Erosion and Accretion Trends Along the Lake Michigan Shore at North Point Marina and Illinois Beach State Park

Year-3 (1997) Report of a Four-Year Study of Coastal Geology and Coastal Geologic Processes

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EXECUTIVE SUMMARY

In 1997, the Illinois State Geological Survey (ISGS) began the third year of a four-year study to examine erosion and accretion trends along the Lake Michigan coast at North Point Marina (NPM) and the North and South Units of Illinois Beach State Park (IBSP/NU and IBSP/SU). This study is funded by the Illinois Department of Natural Resources (DNR) which is responsible for coastal management at these facilities. The goal of the study is to develop a sediment budget for the coastal reach which extends from the Wisconsin-Illinois state line to Waukegan Harbor (the SL-WH coastal reach). This will provide input for planning and implementing long-term strategies for coastal sand management. An immediate objective is to provide information on erosion and accretion trends relevant to ongoing coastal management.

Comparisons of bathymetric data indicate that the nearshore along the SL-WH coastal reach was net accretional during 1996-1997 and that most lake-bottom change occurred in water depths less than 13 ft Low Water Datum (LWD). Net nearshore accretion during 1996-1997 was anomalous compared to longer term (1872-1996) trends that indicate the coastal reach is in a net-erosional state. The variance between the 1996-1997 data and the long-term trend is likely due to the high lake levels during 1997, and to annual variability in weather patterns which influence storm frequency and intensity. Storm characteristics are a key factor in determining rates of erosion, accretion, and littoral sediment transport.

Shoreline recession was prevalent along the coastal reach between summer 1996 and summer 1997 and was a good example of the type of temporary coastal response that can occur when lake levels are higher than average. Significant losses in beach area and erosion of several-hundred-year-old beach ridges landward of the beaches occurred at several sites that were particularly susceptible to the adverse effects of high 1997 lake levels. The erosion of the ridges caused a permanent loss of material from these protective coastal landforms. This loss increased the susceptibility of coastal marshes located immediately behind the ridges to either flooding or burial by sediment during storm events.

The Year-3 sediment budget indicates that a minimum of 72,800 cu yds/yr of beach nourishment would be required at IBSP/NU to mitigate erosion along the northern part of the SL-WH coastal reach. Approximately 53,500 cu yds of sand and gravel were added to the coastal reach during autumn 1997 at NPM, IBSP/NU, and IBSP/SU. More than 60% of this material, primarily from the NPM south parking area and the IBSP/SU site, had been transferred by waves into the nearshore and onto downdrift beaches by late autumn 1997. This contribution to the littoral system will have a beneficial effect on all of the downdrift coastal reach.

During 1996-1997, the nearshore between the WI-IL state line and Camp Logan showed minor net accretion (+3,500 cu yds) for the first year since completion of the marina in 1989. This was an anomaly when compared with recent and historical erosion trends for the area. The net accretion in the nearshore was likely due to sand being supplied directly to the nearshore from 1996 marina dredging, from erosion at the NPM south parking area and the IBSP/NU beach-nourishment stockpile, and from beach erosion between Dead Dog Creek and Camp Logan.

In the vicinity of NPM, net erosion occurred in the North Beach nearshore for the second year in a row in an area that, on an annual basis, has been predominantly net accretional since 1987. An erosional trough persisted along the lakeward side of the NPM north breakwater and was still as much as 1.7 ft deeper than the lake bottom had been in this area prior to marina construction. A pronounced trough also persisted in the approach channel to the NPM recreational boat basin. During 1996-1997, this trough, which has been a site of ongoing erosion since 1990, deepened by about 2 ft so that it was as much as 10.5 ft deeper than the design depth for the approach channel.

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INTRODUCTION

Background (Figures 1-1, 1-2)

The historical record of coastal change along the Illinois shore of Lake Michigan indicates that the most dynamic coastal area in the state is located between the Wisconsin-Illinois (WI-IL) state line and Waukegan Harbor (Fig. 1-1). Severe erosion and pronounced accretion in this area have resulted in some of the most rapid rates of coastal change documented along the entire shore of southern Lake Michigan.

In this report, the 9.7-mile long shore between the state line and Waukegan Harbor is referred to as the WI-IL state line - Waukegan Harbor coastal reach (SL-WH coastal reach). Approximately 6.5 miles, or 67 percent, of the coastal reach is state-owned (Fig. 1-2), consisting of the coast at North Point Marina (NPM) near the state line, and the North and South Units of Illinois Beach State Park (IBSP/NU and IBSP/SU). Both the marina and state park are managed by the Illinois Department of Natural Resources (Illinois DNR) and are among the most heavily used DNR recreation and conservation areas in the state. NPM was built with a state investment of nearly 42 million dollars. It incorporates state-of-the-art marina design for 1500 boat slips, making it the largest marina in the Great Lakes Region. IBSP provides lakeshore recreation and preserves the last remaining stretch of natural lakeshore and concentration of coastal wetlands and dunes in Illinois.

Purpose and Scope

In 1995, the Illinois State Geological Survey (ISGS) began a four-year study of coastal geology and coastal geologic processes along the northernmost segment of the Illinois shore of Lake Michigan. This study focuses on NPM and IBSP, but also examines erosion and accretion trends on a regional scale between the WI-IL state line and Waukegan Harbor. The ultimate goal is to develop a sediment budget for the coastal zone identifying sediment sources and sinks, sediment transport pathways, and average annual rates of lake-bottom change. This information is needed for ongoing and future management of coastal sand resources.

This report is the third in a series of four annual reports that summarize yearly findings during the course of the four-year study. The report generally follows the format of the Year-1 and Year-2 reports (Chrzastowski *et al.*, 1996; Foyle *et al.*, 1997a). Appendix A contains the executive summaries from the previous reports. Because the collection, processing, and interpretation of field data are continuing as this report is submitted, some of the findings presented here are interim in nature. As additional annual data are collected and evaluated, these interim findings may be modified or expanded upon in the study's final Year-4 report.

Project Funding

The primary funding for this study comes from the Illinois Department of Natural Resources (Illinois DNR), Office of Capital Development. Additional funding on a cost-share basis was provided by the ISGS from general revenue funds for ISGS studies of Lake Michigan coastal geology. This report is a contract deliverable for Illinois DNR Contract No. 9643E.

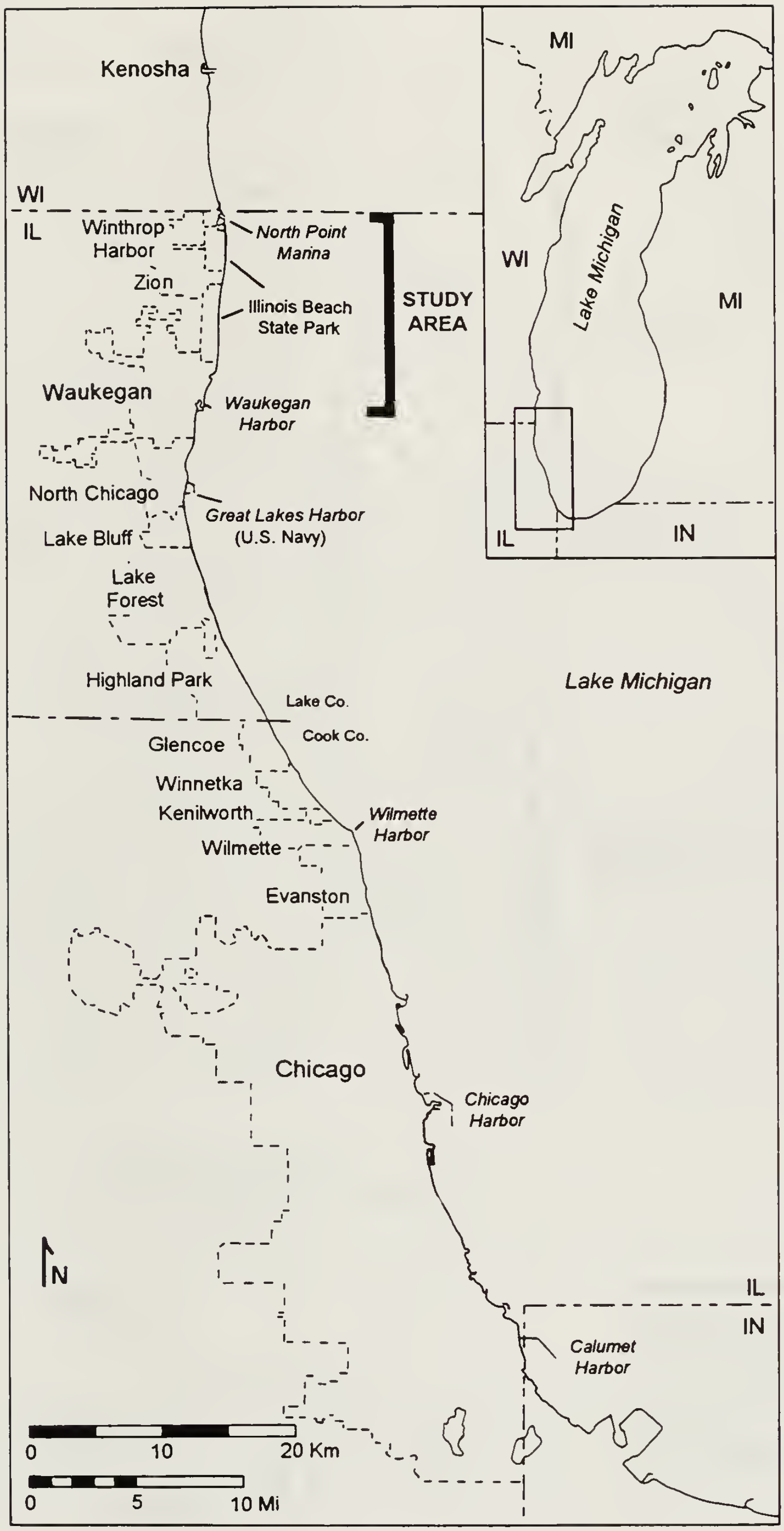


Figure 1-1 Map of the Illinois coast of Lake Michigan showing location of the study area.

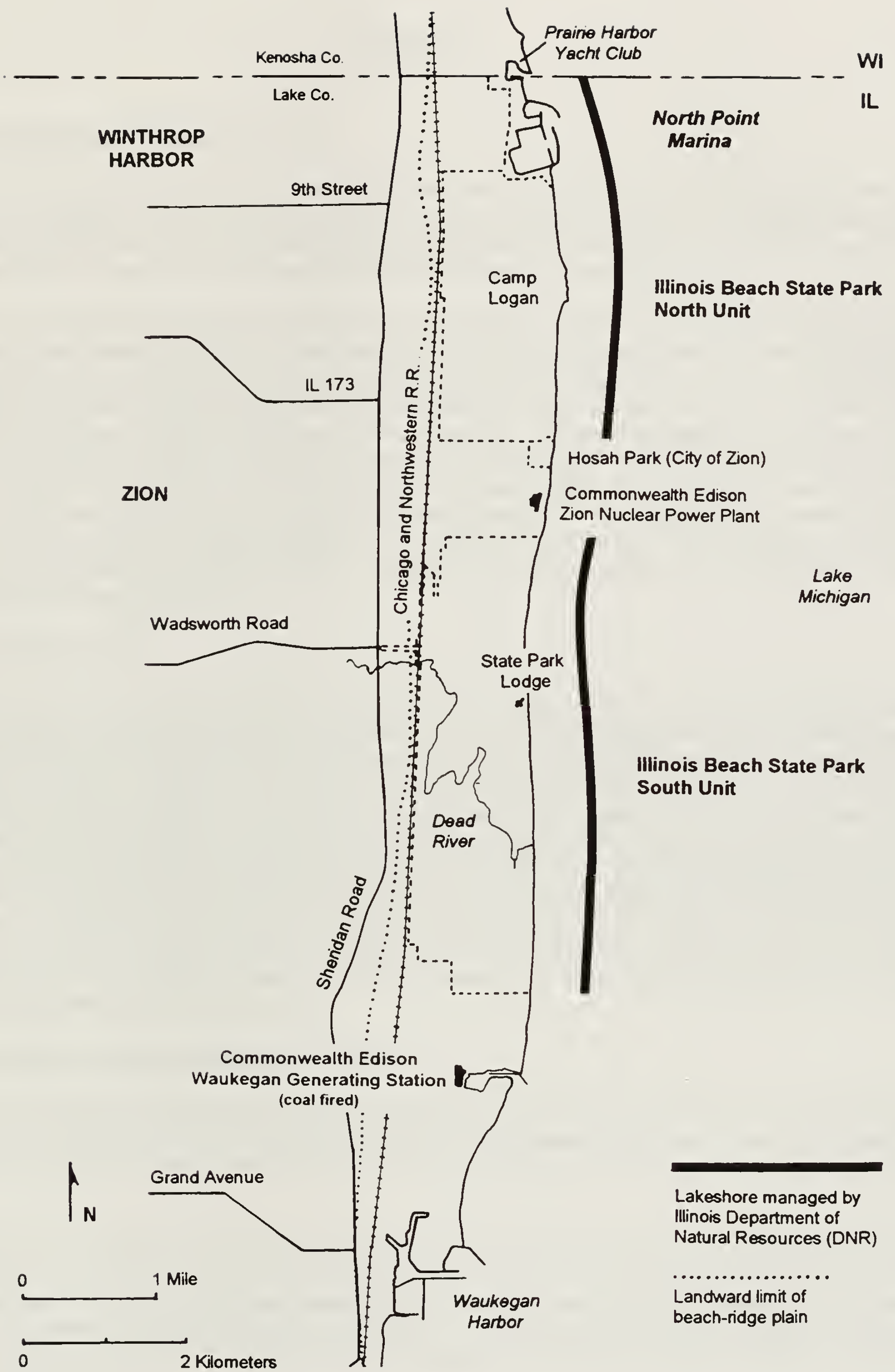


Figure 1-2 Map of the WI-IL state line - Waukegan Harbor (SL-WH) coastal reach, showing major place names and geographic features.

SETTING

Geologic Framework (Figures 1-3, 1-4)

The study area is located along the coast of the Zion beach-ridge plain, a low-lying coastal sand and gravel plain that extends 18 miles from Kenosha, WI, to North Chicago, IL (Fig. 1-1). In Illinois, the western border of the plain is marked by a north-south trending bluff line, which is approximated by the north-south right-of-way of the Union Pacific / Chicago and North Western Railroad (Fig. 1-2).

The Zion beach-ridge plain is the above-water part of a coastal sand body that extends as much as 8000 ft lakeward of the modern shoreline (Fraser and Hester, 1974). In cross section, the sand body is lens-shaped and attains its maximum thickness of 30 to 35 ft near the modern shoreline (Fig. 1-3). Curvilinear beach ridges and dunes mark the approximate locations of former shorelines (Fig. 1-4) and formed as the sand plain migrated southward by the accretion of sand and gravel at its southern end. Radiocarbon dating indicates that the plain first migrated southward across the WI-IL state line about 4000 years ago (Larsen, 1985). Construction of Waukegan Harbor between 1880 and 1906 interrupted southward migration of the sand plain because the harbor jetties formed a partial to near-total barrier to littoral transport (Chrzastowski and Trask, 1995). As a result, the construction of Waukegan Harbor has contributed to the accretion of almost 500 acres of new land to the north of the harbor since the late 1880s (Foyle and Chrzastowski, 1996).

Lake Level (Figure 1-5)

Lake Michigan water levels during 1997 were significantly higher than the long-term (1918-1996) average and were about 1 ft higher than 1996 lake levels (U.S. Army Corps of Engineers, 1997). Monthly mean lake levels during 1997 ranged from 1.4 ft above long-term (1918-1996) average in January, to 1.7 ft above long-term average in June, to 1.5 ft above long-term average in November (Fig. 1-5). During June 1997, mean lake level was almost 1.2 ft above the mean lake level of June 1996. Lake level was highest in July, reaching about 1.8 ft above long-term average and about 3.8 ft above Low Water Datum (LWD). This was the highest recorded lake level since January 1987 (U.S. Army Corps of Engineers, 1997). High lake level in 1997 generally caused beach submergence. When combined with foreshore erosion, this caused the shoreline to move landward along most (75%) of the SL-WH coastal reach which, in turn, caused a net loss of 24 acres of beach as of summer 1997. In general, high lake levels permit higher wave energies to be imparted across the shallow nearshore and at the shoreline, which can induce increased lake-bottom and beach erosion.

Wave Climate and Littoral Sediment Transport

The wave climate between the WI-IL state line and Waukegan Harbor is such that 90 percent of the waves in the nearshore are less than 3 ft in height (Booth, 1994). The highest waves are typically associated with storms occurring between autumn and spring. During severe storms, nearshore wave heights may reach 8 or 9 ft.

The Illinois coast is exposed to waves approaching from either the northeast or southeast quadrants. Northeasterly waves tend to be highest because winds from the northeast quadrant have the longest fetch (*i.e.*, distance over water). The predominance of northeasterly waves is responsible for a net southward transport of sediment along the beaches and nearshore. Southeasterly waves occasionally cause brief reversals in the littoral transport direction by moving sediment northward, but the direction of net littoral transport is to the south.

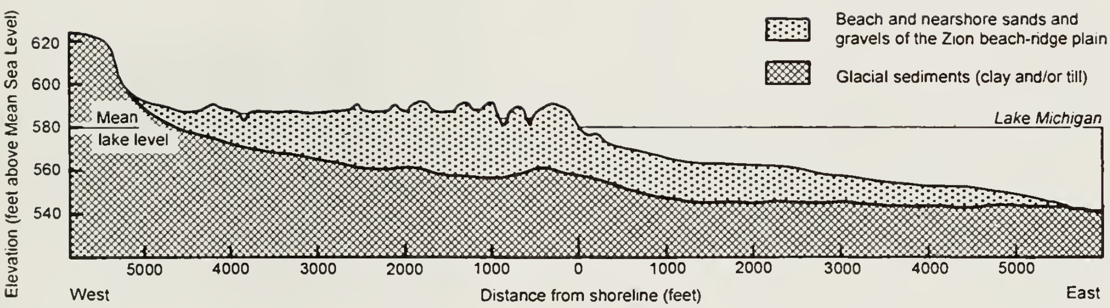


Figure 1-3 Generalized east-west cross section of the Zion beach-ridge plain in the vicinity of Dead River. The maximum sand thickness of 30 to 35 ft typically occurs near the present shoreline (modified from Fraser and Hester, 1974).

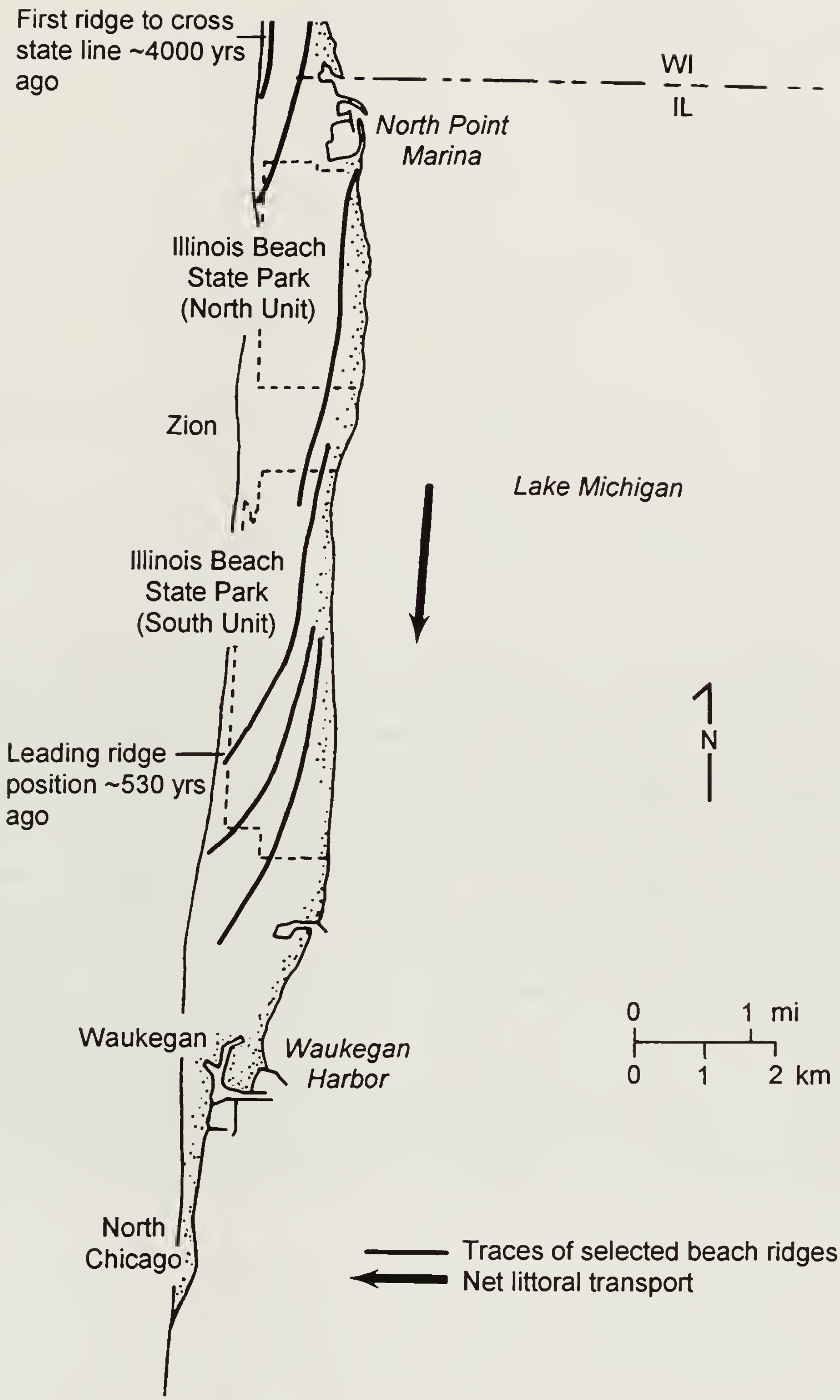


Figure 1-4 Schematic illustration of the Zion beach ridge plain in Illinois showing selected curvilinear beach ridges. Approximate beach-ridge ages are shown in calendar years (modified from Larsen, 1985).

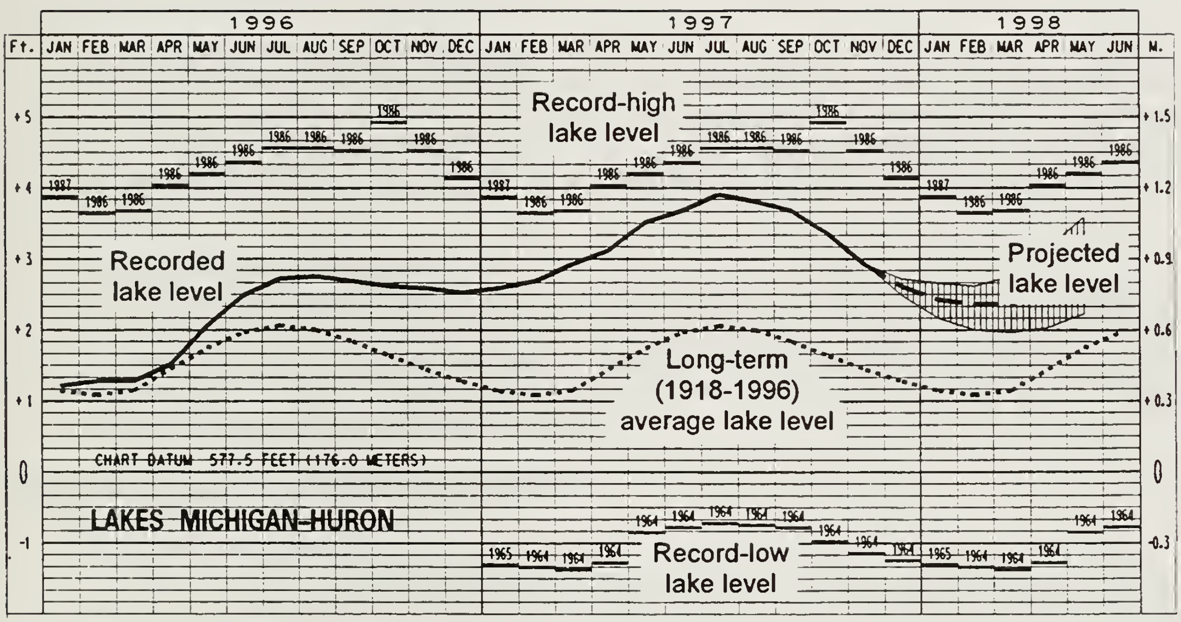


Figure 1-5 1996-1997 lake-level record for Lakes Michigan and Huron. Elevations (feet/meters) are referenced to Low Water Datum (LWD). Projected 1997 and 1998 lake levels are also shown (from U.S. Army Corps of Engineers, Monthly Bulletin of Lake Levels for the Great Lakes, November 1997).

OVERVIEW OF 1997 DATA COLLECTION

General Statement

Data collection during 1997 consisted of two principal components:

- *Site-specific collection of bathymetric-profile and ground-photography data*
  Surveys conducted in 1995 and 1996 were repeated in 1997 to document magnitudes and rates of 1996-1997 coastal change at NPM and at the beach nourishment sites in IBSP/NU and IBSP/SU.

- *Regional data collection*
  Shoreline mapping, topo-bathymetric profiling, and oblique aerial photography were conducted along the entire SL-WH coastal reach to document regional coastal change during 1996-1997.

The following paragraphs provide an overview of 1997 data collection and compilation as of the end of November 1997. Results from the 1997 data are summarized in Part 2 of this report and are discussed in detail in Part 3. Procedures used in data collection and processing, and a glossary of principal terms, are outlined in Appendix B.

North Point Marina (NPM)

- *Bathymetric and topographic surveys*
  Fifty bathymetric profile lines were run between the WI-IL state line and the marina / state park boundary. Sixteen lines were run in the marina entrance and the northern half of the approach to the recreational basin. These data document 1997 bathymetry adjacent to marina property. Comparison of 1997 data with 1996 data permitted evaluation of shoreline and lake-bottom change.

- *South parking area monitoring*
  In spring and summer 1997, approximately 13,500 cu yds of sand were placed as backfill along 1100 ft of riprap-defended shoreline at the NPM south parking area (Charles Price, NPM Harbor Master; pers. comm). As was the case in 1995 and 1996, the sand was applied for reasons of public safety and to help mitigate erosion along the shore. The area was monitored to document shoreline recession and erosion of the backfill.

Illinois Beach State Park / North Unit (IBSP/NU)

- *Bathymetric and topographic surveys*
  Thirty-one topo-bathymetric profile lines were run between the marina / state park boundary and the Camp Logan headland to document 1997 bathymetry and 1996-1997 shoreline and lake-bottom change.

- *Beach-nourishment site monitoring*
  The beach-nourishment site at the north end of the North Unit received 20,000 cu yds of beach nourishment during October 1997 (Robert Grosso, IBSP Site Superintendent; pers. comm.). The topographic and wading survey scheme used during Year-1 and Year-2 was continued during Year-3 to monitor changes at the site.

Illinois Beach State Park / South Unit (IBSP/SU)

- *Beach-nourishment site monitoring*
  The beach-nourishment site at the north end of the South Unit received 20,000 cu yds of beach nourishment during September 1997 (Robert Grosso, IBSP Site Superintendent; pers. comm.). The site was periodically monitored prior to the 1997 nourishment using ground photography to record existing riprap conditions and the stability of new riprap that was placed along the southernmost 350 ft of shore-access road during spring 1997. A topographic and wading survey scheme similar to that used during Year-1 and Year-2 was established following the addition of September 1997 nourishment to monitor changes at the site.

Regional Data Collection

- *Bathymetric and topographic surveys*
  Bathymetric and topographic profiles were collected along 23 east-west range lines that were spaced at 1700- to 1900-ft intervals along the SL-WH coastal reach (Appendix J). All 23 lines have pre-existing bathymetric data available for the years 1872, 1910, 1974, and 1996. The 1997 and 1996 data were compared to delineate areas of erosion and accretion, to measure annual lake-bottom changes, and to provide input to the Year-3 littoral sediment budget.

- *Shoreline survey*
  The 1997 shoreline was surveyed at 100 to 200 ft intervals between the WI-IL state line and Waukegan Harbor. Comparison of the 1997 shoreline with that of 1996 allowed identification of areas of significant shoreline change and calculation of the amount of beach loss resulting from high lake levels during 1997.

- *Dredge records from the Waukegan area*
  Dredge records, compiled initially for the Year-1 report, were updated to incorporate volumes dredged during 1996-1997. Dredge data were available for the Commonwealth Edison Waukegan Generating Station and for Waukegan Harbor. These data were used as input to the Year-3 littoral sediment budget in order to quantify the rate of littoral sediment transport at the downdrift end of Illinois Beach State Park and at the downdrift end of the SL-WH coastal reach.

- *Low-altitude oblique aerial photography*
  The 18 miles of shoreline along the Zion beach ridge plain between Kenosha, WI, and North Chicago, IL, were documented photographically with low-altitude oblique aerial photographs. The resulting slide collection provided information on coastline configuration during April 1997 when lake level was approaching its summer 1997 high.

PART 2: STUDY APPLICATIONS AND SUMMARY

SUMMARY OF KEY YEAR-3 FINDINGS

The following sections summarize the principal results and recommendations derived from Year-3 (1997) monitoring at North Point Marina (NPM) and Illinois Beach State Park (IBSP/NU and IBSP/SU). Geographically-keyed sections in Part 3 of this report address these and other topics in more detail.

<u>North Point Marina Vicinity (Figure 2-1)</u>

During 1996-1997, the 1.5 miles of nearshore between the WI-IL state line and Camp Logan showed minor net accretion (+3,500 cu yds). With the exception of the period during marina construction (1987-1989), this nearshore has historically been net erosional. Net accretion during 1996-1997 was likely due to input of sand to the nearshore from marina dredging, beach erosion, and erosion of the IBSP/NU beach-nourishment stockpile. The most significant changes in the NPM vicinity during 1996-1997 are listed below:

- Shoreline recession was predominant through summer 1997 and was due to a combination of the high summer-1997 lake level that submerged parts of the beaches, and wave-induced erosion. Recession of as much as 80 ft caused the loss of 1.9 acres of beach at North Beach (on the updrift side of NPM) and in IBSP/NU north of Camp Logan (Fig. 2-1).

- Along much of North Beach and just north of Dead Dog Creek in IBSP/NU, the 1997 shoreline was located landward of the position it occupied in 1987 just prior to marina construction.

- Net erosion occurred in the North Beach nearshore for the second year in a row in an area that has been predominantly net accretional since 1987.

- As much as 4.2 ft of accretion occurred in a prominent erosional trough that has persisted along the lakeward side of the NPM north breakwater since 1988. However, the axis of this trough was still as much as 1.7 ft deeper than the lake bottom had been in 1987.

- As much as 2 ft of erosion occurred at a pronounced trough in the approach channel to the NPM recreational boat basin. This trough has been a site of ongoing erosion since 1990. During 1996-1997, the trough increased in length to about 500 ft , moved closer to the north inner breakwater, and became as much as 10.5 ft deeper than the design depth for the approach channel.

- Between March and June 1997, about 13,500 cu yds of sand were placed along 1100 ft of riprap-defended shore at the NPM south parking area. Subsequent erosion transferred most of this sand into the nearshore by early autumn 1997.

- Submerged riprap lakeward of the south parking area continued to subside at an average rate of 0.5 ft/yr. Between the submerged riprap and the shoreline, a trough that had been deepening progressively since 1990 generally shallowed by 1 to 2 ft during 1996-1997.

- Scarp recession persisted along the lakeward side of the IBSP/NU beach-nourishment site during most of 1996-1997 but was temporarily halted or reversed in late autumn 1997 due to the addition of 20,000 cu yds of "pea gravel." Overall, there was a net transfer of sand and gravel into the nearshore and onto downdrift beaches during 1996-1997.

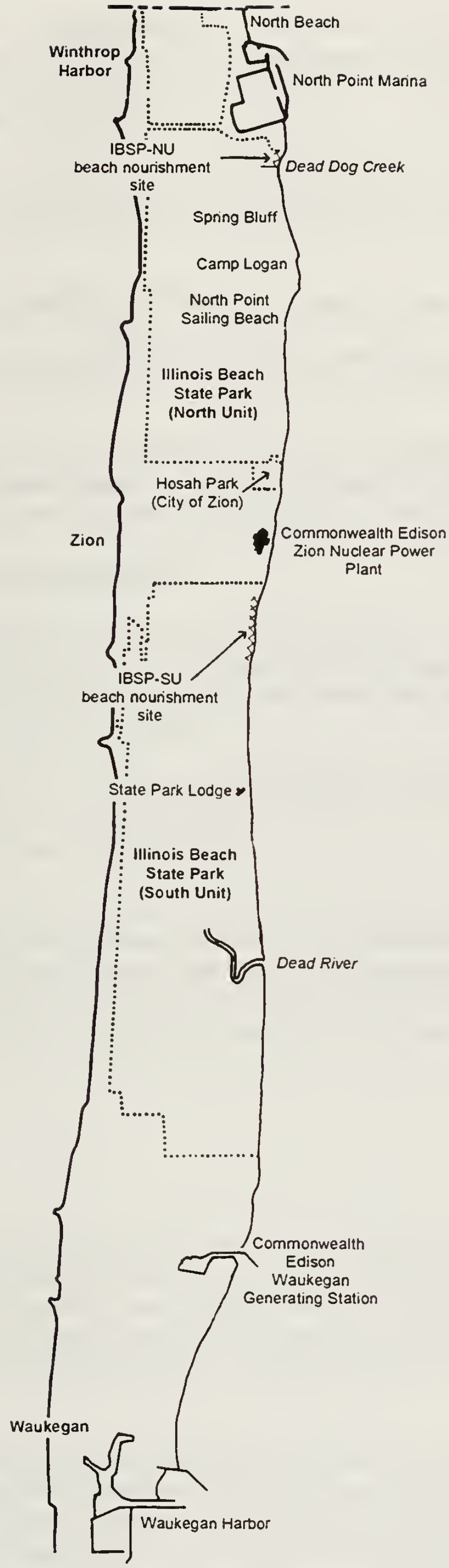


Figure 2-1 Index map of place names within the SL-WH coastal reach.

- The Spring Bluff nearshore, located between the IBSP/NU beach-nourishment site and Camp Logan, was net accretional during 1996-1997. Because this area has historically been net erosional, the accretion was likely due to annual variability in storm frequency and intensity and to the positive effects of beach nourishment.

- Over the past ten years (1987-1997), the nearshore between the state line and Camp Logan has experienced a net loss of sediment (at least 73,000 cu yds) despite ongoing beach-nourishment efforts.

<u>Illinois Beach State Park / North Unit (IBSP/NU) South of Camp Logan</u>

- The nearshore between Camp Logan and Hosah Park was the area that experienced the greatest amount of erosion within the SL-WH coastal reach during 1996-1997 (Fig. 2-1).

- North Point Sailing Beach on the south side of the Camp Logan Headland was the area in IBSP/NU that was most adversely affected by high lake level during 1997. It was the site of the greatest documented shoreline recession (140 ft) anywhere within the SL-WH coastal reach.

<u>Illinois Beach State Park / South Unit (IBSP/SU)</u>

- Riprap shore defense was added to the south end of the beach-nourishment site during summer 1997. The riprap provided protection to the adjacent shore-access road and assured continued public safety by covering a 2 to 4 ft high scarp that had developed along the lakeward side of the access road during late 1996 and early 1997.

- The beach-nourishment site in IBSP/SU received 20,000 cu yds of "pea gravel" nourishment during autumn 1997. Within two months of nourishment, most of this material was transferred into the nearshore and onto downdrift beaches.

- The shore between the IBSP Lodge and Dead River was the area in IBSP/SU that was most adversely affected by high lake level during 1997 (Fig. 2-1). Shoreline recession (as much as 135 ft) through summer 1997 allowed partial erosion of relict beach ridges on the landward sides of the beaches. At one locality, beach sand was washed into adjacent low-lying coastal marshes during an autumn 1997 storm. The lakeward margins of the marsh were buried by 1 to 2 ft of sand and gravel.

<u>Regional Coastal Monitoring</u>

Shoreline recession

Shoreline recession was prevalent along the coastal reach between summer 1996 and summer 1997 and was a temporary response to a rise in lake level of about 1.2 ft. Recession resulted from both the high summer-1997 lake level that submerged the low-elevation parts of beaches, and wave-induced erosion that moved beach material into the shallow nearshore. During summer and autumn, 1997, a seasonal decline in lake level of about 1 ft allowed the shoreline to shift lakeward and the beaches to expand along much of the coastal reach.

During the summer-1997 high lake level phase, significant shoreline recession was documented at six localities that were particularly susceptible to submergence and erosion. At these localities, 80 to 140 ft of shoreline recession caused a decrease in beach width and facilitated partial erosion of several-hundred-year-old beach ridges on the landward sides of the beaches. The erosion of the ridges caused a permanent loss of material from these protective coastal landforms and increased the susceptibility of coastal marshes located immediately behind the ridges to either flooding or burial by sediment during storm events.

Beach erosion

Due to shoreline recession, total beach area along the SL-WH coastal reach decreased by about 24 acres through summer 1997. The NPM vicinity and IBSP/NU lost about 6 acres of beach while IBSP/SU lost almost 10 acres. Beach loss was greatest at North Beach on the updrift side of NPM (4.5 sq yds/ft), and between the Commonwealth Edison Waukegan Generating Station and Waukegan Harbor (4.1 sq yds/ft).

By autumn 1997, some of the losses in beach area that occurred because of high summer-1997 lake levels were being regained. This was related to two factors: (1) a 1 ft drop in lake level between July and November 1997 that allowed the shoreline to translate lakeward; and (2) wave-induced transport of sand, which had temporarily been stored in the shallow nearshore, back onshore to widen the beaches.

Lake-bottom change

The nearshore along the SL-WH coastal reach was net accretional during 1996-1997. Most lake-bottom change in excess of 1 ft occurred in water depths less than 13 ft LWD (Low Water Datum) and was, in general, related to either a 100 ft landward migration of a prominent nearshore bar/trough pair, or to erosion of the beaches and shallow nearshore that accompanied shoreline recession. A component of the net nearshore accretion during 1996-1997 was related to sediment being transferred from the beaches into the nearshore.

Net nearshore accretion during 1996-1997 was an anomaly when compared to a longer term (1872-1996) trend documented in the Year-2 Report that indicates the coastal reach is in a net-erosional state (Foyle *et al.*, 1997a). The variance between the 1996-1997 data and the long-term trend is likely due to the high lake levels during 1997 and annual variability in weather patterns which influence storm frequency and intensity. Storm frequency and intensity are key factors in determining rates of erosion, accretion, and littoral sediment transport.

Littoral sediment budget

The primary goal of this study is to develop a littoral sediment budget for the Lake Michigan coast at NPM and IBSP. Part 3 of this report includes a littoral sediment budget that averages rates of coastal change for the 1992-1997 period. These five-year-average data provide the best approximation of recent rates of littoral sediment transport along the NPM and IBSP nearshore. A comprehensive understanding of the littoral sediment budget will provide input for planning and implementing long-term coastal management strategies along the DNR-managed lakeshore. The following listing summarizes the key components of the Year-3 interim littoral sediment budget.

- Littoral sediment moved south across the WI-IL state line at an average rate of at least 10,000 cu yds/yr between 1992 and 1997. This sediment contributed towards overall net accretion on the updrift side of NPM during the five-year interval but was not sufficient to counteract net erosion during 1995-1996 and 1996-1997.

- Littoral sediment moved southward past the Camp Logan headland at an average rate of at least 72,800 cu yds/yr between 1992 and 1997.

- An average of at least 72,800 cu yds/yr of littoral sediment approached the Waukegan Generating Station from updrift. The proximity of this facility to IBSP/SU means that this is also a minimum estimate for the average volume of littoral sediment in transport along the southern end of IBSP/SU.

