APPENDIX 2D

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LIMNOLOGY PROGRAM
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APPENDIX 2D
LIMNOLOGY PROGRAM
FOR DAVIS-BESSE NUCLEAR POWER STATION

The lake study program as outlined in this appendix is being conducted under the direction of The Toledo Edison Company and the Great Lakes Research Division, Institute of Science and Technology of The University of Michigan was retained by Toledo Edison in 1968 to conduct this study. Dr. John C. Ayers, Research Oceanographer, of the Great Lakes Research Division is in charge of this study.

At our request, a meeting was held in the fall of 1968 with representatives of the Division of Wildlife, Ohio Department of Natural Resources to review the study outline so that all areas of concern to this State Agency could be taken into account and for us to gain the benefit of any State sponsored studies that had been done or that were projected. Since this meeting, other State and Federal agencies have expressed an interest in the study and as a result there will be participation by some of these agencies. While the full degree of participation of each agency has not been finalized, the results of several meetings have indicated that a joint program will follow resulting in a very satisfactory arrangement.

The report covering parts I, II, and III are being submitted with this Amendment No. 5.

Sampling for parts III (Ecology and Radionuclide Reconstruction) was begun 5
in June 1969. Further sampling will be carried out in May 1970 and will be continued prior to station operation to identify any trends in radioactivity levels or biological populations in the lake environment.

In summary, The Toledo Edison Company has initiated a comprehensive lake survey program to provide background data for the design and operation of the Davis-Besse Nuclear Power Station. The program is being coordinated with State and Federal agencies and will first be reported on in October, 1969. All reports prior to and following operation will be distributed to interested parties. An outline of the program follows.

LAKE STUDY PROGRAM FOR THE DAVIS-BESSE NUCLEAR POWER STATION

I PURPOSE

The purpose of the study is to gather lake data. It will be used to establish certain station design criteria and as a design aid to control or minimize any possible adverse affects upon Lake Erie from construction and operation of the proposed Davis-Besse Nuclear Power Station.

II SCOPE

The program is to include a description and evaluation of past, present, and projected future lake use, a field investigation to determine physical, chemical, and biological characteristics of the offshore lake regime and to evaluate the effect of station effluent on aquatic life.

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III SCHEDULE

The gathering of data began in the summer of 1968 and, where necessary to establish trends or background, will continue until operation of the station.

IV OUTLINE OF STUDY

The following is a brief description of each portion of the Lake Study Which we feel is required to satisfy the requirements of the AEC and other interested State and Federal agencies.

Part I General Studies

- The General Area
- Bottom Sediments
- 5 Possible Shore Erosion
- Water Depths
- Temperature Profiles

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Part II Currents and Dilution

- Current Studies
- Dye Dilution Studies
- 5 Source Release Computations

Part III Preliminary Biological and Radiological Studies

- Scope and Status of Studies
- Summary Statement
- Primary Zooplankton Counts
- Benthos Data
- Fish and Fisheries
- Radiological Analyses

V STUDY

The following reports cover parts I, II, and III and cover studies that have been completed to date. Additional study work is still in progress and will be reported when completed.

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HYDROLOGICAL SURVEYS FOR THE DAVIS-BESSE POWER STATION

THE LOCUST POINT REGION

PART I. GENERAL STUDIES

John C. Ayers
and
Robert F. Anderson

Under contract with

The Toledo Edison Company

Special Report No. 45
of the
Great Lakes Research Division
The University of Michigan
Ann Arbor, Michigan
1969

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THE GENERAL AREA

From the mouth of the Detroit River southwestward to Toledo on the mouth of the Maumee River at the western tip of Lake Erie, thence generally southeastward to and beyond Port Clinton, Ohio, the land is the bottom of ancient Lake Maumee; it is low, flat, and virtually featureless. This topography continues for miles inland in the sector from southeast to northwest of the lake shore.

Because of the low land upwind to the prevailing winds, the western basin of Lake Erie is well ventilated. Winds from the north, east, and south quarters are less frequent than winds from the southwest to northwest, but they do occur. It is probably in response to wave-activated sand movement during storms from these directions that most of the western and southwestern shores of Lake Erie have barrier beaches of greater or less extent and degree of development. Between the barrier beaches and the mainland, lie marshes of various extents and degrees of inundation. Tributary rivers and streams entering the western basin of Lake Erie are multi-branched and of low gradient; they and their branches contribute to the extent of the marshes behind the barrier beaches.

Culturally, the lake shore in this part of the western basin of the lake is dominantly of farmland and shore summer cottages with a minor portion occupied by the cities of Monroe, Michigan, and Toledo, Ohio. Port Clinton, Ohio, at the eastern edge of the area of interest, has about 6,000 inhabitants.

Though obviously under the control of man, the barrier beaches and the edges of the mainland tend to a rank growth of trees, shrubs, and vines. Marshes behind the barrier beaches range from small cattail marshes rimmed by trees, to very extensive lagoons edged by rushes, cattails and other marsh plants. Most of the larger marshes are dissected by dikes, causeways, and

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canals created by previous owners (many of whom were hunting clubs). Most of the large marsh areas are now wildlife refuges maintained by the State of Ohio or by the federal government.

On the southwestern shore of the western basin of Lake Erie, Locust Point is a minor protuberance where the trend of shoreline changes from generally southeast. From Toledo to Locust Point is about 22 miles along the shore; from Locust Point to Port Clinton is somewhat less than 10 miles along shore.

BOTTOM SEDIMENTS OF THE LOCUST POINT SITE

In this section we follow the reconnaissance survey of bottom sediments that has been carried out in the western basin of Lake Erie by the Ohio Department of Natural Resources beginning in 1956 and supplemented by local studies since then (State of Ohio 1957). The findings of this survey are shown in Figure 1. They have been checked and confirmed by our own observations on an opportunity-offers basis during our own studies. We have found nothing that causes us to doubt any of the conclusions of the Ohio survey.

According to the Ohio survey and our own observations, the shore from Little Cedar Point at the east edge of Maumee Bay to Port Clinton east of the plant site is of low elevation and comprised of sand overlying a stiff lake-clay. In the Locust Point area the beach and back-beach are of sand with shell admixed. The underwater bottom immediately off shore along the plant site is predominantly of sand with some shell and mud intermixed. This sandy bottom shallowly overlays stiff lake clay and varies from 3/16 mile wide at the west edge of the plant property to 1/8 mile wide at the east property line.

Offshore of the sandy-bottom belt is a dominant band of the stiff lake clay, presumably exposed by wave action, and varying in width from 3/8 mile

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Figure 1
(from State of Ohio 1957)

SCALE IN MILES

1 0 1 2 3 4 5 6 7 8 9

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near the west side of the plant property to 1/4 mile at the east edge of the property.

Off the western side of the plant property the bottom at about 9/16 mile becomes sand with increasing amounts of gravel as one goes further off shore. Eastward of about the middle of the plant property the offshore deposits become dominantly muddy sand. Offshore bottom sediments dominantly of mud do not begin until the mouth of the Toussaint River has been passed going eastward.

In the far-offshore area, 3 to 8 miles, there are four small areas of bedrock, each less than a mile in any dimension, located off the west and central parts of the plant property. No such reefs are situated off the east side of the plant property. These reefs are important in the local fish ecology as spawning grounds; they are, however, not apt to be reached by the plant effluent which should travel eastward.

Beyond these reefs, to the International Boundary at more than 15 miles, the bottom is of mud.

POSSIBLE SHORE EROSION EFFECTS OF THE INTAKE STRUCTURE

It is noted that the sheet-pile-and-fill structure protecting the plant's intake channel will extend lakeward from shore at nearly a right angle. The shore throughout the Locust Point property is primarily of sand overlying stiff lake clay (State of Ohio 1957).

Hartley (1964) and Braidech (1969; personal communication, Appendix A) both indicate a southeastward movement of sand in the littoral drift from Locust Point toward Port Clinton. Both Braidech and the U.S. Lake Survey charts indicate that west of Locust Point the net littoral drift is westward; the charts show sand collection on the east sides of groins and jetties.

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These sorts of information confirm the findings of Hartley, Herdendorf and Keller (1966) that the current of the Detroit River crosses the western basin of Lake Erie and divides into eastward and westward flows at Locust Point. Drift card studies by Olson (1951), as reported by Hutchinson (1957), indicate an oscillatory current off Locust Point. Braidech, correctly, we believe, points out that winds from east to northeast have a longer open-water fetch bearing upon Locust Point, and that wave-generated littoral currents to the westward might be dominant (however slightly) over eastward littoral drift generated by waves under the prevailing SW winds that have relatively little fetch before Locust Point.

We believe that Olson's deduction of oscillatory currents off Locust Point is a reflection of the fact that his cards were in general far enough off shore for the hydraulic pressure of the outflow of the Maumee River to have cancelled the effect of the longer fetch available under easterly winds.

From the total of the evidence available we cannot say that the intake structure will capture littoral sand from the east or the west, in all likelihood it will capture sand from both directions. It is certain that the State of Ohio will oppose any capture of sand that would interfere with the natural littoral transport of sand and hence result in beach-building or shore erosion.

We recommend that the intake structure be equipped with a facility for the pumped by-passing of sand in either direction. Unfortunately there appear to be no data on the size of littoral transport of sand. It appears that the by-pass mechanism need not be excessively large, but that it should be capable of being run in either direction.

WATER DEPTHS OFF THE PLANT SITE

During the first two weeks of October 1968 a detailed survey of water

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depths off the plant property was carried out. The entire frontage from west of the west property line to east of the east property line was measured and used in constructing baseline segments. The centerline of the access road running out to the beach near the west end of the property was used as the reference; this road is shown in Figure 2 by two parallel lines near the west boundary. From the road centerline projected to the beach, all the beach front was measured by steel tape into six straight-line segments each with a transit station at each end. All the baseline segments were related to each other, and hence back to the access road centerline, by forward and back azimuth angles.

Soundings were taken by an outboard launch carrying a Raytheon portable recording fathometer. Sounding lines were run from 12 feet of depth-of-the-day toward shore along parallel courses approximately to the southwest along visual bearings provided by portable range targets set one on the water's edge and the second as far back on the backbeach as possible. The launch, operating at constant rpm, kept the range targets aligned as it came inshore. At the start of each sounding line the launch raised a fluorescent orange flag, and continued to do so at one-minute intervals during its run toward shore; when it was aground on the beach the flag was raised a last time regardless of time since the last raising.

At each raising of the flag, the fathometer record was marked and the two transit-men recorded true-compass azimuth angles to the flag from the ends of the known-position baseline segment in use. Fixes during the sounding runs ranged from nine to sixteen. Between sounding-line runs the portable range markers were moved forward by equal steel-taped distances parallel to the baseline segment in use.

In the region of the proposed intake channel near the west side of the property sounding lines were run on 100-foot spacings. Between the region

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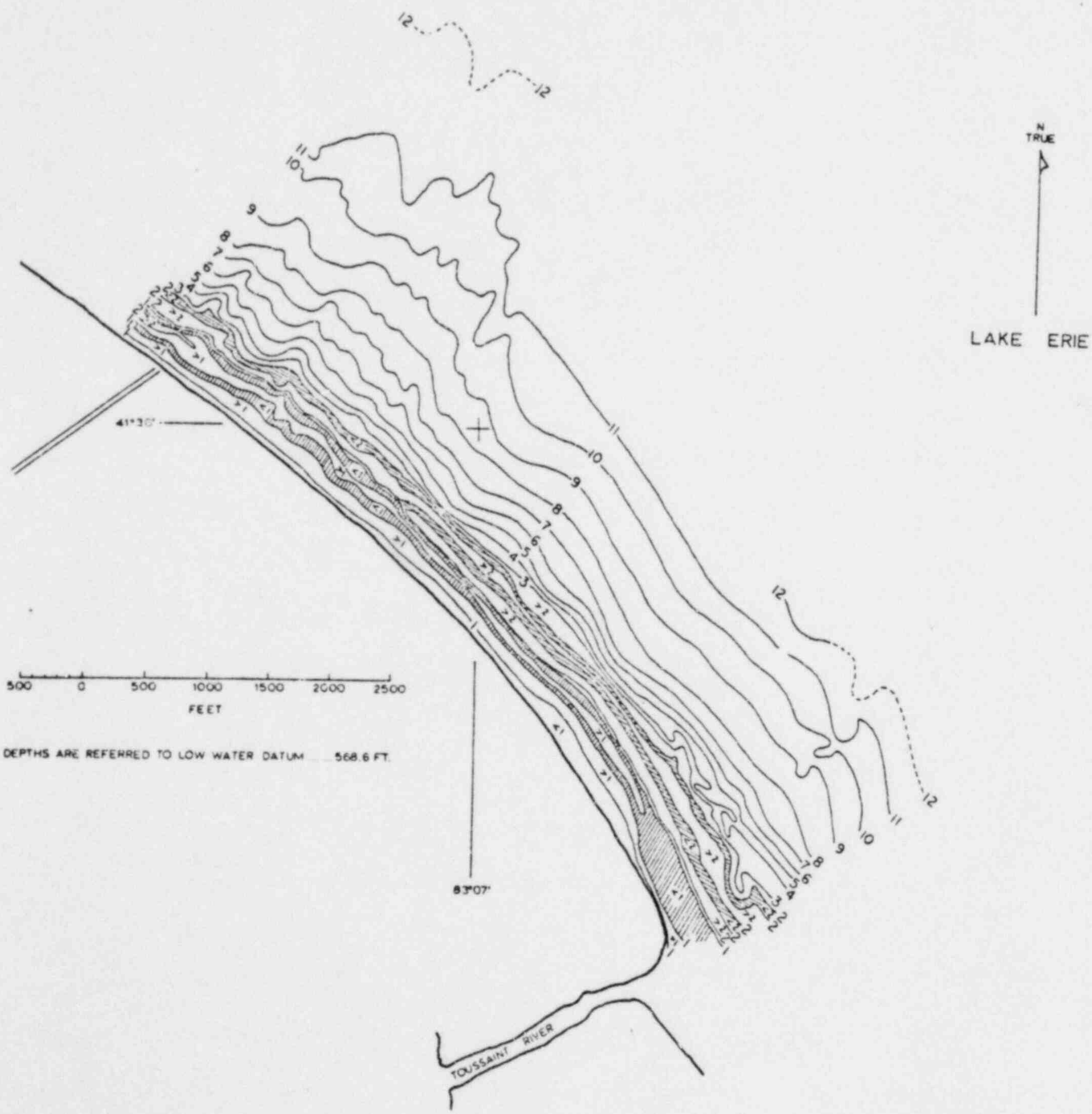

Figure 2

Water Depths off Locust Point, October 1968.

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of the intake channel and the outflow channel the spacing between sounding lines was opened to 200 ft and then to 400 ft; as the outfall region was approached the spacing of sounding lines was reduced to 200 ft and then to 100 ft. Heavy amounts of detail in the intake and outfall regions were thus obtained.

Corrections applied to the raw depth records to bring them to lake datum were the algebraic sums of: monthly mean lake level above datum, the stage of the daily seiche activity (including wind effects), and the depth of the fathometer transducer below water surface. Because a local water-level gauge at Anchor Point (Turtle Creek) was a research gauge not referenced to real lake level, it was necessary to refer the correction factors for seiche activity and monthly mean above datum to the Toledo gauge where both are magnified by the pointed lake-end to greater values than apply at Locust Point; the final corrected depths shown for Locust Point in Figure 2 are, therefore ultraconservative: there is somewhat more water depth at Locust Point than the Figure shows.

Contouring of depth done in Figure 2 is ordinary contouring -- each contour line connects the most inshore occurrences of that depth. This is not the ultraconservative contouring employed (for navigational safety) by the U.S. Lake Survey, who traditionally draw each depth contour *outside* the *outermost* occurrences of that depth.

There are in the finished survey shown in Figure 2 three matters worthy of comment. Deeper water comes closer to shore off the eastern two-thirds of the plant property. Comparison to U.S. Lake Survey boat-sheets of 1962-65 show that there has been erosion off the region of the proposed intake channel and water depths there are deeper than formerly. The presence of three (or four) sand bars parallel to shore and close to the beach indicates a predominance of currents parallel to the beach; the fusion of the two innermost

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sand bars into a sand flat off the eastern end of the station property probably is an expression of some interference with the alongshore currents by the discharge of the Toussaint River.

At both the western and the eastern ends of the station property, dashed portions of the 12-foot contour are estimates based on solid values of 11.75 to 11.98 ft just inshore of them.

TEMPERATURE PROFILES IN WESTERN LAKE ERIE

Temperature profiles in western Lake Erie are relevant in connection with the Davis-Besse Station in that they have bearing upon the temperature of water entering the station intake channel.

According to present plans the intake channel will be open to the lake at 11 feet of depth below Low Water Datum at its lakeward end and will deepen to 14.6 feet after the intake channel crosses the lake beach.

In this study we have drawn upon the records of 250 selected temperature soundings made by bathythermograph in western Lake Erie and in the island region by the State of Ohio, Department of Natural Resources, Division of Geological Survey (Herdendorf 1967) and by the Canadian Coast Guard Ship PORTE DAUPHINE (Rodgers 1962). The two sources contain data for the years 1952, 1953, 1954, 1963, and 1966 from Ohio and for 1961 from the Canadians. The selected records cover the months May to November inclusive.

The criteria involved in the selection of the records used were: 1) only records from the shallow island-region and the shallow west end of the lake west of the islands were used because the Davis-Besse Station will draw water from

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the shallow west end of the lake; 2) records from Maumee Bay and the Detroit River were included in those selected because the Locust Point region is affected by both these sources of influent water (Hartley, Herdendorf, and Keller 1966); 3) records from stations less than 10 feet deep were eliminated because water so shallow could show supratypical warming or cooling not applicable to the Davis-Besse intake; and 4) records from stations deeper than 35 feet were eliminated because these deeper waters might show subtypical warming or cooling not applicable to the Davis-Besse intake.

To eliminate so far as realistically possible any spurious temperature effects from diurnal temperature cycles and from shallow floating water masses from local streams, we have worked out from the 250 selected temperature soundings the monthly mean temperatures at 10 feet of depth for May through November. Monthly mean increments of temperature of surface water over temperature at 10 feet were worked out and added to the 10-foot temperatures to obtain monthly mean surface water temperatures.

For the months of January and February, when ice can be considered to be present, 32°F was used for both depths. For the months of March, April, and December, when the west end of the lake is isothermal from surface to bottom, we have used data from the Collins Park Water Treatment Plant at Toledo. The Toledo intake is at 22 feet.

The monthly mean data derived from the selected bathythermograph soundings were plotted on the day of the month determined by weighted average of the numbers of observations made on different days of the month. Data from other sources are plotted at mid-month.

The resulting data, basic to the two temperature curves shown in Figure 3, are presented in Table 1.

It is evident that water of mean temperature over 75°F will be drawn by the intake during much of July and August. Whether or not increased cooling

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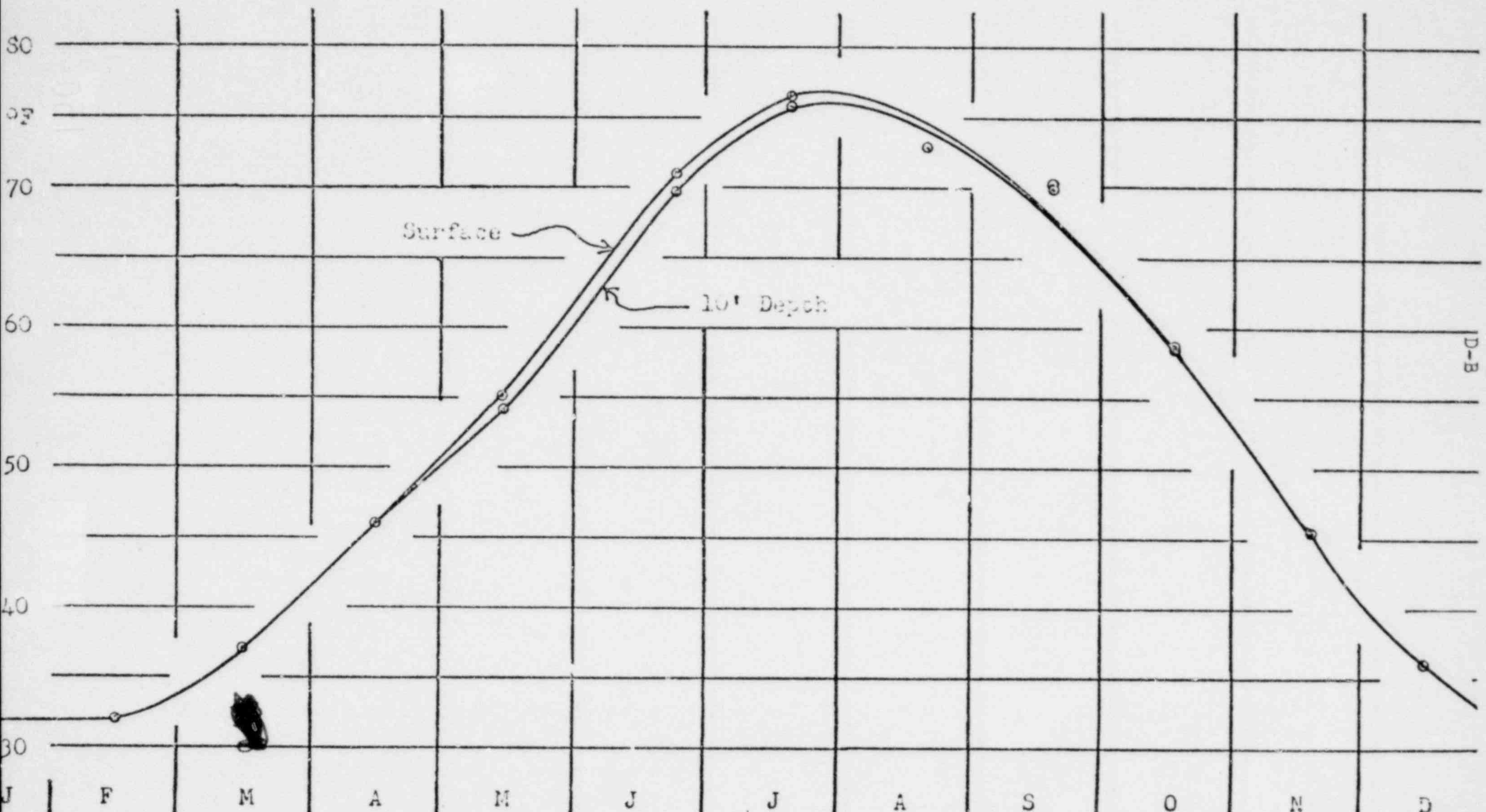

Annual Cycle of Water Temperature at Surface and 10 Feet of Depth, 10'-35' Stations Only.

Figure 3

Table 1. Monthly mean water temperatures in 10-35 feet in western Lake Erie.

Month	No. of Stations	Weighted Mean Day of Month	Mean 10-foot Temperature	Mean Delta-T, 10'-to-Surface	Mean Surface Temperature
January*	--	15th	32.0°F	0.0°F	32.0°F
February*	--	14th	32.0	0.0	32.0
March**	--	15th	37.0	0.0	37.0
April**	--	15th	46.0	0.0	46.0
May	32	14th	54.2	0.9	55.1
June	99	23rd	69.7	1.3	71.0
July	31	20th	75.9	0.5	76.4
August	6	21st	72.7	0.0	72.7
September	7	19th	69.7	0.4	70.1
October	45	17th	58.5	0.1	58.6
November	30	18th	45.4	0.0	45.4
December**	--	15th	36.0	0.0	36.0

* Ice presumed present

** 1966 data of Collins Park Water Treatment Plant, Toledo

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water pumpage during this period would be desirable will be a company decision.

2D-18 to 2D-28 deleted.

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The lengthwise setup of wind tide produces the greatest disturbance of water level. The water level gauging station at Toledo is the major gauging station nearest the plant site. U.S. Lake Survey records of instantaneous maximum and minimum water levels at the Toledo gauge go back to 1941; records based upon hourly scaled values go further back.

From the Lake Survey records we have obtained for the years 1941-1967 inclusive each year's maximum and minimum instantaneous stand of water level at Toledo, expressed as feet above or below the monthly mean lake level at Toledo for the month in which the maximum or minimum occurred. For the 27 years available these maxima and minima of water-stand have been categorized by 1-foot intervals and reduced to recurrence intervals in years per case. The results are as follows:

Table 2. Toledo annual maximum instantaneous levels above monthly mean.

Categories	1 foot	2 feet	3 feet	4 feet	5 feet
Cases	3	10	11	2	1
Cases ≥	27	24	14	3	1
Recurrence Interval, years per case	1.00	1.125	1.925	9.00	27.00

Table 3. Toledo annual minimum instantaneous levels below monthly mean.

Categories	3 feet	4 feet	5 feet	6 feet	7 feet
Cases	5	9	8	4	1
Cases ≥	27	22	13	5	1
Recurrence Interval, years per case	1.00	1.23	2.08	5.40	27.00

Each of these sets of data was plotted on a semilog graph and a least squares regression line computed for it, each regression line being extended to the 100-year recurrence interval. The results are shown in Figure 4.

The regression lines show that a maximum probable water level rise of 7 feet may be expected at Toledo once in 100 years, and that a maximum probable fall of water level of 9.3 feet may be expected at Toledo.

As an additional estimate of the maximum storm tide drawdown of water level at Toledo, recourse was had to the data on 76 wind tides in the 20 years 1940-59 inclusive which were studied by Irish and Platzman. These data were hourly data and were kindly loaned by Dr. Platzman. For each of these storms the minimum hourly water level (maximum drawdown) at Toledo was determined and expressed in feet below the Toledo monthly mean water level of that month. From the 76 storms there were 75 in which the fall of water level at Toledo equalled or exceeded 2 feet. The results are given in the following table:

Table 4. Toledo drawdowns, Irish-Platzman wind tides.

Categories	2 feet	3 feet	4 feet	5 feet	6 feet	7 feet
Cases	15	35	13	7	3	2
Cases ≥	75	60	25	12	5	2
Recurrence Interval, years per case	0.267	0. 333	0.800	1.67	4.00	10.0

These data were plotted on a semilog graph and a least squares regression line computed; the regression line was extended out to the 100 year recurrence interval. This graph is shown in Figure 5.

