BEACH PROCESSES AND COASTAL MORPHOLOGY ALONG A RECURVED SAND SPIT: PRESQUE ISLE, PENNSYLVANIA

KENT TAYLOR and RAYMOND BUYCE
(Mercyhurst College)

INTRODUCTION

Presque Isle is an 11 km long recurved sand spit on the south shore of Lake Erie partially enclosing Pennsylvania's only recreational and commerical shipping port, Presque Isle Bay and the City of Erie (Figure 1). A new $15 million system of detached breakwaters is presently under construction along the lake side of the Presque Isle beaches (Figure 2). The U.S. Army Corps of Engineers and the State of Pennsylvania are sharing the cost of this Shoreline Erosion Control Project. A great diversity of coastal engineering structures have been built along Presque Isle dating from the early 1800's to the present (Figure 3) and beach nourishment has been ongoing since 1955 (see Thomas and others, 1987, p. 33-38). The estimated cost of erosion control including beach nourishment from 1829 is $32 million, of which $20 million was spent since 1975. It is hoped that with the completion of the breakwaters the Presque Isle maintenance and nourishment costs will be reduced by $1 million per year for the next fifty years (personal communication Dale Hamlin, Pennsylvania Bureau of Water Projects, 1990).

The U.S. Corps of Engineers and the State of Pennsylvania have shared the responsibility of protecting Presque Isle from significant erosion. From the U.S. Corps of Engineers perspective the primary goal has been to ensure that the peninsula will continue to protect the Port of Erie. Only recently have the beaches on the lake side of the peninsula played a significant economic role for the City of Erie due to their immense recreational potential. Some conflicts have arisen recently between those who see the primary goal of erosion control projects as maintenance of recreational beaches and others who continue to pursue the long standing goal of harbor protection. Some progress has been made toward addressing both issues. One example is the recent spreading of a fine-grained sand layer over the beach replenishment materials selected for maximum cost effectiveness for erosion control (the so-called dirty sand and gravel taken yearly from upland gravel pits).

Effective erosion control relies on an understanding of the dynamics of the sand spit and preliminary studies have been made, mostly supported by the U.S. Corps of Engineers. The most recent studies include:
(1) The U.S. Army Corps of Engineers Final Phase 1 General Design Memorandum (1980).
(2) An extensive study of a 1:50 scale physical model of the neck of Presque Isle completed at the Waterways Experiment Station at Vicksburg, Mississippi.

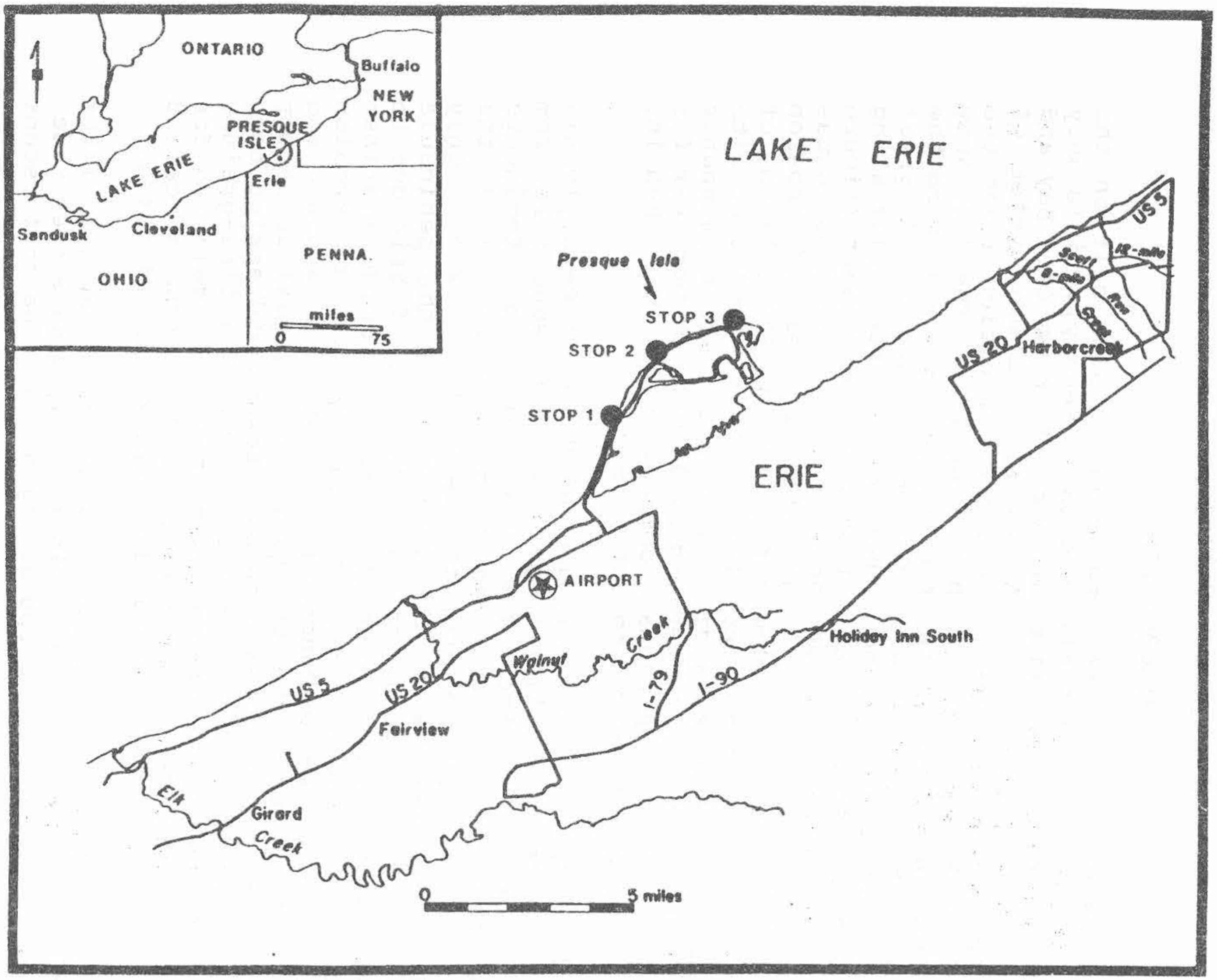
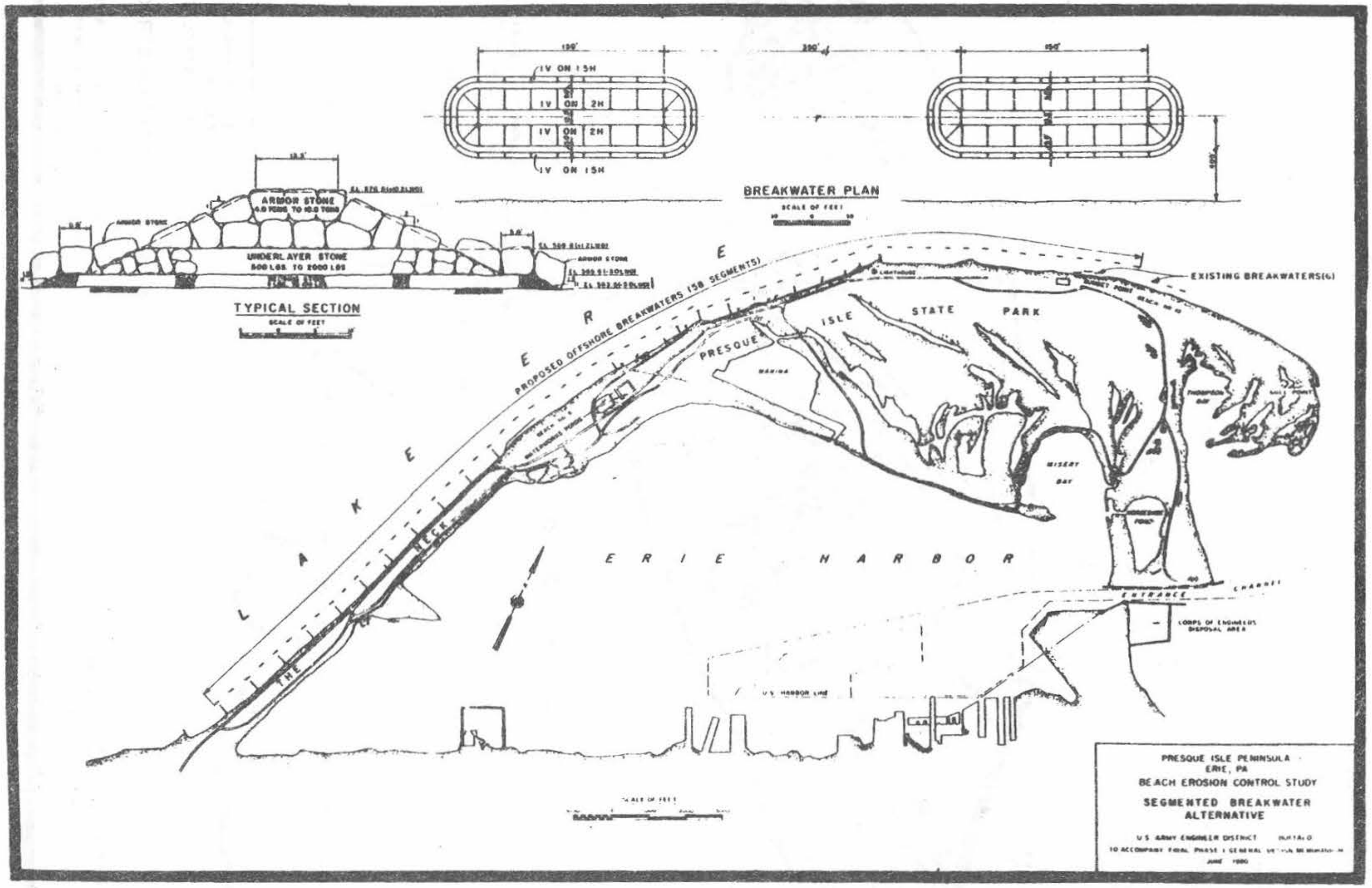


Figure 1. Location map of Presque Isle, PA, showing its position relative to the tri-state area, the route map for the Presque Isle field trip, and the location of the stops at the peninsula.



Sat. F3

Figure 2. U. S. Army Corps Engineers plan for the 58 offshore breakwater segments designed to protect the peninsula's beaches.

