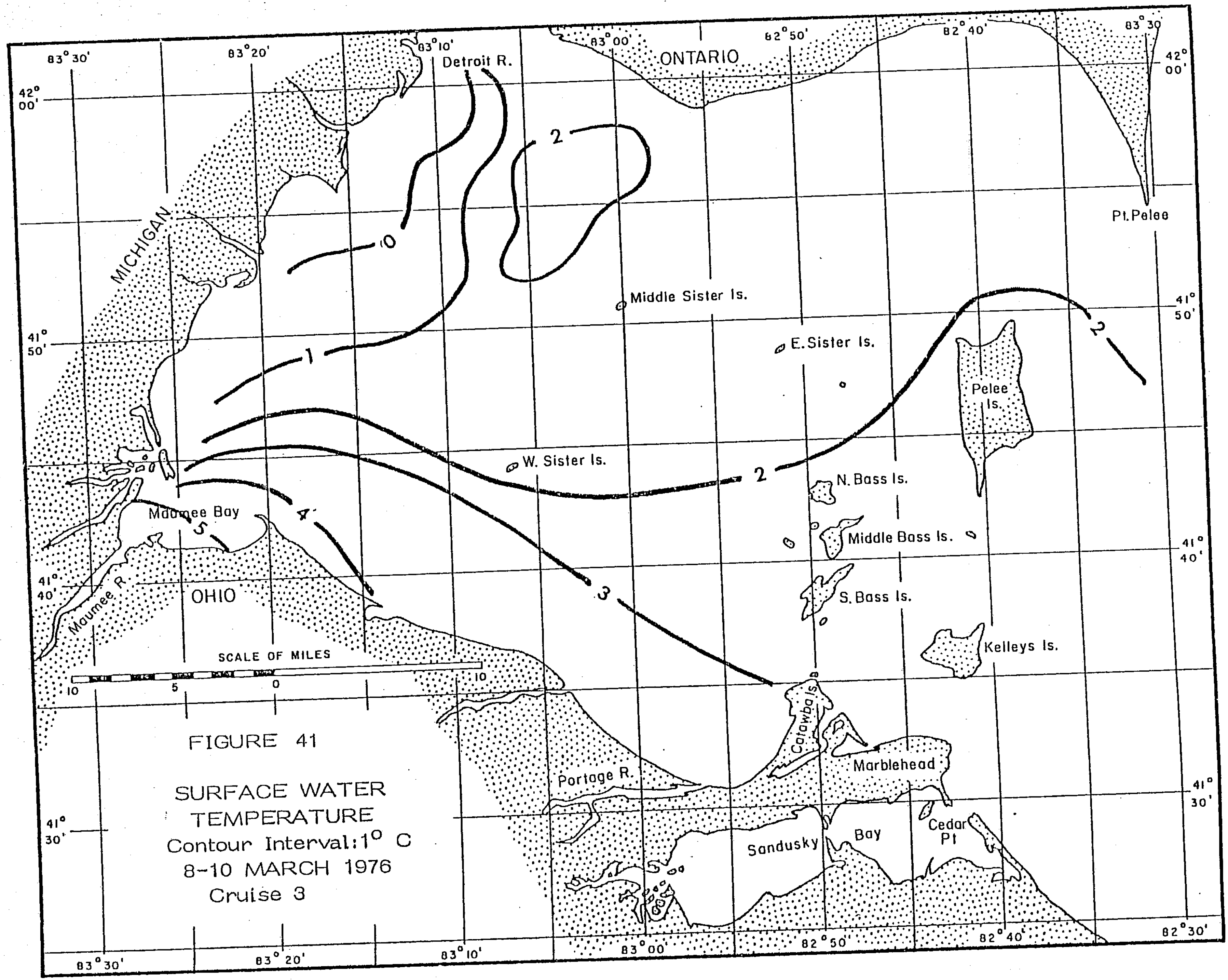


FIGURE 41

SURFACE WATER TEMPERATURE
Contour Interval: 1° C
8–10 MARCH 1976
Cruise 3

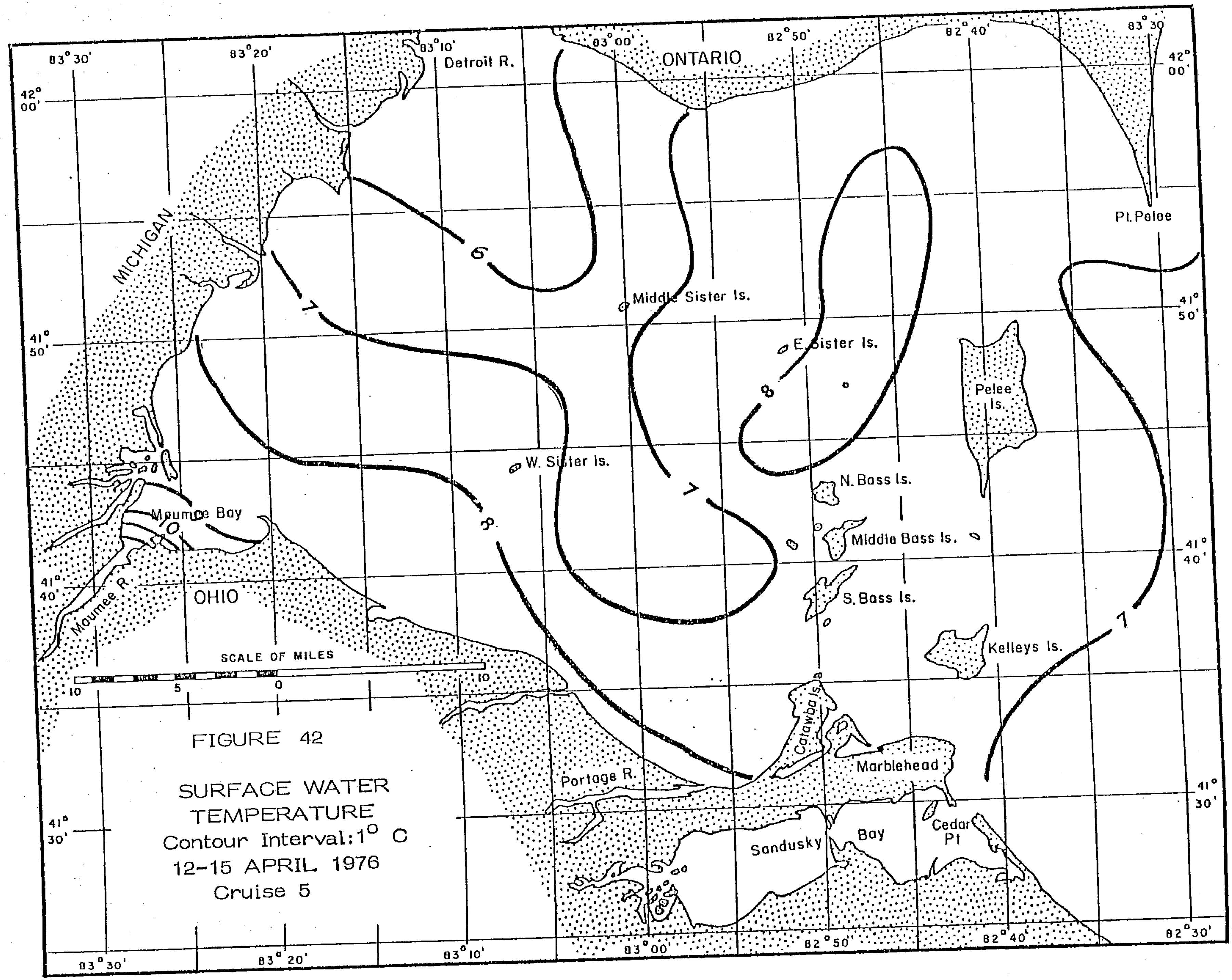


FIGURE 42

SURFACE WATER TEMPERATURE
Contour Interval: 1° C
12–15 APRIL 1976
Cruise 5

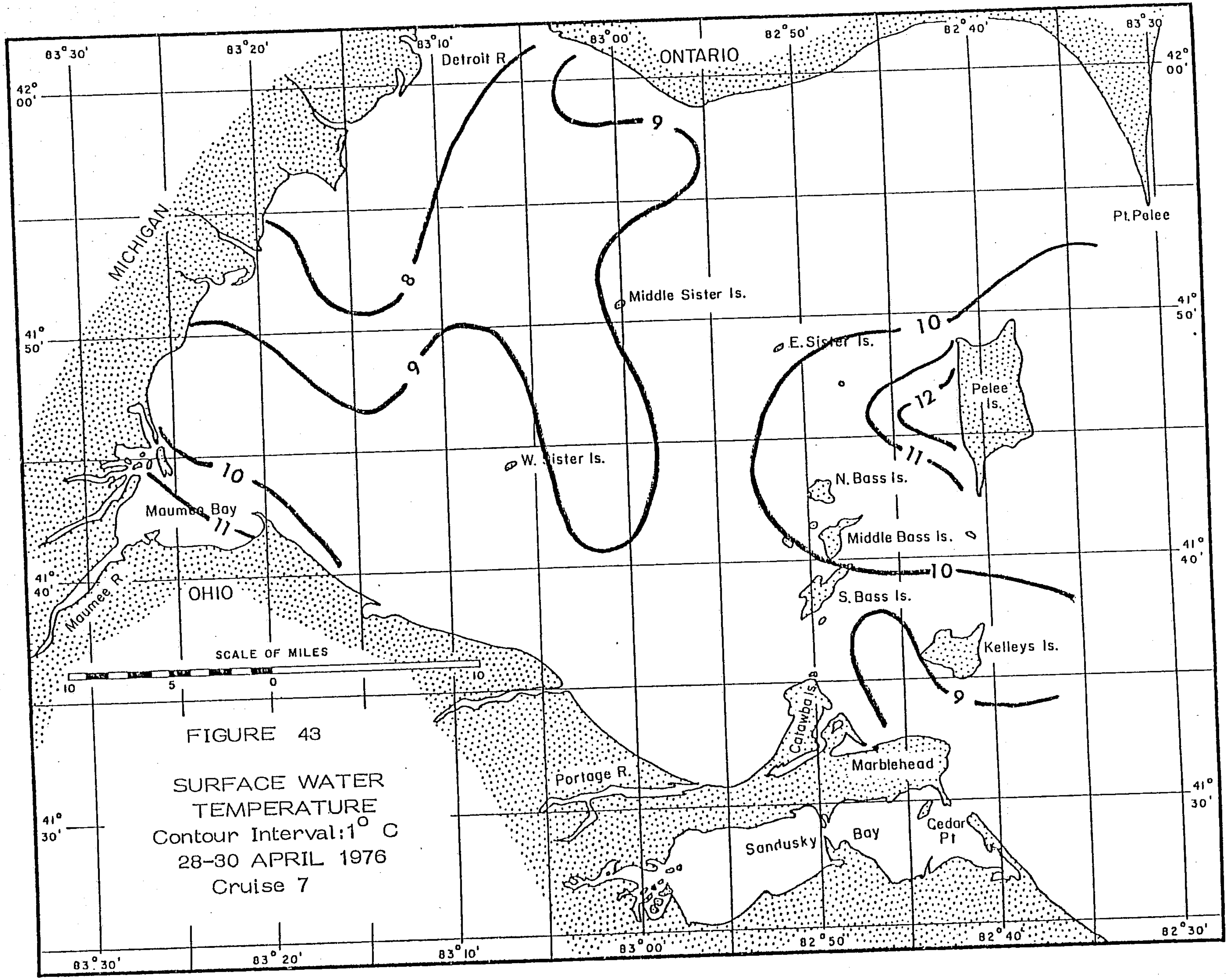


FIGURE 43

SURFACE WATER TEMPERATURE
Contour Interval: 1° C
28-30 APRIL 1976
Cruise 7

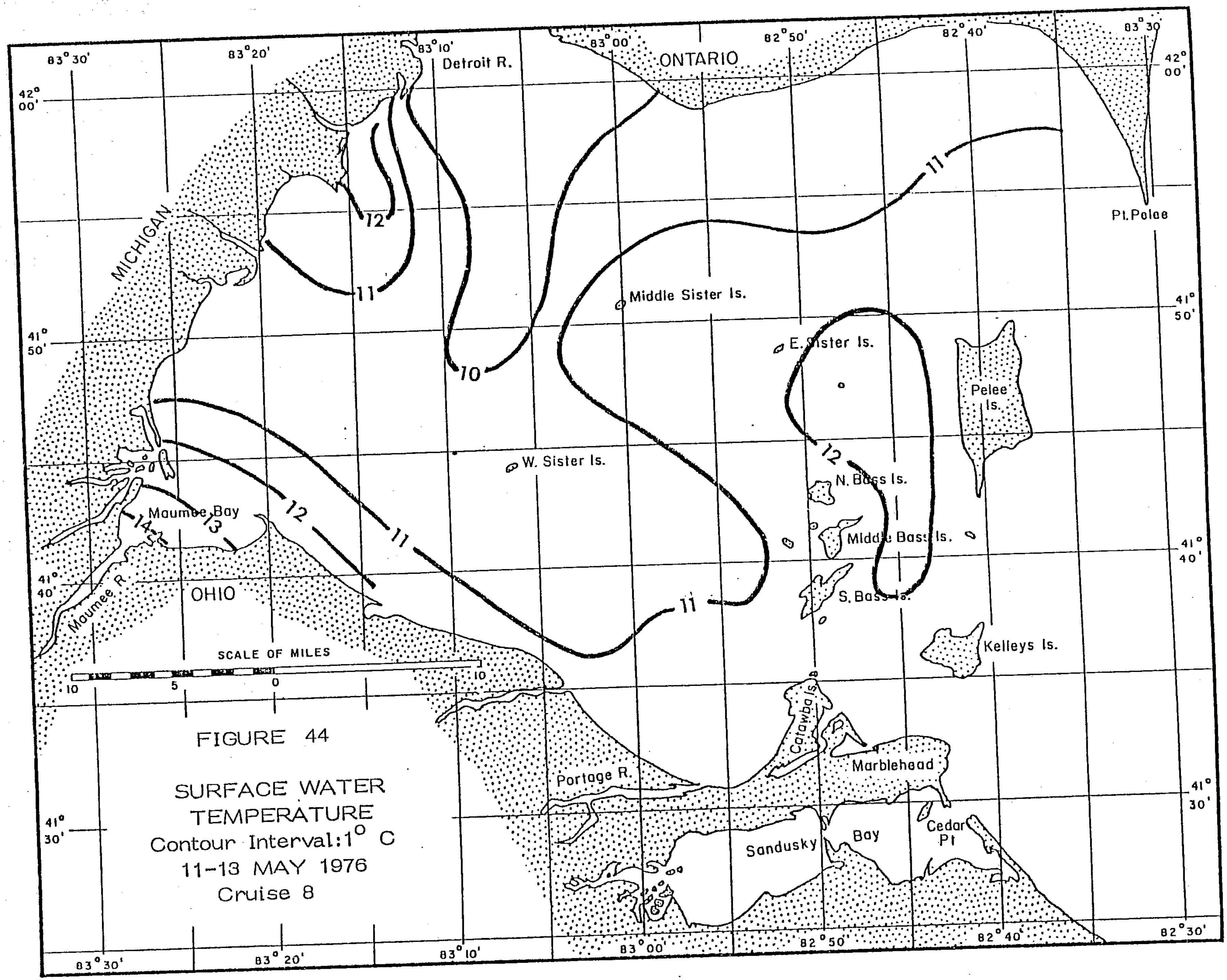


FIGURE 44

SURFACE WATER TEMPERATURE
Contour Interval: 1° C
11–13 MAY 1976
Cruise 8

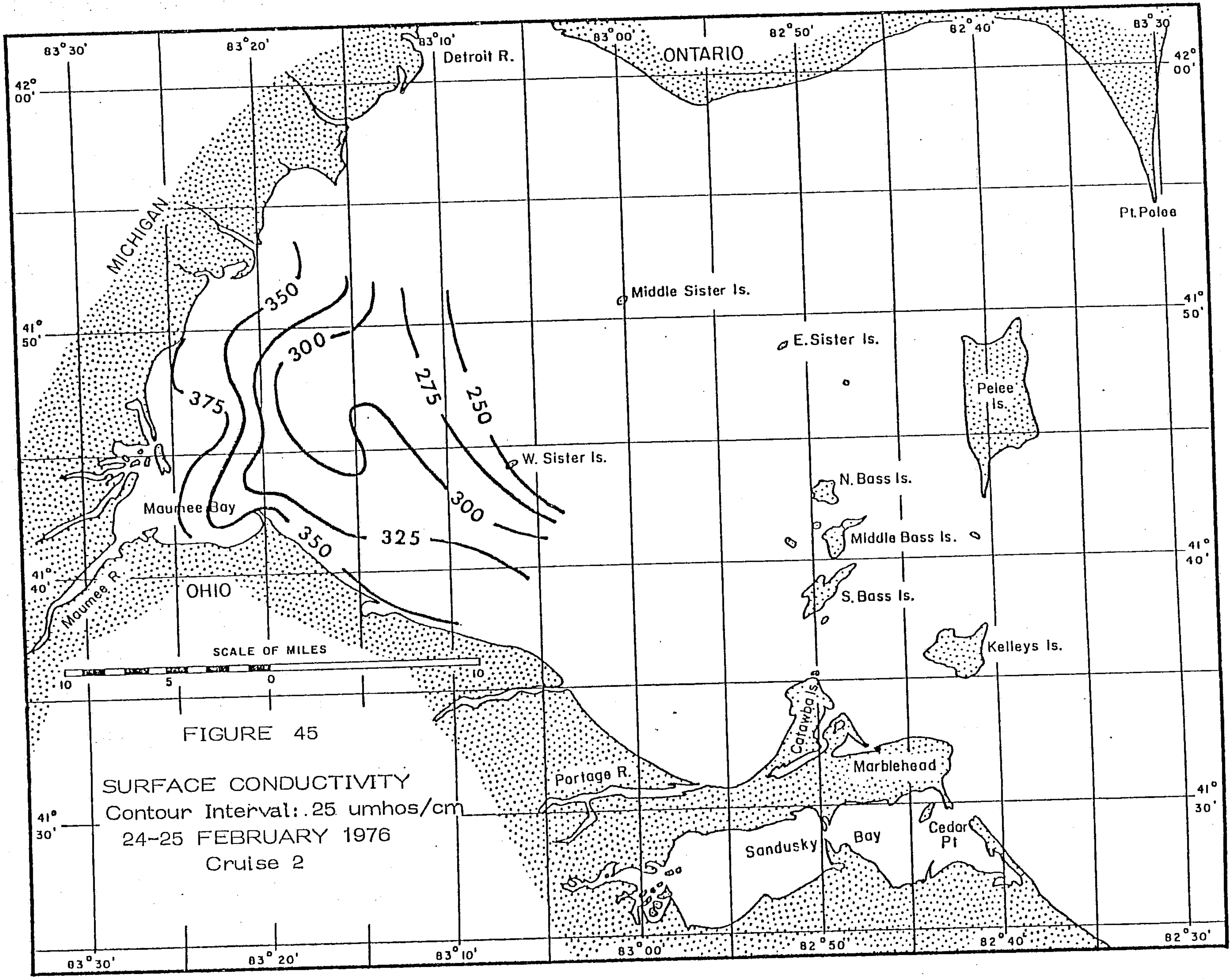


FIGURE 45

SURFACE CONDUCTIVITY
