ENCOUNTERS OF NATURAL, FISCAL AND LEGAL KINDS ON THE COAST OF THE GREAT LAKE ERIE: DEALING WITH HARBOR CONTROVERSY AT NORTH EAST AND HARBORCREEK – SHADES BEACH, PA AND REVISITING THE COST – EFFECTIVENESS OF THE $23 MILLION DOLLAR PRESQUE ISLE EROSION CONTROL PROJECT AT ERIE, PA

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INTRODUCTION

Coastal erosion and deposition effects caused by human generated structures is a key theme of this trip. Although we might assume that the impact of coastal processes on the general public of the United States is restricted to oceanic shorelines we will see that construction on Great Lakes shorelines is fraught with the same difficulties as those faced on the Atlantic and Pacific Oceans. Thus inland colleges with access to Great Lakes shorelines have established Coastal Geology programs that offer hands-on training to their students and advice to local, State, and Federal Government agencies responsible for coastal zone management.

Both erosion and deposition patterns altered by hard structures built on the coast are problematic to those of us who live, work and play there. Proceeding from east to west along the shoreline we will first visit the harbor at North East, PA that is in the latter stages of litigation against those responsible for its construction and management. Our next stop will be at the site of the proposed harbor and detached breakwater at Shades Beach in Harborcreek PA where a federal and state Coastal Zone Management study is underway to avoid such legal complications. And, finally we will revisit the 55 offshore breakwaters of the Presque Isle Erosion Control Project at the peninsula enclosing the harbor at Erie, PA. US Army Corps of Engineers efforts to stabilize the sand spit and thereby to protect the harbor by construction of on-shore hard structures such as groins stretches back to 1828. In spite of these efforts, an average of well over $1 million worth of sand has had to be added to the beaches each year since 1956 (annual nourishment). Completed in 1992, the cost-effectiveness of the latest $23.8 million US Army Corps of Engineers' project will be judged, at least in part, on achieving a major reduction in this annual sand nourishment expenditure. Less sand from off–site has been required subsequent to construction partially due to the newly developed possibility of recycling sand deposited behind some of the breakwaters. However, to date a goal of a 75% reduction in replenishment costs has been elusive. With Lake Erie at its lowest level in decades this year, a new problem has emerged. "Excessive" deposits at the end of the spit threatened to close off a very popular beach (Beach 11) from the open lake rendering it useless due to stagnation, excessive weed growth, and potential pollution. Dredging of 10's of thousands of cubic yards of sand has been required to preserve the recreational resource. The good news is that the sand is being used as a lower cost source of nourishment updrift (to the west) on the peninsula.

The first of our three stops on Presque Isle will give us the opportunity to see how variable the effect of the offshore breakwaters has been on beach erosion and deposition. Near the lighthouse erosion has continued to be severe despite the presence of breakwaters offshore. Immediately downdrift (to the east), "excessive" deposition results in the annual connection of the beach to a breakwater forming a tombolo. The proximity of the two areas will highlight an unexpected benefit of the project; harvesting of the unwanted sand deposits from the tombolo serves as a low cost source of sand which is recycled as nourishment for the nearby area of erosion. We will ascend the lighthouse in small groups to obtain an aerial view of the situation. Our second stop will be at Beach 10 and Gull Point where the nourishment sand from the Beach 11 spit dredging and recycling operation is being placed. The easternmost of the 55 offshore breakwater sequence and three additional earlier constructed prototype breakwaters will also be visible. Not surprisingly, it is the area immediately downdrift from the last of these erosion control structures that was designated as most in need for receiving the dredged sand. The fate of the nourishment sand over the next several months will be monitored by students as part of a undergraduate coastal studies GIS project. The data and project report will be provided to Presque Isle State Park management and to the US Army Corps of Engineers. The final stop of the trip will be at the Beach 11 site of the sand spit which was dredged. The dredging and nourishment project is due for completion in mid-September 1999 so all activity should be over by the time of our visit.

DESCRIPTION AND COMMENTARY ON INDIVIDUAL STOPS

STOP 1. NORTH EAST MARINA , NORTH EAST, PENNSYLVANIA

North East Marina (formerly Safe Harbor Marina) was constructed on the southeast shore of Lake Erie at North East, Pennsylvania in 1989-1990 to provide access to the recreational use of the lake and shelter for boaters. In fact, for boaters caught in a storm, it is the only shelter between Barcelona, New York and Erie, Pennsylvania. Prior to construction, Buyce and Kent Taylor applied for a grant from Coastal Zone Management of NOAA to provide a base line study of the littoral drift system for use in formulating requirements for construction and management of the facility. The study was not funded.

A private corporation, under lease from the Pennsylvania Fish and Boat Commission, obtained the necessary permits from the US Army Corps of Engineers and the Pennsylvania Department of Environmental Resources and constructed the marina. The regulating agencies clearly anticipated that harbor construction would interrupt the normal littoral drift pattern because ongoing nourishment was required by the permits to prevent starvation of the downdrift beaches. The facility managers made only token attempts at nourishment and, because the preconstruction littoral drift volume was unknown due to the lack of a baseline study, it was difficult to specify what would be an adequate annual volume of nourishment. Meanwhile homeowners downdrift (on the east side) instituted lawsuits against everyone involved with the marina as they saw sand accumulating on the west side of the harbor and felt that their beaches were narrowing and bluff erosion potential was being exacerbated in front of their homes.

Caving in to the dual pressures of agencies threatening to revoke permits and to lawsuits the corporation went bankrupt in 1993 and the facility and its problems reverted to the Pennsylvania Fish and Boat Commission who immediately instituted a substantial nourishment program for downdrift beaches. Realizing that, in a litigious environment, an adequate amount of annual nourishment would be difficult to establish to the satisfaction of all concerned, the Fish and Boat Commission wanted objective scientific data. They finally funded a study of the littoral drift system (Taylor and Buyce, 1994 and Buyce and Taylor, 1998).

A major objective of the study was to determine exactly how much and what size sediment would have reached the downdrift beaches each year if the harbor were not constructed. After establishing that no significant volume of sediment was being lost offshore or continuing to reach the downdrift beaches (bypassing the marina) the task was to measure the annual volume of sediment accumulating updrift from the west wall of the harbor and determine its textural characteristics. As beach width is assumed to be inversely related to potential for bluff erosion potential, there was also a need to determine if construction of the marina had, in fact, resulted in the narrowing of downdrift beaches. The examination of historic photographs from 1986 was used to compare to modern beach widths.

The extensive nature of the study is evident below in extracts from Buyce and Taylor, 1998. Selected Results and Discussion are also included:

METHODOLOGY

A variety of data collection techniques were employed to help provide rational coastal management guidance. Repeated detailed topographic mapping of the study area was conducted to provide estimates of annual littoral drift volume, the prerequisite for devising a suitable nourishment protocol. Delineation of littoral-drift-related features on the maps also permitted a better understanding of the processes acting along this stretch of coastline. Repeated precision mapping of the shoreline was also conducted to determine post-construction changes in beach widths of the updrift and downdrift beaches for use in comparison with historic (pre-construction) aerial photographs. Beach width is considered to be inversely related to bluff-erosion potential. Aerial observations were made to identify sediment accumulation features and subaqueous bedrock exposures that may control sediment transport (especially bypassing), recording fathometer surveys were conducted to profile the subaqueous bedrock exposures, and dives were performed to confirm the significance of mapped and remotely observed features for textural analysis. Textural analysis of sediments in the beach and nearshore were employed: (1) to determine whether sediment size can provide clues concerning transport dynamics and bypass potential and (2) to match nourishment material to the natural sediment. Finally, littoral environmental observation (LEO) data were collected to link sediment dynamic parameters such as waves and currents. These methods are described in detail below.

Precision Topographic Mapping and Volume Change Calculation

Maps of the exposed beaches and the nearshore bathymetry adjacent to the harbor were genrated using standard rod-surveying techniques (Figure 1, this guidebook). Topographic contour maps and profiles were generated from Leitz Set-2BII total station survey data using proprietary Sokkia map, Contour, and Profile software packages. The computerized method used for the volumetric analyses involved the following steps: (1) generation of computer-drafted topographic maps using survey data collected from the designated mapping area, (2) projection of each data point to the second topographic surface and creation of an isopach map showing differences in accretion or erosion, and (3)determination of the net vulumetric change for the designated area.

Profiles were mapped in transects extending from the back of the beach, parallel to the roughly north-trending harbor walls, out onto the nearshore zone to a maximum depth of 2.5 m (8.2 ft). Along shore a total of 16 profile transects were mapped at 20m (65.6 ft) intervals; 11 transects were mapped updrift, extending 230m (754.6 ft) west of the western wall of the harbor; and 5 were mapped downdrift, extending 90 m (295.3 ft) east of the eastern wall of the harbor. Transects were also established at 30 m (98.4 ft) intervals along the entire northern perimeter of the harbor.

Two volumetric assessments were completed for the beach and nearshore zone west of the harbor. These analyses were completed in order to determine the annual rate of sediment accumulation on the updrift side of the harbor. Assuming that no natural bypassing is occurring, this entire volume is being withheld from the downdrift beaches and thereby indicates a realistic estimate of beach nourishment requirements. Data suggesting the lack of significant sediment bypassing are presented ...

Beach Width and Potential for Bluff Erosion

The study was also concerned with narrowing of beach width, as such narrowing is considered to coincide with increased potential bluff erosion. Recent beach width and variability was investigated during the study via precise mapping of a 1.8 km (1.1 mi) stretch of coastline extending from a headland ca. 650m (2132.7 ft) west of the harbor to the mouth of Twenty Mile Creek, located 900m (2952.9 ft) east of the harbor. This phase of work was conducted on three separate occasions: 16 October 1993, 16 December in 1993, and 10 June 1994. The resultant maps also provide an accurate modern basis for comparison with pre-construction beach widths. Analysis of historic aerial photographs dated 10 july 1986, provided by the US Army Corps of Engineers permitted the mapping of beach widths for the same stretch of coastline prior to construction of the harbor for comparison with the 16 October 1993 shoreline map. Beach widths were measured at 20m (65.6 ft) intervals up and down the coast and compared between the two maps to determine whether and where net accretion or net erosion had occurred since 1986.

Erosion control structures visible on the photographs were noted and the areas where they occurred were determined to be subject to high potential bluff erosion even before the harbor was constructed. Lake level data for the two map dates, obtained from National Oceanic and Atmospheric Administration (NOAA) and modified with the proper datum corrections, had to be considered in the interpretation of these data. ...

RESULTS

Littoral Drift Volumes

For each volumetric analysis, monthly and yearly accretion rates were calculated using data obtained from the computer-generated total volumetric estimate. The accretion rate for the 16 October 1993 to 10 June 1994 mapping interval was 678 m^3/month (886.8 yd^3/month) or 8136 m^3/year (10,641.9 yd^3/year). The accretion rate for the 4 December 1991 to 10 June 1994 mapping interval was 613 m^3/month (801.8 yd^3/month) or 7361 m^3/year (9628.2 yd^3/year).

Changes in Beach Width

Recent

Mapped widths of the exposed updrift beaches did not change appreciably over the time elapsed in this study. To the east of the harbor, only the October 1993 map represents the system prior to the start of the nourishment which overlapped this study. The nourishment seems to have measurably increased the width of the beaches in the area.

