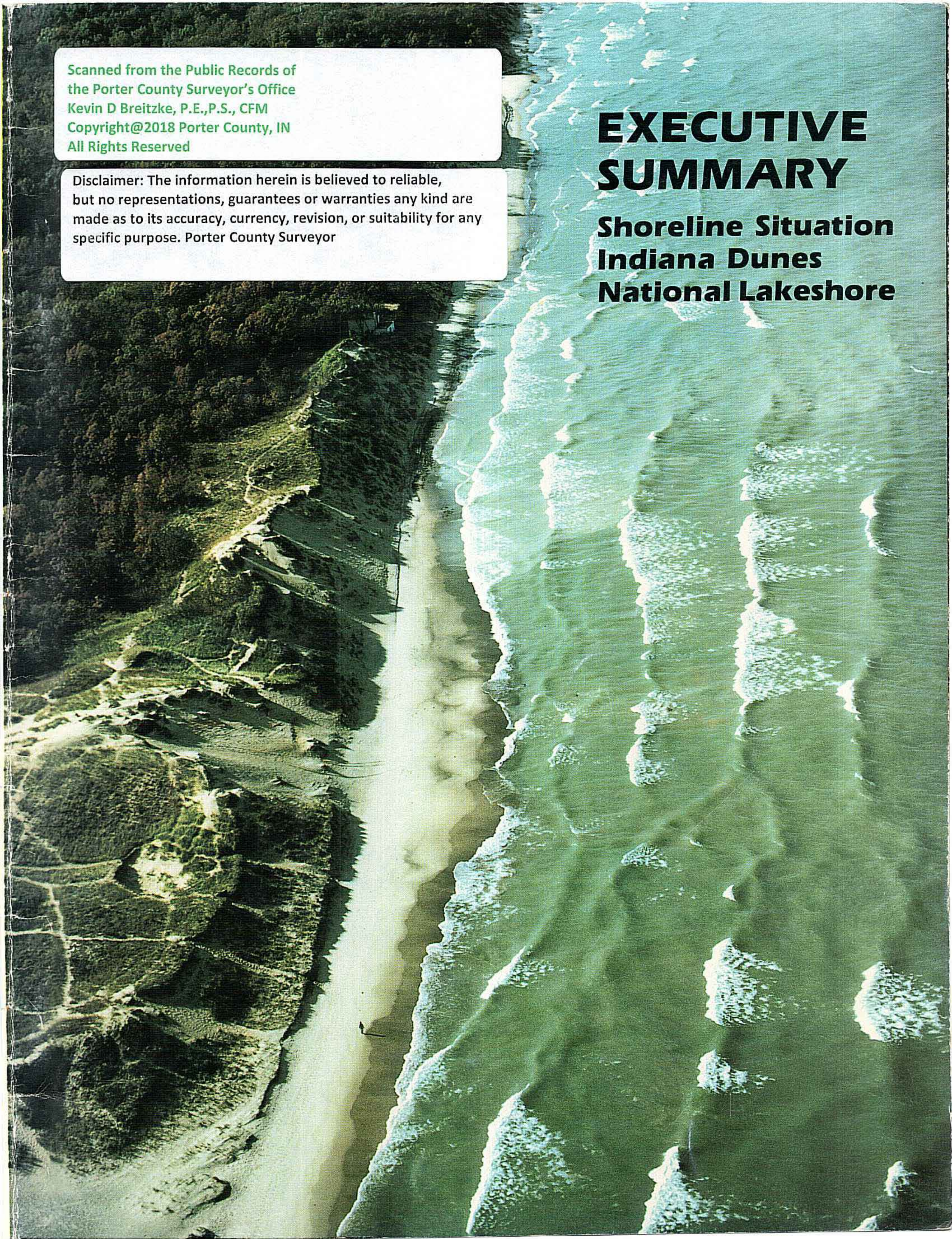
EXECUTIVE SUMMARY

Shoreline Situation Indiana Dunes National Lakeshore



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EXECUTIVE SUMMARY

INDIANA DUNES NATIONAL LAKESHORE SHORELINE SITUATION REPORT

Prepared by

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June, 1986

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INTRODUCTION

The Indiana Dunes National Lakeshore is located along 18 miles of coastline in southern Lake Michigan. This length of coastline is represented by a diversity of federal, state, local and private interests. Among these interests are the Port of Indiana, Indiana Dunes State Park, the communities of Michigan City, Beverly Shores, Porter, Dune Acres, Portage, Ogden Dunes, and Gary and the industries of U.S. Steel, Bethlehem Steel, Midwest Steel and the Northern Indiana Public Service Company (NIPSCO).

In the early 1960's the level of Lake Michigan was going through a period of record lows. Wide beaches and foredunes protected the coastal dune-bluff and provided an abundant recreational resource. From 1964 to 1974 the level of Lake Michigan rose continuously more than 5.5 feet to a new record high. The Indiana Dunes National Lakeshore (IDNLS) was established in 1966 during this period of record rise in lake-level, but at a time when absolute lake-level was still below average. In the early seventies IDNLS was confronted with its first major decision concerning shoreline erosion and coastal protection structures. In 1974 after lengthy study, discussion, and compromise the first major "hard" coastal shore protection structure was constructed along IDNLS coastline. This structure was a 13,000 foot long rock revetment constructed to protect Lake Front Drive in Beverly Shores, Indiana. In that same year a major "soft" shore protection structure, in the form of a beach nourishment fill, was placed in front of Mt. Baldy, immediately west of Michigan City, Indiana. At the time of construction of these two structures National Park Service provided funding through the U.S. Army Corps of Engineers for monitoring their effectiveness and impact along the coast. The Great Lakes Coastal Research Laboratory, Purdue University was selected as the monitoring agency in 1975.

In the decade following construction of these two shore protection structures, lake-levels remained well above average. This persistent condition resulted in additional need for decision making on shore protection and other coastal engineering structures. The National Park Service recognized that there was a need for developing a comprehensive plan for decision making on coastal development along their portion of the 18 miles of multi-interest coastline. As a result of this recognized need the National Park Service provided funding in 1983 for a three year coastal study which would lead to the production of a Shoreline Situation Report on the Indiana Dunes National Lakeshore.

The purpose of this Shoreline Situation Report is to present a complete data base on and rigorous assessment of the shoreline and adjacent nearshore area within the Indiana Dunes National Lakeshore. This report contains a thorough evaluation of coastal parameters and characteristics useful to engineers, planners and managers of Indiana's coastal lands. Emphasis is placed on coastal processes as they relate to historic and contemporary erosion. Particular attention is given to position changes of the shoreline, bluff top, nearshore sand bars, and dune vegetation. Beach and nearshore sediments are analyzed with respect to their contemporary grain properties and compared to historic data to determine areas of change.

An important aspect of this report deals with man-made structures on the coast and their impact on overall coastal stability. Recognizably, the proximity of owners homes to the receding shoreline of Indiana presents a special set of problems. However, poorly conceived coastal erosion control structures can ultimately be more damaging than helpful to overall coastal integrity.

The basic philosophy guiding preparation of this report is that only through judicious planning can optimum benefit be derived from Indiana's coastal resources. The broad data base brought together in this report provides an essential tool for IDNLS planning. Shoreline residents and community governing agencies will also find this report useful for evaluating long and short term impact of proposed coastal development or alteration. It is hoped that this report will provide helpful guidelines to serve IDNLS and the citizens of Indiana in fulfilling a realization of optimizing access, utilization, and protection of its invaluable yet delicate coastal resource.

BACKGROUND

In the fall 1983 the Great Lakes Coastal Research Laboratory Purdue University initiated Phase I of the IDNLS Shoreline Situation Report. Phase I consisted of an extensive study of shoreline and nearshore conditions within a length of coastline identified by the U.S. Army Corps of Engineers as Reach 3 (Figure 1). A report entitled Indiana Dunes National Lakeshore, Shoreline Situation Report, Reach No. 3 Interim Report was completed and distributed in December, 1984. Phase II of this study began in fall 1984 and consisted of hydrographic and topographic surveys, sand sampling, field inventories, aerial photographic analysis, historic data compilation and analysis, and coastal recession and adjustment analysis for IDNLS within U.S. Army Corps of Engineers, Reaches 1, 2, and 3, (Figure 1). The region studied is the shoreline and adjacent nearshore area including all IDNLS property along Lake

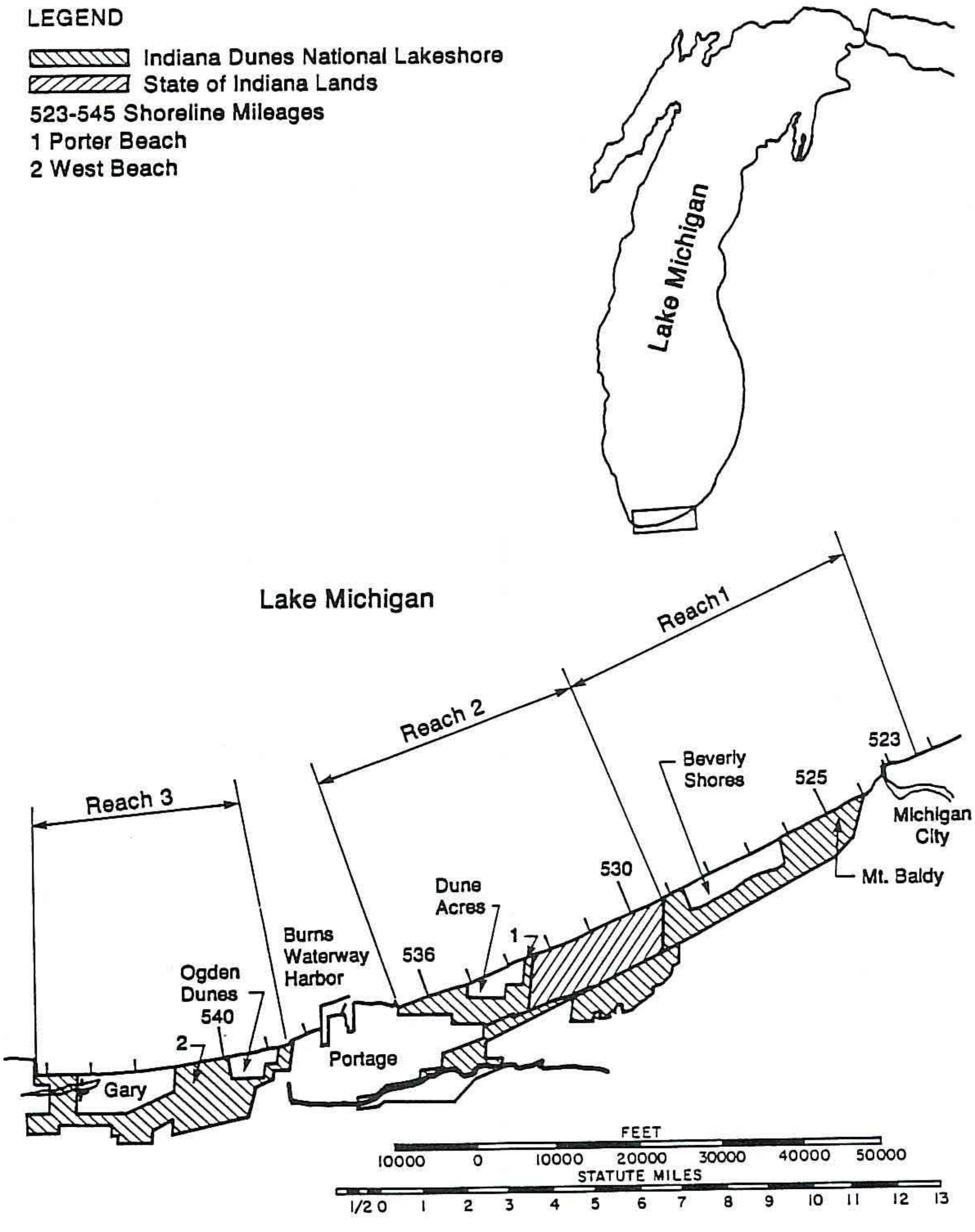

FIGURE 1. Location map of study Reaches 1, 2, and 3.

Michigan between Gary Harbor to the west and Michigan City to the east.

PHYSICAL SETTING

The Indiana Dunes National Lakeshore includes 18 miles of coastline between Michigan City and Gary, Indiana (Figure 1). This coastline of the National Lakeshore consists of a barred tideless beach backed by a vegetatively controlled irregular dune system. There are normally two well defined offshore bars in this region except in areas immediately downdrift of large shore-crossing structures. The outermost bar is relatively stable and is influenced only by severe fall and spring storms. The inner-bar adjusts itself continually to the variable intensity and concentration of breaking wave energy.