Contour Interval: .25 umhos/cm
24-25 FEBRUARY 1976
Cruise 2

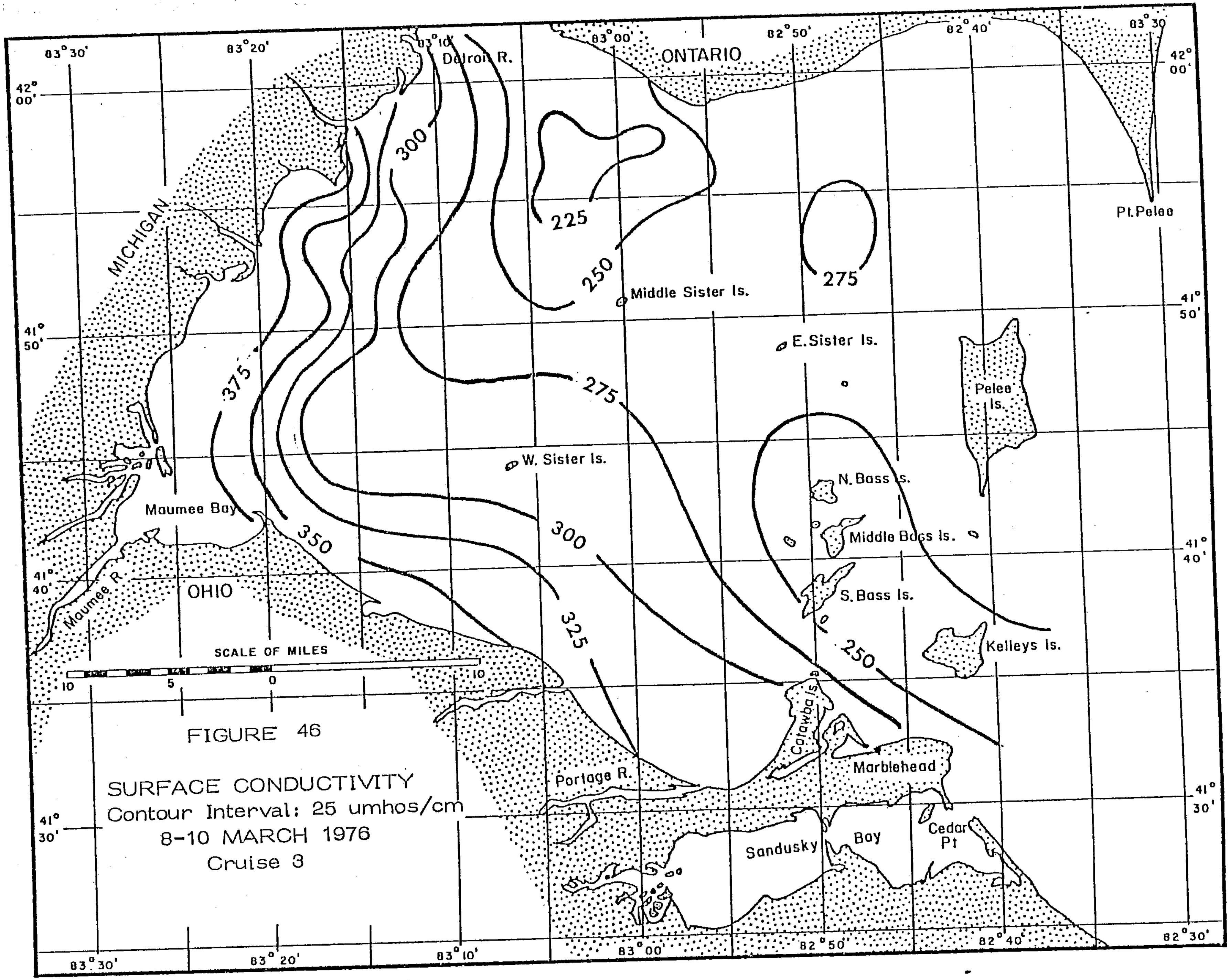


FIGURE 46

SURFACE CONDUCTIVITY
Contour Interval: 25 umhos/cm
8-10 MARCH 1976
Cruise 3

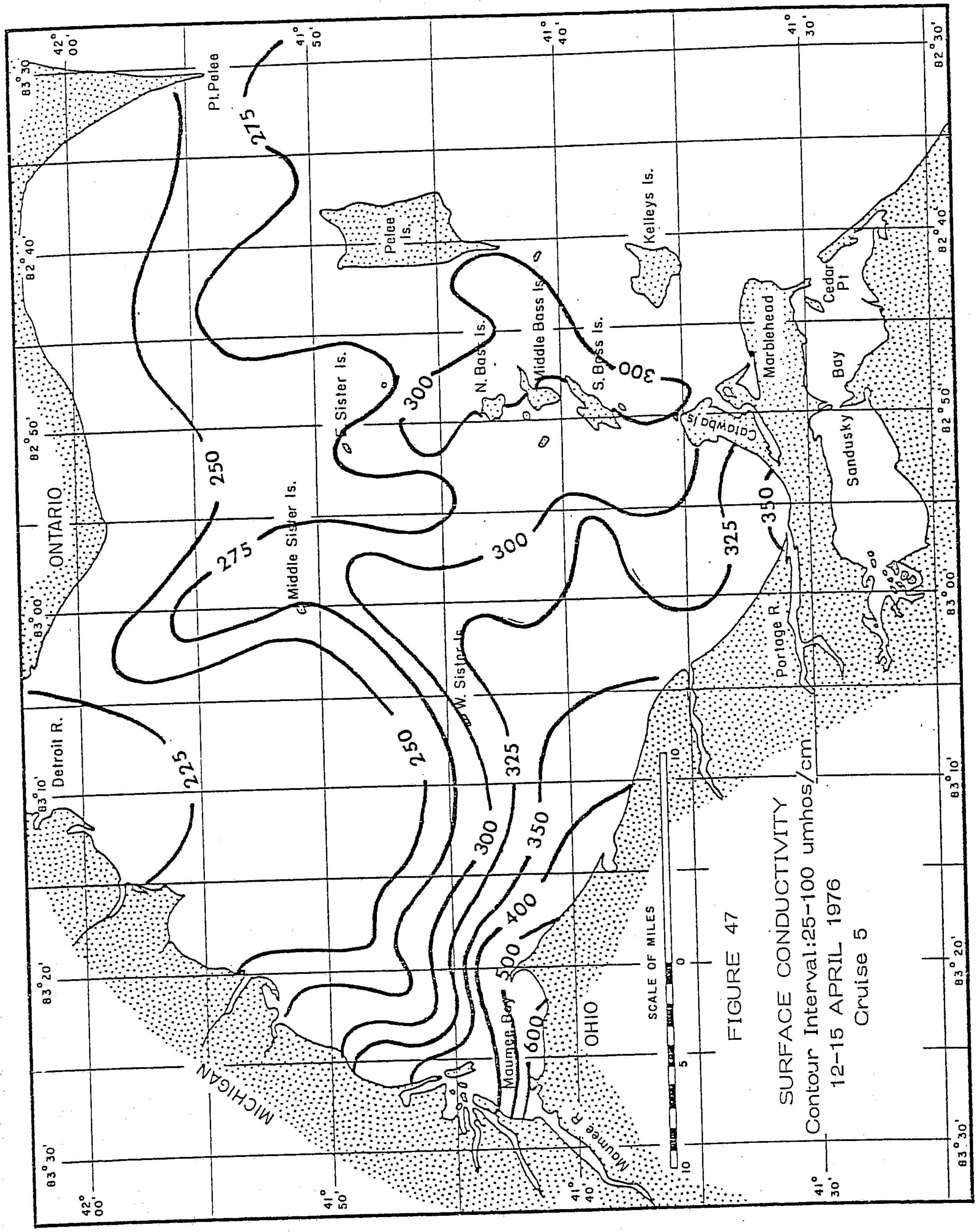


FIGURE 47

SURFACE CONDUCTIVITY
Contour Interval:25-100 umhos/cm
12-15 APRIL 1976
Cruise 5

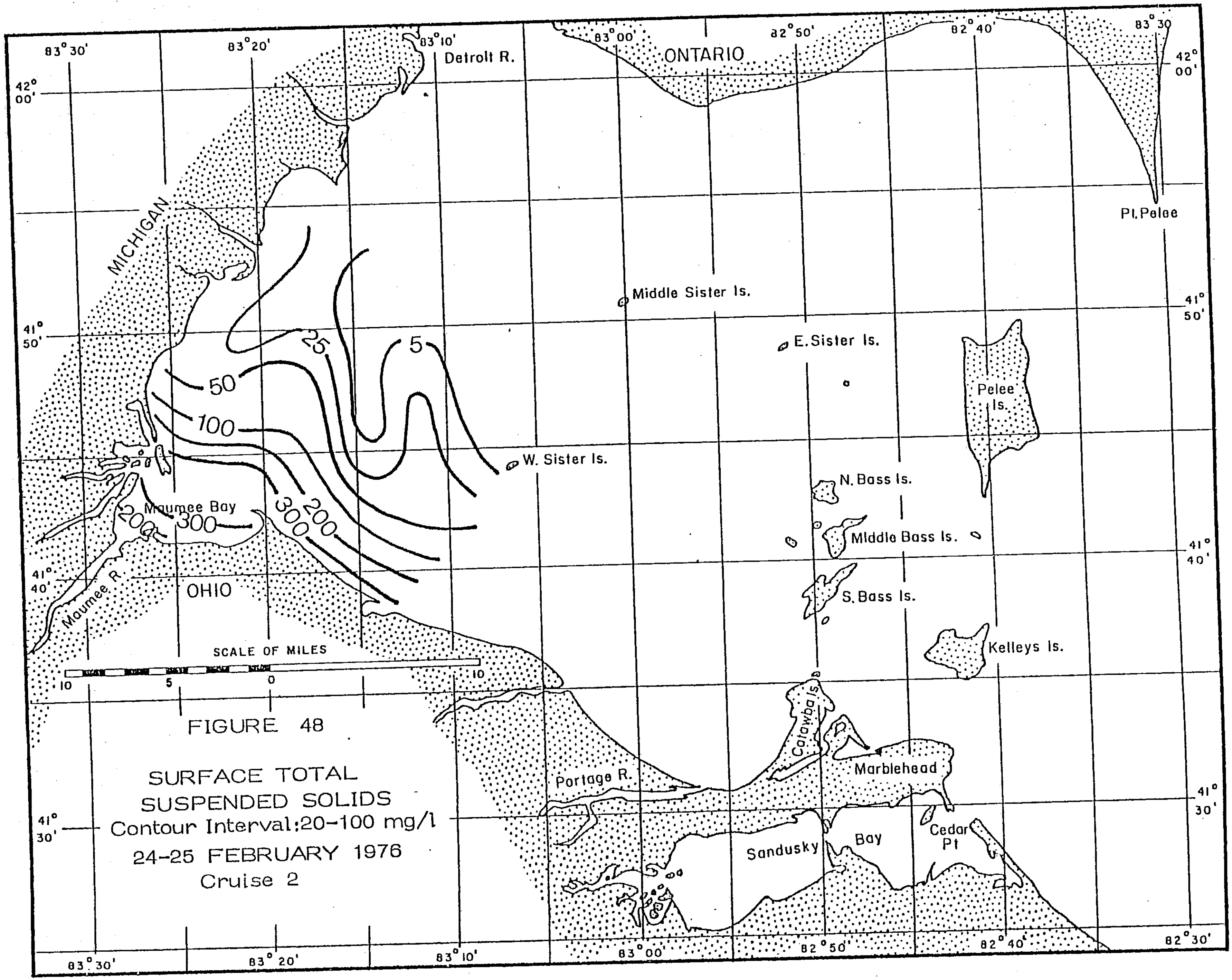


FIGURE 48

SURFACE TOTAL
SUSPENDED SOLIDS
Contour Interval: 20–100 mg/l
24–25 FEBRUARY 1976
Cruise 2

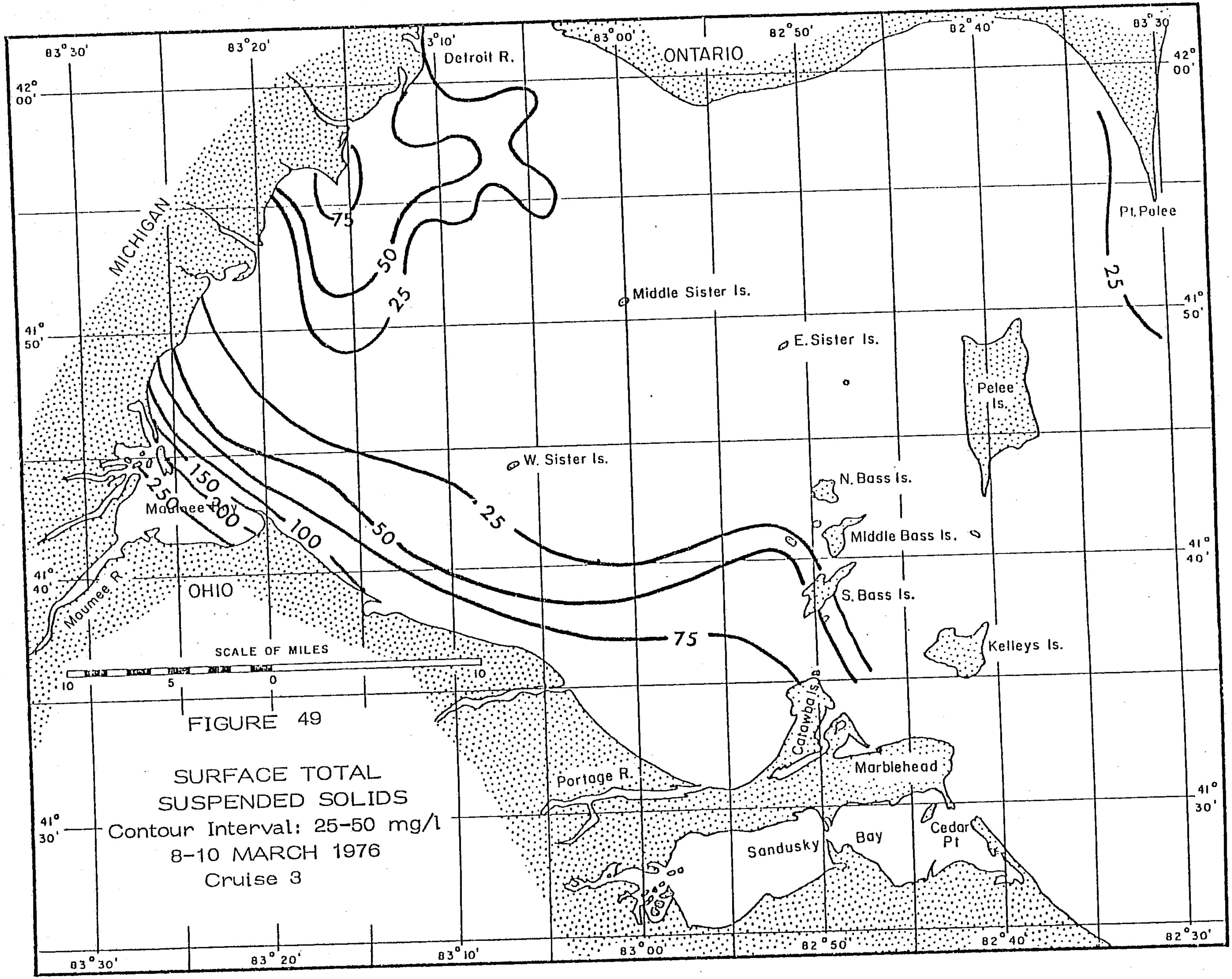


FIGURE 49

SURFACE TOTAL
SUSPENDED SOLIDS
Contour Interval: 25-50 mg/l
8-10 MARCH 1976
Cruise 3