This graph differs from the graph of minimum instantaneous levels only in that it indicates a maximum probable drawdown of 10.3 feet as opposed to

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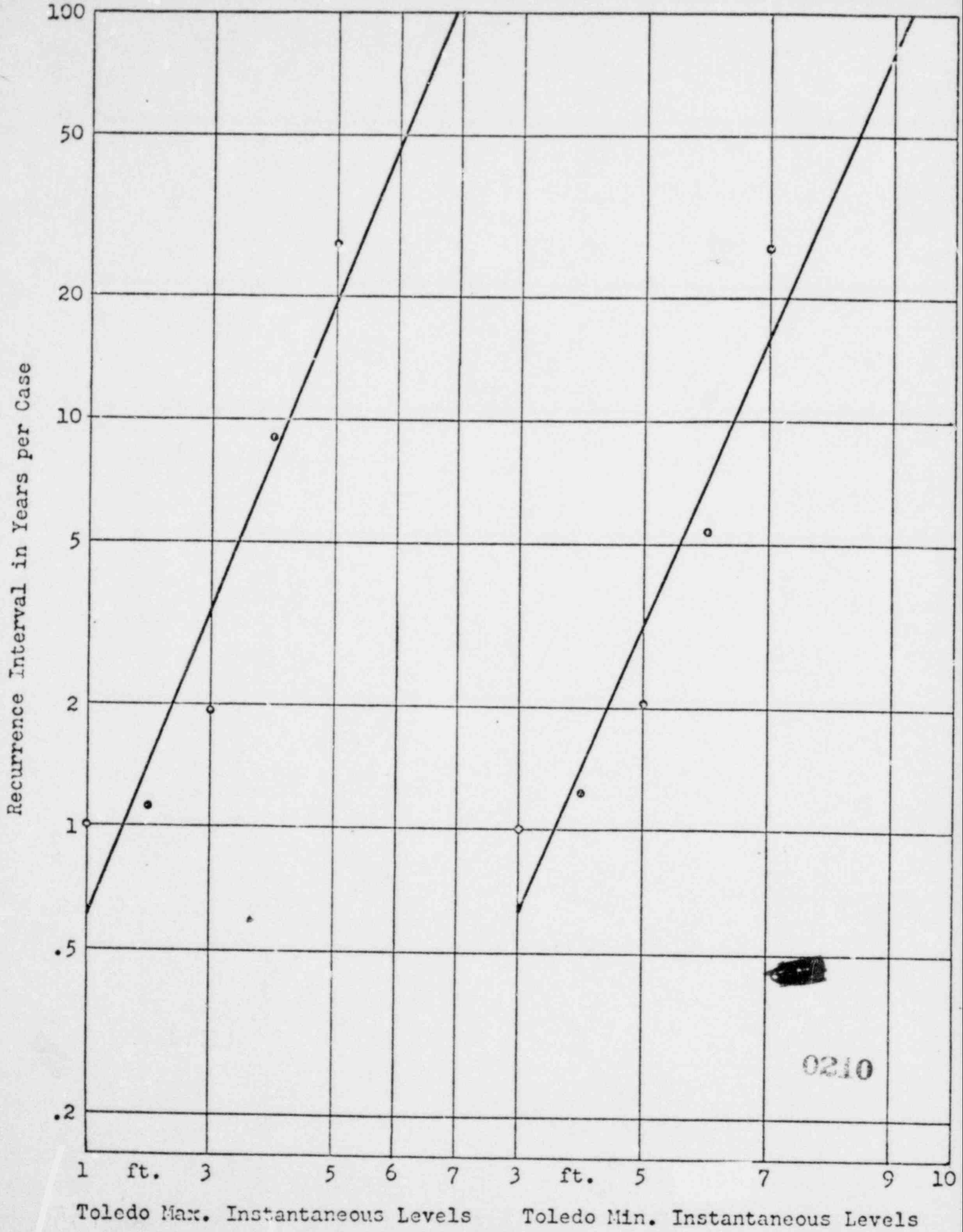
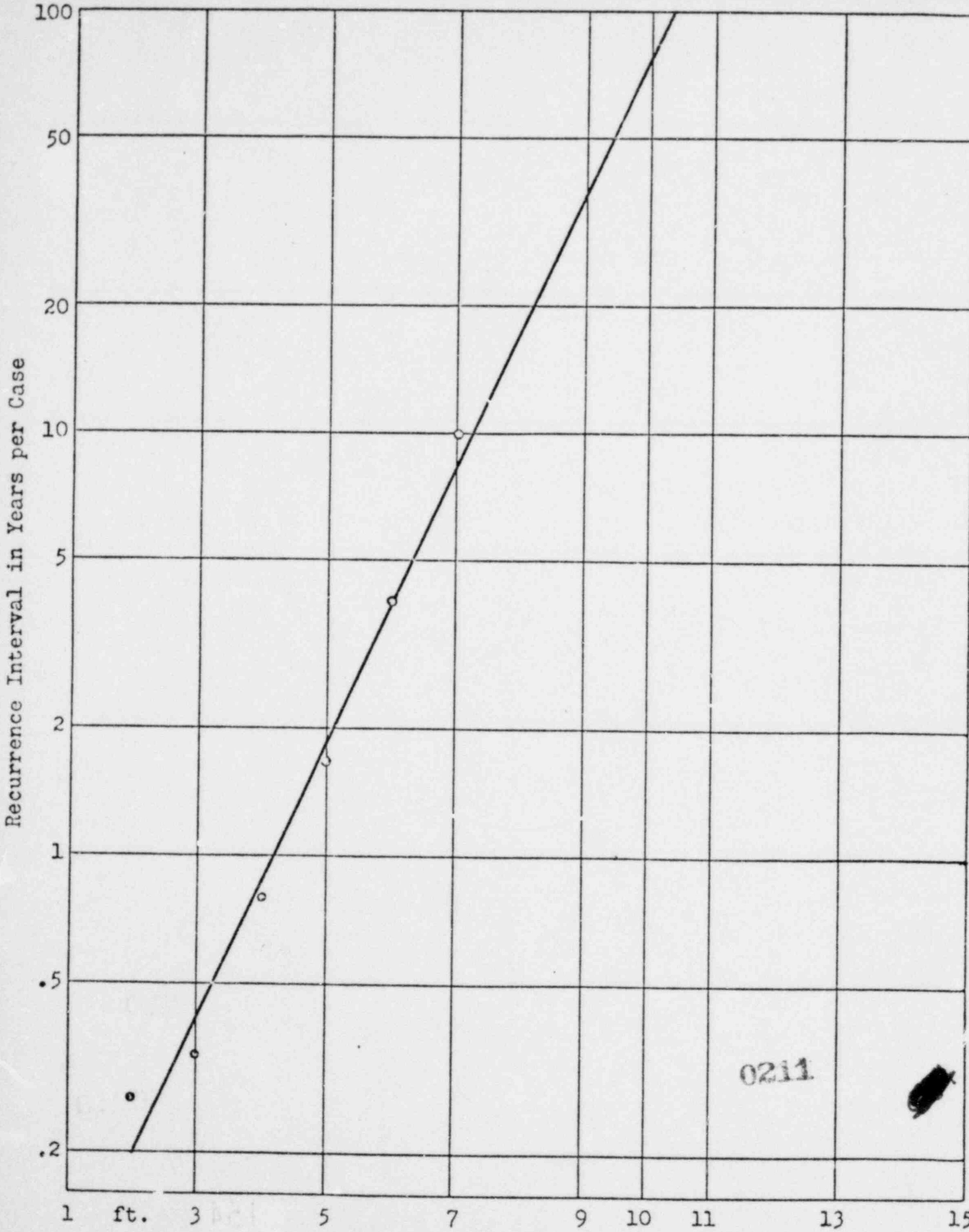

Recurrence Interval in Years per Case
100
50
20
10
5
2
1
.5
.2
1
ft.
3
5
6
7
3
ft.
5
7
9
10
Toledo Max. Instantaneous Levels
Toledo Min. Instantaneous Levels
0210

Figure



Toledo Water-Level Drops, Platzman's 75 Storms.

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9.3 feet. Having no reason to prefer either of these estimates of the probable minimum water level at Toledo, we have accepted the average of the two, 9.8 feet.

Some, but not all, of the roughly cyclical variations in Lake Erie water level could be additative to the maxima and minima at Toledo.

The main uninodal lengthwise seiche of Lake Erie might, when a major storm occurs before the seiche from a previous storm has subsided, provide some increment of wind-tide water-level rise or fall at Toledo but that increment would be included in the observed water level changes. The maximum amplitude of the lengthwise uninodal seiche cannot occur until the storm has lessened or passed, and the setup at one end of the lake or the other has been freed to oscillate. We consider it physically impossible for a maximum wind setup or drawdown at Toledo during a storm to coincide with the maximum amplitude of the uninodal main lengthwise seiche because that maximum amplitude must occur after the storm.

The maximum probable 7-foot rise at Toledo might occur at the top of a 4.2-foot long-term high lake level. It could, further, occur at the top of the 2.75-foot maximum annual rise of record, and it might also occur under such conditions that the transverse seiche of the western basin was adding 1 foot of elevation. The total of this combination is 14.95 feet above datum at Toledo.

The maximum probable 9.8-foot drop of water level at Toledo might occur at the bottom of the 1.2-foot low-lake stage of record. It might, also, occur at the bottom of a 2.75-foot maximum annual variation in level. And it might occur at a time when the transverse seiche of the western basin had removed 1 foot of water level. The total of this particular combination is 14.75 feet below datum at Toledo.

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The Davis-Besse Station is, however, not to be at Toledo which is in narrowed and constricted Maumee Bay at the extreme western end of the lake. Outside of Maumee Bay the cross-section of the lake increases rapidly, and water-level changes which have to be referred to the Toledo gauge may be expected to diminish accordingly.

Apparently only Hunt (1959) has given consideration to the stand of lake level along the lake axis during the major wind tides. Two figures from Hunt for setup levels in the WSW storm of 8 November 1957 are given in Figure 6.

The upper of these figures indicates that the Davis-Besse Station is located at about 0.8 of the straight-line distance from the nodal point of the wind-tide setup to Toledo. The lower of Hunt's figures indicates that at 0.8 of the distance from the nodal point to Toledo the fall of water level would be at least 2 feet less severe than that at Toledo.

Deducting 2 feet from the 14.75 feet of worst-case drawdown at Toledo leaves minus 12.75 feet, and indicates that the 11-foot-deep intake channel at Davis-Besse Station might, at the minimum probable lake level be de-watered by a combination of wind tide on top of long-term and annual lake level variations topped by the short-term transverse seiche of the western basin of the lake.

If materials now in our hands are correct, the plant is to be protected against flooding to 585 feet (16.4 feet above lake datum). If, as Hunt implies, the relationship of lake proportions and depths to setup at Toledo under ENE winds is the same as for setup at Buffalo under WSW winds, then it is appropriate to subtract 2 feet from Toledo's probable maximum setup of 14.95 feet in order to approximate the condition at Davis-Besse.

Under these conditions it appears that the station's 16.4 feet of protection against flooding is adequate.

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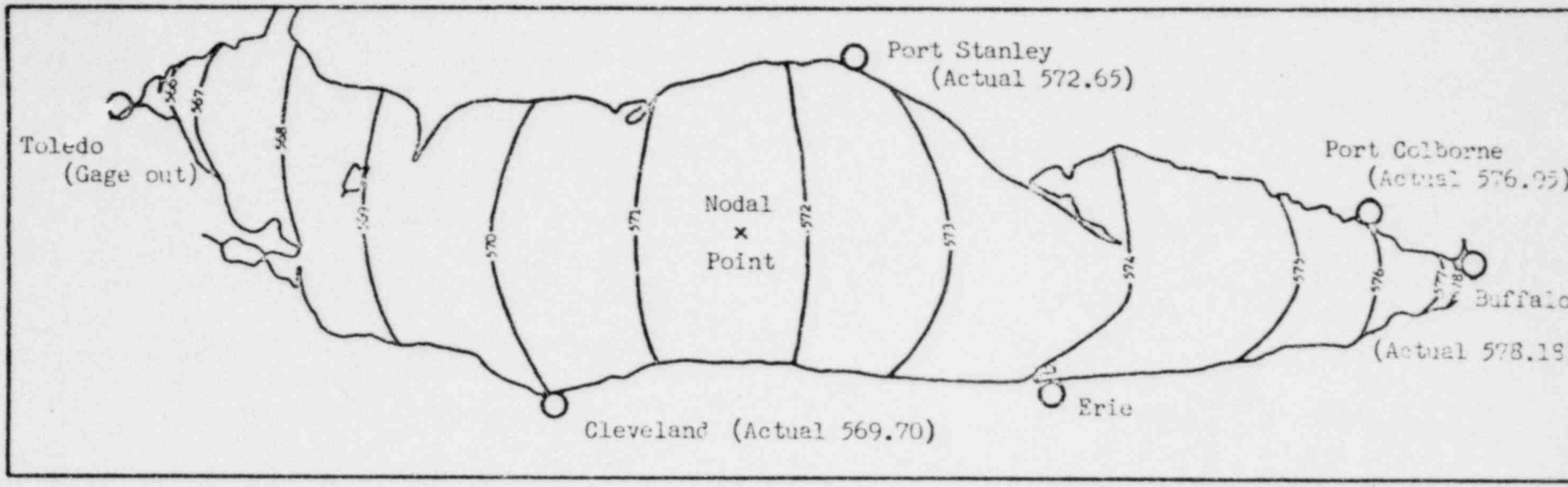

Fig. 10. Contours of computed water levels for 2200 hours, 8 November 1957.

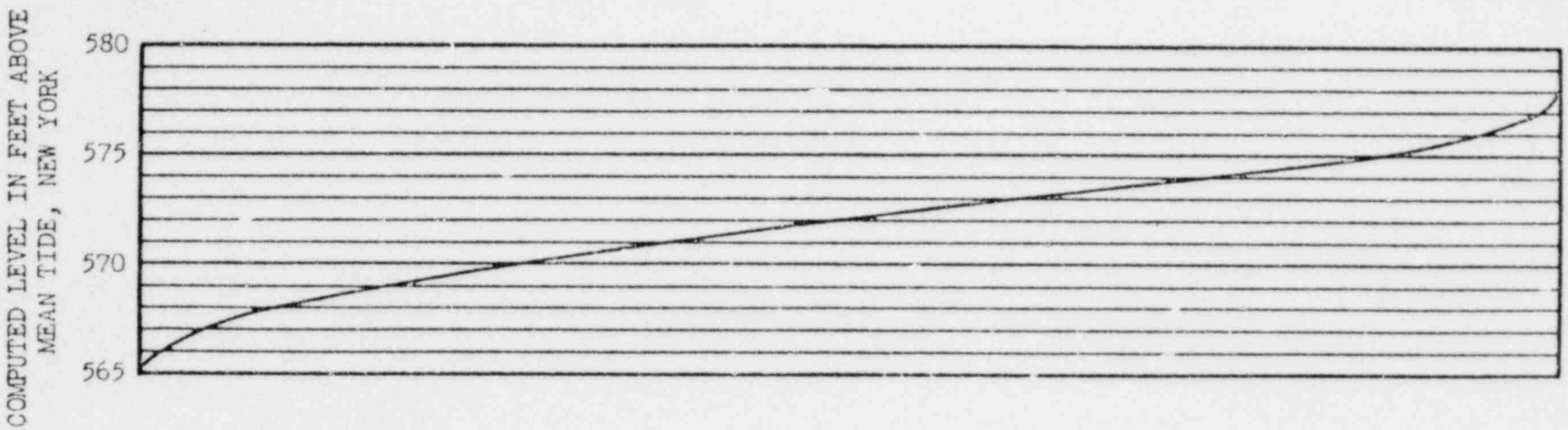

Fig. 11. Profile of computed water levels for 2200 hours, 8 November 1957.

Figure 6 (from Hunt 1959)

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THE MAXIMUM WIND-WAVE

Wind-generated waves are limited in their dimensions by wind velocity, by fetch (open-water distance available for wind action), and by duration of the wind. Higher wind velocities, longer fetches, and longer wind durations all increase the heights, lengths, and velocities of the waves.

Neither wind velocity nor duration of wind are subject to control by the lake basin, but fetch is a physical characteristic of the lake basin. At the Davis-Besse site the available fetch plays an important part in the question of the height of the maximum wave that might arrive at the station, on top of the maximum high water from other causes.

The maximum probable high water that could occur at the Davis-Besse site is predominantly the result of wind setup under prolonged strong wind from the ENE. The station site is in the western basin of Lake Erie, and wind-waves generated by ENE winds over the rest of the lake find their access to the western basin almost completely blocked by the islands that separate the western basin from the central basin. Those parts of waves from the eastern parts of the lake that succeed in passing through the islands are damped, refracted, and reflected into a confused sea around the western sides of the islands. ...n here the ENE wind must construct the maximum wave that will bear upon Locust Point. Toward eastnortheast from the station's site the maximum fetch is 12.5 statute miles, or 20.1 kilometers.

Among the four expressions commonly employed in computation of the maximum wind-wave, that of Stevenson (1852) consistently gives the highest computed "highest waves under the strongest winds". Stevenson's empirical formula is:

$$H = 1/3 \sqrt{F}$$

where H is in meters and F (fetch) is in kilometers. Though the Stevenson equation is empirical and old, it has not been disproven. Defant (1961,Vol.2,p.95)

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says of it: "The formula was established by means of data from lakes, where the value of [fetch] ranged from a few kilometres up to 250 km. For the Mediterranean Cornish has verified the relation for fetches up to 830 km, and it is generally assumed that the relationship holds for values of [fetch] up to 1000 km." Hutchinson (1957, p. 356) says of the Stevenson equation: "For Lake Superior, with a fetch of 482 km., the formula gives 7.3 m. as the height of the highest waves, in good agreement with the 6.9 m. reliably recorded."

Since the Stevenson relation was evolved on lakes, since it has apparently performed well in Lake Superior, and since it gives the greatest predicted wave height, it has been accepted in this case.

Substituting in the equation:

$$H_m = 1/3 \sqrt{20.1 \text{ km}}$$

H = 1.49m or 4.9 ft as the highest wave possible in the fetch available between the islands and Davis-Besse site under ENE winds.

Taking the ratio of wave height to wave length to be 1:10 instead of the theoretical maximum 1:7, we have the wave length of the 4.9 foot wave as 49 feet. Sverdrup et al. (second printing, 1946, pp. 536-537) say: "Short wind waves are nearly unstable in deep water and they therefore break shortly after they have felt bottom....". 'Feeling bottom' consists of the local depth of water becoming less than half the wave length, therefore the maximum wave at the station site of 49 feet wave length should break in something like 24 feet of water depth. If this wave comes in on top of the 12.95 foot maximum probable water level from all other causes, it should break in about 11 feet of charted water depth. Eleven feet of charted depth occurs at 2100 feet from shore at a total distance of 6,900 feet from the station. In this distance another, smaller, maximum wave would form. Applying Stevenson's formula again gives 0.48 m or 1.6 feet for the height of this wave. Its wave length, computed as before, would be 16 feet and its half wave-length 8 feet.

Waves approaching the station from the ENE during a high water of 12.95 feet would enter the station property between the diked intake and outflow channels. The top of the intake channel dikes are to be 13.4 feet above lake datum and the top of the discharge channel dikes are to be 11.4 feet above lake datum. The top of intake channel dikes would be .45 feet above the maximum probable water level and the discharge channel dikes would be covered by 1.55 feet of water. Then the lakeward dikes of the two channels would either stop or trip all but very small waves and cause them to break into the channels. The landward two dikes of the two channels would offer additional wave-breaking capacity if it was needed.

By the time the second wave has been broken directly in front of the station, no fetch remains for additional waves to develop.

We foresee two additional factors that will tend to reduce the possibility of flooding from the maximum wave. Many trees and shrubs of more than 13 feet height exist in the marshes behind the beach; these will be left in place and should have some disruptive effect on waves coming inshore during extreme high water. The sides of the dikes along the two channels will be sloped much more steeply than normal underwater topography. Waves coming inshore during extreme high water will encounter the steep dike sides too abruptly to permit the center of the waves crests to outrun the edges; the harbor-surging type of phenomenon is not expected.

Runup of the Maximum Wave

In our opinion the physical conditions described above preclude runup of the maximum wave as a producer of flooding at the station.

0217

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D-B

HYDROLOGICAL SURVEYS FOR THE DAVIS-BESSE POWER STATION

THE LOCUST POINT REGION

PART II. CURRENTS AND DILUTION

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and
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Under contract with

The Toledo Edison Company

Special Report No. 45
of the
Great Lakes Research Division
The University of Michigan
Ann Arbor, Michigan

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[redacted]

0219

D-B

CURRENT STUDIES IN THE LOCUST POINT REGION

Procedure

Field work was carried out from a Boston Whaler outboard cruiser.

Currents were measured with a shortened version of the U. S. Coast and Geodetic Survey current pole and Rhodamine B dye.

The current poles consisted of 4-foot lengths of commercial 2x4 dimension stock. Each carried a brick at its lower end for ballast and for extra current drag. The poles floated vertically with about 10 inches exposed above the water surface. Each pole was numbered and carried a small orange pennant at its top.

The current poles were set under different wind conditions in front of the plant property in positions so chosen that they would pass over the position of the future plant discharge plume.

Positions of setting, positions during the run, and positions of pole recovery were determined by sextant fixes to charted landmarks ashore. Setting positions and during-run positions are indicated by small dots along the trajectory of each pole in Figures 1 through 20. Recovery positions are indicated by arrowheads in these figures. The identifying pole numbers are indicated at either the start or finish of the pole run.

Wind velocities were measured in the field with a hand-held anemometer.

Each pole was followed as long as the conditions of the day permitted.

Results

The results consist of current pole runs with simultaneous wind data. Runs were made on July 18, 19, 23, 25, 26, 30, 31, August 1, 6, 13, 14, 15, September 6, 10, 12, 13, 17, and 18. Current velocity results and wind data are presented in Tables 3 through 21 and the trajectories of the current poles are given in Figures 1 through 20.

0220

On July 18 there were two current pole runs with resetting between.

The wind directions under which results were obtained are summarized in Table 1.

Table 1. Wind directions under which results were obtained.

Date	Winds from
July 18, 1968	SW 220°
July 19, 1968	NNW 330°
July 23, 1968	E 90°
July 25, 1968	ENE 60°
July 26, 1968	NE 40°
July 30, 1968	E 90°
July 31, 1968	SSW 210°
Aug. 1, 1968	NE 45°
Aug. 6, 1968	WSW 240°
Aug. 8, 1968	SW 200°
Aug. 13, 1968	SW 225°
Aug. 14, 1968	NNW 330°
Aug. 15, 1968	ENE 75°
Sept. 6, 1968	WSW 250°
Sept. 10, 1968	SW 220°
Sept. 12, 1968	NW 315°
Sept. 12,13, 1968	NW 315°
Sept. 17, 1968	SSE 150°
Sept. 18, 1968	SSE 150°

At the Davis-Besse plant site the missing wind directions (N, SE, S, and W) are well enough bracketed by observed winds that the currents there may be considered quite well known.

On 12 September both a dye patch and a set of current poles were followed simultaneously. Figures 16, 17 and 18 show the almost identical movements of the two kinds of current indicators. The poles were allowed to run overnight and were recovered on 13 September.

Only four readings of dye concentration in the dye patch were obtained before it faded into the background reading. Positions of the patch were fixed four more times after reading of concentration was discontinued.

0221

As a test of the general validity of our results we have computed mean current speeds as percentages of the mean winds. Primarily this is a test of whether direct wind pressure on the emergent portion of the current pole was introducing spurious elements of speed. If the indicated current speeds appear correct, then the poles were probably moving with the current alone. Moving with the current alone they would have little or no directional error from direct wind pressure. This test is shown in Table 2.

Table 2. Ratios of daily mean current and wind velocities.

Date	Mean Current	Mean Wind	Current/Wind
July 18, 1968	0.378 mph	14.5 mph	2.60%
July 19, 1968	0.545	14.5	3.76%
July 23, 1968	0.418	10.5	4.00%
July 25, 1968	0.210	13.0	1.60%
July 26, 1968	0.296	6.0	4.90%
July 30, 1968	0.353	13.0	2.70%
July 31, 1968	0.265	14.5	1.80%
Aug. 1, 1968	0.207	8.0	2.60%
Aug. 6, 1968	0.570	12.0	4.80%
Aug. 8, 1968	0.230	8.0	2.90%
Aug. 13, 1968	0.209	9.5	2.20%
Aug. 14, 1968	0.308	6.0	5.10%
Aug. 15, 1968	0.550	14.5	3.80%
Sept. 6, 1968	0.213	10.5	2.00%
Sept. 10, 1968	0.164	8.0	2.10%
Sept. 12, 1968	0.310	6.0	5.20%
Sept. 12,13, 1968	0.218	6.0	3.60%
Sept. 17, 1968	0.373	12.0	3.10%
Sept. 18, 1968	0.490	17.0	2.90%
		Grand Mean	3.25%

The norm to which the test is compared is the finding in Lake Erie that the mean value of surface current is "about 2%" of the wind velocity (see Hutchinson, A Treatise on Limnology, Volume I, John Wiley & Sons, New York, 1957, page 291). Within the limitations of the norm our results appear to be valid.

0222

Conclusions

The current poles used appear to have contributed valid data.

Under most wind directions the local currents at Locust Point are downwind. Under winds from northeast, eastnortheast and east, however, water is driven into the embayment between Port Clinton and Locust Point and from there slides away along shore in a northwestward direction. Under these winds the local currents at Locust Point are dominated by the escapement of water from the embayment. Figures 3, 4, 5, 6, 8, and 13 show this effect.

It is noted that the runs on 12-13 September under northwest wind were deflected lakeward away from the Camp Perry water intake. It appears that there may be clockwise eddy set up along the shore near Camp Perry under this wind.

On the 26th of June, under a northeast wind the Toussaint River was discharging a plume of warm discolored water which tailed off northward along the shore and cooled as it went. It is shown in Figure 5.

0223

Table 3. July 18, 1968. Wind - SW 220°.

Pole no.	Distance traveled feet	Distance traveled miles	Elapsed time hr.	Elapsed time min.	Current velocity (mph)	Wind Dir. from	Wind velocity knots	Wind velocity mph
7	2775	.53	1	47	.36	220°	10-15	12-17
6	2400	.45	1	36	.33	"	"	"
2	3600	.68	1	56	.44	"	"	"
3	1450	.28	1	16	.24	"	"	"
Reset								
3	4800	.91	3	57	.26	"	"	"
7	7175	1.36	3	29	.44	"	"	"
6	7200	1.36	3	11	.44	"	"	"
2	6500	1.23	2	43	.51	"	"	"

TABLE 3, FIGURE 1, July 18, 1968, Wind - SW 220°

0224

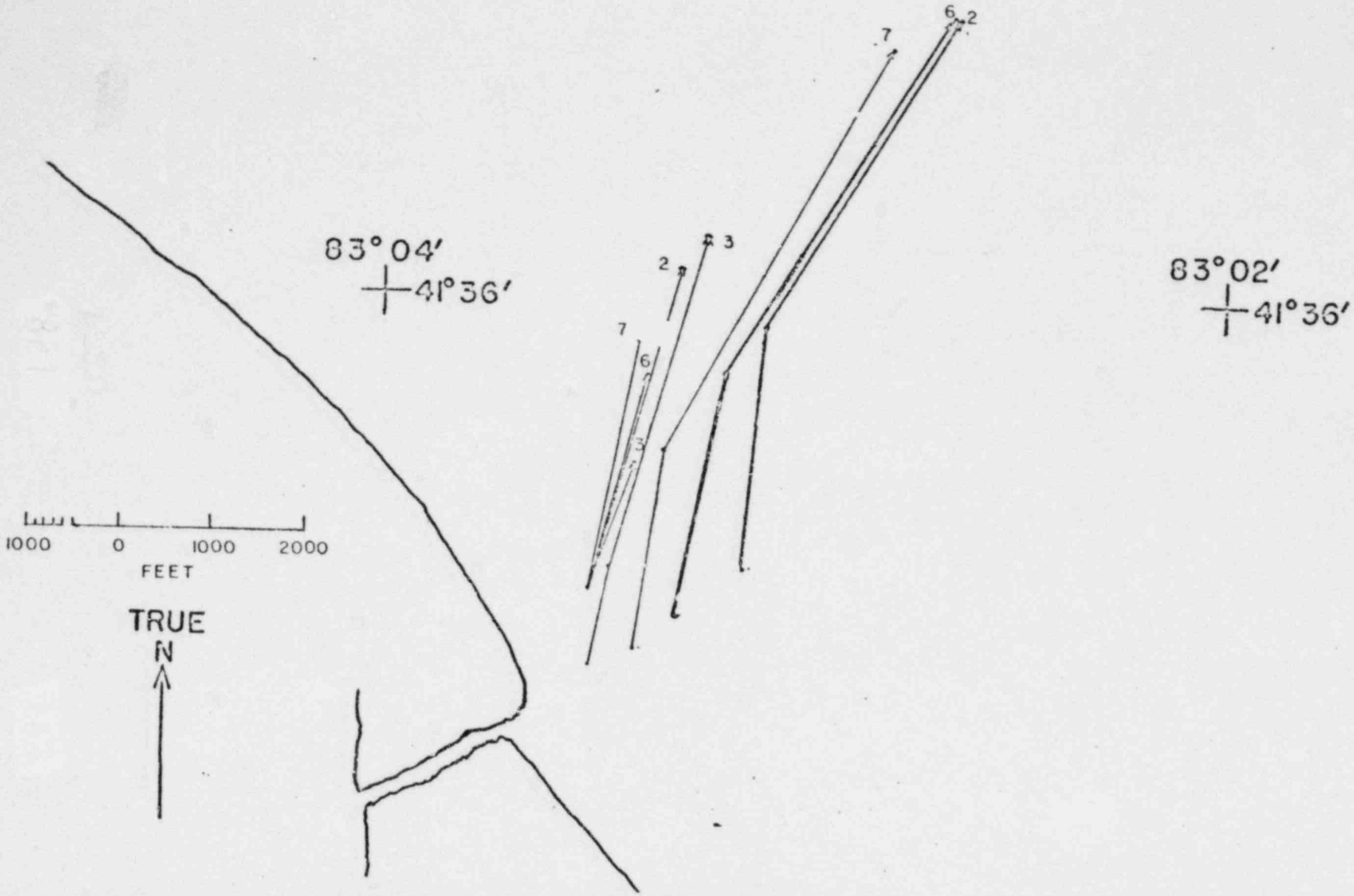

Figure 1. Pole Runs, 18 July 1968. Wind SW.

0225

Table 4. July 19, 1968. Wind - NNW 330°.

Pole	Distance traveled		Elapsed time		Current velocity	W nd		
						Dir.	velocity	
no.	feet	miles	hr.	min.	(mph)	from	knots	mph
1	6525	1.24	3	15	.39	330°	10-15	12-17
3	6400	1.21	2	06	.59	"	"	"
8	6650	1.26	2	08	.61	"	"	"
7	6200	1.17	2	00	.59	"	"	"

0226

TABLE 4, FIGURE 2, July 19, 1968, Wind - NNW 330°

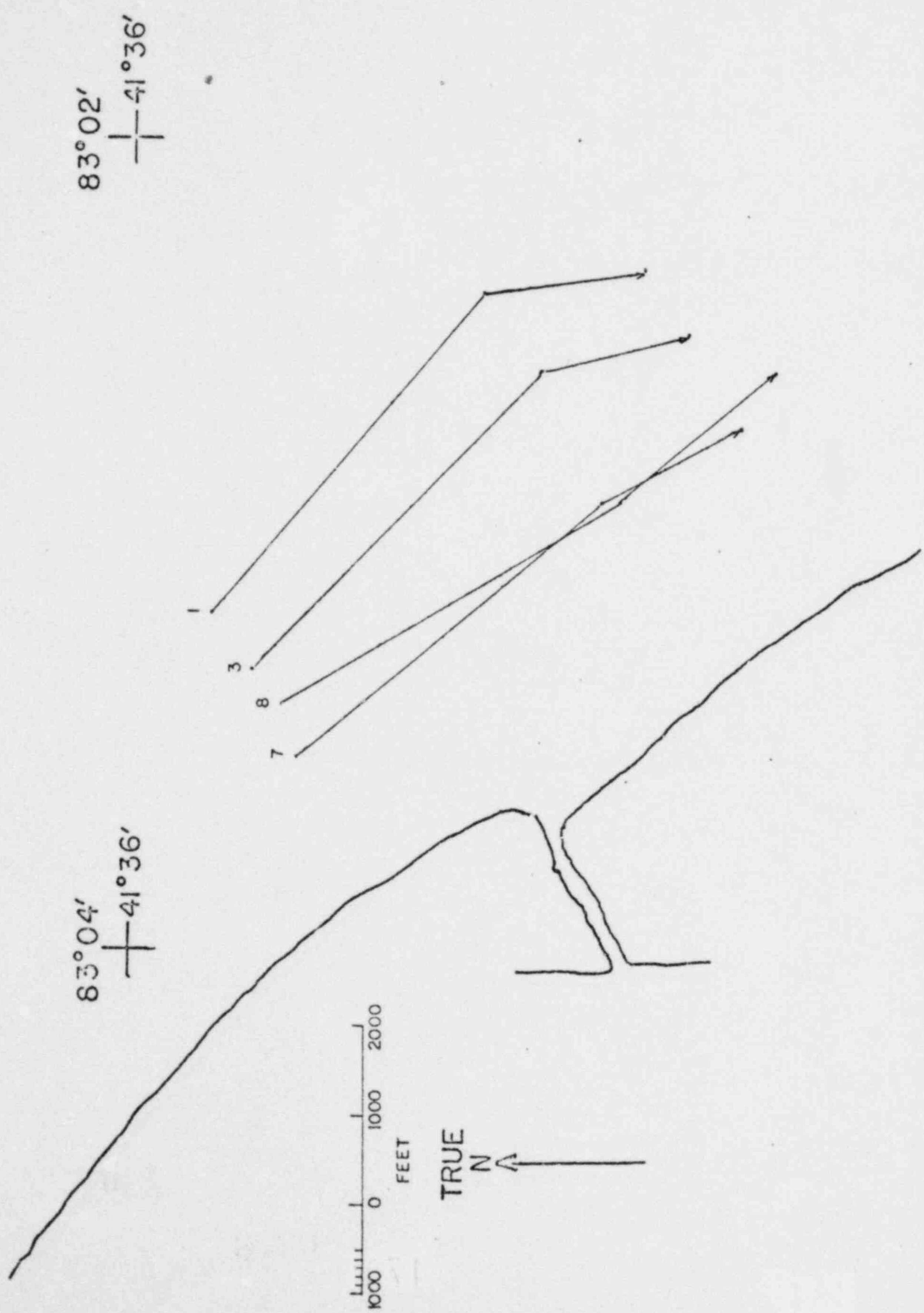

Figure 2. Pole Runs, 19 July 1968. Wind NNW.