Preconstruction Conditions

Observations drawn from 1986 aerial photographs show relatively consistent narrow beach widths both updrift and downdrift of the harbor site prior to its construction. The lake level at Erie, Pennsylvania, was 175.03m (574.27 ft) on 10 July 1986.

Post-Construction Conditions

Close comparison of beach widths on the July 1986 and October 1993 maps documents an obvious substantial increase in the width of the updrift (west) beaches, building to a maximum width eastward toward the west breakwall of harbor. Also confirmed is the impression that the 1986 and 1993 east or downdrift beaches are very similar except for the slight recent accretion close to the east harbor breakwall. Nowhere did the measurements show a reduction in beach width. Lake level at Erie, Pennsylvania, was 174.29 m (571.85 ft) on 16 October 1993, 0.73 m (2.43 ft) lower than on 16 July 1986.

Portions of coastal areas subject to bluff erosion prior to harbor construction were also identified by the presence of erosion control structures observable in the 1986 photographs. Bluff-erosion control structures were present along the entire stretch of coastline in 1986, both in the updrift and downdrift areas. Bluff-erosion protection structures are still observable vestigially behind the present wide beaches to the west attesting to previous vulnerability there.

DISCUSSION

Littoral Drift Volumes

...Based on detailed topographic mapping and computer-generated volumetric calculations, the annual volume of sediment trapped on the updrift side of the harbor breakwaters is 6504-8136 m^3/year (8507.2-10,641.9 yd^3/year). The estimated accretion rate for the 4 December 1991 to 10 June 1994 analysis is 7361 m^3/year (9628.2 yd^3/year).

In all probability, the volumetric estimate of littoral drift presented above are the best that have yet been determined for the Lake Erie shoreline in Pennsylvania because they have been generated using an extremely accurate calculation of actual sediment accumulation in a controlled setting. ...

Changes in Beach Width

If the data obtained from single days in July 1986 and October 1993 truly represent those years and the intervening seven years, the eastern beaches have not changed appreciably in width since the harbor was constructed. It is reasonable to conclude that the bluffs behind those beaches are no more subject to erosion than they were prior to harbor construction. Moreover, the presence in 1986 of bluff-erosion control structures along the entire stretch of coastline, indicates that both segments of the shoreline were at risk prior to harbor construction.

Even prior to the completion of the study the nourishment program instituted by the Pennsylvania Fish and Game Commission exceeded the annual littoral drift estimates determined. Records for each year following similarly exceed the recommended volumes that the downdrift beaches would have received if the harbor had not been constructed. Because the sediment which accumulated on the updrift side of the harbor was used for the replenishment the texture of the material provided downdrift was also the same as the sediment that would have arrived naturally.

The homeowners immediately downdrift apparently were favorably impressed with the efforts of the new managers of the harbor and dropped out of the lawsuit. Improbably the homeowners over 350 m (over1200 ft) downdrift continued to press the lawsuit. The erosion situation along the entire shore line of Lake Erie was severe in the Spring of 1997 due to extremely high lake levels, early spring loss of protective ice dunes, and the incidence of violent and long duration storms striking after the ice dune protection was lost. Lake levels in April, 1997 were within 5 inches of the 1985 all time high (573.62 ft, 174.84 m). At the request of the defense attorneys I mapped the same beaches at Presque Isle which I had mapped in 1995 and provided documentation of severe erosion there which could not have been due to Safe Harbor Marina which was 26 km (16 mi) downdrift (east) along the coast. A portion of the letter report (Buyce, 1997) provided to the attorneys and the court is presented below.

This letter report concerns shore erosion at Presque Isle during the fall of 1996 and the Spring of 1997 as a basis for comparison with the situation adjacent to the marina at North East, PA. I wrote the report " Presque Isle Sediment Transport Study" which documented the 1995 study by Kent Taylor and I in fulfillment of a grant from the PA Department of Natural Resources and the U.S. Coastal Zone Management Agency of the National Oceanic and Atmospheric Administration (NOAA). My studies of the situation at Presque Isle have been ongoing since 1995 as evidenced by the report on tombolo growth onto an offshore breakwater as a symptom of the variable effect along shore of the breakwaters for erosion control on Presque Isle by Wilson, Van Tassel, Buyce, et al. delivered at the NE regional meeting of the Geological Society of America in March 1997. Maps of shorelines attached to this letter were surveyed in May of 1997 and compared to the 1995 shorelines of the same areas (Figures 2 and 3 this guidebook).

The map of the Beach 6 area of Presque Isle shows that the shoreline in May of this year is essentially at the retaining wall for almost the entire west end of the study area, the beach having been almost completely eroded away there (Figure 2). The May 1997 shoreline of the eastern portion of the area is also behind the shorelines of 1995 despite at least 3.6 meters (12 feet) of growth of the beach out from the maximum extent of the erosion during earlier storms (marked by a prominent escarpment behind the present shoreline). The Beach 10 area shows drastic erosion along the eastern end of the study area.. The beach used to extend lakeward to the three easternmost prototype breakwalls but is now eroded back over 75 meters (246 ft.) shoreward from the easternmost breakwall leaving a precipitous escarpment cutting the dune behind the beach. Three control stakes used as survey markers for this part of the beach in the 1995 study were lost to wave erosion of the beach and dune behind it and had to be replaced to make the most recent map (Figure 3).The maps provide documented proof that beach erosion has been unusually severe along this portion of the shore of Lake Erie in the spring of 1997. Unlike the situation near the harbor at Northeast where littoral drift is being interrupted the breakwalls at Presque Isle were put in place to widen and protect the beaches. Recent newspaper reports indicate that Park officials found the project was so effective during the past few years that the annual nourishment was able to be reduced by 75 percent (Erie Daily Times, April 26, 1997... The same article reports that unusually severe erosion this spring have changed the situation so drastically that this year's replenishment is projected to be back to the one million dollar level. Factors other than the interruption of littoral drift must be responsible.

The factors responsible for the exacerbation of erosion along the shores of Lake Erie during the Spring of 1997 include :
a) Lake levels are higher than normal,
b) Beaches were left unprotected by ice dunes much earlier in the spring than normal, and
c) Storms of considerable strength and duration struck the beaches after ice dune protection was lost earlier in the spring than normally occurs.

Figure 4 is an Archived Nowcast Image of Lake Erie water level elevations for the 5 days prior to November 3 including the November 1 storm and shows the water being blown to the east end of the Lake (Buffalo) and away from Toledo on the west end. At Erie PA the so called storm "setup" is less than the 1 meter (3.3 feet) shown for Buffalo but can still be significant. Taken in conjunction with higher than normal lake levels a set up of nearly 0.6 meter (2 feet) rise in the lake level at Erie associated with storm winds blowing the water to the east end of the lake magnifies erosive effects. The set up during spring storms on top of the high lake levels enabled the energy of the storm waves to reach further back on the beaches than in recent years and even to be brought to bear on the bluffs and/or dunes behind the beaches with obvious exacerbation of the erosional effects.

This past fall, a major storm ravaged the shoreline on October 30 to November 1 prior to ice dune formation. Lake levels were down near the end of the seasonal decline of water levels and the breakwaters lessened the potential devastating effects. In the spring, however, the ice dunes melted away earlier than usual and were not there when major storms hit in March and April. The Corps reports that the level of Lake Erie has risen steadily from the November 1996 seasonal low and is projected to peak in June 1997. Lake levels for April 1997 reported by the U.S. Corps of Engineers, "Great Lakes Update" was 573.62 feet (174.84 m) which is only 5.5 inches below the 1985 all time high. Beaches and even dunes behind the beaches were more severely eroded than at any time since the installation of the breakwaters. Another storm on May 2 resulted in overwashing the beaches again and redistributed much of the early nourishment sand emplaced in the most severely eroded portions of the beaches at Beach 6, Stone Jetty Beach and beyond the tombolo at Breakwater # 49 east of Lighthouse Beach.

Thus factors such as
a) Unusually high water levels of the Lake,
b) Early melting away of the normally protective ice dunes and
c) Especially strong and long duration spring storms
have caused particularly severe erosion on the Presque Isle portion of the Lake Erie shore even in the absence of a newly constructed harbor or groin updrift.

Armed with an astute lawyer, the objective scientific data based on exhaustive research and the author as an expert witness the Pennsylvania Fish and Game Commission went to court July 28-30, 1997. And lost.

Studies are underway by the US Army Corps of Engineers to determine possible further engineering steps that might be instituted and actual assessment of "damages" to be paid, if any, by the Pennsylvania Fish and Boat Commission are on hold until results of the study are in. Negotiations were held that resulted in a specified amount of nourishment being placed in front of the homes of the winners until final resolution of the issue could be arrived at.

Participants will observe the physical situation on-site and discuss the possible reasons for the legal outcome.

STOP 2. SHADES BEACH, HARBORCREEK, PENNSYLVANIA

This is the proposed site for construction of both a harbor and a detached breakwater up drift (to the west). The harbor will be similar to the one at North East and the detached breakwater will be similar to those we will see at Presque Isle (Figure 5). To avoid legal complications such as those at North East Marina a federal and state Coastal Zone Management study has been funded and is underway to provide pre-construction baseline data. The coastal marine contractors selected for the study will need to determine the natural, pre-construction, conditions during the course of an ice-free year. Pre-construction conditions include both the shape of the exposed and submerged beach and the dynamics of the littoral drift processes. They will document the configuration of the exposed beach and the nearshore bathymetry and its natural seasonal variability. That, along with the interpretation of the dynamics of waves, currents and sediment transport in the area could be used to predict the effects of the off-shore construction improvements planned as part of the overall Shades Beach Park Development Project. The data and interpretations will be used to predict adverse coastal effects including impacts to downdrift (eastern) bluff areas which may occur in the short and long terms and considering the effects of fluctuating lake levels.

It would be obvious to draw heavily on the lessons learned nearby on the Lake Erie shore at North East (for the harbor) and at Presque Isle (for the offshore breakwater). Significant differences between the Shades Beach site and the others would have to be taken into account. Obviously site-specific differences will have to be considered. Examples of the differences include (1) At Presque Isle there is far more sediment in the system to accrete wide beaches behind offshore breakwaters, (2) Bedrock of the Northeast Shale which outcrops below lake level at North East and is only seen offshore is present a meter or more above lake level at Shades Beach providing the bluff protection from wave erosion here, and (3) At Shades Beach Eightmile Creek brings sediment into the littoral zone immediately downdrift from the proposed harbor whereas, at North East, the nearest input downdrift is from Twentymile Creek 900 m (2953 ft) downdrift.

The geomorphic development of the site is interesting and relevant. Discussed by Schooler (1974) and expanded upon by Delano (in Thomas et al., 1987), the following except is from Delano (p 74-75):

> This township park takes advantage of a rare low flat valley with lake access. The reason for the existence of the flat area which the park occupies is evident from the topographic map of the area (Figure 44) and Figure 45 (Figures 6 and 7 respectively herein) Eightmile Creek, which now enters the lake just east of the access from the park to the lake shore, formerly occupied this valley. Lake erosion and bluff recession caused the shore line to retreat until it intersected a northward meander loop in the entrenched stream valley. The lake effectively captured the stream, leaving the lower valley occupied by a severely underfit stream (and the parking lot -author). Eightmile Creek falls approximately 12 m (40 ft) from the abandoned channel channel upstream of the mouth. This example of piracy is evidence that erosion and bluff recession along the Lake Erie shore are not recent developments. ...