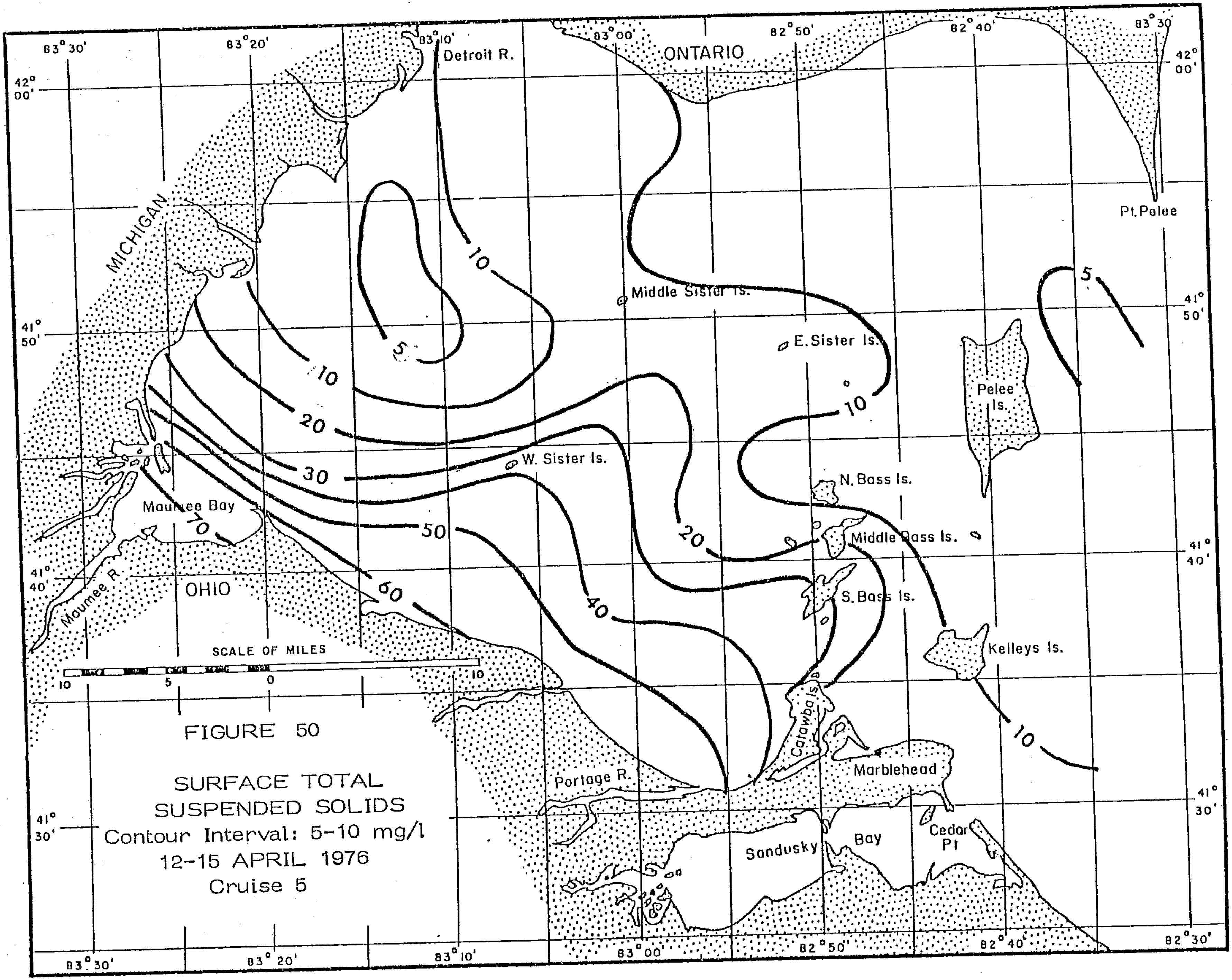


FIGURE 50

SURFACE TOTAL SUSPENDED SOLIDS
Contour Interval: 5-10 mg/l
12-15 APRIL 1976
Cruise 5

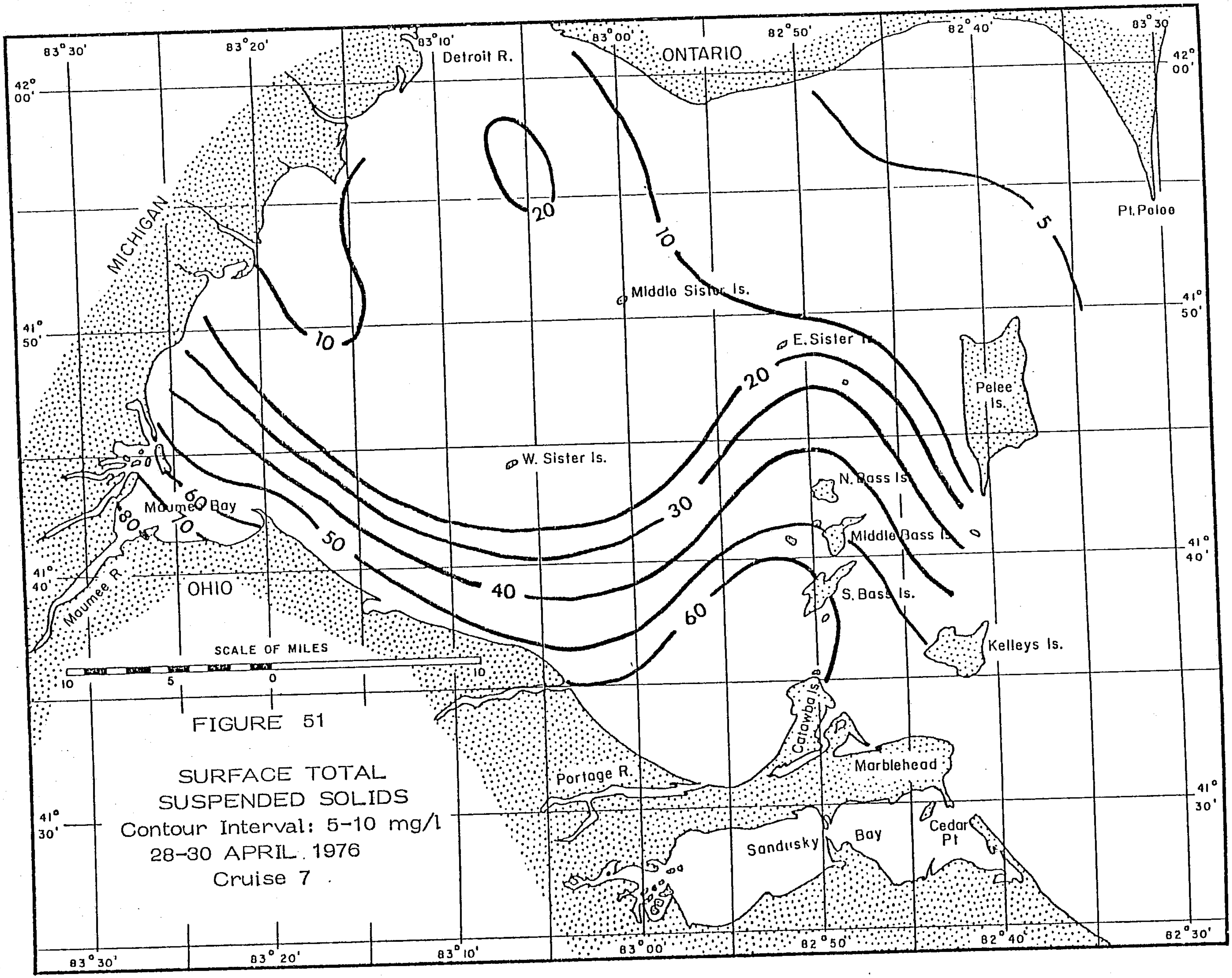


FIGURE 51

SURFACE TOTAL
SUSPENDED SOLIDS
Contour Interval: 5-10 mg/l
28-30 APRIL 1976
Cruise 7

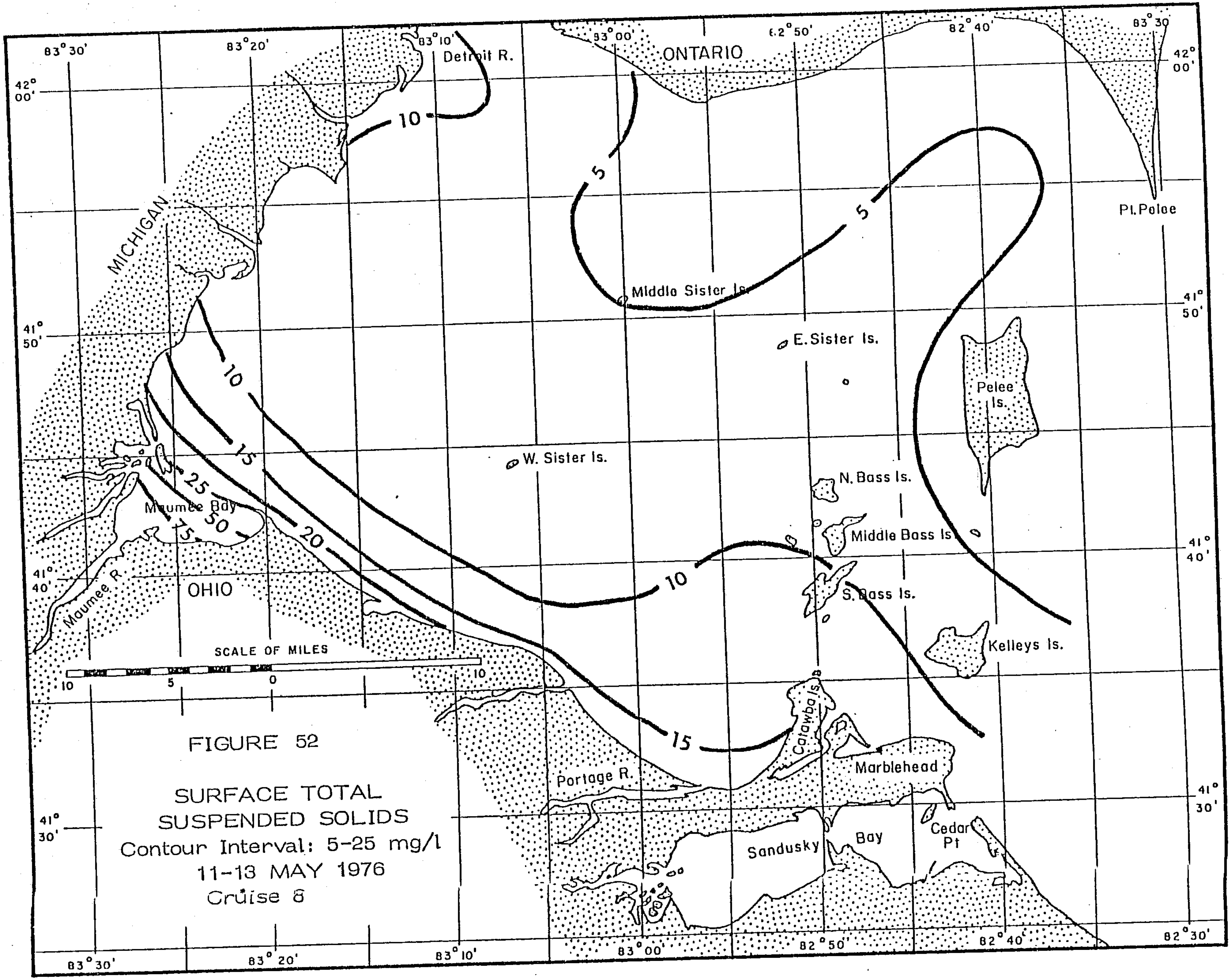


FIGURE 52

SURFACE TOTAL SUSPENDED SOLIDS
Contour Interval: 5-25 mg/l
11-13 MAY 1976
Cruise 8

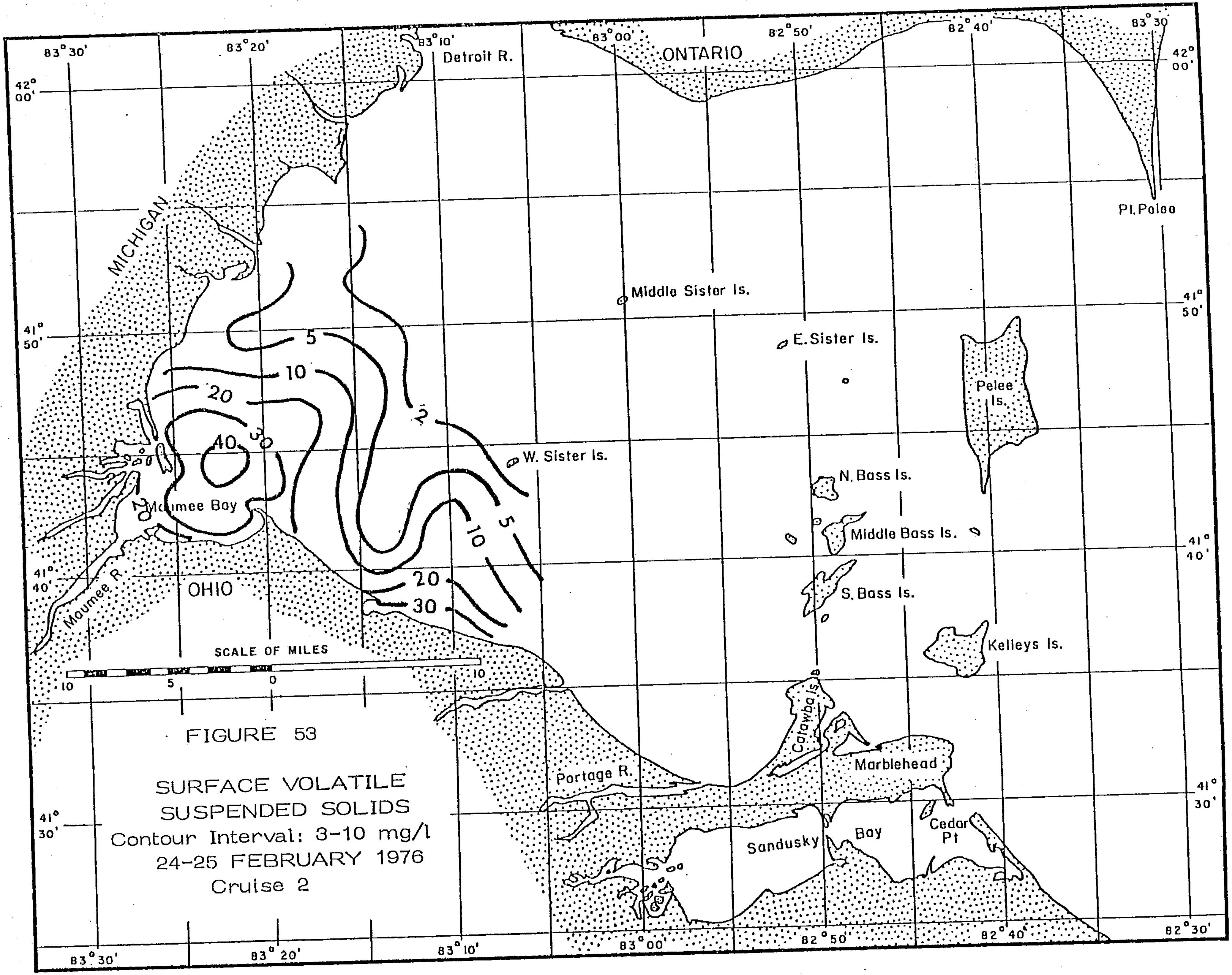


FIGURE 53

SURFACE VOLATILE
SUSPENDED SOLIDS
Contour Interval: 3-10 mg/l
24-25 FEBRUARY 1976
Cruise 2

