Geological Character and Mineral Resources of South Central Lake Erie

by

S. Jeffress Williams and Edward P. Meisburger

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During the summers of 1977 and 1978, a 900-square kilometer region of southern Lake Erie, between the Ohio-Pennsylvania border and Erie, Pennsylvania, was surveyed, using high resolution seismic reflection equipment and long vibracores, to determine the shallow subbottom geologic character of the lake floor. Emphasis was placed on describing the sediments and identifying deposits of sand and gravel that might be dredged and used as fill for beach

(continued)

nourishment projects on Presque Isle Peninsula. A total of 416 kilometers of seismic profiles and 49 cores with an average length of 4.1 meters were analyzed along with 23 grab samples.

Analyses of the seismic profiles, sediment cores, and grab samples show that four major geologic units are present. Paleozoic shale bedrock with a lakeward slope underlies the entire region. Shale crops out at the lake floor shoreward of the -10-meter contour and attains depths of -87 meters about 18 kilometers offshore. Thick units of glacial sediment overlie the bedrock surface and include assorted tills, stratified glaciofluvial sand and gravel, and stiff lacustrine muds. Beach and dune sands are present on the top of the transverse ridge between Long Point, Ontario, and Presque Isle. These sands result from the reworking of the morainal sediments comprising the ridge by coastal processes of an earlier Lake Erie. Modern soft muds are accumulating in deepwater, low-energy areas adjacent to the ridge and Presque Isle platform.

Sand and gravel of suitable size distribution and composition are present in large quantities in two locales. The ridge and platform features contain about 39 million cubic meters of proven resources within 2.3 meters of the lake floor; the seismic profiles of the subbottom show that two to three times that volume may be present if the entire ridge is considered. A second morainal ridge off Dans Beach, west of Erie, is judged to contain several million cubic meters, but its closeness to shore and the distance of 25 kilometers from Erie limit the fill potential of the ridge.

PREFACE

This report provides data and information on the geomorphology, geologic character, and sediment distribution on a part of Lake Erie with specific emphasis on locating, describing, and delineating offshore sand deposits having potential for use as fill material for beach nourishment projects on Presque Isle Peninsula. Seismic reflection data and sediment cores comprise the data base for this study which will contribute to the Beach Erosion Control Study of Presque Isle Peninsula, Erie, Pennsylvania, being conducted by the U.S. Army Engineer District, Buffalo. The work was carried out under the U.S. Army Coastal Engineering Research Center's (CERC) Barrier Island Sedimentation Studies work unit, Shore Protection and Restoration Program, Coastal Engineering Area of Civil Works Research and Development.

The report was prepared principally by S. Jeffress Williams, Geologist, with the assistance of Edward P. Meisburger, Geologist, in all phases of the study, under the general supervision of Dr. C.H. Everts, Chief, Engineering Geology Branch, and Mr. N. Parker, Chief, Engineering Development Division, CERC.

The authors acknowledge the assistance of the following people: D.A. Prins for collecting and reducing the data, J. Pope and D. Clark (Buffalo District) for their support and interest in conducting the study, Professor P. Knuth (Edinboro State College) for providing unpublished data and sediment samples from his own studies and several of his students for their help in collecting the survey data.

Original copies of the seismic profiles, as well as the cores, are stored at CERC. Requests for information relative to these data should be directed to S.J. Williams at CERC.

Technical Director of CERC was Dr. Robert W. Whalin, P.E., upon publication of this report.

Comments on this publication are invited.

Approved for publication in accordance with Public Law 166, 79th Congress, approved 31 July 1945, as supplemented by Public Law 172, 88th Congress, approved 7 November 1963.

TED E. BISHOP
Colonel, Corps of Engineers
Commander and Director

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CONVERSION FACTORS, U.S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U.S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	by	To obtain
inches	25.4	millimeters
	2.54	centimeters
square inches	6.452	square centimeters
cubic inches	16.39	cubic centimeters
feet	30.48	centimeters
	0.3048	meters
square feet	0.0929	square meters
cubic feet	0.0283	cubic meters
yards	0.9144	meters
square yards	0.836	square meters
cubic yards	0.7646	cubic meters
miles	1.6093	kilometers
square miles	259.0	hectares
knots	1.852	kilometers per hour
acres	0.4047	hectares
foot-pounds	1.3558	newton meters
millibars	1.0197×10^{-3}	kilograms per square centimeter
ounces	28.35	grams
pounds	453.6	grams
	0.4536	kilograms
ton, long	1.0160	metric tons
ton, short	0.9072	metric tons
degrees (angle)	0.01745	radians
Fahrenheit degrees	5/9	Celsius degrees or Kelvins[1]

[1] To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use formula: $C = (5/9)(F - 32)$.

To obtain Kelvin (K) readings, use formula: $K = (5/9)(F - 32) + 273.15$.

GEOLOGICAL CHARACTER AND MINERAL RESOURCES
OF SOUTH CENTRAL LAKE ERIE

by

S. Jeffress Williams and Edward P. Meisburger

I. INTRODUCTION

Presque Isle Peninsula is a classic example of a compound recurved sandspit, which extends 4 kilometers into Lake Erie and about 10 kilometers along the Pennsylvania shoreline. Because of its position and morphology, Presque Isle acts as a natural offshore breakwater for Erie Harbor, blocking the prevailing winds and waves from southwest to northwest. However, Presque Isle has experienced severe erosion on the straight "neck" segment, because of its exposed position, while the eastern distal end has undergone continual growth in length and width. Presque Isle is important not only to the service of Erie Harbor, but also as a recreation resource to 3 to 4 million annual visitors. Because of this value several engineering plans have been implemented during the past 40 years in an attempt to diminish erosion and maintain the integrity and position of Presque Isle.

Presque Isle was first surveyed by Army engineers in 1819 because of erosion problems, and it became a federally authorized beach erosion project in 1824. Historically, severe erosion has always plagued the narrow neck part of Presque Isle. On at least four occasions waves have breached the neck and created inlets that separated the peninsula from the mainland; each time, however, the inlets have been closed either by natural processes or by Federal and State action. Serious interest in maintaining Presque Isle for recreation purposes and the protection of Erie Harbor began to grow in the late 1940's.

The first comprehensive coastal engineering plan, which began in 1956, consisted of constructing a system of groins combined with sandfill for beach nourishment along the western side of the peninsula mainland out about two-thirds the length of the peninsula. The sandfill was derived from borrow pits within Erie Harbor and was considered suitable but the mean grain was smaller than the native beach material. Because of this the sand was very unstable in the normal littoral environment, causing subsequent erosion and the rapid removal of the nourished shore. There have been numerous emergency fills and all but one, which was done in 1965, failed to maintain the desired beach width and height because the fine sand placed was highly susceptible to erosion. The 1965 nourishment plan included an experimental phase that placed coarse sand with a mean size of about 0.4 phi (0.75 millimeter), in comparison to native grain size of 2.1 phi (0.23 millimeter), on a 350-meter-long stretch of shore between groins No. 2 and 3 where the greatest erosion occurred (Berg and Duane, 1968). This fill was unique in that it was derived from a State-leased area about 13 kilometers offshore from the project. Sampling and profiling of the groin compartment following the coarse sandfill operation indicated that the shore experienced little loss of sand and maintained a stable profile. Berg and Duane's (1968) findings proved that the use of fill with a coarser size distribution than the native sand, but including all the native profile sizes, can be an effective means of both stabilizing the shore and providing a recreational resource.

The 1974 Water Resources Act provided funding over a 5-year period to plan and conduct new studies to stabilize the Presque Isle shore. The plan being studied by the U.S. Army Engineer District, Buffalo, may include the construction of five segmented offshore breakwaters and the placement of 1.3 million cubic meters of suitable coarse sandfill, along with annual nourishment requirements of about 137 000 cubic meters (U.S. Army Engineer District, Buffalo, 1979). Over a 50-year project life the requirement for sandfill would be about 8.1 million cubic meters.

This report discusses a survey that was conducted in 1977 and 1978, covering about 900 square kilometers of the Pennsylvania region of Lake Erie, by means of high resolution seismic reflection profiles and vibratory cores with the objective of providing detailed information on the character and quantities of submerged sand and gravel deposits. This data base will provide a significant contribution to the Beach Erosion Control Study of Presque Isle Peninsula currently being conducted by the Buffalo District.

1. Scope of Survey.

The study area covered about 900 square kilometers of Lake Erie, from the Ohio-Pennsylvania border east 45 kilometers to the city of Erie, Pennsylvania, with particular emphasis on the offshore areas of the Presque Isle Peninsula (Fig. 1). The area of data collection extended from the shore lakeward generally about 8 kilometers, excluding the area northwest of Presque Isle that contains an elongate submerged ridge extending to Long Point on the Canadian side. Data coverage over the ridge area extends a maximum of 32 kilometers from the shore to the Canadian border. Water depths in the areas surveyed ranged from about -5 to -23 meters. A total of 416 kilometers of high resolution continuous seismic reflection profiles and 49 cores were collected (Fig. 2). Core lengths ranged from 1.3 to 6.1 meters and averaged 4.1 meters. Throughout both the seismic and coring surveys a Motorola Mini-Ranger III electronic positioning system was used to accurately record the positions of the survey vessels. The stated accuracy of this system is ±3 meters. These basic data were supplemented by pertinent scientific and technical literature and available National Ocean Survey (NOS) charts.

The seismic and coring data were collected during summer surveys in 1977 and 1978, as part of the Coastal Field Data Collection Program conducted by the Coastal Engineering Research Center (CERC). Additional funding and administrative support needed for a detail study of the offshore ridge was provided by the U.S. Army Engineer District, Buffalo. The present study is part of a larger investigation by CERC covering the south shore of Lake Erie from Erie to Toledo, Ohio. The Ohio part of the study was done in cooperation with the Ohio Department of Natural Resources Division of Geological Survey and results from those surveys are presented in two other reports, Williams, et al. (1980) and Carter, et al. (in preparation, 1982).

2. Geographic Setting and Lake Floor Topography.

The study area is situated near the southern boundary of the eastern lake section that is part of the Central Lowland Physiographic Province. This entire region has been subjected to multiple episodes of continental glaciation during the past several million years and much of the land topography and drainage has been determined by the glacial events of erosion and deposition. The

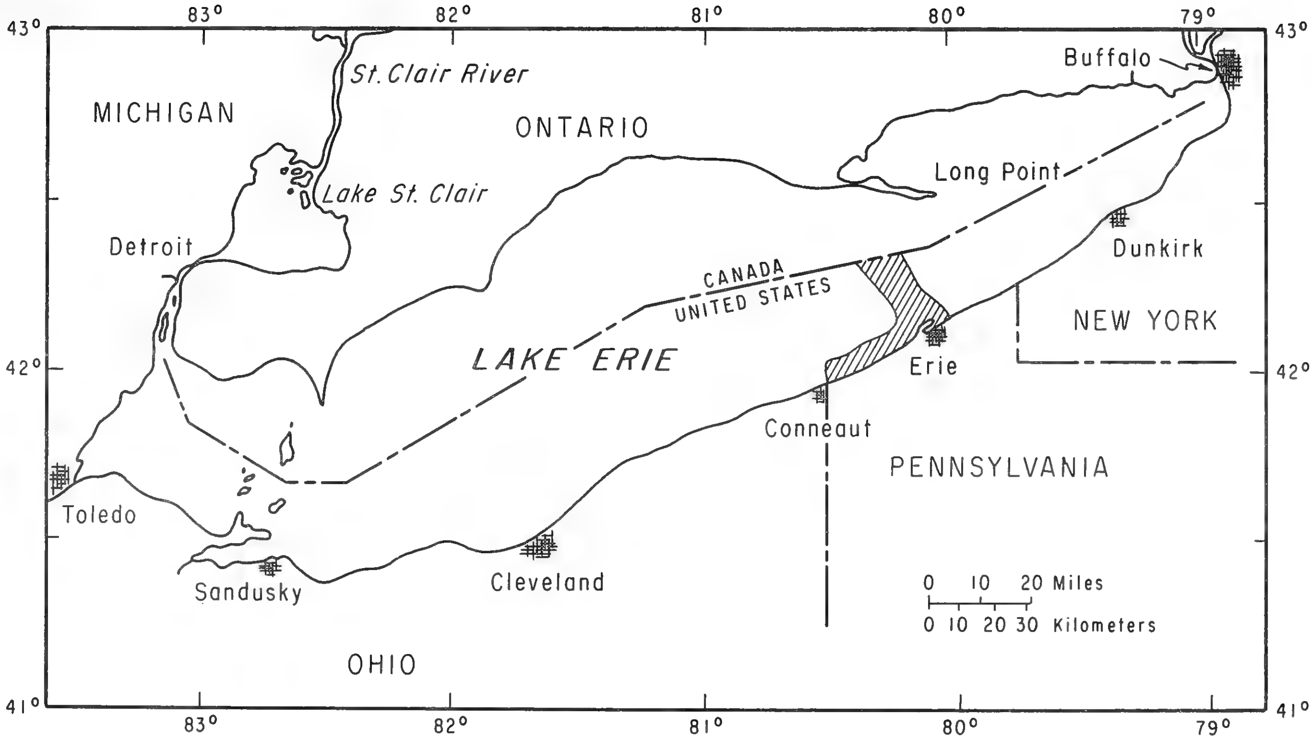


Figure 1. Location map of the study area.

