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A TWO-YEAR STUDY OF THE LAKE AND WIND CURRENTS ON LAKE ERIE NEAR ASHTABULA, OHIO[1]

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ABSTRACT. Lake and wind currents, temperature and transmissivity were monitored as part of a large-scale study involving monitoring of 2 dredged material disposal operations in Lake Erie near Ashtabula, Ohio. The study was carried out from June 1975 to September 1976. During this period at a location 4 km offshore the currents were found to generally flow parallel to the shore with average speeds of 12 cm/sec at 3 m and 5 cm/sec at one meter above lake bottom. The dominant periodic component of the velocity field was the first longitudinal mode of Lake Erie which had a period of approximately 14 hr, During the study currents were generally uniform over the entire study area. Changes in the local winds usually affected the established flow pattern but only after a lag time.

A well-expressed thermocline was observed during the summer season at one and 3 m above lake bottom at a lake depth of 15–20 m. The depth of the thermocline often fluctuated due to slight variations in the wind field. Transmissivity profiles followed the temperature profile closely, transmittance decreasing with depth. Values as high as 39% were observed at the surface during the summer, decreasing to zero during the winter. The general wind flow was towards the northeast during most months. The meteorological data indicated that the site was typical of a near shore environment, generally one to 2 C cooler than farther inland.

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INTRODUCTION

During 1975 and '76 a dredged material disposal operation was monitored in Lake Erie near Ashtabula, Ohio, by the U.S. Army Corps of Engineers Waterways Experiment Station (WES) as part of the Dredged Materials Research Program (DMRP). Baseline data of various environmental parameters were collected monthly at a number of locations during the study period by several consulting groups. Oceanographic studies were included in the overall program as were chemical and biological parameters. The purpose of the program was to determine the short- and long-term environmental impacts on Lake Erie in this area associated with the disposal of dredged material. The oceanographic portion of the study was carried out by a crew from (former) NALCO Environmental Sciences, Northbrook, IL. Baseline information obtained during the study period and reported herein included data on water and wind currents and temperature, solar radiation, and lake level elevation. This article presents data on the lake and wind currents, temperature and transmissivity during 1975 and '76, and their interpretation. The entire study is documented in Danek et al. (1977).

STUDY SITE

The study area is located approximately 8 km offshore Ashtabula Harbor, Ohio, in Lake Erie (fig. 1). The area is approximately 25 km^2. The bottom topography is mostly flat with a slope of one meter/kilometer towards the center of the lake, decreasing from 12 to 20 m depth within the study area. Sediments in the area are primarily fine sand and coarse silt (Alther and Wyeth 1980, Alther 1981).

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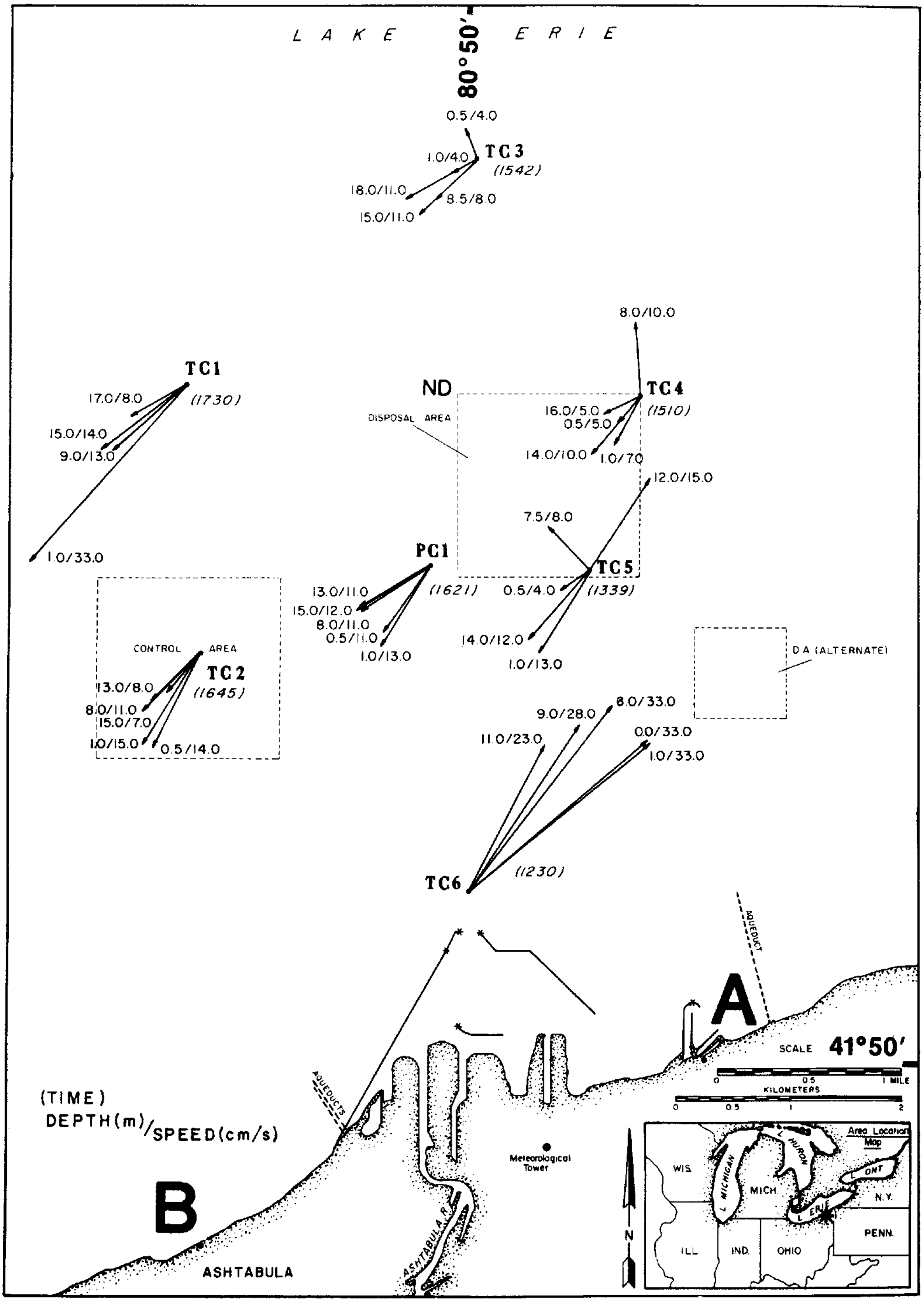

FIGURE 1. Location of permanent mooring for continuous current and temperature measurements (PC1) and locations for vertical profile measurements of temperature, transmissivity, and current (TC1 through TC6) relative to the location of the new disposal site (ND). Over-the-side current velocities shown for 16 November 1975.

A disposal area and a control area were designated by the Army Corps within the study site. Dredged material had been discharged at the disposal area for some 80 years. Baseline data on the physical, chemical and biological nature of the lake were collected at Stations ND, PC1, TC1-TC6 (fig. 1). The location of these sites was determined accurately by a Motorola Mini-Ranger navigational system, whose shore transponders were placed at Stations A and B east and west of Ashtabula Harbor (fig. 1). Dredged material was discharged in 1975 and 1976 at TC4 and TC5, and at ND, respectively.