0227

Table 5. July 23, 1968. Wind - E 90°.

Pole no.	Distance traveled feet	Distance traveled miles	Elapsed time hr.	Elapsed time min.	Current velocity (mph)	Wind Dir. from	Wind velocity knots	Wind velocity mph
6	13,450	2.55	5	27	.48	90°	8-10	9-12
3	12,300	2.33	5	06	.46	"	"	"
7	12,500	2.37	5	16	.46	"	"	"
1	10,950	2.07	5	33	.39	"	"	"
8	10,950	2.07	5	21	.40	"	"	"
9	8,950	1.70	5	24	.32	"	"	"

TABLE 5, FIGURE 3, July 23, 1968, Wind - E 90°

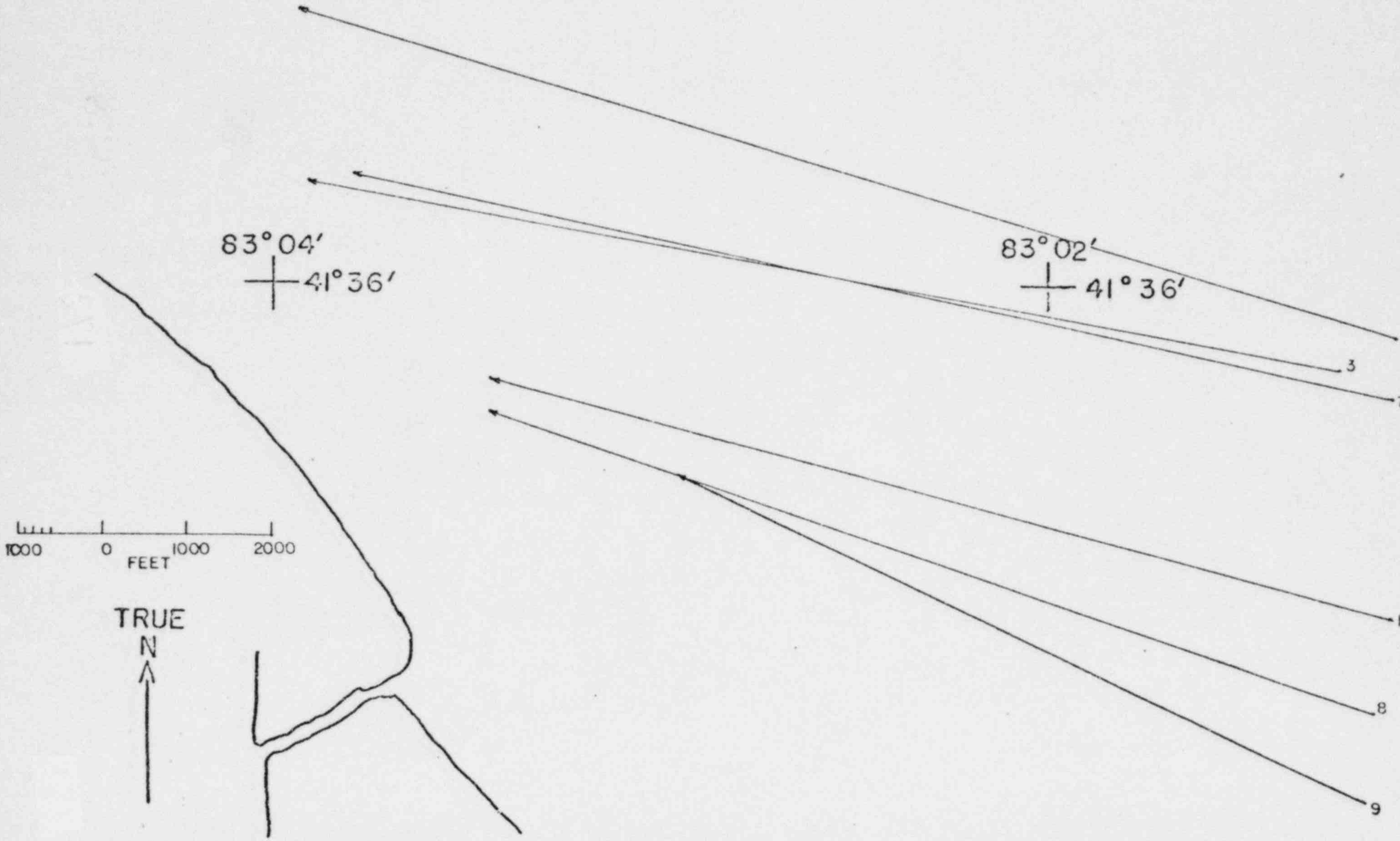

Figure 3. Pole Runs, 23 July 1968. Wind E.

0229

Table 6. July 25, 1968. Wind - ENE 60°.

Pole no.	Distance traveled feet	miles	Elapsed time hr.	min.	Current velocity (mph)	Wind Dir. from	velocity knots	mph
6	4900	.93	4	58	.20	60°	10-12	12-14
9	7325	1.39	5	40	.26	"	"	"
3	5250	99	5	32	.19	"	"	"
7	6700	1.27	6	13	.21	"	"	"
1	6870	1.30	6	42	.21	"	"	"
8	6105	1.16	6	07	.19	"	"	"

0230

TABLE 6, FIGURE 4, July 25, 1968, Wind - ENE 60°

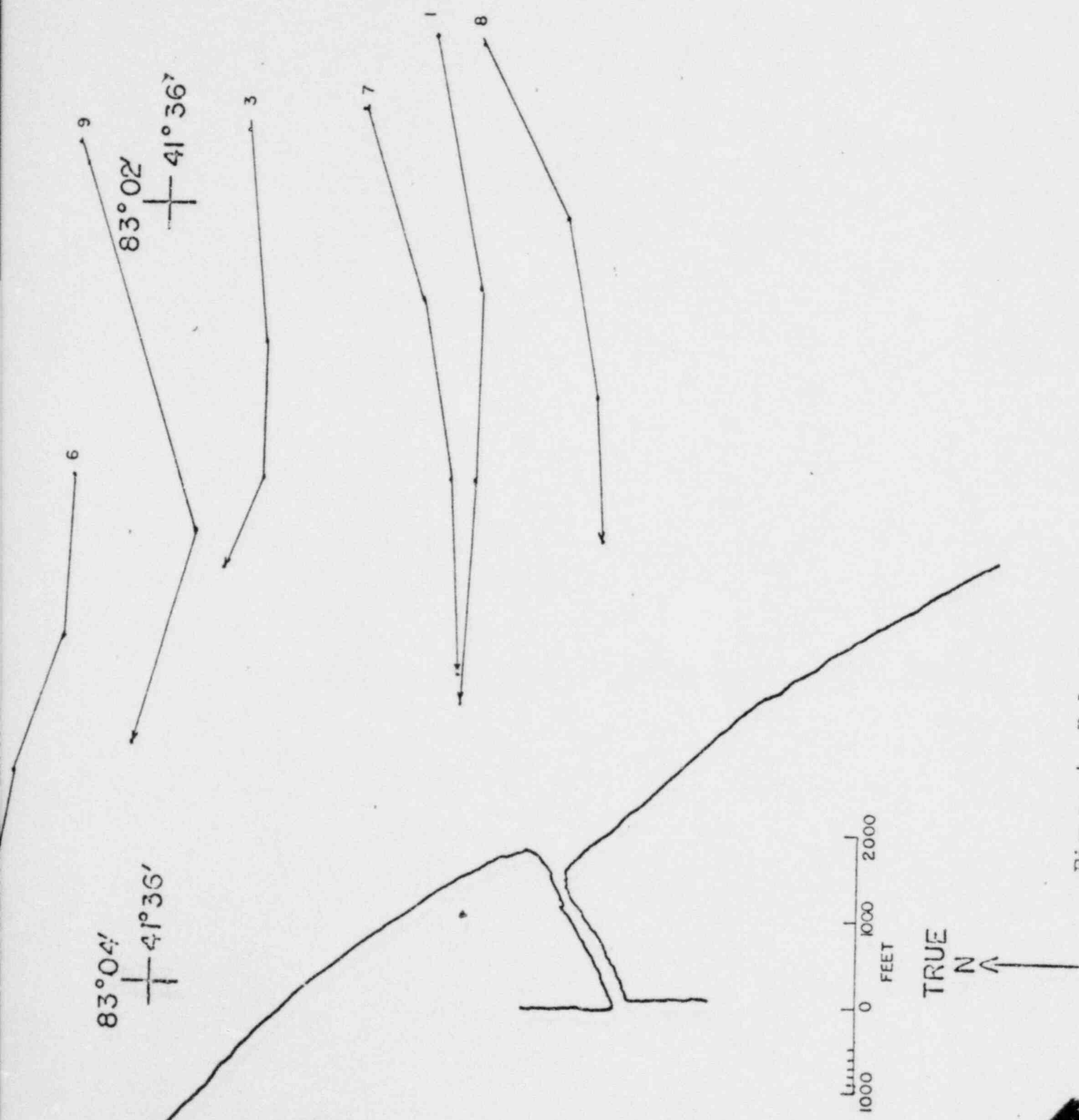

Figure 4. Pole Runs, 25 July 1968. Wind ENE.

0231

Table 7. July 26, 1968. Wind - NE 40°.

Pole no.	Distance traveled feet	Distance traveled miles	Elapsed time hr.	Elapsed time min.	Current velocity (mph)	Wind Dir. from	Wind velocity knots	Wind velocity mph
1	1450	.27	1	05	.26	40°	4-6	5-7
7	1900	.36	1	05	.34	"	"	"
9	1600	.30	1	05	.29	"	"	"

0232

TABLE 7, FIGURE 5, July 26, 1968, Wind - NE 40°

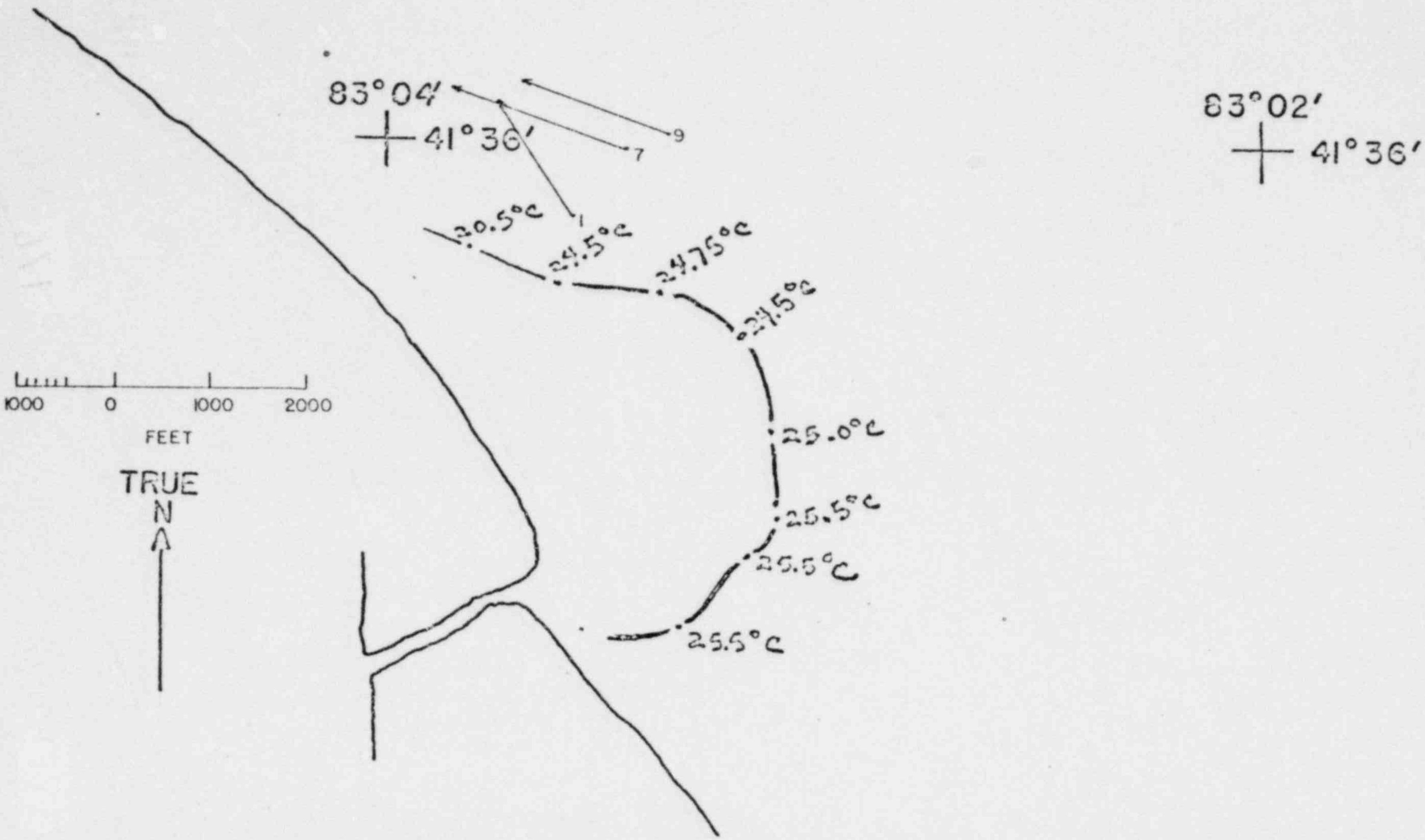

Figure 5. Pole Runs, 26 July 1968, Wind NE.

0233

Table 8. July 30, 1968. Wind - E 90°.

Pole no.	Distance traveled feet	Distance traveled miles	Elapsed time hr.	Elapsed time min.	Current velocity (mph)	Wind Dir. from	Wind velocity knots	Wind velocity mph
1	7500	1.42	4	06	.35	90°	10-12	12-14
7	7925	1.50	4	11	.36	"	"	"
9	6675	1.26	3	58	.35	"	"	"

TABLE 8, FIGURE 6, July 30, 1968, Wind - E 90°

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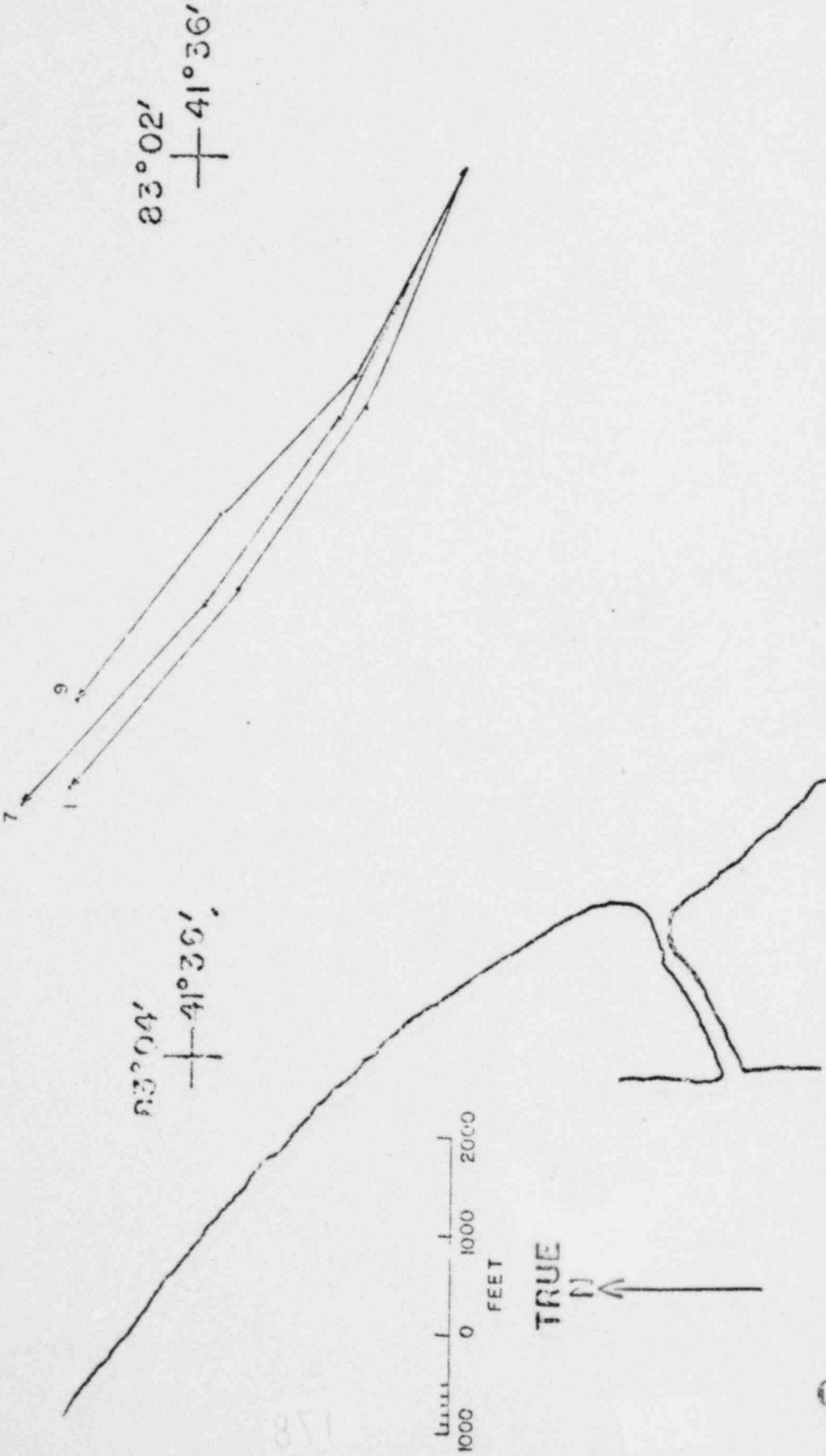

Figure 6. Pole Runs, 30 July 1966. Wind E.

0235

Table 9. July 31, 1968. Wind - SSW 210°.

Pole no.	Distance traveled feet	Distance traveled miles	Elapsed time hr.	Elapsed time min.	Current velocity (mph)	Wind Dir. from	Wind velocity knots	Wind velocity mph
9	4175	.79	4	52	.17	210°	10-15	12-17
7	3850	.73	2	41	.30	"	"	"
1	3900	.74	2	36	.31	"	"	"
3	4900	.93	4	15	.22	"	"	"
8	5250	.99	4	06	.24	"	"	"
6	6200	1.17	3	35	.35	"	"	"

TABLE 9, FIGURE 7, July 31, 1968, Wind - SSW 210°

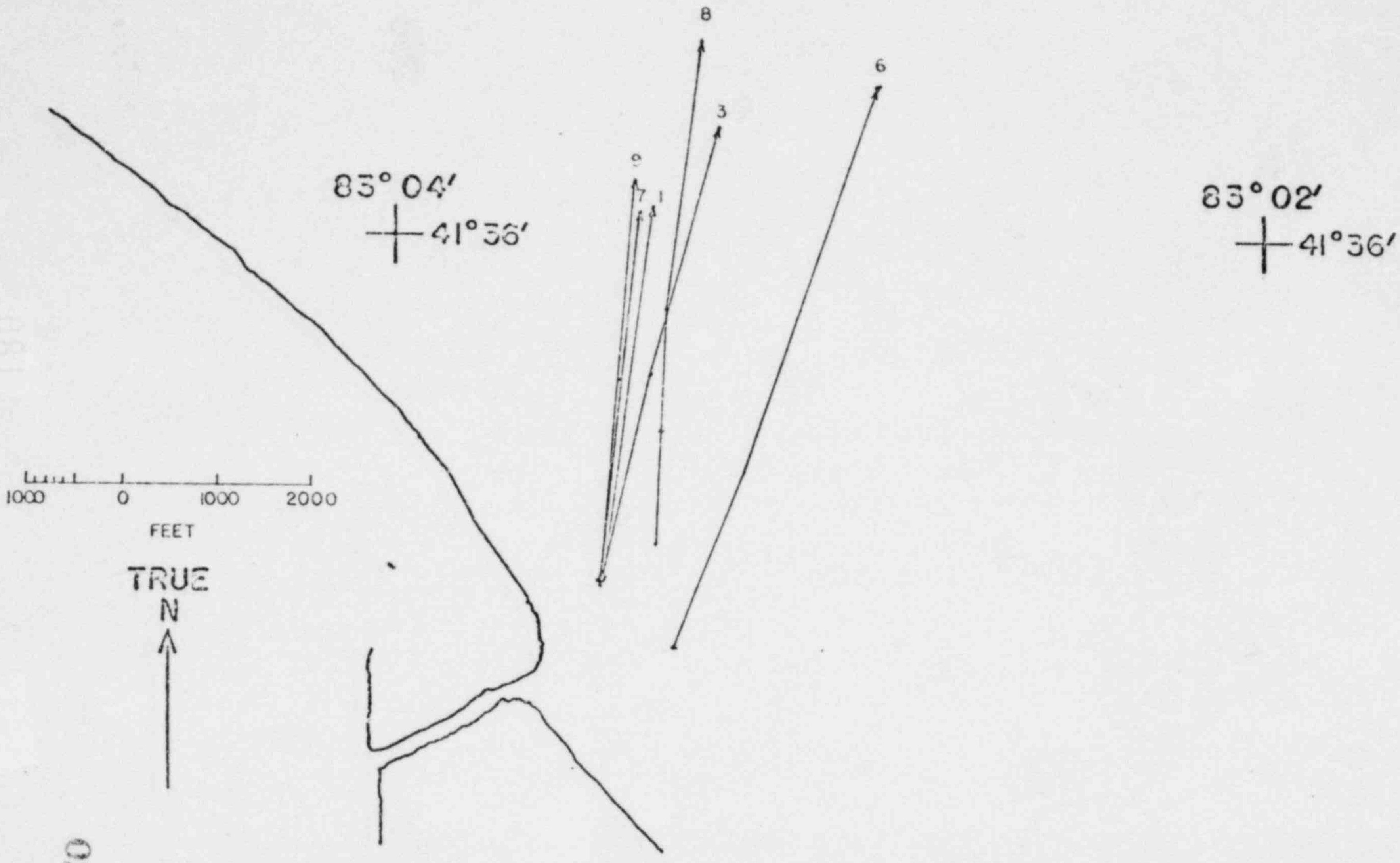

Figure 7. Pole Runs, 31 July 1968. Wind SSW.

0237

Table 10. August 1, 1968. Wind - NE 45°.

Pole no.	Distance traveled feet	miles	Elapsed time hr.	min.	Current velocity (mph)	Wind Dir. from	Wind velocity knots	Wind velocity mph
1	4000	.76	3	54	.22	45°	6-8	7-9
2	4400	.83	3	55	.23	"	"	"
9	3800	.72	4	57	.16	"	"	"
7	4450	.84	4	48	.19	"	"	"
8	4450	.84	4	44	.19	"	"	"
6	4300	.81	3	55	.23	"	"	"
3	5050	.96	4	12	.23	"	"	"

0238

TABLE 10, FIGURE 8, August 1, 1968, Wind - NE 45°

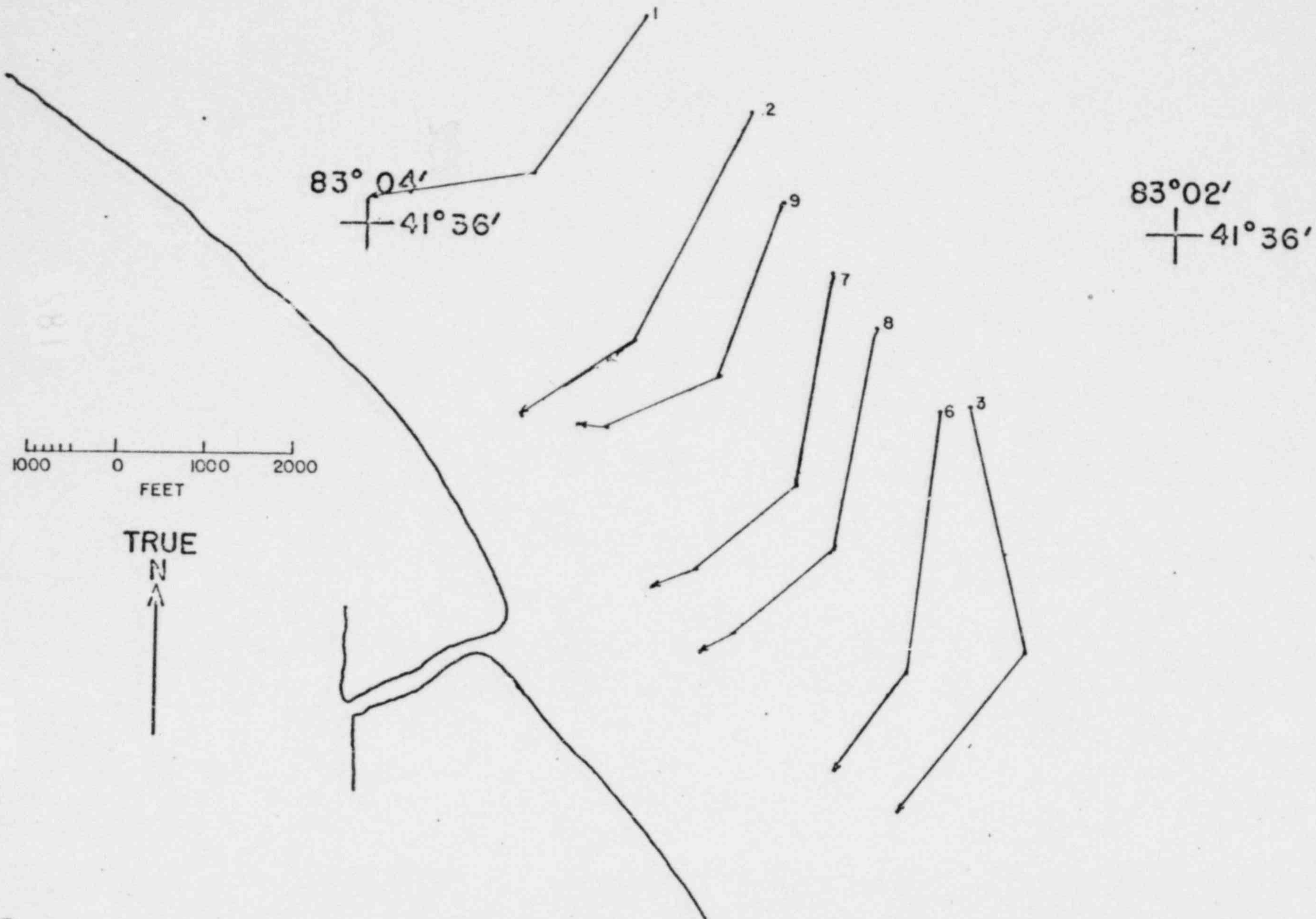

Figure 8. Pole Runs, 1 August 1968. Wind NE.

Table 11. August 6, 1968. Wind - WSW 240°.

Pole no.	Distance traveled feet	Distance traveled miles	Elapsed time hr.	Elapsed time min.	Current velocity (mph)	Wind Dir. from	Wind velocity knots	Wind velocity mph
[illegible]	10,675	2.02	3	48	.58	240°	10	12
1	12,175	2.31	4	39	.53	"	"	"
8	12,000	2.27	4	27	.53	"	"	"
6	11,575	2.19	3	37	.65	"	"	"
3	10,350	1.96	3	47	.56	"	"	"

TABLE 11, FIGURE 9, August 6, 1968, Wind - WSW 240°

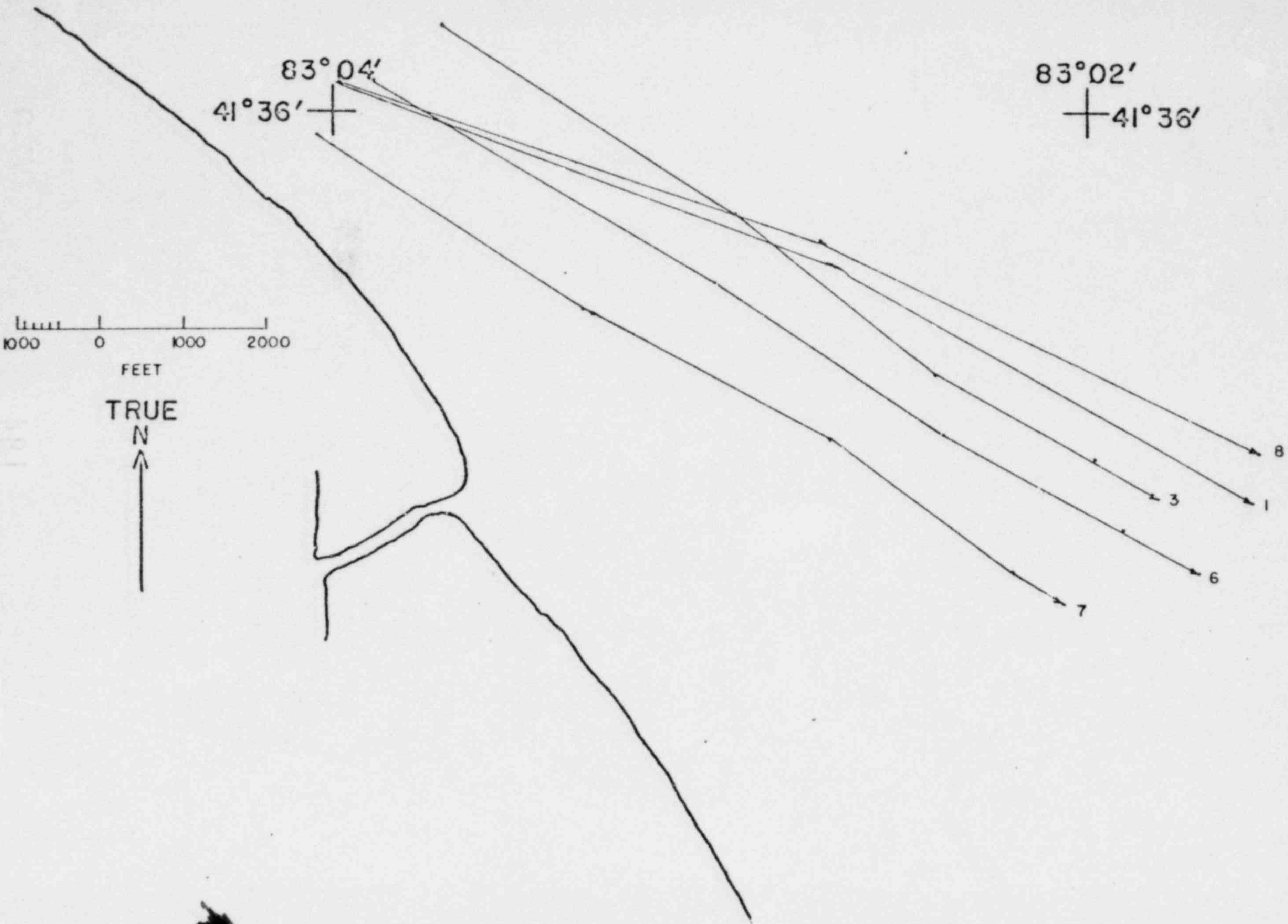

Figure 9. Pole Runs, 6 August 1968. Wind WSW.