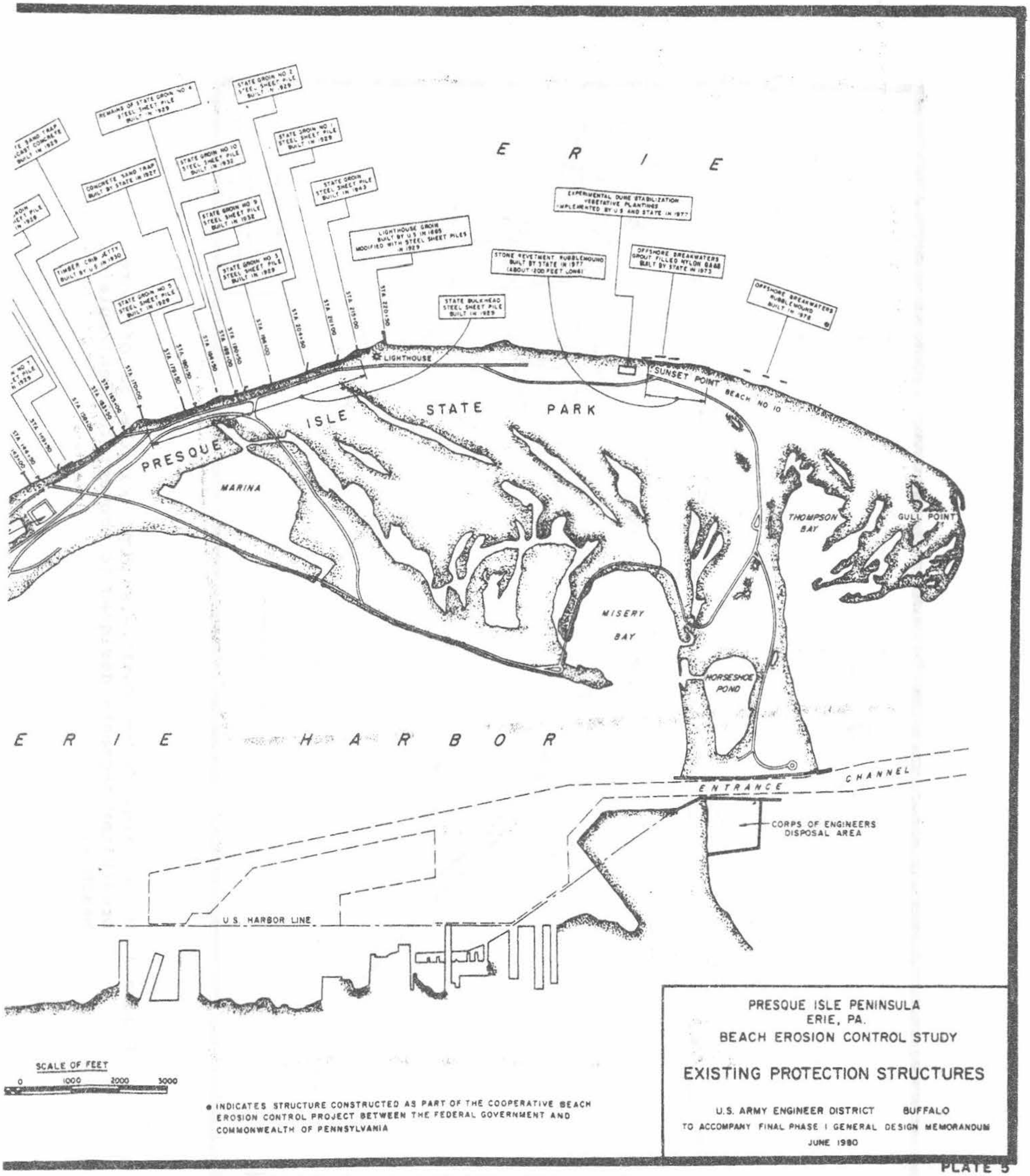
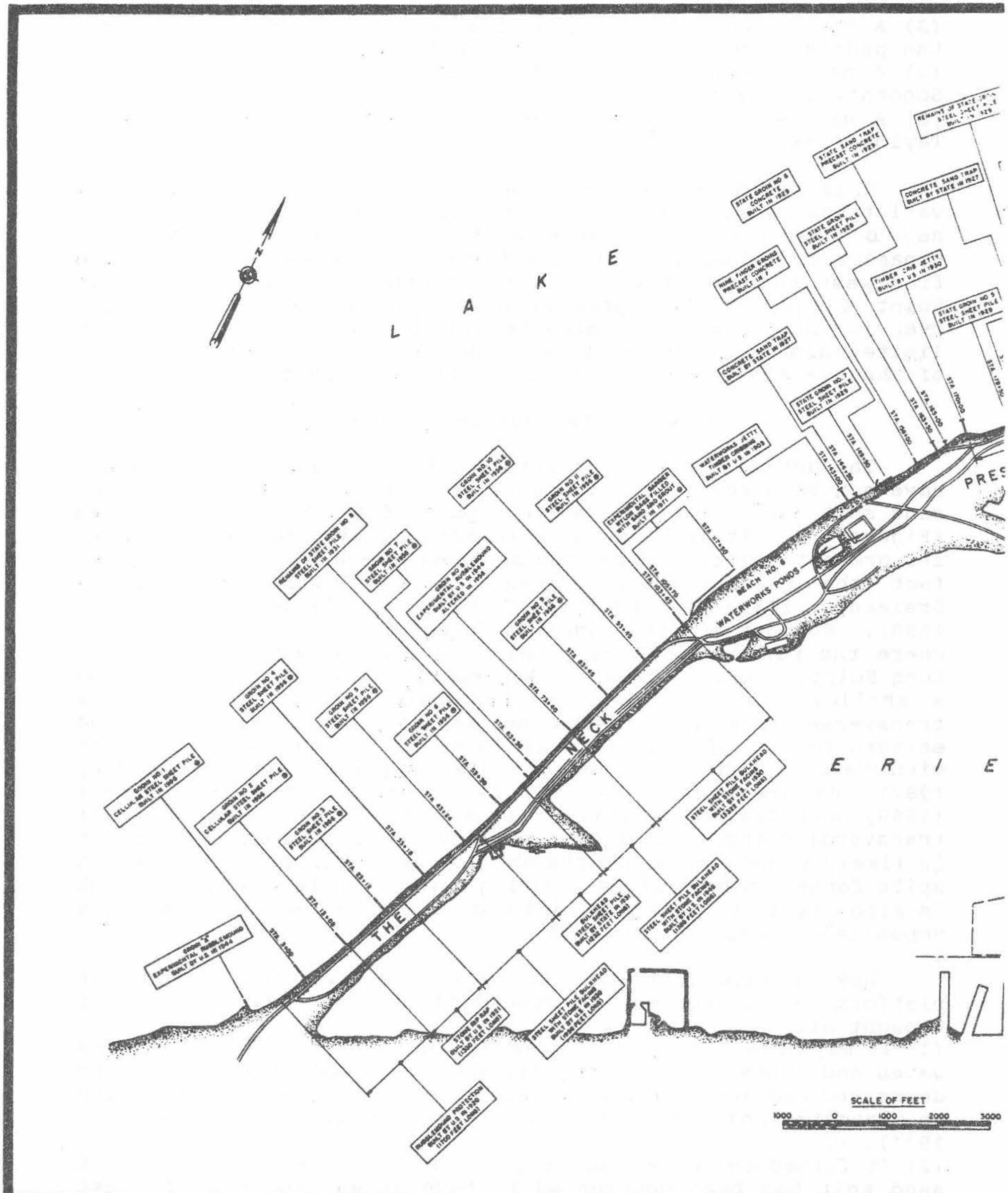


Figure 3. Existing erosion control structures along the Presque Isle shore.


L A K E
E R I E
THE NECK
BEACH NO. 6
WATERWORKS PONDS
PRES
SCALE OF FEET
1000 0 1000 2000 3000
GROIN NO 1 CELLULAR STEEL SHEET PILE BUILT IN 1955
GROIN NO 2 CELLULAR STEEL SHEET PILE BUILT IN 1956
GROIN NO 3 STEEL SHEET PILE BUILT IN 1956
GROIN NO 4 STEEL SHEET PILE BUILT IN 1956
GROIN NO 5 STEEL SHEET PILE BUILT IN 1956
GROIN NO 6 STEEL SHEET PILE BUILT IN 1956
GROIN NO 7 STEEL SHEET PILE BUILT IN 1956
GROIN NO 9 STEEL SHEET PILE BUILT IN 1958
GROIN NO 10 STEEL SHEET PILE BUILT IN 1956
GROIN NO 11 STEEL SHEET PILE BUILT IN 1956
REMAINS OF STATE GROIN NO 8 STEEL SHEET PILE BUILT IN 1931
WATERWORKS JETTY TIMBER CRIBBING BUILT BY U.S IN 1903
CONCRETE SAND TRAP BUILT BY STATE IN 1927
STATE GROIN NO 7 STEEL SHEET PILE BUILT IN 1929
NINE FINGER GROINS PRECAST CONCRETE BUILT IN 1927
STATE GROIN NO 6 CONCRETE BUILT IN 1929
STATE SAND TRAP PRECAST CONCRETE BUILT IN 1929
TIMBER CRIB JETTY BUILT BY U.S IN 1930
STATE GROIN NO 5 STEEL SHEET PILE BUILT IN 1929
CONCRETE SAND TRAP BUILT BY STATE IN 1927

(3) A three year time study of the beach and bar systems along the peninsula by Nummedal (1979, 1980, 1981).
(4) A native sand tracer study of the inner bar at Beach 6 by Sonnenfeld (1981).
(5) A native sand tracer study of the outer bar at Beach 6 by Taylor (1981, unpublished).

This field trip has been devised to allow us to observe a variety of coastal engineering structures including some of the new breakwaters. One stop each is planned for the three dynamically and morphologically distinct segments of Presque Isle from west to east: the Neck, the Lighthouse Beaches, and Gull Point (Figure 6). The optional overflight will permit a dramatic overview of the entire system helping us to fit the necessarily limited number of ground-based observations into the framework of the overall coastal dynamics of the spit system.

ORIGIN OF PRESQUE ISLE PENINSULA

The details of the formation of the Presque Isle peninsula have not been fully established. It is known that the recurved sand spit now sits on the eastern part of a subaqueous platform (Figure 4). It is reasonable to assume that Presque Isle owes its present location along the southern shore of the lake to the fact the platform was present there (Lewis, 1966, 1969; Dreimanis, 1969; Messinger, 1977; U.S. Army Corps of Engineers, 1980). Support for this idea is found directly across the lake where the peninsula is mirrored by a similar but larger spit, Long Point, Ontario, Canada. Apparently Long Point also sits on a shallow platform that is the other end of a subaqueous transverse ridge that crosses the lake separating the central and eastern basins of Lake Erie (Figure 5). The ridge is covered with wave-sorted sands and gravels (Williams and Meisberger, 1982) and has been identified as a glacial moraine by Lewis (1969) and Dreimanis (1969). Thus the glacial moraine ridge transversing the lake at this particular place along its length is likely to have provided the shallow water platforms upon which spits formed on both sides. During lower lake levels the moraine is also likely to have provided sediments that were reworked and deposited as part of the spits.