A permanent current meter and thermograph mooring was installed at PC1. A wave gauge was also placed at this station. A meteorological tower was erected approximately one kilometer onshore near Ashtabula Harbor (fig. 1). Monthly measurements of vertical current, temperature and transmissivity profiles were obtained on all stations. Lake level data were obtained from a gauge in Fairport Harbor 25 km west of Ashtabula, operated by the U.S. Geological Survey.

METHODS AND MATERIALS

TIME CONTINUOUS CURRENT MEASUREMENTS. A permanent mooring was installed at location PC1 on 8 July 1975. ENDECO Type 105 current meters and Type 109 thermographs were secured to the mooring at one meter and 3 m above the bottom (fig. 2). The 2 current meters and 2 thermographs were located at depths of approximately 16 m and 14 m. Current meter measurements were recorded as 30-min averages continuously from June 1975 to September 1976. The instruments were serviced monthly, which included replacement of batteries, film, desiccant bags and a check of the instrument trim.

The current meters were axial flow, ducted impeller instruments specifically designed for use in the near shore zone. Analog values of impeller rotation and magnetic bearing of the instruments comprise the data which were recorded on 16-mm film. Each instrument was calibrated prior to installation in a closely controlled flume to determine threshold speed and accuracy of measurement. The most recent calibrations were conducted by personnel at the Environmental Devices Corporation (ENDECO). Threshold speeds were determined for each current meter and were found to be between 2 and 3 cm/sec. Accuracy of speed measurement was determined to be within ± 0.6 cm/sec of the true speed. Current direction of accuracy was $\pm 5°$ at threshold speed, $\pm 3.6°$ above threshold speed, and resolvable to $\pm 1.0°$.

Time series data of hourly vector averages of current speed and direction were analyzed in several ways. The data were used to construct plots of speed and direction versus time, progressive vector diagrams (PROVECS) (suggesting direction of sediment movement), joint frequency tables of current speed and direction, persistence tables of current speed, and power spectra estimates.

PROVECS were formed by connecting the consecutive velocity vectors head-to-tail to produce a diagram that depicts the history of water motion past a given point. Such diagrams give a continuous picture of the speed and direction of the flow past the disposal site so that episodes of strong currents or velocity changes can be recognized easily. Examination of the wind record prior to changes in the currents observed in the PROVECS helps determine what the response of the current is with respect to changes in the wind. The diagrams also reveal any oscillatory motions such as inertial currents or seiching that are of sufficient magnitude to influence the velocity field and the associated sediment transport.

Joint frequency tables were constructed to show the frequency of joint occurrence of speed (by speed class) and direction (by direction sector). These tables were analyzed to determine the important characteristics of the velocity field. The predominant direction of flow and the predominant speed were determined for each month. When any significant changes were found in the monthly flow pattern, the wind record was consulted to help explain deviations.

The current profile data were averaged vectorially and the resultant speed and direction were determined for each depth. The results were plotted so that vertical shears in the horizontal velocity could be observed. The data collected near PC1 were compared visually with the data from the permanent mooring as a check on the accuracy of the equipment.

CONTINUOUS TEMPERATURE MEASUREMENTS. Continuous temperature measurements were made concurrently with the permanent current meter measurements. Two ENDECO Type 109 recording thermographs were attached to the mooring, one directly beneath each current meter (fig. 2). The 2 thermographs recorded half-hourly averaged temperatures on 16-mm film with a resolution of 0.1 C and an accuracy of +0.2 C. The time constant of the instrument is 10 min. The thermographs were serviced simultaneously with the current meters with the replenishment of new batteries, film, and desiccant bags.

Hourly averages of temperature versus time were plotted for each month and each station. The maximum, minimum, and mean temperatures were de-

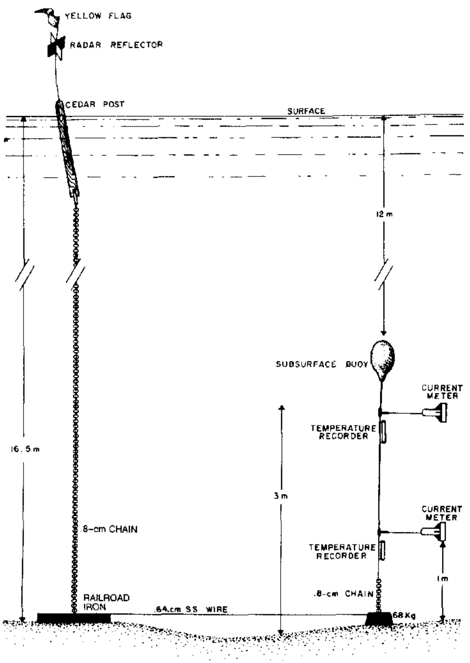

FIGURE 2. Current meter and thermograph mooring.

termined for each month and compared by station and month. Episodes of large temperature fluctuations were noted, and the wind record and current meter records were examined to determine the cause for the variations.

TEMPERATURE PROFILE MEASUREMENTS. Measurements of ambient temperature profiles at Stations TC1-TC6, PC1, and ND were made monthly between July 1975 and September 1976 (with the exception of December 1975, January, February, and August 1976) as well as during disposal operations using a precision thermistor temperature probe (M & F Engineering). This instrument provided a resolution of 0.01 C. and an accuracy of 0.05 C. Temperature measurements were made at one- to 2-m depth intervals. Vertical temperature profiles were plotted for each transect with a computer plot package, and significant changes in the thermocline were examined.

TRANSMISSIVITY. Transmissivity measurements were taken monthly with a Montedoro-Whitney TMA-1A transmissometer. This instrument uses a fixed spacing of one meter between the light source and the sensor and measures the percent of light that is transmitted across the one-meter span. The instrument is designed to work accurately in water up to 100 m deep. The relative accuracy is 2% with a resolution of one percent of the range. The instrument was balanced at every station before obtaining measurements by setting the absorbed light level to 100% with the probe in the air and the mirror and light windows wiped clean. The light source was then covered with a piece of cardboard and the readout adjusted to zero percent. Readings were then obtained at one- or 2-m increments to the bottom. The data were plotted by computer on the same graphs as the temperature data.

METEOROLOGY. A 10-m crank-up tower was erected approximately one kilometer inland from the harbor (fig. 1). A Meteorology Research Incorporated Model 1071 Mechanical Weather Station was secured to the top of the tower, and analogue values of wind speed and direction, and air temperatures were continuously recorded. The wind speed actually was recorded as wind run (time integrated wind speed) and later converted to speed. The threshold of the instrument is 0.34 m/sec for both the vane and the cup anemometer. The speed was recorded with an accuracy of ±2% and the direction with an accuracy of ±3.6° with a resolution of 15°. The weather station was serviced monthly which included the replacement of batteries and strip chart paper.