0241

Table 12. August 8, 1968. Wind - SW 200°.

Pole no.	Distance traveled feet	Distance traveled miles	Elapsed time hr.	Elapsed time min.	Current velocity (mph)	Wind Dir. from	Wind velocity knots	Wind velocity mph
9	3025	.57	4	17	.14	200°	6-8	7-9
7	2400	.46	2	16	.21	"	"	"
3	2850	.54	2	20	.26	" "	"	"
8	2500	.47	1	52	.31	"	"	"

TABLE 12, FIGURE 10, August 8, 1968, Wind - SW 200°

0242

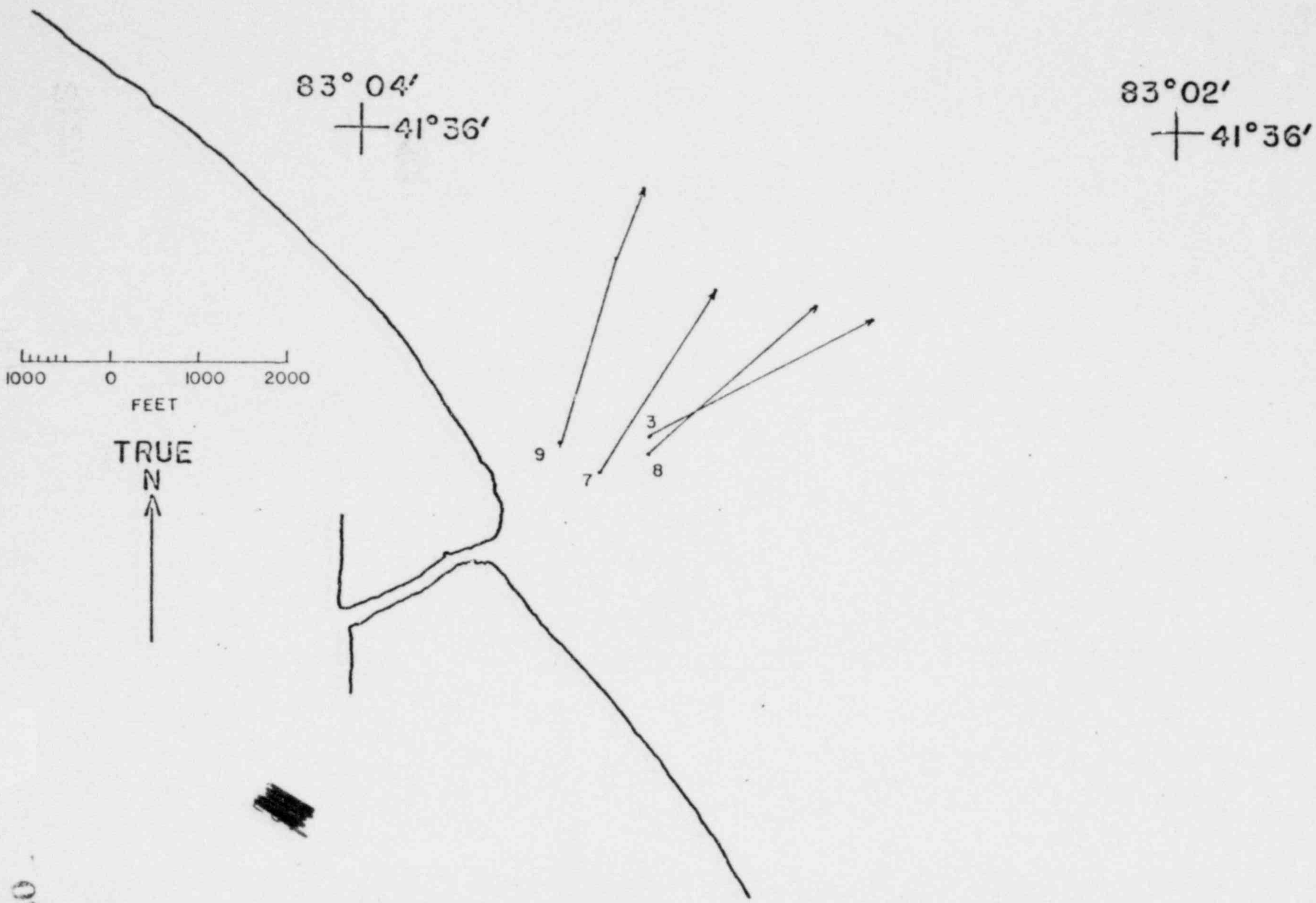

Figure 10. Pole Runs, 6 August 1968. Wind SW.

0243

Table 13. August 13, 1968. Wind - SW 225°.

Pole no.	Distance traveled feet	Distance traveled miles	Elapsed time hr.	Elapsed time min.	Current velocity (mph)	Wind Dir. from	Wind velocity knots	Wind velocity mph
6	7050	1.34	6	13	.22	225°	6-10	7-12
2	8600	1.63	6	06	.27	"	"	"
1	5350	1.01	5	39	.19	"	"	"
8	5950	1.13	5	34	.21	"	"	"
3	4700	.89	5	15	.17	"	"	"
9	3825	.72	4	57	.16	"	"	"
0	5450	1.03	4	30	.24	"	"	"

TABLE 13, FIGURE 11, August 13, 1968, Wind - SW 225°

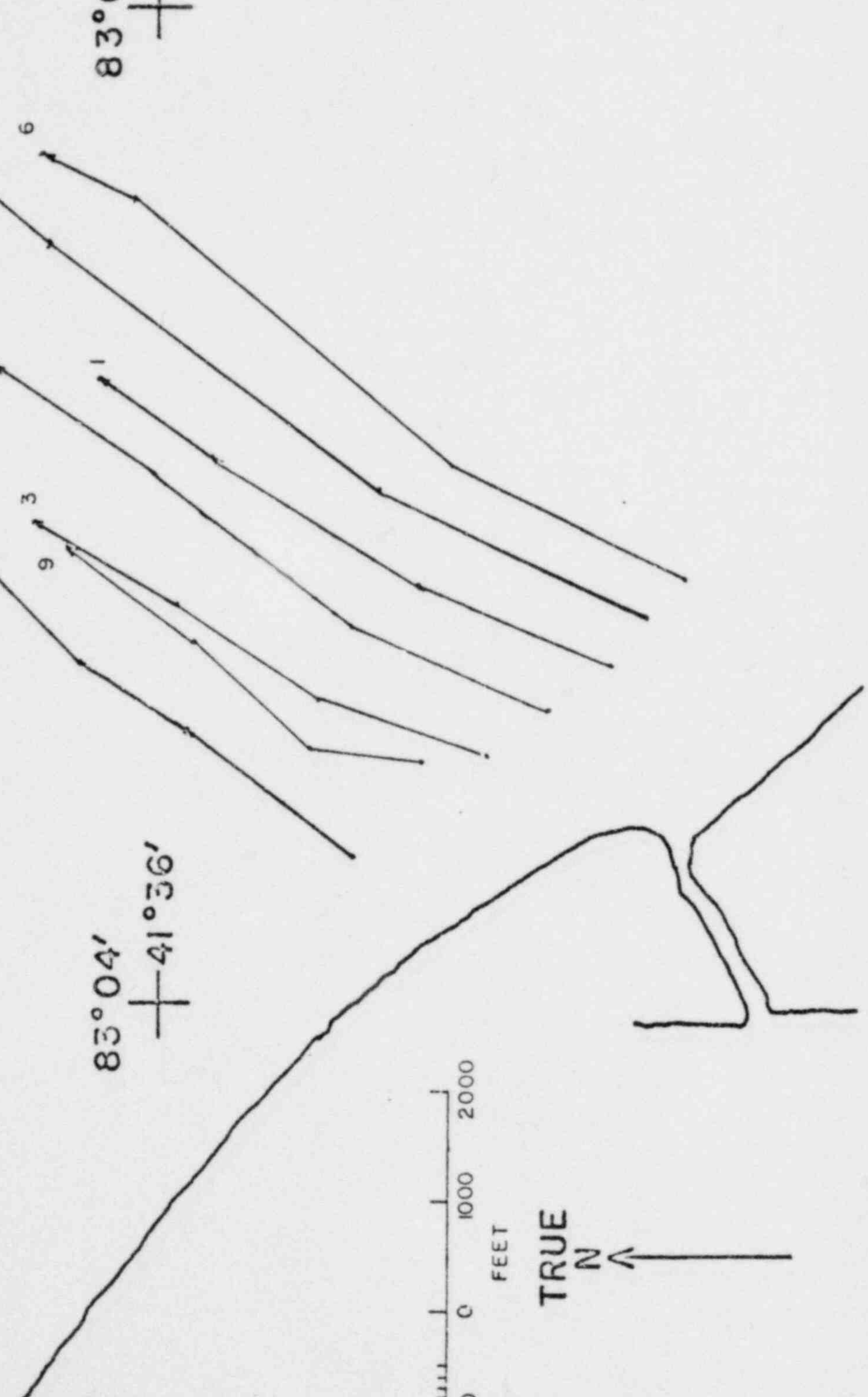

Figure 11. Pole Runs, 13 August 1968. Wind SW.

0245

Table 14. August 14, 1968. Wind - NNW 330°.

Pole no.	Distance traveled feet	Distance traveled miles	Elapsed time hr.	Elapsed time min.	Current velosity (mph)	Wind Dir. from	Wind velocity knots	Wind velocity mph
13	1950	.37	1	39	.27	330°	4-6	5-7
12	2000	.38	1	29	.29	"	"	"
10	2025	.38	1	20	.32	"	"	"
11	2175	.41	1	18	.35	"	"	"

D-B

TABLE 14, FIGURE 12, August 14, 1968, Wind - NNW 330°

0246

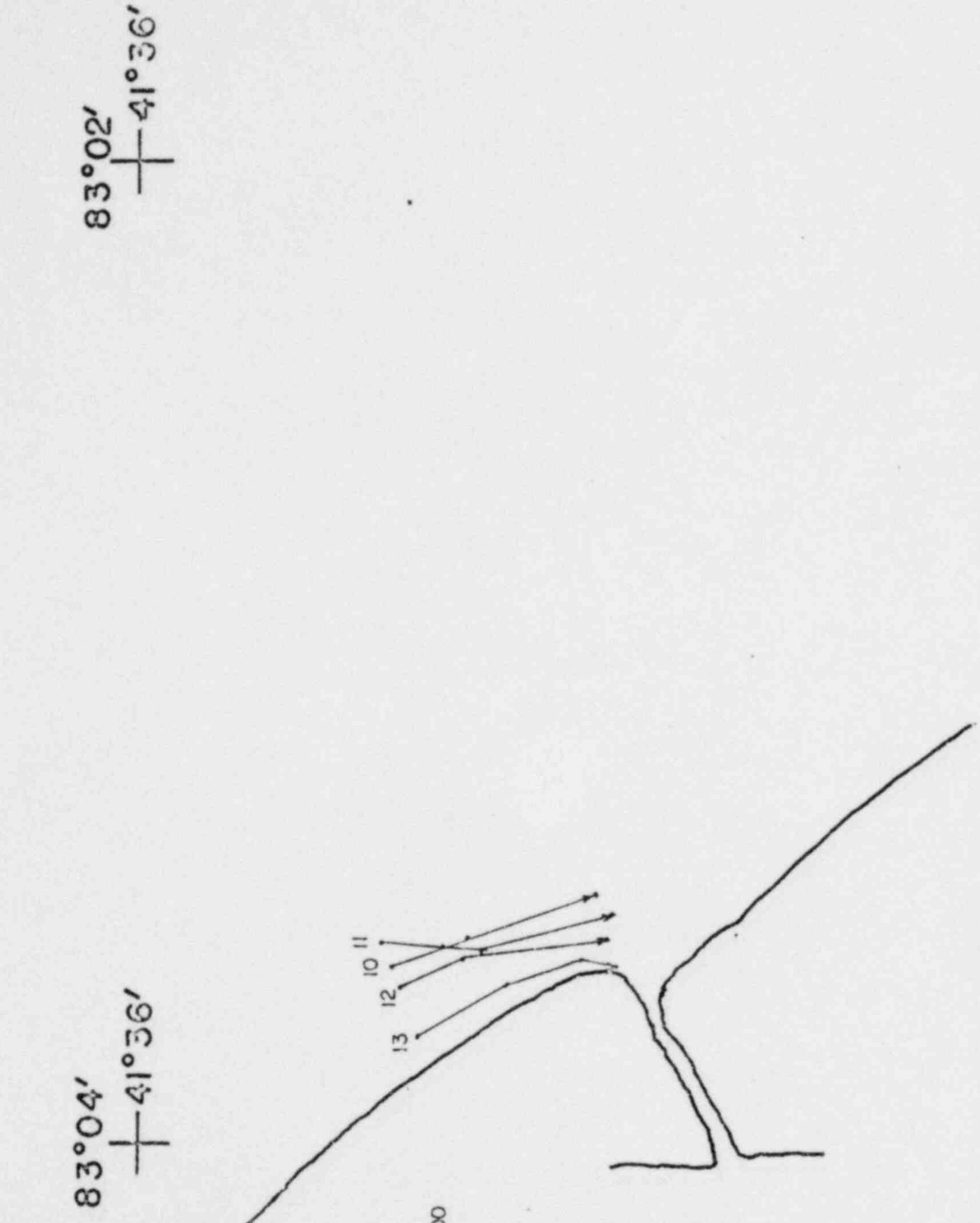

Figure 12. Pole Runs, 14 August 1968. Wind NNW.

Table 15. August 15, 1968. Wind - ENE 75°.

Pole no.	Distance traveled feet	miles	Elapsed time hr.	min.	Current velocity (mph)	Wind Dir. from	velocity knots	mph
14	8300	1.57	2	48	.63	75°	10-15	12-17
10	5650	1.07	2	17	.49	"	"	"
15	8675	1.64	3	25	.51	"	"	"
16	7225	1.37	2	31	.59	"	"	"
13	9375	1.78	3	38	.53	"	"	"

TABLE 15, FIGURE 13, August 15, 1968, Wind - ENE 75°

51

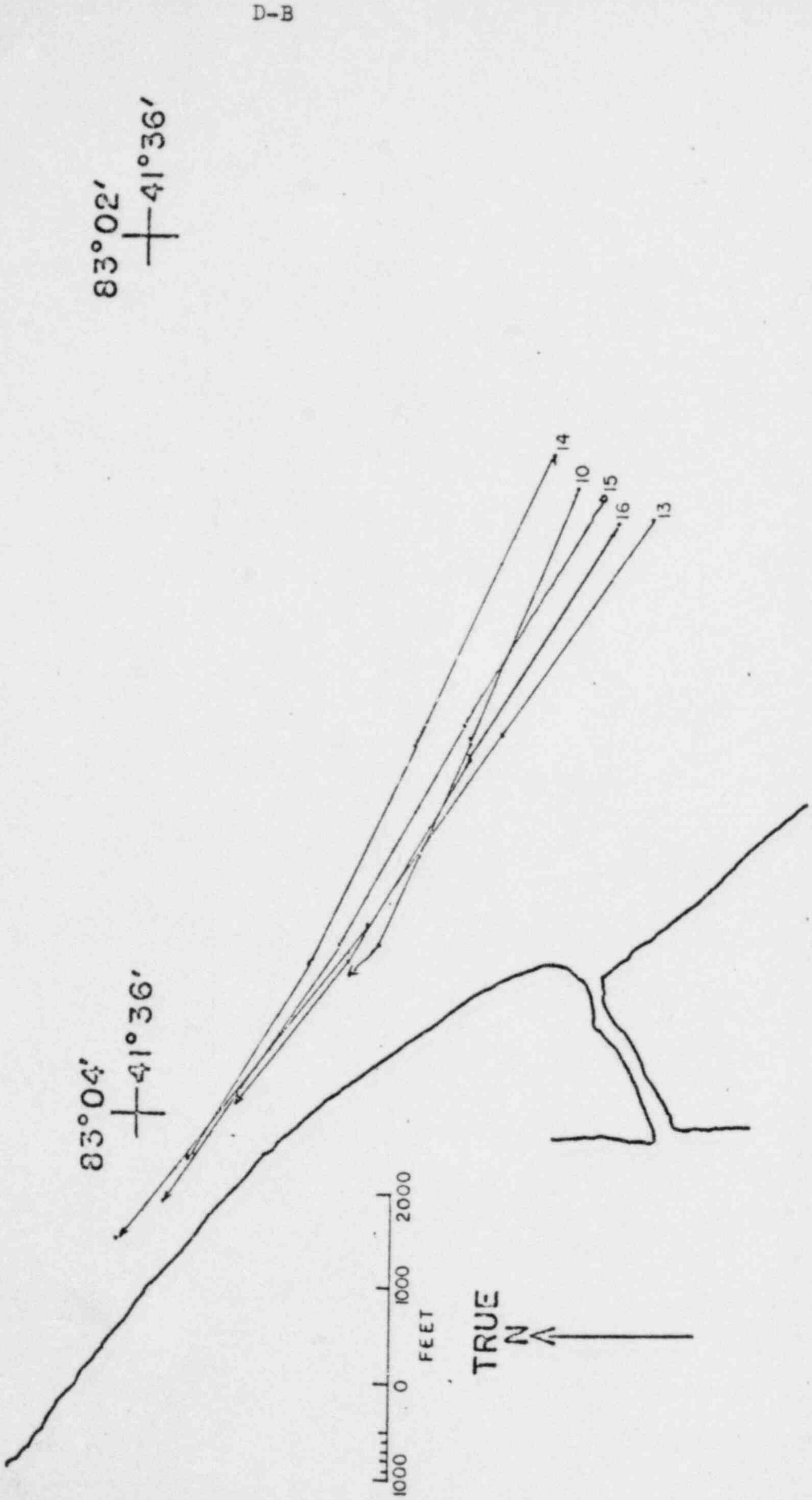

Figure 13. Pole Runs, 15 August 1968. Wind ENE.

0249

Table 16. September 6, 1968. Wind - WSW 250°.

Pole no.	Distance traveled feet	Distance traveled miles	Elapsed time hr.	Elapsed time min.	Current velocity (mph)	Wind Dir. from	Wind velocity knots	Wind velocity mph
11	6000	1.14	4	01	.28	250°	8-10	9-12
10	5800	1.10	4	18	.26	"	"	"
12	6500	1.23	4	10	.30	"	"	"

TABLE 16, FIGURE 14, September 6, 1968, Wind - WSW 250°

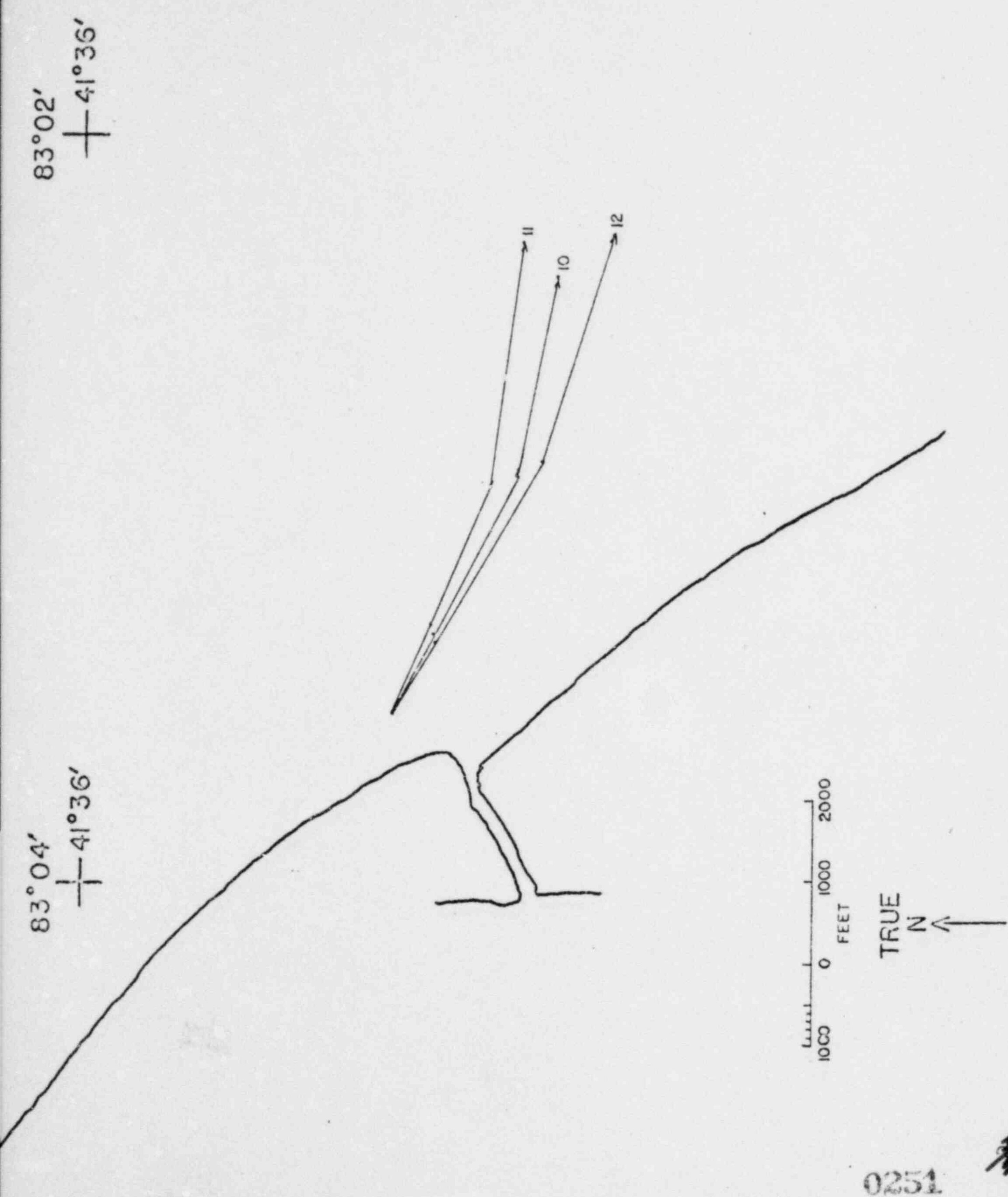

Figure 14. Polc Runs, 6 September 1968. Wind WSW.

0251

Table 17. September 10, 1968. Wind - SW 220°.

Pole no.	Distance traveled feet	Distance traveled miles	Elapsed time hr.	Elapsed time min.	Current velocity (mph)	Wind Dir. from	Wind velocity knots	Wind velocity mph
13	4250	.81	5	32	.15	220°	6-8	7-9
14	3900	.74	5	17	.14	"	"	"
15	5125	.97	5	10	.19	"	"	"
17	4550	.86	5	03	.17	"	"	"
10	3850	.73	3	57	.20	"	"	"
11	3800	.72	3	53	.20	"	"	"
12	2700	.51	4	07	.13	"	"	
16	2200	.42	3	17	.13	"	"	"

TABLE 17, FIGURE 15, September 10, 1968, Wind - SW 220°

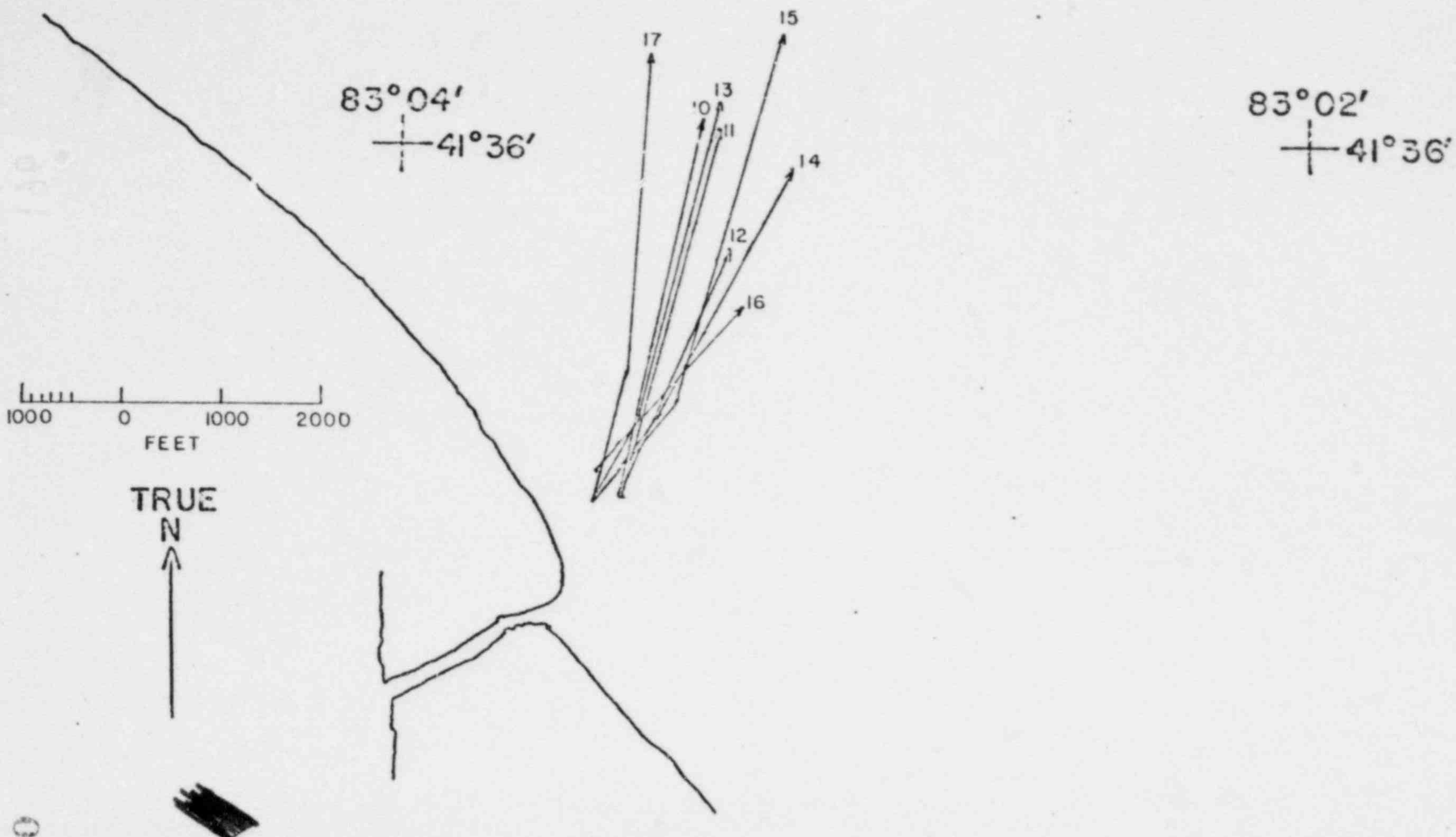

Figure 15. Pole Runs, 10 September 1968. Wind SW.

0253

Table 18. September 12, 13, 1968. Wind - NW 315°.