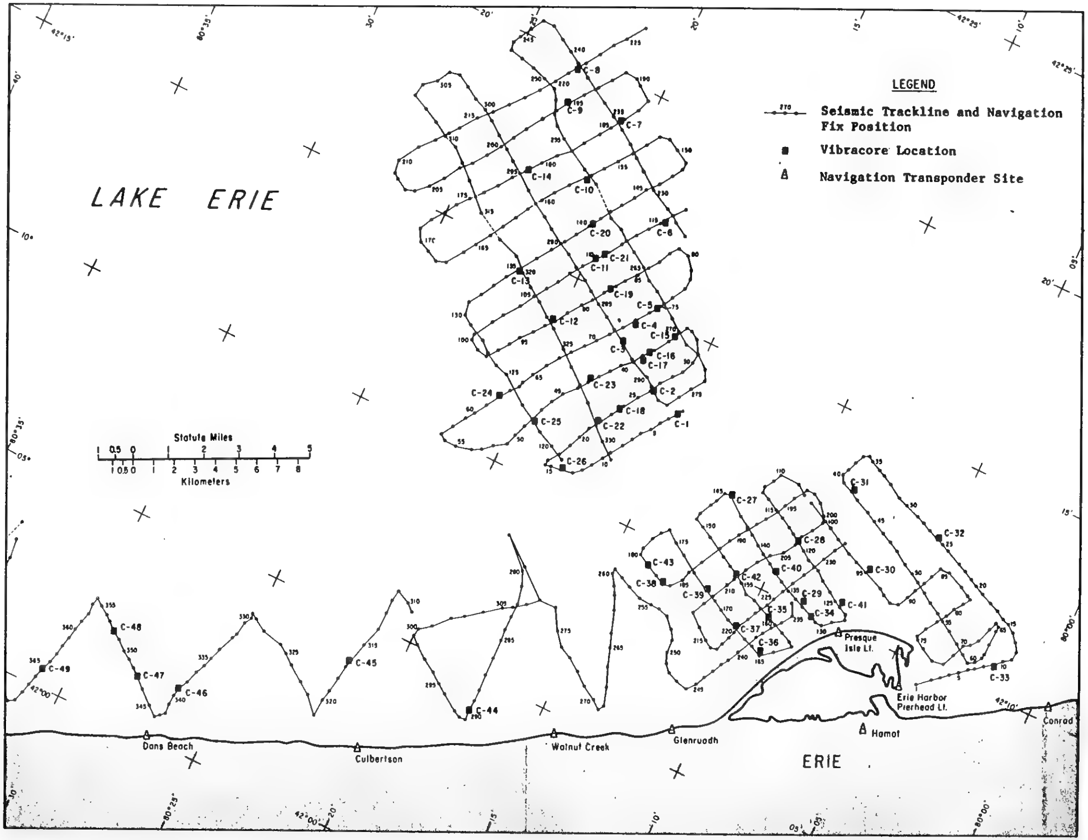


Figure 2. Data coverage of seismic profiles and vibratory cores.

basin comprising present-day Lake Erie was scoured by Pleistocene age glaciers, and numerous ancestral lakes occupied the basin following the latest glacial retreat about 12,000 years ago. These lakes fluctuated considerably in area and water level elevation depending upon climatic conditions and the degree of crustal isostatic rebound of the outlet to the Erie basin at Niagara Falls, New York. The presence of deeply incised stream valleys, shoreline deposits, and wave-cut shore terraces below present lake levels suggests that several lake stages below present have persisted, and these same features plus old lacustrine deposits presently subaerially exposed prove that some lake stages have beem significantly higher than at present. The lacustrine deposits and sandy shoreline deposits are particularly evident in the study area.

Figure 3 shows that the nearshore region in the study area is characterized by generally shore-parallel contours out to -21 meters with the exception of the Presque Isle platform and spit as defined by the -12-meter contour, and a linear topographic feature off Dans Beach that trends northwest. A prominent elongate trough that reaches a maximum depth of about 23 meters parallels the shore about 11 kilometers off Erie. It attains a minimum width of 3.2 kilometers off the base of Presque Isle and widens eastward to a broad and gently sloping plain that reaches depths of 30 meters about 24 kilometers north of Erie. Westward the trough widens gradually to about 6.5 kilometers off the Ohio-Pennsylvania border.

North of the trough is a north-northwest trending linear ridge that is recurved as defined by the 20-meter contours in Figures 3 and 4. It has a crest elevation of about -15 meters and is asymmetrical with a steep slope eastward and a more gradual slope westward to -23-meter water depths. The main body of the ridge is 1.5 to 5.5 kilometers wide and extends northward across Lake Erie to the Canadian shore at the base of Long Point (Fig. 4). This ridge is the major boundary between the deep eastern section of Lake Erie basin and the more shallow central section, and as will be discussed later, has been very important to the origin and evolution of Presque Isle Peninsula.

3. Data Analysis.

The seismic profiles collected were visually examined and marked to establish the primary geologic features to depths of about 23 meters below the lake floor, the maximum penetration and resolution of the systems used. Regional geologic reflectors were mapped, identified, and where possible correlated with sedimentary materials recovered in the cores.

The cores collected were sent to the CERC laboratory where they were split open lengthwise, described, and sampled in detail to include the sediment textural characteristics, sand composition, color, relative strength of cohesive materials, and presence of organic materials that might be radiocarbon dated to give absolute geologic ages of the sediments. Complete logs of the cores (App. A) include water depth at each site, length of recovered sediment, and thickness of each sedimentary unit as measured from the top of the core. The grain-size descriptions are based on the Wentworth classification as shown in Table 1.

Appendix B contains results from grain-size analysis using the Rapid Sediment Analyzer (RSA) for fine- to coarse-grained sands and sieve analysis for

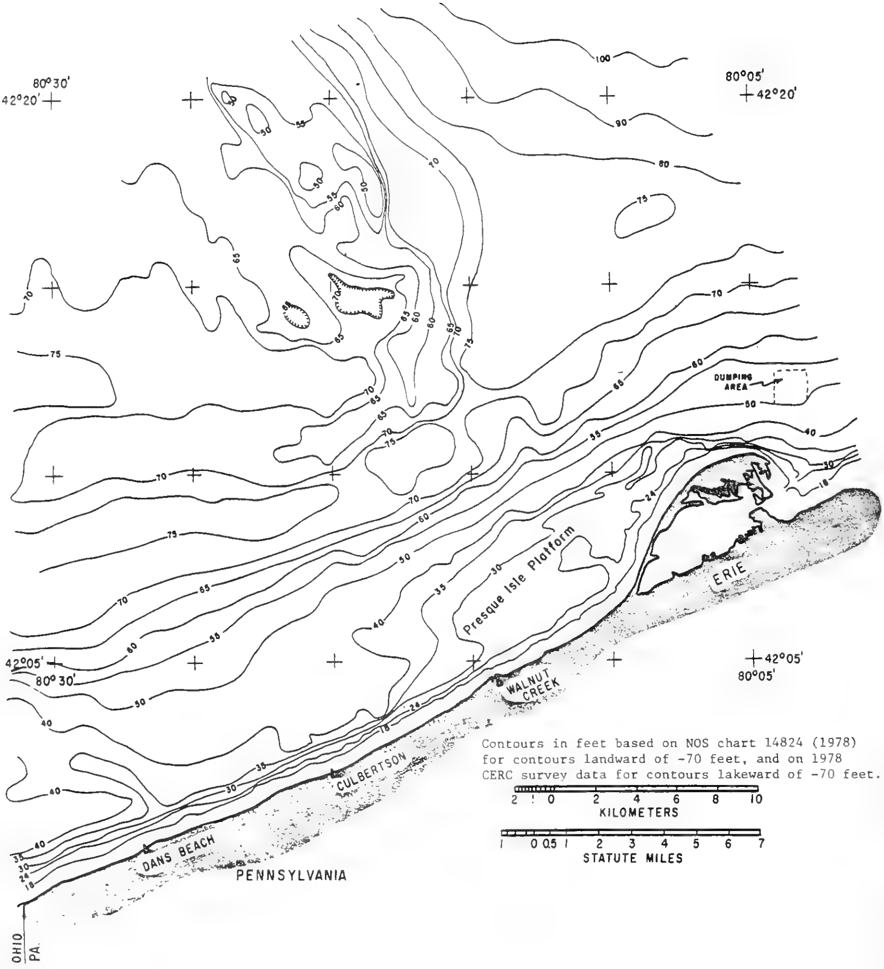


Figure 3. Bathymetric map of the study area.

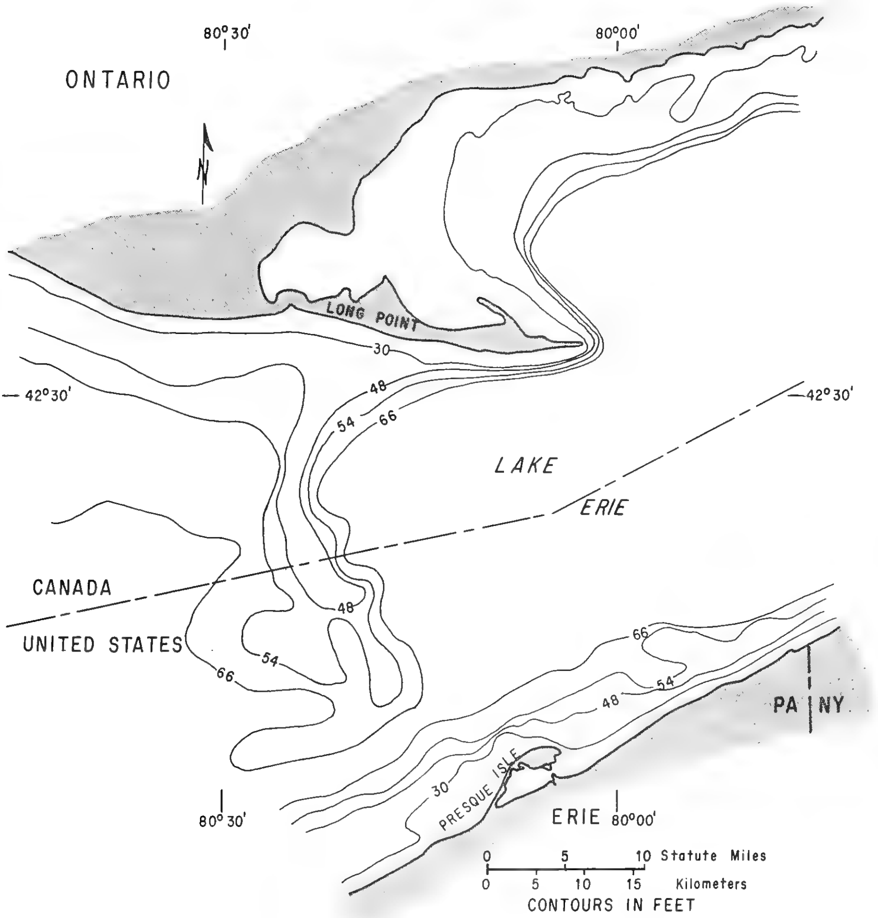
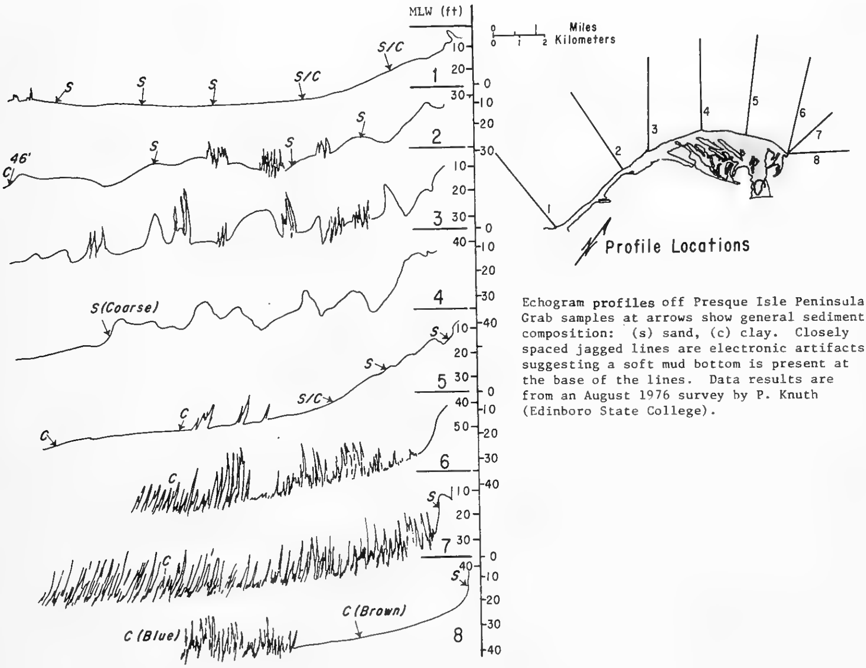


Figure 4. Map of the central Lake Erie basin showing the transverse ridge that connects with Long Point and projects toward Presque Isle.

Table 1. Grain-size scales-soil classification (U.S. Army, Corps of Engineers, Coastal Engineering Research Center, 1977).

Unified Soils Classification	ASTM Mesh	mm Size	Phi Value	Wentworth Classification
COBBLE				BOULDER
		256.0	-8.0	
				COBBLE
		76.0	-6.25	
COARSE GRAVEL				
		64.0	-6.0	
				PEBBLE
		19.0	-4.25	
FINE GRAVEL				
	4	4.76	-2.25	
SAND coarse				
	5	4.0	-2.0	
				GRAVEL
	10	2.0	-1.0	
SAND medium				SAND very coarse
	18	1.0	0.0	
				SAND coarse
	25	0.5	1.0	
				SAND medium
	40	0.42	1.25	
SAND fine				
	60	0.25	2.0	
				SAND fine
	120	0.125	3.0	
				SAND very fine
	200	0.074	3.75	
SILT				
	230	0.062	4.0	
				SILT
		0.0039	8.0	
CLAY				CLAY
		0.0024	12.0	
				COLLOID

coarser core samples; 128 RSA analyses were performed and 20 samples were seived. An additional 23 sediment grab samples from an August 1976 survey of 8 lake floor profiles normal to Presque Isle (Fig. 5), obtained from Professor P. Knuth (Edinboro State College), were analyzed. The RSA and sieve results for these are also in Appendix B.



Echogram profiles off Presque Isle Peninsula. Grab samples at arrows show general sediment composition: (s) sand, (c) clay. Closely spaced jagged lines are electronic artifacts suggesting a soft mud bottom is present at the base of the lines. Data results are from an August 1976 survey by P. Knuth (Edinboro State College).

Figure 5. Shore-normal profiles off Presque Isle.

II. RESULTS

1. Primary Geologic Units.

Analyses of the seismic profiles and the cores show that four major geologic units are present in the study area: (a) Devonian age shale bedrock that comprises the eastern Erie basin and underlies the entire area; (b) Pleistocene age glacial sediments that include a complex assortment of till, stratified glaciofluvial debris, and lacustrine silt and clay from ancestral lakes; (c) beach and dune sand deposits that comprise the offshore ridge and the Presque Isle platform and peninsula; and (d) soft organic muds that cover much of lake floor in deeper areas and mantle the older deposits.

a. Shale Bedrock. Figure 6 shows the extent and general relief of the bedrock surface based on the seismic data and logs from three deep borings. Because of the limited penetration on some profiles, bedrock was not mapped in detail throughout the study area; however, contour trends were drawn from the data points in Figure 6. Shale crops out along the shoreline in the study area but is covered in some areas by glacial and lacustrine deposits and unconsolidated masses of material from cliff slumping. Figures 7, 8 (profile A), and 9 show that the shale surface slopes lakeward and crops out at the lake floor to water depths of 9 to 12 meters. The relief is sometimes irregular; Figure 6 shows that bedrock reaches a maximum depth of -87 meters about 17.6 kilometers northwest of Presque Isle. Clearly, its depth in all areas, except within several hundred meters of the shore, is great enough to not interfere with dredging operations.