Ephemeral bars occur, at irregular intervals, between the inner-bar and shore. These ephemeral bars migrate shoreward and attach themselves to the beach, forming a typical ridge and runnel system. This bar migration process, which is observed in spring and early fall, will bring sand from the shallow water regions to the shore rebuilding the beach profile. The net sediment accumulation from this process is not of major significance, because these accretional forms are eroded by storm waves in the late fall and early spring. However, this material does provide a protective buffer for the first few fall storms.

Longshore currents are responsible for carrying sediment parallel to shore through this region of onshore-offshore transport between the outer-bar and shore. As long as the net sediment transported out of any region, between the outer-bar and the shore, is zero, beach erosion will be minimal. This condition, though trivial, establishes the relationship that longshore sediment transport must be uniform at discrete sequential positions along the shore. If this condition is not met, erosion or accretion must occur within some finite section of the nearshore zone. Thus when structural barriers are introduced across this active zone, sediment transport continuity is no longer maintained and erosion must occur on the downdrift side.

The international Great Lakes Datum of 1955 established low water datum (LWD) for Lake Michigan at 576.8 feet above mean water level in the Gulf of St. Lawrence at Father Point, Quebec. Average monthly surface water levels for Lake Michigan have been recorded since 1860. During that period of time the extreme range of water level variation has been 6.5 feet, from a high of +5.14 feet (LWD) in July, 1886 to a low of -1.45 feet (LWD) in March, 1964. The seasonal variability of the lake level produces highest levels in the summer and lowest levels in the winter. The annual range of water level fluctuation is approximately one to two feet.

From March, 1964 to July, 1974 Lake Michigan experienced the greatest continuous rise in lake-level (+4.7feet) for the 125 year period of record. Lake-levels have remained relatively high throughout the seventies and into the eighties. Current (1986) lake-levels are establishing new monthly record highs for this century. June, 1986 established a new record high for this century of 581.08 feet. Even though lake-levels fluctuated downward in 1976 and 1977 the coastline did not have sufficient time to stabilize dune-bluff slopes and rebuild protective foredunes. Consequently, the buffering normally provided by broad beaches and small foredunes is absent, and high dune-bluffs stand exposed to seasonal storm wave attack. Until a significant reversal or cessation in the current lake-level trend occurs, there is no possibility for the IDNLS coastline to stabilize naturally.

There is very little appropriate data available on wind conditions in the study area and virtually no data on waves. The best available wind data is that collected at the Ogden Dunes, U.S. Weather Bureau Cooperative Station, between 1949 and 1967. These data indicate that the "prevailing" monthly wind is from the south at an annual average speed of 11 knots. However, maximum recorded wind speeds for each month ranged from 44 to 74 knots blowing from the north, northwest, or west. The primary sustained storm periods are in early spring and late fall. It is these sustained storm periods of high winds that cause the greatest coastal erosion and dune-bluff recession in southern Lake Michigan.

Wave measurements in southern Lake Michigan off the Indiana shoreline are essentially non-existent. Visual observations of wave height were made at selected sites along IDNLS during the U.S. Army Corps of Engineers, Littoral Environmental Observation (LEO) program. These data are too subjective and intermittent to be of use in assessing wave climatology and predicting shoreline response. The U.S. Army Corps of Engineers, Coastal Engineering Research Center took limited (2-4 months) wave measurements off Beverly Shores, Indiana in the mid-seventies. These data indicate maximum wave heights at a distance of approximately one-half mile offshore to be between 16 and 20 feet, during extreme storm conditions.

COASTAL PHYSIOGRAPHIC CLASSIFICATION

There is an inherent confusion with terminology applied to the coastal zone. For purposes of this report we intend to limit the use of the term coastal to that region extending from the back-beach bluff and dune system to a water depth of -20 feet from mean still water level (MSWL). This coastal zone will be considered to be composed of three interactive physiographic regions: nearshore, shore and fastland (Figure 2).

The nearshore region begins offshore at a water depth of -20 feet (MSWL) and extends landward to 0 feet (MSWL). Its landward limit is, therefore, the point at which mean still water level intersects the coast, commonly referred to as the shoreline. The -20 foot depth is not selected as an arbitrary offshore limit. Extensive studies along the Indiana coastline by GLCRL (Weishar and Wood, 1979, 1981, and 1983; Wood and Weishar, 1982 and 1984; Wood, Weishar, and Davis, 1979) show that a zone of no net sediment motion exists at depths between -15 and -20 feet (MSWL). The nearshore region is characterized by the presence of one or two permanent longshore sand bars (Figure 2) which migrate onshore and offshore in response to lake-level fluctuation and wind-wave action. Most of the active sediment transport (movement of sand by waves and currents) occurs in this region. Sediment transport within this region usually occurs on a time scale from a few hours to a few days depending on the frequency and duration of local storms. In the region lying at depths greater than -15 to -20 feet (MSWL), which will be referred to as the offshore region , sediment accumulation and depletion occurs on a much longer time scale (annually).

The shore region extends from the shoreline (0 feet MSWL) to the point of intersection of highest high water level with the land. Under current high lake-level conditions the upper limit of this region is usually at the base of the coastal dune or bluff face (Figure 2). Where human structures have been constructed as coastal defenses against erosion, they usually form the upper limit of this region.

The fastland region extends landward from the upper limit of the shore region. For purposes of this report the fastland region will be restricted to the coastal dune-bluff system which is currently exposed to direct wind-wave attack. The fastland region is the site of most construction and human alteration. Stability of the lakeward limit of this region is determined by dune-bluff height, slope of the dune-bluff face, and vegetation.

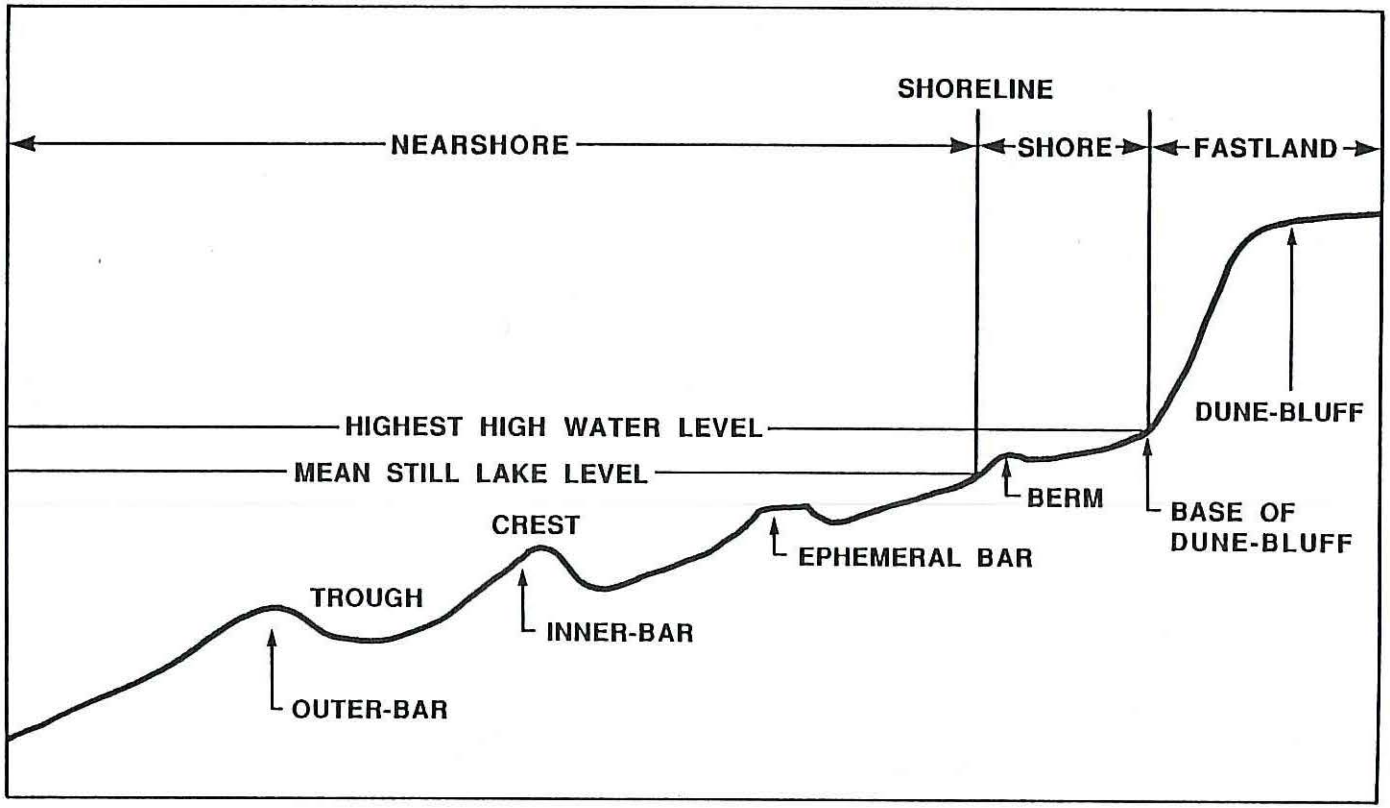

FIGURE 2. Schematic drawing of coastal cross-section.

COASTAL PROCESSES AND RESPONSES

In order to fully understand the results, discussion, and conclusions presented in this summary it is necessary to first have a clear understanding of the coastal process/response system of southern Lake Michigan. Coastal process/response systems of the Great Lakes are generally much more dynamic than their oceanic counterpart. The primary reason for this more dynamic behavior is that mean still water level (MSWL) on the Great Lakes is in a constant state of change. Fluctuations in lake-level on short (1 year) and long (multiple year) time scales are not symmetric. Thus, the annual average variation of MSWL causes an imbalance in the coastal process/response system forcing it to readjust. A change in MSWL does not cause erosion or deposition readjustment in the coastal zone. It does, however, modulate wind-wave energy that is the principal physical force responsible for coastal sediment movement. Technical discussion of this modulation process is presented in Weishar and Wood (1983) and Wood and Weishar (1984).

The primary driving force of Lake Michigan waves and currents is wind. Wind energy transferred to the lake surface is partitioned such that approximately 95% goes into the generation of currents and 5% generates waves (Meadows, 1986). On Lake Michigan, as on all the Great Lakes, wind systems responsible for driving waves and currents are highly variable. Thus, unlike the ocean, currents on Lake Michigan are quite transient both with respect to speed and direction.

As wind-waves approach the coast, they begin to be influenced by the bottom. The shoaling lake bottom slows the wave crests in such a way as to turn (refract) them to aline with the bathymetry. For most of the IDNLS this turning (refraction) tends to aline the wave crests more nearly parallel to the shoreline. As these waves shoal and break they carry water mass shoreward, towards the beach. This rapidly moving water mass is transported in two directions. If waves approach at low angles to the shore (nearly parallel), large quantities of water are carried up the beach and into the back beach dune-bluff toe. This uprush of water, called swash , erodes the dune-bluff base causing slumping and lifts sediment into suspension. Once this water mass rushes up the beach face, it reverses direction and flows rapidly lakeward, called backwash , due to the acceleration of gravity. This backwash carries sediment off the beach face and into the prevailing longshore current.

Erosion and subsequent sediment transport are episodic events which occur in response to the passage of storms at the coast. Figure 3 shows a representative storm track of a low pressure system across Lake Michigan. Also shown in Figure 3 is the sequential development of waves and longshore currents on the IDNLS coast as the storm approaches and passes across the lake. An increase in wave height, as the wind shifts to a more northerly direction, is possible because of an increase in distance over which the wind can transfer energy to the lake surface. Notice also that large waves from the north generate the largest longshore currents (solid arrow), which flow from east to west. The small longshore current (open arrow) flowing west to east, as the storm approaches, is sometimes incorrectly called a flow reversal. It is a current flowing in the opposite direction to the net annual transport direction, but it is not a current reversal. A current reversal is a change in direction of a flowing current brought on by dynamic changes in physical forces which in turn slow the current, stop it, and accelerate it in the opposite direction. The net effect of storms on all three reaches within IDNLS is to direct sediment transport from northeast to southwest.