Delano goes on to consider why bluffs are relatively stable here (p75-77):

> ...Two possible explanations for this are (1) the bedrock ledge protects the bluffs from toe erosion, and (2) the isolation of the bluff section by the abandoned stream channel limits the source area for groundwater, and the resulting small amout of seepage out of the slope face is a factor in the apparent increased stability of the bluff. Both factors are probably important, but the relative importance of each is unknown.

Several features to notice from the beach and from the bluff overlook accessible from a trail beginning in the parking lot are : (1) The beach is very coarse grained with abundant gravel and it extends only a short distance out from the shore line before it gives way to extensive exposed bedrock ledges of Northeast shale (actually an interbedded shale and siltstone facies), (2) The protective ledge extend well above lake level and is overlain by unconsolidated glacial diamict (very poorly sorted boulders, sand, silt and clay) which extends to the top of the bluff, and (3) the poor condition of the concrete remnants of shore line structures provides evidence of the power of Lake Erie to destroy inadequately engineered coastal structures, especially in time of high lake levels.

STOP 3. PRESQUE ISLE: LIGHTHOUSE BEACH AREA

The first of our three stops on Presque Isle will give us the opportunity to see the how variable the effect of the offshore breakwaters has been on beach erosion and deposition. Near the lighthouse erosion has continued to be severe despite the presence of breakwaters offshore and immediately downdrift (to the east) "excessive" deposition results in the annual connection of the beach to a breakwater forming a tombolo. The proximity of the two areas will highlight an unexpected benefit of the project: harvesting of the unwanted sand deposits from the tombolo serves as a low cost source of sand which is recycled as nourishment for the nearby area of erosion. We will ascend the lighthouse in small groups to obtain an aerial view of the situation. A study of one cycle of tombolo growth was completed by undergraduates and reported to the northeastern Section of the GSA (Wilson et al., 1997). The abstract is presented below:

The Presque Isle Shoreline Erosion Control Project's 55 segmented offshore breakwaters constructed at a cost of 23.8 million dollars has had variable effectiveness along the shoreline; stretches of continued erosion alternate with those of salient-widened beaches some of which culminate in tombolo formation. Part of an extensive Coastal Zone Management funded study during 1995 documented erosion and deposition in the Lighthouse beach area, breakwaters (BWs) 43 through 47. The area updrift of the lighthouse jetty opposite BWs 43 and 44 were salient-widened accretionary beaches, but downdrift the littoral-drift sand moves to an extensive offshore bar complex outside of BWs 45,46,47 where the beaches continued to be erosional despite breakwater construction. June, 1995 aerial photographs show the offshore sandbar complex along the erosional beach and downdrift, where it wraps back into the shore at the salient widened beaches behind BWs 48 and 49, the location of the current study.

During June 1996 a tombolo that had attached to BW 49 was harvested to nourish the erosional beach immediately updrift. From June through November the tombolo's regrowth was documented by oblique aerial photographs from the nearby lighthouse, 10 plane-table maps of the shoreline, six sets of Emery profiles along four transects from BWs 47 to 49, and augmented by a current direction study using drogues. The beach was depositional throughout the study period but with significant changes in growth rate. The tombolo grew at a rate of 9 m/mo during July-Sept.,17 m/mo in late Sept.-Oct.,and 46 m/mo in late Oct.-Nov. The earlier study showed a similar, major increase in deposition in late Fall for the Lighthouse beach and nearshore area. The source of the sediment for the growth is at least in part from the nourished erosional beaches updrift as shown by their obvious loss of sediment as beach scarps retreated landward providing sediment to the longshore current documented by the drogue study. The role of the offshore bar complex is not known, but may serve two functions supporting beach growth in the study area: 1) possible addition of bypassed sediment by landfall of bar complex 2)reduction of wave energy arriving at the BWs and beach by stimulation of repeated breaker zones offshore. Future studies are proposed to investigate these possibilities using tracer sand, offshore current studies and mapping, detailed bottom morphology and sediment distribution.

Figure 8 shows the shorelines mapped as the tombolo grew, Figure 9 indicates the remarkable growth rate documented and Figure 10 shows longshore currents documented using a floating device called a current drogue. The aerial photographs referred to were taken from the top of the lighthouse which you will also visit. The internal structure of the beach developed during accretion of a tombolo will be revealed in the trench that you will help excavate at this location.

About one third of all the sand used for nourishment in the last six years was recycled on-site from build-ups such as this one. While not free, the cost of such replenishment of eroded beaches is substantially reduced over that for obtaining and placing sand from elsewhere. Table 1 entitled, Sand Nourishment History for Presque Isle State Park, compiled and provided by Eugene Comoss (Bureau of Facilities Design and Construction Pennsylvania Department of Conservation and Natural Resources) helps us to consider such factors in our attempt to determine the cost effectiveness of the $23.8 million dollar offshore breakwaters. The numbers can be looked at in several ways, of course, but such quantification is crucial to the process. It is important to realize that each ton listed is equal to 0.8 cubic yards, or alternatively each cubic yard is equal to 1.25 tons. You are free to crunch the numbers yourselves but I will give you the benefit some of my own efforts which involve some interpretation as well as selective use of the data. Be warned!

Ignoring 1956, the annual nourishment from 1975 to 1991 was about 228,000 tons/year. Also ignoring the 330,000 tons added as part of construction, the annual nourishment from 1993 to 1998 was about 86,000 tons, which is about 38 % of the earlier total or about a 62% reduction. If the recycled sand volumes are also ignored the annual off-site nourishment is about 57,600 tons annually or 25% of the earlier amount; a 75% reduction. Success? Lets look at the money. For the seventeen years prior to 1992 (again ignoring 1956) the annual cost of nourishment was about $1,312,000. For the last six years (1993 to 1998) the annual cost comes in at about $780,000, 59% of the previous expenditure, or a reduction of 41%. Failure?

A basic assumption inherent in the analysis above is that the annual nourishment provided to the system was enough to maintain healthy beaches over the long term pre-construction studies. Nummedal et al. (1984) found that annual erosion volumes at the neck of the peninsula were matched by accretion volumes at Beach 10 and Gull Point. Our post-construction study (Buyce, 1995) suggested that accretion volumes were substantially less at Beach 10 (and by implication Gull Point) than the erosion volumes at the neck (Figure 11). Apparently the nourishment was not enough to maintain the system at pre-construction levels. Without such volumetric studies to assess the nourishment program it was decided to use the annual growth rate of Gull Point as an indicator. If the surface area of Gull Point continued to grow at least 0.4 acres annually the system was adequately nourished. Data in the US Army Corps of Engineers report, (1999) show that the growth has been below this value since 1996. The same report notes data gathered by new volumetric techniques (SHOALS aerial mapping) indicates substantial subaqueous growth is occurring. The Beach 10 area adjacent to Gull Point has been targeted for major nourishment this year and will receive all the sand derived from the removal of the excessive spit growth that threatened Beach 11.

STOP 4. PRESQUE ISLE: BEACH NO. 10 AND GULL POINT

. Our second stop on Presque Isle will be in the area where the nourishment sand from the spit dredging and recycling operation is being placed. The easternmost of the 55 offshore breakwater sequence and three additional earlier constructed prototype breakwaters are visible updrift (to the west). To the east is the environmentally sensitive area called Gull Point which is a bird sanctuary and has restricted access. Not surprisingly, it is this area immediately down-drift from the last of these erosion control structures that was designated as most in need for receiving the dredged sand. The fate of the nourishment sand over the next several months will be monitored by students as part of a undergraduate coastal studies GIS project. The data and project report will be provided to Presque Isle State Park management and to the US Army Corps of Engineers.

STOP 5. PRESQUE ISLE: BEACH NO.11 AND THOMPSON BAY

The final stop on Presque Isle and of the trip will be at Beach 11, the site of the sand spit which was dredged. Beach 11 is on the southwest shore of Thompson Bay which is bordered on the northeast by Gull Point and opens onto Lake Erie to the southeast. The sand spit developed on the end of Gull Point and began enclosing Thompson Bay from the north. These "excessive" deposits were coincident with very low lake levels. Ultimately the spit detached from Gull point and attached to the eastern end of Beach 11 nearly enclosing the bay (see Figures 12 and 13 from the US Army Corps of Engineers report, (1999).The effects of nearly separating Beach 11 from the open waters of Lake Erie were stagnation, abundant weed growth and threat of frequent beach closing due to pollution. The necessary studies were done to obtain permits and dredging began in the summer of 1999. The dredging and nourishment project is due for completion in mid-September 1999 so all activity should be over by the time of our visit. We will have little to see here, having arrived after the fact but can at least visualize the situation facing the park management. The debate was heated concerning the option of allowing the "natural" processes to proceed. The fact that the Presque Isle has been a heavily managed and, at least partially, an "unnatural" system since at least 1828 apparently won out.

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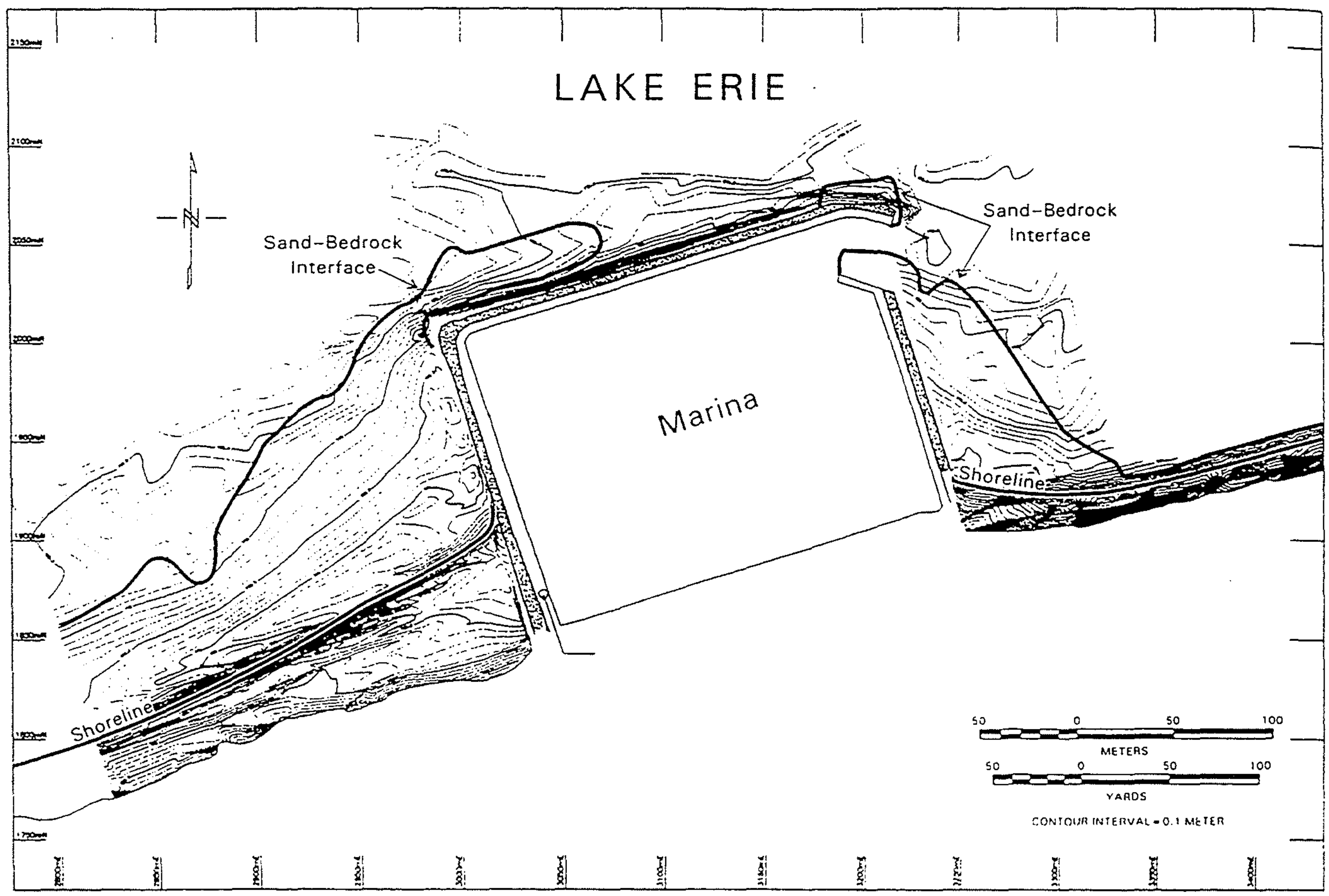