- The minimum volume of littoral sediment reaching the southern end of the SL-WH coastal reach between 1992 and 1997 is estimated to have averaged at least 32,100 cu yds/yr. This is based on the entrapment volume at Waukegan Harbor. It is not known how much sediment naturally

bypassed the harbor to areas farther downdrift.

- The five-year (1992-1997) interim littoral sediment budget indicates that the minimum volume of beach nourishment required to mitigate erosion between NPM and Camp Logan, the area where most erosion typically occurs, is at least 72,800 cu yds/yr.

RECOMMENDATIONS

North Point Marina

1) During 1996-1997, the nearshore on the updrift side of NPM was net erosional for the second year in a row in an area that has been predominantly net accretional since 1987. This may be part of a developing erosional trend or may be due to annual variability in coastal processes. It raises uncertainty, however, concerning the suitability of the site for future dredging and sand-bypassing purposes. It would thus be advisable to delay any future plans to dredge this area until future monitoring can determine whether net sand entrapment will resume.

2) During 1996-1997, the erosional trough on the lakeward side of the north breakwater shallowed by as much as 4.2 ft. Nevertheless, the potential exists for this trough to adversely affect the north breakwater if deepening recurs. Continued monitoring of the trough is warranted.

3) The erosional trough along the north inner breakwater was as much as 10.5 ft below design depth for the approach channel to the recreational boat basin. Deepening in this trough during 1996-1997 indicates that continued monitoring would be prudent.

4) Shore defenses along the south parking area nearshore are susceptible to the adverse effects of long-term lake-bottom erosion, even though net accretion did occur during 1996-1997. Post-construction monitoring of the new revetment and offshore submerged breakwater would be advised.

Illinois Beach State Park

5) The Spring Bluff nearshore has historically been net erosional. The area has remained net erosional over the ten-year (1987-1997) period since marina construction began although net-accretional years, such as 1996-1997, intermittently occur. To maintain beach width and reduce the rates of shoreline recession and nearshore erosion, this part of IBSP/NU will benefit from continued input of sand and gravel at the IBSP/NU beach-nourishment site.

6) During 1996-1997, net erosion characterized the nearshore between the Camp Logan headland and Hosah Park. This nearshore reach would also benefit from continued input of sand and gravel at the IBSP/NU beach-nourishment site and wave-induced southward dispersal of this material.

7) The Year-1 and Year-2 reports (Chrzastowski *et al.*, 1996; Foyle *et al.*, 1997a) concluded that, at a minimum, 68,400 to 82,600 cu yds/yr of beach nourishment would have been needed to prevent shoreline recession and net nearshore erosion between NPM and the Camp Logan headland. This Year-3 report suggests a volume of at least 72,800 cu yds/yr is required, an amount which lies within the range of the earlier estimates.

8) The loss of sediment from several-hundred-year-old beach ridges at numerous sites in IBSP/SU during 1996-1997 illustrates the adverse effects of high lake levels. These effects can be partially mitigated by maintaining beach widths to help protect the beach ridges and the adjacent wetlands against severe storms. This can be achieved through continued beach nourishment efforts.

9) The eight preceding recommendations highlight the continued need for a regional and long-term coastal-management plan to mitigate erosion along the DNR lakeshore. Such a coastal-management plan should incorporate provisions for continued and increased beach nourishment (soft stabilization), as well as evaluate hard-stabilization options such as artificial headlands or offshore structures that would stabilize the shoreline or reduce wave energy impacting the shore. Any engineered shore-protection projects should be monitored post-construction to document their behavior as well as their effects on rates

of shoreline and nearshore change. Ideally, the regional and long-term coastal management plan would address the needs of all lakeshore property managers within the SL-WH coastal reach. For example, the erosional issues along DNR property should be addressed in conjunction with the accretional issues at Waukegan Generating Station and Waukegan Harbor.

PART 3: 1997 STUDY FINDINGS

NORTH POINT MARINA VICINITY

General Statement

The North Point Marina (NPM) vicinity consists of 7700 ft of coastline at NPM and Illinois Beach State Park's North Unit (IBSP/NU) and extends from the WI-IL state line to the Camp Logan headland (Fig. 3-1). During 1996-1997, several events affected coastal change along the shore and are outlined below.

In late February 1997, localized flooding between the state line and the marina's north breakwater caused three small breaches of the dune line and minor beach erosion at North Beach on the updrift side of NPM. A similar event had previously occurred during spring 1996. These dune-washout events supplied minor amounts of sand to the North Beach nearshore from areas at and landward of the primary dune line.

In early April 1997, a concrete-cube sand barrier was completed along an easement adjacent to the property line between Prairie Harbor Yacht Club, WI, and NPM. This 5-ft high structure was built to stop wave-induced transport of sand from North Beach into the south side of the boat basin at Prairie Harbor Yacht Club. Significant sand overwash has not occurred at this site since construction of the sand barrier.

Between March and June, 1997, 12,000 to 15,000 cu yds (average: 13,500 cu yds) of sand backfill were supplied to an 1100-ft length of riprap-defended shore at the NPM south parking area (Charles Price, NPM Harbor Master; pers. comm.). The material was obtained from dredging at Prairie Harbor Yacht Club (Fig. 3-1) and was used to fill large, arcuate, erosional embayments that had developed on the landward side of the concrete-cube and riprap revetment as a result of storms during autumn 1996 and spring 1997. During and immediately following emplacement, erosional embayments began to redevelop as the backfill was transferred into the nearshore through wave action. During 1997, planning continued for building a revetment and submerged offshore breakwater at the NPM south parking area to mitigate erosion at the site. Construction of both the offshore breakwater and the shoreline revetment began in early November.

Between mid October and early November, 1997, 20,000 cu yds of pea gravel were added to the IBSP/NU beach-nourishment site along the northern 400 ft of shore between the marina / state park boundary and Dead Dog Creek in IBSP/NU (Robert Grosso, IBSP Site Superintendent; pers. comm.). The material was obtained from an inland quarry source. Erosion was prevalent along the lakeward side of the nourishment site during 1996-1997, supplying sand and gravel to the nearshore and downdrift beaches.

The 1997 data and observations for the NPM vicinity are discussed under the following headings:

- 1997 shoreline configuration
- 1996-1997 shoreline changes
- 1997 bathymetry
- 1996-1997 lake-bottom change
- North Beach bar
- Lake-bottom erosion adjacent to the NPM north breakwater
- Marina entrance
- Approach channel to the NPM recreational boat basin
- Monitoring at the NPM south parking area
- Submerged riprap at the NPM south parking area
- Monitoring of beach nourishment at IBSP/NU

1997 Shoreline Configuration (Figure 3-1)

The shoreline between the WI-IL state line and the Camp Logan headland (Fig. 3-1) comprises: (1) approximately 950 ft of sandy beach at North Beach; (2) 2600 ft of breakwaters at NPM; (3) 1100 ft of riprap and concrete-cube revetment at the NPM south parking area; (4) 500 ft of boulder-defended shore along the lakeward side of the IBSP/NU beach nourishment stockpile; and (5) 2600 ft of sandy beach at Spring Bluff, which is located between Dead Dog Creek and the Camp Logan headland.

1996-1997 Shoreline Change (Figures 3-2, 3-3)

The 1997 shoreline was mapped during June 1997 and was generally located either coincident with, or landward of, the July 1996 shoreline location. However, 1100 ft of the 1997 shoreline along Spring Bluff was located lakeward of the 1996 shoreline.

Mean lake level in June 1997 was almost 1.2 ft higher than mean lake level of June 1996 (U.S. Army Corps of Engineers, 1997). The predominantly landward movement (recession) of the shoreline during 1996-1997 was caused by a combination of high 1997 lake level that submerged the low-elevation parts of beaches, and wave action on the foreshore that eroded beach material and transferred it further into the nearshore. Loss of sand backfill at the NPM south parking area, and erosion of the sand stockpile at the IBSP/NU beach-nourishment site, were additional factors contributing to shoreline recession at these two specific sites.

The greatest amount of shoreline recession occurred just south of Dead Dog Creek where the shoreline had migrated 80 ft landward during 1996-1997. The longest continuous stretches of recession occurred at North Beach (950 ft) and along 1500 ft of shore in IBSP/NU immediately downdrift of the NPM south parking area. Because of overall landward movement of the shoreline during 1996-1997, the NPM vicinity lost 1.9 acres of beach through summer 1997. Approximately 50% of this loss occurred at North Beach, which constitutes 12% of the total shoreline length, while the remainder occurred between the NPM/IBSP property line and Camp Logan.

Figures 3-2 and 3-3 show the 1997 shoreline position on the north and south sides of the marina relative to selected earlier years. The 1987 shoreline reflects coastal configuration just prior to marina construction. The 1989 shoreline was the most lakeward post-construction shoreline position on the south side of the marina and occurred in response to placement and southward dispersal of NPM dredge material following marina construction (Chrzastowski *et al.*, 1996). Shorelines are also shown for 1995 (Year-1 of this study) and 1996 (Year-2 of this study). With two exceptions, the 1997 shoreline remained lakeward of the preconstruction (1987) shoreline. The first exception was at North Beach where 725 ft of shoreline was located up to 18 ft landward of the 1987 shoreline (Fig. 3-2). The second exception occurred just north of Dead Dog Creek where 150 ft of shoreline was located 15 to 20 ft landward of the 1987 shoreline position (Fig. 3-3).

1997 Bathymetry (Figure 3-4)

The lake bottom in the vicinity of NPM as of summer 1997 was generally a smooth, lakeward-sloping surface with shore-parallel bathymetric contours (Fig. 3-4). Relative contour spacing indicates that nearshore slopes were generally steepest (1:80 to 1:20) between the shoreline and the 15 ft LWD (Low Water Datum) isobath, and less steep (1:140 to 1:100) at depths greater than 15 ft LWD. Water depths a short distance lakeward of the shoreline were variable. On the updrift side of the marina, the 5 ft LWD bathymetric contour, for example, was located 500 to 600 ft lakeward of the shoreline. At the marina and the south parking area, the 5 ft LWD contour was located only 5 to 75 ft offshore, while in the area south of Dead Dog Creek it was generally located 150 to 250 ft offshore.

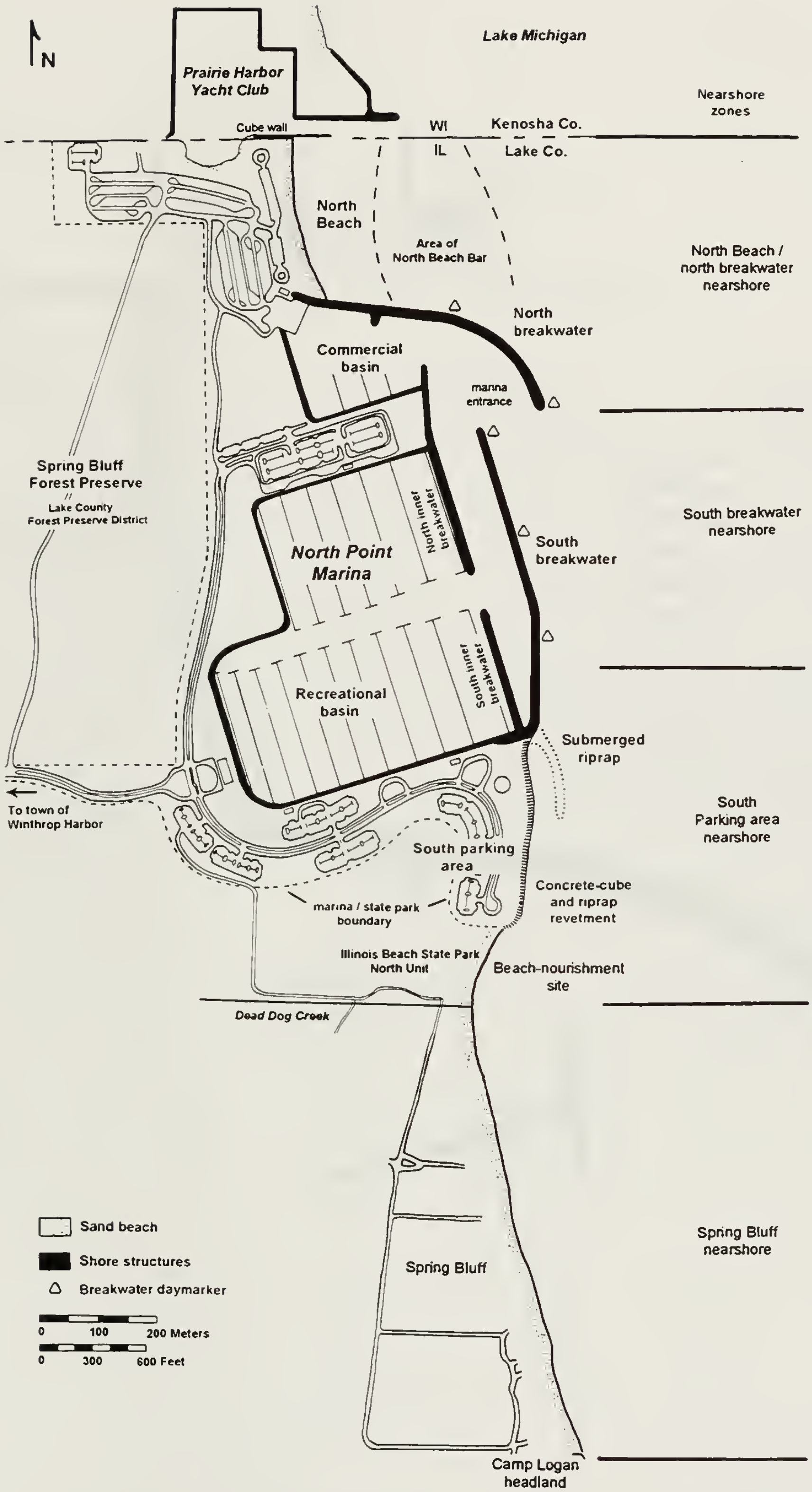


Figure 3-1 Index map of place names in the North Point Marina vicinity.

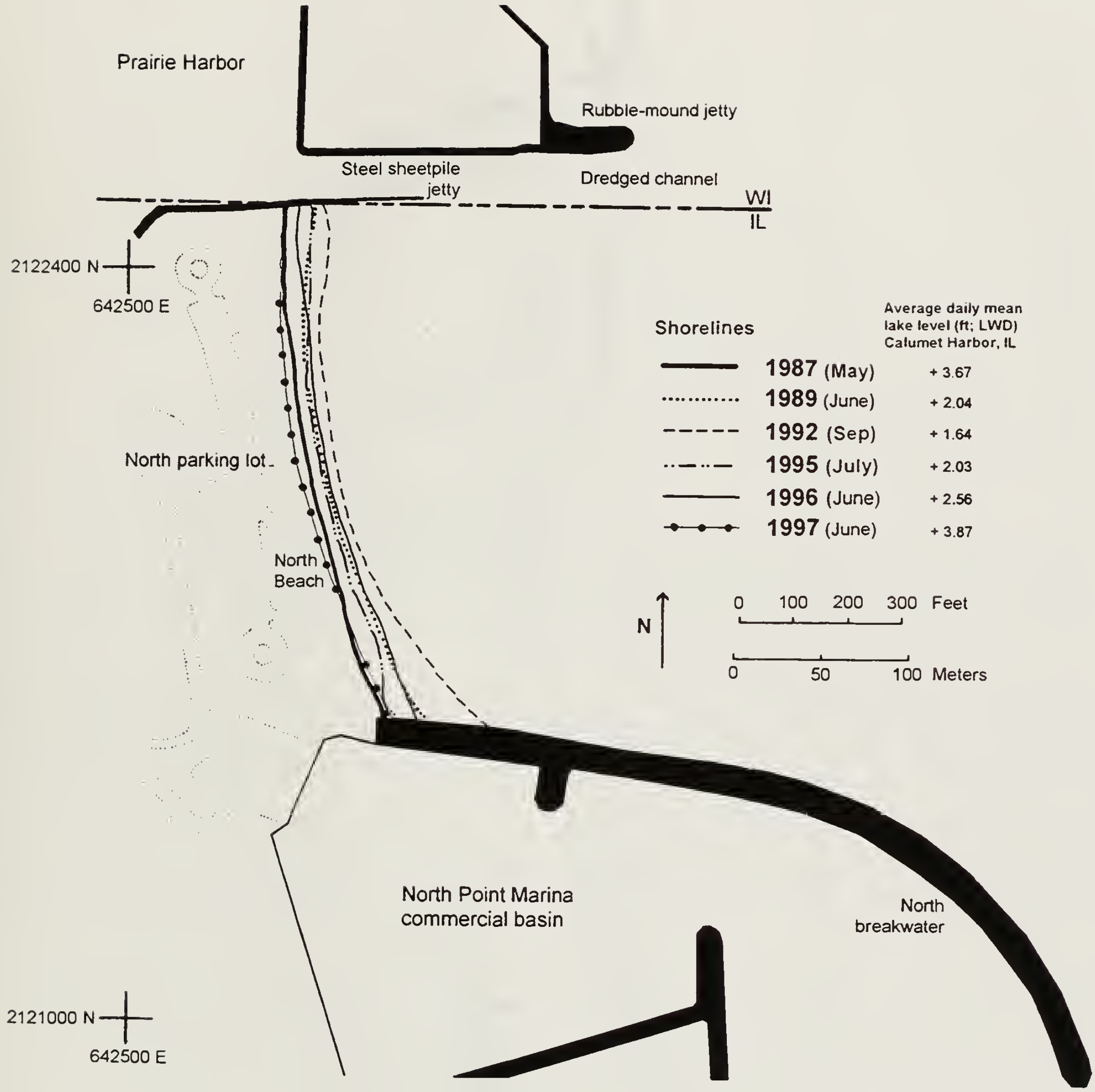


Figure 3-2 Shoreline positions at North Beach on the north side of North Point Marina (1987-1997). Selected shorelines are shown for 1987 (prior to marina construction), 1989, 1992, 1995, 1996, and 1997. Shorelines are for the lake level at the time of survey.

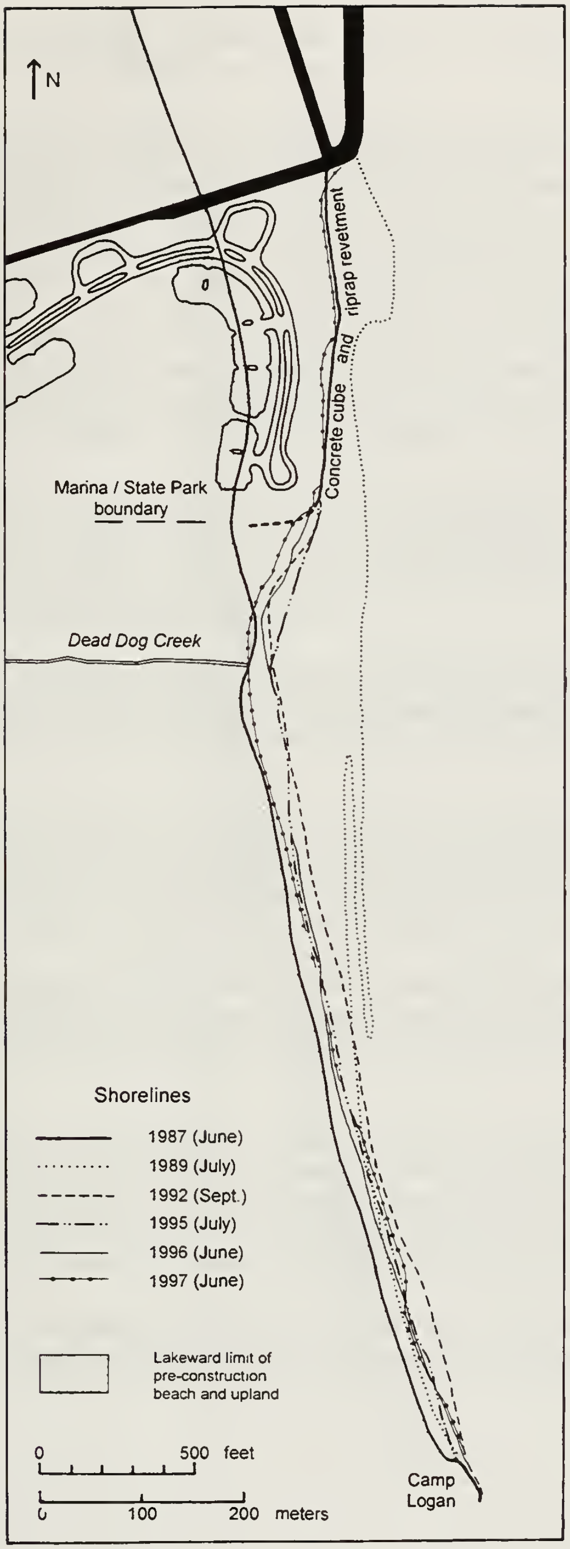


Figure 3-3 Shoreline positions on the south side of North Point Marina (1987-1997). Selected shorelines are shown for 1987 (prior to marina construction), 1989, 1992, 1995, 1996, and 1997. Shorelines are for the lake level at the time of survey.

Several prominent nearshore bathymetric features were present. These are listed below and, where indicated, are discussed in detail in subsequent sections.

- A discontinuous nearshore bar/trough pair was developed updrift of NPM in the North Beach nearshore and downdrift of NPM in the Spring Bluff nearshore; the bar/trough pair was absent along the lakeward side of the marina. Updrift of NPM, the bar was defined by the 4 ft LWD contour and was centered 400 to 450 ft lakeward of the shoreline. Minimum depths along the bar crest ranged from 3.0 to 3.5 ft LWD. A trough was developed on its landward side with a maximum axial depth of 5.6 ft. The role of the North Beach bar as a potentially mineable sand reserve is discussed further in "Part 3: North Beach Bar." Downdrift of NPM, the bar was discontinuous, was defined by the 2- and 3-ft LWD contours, and was generally centered 70 to 150 ft lakeward of the shoreline. Minimum depths along the bar crest ranged from approximately 0.9 ft LWD near Dead Dog Creek to approximately 2.7 ft LWD near the Camp Logan headland. A discontinuous trough developed on its landward side had a maximum axial depth of 4.7 ft LWD.

- Adjacent to the northeast-facing segment of the north breakwater, a 500 ft-long trough was present with axial depths ranging from 10 ft LWD at its northern end to 17 ft LWD at its southern end (Fig. 3-4). At its southern end, this trough opened into a broad depression that had a maximum depth of 17.7 ft LWD east of the tip of the north breakwater (see "Part 3: Lake-Bottom Erosion Adjacent to the NPM North Breakwater").

- At the marina entrance, an asymmetric bathymetric profile existed between the tips of the north and south breakwaters. The deepest part of the profile was associated with a narrow 16-ft deep trough that was centered about 60 ft west of the tip of the north breakwater (see "Part 3: Marina Entrance").

- In the approach channel to the recreational boat basin, an elongate erosional trough with a maximum axial depth of 20.6 ft LWD was located within 35 ft of the north inner breakwater (see "Part 3: Approach Channel to the NPM Recreational Boat Basin"). Depths of this magnitude ordinarily occur much further offshore, at least 650 ft lakeward of the outer breakwaters.

- East-southeast of the marina entrance, an irregular contour pattern in water depths greater than 20 ft LWD has been identified as an area of glacial till outcrop (Chrzastowski *et al.*, 1996). A similar bathymetric irregularity was present at comparable depths to the east of Dead Dog Creek in IBSP/NU.

- Extending about 600 ft southward from the south side of the south breakwater, a line of submerged riprap formed a shoal area with a crest elevation averaging about 5 ft LWD (Fig. 3-4). Between this line of submerged riprap and the riprap-defended shoreline 150 ft to the west, an erosional trough has persisted since 1991; maximum axial depths during 1997 ranged from 9 to 10 ft LWD (see "Part 3: Submerged Riprap at the NPM South Parking Area").

- South of the marina, three localized deflections of the 12 to 15 ft LWD isobaths occurred at 1,500 to 2,000 ft intervals. These marked the locations of subtle, shore-oblique, low-relief sand ridges and swales.

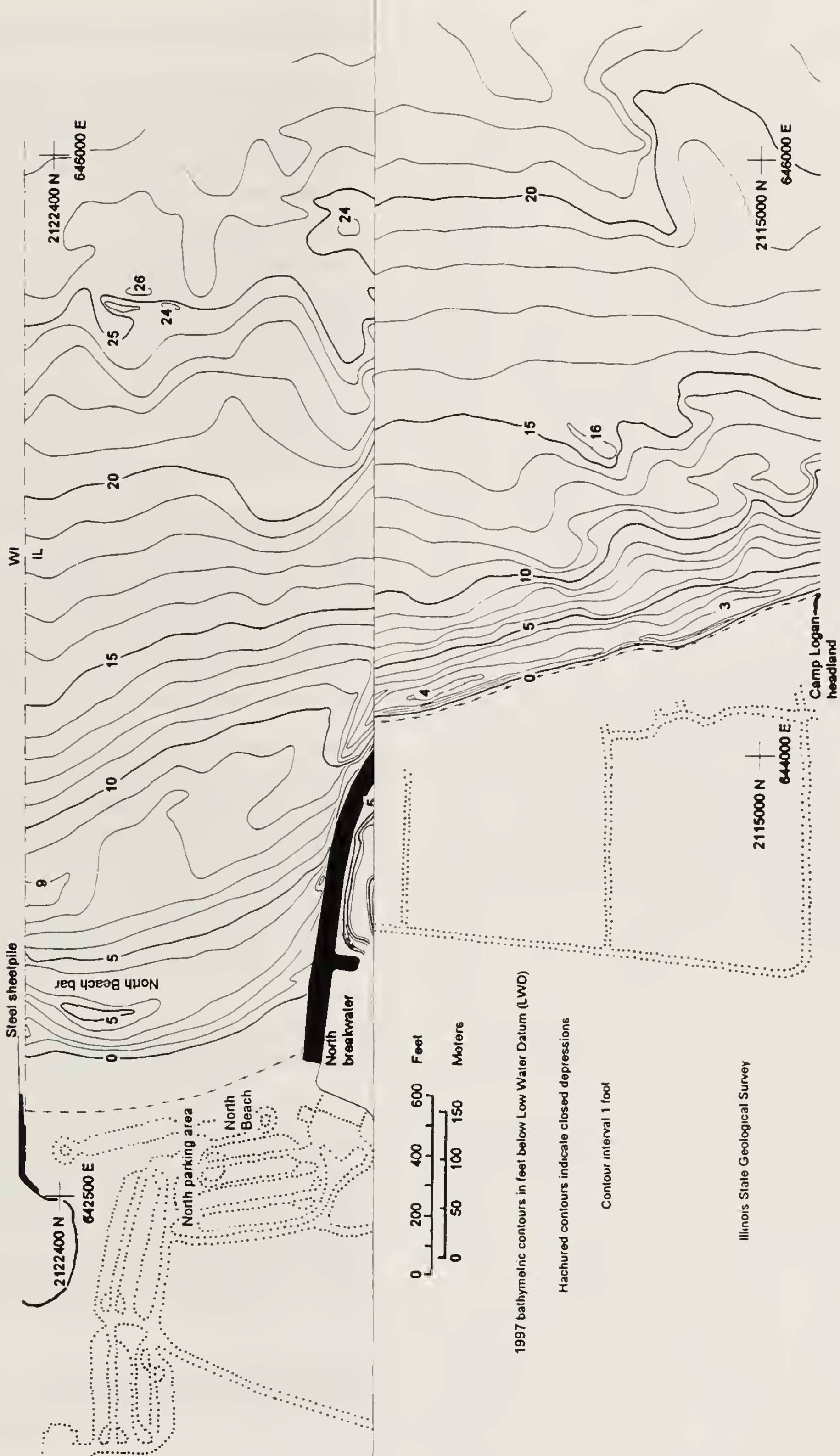
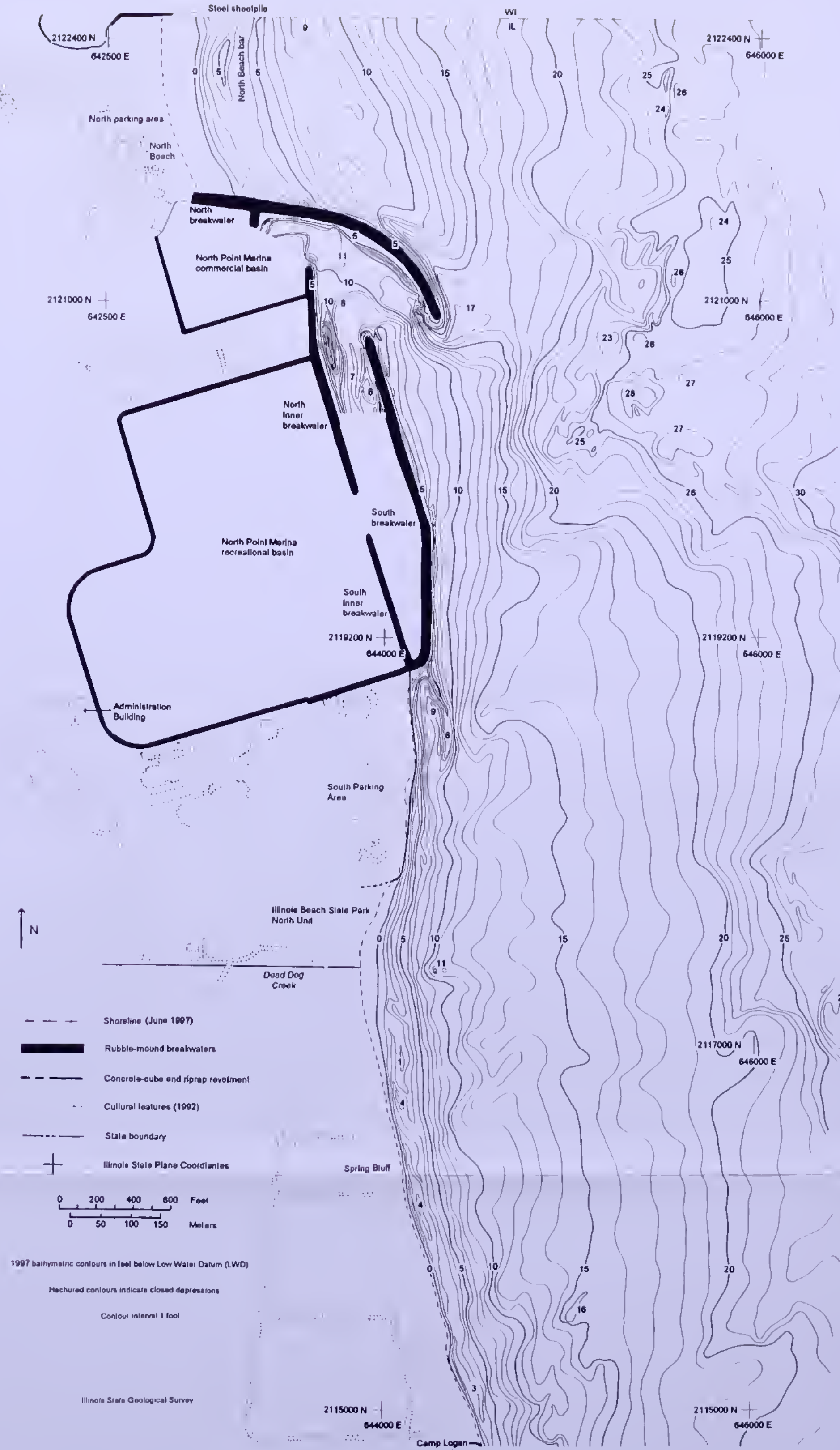


Figure 3-4 1997 bathymetry in the North P

Figure 3-4 1997 bathymetry in the North Point Marina vicinity.



1996-1997 Lake-Bottom Change (Figure 3-5, Table 3-1)

During 1996-1997, the nearshore in the NPM vicinity showed minor net accretion (+3,500 cu yds; Table 3-1). The volume of accretion (+62,300 cu yds) was slightly greater than the volume of erosion (-58,800 cu yds). More than 90% of the lake-bottom erosion and accretion occurred in water depths less than 15 ft LWD which is where previous reports have also documented that most lake-bottom change typically occurs on an annual basis (see Chrzastowski *et al.*, 1996; Foyle *et al.*, 1997a,b).

Table 3-1 Annualized nearshore change volumes between the WI-IL state line and Camp Logan (1992-1997).[1]

	1992-1995[2]	1995-1996	1996-1997
Accretion (cu yds/yr)	34,000	64,800	62,300[4]
Erosion (cu yds/yr)	58,400	204,100	58,800[4]
Total Net Change[3] (cu yds/yr)	-24,400	-139,300	+3,500[4]

[1] All volumes are computed for lake-bottom elevation changes in excess of 1 ft occurring below Low Water Datum (LWD) and include volumetric changes in the marina entrance[4]. Volumes are rounded to the nearest 100 cu yds.
[2] These are annualized volume changes derived from a comparison of Year-1 (1995) data and data available from 1992.
[3] Net accretion is indicated by a positive number and net erosion is indicated by a negative number.
[4] These volumes include 1996-1997 lake-bottom changes in the marina entrance which were influenced by 1996 marina-entrance dredging. Erosion in the marina entrance totaled 1,800 cu yds, accretion was 1,400 cu yds, and net change was erosion of 400 cu yds

In general, the nearshore between the state line and the NPM south parking area was net erosional while that between the south parking area and Camp Logan was net accretional. Figure 3-5 illustrates that the most significant lake-bottom changes during 1996-1997 were associated with: (1) partial infilling of a pre-existing (1996; see Appendix D, Map D-2) erosional trough that extended from the state line across the North Beach nearshore and along the lakeward side of the north breakwater; (2) erosion just east of the marina entrance near the tip of the north breakwater; (3) erosion in the approach channel to the NPM recreational boat basin; (4) accretion within 150 ft of the shoreline along the length of the south breakwater and south parking area; and (5) erosion within 150 ft of the shoreline along most of the shore south of Dead Dog Creek.

Accretion Accretion in excess of 1 ft occurred in four principal areas. These are listed below and, where indicated, are discussed in detail in subsequent sections.

- At North Beach, two distinct NNW-SSE trending accretional bands occurred 400 to 500 ft and 750 to 1000 ft offshore, respectively (Fig. 3-5). The two bands merged near the north breakwater to run along the lakeward side of the breakwater as a single band centered about 100 ft offshore. Along the inner accretional band, a maximum of 2.6 ft of accretion was documented (Fig. 3-5; see "Part 3: North Beach Bar"). Along the outer accretional band, a maximum of 4.2 ft of accretion occurred adjacent to the north breakwater (Fig. 3-5; see "Part 3: Lake-Bottom Erosion Adjacent to the NPM North Breakwater"). Just over 7 ft of localized accretion occurred near the tip of the north breakwater.

- Along the lakeward side of the south breakwater, accretion occurred primarily within a 20- to 100-ft wide elongate band in water depths less than 10 ft LWD. A maximum of 3.6 ft of accretion occurred (Fig. 3-5).

- Along the lakeward side of the south parking area, nearshore accretion averaging 1.5 ft occurred in water depths less than 15 ft LWD. Accretion occurred primarily within a 100-ft wide elongate

band located within 150 ft of the shoreline (see "Part 3: Submerged Riprap at the NPM South Parking Area"). Sand may have been supplied to this area by a redistribution of backfill eroded from several embayments along the south parking area (see "Part 3: Monitoring at the NPM South Parking Area"). Some of the material may also have been remnant sand that was dredged from the marina entrance in 1996 and deposited in this area. Minor areas of accretion occurred in a narrow discontinuous band along the lakeward flank of the submerged riprap.

- South of Dead Dog Creek, accretion occurred in two principal areas. (1) Accretion averaging 2 ft occurred along 1300 ft of nearshore north of the Camp Logan headland. This 20-ft wide accretional band was located 20 to 100 ft offshore in water depths of less than 6 ft and was caused by partial infilling of the 1996 nearshore trough. (2) Accretion averaging 2 ft occurred just south of Dead Dog Creek in a broad area centered 200 to 300 ft offshore in water depths of 3 to 12 ft LWD. Sand was probably supplied to this area from erosion at the IBSP/NU beach nourishment site located just updrift.

Erosion Erosion in excess of 1 ft occurred in six principal areas. These are listed below and, where indicated, are discussed in detail in subsequent sections.

- At North Beach, erosion occurred primarily along a single NNW-SSE trending band located 600 to 700 ft offshore, between the two accretional bands described above. The erosion resulted from profile steepening and from the shrinkage and landward migration of the North Beach bar. A maximum of 2.9 ft of erosion occurred (Fig. 3-4; see "Part 3: North Beach Bar").

- Just east and south of the marina entrance, the lake bottom generally deepened by 1 to 2 ft with a maximum of 4.5 ft.

- 1000 ft east-southeast of the marina entrance, apparent erosion of 1 to 3 ft occurred within several patches located lakeward of the 15 ft LWD isobath. Most of this change took place in the area where glacial till is known to be exposed on the lake bottom. This apparent erosion may be due to uncertainties in year-to-year boat positioning when profiling an irregular lake bottom or may be due to real erosion of mobile sand accumulations located on the till surface.

- In the approach channel to the NPM recreational boat basin, the lake bottom generally deepened by about 2 ft at the site of an erosional trough (see "Part 3: Approach Channel to the NPM Recreational Boat Basin").

- Lakeward of the south parking area, minor erosion occurred in isolated patches in water depths of 10 to 15 ft LWD. The northern part of the trough on the landward side of the submerged riprap deepened by about 1 ft (see "Part 3: Submerged Riprap at the NPM South Parking Area").

- South of Dead Dog Creek, erosion occurred in two general areas (Fig. 3-5). (1) Erosion averaging 2 ft occurred within a narrow elongate band located within 150 ft of the shoreline and in water depths less than 5 ft LWD along most of the shoreline. The erosion was caused by a general steepening of the shallow nearshore profile that accompanied shoreline recession during 1996-1997. (2) A series of shore-oblique erosional patches with an average of 1 ft of erosion occurred southeast of Dead Dog Creek in water depths of 5 to 14 ft LWD. This erosion was related to storm-wave remolding of the sandy lake bottom and development of shore-oblique swales between broad sand ridges (Fig. 3-5).