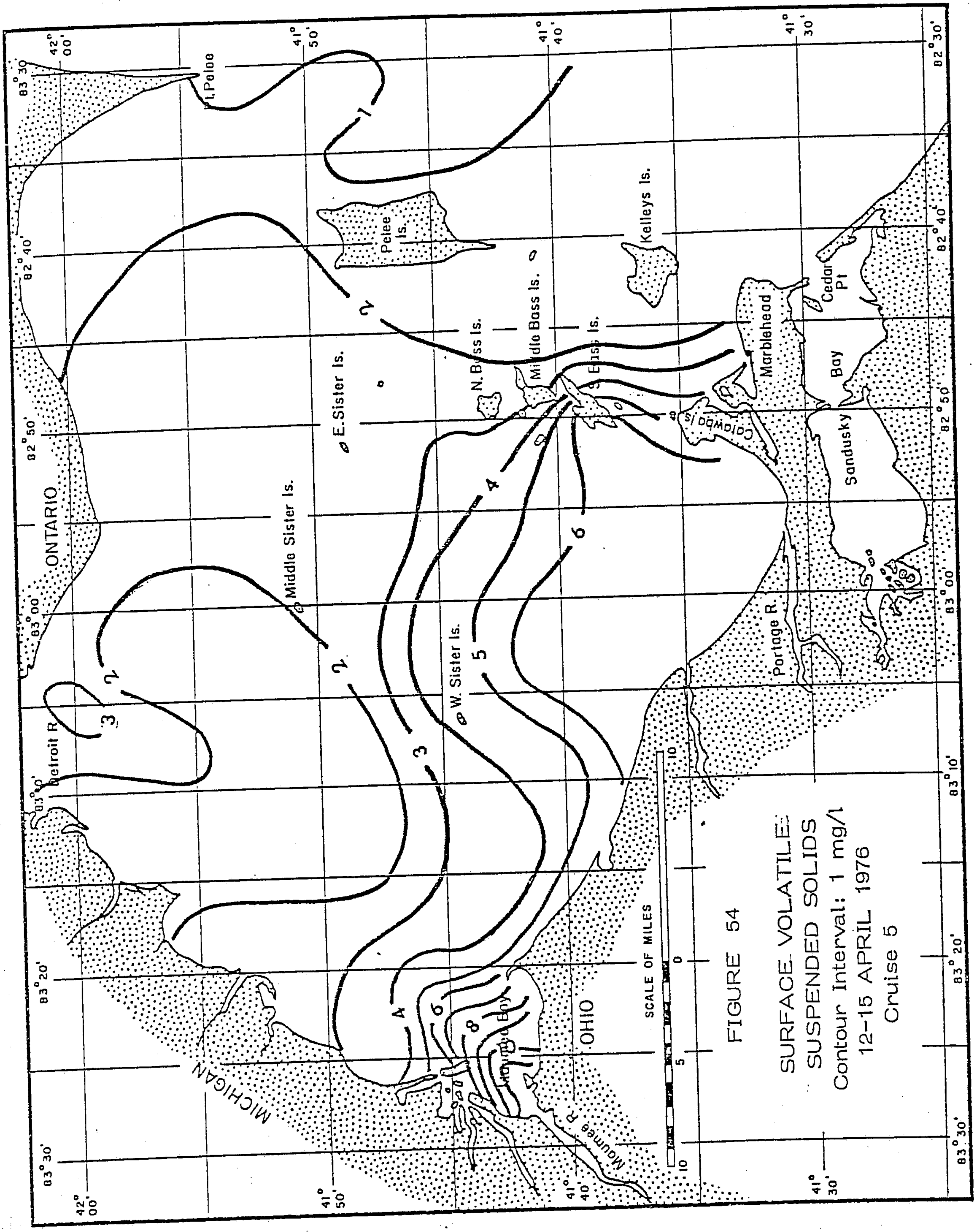


FIGURE 54

SURFACE VOLATILE SUSPENDED SOLIDS
Contour Interval: 1 mg/l
12-15 APRIL 1976
Cruise 5