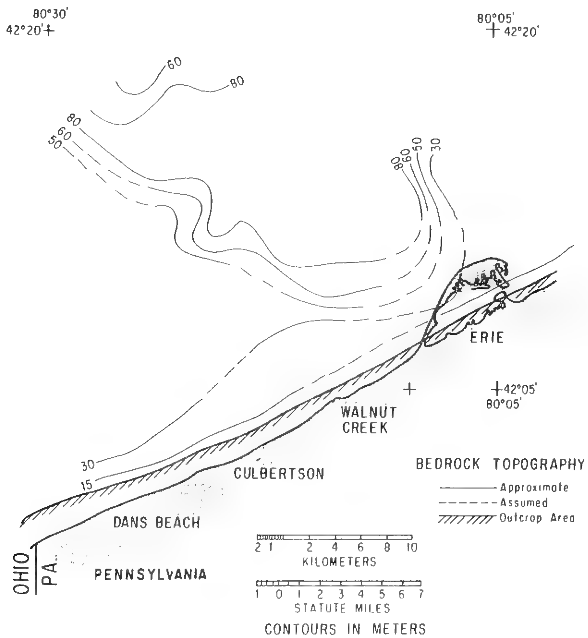


Figure 6. Map of the shale bedrock surface.

b. Glacial Deposits. These unconsolidated sediments, which comprise the largest volume of any sedimentary unit in the region, overlie the shale bedrock and are most important as sources of sand and gravel. Several of the seismic profiles show that the offshore ridge originated as a glacial moraine that crossed the Lake Erie basin and was at one time continuous from shore to shore before development of modern Lake Erie. Its unofficial name is the Long Point-Erie Moraine. Parts of the moraine appear to be unstratified and may contain very coarse materials such as boulders; however, most of the ridge appears to be stratified and composed of poorly sorted, fine to very coarse sands and gravel. The main body

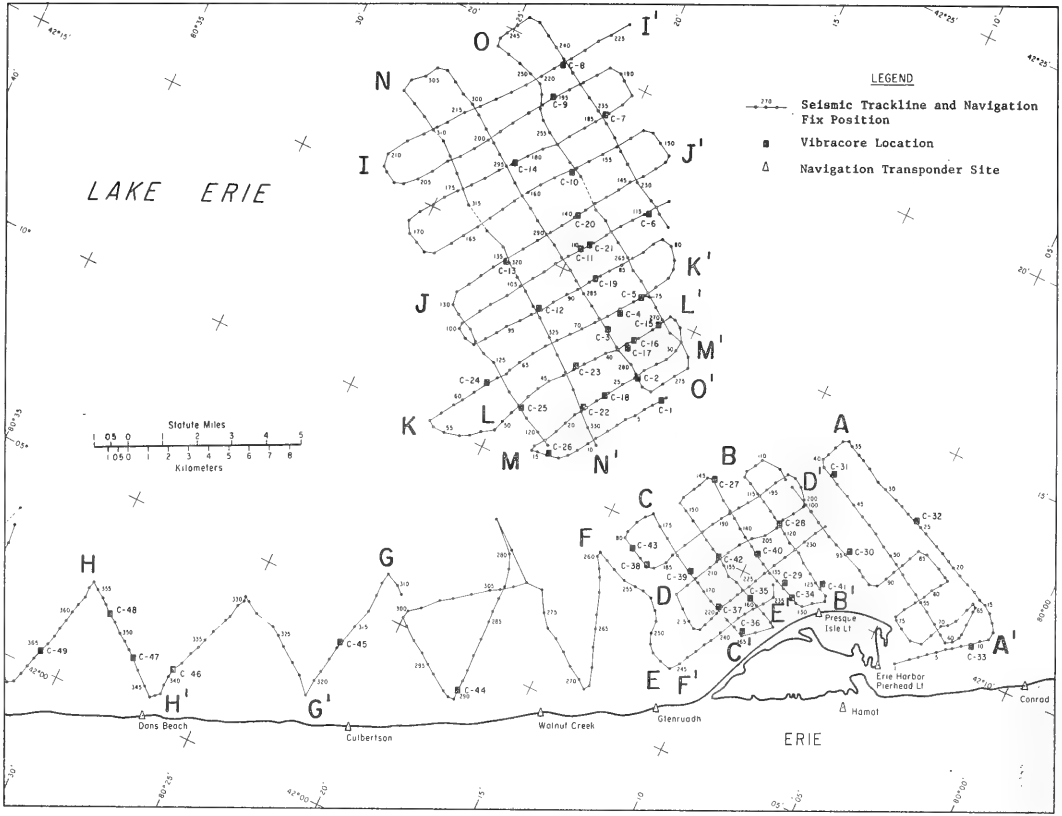


Figure 7. Locations of the interpreted seismic profiles.

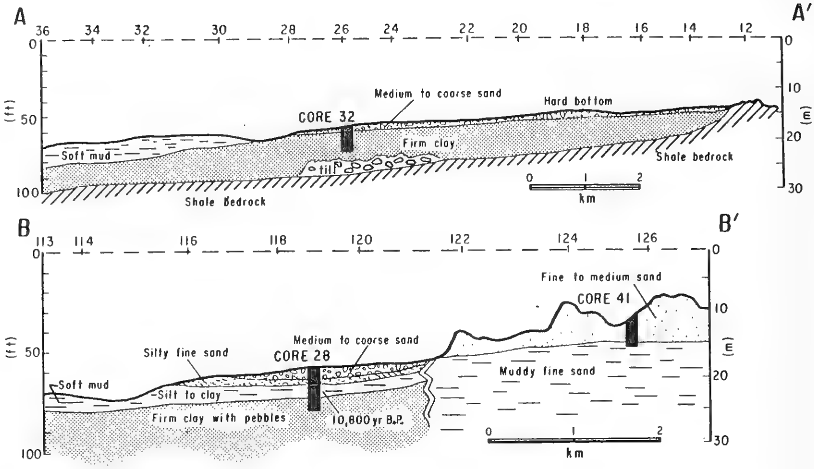


Figure 8. Profiles A and B off Presque Isle.

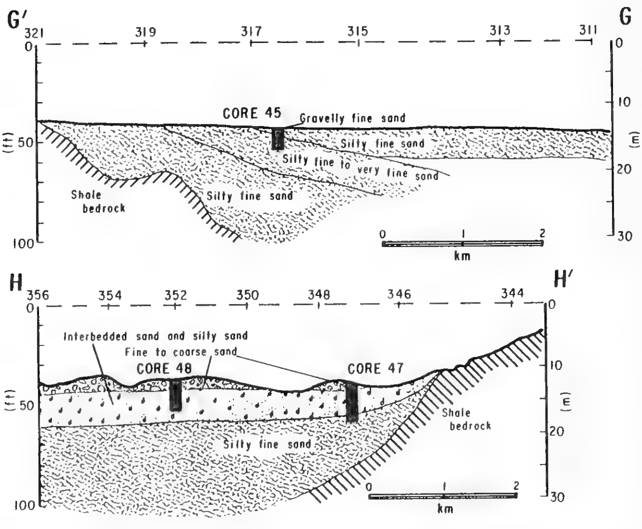


Figure 9. Profiles G and H west of Presque Isle.

of the moraine (Fig. 10) comprises the ridge and the flat elevated platform immediately west of Presque Isle, but there is some evidence that minor glacial deposits or erosional remnants are present several kilometers east of Presque Isle and also northwest of the shore of Dans Beach near the Ohio border. All these glacial deposits appear to be related to the same glacial event, which is likely the Port Huron advance that has been age-dated by several investigators at about 13,000 years before present (B.P.).

Adjacent to the ridge is a gray-brown firm clay unit with scattered rounded pebbles at the lake floor; several cores and seismic profiles show that it has considerable thickness. The unit is most likely lacustrine in origin and was deposited in an earlier Lake Erie formed when the moraine dammed and backed up normal melt-water drainage. The clay unit's firm nature suggests that it is slightly overconsolidated, possibly the result of subaerial exposure when the ridge was breached and the lake level dropped. Erosion of the clay unit to the west of the ridge has left a lag deposit veneer of coarse-grained sediment in places that form isolated ridges with relief of several meters. Some of these small ridges, which are semiparallel to the main ridge, are asymmetric suggesting that they may be active and maintained by bottom currents caused by wind shear or barometric seiche action.

c. Beach and Dune Deposits. Following retreat of the glacier that deposited the Long Point-Erie Moraine, the outlet at Niagara Falls rebounded in elevation and present-day Lake Erie was formed.

The radiocarbon-14 dates of wood fragments contained in cores 4, 18, 23, and 28 (Table 2, Fig. 11) show that as early as about 11,000 years ago lake levels were still at least 22 meters below the present levels and remained there until at least 6,870 ± 150 years B.P. As lake levels gradually rose during this time the ridge and Presque Isle platform were high-energy coastal areas subjected to active littoral processes. The glacial tills were washed and sorted, and much of the fine-grained sediment was carried offshore and ultimately deposited in deeper parts of the basin. The beach and dune deposits that mantle the ridge and platform were derived directly from erosion of local glacial debris. The stabilization of lake levels over the past several thousand years has resulted in the sand being eroded from the ridge-platform and transported eastward to form Presque Isle Peninsula.

d. Modern Soft Mud. Several of the cores in deeper water adjacent to the Presque Isle platform and ridge contain gray, very soft mud with high water content and very low shear strength. Figure 5 shows that mud is especially common east of Presque Isle, and also present in troughs on the platform northwest of Presque Isle. Fine-grained material is being deposited at the present time throughout much of the Lake Erie basin except for relatively high-energy areas, such as along the coast or on elevated areas. The predominance of muddy sediment in the samples east of Presque Isle and the lack of sand suggest that sand from the eastern end of Presque Isle is not being transported eastward off the platform in any significant volume.

2. Potential Sand and Gravel Deposits.

Analyses of the seismic and core data show that two separate areas, the ridge-platform moraine complex and the moraine ridge segment off Dans Beach, contain large quantities of clean (small percentages of silt and clay),

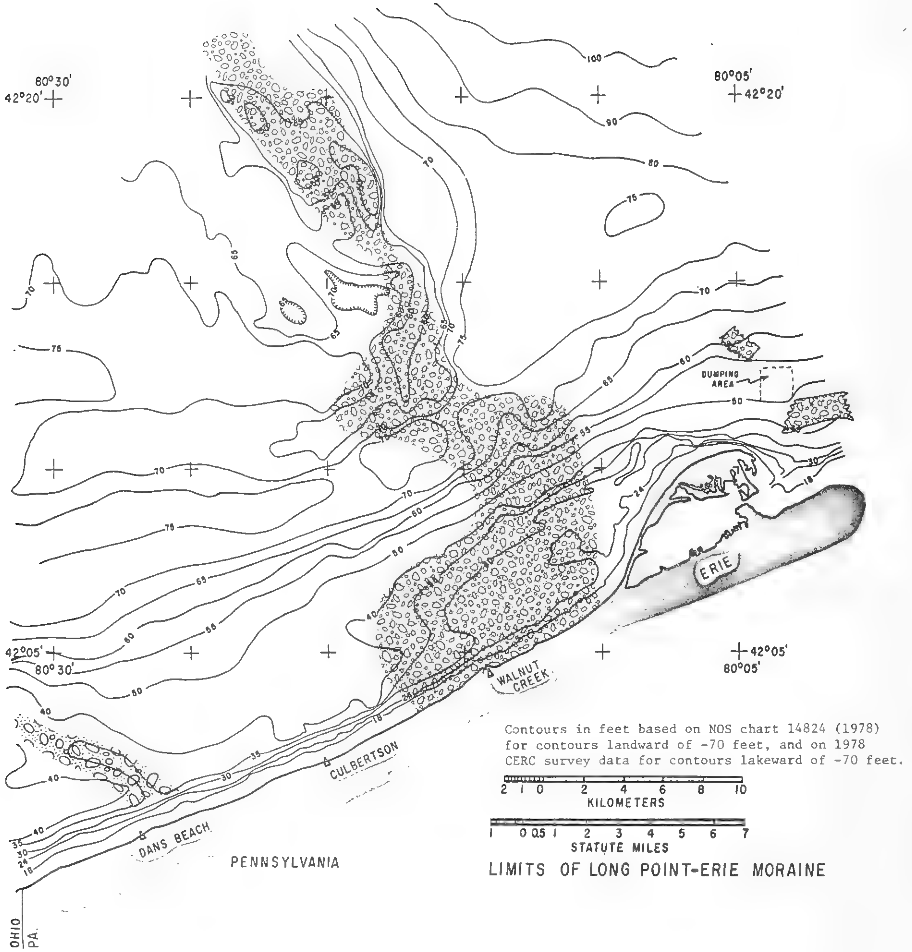


Figure 10. Extent of probable moraine segments in the study area based on the seismic and core data.

Table 2. Summary of wood fragments present in eight cores and radiocarbon-14 age date results.

Cores	Water depth (-m)	Sediment depth to wood (m)	Total depth of wood (-m)	Corrected carbon-14 age (yr B.P.)	Matrix composition
1[1]	23.2	1	24.1		Sand
4	20.4	1	21.5	8,240 ± 210	Silty sand
17[1]	17.7	2.4	20		Sand
18	18.5	3.6	22	6,870 ± 150	Sand
23	19.2	2.2	21.4	8,545 ± 150	Sand
23[1]	19.2	2.5	21.7		Sand
28	18.4	3.5	21.9	10,800 ± 190	Firm clay
39[1]	13	3.3	16.2		Sand

[1] Sample too small for age dating.

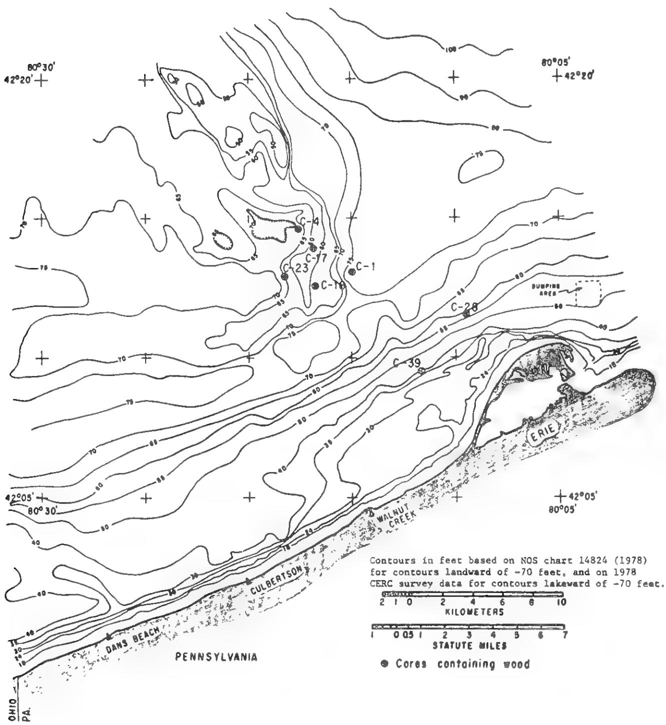


Figure 11. Cores containing wood fragments.

medium- to coarse-grained sand mixed with gravel (Fig. 12). The area with greatest potential is the ridge-platform moraine complex; the moraine ridge segment off Dans Beach is considerably lower in potential. Figure 7 shows the locations of representative profiles B to F and I to O for the first area and profile H for the second area. Interpretations are shown in Figures 8, 9, and 13 to 18.

