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

Year-1 (1995) Report of a Four-Year Study of Coastal Geology and Coastal Geologic Processes

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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.

CONTENTS

FIGURES

TABLES

PART 1: STUDY DESCRIPTION

INTRODUCTION

Background

The historical record of coastal change along the Illinois shore of Lake Michigan documents that the state's most dynamic coastal area is the northernmost 9.7 miles between the Wisconsin-Illinois (WI-IL) state line and Waukegan Harbor (Fig. 1-1). Nowhere else on the Illinois shore has erosion been as severe or has accretion been as pronounced. The temporal scales for erosion and accretion have been short-term resulting in some of the most rapid rates of coastal change documented along the shore of southern Lake Michigan.

Of the total 9.7 miles of lakeshore between the state line and Waukegan Harbor, 6.5 miles (67 percent) is state-owned (Fig. 1-2). This consists of the coastal zone at North Point Marina (NPM) near the state line, and the North and South Units of Illinois Beach State Park (IBSP). 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 represents a state investment of nearly 42 million dollars that incorporates state-of-the-art marina design for 1500 boat slips, making this the largest marina in the Great Lakes Region. IBSP not only provides lakeshore recreation, but also preserves Illinois' last remaining stretch of natural shoreline along Lake Michigan, and has the state's last remaining concentration of coastal wetlands and dunes.

The efficient management of both the marina and state park is dependent on an understanding of the coastal geology and ongoing processes of coastal change. Prior to the mid-1980s, several studies of coastal geology and coastal processes were completed along this segment of the Illinois shore (*e.g.*, Tetra Tech, 1980). Within the last ten years, however, the locations and rates of coastal change have been influenced by record high lake levels (1986) and unprecedented beach and nearshore changes resulting from the 1987-1989 construction of NPM. Near the marina and along much of the state park shore to the south, the beaches, nearshore, and littoral sediment transport system are still adjusting to the addition of this major coastal facility.

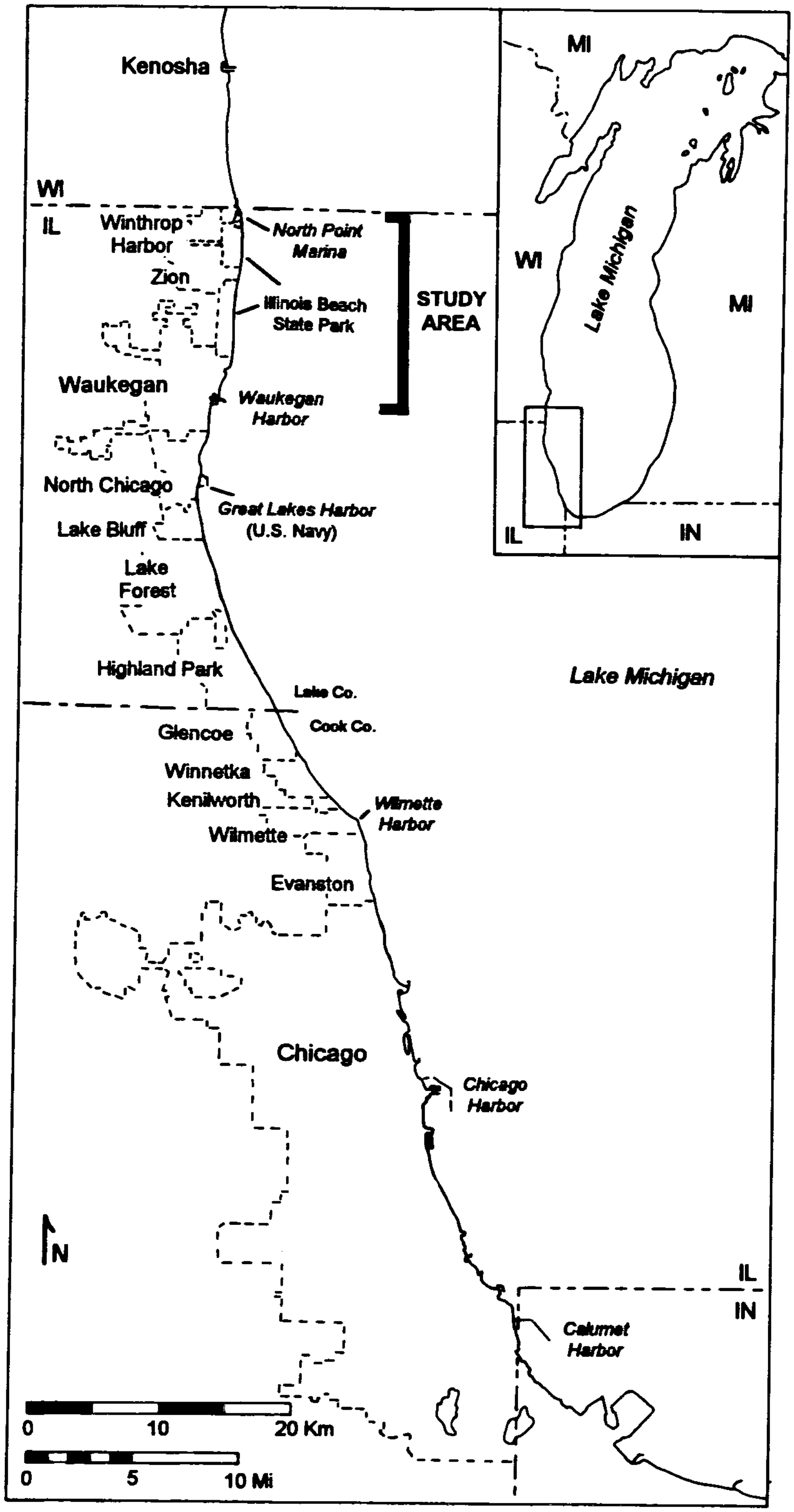

Figure 1-1 Map of the Illinois coast of Lake Michigan showing location of the study area.

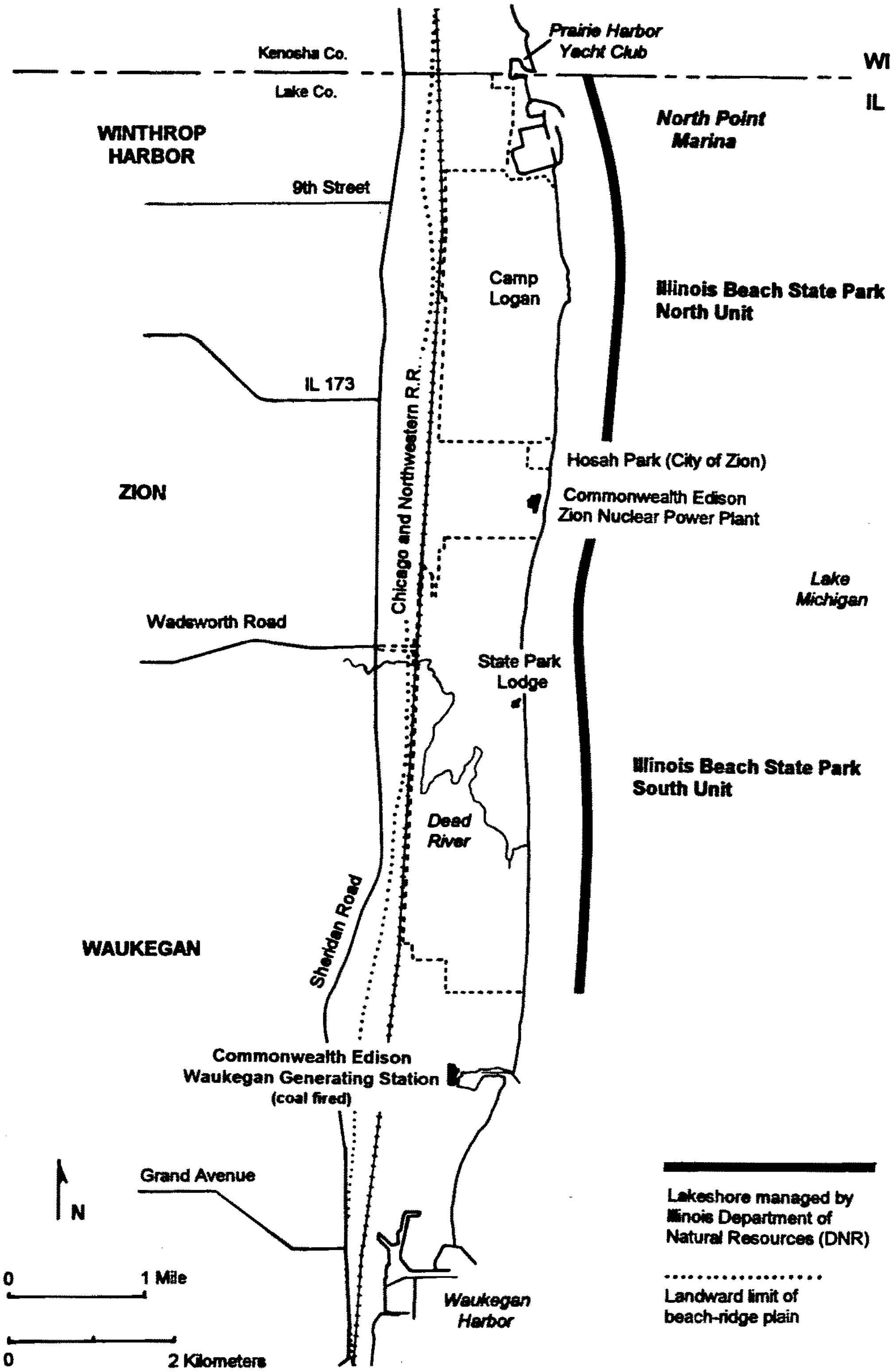

Figure 1-2 Map of the study area showing major place names and geographic features.

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 basis between the WI-IL state line and Waukegan Harbor. The ultimate goal is the development of 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 first in a series of four annual reports that summarizes yearly findings during the course of this four-year study and provides information relevant to ongoing coastal management of NPM and IBSP. Two aspects of this Year-1 report are important as a perspective to the report content and focus.

1) 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 data are collected and evaluated, these interim findings will be expanded in subsequent annual reports.

2) The four-year study will have equal emphasis on coastal erosion and accretion trends at both the marina and the entire state park. However, this Year-1 report focuses primarily on the marina vicinity and on the northern segment of IBSP North Unit, located immediately south of the marina. The reason for this focus is that this part of the study area is the area of most rapid coastal change and has some of the most immediate coastal-management concerns.

Project Funding

The primary funding for the Year-1 study was a contract with the Illinois Department of Conservation (IDOC). A reorganization of state agencies in July 1995 resulted in IDOC merging into a newly formed Illinois Department of Natural Resources (DNR). Additional first-year funding on a cost-share basis was provided by ISGS from general revenue funds for ISGS study of Lake Michigan coastal geology. This Year-1 report is a contract deliverable for DNR (IDOC) Contract No. 9515E.

Units of Measure

All measurements in this report are given in U.S. customary units (*i.e.*, 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 1-1 provides factors for converting to metric units.

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

U.S. customary	Conversion factor	Metric
	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 — This refers to 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.

fan delta — A geologic term used to describe a high-relief and lobate sediment deposit commonly formed where intermontane streams flow out onto a lowland area. In this report, "fan delta" is used to describe the high-relief, lobate sand and gravel reservoir that was formed on the south side of North Point Marina as a result of the hydraulic dredging of the marina basin. The term "fan delta" is used to refer to the entire sand body, both above and below water level.

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 used interchangeably.

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 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 facilitates 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.

nearshore — The nearshore is here defined as the zone between the shoreline and water depths of about 20 to 25 ft. 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 erosion and accretion volumes for an area are summed, the <u>net</u> change is determined.

updrift / downdrift — The predominant (*i.e.*, strongest) waves along a coast produce a net transport direction for littoral sediment. 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. Therefore, updrift implies "to the north," and downdrift implies "to the south."

SETTING

Geologic Framework

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

The Zion beach-ridge plain is a coastal feature that was formed by the accretion of sediment that was transported along the coast by wave action. Although much of the plain appears flat, it consists of hundreds of curvilinear sand and gravel ridges that are relict beach ridges and dunes. These ridges approximate the position of former shorelines and formed as the sand plain accreted southward and lakeward by the addition of sand and gravel. Radiocarbon dating indicates that this plain first migrated southward across the WI-IL state line about 3,700 years ago (3,700 yrs B.P.; Larsen, 1985). Prior to the late 1800s, the leading edge of accretion was along the shore at Waukegan and North Chicago. Beginning in 1883 with the start of construction of Waukegan Harbor, and to a greater degree after expansion of the harbor structures in 1906, the southward migration of the sand plain ceased because the harbor jetties formed a partial to near-total barrier to littoral transport (Chrzastowski and Trask, 1995).

The origin of the sand and gravel that comprise the beach-ridge plain is uncertain. Possibly this was originally a large glaciofluvial deposit located along the coast near Kenosha. Waves would have eroded this material and moved it southward where it was redeposited along the shore to form the beach-ridge plain. The original source area ceased to exist in the last several hundred to thousand years, and since that time the beach-ridge plain has been recycling its sand and gravel supply as it continues to migrate southward. Wave-induced erosion has been occurring along the northern part of the plain; the eroded sediment then moves southward by wave action to accrete along the southern part of the plain. These processes of northern erosion and southern accretion have resulted in a long-term southward migration of the beach-ridge plain that is analogous to the movement of a tank tread. The coast at NPM and IBSP North Unit are within the erosional zone. The transition from net erosion to a stable or net accretional coast occurs in IBSP South Unit along the shore between the state park lodge and the mouth of Dead River (Fig. 1-2).

The long-term historical shoreline recession along the Illinois shore just south of the state line has been the most severe of any documented along the Illinois shore (Jennings, 1990; Illinois State Geological Survey, 1988). Near the present site of NPM, the annual shoreline and nearshore recession has averaged 10 ft/yr between 1872 and 1987 (Fig. 1-3). In 1872, the beach was located at what is now the most lakeward tip of the NPM north breakwater.

Persistent erosion and shoreline recession along this reach was one reason for the late 1970s abandonment of the residential community (Spring Bluff) that previously occupied this lakeshore. One of the impacts of constructing North Point Marina is that the facility now creates a coastal hard point that limits the maximum possible shoreline recession in the area.

Waves and Littoral 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.

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

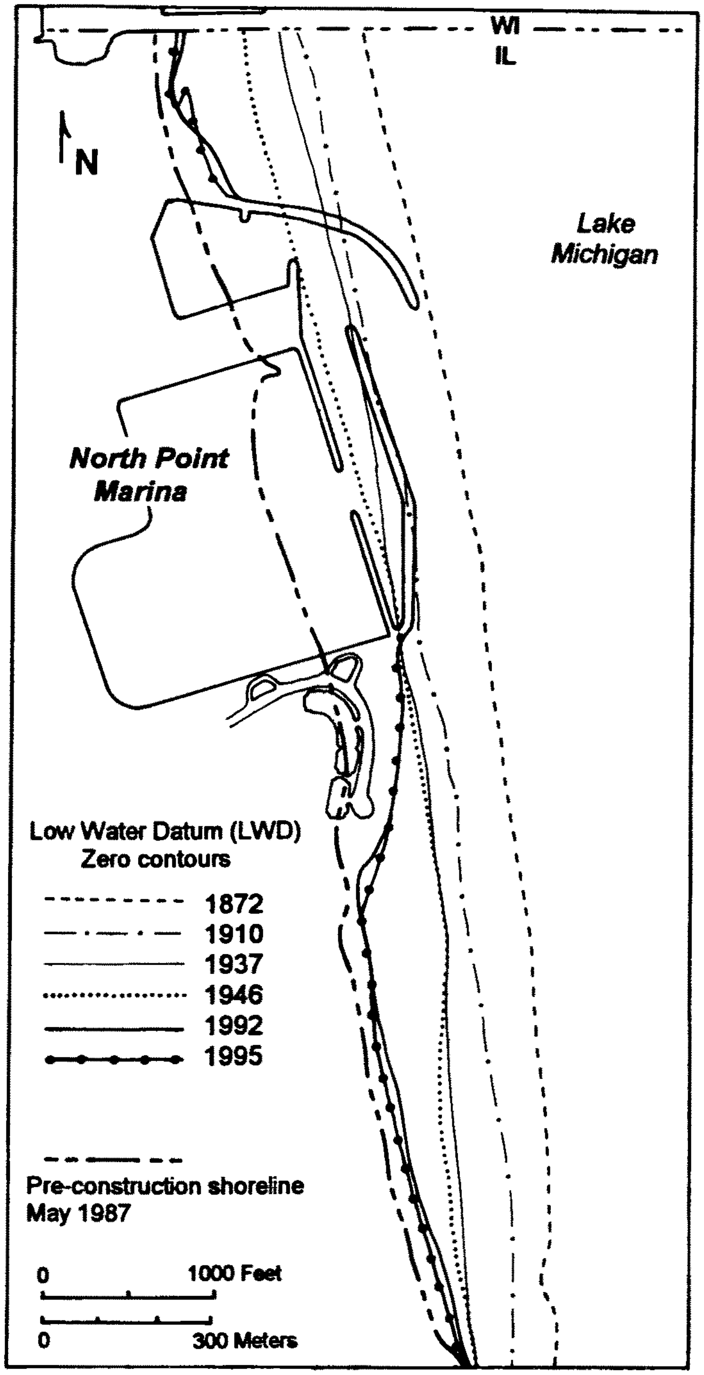

Figure 1-3 Historical positions of the Low Water Datum (LWD) zero-depth contour along the nearshore near the present site of North Point Marina. The LWD reference approximates the shoreline, but permits a comparison that is independent of differences in lake level for the different years mapped. The 1987 shoreline position approximates the shore configuration just prior to marina construction.