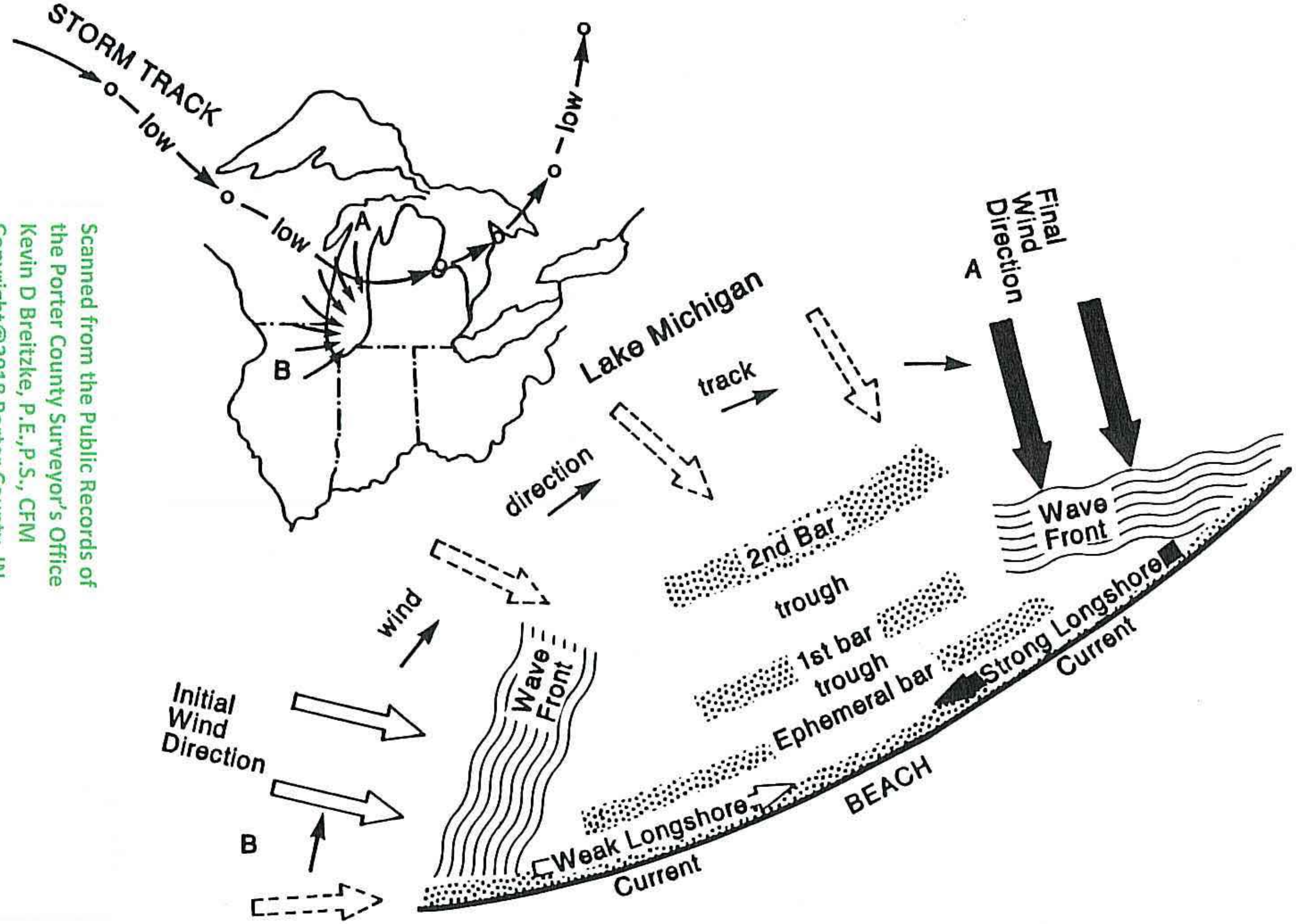

FIGURE 3. Depiction of coastal wave and current conditions during the passage of a low pressure system over Lake Michigan.

COASTAL STRUCTURES

There are four general categories of coastal engineering problems which may require structural solutions: shoreline stabilization, backshore (dune-bluff) protection, inlet stabilization, and harbor protection (Shore Protection Manual, 1984). All four of these categories of coastal engineering structures are present within or adjacent to IDNLS. Figure 4 shows the types of structures or protective works in each of these four coastal engineering problem areas. A listing of factors that should be considered in evaluating each of these problem areas is also given in Figure 4. Hydraulic considerations include wind, waves, currents, storm surge or wind set-up, lake-level variation, and bathymetry. Sedimentation considerations include: sediment size, distribution properties, and characteristics; direction and rate of littoral transport; net versus gross littoral transport; and shoreline trend and alignment. Control structure considerations include selection of the protective works with respect to type, use, effectiveness, economics and environmental impact (Shore Protection Manual, 1984). The other factors listed in Figure 4 are more generally understood and will not be elaborated upon further. It is important to remember that a "no action" alternative should also be considered as a possible solution for any one of these categories of coastal problems.

Classification of coastal structures can be facilitated in various ways depending upon the criteria selected for classification. For the purpose of this report, a classification scheme has been established based upon the degree of impact a structure imposes on the coastal/response system of the beach and nearshore zone. This classification scheme results in three principal groups of structures referred to as primary, secondary and tertitary.

Primary structures are large coastal constructions that form total or near total barriers to sediment transport in the littoral zone. This type of structure is represented by the Michigan City Harbor jetties and breakwater, the Port of Indiana Harbor and adjacent industrial landfill breakwalls and the U.S. Steel landfill breakwalls. Each of these structures extends lakeward across the coastal zone to a distance offshore where sediment transport becomes negligible. Their impact on downdrift shoreline is to increase erosion and subsequent dune-bluff recession as a direct result of longshore sediment transport reduction. Coastal engineers refer to these structures as "total littoral barriers".

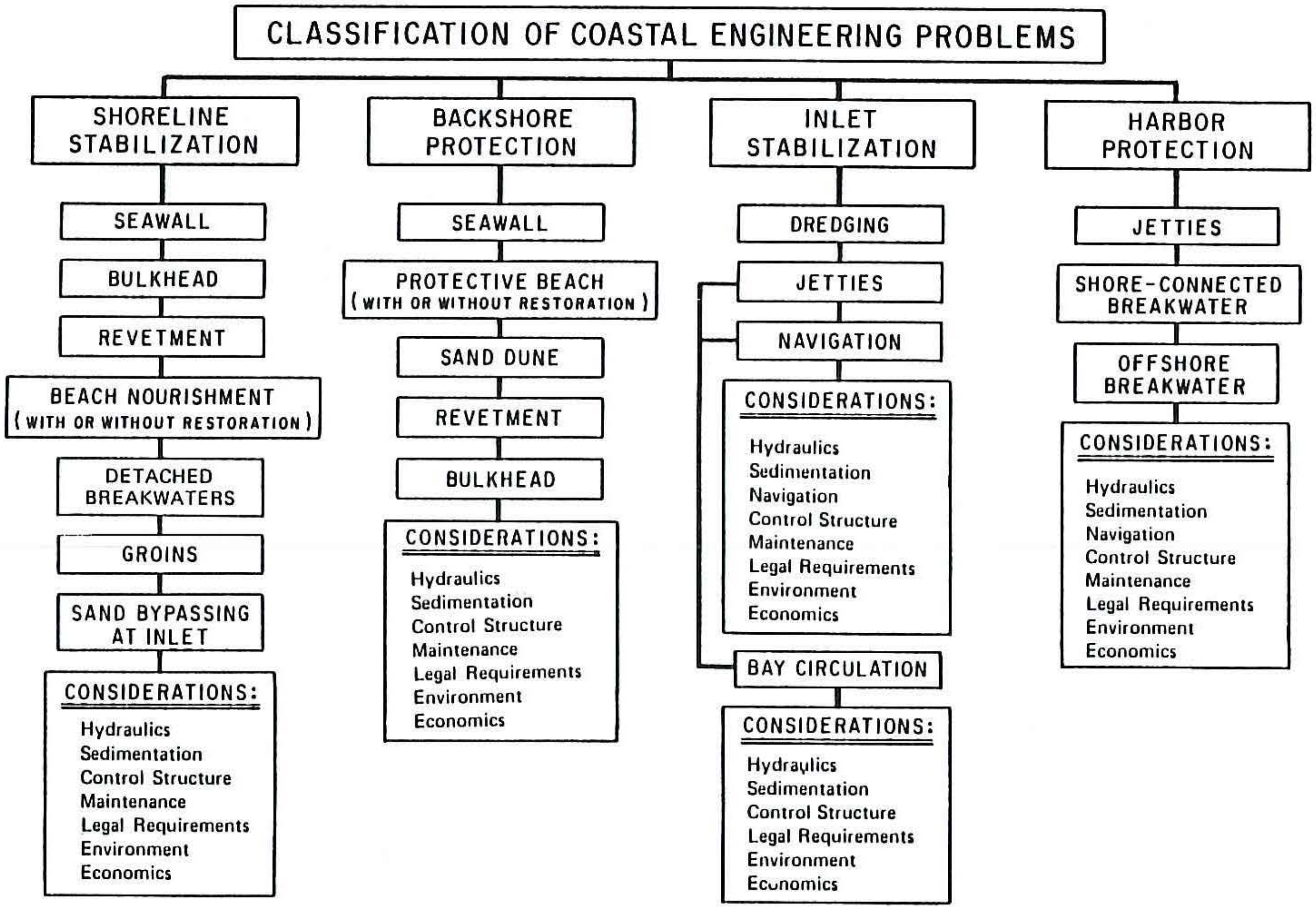

FIGURE 4. Classification diagram of coastal engineering problems. (from CERC, SPM, 1984)

Secondary structures are moderate sized structures that have significant impact on littoral transport, but do not form total littoral barriers. These structures generally affect between 25 and 75 percent of the net sediment transport in the littoral zone. There are three types of secondary structures; shorecrossing, shore-parallel, and combined.

Shore-crossing secondary structures protrude out into the nearshore zone to a distance greater than the inner bar and less than or equal to the outer bar positions. Structures of this type are represented by small inlet jetties such as those at Burns/Portage Waterway in Reach 3. Shore parallel secondary structures are relatively long (100's to 1000's of feet) engineering constructions that significantly influence net sediment transport. These structures can be located onshore such as revetments and seawalls, or offshore such as detached breakwaters. Shore parallel structures are represented by the Beverly Shores Rock revetment in Reach 1 and the sheet steel breakwall system at Porter Beach in Reach 2. Combined secondary structures are those constructed with both shore-crossing and shore-parallel structures. The most common example of this type of structure is a series of shore-crossing groins protruding lakeward from a long rock revetment or conventional seawall system. Structures of this type are not presently exposed in Reaches 1, 2 and 3 of the Indiana shoreline, although such a system was constructed in 1967 in front of NIPSCO at the west end of Reach 2. It is presently burried by sediment.

Tertiary structures are small-sized structures that have localized impact on littoral transport. These structures generally affect less than 10 percent of the net sediment transport in the littoral zone. These structures are typically breakwalls, short groins, longuard tubes, sand bags, and debris piles built or placed on the shore to protect a single coastal residence. Since tertiary structures can be shore-crossing, shore-parallel or combined, their effect on the adjacent shoreline is similar to that of secondary structures. The main difference between secondary and tertiary structures is the distance downdrift and lakeward over which their effect is experienced.

SHORELINE SITUATION REACH 1

Reach 1 contains approximately 7 miles of shoreline and related nearshore area in northeast Indiana. This reach is bounded to the east by the eastern boundary of Washington Park and to the west by the eastern boundary of Indiana Dunes State Park (Figure 1). Reach 1 includes Washington Park, Michigan City Harbor, Beverly Shores, and IDNLS recreation beaches at Mt. Baldy, Central Avenue, and Kemil Road. Michigan City Harbor is a primary structure that forms a total barrier to sediment transport at the eastern end of Reach 1. Breakwater structures have been present at the entrance to Trail Creek since 1836. A series of modifications and additions continued until the present Michigan City Harbor configuration was completed in 1910.

The effect of the harbor on the coastline has been dramatic in both the downdrift (west) and updrift (east) directions. Since construction of the east pier wall, of what is now the parking area at Washington Park, the updrift shore has been dominated by a continuous accumulation of sand. From 1894 to 1923 the updrift shore accreted lakeward at a rate of approximately 10 ft/yr. This accretion fillet extended nearly 1 mile to the east forming a large portion of the present Washington Park beach. In 1930 the beach front at Washington Park was extended to its present position by artificial placement of sand on the beach. This artificial fill extended the beach far enough to reach the lakeward side of the present inner harbor basin.

The dominant westward sediment transport (approximately 60,000 yd^3/yr) continued to carry sand toward the east harbor pier. Some of this sand is transported beyond the east pier at the lighthouse, but it quickly settles to the bottom in the low-energy shadow zone behind the detached outer breakwater. This detached breakwater intercepts wave energy that would normally transport sediment downdrift to the west. Dredging has been required in this area in order to maintain the 18-foot depth required for navigation. From 1920 to 1978 dredging records show that a total of 1.6 million cubic yards of sand have been removed from this harbor area west of the light house.

