BOTTOM CURRENTS IN LAKE ERIE

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ABSTRACT

In the summer of 1965, seabed drifters were released in Lake Erie primarily along the south shore and in the western basin. Returns have indicated clockwise bottom eddies in the Toledo-Detroit area, in the island area, and in mid-lake in the west half of the central basin. They have also indicated eastward bottom flow in a narrow band along the south shore and in a wider band along the north shore of the central basin. Centers of eddies may be significant repositories for pollutants. The center of the large clockwise gyre in the central basin may accumulate material originating all along the south shore of the central basin. The Toledo-Detroit eddy suggests accumulation of materials therein from these cities.

INTRODUCTION

Many attempts have been made to describe the circulation of water in Lake Erie, beginning with the work of Harrington (1895). Most of the work has been on surface currents and has been concentrated in the western basin. Examples are the work of Verber (1955) and Olson (1952). In all of these studies, either floating cards and bottles or near-surface drogues were used.

The Federal Water Pollution Control Administration, in its pollution investigations, recognized the need for more adequate lake flow data and conducted a current measurement program throughout Lake Erie. The program was similar to that conducted in Lake Michigan by Verber (1962), using Richardson self-recording current meters. To supplement the Lake Erie program and to learn more about the transport of bottom and near-bottom suspended materials, seabed drifters were utilized. To our knowledge this was the first time that bottom drifters had been used successfully in Lake Erie. They have been used successfully along the Atlantic coast (Bumpus, 1965) and along the Pacific coast (Morse et al., 1968).

METHODS OF INVESTIGATION

The seabed drifters (Figure 1) were of the type designed by Woodhead and Lee (1960), constructed of polyethylene plastic and shaped like an umbrella. The disc was bright yellow and the stem was red, making them easily visible from a considerable distance. The stem was weighted so that the entire assembly had a slight negative buoyancy in fresh water. The tail drags along the bottom while the disc is pushed, parachute-like, by the near-bottom current. The response to water movement, according to the supplier, is 100% at speeds above 17 centimeters per second. At 5 centimeters per second the rate of travel is approximately 70% of true water speed.

The drifters were marked with return-addressed adhesive-backed labels which requested the finder to note the date and location found and to return. The labels were sequentially numbered with a laundry marking pen.

Ordinarily the entire drifter was returned. Most of the drifters survived their travels in remarkably good condition, attesting to their durability. Nearly all were released during sampling cruises between the first part of June and the middle of August, 1965. Most releases (Figure 2) were near the south shore of the central basin and around the western basin because these are the areas of the most significant tributary inputs to the lake. In addition a few drifters were dropped in mid-lake and near the north shore of the central basin. Two drifters were dropped at each station. In all, 368 drifters were released--118 in the western basin, 234 in the central basin, and 16 in the eastern basin.

RESULTS OF INVESTIGATION

A gross summary of seabed drifter releases and returns is given in Table I, indicating the relative success of this kind of study in each of the lake's basins and in the entire lake.

Drifter returns began shortly after release and they were plotted

TABLE I

SUMMARY OF SEABED DRIFTER RELEASES AND RETURNS

Place of Release	Number Releases	Returns U. S.	Returns Canada	Total % return
Western basin - Canada	48	0	3	6.3
Western basin - U. S.	70	8	3	15.7
Central basin - Canada	16	0	7	43.7
Central basin - U. S.	218	26	37	28.9
Eastern basin - Canada	10	0	0	0.0
Eastern basin - U. S.	6	2	1	50.0
Totals	368	36	51	23.6

according to shortest route. The first returns (Figure 3) indicated a dominant eastward nearshore flow along the south shore of the central basin and a stronger eastward flow along the north shore. Velocities are not known, but, if the shortest times are used, the flow along the south shore netted 1.1 miles per day eastward, and along the north shore 4.1 miles per day, also eastward. Along the south shore the drifters moving eastward averaged 12 times the distance of those moving westward.

In the western basin the first returns suggested bottom flow eastward through the southern island channels. Along the Michigan shore a flow westward toward shore was indicated off Toledo, while near the mouth of the Detroit River a flow away from shore was suggested.

Returns during the first half of 1966 (Figure 4) correlated with previous returns except that a westward bottom flow was indicated at the west end of the central basin.

Drifter returns dwindled by the beginning of summer 1966 and the project had apparently been completed. Then, in the fall of 1966, nearly one and one-half years after the releases, a rash of drifters from the north half of the lake was returned (Figure 5). Some of the drifters were found on shore, but most were picked up in fishing nets. From this time on nearly all returns were from nets and most were forwarded to us by Dr. R. G. Ferguson of the Canada Department of Lands and Forests. Most drifters were found in the broad bay between Pelee Point and Pointe Aux Pins, Ontario, probably because of relatively intense commercial fishing in that area.

Returns were even greater in the spring of 1967 (Figure 6) and were essentially from the same areas. Another pause the following summer was again followed by a similar pattern of returns in the fall (Figure 7). For the first time a western basin drifter was also found in the Pelee Point-Pointe Aux Pins area.

It is significant that in the last one and one-half years only two drifters have been found in the southern half of the lake while 42 have been recovered from the northern half. All but three of those recovered from the north side were released near the south shore.

Plotting all returns on the same chart (Figure 8) with near to shortest paths presents a pattern of total confusion. Many of the paths in the central basin cross at high angles which is a most unlikely occurrence in reality.

DISCUSSION

Bottom drifters are similar to surface drifters in their limitations. Only the end points of travel are known. Travel paths and velocities cannot be determined. Minimum possible velocities can be calculated but these have no great significance after the first few returns. It is likely that low current velocities can exist without drifter movement and that occasional higher velocities can indicate a false net movement. Wave action can also have the same effect. The type of bottom can affect velocities and number of returns. For example, one would expect many drifters to be caught in craggy rock surfaces, to be slowed by dragging through low-density mud, and to be most responsive over smooth hard sand bottoms.

Despite their limitations, it is assumed with some confidence that the seabed drifters released in Lake Erie did respond fairly well to important water motions. With this assumption a movement pattern has been developed on the basis of least conflicting lines of flow, meaning simply that lines of flow should tend to be parallel instead of crossing at high angles.