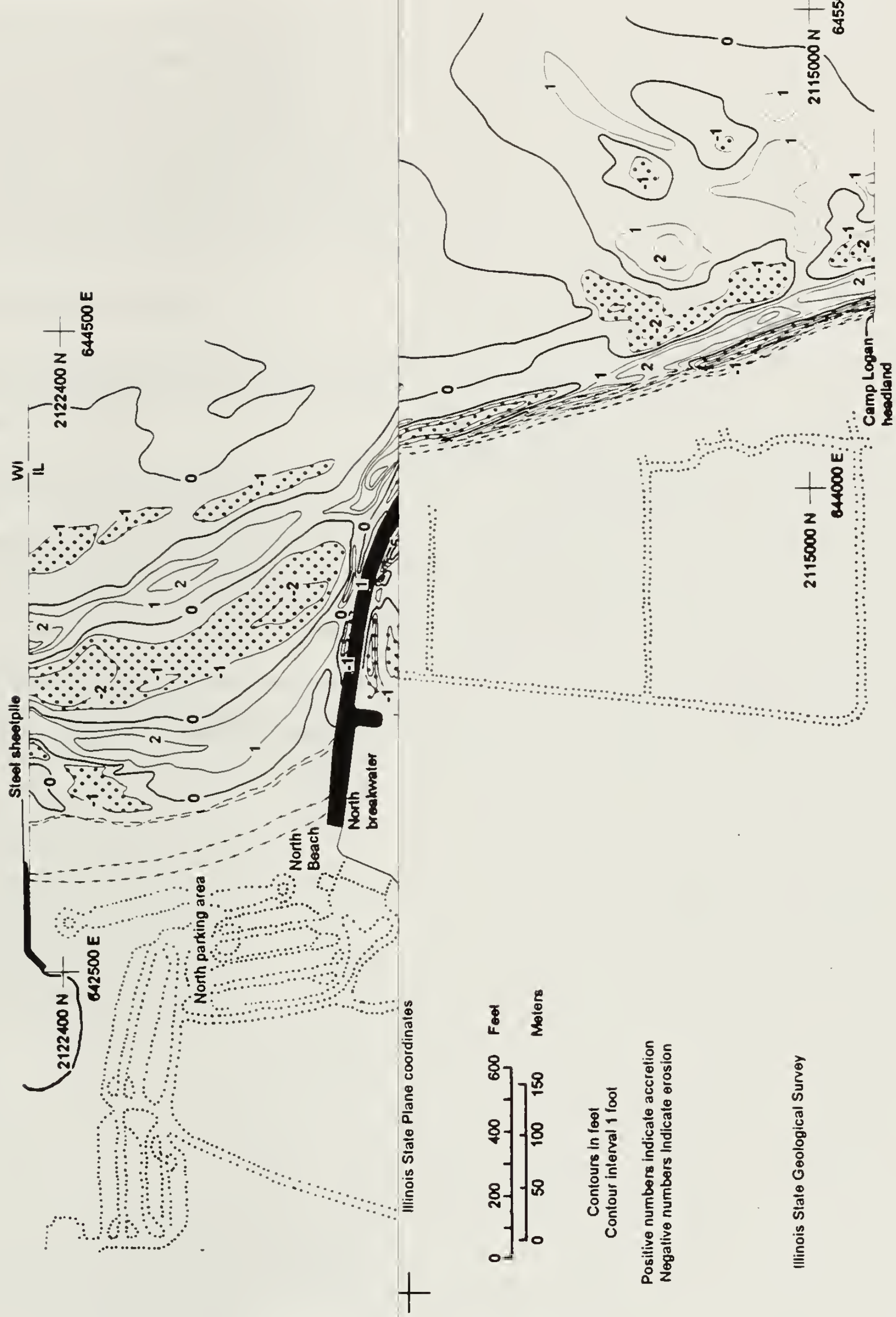


Figure 3-5 1996-1997 lake-bottom change

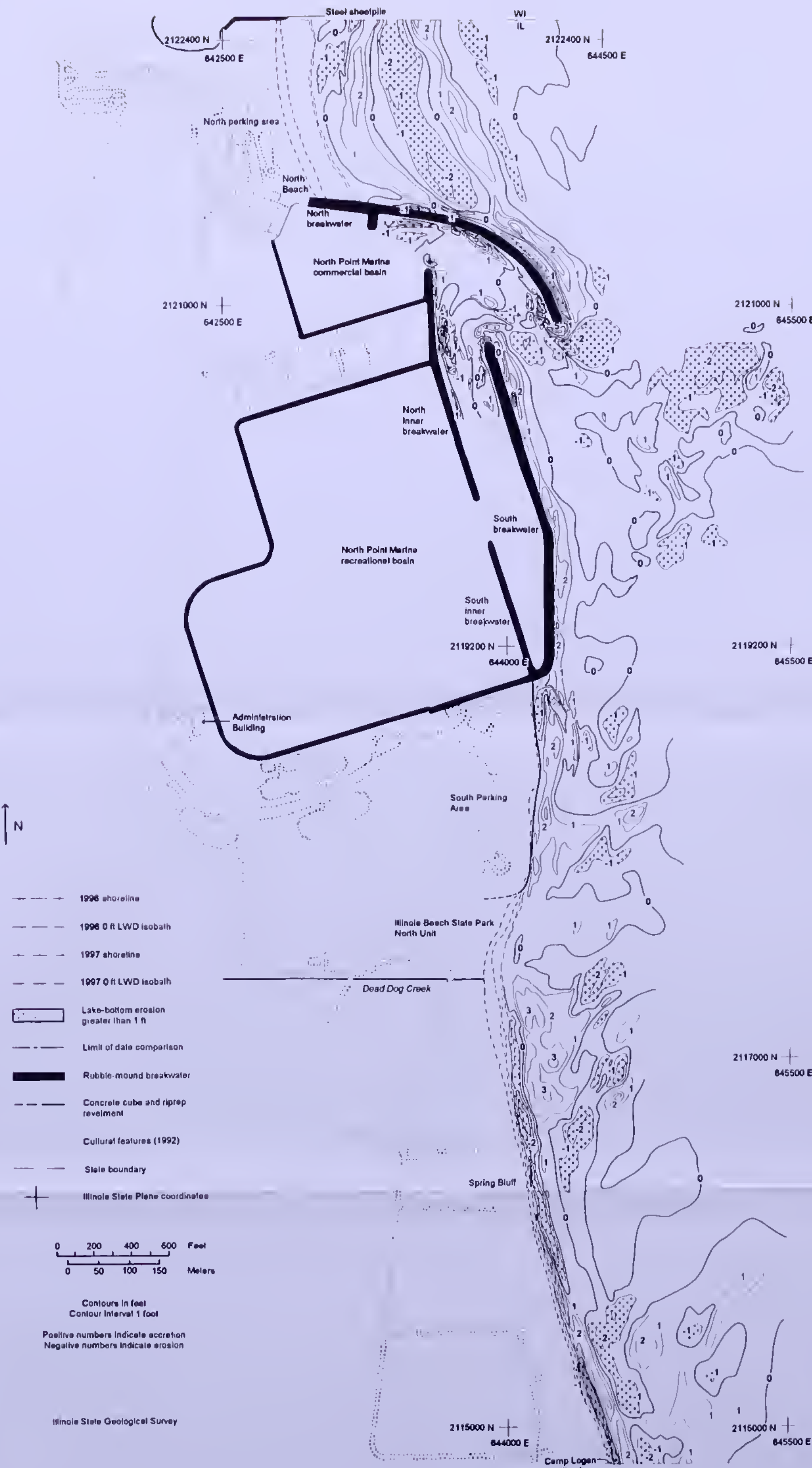


Figure 3-5 1996–1997 lake-bottom change in the North Point Marina vicinity.

North Beach Bar (Figure 3-6, Table 3-2)

Background and significance

The North Beach bar is a submerged nearshore feature that extends from the WI-IL state line southward towards the NPM north breakwater (Figs. 3-1, 3-4). It is part of a relatively continuous bar system that can be found in the nearshore from the state line south to Waukegan Harbor. The bar was absent from the North Beach nearshore in the late 1980s, but since 1990 it has been defined as a shoal area at depths less than 9 ft LWD. The bar is significant within the context of coastal sand management because it is part of the littoral sediment transport pathway and is a temporary storage area for some of the littoral sediment crossing into the Illinois nearshore from the Wisconsin nearshore. The bar is a localized sand reserve that is potentially mineable for downdrift beach nourishment.

1996-1997 bathymetric change

The North Beach bar is a mobile lake-bottom feature. Table 3-2 summarizes the principal morphologic characteristics of the bar since 1990 and Fig. 3-6 schematically illustrates the location of the bar during 1990-1992 and 1995-1997.

During 1996-1997, the North Beach bar moved about 100 ft landward of its 1996 position and into shallower water. The overall landward migration of the bar since 1990 (Fig. 3-6) suggests that it is in the process of accreting or "welding" onto North Beach, a process that will ultimately increase beach width. The bar became a less pronounced feature during 1996-1997 compared with previous years. Significant decreases in bar length, area, and volume indicate that, as of 1997, the bar is not immediately suitable as a mineable resource for beach nourishment purposes.

Table 3-2 Summary morphologic characteristics of the North Beach bar (1990-1997).

	1990	1991	1992	1995	1996	1997
Distance offshore[1] (ft)	700	900	900	600	500	425
Proximity to breakwater[2] (ft)	100	150	200	250	100	450
Shallowest closed contour[3] (ft)	6	8	8	5	4	4
Deepest closed contour[3] (ft)	7	8-9[4]	9	6	5	4[4]
Length[5] (ft)	1000	1000	1000	750	1050	500
Area (sq yds)	10,700	17,100	15,200	14,300	15,600	5,600
Volume[6] (cu yds)	34,000	59,100	51,000	33,700	32,700	9,600

[1] Distance offshore is the average distance to the bar crest measured due east of the shoreline.
[2] Distance between the south end of the bar and the north breakwater
[3] Contours are referenced to Low Water Datum (LWD).
[4] During 1991 and 1997, most of the bar had an atypical plateau-like morphology.
[5] Bar length is measured along the bar axis.
[6] Volumes are rounded to the nearest 100 cubic yards.

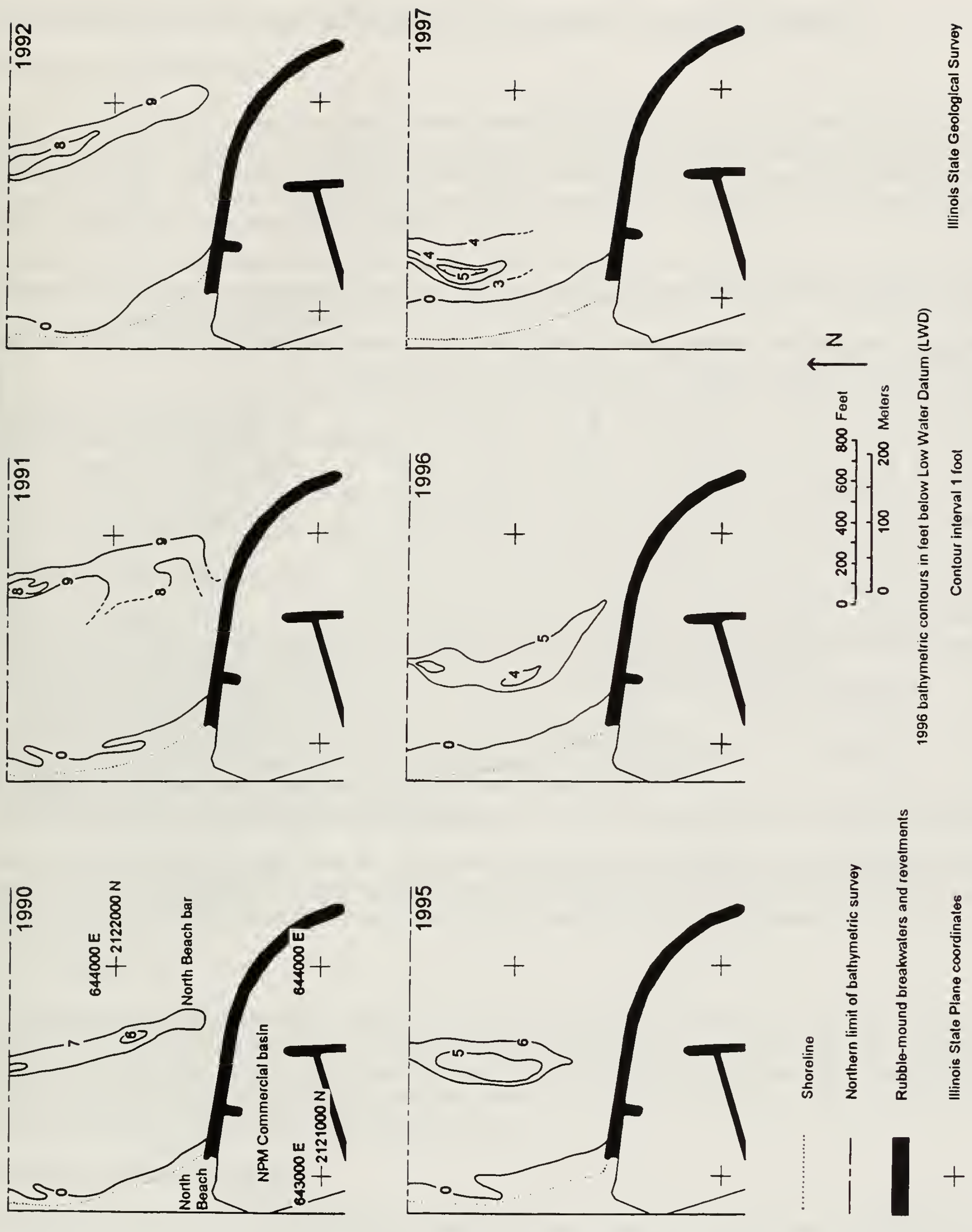


Figure 3-6 Locations of the North Beach bar during 1990, 1991, 1992, 1995, 1996 and 1997. The outline of the bar is generally defined by the deepest closed contour that encloses the bar axis.

Lake-Bottom Erosion Adjacent to the NPM North Breakwater (Figure 3-7, Table 3-3)

Background and Significance

The Year-1 and Year-2 reports documented that an erosional trough has been present along the lakeward side of the north breakwater since 1988. Comparisons of 1987 and 1996 data indicated that the trough was an "erosional hotspot" where, in 1996, the lake bottom was as much as 3 ft deeper than it was in 1987 (Foyle *et al.*, 1997a). Data collected in summer 1997 indicate that the trough was still present but had become less pronounced than it was in 1996 (Table 3-3).

Table 3-3 Summary characteristics of the lake-bottom trough adjacent to the North Point Marina north breakwater (1988-1997).

	1988	1989	1990	1991	1992	1995	1996	1997
Distance from breakwater[1] (ft)	150	200	70	100	90	40	90	80
Max. closed contour[2] (ft LWD)	16	15	13	16	16	11	18	17
Min. closed contour[3] (ft LWD)	15	n/a[6]	13	16	15[7]	n/a[6]	17	n/a[6]
Depression relief[4] (ft)	2	1	2	3	6	2	7	5
Depression length[5] (ft)	280	300	600	650	650	850	820	500

[1] Distance to trough axis is measured orthogonal to the lakeward face of the breakwater from the waterline.
[2] Depth is that of the deepest contour that defines the depression. The north breakwater base elevation adjacent to the depression lies between 13 and 15 ft LWD.
[3] Depth is that of the shallowest closed contour that completely defines the depression.
[4] Difference in elevation between the base of the depression and the lake-bottom immediately to the north and south.
[5] Length of the depression is measured parallel to the lakeward face of the north breakwater.
[6] Depression is a southeastward-opening trough without a contained closed contour.
[7] Depression is part of a larger, southeastward-opening trough.

The trough is significant because it lies adjacent to the lakeward side of the north breakwater. The presence of the trough means that there is the potential for an adverse effect on the breakwater should wave conditions and growth of the trough induce scour near the toe of the breakwater.

1997 bathymetry

During late spring 1997, the trough was approximately 500 ft in length and had axial depths ranging from 10 ft LWD at its northern end to 17 ft LWD at its southern end (Fig. 3-4). At its south end, the trough opened into a broad depression with a maximum depth of 17.7 ft LWD located about 100 ft east of the tip of the north breakwater. This broad depression extended into the marina entrance as a deep narrow trough defined by the 16-ft LWD bathymetric contour.

1996-1997 lake-bottom change

As shown in Figs. 3-5 and 3-7, the erosional trough shallowed by as much as 4 ft during 1996-1997 and became a less pronounced bathymetric feature when compared with 1996 (see Appendix D). While the trough moved slightly closer to the north breakwater during 1996-1997, it decreased in overall length and relief. The axis of the trough in 1997 was only about 1.7 ft deeper than the lake bottom at this site had been in 1987.

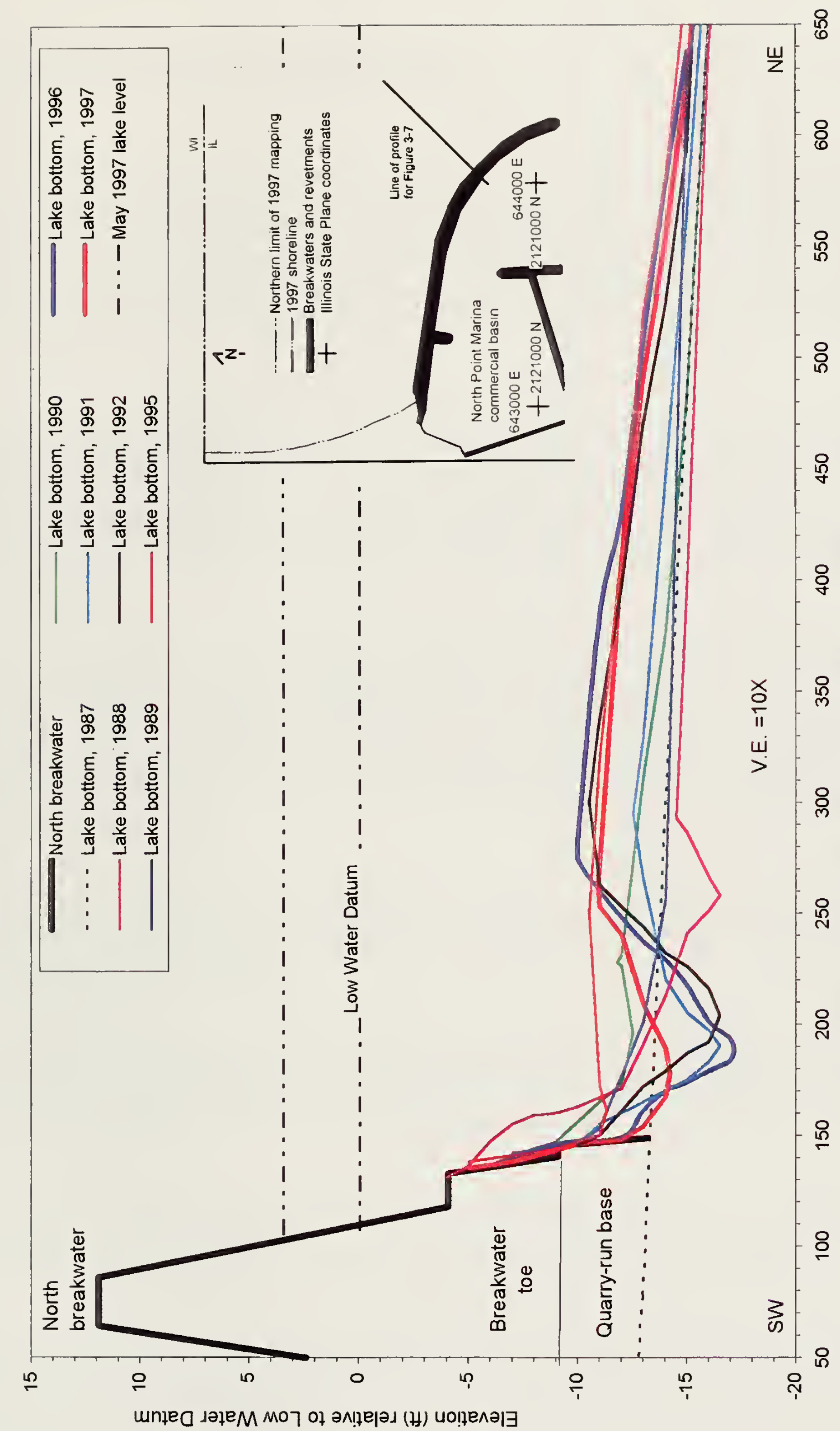


Figure 3-7 Cross-section and profiles showing the relationship between the NPM north breakwater and the adjacent lake-bottom erosional trough. Data are shown for 1987-1992 and 1995-1997.

Marina Entrance (Figures 3-8, 3-9, 3-10; Table 3-4)

Background

The marina entrance is defined as that area bounded by the south tip of the north breakwater, the north tip of the south breakwater, the north tip of the north inner breakwater, and the inner spur on the north breakwater (Fig. 3-1). The marina entrance has trapped littoral sediment since the marina was constructed and the associated shoaling has the potential to hinder navigation at the entrance. Intermittent dredging helps to mitigate the shoaling problem. As of 1997, the most recent dredging was conducted between April and August 1996 when 18,000 cu yds of sand were removed (Foyle *et al.*, 1997a).

1997 bathymetry

The 1997 bathymetry was generally similar to the 1996 bathymetry. An asymmetric lake-bottom profile, first documented in 1989, persisted between the tips of the north and south breakwaters (Fig. 3-8). The asymmetry appears to be a relatively stable configuration maintained by hydrodynamics at the entrance. The maximum recorded water depth in the entrance was 16.6 ft LWD and occurred within a deep narrow trough, defined by the 16 ft LWD closed bathymetric contour (Fig. 3-9), that extended into the entrance from offshore. The axis of this trough was about 1 to 1.5 ft below the design elevation for the base of the north breakwater.

The northeastern side of the marina entrance, leading towards the commercial basin, generally had depths of 10 to 11 ft LWD (Fig. 3-9). A small depression defined by the 12 and 14 ft LWD isobaths has persisted since 1995 in an area located about 50 ft from the tip of the north inner breakwater. On the southwestern side of the marina entrance, leading towards the recreational basin, water depths generally ranged from 5 to 10 ft LWD. The pattern of bathymetric contours in this area was simpler than that of 1996 because waves and currents had smoothed the lake bottom since summer 1996 dredging.

1996-1997 lake-bottom changes

Comparison of 1996 and 1997 bathymetric maps indicates that the marina entrance lost 400 cu yds of sediment during 1996-1997. This was a relatively minor change compared to previous years (Table 3-4). The erosion volume (-1,800 cu yds) was similar to the accretion volume (+1,400 cu yds). Most change took place adjacent to the breakwaters.

Calculation of 1996-1997 lake-bottom change for the marina entrance is complicated by the fact that 1996 data were collected prior to the completion of 1996 dredging. This may have caused an underestimation of the 1996-1997 accretion volume and an overestimation of the 1996-1997 erosion volume. It is, therefore, probable that the marina entrance may have been less net-erosional (and possibly net accretional) during 1996-1997.

Accretion The largest area of accretion in excess of 1 ft occurred adjacent to the north breakwater where there was locally up to 5 ft of accretion (Fig. 3-10). Smaller areas with more than 3 ft of accretion occurred adjacent to the tips of the north inner breakwater, the north breakwater, and the south breakwater. Just over 2 ft of accretion occurred in a small area in the center of the marina entrance.

Erosion Erosion in excess of 1 ft occurred primarily just east of the spur on the north breakwater, and just north of the tip of the north inner breakwater (Fig. 3-10); there was just over 3 ft of erosion in both areas. Small localized patches of erosion occurred near the tip of the north breakwater where the lake bottom deepened by up to 3 ft. Erosion in this area was part of a larger erosional band that extended into the entrance from offshore (Figs. 3-4, 3-10).

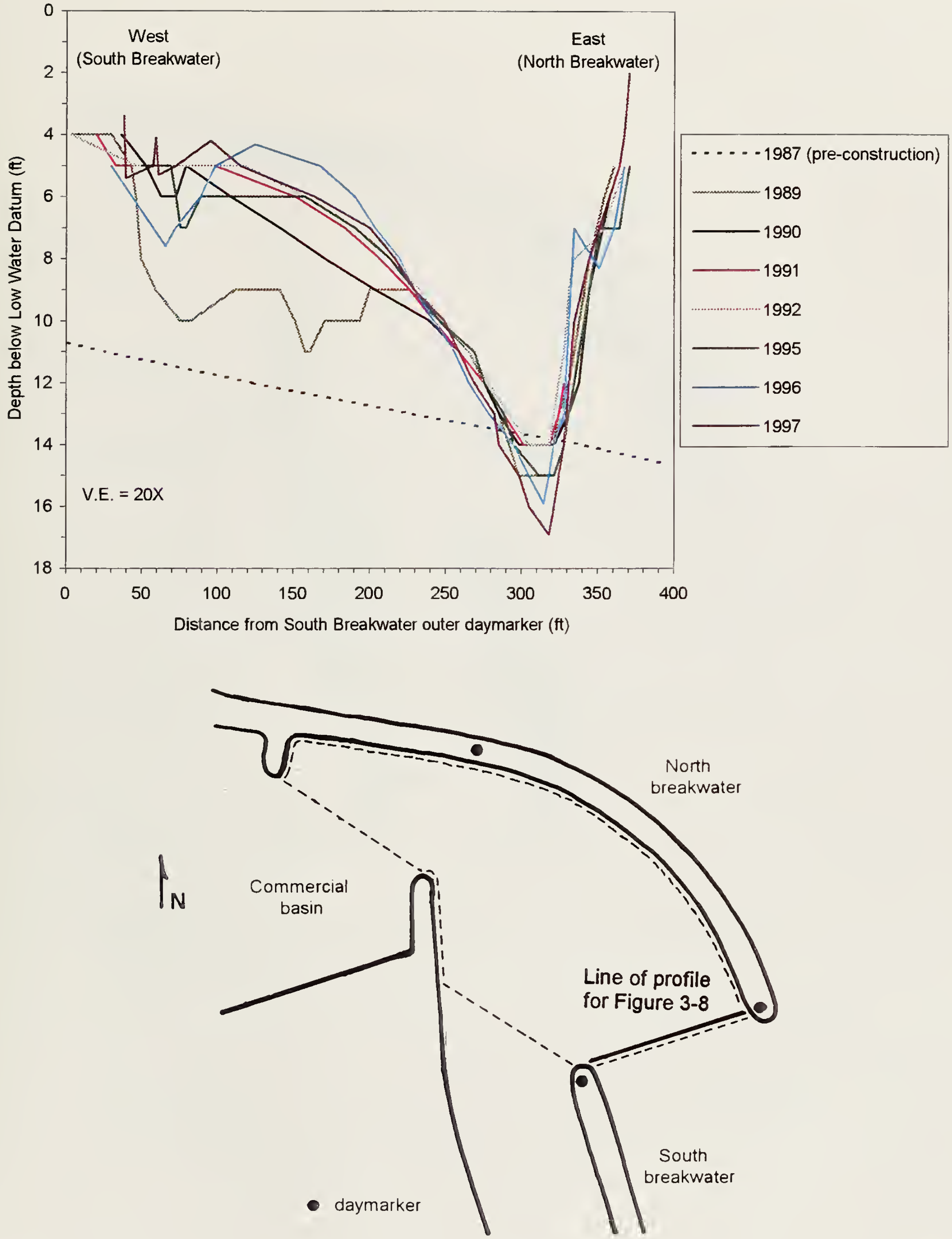


Figure 3-8 Cross-sectional profiles at the entrance to North Point Marina (1989-1997). The line of section extends from the tip of the south breakwater to the tip of the north breakwater. Index map shows profile location and the boundary limits used for annual volume-change calculations in the marina entrance.

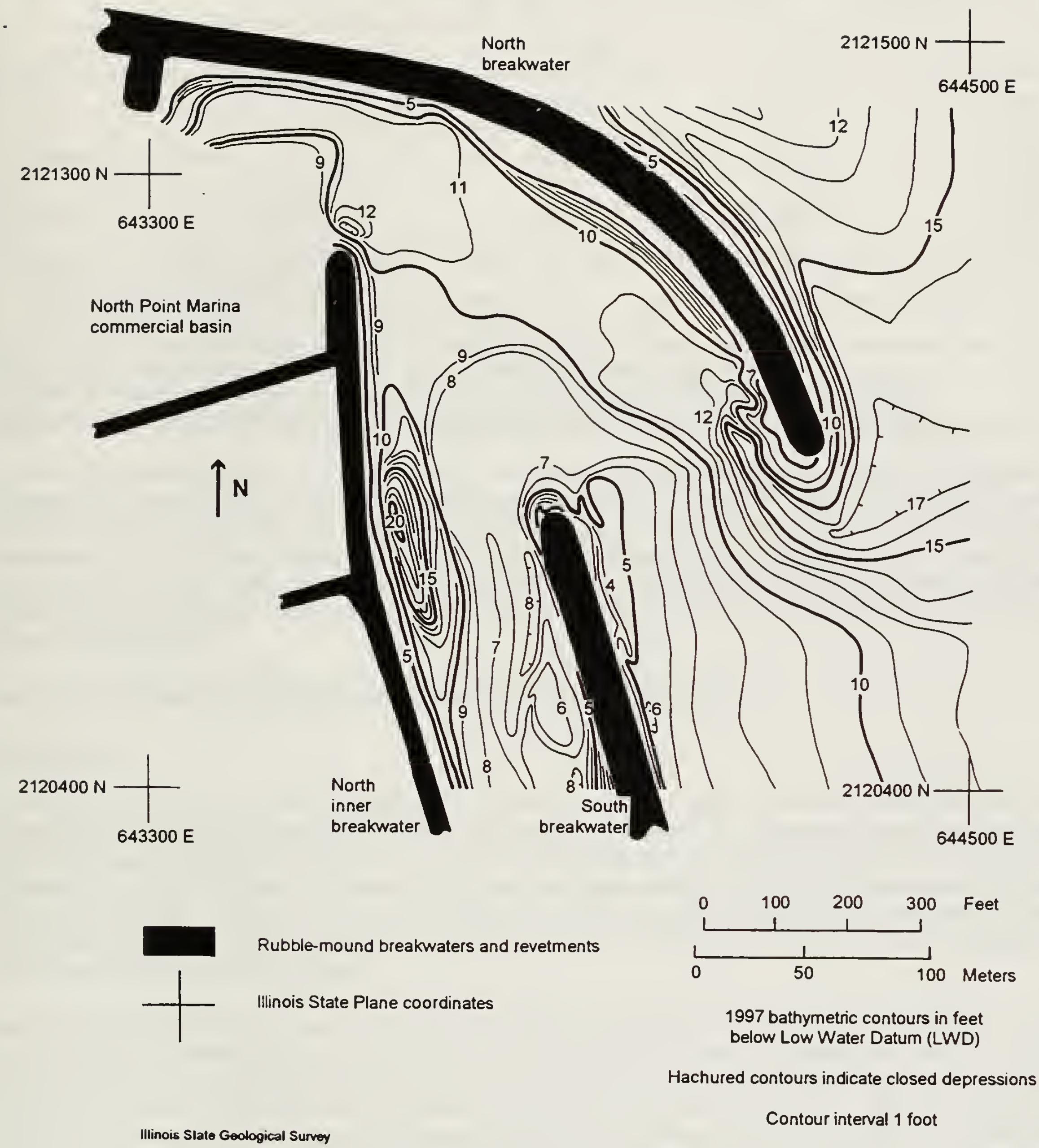


Figure 3-9 1997 bathymetry in the North Point Marina entrance and in the approaches to the recreational boat basin.

Table 3-4 Summary of erosion and accretion volumes in the North Point Marina entrance area.[1]			
	1992-1995[2]	1995-1996	1996-1997
Accretion (+) cu yds	11,800	2,100	1,400
Erosion (-) cu yds	2,600	5,400[3]	1,800
Net change[4] (cu yds)	+9,200	-3,300[5]	-400[6]
Annual net change[4] (cu yds/yr)	+3,100	-3,300[5]	-400[6]

[1] All volumes are computed for lake-bottom elevation changes in excess of 1 ft and occurring below Low Water Datum (LWD). Volumes are rounded to the nearest 100 cu yds.
[2] Three-year comparison between Year-1 data and data available from 1992; erosion and accretion volumes are for the three-year summation and annual net change is a three-year average.
[3] This is an apparent erosion volume. A component of this volume is due to sediment removal during 1996 dredging (see text).
[4] Net accretion is indicated by a positive number and net erosion is indicated by a negative number.
[5] Net change is based on comparison of 1995 and 1996 bathymetry and excludes 1996 dredging effects (see text).
[6] Net change is based on comparison of 1996 and 1997 bathymetry and excludes 1996 dredging effects (see text).

Figure 3-10 indicates that, as of summer 1997, those parts of the marina entrance that were dredged in 1996 generally remained at, or within 2 ft of, their depths as recorded during dredging in June 1996 (Foyle *et al.*, 1997a). However, the asymmetric cross-sectional profile between the tips of the north and south breakwaters (Fig. 3-8) has shown a trend, since 1989, of progressive shallowing along the west side of the entrance near the south breakwater. This suggests that, unless wave climate and littoral sediment supply change significantly over the next five to ten years, there will likely be a need for future dredging in the marina entrance.

<u>Approach Channel to the NPM Recreational Boat Basin (Figure 3-11)</u>

Background

The approach channel to the recreational boat basin is defined as the waterway that connects the recreational boat basin to the marina entrance; it is located between the south breakwater and the north and south inner breakwaters. The northern third of the approach channel was mapped in 1997 to monitor conditions at an erosional trough adjacent to the north inner breakwater that was documented in the Year-2 Report (Foyle *et al.*, 1997a). Water depth at this erosional trough significantly exceeded design depth for the marina. The trough had a maximum depth that was more typical of depths occurring at least 650 ft lakeward of the outer breakwaters.

Available data indicate that, between the time of marina construction and the summer of 1990, a broad bathymetric depression began to form at the north end of the approach channel near the site of the present trough. This bathymetric depression moved closer to the north inner breakwater during 1990-1991 when it had a maximum recorded depth of just over 13 ft LWD (Fig. 3-11). By 1994-1995, the depression had evolved into a closed elongate trough with a maximum depth of just over 17 ft LWD and was located about 50 ft from the north inner breakwater (Patrick Engineering, Inc., 1995a). The 1996 and 1997 data chronicled continued deepening of the trough and a slow westward migration towards the north inner breakwater.

1997 bathymetry

An asymmetric east-west cross-sectional profile characterized 1997 bathymetry in the northern part of the approach channel (Figs. 3-9, 3-11). Water depths were generally 8.5 ft LWD or less along the east side of the channel but attained a maximum of 20.6 ft LWD along the west side of the channel. This maximum

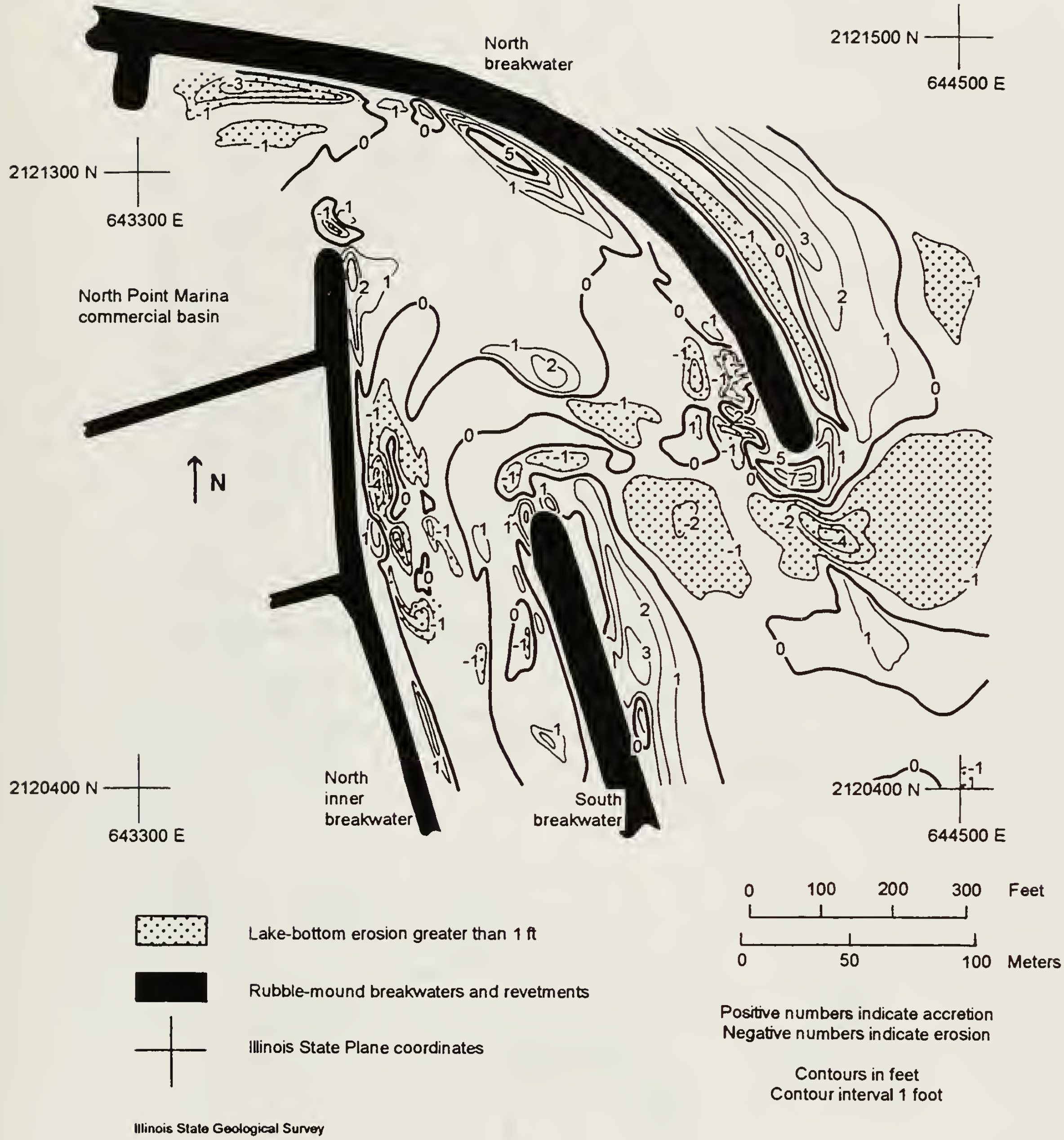
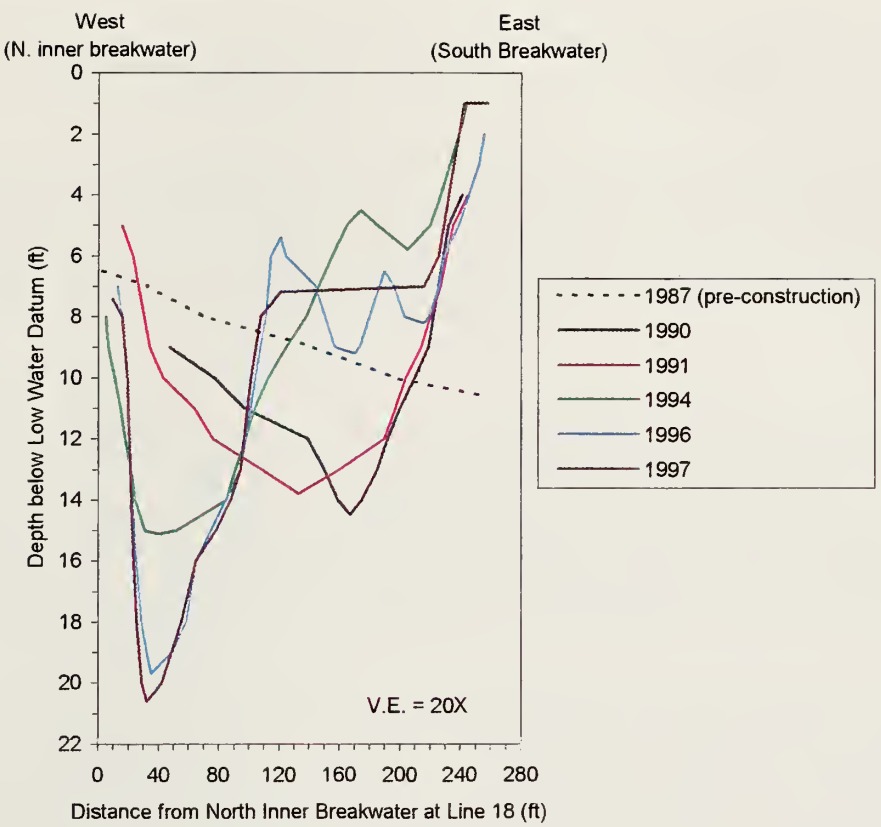


Figure 3-10 1996-1997 lake-bottom change in the North Point Marina entrance and in the approaches to the recreational boat basin. Lake-bottom change in the marina entrance was partly affected by dredging in summer 1996 immediately following collection of 1996 bathymetric data.