Downdrift (west) of the Michigan City Harbor structure, shoreline change is even more dramatic. From 1896 to 1937, total shoreline loss downdrift averaged 170 feet for a distance well over 1 mile. A vivid example of downdrift erosion increase is the loss of the Indiana State Prison pumping station located 0.9 miles west of the western pier wall. From 1907 to 1946 the shoreline at the pumping station location receded 375 feet stranding the station on a small point of land protected by rock revetment. Erosion rates in this area averaged approximately 10 feet per year during that time.

The downdrift shoreline continues to experience severe erosion effects from the Michigan City Harbor structures. Two beach nourishment projects (1974 and 1981) have been implemented in front of IDNLS Mt. Baldy recreation area to help mitigate erosion impact. These two nourishment structures provided protection for previously eroding back beach dune-bluff as well as resupplying sediment to the littoral transport system. By fall 1983 essentially all of the 1981 fill had been eroded from the beach. Present dune-bluff recession rates from the Mt. Baldy recreation area west to Beverly Shores are the highest recorded for this area during the past 20 years.

A 13,000 foot rock revetment was constructed in 1974 along Lake Front Drive in Beverly Shores. This secondary structure covers all but the last 0.7 miles of the western end of Reach 1. This revetment structure has been effective in protecting Lake Front Drive, although it has required maintenance repair in certain areas. The shoreline immediately to the east of this structure has receded continuously to its present position some 150 feet landward (south) of the front edge of the rock revetment. Beach in front of the rock revetment has systematically eroded in the direction of net sediment transport (east to west). The significance of these two erosion/recession trends is that the downdrift (westward) erosion effect of the rock revetment is increasing. This increased erosion effect impacts most directly on the 0.7 miles of unreveted coastline which ends at IDNLS Kemil Beach area.

An additional effect of the Beverly Shores rock revetment is nearshore profile degradation. Maximum profile degradation in front of the revetment has occurred between the inner-bar and the shore. The maximum measured profile degradation occurred between 1978 and 1985 immediately west of the Red Lantern Inn where as much as 5 feet of vertical section was lost between the inner-bar and shore.

Reach 1 is in a state of extreme erosion and disequilibrium from the western side of the Michigan City Harbor structure to the Indiana Dunes State Park. The need for developing an immediate plan for long and short term management of this reach is of major importance at this time. Specific recommendations for developing this plan are given at the end of this section.

A detailed analysis of aerial photographs of Reaches 1 to 3 was performed using zoom transfer scope techniques. This analysis was designed to measure the amount of bluff-top recession and variation in "water edge" (MSWL) position which occurred in the time period between photographs. This analysis was carried out for the entire shoreline for the period from 1967 to

1984.

Cumulative bluff-top recession for the time period from 1967 to 1984 within Reach 1 is shown in Figures 5 and 6. The dashed line drawn across the shoreline map indicates the amount of bluff-top recession or accretion for each length of coastline. These two recession maps show a well defined trend of coastal recession in the eastern end of Reach 1 and a pattern of quasistable adjustment along Beverly Shores. Long term erosion at the eastern end of Reach 1 is greatest from Mt. Baldy to the cut-back embayment immediately west of NIPSCO's sheet-steel pile breakwall. Bluff recession rates in this region averaged around 10 ft/yr over the past 17 years. However, this recession rate is low owing to the placement of two beach nourishment fill structures along this coastline in 1974 and 1981. Considering that these two structures provided protection to the dune-bluff such that there were extended periods of 0 loss rate (1974 to 1978 and 1981 to 1983), actual annual recession rates are considerably higher. From 1984 to 1985 recession rates for this area were between 20 and 30 ft/yr.

Table 1 shows dune-bluff and water's edge recession rates for each of the 22 measurement points shown in Figures 5 and 6. West of Mt. Baldy, average annual dune-bluff recession rates are well in excess of typical southern Lake Michigan rates of 1.0 to 5.0 ft/yr. These consistently high rates of recession persist to the eastern end of the Beverly Shores revetment structure. These high rates of recession are the result of three factors. First, this length of coastline is in the downdrift erosion zone created by the Michigan City Harbor breakwaters, and is extended westward by the NIPSCO sheet-steel pile breakwall. Second, this length of coastline is composed of high dune-bluffs which results in a more critically unstable region than exists on a coast composed of lower dune-bluffs. Third, mean lake-level rose continuously from 1967 to 1973 and has remained high from 1973 to present.

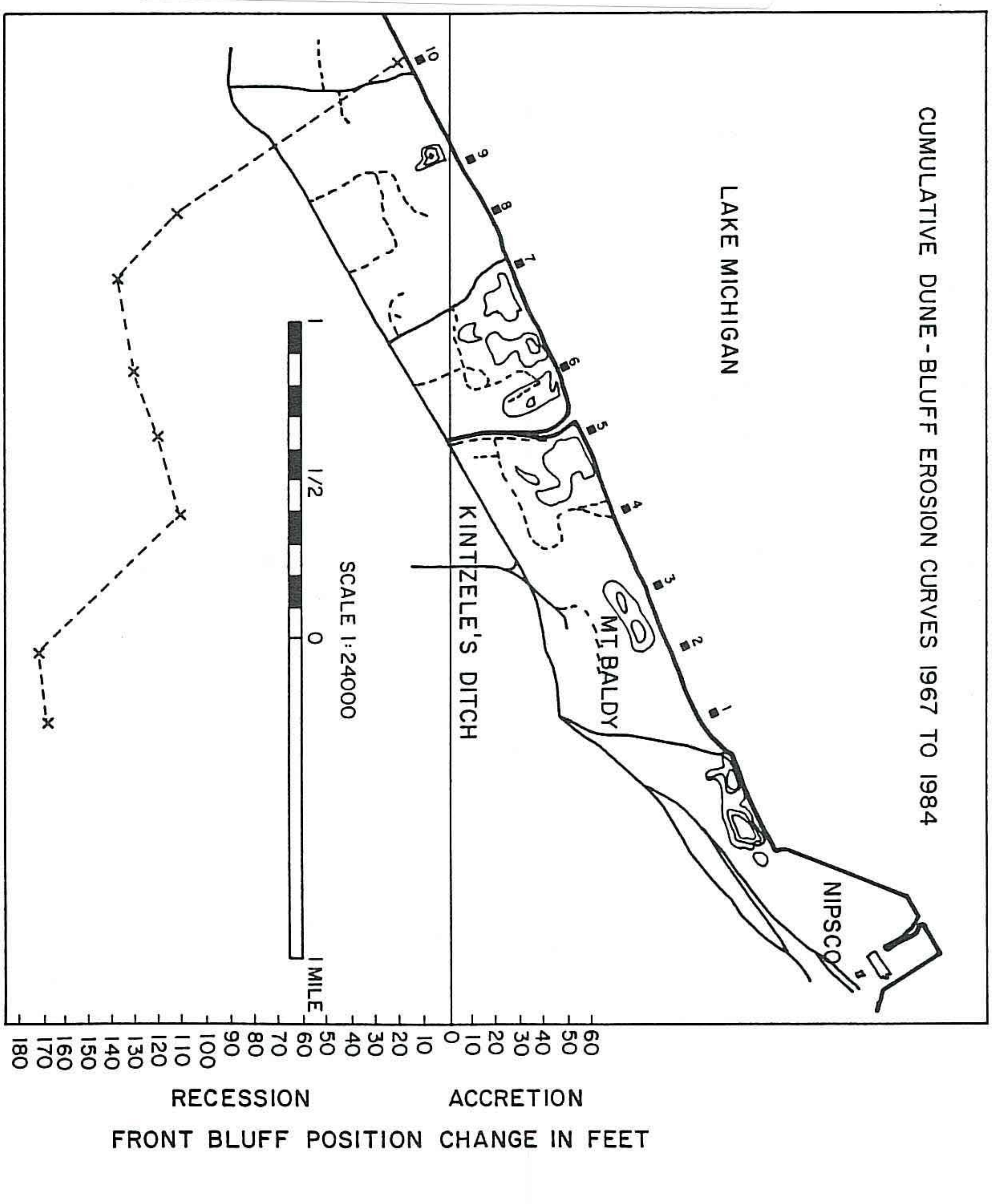

FIGURE 5. Cumulative dune-bluff erosion for the eastern portion of Reach 1.

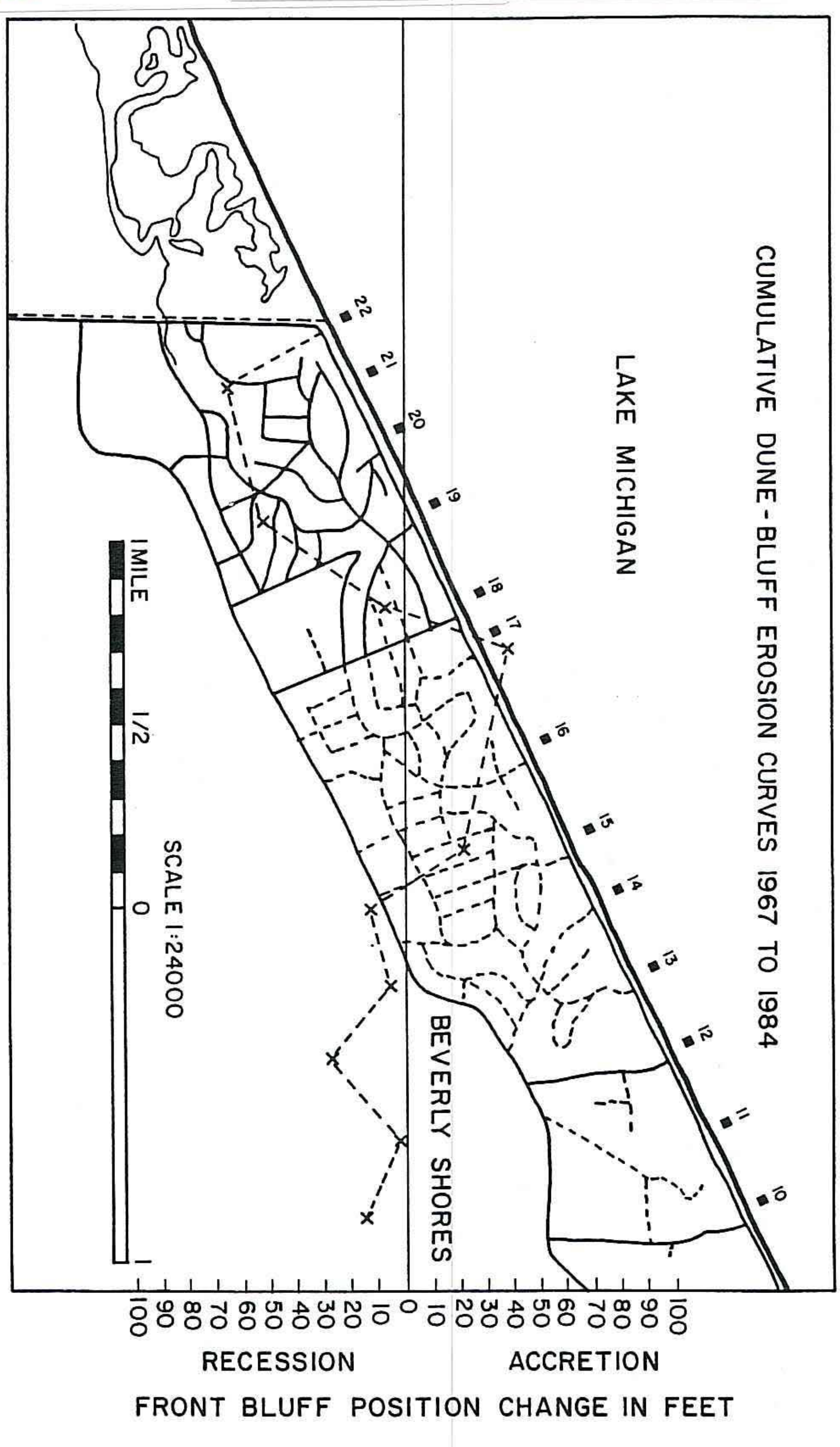

FIGURE 6. Cumulative dune-bluff erosion for the western portion of Reach 1.

Position	Dune-Bluff change (ft) 1967-1984	Dune-Bluff Rate (ft/yr) 1967-1984	Water Edge change (ft) 1967-1984	Water Edge Rate (ft/yr) 1967-1984
1	-167.0	-11.1	-123.0	-8.2
2	-171.0	-10.1	-129.0	-7.6
3	-31.0	-2.1	-60.0	-3.5
4	-114.2	-6.7	-130.6	-7.7
5	-123.2	-7.2	-86.8	-5.1
6	-131.6	-7.7	-145.6	-8.6
7	-137.2	-8.1	-145.6	-8.6
8	-113.8	-6.7	-126.4	-7.4
9	-12.6	-0.7	-44.4	-2.6
10	-14.9	-0.9	-89.4	-5.3
11	-2.8	-0.2	-145.6	-8.6
12	-28.0	-1.7	-137.2	-8.1
13	-5.9	-0.3	-159.8	-9.4
14	-11.8	-0.7	-62.2	-3.7
15	+21.8	+1.3	-27.2	-1.6
16			-61.2	-3.6
17	+37.7	+2.2	-69.6	-4.1
18	-8.3	-0.5	-31.7	-1.9
19	-53.2	-3.1	-116.2	-6.8
20			-98.0	-5.8
21	-66.7	-3.9	-113.1	6.7
22	-30.8	-1.8	-53.2	-3.1

TABLE 1. 1967-1984 Dune-bluff and Water Edge Change. Change in of dune-bluff and water edge from 1967 to 1984 throughout Reach 1. Positions 1 to 22 are shown in Figures 5 and 6.