METHODS[1]

Field Studies

Establishing horizontal and vertical control

All horizontal and vertical control for the field surveys relied on existing bench marks or other survey marks in the study area. Where necessary, 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. A digital record of all survey data was made with a LIETZ SDR20 Electronic Note Book used in conjunction with the Total Station. 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 done in Illinois state plane coordinates. Vertical control (Z data) was referenced to Mean Sea Level and subsequently corrected to Low Water Datum for presentation in map format (see Data Processing).

Surveys of beach profiles and monitoring of beach nourishment

A LIETZ Total Station and one or more prism poles were used for collecting all beach profile data. Beach profile data were typically collected between the backshore vegetated-ridge 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 X (Northing) and Y (Easting) in state plane coordinates, and known elevation (Z). The prism pole was then positioned on successive measurement points along predetermined profile lines, generally at 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). To determine rates of stockpile erosion and magnitudes of volume change, 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.

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

1) Fathometer Method

Bathymetric data beyond wading depths were collected with a ROSS Model 803 Portable Survey Fathometer mounted onboard a 12.5-ft ZODIAC-type inflatable boat. The fathometer measured depth in feet. The calibration was checked 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 includes a control console onboard the survey boat that provides 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) 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.

Data Processing

Datums

Three different datums are used for data compiled in this report. These are:

- 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 1-2 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 were compiled from lake-level gauges at Milwaukee, Wisconsin and Calumet Harbor, Illinois. These gauges are operated by the National Ocean

Table 1-2 Conversion factors for adjustment between 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	——	+ 2.00
NGVD (1929)	– 578.10	– 1.30	+ 2.00	——

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

[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).

Service (NOS) of the National Oceanic and Atmospheric Administration (NOAA). Because the study area is located approximately midway between the gauges at Milwaukee and Calumet Harbor, the hourly lake levels for the two gauges were averaged to compute hourly lake levels 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 1.8 to 2.2 ft for the bathymetric data collected during summer 1995.

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 1-2.

Constructing and Measuring Isopach Maps

Isopach maps were constructed by superimposing bathymetric (and topographic) contour maps to obtain contour intersection points. Elevation changes at these intersection points were used to create an isopach contour map depicting areas and magnitudes of elevation change. The isopach maps were then used to compute erosion and accretion volumes. To compute volumes, an electronic, digital planimeter (LIETZ Planix-7) was used to measure the area within each isopach contour interval. 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. For all calculations, annual lake-bottom changes of less than one foot were not included in the calculations. This cutoff allowed for possible elevation errors in the collection and processing of the fathometer data.

OVERVIEW OF 1995 DATA COLLECTION

General Statement

Data collection during 1995 had two major objectives:

1) To establish baseline data to be used for annual comparisons during the four-year study and for comparison with older data sets;
2) To provide data applicable to the ongoing management of coastal resources in the study area.

The primary areas of data collection were along the beaches and nearshore at NPM and IBSP. Because this four-year study is concerned with the entire coastal setting from the WI-IL state line to Waukegan Harbor, some data collection and data compilation was regional in scope covering the entire reach. The following is an overview of the 1995 data collection and compilation as of the end of November 1995. Results derived from the 1995 data are discussed in the sections following this overview.

North Point Marina (NPM)

- *Bathymetric surveys*
  A total of 49 bathymetric profile lines were run between the WI-IL state line and the marina/state park boundary. An additional 9 lines were run in the marina entrance. These data were collected to document 1995 bathymetry, and were used for comparison with data collected annually between 1987 and 1992.

- *Sand volume calculations at NPM south parking area*
  Pre- and post-construction topographic and bathymetric data were compiled to compute the volume of sand derived from the 1987 marina basin dredging operation that now resides beneath the south parking area.

Illinois Beach State Park (IBSP) / North Unit

- *Bathymetric surveys*
  A total of 17 bathymetric profile lines were run between the marina/state park boundary and the Camp Logan headland to document 1995 bathymetry and for comparison with data collected annually between 1987 and 1992.

- *Beach nourishment monitoring*
  Beach nourishment totaling 20,000 cu yds was placed at the northern end of the North Unit in July 1995. A baseline topographic and wading survey was conducted prior to the placement of the nourishment. Subsequent monitoring was done monthly to document dispersal rates.

- *Transport rate of coarse-grained beach nourishment*
  Beach nourishment totaling 32,000 cu yds of small gravel (pea gravel) was placed at the north end of the North Unit in September 1994. The extent of downdrift dispersion of this gravel was mapped to determine short-term (1994-1995) littoral transport rates.

Illinois Beach State Park (IBSP) / South Unit

- *Beach nourishment monitoring*
  Beach nourishment totaling 24,000 cu yds was placed at the north end of the South Unit in June and July 1995. A baseline survey was done in the early stages of this nourishment to determine pre-fill beach topography and adjacent nearshore bathymetry. Subsequent monitoring was done monthly during and following the nourishment emplacement to document erosion and dispersal rates.

Regional Data Collection

- *Littoral sediment transport near the south end of IBSP*
  Dredge records and records of grain-size analyses were compiled for sediment dredged at the Commonwealth Edison Waukegan Generating Station. These data, combined with similar data for dredging at Waukegan Harbor, were used to estimate minimum littoral sediment transport rates at the downdrift end of the state park.

- *Analysis of historical bathymetric records from 1872 through 1974*
  Bathymetric data sets from 1872, 1910, and 1974 were compiled to assist in evaluation of long-term shoreline position changes, historical lake-bottom changes, and distribution of long-term erosional and accretional zones between the state line and Waukegan Harbor. These analyses will be discussed in the report of 1996 studies.

- *Establishing control for regional nearshore profiling*
  X-Y coordinates were determined for a series of 22 profile lines between the WI-IL state line and Waukegan Harbor. This effort was a precursor for a land survey to establish monuments for these lines and the 1996 collection of bathymetric data.

PREVIOUS COASTAL MONITORING AT NORTH POINT MARINA

General Statement

In order to understand beach and lake-bottom changes that are presently occurring in the vicinity of North Point Marina (NPM), it is valuable to review the construction history of the marina and the changes that occurred along the beaches and nearshore in the early post-construction phase. The following review spans the interval from 1987, which is the year construction began in the nearshore, to 1992, which was the end of a five-year, post-construction monitoring program conducted by ISGS.

Marina Construction History (1987-1989)

NPM is the largest coastal engineering project built along the Illinois coast of Lake Michigan in the last several decades, and it is one of the largest Lake Michigan coastal engineering projects of this century. The marina basin covers approximately 72 acres. The basin straddles the pre-construction shoreline and was built by a combination of dredging a basin into the beach and backshore area, and building shore-attached breakwaters to enclose the lakeward side of the basin. During construction, sediment hydraulically dredged from the basin was discharged along the south side of the south breakwater. Although some uncertainty remains about the exact volume of material dredged and discharged, the best available estimate is 1.5 million cu yds (Moffatt and Nichol Engineers, 1986). The sediment was primarily sand but consisted of a mix of silt, sand, and gravel. The grain-size distribution was similar to that of the existing beach and nearshore.

Ground-breaking ceremonies for the marina occurred on July 18, 1986, but it was in spring 1987 that construction began to significantly alter the beach and nearshore. By summer 1988, dredging had progressed such that the discharge of sand and gravel was raising the beach elevation on the south side of the marina project and extending new beach area into Lake Michigan. This elevated and lobate depositional feature on the south side of the marina has been referred to as a "fan delta" (see Terminology).

In terms of coastal processes at NPM and the IBSP North Unit, the formation of this fan delta was the single most significant event associated with marina construction. The fan delta added a major volume of sediment to the littoral system; it was then the site of the most rapid coastal changes in the first few years following marina construction. Figure 1-4 shows the fan delta when it was nearing its maximum lakeward extent in summer 1988.

Figure 1-4 Oblique aerial view of the North Point Marina construction site on September 14, 1988 looking toward the south. Sediment dredged from the marina basin is being discharged by slurry pipe to create the fan delta. The fan delta reached its maximum lakeward extent within three months after this photograph.

All breakwater construction and dredging was completed by late 1988. By the end of 1988 the surface of the fan delta was graded to an elevation ranging from 14 to 18 ft LWD. This grading was in preparation for construction of marina parking facilities and access roads, now referred to as the "south parking area." Construction began on the access roads and south parking lots in late summer 1989. To defend this south parking area from shoreline erosion, four major phases of constructing shore defenses occurred:

1) In late fall 1988, riprap was placed from the NPM south breakwater southward for a distance of 600 ft along the shoreline of the fan delta. This was apparently in anticipation of the parking area construction which would begin the following year.

2) In November 1989, a revetment consisting of concrete "cubes" (3x3x4 ft), toe stone, and splash stone was constructed lakeward of the southern two-thirds of the parking area.

3) In December 1990, the revetment was extended northward an additional 350 ft to intercept the south breakwater. By this time the riprap placed in 1988 had been undermined sufficiently to become a submerged feature, which made the revetment extension necessary.

4) First in December 1989, and then on several subsequent occasions through at least 1992, additional riprap was placed along the shoreline. These efforts were a remedial action to compensate for lakeward shifting and undermining of the concrete cubes.

Construction of the south parking area atop the fan delta was a major change in land use from the initial project plan to use the fan delta as a "feeder beach" (Moffatt & Nichol Engineers, 1986). The feeder beach was to have served as a sand stockpile that would erode by wave action and supply beach nourishment to the downdrift beach and nearshore areas. The re-assignment of the feeder beach area to serve as a parking area, and the resulting construction of the parking area shore defense, was the impetus for importing additional sand to the beach area south of the parking area to create a substitute feeder beach. Nourishment stockpiles were created here in 1990 (150,000 cu yds), 1994 (32,000 cu yds), and twice in 1995 (20,000 cu yds, July; 33,000 cu yds, December 1995 - January 1996).

Coastal Monitoring (1987-1992)

The bathymetric surveys conducted by the ISGS in the NPM vicinity from 1987 through 1992 extended from the state line southward 7700 ft (1.46 miles) to the Camp Logan headland. Bathymetric data were collected with a fathometer along a series of east-west lines having a 300-foot spacing in 1987, and a 100-foot spacing from 1988 through 1992. In 1987, position control for the survey boat was a visual range-azimuth procedure using an onshore transit and alidade. From 1988 through 1992, position control was an electronic range-azimuth procedure using an onshore transit and a microwave distance-measurement system (MiniRanger III) as discussed in the METHODS section. Profile lines were identified by number from the state line (profile 1) to Camp Logan (profile 78).

Appendix A contains annual bathymetric maps resulting from the six years of data collection between 1987 and 1992. Appendix B contains isopach maps showing areas and vertical magnitudes of annual lake-bottom change during this interval. These lake-bottom change maps were produced by comparing the bathymetry for successive years. Appendix B also contains a table summarizing the major lake-bottom changes that occurred. A brief summary is given below.

Between 1987 and 1992, there was initially widespread accretion to the south of the marina as basin dredging built the fan delta. Once the discharge of dredged sediment ceased, erosion dominated. On the north side of the marina, widespread accretion occurred updrift of the north breakwater and a bar developed extending from the state line to the north breakwater. The accretion and bar development resulted from littoral sediment that came southward across the state line.

The extreme beach and lake-bottom changes were concentrated in the area of the fan delta. The addition of sediment to this area rapidly created an extensive and thick sand body. Once the sediment supply ceased, rapid erosion began, causing landward recession of both the underwater slope and the scarp along the lakeward face of the above-water area. In 1989 and 1990, ISGS monitoring of shoreline and scarp recession lakeward of the south parking area documented the most rapid recession ever recorded along the Illinois lakeshore. A line of riprap along the northern shoreline of the fan delta temporarily halted shoreline recession there, but formed a headland around which wave refraction eroded a hook-shaped embayment to the south opposite the south parking area (Fig. 1-5). The maximum shoreline recession documented between January and October 1989 was 200 ft (Terpstra and Chrzastowski, 1992). By January and February 1990, the riprap had subsided sufficiently to allow erosion to occur landward of it (Fig. 1-6). As of 1995, this submerged riprap remains as prominent lake-bottom feature.

Lake-Bottom Volumetric Changes (1987-1992)

Table 1-3 summarizes the annual lake-bottom accretion, erosion, and net change for the survey area from the WI-IL state line south to Camp Logan, and from the 0 ft LWD contour lakeward to the limit of bathymetric change (about the 20 ft LWD contour). Thus, this is a composite of lake-bottom changes in the marina vicinity that includes both the updrift area north of the north breakwater (North Beach) which was influenced by sediment entering from Wisconsin, and the downdrift area (south of the south parking area) which was influenced by sediment added and eroded at the dredge-discharge and beach nourishment sites. The volumes in Table 1-3 provide a quantitative perspective for the maps in Appendix B.

Net accretion occurred in the two-year interval 1987-1989. This accretion was largely the product of dredging the marina basin and discharging this sediment on the south side of the marina. Within that two-year interval, greater net accretion occurred during 1987-1988, approximately twice that of 1988-1989. The 1987-1988 accretion corresponds with the time of greatest annual discharge of dredge sediment.

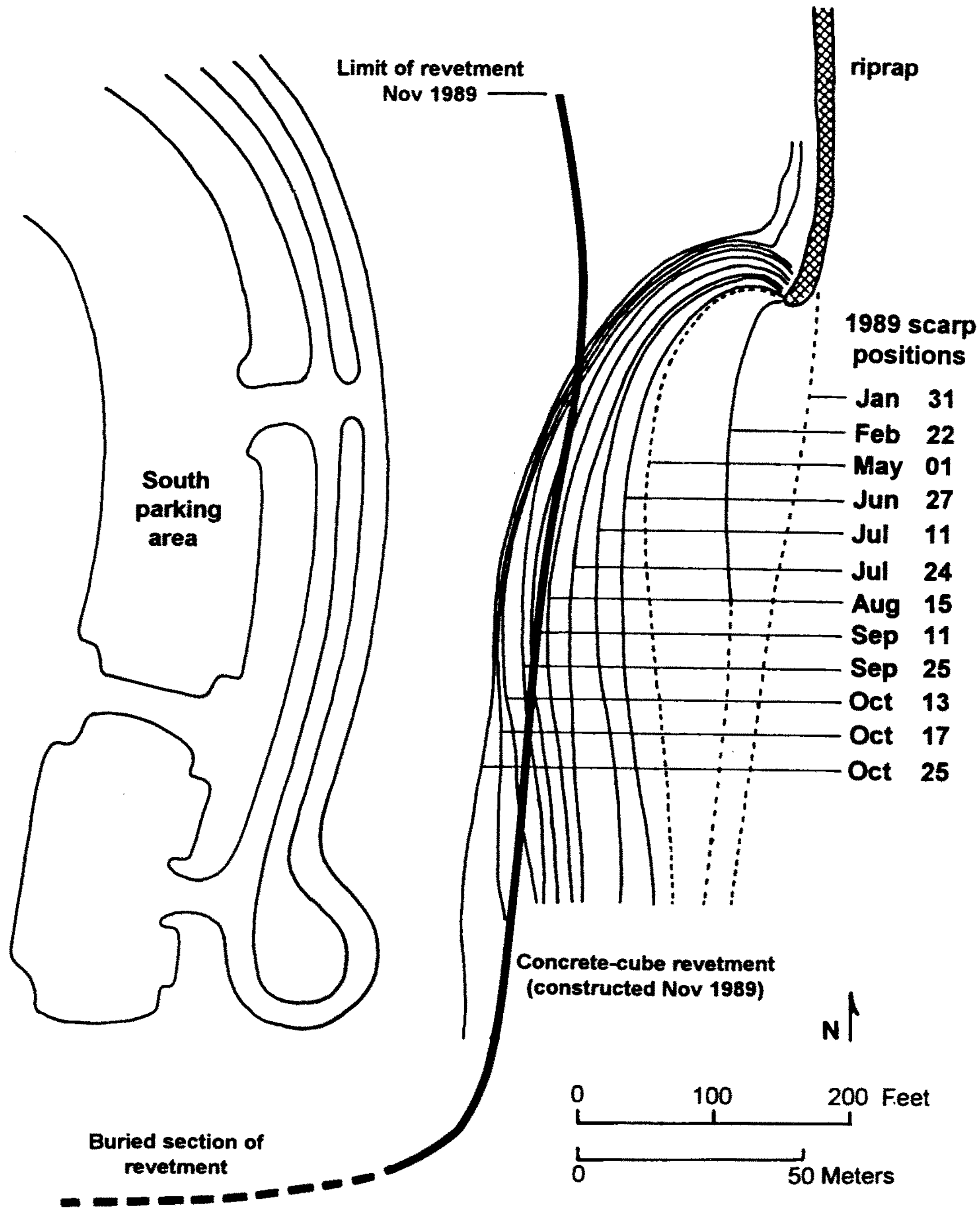


Figure 1-5 Record of 1989 erosion at the fan delta that occurred south (downdrift) of the riprap. These recession lines are along the crest of a 6- to 12-ft high scarp that was parallel to the shoreline. The southern tip of the riprap acted as a headland around which northerly waves refracted and eroded the hook-shaped embayment. Construction of the cube revetment in November 1989 halted the landward recession.