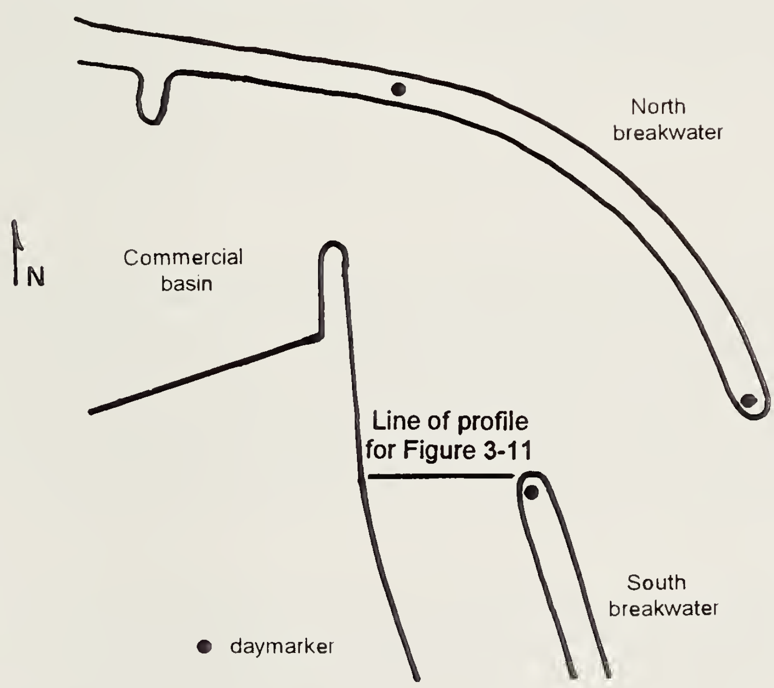


Figure 3-11 Cross-sectional profile across the north end of the approach to the recreational boat basin. Data are available for the years 1990, 1991, 1994/1995 (Patrick Engineering, Inc., 1995a), 1996, and 1997. The line of section extends from the north inner breakwater eastwards to the tip of the south breakwater. Index map shows profile location.

depth occurred in the north-south oriented trough which was located within 35 ft of the north inner breakwater and opposite the tip of the south breakwater (Fig. 3-9). The trough, about 500 ft long, was generally defined by the 10-ft LWD isobath.

The design depth for the northern part of the approach channel changes from 8.1 to 12.1 ft LWD at the site of the trough. The northern half of the trough occurred in an area where the design depth was 12.1 ft LWD and thus lay up to 8.5 ft below design depth. The southern half of the trough occurred in an area where the design depth was 8.1 ft LWD (Moffatt and Nichol Engineers, 1986) and thus lay up to 10.5 ft below design depth. During 1997, the design depth was exceeded all along the west side of the approach channel and in two small areas on the east side of the channel.

1996-1997 lake-bottom change

Most 1996-1997 lake-bottom change in the northern part of the approach channel was associated with erosion that occurred along the west side of the channel in the vicinity of the trough. Accretion was minimal. Erosion was associated almost exclusively with an increase in length and depth of the trough. Trough length, as defined by the 10 ft LWD isobath, increased by 70 ft (14%) to a total length of about 500 ft. The lake bottom in the trough vicinity deepened, on average, by about 2 ft with a maximum deepening of just over 5 ft (Fig. 3-10). The 1997 trough axis lay about 1 ft deeper than it did in 1996 and moved about 10 ft closer to the north inner breakwater. Trough lengthening and deepening resulted in the loss of about 1000 cu yds of sand from the trough vicinity.

Bathymetric data from the approach channel for the years 1990 and 1991 suggest that the trough was not caused by over-dredging during initial construction of the marina (see Appendix A in Chrzastowski *et al.*, 1996). Rather, the trough appears to have been caused largely by current-induced erosion that was probably associated with lake-level setups and setdowns in the recreational boat basin. Deepening of the trough during 1996-1997 is interpreted to be a result of continued current scouring. However, it is possible that this current scouring may have been enhanced by altered flow patterns in the marina entrance and approach channel that could have resulted from dredging of the marina entrance during 1995-1996. Continued annual monitoring of this trough is warranted.

<u>Monitoring at the NPM South Parking Area (Figures 3-12, 3-13)</u>

Background

Between March and June 1997, about 13,500 cu yds of sand were placed along 1100 ft of riprap-defended shore at the NPM south parking area. This was done to fill erosional embayments that had developed on the landward side of the concrete-cube and riprap shore defense during storms that occurred between autumn 1996 and spring 1997. Between December 1995 and July 1996, an estimated 20,000 cu yds of sand had been applied to this area but had largely been eroded by November 1996 (Foyle *et al.*, 1997a). An irregular shoreline developed along the south parking area during 1997 (Fig. 3-4) as the shoreline locally moved landward of the shore defenses. This shoreline shift was caused by both erosion and high 1997 lake level that partially flooded the lakeward parts of several embayments.

Monitoring scheme

The shore at the south parking area was surveyed and photographically monitored between autumn 1996 and autumn 1997. Five east-west topographic/wading profiles were established at 200-ft intervals along the shore. The profile data from these surveys are presented in Appendix H. The erosional scarp along the lakeward side of the backfill was periodically mapped and is shown in Fig. 3-12.

Monitoring observations (November 1996-November 1997)

Figure 3-12 illustrates the location of the scarp crest on the lakeward side of the NPM south parking area

and along the adjacent IBSP/NU beach-nourishment site between November 1996 and November 1997; the latter site is discussed in "Part 3: Monitoring of Beach Nourishment at IBSP/NU." Overall, scarp recession occurred at the south parking area during 1996-1997. Between November 1996 and February 1997, the scarp retreated by as much as 30 ft (Fig. 3-12). Scarp recession was temporarily halted or reversed during late spring as a result of sand being added at the site during March and early April. On April 8, the scarp was located at its most lakeward 1997 position, lying almost 50 ft lakeward of the February 25 position (Fig. 3-12). Scarp retreat continued during the summer months so that by October 21 the scarp lay at or landward of the February 25 position along the entire south parking area. This indicates that most of the 13,500 cu yds of backfill applied during late spring 1997 had been transferred to the nearshore by early autumn 1997. Most of the transfer occurred subsequent to the time of the 1997 bathymetric survey.

Ground photography on October 28, immediately following the first major autumn storm of 1997, indicated that, at the north end of the south parking area, the scarp had moved to within 25 ft of the Tilted Prairie sculpture. At the south end of the parking access road, the scarp was within 18 ft of the roadway. By November 13, the scarp had reached its most landward-documented 1997 position along the northern two-thirds of the south parking area. Construction of the shoreline revetment and offshore submerged breakwater began at this time and caused a lakeward deflection of the November 13 scarp position (by as much as 25 ft; Fig. 3-12) along the southern third of the south parking area.

The least amount of scarp recession at the south parking area during 1996-1997 generally occurred along the northernmost 500 ft of shore. This segment of shore was reinforced with additional riprap in 1994 and was also partially protected from wave energy by a line of offshore submerged riprap (Figs. 3-1, 3-4; see "Part 3: Submerged Riprap at the NPM South Parking Area"). However, 40 ft of scarp recession did occur between November 1996 and November 1997 at a small but pronounced erosional embayment located 200 ft south of the NPM south breakwater (Fig. 3-12; Appendix H, Profile 38).

The greatest scarp recession at the south parking area during 1996-1997 generally occurred along the southern 600 ft of shore that lies due east of the southernmost (public-access) NPM parking lot and the southern half of the adjacent keyed-access parking lot (Fig. 3-13). This erosion was facilitated by the adjacent riprap- and concrete-cube shore defense being easily overtopped by waves.

Submerged Riprap at the NPM South Parking Area (Figure 3-14)

Background and significance

The submerged riprap is located about 150 ft offshore of the riprap-defended shoreline at the south parking area (Fig. 3-1). It is a 600-ft long line of submerged rock that forms an arcuate shoal extending southward from the elbow of the south breakwater (Fig. 3-4) and was originally placed as above-water shore protection in 1988-1989. Lake-bottom erosion in the adjacent nearshore and resultant undermining of the riprap caused its submergence by late 1990. Between 1991 and 1995, the riprap subsided at an average rate of 0.5 ft/yr (Chrzastowski *et al.*, 1996). During 1995-1996, the average subsidence rate was 0.5 to 1 ft/yr (Foyle *et al.*, 1997a). The riprap is significant because it lies within the footprint of a submerged breakwater that is being constructed to protect the south parking area (Patrick Engineering, Inc., 1993, 1995b; Appendix D in Chrzastowski *et al.*, 1996).

As of November 1997, the submerged riprap persisted as a distinctive shoal area (Fig. 3-4) that helped trip incoming storm waves along the northern part of the south parking area. The riprap has also slowed the rate of lake-bottom deepening along the northern part of the south parking area nearshore as illustrated by the relative annual positions of the 10-ft LWD isobath (Fig. 3-14).

1996-1997 riprap change

Crest elevations along the submerged riprap in 1997 ranged from approximately 3 ft LWD near the south

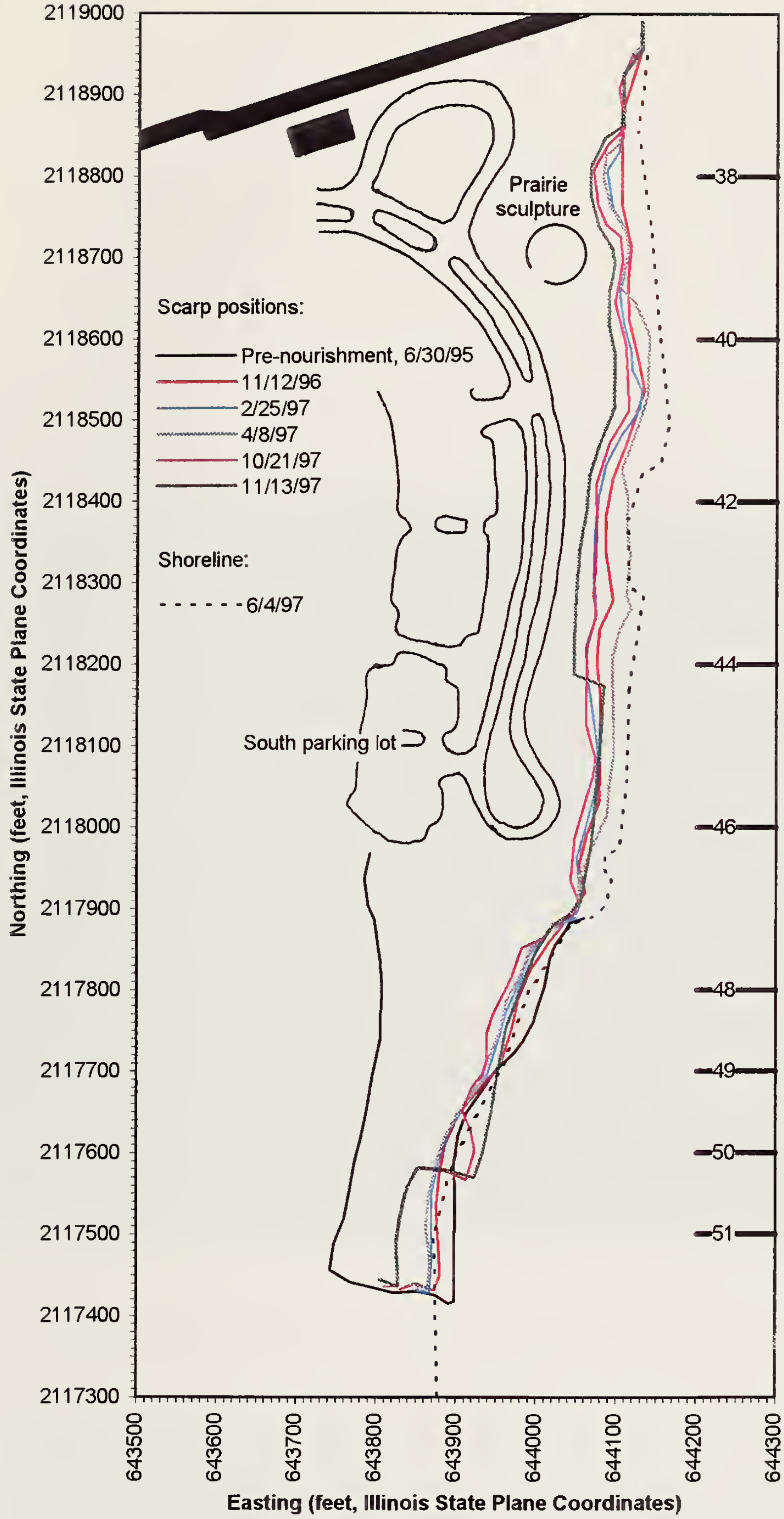


Figure 3-12 Scarp positions at the NPM south parking area lakefront and at the IBSP/NU beach-nourishment stockpile between November 1996 and November 1997. The 1995 scarp defined the stockpile geometry just prior to 1995-1997 nourishment events. With the exception of two indentations (at N2118370 and N2117960), the June 1997 shoreline along the south parking area is coincident with a line of preexisting revetment.

Figure 3-13 Photograph showing the riprap-defended shoreline and erosion of the sand and gravel backfill along the NPM south parking area. Photograph shows ground conditions in the early phase of construction of the shoreline revetment (November 1997; see text). The scarp height ranges from 6 to 7 ft, and as much as 70 ft of scarp recession has occurred since April 1997 when the scarp lay near the line of riprap (left side of photo). The sand and riprap addition associated with construction of the shoreline revetment can be seen in the background. View is to the south from a point due east of the southernmost keyed-access parking lot gate. The Camp Logan headland is visible in the distance (Photo date: November 13, 1997).

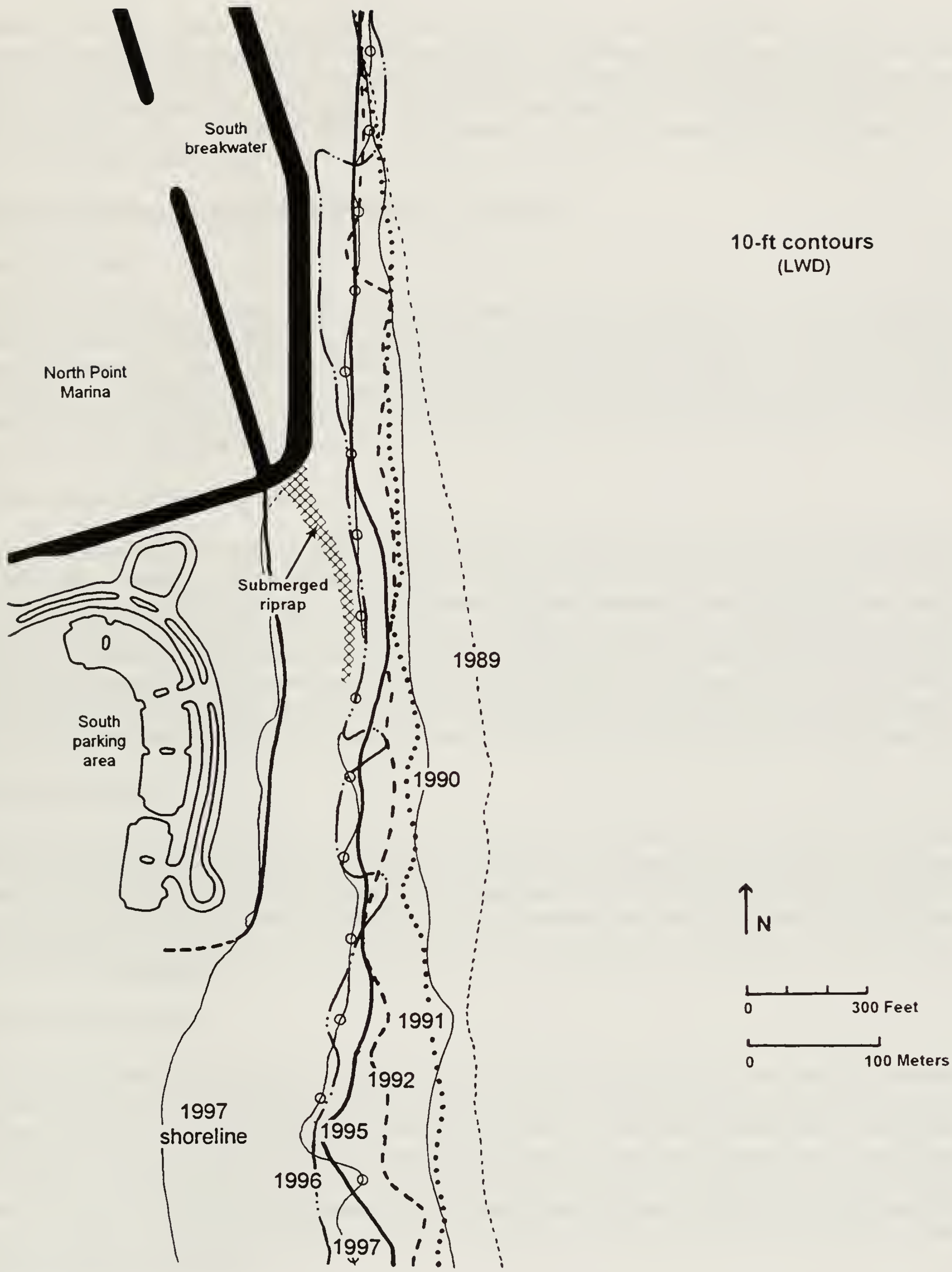


Figure 3-14 Locations of the 10-ft LWD contour lakeward of the south parking area between 1989 and 1997. Landward migration of the 10-ft LWD contour since 1989, which indicates lake-bottom deepening, has been less rapid in the vicinity of the submerged riprap compared to the nearshore immediately updrift and downdrift.

breakwater (Profile 37, Appendix F) to 7.5 ft LWD at the south end of the riprap (Profile 41, Appendix F) and showed only minor changes when compared with 1996. Comparing the 1997 profiles with the 1995 profiles in Appendix F indicates that the crest subsided about 1 ft during 1995-1997, or at a continued rate of 0.5 ft/yr. On the landward side of the riprap, a trough that has been present since 1991 had maximum depths ranging from 7.5 to 10 ft LWD (Fig. 3-4; Appendix F). The trough axis generally shallowed by 1 to 2 ft when compared with 1996.

<u>Monitoring of Beach Nourishment at IBSP/NU (Figure 3-12)</u>

General Statement

The IBSP/NU beach-nourishment site is located along 500 ft of shore between the marina / state park boundary and Dead Dog Creek (Fig. 3-1). The site received 20,000 cu yds of beach nourishment during October and November, 1997. Continuous scarp retreat occurred along the length of the stockpile during 1997 but was temporarily halted or reversed by the autumn beach nourishment (Fig. 3-12). As of November 1997, the new beach nourishment was in the process of being eroded and dispersed into the nearshore and onto downdrift beaches.

Dispersion of Beach Nourishment

Between November 1996 and October 1997, pea gravel that was added to the stockpile in 1994 (Appendix G) was still being eroded along the erosional scarp on the lakeward side of the stockpile (Fig. 3-12). This pea gravel formed a significant component of the beach material between Dead Dog Creek and Camp Logan. An additional 46,000 cu yds of sand that were added to the site during 1995-1996 had largely been removed from the nourishment site by December 1996 and did not contribute to the adjacent nearshore and downdrift beaches during 1997. During late October and November, 1997, the newly-added 1997 pea gravel shielded the older part of the stockpile from wave attack, caused a lakeward deflection of the shoreline (Fig. 3-12), and began to supply gravel to the downdrift nearshore and beaches.

Monitoring scheme

The monitoring scheme used during Year-1 (1995) and Year-2 (1996) was continued in Year-3 to document changes at the beach-nourishment site. The scheme consisted of a series of four east-west profiles spaced at 100-ft intervals that extended from the west side of the nourishment pile into the shallow nearshore. Survey points were also collected around the lakeward perimeter of the stockpile along the scarp crest to document recession. The results of the 1997 monitoring are presented in graphic format in Fig. 3-12 and Appendix H.

Monitoring observations

Figure 3-12 illustrates the location of the scarp crest on the lakeward side of the IBSP/NU beach-nourishment site between November 1996 and November 1997. Continuous scarp recession occurred during most of the twelve-month period but was temporarily halted or reversed between late October and early November due to placement of the 1997 beach nourishment. Overall scarp recession during 1996-1997 indicates that there was a net transfer of sand and gravel into the nearshore and onto downdrift beaches. The scarp occupied its most landward-documented 1997 position on October 21 and occupied its most lakeward-documented 1997 position on November 13 immediately following the 1997 nourishment addition (Fig. 3-12).

The least amount of scarp recession (10 ft) during 1996-1997 occurred midway along the stockpile between profile lines 49 and 50 (Fig. 3-12; Appendix H). This was because an "apron" of boulders and cobbles extends southward along the beach from the riprap and concrete-cube shore defense at the northern limit of the nourishment stockpile. These boulders and cobbles armored the shore and prevented the northern part of the stockpile from eroding as rapidly as would otherwise have occurred.

They also slowed the rate of transfer of nourishment sand into the nearshore.

The greatest amount of scarp recession (about 50 ft) during 1996-1997 occurred along the southernmost 200 ft of the stockpile. Most of this recession occurred prior to mid October when the 1997 nourishment began to be added. The average rate of scarp recession was about 1 ft/week between November 12, 1996, and October 21, 1997 (Profile 51 in Appendix H). This part of the nourishment stockpile was not protected by the "apron" of boulders and cobbles described above.

Completion of 1997 nourishment in November caused a lakeward deflection of the scarp crest (Fig. 3-12) to, or lakeward of, the November 1996 scarp position along the northern two-thirds of the site. The new nourishment caused the scarp crest to move as much as 60 ft lakeward of the November 1996 position and as much as 70 ft lakeward of the pre-nourishment September 1997 position (Appendix H; Profiles 48, 49, and 50). At Profile 51, southward dispersal of some of the nourishment gravel during and immediately following placement caused the beach to increase in width by almost 95 ft between September 18 and November 13 (Appendix H; Profile 51). Beach width also increased by several tens of feet for several hundred feet downdrift (southward) of Profile 51.

ILLINOIS BEACH STATE PARK / SOUTH UNIT

General Statement

1997 data collection within IBSP/SU involved ground photography, shoreline mapping, and the collection of topographic and bathymetric profile data at ten range line locations as part of the regional coastal monitoring scheme (see Appendix J). The results of this monitoring are discussed within the context of regional coastal change in "Part 3: Regional Coastal Monitoring."

Monitoring continued along 2400 ft of riprap-defended shoreline at the beach-nourishment site adjacent to the IBSP/SU camping area (Fig. 3-15). Stone riprap shore protection was placed along the southern 350 ft of shore during spring 1997 to augment preexisting riprap. In late summer 1997, the northern 1200 ft of shore received 20,000 cu yds of pea gravel as part of a beach nourishment effort. The site had most recently received 24,000 cu yds of fine- to medium-grained beach nourishment during summer 1995, most of which had been transferred into the nearshore and onto downdrift beaches by late autumn 1995 (Foyle *et al.*, 1996).

Monitoring of 1997 Beach Nourishment (Figures 3-15, 3-16, 3-17)

Nourishment characteristics and emplacement

During September 1997, approximately 20,000 cu yds of nourishment were placed along the northern half of the beach-nourishment site. The material was trucked onsite from an inland quarry source. The nourishment extended from the southern end of the steel sheetpile, near the north bathhouse, southward to a point about half-way between the north and south bathhouses (Figs. 3-15, 3-16, 3-17). It consisted of moderately-sorted "pea gravel" with a grain size in the range of 5 to 10 mm.

The nourishment material was distributed along the lakeward side of the shore access road to form a broad plateau that sloped lakeward from the access road (elevation 10.5 to 12 ft LWD) with a gradient of 1:30 to 1:60. The scarp crest on the lakeward side of the stockpile was about 4 ft above lake level and the scarp face had a lakeward slope ranging from about 1:1 to 1:1.7. For the most part, the toe of the scarp occurred at or landward of the position of the June 1997 shoreline (Fig. 3-17). The maximum thickness of the nourishment stockpile (estimated at 5 ft) occurred in a narrow zone along its lakeward edge.

Monitoring scheme

ISGS monitored the beach-nourishment site between autumn 1996 and late summer 1997 using ground photography and recorded only minor changes at the site. Monthly topographic and shallow-wading surveys were re-established in September 1997 to document rates and patterns of change following 1997 nourishment. These surveys were conducted at locations established in Year-1 (Fig. 3-15) and extended from the shore-access road into the shallow nearshore. Because the length of shore that was nourished in 1997 was only about half the length of that nourished in 1995, one new topographic/shallow wading profile (MBH) was established in 1997. The scarp crest on the lakeward side of the stockpile was also mapped to document changes in the lakeward extent of the stockpile (Fig. 3-17).

Monitoring observations

Appendix I shows profile comparisons along the two profile lines (NBH and MBH) that transected the 1997 beach nourishment. Figure 3-17 shows scarp positions on the lakeward side of the nourishment stockpile between November 1996 and November 1997.

Overall scarp recession occurred at the beach-nourishment site during 1996-1997, despite the addition of the 1997 pea gravel. In November 1996, the scarp crest lay as much as 75 ft lakeward of the shore access road at the north end of the nourishment site and as little as 5 ft lakeward of the shore access road at the south end of the site (Fig. 3-17). Following beach nourishment in September 1997, the scarp crest moved to its most lakeward-documented 1997 position. Mid-way between the north and south bathhouses, the scarp was located as much as 75 ft from the shore access road. The minimum lakeward extent of the nourishment occurred just to the north of the Grass Knoll where the scarp crest was located 50 ft from the shore-access road (Fig. 3-17).

Scarp retreat resumed following 1997 nourishment so that the October and November scarps lay an increasing distance landward of the September scarp position (Fig. 3-17; Appendix I). Rates of scarp retreat during this eight-week interval were highest near the south end of the nourishment (about 5 ft/week) and lowest (about 2 ft/week) at the north end of the nourishment near the steel sheetpile (Fig. 3-17). By November 1997, the scarp had moved landward of its November 1996 position. This indicates that most of the 1997 nourishment had been transferred to the nearshore and downdrift beaches within an eight-week period.

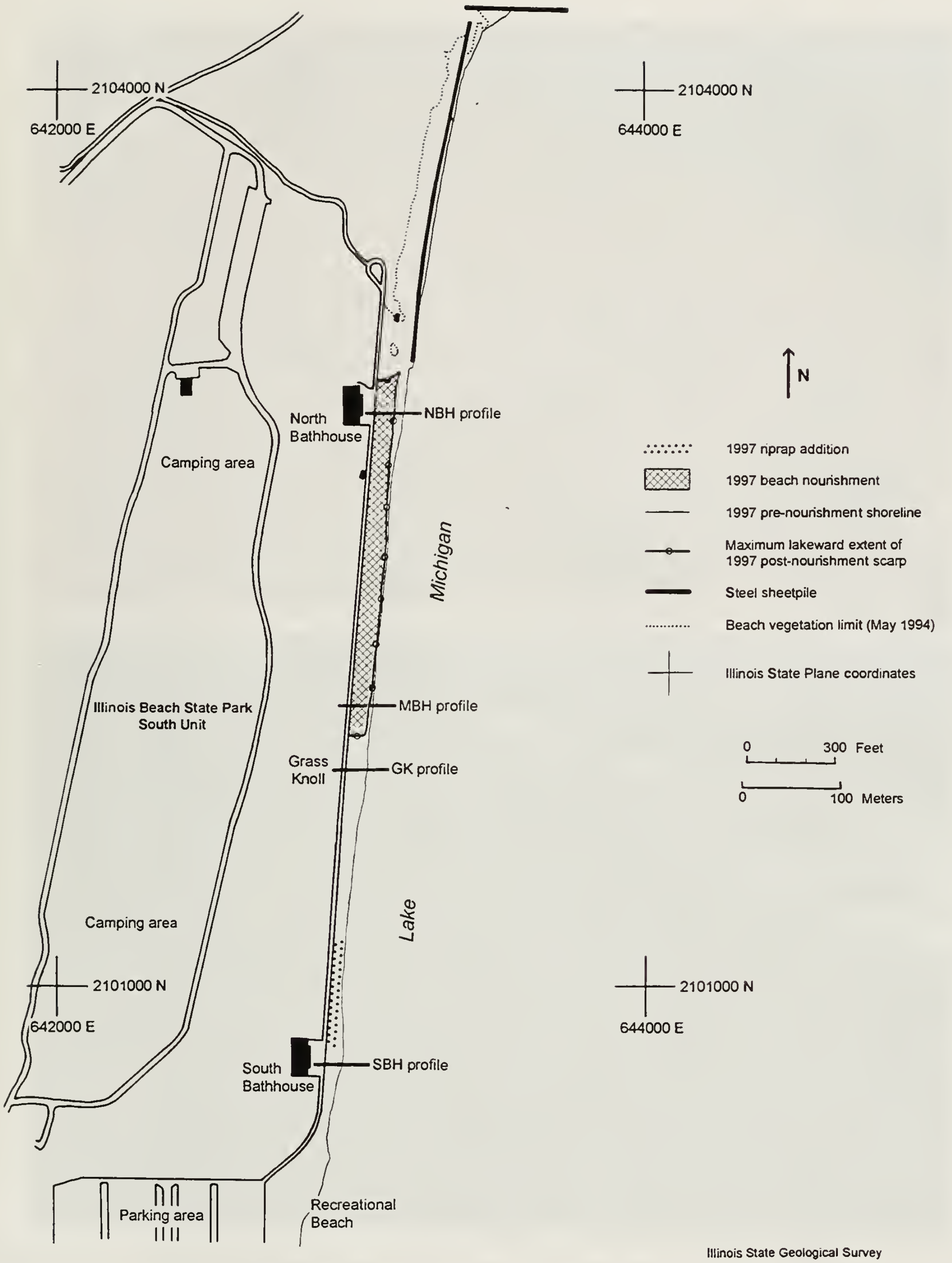


Figure 3-15 Location of the beach-nourishment site in the South Unit of Illinois Beach State Park. The shore between the north and south bathhouses is partly protected from erosion by stone riprap.

Figure 3-16 Photographs showing the IBSP/SU beach-nourishment stockpile. Photographs show stockpile geometry: (A) just prior to completion of 1997 nourishment; and (B) eight weeks following nourishment. View is to the north. Note that concrete cubes and riprap are re-exposed in (B) due to erosion of nourishment material (photo dates: September 17, 1997 (A), and November 14, 1997 (B)).

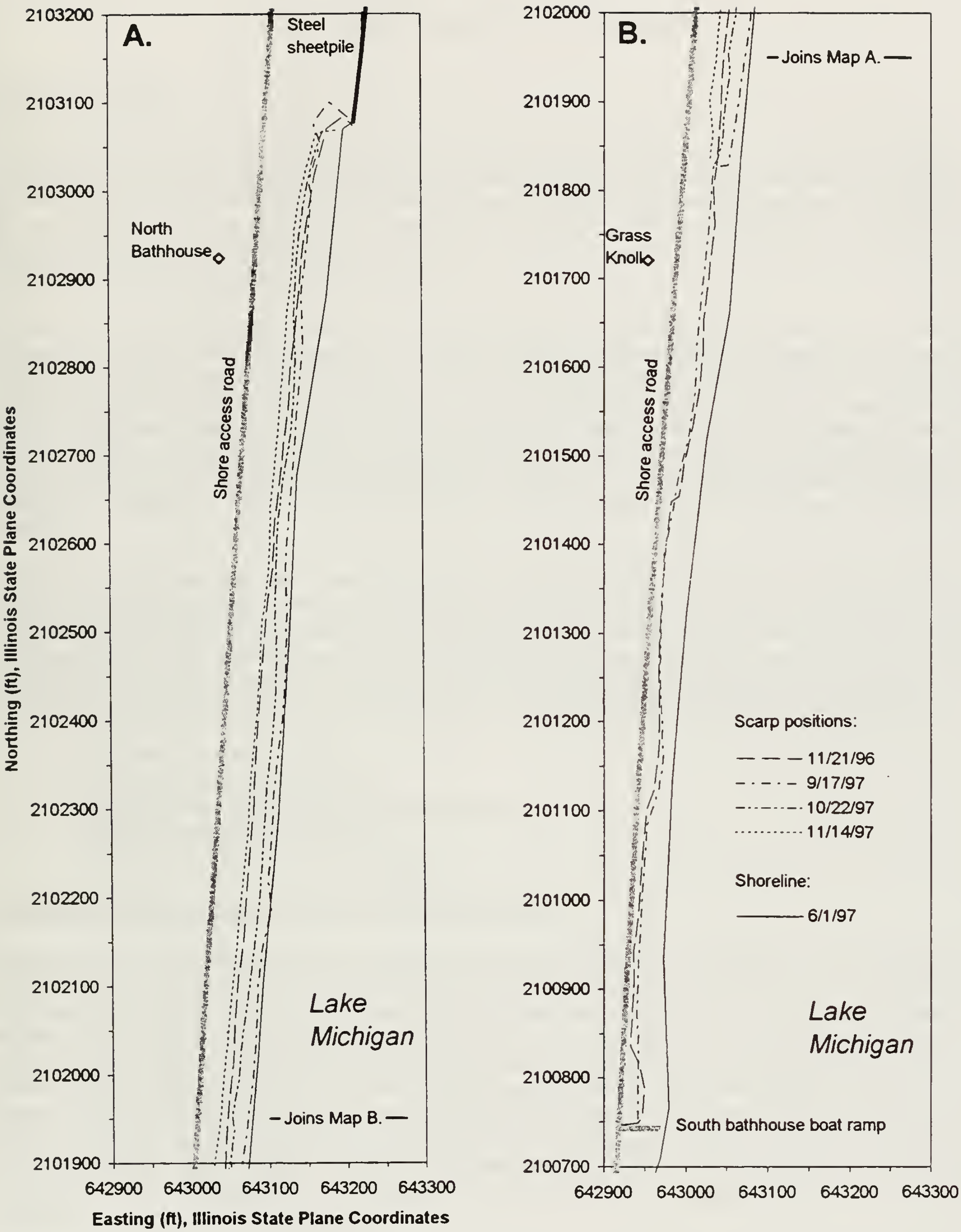


Figure 3-17 Scarp positions at the IBSP/SU beach-nourishment stockpile between November 1996 and November 1997.

REGIONAL COASTAL MONITORING

General Statement

To evaluate the gain, loss, and transport of littoral sediment along the marina and state park properties, and to help predict future coastal change, it is necessary to examine coastal processes from a regional perspective. A regional evaluation would ideally extend along the 18 miles of shore between Kenosha, WI, and North Chicago, IL, which is the lakeshore extent of the Zion beach-ridge plain. For practical purposes, the northern and southern limits of the study area (WI-IL state line, Waukegan Harbor) provide boundaries that define a distinct coastal reach.

At the north end of the study area, the WI-IL state line is a political boundary important to coastal management, but it also corresponds to a partial barrier to littoral sediment transport due to the interception, dredging, and removal of sediment at Prairie Harbor Yacht Club, WI (Fig. 3-1). At the south end of the study area, the jetties and entrance channel at Waukegan Harbor now form a partial barrier to littoral sediment transport and have historically trapped a large percentage of the sediment moving southward along the NPM and IBSP nearshore. Thus, the shore between the WI-IL state line and Waukegan Harbor is treated as a distinct coastal reach having an updrift origin (sediment crossing the state line), a pathway for littoral sediment transport, and a terminus (sediment trapped at Waukegan Harbor).

The following discussion examines changes that occurred along the SL-WH coastal reach during 1996-1997. These annual data are critical for the documentation of short-term changes. However, they may contradict long-term trends or suggest significantly higher or lower rates of change when compared with the long-term averages. Through the process of averaging annual data collected over several years, this annual variability can be smoothed to permit determination of longer-term trends that can then be used for predictive purposes. The 1996-1997 data are described below from five different perspectives:

- 1996-1997 shoreline change
- 1996-1997 beach areal change
- 1996-1997 beach and nearshore profile change
- 1996-1997 lake-bottom change
- Year-3 interim littoral sediment budget

1996-1997 Shoreline Change (Figures 3-18, 3-19, 3-20)

Comparisons of shoreline positions allow rates of shoreline change to be estimated and the associated gains and losses in beach area to be quantified. At long time scales (*e.g.,* 1872-1996), changes in shoreline position tend to record long-term geologic processes such as the progressive southward migration of the Zion beach ridge plain. Comparisons of shoreline data from 1872 through 1996 show persistent shoreline recession (landward shift) along the northern part of the SL-WH coastal reach, relative shoreline stability along the shore centered on the mouth of Dead River, and shoreline progradation (lakeward shift) from just south of Dead River to the entrance channel at Waukegan Harbor (Foyle *et al.*, 1997a). At shorter time scales, annual changes in shoreline position such as those recorded during 1996-1997 tend to be strongly influenced by annual and seasonal fluctuations in lake level and local patterns of beach erosion and accretion. The long term trends may not be "visible" at this shorter sampling frequency.

The 1996 and 1997 shorelines were mapped during the summer months of both years and record shoreline positions for lake level at the times of survey. Changes in shoreline position during 1996-1997 were caused by beach and shallow-nearshore accretion or erosion and by a rise in lake level. A lake-level rise of about 1.2 ft between the times of shoreline mapping may have been the most important factor

affecting shoreline position during 1996-1997.

During 1997, approximately 30% (3 miles) of the shoreline along the coastal reach was defended with either steel sheetpile, concrete-cube revetment, or riprap. The remaining 70% was undefended and characterized by sandy beaches in a natural to near-natural state. During summer 1997, stone riprap was added to existing riprap at the Camp Logan headland, at the Zion-Benton pump house at the east end of 17th Street in Zion (operated by Lake County Public Water District), and along about 350 ft of shore at the beach-nourishment site at the north end of IBSP/SU.

Shoreline recession occurred along 75% of the coastal reach between summer 1996 and summer 1997. Most of this recession took place along natural beach areas (Figs. 3-18, 3-19). The shoreline along the remaining 25% of the coastal reach was either progradational or stable. Shoreline progradation generally occurred along short stretches of natural beach in IBSP/NU and IBSP/SU. The shoreline was essentially stable where shore defenses were present (*e.g.* at the NPM breakwaters, the riprap and steel sheetpile at the Camp Logan headland, the riprap at the Zion-Benton pump house on 17th Street, and the riprap along the northern part of IBSP/SU).

Significant shoreline recession occurred at six specific sites along the coastal reach (Fig. 3-19).

(1) As described in "Part 3: North Point Marina Vicinity," as much as 80 ft of shoreline recession occurred within the northern part of IBSP/NU in the area just south of Dead Dog Creek (Fig 3-1).

(2) The greatest amount of recession within the coastal reach (up to 140 ft) occurred at North Point Sailing Beach in IBSP/NU. Shoreline recession caused the loss of 1.7 acres of beach along this 1400 ft of shore. Riprap and concrete-cube shore defenses on the backshore prevented erosion of areas landward of the beach.

(3) At the north end of IBSP/SU adjacent to the Zion Nuclear Power Plant, as much as 85 ft of recession occurred along 700 ft of shore. This resulted in the loss of about 1 acre of beach and erosion of the lakeward side of a relict (several-hundred-year-old) beach ridge capped by modern dune sands.

(4) South of the steel sheetpile bulkhead at the IBSP Lodge, up to 135 ft of recession occurred along 2000 ft of shore and resulted in the loss of 3.25 acres of beach. Erosion of the lakeward side of a relict beach ridge and a localized breach of the ridge line were also documented in this area (Fig. 3-20). The breach in the ridge line allowed transport of beach sand into adjacent marshes during autumn 1997 storms. Locally, this allowed the lakeward edge of the marsh to be buried under 1 to 2 ft of sand and gravel.

(5) Just south of the mouth of Dead River in IBSP/SU, as much as 100 ft of shoreline recession caused significant beach loss.

(6) About 2000 ft south of the Commonwealth Edison Waukegan Generating Station, up to 115 ft of recession near Range Line 6A caused beach loss and erosion of the toe of a relict beach ridge and its veneer of modern dune sands (Fig. 3-19).

Shoreline progradation occurred at several sites along the length of the coastal reach. The greatest continuous length of prograding shoreline was near the south end of IBSP/SU. In this area, the shoreline moved lakeward by up to 70 ft along 2000 ft of shore. The second-longest continuous stretch of prograding shore occurred between NPM and Camp Logan where 1100 ft of shoreline moved lakeward by as much as 40 ft.