The dune-bluff recession rates from 1967 to 1984 for Beverly Shores (Figures 5 and 6) are highly variable. Since 1974, when the rock revetment structure was constructed, dune-bluff recession rates have increased in the western end of Beverly Shores, west of the Red Lantern Inn. This result would be anticipated since this is the only area of Beverly Shores coastline which lacks revetment structures. (Note: A 450 foot length of revetment has recently been placed along a portion of this coast to protect a failing section of Lake Front Drive.) The variability of dune-bluff recession rates is a direct result of private home locations and tertiary protection structures which cause differential trapping of sediment and pocket beach formation.

The revetment structure has been in place at Beverly Shores from 1974 to present, therefore, a set of dune-bluff and water edge recession rates were calculated for the period of lake-level rise from 1967-1973. These values are shown in Table 2. Dune-bluff recession rates for this time period show the same variability as they did for the longer time period (see Table 1).

The most striking results of these calculations is the extremely high rate of water edge recession. Water edge recession rates for 1967 to 1973 are 2 to 5 times higher than those from 1967 to 1984. This is a direct result of the rapid rise in lake-level from 1964 to 1973, but there is an important point to note. The coastline of Beverly Shores in 1960 is characterized by a broad sandy expanse of beach with small foredunes and little vegetation. The vegetated dune-bluff in many areas was in approximately the same position as it is in 1984. In 1967, increase in lake-level had resulted in narrower beach widths, but still had not caused adverse dune-bluff recession. By 1973 lake-level rise had greatly narrowed beach width throughout Beverly Shores resulting in total elimination of beach in front of 4 prominent lakeside buildings (including the Red Lantern Inn). Tertiary armor structures were present and the differential erosion caused by these structures mirrored the situation in extreme western Beverly Shores in 1985. However, in many areas of Beverly Shores dune-bluff position in 1973 had remained relatively stationary (see Table 2). A rock revetment was then placed in late 1973-1974 resulting in an armoring of the dune-bluff with beach in front of most of the 13,000 lineal feet of structure. From 1973 to present, water edge recession represents a real loss of beach material from in front of the revetment structure. Spring 1984 aerial photography, and a 1985 site inspection, showed that the eastern half of Beverly Shores is devoid of beach in front of the revetment structure. Beach conditions in 1986 are even more degraded with the only usable beach being the one trapped east of the Red Lantern Inn and the IDNLS Kemil Beach recreation area. It is possible that the trapped beach east of the Red Lantern Inn will be removed in the fall 1986 - winter 1987 storm season.

Position	Dune-Bluff change (ft) 1967-1973	Dune-Bluff Rate (ft/yr) 1967-1973	Water Edge change (ft) 1967-1973	Water Edge Rate (ft/yr) 1967-1973
10	0	0	-74.5	-12.4
11			-112.0	-18.7
12			-72.8	-12.1
13	+37.0	+6.2	-136.2	-22.7
14	-17.8	-3.0	-29.6	-4.9
15	+16.3	+2.7	-43.5	-7.3
16			-61.2	-3.6
17	+37.7	+6.2	-78.3	-13.1
18	-4.1	-0.7	-82.8	-13.8
19	-19.6	-3.3	-72.8	-12.1
20	+53.2	+8.9	-53.2	-8.9
21	-75.4	-6.3	-100.1	-16.7
22	-29.4	-4.9	-33.6	-5.6

TABLE 2. 1967-1973 Dune-Bluff and Water Edge Change. Change in position of dune-bluff and water edge from 1967 to 1973 along Beverly Shores, Indiana coastline. Positions 10 to 22 are shown in Figure 6.

Summary and Recommendations

There are two distinct sections of coastline which make up most of the coastal extent of Reach 1. The eastern section, from Michigan City to the eastern end of the Beverly Shores revetment, is an area of high dune-bluff recession. Recession rates range from 2 to 4 times above normal (in the Mt. Baldy area) to the upper limits of normal recession (west of Kintzele's Ditch). The beach nourishment fills in 1974 and 1981 were extremely effective in reducing dune-bluff recession at and adjacent to Mt. Baldy. From early spring, 1984 to the present, this eastern section of Reach 1 has undergone devastatingly high rates of dune-bluff recession, ranging from 10 to 30 feet per year. The western section, extending along 13,000 feet of revetment in Beverly Shores, is an area that either lacks beach at the shoreline or has limited sections of "trapped" beach. This area is currently "stabilized" at the shoreline by the presence of a revetment structure. However, nearshore bottom changes indicate that profile erosion is taking place in front of the revetment structure. This loss of profile contributes to toe failure of the revetment.

The following is a list of conclusions and recommendations for consideration in future planning and management of Reach 1:

1. It is important that the large beach nourishment project planned for the eastern portion of Reach 1 be completed as soon as possible. This project completion is necessary for shore protection as well as for the maintenance of safe bathing conditions in front of Mt. Baldy. The existing exposed clay layers in front of Mt. Baldy create an unsuitable condition for optimum bather safety.

2. If Lake Front Drive is going to be maintained, it will be necessary to construct shore protection structures to prevent further dune-bluff recession. Portions of the roadway west of the Red Lantern Inn are in most immediate danger of failure. *It must be recognized that construction to mitigate existing dune-bluff recession will have negative impact on adjacent and downdrift shoreline.* Recreational beach at Kemil Road (East State Park Road) will be greatly reduced or lost entirely.

3. In order to maintain the effectiveness of the existing revetment structure in Beverly Shores, continued maintenance and additional construction will be necessary. Future costs related to this maintenance and construction will most likely exceed the cost of the existing structure.

SHORELINE SITUATION REACH 2

Reach 2 contains approximately 6.5 miles of shoreline and related nearshore area in Northwest Indiana, bordered by the eastern boundary of the Indiana Dunes State Park to the east and the Bethlehem Steel landfill breakwater to the west (Figure 1). This reach includes the Indiana Dunes State Park, the community of Dune Acres, a portion of the community of Porter, and an undeveloped portion of IDNLS. The town of Porter and most of Dune Acres have a nearly continuous series of sheet steel seawalls. A number of these structures are currently threatened, failing or under repair. Their impact on the IDNLS undeveloped coastline in western Reach 2 is minimal to non-existent.

Cumulative bluff-top recession for the time period from 1967 to 1984 within Reach 2 is shown in Figures 7 and 8. The dashed line drawn across the shoreline map indicates the amount of bluff-top recession or accretion for each length of coastline. These two recession maps show low rates of recession interspersed with accretion throughout most of Reach 2. This pattern of erosion and build-up is indicative of a relatively stable coastline. Table 3 shows the dune-bluff and water edge recession rates from 1967 to 1984 for Reach 2. It is interesting to note that the area of western Porter beach and eastern Dune Acres (positions 29 and 30) is characterized by high dune-bluff recession rates. It is not clear why this area should experience higher than normal recession. There are no unique physical or physiographic factors which appear to be responsible for this recession. It is possible that these high rates resulted from the historic impact of seawall construction in this region of coast.

The coastline from western Dune Acres to the Bethlehem Steel landfill breakwater is generally accreting. This build-up of material at the shoreline is shown in Figure 8 at positions 31, 32 and 33. In order to show the extensive accretion updrift from the Bethlehem Steel breakwater a cumulative water edge position curve was calculated for the western half of Reach 2, Figure 9. The dashed curve in Figure 9 becomes positive (accretion) at position 33 and continues to expand westward to position 39. The rates of water edge accretion are given in Table 3, positions 33 to 39. The undeveloped portion of IDNLS within Reach 2 is located in this region of rapidly accreting shoreline.

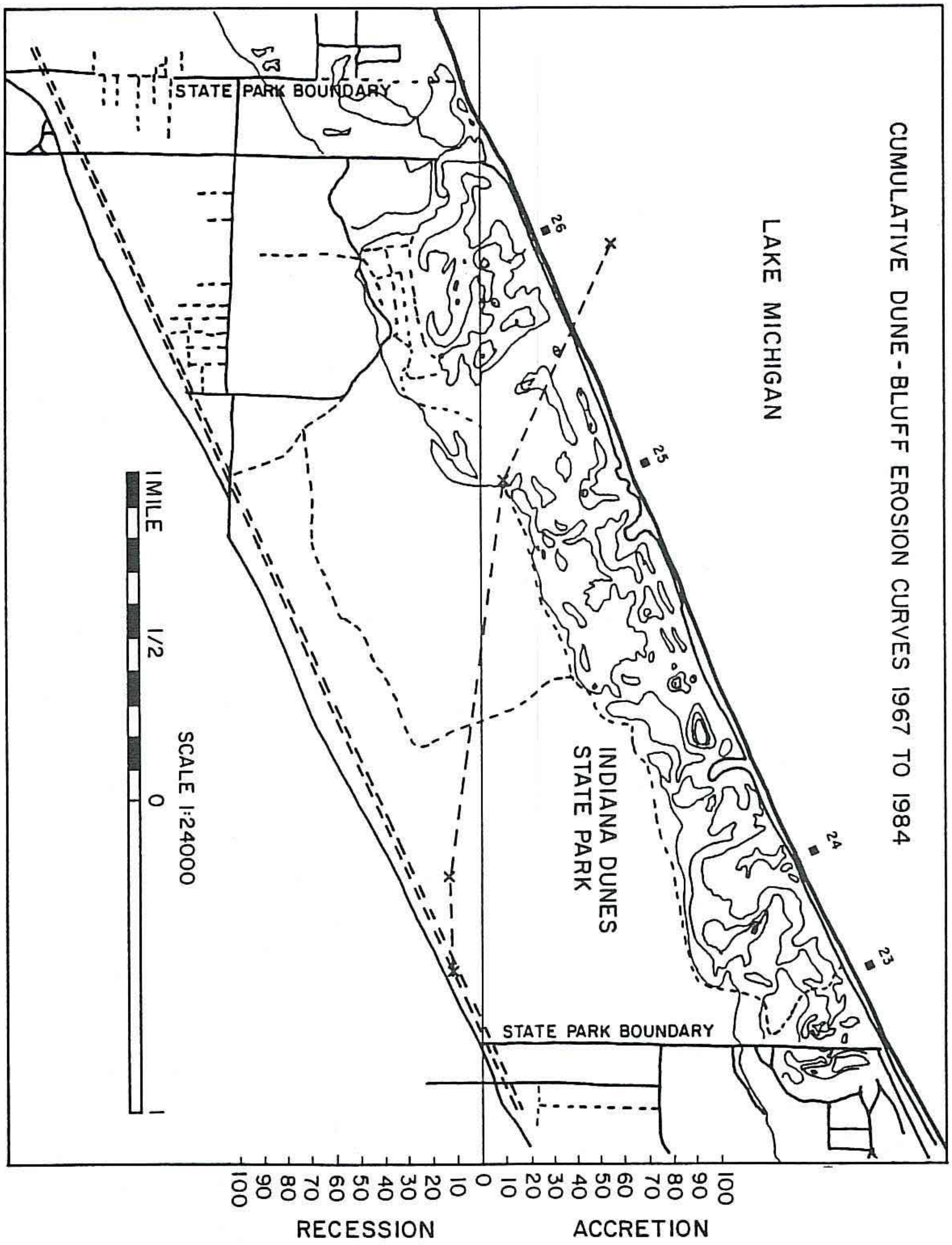

FIGURE 7. Cumulative dune-bluff erosion for the eastern portion of Reach 2.