Pole no.	Distance traveled feet	Distance traveled miles	Elapsed time hr.	Elapsed time min.	Current velocity (mph)	Wind Dir. from	Wind velocity knots	Wind velocity mph
10	28,625	5.42	25	28	.21	315°	4-6	5-7
12	7,500	1.23	6	07	.20	"	"	"
13	32,250	6.11	26	54	.23	"	"	"
14	31,250	6.10	26	21	.23	"	"	"

TABLE 18, FIGURES 16 and 17, September 12, 13, 1968, Wind - NW 315°

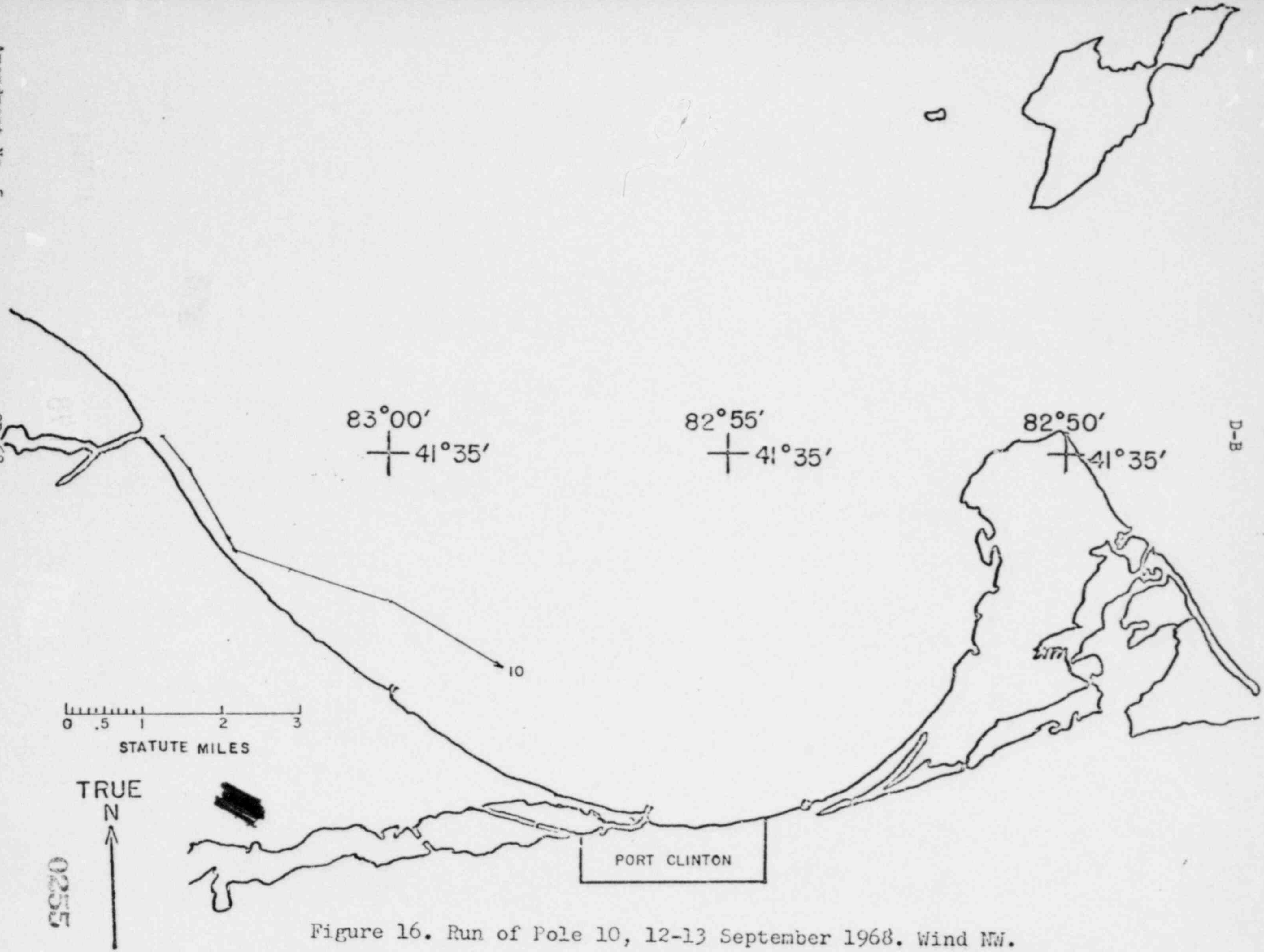

Figure 16. Run of Pole 10, 12-13 September 1968. Wind NW.

0255

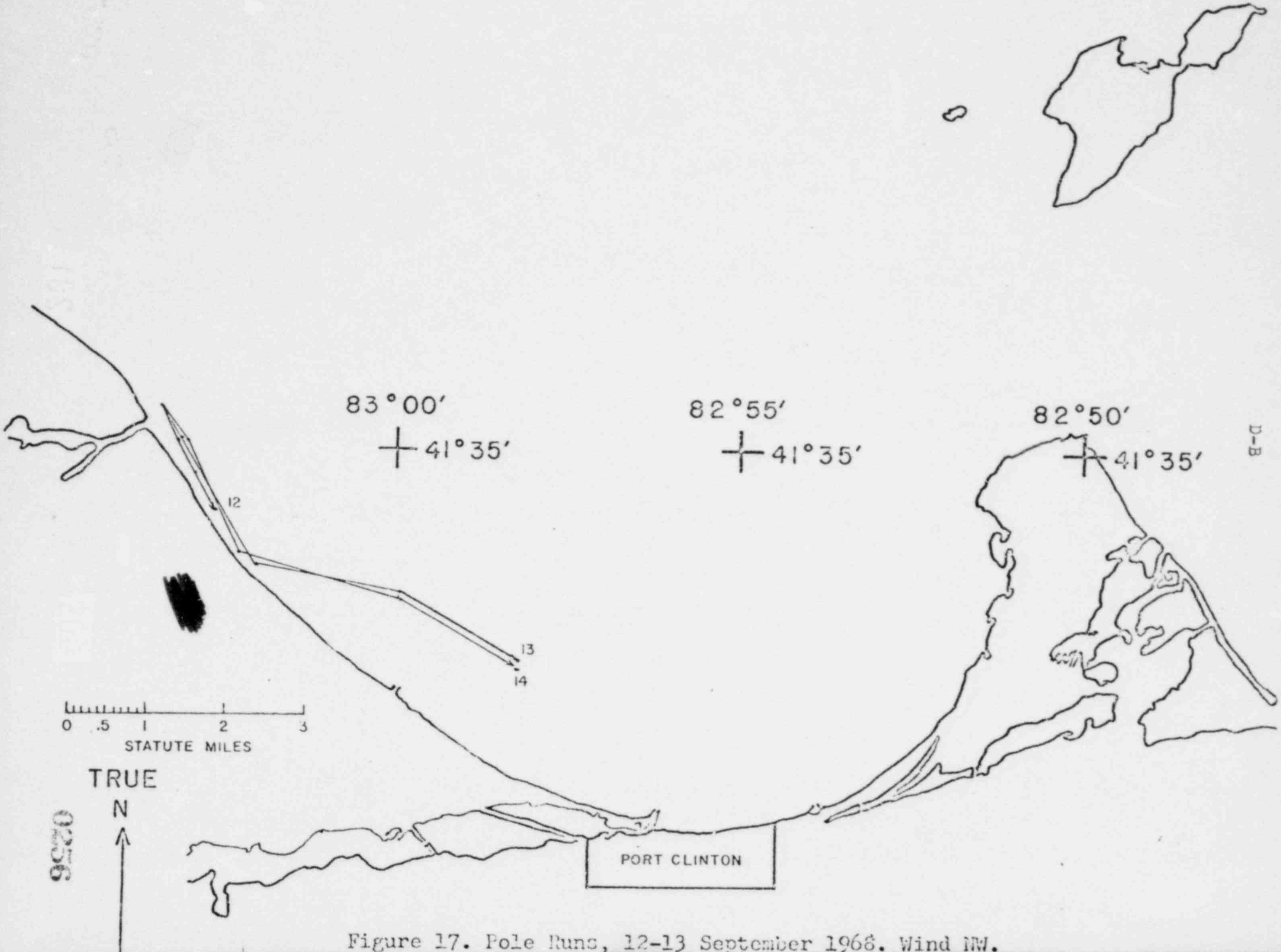

Figure 17. Pole Runs, 12-13 September 1968. Wind NW.

0256

Table 19. September 12, 1968. Wind - NW 315°.

Dye Positions	Distance traveled feet	miles	Elapsed time hr.	min.	Current velocity (mph)	Wind Dir. from	Wind velocity knots	mph
1	2640	.50	1	21	.41	315°	4-6	5-7
2	1840	.35	0	38	.92	"	"	"
3	528	.10	0	43	.23	"	"	"
4	1267	.24	0	45	.53	"	"	"

D-B

TABLE 19, FIGURE 18, September 12, 1968, Wind - NW 315°

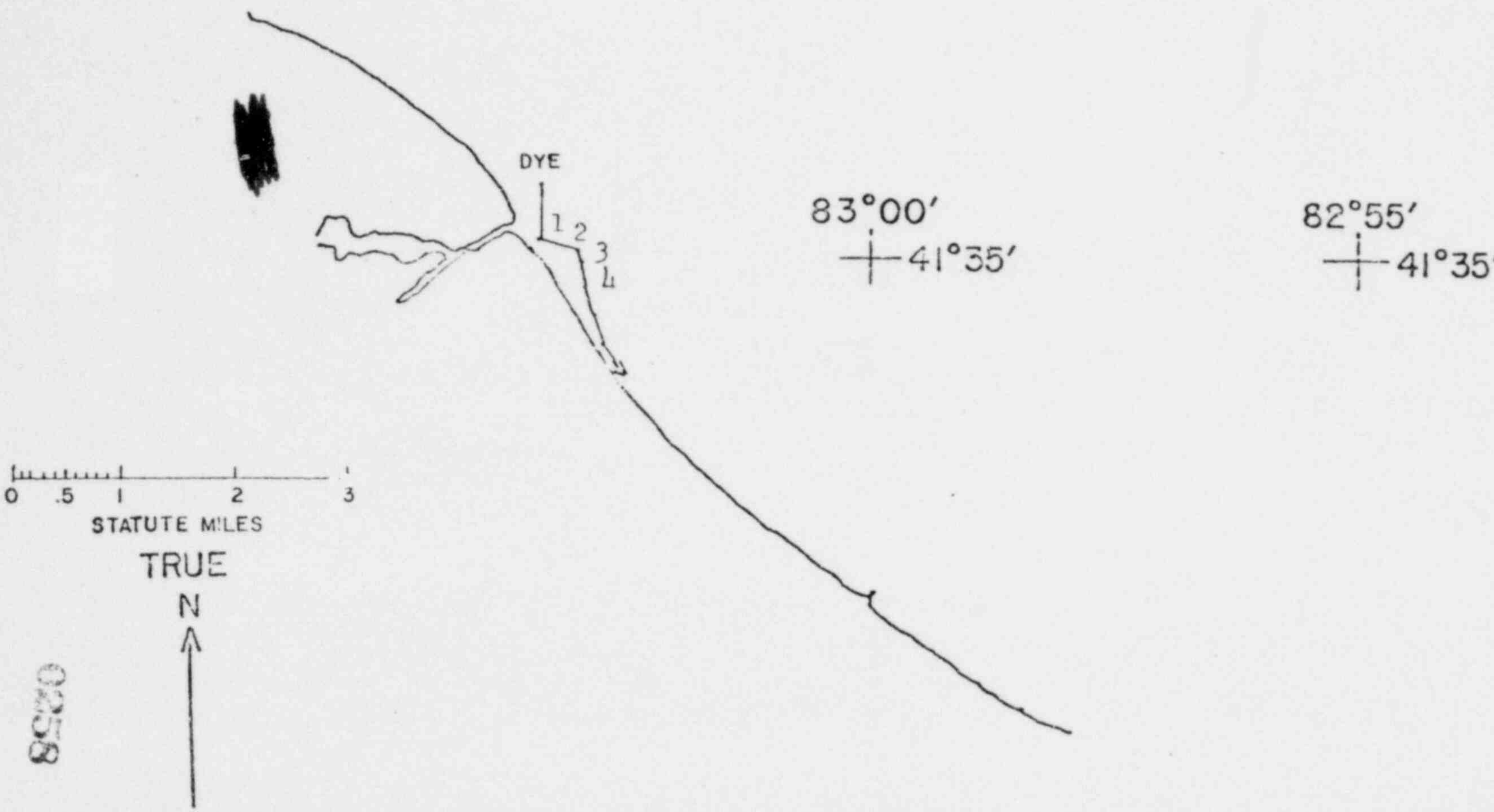

Figure 18. Dye Run, 12 September 1968. Wind NW.

Table 20. September 17, 1968. Wind - SSE 150°.

Pole no.	Distance traveled feet	miles	Elapsed time hr.	min.	Current velocity (mph)	Dir. velocity from	knots	mph
11	12,200	2.31	6	07	.38	150°	10	12
12	12,350	2.34	6	31	.37	"	"	"
16	12,475	2.36	6	21	.38	"	"	"
17	12,300	2.33	6	43	.36	"	"	"

TABLE 20, FIGURE 19, September 17, 1968, Wind - SSE 150°

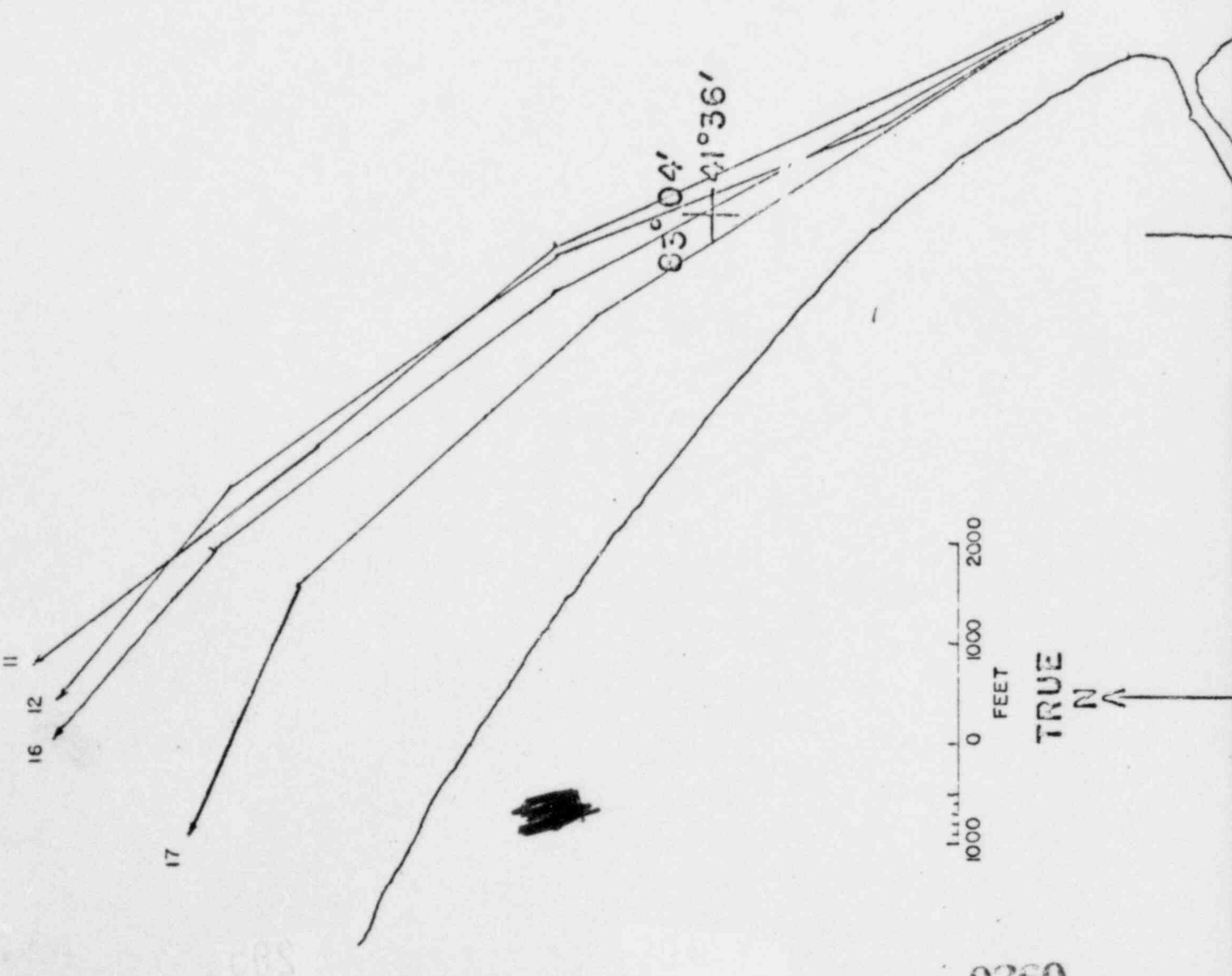

Figure 19
Pole Runs, 17 September 1968
Wind SSE

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Table 21. September 18, 1968. Wind - SSE 150°.

Pole no.	Distance traveled feet	Distance traveled miles	Elapsed time hr.	Elapsed time min.	Current velocity (mph)	Wind Dir. from	Wind velocity knots	Wind velocity mph
16	5825	1.10	2	07	.53	150°	15	17
11	5950	1.13	2	20	.51	"	"	"
17	5500	1.04	2	26	.46	"	"	"
12	5650	1.07	2	35	.46	"	"	"

TABLE 21, FIGURE 20, September 18, 1968, Wind - SSE 150°

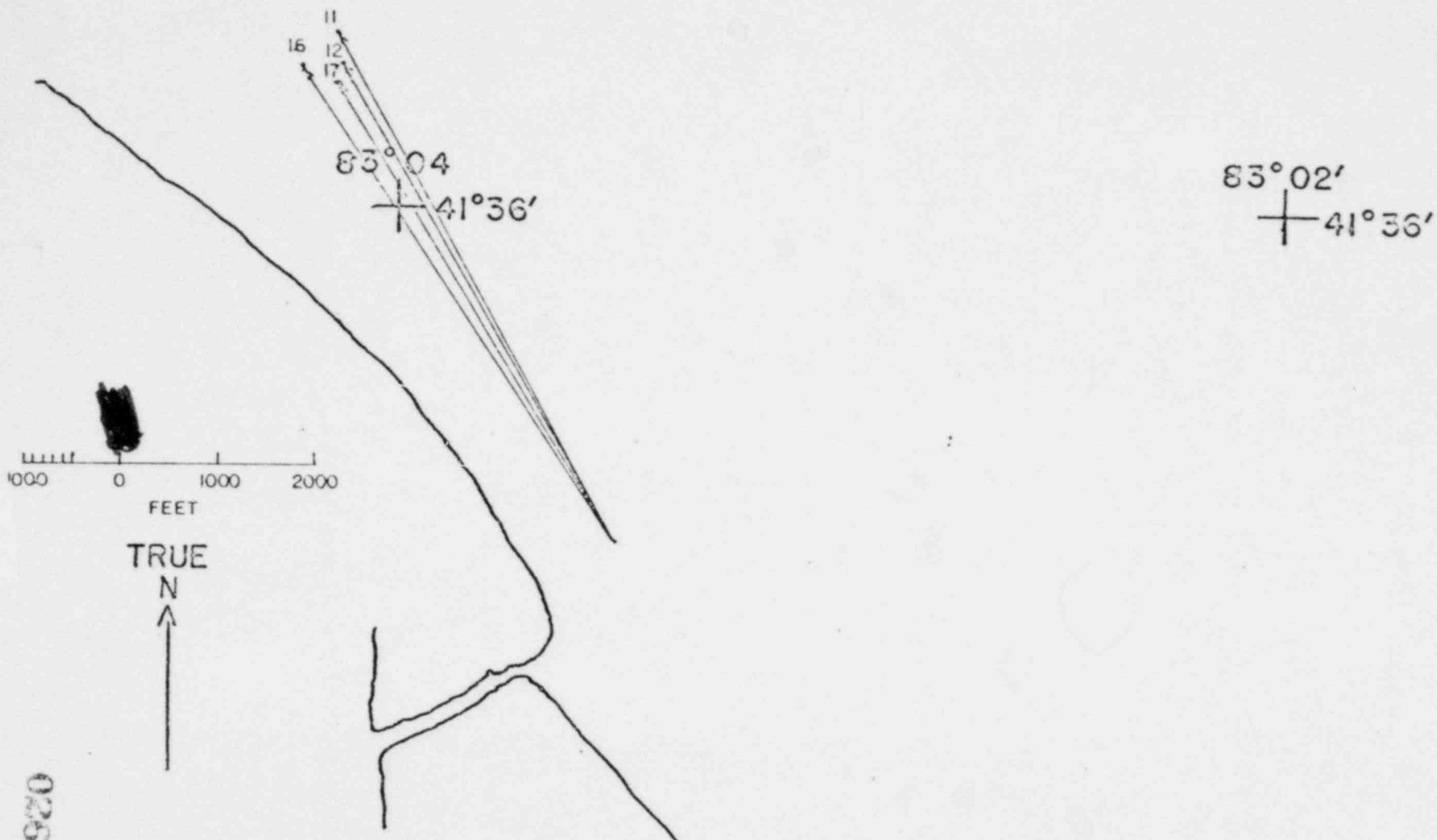

Figure 20. Pole Runs, 18 September 1968. Wind SSE.

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DYE DILUTION STUDIES IN THE LOCUST POINT REGION

Our in situ studies of natural dilution rate in the alongshore water off the plant site used the red fluorescent dye, Rhodamine B. Stock dye in a 40% solution in acetic acid was used. It has a small negative buoyancy and requires dilution with an alcohol to become neutrally buoyant. Our dye sets consisted of one quart of the dye stock diluted with six quarts of methanol antifreeze. Concentration at setting was taken to be 6%. Dilutions were made in a plastic garbage can and introduced by gently lowering the can into the water until the dye floated out. After an interval to allow surface tension effects caused by the alcohol to die away, the initial measurement of dye concentration was made by slowly coasting the boat through the visibly-heaviest part of the dye patch. Slow coasting with the screw stopped allowed the boat to pass through the dye with little if any artificial mixing. Error from rapid spreading due to the surface tension effect of the alcohol has been compensated in the calculations.

Measurements of dye concentration were made with the ultraviolet fluorometer of Noble and Ayers (Limnology and Oceanography, Vol. 6, No. 4, 1961). In this instrument the fluorescence of the dye under ultraviolet light is measured photoelectrically and converted by calibration curve to concentration of dye. Colored water of the dye patch was pumped continuously through the fluorometer during each pass through the patch. Only the highest concentration noted during each pass was recorded and used in dilution computations, to obtain the most conservative dilution figures.

The stations for setting of the dye patches were in 4-6 feet of water, between 200 ft and 1000 ft offshore from the plant outfall. We have no reason to think that dilution figures obtained off other parts of the plant property would be significantly different from those presented here (Table 22).

In Table 22 the incremental dilution between two successive passes through

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a dye patch was obtained by dividing the earlier dye concentration by the later. Each initial incremental dilution was severely rounded off to compensate for surface tension effects of the alcohol. Cumulative dilution was obtained by progressive multiplication of the incremental dilutions. After each multiplication the product was rounded to the nearest whole number before the next multiplication.

In the dye dilution experiments deliberate effort was exerted to run experiments on the calmest days possible, for low wind and minimum wave action produce least mixing and dilution, hence giving "worst condition" figures for dilution. Effort was also directed to obtaining observations under winds from as many directions as possible.

Successful dilution experiments were run on 6, 10, 12, 16, 17 and 18 September.

The alongshore current direction shown by the dye patch observed on September 12 (Table 19, and Fig. 18) is reported in the section on local currents. All the dye dilution data are summarized in Table 22.

On the basis of the data available, there appears to be a reasonable dilution rate inherent in the natural regimen of alongshore currents. The natural regimen will, however, be modified by the current created by the flow of plant effluent.

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Table 22. Results of Dye Dilution Experiments.

Time Since Set	Dye Concentration	Incremental Dilution	Cumulative Dilution
6 Sept. 1968	Wind WSW 9-12 mph	Set at regular station	
Set	6×10^{-2}		
		7000X	
1 hr. 15 min.	8.4×10^{-6}		7000X
		2.8X	
1 hr. 38 min.	3.0×10^{-6}		20000X
		1.3X	
2 hr. 01 min.	2.3×10^{-6}		26000X
		1.9X	
3 hr. 05 min.	1.2×10^{-6}		49000X
		4.0X	
3 hr. 31 min.	3.0×10^{-7}		197000X
10 Sept. 1968	Wind SW 7-9 mph	Set at regular station	
Set	6×10^{-2}		
		1500X	
1 hr. 18 min.	3.0×10^{-5}		1500X
		3.6X	
3 hr. 15 min.	8.4×10^{-6}		3400X
		2.7X	
4 hr. 08 min.	3.1×10^{-6}		10000X
		2.6X	
4 hr. 40 min.	1.2×10^{-6}		26000X
12 Sept. 1968	Wind NW 5-7 mph	Set at regular station	
Set	6×10^{-2}		
		20000X	
1 hr. 21 min.	2.9×10^{-6}		20000X
		1.1X	
1 hr. 59 min.	2.8×10^{-6}		22000X
		2.6X	
2 hr. 42 min.	1.1×10^{-6}		57000X
		1.0X	
3 hr. 27 min.	1.1×10^{-6}		57000X
16 Sept. 1968	Wind ENE 12 mph	Set at regular station	
Set	6×10^{-2}		
		10000X	
1 hr. 01 min.	5.5×10^{-6}		10000X
		2.4X	
1 hr. 28 min.	2.3×10^{-6}		24000X
		2.1X	
1 hr. 58 min.	1.1×10^{-6}		50000X
		1.0X	
2 hr. 22 min.	1.1×10^{-6}		50000X

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Table 22. (Continued)

Time Since Set	Dye Concentration	Incremental Dilution	Cumulative Dilution
17 Sept. 1968	Wind SS .2 mph	Set at regular station	
Set	6×10^{-2}		
1 hr. 05 min.	5.0×10^{-6}	10000X	10000X
1 hr. 43 min.	2.2×10^{-6}	2.3X	23000X
2 hr. 21 min.	1.1×10^{-6}	2.0X	46000X
2 hr. 51 min.	2.3×10^{-7}	4.8X	140000X
18 Sept. 1968	Wind SSE 17 mph	Set at regular station	
Set	6×10^{-2}		
1 hr. 00 min.	5.2×10^{-6}	11000X	11000X
1 hr. 30 min.	2.4×10^{-6}	2.2X	24000X
2 hr. 00 min.	1.6×10^{-6}	1.5X	36000X
2 hr. 54 min.	7.2×10^{-7}	2.3X	82000X
3 hr. 33 min.	4.6×10^{-7}	1.6X	130000X

The studies reported above were designed to measure the present-day ability of the Locust Point area to dilute conservative material batch-released in the absence of the plant's plume of effluent warmed water.

They underestimate the dilution conditions that will exist for batch releases during the presence of a warm-water plume. Diluting lake-water will be entrained into the plume at its source. The released material will travel outward through the floating plume until, along the plume perimeter, cooling breaks down the temperature-induced density gradient and the released material can "fall off the edge" of the plume into the ambient lake water along an extensive line rather than at a point source.

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COMPUTATIONS FOR A CONTINUOUS POINT-SOURCE RELEASE

This section consists of computations which were hired, because of our unfamiliarity with the model used. They were made by Dr. Joseph C-K. Huang, formerly of the University of Michigan, who is now with Scripps Institution of Oceanography at La Jolla, California. Because we cannot do so, Dr. Huang will answer questions stemming from this section. He should be addressed directly.

Per our instructions Dr. Huang has computed for that possibly unlikely case (see Figures 16 and 17) wherein a northwest wind was to hold the plant plume tightly against shore from Locust Point to well beyond the Camp Perry water intake.

Dr. Huang's results are presented verbatim below.

Estimation for Concentration Distributions for Conservative Material Released from a Continuous Point Source on the West Basin of Lake Erie

Joseph C-K. Huang

Most mathematical models describing the distribution of conservative material in a plume emanating from a continuous fixed source in the atmosphere or ocean are based on the assumptions that the turbulent field is homogeneous and stationary. The theoretical steady-plume models are deduced from the super-position of an infinite number of patch distributions in the presence of a mean current. If the flow field has a detectable mean velocity the diffusion in the direction of the current can be ignored. Furthermore, if the material distribution within any individual disk-element in the plume is assumed Gaussian, which is in general approximately the case, then the concentration at any point in a plume can be estimated by Gifford's (1959) two-dimensional model. In the lake, the mean concentration at any point

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downstream from the continuous point source is given by

$$\bar{C}\ (x,\ y,\ z) = \frac{Q}{\pi(\bar{\sigma}_y^2\ \bar{\sigma}_z^2)^{1/2}\ \bar{U}}\ \text{Exp}\ -\left[\frac{y^2}{2\bar{\sigma}_y^2} + \frac{z^2}{2\ \bar{\sigma}_z^2}\right], \tag{1}$$

where x, y, z are coordinates, x is in the direction of mean current, y is horizontal and perpendicular to the current direction, z is vertical; Q is the steady rate of discharge of conservative material from a point source in units/sec; $\bar{\sigma}^2$,s are the coordinate variances of the material distribution in cm^2; $\bar{U}$ is the mean current speed in cm/sec. Note that the above diffusion model is anisotropic.

The peak concentration on the surface of the lake is

$$\bar{C}_{max}(x) = \frac{Q}{\pi(\bar{\sigma}_y^2 \bar{\sigma}_z^2)^{1/2}\ \bar{U}} \tag{2}$$

In a stationary homogeneous turbulent field, after a long period of time the diffusivity is considered to approach asymptotically a constant.

Csanady (1964) and Okubo and Farlow (1967) studied the turbulent diffusion in the West Basin of Lake Erie and have shown the effective lateral eddy diffusivity is about 10 cm /sec to 6 x 10 cm /sec and the vertical eddy diffusivity is about 1 - 10 cm /sec. Knowing the mean velocity of the current and the longitudional distance from the source, the mean coordinate variances can be estimated from

$$\bar{\sigma}^2 = \frac{2\ Kx}{\bar{U}} \tag{3}$$

where K is the diffusivity.

During the summer of 1968, we ran patches of Rhodamine B dye near Locust Point in Lake Erie. At the same time the mean currents were measured by surface drogues. The peak concentrations of the dye patch as a function of

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time (or distance) were recorded from the fluorometer readings. The mean concentration distribution across the patch is approximately Gaussian.

As we are more interested in the concentration distribution of the conservation material in the effluent under the worst conditions, that is diffusion under an along-shore slow current, the lowest observed mean current about 10 cm/sec along the lake shore is used in this study.

The lower limit of coordinate variances for the continuous point source are taken from the variances calculated by equation (3) of the dye patch study with a lower limit value of diffusivity. Equivalently the concentrations predicted by equation (1) using the dye patch variances are the upper limit of the material concentration distributions.

Conservatively we are using the following data for the calculation of the point source concentration distributions:

$Q = 1$ unit/sec

$\overline{U} = 10$ cm/sec

$Ky = 10^3$ cm^2/sec

$Kz = 1$ cm^2/sec

Then from equation (3), the variances are

$= 2 \times 10^2$ X,

$= 0.2$ X.