The data were read from the analogue records and digitized as hourly averages. The results then were used to construct plots of speed and direction versus time, and also to make progressive vector diagrams (PROVECS), joint frequency tables of wind speed and direction, and persistence tables of wind speed. Hourly temperature data, which were recorded with an accuracy of ±1 C, were also tabulated. An Eppley Black and White Pyranometer Model 8-48 was installed approximately 3 m above ground on the south side of a tower at Sutherland Marina, Ashtabula. The instrument records the solar radiation in langely/min with an accuracy of ±2%. An analogue recorder for the solar radiation data was placed inside a trailer next to the tower. No shadows from obstructions were cast on the pyranometer at any time during the day. It was cleaned and serviced monthly.

RESULTS AND DISCUSSION

CONTINUOUS CURRENT MEASUREMENTS. PROVECS were plotted using a single map scale for both the one- and 3-m data whenever possible. However, the speeds measured 3 m above the bottom were so much greater than the one-meter values that in several cases 2 different scales had to be used to properly illustrate the data. In spite of speed differences between the 2 levels, the directions of flow were generally about the same, although there were a few exceptions where the flows were in opposite directions (e.g. February 1976). The primary direction of flow was to the northeast with a secondary direction to the southwest.

The PROVECS were examined to locate periods of sudden changes in the current speed and direction, and the wind record was examined in an attempt to explain these episodes. The examination of several of these events indicated that the wind was not the sole, direct cause for changes in the currents at the disposal site. At one time the currents at both levels moved to the northwest, but then the flow changed suddenly to the east with speeds reaching over 40 cm/sec. The wind during this period was generally out of the south with no sudden changes to cause the dramatic change in the currents. In July 1975 the currents at the 3-m level moved to the east under southwest winds, but on 26 July the flow reversed direction even though there was only a small change in the wind field.

There were some events, however, that could be explained by changes in the local winds; in a later instance it was observed that the currents changed from easterly to westerly which matched well with corresponding changes in the local wind.

Even though a few events seemed to be caused by local wind changes, the results indicate that the currents at the disposal site were influenced more by other forces. The wind undoubtedly drives large-scale circulations in Lake Erie whose patterns are determined by the bathymetry and possibly influenced by seiching, tides, and inertial motions. These large-scale currents, in turn, determine the flow measured at the disposal site. This conclusion seems most probable since local wind changes at the study site alone cannot account for the variability of the currents. In order to properly interpret the cause and effect of currents measured at a single point, data for the circulation patterns in Lake Erie are required (Blanton and Winklhofer 1971).

The PROVECS and speed-direction plots were also examined to locate any periodic components in the flow field. A direction plot of June 1976 (figs. 3 and 4) showed periodicity with the direction varying uniformly from zero to 360° over a period of 18 hr. The corresponding PROVEC showed circular or cuspid motions which were characteristic of inertial currents (Mortimer 1971).

In order to determine the exact periods of the observed oscillation and to estimate the relative amounts of energy for each frequency, the directional components of the velocity field were analyzed with spectral calculations. Samples of the results (fig. 5) showed that there were energy concentrations for periods between 12 and 18 hr. The largest and most consistent energy peaks were found at the 14-hr period which was the first longitudinal seiche mode of Lake Erie (E_1) (Rockwell 1964). There was a small concentration of energy for the second seiche mode of Lake Erie (E_2) at 8 hr, though the peak was quite small and barely distinguishable from the background noise. These spectra also showed that most of the energy was in the eastwest component which agreed with the PROVECS in that the currents were usually parallel to shore. The energy in the currents one meter from the bottom was an order of magnitude less than that at the 3-m level which agreed with the current speed plots.

Current speed persistence tables showed that most of the current speed data had persistences of only one or 2 hr, suggesting that the recorded speeds remained the same (remained within a speed group) for only a short period of time. The speed remained the same for 5 hr or more only about 20% of the time. For a few episodes high persistence values were computed; for example in November 1975 at the one-meter level the speed remained less than 3 cm/sec for 123 hr. During the same month at the same level there were also 6 episodes when the speed became greater than 26 cm/sec, the longest lasting 4 hr. This finding indicated that there was probably more sediment resuspension and transport during this month than any other month. These high speeds were produced by storms during November, which not only generated fast currents at the one-meter level but also produced 17 episodes of speeds greater