How Presque Isle came to be on the eastern part of the platform is the subject of some disagreement. Two schools of thought are:
(1) It may have formed on the eastern portion - Eastward directed waves and longshore currents may have reworked, transported and deposited sediments on the leeward side of the platform producing an elongate sand body that evolved into Presque Isle (Messinger, 1977). or
(2) It formed on the western portion and migrated eastward - The sand spit has been documented to have moved from west to east based on botanical data (e.g. age of trees on different parts of the peninsula) and on charts and surveys dating back to 1730 (Jennings, 1930). Using the rate of migration established from

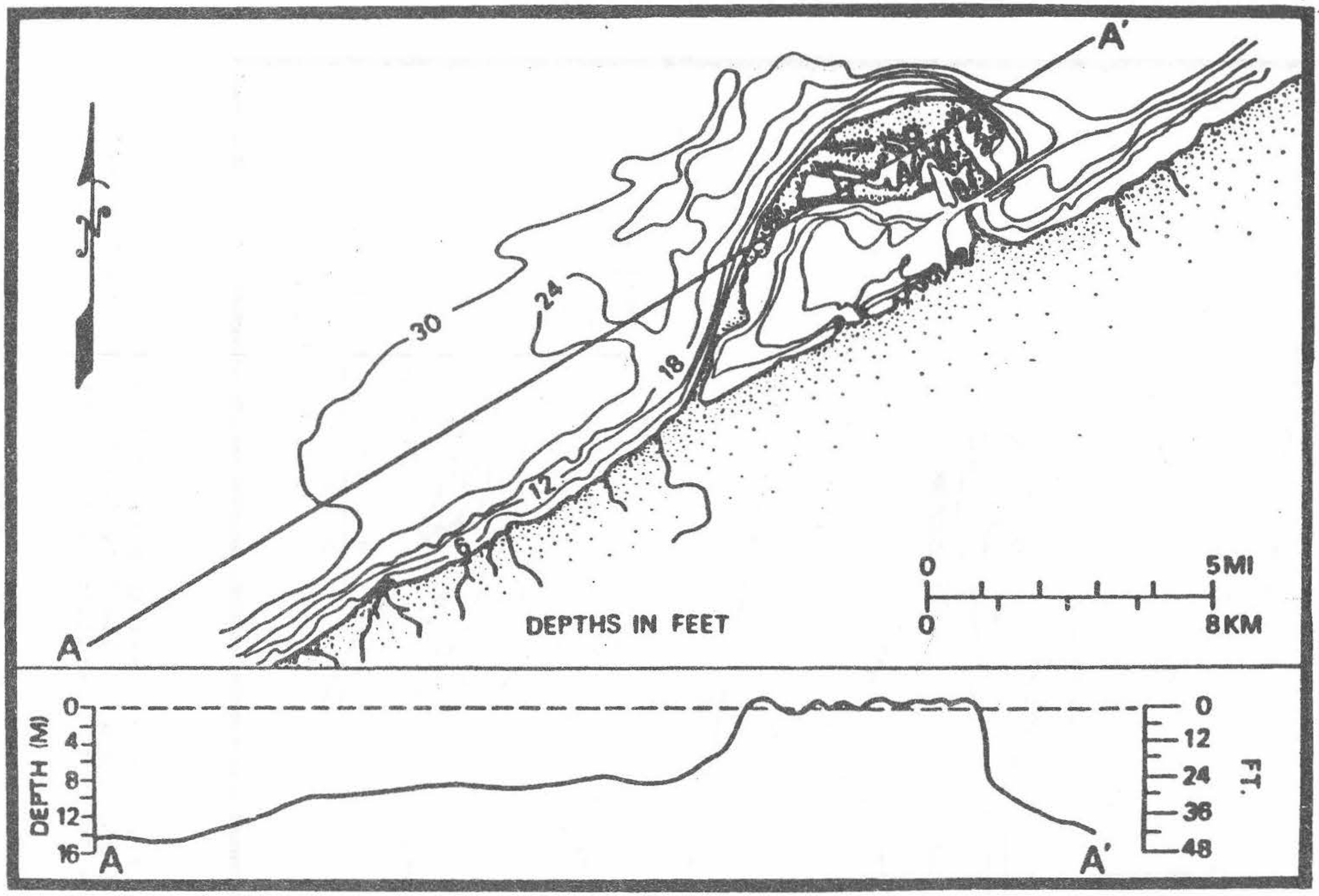


Figure 4. Bathymetry of the lake area surrounding Presque Isle, showing the platform on which the spit is built (from Nummedal, 1983).

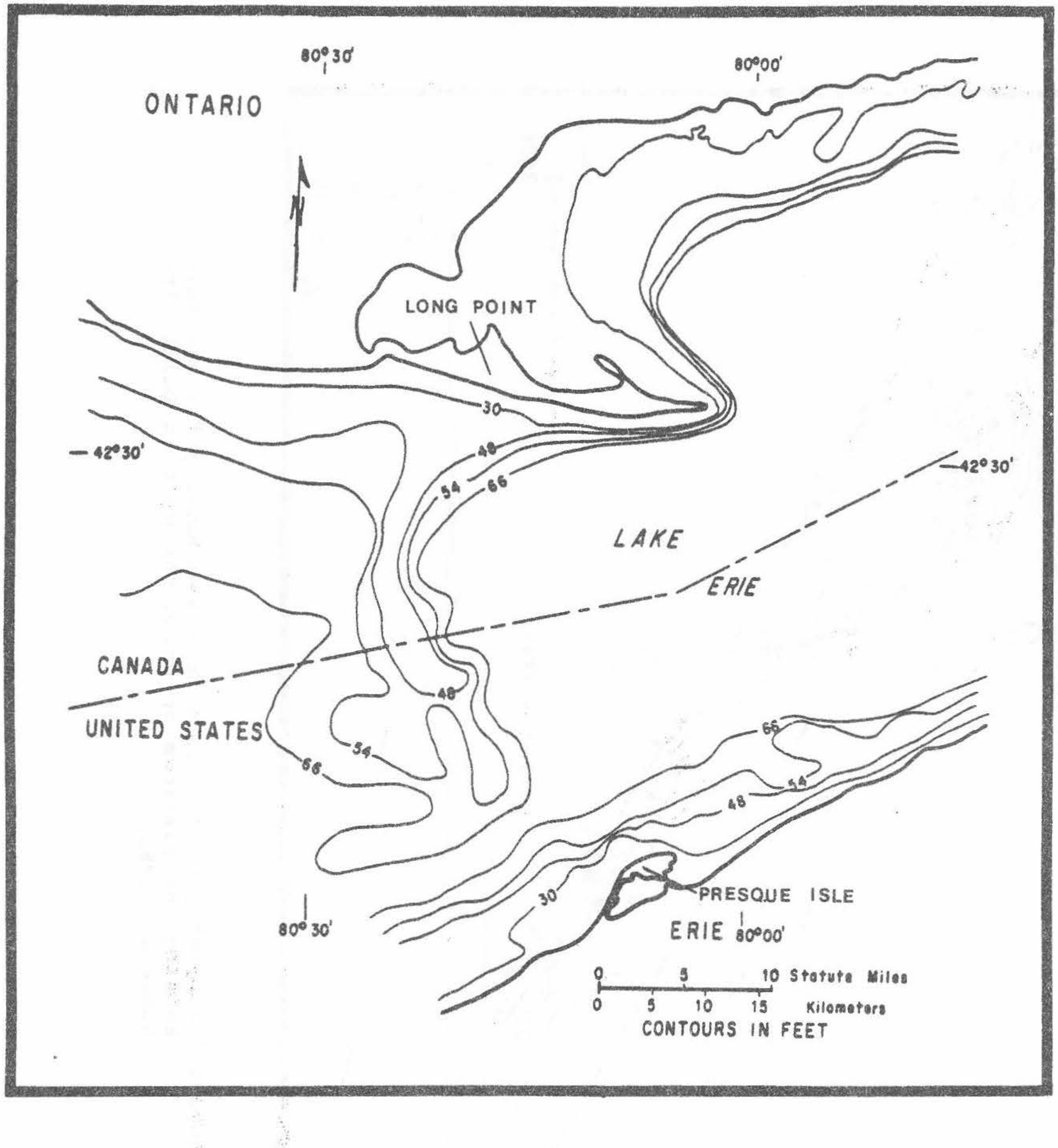


Figure 5. Map of the central Lake Erie basin showing the traverse ridge that connects with Long Point and projects toward Presque Isle (from Williams and Meisburger, 1982).

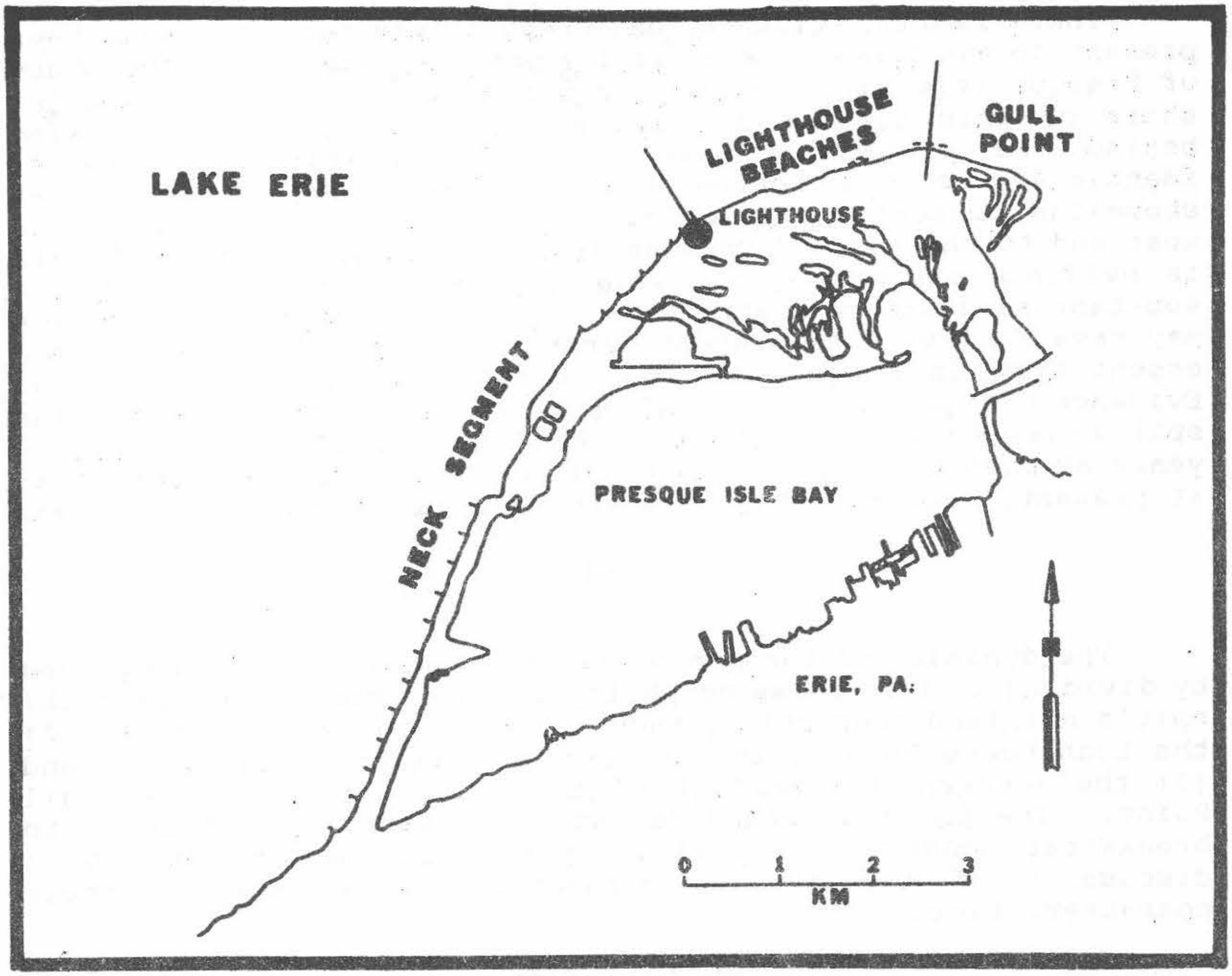


Figure 6. Location of the three major morphologic zones of Presque Isle. The divisions are based on changes in the physiography of the spit and the nearshore zone.