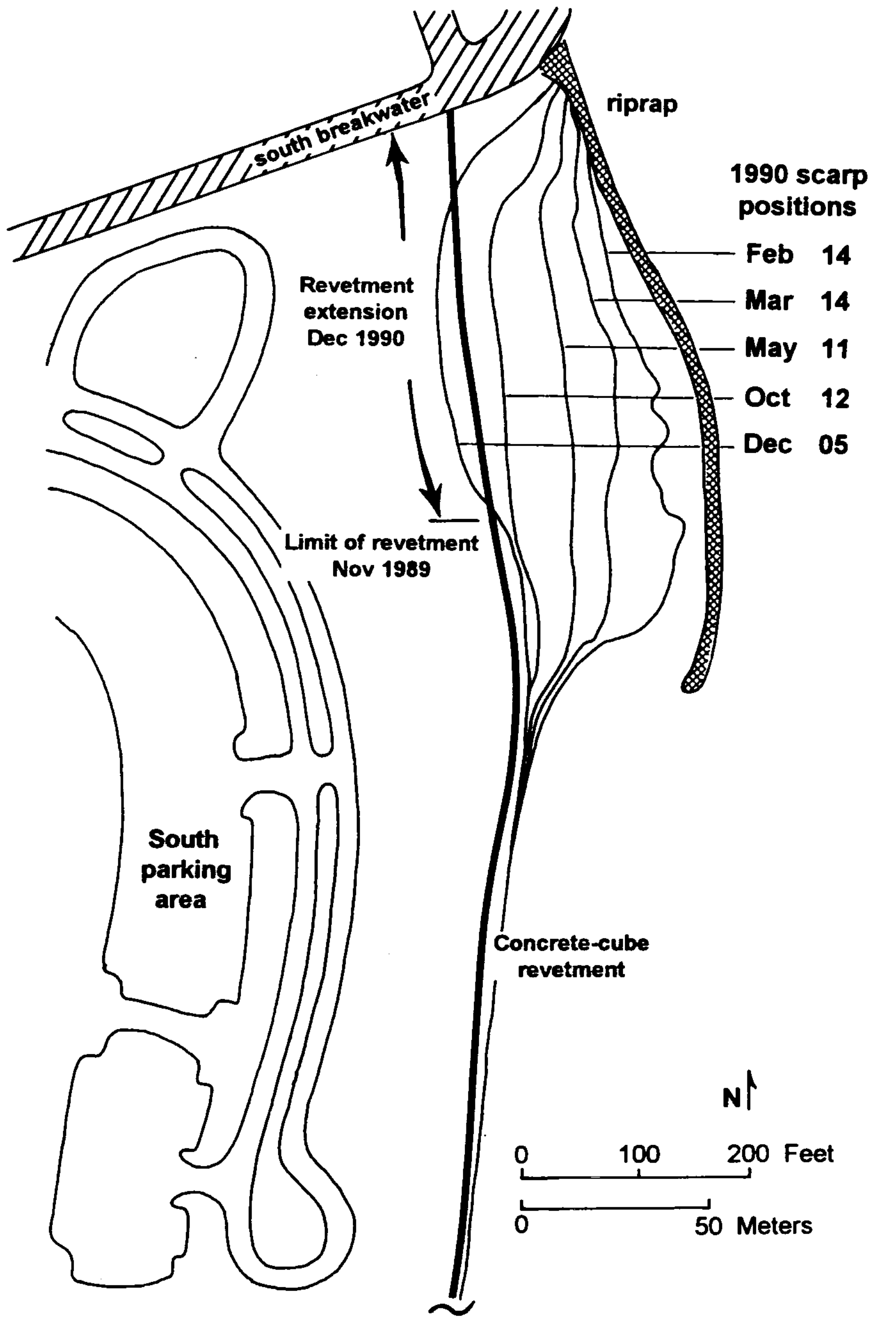


Figure 1-6 Record of the 1990 erosion at the fan delta that occurred landward of the line of riprap. These recession lines are along the crest of a 6- to 10-ft scarp that was parallel to the shoreline. In December 1990, construction of a northward extension of the original cube revetment halted the landward recession. The riprap is now a submerged feature.

Table 1-3 1987 through 1992 annual accretion and erosion volumes and net volumetric change for the nearshore area between the Wisconsin-Illinois state line and the north steel sheetpile at Camp Logan.[1]

Year Interval	Accretion		Erosion		Net Change (+ accretion; – erosion)	
	cu yds	cu yds per shoreline ft [2]	cu yds	cu yds per shoreline ft [2]	cu yds	cu yds per shoreline ft [2]
1987-88	309,000	40	52,000	7	+257,000	+33
1988-89	235,000	31	107,000	14	+128,000	+17
1989-90	112,000	15	241,000	31	–129,000	–17
1990-91	105,000	14	126,000	16	–21,000	–3
1991-92	65,000	8	165,000	21	–100,000	–13
Summation 1987-1992	826,000	108	691,000	89	+135,000	+17

[1] All volume calculations are for lake-bottom changes greater than 1 foot and are recorded to the nearest thousand cu yds. Nearshore area 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. Annual comparisons are for data collected in the late spring or summer of each year.

[2] Numbers are 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.

From 1989 through 1992, the annual net change was erosion. The severe erosion in 1989-1990 is interpreted to be due to rapid removal of sediment from over-steepened nearshore slopes and other unstable areas at, and adjacent to, the fan delta. This period of rapid erosion also corresponds to the time when shore protection was first placed lakeward of the south parking area. Though the net change during 1990-1991 was erosion, the magnitude of this erosion (21,000 cu yds) was significantly lower than that of the preceding and following one-year interval. This is in part due to the addition of approximately 150,000 cu yds of sand and gravel to the shore south of the marina in autumn 1990. This sediment was obtained from dredging Prairie Harbor Yacht Club. Erosion of this stockpile was a major source of sand to the nearshore.

The 1987 to 1992 summation of nearshore volume changes results in net accretion. Even if the volumes are corrected for 54,200 cu yds of nearshore sediment "locked up" beneath the south parking area (see Volumetric Analysis of Sand Beneath the South Parking Area), the 1987-1992 net change is accretion totaling 80,800 cu yds. Net erosion dominated from 1989 through 1992, but the total loss of sediment was less than that gained between 1987 and 1989 from marina dredging. 1995 data indicate that it was at some time between 1992 and 1995 that total erosion in the nearshore exceeded gains resulting from dredging the marina basin.

PART 2: 1995 STUDY FINDINGS

NORTH POINT MARINA

General Statement

The primary maintenance operation at North Point Marina (NPM) during 1995 that impacted either the beach or nearshore involved hydraulic dredging within the marina along the approach to the recreational basin. The dredging occurred between June and August. The area dredged had experienced shoaling over several years, and dredging was necessary to maintain project depths. A total of approximately 7,000 cu yds was dredged (J. LaBelle, North Point Marina General Manager, pers. com.), transported by dredge pipe along the crest of the south breakwater, and discharged on the lakeward side of the south breakwater at the junction with the riprap-defended south parking area. The sediment input to this area resulted in a short-lived beach and shoal area at the junction between the south breakwater and the riprap shore defense. By September, the accretion in the dredge-discharge area had eroded such that no above-water area remained.

Along the shore at the south parking area, no additional riprap or sand was added prior to December 1995. No regrading occurred across the sand fill landward of the line of riprap and other stone. Large, arcuate erosional scars were present on the top surface of this fill resulting from storm events in spring 1995 and the preceding winter. During 1995, planning continued for building a submerged breakwater (or "reef") and a shoreline revetment to together protect the shore of the south parking area from further erosion. No construction occurred in 1995.

The following discussion summarizes 1995 data and observations for specific locations in the NPM vicinity. Figure 2-1 is an index map of place names in the NPM vicinity referred to in this report. 1995 studies at NPM are discussed under the following headings:

- I North Beach
- II North Beach / North Breakwater Nearshore
- III North Beach Bar
- IV Marina Entrance
- V South Breakwater Nearshore
- VI South Parking Area Nearshore
- VII Submerged Riprap
- VIII South Parking Area Proposed Shore Protection
- IX Volumetric Analysis of Sand Beneath the South Parking Area
- X Breakwater Conditions

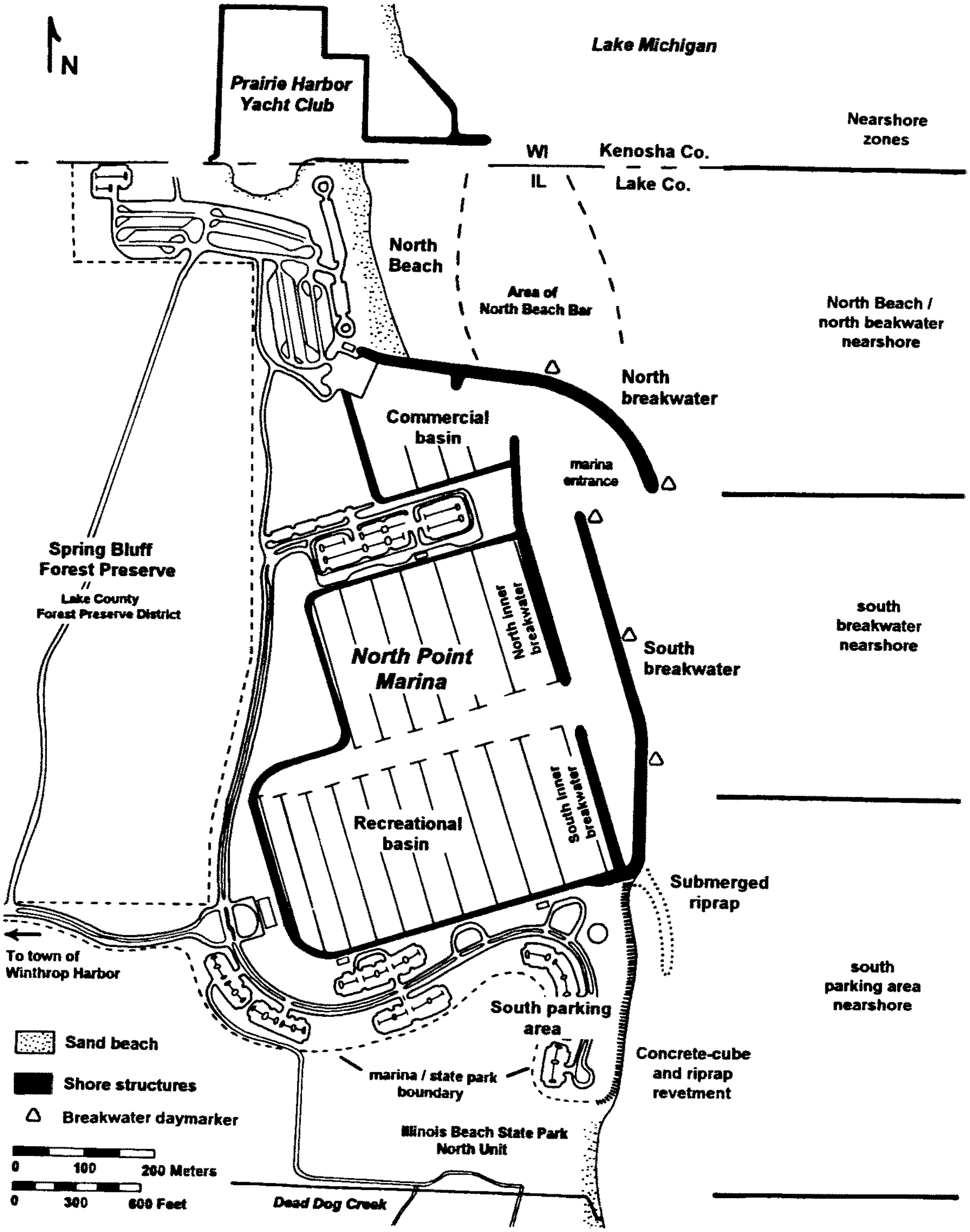


Figure 2-1 Index map of place names in the North Point Marina vicinity.

I North Beach

North Beach is the name given to the recreational beach adjacent to the north side of North Point Marina. This beach extends for approximately 1,000 ft between the steel sheetpile jetty at the WI-IL state line and the NPM north breakwater (Fig. 2-1). Prior to NPM construction, Moffatt & Nichol Engineers (1986) reported on potential impacts of the marina construction on North Beach and the adjacent nearshore. It was anticipated that North Beach would accrete as the north breakwater acted as a barrier to net southward transport of littoral sediment. During the seven years since breakwater construction (1988-1995), North Beach has been accretional, with the 1995 shoreline positioned as much as 60 ft lakeward of the 1987 shoreline. However, when compared with changes predicted prior to the time of construction, the shoreline changes at North Beach have been minimal.

Anticipated accretion history

Figure 2-2 shows one of several models of anticipated beach accretion at North Beach presented by Moffatt & Nichol Engineers in 1986. This model assumes that North Beach and the adjacent nearshore receives a littoral sediment supply of 60,000 cu yds/yr. This was considered one of the best estimates of littoral transport at the time of making the model. A rapid shoreline advance was predicted to occur in the first year following breakwater construction. The annual rate of shoreline advance was predicted to gradually decrease as the beach and nearshore built into deeper water.

About two to three years after breakwater construction, beach accretion was predicted to result in a shoreline that was tangential to the curved, northeast face of the north breakwater. When this shoreline configuration occurred, North Beach would be at or near its accretion capacity, and natural bypass of the north breakwater would begin. The potential adverse impact of this natural bypass would be the deposition of sand as a submerged spit extending southward from the south end of the north breakwater, or as a shoal area in the marina entrance. Either scenario would result in undesirable shoaling at the entrance area. In order to mitigate this potential for marina entrance shoaling, Moffatt & Nichol Engineers (1986) recommended that the anticipated accretion at North Beach be monitored. It was also recommended that the predicted accretional area at North Beach be dredged and the material artificially bypassed to the nearshore south of the marina.

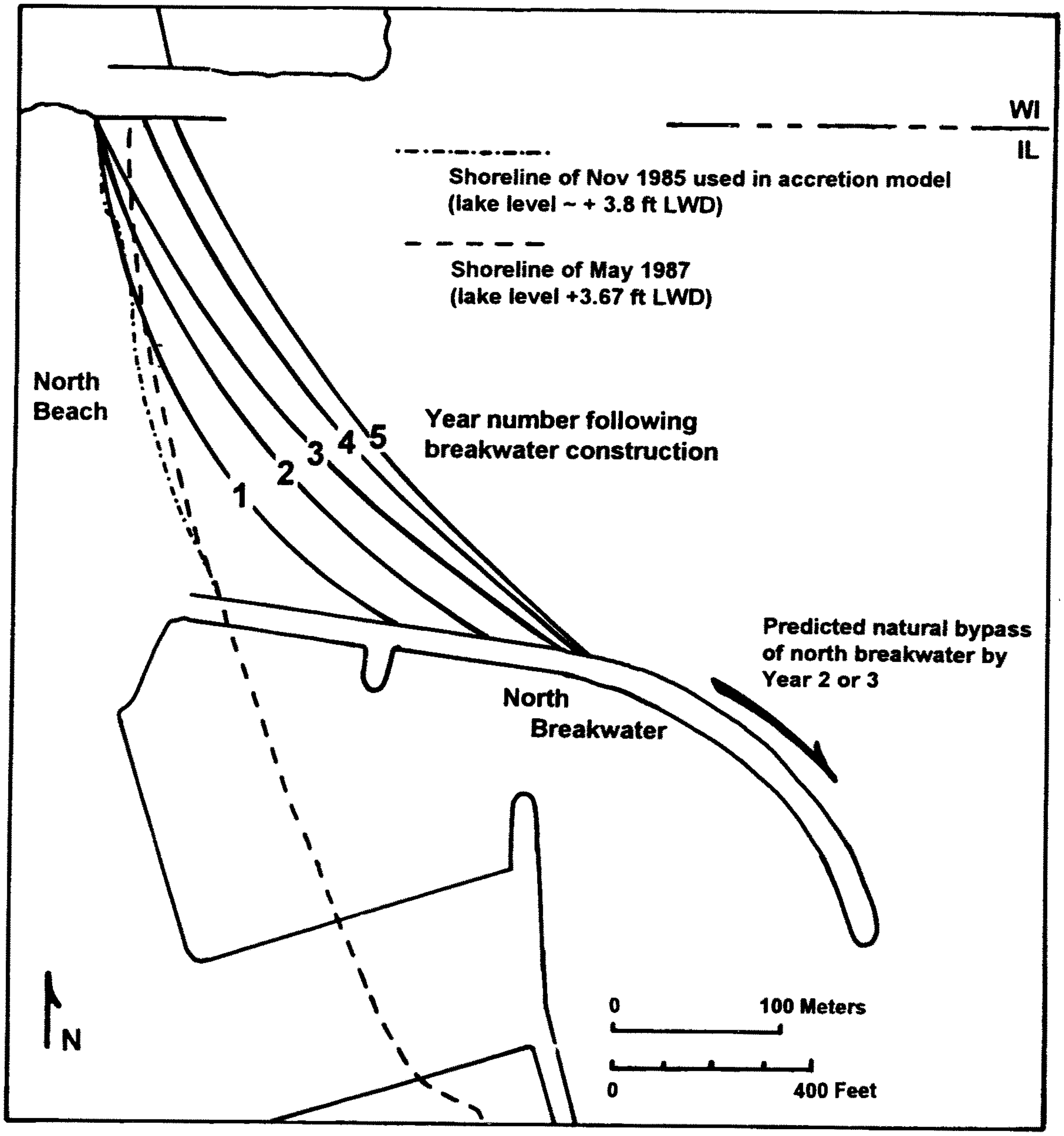


Figure 2-2 Anticipated shoreline accretion history at North Beach for the first five years following completion of the NPM north breakwater (modified from Moffatt and Nichol Engineers, 1986). Model is based on a littoral-sediment input of 60,000 cu yds/yr.

Actual accretion history

Figures 2-3 and 2-4 show the actual accretion history at North Beach by comparing the locations of annual shorelines (Fig. 2-3) and zero-ft LWD contours (Fig. 2-4) for 1987 (pre-construction) through 1992, and for 1995. Comparison of the shorelines shows differences in the extent of the emergent beach from year to year. The advantage of comparing the locations of the 0-ft LWD is that annual changes in the location of this contour are independent of annual fluctuations in lake level.