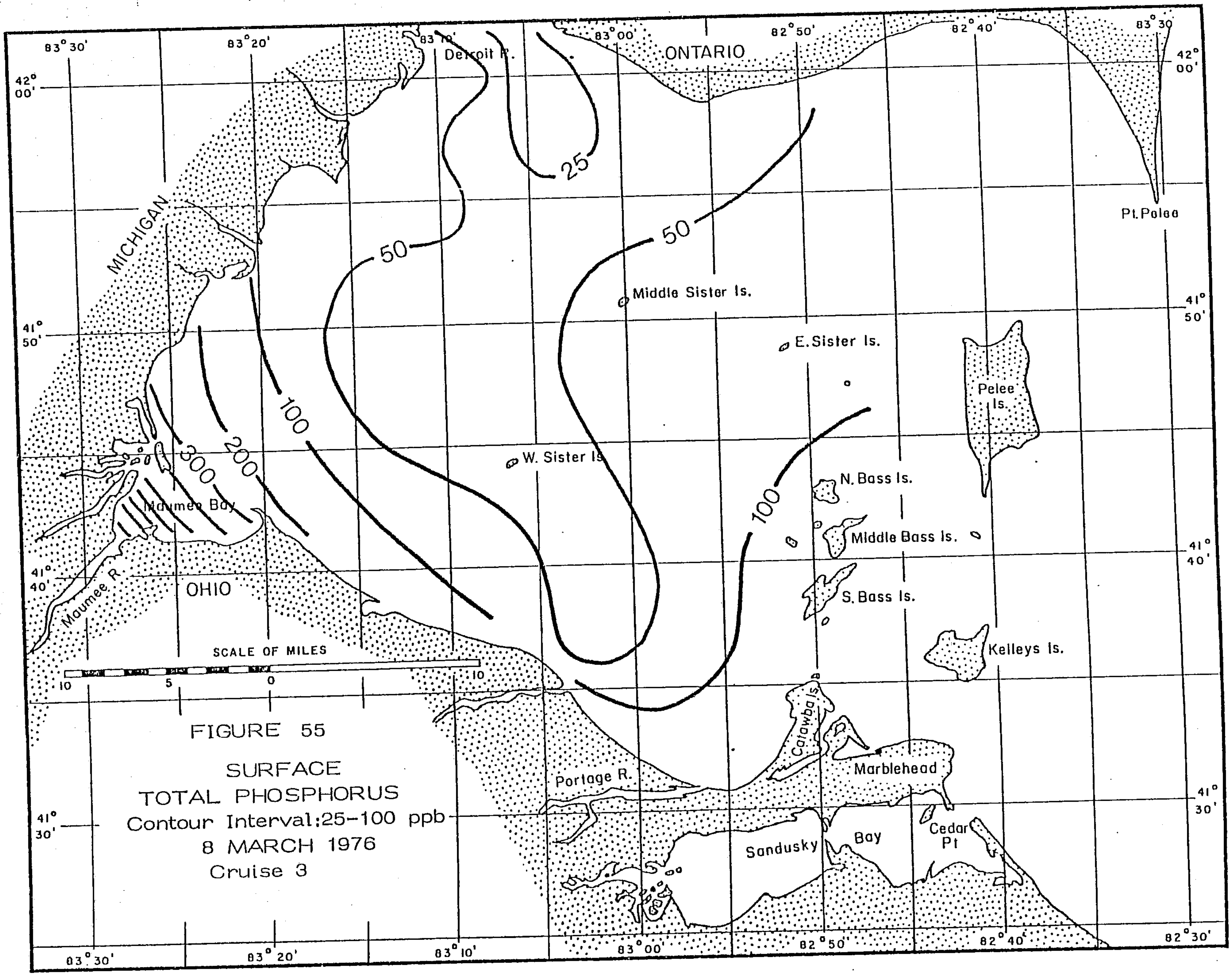


FIGURE 55

SURFACE
TOTAL PHOSPHORUS
Contour Interval: 25-100 ppb
8 MARCH 1976
Cruise 3

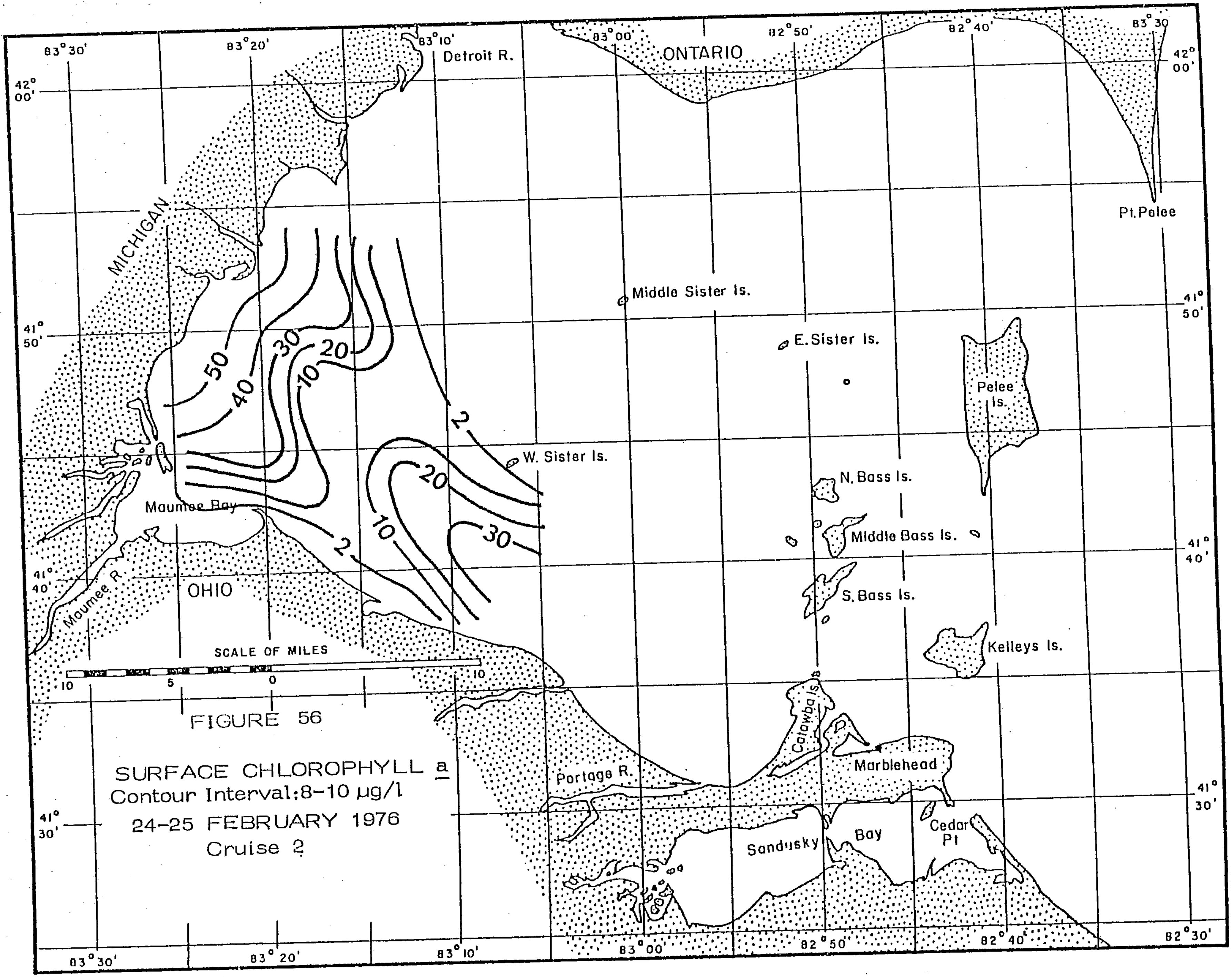


FIGURE 56

SURFACE CHLOROPHYLL a
Contour Interval: 8-10 μg/l
24-25 FEBRUARY 1976
Cruise 2

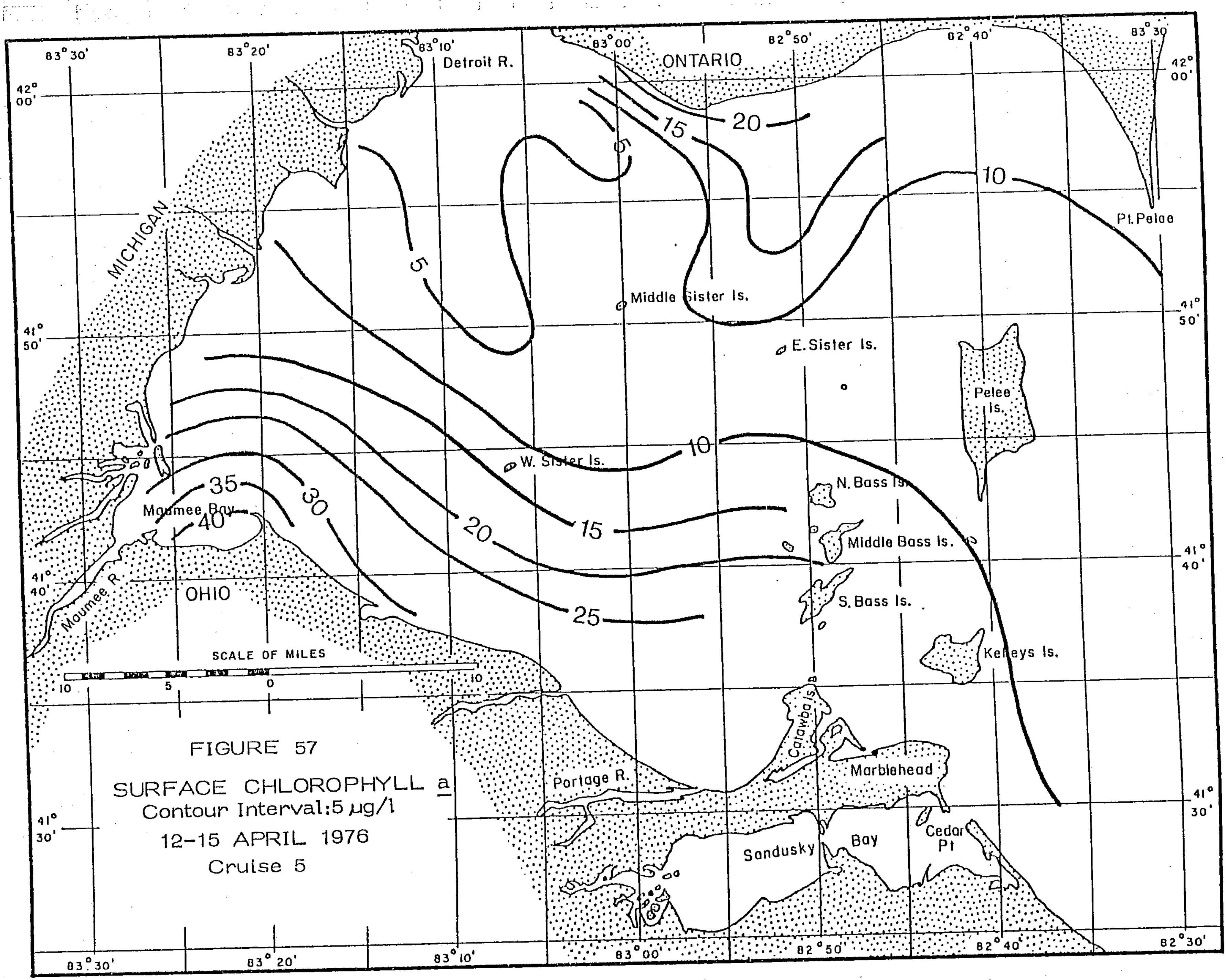


FIGURE 57

SURFACE CHLOROPHYLL a
Contour Interval: 5 µg/l
12–15 APRIL 1976
Cruise 5

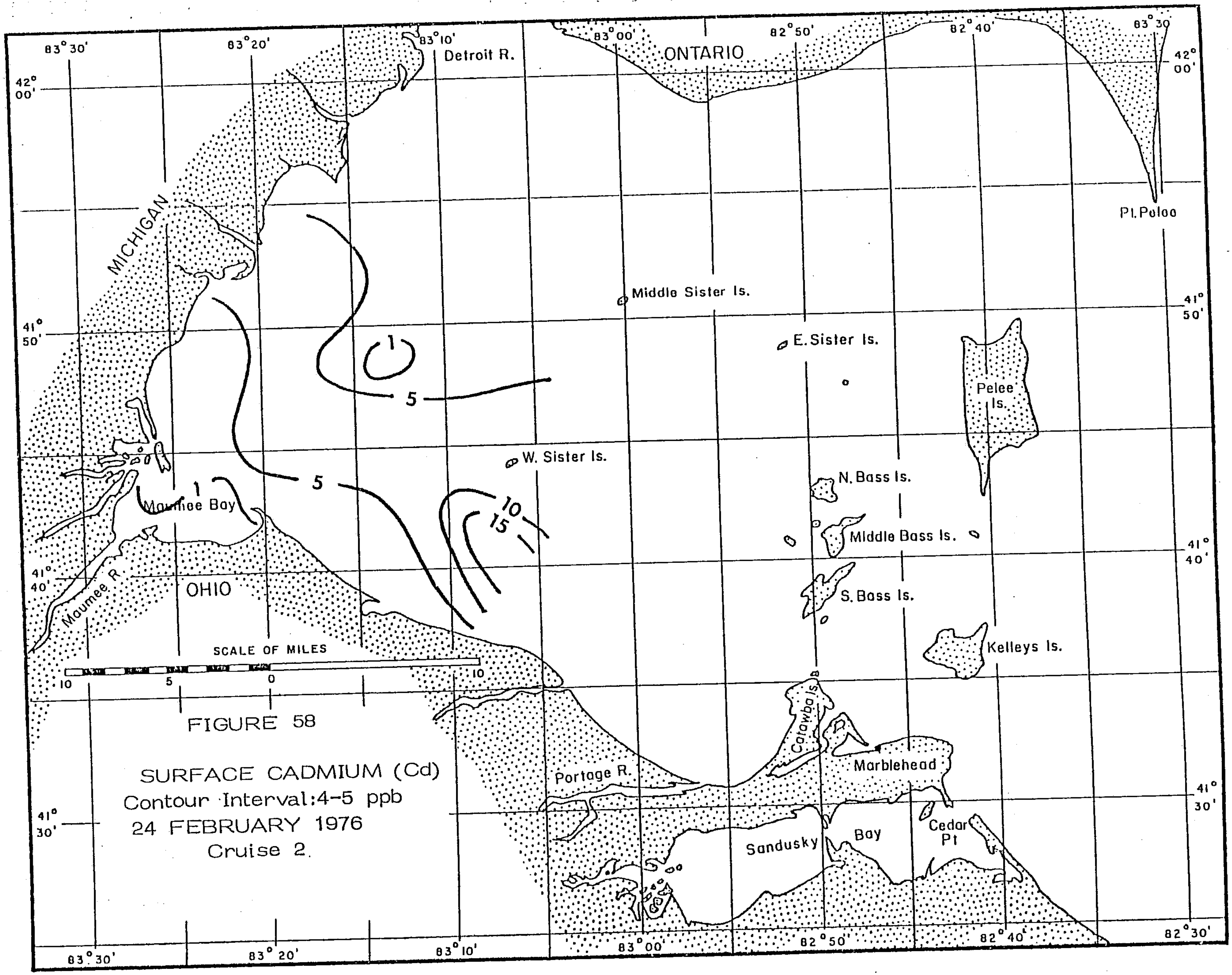


FIGURE 58

SURFACE CADMIUM (Cd)
Contour Interval: 4-5 ppb
24 FEBRUARY 1976
Cruise 2.

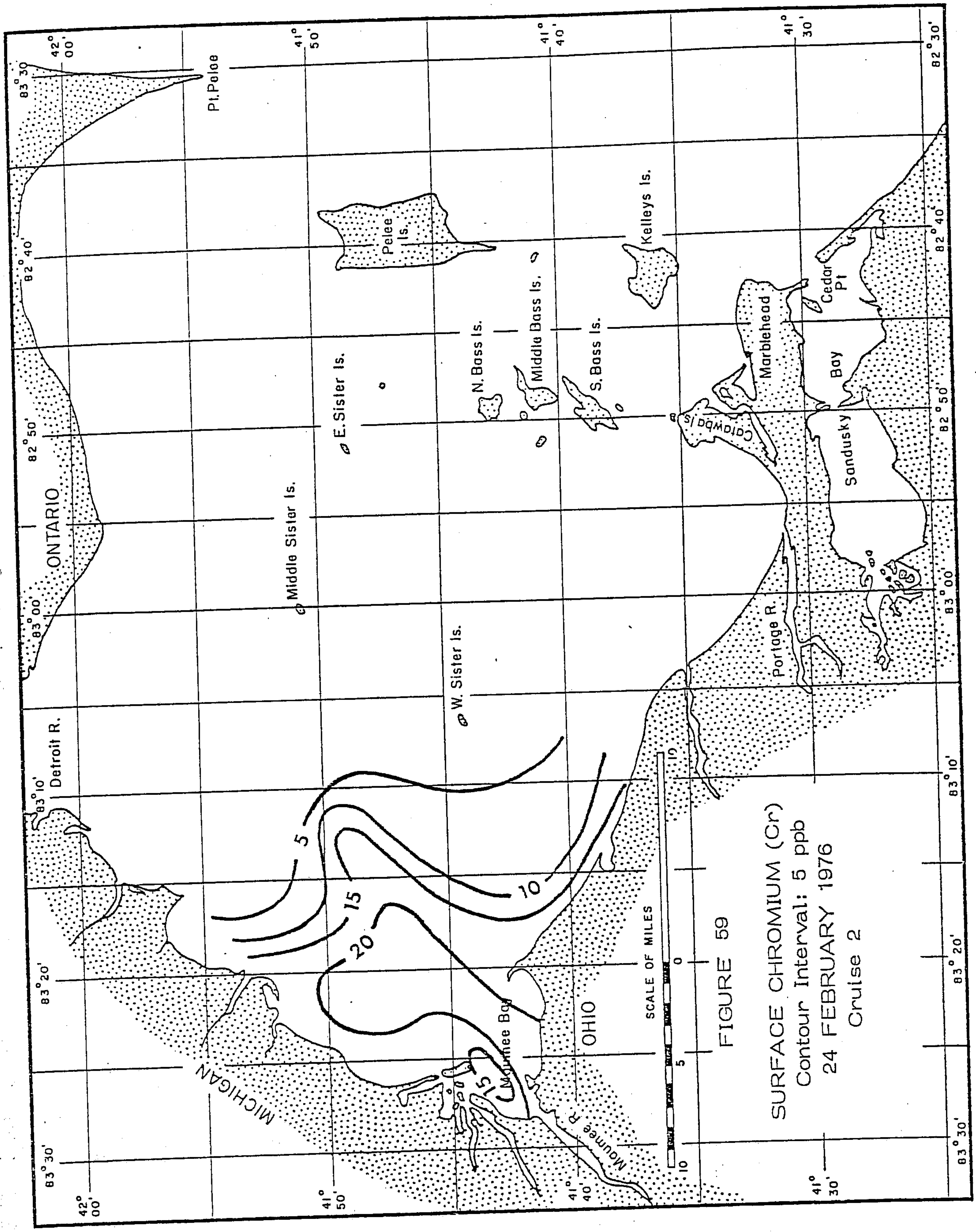


FIGURE 59
SURFACE CHROMIUM (Cr)
Contour Interval: 5 ppb
24 FEBRUARY 1976
Cruise 2

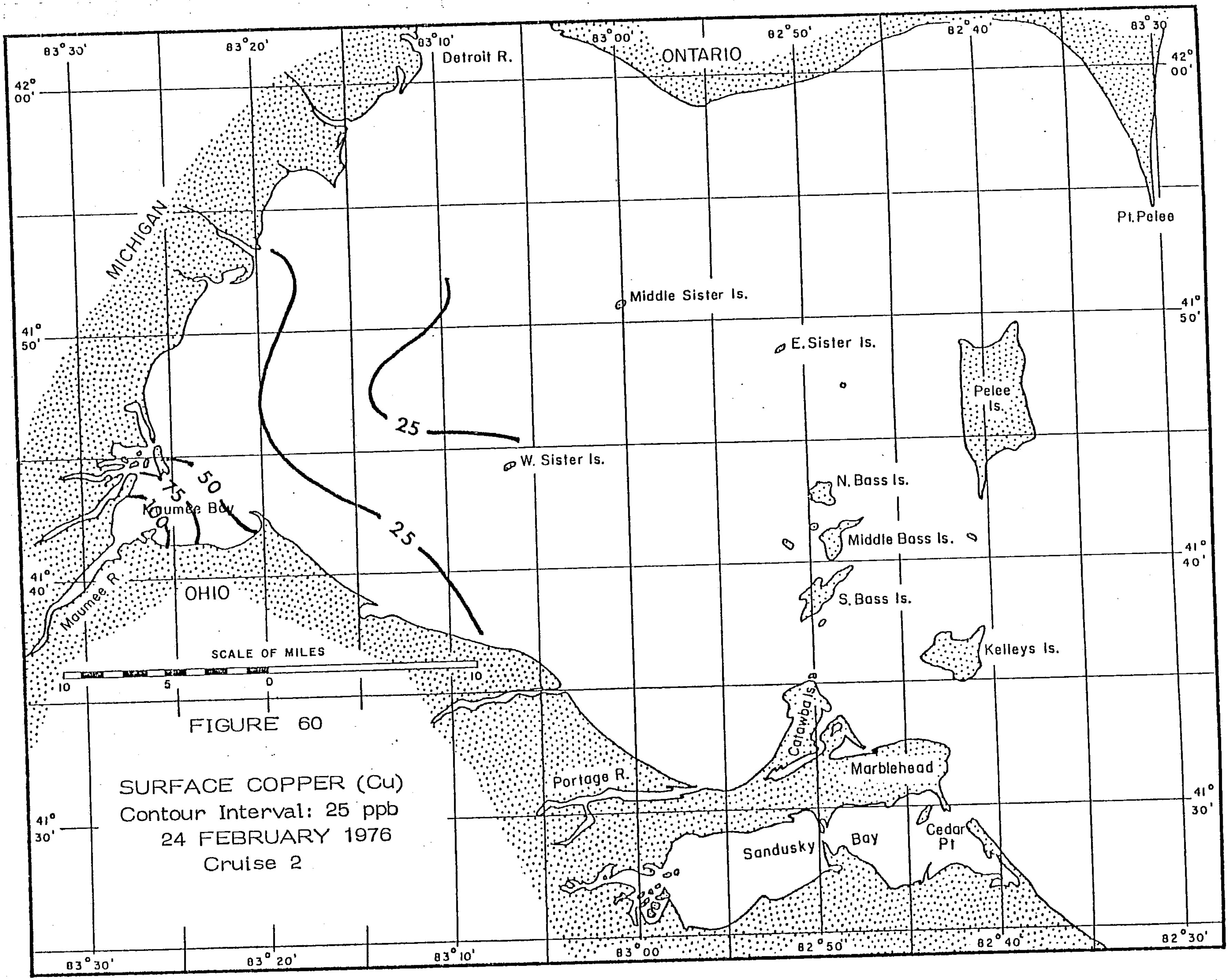


FIGURE 60

SURFACE COPPER (Cu)
Contour Interval: 25 ppb
24 FEBRUARY 1976
Cruise 2

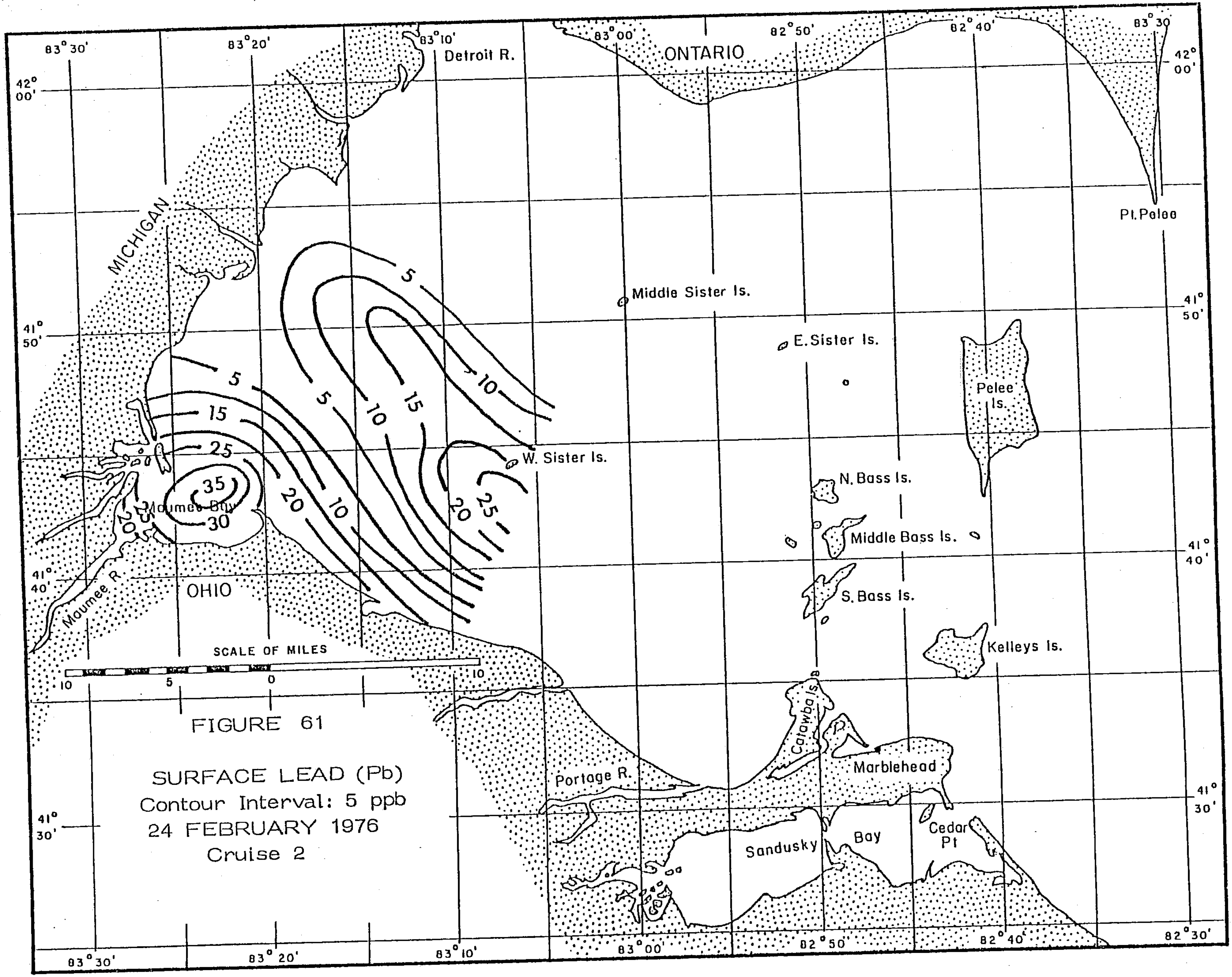


FIGURE 61

SURFACE LEAD (Pb)
Contour Interval: 5 ppb
24 FEBRUARY 1976
Cruise 2

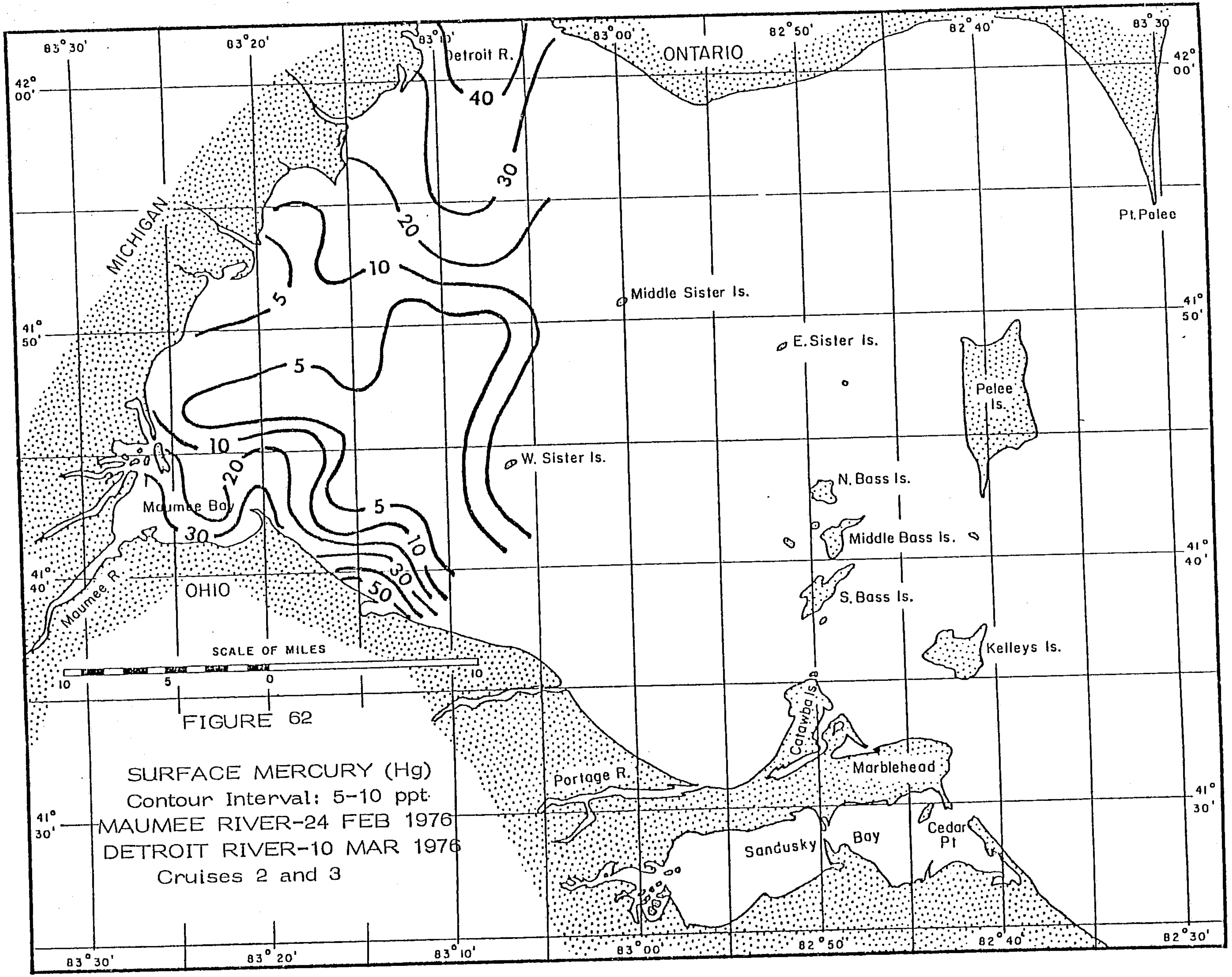


FIGURE 62

SURFACE MERCURY (Hg)
Contour Interval: 5–10 ppt
MAUMEE RIVER–24 FEB 1976
DETROIT RIVER–10 MAR 1976
Cruises 2 and 3