The development of the bottom flow pattern (Figure 9) was vastly aided by correlating the predominant directions of flow as recorded by the lowermost meters at current metering stations. Although other patterns have been drawn to fit the data and bottom topography, all indicate similar major bottom flow features.

In the western basin a clockwise bottom flow exists between the Detroit River inflow and the western shore of Lake Erie. A predominant flow out of the northern channel, Pelee Passage, and a lesser flow out South Passage are indicated with perhaps a clockwise gyre around Pelee Island and Kelleys Island. Scarcity of returns from releases in the mid-portion of the basin indicate sluggishness of bottom flow in that area.

Bottom flow from the western basin appears to be directed southward toward the south shore with some turning westward but most deflected toward the east. Some of this flow continues eastward as part of the general eastward flow along the remainder of the south shore. Much appears to be caught up in a huge clockwise bottom flow gyre of the central basin. This gyre is centered about 20 miles south of Pointe Aux Pins, Ontario in the western half of the central basin. Flow is strongly toward the east in the northern third of the basin while the southern two-thirds is characterized by a slower westward flow. The south shore eastward flow is a narrow band usually separate from the gyre.

In the eastern basin the bottom flow is less distinct but appears to have a central clockwise gyre in the deep part and a strong eastward south shore flow turning toward the north shore in the eastern half of the basin. There appears to be a flow toward shore along most of the north shore. The south shore flow appears to feed the Niagara River.

The bottom flow pattern shown in Figure 9 is caused primarily by prevailing westerly winds and is consistent with them. In general, westerly and northerly flowing bottom currents are the balancing response to relatively rapid eastward currents in the upper layers. Eastward flowing bottom currents are probably caused mainly by wind-driven surface currents which reach to the bottom in addition to the requirements for continuity of flow.

The flow patterns of the central and eastern basins suggest also a vertical circulation with upwelling along almost the entire north shore and corresponding downwelling near the south shore. This is required to feed the eastward surface flow which is much greater than could be fed by drainage inputs.

In the western basin the bottom currents are probably dominated by the large Detroit River inflow. The large flow out Pelee Passage and the shoreward movement along the Michigan shore are reinforced by the prevailing winds.

CONCLUSIONS

The seabed drifter project along with other investigations of water motion in Lake Erie have led to several conclusions important to the studies of pollution.

Suspended materials, many of which are damaging to the lake environment, will accumulate in areas of eddy motion. Such areas are indicated off Toledo and near the Michigan shore, in the island area, in the large eddy area in mid-lake in the western half of the central basin, and in the deep part of the eastern basin.

Prime sources of suspended materials which would be expected in bottom flow are at or near the origin of the eddies. For example, wastes from Detroit and Toledo are fed into the eddy of that area and, to a lesser extent, the one around the islands. Wastes from the entire south shore of the central basin, when they escape the nearshore flow, feed into the large eddy in that basin. It is suspected that this becomes significant in late fall with colder tributary flow under-running lake water and in spring with under-running of silt-laden tributary water. The paucity of mid-lake drifter returns in the fall of 1965 and spring of 1966 suggests that the drifters were mainly in the nearshore flow zone until the spring of 1966, and then were forced lakeward by this phenomenon.

Only the eddy in the eastern basin is remote from prime sources of wastes, there being no large sources along the Canadian shore.

Surface currents in the central and eastern basins originate along the north shore and move away from it toward the south shore. This surface water is productive and as it nears the shore it becomes more so. This results in large crops of algae along the south shore. When these algae die and sink they can be carried back to the center of the lake by bottom currents where they damage bottom water quality.

The eddies in the western basin exist top to bottom, suggesting that productivity should be higher in these areas. The eddies in the central and eastern basins are in bottom water only, indicating that productivity of surface waters would not necessarily be higher in these areas.

The lack of returns during the summer months from mid-lake in the central basin indicates that a definite pattern of flow may not have existed below the thermocline and that the drifters were trapped in the hypolimnion. Current meters have shown occasionally rapid motion in the hypolimnion, but it is generally to and fro. A gyre-like motion in the hypolimnion probably does not exist, while above the hypolimnion it does exist. In effect then the thermocline, although flexible, acts as the summer lake bottom for the pattern of Figure 9.

Bottom flow in the central basin is strong in late fall and spring according to returns. It is perhaps also strong in winter but there is little chance of retrieving drifters during that time. Many Canadian fishermen report that drifters are most often found just after a storm, particularly a northwester. They also report that their nets are cluttered with debris, organic detritus, and sometimes garbage.

This suggests rather rapid transport from waste source areas and also that direct inputs of man-made wastes may have a measurable pollution effect on mid-lake waters. This has previously been considered insignificant.

One of the more important conclusions of this investigation is that transboundary bottom water motion exists and it is predominantly from the American side toward the Canadian side. If suspended pollutional materials can be construed as similar in response to bottom drifters, we have strong evidence that materials originating on the American side can be transported and deposited on the Canadian side of Lake Erie.

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List of figures for "Bottom Currents in Lake Erie", Hartley

Figure 1 - Woodhead seabed drifter used in this investigation.

Figure 2 - Locations of seabed drifter release in Lake Erie during the spring and summer of 1965. Each circle denotes the release location of 2 drifters. Releases totalled 368.

Figure 3 - Seabed drifter returns during last half of 1965.

Figure 4 - Seabed drifter returns during first half of 1966.

Figure 5 - Seabed drifter returns during last half of 1966.

Figure 6 - Seabed drifter returns during first half of 1967.

Figure 7 - Seabed drifter returns during last half of 1967.

Figure 8 - Seabed drifter returns during all of period from summer 1965 through fall 1967.

Figure 9 - Prevailing bottom water circulation as inferred from seabed drifter returns with paths plotted as near to parallel lines and correlated with metered directions.