In the first year following breakwater construction, accretion did occur in the nearshore of the southern half of the beach. This was the maximum single-year accretion. It is illustrated north of the north breakwater by the 1988 0-ft LWD contour lying up to 140 ft lakeward of the 1987 0-ft LWD contour (Fig. 2-4). During the 1987-1988 interval, erosion occurred along the middle and northern sections of North Beach as the beach and nearshore was being reconfigured into an arcuate shape. Between 1988 and 1992, the position of the zero contour remained fairly stable. The major change to occur was vertical accretion up to 2 ft in the nearshore along the southern end of the beach between 1991 and 1992. This accretion caused the 1992 0-ft LWD contour to migrate up to 80 ft lakeward of its 1991 location.

By 1995, the 0-ft LWD contour occupied a position similar to that held during 1991. In the southern part of North Beach, the 0-ft LWD contour moved landward approximately 100 ft, while along the central part of the beach, the 1995 0-ft LWD contour had moved approximately 100 ft lakeward of its 1992 location. The 1995 shoreline was, on average, approximately 35 ft landward of its 1992 location indicating a less steep inner nearshore in 1995. The 1995 shoreline closely approximated the 1989 shoreline.

Rather than the crescent-shaped beach that was anticipated, North Beach has maintained a rather uniform shoreline configuration since 1988. Substantial accretion has occurred across the shallow nearhore such that out to 200 ft from the 1995 shoreline, lake-bottom elevations are shallower than 2 ft LWD. This shoaling has been beneficial to the recreational use of this beach by providing a broad area for shallow wading, and eliminating the steep, lake-bottom slope common along much of the neighboring recreational shore at IBSP.

Reasons for variance from anticipated shoreline accretion at North Beach

The lack of major beach accretion at North Beach, contrary to the 1986 model prediction by Moffatt & Nichol Engineers, can be attributed to two factors:

1) The volume of littoral sediment crossing the WI-IL state line annually has been less than the 60,000 cu yds/yr assumed in the model;

2) Changes have occurred to the shoreline, shore structures, and sand management practices on the Wisconsin side of the state line since the model was made.

The volume estimate of 60,000 cu yds/yr used in the model prepared by Moffatt & Nichol Engineers was in fact an over-estimate. As discussed in the subsequent section on the North Beach/north breakwater nearshore, accretion history in the area has averaged 10,800 cu yds/yr. As discussed in a later section on preliminary sediment budget (page 105), the minimum estimate of transport across the state line is 14,200 cu yds/yr, or 4.2 times less than the estimated 60,000 cu yds/yr.

An equally important factor in restricting major changes in the location of the North Beach shoreline may be related to changes on the neighboring Wisconsin shore. Since completion of NPM, significant changes have been made at Prairie Harbor Yacht Club (previously called Prairie Harbor and Prairie Cove Marina). In 1989, the marina basin was dredged and enlarged, and new jetties were constructed at the marina entrance. Annual and semi-annual maintenance dredging of the Prairie Harbor entrance channel captures sand that might otherwise add to the volume crossing the state line. The dredged sand is stockpiled inland or backpassed to the updrift shore. For the littoral sediment that does cross the state line, the transport pathway is influenced by the Prairie Harbor north jetty which is a rubble-mound structure extending 150 ft. lakeward of the shoreline (Fig. 2-1). Since it was constructed, the structure has apparently influenced southward littoral transport pathways by partially deflecting sediment transport away from North Beach. The offshore-deflected sediment stream is then better aligned to bypass the NPM north breakwater. This influence is best demonstrated by the location and orientation of the North Beach bar (Fig. 2-1).

If past trends continue, North Beach can be expected to be a low-maintenance beach with no adverse trends in shoreline accretion or erosion. However, persistent accretion is occurring across much of the shallow nearshore, and dredging may be necessary to prevent this area from becoming akin to a tidal flat.

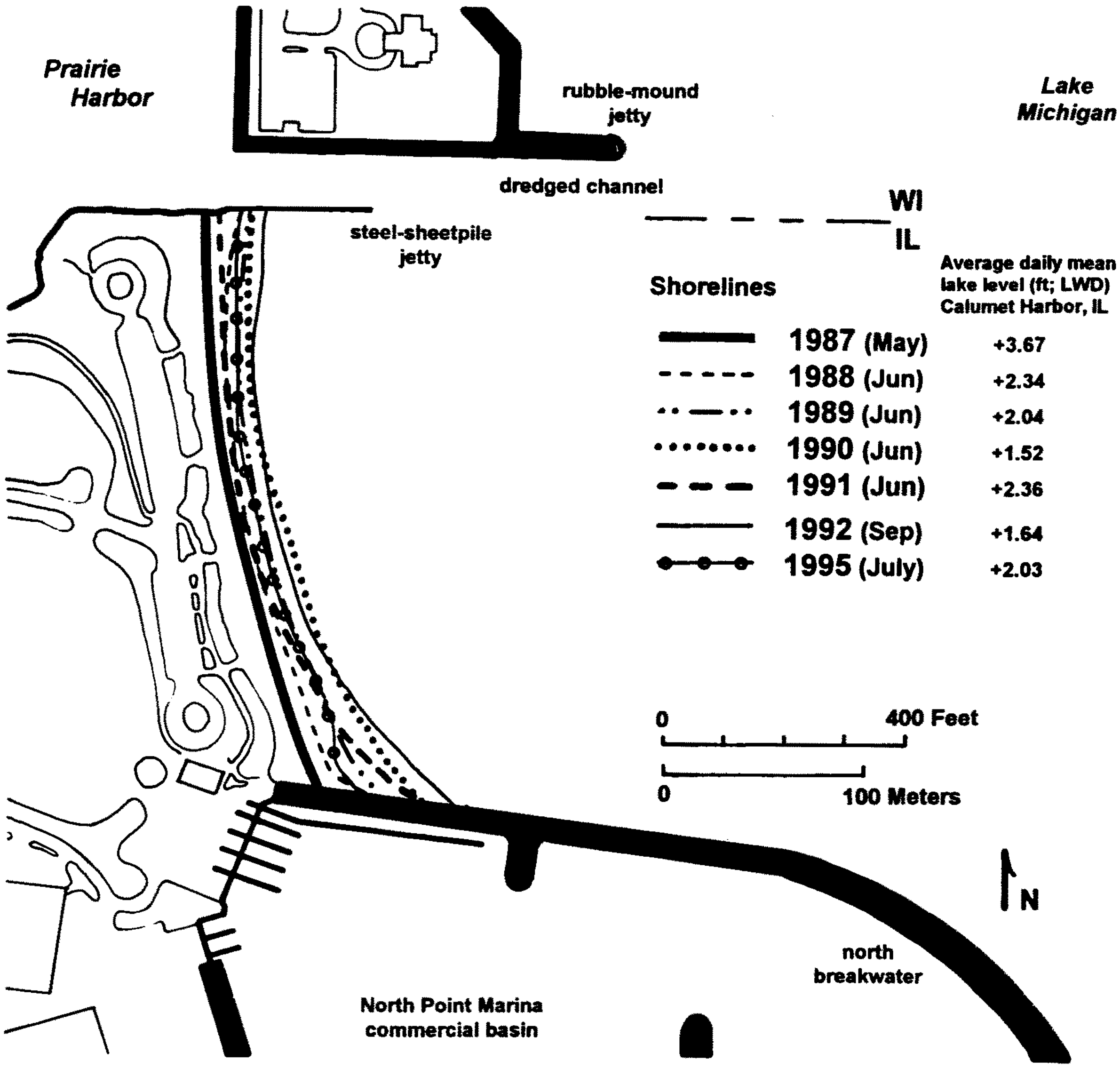


Figure 2-3 1995 shoreline position at North Beach and annual shorelines for the six years 1987 through 1992. The 1987 shoreline approximates conditions prior to construction of the north breakwater. The differences in shoreline positions are in part influenced by differences in lake level.

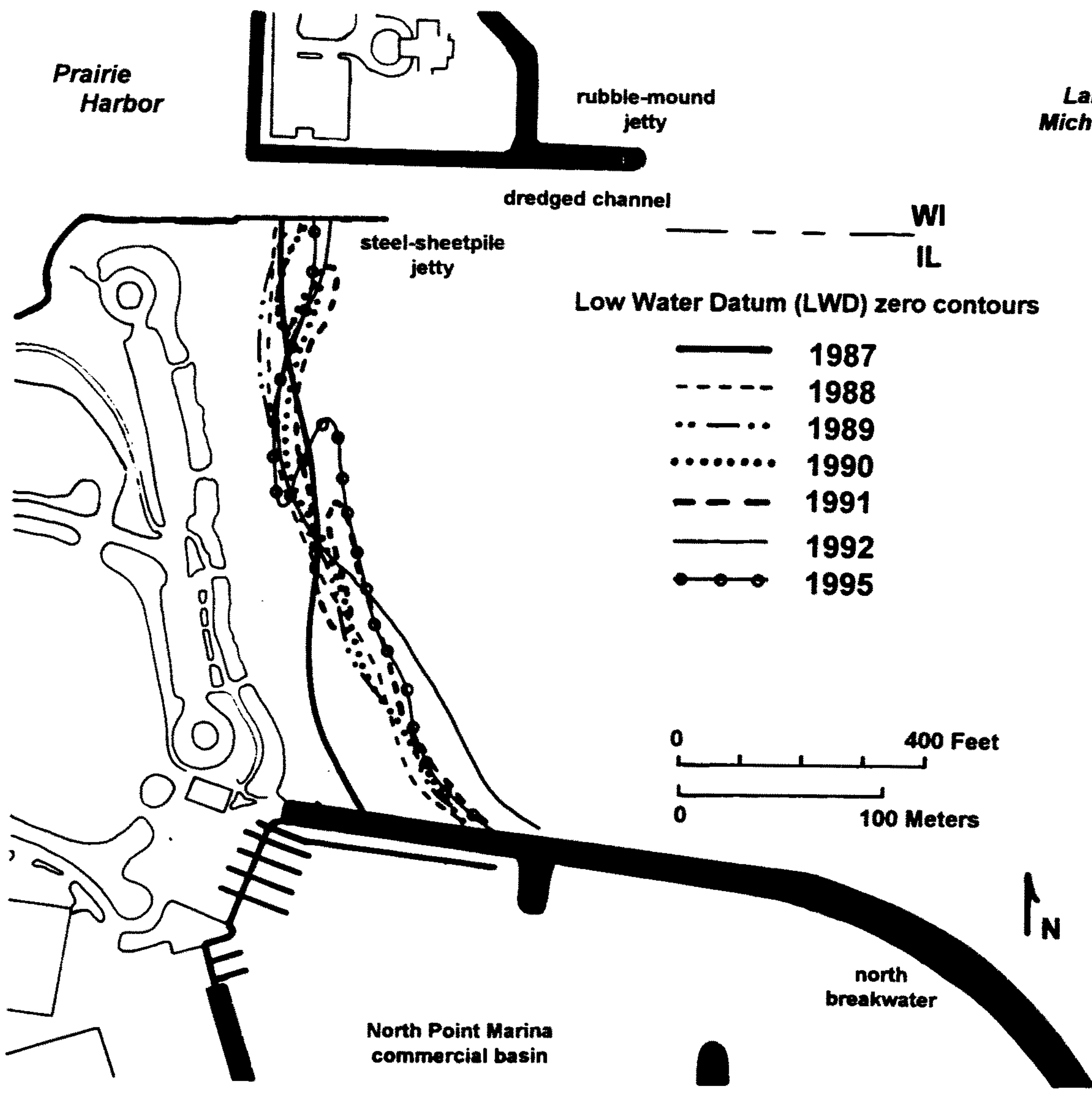


Figure 2-4 1995 position of the of the LWD zero-depth contour at North Beach compared to the annual position of this contour for 1987 through 1992. The 1987 zero contour approximates conditions prior to construction of the north breakwater.

II North Beach / North Breakwater Nearshore

The North Beach/north breakwater nearshore is here defined as the lake bottom between the WI-IL state line and the southern tip of the north breakwater (Fig. 2-1). Bathymetric data from this nearshore area provide a means of mapping lake-bottom changes and computing volumetric changes at the updrift end of the study area. These data are particularly valuable for calculating the volume of sediment coming across the WI-IL state line.

Figure 2-5 shows the 1995 nearshore bathymetry. For an analysis of nearshore changes, two lake-bottom comparisons were made. The first map comparison, for 1992 to 1995 (Fig. 2-6), compares the most recent three years of change. The second map of lake-bottom change, for 1987 to 1992 (Fig. 2-7), compares bathymetry prior to construction (1987) with bathymetry five years following construction. Table 2-1 presents the volume-change data in tabular form.

1995 bathymetry (Figure 2-5)

The North Beach/north breakwater nearshore generally has a smooth lake bottom from the shoreline out to depths of 22 ft LWD. At greater depths an irregular lake bottom suggests a bottom of exposed clay (*i.e.*, glacial till). Prominent 1995 bathymetric features in the 1995 bathymetry are the North Beach bar centered about 650 ft lakeward of the North Beach shoreline, and a lake-bottom depression along the northeast-facing section of the north breakwater (Fig. 2-5).

1992-1995 lake-bottom changes (Figure 2-6)

For the three-year interval 1992-1995, the North Beach/north breakwater nearshore was net accretional. The accretion volume (+44,100 cu yds) exceeded the erosion volume (-13,100 cu yds) by a factor of 3.4. The net accretion totaled 31,000 cu yds (Table 2-1).

Accretion All accretion in excess of 1 ft occurred in a NNW-SSE trending band that closely corresponded in position to where a large offshore trough was located in 1992 (Appendix A; Map A-6). This elongate accretionary zone, defined by the +1-ft isopach contour, can be traced southeastward along the lakeward side of the north breakwater to just offshore of the breakwater's southern tip (Fig. 2-6). This accretion lobe wraps around the south tip of the north breakwater and extends into the marina entrance (see Marina Entrance). Along the southern third of this accretionary zone, accretion between 5 to 6 ft is associated with partial infilling of a 16-ft deep elongate trough that was present on the 1992 bathymetric map (Appendix A; Map A-6). This partial infilling caused the axis of the trough to shallow (to 11 ft LWD) and move closer to the toe of the north breakwater (Fig. 2-5).

Table 2-1	Summary of erosion and accretion volumes in the North Beach nearshore.[1]		
	1987-1992	1992-1995[2]	1987-1995
Accretion (+) (cu yds)	75,000	44,100	119,100
Erosion (-) (cu yds)	19,800	13,100	32,900
Net change (cu yds)[3]	+55,200	+31,000	+86,200
Annual net change (cu yds/yr)[3]	+11,000	+10,300	+10,800
Normalized annual net change (cu yds/yr/shoreline ft)[4]	+7	+6	+7

[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; erosion and accretion volumes are for the three-year summation and annual net change is a three-year average.
[3] Net accretion is indicated by a positive number and net erosion is indicated by a negative number.
[4] Shoreline distance (1600 ft) is based on measurement along a north-south line bounded to the north and south by the defined limits of the nearshore reach. Numbers are rounded to the nearest whole number. Net accretion is indicated by a positive number and net erosion is indicated by a negative number.

Erosion A large erosional area, bounded by the -1 ft contour and the north breakwater, is present landward of the 1995 North Beach bar along the southern part of the North Beach nearshore (Fig. 2-6). The maximum erosion is 3 ft within a narrow band lying along the north-facing section of the north breakwater. Between 1987 and 1992 this area had been accretional (Fig. 2-7).

1987-1992 lake-bottom changes (Figure 2-7)

Between 1987 and 1992, the North Beach/north breakwater nearshore was also net accretional. The accretion volume (+75,000 cu yds) exceeded the erosion volume (-19,800 cu yds) by a factor of 3.8. The net accretion totaled 55,200 cu yds (Table 2-1). Most accretion (between 4 and 5 ft) occurred in a NNW-SSE trending band approximately 1000 ft offshore. This accretional band is associated with the 1992 location of the North Beach bar (see North Beach Bar) which extended southward from the WI-IL state line towards the NPM north breakwater. The second major accretional area in the 1987-1992 comparison occurred in a WNW-ESE trending band (300 to 900 ft in N-S width) in the southern part of the North Beach area. This accretion area extended from the 1987 0-ft LWD contour east-southeast toward the North Beach bar. This localized accretion resulted from entrapment of littoral drift by the NPM north breakwater, as well as probable sediment input related to construction of the north breakwater. Minimal accretion occurred lakeward of the 1992 location of North Beach bar.

Two major erosional areas are evident in the 1987-1992 comparison (Fig. 2-7). One is a broad area located landward of the 1992 North Beach bar and approximately 300 to 800 ft lakeward of the northern half of North Beach. Here, maximum erosion was between 3 and 4 ft. This erosion is assumed to be related to an adjustment of the lake bottom as a result of development of North Beach bar. The other major erosion area was a NW-SE trending narrow erosional zone along the lakeward side of the north breakwater. Here, erosion between 2 to 3 ft occurred approximately 70 ft northeast of the north breakwater.