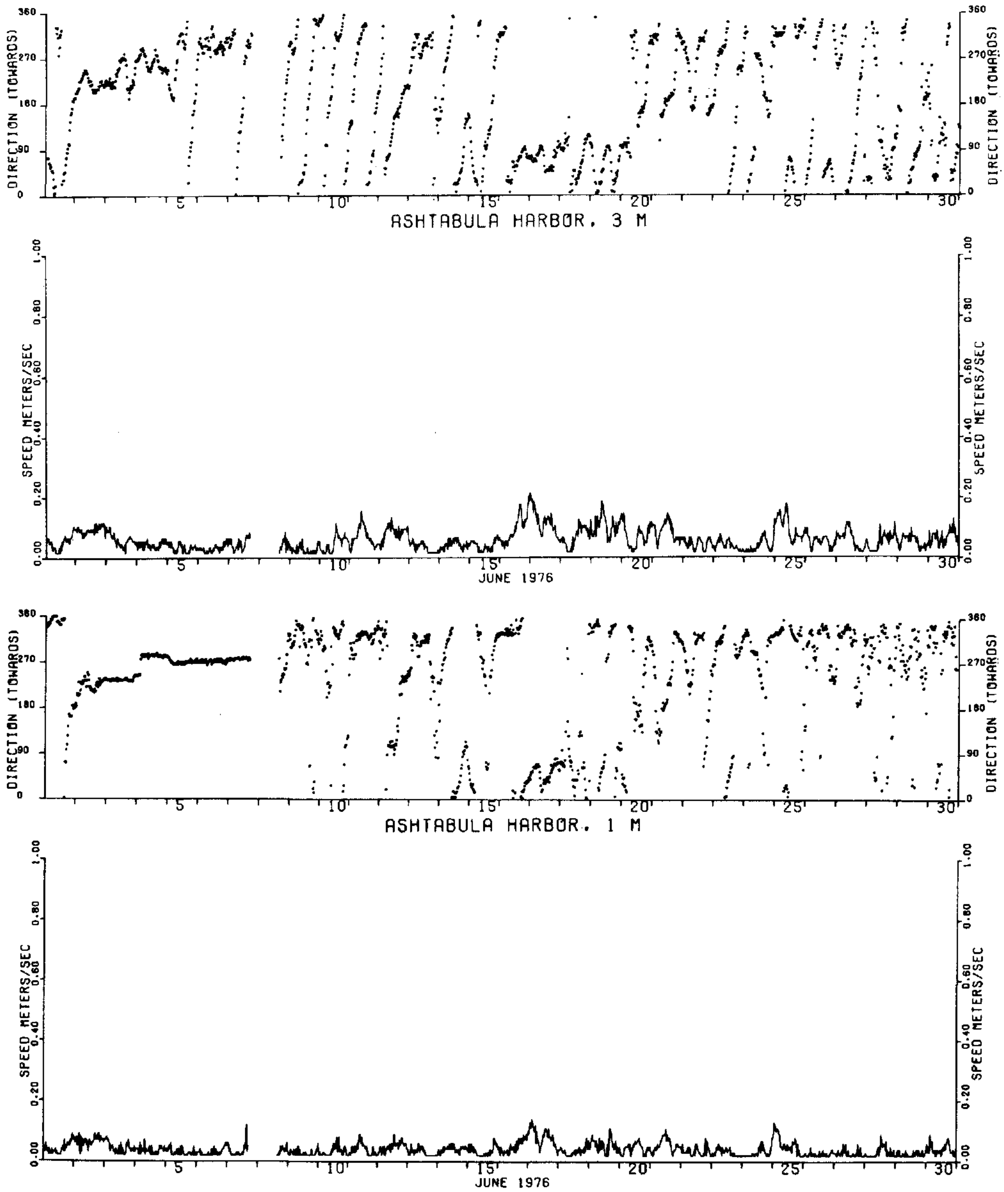

FIGURE 3. Current speed and direction plots for June 1976.

than 26 cm/sec at the 3-m level with the longest event lasting 14 hr. Increased wave activity was also a factor (Danek and Alther 1982, Alther 1981).

Joint frequency distribution tables of current speed and direction from the continuous current meter data also showed that the speeds were significantly greater 3 m above the bottom than at the one-meter level. Of all the measurements taken in 1975 at the 3-m level, 7% were greater than 26 cm/sec, whereas at one meter only one percent were greater than 26 cm/sec. For the 1976 data at 3 m, 3% of the readings were greater than 26 cm/sec. At one meter only about 2% of the time was the

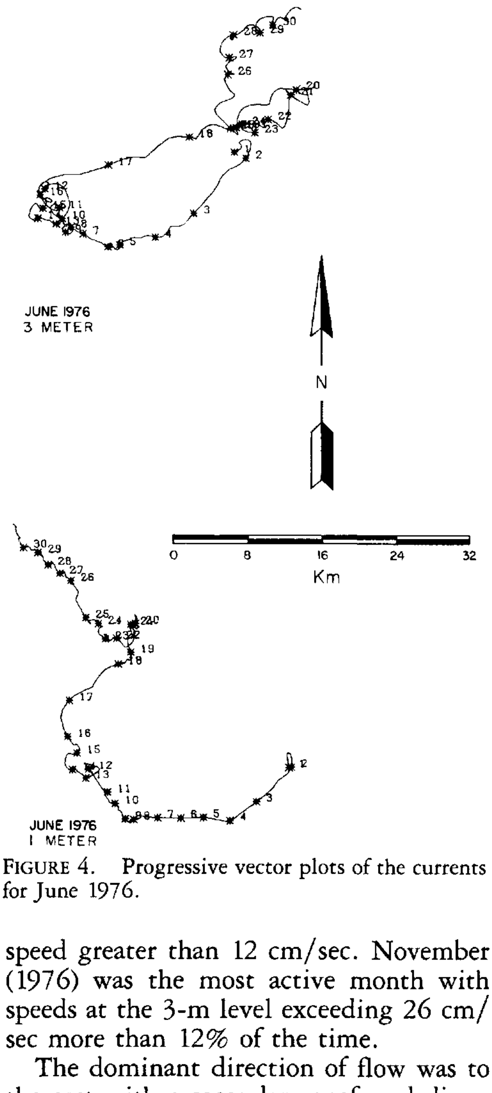

FIGURE 4. Progressive vector plots of the currents for June 1976.

speed greater than 12 cm/sec. November (1976) was the most active month with speeds at the 3-m level exceeding 26 cm/sec more than 12% of the time.

The dominant direction of flow was to the east with a secondary preferred direction to the west. Current roses developed from distribution tables, show monthly and yearly wind roses to compare wind direction with the corresponding currents (fig. 6). The predominant wind direction was out of the south southwest with a secondard occurrence out of the west. The currents were strongly affected by the bathymetry which resulted in flows parallel to shore. These patterns also significantly influenced sediment movement patterns as shown in earlier papers (Alther 1981, Alther and Whyett 1980, 1981).

A monthly average speed plot developed from the joint frequency distribution data (fig. 7) shows the average monthly speed of the currents recorded at both the one- and 3-m levels and the average monthly wind speed. The monthly speed at the 3-m level varied from a high in November and December 1975 of 13 cm/sec to a low in April and May 1976 of only 5 cm/sec. The speeds at one meter were less variable, fluctuating between 3 and 7 cm/sec. The increase in speeds at the 3-m level during November was in response to increased wind speeds as well as unstable conditions produced by cold air flowing over warm water. The drop in the current speed between February and March 1976, even though the wind speed was at its peak of over 5 m/sec, was caused by warmer air flowing over cold water. This situation produced a cold air layer at the water-air interface which greatly reduced the wind drag on the surface water. The current speed at the 3-m level picked up again in August 1976 as the difference between the air and water temperatures decreased.

OVER-THE-SIDE CURRENT MEASUREMENTS. In order to illustrate the vertical variations in the horizontal velocity, plots of the current speed and direction as a function of depth were constructed (fig. 1). The recorded current directions were quite variable, especially during low current speed, and there were frequently large fluctuations over only a one-meter change in depth. This change indicated that the variability might have been caused by the sampling method because such large velocity shears are unlikely. The vessel was anchored from only one point which allowed the boat to swing on the anchor line, causing motion of sufficient magnitude to significantly alter the current readings. Also, the wave activity could have affected the results because of their associated orbital velocities and because of the motion they transferred to the boat which induced movement to the probe.

The results showed several trends in the velocity distribution with depth. The speeds measured near the surface were gen-