Figure 3-18 Shoreline recession in IBSP/NU. As of autumn 1997, the 2400-ft shoreline in this photo had retreated 25 ft (foreground) to 75 ft (background) landward of its summer 1996 position. Shoreline recession was accompanied by a decrease in beach area of 1.75 acres. View is to the south from the concrete-cube and riprap-protected headland at the Zion-Benton pump house on 17th Street (just south of North Point Sailing Beach; Fig. 3-19). For scale, the concrete cubes in the foreground measure 3 ft by 4 ft by 4 ft (photo date: October 22, 1997).

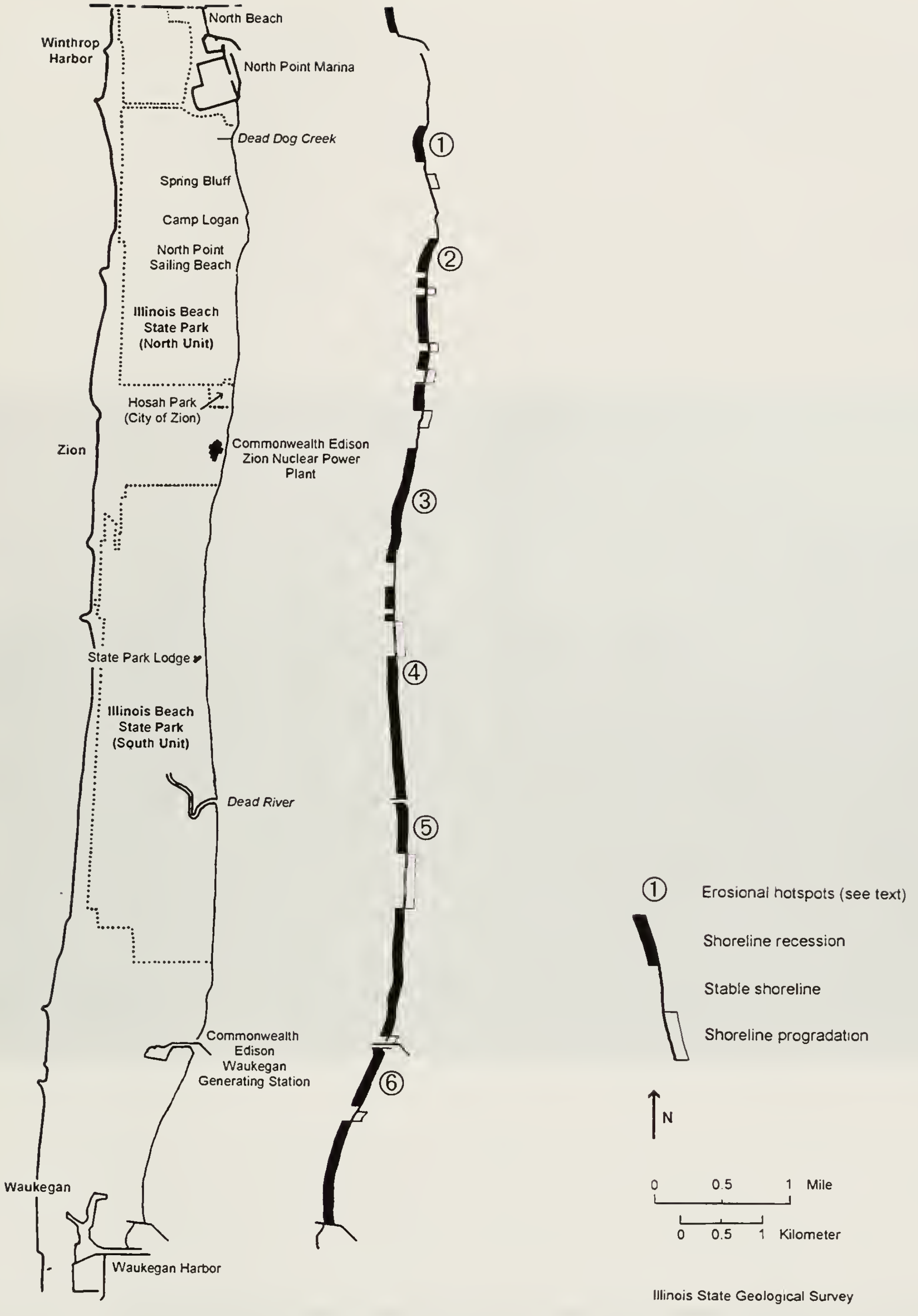


Figure 3-19 Schematic illustration of shoreline changes along the SL-WH coastal reach between summer 1996 and summer 1997. Erosional hotspots referred to in text are shown. The width of the bar pattern denoting shoreline changes is purely schematic and does not indicate the amount of absolute change.

Figure 3-20 1997 shoreline recession and erosion of a relict beach ridge in IBSP/SU. The relict beach ridge is capped by dune sands at this locality. During summer 1996, the shoreline was located just to the right of the field of view. Green line shows approximate ridge outline and beach surface during summer 1996. View is to the north. The south end of the stone riprap and steel sheetpile bulkhead at the IBSP Lodge is visible in the distance (photo date: November 14, 1997).

1996-1997 Beach Areal Change (Figures 3-21, 3-22; Table 3-5)

The net result of overall shoreline recession between summer 1996 and summer 1997 was a loss of beach area. In total, almost 24 acres of beach were lost along the SL-WH coastal reach due to both foreshore erosion and beach submergence (Table 3-5; Fig. 3-21). NPM and IBSP/NU lost almost 6 acres of beach while IBSP/SU lost almost 10 acres.

Table 3-5 Summary of net beach areal changes for the principal property units along the SL-WH coastal reach (1996-1997).

	Net areal change[1] (acres)	Shoreline length[2] (feet)	Normalized[1,3] change (sq yds/ft)
NPM North Beach	-0.9	1,000	-4.5
IBSP/NU (NPM - Camp Logan)	-9.8	3,100[4]	-1.4
IBSP/NU (Camp Logan-Hosah Park)	-4.0	6,900	-[illegible].7
Hosah Park & Zion Nuclear Plant	-0.5	3,700	-0.7
IBSP/SU	-9.8	18,500	-2.6
IBSP/SU - Commonwealth Edison	-1.9	3,200	-2.8
Com Edison - Waukegan Harbor	-[illegible].5	6,900	-4.1
TOTAL CHANGE	-23.9	46,900	-2.5

[1] Negative numbers indicate net erosion
[2] Shoreline length is based on measurement along a north-south line and is rounded to the nearest 100 ft
[3] Normalized change units are in square yards of beach per shoreline foot
[4] Shoreline length does not include 3,700 ft of lakefront along the NPM breakwaters and south parking area

Beach loss was least severe along the lakefront at Hosah Park and the Zion Nuclear Power Plant where only 0.7 square yards of beach per shoreline ft (sq yds/ft) were lost (Table 3-5; Fig. 3-21). Significant beach loss (4.1 sq yds/ft) occurred between the Commonwealth Edison Waukegan Generating Station and Waukegan Harbor while the greatest recorded beach loss (4.5 sq yds/ft) occurred along 1000 ft of shore at North Beach on the updrift side of NPM (Table 3-5; Fig. 3-21). The high rates of beach loss at North Beach and along the south end of the coastal reach occurred partly because the broad, low-gradient and low-elevation beaches in these two areas were easily submerged during the 1996-1997 rise in lake level.

At the erosion hotspots shown in Fig. 3-19, erosion of relict beach ridges and their capping modern-dune sands generally occurred along stretches of natural beach that were initially relatively narrow. Figure 3-22 shows examples of significant beach loss and (or) erosion of relict beach-ridge and dune sands that occurred at two sites (Range Lines 4B and 4C) located between the IBSP Lodge and Dead River. These cross-sectional profiles illustrate that shoreline recession accompanying 1996-1997 lake-level rise caused beach narrowing and was generally accompanied by erosion in the shallow nearshore. Beach narrowing exposed the relict beach ridge to wave runup and attack in areas where the preexisting beach was already narrow. This was the case at Range Line 4B where erosion of the beach ridge occurred in an area where the preexisting beach was only about 25 ft wide. At Range Line 4C, the preexisting beach was sufficiently wide (at least 60 ft) that shoreline recession did not expose the relict beach ridge and capping dune sands to wave attack.

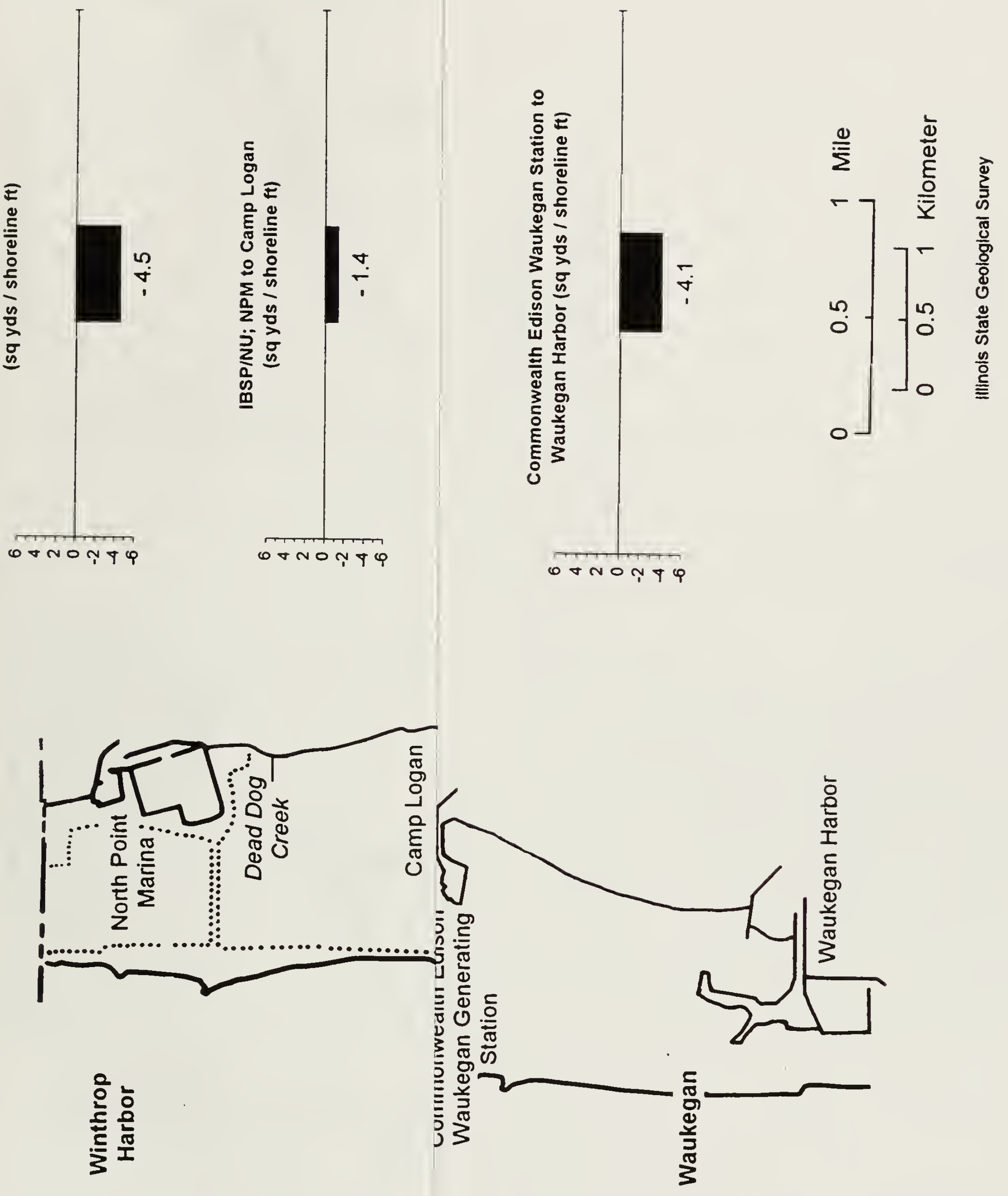


Figure 3-21 Normalized rates of beach-are
coastal reach (1996-1997). Nor
linear foot of shoreline (sq yds/s

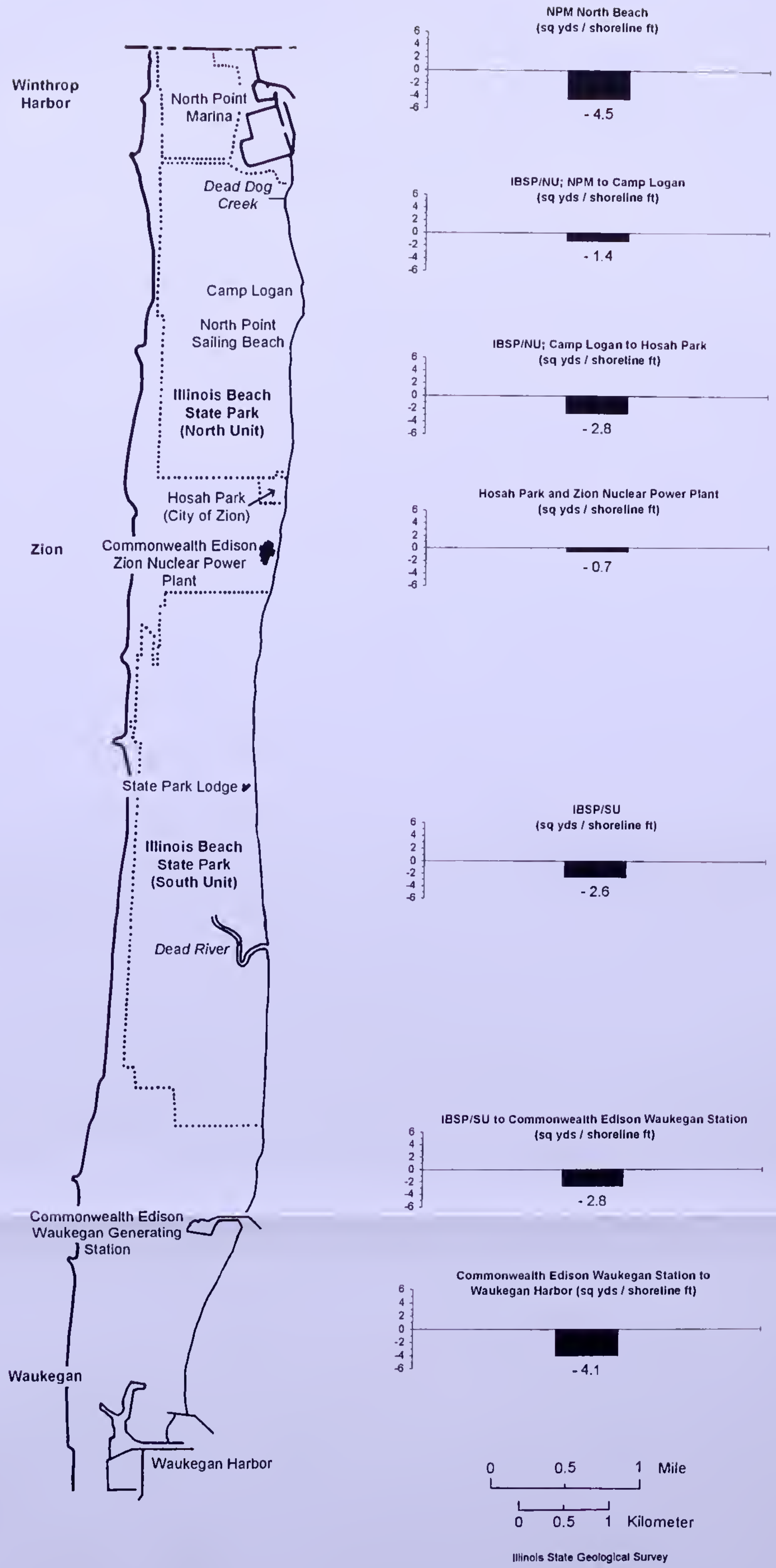
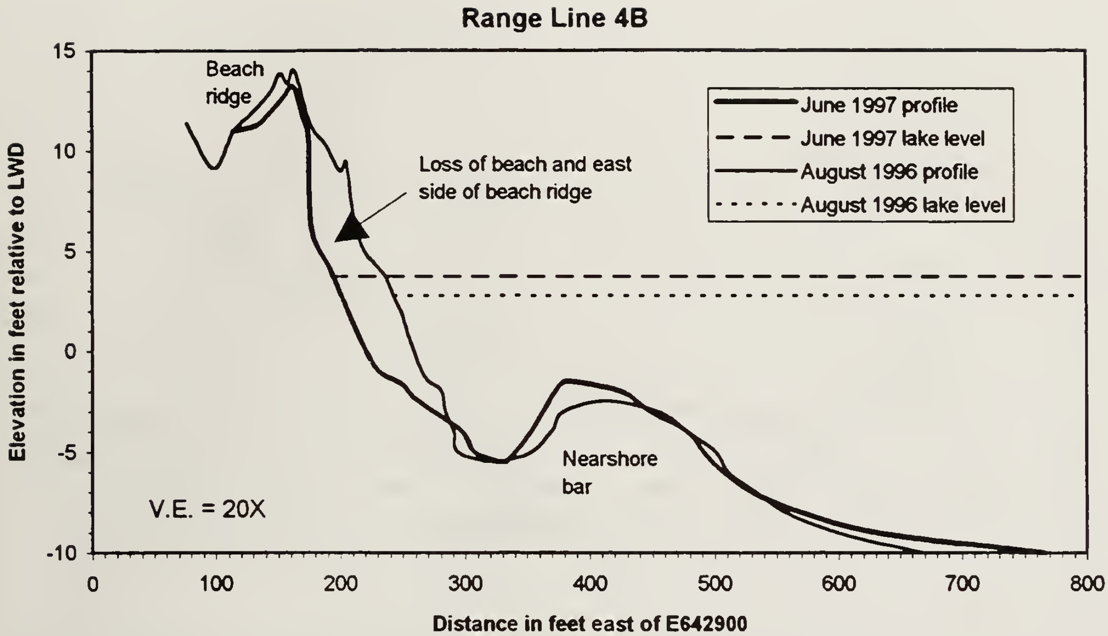


Figure 3-21 Normalized rates of beach-area loss for the principal property units along the SL-WH coastal reach (1996-1997). Normalized rates are in units of square yards of beach per linear foot of shoreline (sq yds/shoreline ft) and are derived from Table 3-5.

Range Line 4B



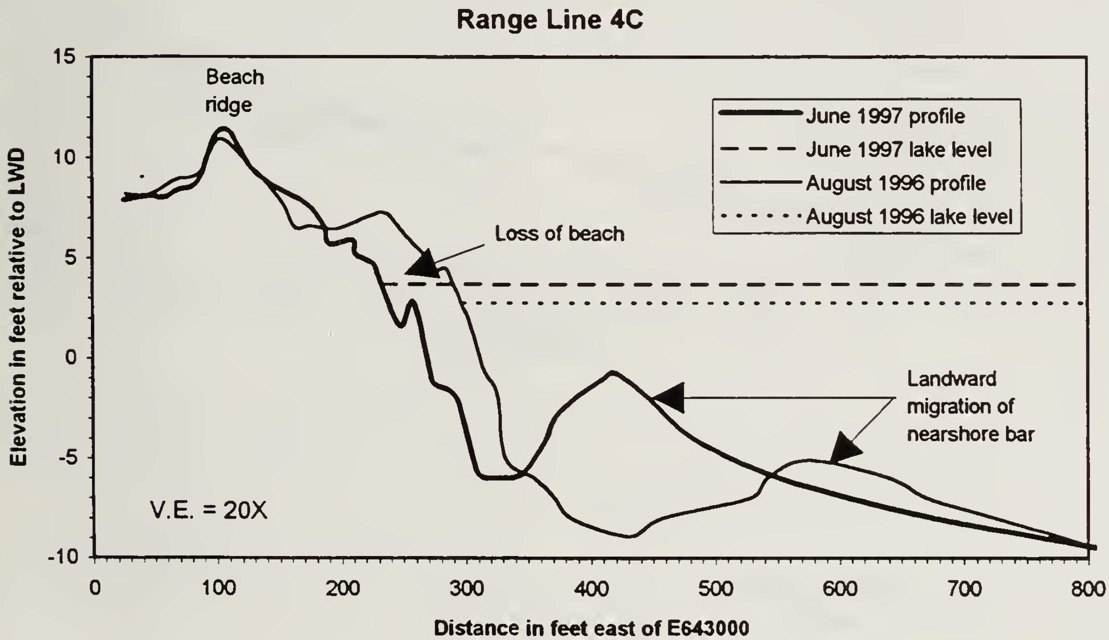
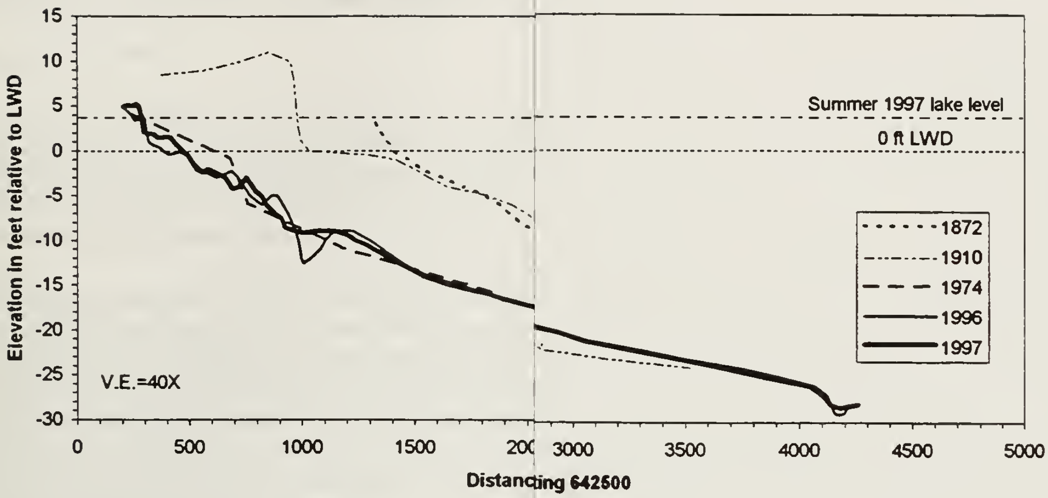
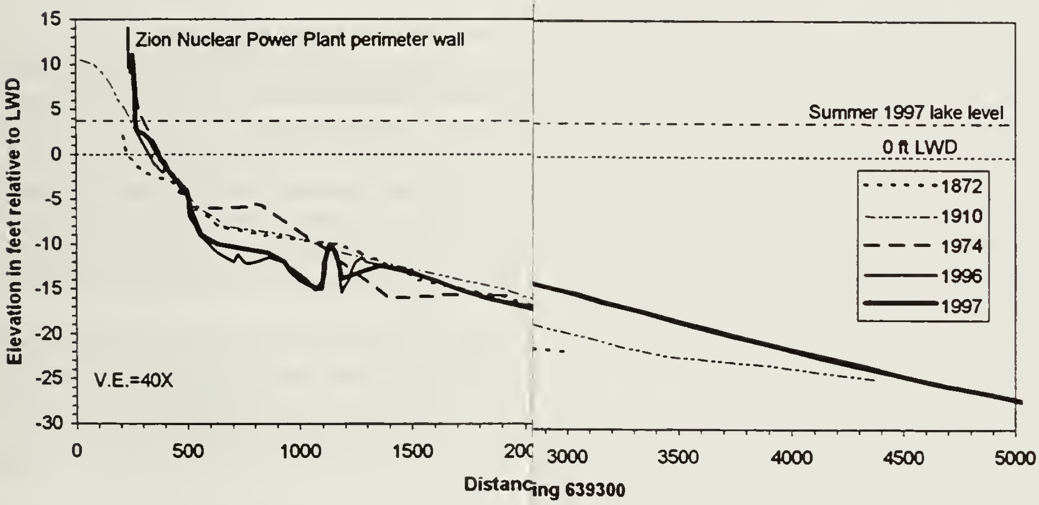


Figure 3-22 Topo-bathymetric profiles at Range Lines 4B and 4C in IBSP/SU. Profiles are located between the IBSP Lodge and the mouth of Dead River (see Appendix J for location). Both profiles show beach loss that accompanied 50 to 70 ft of shoreline recession. Range Line 4B also shows significant erosion of the relict beach ridge and overlying dune sands at elevations above about 6 ft LWD.





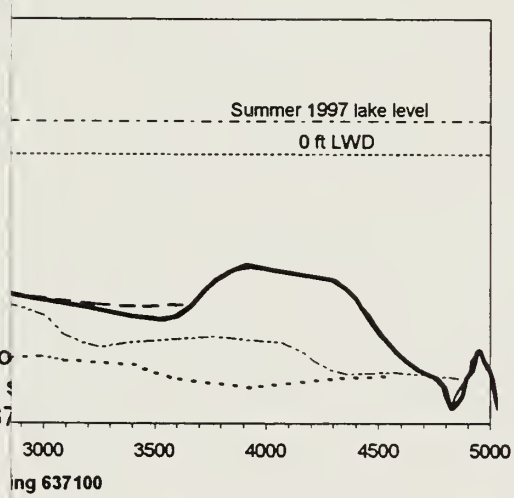


Figure 3-23 1996 and 1997 comparative topo
coastal reach. Profiles are s
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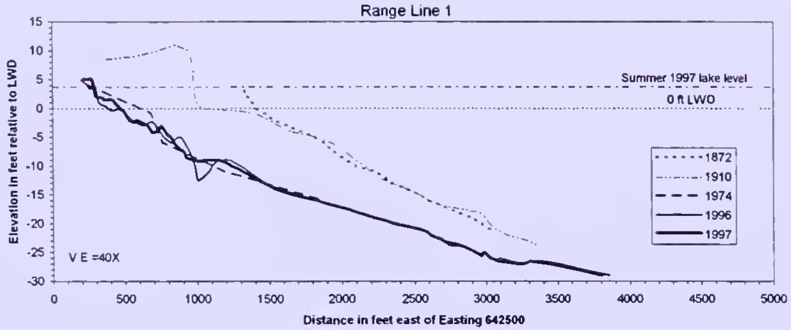

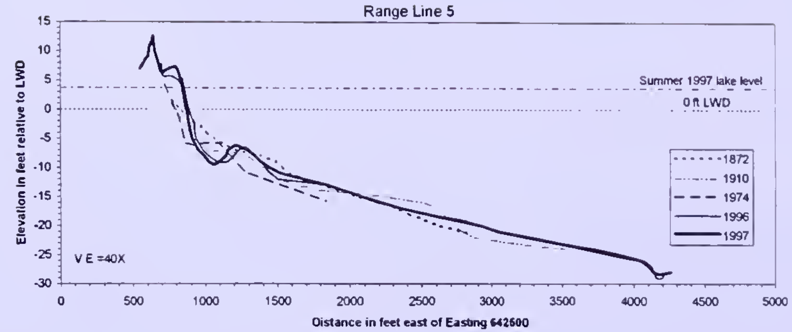

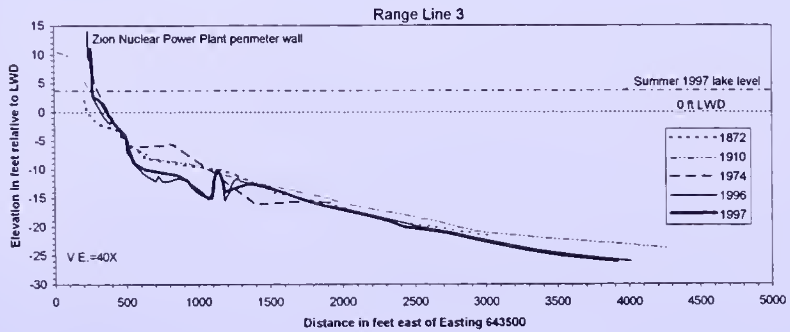

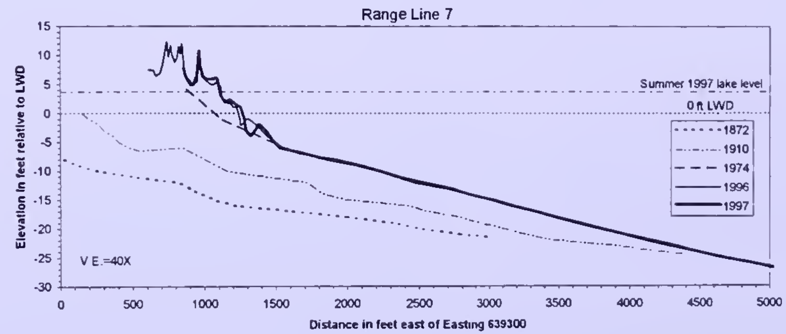

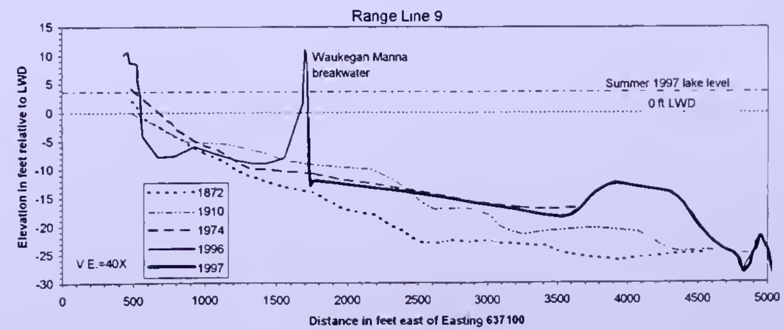

Figure 3-23 1996 and 1997 comparative topo-bathymetric profiles at selected sites within the SL-WH coastal reach. Profiles are shown for Range Lines 1, 3, 5, 7, and 9 and are supplemented by data from 1872, 1910, 1974, and 1996 (Appendix C, J).

1996-1997 Lake-Bottom Change (Figures 3-24, 3-25)

General statement

The 1997 and 1996 bathymetric data from the 23 range lines along the SL-WH coastal reach and from 79 profile lines in the NPM vicinity were compared to obtain an estimate of the volumes of 1996-1997 accretion, erosion, and net lake-bottom change. The 1996-1997 volumes are shown in Fig. 3-24 where they contrast significantly with historical averages. Figure 3-25 shows, in map view, the areal distribution of erosion and accretion along the coastal reach.

The range line scheme used to monitor regional lake-bottom change along the SL-WH coastal reach is best suited for documentation of long-term (decadal) changes. Annual comparisons, such as 1996-1997, are likely to have large "error bars" associated with them because of the generally small and variable annual changes recorded at each profile location (Fig. 3-23) and the relatively large distances (1700 to 1900 ft) between many profile lines which necessitates significant interpolation. These factors dictate that the volumes of 1996-1997 erosion, accretion, and net change shown in Fig. 3-24 should be viewed only as order-of-magnitude approximations. Similarly, Fig. 3-25 shows a very generalized representation of 1996-1997 lake-bottom change.

Lake-bottom change

Most lake-bottom change in excess of 1 ft during 1996-1997 occurred in water depths less than 13 ft LWD and within 1000 ft of the 1997 shoreline (Fig. 3-25). Change was associated primarily with landward or lakeward movements of the nearshore bar/trough pair that typically lay about 200 to 300 ft offshore, and with shallow-nearshore erosion that accompanied shoreline recession. Aerial photographs and profile data indicate that the nearshore bar/trough pair was present along most of the shore with the exception of areas lakeward of shore defenses such as at NPM, Camp Logan, and Zion Nuclear Power Plant. Along the southern part of the coastal reach, the bar/trough pair bifurcates into a double bar/trough pair. Movements of the bar/trough pair(s) during 1996-1997 were responsible for the strong linear patterns of lake-bottom erosion and accretion shown in Fig. 3-25.

Figure 3-25 shows that both nearshore accretion and erosion in excess of 1 ft occurred at most locations along the SL-WH coastal reach during 1996-1997. Net accretion occurred in all nearshore areas with the exception of the IBSP/NU nearshore between Camp Logan and Hosah Park where net erosion occurred. Net accretion was greatest along the Hosah Park, Zion Nuclear Power Plant, and IBSP/SU nearshore areas.

The order-of-magnitude and positive sign of the net volume of lake-bottom change (Fig. 3-24) strongly suggest that, even allowing for the 24-acre loss in beach area described earlier, the coastal reach was net accretional during 1996-1997. This one-year net accretion is anomalous when compared with the long-term (1872-1996) trend of increasing erosion and decreasing accretion documented in the Year-2 Report (Foyle *et al.*, 1997a) and also illustrated in Fig. 3-24. The net accretion was also anomalous when compared with the net erosion that was recorded during the 1974-1996 interval (Fig. 3-24). The divergence of the 1996-1997 data from the long-term trends is likely due to a combination of annual variability in coastal processes and the limitations imposed by the range-line spacing with regard to accurate measurement of annual change.

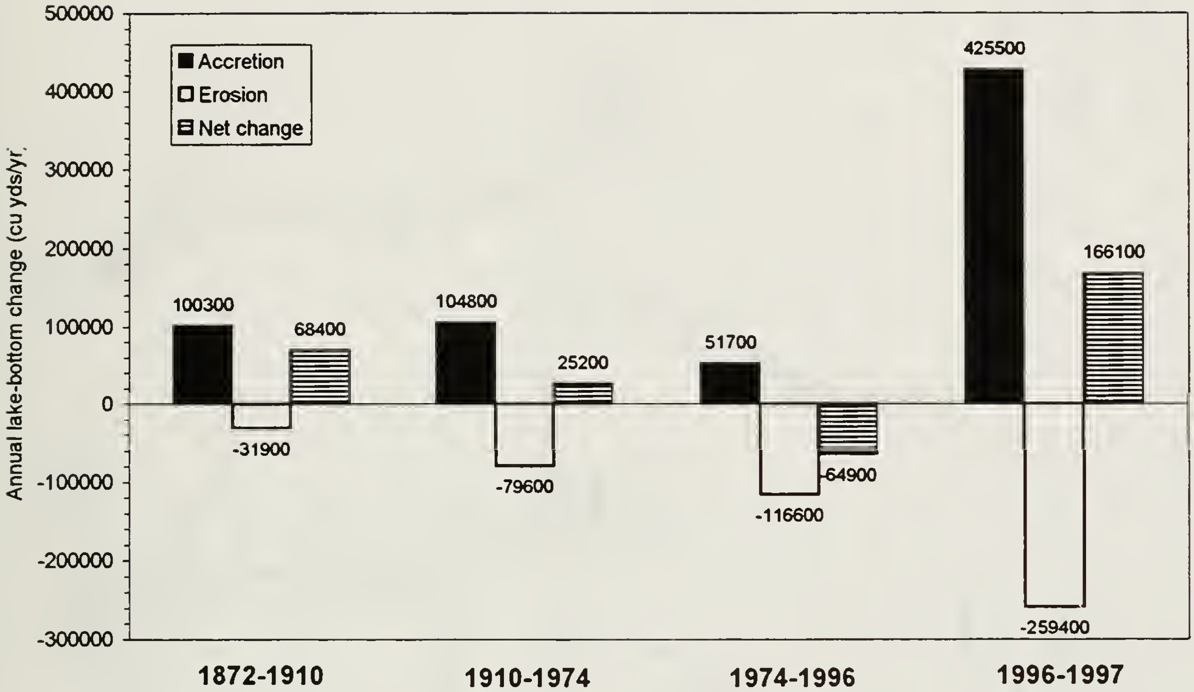

Figure 3-24 Histogram showing annualized lake-bottom change volumes for the SL-WH coastal reach (1872-1997). 1996-1997 data are shown for comparison with average long-term, multi-year data for the intervals 1872-1910, 1910-1974, and 1974-1996 (see Foyle *et al.*, 1997a for discussion of historical data). Volumes are rounded to the nearest 100 cu yds and are computed from lake-bottom elevation changes in excess of 1 ft occurring below Low Water Datum (LWD). 1996-1997 data are accurate to order-of-magnitude level.

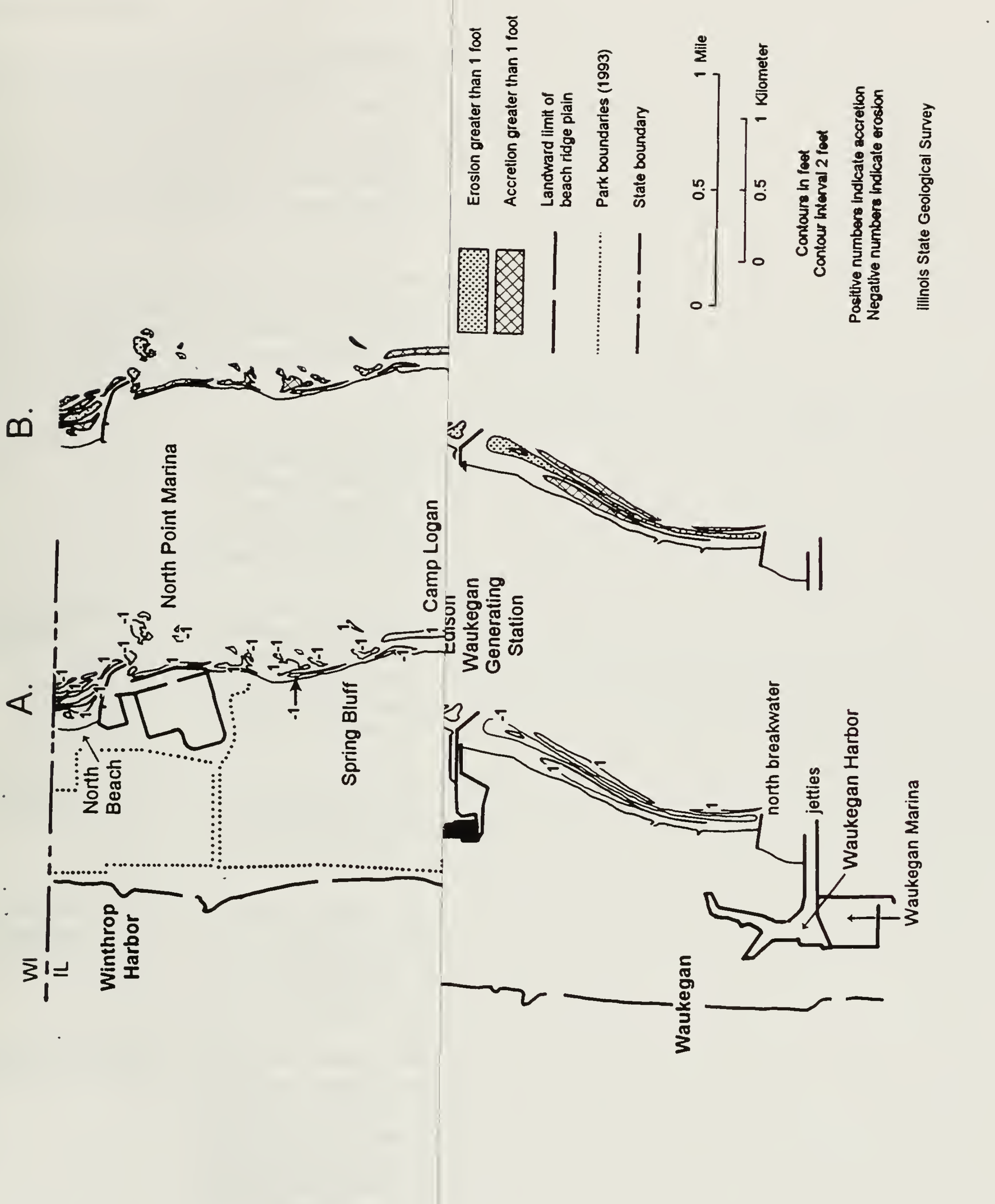

Figure 3-25 Map showing 1996-1997 lake-bot
shoreline is shown. Lake-bottom
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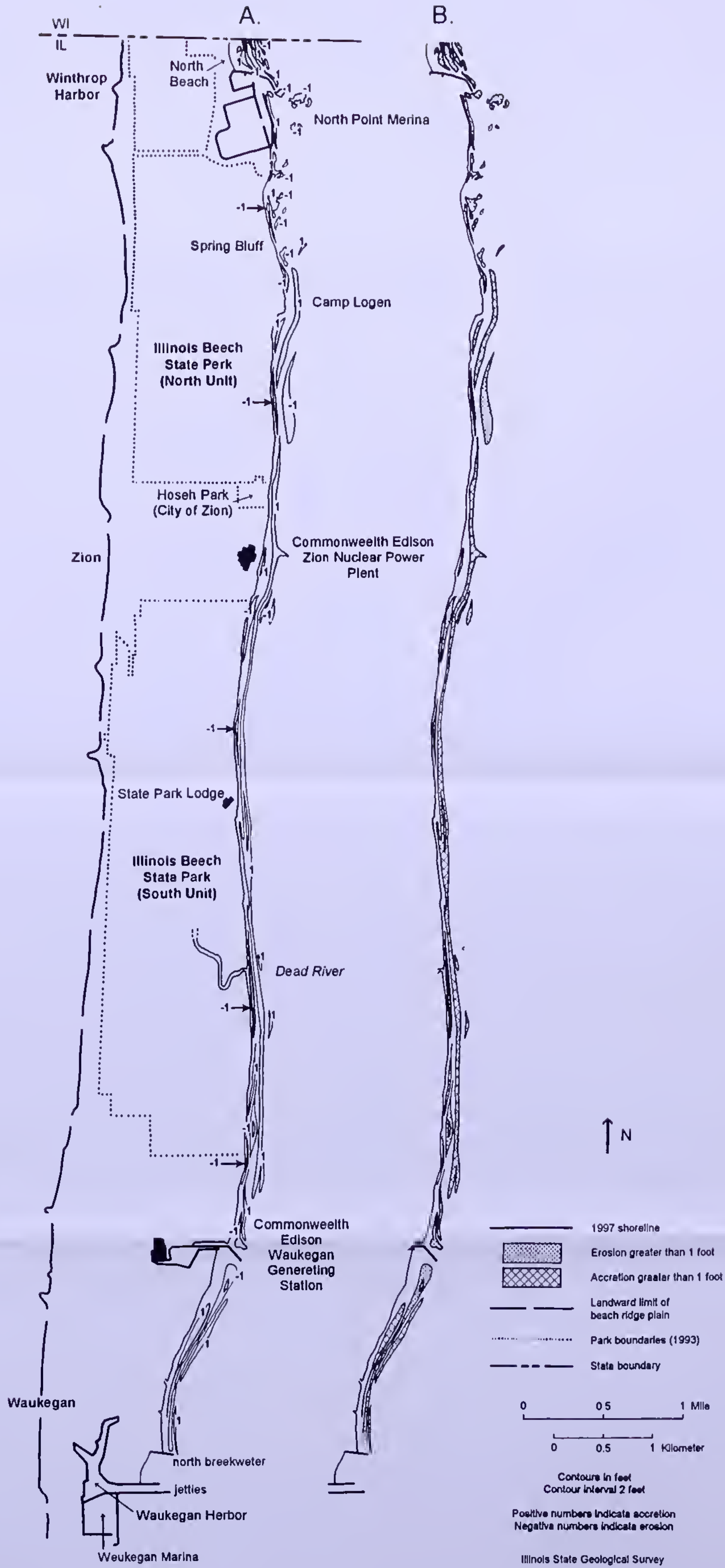

Figure 3-25 Map showing 1996-1997 lake-bottom change along the SL-WH coastal reach. The 1997 shoreline is shown. Lake-bottom changes are shown in contour format (A) and shaded-area format (B). Data between the state line and Camp Logan is derived from Fig. 3-5.