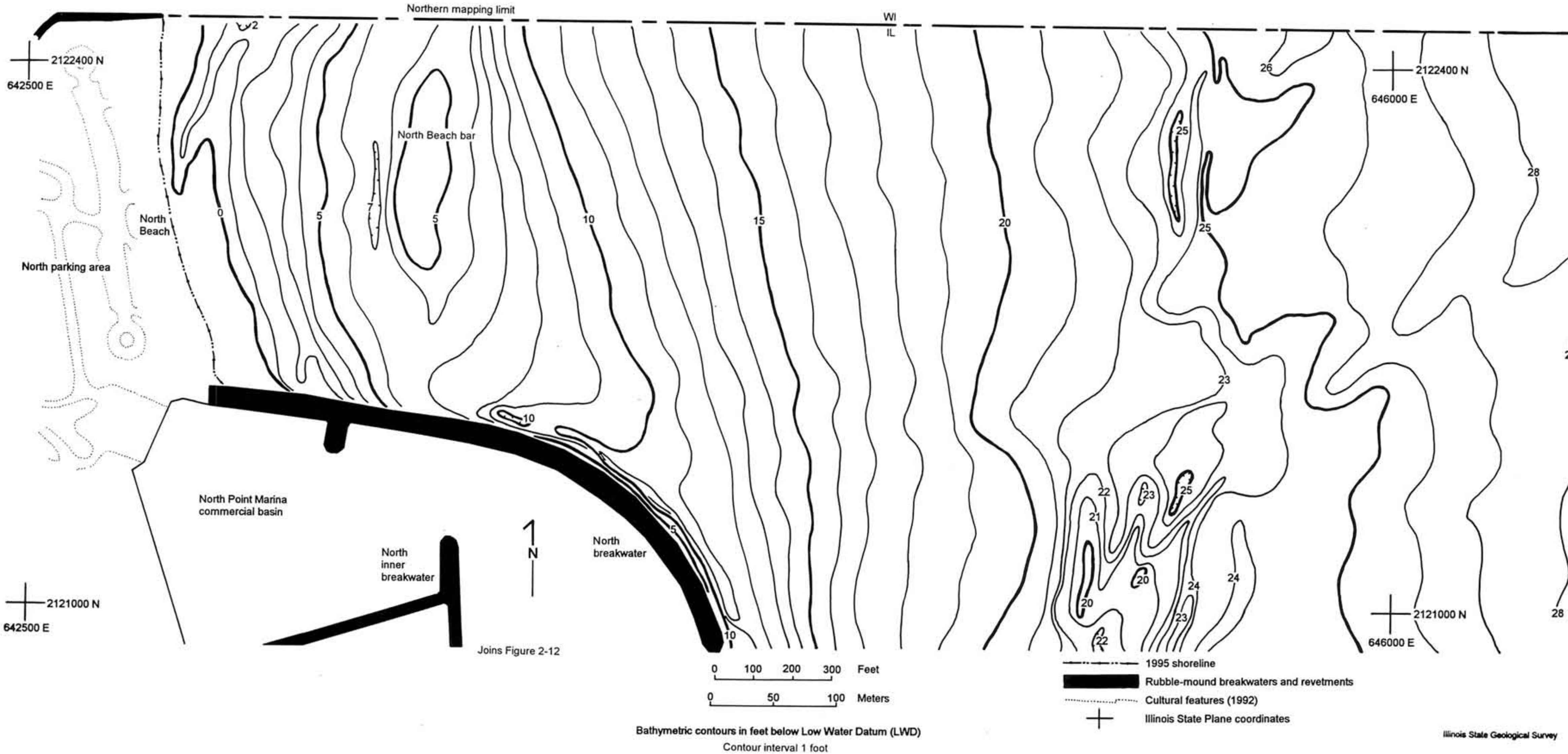


Figure 2-5 1995 bathymetry of the North Beach/north breakwater nearshore.

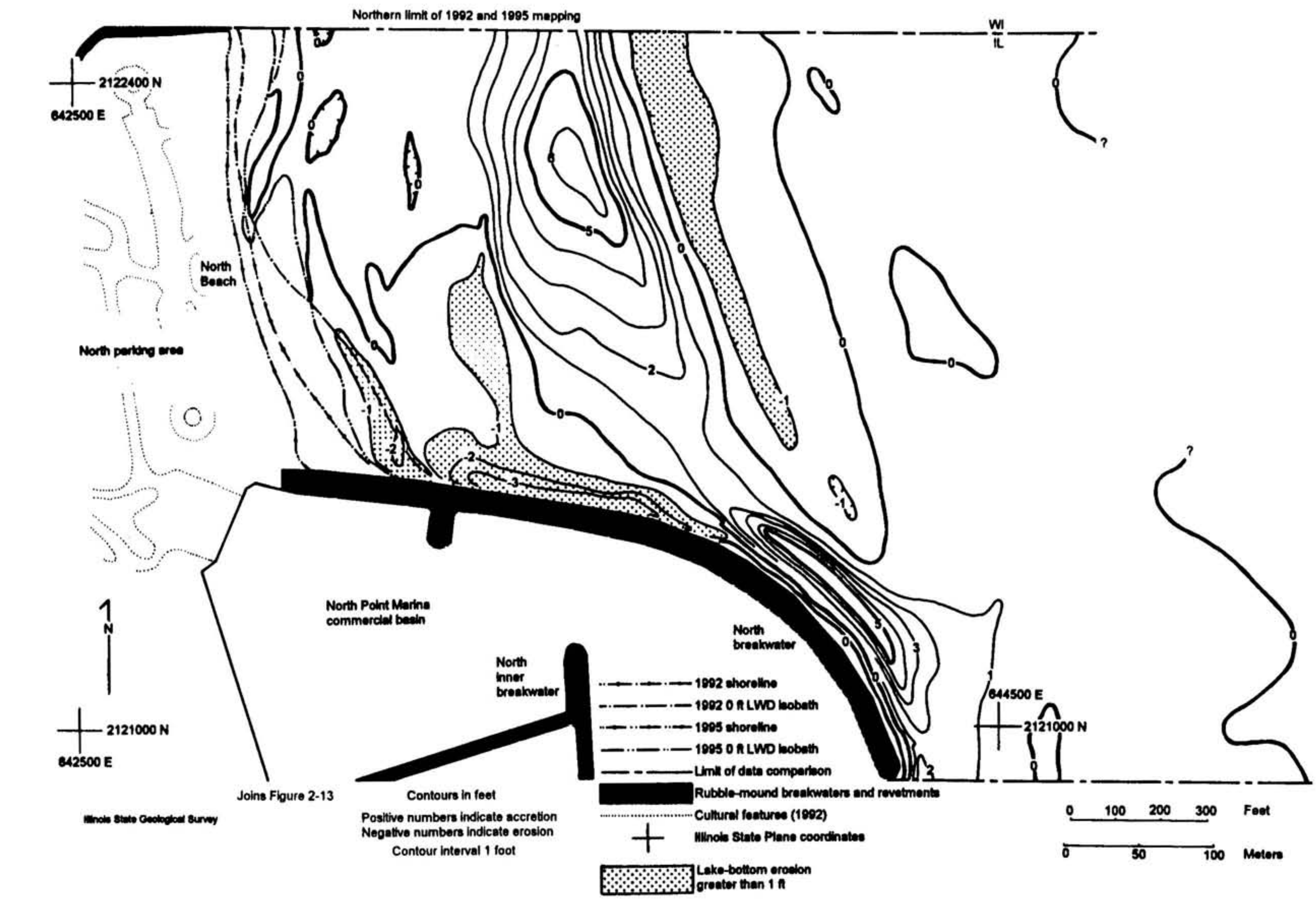


Figure 2-6 Isopach map of 1992-1995 lake-bottom changes in the North Beach/north breakwater nearshore.

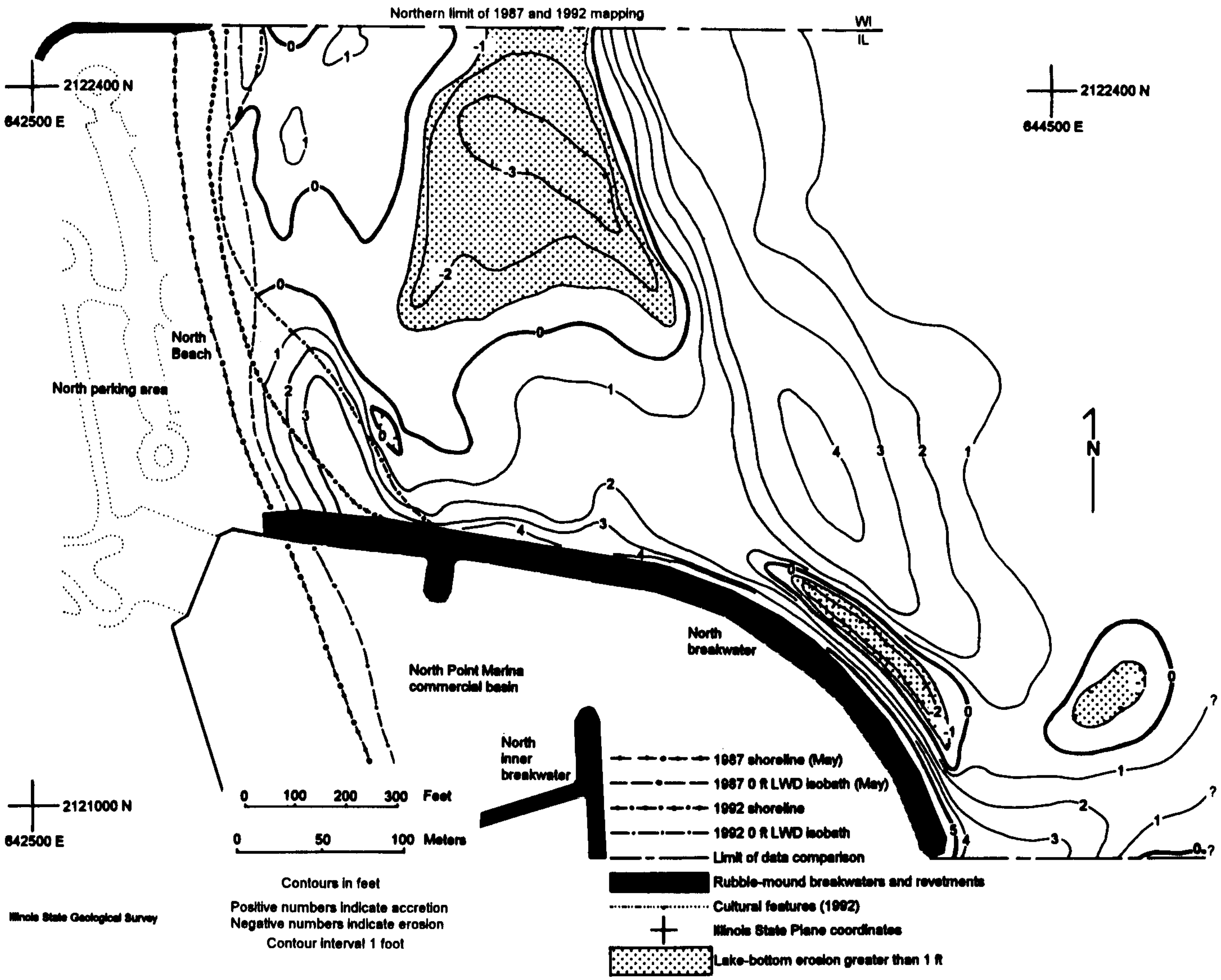


Figure 2-7 Isopach map of 1987-1992 lake-bottom changes in the North Beach/north breakwater nearshore.

Summary of 1987-1995 lake-bottom changes

During the eight-year interval 1987-1995, the loci of erosion and deposition in the North Beach nearshore varied (Appendix B, Maps B-1 to B-5; Figs. 2-6 and 2-7). The major changes were related to repositioning of the North Beach bar. This is discussed further in the next section. What has been consistent through the eight years has been a trend of net accretion. Between 1987 and 1995, accretion was 86,200 cu yds (Table 2-1), which gives an average net accretion over these eight years of 10,800 cu yds/yr.

The significance of this accretion volume is that it documents that the lake bottom updrift of the north breakwater has been a net accretional area since the marina was constructed. The north breakwater has acted as a partial barrier to littoral transport. The accretion volume provides data important in calculating a minimum estimate of the average annual supply of littoral sediment that crosses the WI-IL state line. This is done in a subsequent section discussing the sediment budget (see Regional Coastal Monitoring). One value of comparing two time intervals is to identify any possible trends of increasing or decreasing rates of lake-bottom change. For these two comparisons (1987-1992 and 1992-1995), the trend has consistently been net accretion across this nearshore at a relatively constant rate of 10,800 cu yds/yr.

III North Beach Bar

Background and significance

The North Beach bar is a submerged bar that extends from the WI-IL state line southward toward the NPM north breakwater (Figs. 2-1; 2-5; 2-8). The bar is a prominent depositional feature that was first documented in the ISGS bathymetric survey of 1990 (Appendix A; Map A-4) and has persisted to 1995. Several characteristics pertaining to the bar are:

- The bar as a prominent lake-bottom feature was not present between 1987 and 1989, although in both 1987 and 1989 accretional areas just south of the state line may have been precursors of the bar (Appendix A; Map A-1, Map A-3).
- Since 1990, the bar has been defined as a shoal area above the 6-, 7-, or 9-ft LWD contours.
- The bar has consistently been located at least 550 ft lakeward of its contemporaneous shoreline.
- Between 1990 and 1995, the maximum crest elevation of the bar occurred in 1995 between 4 and 5 ft LWD.

The significance of the North Beach bar within the context of coastal management at the marina and state park is that:

1) of the littoral sediment that crossed the state line between 1990 and 1995 and accreted updrift of the NPM north breakwater, the greatest accretion thicknesses were associated with the bar;

2) the bar identifies part of a primary pathway of sediment transport, extending from the state line toward the NPM north breakwater and further southward toward the marina entrance;

3) the bar is a localized sand reservoir that could be mined for downdrift beach nourishment.

Bathymetric changes (Figure 2-8)

The North Beach bar has been a dynamic lake-bottom feature since it first developed in 1990. Figure 2-8 is a schematic diagram showing locations of the bar axis during 1990, 1991, 1992 and 1995. Table 2-2 summarizes morphologic characteristics of the bar. From 1990 to 1992, the axis of the bar moved progressively lakeward which appears to have facilitated eventual sediment bypassing around the NPM north breakwater between 1992 and 1995. By 1995, a significant change had occurred with the bar axis moving landward and developing a north-south orientation. Bathymetric data over the next few years will be needed to determine whether this change in location and orientation is a short-lived phenomenon, or whether it signifies major change in littoral sediment supply and/or nearshore dynamics.

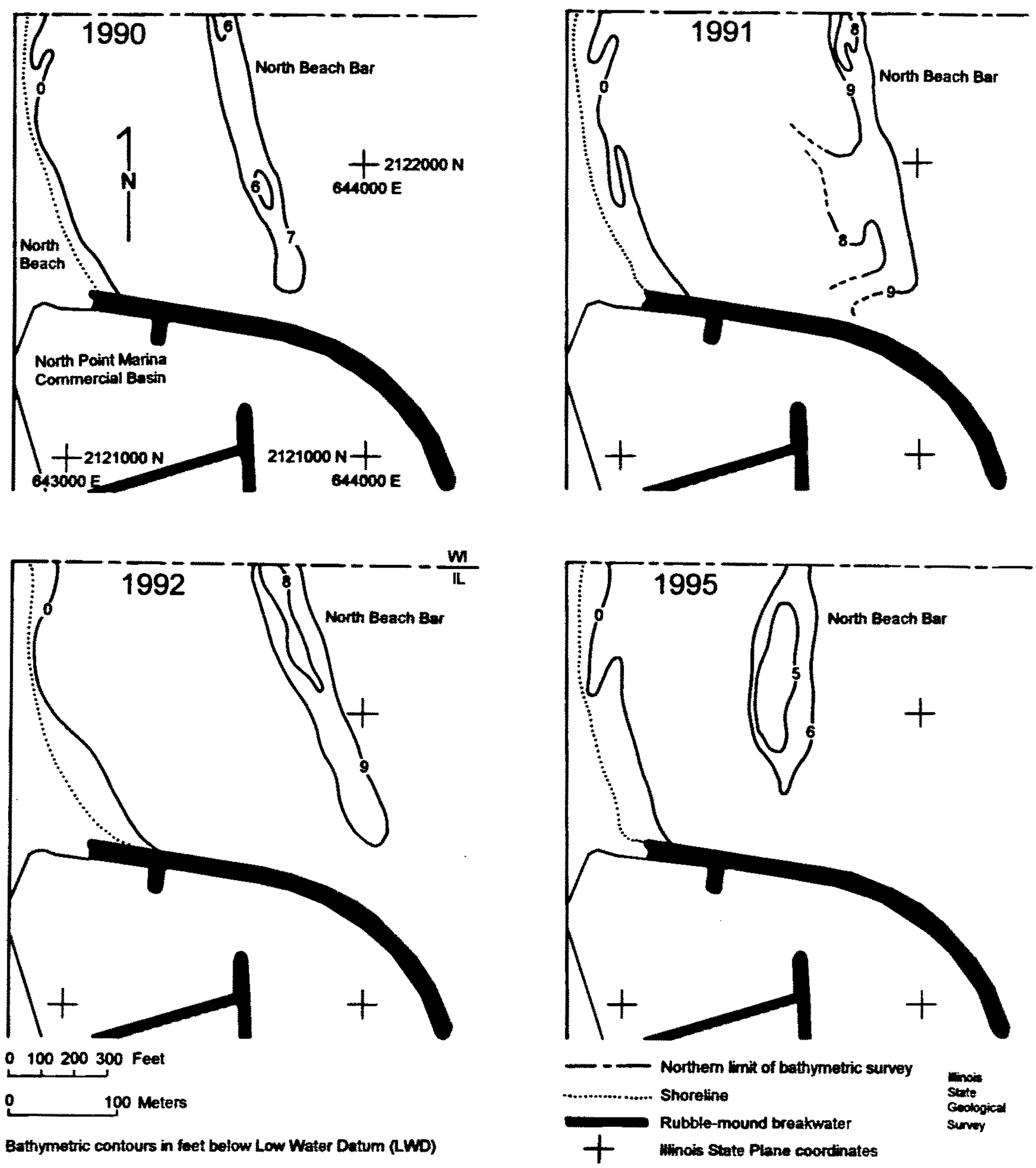


Figure 2-8 Schematic illustration of the location of North Beach bar for the years 1990, 1991, 1992, and 1995. Shown is the deepest lake-bottom closed contour that defines the outline of the bar and encloses the bar axis.