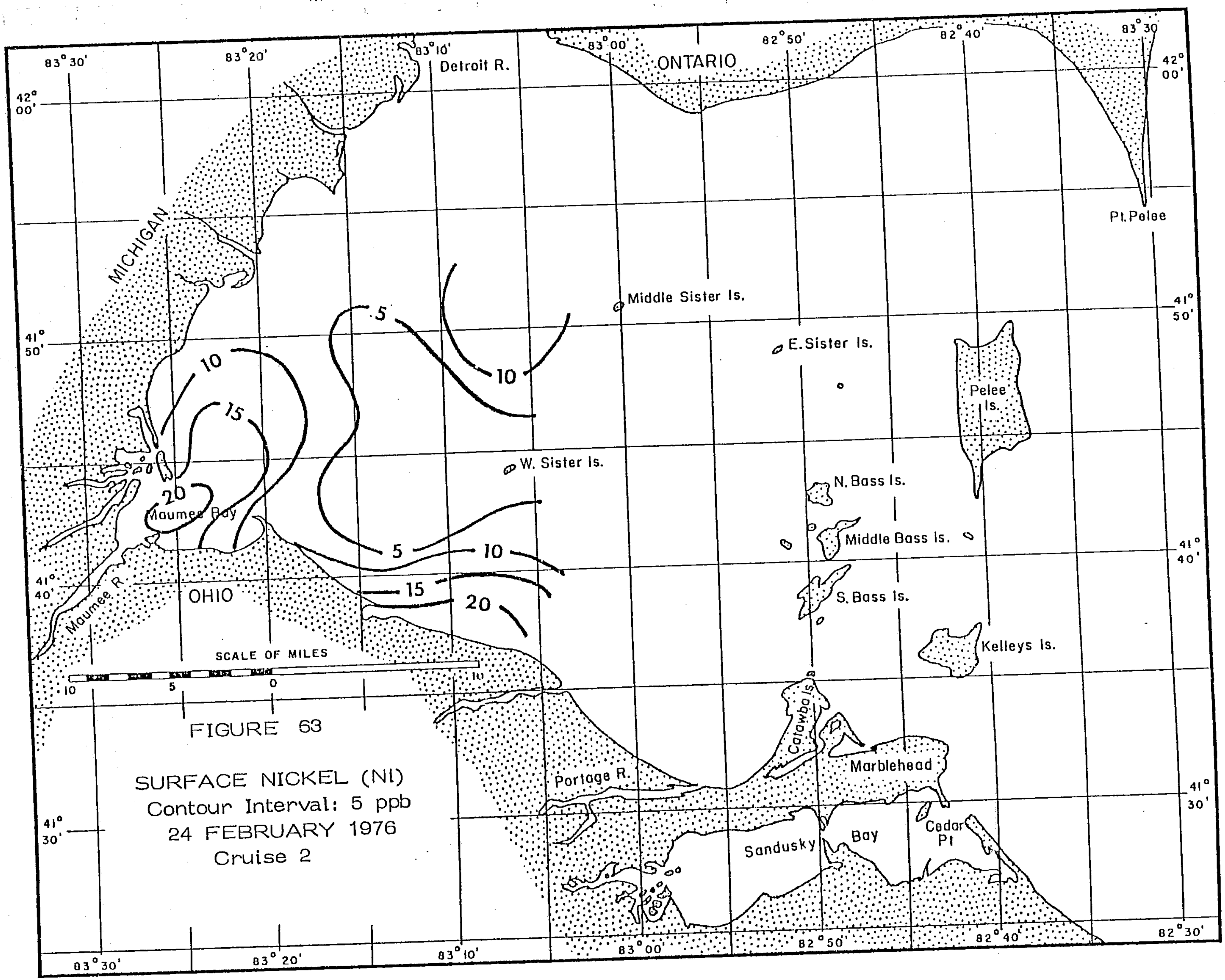


FIGURE 63

SURFACE NICKEL (NI)
Contour Interval: 5 ppb
24 FEBRUARY 1976
Cruise 2

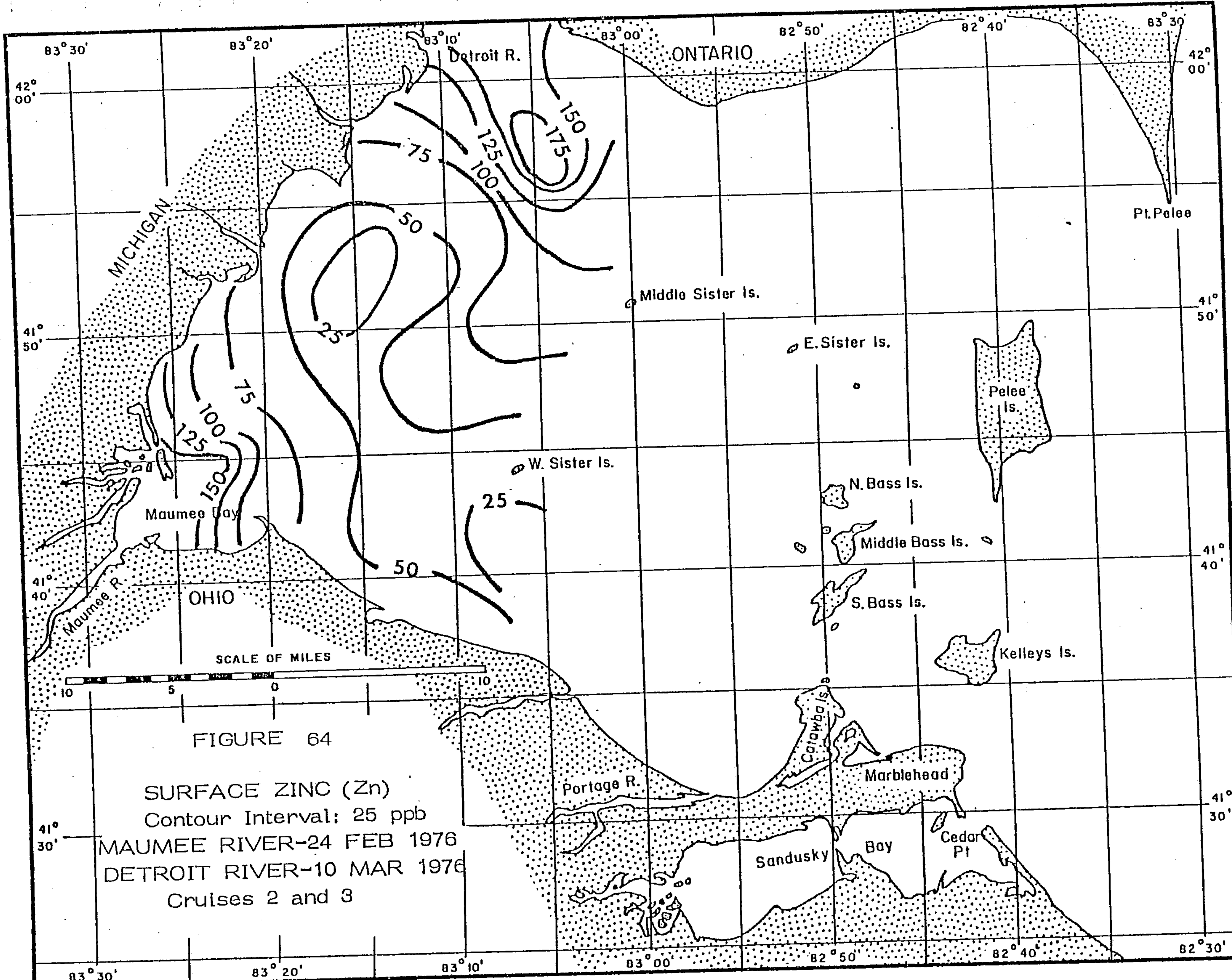


FIGURE 64

SURFACE ZINC (Zn)
Contour Interval: 25 ppb
MAUMEE RIVER-24 FEB 1976
DETROIT RIVER-10 MAR 1976
Cruises 2 and 3

FIGURE 65

CONCENTRATIONS OF MERCURY IN SURFACE WATER OF WESTERN LAKE ERIE ALONG THREE TRANSECTS - 24 FEBRUARY 1976

Location Map of Transects on Figure 1.

A - Toledo - northeastward for 15 miles
B - Toledo - eastward for 15 miles
C - Monroe - eastward toward West Sister Is.

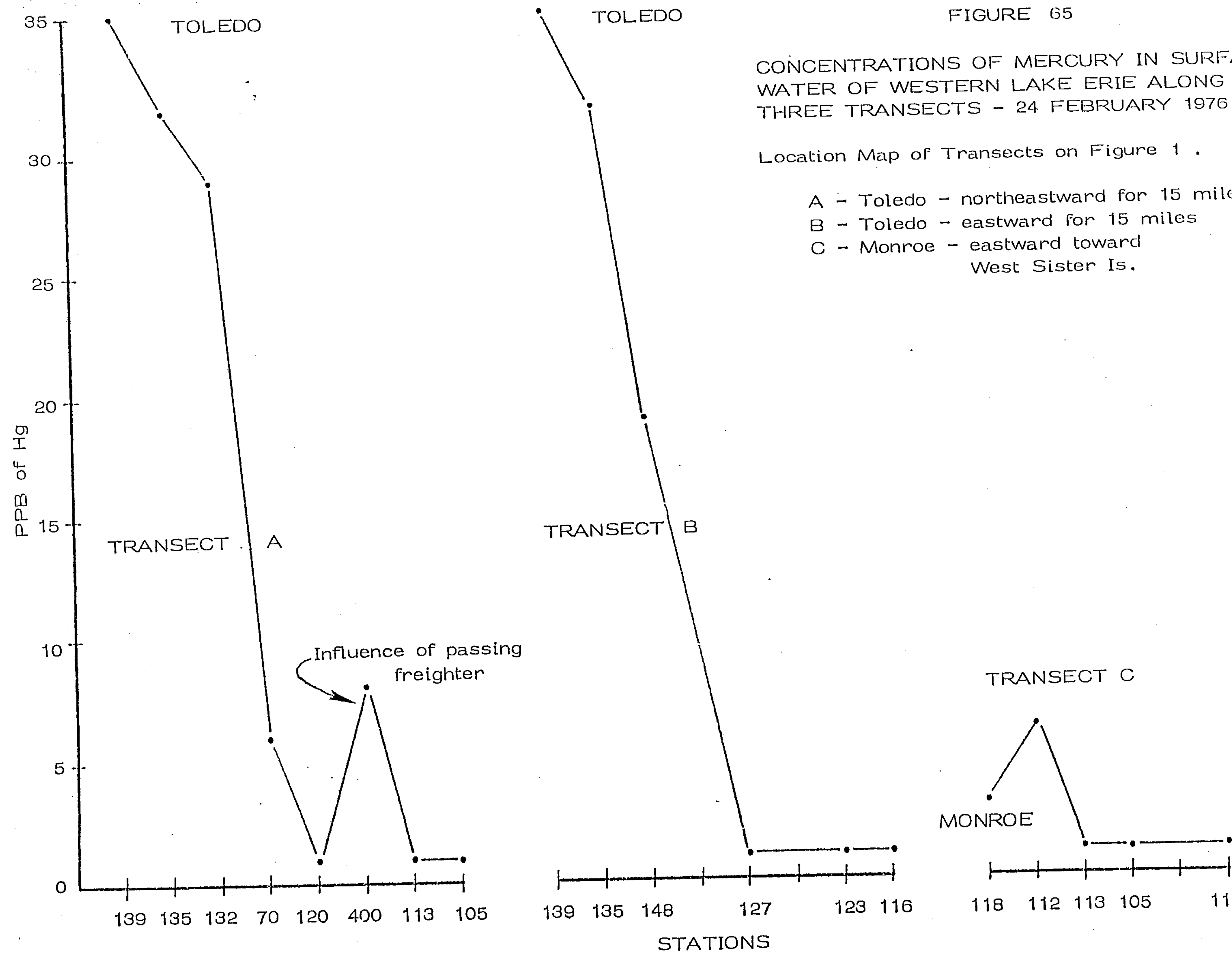


FIGURE 66

CONCENTRATIONS OF ZINC IN SURFACE WATER OF WESTERN LAKE ERIE ALONG THREE TRANSECTS - 24 FEBRUARY 1976

Location Map of Transects on Figure 1.