1730 to present to project the location of Presque Isle back 500 years and more ago is not necessarily valid.

There is good evidence that Presque Isle has not always been present on the lakeward side of the present location of the shore of Presque Isle Bay. The wave-cut bluffs that extend along the shore of this portion of lake are A) not displaced lakeward behind the protective shield of the present spit and B) identically eroded behind the spit as along stretches of shoreline presently exposed to lake waves and currents to the west and to the east of Presque Isle. It is not clear that this is evidence supporting the idea that the spit has migrated a substantial distance eastward to its present location; the coast may have achieved its present morphology before the spit formed essentially in place with only a minor amount of migration. Evidence has not yet been obtained establishing the time when the spit began to form; certainly it cannot be older than 12,000 years BP when the level of Lake Erie was some 120 feet lower than at present. How recently it may have begun forming is unknown.

PHYSIOGRAPHY

The dynamics of the peninsula can be more easily understood by dividing it into three morphologic zones (Figure 6). From the spit's mainland connection, they are: (1) the Neck segment, (2) the Lighthouse Beaches in the central portion of the spit, and (3) the eastern-most portion of the spit, referred to as Gull Point. The physical characteristics of each segment prior to breakwater construction will first be described followed by a discussion of the dynamic parameters which generate their characteristics.

Neck Segment

From its connection with the mainland, extending 3.2 km to the northeast, the neck of Presque Isle is narrow and low in relief. Its average width is 245 m and the maximum elevation is 2.5 m above low water datum (LWD for Lake Erie is 173.3 m (568.6 ft) (IGLD, 1955). This segment has a history of severe erosion and has been breached several times by intense storms. Pre-breakwater shore protection structures along this segment include eleven sheet pile groins located at 300 m intervals, several sheet pile bulkheads reinforced with armor stone, and a barrier of grout- and sand-filled nylon bags. An extensive beach nourishment program has also been an important part of the erosion control program since 1955.

Prior to construction of breakwaters along the neck segment the morphology of the nearshore zone included an ephemeral inner bar and a single permanent outer bar, separated by a deep (4.0-4.5 m) through (Figure 3 from Nummedal, 1979). A third poorly developed outer bar was sporadically present along portions of this segment. The inner bar within the groin field was linear or crescentic in plan view. The bar crested in 0.5-1.5 m of water, and was located 10-50 m offshore. The outer bar was located 150-200 m offshore, with the crest of the bar in 3.5 m of water. The outer bar was also crescentic in plan view, with lows or "saddles" separating the 400-1000 m segments. In profile, this bar was typically asymmetric, with a steep landward flank and a gentle lakeward flank. The trough separating the inner and outer bar was typically 4.0-4.5 m deep, giving the outer bar substantial relief.

Lighthouses Beaches

East of the neck, the Lighthouse Beaches segment of the peninsula widens abruptly to more than 1.5 km, and the maximum elevation increases to 6.0 m above low water datum. The orientation of the shoreline changes abruptly at the lighthouse, as the peninsula's shoreline begins to turn landward. The dominant features of the inland portion of the spit include sand plains, east-west trending dune ridges, and ponds or swales occupying the areas between the ridges. Repetition of these features throughout the interior of this segment illustrates the accretionary nature of the spit throughout its evolution. Unlike the neck, pre-breakwater shore protection structures are less regular in spacing and type having been built to stabilize specific pockets of erosion. Groins, stone filled crib jetties, sheet pile bulkheads, rip-rap revetments, detached breakwater segments, and beach nourishment have all been employed to help stabilize the beaches.

Prior to breakwater construction the morphology of the beaches and the nearshore zone changed significantly to the east of the lighthouse. Both the average depth and the slope of the nearshore zone decreased. The outer bar system in this broad platform area consisted of multiple longshore bars, and a system of transverse bars (Figure 7 modified from Nummedal, 1979). The inner bars were usually straight, with their crests located 50 meters offshore in 1.0-1.5 m of water. Megacusps were common features along the beaches of this segment. The megacusps were rhythmic features, with a wavelength of 230 m and an amplitude of 11 m (Nummedal, 1979).

Gull Point

The eastern-most portion of Presque Isle, referred to as Gull Point, is the only depositional area along the peninsula. A series of beach ridges, separated by captured ponds reflects the rapid growth of this segment. This growth occurs by the process of west to east migration of megacusps and welding of offshore bars to the beach along Gull Point (Nummedal, 1978). Although the slopes are much steeper the bar morphology of the nearshore zone along Gull Point is similar to that described for the pre-breakwater neck segment. Bar forms include a single recurved inner bar, and a single high relief outer bar. (Figure 7 from Nummedal, 1979).

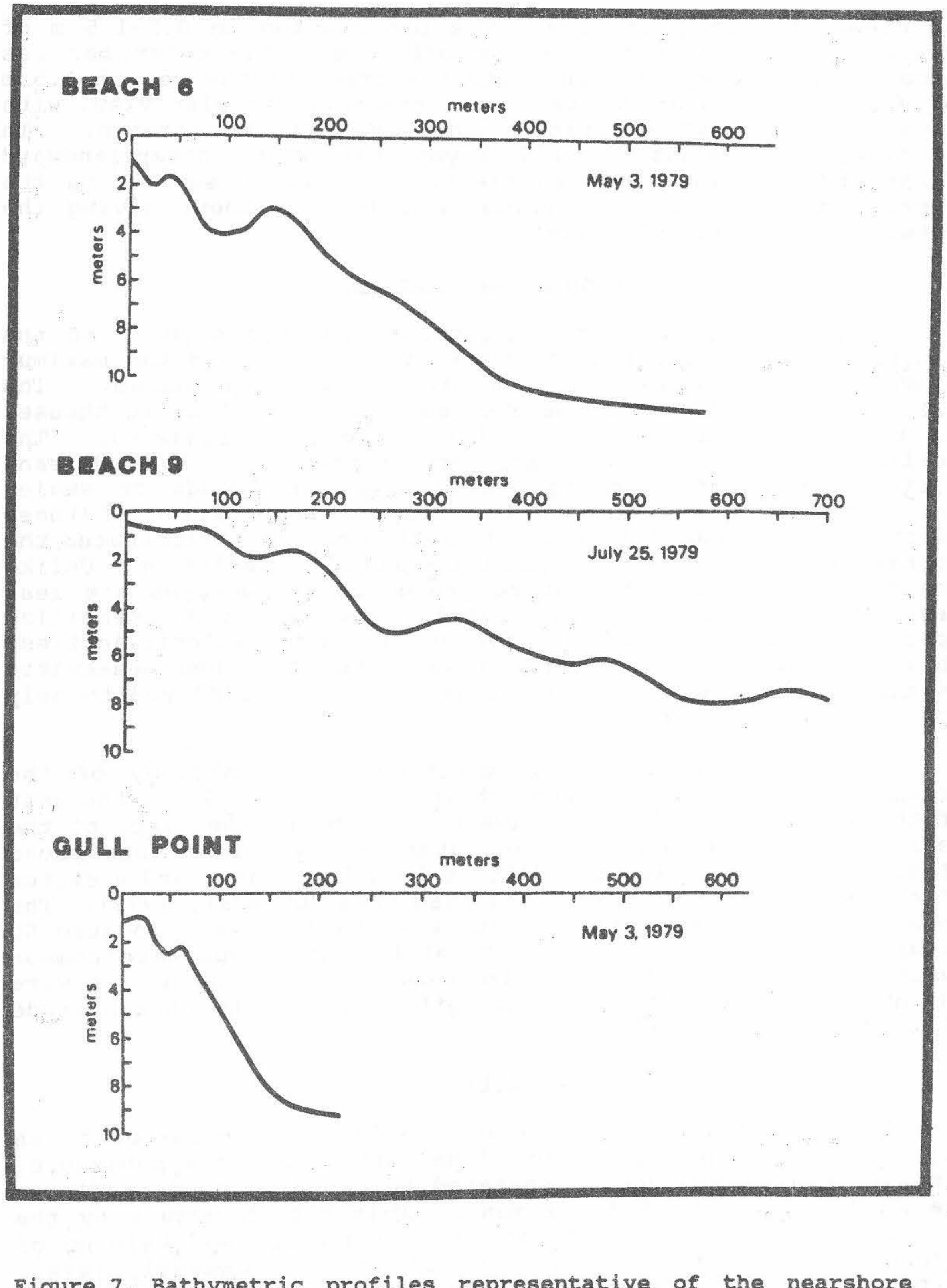


Figure 7. Bathymetric profiles representative of the nearshore bathymetry for each field stop (Beach 6 - neck segment (Stop 1): Beach 9 - lighthouse beaches (Stop 2): Gull Point - Stop 3) (Nummedal, 1979).

WAVE CLIMATE

The wave climate for Lake Erie is best described as a storm wave environment (Nummedal et al., 1976). Long periods of calm are punctuated by short-lived, high energy storm events. Calm conditions, or wave heights less than 0.15 m occur 75% of the time along the Presque Isle shoreline (Nummedal et al., 1984).

The wave climate also has a seasonal aspect. High intensity storms occur in the fall (October and November) before the lake freezes and during the spring (March, April and May) after the lake ice begins to break-up (Nummedal et al., 1974). The summer months are dominated by moderate to low wave energies.

The dominant winds responsible for wave generation on Lake Erie are most commonly a function of extratropical cyclone activity (Nummedal et al., 1976). Low pressure systems generated to the west commonly track eastward along the north shore of Lake Erie (Figure 8A). As the lows pass to the north of the lake, the counter-clockwise circulation causes the wind to shift from the south, through the southwest, to the northwest (Figure 8C). The strongest winds associated with the passage of the lows are from the southwest to west which corresponds to the maximum fetch direction for Lake Erie.