Table 2-2 Summary characteristics of the North Beach bar.	1990	1991	1992	1995
Distance offshore of North Beach (ft)[1]	600	800	750	550
Proximity of southern tip to NPM north breakwater (ft)	100	150	200	250
Shallowest closed contour (ft)[2]	6	8	8	5
Deepest closed contour (ft)[2]	7	8-9 [3]	9	6
Length (ft)[4]	1000	1000	1100	750
Area (sq yds)	10,700	17,100	15,200	14,300
Volume (cu yds)[5]	34,000	59,000	51,000	34,000

[1] Distance offshore is the average distance measured due east of the shoreline.
[2] Contours are referenced to Low Water Datum (LWD).
[3] During 1991, most of the bar, with the exception of the northern part, had an atypical plateau-like morphology.
[4] Bar length is measured along the bar axis.
[5] Volumes are rounded to the nearest thousand cubic yards.

Volumetric analysis

Annual sediment volumes were calculated for the North Beach bar by subtracting an inferred non-barred bathymetric profile from the barred bathymetric profile for each of the years of survey (1990, 1991, 1992, and 1995). Four east-west profiles were used (ISGS Profiles 2, 4, 6, and 8) to obtain representative bar 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.

During the four years of measurement, the bar volume ranged between 34,000 and 59,000 cu yds. Peak volumes were attained in 1991 and 1992. By 1995, the bar volume had returned to that of 1990. These variations in bar volume are likely a natural response to changes in wave climate, sediment supply, and lake level. During these four years of measurement, the average bar volume was 44,500 cu yds.

IV Marina Entrance

Background

The marina entrance developed a well-defined accretional area soon after breakwater construction (Appendix B; Map B-1). When entrance shoaling was first recognized in 1988, some debate ensued concerning the source of the sediment. Bathymetric data collected by ISGS suggested that some or all of this sediment may have been derived from erosion of the fan delta on the south side of the marina. At its maximum extent in 1988, the emergent and submerged parts of the fan delta extended further lakeward than the north-south segment of the south breakwater. Northward transport of sediment from this discharge area by waves from the south and southeast could readily move sand into the sheltered marina entrance area. Comparison of ISGS bathymetric data collected along the south breakwater in 1988 and 1989 (Appendix B; Map B-2) show northward progression of an accretionary wedge along the south breakwater consistent with this premise of northward sediment transport. An alternate mechanism for the entrance shoaling was presented by Moffatt & Nichol Engineers (1990). They suggested that the sediment was derived from the considerable volumes of sand that were distributed as roadbed along the north and south breakwaters during construction. Wave action during and following construction would have allowed some of this roadbed material to leak out of the breakwaters and cause lake-bottom accretion at the marina entrance.

Data collection

The ISGS began collecting limited profile data in the marina entrance area in 1989. This profiling consisted of a series of nine lines aligned between landmarks such as the ends of breakwaters or breakwater daymarkers. The data collection focused on the area between the tips of the north and south breakwaters and the entrance to the commercial basin. However, one line extended from the north breakwater to the entrance to the recreational basin. Data from these surveys are incorporated in bathymetric maps A-3 through A-6 (Appendix A). Maps B-3 through B-5 (Appendix B) document 1989-1992 annual lake-bottom changes in the marina entrance.

All nine marina-entrance survey lines were resurveyed in July 1995 to allow profile comparisons with data from 1989 through 1992. During July and August 1995, maintenance dredging was underway in the approach channel to the recreational basin. Dredging was planned for the marina entrance area, but none occurred here in 1995.

1995 bathymetry (Figure 2-9)

The 1995 bathymetry in the marina entrance (Fig. 2-9) documents the lake-bottom asymmetry between the ends of the north and south breakwaters. The 10 ft LWD contour defines a trough area extending from the marina entrance toward the commercial basin. This trough is likely a primary pathway for currents flowing into and out of the marina. Such currents develop when differences in water level occur between the open lake and the marina basin.

1992-1995 lake-bottom changes (Figure 2-10)

Figure 2-10 is an isopach map identifying lake-bottom changes in the marina entrance between 1992 and 1995. Two accretional tends are significant. First, the area of maximum accretion (up to 6 ft) occurs about 200 ft northwest of the north end of the south breakwater. Second, an accretionary lobe extends around from the lakeward side of the north breakwater and turns into the marina entrance. This latter feature indicates that, between 1992 and 1995, there was sediment bypass of the north breakwater, at least as far south as its southern tip. This accretional lobe is part of a narrow accretional zone that extends southward from the WI-IL state line (see Fig. 2-6). Thus, some of the sediment that accumulated within the marina entrance area between 1992 and 1995 was likely derived from updrift of the north breakwater and from north of the WI-IL state line. The only other time such an accretional lobe was documented from the state line to the marina entrance was between 1989 and 1990 (Appendix B; Map B-3). Detailed sediment transport studies are needed to conclusively verify that sediment from updrift of the marina has accumulated within the marina entrance. However, the overall configuration of the 1992-1995 isopach contour pattern is consistent with such a transport pathway.

1989-1995 lake-bottom changes (Figures 2-11A,B)

The principal area of lake-bottom change in the marina entrance area between 1989 and 1995 occurred around the north end of the south breakwater. Figure 2-11A shows profile data across the marina entrance between the ends of the north and south breakwaters. In 1987, prior to breakwater construction, the lake bottom sloped gently from about 11 ft LWD at what is now the tip of the south breakwater, to about 14.5 ft LWD at what is now the tip of the north breakwater. Subsequent shoaling and erosion resulted in development of a cross-sectional asymmetry with a broad shoal area on the western two-thirds of the entrance and a narrow trough on the eastern third adjacent to the north breakwater. Maximum accretion in the entrance area occurred between 1989 and 1990, then slowed between 1990 and 1991. The overall profile configuration has remained rather uniform since 1991. As of 1995, the marina entrance trough had a maximum depth of about 15 ft LWD. This is about 0.5 ft below the base of the nearby north breakwater. It is unknown if the stability of the breakwater toe has been affected by this depression, but no shifting of breakwater stone can be seen above water.

The trough axis has apparently assumed a stable position, but continued monitoring of this feature is warranted. If the trough is caused by the deflection and channeling of currents along the west (marina basin) side of the north breakwater, then the depression would occur even if the shoal area adjacent to the south breakwater was absent. Alternatively, it is possible that if the shoal area adjacent to the northern tip of the south breakwater is dredged, the increased cross-sectional area of the entrance would result in currents no longer being channeled along the northeastern side of the entrance. Deposition would then occur and reduce the depth of the trough adjacent to the north breakwater. In either case, continued monitoring is important since the lake bottom in this area is at or below the base elevation of the adjacent breakwater and could lead to undermining of the breakwater.

Figure 2-11B shows profile comparisons running approximately north-south between the north end of the south breakwater and the middle daymarker of the north breakwater. Lateral accretion on the northward nose of the south breakwater shoal has persisted since 1989. Between 1992 and 1995, lateral accretion advanced the shoal northward by about 60 ft and was accompanied by up to 6 ft of vertical accretion. There has also been persistent lake-bottom accretion on the lake bottom in the northern half of this profile near the approach to the commercial basin. Between 1989 and 1995, accretion reduced depths from 13 ft LWD to about 11 ft LWD. Just under 1 ft of accretion occurred here between 1992 and 1995. Nearby, at the entrance to the commercial basin, 3 to 4 ft of accretion occurred between 1992 and 1995 (Fig. 2-10).

The isopach map shown in Figure 2-10 was used to compute the volume of net accretion occurring in the marina entrance between 1992 and 1995. The limits for the volume computation are shown on the index map in Figure 2-11A. For this three-year period, the net accretion within this area totaled 9,200 cu yds. This is an average annual net accretion of 3,100 cu yds/yr.

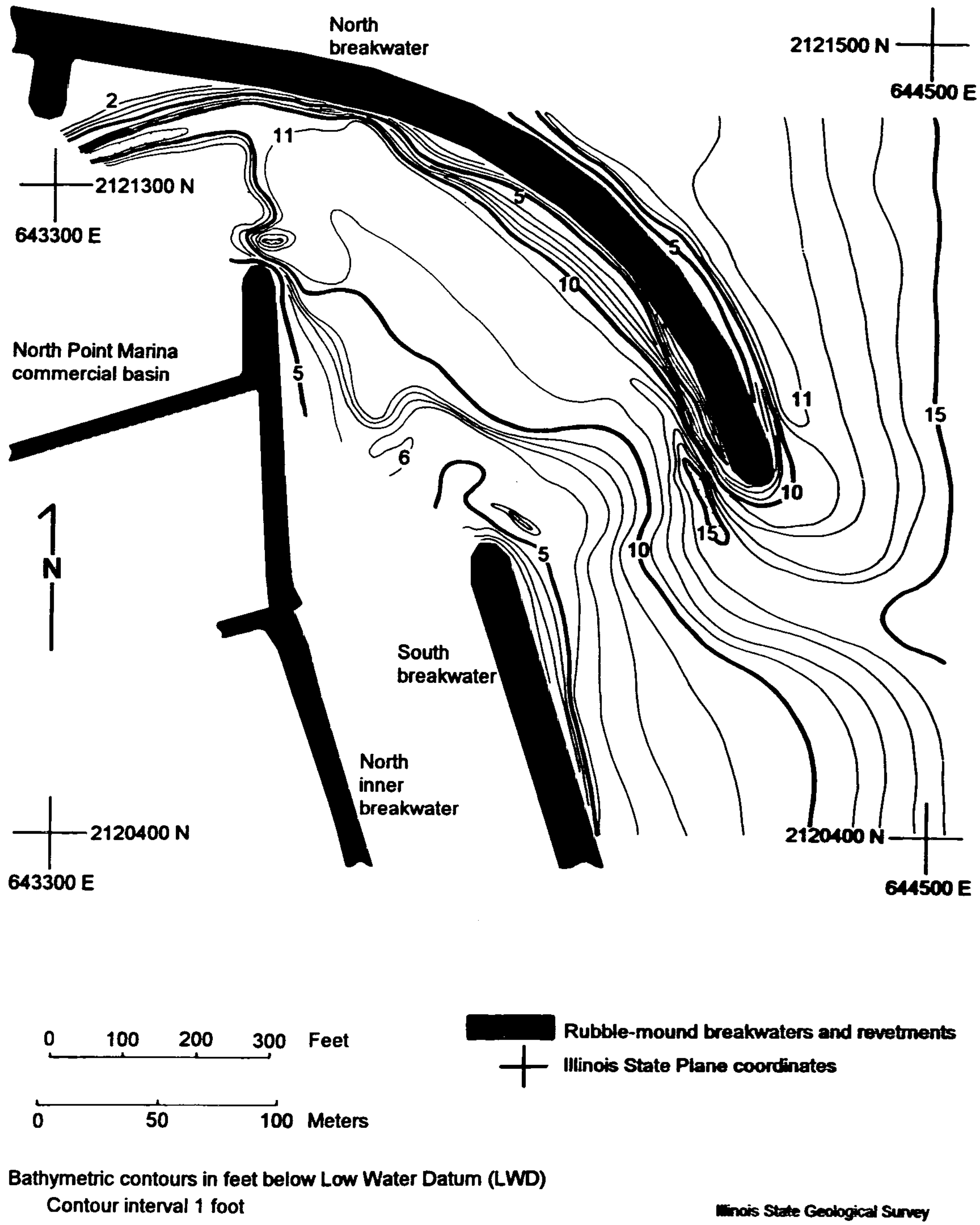


Figure 2-9 1995 bathymetry in the North Point Marina entrance area.

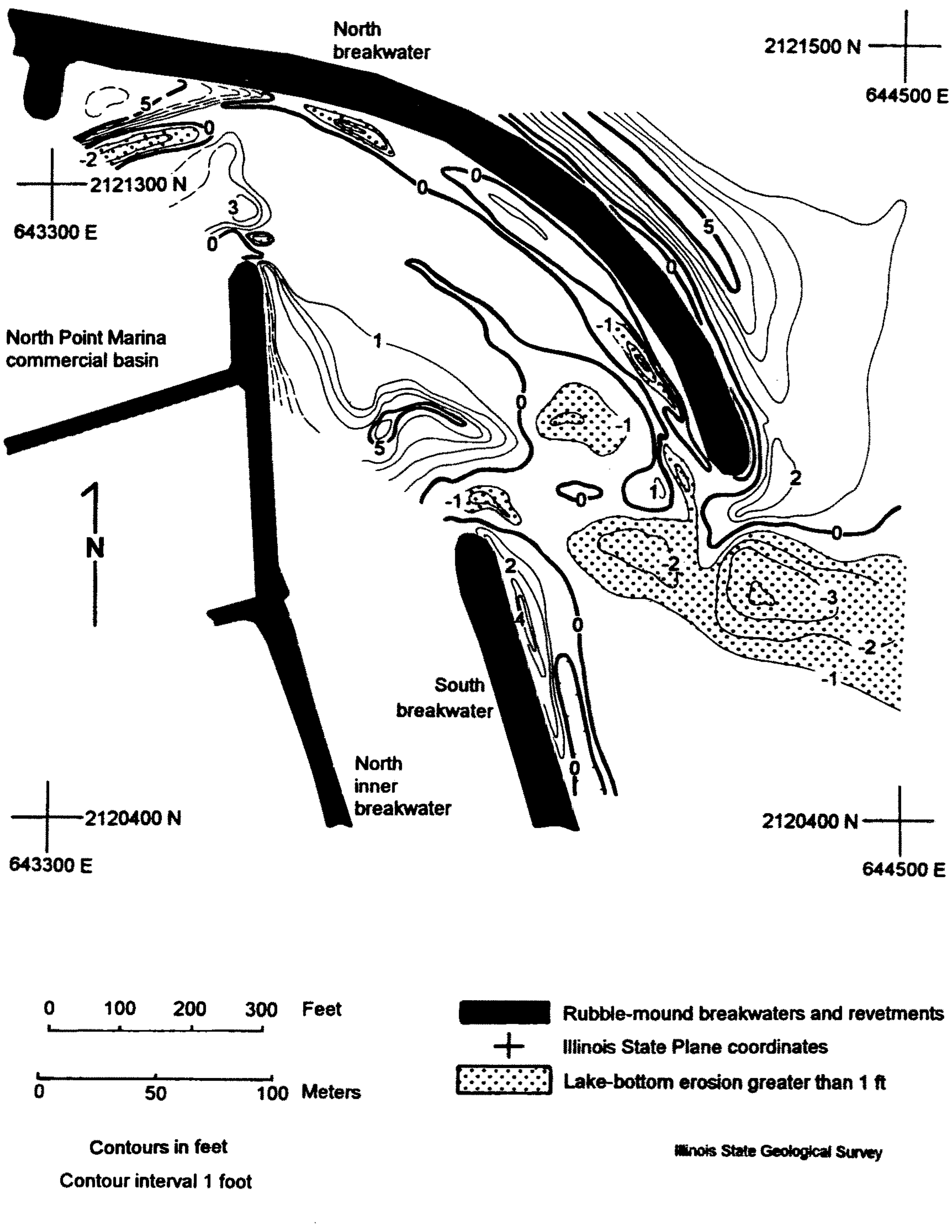
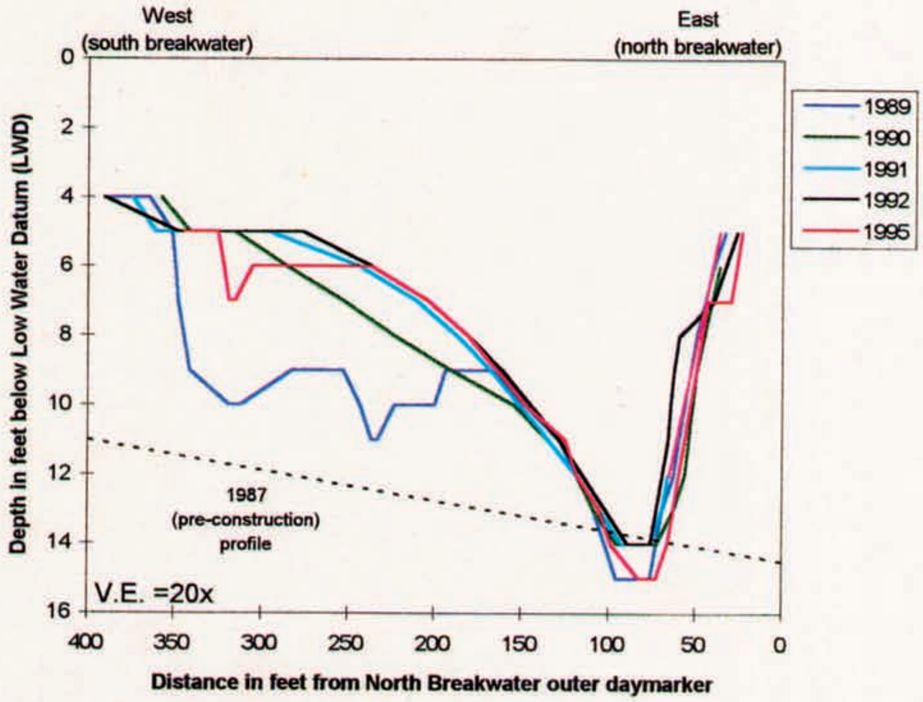


Figure 2-10 Isopach map of 1992-1995 lake-bottom changes in the North Point Marina entrance area. The accretional lobe along the south and east side of the north breakwater is the southern part of a 1992-1995 accretional lobe that is continuous from the WI-IL state line (see Figure 2-6).