The surface concentration distribution is plotted as shown in Figure 21. The concentrations along the beach (maximum conc.) and 100 m. away from the beach for each successive 1 Km downstream are listed in Table 23.

In treating the large scale diffusion phenomena, such as in this case with a large volume of discharged effluents from the power plant, it is more realistic to use the two-dimensional volume source model. In the volume source equation the variances at the origin is an essential parameter in

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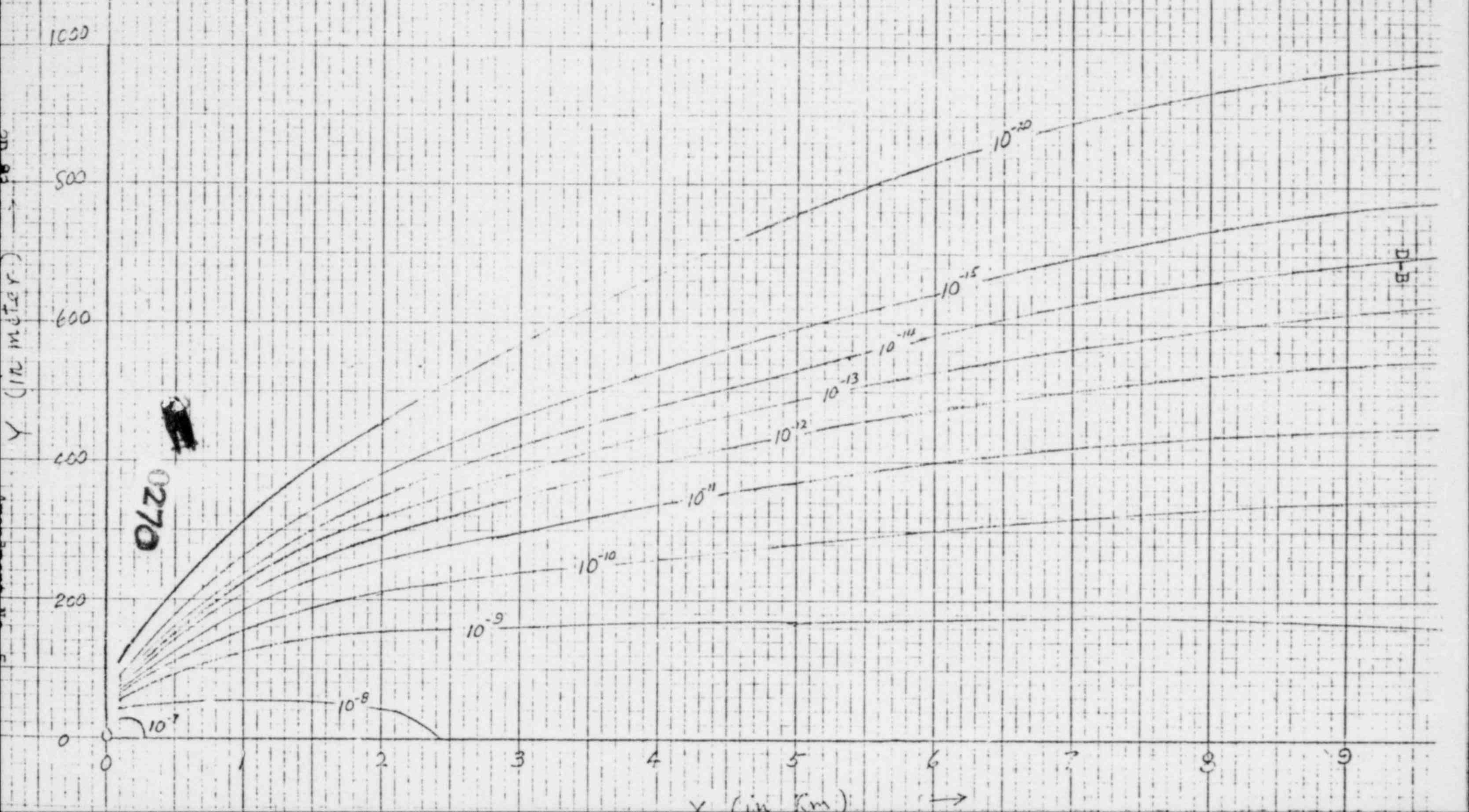
Fig. 21

Estimated Concentration Distributions From a Point Source



describing the concentration distributions. Since we have no similar survey to estimate the original variances of the volume source effluent, we cannot but use the point source equation which results in higher concentration distributions than the volume source (Foxworthy, *et al.* 1966). Note that the point source equation is not valid at the origin.

Due to our conservative estimation, using the lower limit of variance and the high concentration-predicting equation, the concentration distribution shown in Figure 21 is higher than that expected in the realistic situation in the lake away from the source.

Table 23. Surface concentration distribution along the beach and 100 meters away from the beach in the downstream direction from a unit/sec continuous point source.

Distance. X in Km	Conc. along beach	Conc. 100m. away from the beach
1/10	2.5×10^{-7}	3.5×10^{-17}
1	2.5×10^{-8}	2.1×10^{-9}
2	1.3×10^{-8}	3.6×10^{-9}
3	8.4×10^{-9}	3.6×10^{-9}
4	6.3×10^{-9}	3.4×10^{-9}
5	5.0×10^{-9}	3.1×10^{-9}
6	4.2×10^{-9}	2.8×10^{-9}
7	3.6×10^{-9}	2.5×10^{-9}
8	3.1×10^{-9}	2.3×10^{-9}
9	2.8×10^{-9}	2.1×10^{-9}
10	2.5×10^{-9}	2.0×10^{-9}

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HYDROLOGICAL SURVEYS FOR THE DAVIS-BESSE POWER STATION

THE LOCUST POINT REGION

PART III. PRELIMINARY BIOLOGICAL, FISHERIES, AND RADIOLOGICAL STUDIES

John C. Ayers
Robert F. Anderson
Norbert W. O'Hara
Dean E. Arnold
Charles C. Kidd

Under contract with

The Toledo Edison Company

Special Report No. 45
of the
Great Lakes Research Division
The University of Michigan
Ann Arbor, Michigan

January 16, 1970

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This report covers those biological and radiological studies that have been completed to date. Additional biological and chemical analyses are still in progress and will be reported when they reach completion.

The materials reported here are:

1. Locust Point
   Phytoplankton, May 1969
   Zooplankton, May 1969, October 1969
   Benthos, May 1969, October 1969

2. Enrico Fermi
   Phytoplankton, June 1969
   Zooplankton, June 1969
   Benthos, June 1969

3. Locust Point
   Preliminary assessment of fish data

4. Locust Point, Big Rock, Fermi
   Studies on radionuclide uptakes by parts of the food chain

Still being processed are the phytoplankton samples from the Locust Point survey of October. Still to be processed are bulk samples of phytoplankton, zooplankton, and benthos; these will be analysed for the stable isotopes of metals to be expected in radwaste. Heavy pressure on the analytical equipment makes it unlikely that these analyses can be carried out before March.

The three surveys here reported were carried out to investigate biological conditions at Locust Point and to give comparison data from the region of the Enrico Fermi plant at Lagoona Beach in shallow northwest Lake Erie.

Station designations were arbitrarily chosen so that they showed the survey involved. Stations bearing an LPP (Locust Point Power) indicate the May 1969 coverage of the Locust Point region. Stations labelled with PL (Point Locust) mean the October 1969 coverage of Locust Point environs. Stations headed FP (Fermi Power) designate the June 1969 survey at Fermi.

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The October Locust Point survey revisited the stations of the May survey, but the same station numbers were not retained. The station equivalency is as follows:

LPP-1 = PL-19	LPP-9 = PL-17
LPP-2 = PL-11	LPP-10 = PL-16
LPP-3 = PL-12	LPP-11 = PL-2
LPP-4 = PL-9	LPP-12 = PL-3
LPP-5 = PL-8	LPP-13 = PL-20
LPP-6 = PL-18	LPP-14 = PL-14
LPP-7 = PL-6	LPP-15 = PL-15
LPP-8 = PL-5	

The same station designations were used by C. Kidd in parts of the radiological studies which are reported below.

The surveys were in spring and fall to avoid the height of summer when emergent species of the benthos temporarily reduce the benthos by their nuptial flights. By fall the offspring of the mating flights are again back in the benthic community.

PRELIMINARY RESULTS

Although our studies of the data are far from complete, there are certain preliminary results that can be reported at this time.

<u>May Phytoplankton, Locust Point</u>:

Stations LPP-1, LPP-6, and LPP-9 immediately along the front of the plant property had relatively low phytoplankton counts, though lower ones occurred at stations off the mouth of the Toussaint River and off Camp Perry.

<u>May and October Zooplankton, Locust Point</u>:

In general, May zooplankton counts over the whole area tended to be higher and October counts tended to be low. As a rough index the sum of the numbers present <u>in both months</u> in the duplicated stations of both cruises has been used. When the catches are summed, the least total is 37.50 organisms per liter for Station LPP-6 (= PL-18); followed by 41.40 at Station LPP-9 (= PL-17); then

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46.09 for LPP-3 (= PL-12); with 69.39 at LPP-15 (= PL-15); and 76.51 at LPP-1 (= PL-19); the remaining duplicated stations have substantially higher combined counts. Except for station 15, the low values are along the shore of the plant property.

<u>May and October Benthos, Locust Point</u>:

Benthos in the Locust Point region are sparse compared to areas further offshore. This is attributable to wave action which winnows out finer sediments and detrital food materials.

In the inshore stations most apt to be effected by the plant discharge (LPP-1, 6, 9, 13, 2, and 3; PL-19, 10, 18, 7, 17 and 4) the benthos are exceedingly sparse.

<u>June Phytoplankton, Fermi</u>:

In summary the phytoplankton types off the Fermi plant were about the same as those off Locust Point. There were some additional genera and species at some of the Fermi stations, which may be related to the direct influence of the Detroit River. Phytoplankton cell counts per liter were consistently lower than at Locust Point, probably reflecting the greater degree of pollution in the Detroit area.

<u>June Zooplankton, Fermi</u>:

Except at station FP-1 which is in Brest Bay about 6 miles from Fermi, the zooplankton of the area were very rare. Again, this appears to be a reflection of pollution in the area.

<u>June Benthos, Fermi</u>:

At Fermi only the Sphaeriids (finger nail clams) and the pollution-tolerant oligochaetes were more numerous than at Locust Point. The clean-water loving amphipods were practically absent from the Fermi region.

SUMMARY STATEMENT

Preliminary assessments of the biological data now worked up show that the inshore waters at Locust Point are, compared to regions further offshore, a sort of "biological desert" only sparsely inhabited by plankton and benthos. Such is also true at other plant sites we have studied.

Preliminary examination of the fishery data available, suggests that the sampling stations used are too far from Locust Point and too far offshore to be adequately representative of fish populations close to the Point. This conclusion is preliminary and may be modified by further study. It may be significant that local fishermen reduce or cease their operations at Locust Point during the height of the summer "because the fish leave the area" (Ohio Division of Wildlife).

Present evidence, though incomplete, suggests that in the critical peak-of-summer condition there are but few biological organisms present to be damaged in the area of the plant outfall where the greatest of waste heat will exist.

Comparative studies in the Fermi region are disappointing because they predominately indicate the polluted nature of the area.

In radiological studies presently completed the amphipod, Pontoporeia affinis, shows a greater affinity for zinc-65 than for cerium-144, manganese-54, cesium-137, zirconium-95, ruthenium-106, or strontium-90. Uptake of zinc and strontium was enhanced somewhat when the amphipod was cultured with sediment in the aquarium.

Lake Erie chironomids (tendepedidae) and oligochaetes when similarly cultured with sediments also showed their affinities for zinc-65 to be greater than for manganese-54, cesium-137, or strontium-85.

Lake Erie clams similarly cultured had soft-tissue affinities for cesium-137 greater than for zinc, manganese, or strontium. Clam shell appeared to concentrate both cesium and manganese more readily than the others.

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Despite the fact that Fermi has operated nuclear there are no significant differences in gross beta activity or cesium-137 activity between Fermi and Locust Point sediments.

Amphipods captured in the vicinity of the Big Rock reactor showed small increases in gross gamma and gross beta activities in a limited area in front of the plant.

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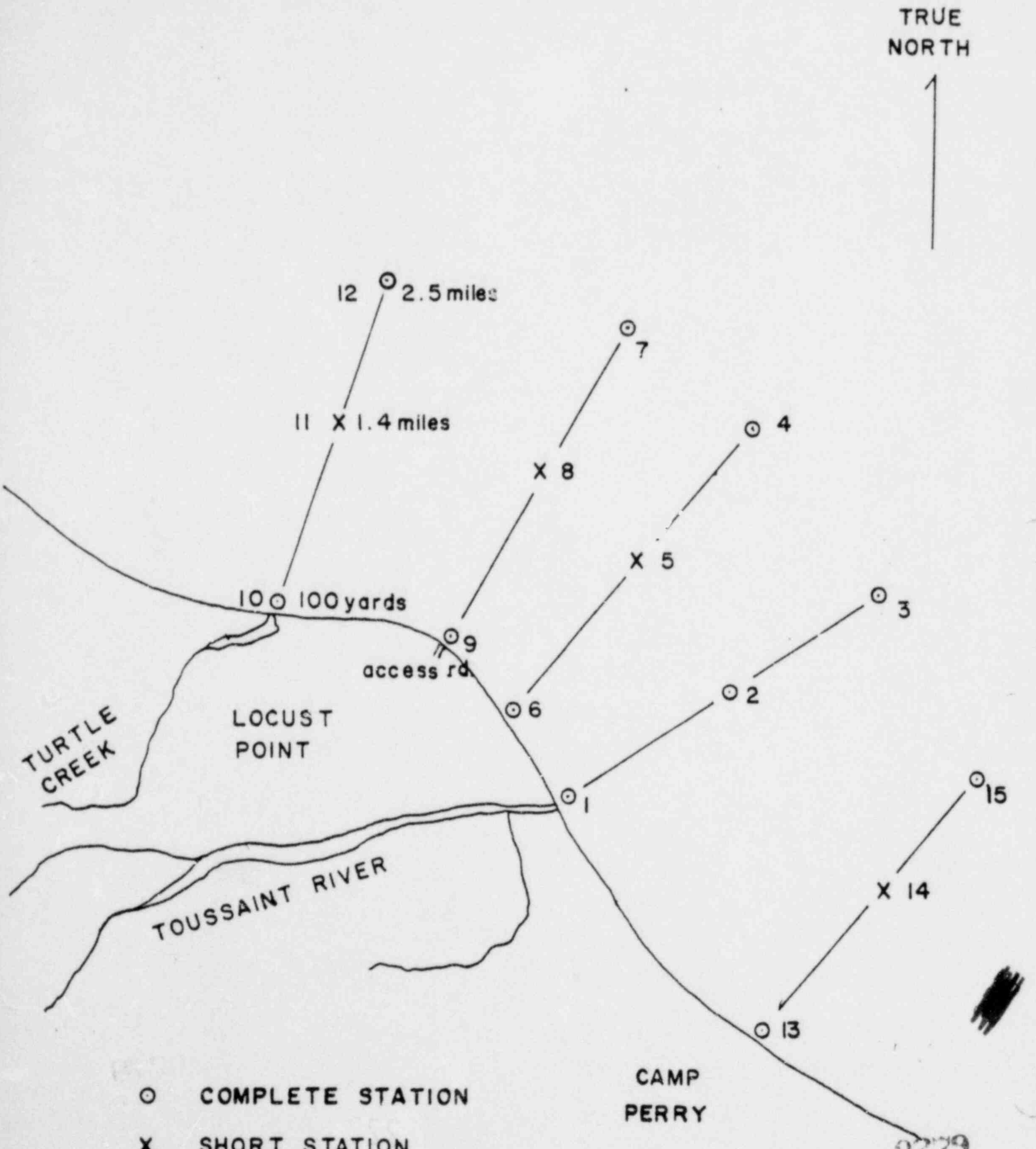
STATION MAP OF LOCUST POINT PROJECT

MAY 1969, SAMPLING



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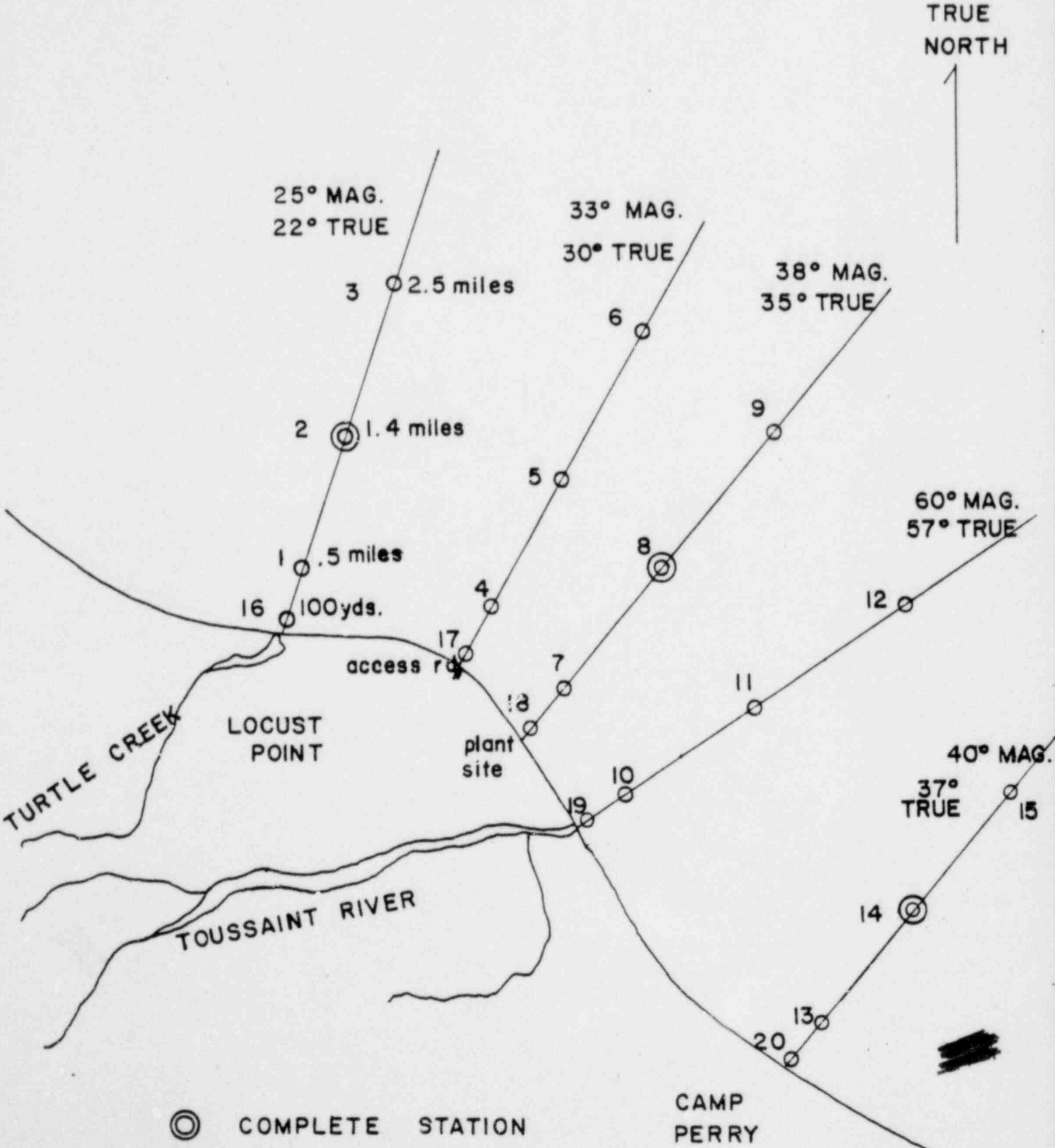
STATION MAP OF LOCUST POINT

OCTOBER 1969, SAMPLING



◎ COMPLETE STATION

○ SHORT STATION

Phytoplankton Population
Locust Point, 15-16 May 1969

Diatoms

- Diatoma tenuis v. elongata
- Melosira binderana
- Melosira granulata
- Synedra ulna
- Synedra acus
- Fragilaria intermedia
- Fragilaria capucina
- Fragilaria crotonensis
- Asterionella formosa
- Cyclotella spp
- Navicula spp
- Tabellaria fenestrata
- Surirella spp
- Nitzschia spp
- Stephanodiscus spp
- Cymbella spp
- Gomphonema spp

Greens

- Ulothrix spp
- Pediastrum duplex
- Scenedesmus abundans
- Scenedesmus quadricauda
- Dictyosphaerium pulchellum
- Ankistrodesmus spp
- Ankistrodesmus falcatus
- Scenedesmus spp
- Micractinium pusillium
- Oocystis solitaria
- Lagerheimia longiseta
- Golenkinia radiata
- Actinastrum Hantzschii
- Closteriopsis longissima

Blue Greens

- Oscillatoria spp

D-B

Phytoplankton

Station LPP-1, Locust Point
15 May 1969

Organism	No. of Colonies	Cell per Liter
Oscillatoria spp		3,747
Fragilaria crotonensis	1,874	51,524
Ankistrodesmus falcatus		937
Diatoma tenuis v. elongata	42,156	287,598
Melosira binderana	66,513	526,482
Asterionella formosa	6,558	49,651
Fragilaria capucina	49,651	2,243,636
Cyclotella spp		7,494
Navicula spp		937
Oocystis solitaria		937
Scenedesmus quadricauda		937
Synedra ulna		937
Tabellaria fenestrata	4,684	30,914
Surirella spp		937

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Phytoplankton

Station LPP-2, Locust Point
15 May 1969

Organism	No. of Colonies	Cells per Liter
Synedra ulna		17,666
Synedra acus		6,625
Tabellaria fenestrata	2,208	15,458
Pediastrum duplex		2,208
Melosira binderana & M. granulata combined	516,742	4,891,385
Diatoma tenuis v. elongata	99,374	1,355,896
Asterionella formosa	24,291	249,538
Fragilaria crotonensis	4,417	117,040
Fragilaria capucina	105,998	5,284,462
Cyclotella		6,625
Scenedesmus abundans		2,208
Oocystis solitaria		2,208
Oscillatoria spp		2,208

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Phytoplankton

Station LPP-3, Locust Point
15 May 1969

Organism	No. of Colonies	Cells per Liter
Diatoma tenuis v. elongata	47,917	242,675
Oscillatoria spp		1,546
Ulothrix spp		1,546
Melosira binderana	61,828	930,512
Synedra acus		4,637
Synedra ulna		6,183
Fragillaria intermedia	17,003	630,646
Fragillaria capucina	4,637	98,925

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Phytoplankton

Station LPP-4, Locust Point
15 May 1969

Organism	No. of Colonies	Cells per Liter
Synedra ulna		13,138
Tabellaria fenestrata	10,049	57,202
Diatoma tenuis v. elongata	66,478	672,510
Melosira binderana & M. granulata combined	202,526	937,649
Fragilaria crotonensis	1,546	58,748
Asterionella formosa	17,006	135,275
Fragilaria capucina	85,030	3,237,324
Lagerheimia longiseta		773
Golenkinia radiata		773
Cyclotella spp		3,865
Oscillatoria spp		2,319
Dictyosphaerium pulchellum		1,546
Scenedesmus quadricauda		773
Synedra acus		2,319

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Phytoplankton

Station LPP-6, Locust Point
15 May 1969

Organism	No. of Colonies	Cells per Liter
Fragilaria crotonensis	2,132	14,924
Surirella spp		1,066
Synedra ulna		6,396
Synedra acus		1,066
Dictyosphaerium pulchellum		1,066
Ankistrodesmus spp		1,066
Oscillatoria spp		2,132
Tabellaria fenestrata	7,462	33,046
Diatoma tenuis v. elongata	74,620	380,562
Melosira binderana & M. granulata combined	105,534	891,176
Fragilaria capucina	49,036	1,557,426
Scenedesmus abundans		1,066
Closteriopsis longissima		1,066

Phytoplankton

Station LPP-7, Locust Point
15 May 1969

Organism	No. of Colonies	Cells per Liter
Synedra ulna		4,936
Surirella sp		997
Oocystis solitaria		997
Melosira binderana & M. granulata combined	101,714	622,253
Diatoma tenuis v. elongata	50,857	283,205
Asterionella formosa	9,972	81,770
Tabellaria fenestrata	3,989	12,964
Fragilaria capucina	49,860	1,471,867
Micractinium pusillum		1,994
Oscillatoria spp		1,994

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Phytoplankton

Station LPP-9, Locust Point
15 May 1969

Organism	No. of Colonies	Cells per Liter
Oscillatoria spp		5,888
Micractinium pusillum		1,472
Scenedesmus quadricauda		1,472
Synedra ulna		8,832
Cyclotella spp		10,304
Gomphonema sp		1,472
Stephanodiscus spp		2,944
Synedra acus		7,360
Melosira binderana & M. granulata combined	113,344	1,149,632
Asterionella formosa	5,888	27,968
Tabellaria fenestrata	1,472	8,832
Diatoma tenuis v. elongata	75,072	450,432
Fragilaria crotonensis	2,944	79,488
Fragilaria capucina	41,216	585,856

0288

Phytoplankton

Station LPP-10, Locust Point
16 May 1969

Organism	No. of Colonies	Cells per Liter
Fragilaria crotonensis	6,183	74,191
Synedra acus		15,457
Synedra ulna		6,183
Oscillatoria spp		15,457
Melosira binderana & M. granulata combined	420,417	3,159,309
Fragilaria capucina	108,196	2,550,323
Scenedesmus spp		3,091
Cyclotella spp		9,274
Ankistrodesmus falcatus		3,091
Nitzschia spp		9,274
Diatoma tenuis v. elongata	272,034	1,415,815
Asterionella formosa	12,365	83,465
Tabellaria fenestrata	6,183	27,823

0289

Phytoplankton

Station LPP-12, Locust Point
16 May 1969

Organism	No. of Colonies	Cells per Liter
Synedra ulna		4,314
Oscillatoria spp		6,470
Actinastrum Hantzschii		2,157
Diatoma tenuis v. elongata	42,058	208,131
Melosira binderana & M. granulata combined	73,331	815,270
Asterionella formosa	4,314	38,822
Tabellaria fenestrata	5,392	20,490
Fragilaria capucina	21,570	628,707
Scenedesmus abundans		1,078
Cyclotella		3,235

0230

Phytoplankton

Station LPP-13, Locust Point
16 May 1969

Organism	No. of Colonies	Cells per Liter
Scenedesmus quadricauda		1,546
Oscillatoria spp		12,368
Stephanodiscus spp		9,276
Synedra acus		10,822
Dictyosphaerium pulchellum		6,184
Ankistrodesmus spp		3,092
Actinastrum Hantzschii		3,092
Cyclotella spp		9,276
Micractinium pusillum		3,092
Synedra ulna		6,184
Tabellaria fenestrata	6,184	30,920
Diatoma tenuis v. elongata	123,680	1,004,900
Melosira binderana & M. granulata combined	536,462	5,468,202
Fragilaria capucina	40,196	1,456,332
Cymbella sp		1,546
Asterionella formosa	4,638	30,920

0291

Phytoplankton

Station LPP-15, Locust Point
15 May 1969

Organism	No. of Colonies	Cells per Liter
Oscillatoria spp		6,624
Ankistrodesmus spp		2,208
Navicula sp		1,104
Synedra acus		4,416
Fragilaria crotonensis	1,104	37,536
Melosira binderana & M. granulata combined	59,616	623,760
Diatoma tenuis v. elongata	44,160	195,408
Tabellaria fenestrata	9,936	40,848
Asterionella formosa	1,104	11,040
Fragilaria capucina	28,704	1,065,360
Synedra ulna		2,208
Cyclotella spp		6,624
Closteriopsis longissima		1,104

0292

POWER PLANT SURVEYS - PRIMARY ZOOPLANKTON COUNTS - LOCUST POINT, LAKE ERIE (NO. ORG./LITER)

	LPP-1 5/15/69	PL-19 (=LPP-1) 10/29/69	LPP-3 5/15/69	PL-12 (=LPP-3) 10/21/69	LPP-4 5/15/69	PL-9 (=LPP-4) 10/21/69	LPP-6 5/15/69	PL-18 (=LPP-6) 10/29/69	LPP-7 5/15/69	PL-6 (=LPP-7) 10/24/69
CALANOID COPEPODS:										
Diaptomus sp.	3.82	0.71	2.76	0.40	4.21	0.48	1.37		7.43	0.15
Eurytemora affinis		0.59		0.20				0.13		0.46
Others										
CYCLOPOID COPEPODS	29.72	3.18	14.60	3.69	33.97	4.96	10.88	0.47	77.86	2.39
ROTIFERS:										
Asplanchna sp.	3.47	0.12	1.75	0.30	1.81	0.48	2.05		5.99	
(Others too small for this net)										
CLADOCERA:										
Daphnia retrocurva	15.62	1.06	5.51	0.66	34.66	0.31	14.47	0.13	46.33	0.25
Other Daphnia	0.20	0.12	0.13	0.07	0.08		0.06		0.20	
Bosmina sp.	3.20	13.55	4.24	11.23	4.09	10.70	3.76	3.48	5.15	4.62
Chydorus sphaericus	0.13		0.13		0.04			0.07		
Ceriodaphnia reticulata										
Leptodora kindtii	0.27	0.12	0.35	0.03	0.84	0.04	0.63		0.98	
Sida crystallina										
OTHER GROUPS:	0.51	0.12	0.04		0.04					Hydra 0.05
(Ostracods unless otherwise noted)										
REMARKS:								Very dirty sample		

D-B

0293

POWER PLANT SURVEYS - PRIMARY ZOOPLANKTON COUNTS - LOCUST POINT, LAKE ERIE (NO. ORG./LITER)