Because the dominant wind direction corresponds to the long axis of the lake, the wave energy flux is also at a maximum from the west-southwest (Nummedal et al., 1974). An annual wave-energy budget based on hindcast wave conditions was calculated by Saville (1953). Figure 9 summarizes the relationship between the fetch length and Saville's calculations for wave energy flux along specified bearings for Erie, PA. The diagram emphasizes that:

(1) the maximum wave power approaches Presque Isle's shoreline from the west and (2) the eastward directed wave energy flux would result in the generation of eastward directed coastal currents.

SEDIMENT TRANSPORT RATES

Nummedal. (1983) has demonstrated that changes in shoreline orientation with respect to the dominant wave approach direction are responsible for increases and decreases in the rate of net sediment transport along Presque Isle. Completion of the detached breakwater project will result in changes that are unpredictable. The rest of this discussion of sediment transport refers to the dynamics and morphology prior to breakwater construction. Figure 10 gives the rates of longshore sediment transport and the rates of net erosion and net accretion for five shoreline segments along the lakeward perimeter of Presque Isle (Nummedal, 1983). The Neck segment of this guide includes Nummedal's I, II, and III segments; the Lighthouse Beaches

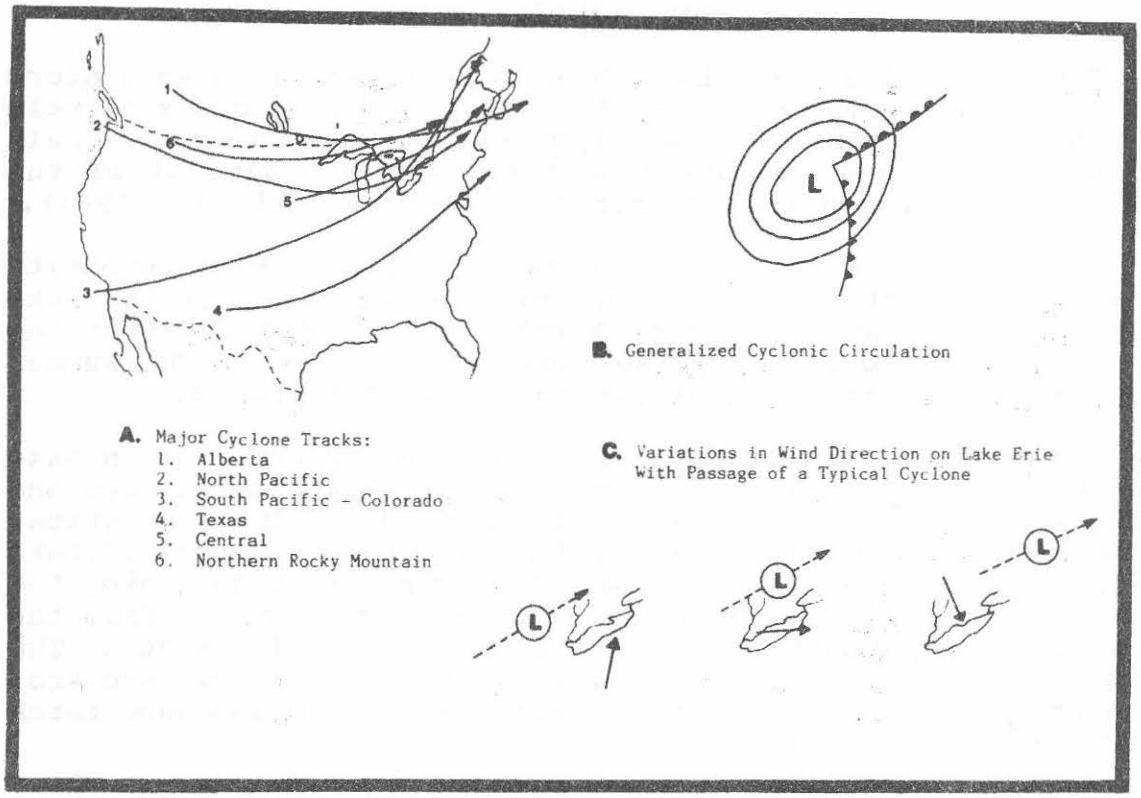


Figure 8. The characteristics and migration of major cyclones effecting the Great Lakes Region.

(A) Major North American Cyclone tracks. Five of six major cyclone tracks converge, and track to the north of Lake Erie. Lows passing to the north of Lake Erie are generally responsible for the generation of storm events. Data from Goode's World Atlas (1970) and Petterson (1969).

(B) Generalized cyclonic pattern. Geostrophic winds are controlled by the equilibrium beetween the pressure gradient and the Coriolis force.

(C) Variation in wind direction on Lake Erie with the passing of a cyclone. Winds change in direction from the south, through west, to northwest as the low tracks to the northeast. (Nummedal et al., 1974)

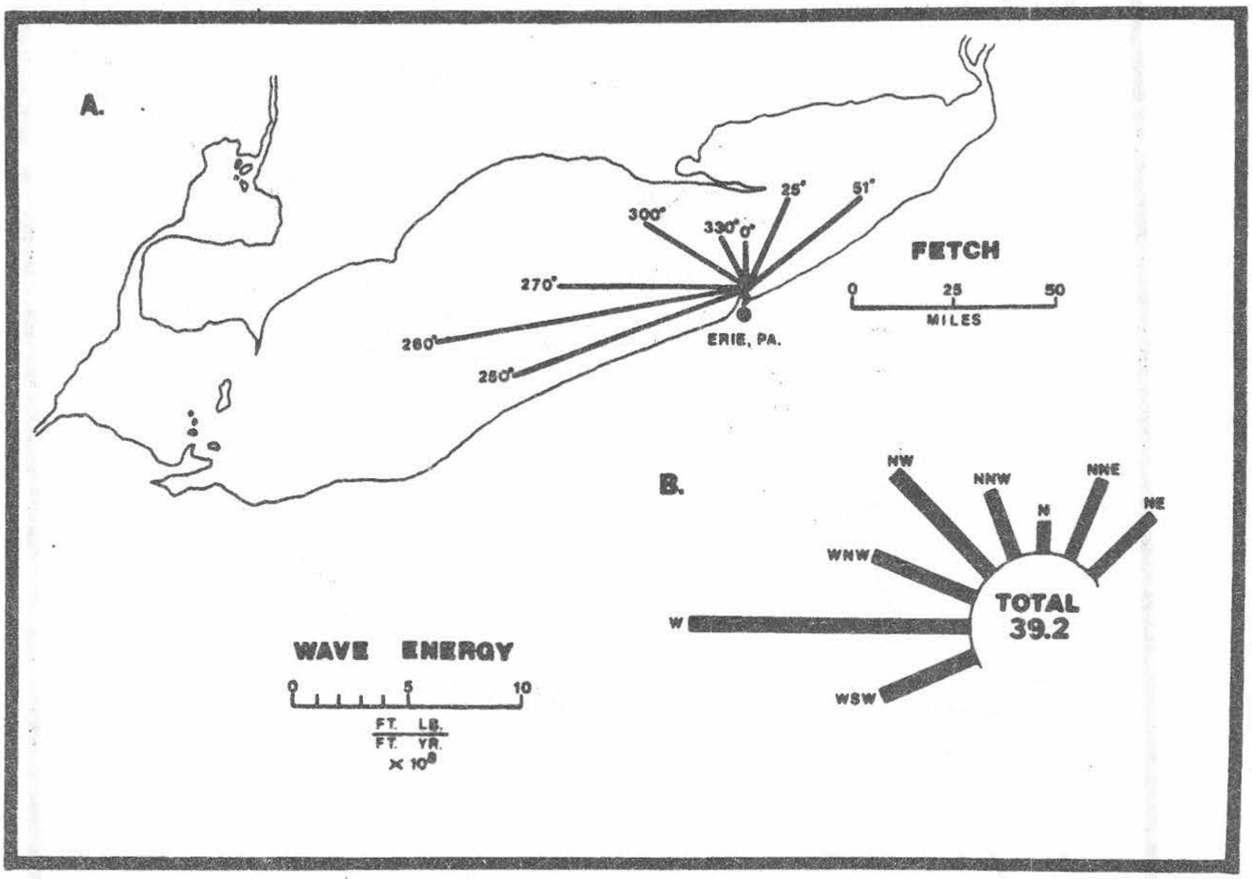


Figure 9. Relationship between fetch and wave energy flux for Erie, PA.

(A) Fetch diagram for Lake Erie with respect to Erie, PA. Bar lengths are proportional to the fetch along the specified azimuths.

(B) Summary of annual wave energy flux for Erie, PA. The principle direction of wave energy flux is from the west. Note the close correlation between the direction of maximum fetch and wave power.