A - Toledo - northeastward for 15 miles
B - Toledo - eastward for 15 miles
C - Monroe - eastward toward West Sister I

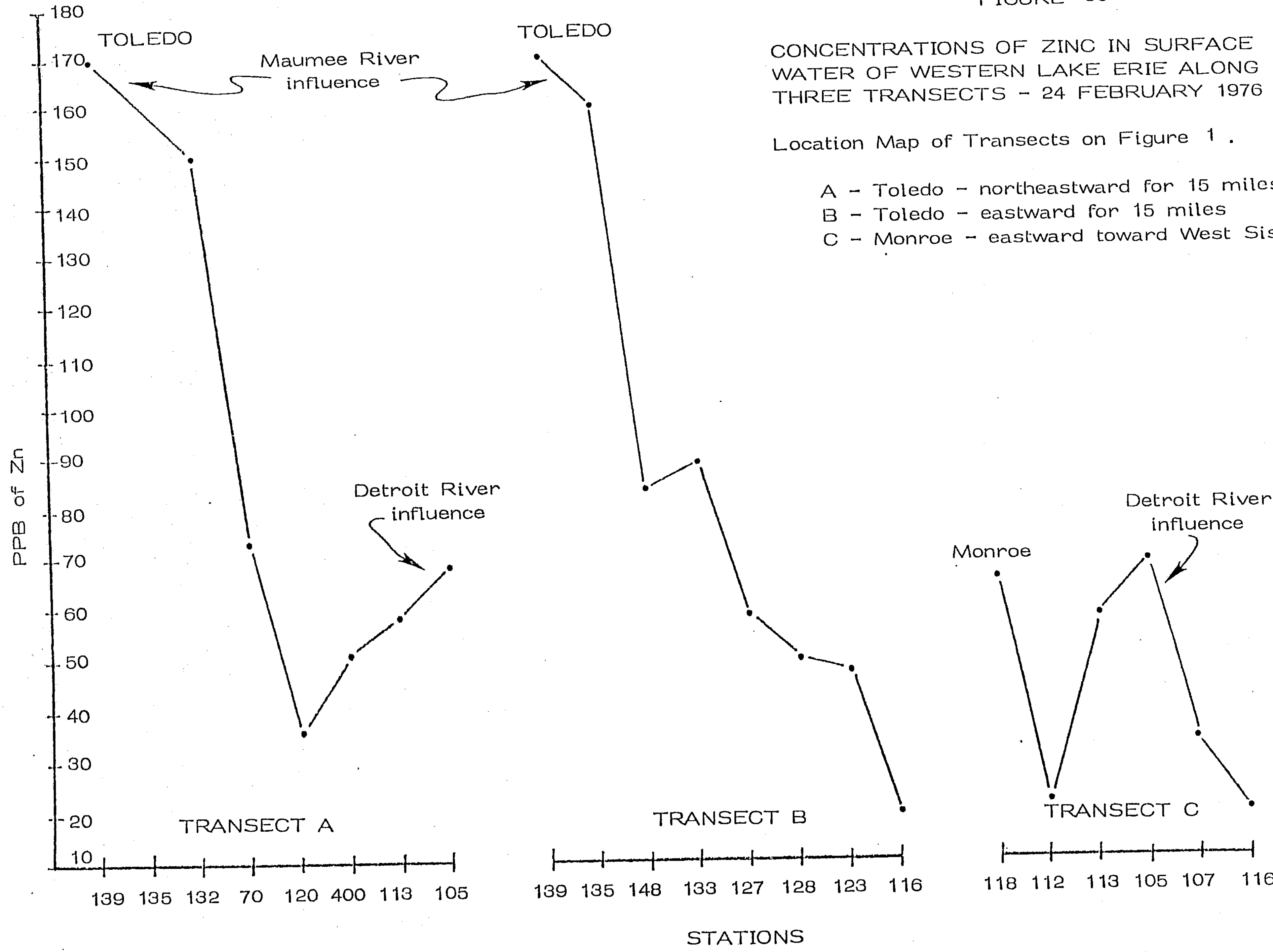
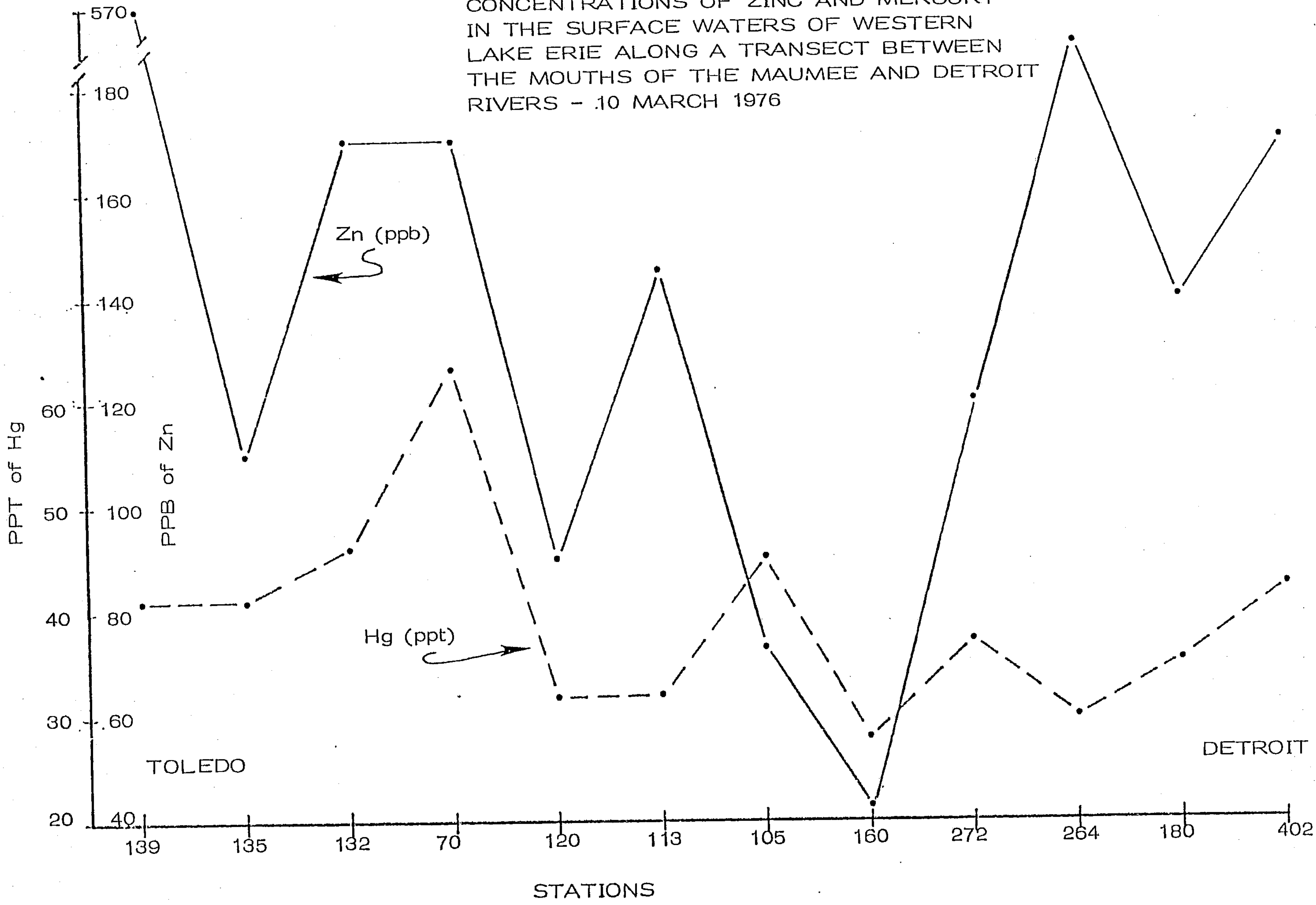


FIGURE 67

CONCENTRATIONS OF ZINC AND MERCURY IN THE SURFACE WATERS OF WESTERN LAKE ERIE ALONG A TRANSECT BETWEEN THE MOUTHS OF THE MAUMEE AND DETROIT RIVERS - 10 MARCH 1976