	LPP-9 6/15/69	PL-17 (=LPP-9) 10/29/69	LPP-10 5/16/69	PL-16 (=LPP-10) 10/28/69	LPP-12 5/16/69	PL-3 (=LPP-12) 10/24/69	LPP-13 5/16/69	PL-20 (=LPP-13) 10/29/69	LPP-15 5/16/69	PL-15 (=LPP-15) 10/27/69
CALANOID COPEPODS:										
Diaptomus sp.	1.65		3.76	0.62	6.51	0.04	28.77	0.15	5.63	0.37
Eurytemora affinis		0.71		1.87		0.32		0.53		0.51
Others										
CYCLOPOID COPEPODS	9.97	0.59	42.34	3.50	56.55	1.56	132.80	2.05	53.53	1.11
ROTIFERS:										
Asplanchna sp.	1.24	0.12	12.62	0.19	1.11		0.23	0.30	1.83	0.03
(Others too small for this net)										
CLADOCERA:										
Daphnia retrocurva	8.16	0.82	22.87	2.74	12.30	0.28	4.49	0.38	1.90	0.10
Other Daphnia					0.08				0.10	
Bosmina sp.	2.95	13.67	8.01	30.53	2.87	6.94	19.79	14.94	2.47	1.01
Chydorus sphaericus	0.03									0.03
Ceriodaphnia reticulata			0.06					0.15		
Leptodora kindtii	1.49		3.46	0.05	0.34		0.12	0.15	0.07	0.03
Sida crystallina										
OTHER GROUPS: (Ostracods unless otherwise noted)									0.67	

REMARKS:

POWER PLANT SURVEYS - PRIMARY ZOOPLANKTON COUNTS - LOCUST POINT, LAKE ERIE (NO. ORG./LITER)

	PL-1 fall only 10/24/69	PL-2 fall only 10/24/69	PL-4 fall only 10/24/69	PL-5 fall only 10/24/69	PL-7 fall only 10/21/69	PL-8 fall only 10/21/69	PL-10 fall only 10/21/69	PL-11 fall only 10/21/69	PL-13 fall only 10/20/69	PL-14 fall only 10/20/69
CALANOID COPEPODS:										
Diaptomus sp.	0.69	0.06	0.04		0.56	0.57	0.30	0.16	0.57	0.38
Eurytemora affinis		0.44	0.84	0.67	0.11	0.08		0.06	0.04	0.05
Others										
CYCLOPOID COPEPODS	2.71	0.25	1.52	0.28	7.89	2.62	3.28	0.94	2.53	2.10
ROTIFERS:										
Asplanchna sp.	0.13	0.06	0.11		0.11	0.11		0.28	0.26	0.14
(Others too small for this net)										
CLADOCERA:										
Daphnia retrocurva		0.57	0.19	0.39	0.61	0.27	0.55	0.31	1.09	1.39
Other Daphnia										
Bosmina sp.	7.24	4.05	9.53	3.15	15.61	7.22	7.07	3.56	11.04	11.09
Chydorus sphaericus										
Ceriodaphnia reticulata										
Leptodora kindtii			0.08							
Diaphanosoma leuchtenbergianum	0.06									
OTHER GROUPS:										
(Ostracods unless otherwise noted)										

REMARKS:

D-B

0235

LOCUST POINT POWER PROJECT

Benthos Data

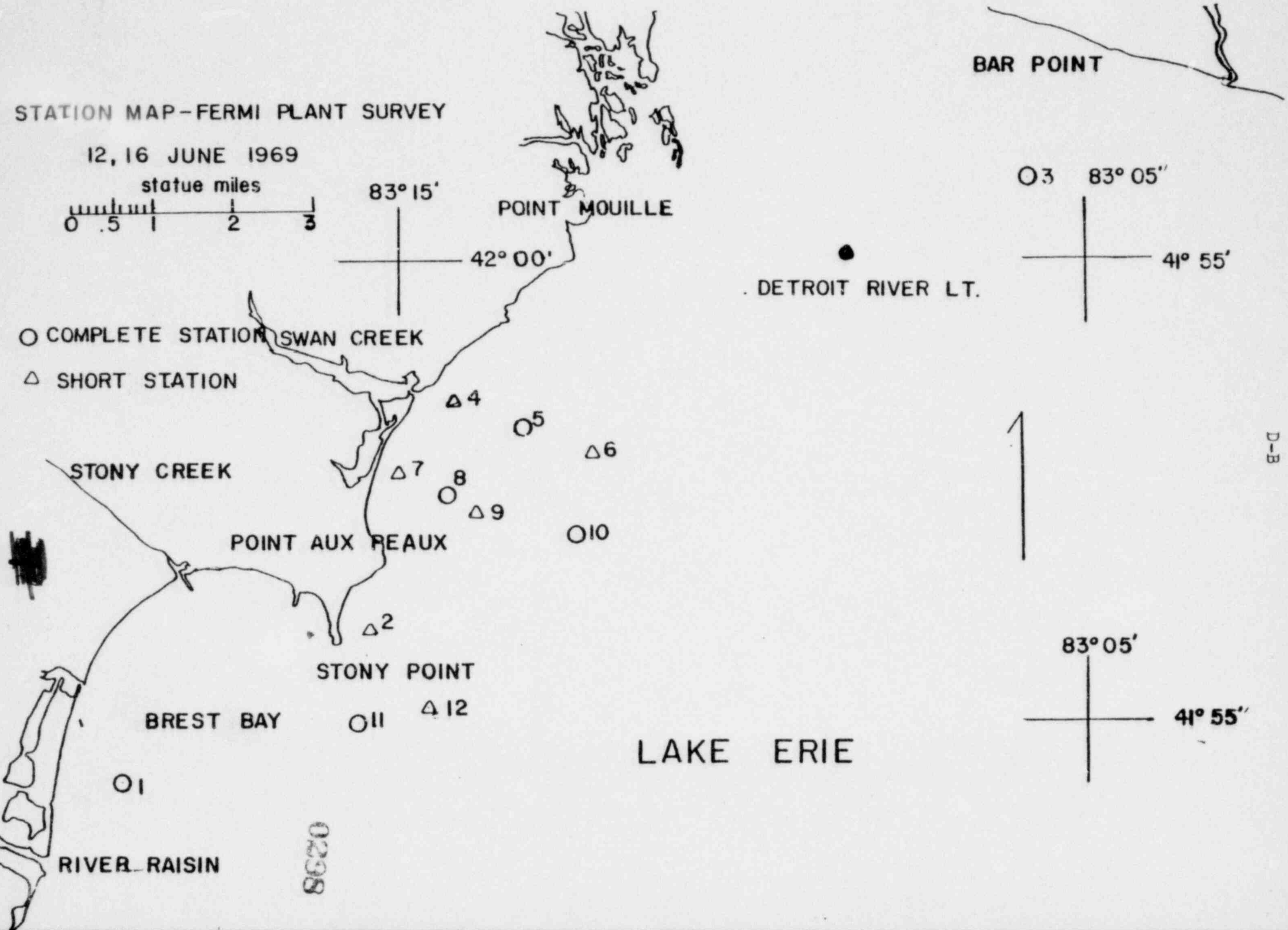
Station Number	Date	Organisms per meter^2: Amphipods	Oligochaetes	Sphaeriidae	Tendipedidae	Other		Ratio: Amphi/Oligo
LLP-1	5/15/69	0	4877	17	965	Snail	52	0
-2	5/15/69	26	5364	26	1165	0		0.0048
-3	5/15/69	0	86	0	43	Snail shells		0
-4	5/15/69	8	1452	34	991	Daphnia	26	0.0059
-5	5/15/69	52	2269	34	565	Daphnia	17	0.0229
-6	5/15/69	0	26	0	78	Snail	17	0
						Cyclops	43	
						Copepod	8	
-7	5/15/69	26	2399	121	39	Cyclops	113	0.0108
						Daphnia	443	
						Snail	339	
-8	5/15/69	52	1217	17	286	Cyclops	43	0.0428
						Daphnia	34	
						Snail	782	
-9	5/15/69	17	165	0	199	Daphnia	43	0.1052
						Cyclops	252	
-10	5/16/69	26	121	0	234	0		0.2142
-11	5/16/69	34	808	8	452	Daphnia	8	0.0430
-12	5/16/69	26	26	8	982	Snails	26	1.0000
						Cyclops	130	
						Daphnia	956	
-13	5/16/69	0	113	0	191	Snail	8	0
						Daphnia	460	
						Cyclops	156	
-14	5/16/69	0	895	8	295	Cyclops	78	0
						Daphnia	60	
-15	5/16/69	0	686	8	1278	0		0

LOCUST POINT POWER PROJECT

Benthos Data

Station Number	Date	Organisms per meter^2 Amphipods	Oligochaetes	Sphaeriidae	Tendipedidae	Other		Ratio: Amphi/Oligo
P1-1	10/24/69	0	1139	0	348	Clam	9	0
-2	10/29/69	0	678	0	730	Leech	9	0
						Clam	9	
-3	10/24/69	0	556	17	565	0		0
-4	10/24/69	0	3148	0	270	0		0
-5	10/24/69	0	956	17	565	0		0
-6	10/24/69	17	1026	17	539	Clam	17	0.0166
-7	10/21/69	9	522	0	70	0		0.0172
-8	10/21/69	35	1252	0	130	Leech	26	0.0280
-9	10/21/69	104	391	278	70	Leech	174	0.2660
-10	10/21/69	43	461	17	165	Leech	9	0.0933
-11	10/21/69	0	617	78	130	0		0
-12	10/21/69	400	130	96	52	Leech	9	3.0769
						Clam	9	
-13	10/20/69	104	96	26	78	Leech	9	1.0833
-14	10/20/69	78	157	9	35	Leech	17	0.4968
-15	10/29/69	61	261	35	130	Leech	35	0.2337
-16	10/29/69	0	70	0	61	0		0
-17	10/29/69	0	0	0	0	0		0
-18	10/29/69	0	26	0	0	0		0
-19	10/29/69	17	96	35	87	0		0
-20	10/29/69	9	1530	0	78	0		0

0232


STATION MAP-FERMI PLANT SURVEY
12, 16 JUNE 1969
statue miles
0 .5 1 2 3
83° 15'
42° 00'
POINT MOUILLE
BAR POINT
O3 83° 05"
DETROIT RIVER LT.
41° 55'
O COMPLETE STATION
△ SHORT STATION
SWAN CREEK
△4
O5
△6
STONY CREEK
△7
O8
△9
O10
POINT AUX PEAUX
△2
STONY POINT
83° 05'
△12
BREST BAY
O11
41° 55"
LAKE ERIE
O1
RIVER RAISIN

D-B

0298

Phytoplankton

Station FP-1, near Enrico Fermi
12 June 1969

Organism	No. of Colonies	Cells per Liter
Cyclotella spp		32,621
Oocystis spp		1,546
Actinastrum Hantzschii		6,184
Scenedesmus spp		6,802
Micractinium ? spp		6,493
Dictyosphaerium spp		2,010
Ankistrodesmus spp		1,237
Peridinium sp		618
Gomphosphaeria lacustris		155
Oscillatoria spp		7,421
Closteriopsis longissima		1,701
Melosira spp	1,546	9,121
Synedra sp		1,237
Asterionella formosa	155	618
Fragilaria pinnata	309	5,411
Diatoma tenuis v. elongata	155	618
Stephanodiscus sp		618
Coelastrum sp		773
Tetraedron sp		309
Coscinodiscus sp		155
Pediastrum sp		309
Closteridium sp		309
Navicula sp		309
Nitzschia sp		309

[redacted] 0299

Phytoplankton

Station FP-3, near Enrico Fermi
16 June 1969

Organism	No. of Colonies	Cells per Liter
Dinobryon divergens	1,288	18,032
Oscillatoria spp		7,084
Synedra acus		27,048
Synedra ulna		17,388
Rhizosolenia eriensis		47,656
Nitzschia sp		644
Tabellaria fenestrata	22,540	155,848
Asterionella formosa	10,948	71,484
Diatoma tenuis v. elongata	15,456	94,024
Fragilaria capucina	4,508	144,900
Melosira binderana & M. granulata combined	1,932	12,880
Gloeocystis sp		2,576
Cyclotella spp		10,304
Micractinium sp		644

0300

[redacted]

D-B

Phytoplankton

Station FP-5, near Enrico Fermi
16 June 1969

Organism	No. of Colonies	Cells per Liter
Oocystis sp		86
Diatoma spp	602	2,494
Tabellaria fenestrata	774	4,816
Melosira spp	258	2,322
Synedra spp		1,204
Fragilaria pinnata	344	7,224
Asterionella spp	258	1,290
Cyclotella sp		344

[redacted] 0301

Phytoplankton

Station FP-8, near Enrico Fermi
16 June 1969

Organism	No. of Colonies	Cells per Liter
Stephanodiscus spp		883
Synedra acus		4,416
Synedra ulna		3,386
Cyclotella spp		7,949
Diatoma tenuis v. elongata	4,564	24,290
Nitzschia spp		1,030
Melosira binderana & M. granulata combined	12,366	92,889
Fragilaria pinnata	3,091	117,621
Fragilaria crotonensis	1,325	25,320
Navicula spp		442
Coelastrum sp		147
Oscillatoria spp		442
Rhizosolenia spp		442
Oocystis solitaria		147
Actinastrum Hantzschii		294
Cosmarium sp		294
Ankistrodesmus sp		147
Dinobryon sp		294
Tabellaria fenestrata	8,244	67,569
Asterionella formosa	3,091	23,406
Pediastrum duplex		442
Cymbella sp		147
Coscinodiscus sp		147

Phytoplankton

Station FP-10, near Enrico Fermi
16 June 1969

Organism	No. of Colonies	Cells per Liter
Diatoma tenuis v. elongata	6,901	37,801
Tabellaria fenestrata	6,283	83,327
Asterionella formosa	4,223	30,385
Oscillatoria spp		1,133
Rhizosolenia spp		1,030
Pediastrum sp		309
Stephanodiscus sp		515
Synedra spp		13,184
Melosira spp	7,210	48,925
Cyclotella spp		1,545
Fragilaria crotonensis & F. pinnata combined	5,562	194,876
Nitzschia spp		515
Dinobryon spp	1,236	12,875
Ankistrodesmus sp		206
Scenedesmus sp		103

0303

Phytoplankton

Station FP-12, near Enrico Fermi
16 June 1969

Organism	No. of Colonies	Cells per Liter
Micractinium spp		10,626
Coelastrum sp		7,728
Asterionella formosa	7,728	51,198
Ankistrodesmus falcatus		2,898
Dictyosphaerium pulchellum		5,796
Cyclotella spp		176,778
Melosira spp	178,710	1,109,934
Diatoma tenuis v. elongata	11,592	90,804
Rhizosolenia eriensis	966	1,932
Pediastrum sp		7,728
Nitzschia sp		1,932
Actinastrum Hantzschii		15,456
Oscillatoria spp		163,254
Scenedesmus spp		29,946
Tabellaria fenestrata	22,218	118,818
Synedra spp		35,742
Fragilaria capucina	5,796	168,084
Fragilaria crotonensis	1,932	69,552
Oocystis sp		2,898
Navicula sp		966
Anabaena sp		966

0304

POWER PLANT SURVEYS - PRIMARY ZOOPLANKTON COUNTS - ENRICO FERMI, LAKE ERIE (NO. ORG./LITER)

	FP-1	FP-3	FP-5	FP-8	FP-10	FP-12
	6/12/69	6/16/69	6/16/69	6/16/69	6/16/69	6/16/69
CALANOID COPEPODS:						
Diaptomus sp.	0.53	0.41	0.10	0.13	0.21	0.07
Eurytemora affinis		0.05			0.04	
Others						
CYCLOPOID COPEPODS	122.01	0.51	0.24	1.00	0.08	11.28
ROTIFERS:						
Asplanchna sp.		0.66	0.29	0.63	1.48	0.07
(Others too small for this net)						
CLADOCERA:						
Daphnia retrocurva	0.75			0.04		2.38
Other Daphnia						0.10
Bosmina sp.	0.32	0.41	0.05	0.75	0.13	1.98
Chydorus sphaericus	0.53	0.31	0.19			0.07
Ceriodaphnia reticulata						0.07
Leptodora kindtii	0.11					0.10
Diaphanosoma leuchtenbergianum						
OTHER GROUPS:						
(Ostracods unless otherwise noted)						

REMARKS:

0305

ENRICO FERMI POWER PLANT

Benthos Data

Station Number	Date	Organisms per meter^2					Ratio: Amphi/Oligo
		Amphipods	Oligochaetes	Sphaeriidae	Tendipedidae	Other	
FP-1	6/24/69	0	2964	0	1312	0	0
-2	6/29/69	0	4817	17	1043	0	0
-3	5/18/69	0	2060	1399	530	Egg Sac 156 Snail 321	0
-4	6/16/69	0	95	8	0	0	0
-5	6/25/69	0	1869	8	34	0	0
-6	6/20/69	0	5634	60	17	0	0
-7	7/1/69	8	69	17	8	0	0.125
-8	6/23/69	0	339	0	60	0	0
-9	6/16/69	0	1243	26	95	0	0
-10	6/16/69	0	4790	321	17	0	0
-11	6/25/69	0	921	460	90	Snail 26 Leech 8	0
-12	6/26/69	0	1225	43	52	0	0

FISH AND FISHE: IES IN THE AREA OF THE PROPOSED LOCUST POINT POWER PLANT

Due to lack of time and equipment, data on the fish situation was not collected directly, but was obtained from various government reports and from interviews with fisheries biologists working in the area. The U. S. Bureau of Commercial Fisheries established an "index" station, known as Bono or No. 7, in 1959. Annual collections were made at this station until 1965 and are summarized in table 1. The station is located 8-1/2 miles northwest of Locust Point and is 2 miles offshore with a depth of 20 feet (figure 1). Unfortunately the bottom at the Bono station is mostly mud, whereas the bottom at the same distance and depth off Locust Point is sandy gravel (Herdendorf, 1968; Ayers and Anderson, 1969). This difference and the distance involved may cause significant differences in the relative abundance of various fish species at the two locations. Nevertheless, these data provide a convenient summary of the fish populations in the Locust Point area. Growth rate data, which would also be of interest in evaluating power plant effects, is available for only a few species and times. Since the fish populations of Lake Erie have been somewhat unstable over the last decade, and the USBCF data extends only through 1965, present relative abundance of the fish species may be somewhat different from that implied by table 1.

The Ohio Division of Wildlife fishery studies in western Lake Erie are concentrated on the walleye, which is the only remaining "high-value" (in the traditional sense) fish in the commercial catch, and which is in danger of population collapse (Arnold, 1969a; Regier, Applegate, and Ryder, 1969). They also have records from trap net and haul seine commercial fisheries near Locust Point but inasmuch as the fishermen specialize in one or two species and generally report only those fish selected for market, this data was not particularly useful for our purposes.

Approximately 14 major and 5 minor species of fish occur around Locust Point. The species composition is heavily in-

Table 1: Summary of USBCF index collections at Bono (#7) station
(Means of 2 10-minute hauls of 26' trawl, ½-inch mesh.)

Species	age group	June 1959	Aug. 1959	Oct. 1959	Aug. 1960	Aug. 1961	Aug. 1962	Aug. 1963	Aug. 1964	Aug. 1965
Yellow Perch	adult	26	15	3	6	3	4	48	97	73
	yearling	24		3	49		8	260	37	29
	young of year		195	144	109	519	162	104	25	205
Emerald Shiner	adult	76	89	78	3	55	55	1	52	
	yearling	139				986	47	1	92	2
	young of year				1			1		
Spottail Shiner	adult	6	23	61	48	17	4	21	22	3
	yearling	17		9		19	12	72	36	8
	young of year		14	67	97	56	2	29	66	246
Smelt	adult	1								
	yearling									
	young of year				1	66		9		1
Troutperch	adult	5	3	22	15		1	1	2	
	yearling	7				2	1	4	3	8
	young of year		3		22	7		9	38	22
Sheepshead	adult	1			6		1		3	10
	yearling	2				1			2	6
	young of ye		1					1	3	71
Channel Catfish	adult				4	1			1	1
	yearling	1								1
	young of year									
Walleye	adult				1					
	yearling									
	young of year			1		2			1	
Carp	adult				1	4				
	yearling			1						1
	young of year									1
Alewife	adult									
	yearling									
	young of year			10		80	265	24	56	3
White Bass	adult									
	yearling									
	young of year		15	6	19	153	165	121	17	10
Others		3	1	1	1		5	21	20	2

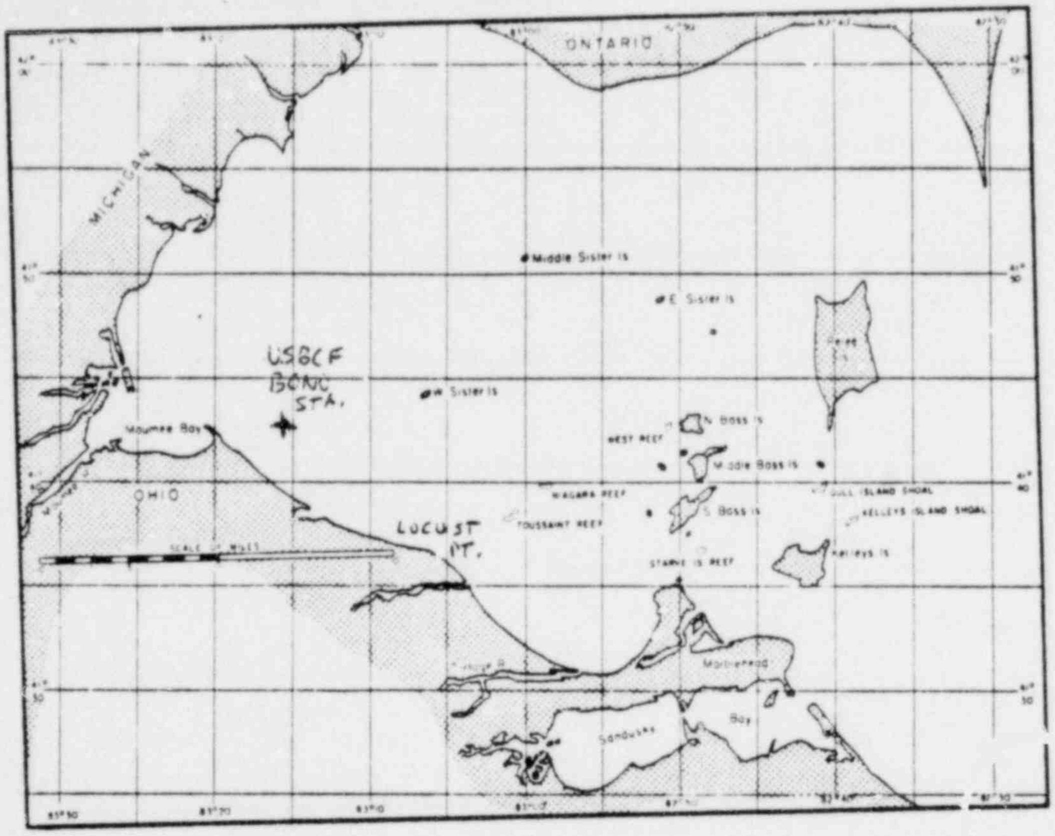


Figure 1: Western Lake Erie showing major islands and reefs plus USBCF sampling station #7 ("Bono"). Modified from Herdendorf, 1968.

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fluenced by the extensive marsh habitat in the vicinity, which serves as spawning and food producing area for some species and primary habitat for others. The commercial fishery in the area consists largely of trap nets, plus a shore seine fishery for carp which operates in spring. The fisheries are somewhat restricted by test firing from Camp Perry. The chief species taken are walleye (discussed below), white bass, yellow perch, sheepshead, carp, goldfish, channel catfish, and suckers, plus a few whitefish in spring. The latter species, however, is already at or near its upper temperature limit in this area. Several forage fishes are present in abundance, partially contributing (along with the spawning reefs) to the persistence of fairly good walleye populations in the Locust Point area while those in many other areas have almost disappeared. These species include shiners, troutperch, gizzard shad, and alewife.

The Kelleys Island - Bass Island reef and the reefs off Locust Point (figure 1) are the only remaining spawning areas used by significant numbers of walleyes (Regier, et al., 1969). Walleyes tend to move counterclockwise around the basin on a yearly cycle, being concentrated near the north shore in fall and arriving on the spawning reefs during the winter. In 1968, peak spawning occurred between April 10 and 18, when water temperatures ranged from 45 to 52 degrees F. (Baker, 1969). It is generally believed that the upper limit for walleye spawning is about 55 degrees F. (W. Hartman, personal communication).

Locust Point Reef, the spawning area closest to the plant site (figure 2) showed a higher number of eggs per sample than five of the other areas in 1968, and was reported as a major spawning area for the first time (Baker, 1969). This reef is less than 3 miles offshore, while the other reefs (figure 2) range from 3 to 7 miles off. According to present best predictions if, due to unfavorable wind and current conditions, the plant discharge plume were to reach the reef area, walleye spawning would be exposed to a rise of 1 or 2 degrees. A prolonged rise might induce earlier spawning if the rise were uninterrupted, but it is more likely that the spawners would move out rather than spawn in warmer water.

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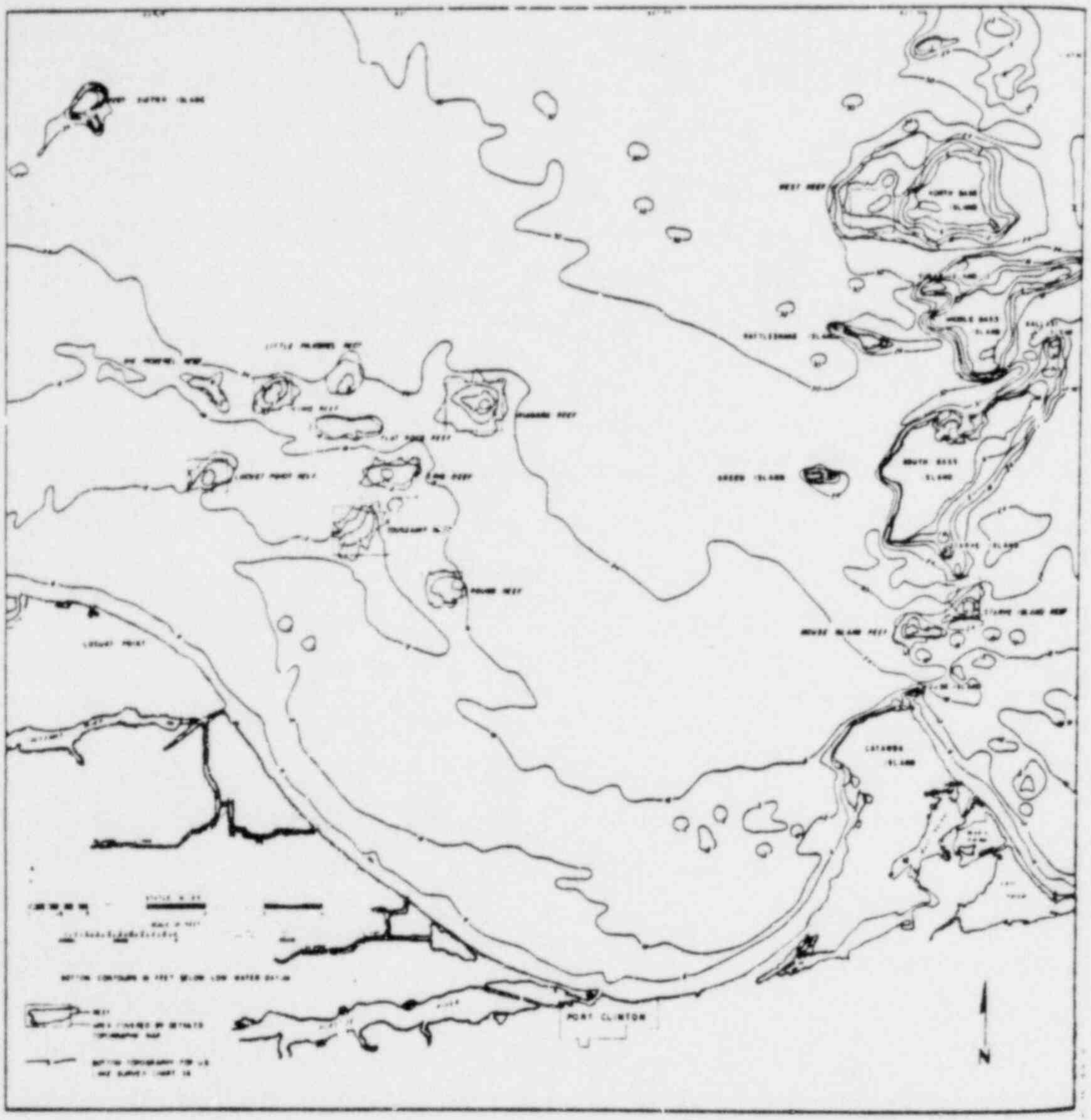

Figure 2: Major spawning reefs in western Lake Erie. From Hartley, Herdendorf, and Keller, 1966.

Another concern relates to blooms of blue-green algae, which are becoming common in western Lake Erie (Casper, 1965), and were particularly bad in 1969 (W. L. Hartman, personal communication). These algae are favored by warm temperatures and are unfavorable to forage fish and invertebrate fish food organisms (Gorham, 1965; Arnold, 1969b).

ZOOPLANKTON IN THE LOCUST POINT AREA

Zooplankton samples showed considerable differences between spring and fall, and within each season were quite consistent throughout the sampling area. May samples were dominated by cyclopoid copepods (mostly Cyclops bicuspidatus) and the cladoceran Daphnia retrocurva. In the October samples, these groups were relatively low in abundance, and the cladoceran Bosmina became highly dominant.(see attached tables). These conditions were not unexpected on the basis of previous studies, but a large part of the Bosmina appeared to be of a new species or subspecies. This possibility is now being studied.