A total of 13 cores (2, 5 to 10, 15 to 18, 22, and 25) are fairly evenly distributed over the Long Point-Erie ridge to the Canadian border and all contain clean, generally medium to coarse sand with varying percentages of pebbles and gravel. The minimum thickness of sand is 0.76 meter (core 22, Fig. 17), while the maximum recovery is 3.9 meters (core 17, Fig. 16). The average sand thickness for the 13 cores is 2.3 meters; however, the seismic profiles show that sand and gravel are about 5 to 6 meters thick in the main body of the ridge and thin to zero at the flanks where contact is made with the firm lacustrine clay.

The area of the ridge shown in Figure 12 has been computed to be 20.3 million square meters; using a conservative figure of 1.7 meters for thickness, the estimated volume of sand is 37.2 million cubic meters.

The platform to the west and slightly lakeward of Presque Isle has a glacial origin in common with the Long Point-Erie ridge, and the seismic profiles and cores 28, 40, and 41 show the platform is composed of generally medium to coarse sand and pebbles overlying silty fine sands or firm lacustrine clay. Detailed bathymetric charts and the profiles (see Fig. 8, profile B) show that the platform surface is made up of several irregular shoals which semiparalled the Presque Isle shore and have maximum relief of about 4.5 meters. The origin of these shoals is likely to be related to glacial processes with subsequent reforming and winnowing of the topmost sediment by modern lake processes. However, the shoals could also be relict, drowned beach ridges from an earlier and more lakeward position of Presque Isle.

Although there has been some speculation, based on historic migration rates, that Presque Isle has migrated considerable distances since its formation, this study has shown that it is the product of erosion of glacial sediments on the adjacent platform and ridge. This suggests that Presque Isle has migrated no more than 8 kilometers in the past several thousand years.

The area on the platform encompassing cores 28, 40, and 41 (Fig. 12) is about 1.7 million square meters, using a sand thickness of 0.9 meter, the estiimated volume of material is 1.6 million cubic meters. However, there are several important factors that should be considered before the shoals on the platform are viewed as borrow sources. The other CERC cores on the platform and the grab samples show that the sediments from the platform are more variable in grain size and composition than the sediments from the offshore ridge. Therefore, the chances are greater that this material may have high proportions of silt, clay, and very fine sand, which would lessen its potential for being stable as fill. A second and possibly even more important consideration is that these shoals may be directly related to the nearshore sand transport regime, which would affect alongshore wave energy distributions along Presque Isle. Sand from Presque Isle beaches may move offshore and incorporate with the shoals under storm conditions, and then return to the shoreface-beach under fair-weather conditions. If a borrow pit were dredged in water that is too shallow littoral processes may remove sand from the shore zone in an attempt to refill the

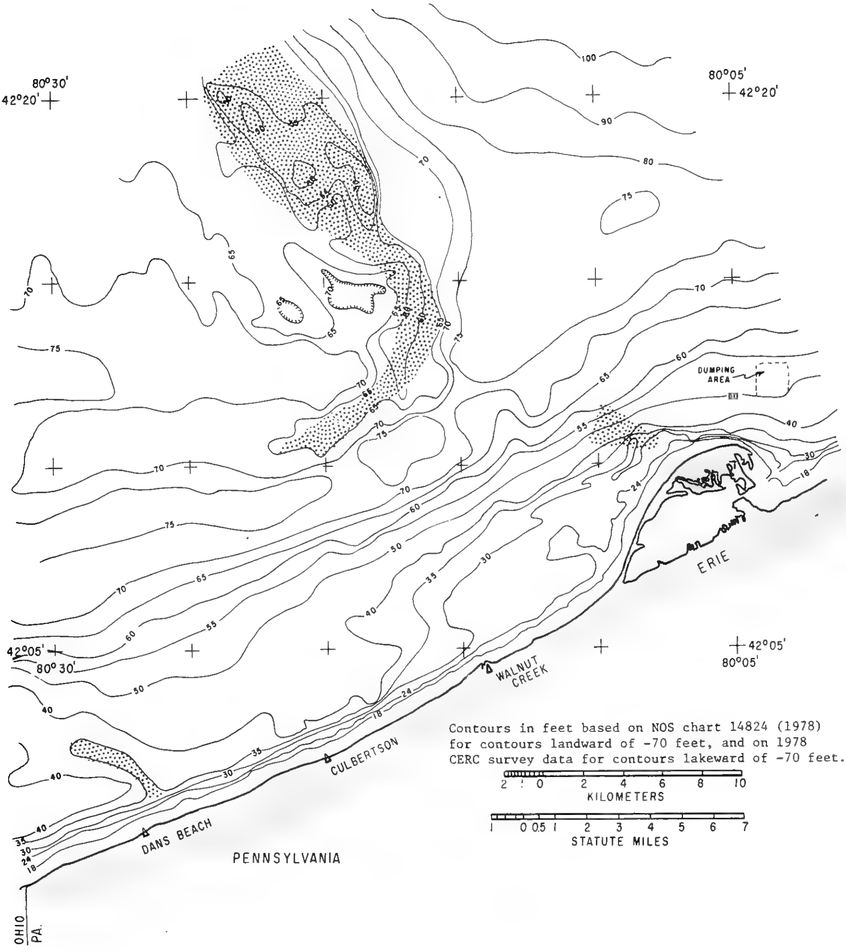


Figure 12. Map of potential borrow areas for sand and gravel.

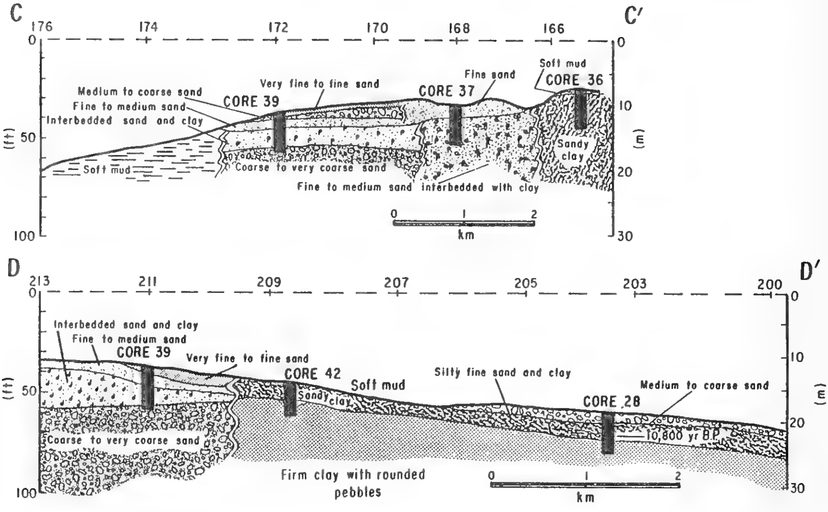


Figure 13. Profiles C and D.

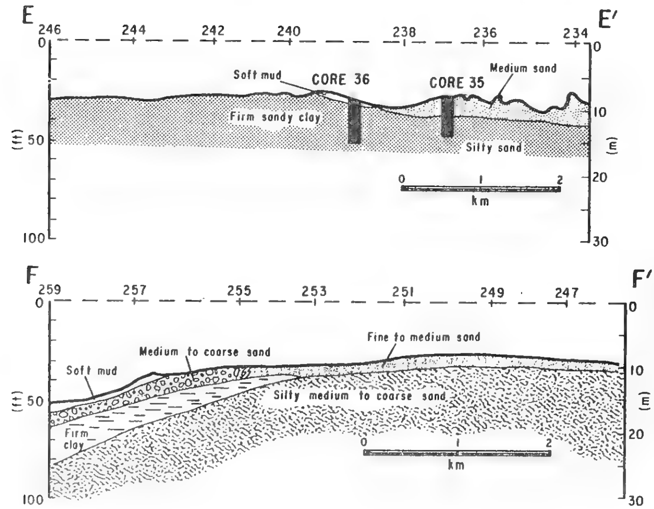


Figure 14. Profiles E and F.

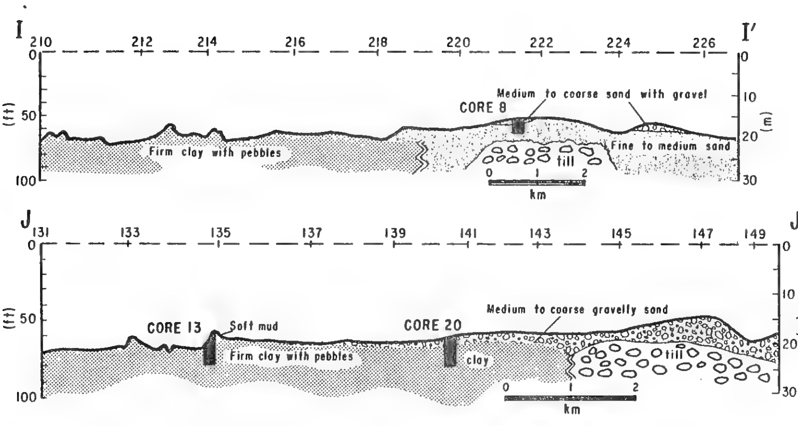


Figure 15. Profiles I and J.

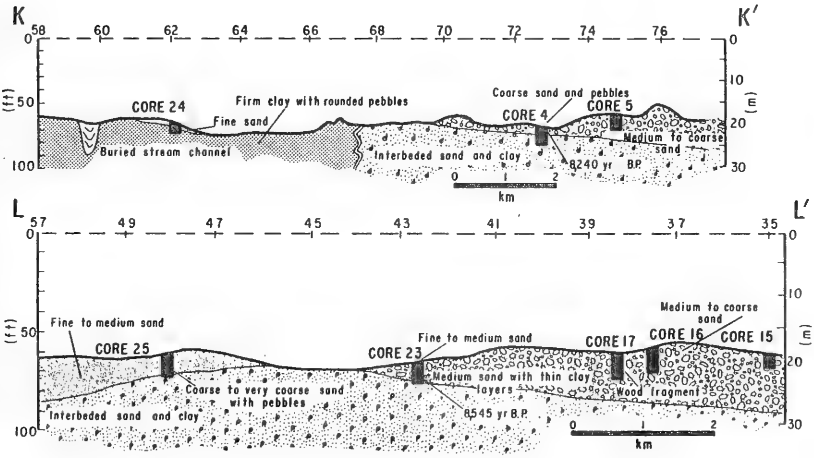


Figure 16. Profiles K and L.

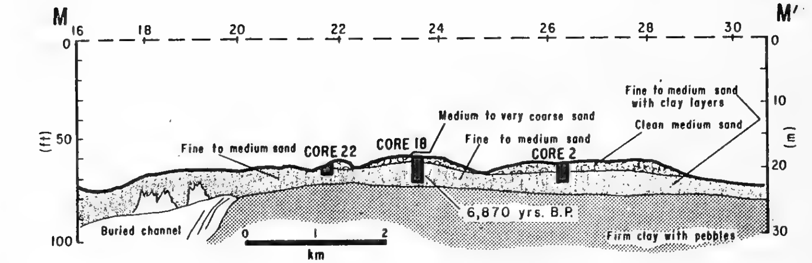


Figure 17. Profile M.

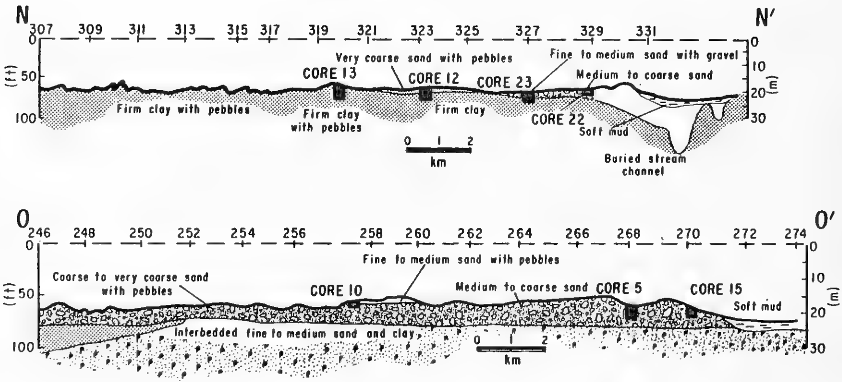


Figure 18. Profiles N and O.

pit and maintain an equilibrium shoreline profile. Also, the shoals on the platform may act to filter and dissipate wave energy, and removal of sand from the shoal crests could increase levels of wave energy impinging on Presque Isle.

The morainal ridge segment off Dans Beach (Fig. 9, profile H) is shown by cores 47 and 48 to contain 0.5 and 1.6 meters, respectively, fine to coarse sand. The ridge feature is 4.8 kilometers long and several hundred meters wide and is judged to contain several million cubic meters of sand. However, its distance of 25 kilometers from Presque Isle and its closeness to shore detract significantly from the potential of the ridge as a source of borrow material.

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APPENDIX A

CORE SEDIMENT DESCRIPTIONS

Table. Sediment descriptions of Lake Erie cores (based on Wentworth classification).

Core No.	Water depth (m)	Core length (m)	Interval (m)	Description
1	23.2	3.9	0 to 1.2	Dark gray, fine to medium sand, well laminated, 10-cm-long wood fragment at -1.0 m.
			1.2 to 2.6	Interbedded fine to medium sand and clay.
			2.6 to 2.7	Clean, medium to very coarse sand with pebbles.
			2.7 to 3.9	Tan-gray, cohesive clay containing several rounded pebbles (≤ 7.5-cm diameter).
2	19.6	3.2	0 to 1.7	Clean, moderately well sorted medium sand.
			1.7 to 3.2	Fine to medium sand with thin clay layers.
3	20.1	2.7	0 to 0.5	Clean, moderately sorted, medium sand with scattered pebbles (≤ 2.5-cm diameter).
			0.5 to 0.8	Moderately well sorted, fine sand with thin clay layer at -0.6 m.
			0.8 to 0.9	Fine sand, abundant mollusk shells.
			0.9 to 2.7	Fine sand with thin clay layers.
4	20.4	4.2	0 to 0.2	Medium to coarse sand with rounded pebbles (≤ 2.5-cm diameter).
			0.2 to 0.7	Interbedded, gray clay and fine to medium sand, sharp contacts; clay predominates.
			0.7 to 2.4	Same as above interval but sand predominates; wood fragment at -1.0 m.
			2.4 to 3.1	Tan-gray clay with thin fine sand layers.
			3.1 to 3.8	Dark brown, medium sand.
			3.8 to 3.9	Tan-gray clay.
			3.9 to 4.2	Dark brown, fine sand.
5	19.6	3.0	0 to 3.0	Gray, medium to coarse sand becoming fine with depth; shell fragments at -2.7 m.
6	15.0	2.7	0 to 2.7	Clean, gray, medium to coarse, well sorted sand; no layering, shells or pebbles.
7	16.5	1.7	0 to 1.5	Clean, gray, fine to medium, moderately well sorted sand; no layering, shells or pebbles.
			1.5 to 1.6	Clean, gray, coarse to very coarse sand and gravel (≤ 1.2-cm diameter).
			1.6 to 1.7	Clean gray, fine to medium sand.
8	15.8	3.3	0 to 0.8	Clean, gray-brown, medium to coarse sand.
			0.8 to 1.1	Gray-brown, coarse to very coarse sand with rounded pebbles (≤ 4-cm diameter).
			1.1 to 3.3	Clean, gray, medium sand, grading down to fine sand.
9	17.1	4.8	0 to 1.5	Clean, gray-brown, coarse and very coarse sand with rounded pebbles (≤ 4-cm diameter); 0.2-m lag deposit of pebbles on top
			1.5 to 2.1	Clean, gray, fine to medium sand.
			2.1 to 3.0	Interbedded, fine sand and clay (equal volumes of sand and clay).
			3.0 to 3.5	Same as above interval but clay predominates over sand.
			3.5 to 4.8	Gray-brown, firm, cohesive clay.
10	17.7	1.9	0 to 0.3	Clean, gray-brown, fine to medium sand with coarse grains, shells and rounded pebbles (≤ 8-mm diameter).
			0.3 to 1.5	Clean, gray, fine to medium sand; no shells or pebbles.
			1.5 to 1.6	Brown, cohesive clay; sharp contacts with sand above and below.
			1.6 to 1.9	Same as second interval above.
11	19.6	4.8	0 to 2.0	Gray-brown, soft, uniform textured mud; becomes firmer with depth; rounded pebbles (≤ 3.5 cm long) on top.