Figure 1. Detailed 10 June topographic map of the beach and nearshore zones for the perimeter of the harbor at North East, Pennsylvania. Sand/bedrock interface indicates sediment accumulation against the updrift (west) wall and extending a short distance around the northwest corner of the harbor. Along the eastern harbor the sand/bedrock interface indicates a narrow accumulation zone extending into the harbor entrance and grading into a cobble/bedrock interface to the east.(from Buyce and Taylor, 1998)

Figure 2. Presque Isle Beach 6 Shorelines. Compared to 1995 shorelines the May 1997 shoreline is eroded back due to higher lake levels and severe spring storms impinging on beaches unprotected by ice dunes. On the west the beach has been removed back to the retaining wall.

Sat. D14

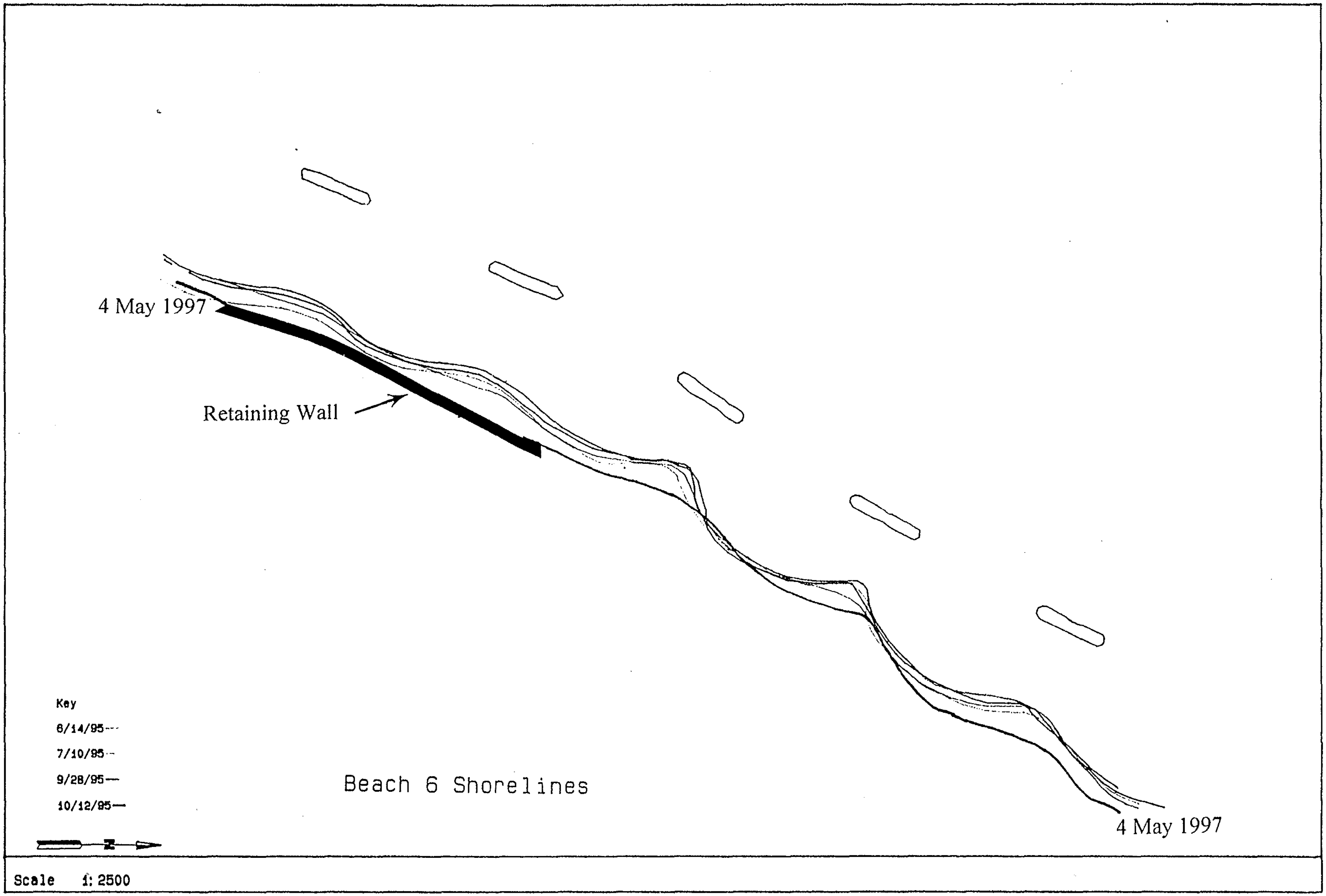

4 May 1997
Retaining Wall
4 May 1997
Key
6/14/95
7/10/95
9/28/95
10/12/95
Beach 6 Shorelines
Scale 1: 2500

Figure 3. Presque Isle Beach 10 Shorelines. . Compared to 1995 shorelines the May 1997 shoreline is eroded back due to higher lake levels and severe spring storms impinging on beaches unprotected by ice dunes. The beach was largely removed from behind the three prototype breakwaters and the scarp was into dunes behind the beach.

Sat. D16

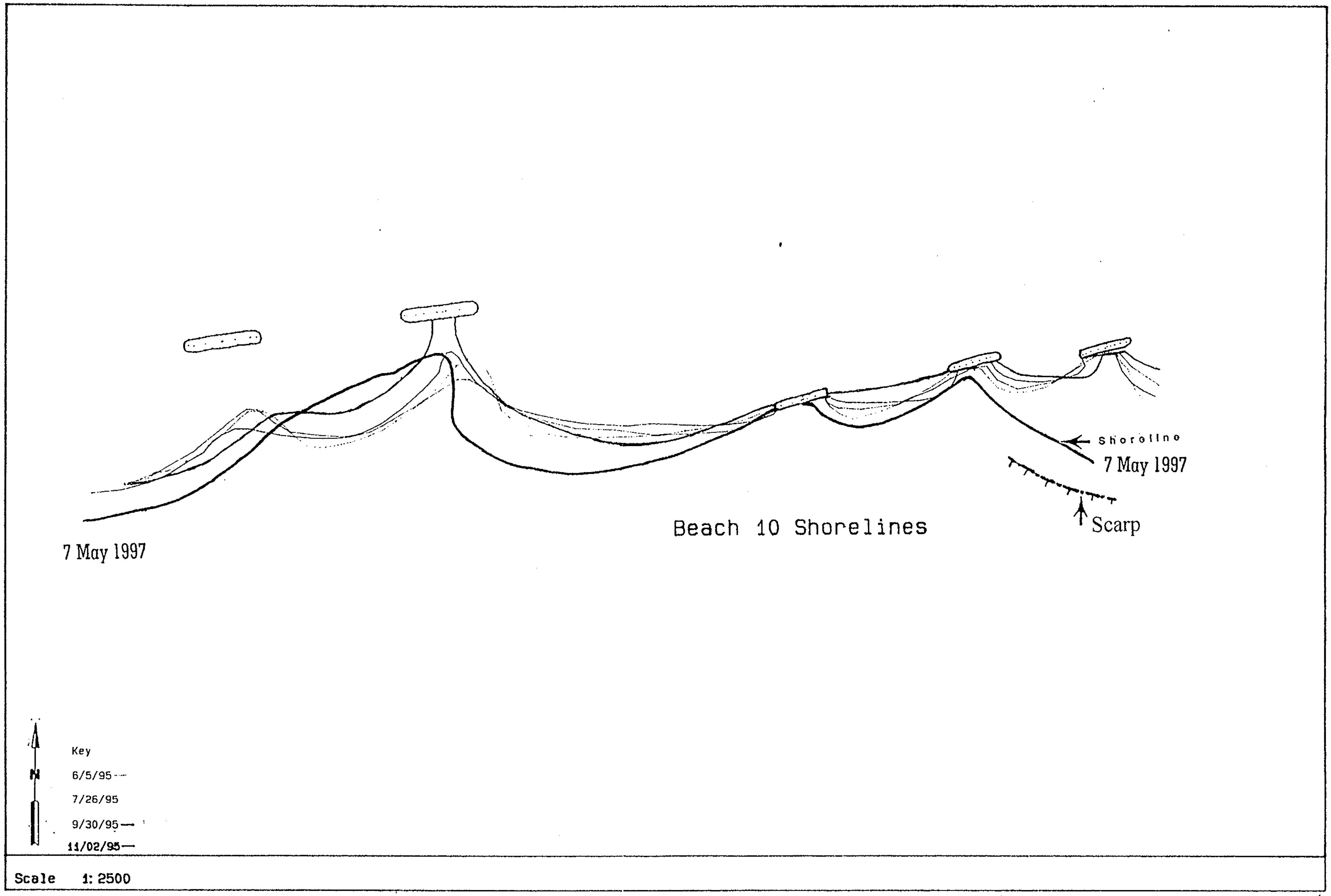
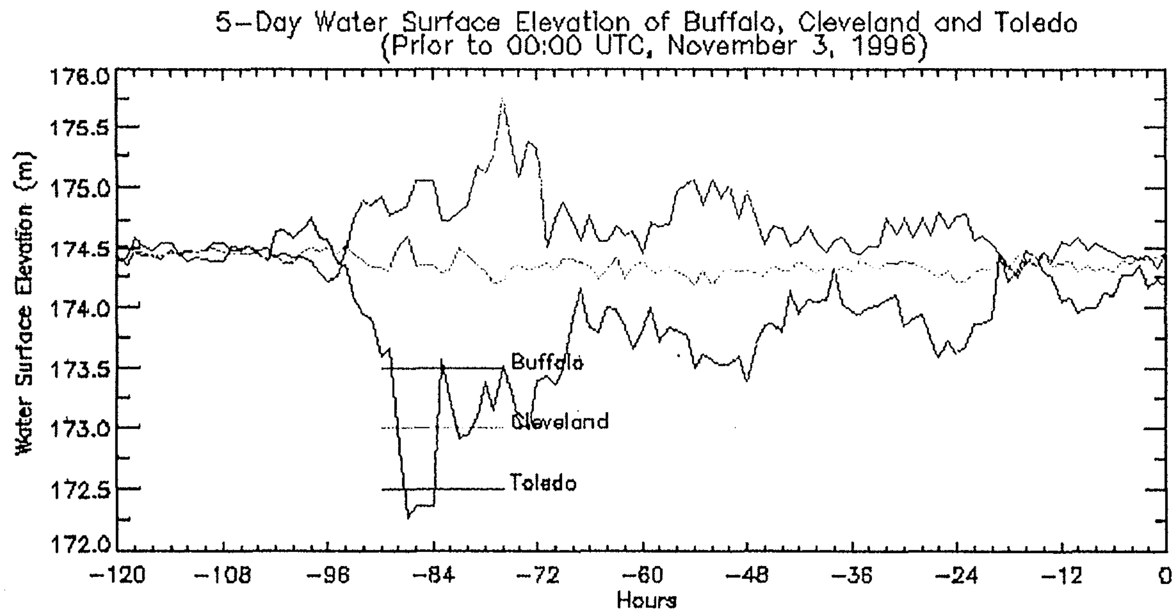