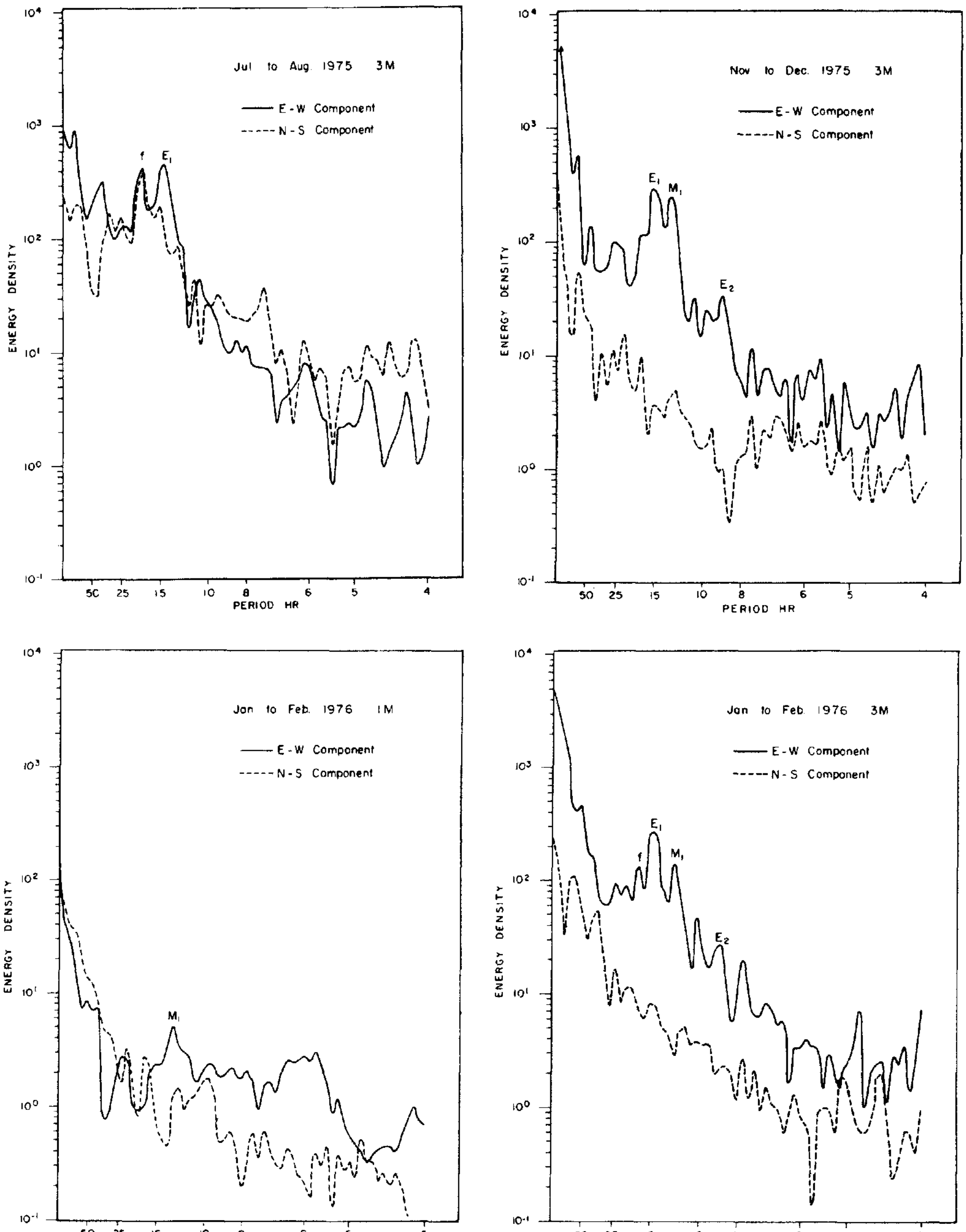

FIGURE 5. Power spectra of velocity components from permanent current meter data. Energy density is given in cm^2/sec^2-hr. Degrees of freedom are approximately 16.

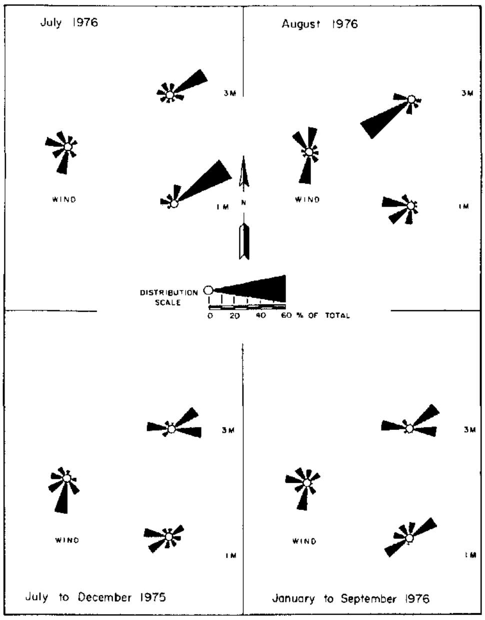

FIGURE 6. Monthly and yearly current roses and wind roses.

erally higher due in part to the orbital velocity of the waves (Danek and Alther 1982) as well as the wind stress at the surface. The majority of the profiles showed a fairly uniform decrease in speed with depth although there were frequent exceptions. Several times the maximum speed occurred near the bottom. These erratic results made it impossible to determine a typical current speed profile and thus any shear stress calculations would be invalid.

Since the current measurements were taken at several locations in the study area approximately the same time, an estimation of the horizontal variability of the velocity field could be made. The computed velocity vectors for each depth at each station were plotted on a base chart for each day of observation and revealed considerable variability with depth at each station. However, if a single flow direction was estimated at each station by visual

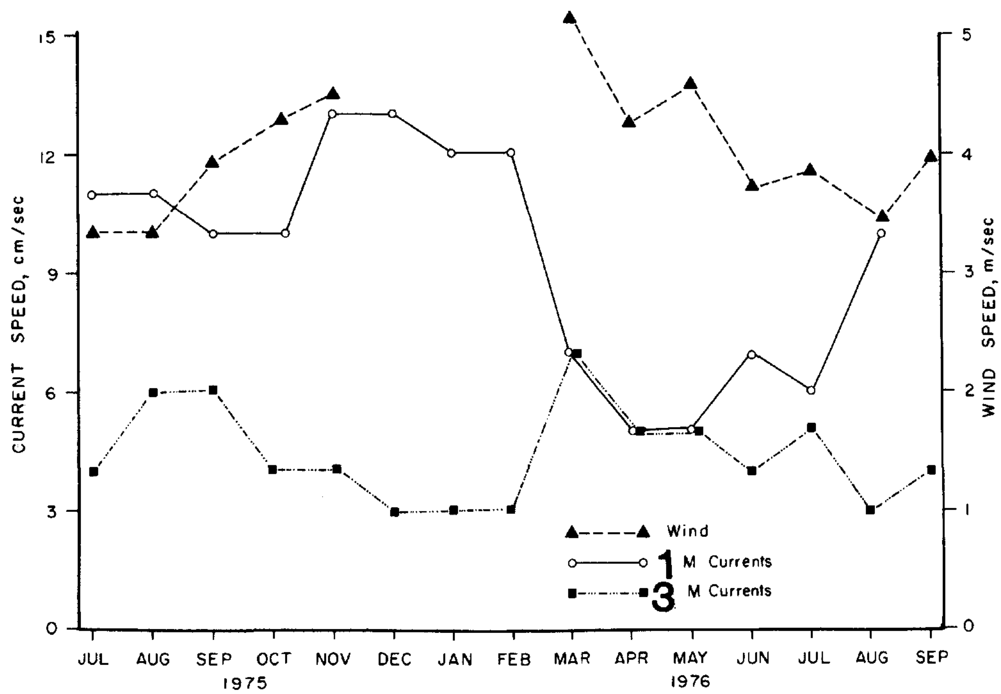

FIGURE 7. Monthly average current speed at one and 3 m and monthly average wind speed.

averaging the velocity vectors for each depth, then general flow patterns over the entire study area could be observed. Fig. 1 shows a predominant southwest direction of currents at most depths, except TC6. The near shore measurements at TC6 indicated strong flow to the northeast. These reverse flows near shore were probably caused by longshore currents that were deflected around the breakwall of the harbor. The Ashtabula River flow might also have influenced the currents in that area although the river discharge for these periods were quite low compared to the usual fall levels.