Table. Sediment descriptions of Lake Erie cores (based on Wentworth classification). --Continued

Core No.	Water depth (m)	Core length (m)	Interval (m)	Description
			2.0 to 3.6	Same as above but thin sand layers also present.
			3.6 to 4.8	Tan, firm, cohesive clay with scattered rounded (drop stone) pebbles, 5 cm long at -4.0 m.
12	19.2	4.4	0 to 0.09	Very coarse sand and well-rounded pebbles, ≤ 3 cm long.
			0.09 to 0.4	Clean, brown, very coarse sand, granules, and rounded pebbles.
			0.4 to 0.7	Sharp contact, moderately firm, tan-gray clay.
			0.7 to 0.8	Brown, coarse to very coarse sand and rounded pebbles.
			0.8 to 4.4	Moderately firm, tan-gray clay.
13	20.3	5.3	0 to 0.06	Soft gray clay.
			0.06 to 5.3	Tan, moderately firm clay, very cohesive with scattered rounded pebbles.
14	19.6	3.0	0 to 0.09	Brown, silty, very coarse sand.
			0.09 to 3.0	Brown, firm clay with scattered rounded pebbles.
15	18.6	1.8	0 to 1.8	Clean, dark gray, moderately well sorted, medium to coarse sand fining downward; no layering, pebbles or shells.
16	20.4	3.6	0 to 3.6	Clean dark gray, well-sorted, medium to coarse sand.
17	17.7	3.9	0 to 3.9	Moderately well sorted, fine to medium sand with few thin silt and very fine sand layers; wood fragments at -2.4 m.
18	18.5	3.6	0 to 1.0	Clean, gray, medium to very coarse sand that coarsens with depth; thin mud layer at 0.9 m.
			1.0 to 3.6	Sharp contact, moderately well sorted fine to medium sand, no layering, shells or pebbles; wood fragment at -3.6 m.
19	20.4	6.1	0 to 0.7	Clean, gray, moderately sorted, medium to coarse sand.
			0.7 to 2.1	Gray, interbedded clay and silty sand.
			2.1 to 2.4	Gray, silty, fine to medium sand with a few thin clay layers.
			2.4 to 4.4	Gray, interbedded clay and silty sand.
			4.4 to 6.1	Dark brown, moderately stiff, very plastic clay.
20	18.6	5.3	0 to 1.2	Clean, gray-brown, moderately well sorted, medium to coarse sand; becomes gravelly at -1.1 m.
			1.2 to 1.4	Gray, fine sand.
			1.4 to 5.3	Gray-brown, soft clay.
21	18.4	6.1	0 to 1.1	Clean, moderately well sorted, light gray, medium to coarse sand.
			1.1 to 1.3	Clean, gray, coarse and very coarse sand with pebbles.
			1.3 to 1.4	Gray, moderately firm clay with granules.
			1.4 to 6.1	Gray-brown soft clay.
22	18.8	1.4	0 to 0.8	Clean, gray, medium to coarse to very coarse sand, thin mud layer at -0.8 m.
			0.8 to 1.4	Clean, gray, fine to medium sand.
23	19.2	3.1	0 to 0.3	Clean, brown, fine to medium sand, gravelly from 0.2 m to 0.3 m.
			0.3 to 2.2	Clean, light gray to brown, fine to medium sand with 2.5-cm clay layer at 2.0 m; wood fragment at -2 m.
			2.2 to 3.1	Light brown, medium sand with occasional 1 cm clay layers, wood fragment at -2.5 m.
24	21.7	1.7	0 to 0.7	Gray, silty, moderately sorted fine sand.
			0.7 to 1.7	Sharp contact; light brown-gray, stiff clay with scattered rounded pebbles.
25	18.6	3.8	0 to 2.7	Clean, gray moderately well sorted, fine to medium sand.

Table. Sediment descriptions of Lake Erie cores (based on Wentworth classification).--Continued

Core No.	Water depth (m)	Core length (m)	Interval (m)	Description
			2.7 to 2.9	Medium to very coarse, poorly sorted sand with scattered rounded pebbles.
			2.9 to 3.2	Interbedded clay and fine to medium sand; 3.5-cm pebble at -3 m.
			3.2 to 3.8	Silty, very coarse sand, poorly sorted with aboundant rounded pebbles (≤ 3.3-cm diameter).
26	23.3	5.8	0 to 1.2	Gray, very soft, sandy clay, 2.5 cm sand layer at 1.2 m.
			1.2 to 5.8	Gray, soft clay; sandy at bottom
27	23.2	3.4	0 to 0.3	Clean, brown-gray, fine to medium sand.
			0.3 to 0.7	Gray, firm, muddy fine sand.
			0.7	Gray clay.
			0.7 to 1.2	Slightly muddy fine sand.
			1.2 to 3.4	Brown-gray firm clay.
28	18.4	6.1	0 to 1.3	Clean, brown-gray, medium to coarse sand.
			1.3 to 2.2	Sharp contact; gray, silty fine sand.
			2.2 to 3.7	Gray, firm, silty clay; sharp contact; wood at -3.5 m.
			3.7 to 6.1	Brown-gray firm clay with many rounded pebbles.
29	12.5	6.1	0 to 3.0	Clean, gray, fine to medium sand.
			3.0 to 5.1	Gray, fine sand becomes silty with depth.
			5.1 to 5.6	Coarse sand with many small pebbles.
			5.6 to 6.1	Gray-brown, moderately firm clay.
30	15.6	3.8	0 to 2.6	Very soft gray mud.
			2.6 to 2.7	Silty, medium to coarse sand.
			2.7 to 3.2	Firm, sandy clay.
			3.2 to 3.7	Moderately firm, slightly sandy clay.
			3.7 to 3.8	Brown-gray, moderately firm clay.
31	21.5	6.1	0 to 3.1	Gray, soft to very soft clay.
			3.1 to 3.2	Gray, silty sand.
			3.2 to 3.6	Gray, soft to very soft clay.
			3.6 to 4.6	Gray, silty, fine sand, slightly cohesive.
			4.6 to 4.7	Clayey sand with granules and pebbles.
			4.7 to 6.1	Brown-gray, moderately firm clay.
32	18.2	4.6	0 to 0.3	Clean, gray, medium to coarse sand.
			0.3 to 0.4	Clay.
			0.4 to 0.9	Clean, gray, medium to coarse sand, sharp contact at top.
			0.9 to 4.6	Brown-gray, moderately firm clay.
33	13.1	2.3	0 to 2.1	Dark gray, slightly firm mud; increasing silt with depth.
			2.1 to 2.3	Same as above but firmer; few rounded pebbles (≤ 2.5-cm diameter) and 5-cm-long elongate shale fragment.
34	10.6	6.1	0 to 3.1	Clean, gray, moderately well sorted, fine sand.
			3.1 to 3.6	Gray, slightly silty, fine sand.
			3.6 to 6.1	Gray, silty, fine sand becomes more muddy toward bottom with secondary thin sandy layers.
35	9.5	6.1	0 to 2.7	Clean, gray, moderately well sorted medium sand.
			2.7 to 2.8	Clay.
			2.8 to 2.9	Yellow-brown, clean, medium sand.
			2.9 to 3.2	Silty, very fine sand.
			3.2 to 3.5	Gray-brown clay.
			3.5 to 5.9	Very fine, silty sand.
			5.9 to 6.1	Clean, light brown, fine sand.

Table. Sediment descriptions of Lake Erie cores (based on Wentworth classification). --Continued

Core No.	Water depth (m)	Core length (m)	Interval (m)	Description
36	11.1	6.1	0 to 0.5	Gray, very soft mud; sharp contact at base.
			0.5 to 1.5	Firm, gray, sandy clay; sharp contact at base.
			1.5 to 3.2	Gray, firm, slightly sandy clay.
			3.2 to 6.1	Gray, firm, slightly sandy clay; shells near bottom.
37	10.2	6.1	0 to 1.5	Clean, gray fine sand.
			1.5 to 6.1	Gray, fine to medium sand interbedded with clay layers 2.5 to 5.0 cm.
38	14.7	3.7	0 to 2.5	Clean, gray, fine to medium sand.
			2.5 to 3.3	Gray, firm clay
			3.3 to 3.7	Gray, muddy, medium to coarse sand.
39	13.0	6.1	0 to 0.6	Clean, gray, very fine to fine sand.
			0.6 to 0.9	Clean, gray, medium to coarse sand.
			0.9 to 2.4	Clean, gray, fine to medium sand.
			2.4 to 3.7	Thin (2 to 5.0 cm) layers of clay, sandy clay, and fine to coarse sand, wood fragment at -3.3 m.
			3.7 to 4.9	Gray, fine to medium, clayey sand, interbedded with 1.3 cm clay layers.
			4.9 to 5.8	Gray, firm clay; sandy in places.
			5.8 to 6.1	Clean, gray, coarse and very coarse sand.
40	15.7	4.1	0 to 0.5	Clean, brown, coarse to very coarse sand with rounded pebbles.
			0.5 to 0.8	Gray, medium to coarse sand; grading to fine sand at -0.8 m.
			0.8 to 0.9	Brown-gray, medium to coarse sand.
			0.9 to 1.8	Gray, silty, fine sand.
			1.8 to 4.1	Gray-brown, moderately firm clay, rounded pebble at -2.0 m.
41	11.1	4.0	0 to 4.9	Clean, gray, fine to medium sand, grading slightly finer with depth; 2.5-cm layer at -3.4 m.
42	15.7	4.5	0 to 0.2	Very fine, sandy soft gray mud.
			0.2 to 0.7	Same as above but more sand.
			0.7 to 2.2	Same as above but firmer mud.
			2.2 to 2.7	Gray, muddy, coarse to very coarse sand, granules, and pebbles.
			2.7 to 4.5	Moderately firm, gray clay with rounded pebbles.
43	17.0	5.5	0 to 0.5	Gray, fine sand, very soft mud.
			0.5 to 1.2	Gray, moderately firm sandy clay.
			1.2 to 1.3	Coarse and very coarse sand, granules, and pebbles.
			1.3 to 3.5	Clean, gray-brown, medium to coarse sand.
			3.5 to 3.6	Gray, fine clayey sand; slightly cohesive.
			3.6 to 5.5	Gray-brown, firm clay.
44	10.6	1.3	0 to 0.9	Mottled silt and clay layers.
			0.9 to 1.3	Pebbles and granules on top (lag deposit); moderately stiff, silty mud.
45	14.2	3.1	0 to 0.09	Gravelly fine sand($\leq$ 2.5-cm diameter).
			0.09 to 0.2	Fine sand.
			0.2 to 3.1	Very fine to fine sand with silt layers.
46	13.0	4.1	0 to 0.3	Medium sand, moderately well sorted.
			0.3 to 1.3	Sandy silt.
			1.3	Silty, medium sand.
			1.3 to 3.9	Moderately firm mud.
			3.9 to 4.1	Silty, very fine sand; 10-cm-diameter rock fragment at -4.0 m.
47	13.0	5.8	0 to 0.4	Medium sand, moderately well sorted.
			0.4 to 0.5	Medium to coarse sand.
			0.5 to 4.8	Silt and silty sand.
			4.8 to 4.9	Clay and pebbles.

Table. Sediment descriptions of Lake Erie cores (based on Wentworth classification).--Continued

Core No.	Water depth (m)	Core length (m)	Interval (m)	Description
			4.9 to 5.8	Silt and fine sand.
48	12.6	4.8	0 to 1.6	Fine, medium and coarse sand with thin clay layers.
			1.6 to 1.7	Silt and clay.
			1.7 to 2.1	Fine to medium sand with thin clay layers.
			2.1 to 2.5	Silt and clay, grading down to fine to medium sand.
			2.5 to 2.6	Sandy silt.
			2.6 to 2.7	Fine to medium sand.
			2.7 to 4.6	Mottled silt and clay.
			4.6	Well-sorted, fine sand.
			4.6 to 4.8	Silt and clay.
49	14.2	4.8	0 to 0.7	Muddy sand.
			0.7 to 0.8	Silt grading down to fine to medium sand.
			0.8 to 0.9	Coarse sand and pebbles.
			0.9 to 3.1	Silt and clay.
			3.1 to 3.2	Silty medium sand.
			3.2 to 3.5	Silt and clay.
			3.5 to 3.6	Medium to coarse sand.
			3.6 to 4.8	Silt and clay.

APPENDIX B

SEDIMENT GRAIN-SIZE DATA

Table B-1. RSA Granulometric Data, Lake Erie Cores.