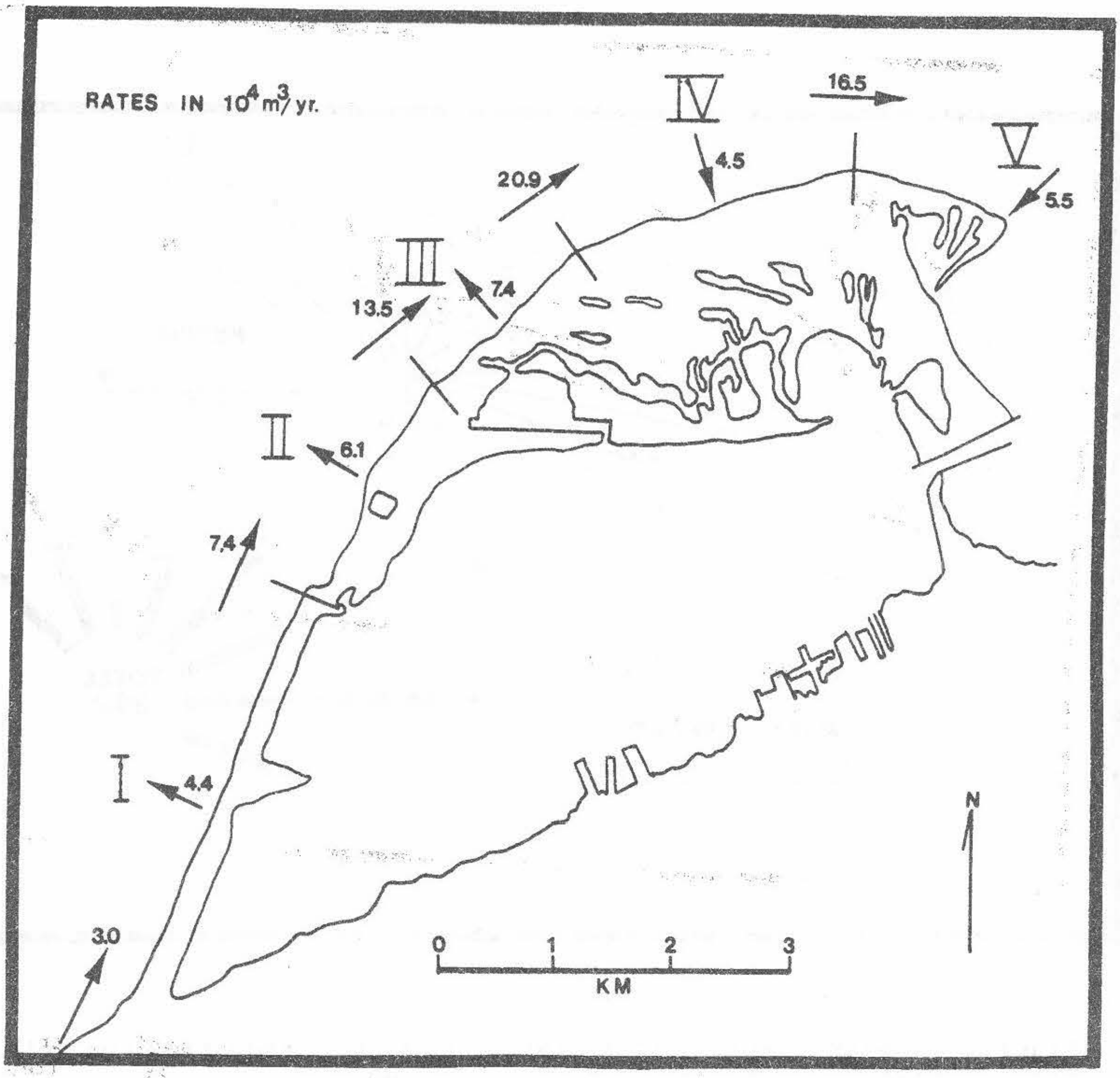


Figure 10. Calculated rates of sediment transport, erosion, and accretion along Presque Isle (Nummedal, 1983). The rates of sediment transport are derived from the longshore distribution of wave power calculated from hindcast wave data, historical accretion rates at Gull Poiont, and Erie Harbor dredging records. The arrows parallel to the shoreline indicate the longshore sediment transport rate for each segment. The arrows perpendicular to the shore line indicate the net loss (arrows directed offshore) or the net gain (arrows directed onshore) of sediment for a given segment. The neck of the Peninsula includes segments I, II and III; the lighthouse beaches correspond to segment IV and Gull Point to segment V.

correspond to his segment IV and Gull Point to segment V. The distribution of wave power along the shore controls the rate of sediment transport and therefore the rate of erosion or accretion along the spit. The differences in the rate of longshore sediment transport are reflected by systematic changes in the characteristics of the beaches and bar systems along the peninsula's shoreline.

The net longshore wave power, and therefore the rate of longshore sediment transport, increases systematically along the Neck of Presque Isle from shoreline segment I to shoreline segment III (Figure 10). The shoreface is eroded as each segment suffers a net loss of sediment. These conditions are reflected in the nearshore zone by: (1) a steep shoreface slope, (2) a single outer bar and trough, and (3) systematic losses of sediment from the beaches (Nummedal, 1983). Dominant storm waves approach segments I through III from the west-southwest and strike normal to the shore producing a strong cell circulation pattern, particularly within the groin field. Sediments are transported offshore by a series of groin-associated rip currents, and alongshore by coastal currents directed to the east. Along these segments 80% of the mean longshore sediment transport occurs within the outer bar-trough system (Nummedal, 1979).

East of the lighthouse (segment III-IV boundary), the orientation of the peninsula's shoreline changes with respect to the dominant wave approach direction. This results in a decrease in the longshore wave power and a decrease in the rate of longshore sediment transport (Figure 10). Consequently, segment IV (Lighthouse Beaches segment) has a positive sediment budget and is accretional through time. Formation of a large nearshore platform within this segment reflects the large influx of sediments from the peninsula's neck to the west (Nummedal, 1983). Associated with the platform is: (1) shallow water depths, (2) a decrease in the shoreface slope, and (3) multiple longshore bars and a transverse bar component (Nummedal, 1983).

Segment V (Gull Point segment) is dominated by net spit progradation (Figure 10). Storm waves from the west-southwest lose their effectiveness as the shoreline curves to the southeast. As a result the longshore energy flux decreases and the segment undergoes a net gain of sediment through time. Sediments carried in the littoral system are deposited along the beach as bar systems migrate landward. The shoreface slope is steep, and a single outer bar may be present close to shore (Nummedal, 1983).

PROGNOSIS

Presque Isle Peninsula is many things to many people but all agree that it is a valuable resource worth protecting. How the 1989-91 Segmented Breakwater Project will function to accomplish that goal is still an open question and the subject of some heated debate. The balancing of priorities among its values as a scientific phenomenon, an aesthetic treasure, a recreational resource, and a protective shield for a Great Lakes port is a formidable task. Those who feel that the sand spit should be allowed to evolve naturally responding freely to the dynamics of wind and wave should remember that the natural geologic feature has been the site of extensive coastal engineering dating back to the 1820's. It is fortunate that we do have the results of some scientific studies referred to herein to serve as a basis for the understanding of the dynamics of the system prior to breakwater construction. Part of the construction cost has been allocated to monitoring studies because no one really knows in detail how the peninsula will respond to this latest engineering project. These and other scientific studies will take place during and after the breakwater installation and we invite everyone to observe carefully today and to keep track of Presque Isle in the years that follow to see what happens.

ROAD LOG

The road log begins at Exit 5: I-79 North-Erie of Interstate 90 in Pennsylvania.

Cumm. Miles	Miles from last point	Description
0.0	0.0	Turn right off I-90 at Exit 5: Interstate 79 North-Erie. Proceed to the end of I-79 (12th Street West).
5.5	5.5	End of I-79. Exit onto 12th Street West - PA Rt. 5 West.
7.1	1.6	Intersection Rt. 832 N, Peninsula Drive leads to Presque Isle State Park. Continue on PA Rt. 5W to Erie Airways at Airport for overflight.
8.3	1.2	Intersection Rt. 299N, Powell Avenue. Continue on PA Rt. 5W.
9.2	0.9	Entrance Erie International Airport on left. Do not turn! Continue on PA Rt. 5W.
9.7	0.5	Turn left (S) on Asbury Road. Turn left again immediately onto Kudlak Drive.
9.75	0.05	Turn left on Kudlak Drive. First building on left is Erie Airways.

OVERFLIGHT DEPARTURE POINT

Cumm. Miles	Miles from last point	Description
9.75	0.0	Turn right (S) from Kudlak Drive onto Asbury Road.
9.80	0.05	Turn right (E) onto PA Rt. 5 East.
11.2	1.4	Cross Rt. 299 Powell Avenue. Continue on Rt. 5E.
12.4	1.2	Turn left (N). Intersection Rt. 832 N, Peninsula Drive. Proceed North to Presque Isle Park.
12.7	0.3	Intersection Alt. Rt. 5 West Lake Road. Continue on Rt. 832 N.
12.8	0.1	Intersection West Sixth Street. Continue on Rt. 832 N.

13.4	0.6	New condominiums on left. Pile of large sandstone blocks is remains of 1948 vintage seawall, which was removed during condo construction.
13.5	0.1	Entrance to Presque Isle State Park. Bike path leaves road on right.
13.6	0.1	View of Presque Isle Bay (Erie Harbor) to right.
14.5	0.9	Extensive swampy land.
15.7	1.2	Park headquarters building on right.
16.0	0.3	Niagara boat launch area on right.
16.2	0.2	Turn right into parking area for Cookhouse Pavilion. LUNCH STOP
16.3	0.1	Leave parking lot. Cross median strip and TURN LEFT onto Peninsula Drive.
16.4	0.1	Waterworks on right.
16.8	0.4	Turn right into entrance to Beach No. 6 parking lot.
16.9	0.1	Stop sign. Experimental electric generating windmill on right. Turn left. Go past bathhouse into west parking lot. Proceed to far end of parking lot.
17.0	0.1	STOP 1. NECK SEGMENT
		Leave Stop 1. Retrace route through parking lot. Turn right at windmill and bathhouse.
17.3	0.3	Stop sign at main park road. Cross median and TURN LEFT. Park office is straight ahead.
17.8	0.5	Cookhouse pavilion entrance on right.
18.0	0.2	Swampy area on right, large number of dead trees due to high lake levels during the last several years.

18.1	0.1	Road to Marina and West Pier on right runs along an old dune ridge. It was the old park perimeter road before the 1956 dredging of nourishment material opened the Marina area.
18.4	0.3	Dunes and beach visible to left.
18.7	0.3	GET IN LEFT LANE, TURN LEFT at stop sign.
18.8	0.1	Stop sign. Turn right onto Pine Tree road. Dunes and beaches visible on left, old dune ridges on right.
19.0	0.2	Entrance to park maintenance area on right.
19.3	0.3	Lighthouse (built in 1871) on left. Sidewalk Trail trailhead on right. This concrete paved trail runs along the base of a dune ridge from the lighthouse to the bay shore near the East Boat Livery. It is shown on the 1900 15-minute topographic map, and was originally used as an access route for the lighthouse keepers, who crossed from Erie by boat. It was paved in 1913. The park road originally ran in front of the lighthouse, but was damaged by erosion in 1946, and relocated to its present position in 1948.
19.7	0.4	Stop sign. Road curves right, go straight ahead into parking lot for Beach No. 9.
19.8	0.1	Park in parking lot.

STOP 2. LIGHTHOUSE BEACHES

19.9	0.1	Leave parking lot, turn left at stop sign.
20.6	0.7	Sunset Point area, beach and lake visible to left.
20.8	0.2	Parking lot entrance on left.

20.9	0.1	West end of Budny Beach parking lot, bathhouse on left.
21.0	0.1	Turn left into east section of Budny Beach (Beach No. 10) parking lot. Proceed to far east end of lot.
21.1	0.1	Park in parking lot.

STOP 3. GULL POINT

		Leave Stop 3. Retrace route out of parking lot.
21.3	0.2	Leave parking lot. Turn left at stop sign onto Thompson Drive.
21.7	0.4	Thompson Circle loop road on right.
21.8	0.1	Road to Coast Guard Station on left.
21.9	0.1	Entrance to Beach No. 11 on left.
22.2	0.3	Misery Bay on left. Admiral Perry's fleet returned here after the battle of Lake Erie to spend the winter. The Perry Monument is visible on the point across the bay. Niagara Pond is on the right.
22.3	0.1	Lawrence Boat Launch on left.
22.7	0.3	South end of Sidewalk Trail on right.
22.8	0.1	Entrance to East Boat Livery (Park franchised boat rental area).
22.9	0.1	Grave Yard Pond on right.
22.1	0.2	Cross Misery Bay Bridge.
23.2	0.1	Parking area for Perry Monument on left.
23.7	0.5	Bike trail crosses road. Stone rip-rap along bay shore on left. View to left across Erie Harbor to city of Erie.
24.1	0.4	Entrance to East Pier area parking on left, Continue straight.