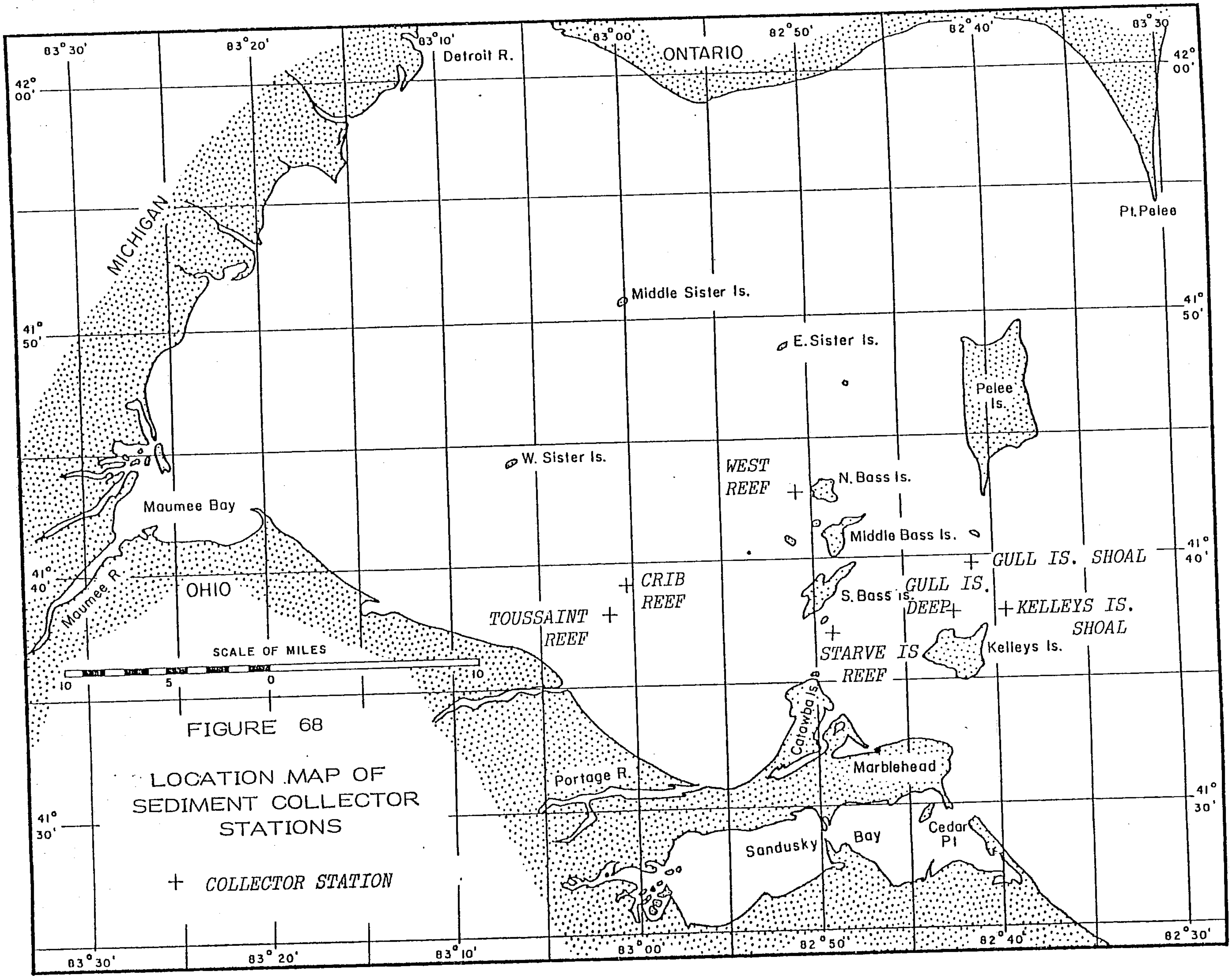


FIGURE 68

LOCATION MAP OF SEDIMENT COLLECTOR STATIONS

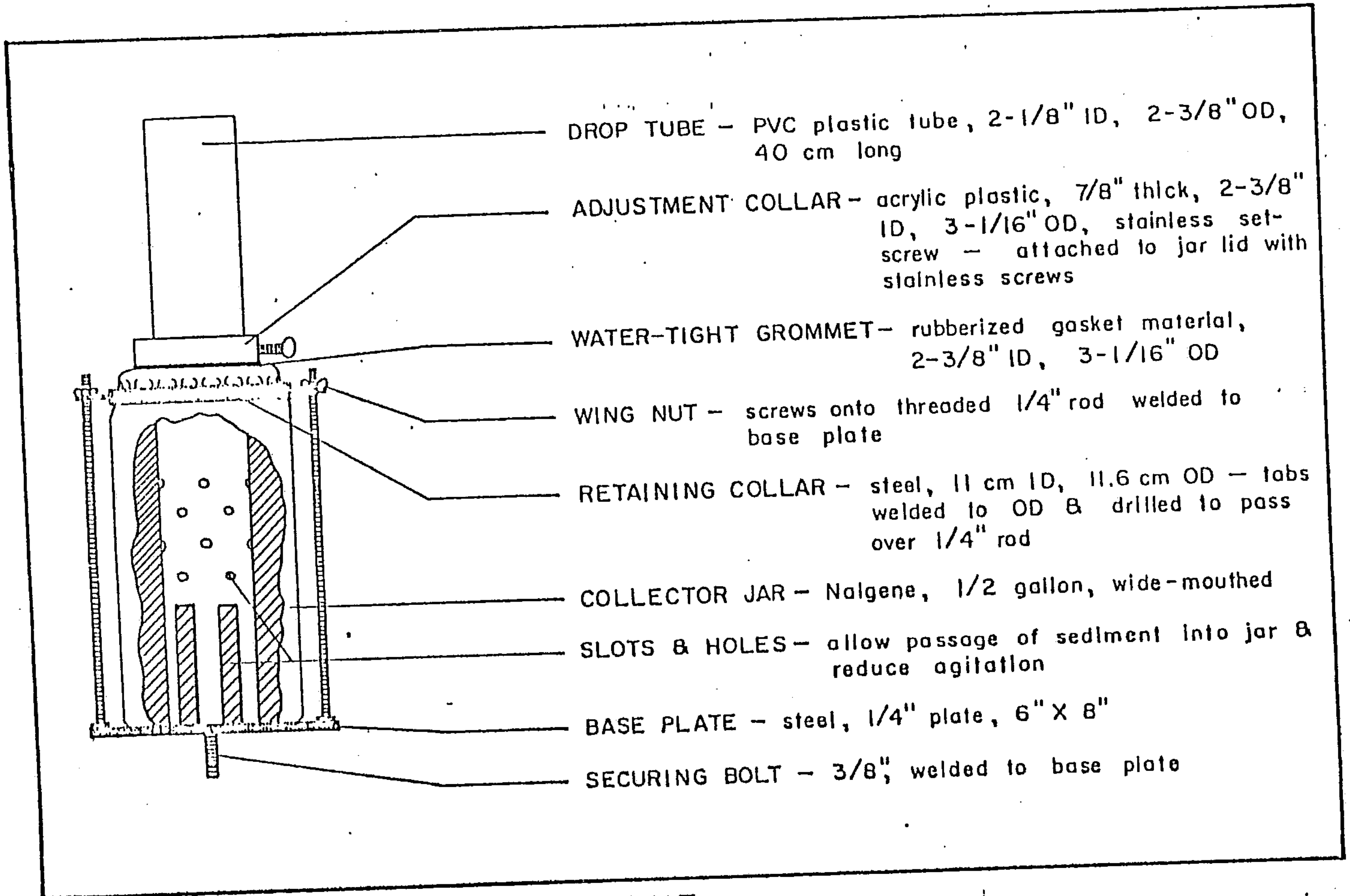


FIGURE 69. SEDIMENT COLLECTION DEVICE

FIGURE 70

MEAN DAILY SEDIMENT DEPOSITION RATE IN WESTERN LAKE ERIE: 1967

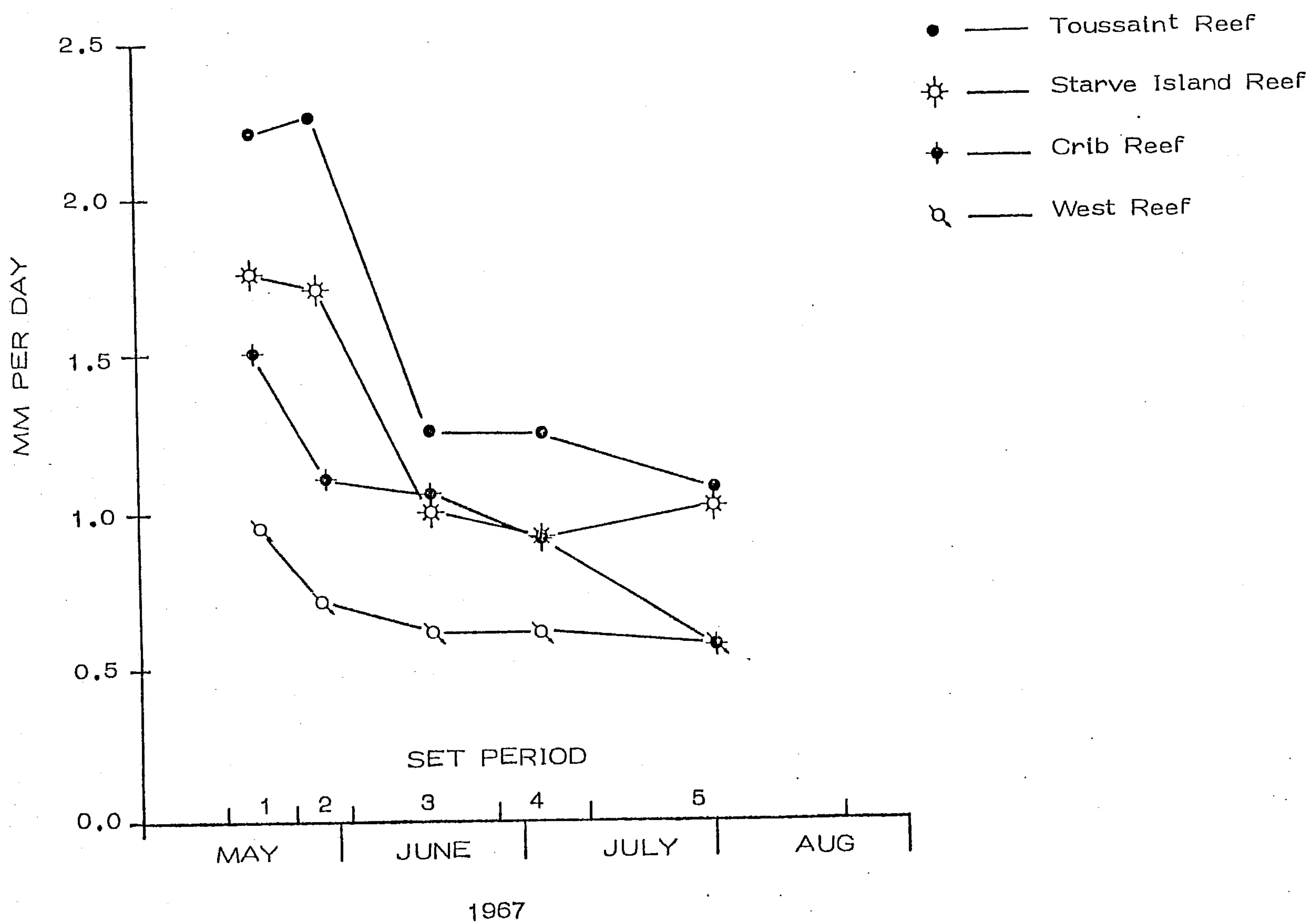


FIGURE 71

MEAN DAILY SEDIMENT DEPOSITION RATE IN WESTERN LAKE ERIE: 1968

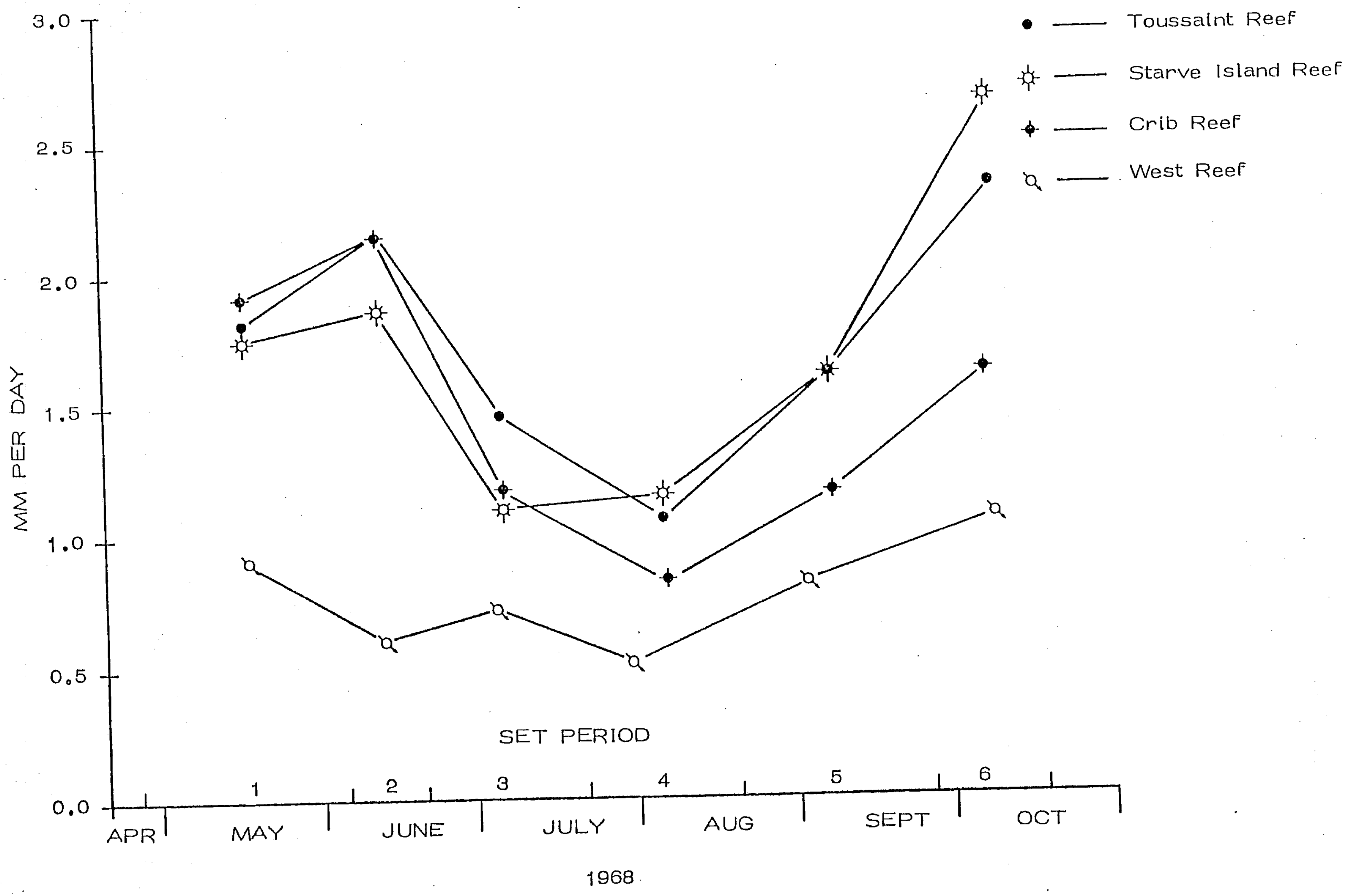
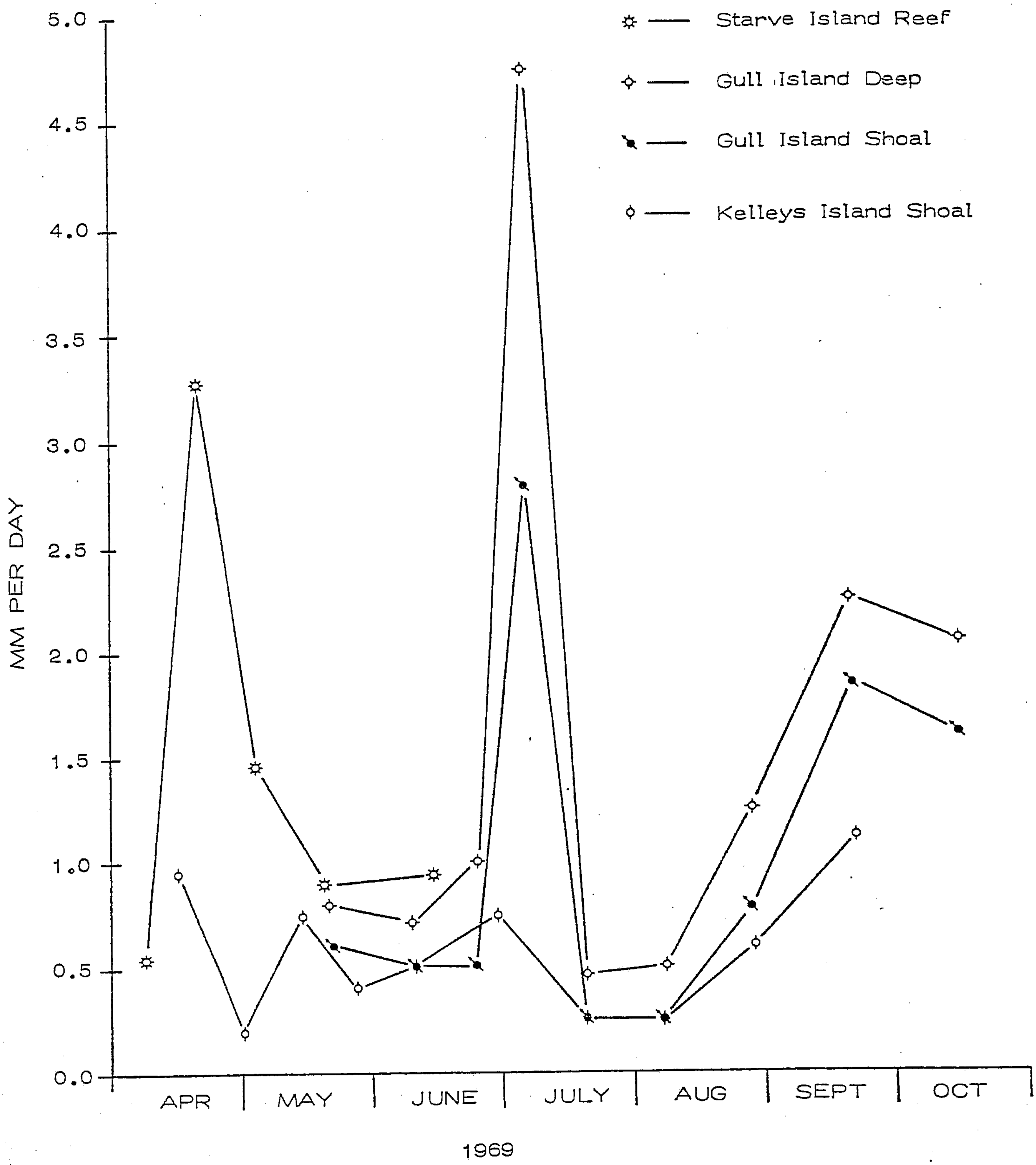


FIGURE 72
MEAN DAILY SEDIMENT DEPOSITION RATE IN WESTERN LAKE ERIE: 1969



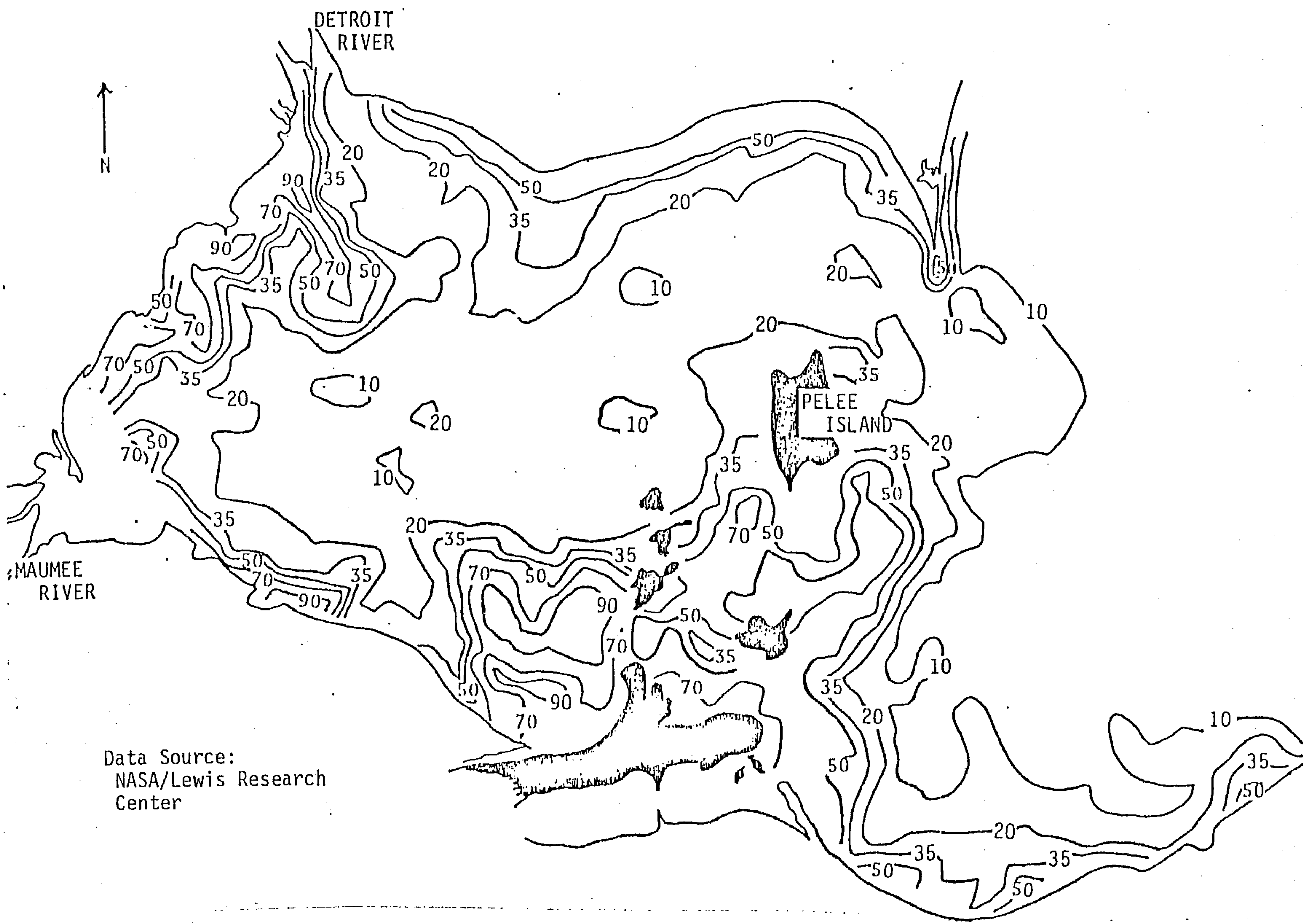


FIGURE 73. CONTOUR MAP OF TOTAL SUSPENDED SOLIDS CONCENTRATION (mg/l) IN WESTERN LAKE ERIE ON 23 MARCH 1976

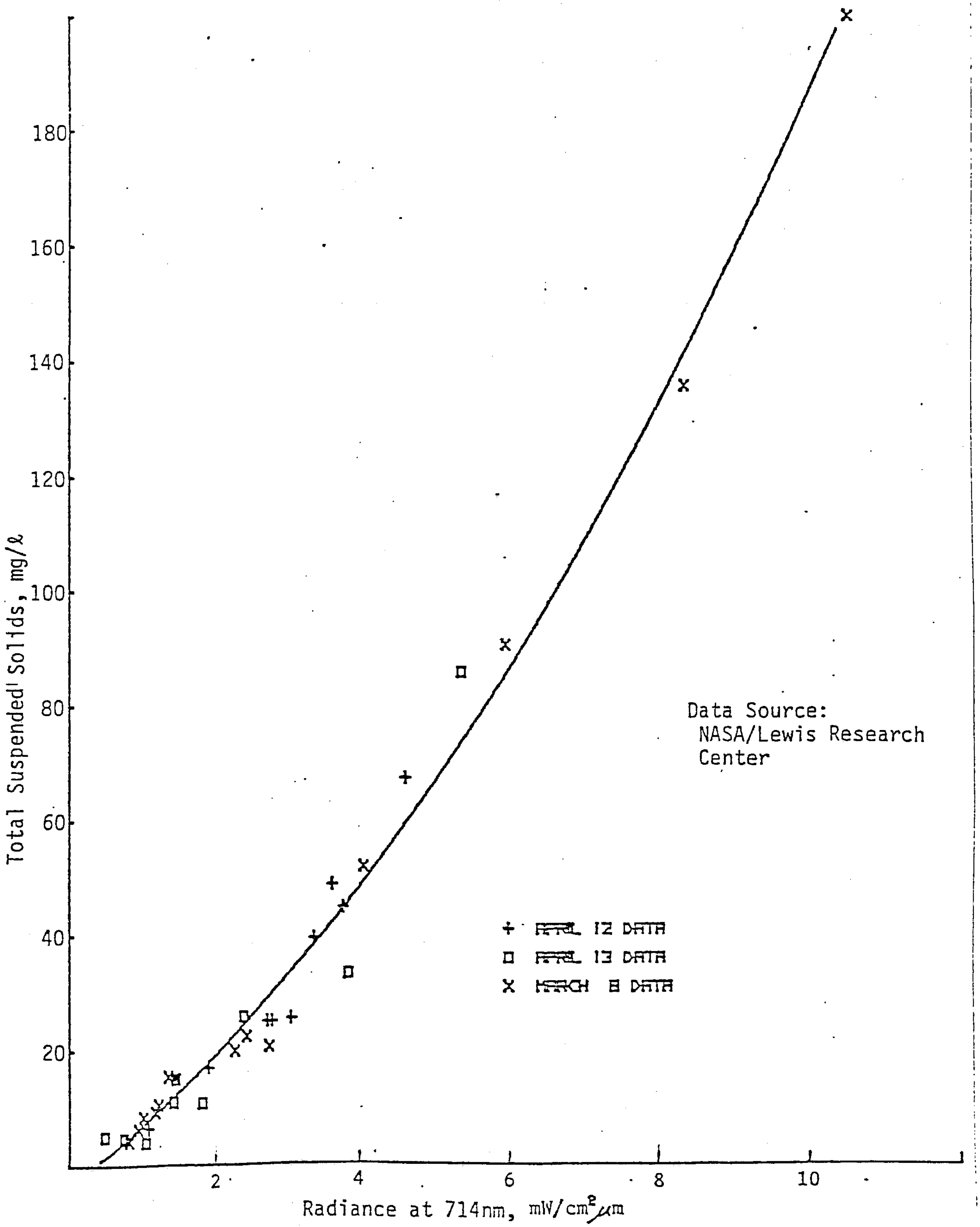


FIGURE 74. GENERALIZE CORRELATION FOR TOTAL SUSPENDED SOLID DATA AND OCS CHANNEL 8 MEASUREMENTS IN WESTERN LAKE ERIE IN SPRING 1976.