Most of the results agreed with the above observations in that the flow was generally unidirectional over the entire study area except for occasional reversals of flow near shore, supporting the previous conclusion, with some exceptions that the currents in the area were controlled primarily by the large-scale circulation in Lake Erie rather than the local wind patterns.

CONTINUOUS TEMPERATURE MEASUREMENTS. In July 1975 plots showed that the thermocline had penetrated to within 3 m of bottom by 11 July. The large temperature fluctuations in the record between 11 and 15 July indicated that the thermograph was located near the thermocline and had detected oscillations of the interface caused by internal waves. By 15 July the thermocline had descended below the 3-m thermograph and by 20 July it was less than one meter from bottom. During August slight variations in the wind field caused the depth of the thermocline to fluctuate between the one- and 3-m levels. By the first of September (fig. 8) the water had become isothermal at a temperature of about 22 C. The water then began to cool steadily at both the one- and 3-m levels, and the temperature decreased steadily from September 1975 until January 1976 where it flattened out at nearly zero.

VERTICAL TEMPERATURE PROFILE MEASUREMENTS. The July 1975 results showed a well-developed thermocline about one meter above the bottom with a nearly isothermal epilimnion at about 24 C. The thermocline was prominent at all stations except TC6 which was located near the harbor entrance with only 12 m of water. The water column at this station was completely isothermal. By 1 August 1975 (fig. 9) surface temperature had increased to over 26 C, but there was still a well-defined thermocline about one meter from the bottom. The thermocline was so well developed that there was as much as 11 C temperature drop over less than one meter, and the interface actually appeared on the fathometer traces in the form of planktons which tend to accumulate at the thermocline. The sharp temperature gradient located at this depth agreed well with the results from the thermographs.

The temperature profiles changed very little through the middle of August, but by mid-September the thermocline had disappeared leaving a single layer of water at a temperature of about 20 C. The temperature then decreased uniformly throughout the water column to 15 C in mid-October to 11 C by 16 November, and to 3 C by mid-December.

In March 1976, the entire water column was at the maximum density temperature of about 4 C. The temperature increased through April and May, but no stratification was apparent until a weak thermocline began to develop again in June. The winds kept the water column well mixed, however, and no stratification was apparent in July even though the water temperature had increased to 22 C. By September there was again a thermocline within one meter of the bottom similar to the one observed in August 1975.

TRANSMISSIVITY. Vertical profiles of transmissivity were taken at the same stations as the temperature measurements. The first readings taken on 1 August 1975 (fig. 9) revealed that the profile of the transmissivity was quite similar to the vertical profile of the temperature (fig. 9). The values were relatively constant with a transmissivity of about 20% in the epi-

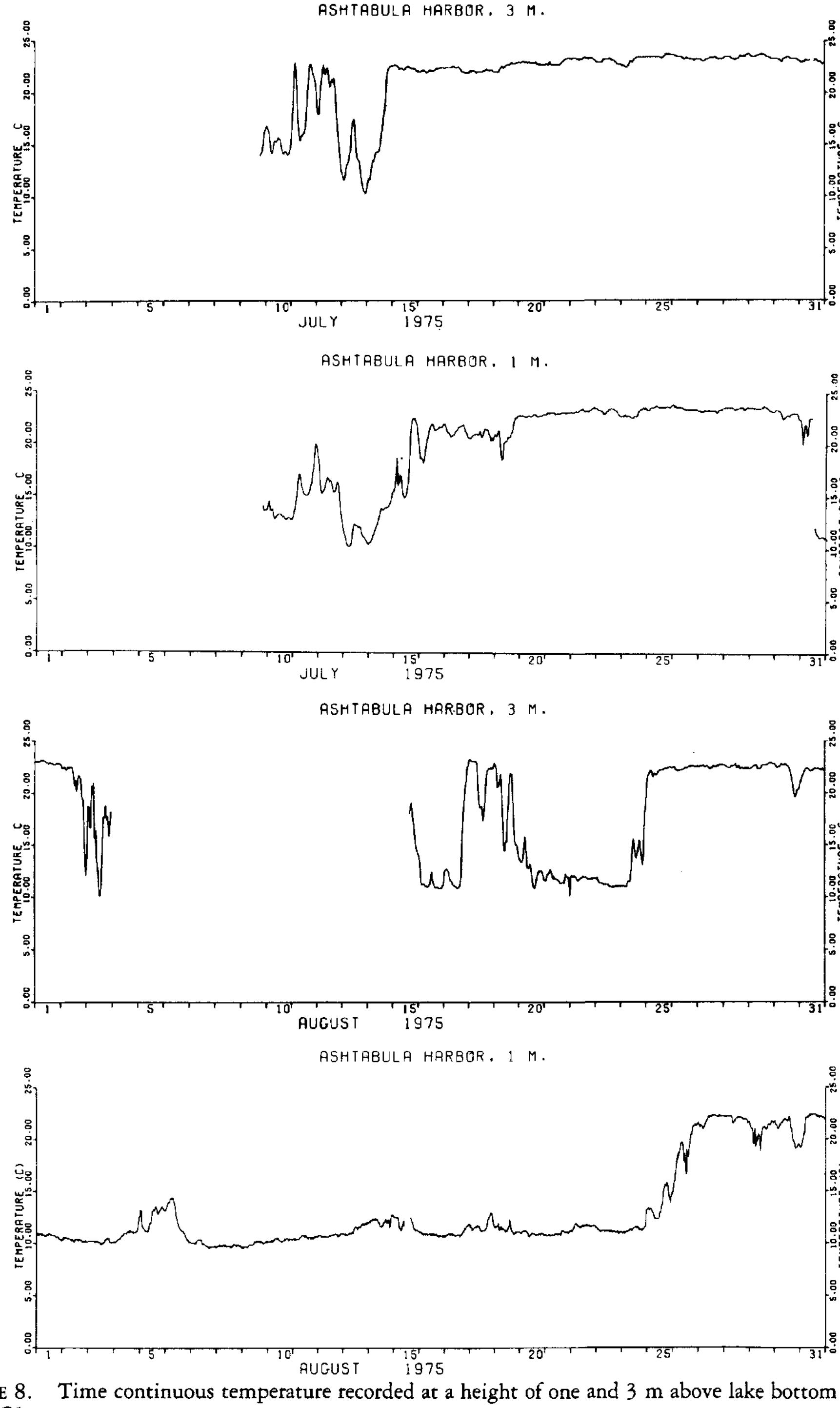

FIGURE 8. Time continuous temperature recorded at a height of one and 3 m above lake bottom at Location PC1.