Beach 10 Shorelines
7 May 1997
Shoreline
7 May 1997
Scarp
N
Key
6/5/95
7/26/95
9/30/95
11/02/95
Scale 1: 2500

Figure 4. Archived Nowcast Image of Lake Erie water level elevations for the five days prior to 3 November 1996 including the 1 November storm date. A storm "setup" is shown with water being blown to the east end of the lake (toward Buffalo) and away from Toledo on the west end. This short-term lake level rise magnifies the erosive effects of storm waves.

Archived Nowcast Images

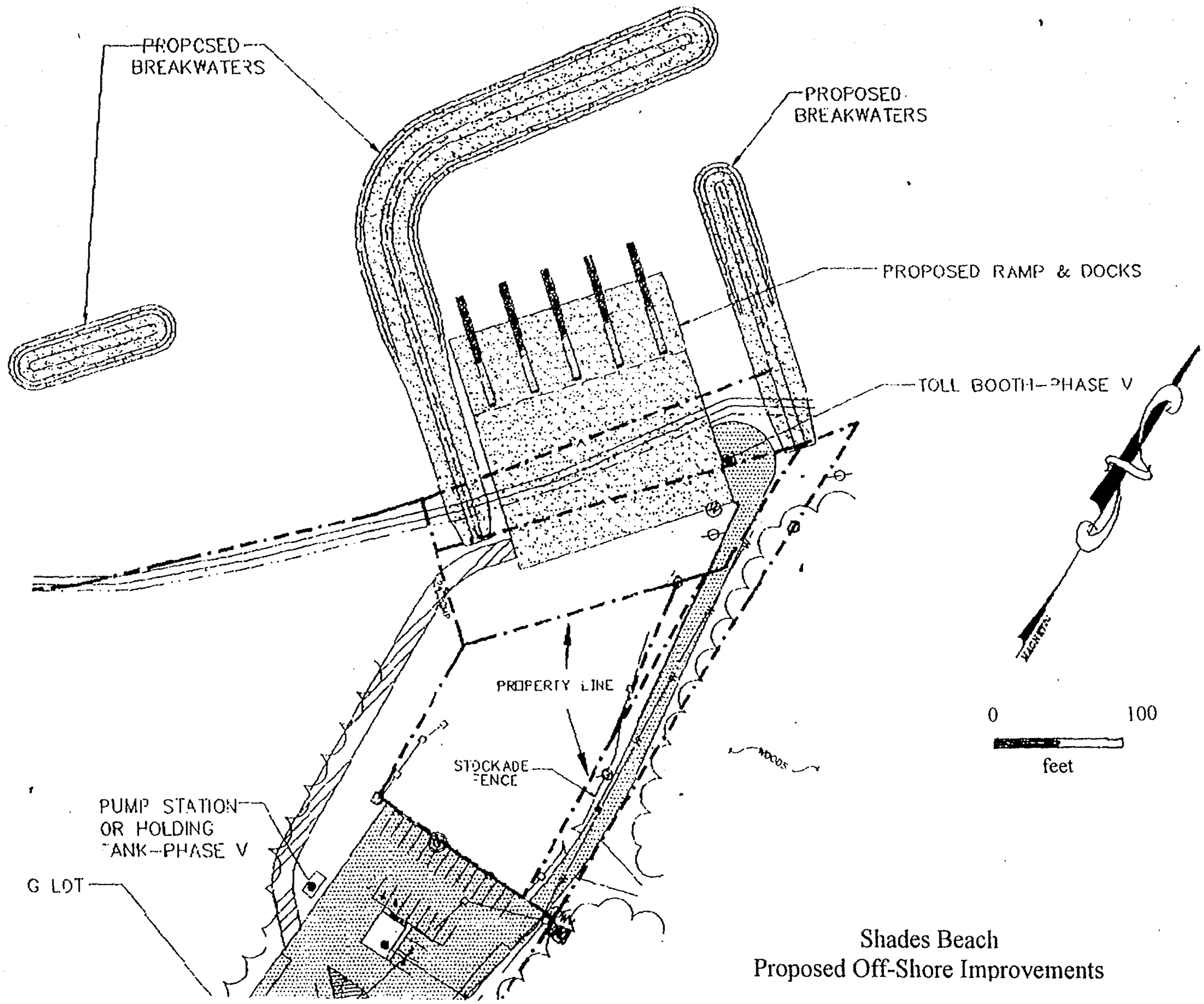
Time Series Water Elevation (File : stn9630800.gif)



Sat D.18

Figure 5. Shades Beach Proposed Off-Shore Improvements. Notice that the plan includes a harbor similar to North East Marina and an offshore breakwater similar to those at Presque Isle. The sketch was provided to bidders on the pre-construction littoral drift study funded by the Coastal Zone Management Division of NOAA.

Sat. D20



Shades Beach
Proposed Off-Shore Improvements

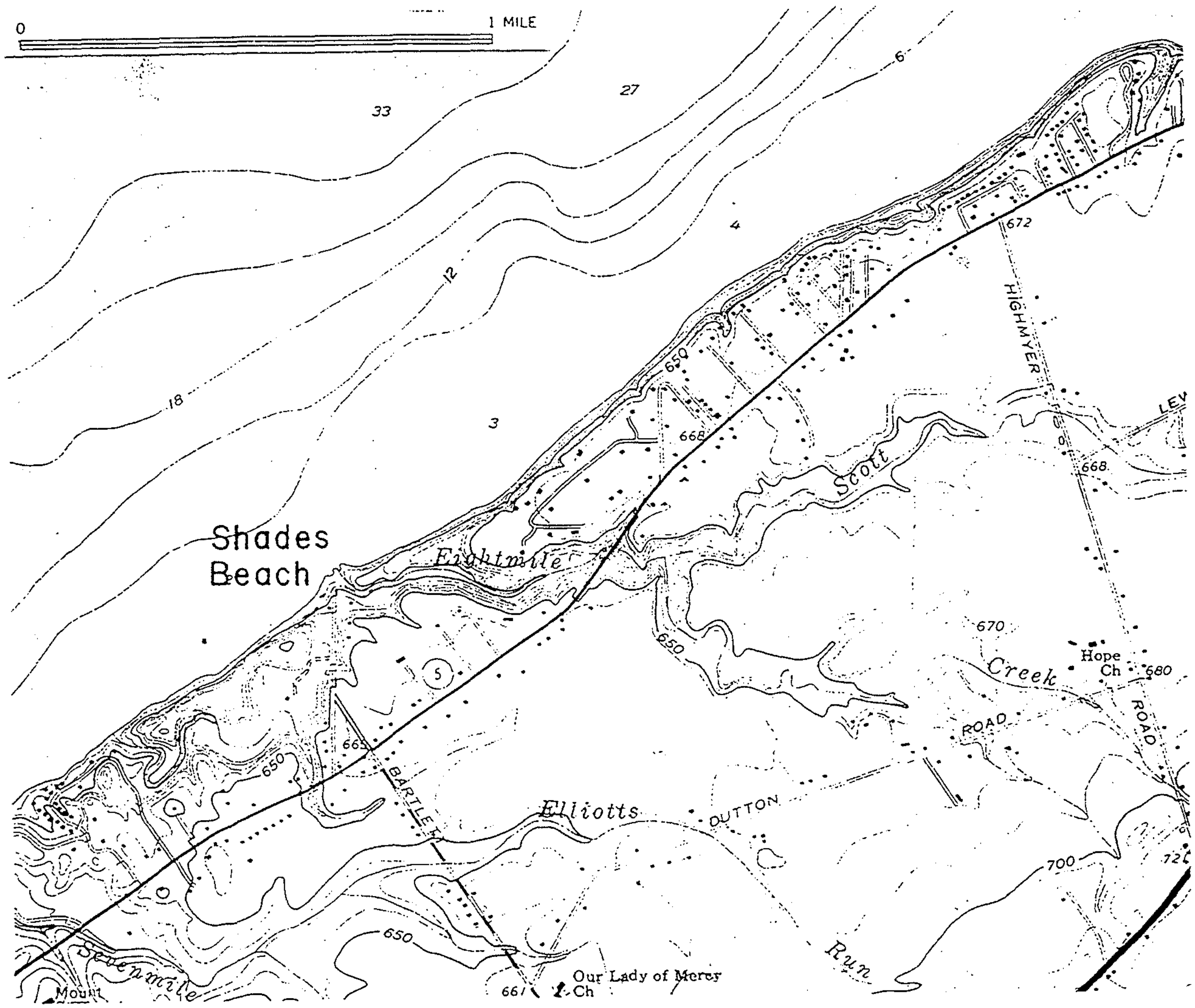


Figure 6. Location map for Stop 2 (from Harborcreek, PA 7.5 minute topographic map)

Figure 7. Schematic diagram showing hypothesized origin of the topography at Shades Beach Park. A similar but less detailed diagram is shown by Schooler (1974, Fig. 5, p. 18)

A. Reconstruction of drainage pattern at a time before extensive bluff erosion.

B. Shoreline erosion led to bluff recession and "stream capture" by the lake.

C. Present drainage pattern and the abandoned channel of "7 &1/2 mile Creek."

(from Delano in Thomas et al. 1987, p.76)