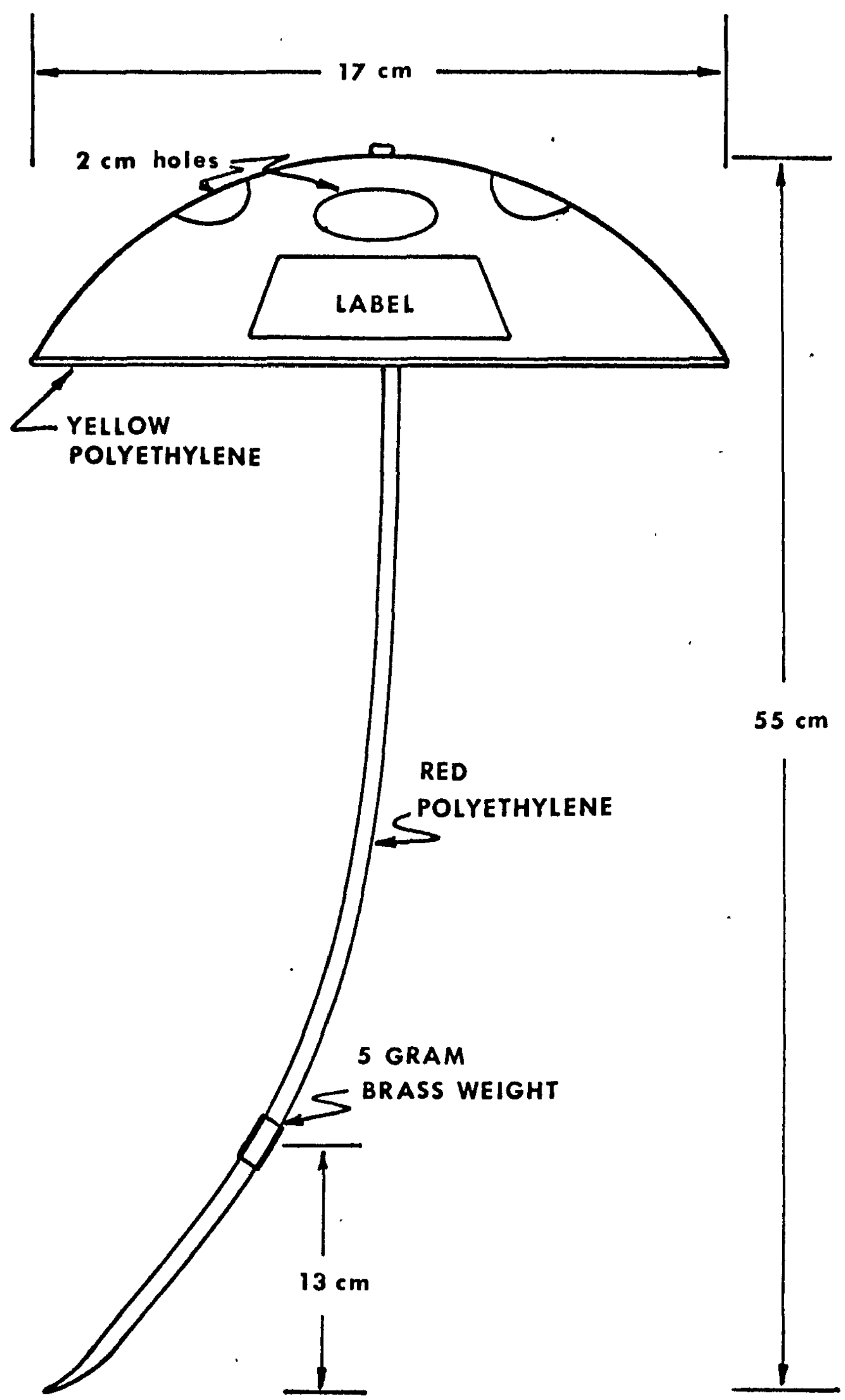
17 cm
2 cm holes
LABEL
YELLOW
POLYETHYLENE
55 cm
RED
POLYETHYLENE
5 GRAM
BRASS WEIGHT
13 cm

FIG. 1

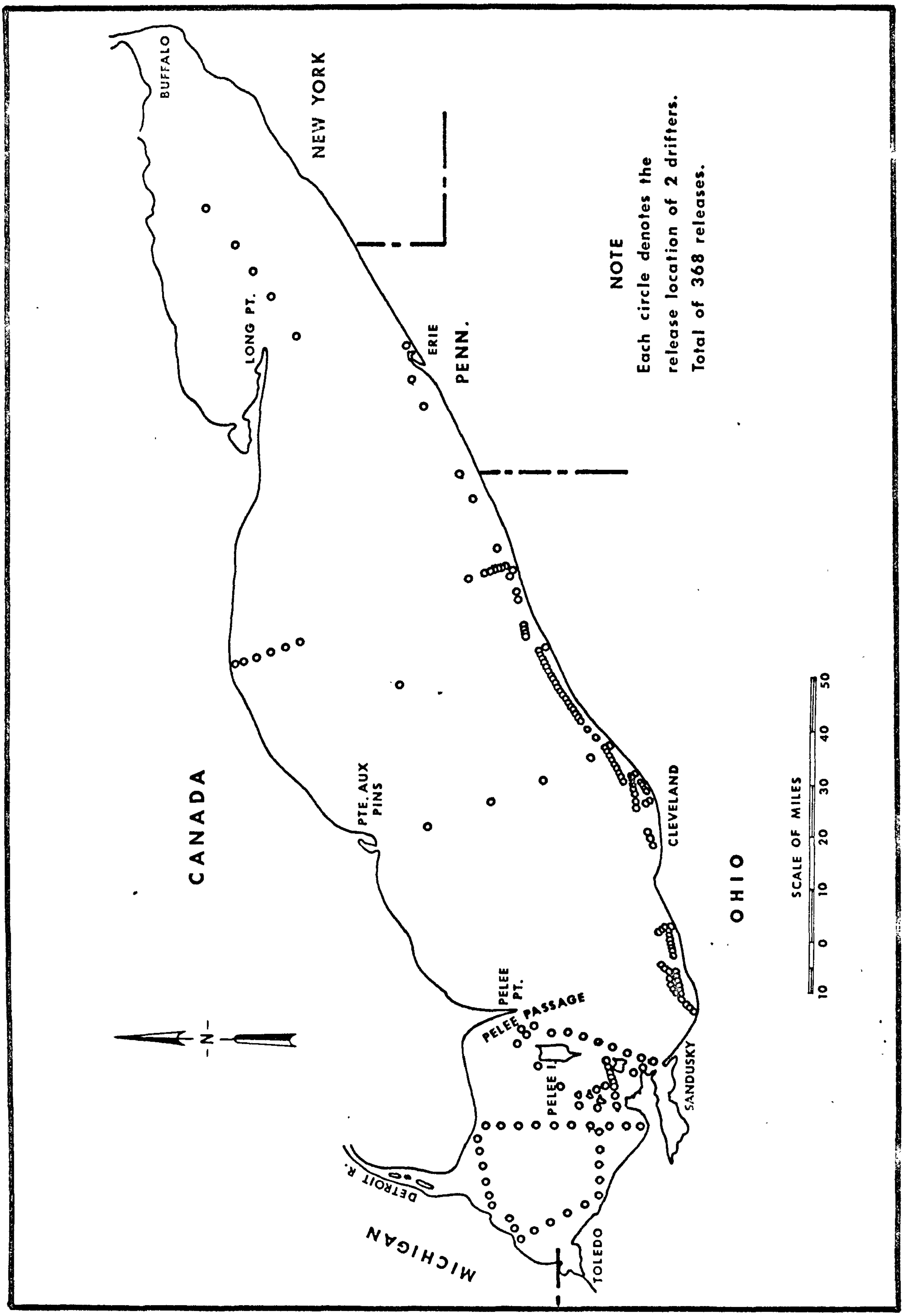
BUFFALO
NEW YORK
NOTE
Each circle denotes the release location of 2 drifters. Total of 368 releases.
LONG PT.
ERIE
PENN.
CANADA
PTE. AUX PINS
CLEVELAND
OHIO
SCALE OF MILES
10 0 10 20 30 40 50
PELEE PT.
PELEE PASSAGE
PELEE I.
SANDUSKY
DETROIT R.
MICHIGAN
TOLEDO
N