Core No.	Depth (m)	Mean (phi)	Mean (mm)	Median (phi)	Median (mm)	Standard deviation
1	Top	2.5	0.18	2.4	0.19	0.59
	1.5	2.7	0.15	2.7	0.15	0.68
2	Top	1.6	0.33	1.5	0.37	0.61
	0.5	1.5	0.36	1.3	0.40	0.65
	0.9	1.7	0.32	1.4	0.37	0.69
	2.3	2.1	0.23	2.2	0.22	1.03
	3.2	2.4	0.19	2.3	0.20	0.68
3	Top	1.7	0.30	1.3	0.40	0.87
	0.3	1.5	0.40	1.3	0.40	0.62
	0.6	2.9	0.15	2.9	0.13	0.57
	1.4 to 1.9	2.5	0.20	2.7	0.16	1.03
	2.3	2.7	0.16	2.7	0.16	0.47
4	0.8	2.3	0.20	2.3	0.21	0.66
	2.1	2.5	0.18	2.6	0.16	0.94
	3.1	2.4	0.19	2.3	0.20	0.66
	4.0	2.6	0.17	2.6	0.16	0.88
5	Top	2.0	0.25	1.8	0.29	0.78
	0.6	2.4	0.19	2.4	0.19	0.52
	1.5	2.6	0.17	2.5	0.18	0.44
	2.4	2.5	0.17	2.5	0.17	0.45
	3.0	2.6	0.16	2.6	0.17	0.46
6	Top	1.9	0.27	1.8	0.28	0.47
	0.6	1.8	0.30	1.7	0.32	0.46
	1.2	1.9	0.28	1.8	0.30	0.49
	1.9	1.9	0.28	1.8	0.30	0.57
	1.9	1.9	0.27	1.8	0.28	0.51
7	Top	2.1	0.24	2.2	0.22	0.65
	0.6	2.0	0.25	2.1	0.23	0.79
	1.2	2.0	0.26	2.0	0.26	0.47
	1.5	2.2	0.23	2.2	0.21	1.01
8	Top	1.8	0.29	1.9	0.27	0.65
	0.6	1.8	0.29	1.9	0.28	0.63
	1.2	2.0	0.25	1.9	0.27	0.81
	1.9	2.3	0.21	2.3	0.20	0.67
	2.4	2.5	0.17	2.5	0.18	0.43
	3.3	2.4	0.19	2.5	0.18	0.53
9	1.9	2.6	0.16	2.6	0.17	0.56
	2.4	2.2	0.21	2.7	0.15	1.32
10	Top	2.1	0.24	2.1	0.24	0.62
	0.6	2.5	0.18	2.4	0.20	0.54
	1.2	2.3	0.21	2.3	0.20	0.56
	1.9	2.0	0.25	2.1	0.23	1.04
15	Top	2.0	0.26	1.9	0.27	0.51
	0.9	1.9	0.27	1.9	0.27	0.56
	1.9	2.3	0.20	2.3	0.21	0.65

Table B-1. RSA Granulometric Data, Lake Erie Cores.--Continued

Core No.	Depth (m)	Mean (phi)	Mean (mm)	Median (phi)	Median (mm)	Standard deviation
16	Top	2.0	0.26	1.9	0.28	0.54
	0.9	1.9	0.27	1.9	0.28	0.42
	1.9	2.0	0.26	1.9	0.28	0.57
	2.4	2.0	0.25	1.8	0.28	0.75
17	Top	1.8	0.28	1.7	0.30	0.51
	0.6	2.0	0.26	1.8	0.29	0.61
	0.9	1.9	0.26	1.8	0.29	0.61
	1.1 to 1.2	2.0	0.25	1.9	0.28	0.64
	2.5	2.0	0.25	1.9	0.26	0.56
	3.1 to 3.2	2.1	0.23	2.0	0.26	0.69
	3.9	3.0	0.13	2.9	0.13	0.20
18	Top	1.9	0.27	1.8	0.29	0.55
	0.5	1.0	0.50	1.3	0.42	0.56
	0.9	1.6	0.32	1.4	0.38	1.08
	1.9	2.2	0.21	2.2	0.22	0.44
	2.7	2.2	0.22	2.1	0.23	0.61
	3.6	2.2	0.22	2.1	0.23	0.61
19	Top	1.61	0.33	1.2	0.42	0.86
	0.3	1.54	0.34	1.3	0.40	0.57
	0.6	1.4	0.38	1.2	0.45	0.84
20	Top	1.9	0.27	1.8	0.28	0.64
	1.2	1.7	0.31	1.2	0.44	1.27
21	Top	1.6	0.32	1.4	0.38	0.57
	0.9	2.4	0.19	2.2	0.21	0.70
22	Top	1.2	0.45	0.9	0.54	0.90
	0.6	1.3	0.40	1.2	0.43	0.76
	0.9	2.2	0.22	2.2	0.22	0.50
	1.4	2.1	0.24	2.1	0.24	0.64
23	Top	2.0	0.25	2.0	0.25	0.56
	0.9	2.0	0.25	2.0	0.26	0.50
	1.9	2.1	0.23	2.1	0.23	0.59
	3.1	3.2	0.11	3.2	0.11	0.56
24	Top	2.4	0.19	2.6	0.17	0.86
	0.6	2.4	0.19	2.6	0.17	1.02
25	0.6	2.1	0.23	2.0	0.24	0.56
	1.2	2.1	0.23	2.1	0.23	0.51
	1.9	2.2	0.22	2.2	0.22	0.58
	2.7	2.0	0.25	2.3	0.21	1.15
27	Top	2.1	0.23	2.0	0.26	0.72
	0.3	1.8	0.28	1.8	0.29	1.04
28	Top	1.3	0.41	1.1	0.47	0.77
	0.6	1.5	0.35	1.2	0.42	0.91
	1.2	2.0	0.25	1.9	0.28	0.85
29	Top	2.3	0.20	2.3	0.20	0.80

Table B-1. RSA Granulometric Data, Lake Erie Cores.--Continued

Core No.	Depth (m)	Mean (phi)	Mean (mm)	Median (phi)	Median (mm)	Standard deviation
32	Top	1.5	0.36	1.3	0.40	0.59
	0.2	1.6	0.33	1.5	0.36	0.54
	0.8	1.8	0.28	1.7	0.31	0.58
34	Top	2.2	0.22	2.1	0.24	0.57
	0.6	2.3	0.20	2.3	0.20	0.67
	1.5	2.6	0.17	2.5	0.18	0.55
	3.0	2.6	0.16	2.6	0.17	0.59
35	Top	2.4	0.19	2.3	0.20	0.57
	1.2	2.3	0.20	2.3	0.21	0.59
37	Top	2.4	0.20	2.4	0.19	0.81
	0.3	2.4	0.19	2.4	0.18	0.49
	0.6	2.3	0.20	2.4	0.20	0.53
	1.2	2.5	0.18	2.5	0.18	0.59
	1.9	2.6	0.16	2.6	0.17	0.61
	3.0	2.6	0.17	2.7	0.15	1.03
	4.6	2.0	0.26	2.8	0.15	1.66
	5.5	2.8	0.15	3.2	0.11	1.18
38	Top	2.6	0.16	2.7	0.15	0.73
	1.5	2.0	0.25	2.5	0.18	1.37
	3.7	1.4	0.39	1.2	0.45	0.61
39	Top	3.2	0.11	3.1	0.11	0.09
	0.7	1.3	0.39	1.0	0.49	0.94
	2.1	2.3	0.21	2.3	0.21	0.74
	3.0	2.7	0.15	2.7	0.16	0.50
	4.7	2.5	0.18	2.7	0.15	1.09
	6.0	1.8	0.28	1.6	0.33	0.75
40	0.8	2.4	0.19	2.4	0.19	0.75
41	Top	1.9	0.26	1.8	0.28	0.56
	1.2	2.0	0.25	2.0	0.26	0.53
	2.4	2.3	0.20	2.3	0.21	0.53
	3.9	2.5	0.18	2.4	0.19	0.53
42	2.6	1.0	0.49	1.0	0.59	0.84
46	Top	2.0	0.25	2.0	0.25	0.52
47	Top	1.5	0.35	1.5	0.36	0.52
	0.2 to 3.0	1.7	0.32	1.7	0.31	0.51
	0.5	1.3	0.41	1.1	0.47	1.04
48	Top	2.0	0.27	2.0	0.24	0.85
	0.9	2.2	0.22	2.2	0.22	0.83
	1.9	2.2	0.21	2.2	0.22	0.73

Table B-2. Preliminary size distribution data of selected top samples from Lake Erie ICONS cores.

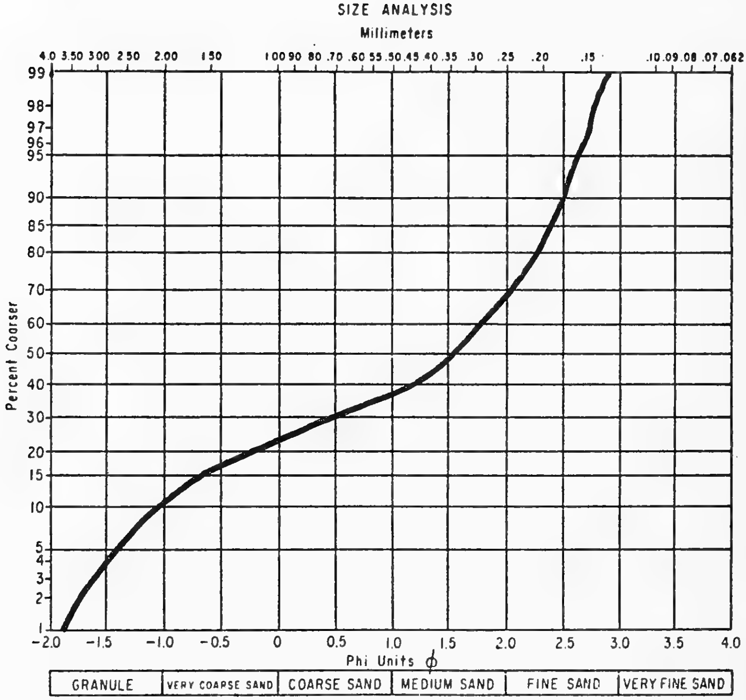
Core No.	Size Distribution (pct) >0.850 (mm)	0.425 to 0.850 (mm)	0.250 to 0.425 (mm)	0.250 (mm)	0.25 to 1.0 pct medium and coarse
1	0.2	0.5	46.0	53.3	46.7
2	0	25.2	44.5	30.3	69.7
3	0	31.3	54.7	14.0	86.0
4	0.1	22.8	48.6	28.5	71.4
5	9.3	3.9	27.7	59.1	40.9
6	0.2	4.9	48.8	46.3	53.9
7	3.6	2.8	7.6	86.0	14.0
8	2.9	51.3	14.5	31.3	68.7
9	Coarse sand and pebbles				
10	7.3	2.1	23.4	67.3	32.8
15	2.2	16.8	44.7	36.3	63.7
16	0.2	28.5	35.9	35.6	64.6
17	7.0	10.0	47.8	35.4	64.8
18	0.1	3.3	47.8	48.0	51.2
19	0.4	46.7	45.6	7.7	92.7
20	2.2	2.6	63.7	31.3	68.7
21	0	2.3	82.9	14.8	85.2
22	36.2	25.4	22.3	16.0	83.9
23	0.1	0.5	24.2	74.7	24.8
24	29.4	2.3	2.3	66.0	34.0
25	71.1	16.4	7.8	4.6	95.3

Table B-3. RSA grain-size data, grab samples.

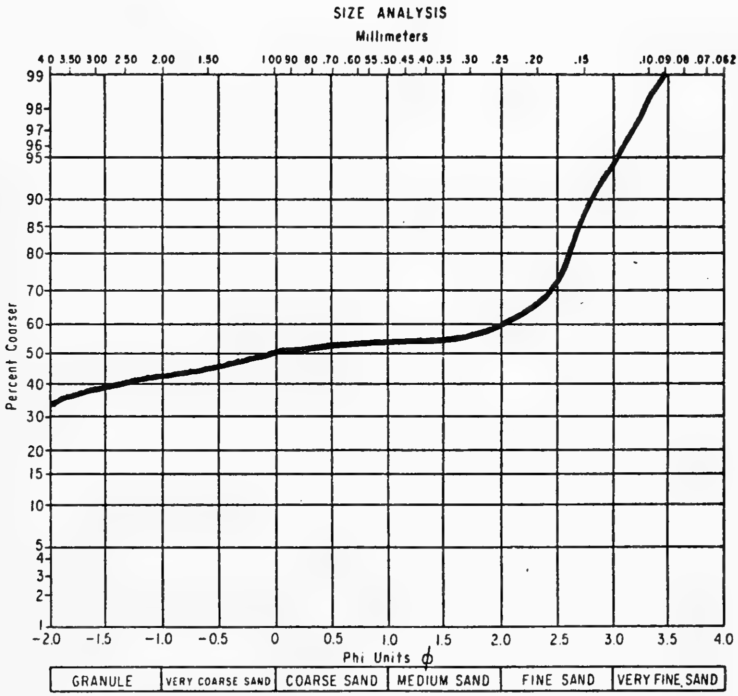
Sample No.	Depth (m)	Mean (phi)	Mean (mm)	Median (phi)	Median (mm)	Standard deviation
1-2	8.0	2.8	0.15	2.7	0.15	0.61
1-3	7.0	2.3	0.21	2.4	0.20	0.50
1-4	8.5	2.3	0.21	2.4	0.19	0.71
2-1	4.0	2.9	0.13	3.0	0.13	0.50
2-2	7.3	2.3	0.20	2.3	0.20	0.42
2-3	8.5	2.5	0.18	2.5	0.18	0.50
2-4	9.1	2.4	0.20	2.4	0.19	0.50
3-1	2.4	2.5	0.17	2.5	0.17	0.48
3-2	8.5	Too coarse for RSA analysis, see sieve sheet				
3-3	9.1	2.5	0.18	2.4	0.17	0.72
3-4	12.8	2.7	0.16	2.6	0.16	0.52
4-1	3.0	2.3	0.20	2.3	0.20	0.60
4-2	9.1	2.0	0.26	2.0	0.25	0.48
4-3	9.1	1.6	0.34	1.4	0.39	0.69
4-4	13.7	1.5	0.37	1.2	0.44	0.92
5-1	0.9	Too coarse for RSA analysis, see sieve sheet				
5-2	3.0	Predominantly mud, too fine for RSA analysis				
5-3	7.3	2.1	0.23	2.0	0.25	0.88
5-4	9.8	1.9	0.28	1.7	0.30	0.69
5-5	15.2	Predominantly mud, too fine for RSA analysis				
6-1	1.2	1.9	0.26	2.0	0.26	0.63
6-2	12.1	Predominantly mud, too fine for RSA analysis				
6-3	15.2	Predominantly mud, too fine for RSA analysis				
7-1	7.9	Predominantly mud, too fine for RSA analysis				
7-2	2.1	Predominantly mud, too fine for RSA analysis				
7A-1	4.0	2.0	0.25	1.9	0.26	0.72
7A-2	13.4	Predominantly mud, too fine for RSA analysis				