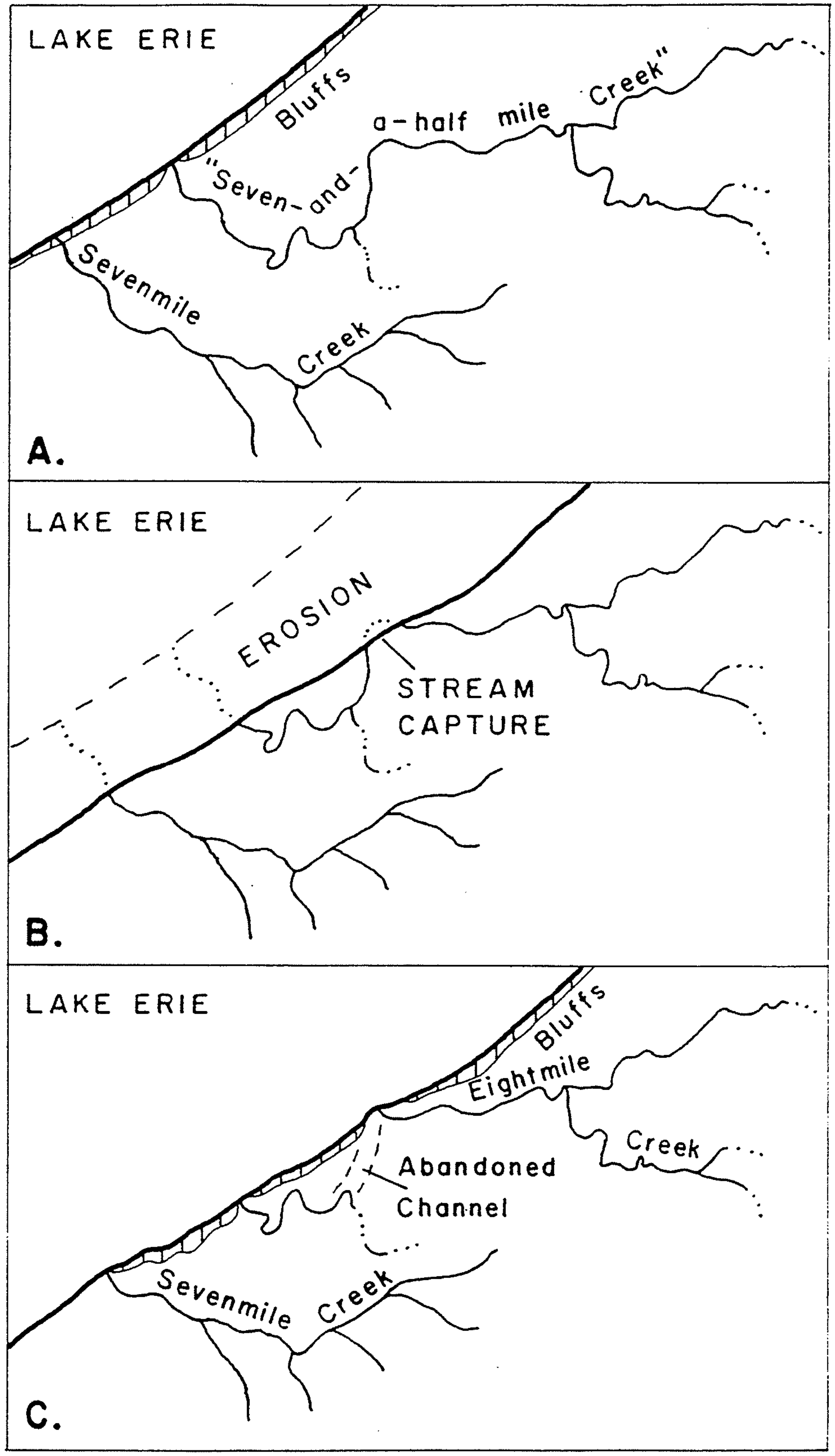
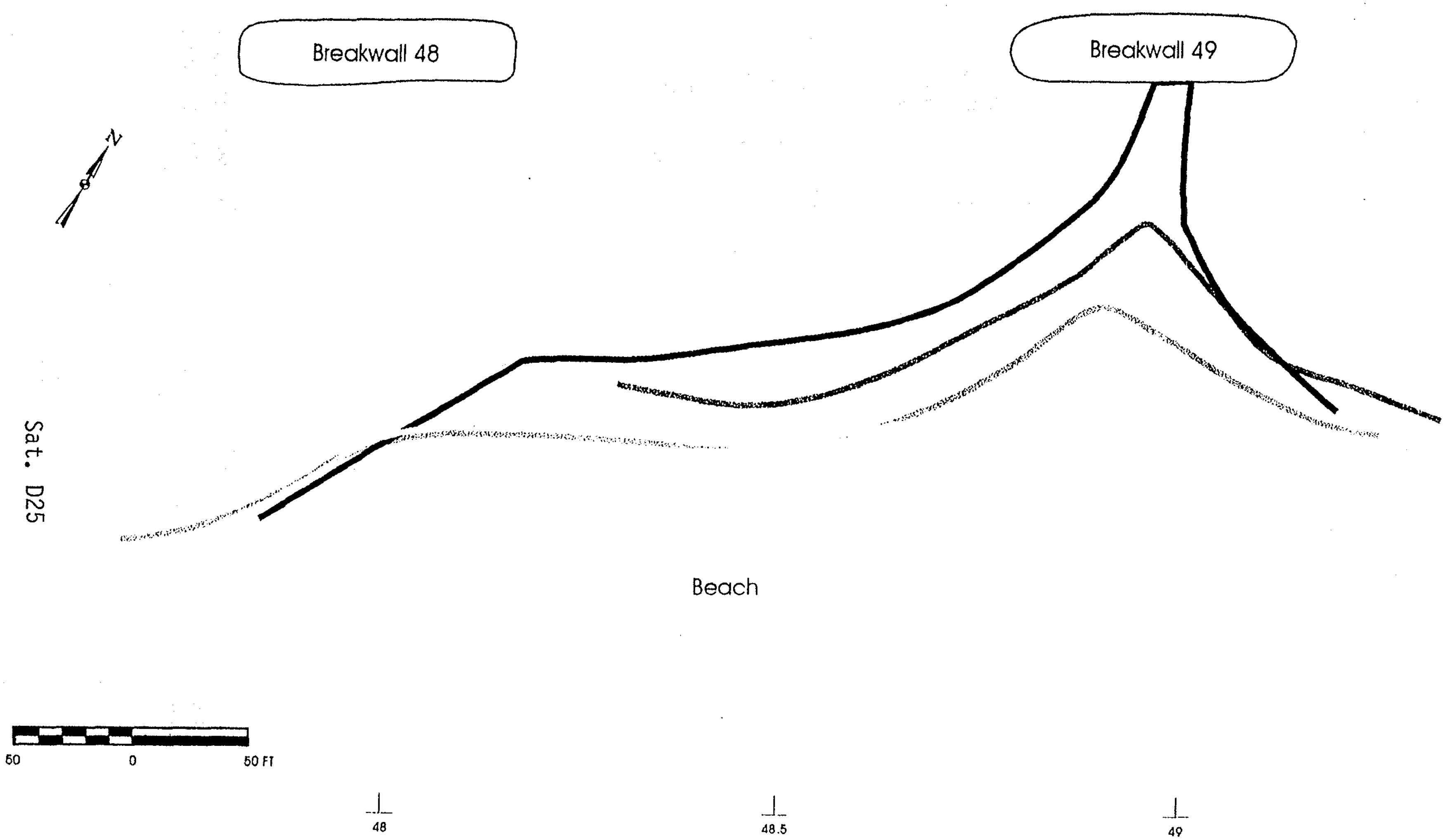

LAKE ERIE
Bluffs
"Seven-and-a-half mile Creek"
Sevenmile Creek
A.
LAKE ERIE
EROSION
STREAM CAPTURE
B.
LAKE ERIE
Bluffs
Eightmile Creek
Abandoned Channel
Sevenmile Creek
C.

Figure 8. Presque Isle lighthouse beach shorelines as the tombolo grew in the fall of 1996. The shorelines shown were mapped on 22 July, 6 September, 17 October , and 5 November 1996.



Sat. D25

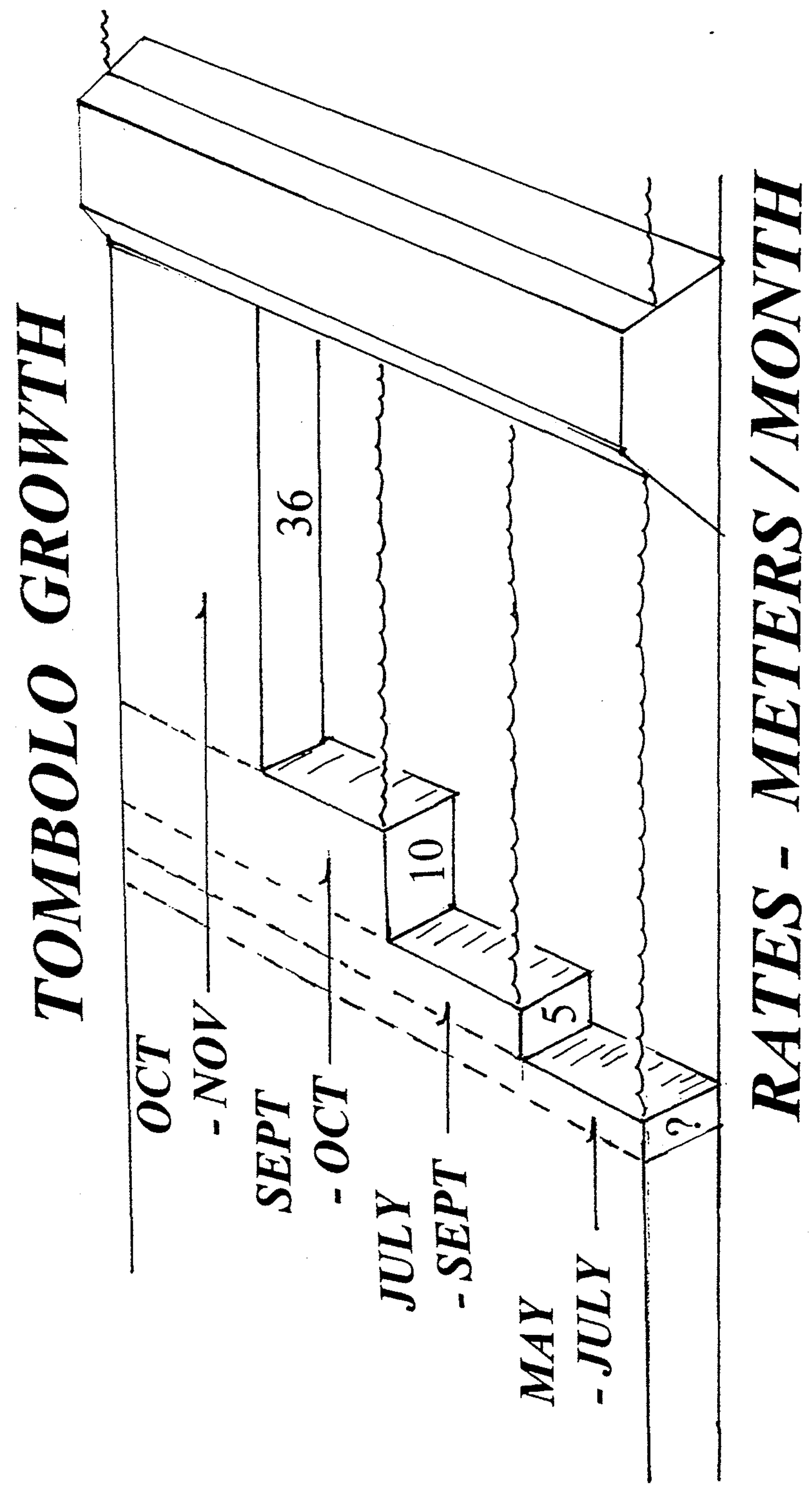
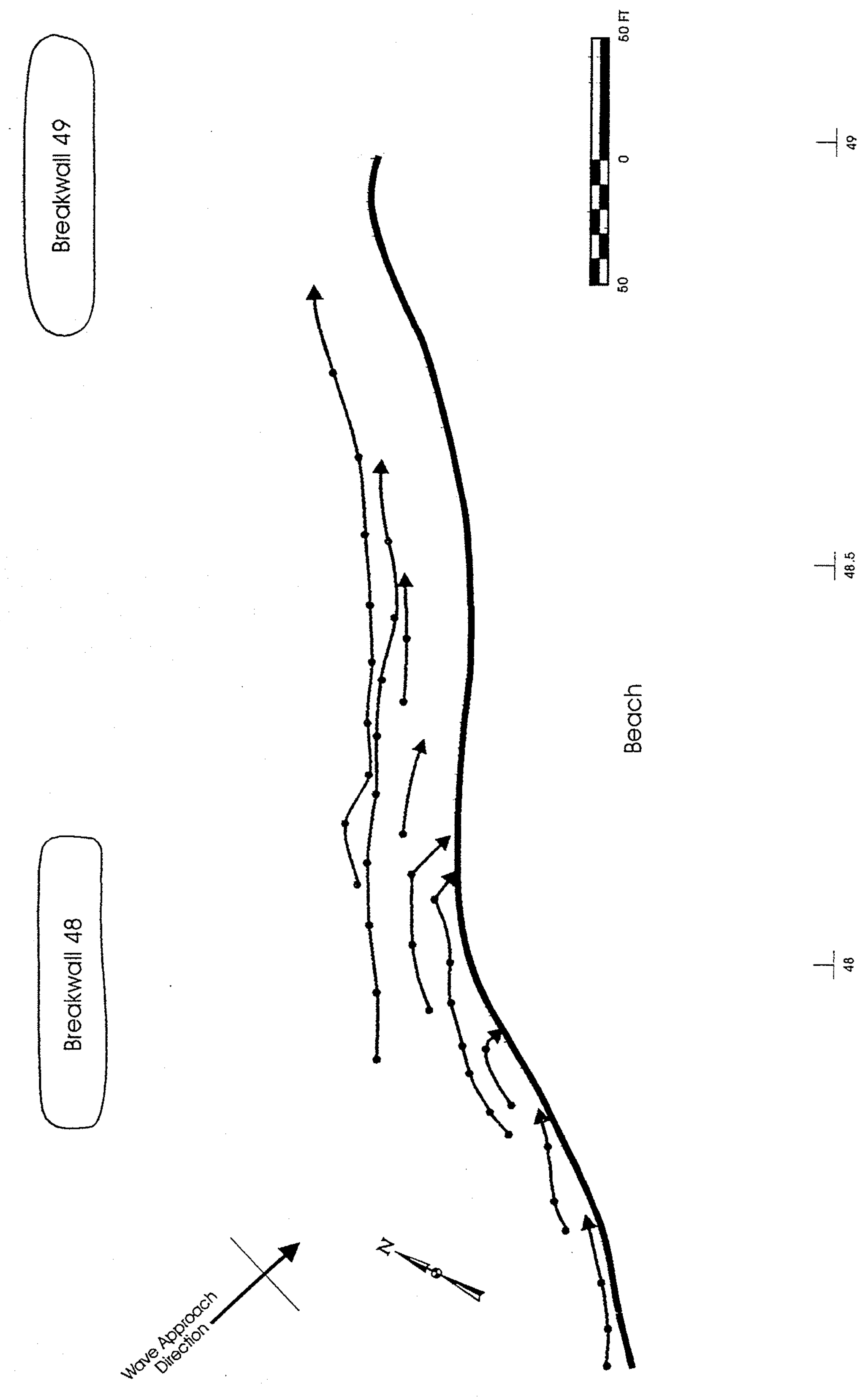