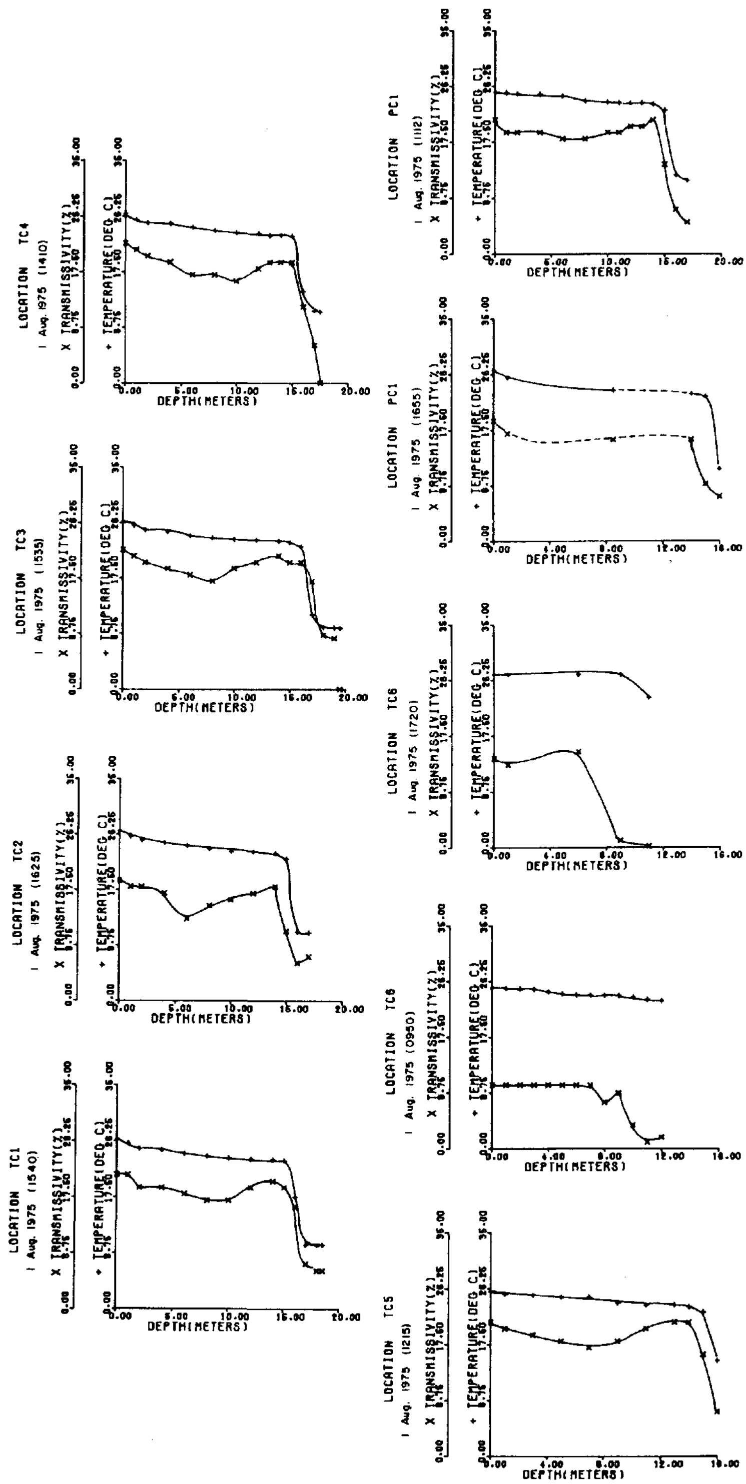

FIGURE 9. Vertical profiles of temperature and transmissivity measured on 1 August 1975.

limnion, but at the thermocline there was a sharp decrease to about 6% for the one-meter layer between the bottom and the thermocline. This increase in turbidity in the hypolimnion was caused by the density discontinuity produced by the thermocline. Resuspended sediments could not migrate through the thermocline because of the relatively large amount of energy required to overcome the density gradient. Only under storm conditions, when there was sufficient energy to break down the thermocline, could the resuspended sediments mix freely throughout the water column.

The transmissivity generally increased with distance offshore with the surface values varying from 14% near the harbor (TC6) to 22% for the station farthest offshore (TC3). The shallowness of the water column, which allowed for penetration of the wave energy for sediment resuspension, as well as nearness to the breaker zone and longshore currents were probably the major causes for the decrease in transmissivity for this area. The Ashtabula River discharge was very low for this sampling period so it affected the transmissivity to only a limited extent. The harbor, however, was continually agitated by shipping activity, and diffusion of the turbid water to areas outside the harbor influenced the transmissivity in the near shore zone.

The transmissivity increased in the middle of August to surface values as high as 39% although the near shore station was still quite turbid. By the middle of September 1975, the values dropped sharply to less than 10% with the near shore station displaying a transmissivity of less than one percent. This sampling interval followed a period of heavy rains and high river discharge which affected the values. The near shore station was most affected by the increased river discharge, but it is difficult to tell if the other stations were affected by the river plume or just by the increased wave and current activity associated with the rainstorms.

The readings in October showed that the transmissivity was uniform throughout the water column with values between 10 and 13%, but in November the readings at all stations dropped to zero. These measurements were taken 2 days after a storm on 14 November where wave height reached 2 m and current speeds reached 40 cm/sec which resuspended sediments. A similar rapid change in transmissivity was observed during the September 1976 sampling by the diver who reported visibilities of between 2 and 3 m before a storm but near zero after the storm.

The strong susceptibility of the transmissivity values to previous meteorological conditions make it difficult to characterize the values by seasons since the time of sampling relative to the last storm greatly influenced the readings. As a general rule though, the transmissivity was fairly uniform with depth during the unstratified seasons. Transmissivity decreased below the thermocline during thermally stratified seasons and dramatically decreased following storm conditions.

METEOROLOGY. The maximum wind speed recorded during the period from June 1975 through September 1976 (without December, January and February) was 13.4 m/sec which last occurred in November 1975. The valid data recovery rate for the entire period was greater than 90% for both the wind speed and wind direction data.

Joint frequency distributions of wind speed and wind direction showed that the predominant wind direction at the site during the June 1975 through December 1975 period and during the March 1976 through September 1976 period was from the south with a secondary flow from the west. The predominant wind speed class was the 1.8–3.6 m/sec class.

Fifty percent of the hourly averaged wind speeds persisted for 2 hr or less and 90% persisted for 8 hr or less. The flow was toward the northeast during most months. An example of wind flow during June 1976 is shown in figs. 10 and 11. This can be compared with figs. 3 and 4, the current data.