FIG. 2

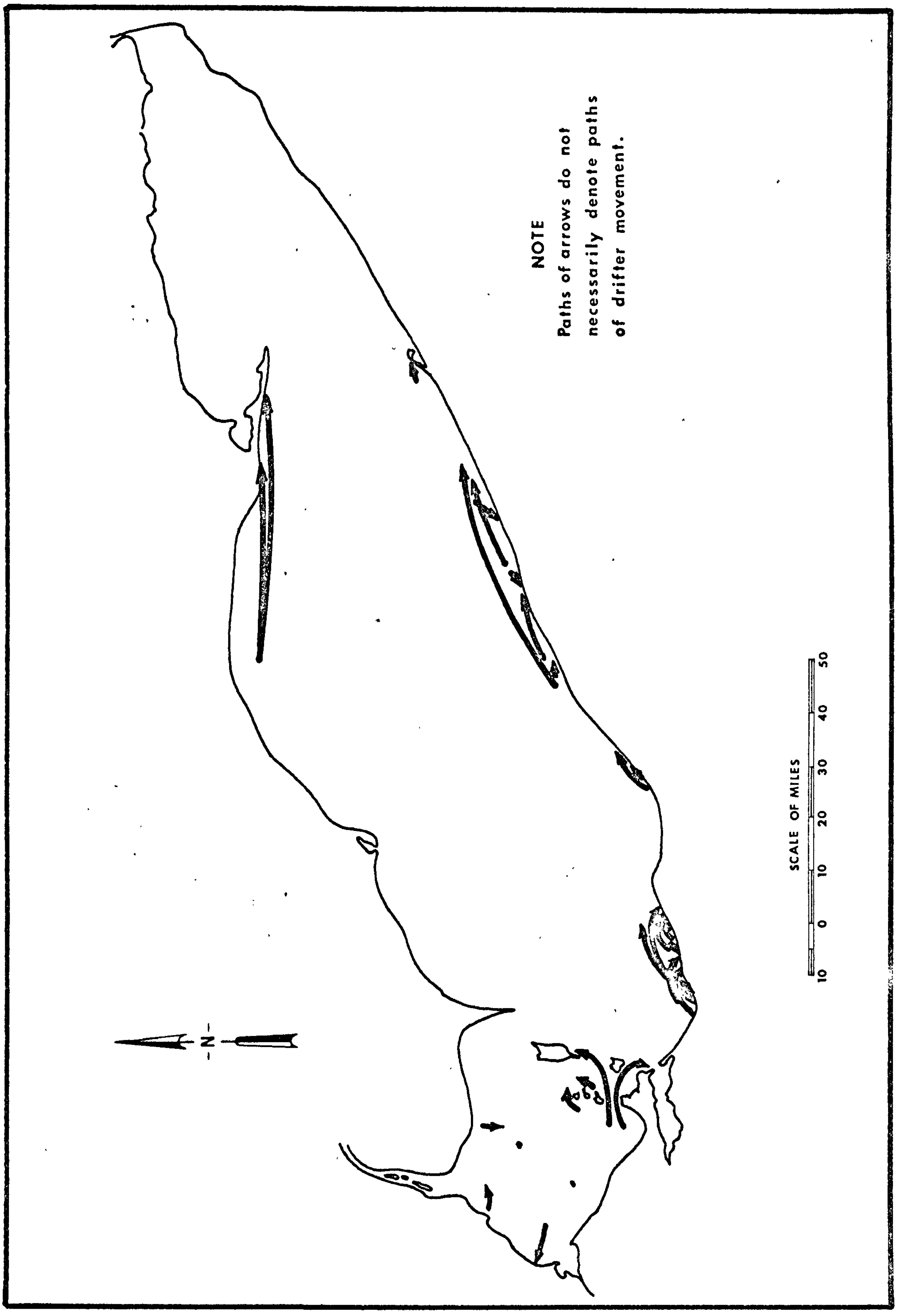
NOTE
Paths of arrows do not
necessarily denote paths
of drifter movement.
SCALE OF MILES
10 0 10 20 30 40 50
N