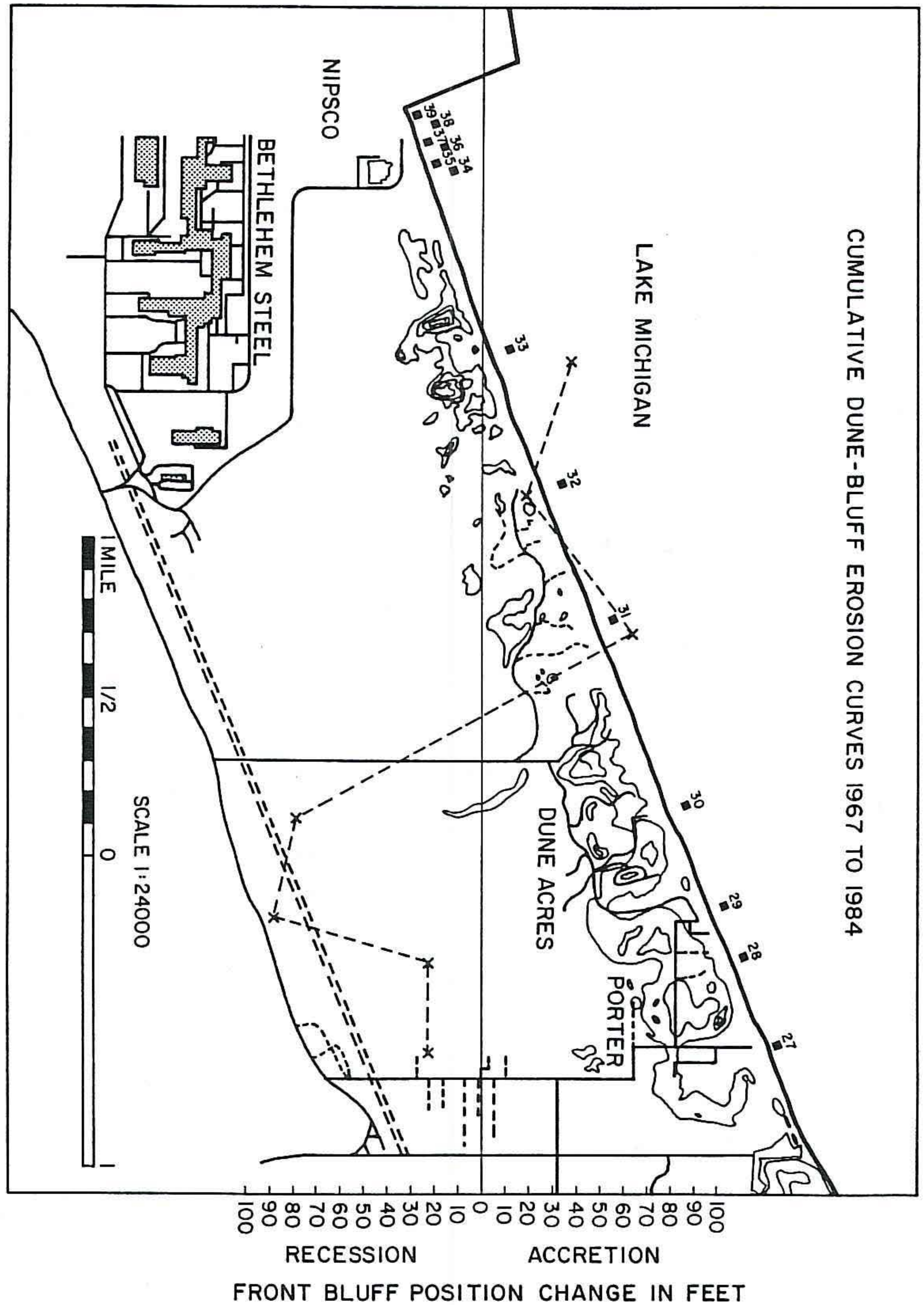

FIGURE 8. Cumulative dune-bluff erosion for the western portion of Reach 2.

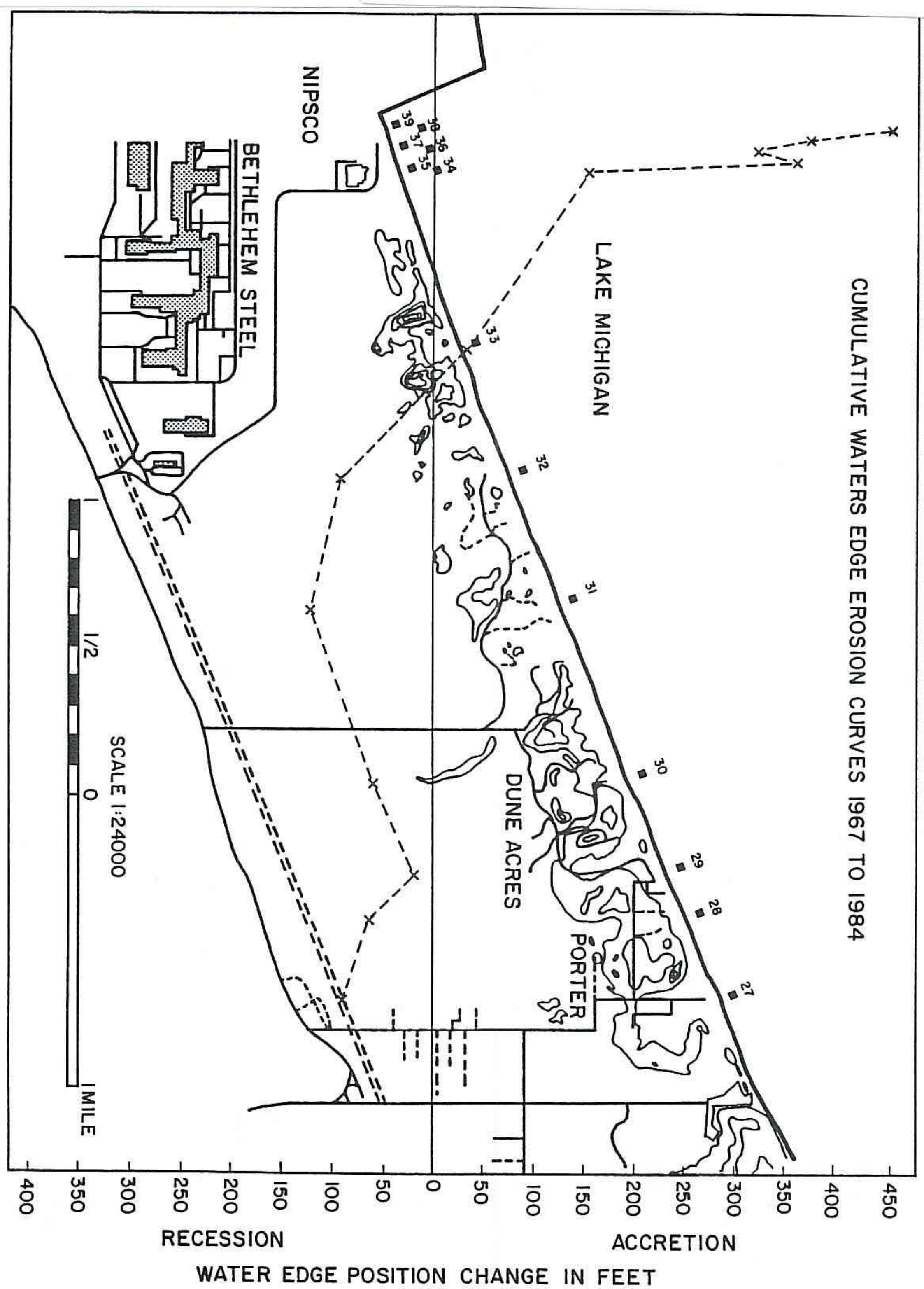

FIGURE 9. Cumulative water edge position change for the western portion of Reach 2

Position	Dune-Bluff (ft) 1967-1984	Dune-Bluff Rate (ft/yr) 1967-1984	Water Edge (ft) 1967-1984	Water Edge Rate (ft/yr) 1967-1984
23	-11.6	-0.7	-53.7	-3.2
24	-12.9	-0.8	-14.3	-0.8
25	+9.2	+0.5	-19.9	-1.2
26	+55.1	+3.2	-5.8	-0.3
27	-20.4	-1.2	-90.5	-5.3
28	-20.7	-1.2	-65.1	-3.8
29	-88.4	-5.2	-20.8	-1.2
30	-78.8	-4.6	-61.3	-3.6
31	+64.4	+3.8	-123.2	-7.2
32	+19.6	+1.2	-89.6	-5.3
33	+36.4	+2.1	+36.4	+2.1
34			+145	+8.5
35			+153	+9.0
36			+361	+21.2
37			+324	+19.1
38			+372	+21.9
39			+449	+26.4

TABLE 3. 1967-1984 Dune-Bluff and Water Edge change. Change in position of dune-bluff and water edge from 1967 to 1984 throughout Reach 2. Positions 23 to 39 are shown in Figures 7 and 8.

There is currently a plan to dredge material from the nearshore area of this zone of accretion in western Reach 2. This proposed dredging should not adversely influence shoreline stability along IDNLS property. Material removed from this accretion area should be bypassed to downdrift beach areas or transported back updrift to eroding shoreline areas.

Summary and Recommendations

Most of Reach 2 shoreline is receding at normal "background" erosion rates or is accreting. In the vicinity of human shore protection structures, recession rates appear to be above average for this reach. In the extreme western end of Reach 2 where IDNLS property is located, large amounts of sediment are being trapped by the Bethlehem Steel breakwater structures. This sediment trapping has resulted in a large depositional fillet along IDNLS property.

The following is a list of conclusions and recommendations for consideration in future planning and management of Reach 2.

1. It is important to try to maintain the present shoreline balance in Reach 2. However, erosion, aggravated by existing high lake-levels, will most likely result in more tertiary shore protection structures being built in the community of Dune Acres and along Porter beach. If these protective constructions are small scale they should not have significant impact on IDNLS beach to the west, but they may cause higher local loss of beach in Dune Acres and Porter Beach.

2. Development of access to IDNLS beach in Reach 2 may be desirable. This stretch of beach is wide and will remain so owing to its location updrift from Bethlehem Steel's landfill breakwater.

3. Future periodic dredging of the accreting nearshore area in western Reach 2 will most likely be necessary. Dredged material should be bypassed to down drift beaches or transported back updrift to eroding shoreline areas.

SHORELINE SITUATION REACH 3

Reach 3 contains approximately 6 miles of shoreline and related nearshore area in northwest Indiana, bordered by two primary structures; Burns Waterway Harbor to the east and the U.S. Steel landfill to the west (Figure 1). This reach includes the community of Ogden Dunes, IDNLS's West Beach Unit, the city of Gary's beach (in front of the community of Miller), Gary's Marquette Park, and the IDNLS's Miller Woods.

A series of four maps, Figures 10 to 13, drawn for the region from Burns/Portage Waterway to U.S. Steel show the cumulative bluff-top recession for the period from 1955 to 1979. The dashed line drawn across the shoreline map indicates the amount of bluff-top recession or accretion for each length of coastline. These four maps show very marked erosion at the eastern end (Burns/Portage Waterway area) and deposition at the western end (U.S. Steel breakwater) of this section of coastline. Long term erosion at the eastern end of Reach 3 is greatest at Burns/Portage Waterway (approximately 125 feet of recession from 1955 to 1979) and reaches a point of zero recession approximately five houses into the eastern end of Odgen Dunes. During this same time period the remainder of Odgen Dunes shoreline shows a "net" gain (lakeward accretion) in bluff-top position which ranges from a high of +43 feet to a low of +20 feet. West of Ogden Dunes in the IDNLS West Beach Unit the "net" bluff-top recession is essentially zero for the same time period, 1955 to 1979. This trend continues to just west of Marquette Park where "net" accretion begins, and continues to the U.S. Steel breakwater. In 1967 the large breakwaters forming Burns Waterway Harbor were constructed at the east or updrift end of Reach 3. These structures impacted significantly on the littoral (sediment) drift which would normally pass into Reach 3. Lake-level during the period from 1955 to 1964 dropped almost continuously to a record low of 575.40 feet (LWD). The effect of this drop in lake-level on the shoreline recession data presented so far is to minimize apparent shoreline loss. This minimization occurs because the accretion of "beach dunes" and the resulting lakeward advance (positive values) of the new bluff-top between 1955 and 1966 (when the lake began to rise again) is a buffer to the high loss rates (negative values) of the most recent 17 years. To better represent recent shoreline conditions, another bluff-top recession map was prepared using aerial photographs from 1969 to 1979.