During this period a maximum temper-

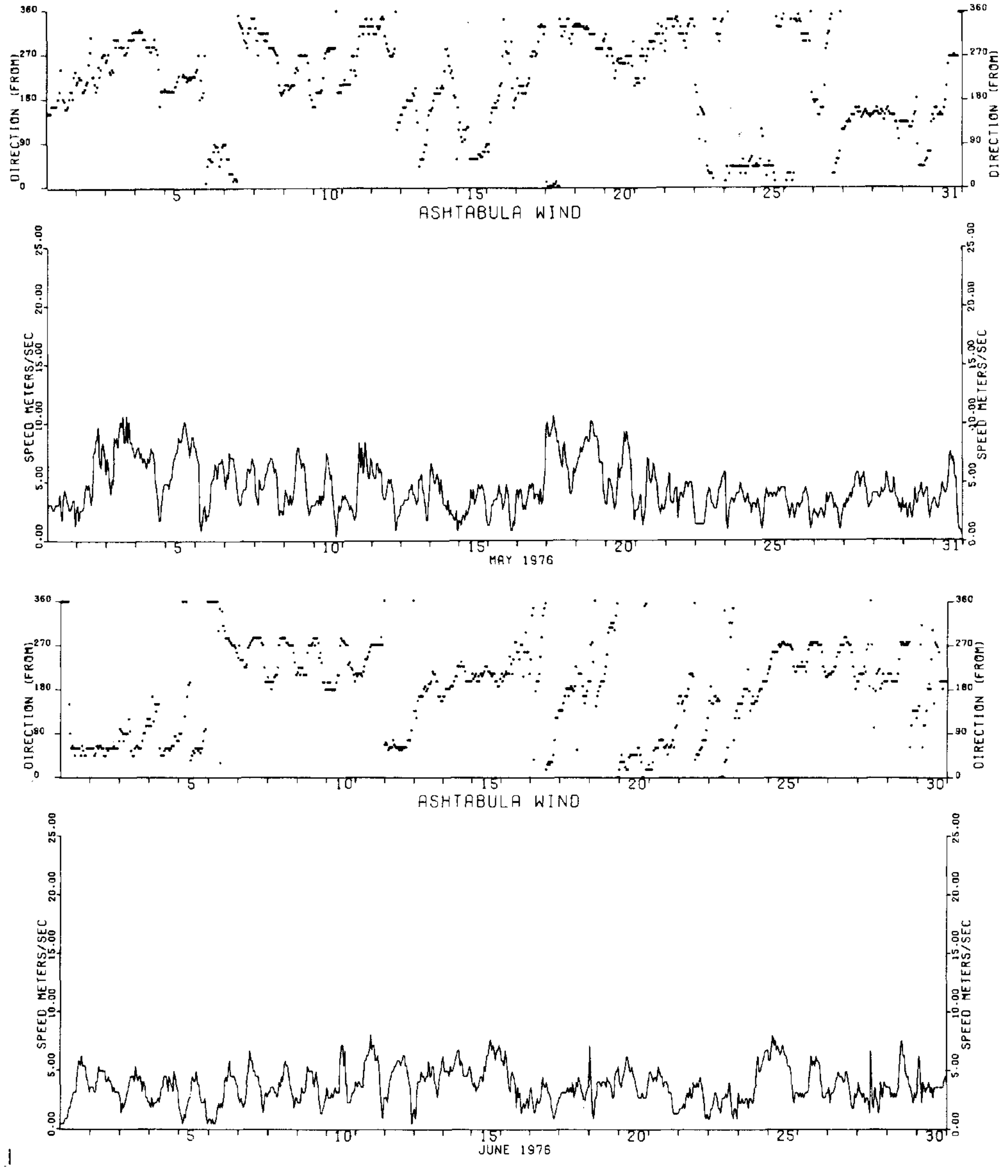

FIGURE 10. Wind speed and direction plots for May and June 1976.

ature of 32.2 C occurred on 6 July 1985 and a minimum temperature of −6.7 C occurred on 7 December 1975.

The maximum solar radiation for the site occurred during July and the minimum occurred during December and January.

In general, the meteorological data collected on site indicated that the site area was typical of a shore line environment. This observation was evident from the fact that the range of temperature was not as great at Ashtabula as it was at stations located further inland. For example, dur-

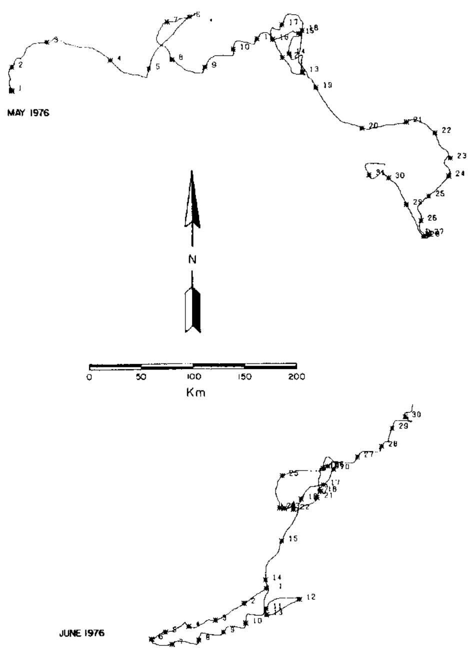

FIGURE 11. Progressive figure plots of the wind for May and June 1976.

ing the period from July 1975 through June 1976 the daily maximum temperature value at Ashtabula (this station is located about one kilometer from the Lake Erie shore line) averaged about 1.7 C cooler than at the Cleveland National Weather Service Station. The daily minimum temperature at Ashtabula was 1.2 C warmer than at Cleveland.

HYDROLOGY. Hourly lake level values for periods when bathymetric surveys were conducted and daily average lake levels values for the entire period of the study were collected.

Since the study site was located approximately midway along the major axis of the lake, the water level fluctuations were not as great as those typically observed at the eastern or western ends of the basin. The maximum recorded water level during the study period occurred in June 1976 and was 174.90 m; the minimum was 173.74 m and occurred in November 1975. The water level was lower during the winter months with January 1976 recording the lowest monthly mean level at 174.25 m. The maximum monthly mean occurred in May 1976 with an average water level of 174.63 m. (Data were adjusted to "IGLD" 1955.)

CONCLUSIONS

The currents in the disposal area generally flow parallel to the shore with average speeds of 12 cm/sec at the 3-m level and 5 cm/sec at the one-meter level. The dominant periodic component of the velocity field was the first longitudinal mode of Lake Erie which had a period of 14 hr. The currents generally were uniform over the entire study area, and changes in the local winds did not immediately affect the established flow pattern.

Continuous temperature measurements at one and 3 m above lake bottom and vertical profiles revealed a well-expressed thermocline at one to 3 m above bottom during the summer months. The thermocline did not develop until late summer in 1976. The depth of the thermocline often fluctuated due to slight variations in the windfield. During the winter season, temperature decreased to above 4 C.

Transmissivity profiles followed that of the temperature closely during the summer season, reaching transmittance values of 39%. During the winter months the transmissivity decreased to zero.

Meteorological data indicated that the site was typical of a near shore environment, generally one to 2 C cooler than inland. The general flow of the wind was toward the northeast during most months. Maximum water level fluctuation during the study period was one m.

The most telling conclusion from this study is that local storms dramatically affect the environment. Wave and current activity often changes due to storms; temperature gradiants are disrupted, and transmissivity values decrease. The clearest expressions of the stratigraphy of the lake are during the calm mid-summer months.

Dredged material can thus easily be resuspended and transported to other areas during local winter storms. This integrated approach is a useful tool to discern the events that cause migration of sediments.

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