Year-3 Interim Littoral Sediment Budget (Figure 3-26, Table 3-6)

General statement

Preceding sections of this report documented that the 1996-1997 rates and patterns of shoreline and lake-bottom change can be markedly different from those derived from recent (1992-1995; 1995-1996) and long-term (*e.g.* 1872-1996) data in the Year-1 and Year-2 reports. This variability in short-term (annual) data is caused primarily by fluctuations in sediment supply, wave climate, and lake level, but may also be partly due to some limitations caused by widely spaced profile lines. However, annual data such as the 1996-1997 data are critical for documentation of short-term changes, and it is by averaging several years of annual data that multi-year trends can be developed. These multi-year trends can be used for predictive purposes and in making decisions concerning sand-resource management.

The Year-3 littoral sediment budget is presented below. As was the case for Year-1 and Year-2, it is an interim budget that will ultimately be used to compile a sediment budget in the Year-4 final report. The Year-3 budget calculation follows the procedure used in Year-1 and Year-2 by quantifying the volumes of littoral sediment moving southward past five specific geographic reference points, listed below, within the SL-WH coastal reach:

WI-IL State Line	This marks the updrift end of the SL-WH coastal reach. Sediment moving southward across the state line is derived from erosion along the Wisconsin shore. Sediment crossing the state line is the principal source of new sediment to the SL-WH coastal reach. A minimum estimate of the volume of this input is obtained by summing net-accretion volumes from areas just downdrift of the state line and in the vicinity of North Point Marina.
Camp Logan headland	The Camp Logan headland is a subtle promontory at Camp Logan that has been stabilized by several generations of shore defense. The headland is a useful reference point for monitoring littoral sediment transport because substantial data exist for beach and nearshore erosion between the marina and the headland. Net erosion volumes from the updrift beaches and nearshore provide an estimate of the volume of littoral sediment moving south past Camp Logan.
South end of IBSP/SU	The south end of IBSP/SU is used as a reference point to highlight the rates of littoral sediment transport at the south end of DNR property at IBSP. Littoral sediment moving past this point is partly trapped at either Waukegan Generating Station or Waukegan Harbor further downdrift.
Waukegan Generating Station	Dredging at Waukegan Generating Station makes this site a useful observation point because the material dredged had to have moved southward in the nearshore past IBSP/SU. Dredge volumes can be used, in conjunction with dredge volumes from Waukegan Harbor, to estimate rates of littoral sediment transport at the south end of IBSP/SU.
Waukegan Harbor	The harbor entrance forms the south end of the SL-WH coastal reach. Littoral sediment moving southward out of the coastal reach is partly trapped at Waukegan Harbor. Dredge data from the harbor entrance can be used in conjunction with data from Waukegan Generating Station to estimate rates of littoral sediment transport at the south end of IBSP/SU. Dredge data solely from Waukegan Harbor can be used to estimate rates of littoral sediment transport at the downdrift end of the SL-WH coastal reach.

The Year-3 interim littoral sediment budget is an update of the Year-1 and Year-2 budgets and incorporates results derived from both Year-1 and Year-2 data collection as a step towards obtaining a

multi-year sediment budget. Table 3-6 summarizes the volumes of littoral sediment transport at the five reference points listed above using a three-year average (1992-1995) from the Year-1 report, a four-year average (1992-1996) from the Year-2 report, the most recent annual change (1996-1997), and a five-year average (1992-1997). The following budget discussion focuses primarily on the recent one-year (1996-1997) and five-year (1992-1997) data. As of this annual report, the five-year average provides the best approximation of littoral sediment transport rates along the SL-WH coastal reach.

Minimum sediment volume crossing the WI-IL state line

The annual volume of littoral sediment crossing the state line can be computed by summing net accretion volumes in the vicinity of NPM. This general procedure was used in Year-1 and Year-2 to generate the three-year and four-year budgets shown in Table 3-6.

During 1996-1997, net accretion in the vicinity of NPM totaled 3,500 cu yds (Table 3-1) which would initially suggest that at least 3,500 cu yds of littoral sediment crossed the WI-IL state line. However, as discussed further below, this net accretion can be accounted for by shore erosion between the marina and Camp Logan. The volume crossing the state line is therefore indeterminate using 1996-1997 bathymetric comparisons. It can be stated, however, that the volume of littoral sediment crossing the state line was greater than zero because of the requirement for 1997 dredging in the entrance channel to Prairie Harbor Yacht Club, WI, where accretion was consistent with a sediment supply from the north. Since the entrance channel was unlikely to have been a 100%-efficient trap for littoral sediment, a component of the littoral sediment in transport along the southern Wisconsin nearshore would have bypassed the channel and crossed the WI-IL state line.

The data in Fig. 3-24 suggest that the entire SL-WH coastal reach was net accretional during 1996-1997. Assuming net accretion, the volume of material dredged from Waukegan Generating Station and from Waukegan Harbor during 1996-1997 (49,000 cu yds; Appendix K) becomes an important factor when estimating littoral sediment transport across the WI-IL state line. To maintain net accretion in the nearshore for the entire coastal reach, the 49,000 cu yds of sediment lost from the littoral system through accumulation and subsequent removal at the two dredge sites had to be replaced by an equal, if not greater, volume of sediment entering the coastal reach's littoral system. Some of this sediment came from beach-ridge, dune, beach, and foreshore erosion within the coastal reach. Topo-bathymetric data suggest that about 15,300 cu yds were supplied in this manner along the coast between Camp Logan and Waukegan Harbor. In addition, an estimated 30,000 cu yds of sand were supplied to the nearshore during 1996-1997 from losses at the IBSP/NU beach-nourishment stockpile, from nearshore disposal of sand dredged from NPM during 1996, and from beach and foreshore net erosion in the NPM vicinity. Shore erosion along the entire SL-WH coastal reach therefore supplied about 45,300 cu yds of sand to the littoral stream. The difference between this volume (45,300 cu yds) and the dredged volume (49,000 cu yds) is 3,700 cu yds. When this volume is combined with the 3,500 cu yds of net accretion in the NPM-vicinity nearshore, the minimum estimate of the volume of littoral sediment crossing the state line increases from 3,500 to 7,200 cu yds. This is a conservative estimate of the volume of littoral sediment that must have entered the SL-WH littoral system during 1996-1997 by crossing the WI-IL state line (Table 3-6).

A five-year (1992-1997) average rate of littoral sediment transport can be obtained by averaging the 1992-1996 four-year data with the 1996-1997 data in Table 3-6. This yields a five-year average littoral sediment transport volume crossing the state line of at least 10,000 cu yds/yr (Table 3-6, Fig. 3-26).

Minimum littoral sediment transport rate at the Camp Logan headland

Net accretion of 3,500 cu yds was documented in the nearshore between the WI/IL state line and the Camp Logan headland during 1996-1997. Because net nearshore erosion did not occur, the volume of littoral sediment moving southward past Camp Logan cannot be determined using the bathymetric comparison methods employed during Year-1 and Year-2. However, an estimate of the littoral sediment transport rate at Camp Logan can be obtained by comparing the net 1996-1997 lake-bottom change

volume for the NPM vicinity (+3,500 cu yds) with known inputs to that nearshore during the same period.

During 1996-1997, net erosion along the beach and at the beach-nourishment stockpile supplied approximately 5,000 cu yds of sand to the nearshore between the state line and Camp Logan. Additionally, supply of marina-dredged sand to the south parking area nearshore (Fig. 3-1) in late summer 1996, and erosion along the lakefront at the NPM south parking area between late summer 1996 and spring 1997, supplied a further 25,000 cu yds of sand to the nearshore in the NPM vicinity. Most of the 13,500 cu yds of sand added to the lakefront at the south parking area during late spring 1997 was not transferred into the nearshore until after the May 1997 bathymetric survey. Thus, a total of 30,000 cu yds of sand were supplied to the nearshore between the state line and Camp Logan in the period between the 1996 and 1997 bathymetric surveys. However, the nearshore had only 3,500 cu yds of net accretion (Table 3-1; Fig. 3-5). The difference, 26,500 cu yds, is a minimum estimate of the volume of littoral sediment that must have moved southward past the Camp Logan headland during 1996-1997.

Table 3-6 Annualized littoral sediment transport volumes at specific reference points along the SL-WH coastal reach.[1]

	3-year average (1992-1995)	4-year average (1992-1996)	1-year change (1996-1997)	5-year average (1992-1997)
Crossing the WI-IL state line	>14,200	>10,700	>7,200	>10,000
Passing the Camp Logan headland	>43,100	>82,600	>33,700	>72,800
Passing south end of IBSP/SU	>60,500	>78,700	>49,000	>72,800
Entrapment at Waukegan Generating Station	34,400[2]	45,800[3]	20,000 planned	40,700
Entrapment at Waukegan Harbor	26,100[2]	32,900[3]	29,000	32,100

[1] All volumes are rounded to the nearest 100 cu yds.
[2] This volume is based on an interpolation of dredge volumes for the interval 1992-1995. See Appendix K in Foyle *et al* (1997a).
[3] This volume is based on an interpolation of dredge volumes for the interval 1992-1996. See Appendix K in Foyle *et al* (1997a).

However, if it is again assumed that the entire coastal reach was net accretional during 1996-1997, then the dredge data from Waukegan Generating Station and from Waukegan Harbor (Appendix K) allow the 26,500 cu yd estimate to be refined further. The dredge data suggest that at least 49,000 cu yds of littoral sediment had to move into the nearshore south of Camp Logan to replace the volume trapped at Waukegan Generating Station and Waukegan Harbor in order to maintain the observed net nearshore accretion along that stretch of coast. Erosion of beach ridges, dunes, beaches, and foreshore areas between Camp Logan and Waukegan Harbor contributed about 15,300 cu yds to the nearshore. The difference between this volume and the 49,000 cu yds removed from the dredge sites is 33,700 cu yds. This is a closer estimate of the minimum volume of littoral sediment that moved south past the Camp Logan headland during 1996-1997 (Table 3-6).

A five-year (1992-1997) average rate of littoral sediment transport past Camp Logan can be obtained by averaging the 1992-1996 four-year data with the 1996-1997 data in Table 3-6. This yields a five-year average littoral sediment transport volume passing the Camp Logan headland of at least 72,800 cu yds/yr (Table 3-6, Fig. 3-26).

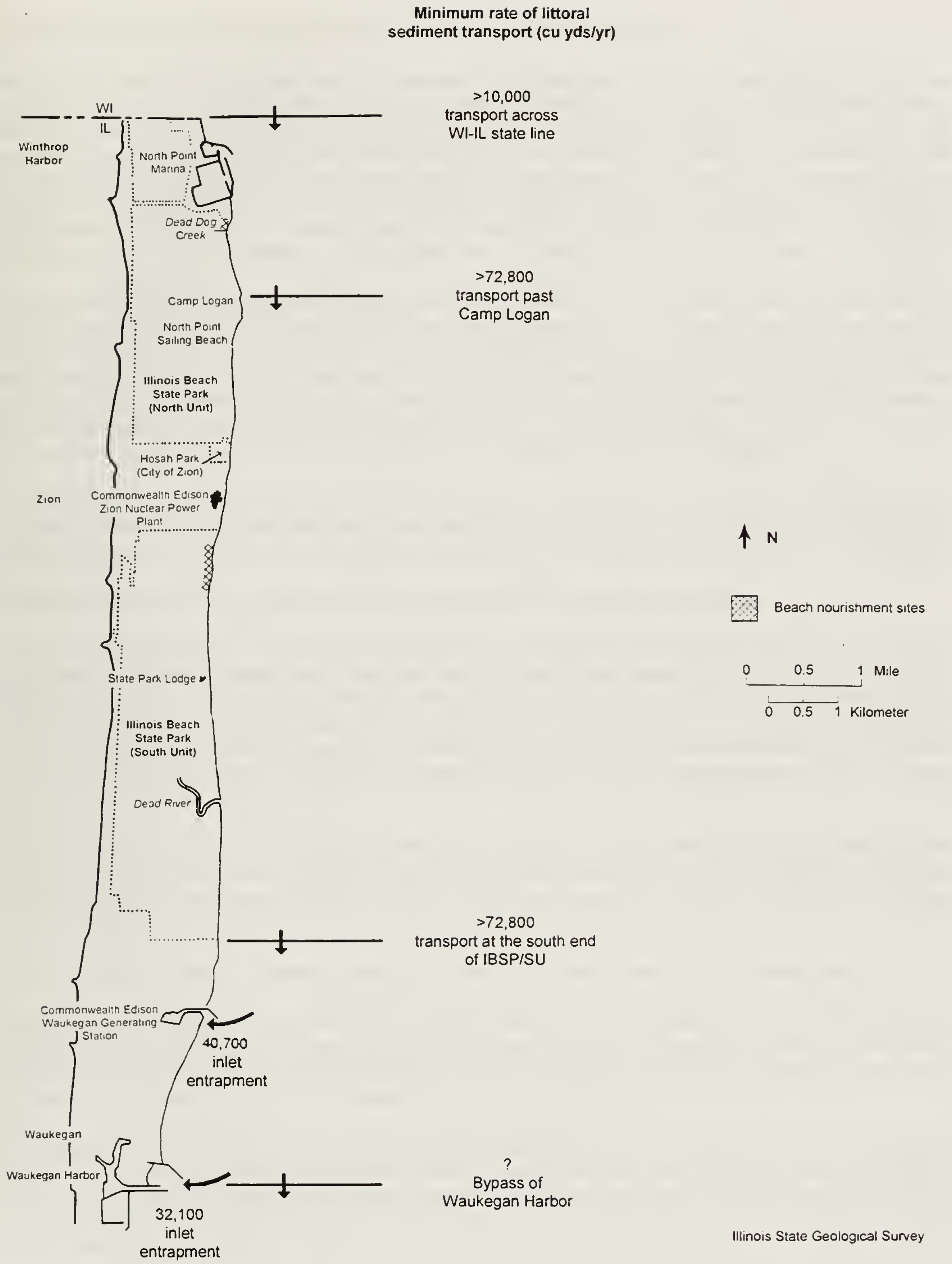

Figure 3-26 Schematic illustration of the five-year (1992-1997) interim littoral sediment budget model for the SL-WH coastal reach.

Minimum littoral sediment transport rate at the south end of IBSP/SU

Dredge volumes from Waukegan Generating Station and Waukegan Harbor can be used to estimate the volume of littoral sediment in transport at the south end of IBSP/SU. In using these dredge data, a long-term (decade-scale) average is advantageous because it minimizes variability caused by annual to biennial fluctuations in the volume of material dredged and the frequency of dredging. However, it is also beneficial to utilize dredge volumes exclusively from the 1990s as they may be more representative of the dredge volumes that are currently required to maintain design depths at the dredge sites. Post-1990 dredge data are utilized in the following paragraphs and in the calculation of multi-year-average dredge volumes for Table 3-6. The method of computation is summarized in Appendix K of Foyle *et al.* (1997a).

During 1996-1997, dredging at Waukegan Generating Station and Waukegan Harbor removed 49,000 cu yds of sand from the south end of the SL-WH coastal reach. Because this dredging occurred in nearshore areas to the south of IBSP/SU, and because the nearshore was net accretional between the two dredge sites and between the dredge sites and IBSP/SU, then at least 49,000 cu yds/yr of sediment had to have moved southward in the nearshore at the south end of IBSP/SU during 1996-1997 (Table 3-6). This would have consisted of the 33,700 cu yds that moved past Camp Logan (Table 3-6) as well as the sediment supplied by dune, beach, and foreshore erosion south of Camp Logan.

A five-year (1992-1997) average rate of littoral sediment transport at the south end of IBSP/SU can be obtained by averaging the 1992-1996 four-year data with the 1996-1997 data in Table 3-6. This yields a five-year average littoral sediment transport volume of at least 72,800 cu yds/yr (Table 3-6, Fig. 3-26).

Minimum rate of littoral sediment transport at Waukegan Generating Station

The nearshore between the south end of IBSP/SU and Waukegan Generating Station, and between Waukegan Generating Station and Waukegan Harbor, was net accretional during 1996-1997. For this reason, the one-year rate of littoral sediment transport at Waukegan Generating Station is inferred to be approximately equal to that at the south end of IBSP/SU, that is, at least 49,000 cu yds/yr. Dredging data for 1997 indicate that 20,000 cu yds of this volume became trapped in, and was subsequently dredged from, the vicinity of the jetty at Waukegan Generating Station while the remainder continued to move southward towards Waukegan Harbor.

For reasons similar to those outlined for the IBSP/SU calculation, the five-year (1992-1997) average rate of littoral sediment transport at Waukegan Generating Station is inferred to be at least 72,800 cu yds/yr. Over the same five-year interval, 40,700 cu yds/yr of this volume became trapped, and were then dredged from, the jetty area (Table 3-6).

Minimum rate of littoral sediment transport at the south end of the SL-WH coastal reach

During 1996-1997, dredging removed 29,000 cu yds of sand from Waukegan Harbor at the south end of the coastal reach (Table 3-6). Because the dredge site may capture most of the littoral sediment in transport in this area, this value is representative of the minimum volume of sediment that was moving southward at the southern end of the coastal reach during 1996-1997.

A five-year (1992-1997) average rate of littoral sediment transport at the south end of the SL-WH coastal reach can be obtained by averaging the 1992-1996 four-year data with the 1996-1997 data in Table 3-6. This yields a five-year average littoral sediment transport volume of at least 32,100 cu yds/yr (Table 3-6). In addition, an unknown volume bypassed the harbor entrance and dredge site and continued to areas farther downdrift.

Littoral sediment budget summary

The five-year-average data in Table 3-6 provide the best approximation of recent rates of littoral sediment

transport along the NPM and IBSP nearshore. All volume estimates are interim values that will ultimately be incorporated into a final sediment-budget model in the Year-4 report. The following listing summarizes the key components of the Year-3 interim littoral sediment budget.

- Littoral sediment moved south across the WI-IL state line at an average rate of at least 10,000 cu yds/yr between 1992 and 1997. This sediment contributed towards overall net accretion on the updrift side of NPM during the five-year interval but was not sufficient to counteract net erosion during 1995-1996 and 1996-1997.

- At least 7,200 cu yds of sediment crossed the WI-IL state line during 1996-1997. Combined with sediment input from beach nourishment and beach erosion, this allowed the nearshore between the state line and Camp Logan to become net accretional for the first year since completion of the marina in 1989 (see Table C-1 in Appendix C). However, net accretion was an anomaly given the longer term erosional trends in this area.

- Between 1992 and 1997, an average of at least 72,800 cu yds/yr of littoral sand moved southward past the Camp Logan headland.

- Combining the volume of material dredged from Waukegan Generating Station and from Waukegan Harbor between 1992 and 1997 provides a minimum estimate of 72,800 cu yds/yr for the average littoral sediment supply approaching Waukegan Generating Station from updrift. The proximity of this facility to IBSP/SU means that this is also a minimum estimate for the average volume of littoral sediment in transport along the southern end of IBSP/SU.

- The minimum volume of littoral sediment reaching the southern end of the SL-WH coastal reach between 1992 and 1997 is estimated to average at least 32,100 cu yds/yr. This is based on the entrapment volume at Waukegan Harbor. It is not known how much sediment naturally bypassed the harbor to areas farther downdrift.

The Year-1 report used the volume of littoral sediment in transport at the south end of IBSP/SU to approximate the "carrying capacity" of the littoral system along the SL-WH coastal reach. The carrying capacity was determined from a 32-year average of dredge volumes at both Waukegan Generating Station and at Waukegan Harbor and was used to provide an estimate of the minimum volume of beach nourishment that would be required to mitigate long-term erosion along the shore between NPM and Camp Logan. The same procedure was used in Year-2 to derive a four-year average carrying capacity of 78,700 cu yds/yr (Table 3-6).

Updating the data to a five-year average by incorporating 1996-1997 data yields a carrying capacity of 72,800 cu yds/yr (Table 3-6) which agrees to within 10% of the three-year and four-year averages. These data suggest that, for the 1992-1997 five-year interval, the minimum volume of beach nourishment required to mitigate erosion between NPM and Camp Logan, the area where most erosion typically occurs, would be at least 72,800 cu yds/yr.

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APPENDIX A: EXECUTIVE SUMMARIES FROM THE YEAR-1 (1995) AND YEAR-2 (1996) REPORTS

This appendix provides the Executive Summaries from the Year-1 and Year-2 Reports. These are presented here to provide continuity for the reader on a year-to-year basis during this four-year study:

Year-1 (1995) Executive Summary

The Illinois State Geological Survey (ISGS) began a four-year study in 1995 to examine erosion and accretion trends along the Lake Michigan shore at North Point Marina (NPM) and the North and South Units of Illinois Beach State Park (IBSP). This study is funded by the Illinois Department of Natural Resources (DNR) which is responsible for coastal management at these facilities. The goal of the study is to develop a sediment budget for the coastal system to provide a basis for planning and implementing long-term coastal-management strategies. An immediate objective is to provide information on erosion and accretion trends relevant to ongoing coastal-management concerns.

In the marina vicinity, and in the northern part of the IBSP North Unit, survey data collected in 1995 were compared with data from 1987 through 1992. In the three-year interval 1992-1995, a minimum of 14,200 cu yds/yr of littoral sediment moved south across the WI-IL state line. Most of this sediment accumulated in the nearshore between the state line and the NPM north breakwater. Some sediment was transported southward around the north breakwater and accumulated lakeward of the marina entrance and inside the entrance. The marina entrance has been a sediment trap since the breakwaters were constructed in 1988-89. The 1992-95 data comparison strongly suggests that littoral sand crossing the state line has bypassed the north breakwater and has contributed to shoaling in the marina entrance.

Net erosion dominated across the lake bottom from the marina south breakwater to the Camp Logan headland. Locally, this erosion lowered the lake bottom to elevations below those that existed in 1987 prior to marina construction. For the entire shore along the marina property, the most severe erosion continues lakeward of the south parking area, undermining the existing line of shore defense. Without additional engineering measures to protect this area, additional subsidence of the existing shore defense is certain. As this shore defense subsides, erosion will advance landward toward the parking access roads.

The shore in the northern part of the IBSP North Unit, between the marina/state park boundary and the Camp Logan headland, has undergone extreme coastal change. Shoreline and nearshore changes between 1987 and 1995 were evaluated to assess overall trends. Between 1987 and 1989 the reach gained 13 acres of beach from the southward dispersion of sediment dredged from the marina basin. Since 1989, shoreline recession has occurred. As of 1995 only 5 acres remains of this previous 13-acre gain. The 1989-1995 rate of beach area loss has been 1.3 acres/yr. During this same time interval, a total of 202,000 cu yds of beach nourishment was supplied to this shore (avg. 33,700 cu yds/yr). The nourishment slowed the rate of shoreline recession, but the nourishment volumes have been insufficient to counteract an annual net loss of sediment from the beach and nearshore. A preliminary analysis of the nearshore sediment budget suggests that a nourishment rate of at least 68,400 cu yds/yr would be required annually downdrift of the marina to maintain a balanced sediment budget and to halt net erosion.

In July 1995, beach nourishment consisting of fine to medium sand was supplied to the north ends of both the North Unit (20,000 cu yds) and the South Unit (24,000 cu yds). Monitoring of the nourishment documented that the sand was nearly all dispersed into the shallow nearshore by November 1995. At both sites, the most rapid dispersion occurred during a single storm on September 7-8.

Year-2 (1996) Executive Summary

In 1996, the Illinois State Geological Survey (ISGS) began Year-2 of a four-year study to examine erosion and accretion trends along the Lake Michigan shore at North Point Marina (NPM) and the North and South Units of Illinois Beach State Park (IBSP). This study is funded by the Illinois Department of Natural Resources (DNR) which is responsible for coastal management at these facilities. The goal of the study is to develop a sediment budget for the coastal reach which extends between the WI-IL state line and Waukegan Harbor (the SL-WH coastal reach). This will provide input for planning and implementing long-term strategies for coastal management. An immediate objective is to provide information on erosion and accretion trends relevant to ongoing coastal management.

Comparison of 1872-1996 data on lake-bottom (nearshore) change indicates that the northern part of the SL-WH coastal reach has become increasingly important as a source area for sediment supply to areas further south. Between 1974 and 1996, all accretion along the southern segment of the coastal reach could be accounted for by erosion along the northern segment of the reach. Most of the erosion occurred along present-day DNR lakeshore while most of the accretion occurred in areas to the south of DNR property. The 124-year record also suggests that the greatest beach and nearshore erosion will likely continue to be focused in the area between the WI-IL state line and Camp Logan.

Net erosion has characterized the beaches and nearshore along the 7700-ft stretch of shore between the WI-IL state line and Camp Logan both prior to, and subsequent to, marina construction (1987-1989). During 1995-1996, net nearshore erosion along this shore totaled 139,300 cu yds. This was almost a six-fold increase in the annual net erosion rate when compared with the 1992-1995 interval. The area of most extensive lake-bottom erosion occurred between the marina / state park boundary and Camp Logan. For the shore along the marina property, the most severe erosion continued to occur lakeward of the south parking area, undermining the existing line of shore defense and causing loss of backfill.

The nearshore on the updrift (north) side of NPM was net accretional between 1987 and 1995 due to sediment entrapment on the updrift side of the north breakwater. During 1995-1996, this nearshore became net erosional, losing 21,100 cu yds of sand. This may be a one-year erosional anomaly or it may indicate the start of a new erosional trend. It does indicate, however, that accretion does not necessarily occur on the updrift side of this facility on an annual basis. An erosional trough has been located about 90 ft offshore of the NPM north breakwater since 1988. During 1995-1996, this trough deepened by 7 ft to its greatest recorded depth of 18.6 ft Low Water Datum (LWD) and was up to 5 ft deeper than the design base elevation of the north breakwater. Sediment lost from this part of the nearshore moved downdrift causing accretion in the shallow nearshore along the south breakwater.

As of June 1996, the marina entrance had experienced a net loss of sediment during 1995-1996 (-3,300 cu yds). It had been net accretional during 1992-1995 (+3,100 cu yds/yr). The net loss of sediment is primarily attributed to 1995-1996 dredging which was completed in August 1996. In the recreational and commercial basins, average water depths in 1996 generally remained at or greater than the design depth of 8.1 ft LWD. A 19-ft deep erosional trough, located 50 ft east of the north inner breakwater near the marina entrance, was 7 ft deeper than the design depth for the base of the north inner breakwater.

The northern part of the IBSP North Unit, between the marina / state park boundary and the Camp Logan headland, underwent severe lake-bottom erosion during 1995-1996. However, the 1996 beach area remained similar to that of 1995 (8 acres). This can be attributed to reduced shoreline recession caused by the input of beach nourishment at the updrift end. While beach nourishment in 1995-1996 slowed the rate of shoreline recession, it was not sufficient to counteract the net loss of 65,200 cu yds of sand, silt, and gravel from the nearshore. The Year-2 interim littoral sediment budget suggests that a nourishment rate of at least 82,600 cu yds/yr would be required annually at the North Unit nourishment site to initiate a balanced sediment budget and to halt net erosion.

APPENDIX B: METHODS AND TERMINOLOGY

Units of Measure

All measurements in this report are given in U.S. customary units (*e.g.*, feet, miles, acres, cubic yards). This is to facilitate comparison of present-year data with previous coastal monitoring data and with past and present engineering projects at the marina and state park. Table B-1 provides factors for converting U.S. customary units to metric units.

Table B-1 Factors for converting from U.S. customary units to metric units.

U.S. customary units	Conversion factor	Metric units
Length		
foot	0.3048	meter
mile	1.609	kilometer
Area		
square foot	0.0929	square meter
square yard	0.8361	square meter
square mile	2.59	square kilometer
acre	0.4047	hectare
Volume		
cubic yard	0.7646	cubic meter

To convert from U.S. customary units to metric units, multiply by the conversion factor in the central column.

Terminology

Terms used in this report which are common to Lake Michigan coastal monitoring are defined as follows:

bathymetry The measurement of water depths. The compilation of water-depth data along a survey line is the basis for constructing a bathymetric profile of the lake bottom; compilation of such data across an area is the basis for producing a bathymetric map.

erosion / accretion The loss (erosion) or gain (accretion) of sediment. Erosion and accretion can have a vertical component as well as a lateral component. Unless otherwise stated, the erosion and accretion discussed in this report refer to vertical change.

erosion hotspot A localized area where the measured amount of beach or lake-bottom erosion is increased relative to that of other coastal areas within the SL-WH coastal reach.

foreshore In the context of this report, the foreshore is that part of the beach and shallow nearshore that lies within the zone of wave swash. During normal and storm wave conditions, the foreshore is alternately submerged and exposed by breaking waves.

isobath A line on a bathymetric map connecting points of equal water depth or equal lake-bottom elevation (*i.e.*, equal bathymetry). In this report, the terms "isobath" and "bathymetric contour" are synonymous.

isopach A line on a map connecting points of equal thickness of a specific material. In this report, isopach maps are presented for the thickness of sediment gained or lost between given time intervals. These isopach maps indicate the vertical amount of lake-bottom erosion and accretion that are determined from a temporal comparison of bathymetric data.

littoral sediment transport The movement of sediment along the beaches and nearshore by waves and wave-induced currents. The sediment involved in the transport is referred to as "littoral drift."

Low Water Datum (LWD) This is the reference plane, or datum, for measuring lake levels and lake-bottom depths (bathymetry). The datum allows comparison of lake-bottom elevations from different months or years independent of changes in lake level. All lake-bottom elevations in this report are referenced to LWD (see "Data Processing" and Table B-2).

nearshore The nearshore is here defined as the zone between the shoreline and water depths of about 20 to 25 ft LWD. This is the zone of major littoral sediment transport along the lake bottom. The nearshore does not include the beach or any other areas above mean lake level.

net erosion / net accretion When all the erosion and accretion volumes for an area are summed, the <u>net</u> change (net erosion or net accretion) is determined.

normalized change In the context of this report, this refers to stating changes in beach or nearshore areas or volumes in terms of change per foot of shoreline. Units are square yards per foot of shoreline (sq yds/ft), or cubic yards per foot of shoreline (cu yds/ft); shoreline length is measured along a north-south line.

updrift / downdrift The predominant (or strongest) waves along a coast cause net littoral sediment transport away from the direction of wave attack. Updrift refers to the direction from which net transport originates; downdrift refers to the direction towards which net transport occurs. For the segment of Illinois coast discussed in this report, net littoral transport is southward, driven by northerly waves. Thus, updrift means "to the north" and downdrift means "to the south."

<u>Field Procedures</u>

Establishing horizontal and vertical control

All horizontal and vertical control for field surveys relied on existing bench marks or other survey marks in the study area. New control points were established by running traverses from existing control. All survey work for establishing and verifying horizontal and vertical control used a LIETZ/SOKKISHA Set 4-A Total Station.[1] A LIETZ SDR20 or SDR33 Electronic Note Book was used in conjunction with the Total Station to provide a digital record of all survey data. Data were downloaded at the end of each field day

onto a laptop computer and later processed using MICROSOFT Excel spreadsheet software. All horizontal control (X-Y data) was recorded using Illinois State Plane coordinates. Vertical control (Z data) was referenced to Mean Sea Level (MSL) and subsequently corrected to Low Water Datum (LWD) for presentation in map format (see Data Processing).

Beach profiling and beach-nourishment monitoring

A LIETZ/SOKKISHA Set 4-A Total Station and one or more prism poles were used for collecting all beach profile data. Beach profile data were typically obtained between the backshore vegetated-dune line and the shallow nearshore (to depths of approximately 5.5 ft below lake level at the time of survey). The Total Station and back-sight prism were set at reference points of known State Plane Easting (X), Northing (Y), and elevation (Z). The prism pole survey rod was positioned on successive measurement points along predetermined profile lines, generally along a given Northing, and the respective X, Y, and Z data were obtained for each point. To monitor nourishment stockpiles, a similar procedure was employed to determine stockpile topography (profile survey) and areal extent (circumnavigation survey). Each stockpile profile generally originated on a stable substrate such as an adjacent access road or the landward semi-vegetated crest of the stockpile. To determine rates of stockpile erosion, the location of the crest along the stockpile's erosional scarp was mapped by positioning the prism pole at 45-ft increments along this line. Elevations along the scarp crest were typically 1 to 12 ft above lake level at the times of survey.

Collection of bathymetric data

Bathymetric data were collected using one of two methods:

1) Fathometer Method: Bathymetric data beyond wading depths were collected with a ROSS Model 803 Portable Survey Fathometer mounted onboard a 15 ft ZODIAC-type inflatable boat. The fathometer measured depth in feet. Fathometer calibration was performed at the beginning of each day of data collection. During profiling, the survey boat was maintained on the desired profile line by a person onshore using a transit fixed on the azimuth of the line (typically N90E). Radio or visual signals to the boat operator were used to keep the boat within one boat width (5.6 ft) of the line. Offshore distance to the boat was measured by a MOTOROLA Mini-Ranger III system (accurate to ± 10 ft) which uses a microwave signal to determine distance between a transceiver mounted on the boat and an onshore transponder. The Mini-Ranger III system included a control console onboard the survey boat that provided an LED display of distance in meters from the onshore transponder. The fathometer operator monitored the console display to make fix marks and annotations on the fathometer record to provide a location reference for the depth (Z) data.

2) Wading Method: Shallow-water bathymetric data were collected to wading depths (approximately 5.5 ft below lake level at the time of survey) to provide coverage for shallow-water areas where the boat-mounted fathometer could not always provide a good record. This procedure, which was an extension of the beach-profiling transects, involved a person wading into the water along the designated profile line holding a prism pole on successive points. An onshore Total Station operator then shot these points to obtain X-Y-Z data. Data-point spacing was such that all significant lakebed elevation changes (> 0.5 ft) were recorded. A wet suit aided prolonged stay in the water.

<u>Data Processing</u>

Datums

Three different datums are commonly used in the presentation of topographic and bathymetric data from the Great Lakes region. These are:

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[1]Note: Use of specific product names in this report is for informational purposes only and does not constitute endorsement by the Illinois State Geological Survey.

- Lakes Michigan-Huron Low Water Datum (LWD)
- International Great Lakes Datum (IGLD) 1955 or 1985
- National Geodetic Vertical Datum (NGVD) 1929
  (also called Mean Sea Level (MSL))

Table B-2 shows conversion factors for adjusting elevations between these different datums.

Datums for bathymetry All bathymetric profiles and maps in this report are referenced to LWD. All bathymetric measurements collected by boat-mounted fathometer required a correction to LWD based on lake level relative to LWD at the time of each bathymetric profile. For these corrections, hourly lake-level data (meters, IGLD 1985) were compiled from lake-level gauges at Milwaukee, Wisconsin and Calumet Harbor, Illinois. These gauges are operated by the National Ocean Service (NOS) of the National Oceanic and Atmospheric Administration (NOAA).

Table B-2 Conversion factors for different lake-level and topographic datums used in this study.

Given Datum (in feet)	To convert to Datum (in feet)			
	LWD[1]	IGLD[2] (1955)	IGLD[2] (1985)	NGVD[3] (1929)
LWD	——	+ 576.80	+ 577.50	+ 578.10
IGLD (1955)	– 576.80	——	+ 0.70	+ 1.30
IGLD (1985)	– 577.50	– 0.70	——	+ 0.6
NGVD (1929)	– 578.10	– 1.30	- 0.6	——

Acronyms: LWD = Low Water Datum (also called Chart Datum)
IGLD = International Great Lakes Datum
NGVD = National Geodetic Vertical Datum (also called Mean Sea Level)

[1]LWD is the datum used for all lake-bottom depths reported by the ISGS. This is also the datum used for all depths on Lake Michigan nautical charts published by the National Ocean Service (NOS), and is commonly the datum used for profile data reported by the U.S. Army Corps of Engineers (COE).

[2]IGLD is the international datum for reporting Great Lakes water levels. The datum adjustment from 1955 to 1985 was necessary to compensate for regional crustal uplift due to post-glacial rebound. All lake levels reported by NOS and COE since 1992 are referenced to IGLD 1985.

[3]NGVD (1929) is the datum used for all topographic information on U.S. Geological Survey topographic maps of the Illinois coast of Lake Michigan. This datum is also referred to as Mean Sea Level (MSL).

Because the study area is located approximately midway between the gauges at Milwaukee and Calumet Harbor, hourly lake levels for the two gauges were averaged to compute hourly lake levels in the study area during the times of bathymetric survey. The difference between these hourly lake levels and LWD was an hourly correction used to reference fathometer-derived lakebed elevations to the LWD reference plane. This correction ranged from 3.3 to 4.0 ft for the bathymetric data collected between May and July 1997.