Figure 14 shows a map of bluff recession from 1969-1979. This map shows bluff-top recession occurring throughout the eastern portion of Reach 3. The maximum cumulative recession is still at Burns/Portage Waterway (-225

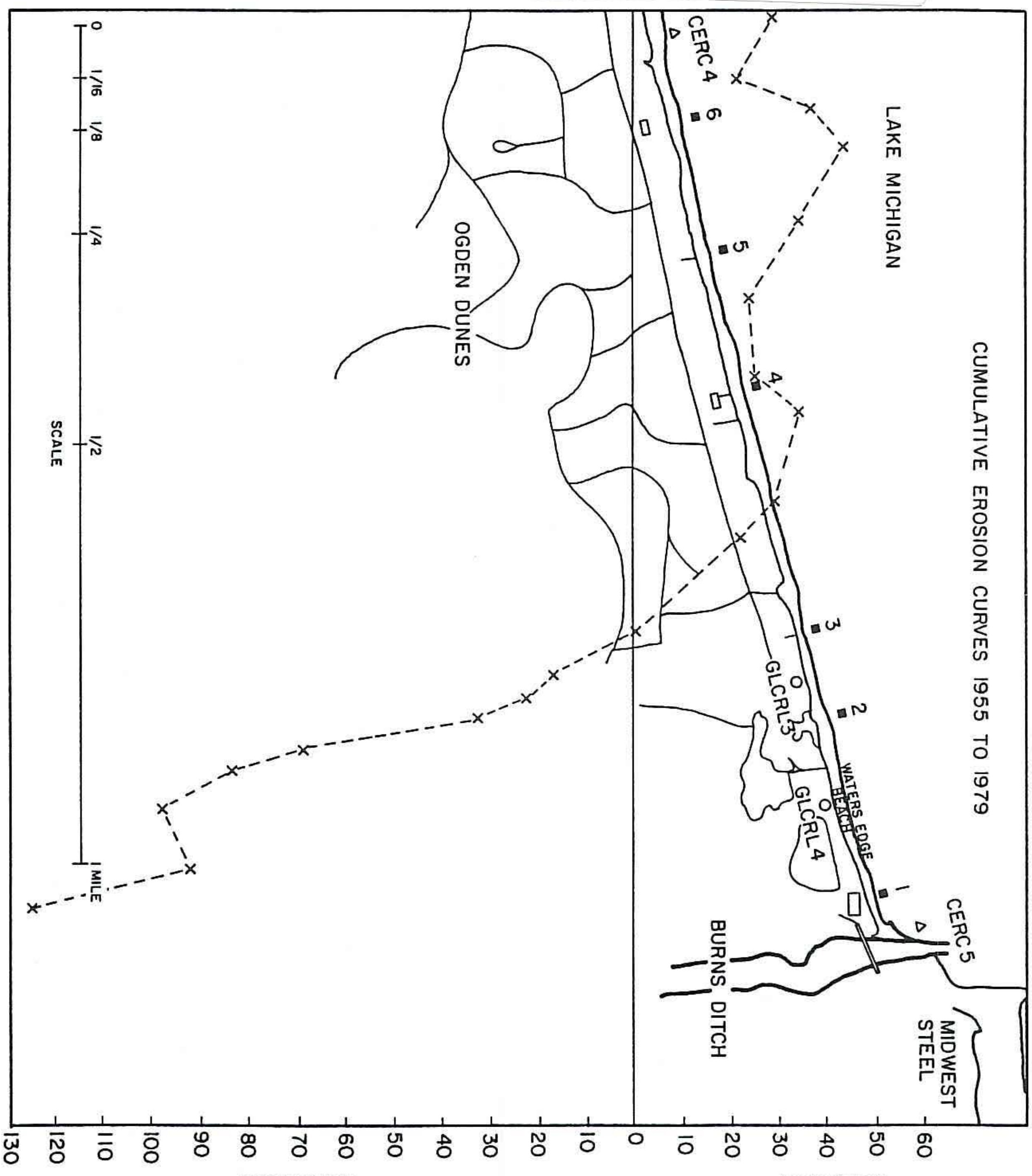

FIGURE 10. Cumulative dune-bluff erosion for the eastern portion of Reach 3.

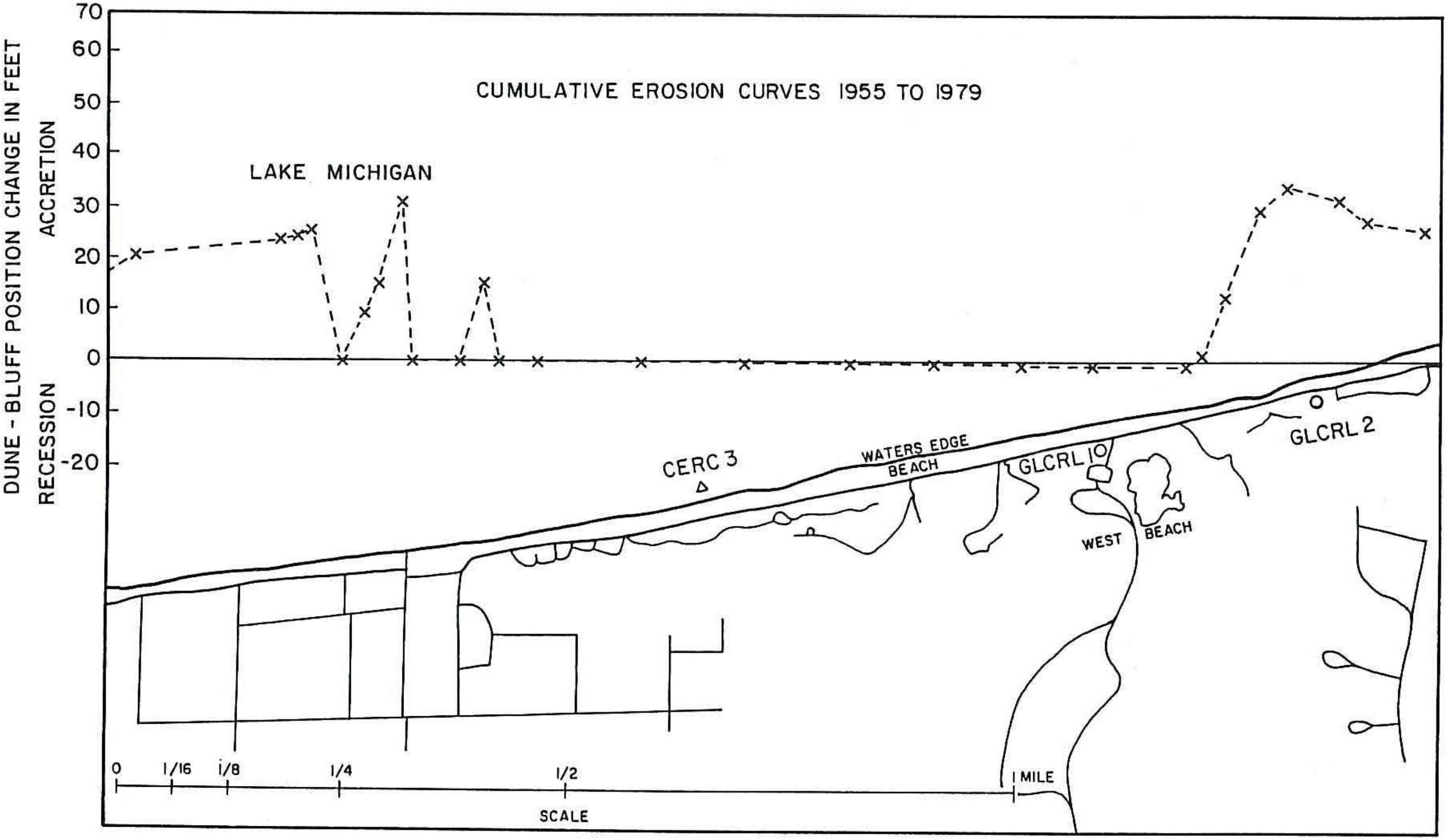

FIGURE 11. Cumulative dune-bluff erosion for the east-central portion of Reach 3.

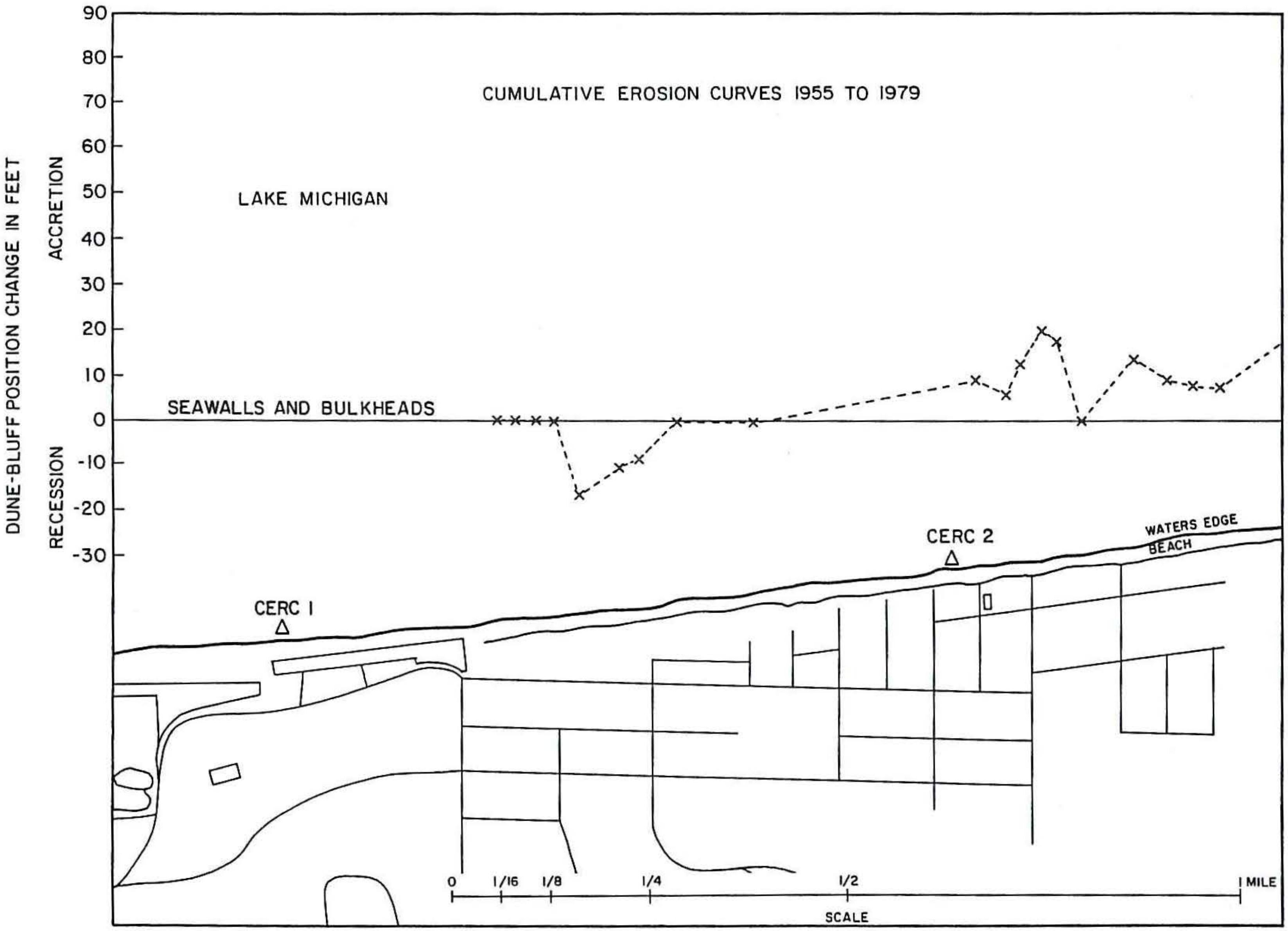

FIGURE 12. Cumulative dune-bluff erosion for the west-central portion of Reach 3.