APPENDIX C

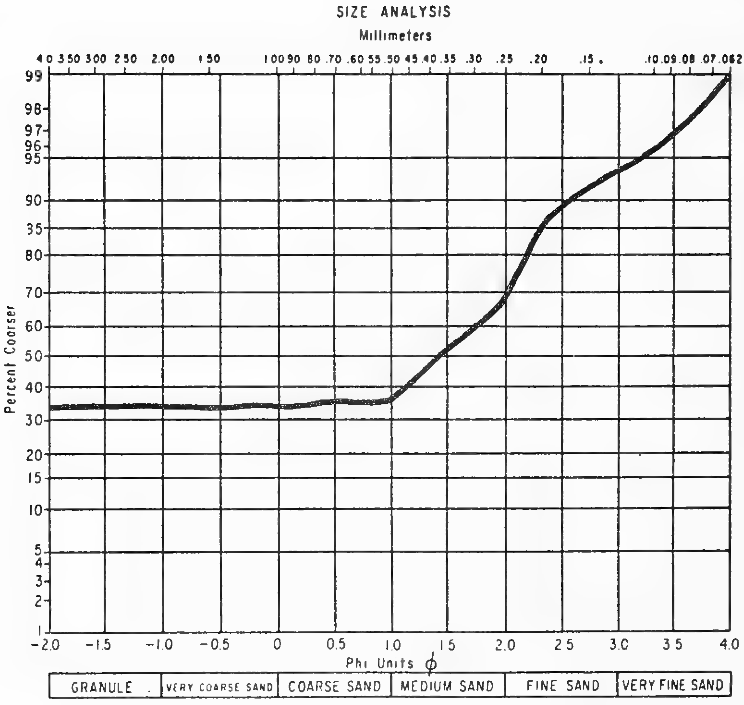
RSA SIZE ANALYSIS



Presque Isle grab sample 5-1

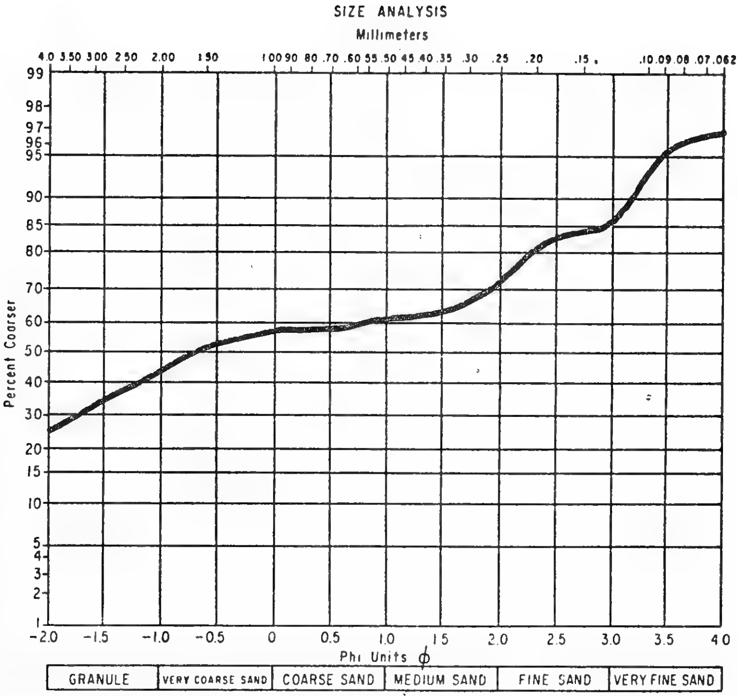


Presque Isle grab sample 3-2



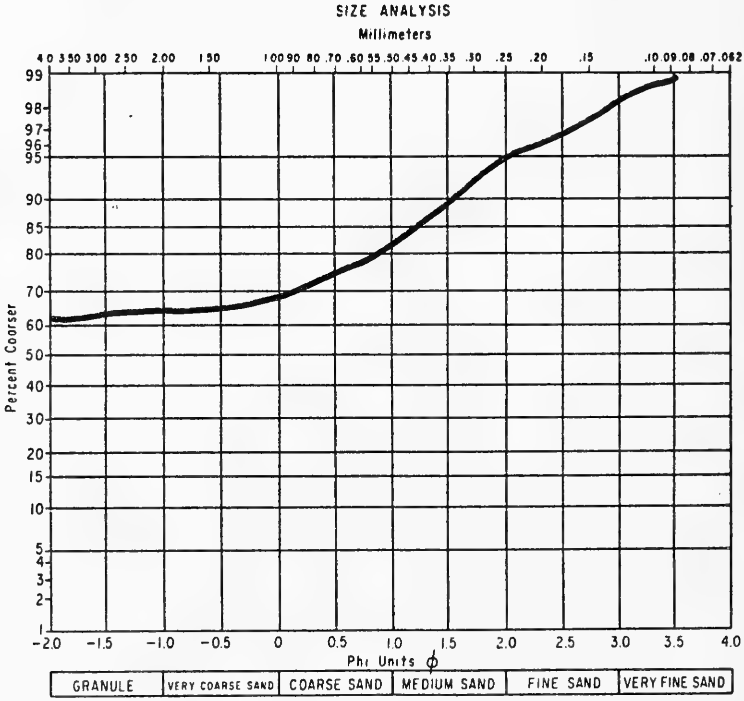
Core 4, (top)

M_d = 1.6 phi
0.33 mm

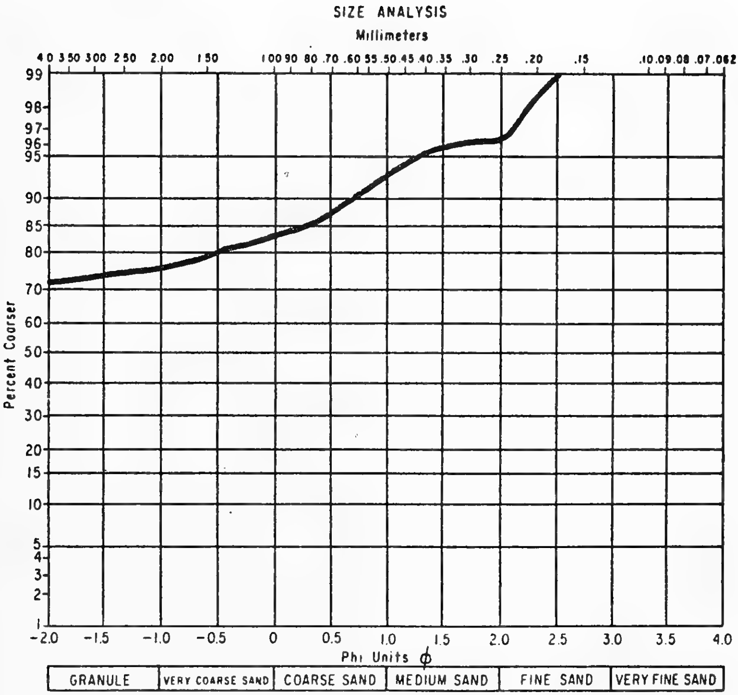


Core 7, -1.6 m

M_d = -0.75 phi
1.68 mm

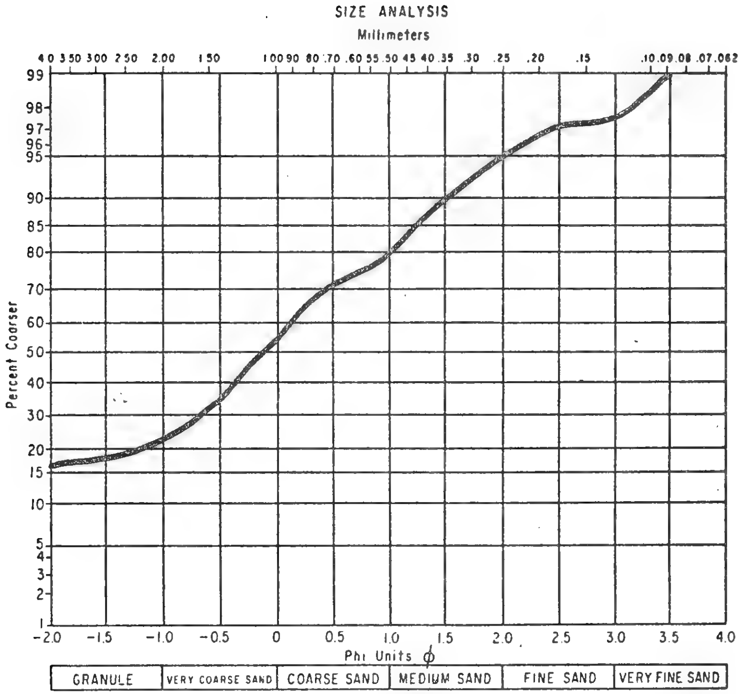


Core 8, 0.8 to 1.1 m


SIZE ANALYSIS
Millimeters
4.0 3.50 3.00 2.50 2.00 1.50 1.00 .90 .80 .70 .60 .55 .50 .45 .40 .35 .30 .25 .20 .15 .10 .09 .08 .07 .062
Percent Coarser
99 98 97 96 95 90 85 80 70 60 50 40 30 20 15 10 5 4 3 2 1
-2.0 -1.5 -1.0 -0.5 0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0
Phi Units ϕ
GRANULE
VERY COARSE SAND
COARSE SAND
MEDIUM SAND
FINE SAND
VERY FINE SAND

Core 9, (top)

Core 9, -0.3 m M_d = 0.1 phi
(excludes one pebble @ 3/4 sieve) 1.07 mm

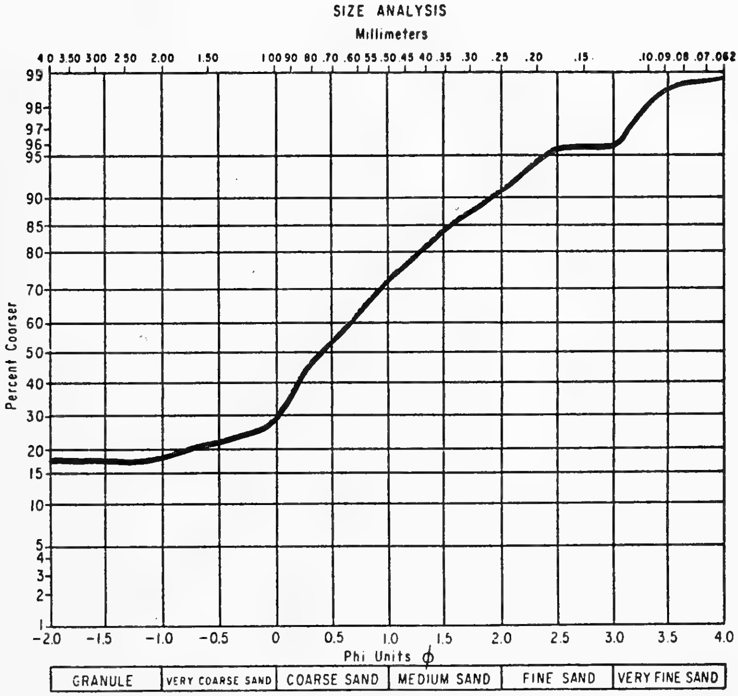


Core 9, -0.6 m

M_d = -0.1 phi
1.07 mm

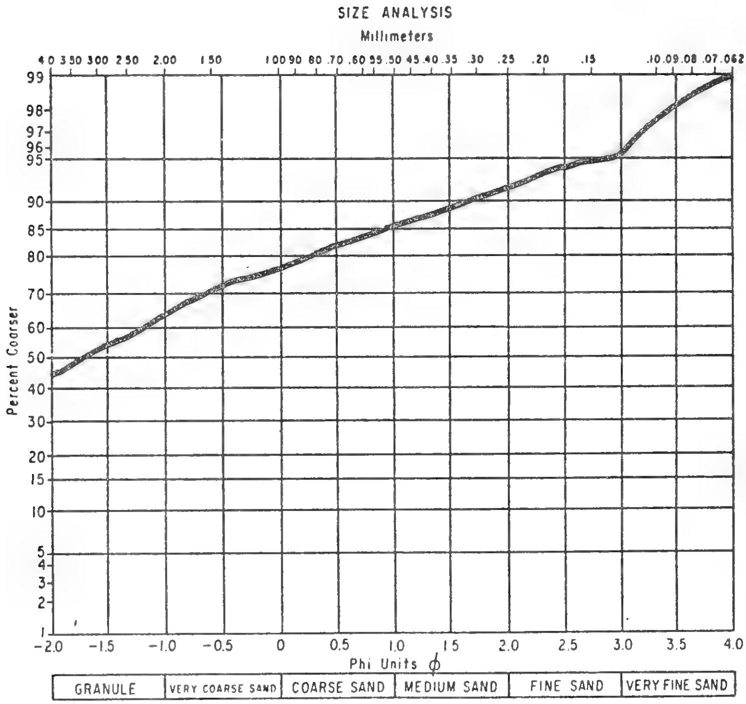
Core 9, -0.9 m
(includes pebble @ 7/16 sieve)