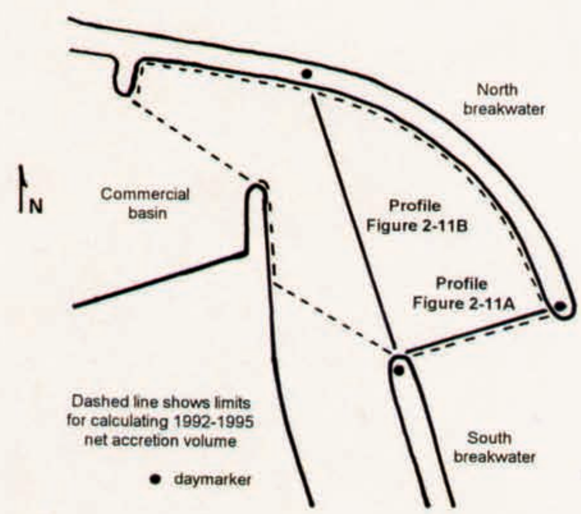


Figure 2-11A Profile comparisons across the NPM marina entrance from 1989 through 1995. Profile line runs approximately west to east between the ends of the south and north breakwaters. Index map shows profile locations and limits of 1992-1995 volume calculation.

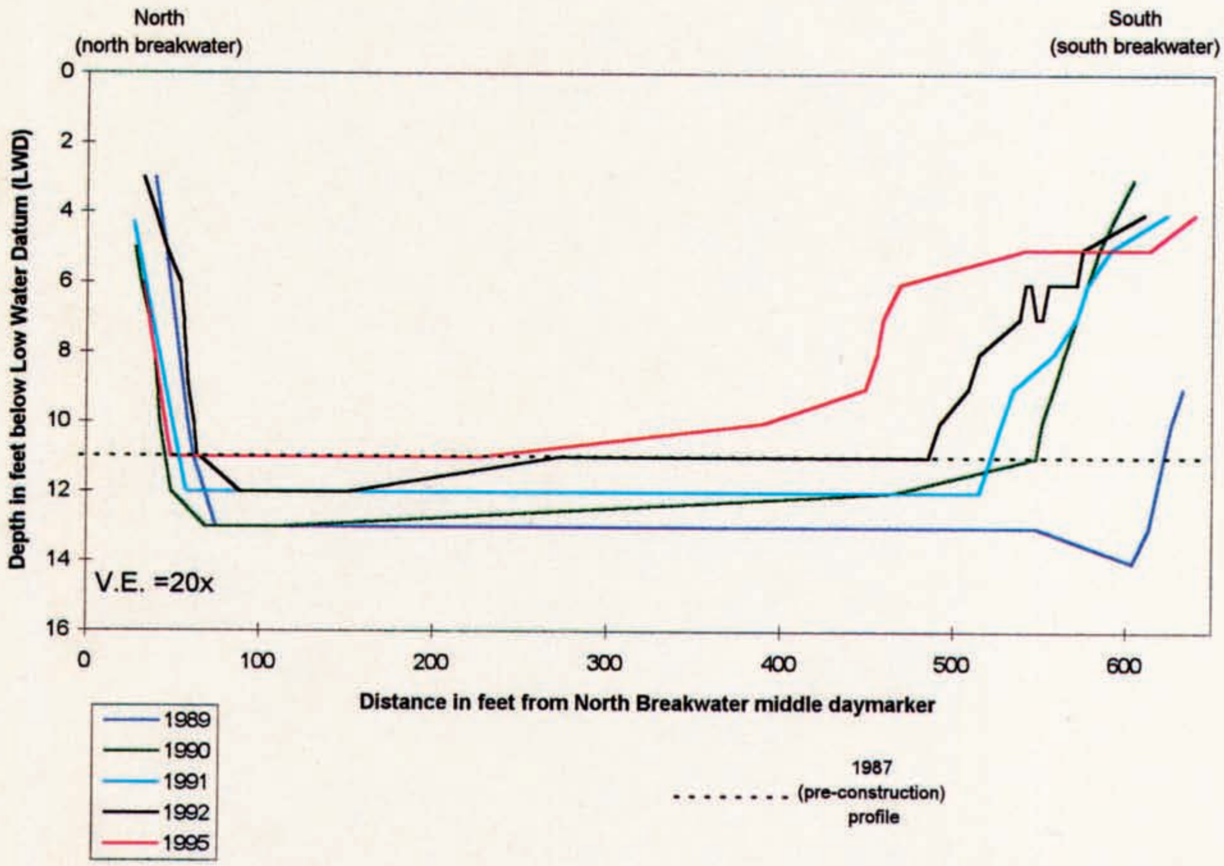


Figure 2-11B Profile comparisons across the inner part of the marina entrance from 1989 through 1995. Profile line runs approximately north to south, from the middle daymarker of the north breakwater to the north end of the south breakwater. See inset map on Figure 2-11A for location.

Implications of accretion and erosion trends

The bathymetric data for the marina entrance from 1989 to 1995 indicate the following:

1) Since the construction of the breakwaters, the marina entrance has been a sediment trap. Some lake-bottom erosion has occurred forming a trough along the inner side of the north breakwater, but the net change has been accretion. The major area of accretion is located adjacent to the north end of the south breakwater.

2) Between 1991 and 1995, the lake-bottom profile between the ends of the two breakwaters did not change significantly. Thus along this profile an equilibrium configuration was achieved by 1991 which has persisted. Subsequent to 1991, sediment coming into the marina entrance was deposited further inside the entrance area.

3) Comparison of the 1992 and 1995 bathymetric data indicates an accretional lobe extending down the lakeward side of the north breakwater and wrapping around the tip of the breakwater. This feature indicates that sand from updrift of the marina has bypassed the north breakwater and has a pathway into the marina entrance. If sediment transport persists along this pathway, shoaling in the marina entrance will persist.

4) Over the past three years (1992-1995) the average annual accretion solely in the marina entrance area has been just over 3,000 cu yds/yr. The need for future maintenance dredging in this area should be anticipated. This dredging will likely need to extend into the commercial basin.

V South Breakwater Nearshore

The south breakwater nearshore is here defined as the area lying between the southern tip of the north breakwater and the approximate mid-point in the north-south segment of the south breakwater (Fig. 2-1). The northern and southern boundaries are coincident with ISGS profile lines 17 and 32, respectively.

1995 bathymetry (Figure 2-12)

The 1995 bathymetry of the south breakwater nearshore is shown in Figure 2-12. No nearshore bar is present. A prominent feature is a trough that extends from the marina entrance lakeward to at least the 16 ft LWD isobath. A similar feature most recently occurred in 1989 and 1990 (Appendix A; Maps A-3 and A-4). Depths within 100 ft of the south breakwater range from 6 to 10 ft LWD; the shallower depths occur adjacent to the north end of the breakwater at the marina entrance. A regular contour pattern lakeward to depths of about 30 ft LWD suggests a sandy lake bottom. However, an irregular contour pattern occurs between the 21 and 27 ft LWD isobaths, approximately 1000 ft lakeward of the marina entrance. Diver inspections in 1992 confirmed that an outcrop of compacted clay (*i.e.*, glacial till) dominates this area (Ellen Marsden, Illinois Natural History Survey, pers. com).

1992-1995 lake-bottom changes (Figure 2-13)

The south breakwater nearshore was net erosional during the three-year interval 1992-1995 (Table 2-3). With the exception of one large accretional area, most of the 1995 lake bottom lies approximately 1 ft lower in elevation than the 1992 lake bottom. Development of the trough that extends lakeward from the marina entrance locally resulted in 4 ft of lake-bottom erosion.

Accretion The most significant accretion on the 1992-1995 isopach map (Fig. 2-13) is a lobate accretional area having an axis running NNE-SSW. The orientation and configuration of this feature indicates an influx of littoral sediment from the north. Up to 350 ft in width, and with vertical accretion of up to 3 ft, this feature extends south-southwestward from a position approximately 500 ft lakeward of the south tip of the north breakwater to a position approximately 200 ft lakeward of the southern part of the south breakwater. The feature is not apparent on the 1995 bathymetric map (Fig. 2-12) because most of the deposition occurred within a depression on the 1992 lake bottom. This accretion is separate from the previously discussed accretional lobe that extends along the north breakwater. The accretion possibly represents a deeper-water sediment transport pathway extending southward from the North Beach / north breakwater nearshore.

Erosion The greatest amounts of erosion occur in patches along the lakeward side of the south breakwater, and in a zone extending east-southeastward from the manna entrance (see the Marina Entrance section). The lake bottom is primarily erosional landward and lakeward of the lobate accretional feature discussed above, with 4 ft maximum erosion occurring along the trough leading lakeward from the marina entrance.

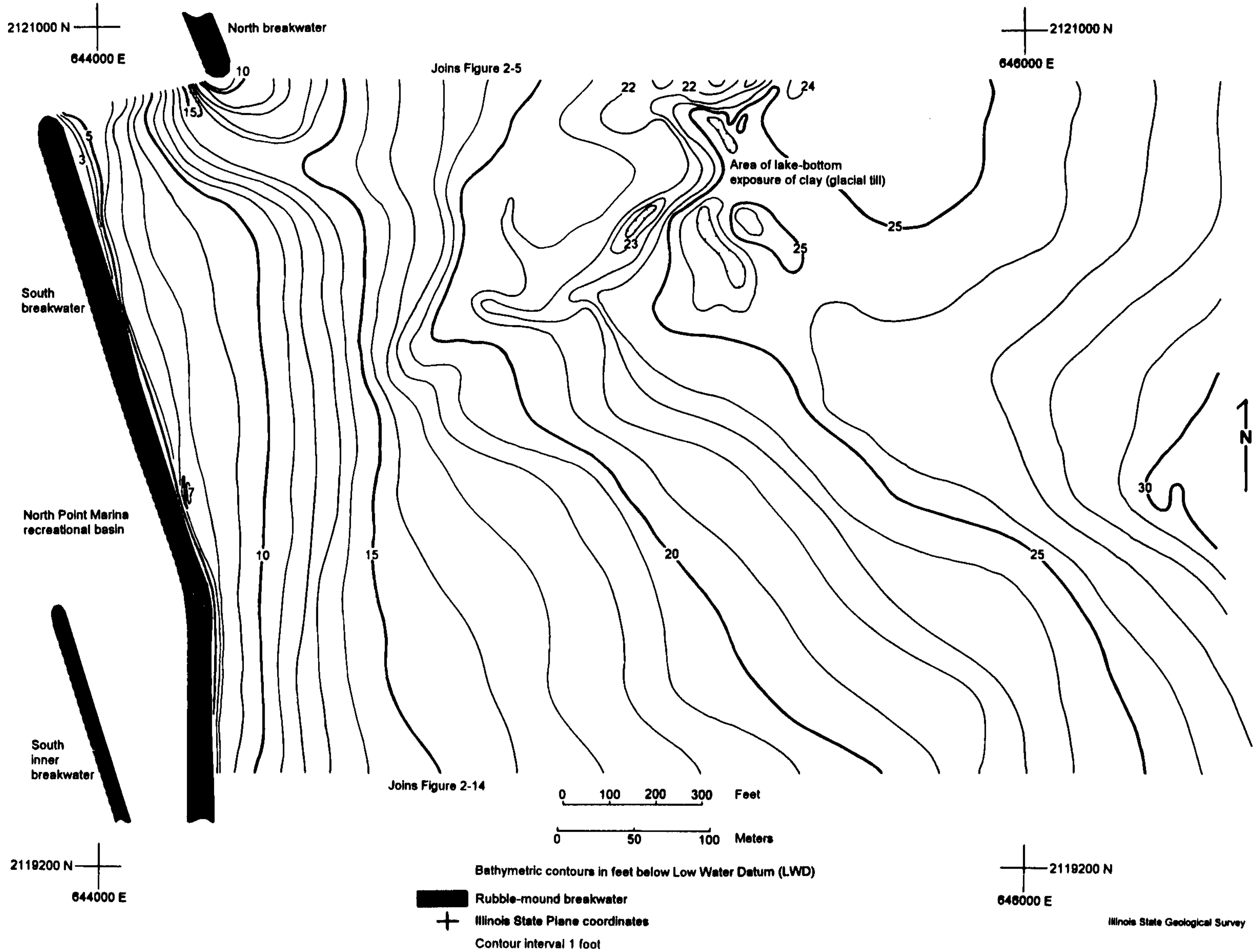


Figure 2-12 1995 bathymetry of the south breakwater nearshore.

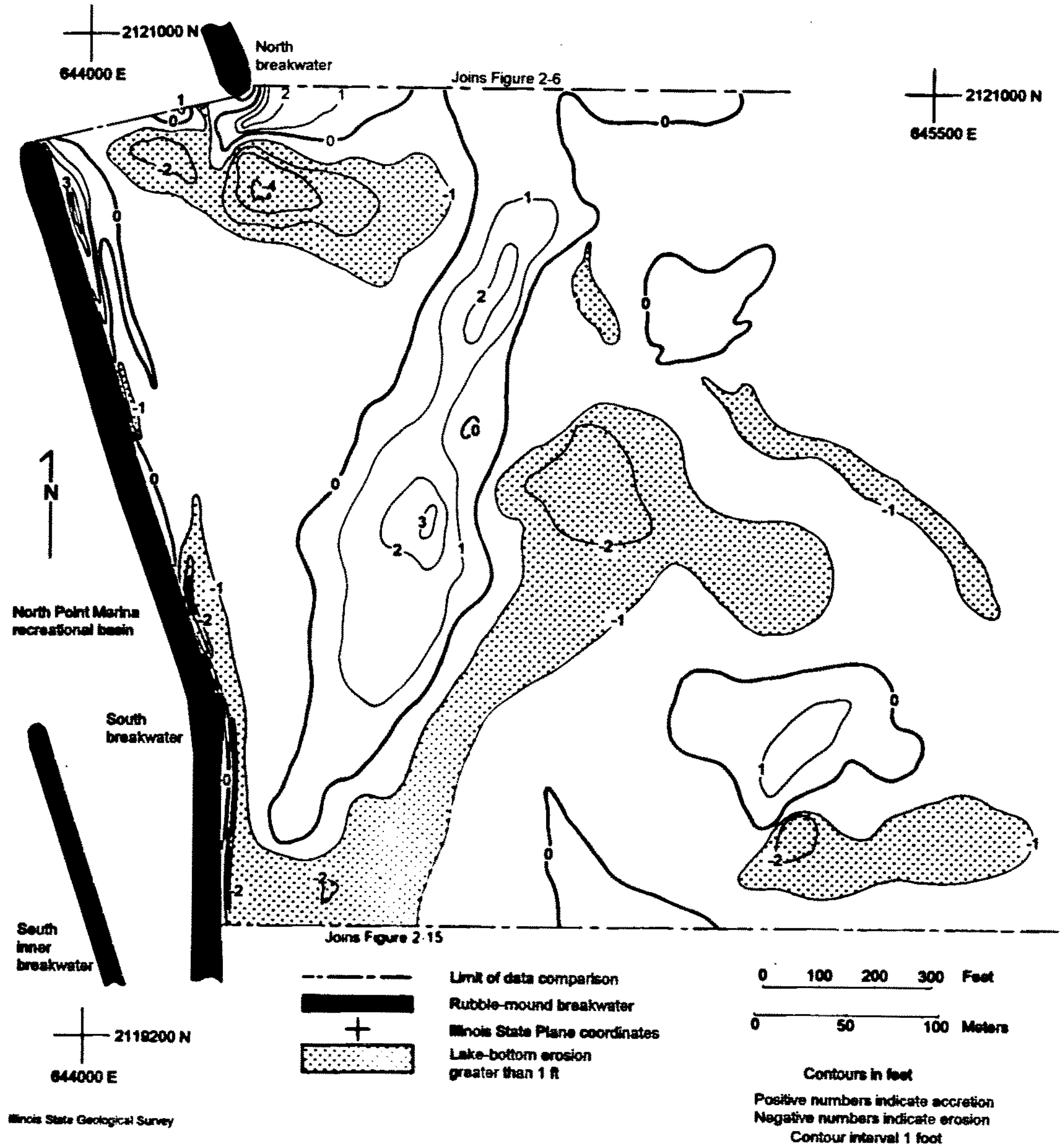


Figure 2-13 Isopach map of 1992-1995 lake-bottom changes in the south breakwater nearshore.

1987-1992 lake-bottom changes

The south breakwater nearshore had net accretion between 1987 and 1992 (Table 2-3). Accretion occurred primarily along the length of the south breakwater and adjacent to the southern tip of the north breakwater. Most accretion occurred between 1988 and 1989 along the south breakwater (Appendix B; Map B-2). This accretion is interpreted as the result of southerly waves and wave-induced currents moving sediment northward from the fan delta. This accretion along the south breakwater became subject to major erosion between 1989 and 1990 (Appendix B; Map B-3).

Table 2-3 Summary of erosion and accretion volumes in the south breakwater nearshore.[1]

	1987-88	1988-89	1989-90	1990-91	1991-92	**1992-95[2]**
Accretion (+) (cu yds)	10,300	54,800	15,200	22,000	14,600	**9,100**
Erosion (-) (cu yds)	29,400	16,900	39,600	10,000	11,700	**28,900**
Annual net change (cu yds/yr)[3]	-19,100	+37,900	-24,400	+12,000	+2,900	**-6,600**
Normalized annual net change (cu yds/yr/shoreline ft)[4]	-13	+25	-16	+8	+2	**-4**

[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; erosion and accretion volumes are for the three-year summation and annual net change is a three-year average. Total net change from 1992-1995 equals -19,800 cu yds.**
[3] Net accretion is indicated by a positive number and net erosion is indicated by a negative number.
[4] Shoreline distance (1500 ft) is based on measurement along a north-south line bounded to the north and south by the defined limits of the nearshore reach. Numbers are rounded to the nearest whole number. Net accretion is indicated by a positive number and net erosion is indicated by a negative number.