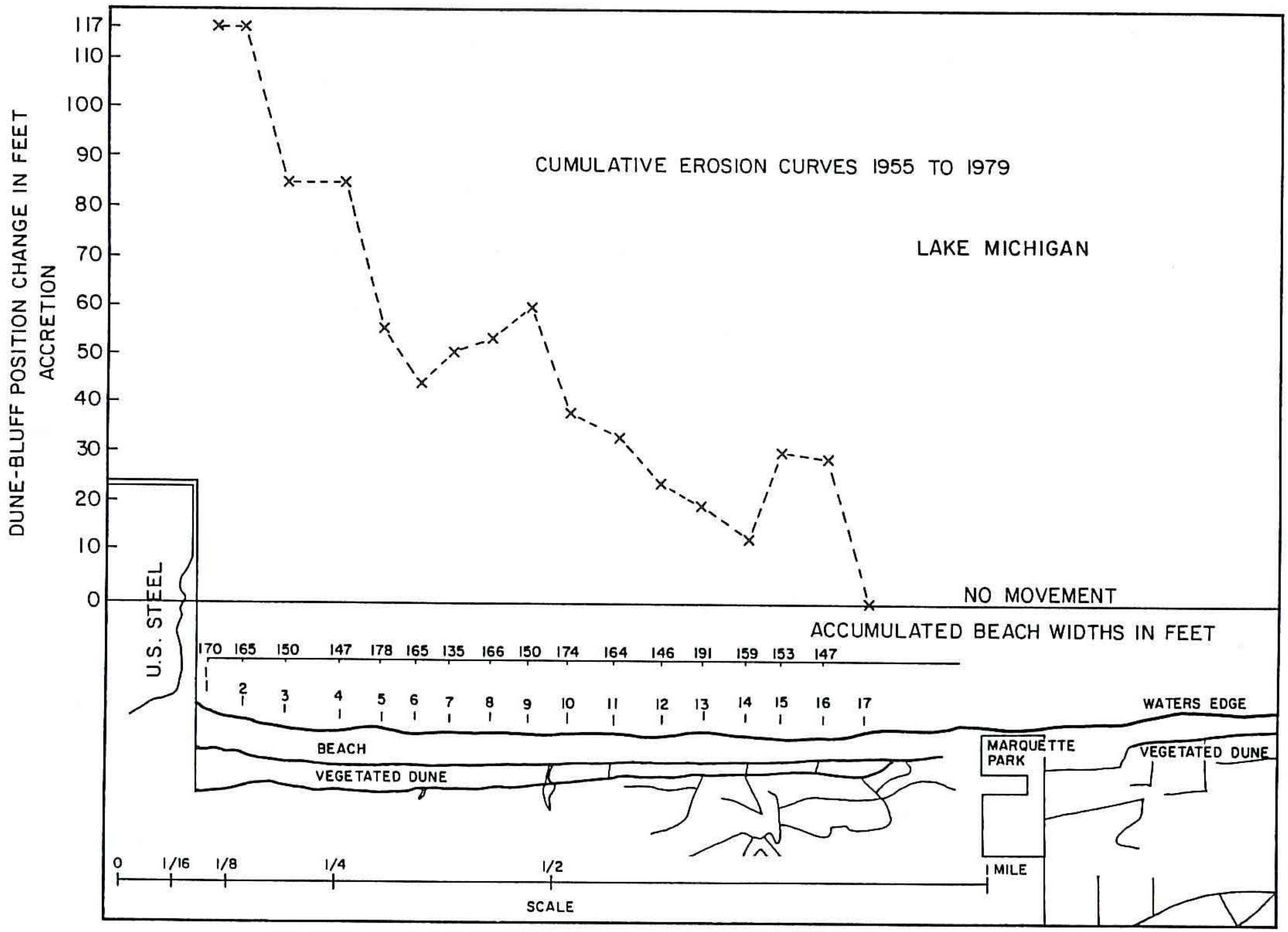

FIGURE 13. Cumulative dune-bluff erosion of the western portion of Reach 3.

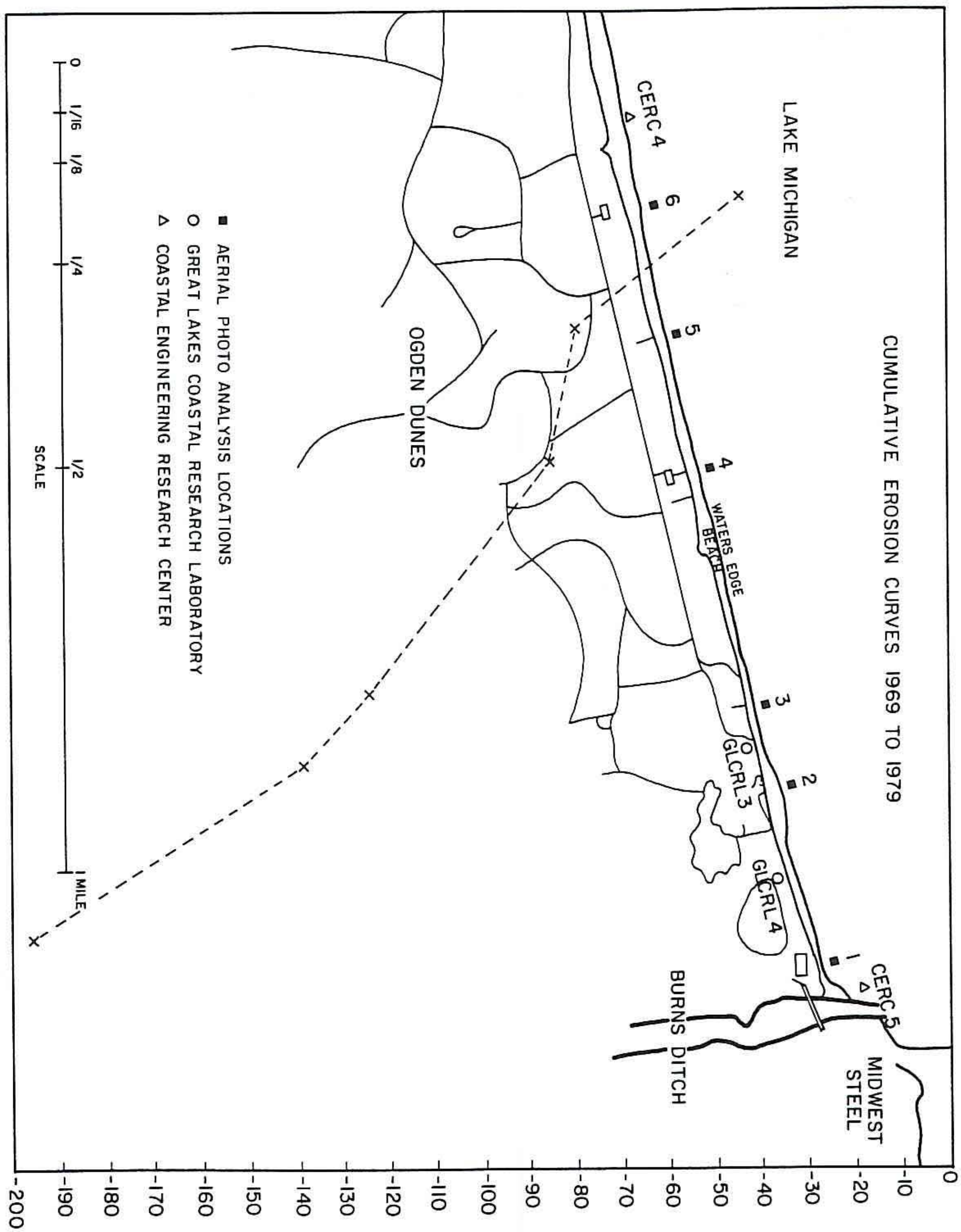

FIGURE 14. Cumulative dune-bluff erosion from 1969 to 1979 for the eastern portion of Reach 3.

feet), but the point of zero recession is now west of Ogden Dunes in the IDNLS West Beach Unit. Two factors contribute to the continuous erosion along this section of coastline during the past 10 to 15 years. First, lake-level has been rising and is remaining at near record high levels. Second, the updrift structures at Burns Waterway Harbor and, to a lesser degree, Burns/Portage Waterway are restricting sediment transport along the Indiana shoreline just east of Ogden Dunes.

Table 4 lists the specific amounts of linear bluff recession for the period of analysis from 1969 to 1984. The maximum lake-level which occurred between each measurement period is recorded in the column labeled High Lake-Level. This table also shows the episodic nature of bluff-top recession. Notice that the amount of bluff-top loss in each sequential year is highly variable. As anticipated, the years of near record high lake levels (1973 and 1974) correspond to periods of high bluff-top loss.

The average rates of bluff-top recession range from -17.0 feet per year at Burns/Portage Waterway (site 1) to -3.3 feet per year at the eastern end of IDNLS West Beach Unit (site 6). This latter loss rate of -3.3 feet per year is within the typical range of 'background erosion' observed for the total Lake Michigan shoreline.

Sediment transport volume in the actively eroding eastern section of Reach 3 (Figure 14) was calculated from shoreline erosion loss rates. Calculations using bluff-top recession and bluff height were performed to determine the amount of material which is available for sediment transport in the region from Burns/Portage Waterway to the east end of Odgen Dunes. These calculations were carried out for the years 1969 to 1978. 1978 is used as the ending year for the calculations because there is no change in bluff position from 1978 to 1979. The total loss of material from the bluff is calculated to be 125,339 cubic yards in 8 years. This results in an average loss of approximately 14,000 cubic yards per year.

Year	1	2	3	4	5	6	High Lake Level
1955							
	+106	-	-	-	-	-	
1969							579.85
	-23	0	0	-5	0	0	
1970							579.32
	-12	-25	-24	-10	0	0	
1971							579.90
	-10	-5	-10	0	-11	0	
1972							580.27
	-81						
1973							581.00
			NO PHOTOGRAPHS				
1974							581.13
	-47	-79	-77	-69	-55	-42	
1975							580.50
	-23	-17	0	0	0	0	
1976							580.50
	0	-12	-12	0	-12	0	
1977							578.56
	0	0	0	0	0	0	
1978							578.99
	0	0	0	0	0	0	
1979							580.05
	-59	-20	-32	-18	-19	-7	
1984							580.21
Net Loss 1969-84	-255	-158	-155	-102	-97	-49	
Rate (ft/yr)	-17.0	-10.5	-10.4	-6.8	-6.5	-3.3	

TABLE 4. Bluff-top recession rates in feet for six selected sites from Burns/Portage Waterway to the west end of Ogden Dunes. Site positions are shown on bluff-top recession maps.

Summary and Recommendations

Reach 3 is located along the shoreline of northwest Indiana, bordered by Burns Waterway Harbor to the east and the U.S. Steel landfill to the west. The "net" transport of sediment throughout Reach 3 is from east to west.

The eastern portion of Reach 3 is highly industrialized comprising Bethlehem Steel, Burns Waterway Harbor, Midwest Steel, and the new harbor facility at Burns/Portage Waterway. The shoreline in this eastern portion is composed primarily of rock revetment breakwater and shore protection structures except for 3600 feet of open coast fronting the property of Midwest Steel. The Burns Waterway Harbor (constructed in 1967) presently acts as a total littoral barrier to sediment transport along the coastline. This has resulted in a dramatic increase in erosion rates for a distance of approximately 1 to 2 miles downdrift (westward) from this primary coastal structure. Midwest Steel has started to construct a rock revetment along the only open shoreline in the eastern portion because of the severe erosion conditions that result from the blockage of updrift sediment input to the shoreline.

The central portion of Reach 3 is bounded by Ogden Dunes to the east and the Gary community of Miller to the west. Between these two communities is "natural" coastline comprising the IDNLS West Beach Unit. The shoreline has, until recently, been open beach and natural dune-bluffs. The severe erosion rates originally impacting on the downdrift (west) side of Burns/Portage Waterway have been displaced westward by the construction of the new Burns/Portage Waterway harbor. The effect of transferring these high erosion rates westward has been temporarily mitigated by the placement of a modest "beach nourishment" on IDNLS property. The total impact of the new structure will not be fully evident until the nourishment has been depleted and erosion of the dune-bluff resumes. The overall impact of increased erosion rates initiated by the construction of Burns Waterway Harbor is evident to the far west end of Ogden Dunes and may be expected to move farther west as a result of the construction of the new Burns/Portage Waterway harbor.

In response to these increased erosion rates, the homeowners in Ogden Dunes have begun to construct private shore protection structures along their coastline which will most likely extend the erosion impact farther west into the IDNLS West Beach area. The central section of the IDNLS West Beach Unit has had low to zero shoreline and bluff loss since 1955 which is true for the rest of the central portion of Reach 3. There are small isolated areas that have experienced higher erosion rates during periods of high lake-level, but the general condition appears to be one of coastal stability.

The western portion of Reach 3 is composed of Marquette Park Municipal Beach and IDNLS Miller Woods "natural" area. The shoreline is characterized as open beach and natural dune-bluffs. Marquette Park has experienced the same low to zero erosion and recession as the IDNLS West Beach Unit. The IDNLS Miller Woods natural area has experienced modest to high rates of sediment gain as a result of the sediment trapping effect of the U.S. Steel landfill breakwall. The effect of sediment trapping can be seen approximately 1 mile updrift (eastward) from the structure and increases rapidly as the trap structure is approached. The trapped sediment has greatly expanded the beach lakeward along the landfill wall and has resulted in the building of low, vegetated, beach dunes on the back beach areas.

The following are recommendations for consideration in future planning and management of Reach 3.

1. Beach nourishment should be maintained in the area immediately downdrift of the new Burns/Portage Waterway harbor to mitigate erosional impact on the beach and bluff along IDNLS and Ogden Dunes shoreline.

2. If Ogden Dunes plans to construct large scale (secondary) shore protection structures, National Park Service should be concerned about downdrift impact on IDNLS West Beach Unit.

3. Any type of shoreline construction in the western portion of Reach 3 could potentially disrupt existing low erosion/recession conditions and should therefore be carefully evaluated by National Park Service.

4. A shoreline monitoring program should be maintained to determine the affect construction of recent shore protection structures is having on beach, nearshore and offshore stability.