Datums for topography LWD was also the datum used for elevations above lake level such as beach elevations and elevations on the beach-nourishment stockpiles. LWD was used because it permitted direct comparison of profile and map data above and below water. Any compiled elevation data that were referenced to IGLD, NGVD, or MSL were adjusted to LWD using the correction factors given in Table B-2.

Constructing and measuring maps of lake-bottom change (isopach maps)

All maps of lake-bottom change (isopach maps) recorded changes in excess of 1 foot. This cutoff allowed for possible elevation errors in the collection and processing of the fathometer data. Only lake-bottom changes occurring below the 0-ft LWD plane were used in volume calculations. The landward limit of contoured map data occurs along the line of intersection between the most landward topo-bathymetric profile and the 0-ft LWD plane. The lakeward limit of contoured data occurs at the limit of data overlap between the two comparative years. The shoreline shown on each isopach map is the most recent shoreline of the two comparative years.

Isopach maps were constructed using one of two methods. With the first method, bathymetric (and topographic) contour maps were superimposed to obtain contour intersection points. Elevation changes at these intersection points were then used to create an isopach contour map depicting areas and magnitudes of elevation change. With the second method, topo-bathymetric profiles were used. At given range-line locations along the shore, the elevation difference between two comparison profiles was determined at approximate 100-ft intervals extending offshore to the limit of data overlap. The data points were then plotted along each range line marked on a base map and subsequently contoured.

Isopach maps created using either of the above two methods were used to compute erosion and accretion volumes. To compute volumes, the area within each isopach contour interval was measured with a LIETZ Planix-7 digital planimeter. Each of these areas was multiplied by the mid-contour value to give volume (*e.g.*, the area between the 2 and 3 ft contours was multiplied by the mid-contour value, 2.5 ft). All volumes between contours were then summed to give total erosion and accretion volumes and net volume change.

Volumetric analysis of the North Beach Bar

Annual sediment volumes were calculated for the North Beach bar by subtracting an inferred non-barred bathymetric profile from the barred bathymetric profile for the year of survey (*e.g.*, 1997). East-west profile data were used to obtain representative cross-sectional areas along the length of the bar. Areas were measured using a digital planimeter. The cross-sectional areas were then integrated along the north-south length of the bar to provide the bar volume for each year.

Determining the bar volume was dependent on the boundaries chosen to define this bathymetric feature. The following boundaries were used:

- North boundary: The WI-IL state line (note: the bar apparently continues north of the state line, thus these volume calculations apply only to the Illinois segment).
- West boundary: A line along the axis of the trough on the landward side of the bar/trough pair (as seen on bathymetric profiles).
- South boundary: Defined by the southern edge of the bar, as interpreted from bathymetric maps.
- East boundary: Defined as the break in slope between the lakeward edge of the bar and the smooth lake bottom lying lakeward of the bar (as seen on bathymetric profiles). Of the four boundaries, this was the most subjective.

APPENDIX C: PREVIOUS COASTAL MONITORING

General Statement

The following paragraphs summarize previous coastal monitoring along the northern Illinois shore of Lake Michigan from which data were extracted for this study. Summary results of previous ISGS monitoring at North Point Marina between 1987 and 1992 were presented in the Year-1 Report (Chrzastowski *et al.*, 1996). Compilation of earlier regional-scale coastal data from several state and federal agencies permits the documentation of long-term, regional-scale coastal changes adjacent to NPM and IBSP.

Nearshore bathymetric data for the Illinois shore of Lake Michigan between the WI-IL state line and Waukegan is available as far back as 1872. The first comprehensive bathymetric data sets were collected by the U.S. Lake Survey during 1872-1873 and 1909-1911. Subsequent regional surveys were conducted by the U.S. Army Corps of Engineers in 1946 (U.S. Army Corps of Engineers, 1953), by the Illinois Division of Waterways in the early 1950s (State of Illinois, Division of Waterways, 1958), and by the Illinois State Geological Survey (ISGS) in 1974 (Illinois State Geological Survey, 1975, 1988). Between 1987 and 1992, the ISGS conducted a five-year monitoring program in the vicinity of NPM between the WI-IL state line and Camp Logan. In 1994, Hydrographic Survey Company, Inc. was contracted by the Illinois Department of Conservation (IDOC) to conduct a bathymetric survey of the recreational and commercial boat basins at NPM (Hydrographic Survey Company, Inc., 1994). During 1994 and early 1995, Patrick Engineering, Inc. conducted a bathymetric survey in the approaches to the recreational boat basin at NPM (Patrick Engineering, Inc., 1995a). In 1995, the ISGS resumed bathymetric work at NPM and along the northern Illinois shore as part of this study.

Bathymetric Surveys in the vicinity of North Point Marina (1987-1992 and 1995-1997)

Bathymetric surveys were conducted by the ISGS in the NPM vicinity between 1987 and 1992, in the area between the WI-IL state line and Camp Logan. This study's Year-1 Report (Chrzastowski *et al.*, 1996) contains bathymetric and lake-bottom change maps from 1987 through 1992 for this area. Table C-1 summarizes the annual lake-bottom accretion, erosion, and net volumetric changes documented in that five-year study and also incorporates results from Year-1, Year-2, and Year-3 of this study. The 1987 to 1997 summation of lake-bottom change volumes illustrates net nearshore erosion (-73,000 cu yds) over the ten-year interval.

During summer 1995, the nearshore between the WI-IL state line and the Camp Logan headland contained 63,000 cu yds of sand more than it contained in 1987 just prior to marina construction (Table C-1). Significant erosion during 1995-1996 caused the system to become net erosional by 1996, a condition that persisted through 1997 even though minor net accretion occurred during the 1996-1997 interval. As of 1997, therefore, the nearshore had lost 73,000 cu yds more sand than it had gained from beach nourishment and littoral sediment input during the 1987-1997 interval.

Regional Bathymetric Surveys of 1872, 1910, 1946, and 1974

The U.S. Lake Survey (1872, 1873, 1909-1911, 1910-1911) published the first comprehensive set of maps documenting nearshore water depths along the northern Illinois shore of Lake Michigan. Data were presented as a series of 1:20,000-scale soundings maps. The U.S. Army Corps of Engineers (1953) published bathymetric profiles and regional bathymetric- and shoreline-position maps based on data collected by the Corps in 1946 and on data collected by the U.S. Lake Survey during 1872 and 1909-1911. Multi-year bathymetric profiles (1872, 1910, 1946) were presented for five of 9 range lines spaced at 0.3 to 1.8 mile intervals between the WI-IL state line and Waukegan Harbor. Subsequently, the State of Illinois Division of Waterways (1958) also published multi-year bathymetric profiles along these range lines, as well as shoreline-position maps, using data primarily from the late 1940s and early 1950s.

Two ISGS coastal atlases (Illinois State Geological Survey, 1975, 1988) presented nearshore bathymetric contour maps based primarily on data collected by ISGS in 1974. Data were extracted from these maps to augment profile data along the 9 range-line transects between the WI-IL state line and Waukegan Harbor (see "Part 3: Regional Coastal Monitoring"). Thus, at each range line location, historical data exist for the years 1872, 1910, 1946, and 1974.

Table C-1 1987-1997 annual nearshore accretion and erosion volumes and net volumetric change between the WI-IL state line and the Camp Logan headland.[1]

Year Interval	Accretion	Erosion	Net Change (+ accretion; – erosion)	
	cu yds	cu yds	cu yds/yr	cu yds/yr/shoreline ft [2]
1987-88	309,000	52,000	+257,000	+33
1988-89	235,000	107,000	+128,000	+17
1989-90	112,000	241,000	–129,000	–17
1990-91	105,000	126,000	–21,000	–3
1991-92	65,000	165,000	–100,000	-18
1992-95	102,000[3]	175,000[3]	-24,000[4]	+17
1995-96	65,000	204,000	-139,000	-18
1996-97	62,000	59,000	+3,000	0
Summation 1987-1997	+1,055,000	-1,129,000	-73,000	-10

[1] All volume calculations are for lake-bottom changes greater than 1 foot and are recorded to the nearest thousand cu yds. The nearshore is defined as that area between the shoreline and approximately the 20 ft LWD isobath. The upper boundary to the volume calculations is 0 ft LWD. Volumes are derived from comparison of annual bathymetric data collected in the late spring or summer of each year.

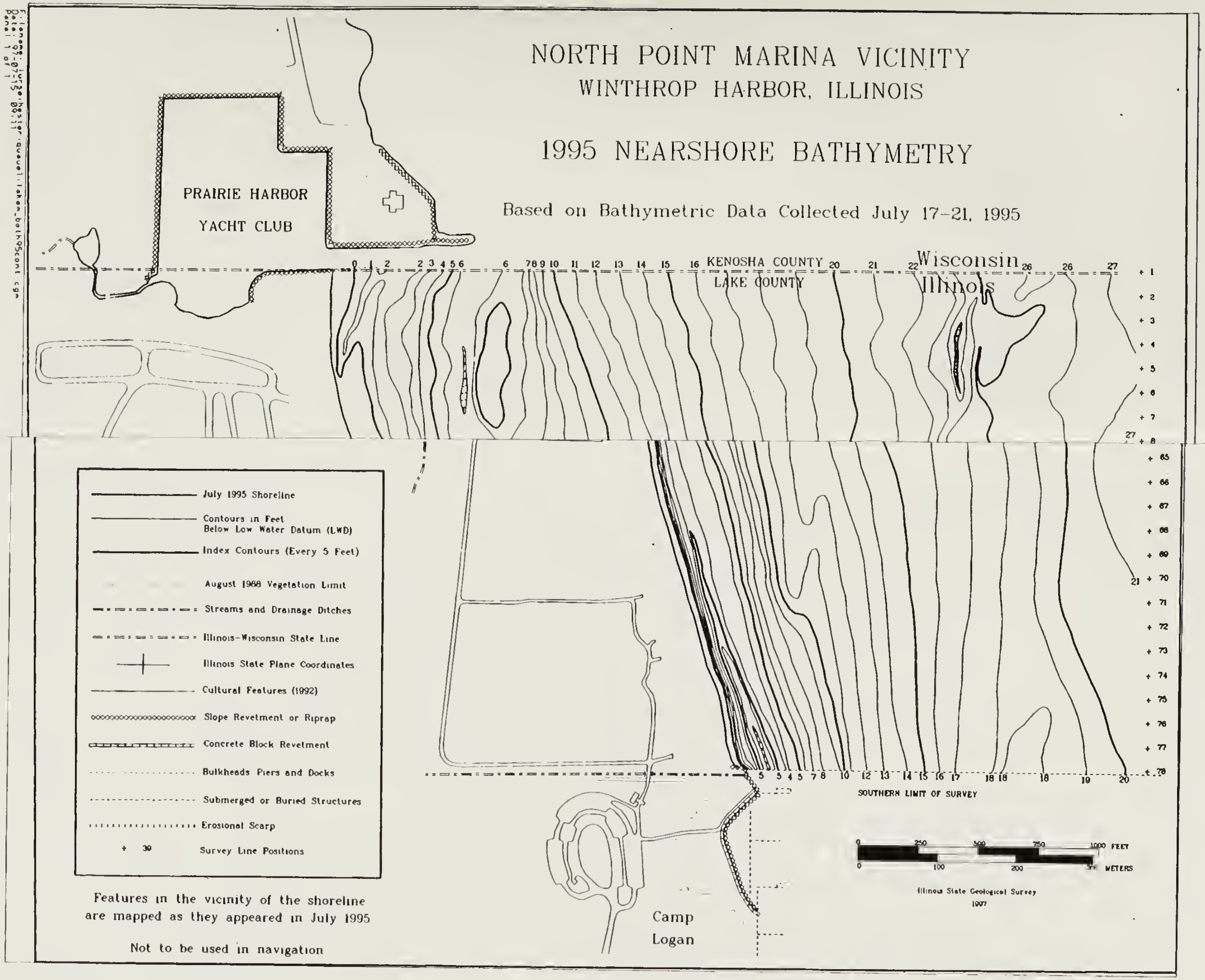
[2] Normalized volume is based on a shoreline distance of 7700 ft which is the north-south distance between the WI-IL state line and the limit of mapping at the Camp Logan headland; values are rounded to the nearest whole number.

[3] Accretion and erosion volumes for 1992-1995 are a three-year summation.

[4] This is the annualized net change for the three-year interval. Normalized volume is adjusted to the annual rate

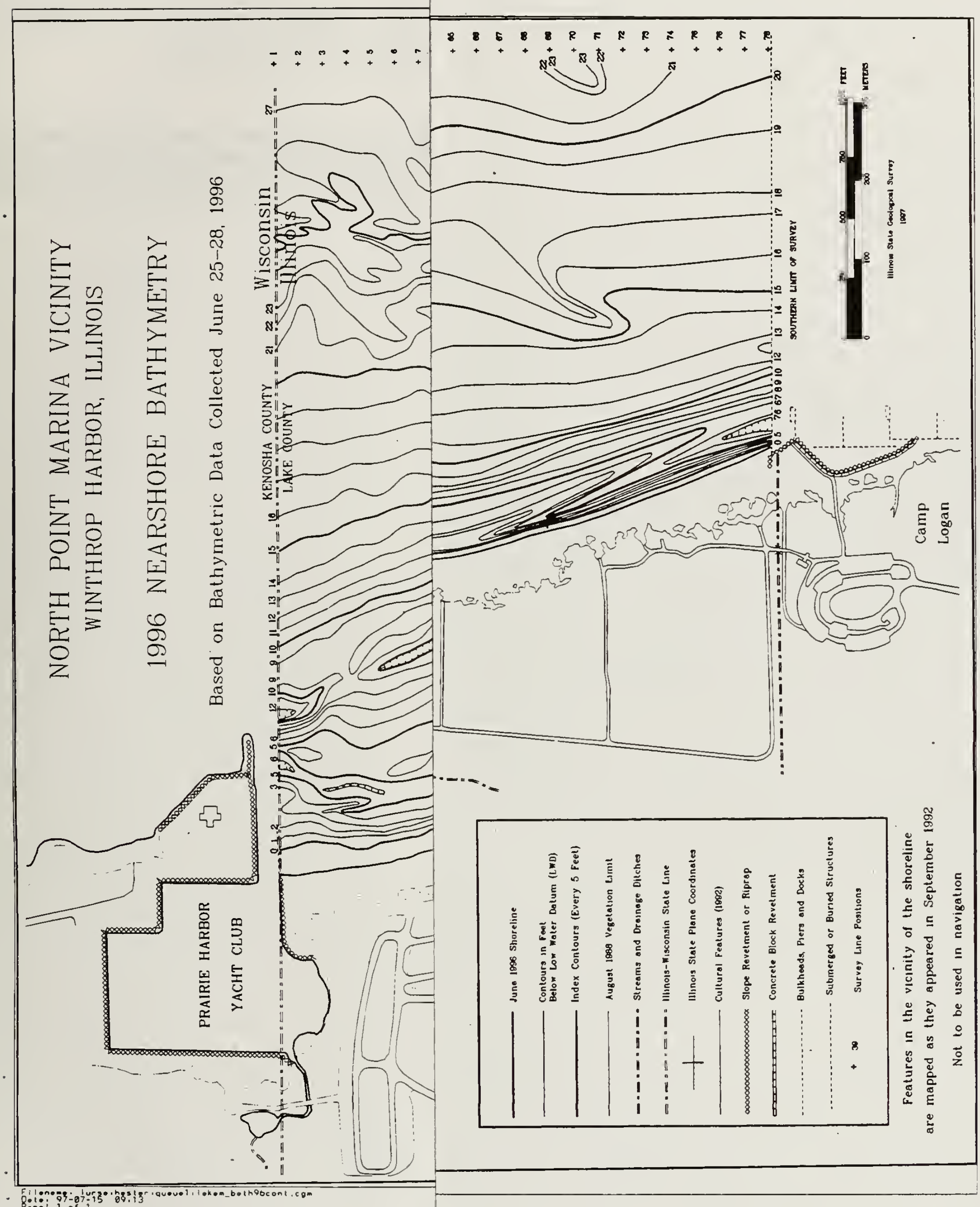
APPENDIX D: YEAR-1 (1995) AND YEAR-2 (1996) BATHYMETRIC CONTOUR MAPS FOR THE NORTH POINT MARINA VICINITY

The two bathymetric maps in Appendix D are based on fathometer and total-station data collected by ISGS during Year 1 (Map D-1) and Year 2 (Map D-2) of this study. All contours are in feet and are referenced to Low Water Datum (LWD). The maps were plotted using the ARC/INFO Geographic Information System.


NORTH POINT MARINA VICINITY
WINTHROP HARBOR, ILLINOIS
1995 NEARSHORE BATHYMETRY
Based on Bathymetric Data Collected July 17-21, 1995
PRAIRIE HARBOR
YACHT CLUB
KENOSHA COUNTY
LAKE COUNTY
Wisconsin
Illinois
SOUTHERN LIMIT OF SURVEY
Camp
Logan
July 1995 Shoreline
Contours in Feet Below Low Water Datum (LWD)
Index Contours (Every 5 Feet)
August 1988 Vegetation Limit
Streams and Drainage Ditches
Illinois-Wisconsin State Line
Illinois State Plane Coordinates
Cultural Features (1992)
Slope Revetment or Riprap
Concrete Block Revetment
Bulkheads Piers and Docks
Submerged or Buried Structures
Erosional Scarp
Survey Line Positions
Features in the vicinity of the shoreline are mapped as they appeared in July 1995
Not to be used in navigation
0 250 500 750 1000 FEET
0 100 200 300 METERS
Illinois State Geological Survey
1997


NORTH POINT MARINA VICINITY
WINTHROP HARBOR, ILLINOIS
1995 NEARSHORE BATHYMETRY
Based on Bathymetric Data Collected July 17-21, 1995
PRAIRIE HARBOR YACHT CLUB
KENOSHA COUNTY
LAKE COUNTY
Wisconsin
Illinois
COMMERCIAL BASIN
RECREATIONAL BASIN
Administration Building
N
Camp Logan
SOUTHERN LIMIT OF SURVEY
Features in the vicinity of the shoreline are mapped as they appeared in July 1995
Not to be used in navigation

Map D-1 (1995)


NORTH POINT MARINA VICINITY
WINTHROP HARBOR, ILLINOIS
1996 NEARSHORE BATHYMETRY
Based on Bathymetric Data Collected June 25-28, 1996
Wisconsin
Illinois
KENOSHA COUNTY
LAKE COUNTY
PRAIRIE HARBOR
YACHT CLUB
Camp
Logan
SOUTHERN LIMIT OF SURVEY
FEET
METERS
Illinois State Geological Survey
1997
June 1996 Shoreline
Contours in Feet
Below Low Water Datum (LWD)
Index Contours (Every 5 Feet)
August 1988 Vegetation Limit
Streams and Drainage Ditches
Illinois-Wisconsin State Line
Illinois State Plane Coordinates
Cultural Features (1992)
Slope Revetment or Riprap
Concrete Block Revetment
Bulkheads, Piers and Docks
Submerged or Buried Structures
Survey Line Positions
Features in the vicinity of the shoreline
are mapped as they appeared in September 1992
Not to be used in navigation
Date: 97-07-15 09:13
Panel 1 of 1

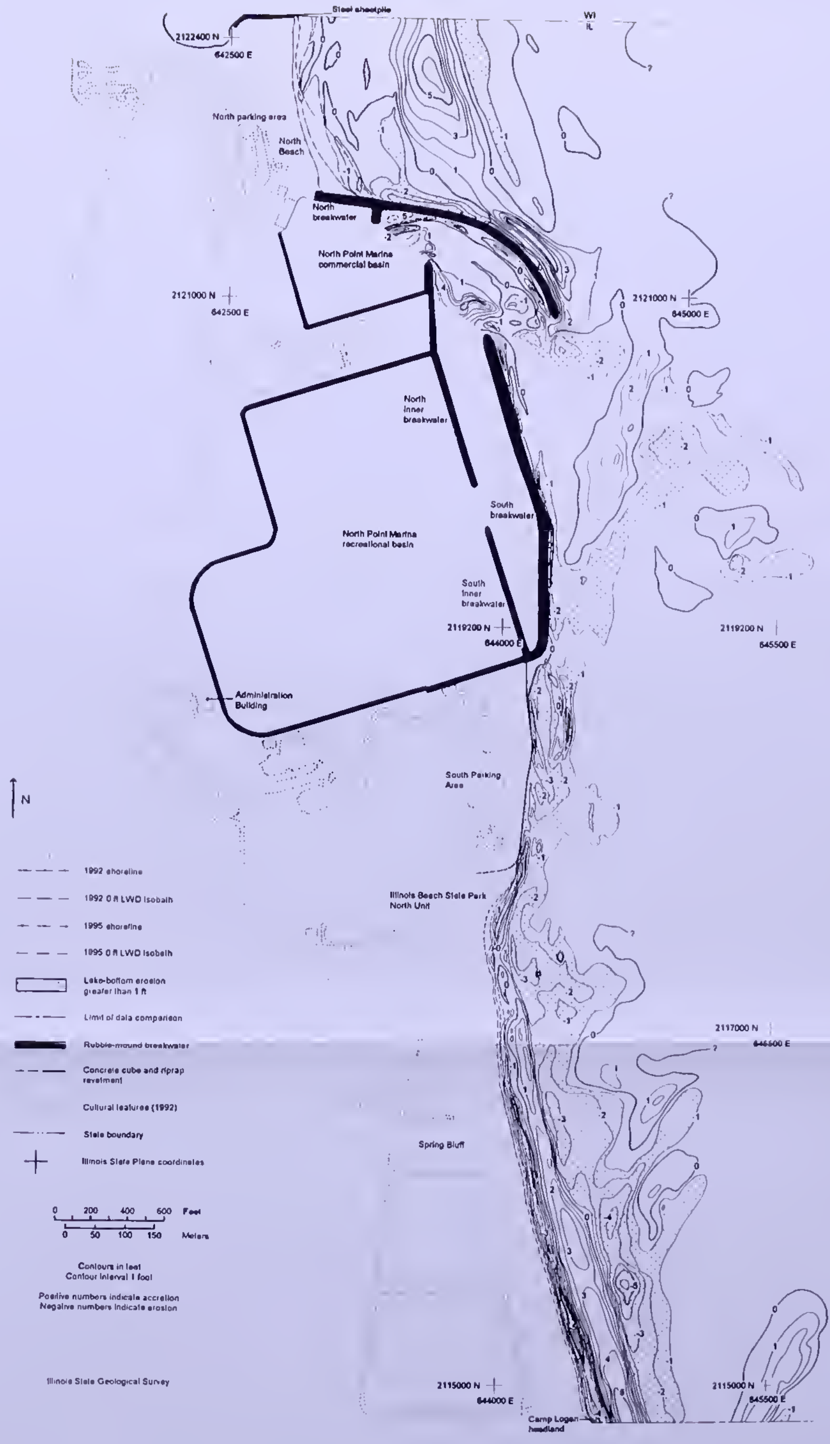
NORTH POINT MARINA VICINITY
WINTHROP HARBOR, ILLINOIS
1996 NEARSHORE BATHYMETRY
Based on Bathymetric Data Collected June 25-28, 1996
PRAIRIE HARBOR
YACHT CLUB
KENOSHA COUNTY
LAKE COUNTY
Wisconsin
Illinois
COMMERCIAL BASIN
RECREATIONAL BASIN
Administration Building
N
Index Contours (Every 5 Feet)
Streams and Drainage Ditches
Features in the vicinity of the shoreline
are mapped as they appeared in September 1992
Not to be used in navigation
Camp
Logan

Map D-2 (1996)

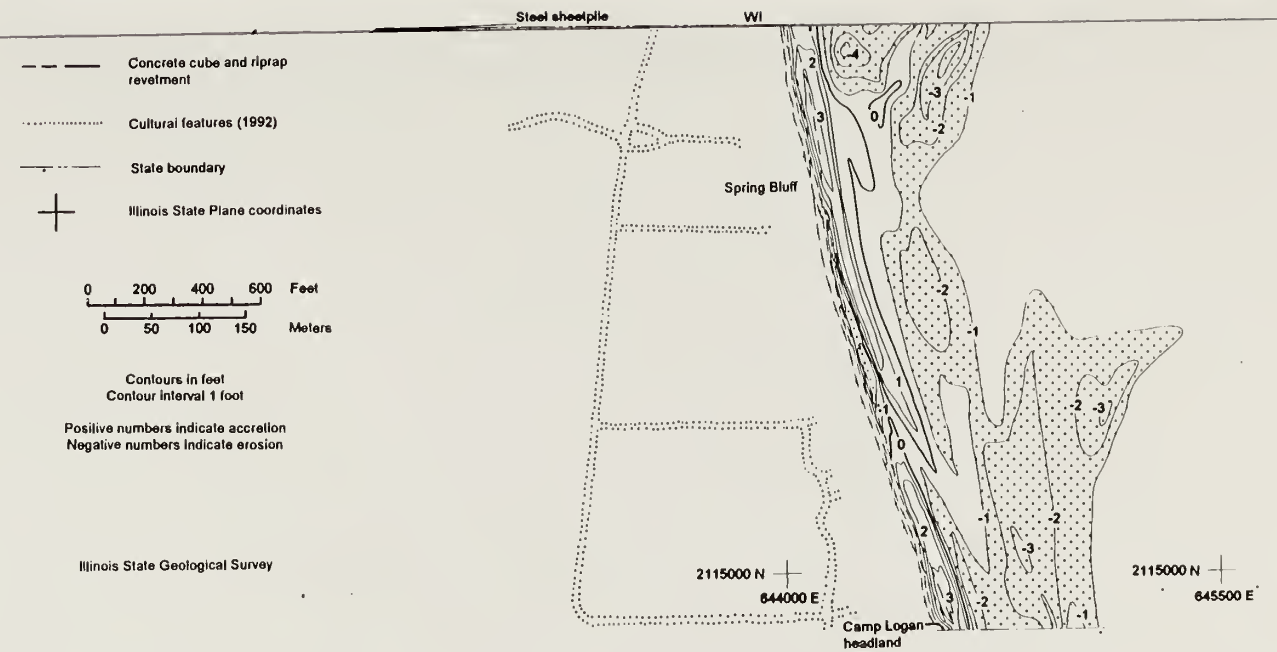
APPENDIX E: YEAR-1 (1995) AND YEAR-2 (1996) LAKE-BOTTOM CHANGE MAPS FOR THE NORTH POINT MARINA VICINITY

The two lake-bottom change maps in Appendix E are based on comparisons of bathymetric data collected by ISGS during 1992 and 1995 (Map E-1) and 1995 and 1996 (Map E-2). Areas of lake-bottom change in excess of 1 foot are shown and all contours are in feet.

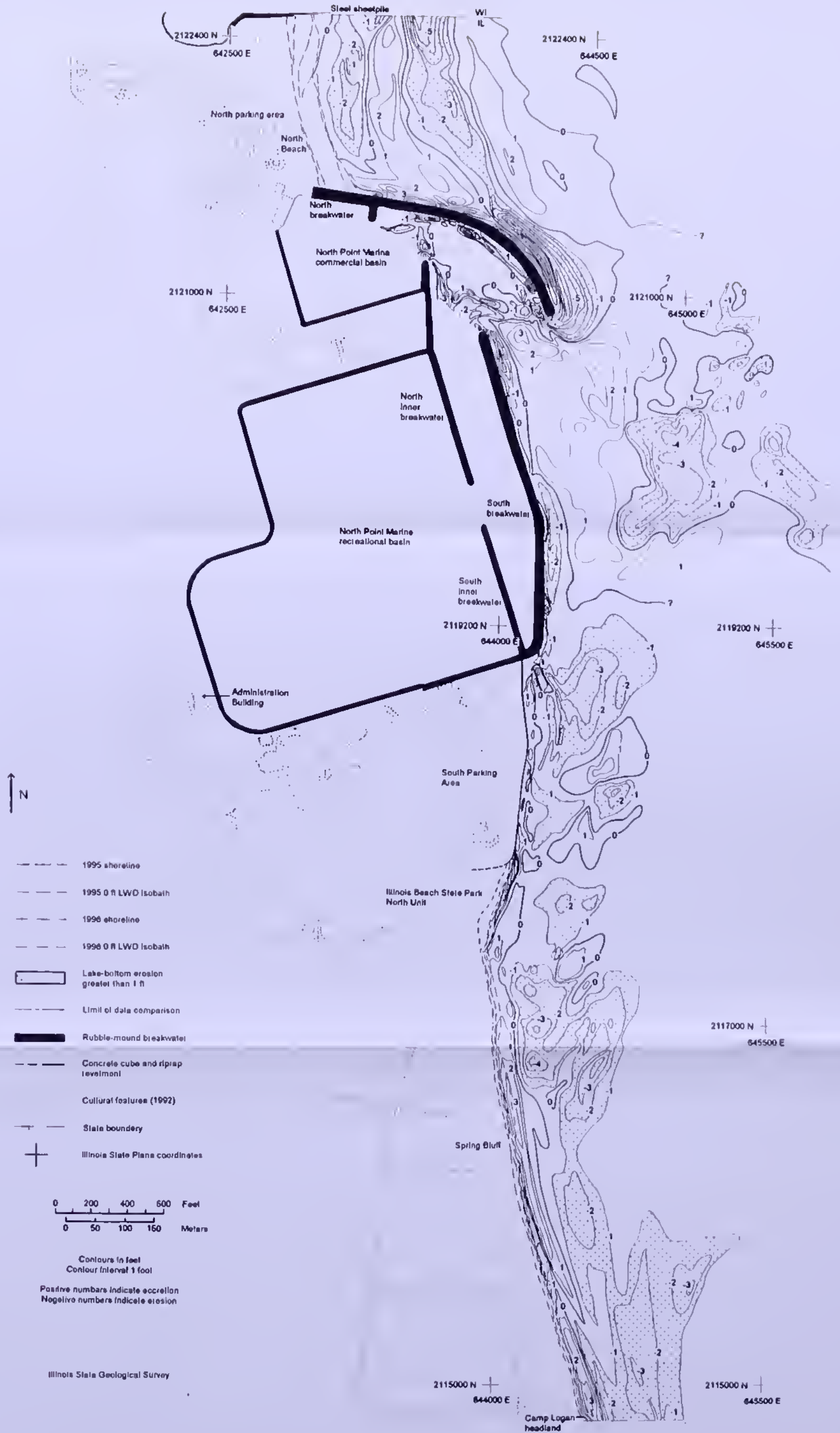
p E-1 (1992-1995)



Map E-1 (1992-1995)



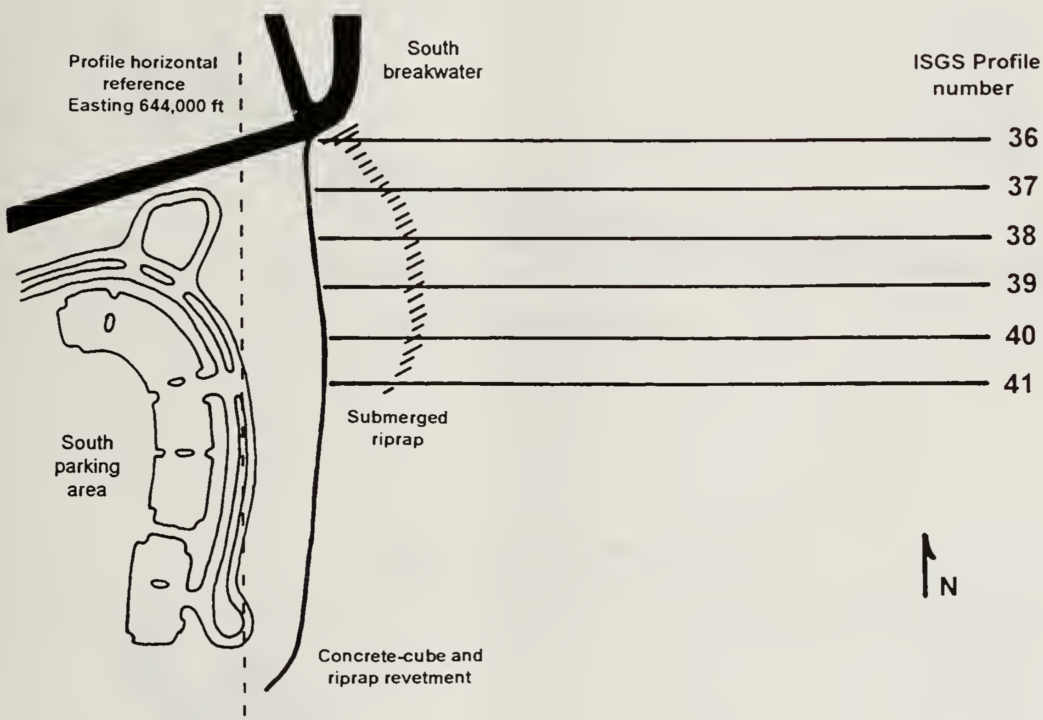
8 E-2 (1995-1996)



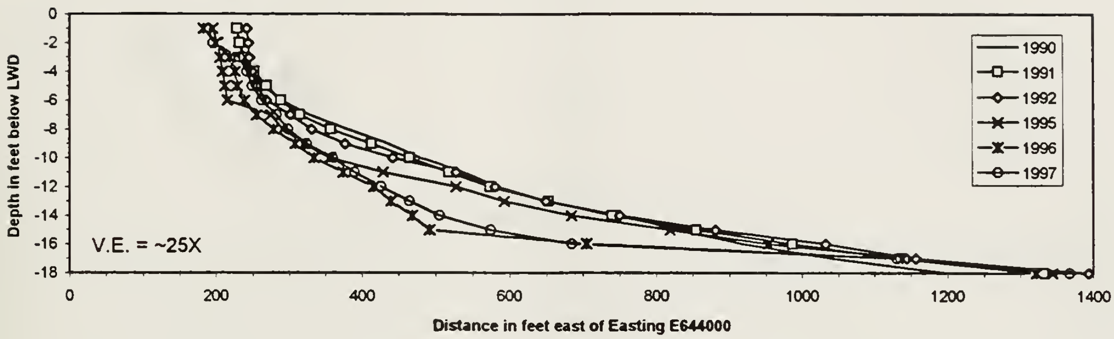
Map E-2 (1995-1996)

APPENDIX F: BATHYMETRIC PROFILES ACROSS THE NPM SOUTH PARKING AREA SUBMERGED RIPRAP (1990-1997)

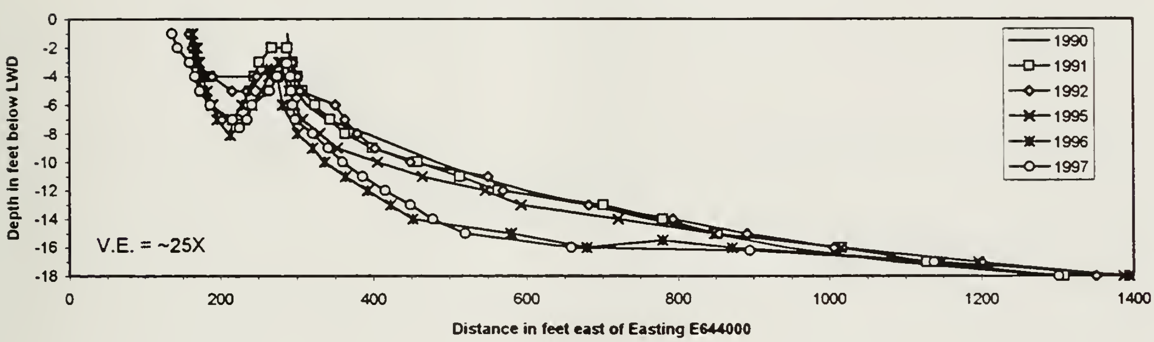
The five profiles in Appendix F are based on fathometer data collected between 1990 and 1997. The index map below shows the locations of these profiles at the south parking area. The 1990 profiles originate at the riprap which was then still emergent (see Chrzastowski *et al.*, 1996). By the time of the 1991 bathymetric survey, sufficient subsidence had occurred to allow data to be collected across the riprap during 1991 and later years.



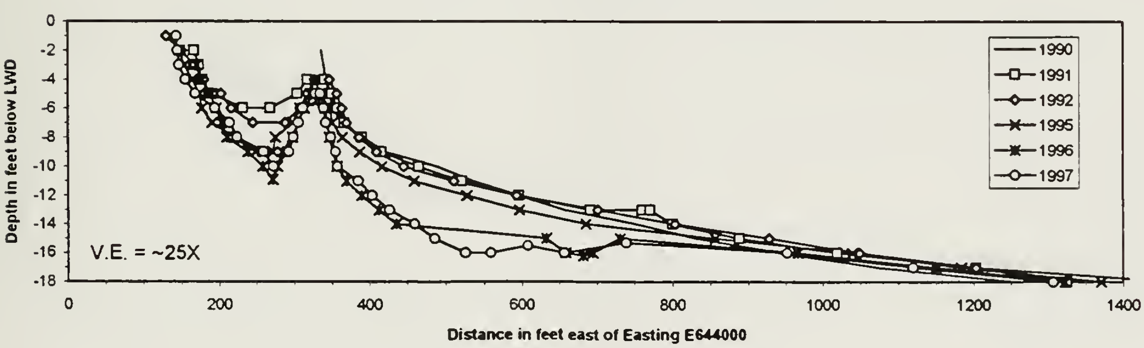
Profile Line 36 (Northing N2119000)



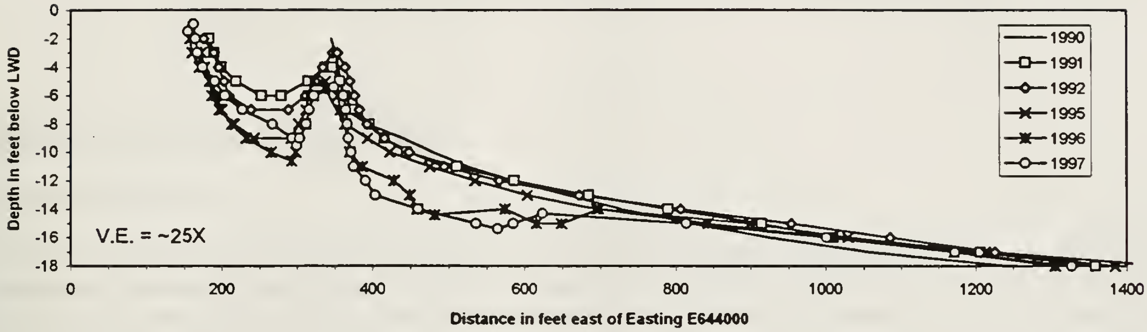
Profile Line 37 (Northing N2118900)



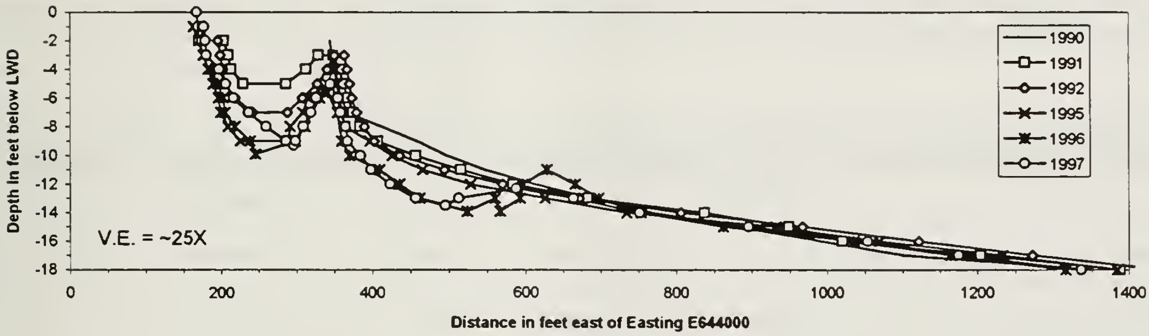
Profile Line 38 (Northing N2118800)



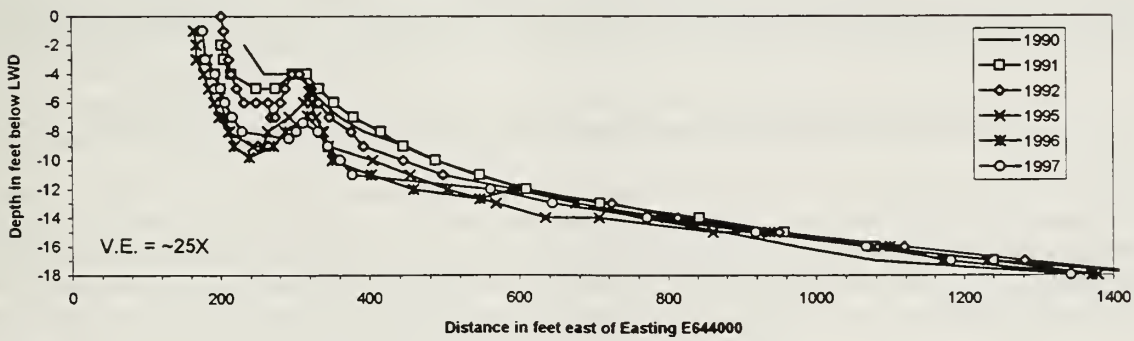
Profile Line 39 (Northing 2118700)



Profile Line 40 (Northing N2118600)



Profile Line 41 (Northing N2118500)



APPENDIX G: SUMMARY OF BEACH NOURISHMENT EVENTS AT ILLINOIS BEACH STATE PARK'S NORTH UNIT AND SOUTH UNIT (1987-1997)

Illinois Beach State Park / North Unit

General Statement

Beach nourishment has been placed periodically at the IBSP/NU beach-nourishment site since 1987 when significant construction first began at NPM. Located at the north end of IBSP/NU (Figs. 1-2, 3-1), the beach-nourishment stockpile functions as a "feeder beach" that supplies sand to downdrift beach and nearshore areas. Table G-1 provides a time-series summary of the individual beach nourishment events that supplied a total of approximately 1,748,000 cu yds of sand and gravel between 1987 and 1997.