FIG. 3

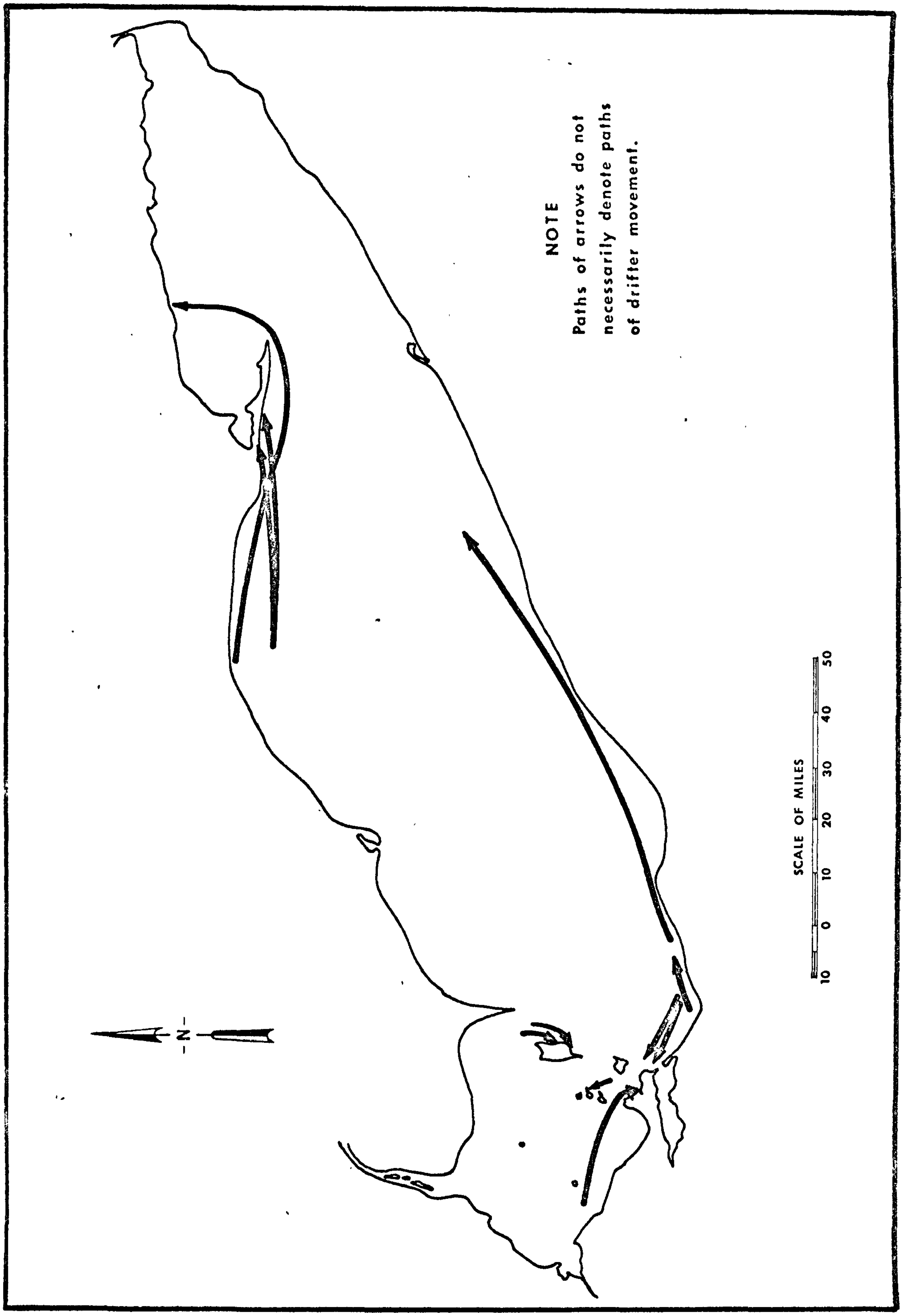
NOTE
Paths of arrows do not necessarily denote paths of drifter movement.
SCALE OF MILES
10 0 10 20 30 40 50
N