Figure 9. Tombolo Growth. The fall 1996 growth rates of the light house beach tombolo which formed behind breakwater 49 on Presque Isle. After very little accretion in summer the growth rate accelerated significantly through the fall until connection was achieved.

Figure 10. Presque Isle light house beach longshore current directions in early summer 1996. Sediment moved to the beach behind breakwater 49 where a tombolo ultimately formed can be inferred to have come from beaches to the west via the currents mapped by tracking a floating current drogue.


Breakwall 49
Breakwall 48
Beach
50 FT
0
50
49
48.5
48
Wave Approach Direction
N

Sat. D28

Figure 11. Presque Isle sediment transport volumes in 1995. The accretion volume at Beach 10 (and by implication at Gull Point) is substantially less than the erosion volume at the neck of the Peninsula (Beach 6). Prior to construction accretion volumes roughly balanced erosion volumes (Nummedal, 1984). Evidently the volume of artificial nourishment (much reduced in anticipation of benefits from the presence of the breakwaters) was inadequate to maintain pre-construction conditions.

Transport Volumes
1995

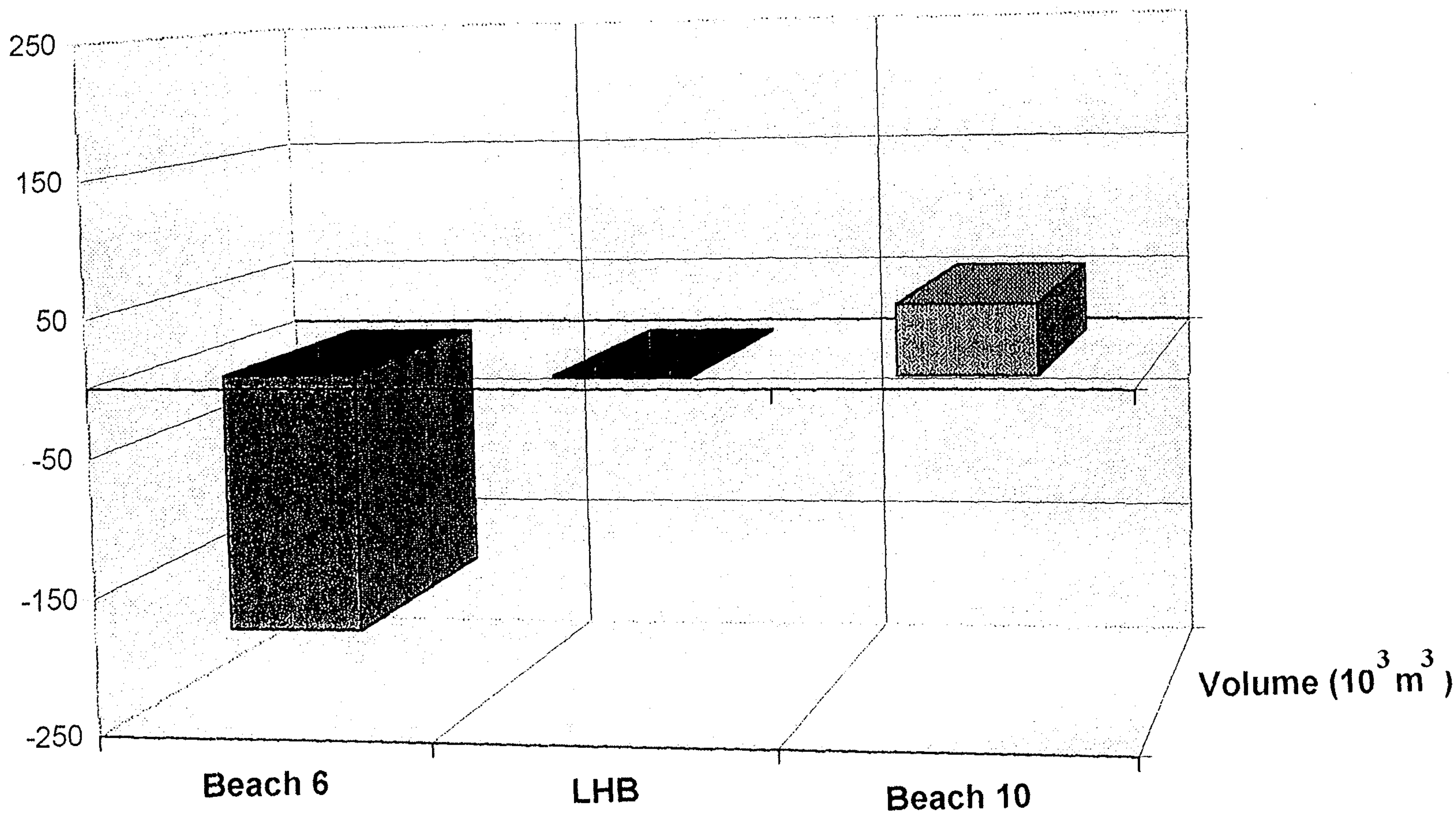
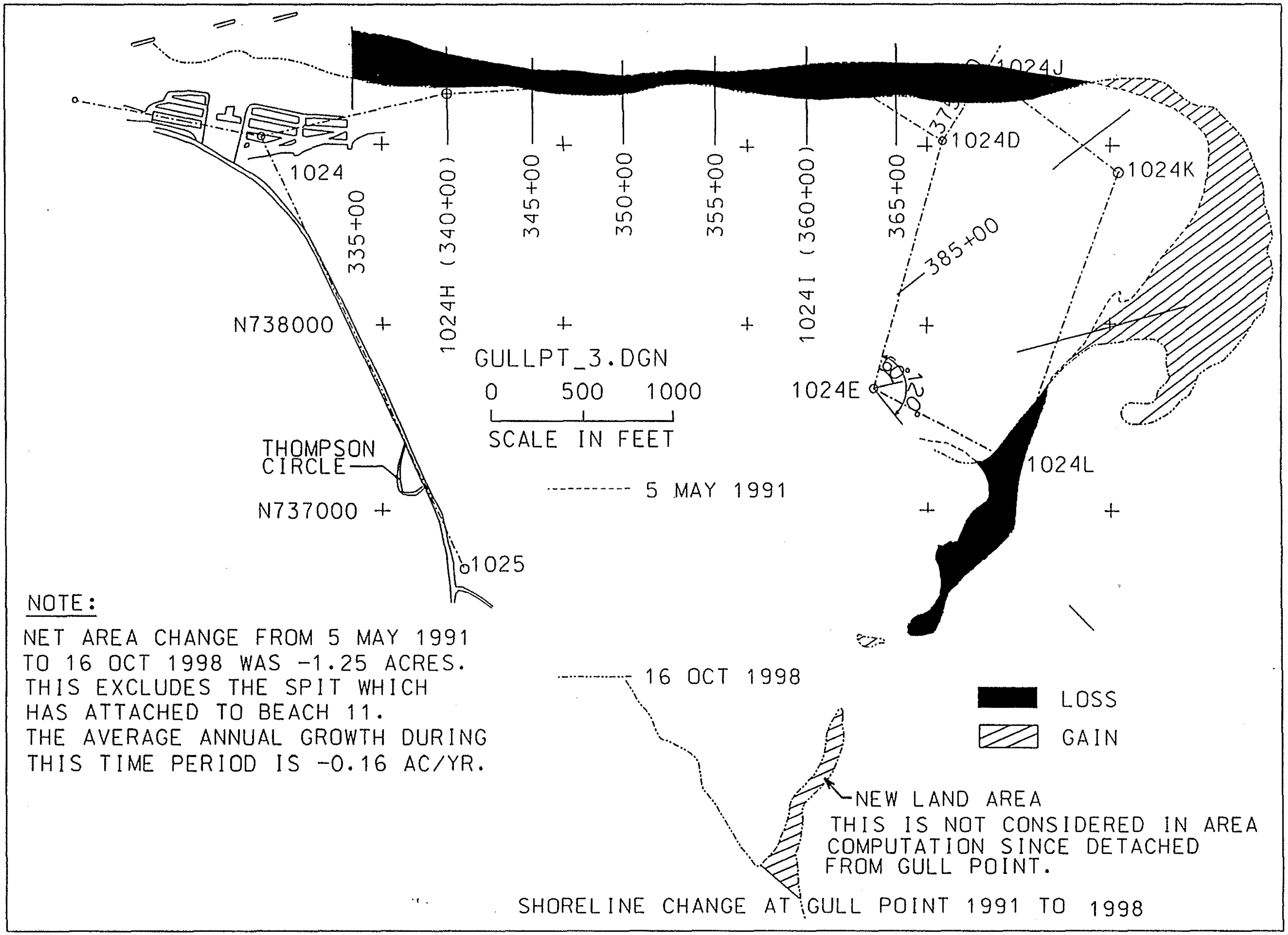


Figure 12. Aerial Photograph of Gull Point, June 1998. The grid pattern on the lower left is the Beach 11 parking area. The "excessive" deposition represented by the spit is evident at the bottom of Beach 11. It threatens to enclose the waters of Thompson Bay between Beach 11 and Gull Point. See Figure 13. Source: US Army Corps of Engineers, 1999.