M_d = 0.4 phi
0.76 mm



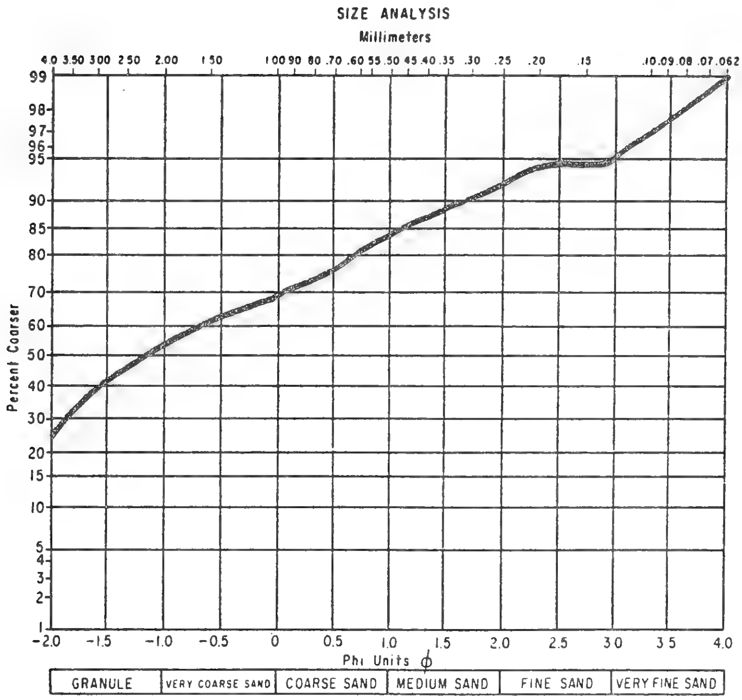
Core 9, -1.4 m

M_d = 0.4 phi
0.76 mm



Core 12, -0.2 m

M_d = -1.75 phi
3.36 mm

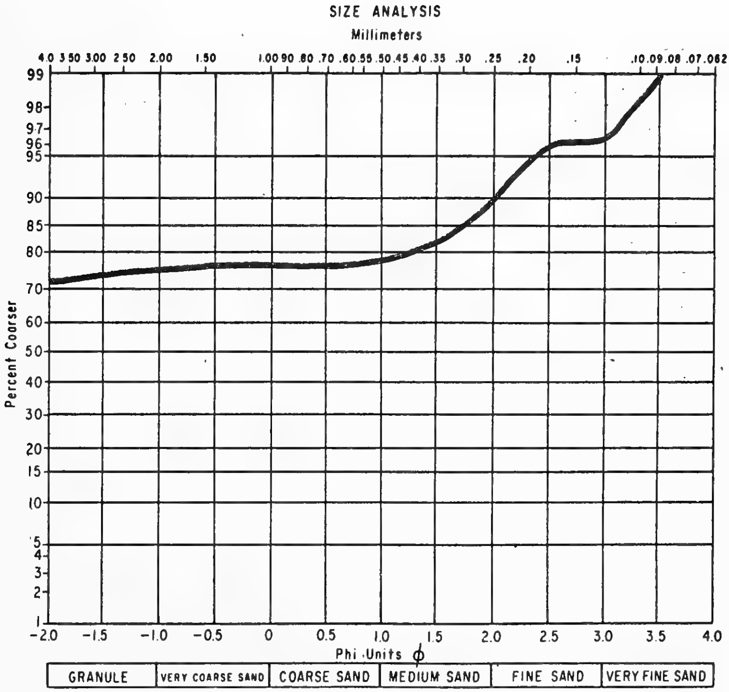


Core 12, -0.4 m

M_d = -1.2 phi
2.30 mm

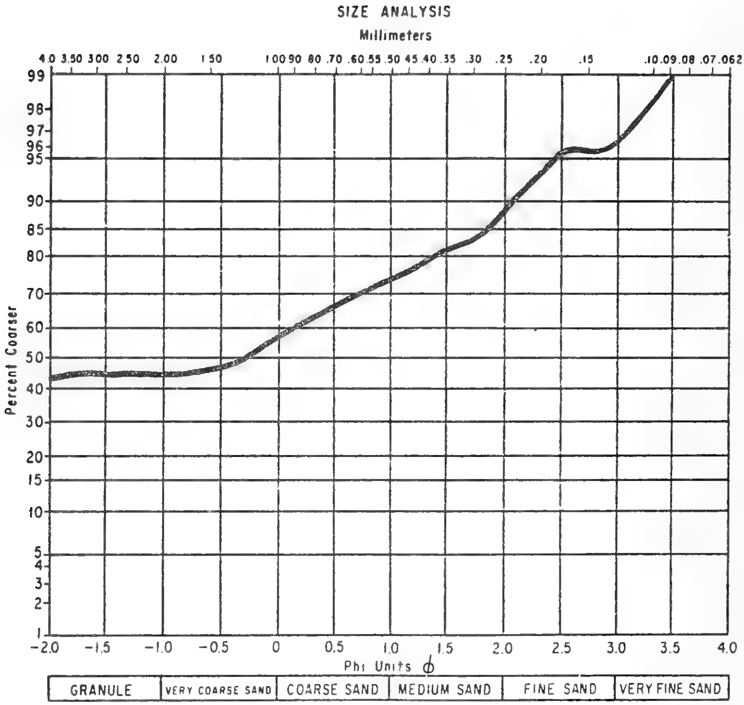
Core 12, -0.7
(exclude one pebble @ 7/8 sieve)

M_d = 0.3 phi
0.81 mm



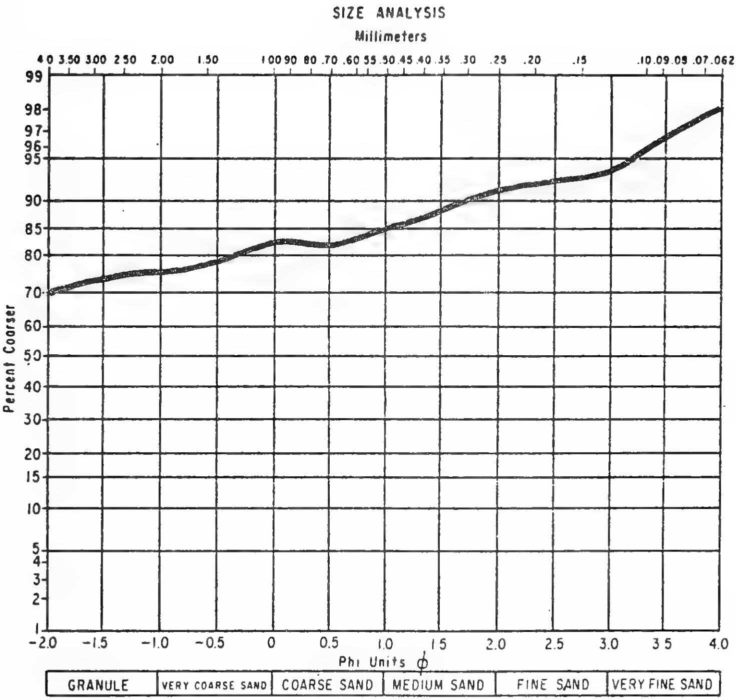
SIZE ANALYSIS
Millimeters
4.0 3.50 3.00 2.50 2.00 1.50 1.00 .90 .80 .70 .60 .55 .50 .45 .40 .35 .30 .25 .20 .15 .10 .09 .08 .07 .062
Percent Coarser
99
98
97
96
95
90
85
80
70
60
50
40
30
20
15
10
5
4
3
2
1
-2.0 -1.5 -1.0 -0.5 0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0
Phi Units ϕ
GRANULE
VERY COARSE SAND
COARSE SAND
MEDIUM SAND
FINE SAND
VERY FINE SAND

Core 21, -1.3 m



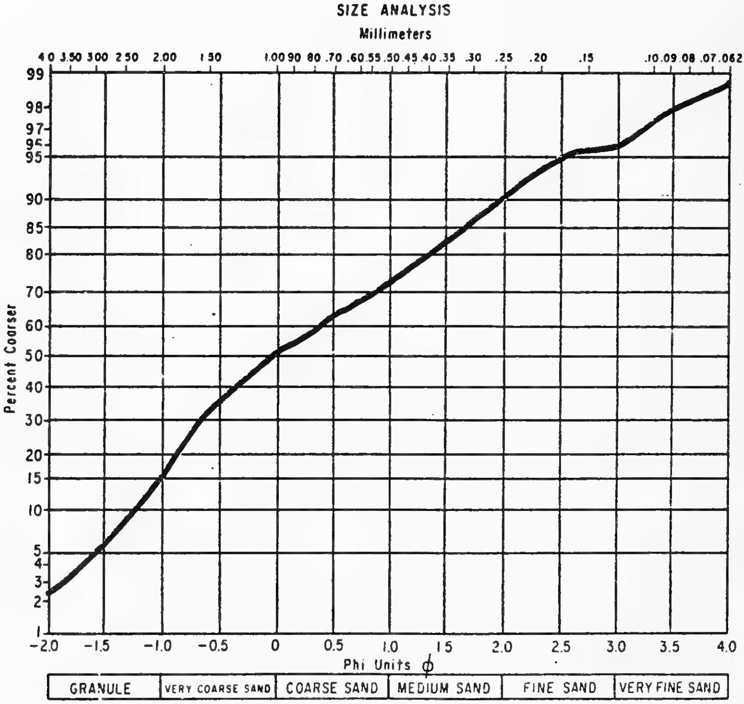
Core 23, -0.2 m

M_d = -0.24 phi
1.18 mm



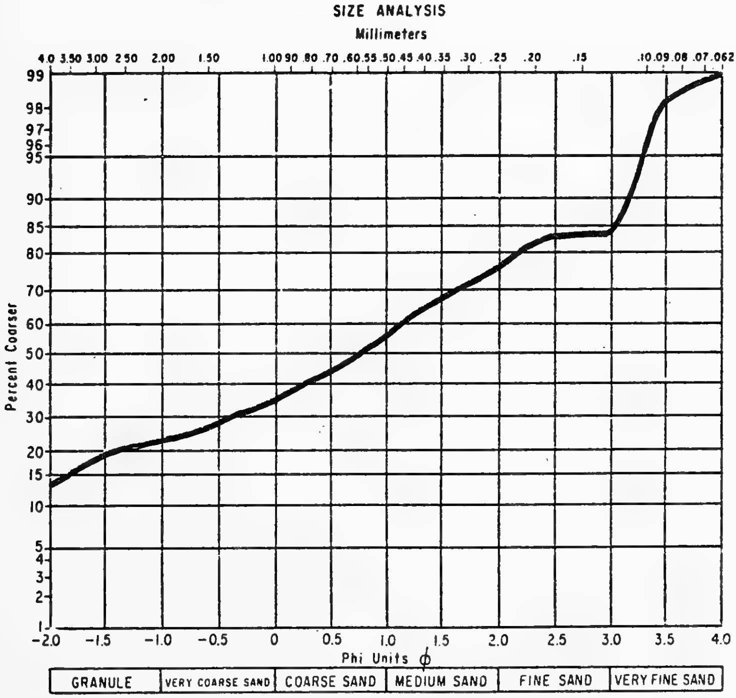
SIZE ANALYSIS
Millimeters
4.0 3.50 3.00 2.50 2.00 1.50 1.00 .90 .80 .70 .60 .55 .50 .45 .40 .35 .30 .25 .20 .15 .10 .09 .08 .07 .062
Percent Coarser
99 98 97 96 95 90 85 80 70 60 50 40 30 20 15 10 5 4 3 2 1
-2.0 -1.5 -1.0 -0.5 0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0
Phi Units ϕ
GRANULE
VERY COARSE SAND
COARSE SAND
MEDIUM SAND
FINE SAND
VERY FINE SAND

Core 25, -3.4 m



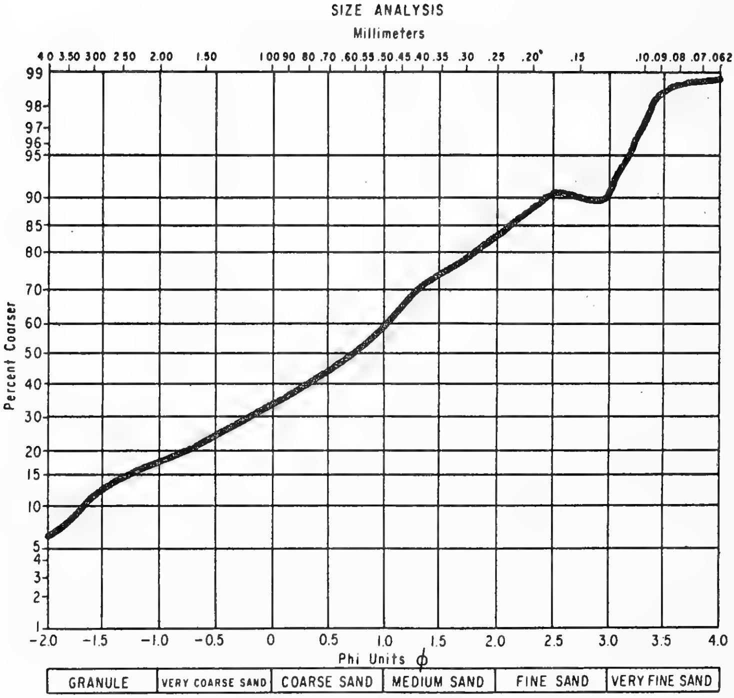
Core 39, -6.1 m

M_d = -0.1 phi
1.07 mm



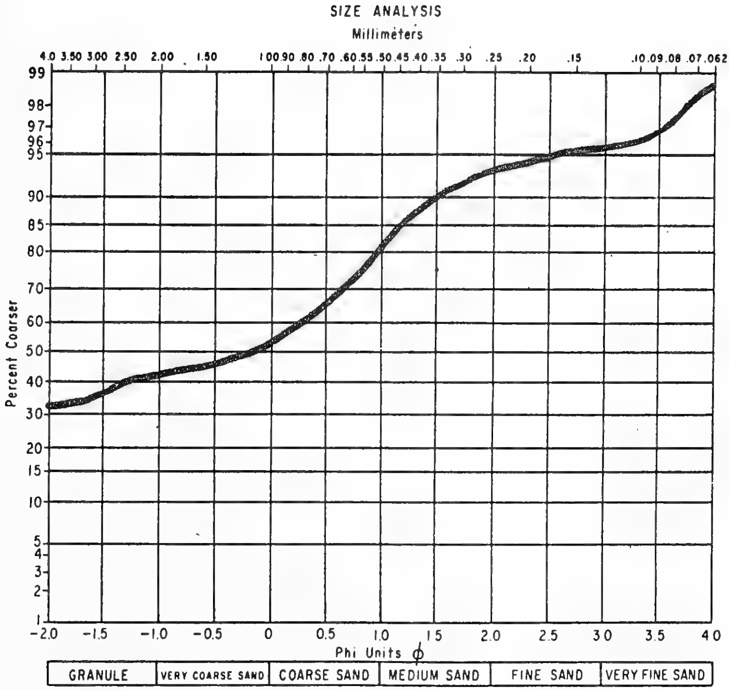
Core 40 (top)

M_d = 0.8 phi
0.57 mm



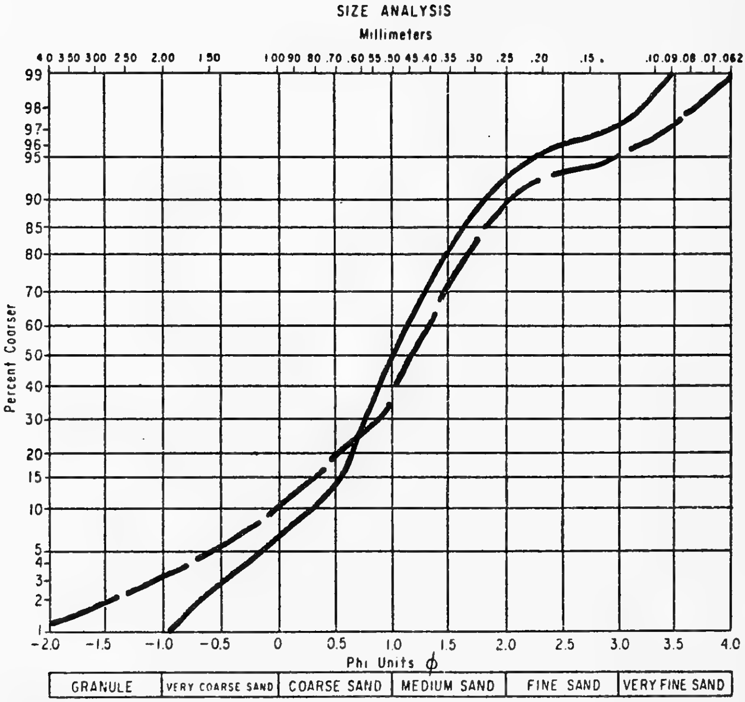
Core 40, -0.3 m

M_d = 0.8 phi
0.57 mm



Core 43, -1.2 m

M_d = 0.75 phi
0.60 mm



-- Core 43, -1.6 m M_d = 1.2 phi, 0.44 mm

\- Core 43, -3.0 m M_d = 1.15 phi, 0.45 mm

Williams, S. Jeffress
Geological character and mineral resources of south central Lake Erie / by S. Jeffress Williams and Edward P. Meisburger--Fort Belvoir, Va. : U.S. Army, Corps of Engineers, Coastal Engineering Research Center, Springfield, Va. : available from NTIS, 1982.
[62] p. : ill. ; 28 cm.--(Miscellaneous report / Coastal Engineering Research Center ; no. 82-9)
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"October 1982."
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TC203 .U581mr no. 82-9 627

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