FIG. 4

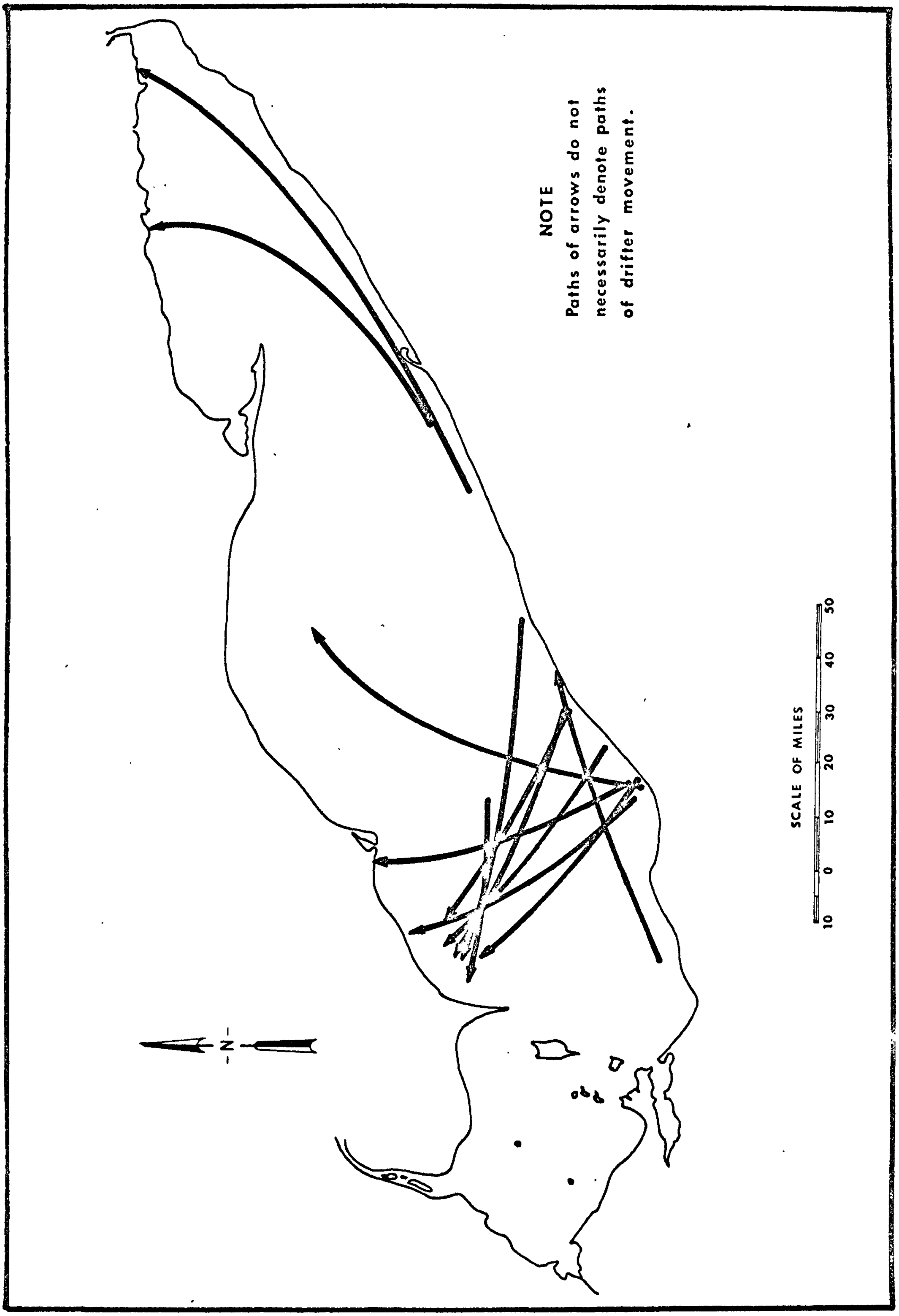
NOTE
Paths of arrows do not necessarily denote paths of drifter movement.
SCALE OF MILES
10 0 10 20 30 40 50
N

FIG. 5

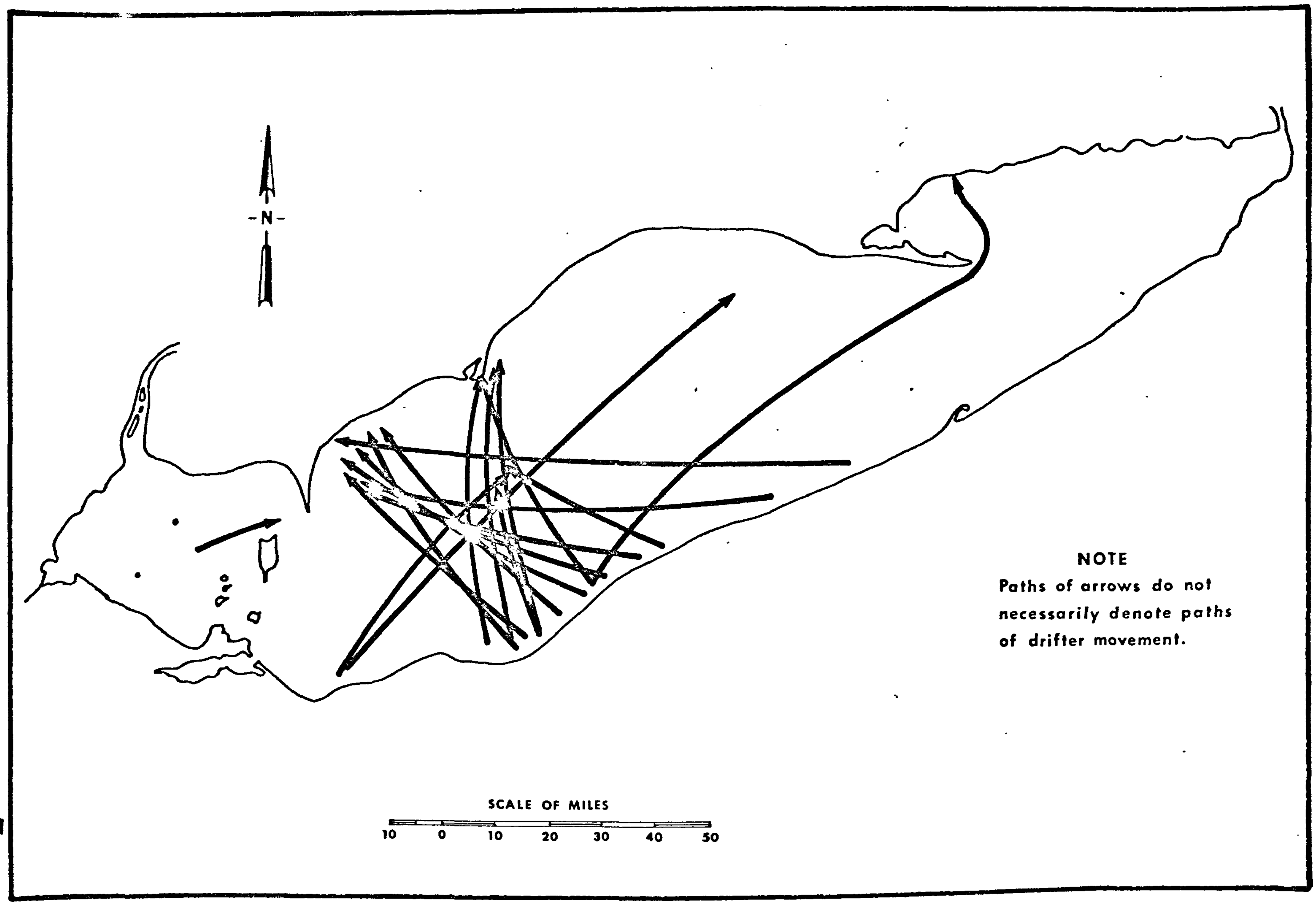
N
NOTE
Paths of arrows do not necessarily denote paths of drifter movement.
SCALE OF MILES
10 0 10 20 30 40 50