24.4	0.3	Dredged harbor area on left is location of the park Marina. This area supplied much of the initial beach nourishment material in the 1950's. Range lights on left and right are navigational aids for marking the marina entrance.
24.7	0.3	Bridge over inlet to Long Pond.
24.9	0.2	Bike trail crosses road. Road divides, BEAR RIGHT.
25.0	0.1	Stop sign, turn left onto Peninsula Drive. This is an area of frequent winter washovers and dune migration across road.
25.3	0.3	Junction with old shore road on right.
25.6	0.3	Pettinato Beach entrance on right.
25.9	0.3	Waterworks lagoons on right, picnic area on left.
26.4	0.5	Beach No. 6 entrance on right.
27.4	1.0	Modern restrooms on right (Barracks Beach access).
27.8	0.4	Nature Center on right.
28.4	0.6	Beach No. 1 entrance on right.
28.5	0.1	Leave park.
29.4	0.9	Peninsula Drive and 6th Street traffic light. GO STRAIGHT.
29.5	0.1	Peninsula Drive and 8th Street traffic light. GO STRAIGHT.
29.8	0.3	Peninsula Drive and 12th Street (PA Route 5) traffic light. GET IN LEFT LANE and TURN LEFT.
30.4	0.6	Villa Maria College on left. GET INTO RIGHT LANE.
30.6	0.2	Traffic light at shopping center entrance. GO STRAIGHT.

30.65	0.05	Traffic light at Pittsburgh Avenue. GO STRAIGHT.
30.9	0.25	BEAR RIGHT onto entrance ramp for I-79 South.
36.2	5.3	Junction I-79 and I-90 West. STAY on I-79.
36.6	0.4	Junction I-79 South and I-90 East. TURN RIGHT onto I-90 East.

PRESQUE ISLE OVERFLIGHT: ERIE AIRWAYS, ERIE INTERNATIONAL AIRPORT

The overflight of Presque Isle will set the stage for the ground based field stops and will help you visualize Presque Isle as a dynamic coastal system. The half-hour overflight will be just enough time to make one complete circuit around the peninsula and several circles around the Gull Point area. Before the overflight, familiarize yourself with Figure 11, and review the list of suggested observations provided below.

<u>The Neck Segment (Includes location of Stop 1)</u>

(1) Notice the system of sheet pile groins along the neck and their relationship to beach morphology and orientation.
(2) Notice the orientation of incident waves with respect to the shoreline and look for patterns of wave refraction (wave bending).
(3) Look for evidence of nearshore currents as evidenced by turbidity plumes along the beaches and adjacent to the groins.
(4) Look for nearshore bars if the water is clear or look for linear patterns of surf that may be the result of waves breaking over the crests of nearshore bars.
(5) Notice the characteristics of the backshore area including the discontinuous vegetated dune ridge along the neck.
(6) Notice the newly constructed breakwaters offshore along the neck.

<u>The Lighthouse Beaches (Includes location of Stop 2)</u>

(1) Notice how the orientation of the shoreline changes to the east of the lighthouse.
(2) Look for changes in nearshore processes (wave angle with respect to the shoreline, nearshore currents, etc.).
(3) Look for changes in the morphology of the beaches and notice the presence of megacusps and other rhythmic features.
(4) Notice the beach ridges, ponds and climax forest in the interior of the spit.
(5) Observe the effects of different types of engineering structures on the morphology of the beaches along this segment (e.g. buildup of sediment on the updrift side of structures and erosional bays immediately downdrift).

<u>Gull Point (Includes location of Stop 3</u>

(1) Notice how the shoreline orientation continues to rotate to the southeast.
(2) Look for the orientation of incident waves and note wave refraction patterns.
(3) Look for megacusps and evidence of nearshore bars welding to the beaches.
(4) Notice the newly formed spits at the end of Gull Point.
(5) Try to pick out the location and orientation of relic shorelines and spit complexes.

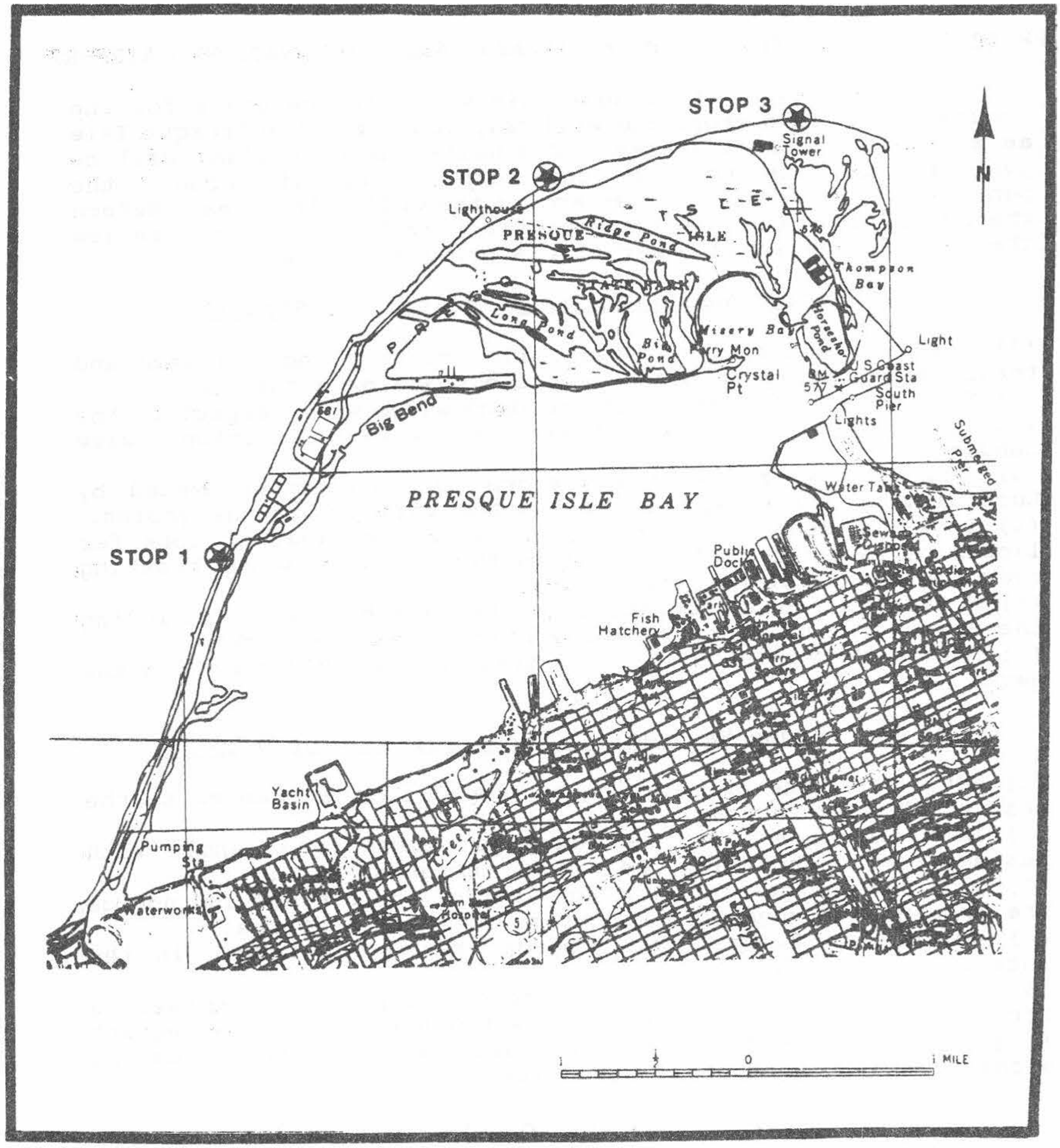


Figure 11. Stop locations for the field trip. Stop 1 is located just west of Beach 6, Stop 2 is located at Beach 9 and Stop 3 is located east of Beach 10 on Gull Point.

(6) Observe the orientation and spacing of the dune ridges and look for changes in their stage of development, particularly the succession of vegetation types associated with the ridges

STOP DESCRIPTIONS

STOP 1. BEACH 6: NECK SEGMENT

This stop is located to the west of Beach 6 between Groins 10 and 11 on the Neck segment of Presque Isle (Figure 11). Beach 6 is at the downdrift end of the groin field constructed to stabilize the Neck as part of the cooperative shore protection program beginning in 1954. This area is one of the erosional hot-spots along the peninsula's neck. Each year approximately 75,000 cubic yards of sand are dumped at this site as part of Presque Isle's annual beach nourishment program. This sand usually disappears by December after the intense storms in the fall.

Storm waves commonly arrive nearly perpendicular to this section of the Presque Isle shore. A large portion of the wave energy is transformed into storm water-level set-up against the beach. This results in a stratified current pattern with net lakeward underflow along the bottom. During severe storms with strong winds from the southwest, high waves superimposed on elevated lake levels commonly wash over the roadways and sometimes entirely across the spit into the bay.

Within the groin field the nearshore slope is steep. Bar forms include an outer bar and an inner bar separated by a bar trough. The inner bar is linear or crescentic in form. The outer bar is crescentic with lows or saddles separating the 400-1000 m segments. The beaches within the groin field are narrow and generally erosional. Downdrift offsets of the beaches adjacent to the groins demonstrates the net west to east transport of sediment called littoral drift. Other engineering structures such as rip-rap revetments significantly influence the character of the beaches.

Results of a comprehensive nearshore current study and native-sand tracer study completed prior to breakwater construction on the inner bar system (Sonnenfeld, 1981) and the outer bar-trough system (Taylor, 1981) indicate the following nearshore dynamics for storm events (wave heights greater than 60 cm):

(1) Sediment from the beach and the inner bar is transported lakeward towards the outer bar trough by rip currents located on the updrift sides of the groins, rip currents associated with cell circulation systems located between the groins and the net lakeward flow near the bed.

(2) Sediment from the lakeward flank of the outer bar and the bar crest is transported toward the trough inside the outer

bar (outer-bar trough) in response to currents generated by incident waves shoaling and breaking on the outer bar.

(3) Sediment within the outer bar trough is transported by an eastward directed shore parallel current within the trough producing an effective mechanism for sediment bypassing the beaches downdrift of the source areas.

(4) Scouring within the outer bar trough is common during these conditions and results in an increase in the relief of the outer bar.

For wave heights less than 60 cm, the net sediment transport is onshore and alongshore. Sediments move from the outer bar crest into the bar trough resulting in a decrease in bar relief. The inner bar moves onshore and may weld to the beach forming a cuspate berm.

At this time it is unclear what effect(s) the new breakwaters will have on the morphodynamics of the peninsulas neck. Some questions that need to be addressed include:

(1) What effect will the breakwaters have on sediment exchange between the beaches and the nearshore zone?

(2) What kinds of currents will be generated by the interaction of incident waves and the breakwaters?

(3) How much nourishment, if any, will be required to maintain the beaches?

(4) What will be the fate of the outer bar if offshore sediment transport is decreased?

THINGS TO LOOK FOR

* Notice wave height and approach direction with respect to the shoreline orientation.

* Notice longshore current direction and speed and look for evidence of rip currents (e.g. wave suppression in certain areas due to current outflow and suspended sediment plumes)

* Observe the texture of sediments including the beach replenishment materials.