Chronology of Beach Nourishment

The initial placement of at least 1,500,000 cu yds of sand (Moffatt and Nichol Engineers, 1986) was the result of dredging and construction of the 72-acre NPM facility. Most of the dredged material was placed on the south side of the south breakwater under what is now the NPM south parking area and the IBSP/NU beach-nourishment site (Fig. 3-1). This material was a sand, silt, and gravel mix reflecting the grain-size composition of the Zion beach ridge plain. It was supplied to the nourishment site via slurry pipe and resulted in the formation of a large fan delta.

Table G-1 Summary of beach nourishment volumes placed at the IBSP/NU beach-nourishment site.[1]

Year	Volume[1]	Comments
1987-89	1,500,000[2]	Minimum estimate; nourishment supplied from construction of NPM
1990	150,000	Beach nourishment supplied from dredging at Prairie Harbor Yacht Club
1994	32,000	Beach nourishment with a quarry-derived pea gravel
1995	~46,000	Nourishment applied in July 1995 and in December 1995-January 1996
1996	0	See text for reference to sand addition at NPM south parking area
1997	20,000	Beach nourishment with a quarry-derived pea gravel
1987-97	1,748,000	

[1] Volumes are rounded to the nearest 100 cu yds.
[2] In 1996, approximately 330,500 cu yds of this volume was still retained beneath the NPM south parking area (295,100 cu yds) or at the IBSP/NU beach nourishment site (35,400 cu yds). Most of this volume was still present during 1997.

In 1990, 150,000 cu yds of nourishment were added to the site (Fig. 3-1). The material was derived from dredging of Prairie Harbor Yacht Club, WI, and was trucked to the site. This material was primarily a fine- to medium-grained sand with a gravel component. It was applied solely to the area between the marina / state park boundary and Dead Dog Creek located 500 ft to the south in IBSP/NU (Fig. 3-1). Nourishment was limited to this 500 ft stretch of shore because the northernmost 1000 ft of the pre-existing nourishment pile had been paved-over to form the NPM south parking area in 1989.

In 1994, 32,000 cu yds of quarry-derived "pea gravel" were added to the 500 ft of shore between the

marina / state park boundary and Dead Dog Creek. The material was a fine gravel with a median grain size of approximately 6 mm. It was obtained from an inland quarry and was trucked onsite.

Two beach-nourishment events occurred in 1995. In July, 20,000 cu yds of fine- to medium-grained sand were placed at the beach nourishment site between the marina / state park boundary and Dead Dog Creek. Wave erosion had removed most of this material by November 1995.

Between early December 1995 and early January 1996, about 26,000 cu yds of nourishment were added to the North Unit stockpile as part of a 33,000 cu yd addition to the stockpile and the adjacent lakefront along the NPM south parking area (see below). The approximately 26,000 cu yds of nourishment were trucked onsite and placed along the 500 ft of shore on the lakeward side of the existing stockpile. In the case of both 1995 nourishment projects, the nourishment material was obtained from storage stockpiles at the Commonwealth Edison Waukegan Generating Station (Fig. 1-2). The material was originally derived from maintenance dredging of that facility's intake and discharge channels and cooling-water basin.

During October and November, 1997, about 20,000 cu yds of nourishment were added to 400 ft of shore extending southward from the marina / state park boundary. The nourishment was a "pea gravel" with a grain size in the range of 5 to 10 mm and was trucked to the site from an inland quarry.

The lakefront and nearshore along the NPM south parking area, located just updrift of the IBSP/NU beach-nourishment site, has received significant volumes of sand and silt that do not fall within the scope of beach nourishment efforts at IBSP/NU. These volumes, nevertheless, are documented in the following paragraph because they represent a sand contribution to the littoral system.

Between summer 1995 and summer 1996, approximately 24,000 cu yds of sand were dredged from the entrance at NPM. This material was transferred by slurry pipe to the shallow nearshore between the riprap-defended shore at the south parking area and the offshore submerged riprap on the south side of the NPM south breakwater. Between December 1995 and July 1996, an estimated 20,000 cu yds of sand were added to the shore along the NPM south parking area. Between March and June 1997, a further 12,000 to 15,000 cu yds (average: 13,500 cu yds) of sand were added. In both cases, the sand was derived primarily from dredging of Prairie Harbor Yacht Club, WI. However, about 7,000 cu yds placed as part of the December 1995 - January 1996 addition were obtained from the stockpile at Commonwealth Edison Waukegan Generating Station. Both sand additions are part of recent efforts to fill erosional embayments that develop along the NPM south parking area lakefront during storms.

<u>**Illinois Beach State Park / South Unit**</u>

General Statement

The beach nourishment site in IBSP/SU serves the same function as the nourishment site in IBSP/NU and has been active since 1995. Sand is placed on the shore to build a long narrow feeder beach that is intended to supply sand to the nearshore and downdrift beaches. The beach-nourishment site is located along 2400 ft of riprap-defended shore at the north end of IBSP/SU (Fig. 3-15). Table G-2 provides a time-series summary of the individual beach nourishment events that supplied a total of approximately 44,000 cu yds of sand between 1995 and 1997.

Chronology of Beach Nourishment

During June and July 1995, 24,000 cu yds of beach nourishment were placed at the nourishment site. The material was obtained from the storage stockpiles at the Commonwealth Edison Waukegan Generating Station. Most of this beach nourishment had been transferred to the nearshore and onto downdrift beaches by November 1995.

During September 1997, about 20,000 cu yds of nourishment were added along the northern 1200 ft of the nourishment site. The nourishment was a "pea gravel" with a grain size in the range of 5 to 10 mm and was trucked to the site from an inland quarry. Most of this beach nourishment had been transferred to the nearshore and onto downdrift beaches by November 1997.

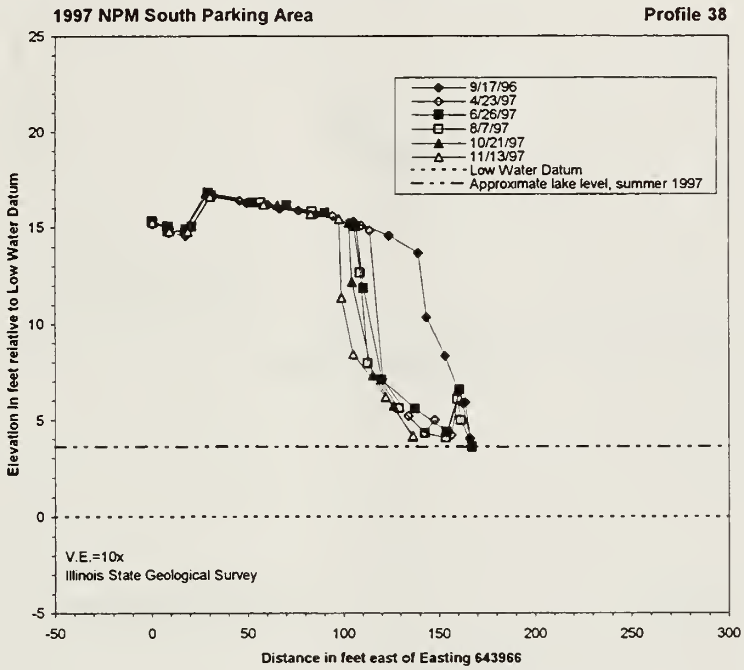
Table G-2 Summary of beach nourishment volumes placed at the IBSP/SU beach-nourishment site.[1]

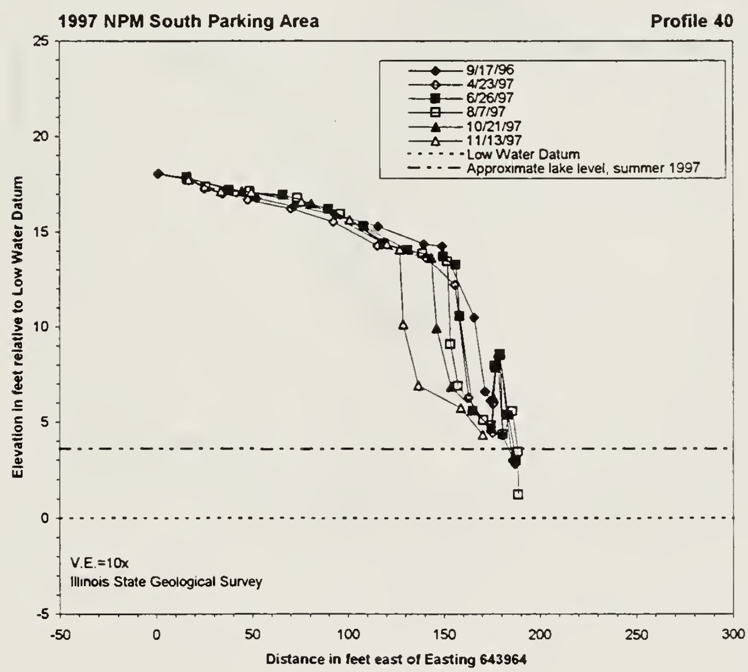
Year	Volume[1]	Comments
1995	24,000	Nourishment supplied from dredging at Waukegan Generating Station
1996	0	
1997	20,000	Beach nourishment with quarry-derived pea gravel
1987-97	44,000	

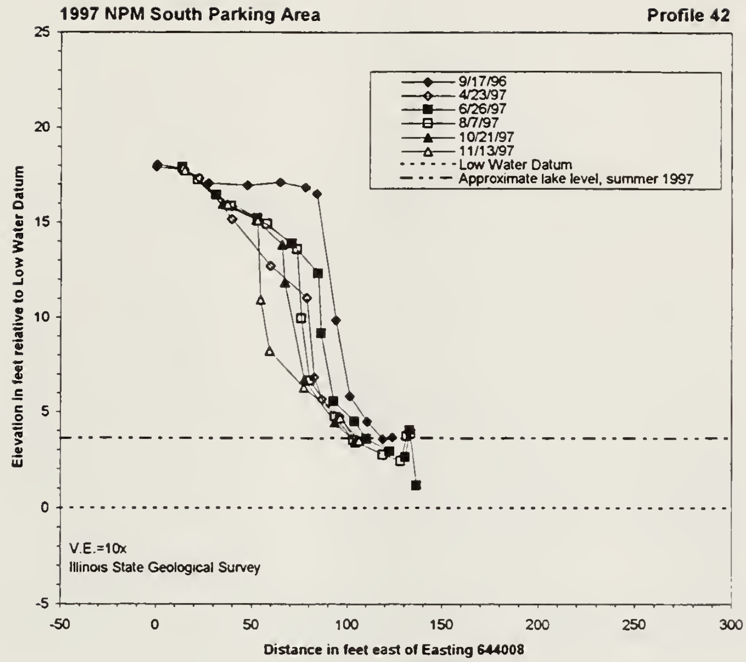
[1] Volumes are rounded to the nearest 100 cu yds.

APPENDIX H: PROFILES ACROSS THE NPM SOUTH PARKING AREA LAKE-FRONT AND THE IBSP/NU BEACH-NOURISHMENT SITE

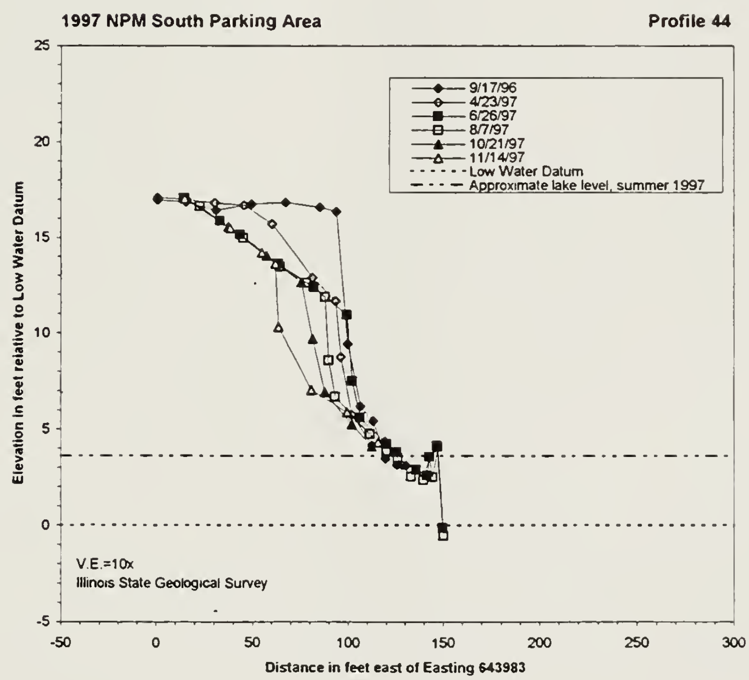
The nine profiles in Appendix H are based on total-station data collected between November 1996 and November 1997. The locations of these profiles are shown in Fig. 3-12. The origins of Profiles 38 through 46 are located on sidewalks or roadways at the south parking area. The origins of Profiles 48 through 51 are located on the west side of the IBSP/NU beach-nourishment stockpile.



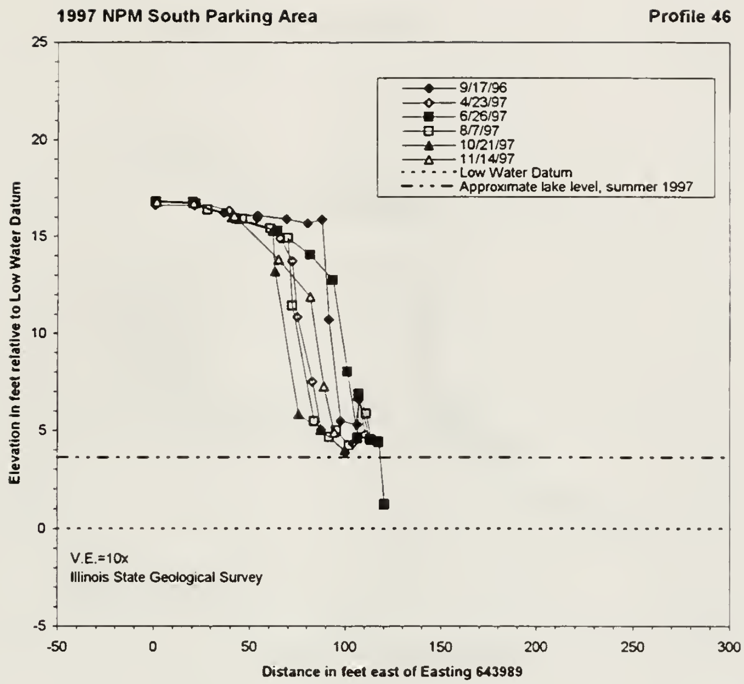




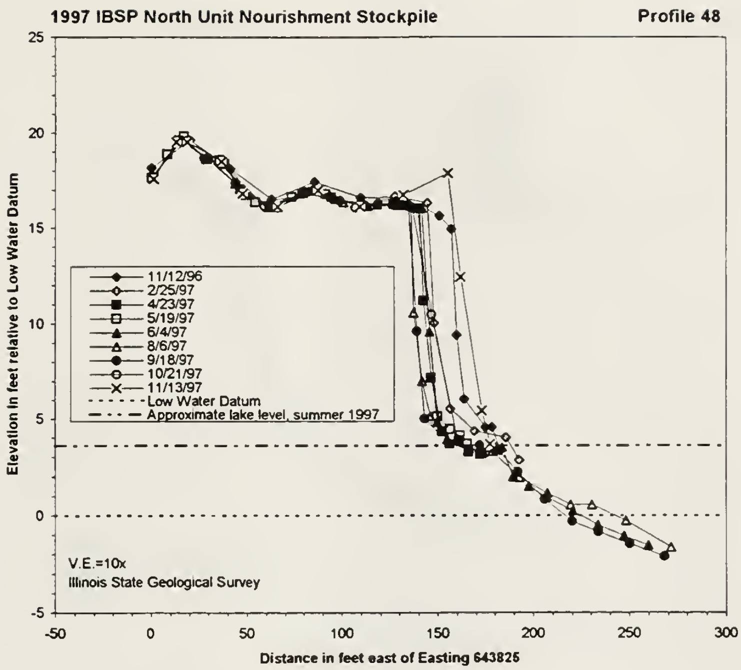
1997 NPM South Parking Area
Profile 42
9/17/96
4/23/97
6/26/97
8/7/97
10/21/97
11/13/97
Low Water Datum
Approximate lake level, summer 1997
Elevation in feet relative to Low Water Datum
V.E.=10x
Illinois State Geological Survey
Distance in feet east of Easting 644008

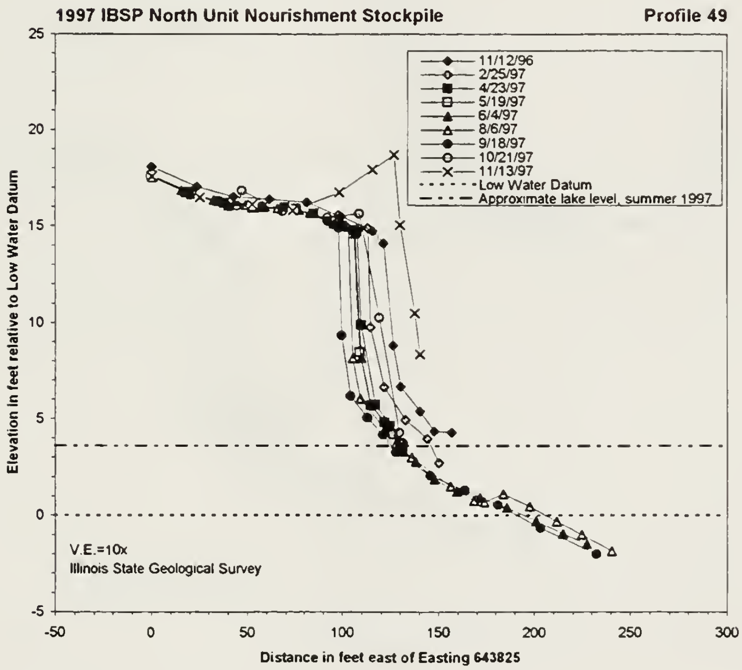


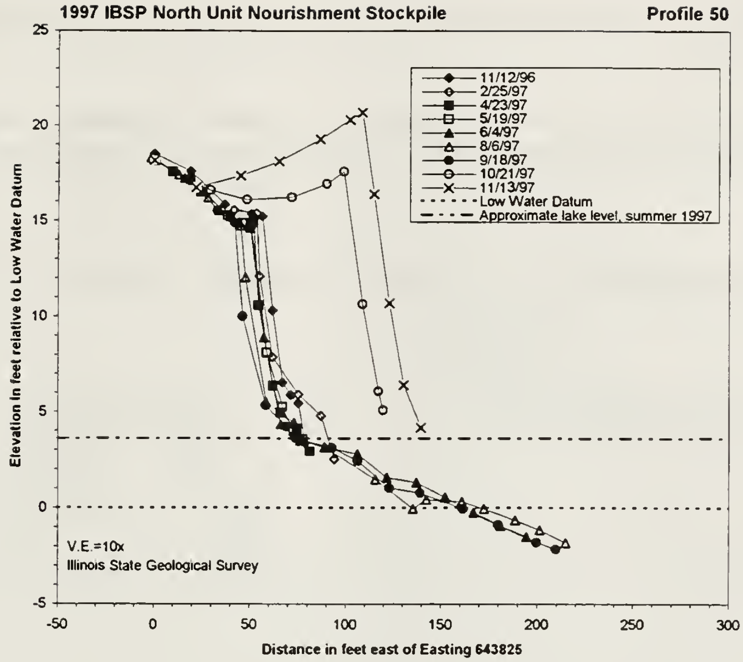
1997 NPM South Parking Area
Profile 44
9/17/96
4/23/97
6/26/97
8/7/97
10/21/97
11/14/97
Low Water Datum
Approximate lake level, summer 1997
Elevation in feet relative to Low Water Datum
V.E.=10x
Illinois State Geological Survey
Distance in feet east of Easting 643983

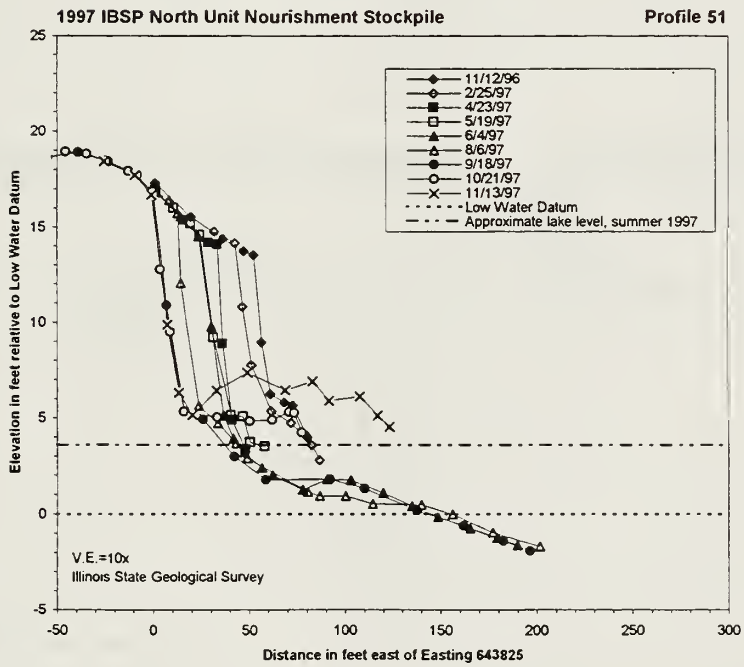


1997 NPM South Parking Area
Profile 46
9/17/96
4/23/97
6/26/97
8/7/97
10/21/97
11/14/97
Low Water Datum
Approximate lake level, summer 1997
Elevation in feet relative to Low Water Datum
Distance in feet east of Easting 643989
V.E.=10x
Illinois State Geological Survey
25
20
15
10
5
0
-5
-50
0
50
100
150
200
250
300


1997 IBSP North Unit Nourishment Stockpile
Profile 48
11/12/96
2/25/97
4/23/97
5/19/97
6/4/97
8/6/97
9/18/97
10/21/97
11/13/97
Low Water Datum
Approximate lake level, summer 1997
V.E.=10x
Illinois State Geological Survey
Elevation in feet relative to Low Water Datum
Distance in feet east of Easting 643825

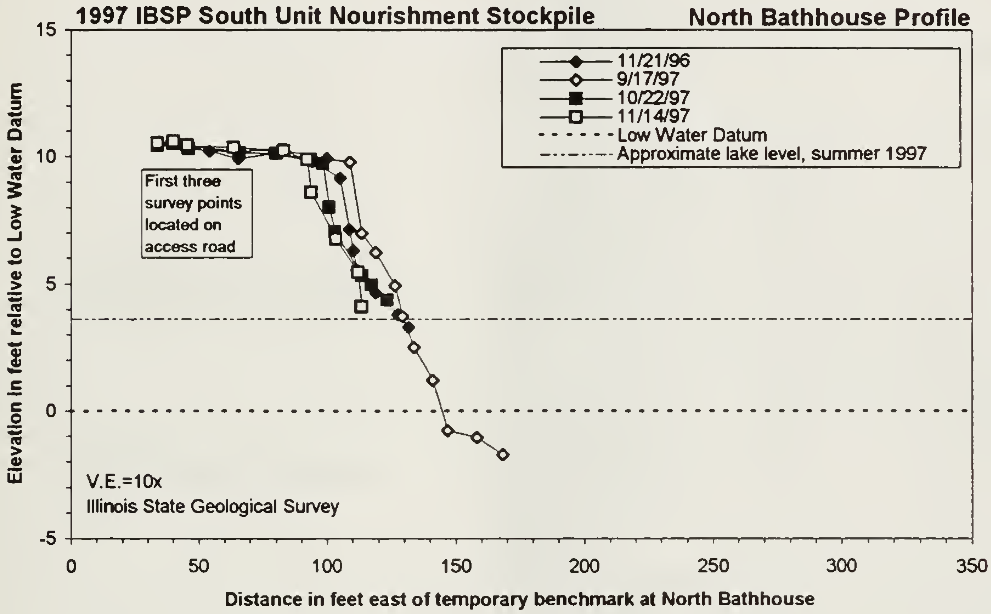

1997 IBSP North Unit Nourishment Stockpile
Profile 49
11/12/96
2/25/97
4/23/97
5/19/97
6/4/97
8/6/97
9/18/97
10/21/97
11/13/97
Low Water Datum
Approximate lake level, summer 1997
V.E.=10x
Illinois State Geological Survey
Elevation in feet relative to Low Water Datum
Distance in feet east of Easting 643825

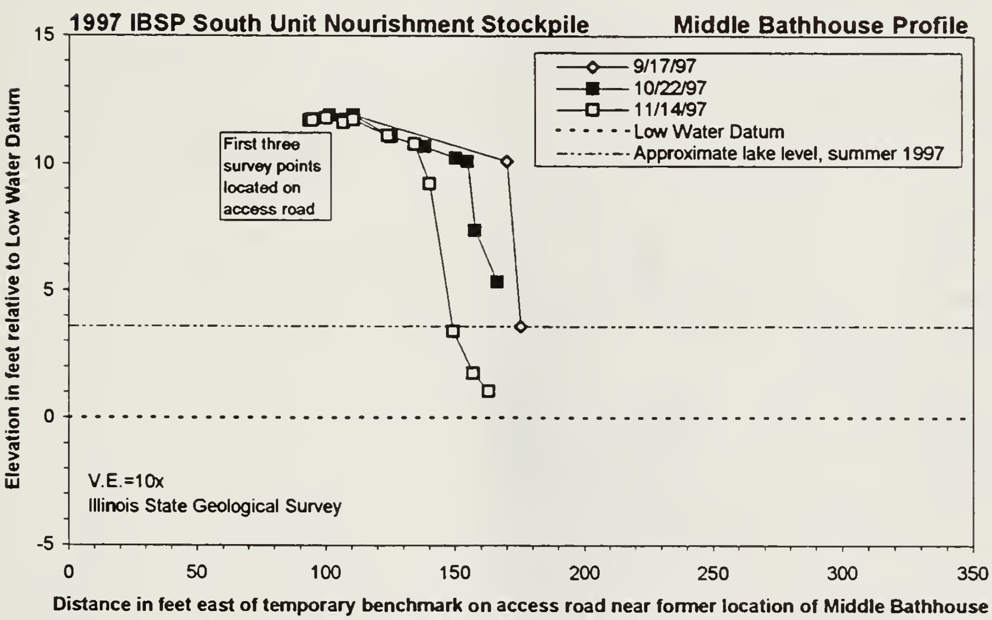

1997 IBSP North Unit Nourishment Stockpile
Profile 50
11/12/96
2/25/97
4/23/97
5/19/97
6/4/97
8/6/97
9/18/97
10/21/97
11/13/97
Low Water Datum
Approximate lake level, summer 1997
V.E.=10x
Illinois State Geological Survey
Elevation in feet relative to Low Water Datum
Distance in feet east of Easting 643825


1997 IBSP North Unit Nourishment Stockpile
Profile 51
11/12/96
2/25/97
4/23/97
5/19/97
6/4/97
8/6/97
9/18/97
10/21/97
11/13/97
Low Water Datum
Approximate lake level, summer 1997
V.E.=10x
Illinois State Geological Survey
Elevation in feet relative to Low Water Datum
Distance in feet east of Easting 643825

APPENDIX I: PROFILES ACROSS THE IBSP/SU BEACH-NOURISHMENT SITE

The two profiles in Appendix I are based on total-station data collected between November 1996 and November 1997. The locations of these profiles are shown in Fig. 3-15. The origins of the profiles are located on the shore-access road at the IBSP/SU beach-nourishment site.





APPENDIX J: 1997 REGIONAL BATHYMETRIC PROFILING SCHEME WITHIN THE SL-WH COASTALREACH

Range lines established by the Illinois Division of Waterways in 1946 with profile data available subsequent to 1872

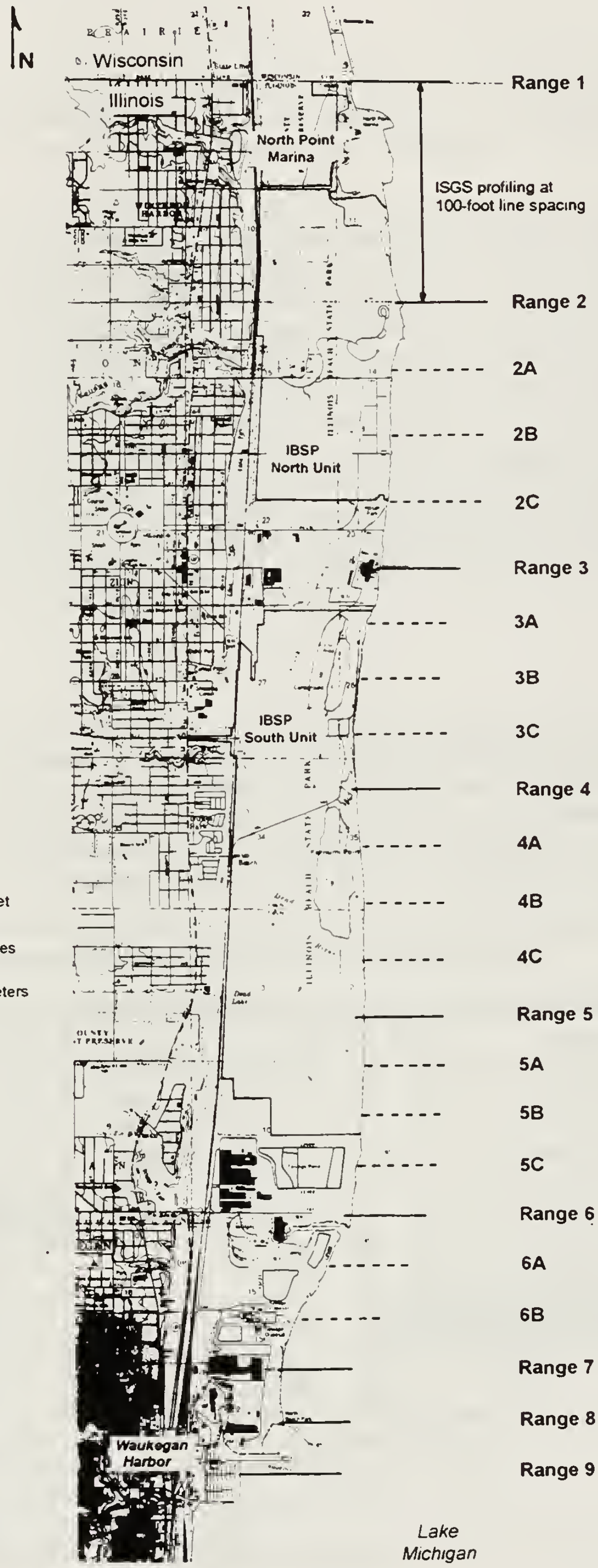
Intermediate range lines established in 1996 by Illinois State Geological Survey

0 10,000 Feet

0 1 2 Miles

0 1 2 3 Kilometers

Base map U.S. Geological Survey Zion (IL-WI) and Waukegan (IL) 7.5-minute quadrangles (1993)



APPENDIX K: NEARSHORE DREDGE VOLUMES

General Statement

Two principal dredging sites exist within the SL-WH coastal reach. These are located at the Commonwealth Edison Waukegan Generating Station and at Waukegan Harbor (Fig. 1-2). Tables K-1 and K-2 tabulate available records concerning dredging dates and volumes at both sites.

Dredge volumes provide information important to the management of coastal sand resources. Firstly, the data indicate the amount of material that is being removed through non-natural processes from the nearshore. Secondly, the amount of material dredged can be used to provide an estimate of the amount of sediment trapping occurring at the dredge site. This in turn permits estimation of the amount of littoral sediment transport occurring at that site. In using dredge data to obtain estimates of littoral sediment transport, the following assumptions are made: (1) the lake bottom at each dredge site is returned to a similar bathymetric configuration each time the area is dredged; (2) any short-term (*e.g.* yearly) variations in the volume of material removed during dredge events do not necessarily correlate directly with variations in littoral sediment transport along the coastal reach; (3) long-term trends in dredge volumes (*e.g.* an increase or decrease in the volumes dredged over a time scale of several decades or more) likely correlate with long-term changes in littoral sediment transport along the coastal reach; and (4) both short-term and long-term variations in dredge volumes likely affect the amount of littoral sediment that naturally bypasses each dredge site and the south end of the coastal reach. The data provided below are used in "Part 3: Regional Coastal Monitoring."

Waukegan Generating Station

Construction of the Waukegan Generating Station jetty, cooling-water basin, and intake channel occurred between 1923 and 1938. Dredge records are available for a 39-year period from 1958 through 1997 when dredging was done, on average, once every two years (Table K-1). Dredging was confined to the cooling basin, to the water intake/discharge channels, and along the jetty out to water depths of approximately 8 ft LWD. Because dredging occurred primarily in areas landward of the jetty, the resulting bathymetric changes typically were not documented in federal- and state-agency bathymetric surveys.

Table K-1 Dredge volumes for Commonwealth Edison Waukegan Generating Station (1958-1996).[1,2]

Year	Volume[2]	Year	Volume[2]	Year	Volume[2]	Year	Volume[2]
1872-1910	0[3]	1972	100,000	1981	20,000	1992	114,000[5]
1958	100,000	1973	103,000	1983	42,000	1995	100,000[5]
1961	125,000	1910-1974	718,000	1986	102,700	1996	none
1963	50,000	1976	78,700	1987	50,700[4]	1997	~20,000
1965	100,000	1977	105,500	1988	7,000	1974-1997	723,100
1968/69	120,000	1979	47,000[4]	1990	35,500		

[1] Volumes are rounded to the nearest 100 cu yds. All dredged material was placed at an onshore stockpile
[2] Volumes were provided by T.B Platt, Regulatory Compliance Engineer, Commonwealth Edison.
[3] This interval was prior to construction of Waukegan Generating Station.
[4] Records show two possible dredge volumes. The lesser volume of the two is listed.
[5] Volumes were accurately determined from stockpile surveys following placement.

Because a component of the littoral sediment in transport past Waukegan Generating Station is trapped at or landward of the jetty, these dredge volumes provide an estimate of littoral sediment transport along this reach of the Illinois shore. It is a minimum estimate because long-term nearshore accretion and shoreline progradation to the south, and the requirement for periodic dredging at Waukegan Harbor, suggest that littoral sediment bypasses the facility. Between 1958 and 1997, the total volume dredged at Waukegan Generating Station was 1,441,100 cu yds. For this 39-year interval, this yields an average dredging rate of 37,000 cu yds/yr.

Waukegan Harbor

Construction of Waukegan Harbor began in 1880 and the harbor had attained its present configuration

Table K-2 Dredge volumes for Waukegan Harbor (1889-1997).[1]

Year	Volume[2]	Year	Volume[2]	Year	Volume[2]	Year	Volume[2]
1889	17,800	1914	31,900	1931	90,200	1974	~10,000
1890	63,100	1916	31,200	1933	28,500	1910-1974	1,566,200
1892	9,700	1916	37,100	1934	29,000	1975	~48,400
1893	50,300	1917	73,600	1939	18,700	1976	34,700
1898	128,900	1918	28,900	1997	49,500	1977	130,000
1898	58,200	1916	50,500	1939	23,900	1982	85,400
1903	33,700	1920	16,800	1988	58,000	1984-1985	81,000
1903	26,700	1921	36,800	1950	28,500	1965	26,200
1906	280,900	1922	59,500	1958	108,200	1988	101,000
1906	5,000	1928	36,000	1980	12,600	1980	49,500
1908	9,100	1920	50,000	1961	39,900	1997	49,500
1908	6,400	1925	41,700	1993	47,200	1993	66,600
1903	14,900	1925	60,500	1964	50,800	1964	44,900
1910	53,500	1927	73,600	1965	41,300	1965	53,300[3]
1872-1910	758,200	1928	77,400	1950	49,400	1997	29,000[3]
1910	7,800	1929	unknown	1997	32,500	1974-1997	829,500
1913	10,200	1930	111,500	1969	33,500		

[1] Dredge data were obtained from annual reports of the U.S. Army Corps of Engineers and from data on file at the offices of the Chicago District. All dates from 1889 to 1975 are for federal fiscal years July through June; dates from 1976 to 1997 are for federal fiscal years October through September.
[2] Volumes are bin measures which are a measure of both sediment and water. Estimated water volume is 10 to 20 percent. The dredge volumes are not corrected for water content. All volumes are rounded to the nearest 100 cu yds
[3] M.K. Tibbetts, U.S. Army Corps of Engineers (pers. comm.).

by 1932 (Chrzastowski and Trask, 1995). The jetties, shore-attached breakwater, and the deep-water entrance channel combine to make Waukegan Harbor the largest barrier to littoral sediment transport on the northern Illinois coast, and one of the largest littoral transport barriers in the Great Lakes region. Table K-2 summarizes the dredge records for Waukegan Harbor from 1889 through 1997.

Dredging to maintain a harbor at Waukegan began in 1889 . Prior to 1977, and again in 1982, sediment dredged from the harbor was discharged into deep water about 2.5 miles lakeward (east) of the harbor entrance. First in 1977, and consistently since 1984, dredged material has been discharged into a nearshore disposal area about one mile south of the harbor entrance.

In general, dredging at Waukegan Harbor occurred every one to two years. The primary dredging area was the channel between the jetties and the lakeward approach to this channel. Historical bathymetric data verifies that some natural bypass of the harbor jetties occurred during this time (Chrzastowski and Trask, 1995). Thus, the dredge record at Waukegan Harbor provides a minimum estimate of littoral sediment transport at the south end of the study area. During the interval 1889-1997, 3,153,900 cu yds of sand were dredged from the Waukegan Harbor area. For this 108-year period, this yields an average dredging rate of 29,200 cu yds/yr.