FIG. 6

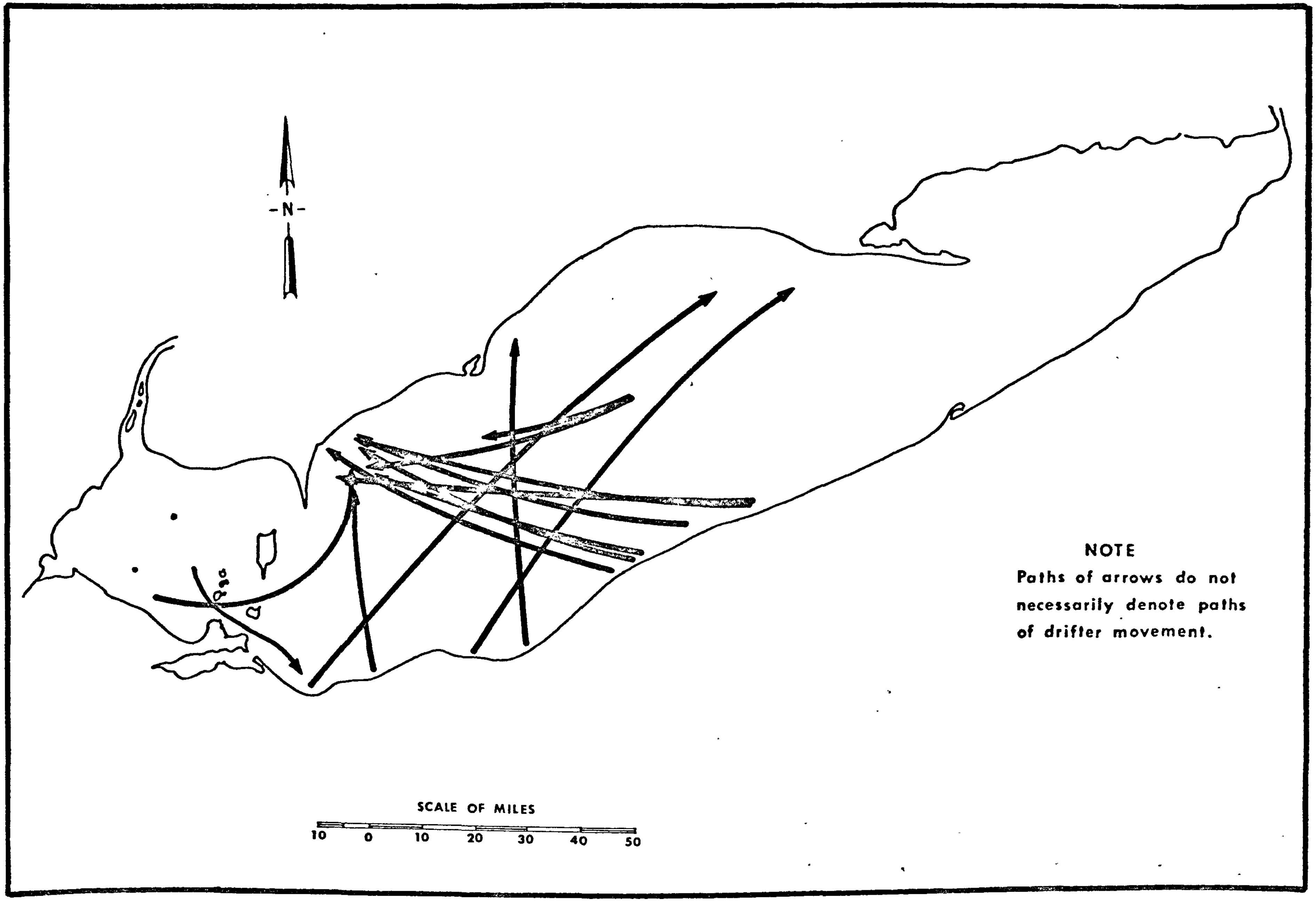
N
NOTE
Paths of arrows do not necessarily denote paths of drifter movement.
SCALE OF MILES
10 0 10 20 30 40 50