10-16-98
1"=800'
NCB PRES. IS.
83
0 800
SCALE IN FEET
AERIAL PHOTOGRAPH OF GULL POINT

Figure 13. Shoreline change at Gull Point 1991 to 1998. The spit which threatened to enclose Thompson Bay and Beach 11 is labeled, "new land area". See Figure 12. Source: US Army Corps of Engineers, 1999.

Sat. D34



NOTE:

NET AREA CHANGE FROM 5 MAY 1991 TO 16 OCT 1998 WAS -1.25 ACRES. THIS EXCLUDES THE SPIT WHICH HAS ATTACHED TO BEACH 11.
THE AVERAGE ANNUAL GROWTH DURING THIS TIME PERIOD IS -0.16 AC/YR.

SHORELINE CHANGE AT GULL POINT 1991 TO 1998

Table 1. Sand nourishment history for Presque Isle State Park. Compiled by Eugene Comoss, Bureau of Facilities and Construction, Department of Conservation and Natural Resources.

Sand Nourishment History for Presque Isle State Park

Tuesday, June 22, 1999

Year	*Primary Sand Amount in Tons*	*Primary Sand Source*	*Secondary Sand Source*	*Funds Expended*
1956	4,150,000 cy	pumped from bayside	none	$2,451,270.00
1975	186,700	offshore borrow area	none	$1,097,000.00
1976	183,000	offshore borrow area	none	$1,109,500.00
1977	287,000	upland sand source	none	$1,077,000.00
1978	173,000 (3 prototype breakwaters constructed at Beach 10)	upland sand source	none	$1,073,400.00
1979	216,000	upland sand source	none	$1,060,500.00
1980	216,000	upland sand source	none	$1,082,100.00
1981	236,000	upland sand source	none	$1,213,400.00
1982	284,000	upland sand source	none	$1,424,400.00
1983	194,000	upland sand source	none	$1,049,000.00
1984 & 1985	505,000	upland sand source	29,500 tons of gravel on test Beach 5.	$3,007,000.00
1986	258,000	upland sand source	none	$1,631,400.00

Sat. 036

TABLE 1

Year	*Primary Sand Amount in Tons*	*Primary Sand Source*	*Secondary Sand Source*	*Funds Expended*
1987	173,000	upland sand source	45,000 tons coarse sand and 10,000 tons of fine sand from offshore borrow area	$1,671,500.00
1988	211,000	upland sand source	27,000 tons fine sand from offshore borrow area	$1,529,200.00
1989	234,066	upland sand source	35,500 tons offshore borrow area	$1,400,000.00
1990	99,403	upland sand source	13,000 tons offshore borrow area	$600,000.00
1991	55,824	upland sand source	23,000 tons offshore borrow area; 230,000 from offshore borrow area as part of breakwater project	$2,273,600.00
1992	330,000	offshore sand sources	none	$2,580,600.00
1993	47,870	offshore sand source	29,825 cy recycled tombolo sand	$675,000.00
1994	53,069	offshore sand source	19,000 cy recycled tombolo sand	$650,000.00
1995	50,936	offshore sand source	29,500 cy recycled tombolo sand	$700,000.00
1996	51,108	offshore sand source)	49,000 cy recycled tombolo sand	$730,000.00
1997	90,500	offshore sand source	40,500 cy recycled tombolo sand	$1,110,000.00
1998	52,342	offshore sand source	44,000 cy recycled tombolo sand	$810,000.00
			Total Funds Expended	$32,005,870.00

TABLE 1

Sat. D37

ROAD LOG

Mileage (INC.= INCREMENTAL CUM=CUMULATIVE) INC	CUM	Route Description
0.0	0.0	START: I-90, Exit 11 PROCEED NORTH on Route 89
1.4	1.4	Blinking light – East Wellington St.
0.2	1.6	Jct. Rt. 426 South
0.5	2.1	Jct. Rt. 20, Downtown North East
0.3	2.4	Mercyhurst College – North East Campus
0.2	2.6	Sunset Drive – North East Schools
0.9	3.5	End Rt. 89. TURN RIGHT (east) on Rt. 5
2.5	6.0	North East Marina, TURN LEFT

STOP 1. NORTH EAST MARINA. Stop at office. Proceed to bottom of hill and park opposite marina. Proceed downdrift (east) along shore. Notice nourished beach width, bluff, and any erosion control structures. Return to harbor continuing to updrift (west) side noticing partially- harvested beach width, bluff, and any erosion control structures.

0.1	6.1	Leave North East Marina. TURN RIGHT (west) on Rt. 5
2.5	8.6	Jct. 89 South
1.6	10.2	Penn Shore Winery
1.4	11.6	Catholic Cemetery Rd.
1.7	13.3	Shoreward Rd., Harborcreek
2.8	16.1	Bartlett Rd., TURN RIGHT, Shades Beach Sign
0.3	16.4	Shades Beach, Parking lot.

STOP 2. SHADES BEACH. Park in lot at foot of first hill. Walk to shore. Observe site of new harbor and offshore breakwater. Notice bedrock of the Northeast Shale (and siltstone) extending well above the lake level protecting the bluff from wave erosion. Glacial till (unconsolidated boulders, sand, silt and clay) extends to the top of the bluff.

Return to parking lot and follow trail to bluff top. Aerial view from bluff edge may show the limited amount of sediment in littoral drift system tucked up against the shoreline with extensive exposed bedrock on the lake floor beyond.

0.3	16.7	Route 5, TURN RIGHT (west)
0.9	17.6	Mount Saint Benedict Monastary
1.4	19.0	Bonnie Brae Rd.
1.6	20.6	Jct. 955 East. Continue on Rt. 5. GE Plant on left.
0.9	21.5	Rt. 5 split to Rt. 5 & Alt Rt. 5. STRAIGHT AHEAD on Alt. Rt. 5
1.5	23.0	East Ave. Continue Alt. Rt. 5. Follow signs to Bayfront Parkway
0.2	23.2	Bayfront Parkway. TURN RIGHT.
0.5	23.7	Left arrows. Continue on Bayfront Parkway.

0.8	24.5	Holland St. Erie Co. (Blasco) Library
0.2	24.7	State St., Erie. Dobbins Landing Continue on Bayfront Parkway. Presque Isle Bay (Erie Harbor) enclosed by Presque Isle sand spit, locally called "ThePeninsula"
2.0	26.7	8th St. traffic light. TURN RIGHT
0.4	27.1	Lincoln St. light. TURN RIGHT
0.1	27.2	West 6th St. TURN LEFT
1.1	28.3	Tracey School
0.4	28.7	Peninsula Drive. TURN RIGHT.
0.6	29.3	Sara Coyne Plaza
0.2	29.5	Presque Isle State Park. "The Peninsula", Bear right.
0.9	30.4	Stull Interpretive Center, on left. Presque Isle Bay (Erie Harbor) and City of Erie, on right.
1.3	31.7	Park office, Beach 6 entrance
0.6	32.3	Cookhouse, Waterworks (previous water supply for City of Erie)
0.9	33.2	To Lighthouse. TURN LEFT
0.0	33.2	Stop Sign. TURN RIGHT
0.6	33.8	Lighthouse
0.1	33.9	Lighthouse Beaches

STOP 3. Assemble on Beach by Lighthouse groin. Small groups (12 or less) will ascend lighthouse for aerial view of lighthouse beaches and tombolo area. The beaches immediately downdrift (east) of the lighthouse groin behind breakwaters 45, 46, and 47 remain erosional in spite of the new structures. Excessive deposition begins further downdrift culminating in the annual formation of a connection of the beach to breakwater 49 each fall (a tombolo)

Walk beaches from lighthouse groin east past breakwater 45 to beach opposite breakwater 49 (site of tombolo growth)

LUNCH

Participate in digging beach trench to expose stratigraphy developed during growth of tombolo.

0.0	33.9	Continue east on Peninsula Drive
0.4	34.3	Bear right. Stop sign.
1.0	35.3	Beach 10, Budny Beach

STOP 4. Enter parking lot beyond BathHouse. From beach observe to the west, the east end of the sequence of 55 offshore breakwaters with the three prototype breakwaters extending beyond to this location. Nourishment sand widens the beach here and evidence of previous erosion is evident behind the beach downdrift (to the east).

0.2	35.5	Leave Beach 10. TURN LEFT and continue east on Peninsula Drive.
0.5	36.0	West entrance to Beach 11. TURN LEFT.

0.3	36.3	Parking lot by Beach 11 Bath House.

STOP 5. Observe Gull Point and Thompson Bay. Note site of spit deposition that had to be removed to prevent the closing off of Beach 11 from the open waters of the Lake Erie.

0.0	36.3	Proceed through the parking lot to exit Beach 11 via east entrance road.
0.2	36.5	Peninsula Drive and east entrance to Beach 11. TURN LEFT.
1.2	37.7	Perry Monument and ferry dock.
		Presque Isle Bay (Erie Harbor) on left. Lagoons and dune ridges, right.
1.8	39.5	All traffic right signage. TURN RIGHT.
0.0	39.5	Stop sign. TURN LEFT. Return to park entrance.
1.4	40.9	Beach 6 entrance and Park Office.
1.4	42.3	Stull Interpretative Center
0.9	43.2	Park Entrance
0.8	44.0	6^{th} Street
0.1	44.1	8^{th} Street
0.3	44.4	12^{th} St., Rt. 5. TURN LEFT.
0.8	45.2	Pittsburgh Ave.
0.3	45.5	I-79 South. TURN RIGHT
3.0	48.5	Millcreek Mall
2.9	51.4	I-90 East, Buffalo. TURN RIGHT.

-- END ROAD LOG --