D. E. Arnold - 1/8/70

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TABLE 2 COMPARISON OF WALLEYE EGG SAMPLING DATA BY INDEX STATIONS 1960 THROUGH 1968 (From Baker, 1969)

YEAR		STATION OR REEF AREA							
		#8 NIAGARA	#9 CRIB	#23A STARVE	#25 KELLEYS	#26 GULL	#31 TOUSSAINT	#33 WEST	TOTALS
1960	No. of Samples	8	5	---	6	5	2	1	27
	No. Eggs per Sample	202	178	---	973	189	190	60	363
	% Viable	37.5	62.2	---	49.5	44.2	46.5	66.9	49.5
1961	No. of Samples	16	22	---	15	13	---	13	79
	No. Eggs PerSample	198	609	---	910	106	---	34	406
	% Viable	23.3	18.1	---	29.0	9.7	---	11.1	21.6
1962	No. of Samples	4	4	---	5	5	4	6	28
	No. Eggs PerSample	408	256	---	146	38	316	35	180
	% Viable	44.9	35.4	---	33.4	35.2	38.6	15.7	37.4
1963	No. of Samples	12	13	9	13	13	12	11	83
	No. Eggs PerSample	131	143	189	217	112	194	1.3	142
	% Viable	30.0	27.0	46.0	30.0	21.0	33.0	7.0	31.8
1964	No. of Samples	11	8	9	10	9	8	7	62
	No. Eggs PerSample	682	301	157	1,072	58	699	4.1	455
	% Viable	38.4	50.9	62.9	11.4	12.8	32.2	55.1	35.3
1965	No. of Samples	12	10	13	11	9	11	13	79
	No. Eggs PerSample	46	91	266	3,325	155	177	11	569
	% Viable	48.7	45.3	45.7	28.8	14.8	44.6	41.1	35.4
1966	No. of Samples	18	21	23	23	15	25	16	141
	No. Eggs PerSample	119	111	262	380	14	177	43	174
	% Viable	25.4	31.9	15.9	11.5	39.7	25.9	19.2	19.4
1967	No. of Samples	23	24	21	19	1	25	10	123
	No. Eggs PerSample	121	139	279	119	3	238	2	164
	% Viable	38.3	33.5	34.9	25.2	33.3	40.6	0.0	35.3
1968	No. of Samples	26	26	2[illegible]	17	---	25	13	127
	No. Eggs PerSample	45	78	63	376	---	124	6	110
	% Viable	26.1	24.8	17.8	17.1	---	26.1	34.1	21.9

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0314

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CURRICULUM VITAE

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A. B. University of Rochester, 1961. General science, biology
M. S. Cornell University, 1965. Fishery biology, limnology
Ph.D. Cornell University, 1969. Aquatic ecology, fishery science, phycology.

U. S. Navy, 1961-1963 (lieutenant j.g., engineering officer of oceanographic survey ship)

Research Assistant, Cornell University, 1963-1965 (fisheries)
Research Associate, Assistant Project Leader, Warmwater Fisheries Investigations, Cornell University, 1965-1966
Teaching Assistant, Cornell University, 1966-1968 (limnology)
N. I. H. Predoctoral Fellow, Cornell University, 1967-1968 (aquatic ecology)
Assistant Research Limnologist, University of Michigan, 1969-

Professional Societies:

- American Society of Limnology and Oceanography
- International Association for Theoretical and Applied Limnology
- American Fisheries Society (Certified Fishery Scientist)
- Ecological Society of America
- International Association for Great Lakes Research

Publications and theses:

- 1966. Marking fish with dyes and other chemicals. M. S. Thesis, Cornell University.
- 1966. Marking fish with dyes and other chemicals. Tech. Paper 10, U. S. Bureau Sport Fish. Wildl. 44 p.
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- 1969. The ecological decline of Lake Erie. N. Y. Fish Game J. 16(1):27-45.
- 1969. Feeding studies on Daphnia pulex using seven blue-green algae. Ph.D. thesis, Cornell University.

Radiological Analyses

The following reports by Charles C. Kidd present a part of the studies of accumulation of radionuclides in the food chain, which have been carried on with funds from Indiana and Michigan Electric Company and from Toledo Edison.

Other studies, similarly supported are incorporated in a PhD thesis by Kidd which should be completed in the near future.

These reports by Kidd have just recently been received.

J. C. Ayers

RADIOLOGICAL HEALTH RESEARCH

PROGRESS REPORT

"THE ACCUMULATION OF RADIONUCLIDES BY PONTOPOREIA AFFINIS"

Submitted by, CHARLES C. KIDD

0317

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INTRODUCTION:

Earlier experiments conducted by the writer during the period 1 Aug. 1968 thru 31 Oct. 1968 were designed to reveal the ability of the amphipod, Pontoporeia affinis, to accumulate radioactive elements in solution. In these experiments the amphipods were exposed to waste waters from a nuclear fuel reprocessing plant and a nuclear power reactor. These wastes contained significant quantities of radioactive zinc, zirconium, ruthenium, barium and cesium. Results of these experiments indicated that the organism only demonstrated an affinity for zinc as indicated by the accumulation of zinc-65. The concentration of radioactive zinc in the amphipods was approximately 250 times greater than the concentration of the isotope in solution after a 3-day exposure period. In order to confirm this observation, and to measure the ability of Pontoporeia to accumulate other radioactive elements the experiments described in this report were conducted. Some of the radioactive elements used in these experiments are peculiar to waste from nuclear facilities (activation products) and some may be present in the environment as a result of nuclear facilities operations or testing of nuclear devices (fission products). In some of the experiments the amphipods were exposed to radioactive elements in the absence of sediment from which they are known to obtain most of their food. By comparing experimental results of

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tests "with" and "without" sediment those accumulated isotopes involved in metabolic processes will be identified.

METHODS AND MATERIALS:

The seven radioactive elements used in these experiments were cerium-144, manganese-54, zinc-65, cesium-137, zirconium-95, ruthenium-106 and strontium-90. A total of 14 plastic aquaria were used each containing 250 ml. of lake water. Thirty grams of sediment was added to 7 of the aquaria. Equal volumes of each solution containing a radioactive element were added to an aquarium without sediment and to one with sediment. Twelve amphipods were placed in each aquarium and all test animals were maintained at 10°C for 72 hours. At the end of this time all the water in the aquaria with sediment was slowly siphoned off into plastic cups. The amphipods were removed by flushing the sediment through a screen which retained them. Amphipods were removed from the aquaria without sediment with a small tea strainer. The 12 amphipods from each aquarium were divided into 3 groups of 4 animals each. The wet weight of each group of amphipods was determined immediately. All amphipods and water from tests involving gamma emitters with and without sediment were analysed for 200 minutes by a gamma spectrometer. Pontoporeia which had not been exposed to radioactive isotopes in the laboratory and were from the same area of Lake Michigan were also weighed and radioassayed. After adjusting each spectrum of gamma radioactivity obtained from analysis of the amphipods for the contribution of

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activity from unirradiated amphipods the specific activity, picocuries (pCi) per gram, was calculated for each isotope under both sets of test conditions. The residual activity per ml. in all tests waters was also calculated. Amphipods exposed to strontium-90 were wet-digested with nitric acid and the neutralized dry residue counted for 50 minutes in a Beckman Low Background Beta Counter. A sample of unirradiated amphipods was also analysed in this manner. Waters from the strontium tests were evaporated to dryness and analysed in the low background beta counter.

RESULTS:

Tables #1 and #2 are "budgets" which reveal the fate of radionuclides used in each experiment. Significant percentages of all radioisotopes with the exception of ruthenium were removed by the amphipods in the tests without sediment. The largest accumulation multiple, (pCi per gram/pCi per ml.) resulting from this experiment was 29 as observed for manganese and zinc. (see table #3). Results of the experiment with sediment revealed that significant percentages of manganese-54, zinc-65, strontium-90 were removed by the amphipods. Accumulation multiples for these isotopes were 29, 273 and 70, respectively. It was observed also that a large percent of each isotope added became associated with the sediment and thereby available to the amphipods.

0320

CONCLUSIONS:

The results of the experiments described above indicate that Pontoporeia affinis has a greater affinity for zinc than any other isotope tested. It is also concluded the accumulation of strontium and zinc are enhanced by their availability in the sediment and that their accumulation involves metabolic processes.

Experiments will be initiated shortly to determine maximum accumulation multiples for radioactive strontium, zinc and manganese. Strontium-85, a gamma emitter, will be used in these experiments to permit the simultaneous measurement of radioactivity due to all three isotopes by gamma spectrometry. Having reached a maximum specific activity test organisms will be placed in aquaria containing no added radionuclides. The loss of activity in time will permit the calculation of the effective and biological half-lives of each radioisotope in the amphipod.

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TABLE #1

BUDGET OF RADIONUCLIDES FOR 72 HOURS LABORATORY UPTAKE EXPERIMENT WITHOUT SEDIMENT:

RADIONUCLIDE	TOTAL ACTIVITY ADDED (pCi)	ACTIVITY REMAINING IN SOLUTION (pCi)	ACTIVITY REMOVED BY AMPHIPODS (pCi)	PERCENT REMOVAL
Ce^{144}-Pr^{144}	820	818	2	0.24%
Mn^{54}	214,000	212,843	1,157	0.54%
Zn^{65}	32,300	32,132	168	0.52%
Cs^{137}	1,745	1,736	9	0.52%
Zr^{95}-Nb^{95}	2,950	2,948	2	0.06%
Ru^{106}-Rh^{106}	30,600	>30,599	<1	<0.003%
Sr^{90}-Y^{90}	1,825	1,819	6	0.33%

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TABLE #2

BUDGET OF RADIONUCLIDES FOR 72 HOUR LABORATORY UPTAKE-EXPERIMENT WITH SEDIMENT:

RADIONUCLIDE	TOT. ACTIVITY ADDED (pCi)	ACTIVITY REMAINING IN SOL. (pCi)	ACTIVITY REMOVED BY SED. (pCi)	% REMOVAL	ACTIVITY REMOVED BY AMPHIPODS (pCi)	% REMOVAL
$Ce^{144}-Pr^{144}$	820	338	482	58.80%	0	0
Mn^{54}	214,000	30,942	182,937	85.44%	121	0.06%
Zn^{65}	32,300	1,696	30,541	94.50%	63	0.20%
Cs^{137}	1,745	280	1,465	84.00%	0	0
$Zr^{95}-Nb^{95}$	2,950	374	2,576	87.30%	0	0
$Ru^{106}-Rh^{106}$	30,600	6,833	23,764	77.61%	3	0.01%
$Sr^{90}-Y^{90}$	1,825	765	1,052	57.60%	8	0.50%

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TABLE #3:

SPECIFIC ACTIVITIES AND ACCUMULATION MULTIPLES IN PONTOPOREIA AFFINIS RESULTING FROM 72 HOUR LABORATORY UPTAKE EXPERIMENTS:

RADIONUCLIDE	SPECIFIC ACTIVITY (pCi/gram)		ACCUMULATION MULTIPLE (pCi/gram / pCi/ml.)	
	WITHOUT SED.	WITH SED.	WITHOUT SED.	WITH SED.
Ce^{144}-Pr^{144}	46	0	20	0
Mn^{54}	24,450	3,641	29	29
Zn^{65}	3,730	1,854	29	273
Cs^{137}	155	0	22	0
Zr^{95}-Nb^{95}	109	0	9	0
Ru^{106}-Rh^{106}	6	71	0.8	3
Sr^{90}-Y^{90}	122	212	17	70

0324

ACCUMULATION OF RADIOACTIVE ISOTOPES BY LAKE ERIE BENTHIC WORMS:

C. Kidd, 24 July '69

ISOTOPE	SAMPLE #	TYPE	WET WT.(g)	7-DAY ACTIVITY		CONCEN-TRATION FACTOR
				In water	In worms	
Mn^{54}	1	Chironominae	0.112	4.18 $\frac{cpm}{ml}$	411 $\frac{cpm}{g}$	98.3
	2	Oligochaetes	0.129		388 "	93.0
Cs^{137}	3	Chiron.	0.259	3.95 $\frac{cpm}{ml}$	467 $\frac{cpm}{g}$	118
	4	Oligo.	0.201		323 "	81.7
Zn^{65}	5	Chiron.	0.039	2.30 $\frac{cpm}{ml}$	1692 $\frac{cpm}{g}$	736
	6	Oligo	0.176		369 "	160
Sr^{85}	7	Chiron.	----	----	----	----
	8	Oligo.	0.071	30.2 $\frac{cpm}{ml}$	676 $\frac{cpm}{g}$	22.4

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ACCUMULATION OF RADIOISOTOPES BY FRESHWATER CLAMS (LAKE ERIE):

C. Kidd 24, July 1969: 72 Hour Test

ISOTOPE	SAMPLE	SOFT TISSUE WET WEIGHT	TOT. ACTIVITY IN SOFT TISSUE (cpm)	(cpm/g) CONC. OF ACTIVITY IN SOFT TISSUE	(cpm/ml) ACT. CONC. IN WATER	CONC. FACTOR IN SOFT TISSUE	WEIGHT OF SHELL	TOT.ACT. IN SHELL (cpm)	CONC. OF ACTIVITY IN SHELL (cpm/g)	CONC. FACTOR IN SHELL
Sr^{85}	8	32.1	387	12.1	19.9	0.61	30.5	533	17.5	0.88
	9	28.1	309	11.0		0.55	7.20	501	69.5	3.56
	10	32.7	139	4.25		0.21	8.30	444	53.4	2.68
	13	87.9	688	7.83		0.39	61.9	878	14.2	0.71
Cs^{137}	8	32.1	536	16.7	6.90	2.42	30.5	2011	65.9	9.55
	9	28.1	1095	39.0		5.65	7.20	1774	246	35.7
	10	32.7	1675	5.18		0.75	8.30	1164	140	20.2
	13	87.9	1428	16.2		2.34	61.9	2441	39.4	5.7
Mn^{54}	8	32.1	209	6.51	3.30	1.97	30.5	304	9.96	3.02
	9	28.1	90.0	3.20		0.97	7.20	377	52.4	15.9
	10	32.7	0	0		0	8.30	420	506	153
	13	87.9	17.0	0.19		0.06	61.9	542	8.75	2.65
Zn^{65}	8	32.1	151	4.70	3.23	1.45	305	209	6.85	2.12
	9	28.1	0	0		0	7.20	322	44.7	13.8
	10	32.7	2.00	0.06		0.02	8.30	288	34.6	10.7
	13	87.9	30.0	0.34		0.11	61.9	433	6.99	2.16

RADIOLOGICAL ANALYSIS OF SEDIMENT SAMPLES - C. Kidd
July 24, 1969

SAMPLE NO.	SAMPLE STATION	WET WEIGHT OF SOIL SAMPLE (g)	DEPTH	GROSS √ ACTIVITY		Cs^{137} ACTIVITY	
				cpm/g	pCi/g	cpm/g	pCi/g
1	LPP-15	239.3	7 m	1.68	21.2	0.33	3.25
2	FP-9	352.1		0.68	8.57	0.07	0.69
3	FP-6	316.7		0.65	8.19	0.07	0.69
4	FP-4	432.2		0.75	9.45	0.09	0.89
5	FP-10	574.4		0.62	7.31	0.09	0.89
6	FP-8	213.5		1.91	24.1	0.43	0.42
7	FP-1	229.5		1.15	14.5	0.18	1.77
8	FP-7	131.8		1.57	19.8	0.17	1.68
9	FP-12	394.8		0.97	12.2	0.18	1.77
10	FP-3	238.8		1.79	22.6	0.40	3.94
11	FP-2	209.4		1.43	18.0	0.25	2.47
12	FP-5	205.1		1.10	13.9	0.15	1.48
13	FP-11	345.8		1.26	15.9	0.29	2.86
14	LPP-13	208.0	2 m	1.09	13.7	0.19	1.87
15	LPP-10	136.5	3 m	1.75	22.0	0.30	2.96
16	LPP-1	164.9	5.5 m	1.46	18.4	0.14	1.38
17	LPP-6	222.3	1.5 m	1.11	14.0	0.09	0.89
18	LPP-4	175.8	5.5 m	1.44	18.1	0.18	1.77
19	LPP-7	142.2	5 m	0.54	6.80	0.14	1.38
20	LPP-9	139.2	1.5 m	0.83	10.5	0.15	1.48
21	LPP-2	181.5	5 m	1.55	19.5	0.19	1.87
22	LPP-3	157.5	1.5 m	1.29	16.3	0.12	1.18

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REPORT OF RADIOASSAY OF FIELD SAMPLES

SUBMITTED BY, CHARLES C. KIDD

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AVE. LPP - STATION:	GROSS γ - ACTIVITY	=	16.1 $\frac{pCi}{g}$
	Cs^{137} ACTIVITY	=	1.80 pCi/g
AVE. FP - STATION:	GROSS γ - ACTIVITY	=	14.6 pCi/g
	Cs^{137} ACTIVITY	=	1.96 pCi/g

0329

INTRODUCTION:

Radioassay of macrobenthos samples collected in July, 1968 during an environmental survey of Lake Michigan in the vicinity of The Big Rock Nuclear Power Plant indicated that levels of gross beta and gamma radioactivity in Pontoporeia affinis might possibly reflect the influence of radionuclides released in the waste from the plant. However, the samples taken at that time did not contain many amphipods. Moreover, there were insufficient sampling locations to discern any pattern or trend in levels of radioactivity. On October 18, 1968 the writer returned to the area and working off The Great Lakes Research Division's ship "The Mysis", obtained more benthos samples from nine sampling points (see figures #1 and #2) in the vicinity of The Big Rock Nuclear Power Plant. The objective of the study described in this report is to detect any pattern in the distribution of radioactivity as results from the radioassay of the amphipods collected. The degree to which Pontoporeia affinis responds to the low levels of radioactivity encountered in the study area is reflective of their usefulness as biological indicators of environmental radioactivity.

METHODS AND MATERIALS:

Bottom samples were taken with a Ponar Dredge. The dredge was lowered four times at each sampling point. This represented a sampling area of approximately 0.25 square meters. Sampling depth ranged from 70 feet to 300 feet. All samples were washed free of mud and put in 1-pint Mason Jars. A small amount of Formalin was added to preserve each sample. In the laboratory the Pontoporeia were picked from each sample and weighed. They were then wet digested in nitric acid. The neutralized residue was dried on stainless steel planchets and analysed for 200 minutes in a gamma spectrometer. The samples were also analysed for 200 minutes in The Beckman Low-Background Beta Counter. The average gamma detection efficiency for the 5 inch NaI(Tl) crystal and multichannel analyser combination is 20% over the energy range of 0.02 to 2.0 million electron volts. This value was used to calculate the gross gamma radioactivity as indicated by the 200 minute count. The efficiency of the low-background beta counter was 42% for gross beta counting. Gross gamma and beta radioactivity was calculated and recorded as picocuries per gram (pCi/gram) of amphipod (see table #1).

RESULTS:

Gross beta radioactivity in the amphipods ranged from 0.55 to 10.93 pCi/gram. The range of gross gamma radioactivity in the amphipods was 4.07 to 40.20 pCi/gram. When gross beta and gamma activities were plotted on a scaled map of the study area the patterns of radioactivity shown in figures #1 and #2 were drawn.

CONCLUSIONS:

The patterns of both types of radioactivity reveal the influence of the nuclear power plant on levels of environmental radioactivity. Water from an area near the discharge channel of the power plant was previously assayed and contained 54 pCi per liter, gross gamma activity. Gross gamma activity in P. affinis used in this experiment apparently exceeds the concentration in the water tested by from 76 to 745 times. More water samples from the study area are being analysed for gross radioactivity. The results of these tests will be compared with levels of radioactivity reported for the study area prior to plant operation.

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TABLE #1:

RESULTS OF RADIOASSAY OF PONTOPOREIA AFFINIS FROM BENTHOS SAMPLES TAKEN IN THE VICINITY OF THE BIG ROCK NUCLEAR POWER PLANT:

SAMPLING POINT*	WET WEIGHT OF SAMPLE (GRAMS)	RADIOACTIVITY (pCi/gram) GROSS BETA	GROSS GAMMA
1	0.89	1.66	7.83
2	1.79	1.27	4.20
3	1.22	1.44	4.91
4	1.65	1.25	4.07
5	1.32	1.69	7.05
6	0.74	1.10	14.69
7	2.32	0.55	4.86
8	0.10	3.44	40.20
9	0.79	10.93	9.86

*SEE FIGURES 1 & 2 FOR LOCATION OF SAMPLING POINTS.

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FIGURE #1 ISO-ACTIVITY CONTOURS, GROSS GAMMA RADIOACTIVITY, (pCi/gram) in PONTOPORIEA AFFINIS

BENTHOS SAMPLING POINTS — •

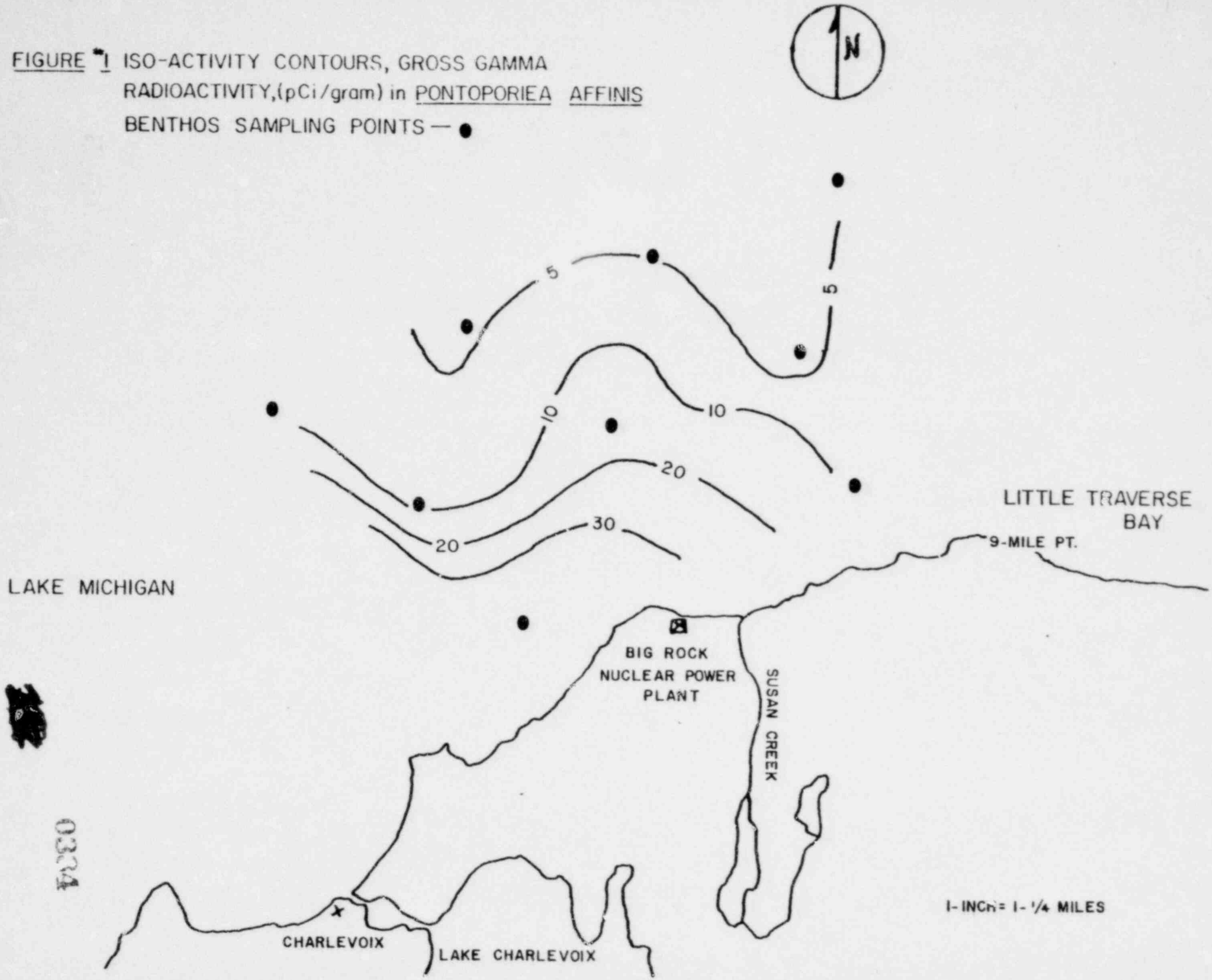
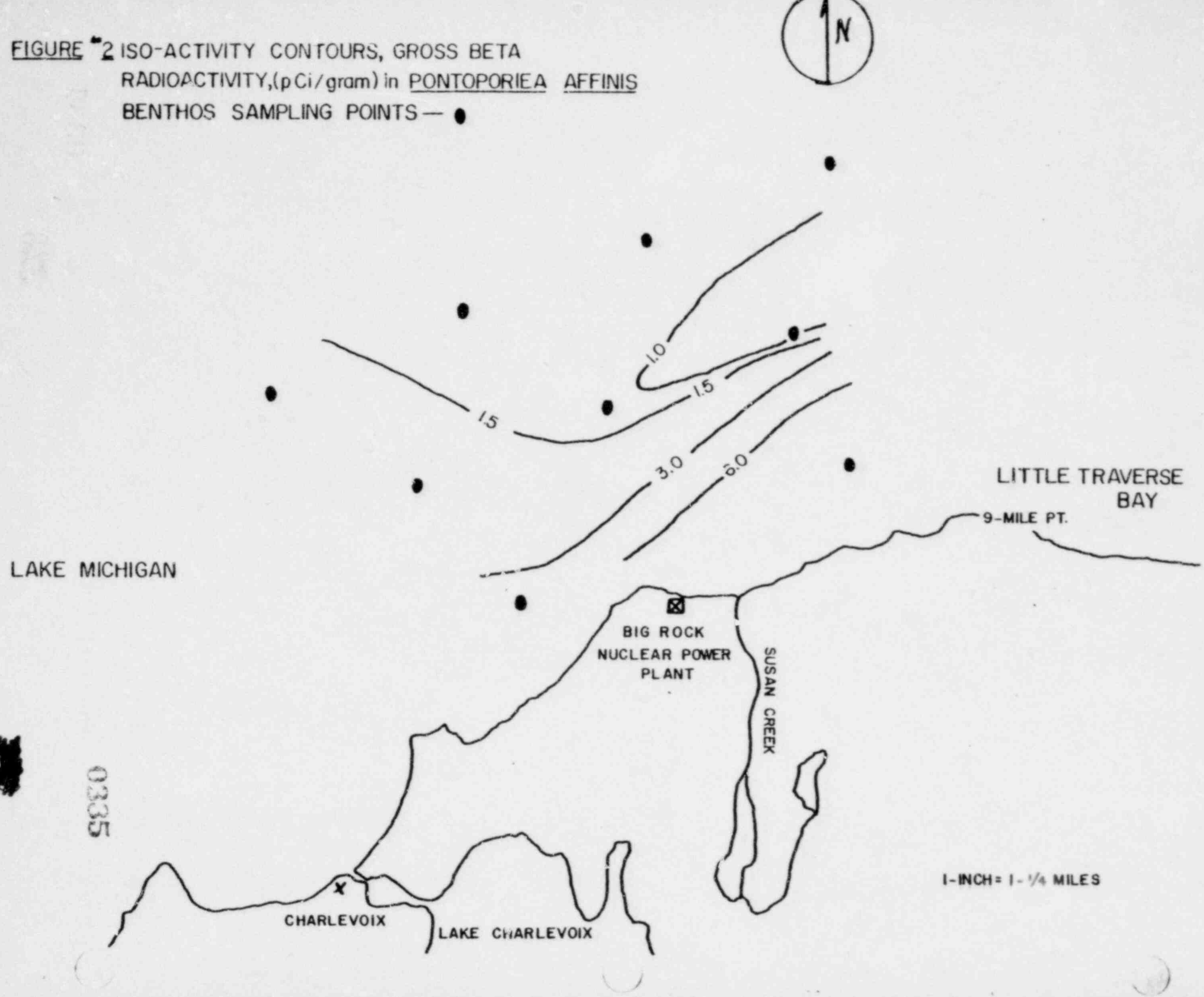


FIGURE 2 ISO-ACTIVITY CONTOURS, GROSS BETA RADIOACTIVITY, (pCi/gram) in PONTOPORIEA AFFINIS

BENTHOS SAMPLING POINTS — ●



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Born: Marcellus, Michigan, October 4, 1912.

Education:

Kalamazoo College	AB in Chemistry, 1934
Kansas State College	MS in Zoology, 1936
Duke University	PhD in Zoology, 1939

Positions Held:

Instructor in Biology, Univ. of South Carolina, 1939-41.
Adjunct Prof. of Biology, " " " 1941-43.
Instructor, Physics & theory of flight, U. S. Naval Flight Prep. School, 1943-44.
Research Associate, Woods Hole Oceanographic Institution, 1944-49.
Asst. Prof. of Oceanography, Cornell University, 1949-52; Assoc. Prof. 1952-56,
Assoc. Prof. of Zoology, Univ. of Michigan, 1956-58; Prof., 1958-63.
Research Director, Great Lakes Research Institute, Univ. of Michigan, 1956-60.
Research Oceanographer, Great Lakes Research Division, Univ. of Michigan, 1960-.
Prof. of Oceanography, University of Michigan, 1963-.

Scientific Societies:

American Society of Limnology and Oceanography
Vice President 1962-63; President 1963-64.
Chairman, Comm. on Education & Recruitment 1961-.
Co-chairman, Program Committee, 1964-.
American Association for the Advancement of Science
Sigma Xi Honorary Society
International Association for Great Lakes Research

Professional Activities:

Member of Corporation, Marine Biological Laboratory, Woods Hole, Massachusetts, 1953-.
Official collaborator, Marsh Ecology Research, N. Y. State Dept. of Conservation. 1958.
General Chairman, Third Conference on Great Lakes Research. 1959.
Consultant to Power Reactor Development Company, 1958-1961; Canadian-American Committee on Great Lakes Water Pollution, 1959; Upper Peninsula Office, Michigan Dept. of Health, 1959; Huron-Clinton Metropolitan Park Commission, 1960; Consumers Power Co., 1961; American Electric Power Service Corporation, 1966-; Oxford Paper Co., 1967-68; Toledo Edison Co., 1968-; Great Lakes Basin Commission, 1968-.

Principal Publications:

Relationship of habitat to oxygen consumption by certain estuarine crabs. Ecology, 19: 523-527, 1938.

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Studies on the environment and eutrophication of Lake Michigan. (With D. C. Chandler, Eds.) Univ. Michigan, Great Lakes Res. Div. Spec. Rep. No. 30, 1967. 415 p.

Current patterns and lake slope. (With F. R. Bellaire.) Proc. 10th Conf. on Great Lakes Res., p. 251-263, 1967.