FIG. 7

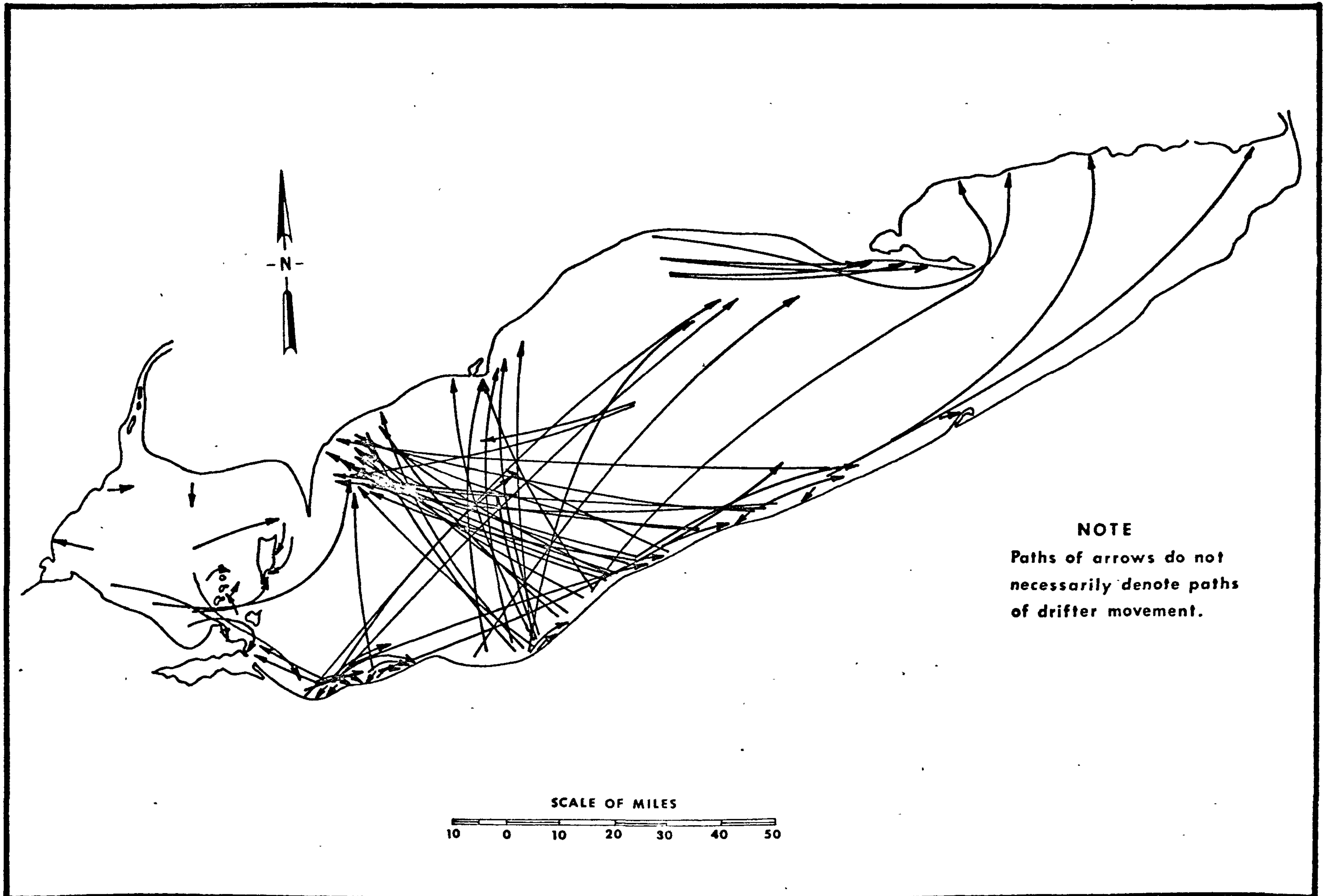
N
NOTE
Paths of arrows do not necessarily denote paths of drifter movement.
SCALE OF MILES
10 0 10 20 30 40 50

FIG. 8

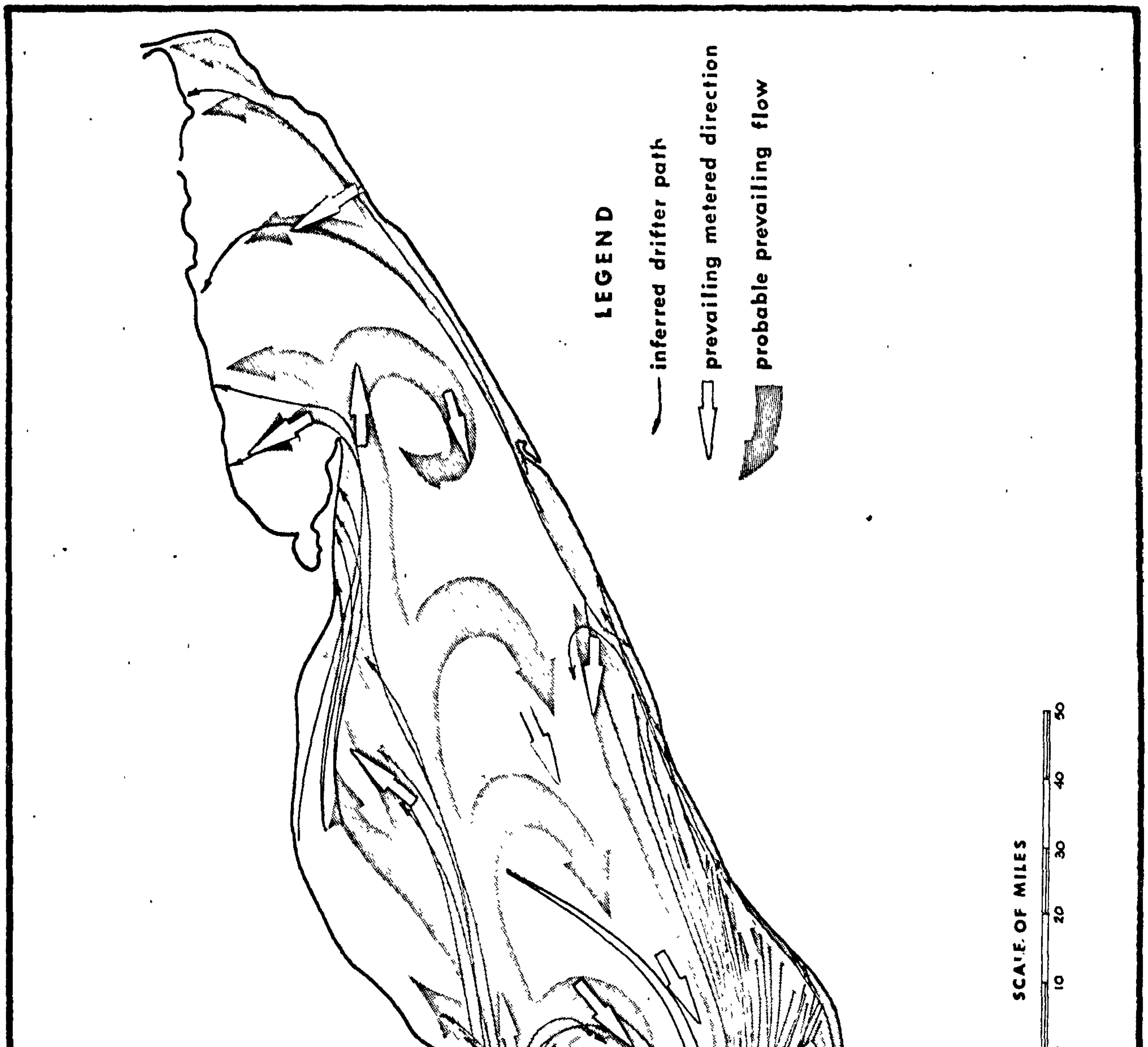
LEGEND
inferred drifter path
prevailing metered direction
probable prevailing flow
SCALE OF MILES
10 0 10 20 30 40 50
N

FIG. 9