* Observe the effects of engineering structures on beach morphology and wave reflection and refraction patterns.

* Notice the washovers in the backshore areas.

* Notice the newly constructed detached breakwaters. Can you see any difference in the beach behind the structures?

* Zebra mussels

STOP 2. BEACH 9: LIGHTHOUSE BEACHES

This stop is located to the east of the lighthouse at Beach 9. The dramatically different morphology and dynamics along this section of the peninsula are a consequence of the change in shoreline orientation with respect to the dominant southwest wave approach direction and the influx of sediment eroded from the peninsula's neck.

The Lighthouse Beaches (Figure 11) are much wider with established multiple vegetated dune ridges on the backshore. Relic coastal dune ridges, separated by swales and ponds dominate the climax forest behind the beaches. The most striking feature of the beaches is the system of large-scale shoreline megacusps spaced at 400-800 m. These rhythmically spaced features are substantial packets of sand which typically migrate eastward maintaining their identifiable form over periods ranging from months to years. Sediment which is transported along the beach itself occurs within these features. It may be that as little as 20 percent of sediment transported along the Lighthouse Beaches occurs as beach transport; the bulk of sediment transport takes place offshore. As megacusps move eastward so do the rip-channel embayments between them. Beach erosion is tied to these rip-channel embayments and consequently it is these pockets of erosion that have been targets of beach nourishment. It has been established that little net erosion or deposition of the lighthouse shoreline occurs through time (Nummedal, 1979).

The nearshore zone morphology of the Lighthouse Beaches is the most complex of the three segments. It includes up to four longshore bars parallel to the beach which are superimposed on transverse bar components and an arcuate bar system (Figure 7). The significantly gentler slope of this multibarred nearshore zone is a direct consequence of the high rate of sediment supply to this area. The large sediment load for the nearshore zone is largely derived from sources updrift (west of the lighthouse along the erosional neck) rather than the local beaches.

Sediment exchange between the beach and offshore bars is limited to the arcuate bar system and megacusps. Sediment moves eastward along the arcuate bar system with some sediment re-entering the beach where the bars attach to the horns of the megacusps. The rest of the sediment continues along the bar system. Sediment is transferred back to the bar system from the beach by rip currents flowing within bar-rip channels emerging from the embayments between megacusps. The entire megacusp system is strongly skewed to the east because of eastward directed incident waves.

Many questions about the spatial and temporal nature of the shore parallel and transverse bar components remain to be answered. For example, the rates, patterns and mechanisms for sediment dispersal in the deeper portion of the nearshore zone are not understood. It is difficult to assess how the detached breakwaters will effect the dynamics of this area.

THINGS TO LOOK FOR

* Notice the wave height, wave approach direction and shoreline orientation.

* Notice the longshore current direction and speed.

* Observe the texture of sediments at different locations on the beach and backshore.

* The characteristics and spacing of megacusps and inner bars that may be recognized by observing waves breaking over their crests.

* Notice the distribution of pockets of erosion and deposition along the beach and their relationship to beach morphology.

* Notice the vegetated dune ridges and incipient dunes formed by the interaction of vegetation and aeolian activity in the backshore.

* Notice beach ridges and climax forest across the road.

STOP 3. BEACH 10 AND EAST: GULL POINT

This stop on the Gull Point segment of Presque Isle (Figure 11) features the beaches east of the prototype breakwaters built at beach 10 in 1978. Depending on the time available we will walk eastward onto Gull Point to see the extensive sand plain and series of accretionary dune ridges.

By this stage in your observations, it must be clear to you that Presque Isle is an eastward migrating spit system that feeds upon itself as it migrates. Within this system, sediment is eroded from the neck, transported across the broad shallow multibarred nearshore zone of the Lighthouse Beaches and is finally deposited adding to Gull Point, the only net depositional feature along the peninsula. The rapid growth of Gull Point is evidenced by the formation of a series of beach ridges superimposed on recurved spits which wrap around the end of the spit enclosing ponds.

The rapid accretion of Gull Point began in the 1930's possibly in response to the sudden increase in available sand supply from the breached neck in 1917-23, and is continuing today in response to the annual nourishment program. According to the U.S. Army Corps of Engineers (1979) the present volumetric migration rate of 289,100 cubic yards per year reflects the replenishment input which has averaged 259,000 cubic yards per year since 1955. The peninsula's continued eastward migration operates at an annual sediment budget deficit. The present deficit results partly from the spit having migrated to the eastern edge of its underlying platform in response to a long-term rise in lake level (post glacial rise of 1 ft. per 300 yr.). Each future increment of eastern migration of Gull Point requires much larger volumes of sand because the platform itself must prograde into deep water before the spit can be superimposed. Also, the present sediment volume being supplied to the Neck from streams and bluff recession updrift has been estimated at only 30,000 cubic yards per year (Nummedal, 1984).

The Gull Point beaches receive the lowest annual wave power along the entire outer shore of the peninsula. The orientation of the shoreline is such that only storms with incident waves from the northeast can generate sufficient energy for offshore transport and shoreface broadening. Such storms are infrequent and moderate in strength. This wave climate is such that sediment is kept close to shore maintaining a steep prograding profile.

Because the nearshore slope is steep and the surf zone is narrow only one, or at most two, longshore bars are present close to shore. Because the strongly eastward directed incident waves, rip channels and transverse bar components are strongly skewed to become nearly shore-parallel. This offshore profile is maintained by the prevailing onshore transport of sediments.

The beaches are dominated by megacusps with a spacing of 700-800 m. These megacusps are closely associated with inner bars that commonly weld onto the beaches. The welding bars are much like ridge and runnel systems (swash bar complexes) of ocean beaches in form and behavior. Of course we have no tidal effects here so the dynamics are necessarily different. Migration of megacusps produce rapid changes in beach orientation and beach slope along the Gull Point beaches.

THINGS TO LOOK FOR

* Notice the wave height, wave approach direction, shoreline orientation and longshore current direction and speed.

* Observe the changes in sediment texture with respect to changes in beach morphology and distance from the shoreface. Notice also the heavy mineral concentrations.

* Observe the areas of erosion and deposition along the beach including any evidence of bars in the process of welding to the beach.

* Notice the washovers in areas where the primary dune ridge has been eroded away.

*** Notice the different stages of dune ridge formation including the succession of vegetation types that accompanies dune ridge growth**

REFERENCES CITED

Berg, D. W., 1965, Factors affecting beach nourishment requirements at Presque Isle Peninsula, Erie, Pennsylvania: Proceedings of the Eighth Conference on Great Lakes Research, Publication No. 13, Great Lakes Research Division, University of Michigan, p. 214-221.

Berg, D. W., and Duane, D. B., 1968, Effect of particle size and distribution on stability of artificially filled beach, Presque Isle Peninsula, Pennsylvania: Proceedings of the Eleventh Conference on Great Lakes Research, International Association for Great Lakes Research, p. 161-178.

Dreimanis, A., 1979, Late-Pleistocene Lakes in the Ontario and Erie Basins. 12th Conf. Great Lakes Res. Proc., p. 170-180.

Jennings, O. E., 1930, Perigrinating Presque Isle: Carnegie Magazine, v. 4, p. 171-175.

Lewis, C. F. M. et al., 1966, Geological and Palynological studies of Early Lake Erie deposits. 9th Conf. Great Lakes Res. Proc., p. 176-191.

Lewis, C. F. M., 1969, Late Quaternary events in Lake Huron and Lake Erie basins. 12th Conf. Great Lakes Res. Proc., p. 250-270.

Messinger, D. J., 1977, Form and change of a recurved sandspit, Presque Isle, PA: unpublished M. S. thesis, State University of New York College at Fredonia, 121 p.

Nummendal, D., Monitoring of shoreline changes, Presque Isle, PA, Annual Report for Contract no. DACW49-78-C-0020, U. S. Army Engineers District, Buffalo, 50 pp., 1978.

Nummedal, D., Monitoring of shoreline changes, Presque Isle, PA, Annual Report for Contract no. DACW49-79-C-0020, U. S. Army Engineers District, Buffalo, 52 pp., 1979.

Nummedal, D., Monitoring of shoreline changes, Presque Isle, PA, Annual Report for Contract no. DACW49-78-C-0055, U. S. Army Engineers District, Buffalo, 72 pp., 1980.

Nummedal, D., 1983, Sediment transport and morphodynamics of the Presque Isle shoreface: Louisiana State University, Department of Geology, Coastal Research Group, Technical Report 83-1, 33 p.

Nummendal, D. et al., 1974, Littoral processes and sedimentation in the Cattaraugus Embayment, NY: Final Report. Contract No. DACW49-74-C-0118, 246 p. (ref. Clemens, 1976).

Nummedal, D., and Sonnenfeld, D., 1983, A tracer study of sediment movement in the bar system at Presque Isle, Pennsylvania: Report to the U. S. Army Corps of Engineers, Buffalo, for contract DACW49-81-C-0019, 80 p.

Nummedal, D., Sonnenfeld, D. L., and Taylor, K., 1984, Sediment transport and morphology at the surf zone of Presque Isle, Lake Erie, Pennsylvania, in Greenwood, B., and Davis, R. A., Jr., eds., Hydrodynamics and sedimentation in wave-dominated coastal environments: Marine Geology, v. 60, p. 99-122.

Pope, J., and Gorecki, R. J., 1982, Geologic and engineering history of Presque Isle Peninsula, PA, in Buehler, E. J., and Calkin, P. E., eds., Geology of the Northern Appalachian Basin, Western New York: Guidebook, New York State Geological Association 54th Annual Meeting, Amherst, New York, p. 183-216.

Saville, T., 1953, Wave and lake level statistics for Lake Erie: Beach Erosion Board, Technical Memo No. 37, 24 p.

Sonnenfeld, D. L., 1983. Inner bar sediment dynamics, Presque Isle, PA. Unpublished M. Sc. thesis, Louisiana State University, Baton Rouge, LA.

Thomas, D. J., et al., 1987, Pleistocene and holocene geology on a dynamic coast: 52nd Annual Field Conference of Pennsylvania Geologists. Department of Environmental Resources, Bureau of Topographic and Geologic Survey, Harrisburg, PA, 88 p.

U. S. Army Corps of Engineers, 1953, Presque Isle Peninsula, Erie, Pennsylvania: Beach Erosion Control Study. House Document No. 231, 83rd Congress.

U. S. Army Corps of Engineers, Buffalo District, 1980. Presque Isle Peninsula, Erie, Pennsylvania: Final Phase 1 General Design Memorandum, Buffalo, NY.

Walton, J. C., 1978, Sediment characteristics and processes of beaches and bars, Presque Isle, Erie, Pennsylvania (6/22/74-8/10/74): unpublished M. S. thesis, State University of New York College at Fredonia, 157 p.

Williams, S. J., and Meisburger, E. P., 1982, Geological character and mineral resources of south central Lake Erie: U. S. Army Corps of Engineers, CERC Miscellaneous Report 82-9, 62 p.