Summary of 1987-1995 nearshore bathymetric change

The net, eight-year lake-bottom change lakeward of the south breakwater between 1987 and 1995 amounts to net erosion of 10,500 cu yds (Table 2-3). Between 1987 and 1992, the annual net change varied from year to year because of gains and losses associated with the supply and transport of sediment from the fan delta. Between 1992 and 1995 this nearshore became net erosional. The development of the 7,200 cu yd accretional lobe between 1992 and 1995 was not of sufficient volume to outweigh the total erosion.

Most of the construction-related accretion between 1987 and 1989 occurred between the breakwater and about 400 ft lakeward of the breakwater (Appendix B; Maps B-1, B-2). Within this band, which generally lies landward of the 1995 12-ft LWD contour, the 1995 bathymetry indicates that the bottom elevations are now 1 to 4 ft shallower than the 1987 pre-construction lake bottom. Thus some of the construction-related accretion still resides along this zone. In contrast, lakeward of the 1995 12-ft contour, much of the 1995 lake bottom generally lies 1 ft lower than the 1987 lake bottom.

VI South Parking Area Nearshore

The south parking area nearshore is here defined as the area lying between the approximate mid-point of the north-south segment of the NPM south breakwater, and a line projected east of the east-west trending section of Dead Dog Creek located about 2000 ft to the south (Fig. 2-1). These northern and southern limits correspond to ISGS profiles 32 and 52 respectively. These limits were chosen in consideration of a proposal to construct a submerged offshore breakwater (or reef) to protect the south parking area (Appendix D). The southern part of this nearshore reach crosses south of the marina/state park boundary. Figure 2-14 shows the 1995 bathymetry in the south parking area nearshore. Figure 2-15 is an isopach map showing lake-bottom changes based on a comparison of 1992 and 1995 bathymetry.

1995 bathymetry (Figure 2-14)

The two prominent features on the lake bottom off the south parking area are the submerged riprap that extends for about 600 ft southward from the south breakwater, and an enclosed trough that occurs between the submerged riprap and the shoreline (Fig. 2-14). Minimum depths across the submerged riprap in 1995 ranged from 5 to 3 ft LWD; a 9 ft LWD contour defines the enclosed trough. Characteristics of the submerged riprap are discussed in a subsequent section. Other than the area of the submerged riprap, the lake bottom opposite the south parking area is mostly featureless to at least 20 ft LWD, and contours are generally parallel to the shoreline. An irregular contour pattern lakeward of the 22 ft LWD contour suggests exposed clay (*i.e.*, glacial till). The steepest lake-bottom slopes occur adjacent to the shoreline and along the margins of the submerged riprap.

1992-1995 lake-bottom changes (Figure 2-15)

The south parking area nearshore was net erosional between 1992 and 1995 (Fig. 2-15). Between the shoreline and the 12-ft LWD contour, which generally lies within 400 ft of the shoreline, erosion lowered the lake bottom at an average rate of approximately 0.25 ft/yr. Approximately 80 percent of the 1995 lake bottom lies at an elevation below that of the 1992 lake bottom. The maximum erosion, up to 5 ft, occurred within 200 ft of the shoreline.

Accretion Accretion in excess of 1 ft was confined to a narrow strip of nearshore within 100 ft of the shoreline of the IBSP-North Unit beach nourishment site, located at the south end of the south parking area. Accretion was the direct result of beach nourishment during September 1994 and July 1995. Most of the accretion is attributed to placement of the 1995 nourishment, since the area was mapped during and soon after placing the nourishment and before the material could be redistributed by waves.

Minor accretion occurred in the small embayment where the south breakwater joins the riprap shore defense along the south parking area. This accretion during summer 1995 resulted from accumulation of material that was being dredged from the NPM entrance and being dumped, via slurry pipe, at the south end of the south breakwater. By September 1995, all subaerial expression of this feature had been removed by wave erosion.

Erosion Erosion was pervasive along this 2000 ft stretch of nearshore. The most severe erosion occurred in a narrow swath landward of the 10 ft LWD isobath and within approximately 300 ft of the 1995 shoreline. Most lake-bottom erosion was on the order of 1 to 2 ft (Fig. 2-15) with a localized maximum of 5 ft. This erosion maximum occurred along the shallow nearshore adjacent to the concrete cube and riprap revetment that protects the south parking area. Erosion also occurred farther offshore along the line of submerged riprap (see Submerged Riprap).

1987-1992 lake-bottom changes

The south parking area nearshore between 1987 and 1992 had net accretion (Table 2-4). Most of the nearshore accretion occurred between 1987 and 1989 (Appendix B, Maps B-1 and B-2) and was the direct result of building the fan delta (244,500 cu yds). However, some of this accretion (54,200 cu yds; Table 2-4) is now located landward of the south parking area's concrete cube and riprap revetment that was installed between October 1989 and December 1990. This 54,200 cu yds has thus been "locked up" and unavailable to the nearshore system since 1989-1990. Thus, while 229,600 cu yds of net nearshore accretion occurred between 1987 and 1989, only 175,400 cu yds of this material remained accessible to any subsequent erosion. In comparing rates of change in the nearshore, the latter volume is a more accurate representation of change during the 1987-1989 period. Using the adjusted volume, the net accretion between 1987 and 1992 amounted to 6,800 cu yds.

Erosion volumes were greatest between 1989 and 1990 when the supply of dredge material had ceased and the oversteepened and unstable beach and nearshore started to erode rapidly. Erosion has continued since 1990, but at decreasing annual rates (Table 2-4).

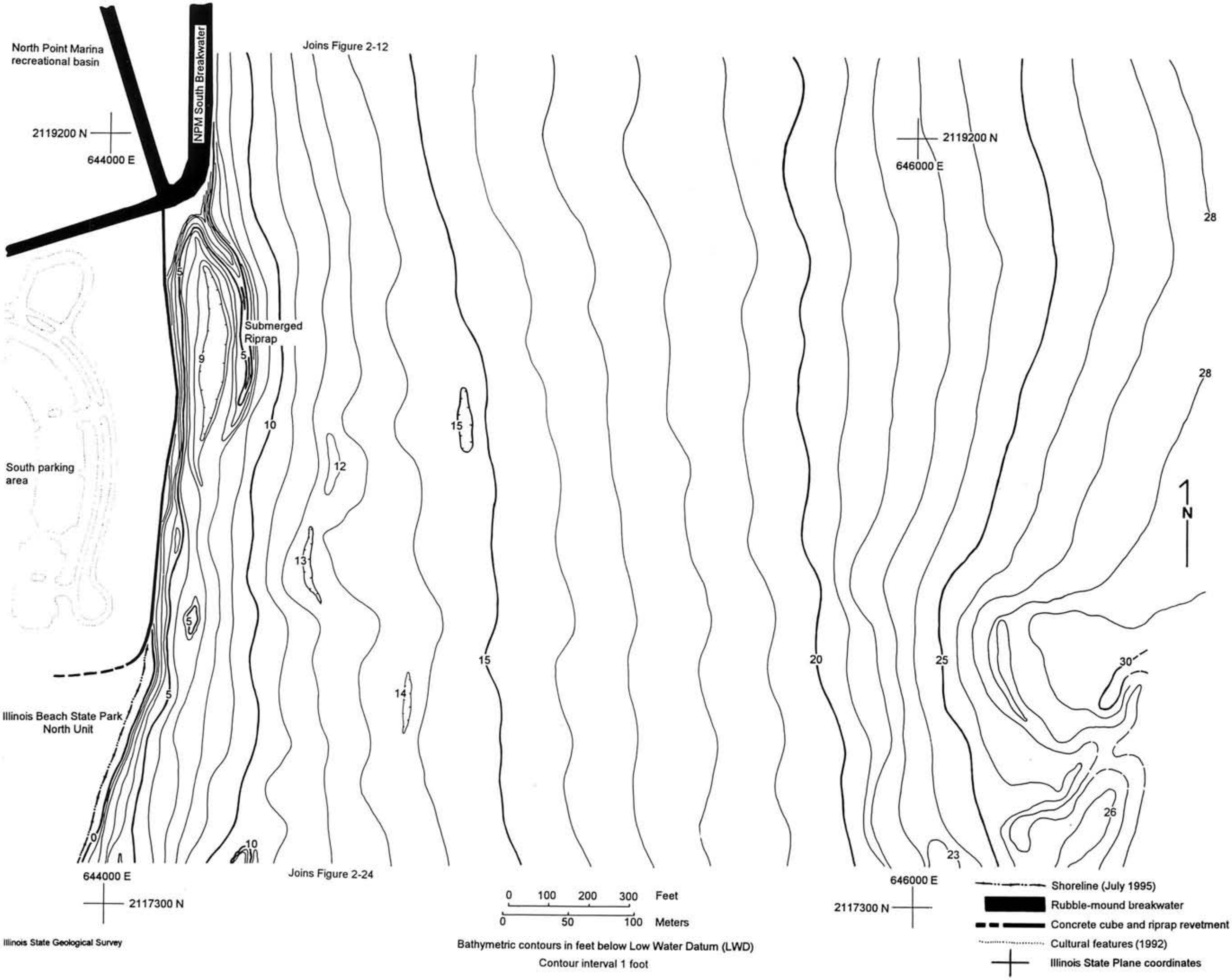


Figure 2-14 1995 bathymetry of the south parking area nearshore.

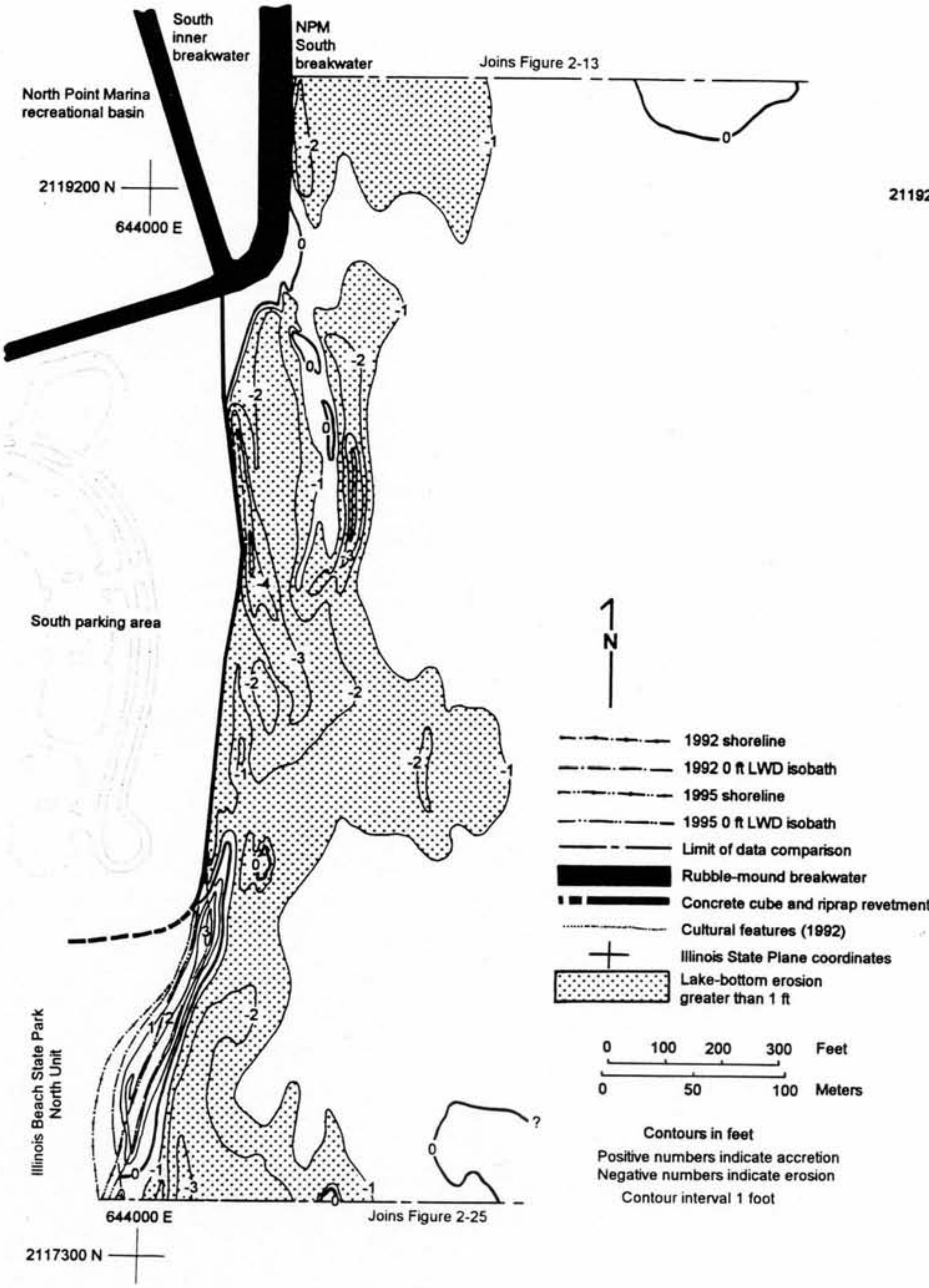


Figure 2-15 Isopach map of 1992-1995 lake-bottom changes in the south parking area nearshore.

Table 2-4	Summary of erosion and accretion volumes in the south parking area nearshore.[1]					
	1987-88	1988-89	1989-90	1990-91	1991-92	**1992-95[2]**
Accretion (+) (cu yds)	69,200[5] 122,100	121,100[5] 122,400	400	1,300	600	**1,500**
Erosion (-) (cu yds)	12,000	2,900	105,200	33,900	31,800	**33,300**
Annual net Change (cu yds/yr)[3]	+57,200[5] +110,100	+118,200[5] +119,500	-104,800	-32,600	-31,200	**-10,600**
Normalized annual net change (cu yds/yr/ shoreline ft)[4]	+29[5] +55	+59[5] +60	-52	-16	-16	**-5**

[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; erosion and accretion volumes are for the three-year summation and annual net change is a three-year average. Total net change for 1992-1995 equals -31,800.**
[3] Net accretion is indicated by a positive number and net erosion is indicated by a negative number.
[4] Shoreline distance (2000 ft) is based on measurement along a north-south line bounded to the north and south by the defined limits of the nearshore reach. Numbers are rounded to the nearest whole number. Net accretion is indicated by a positive number and net erosion is indicated by a negative number.
[5] Volume excludes 54,200 cu yds of sediment now lying beneath the south parking area landward of the cube revetment and therefore unavailable to the nearshore.

Summary of 1987-1995 nearshore bathymetric change

The net, eight-year, lake-bottom change between 1987 and 1995 amounted to -25,000 cu yds, indicating an erosional nearshore. This number excludes the 54,200 cu yds of material now trapped behind the south parking area revetment and located below 0 ft LWD, as discussed above. Net accretion occurred between 1987 and 1989, but since 1989, net erosion has dominated. The transition from an accretional to an erosional nearshore resulted from termination of dredge disposal operations at the fan delta in 1988. Addition of beach nourishment at IBSP-North Unit since 1990 has not been sufficient to counteract nearshore erosional losses.

An important observation lakeward of the south parking area is that the 1995 lake bottom in this area between the 5 and 12 ft LWD contours (100-400 ft offshore) lies 2 to 6 ft deeper than it did in 1987. The average deepening has been 2 to 3 ft. Thus, erosion has not only removed all sediment derived from the fan delta, but it has also lowered the lake bottom below the elevation that existed prior to marina construction. Lakeward of the 12 ft LWD contour, the 1995 lake bottom lies about 1 ft deeper than it was in 1987. The lake-bottom lakeward of the south parking area has had the most severe lake-bottom erosion observed anywhere in the nearshore adjacent to the marina. However, the erosion to the south, in the North Unit nearshore, is even more severe (see IBSP North Unit, Spring Bluff nearshore).

VII Submerged Riprap

Background

The name "submerged riprap" refers to approximately 600 ft of submerged rock that was originally placed as above-water shore protection along the lakeward edge of the fan delta between late autumn 1988 and early winter 1989. This riprap subsequently was undermined and eventually became submerged. The undermining was caused by wave-induced erosion of sand lakeward of and beneath the riprap. The location of the submerged riprap relative to the NPM facility is shown in Figure 2-1. The 1995 bathymetry at the submerged riprap is shown in Figure 2-14. In general, the submerged riprap forms a broad arc extending southward from the elbow in the south breakwater. The submerged riprap is important because it has significantly influenced the lake-bottom morphology lakeward of the northern half of the south parking area. In addition, the submerged riprap will lie beneath a segment of a proposed submerged reef which is part of planned shore protection for the south parking area (Appendix D; Patrick Engineering, 1993, Exhibit V-5; 1995, Sheet C-1).

The source of the riprap material was excess breakwater and revetment stone left over from marina construction, demolition debris from the construction site, and other miscellaneous stone, brick, and debris from the site. This material was dumped along the lakeward flank of the fan delta from the waterline up to the top surface of the sand pile which was then about four to six feet above lake level. Originally, no stone was placed below the water line. The southern limit of the riprap was determined by the amount of available stone and debris. Placement of the riprap was intended to halt the rapid recession of the shoreline that was occurring in fall 1988 along the northern edge of the fan delta. Although the riprap temporarily halted shoreline recession, the riprap rapidly shifted and subsided as erosion continued to remove underlying sand across the submerged part of the fan delta. The riprap was entirely submerged within two years of its placement. Comparison of the photographs in Figures 2-16 and 2-17 shows the amount of shifting and settling that occurred over one winter (winter of 1989-90).

In the discussion of coastal monitoring at NPM between 1987 and 1992 in Part 1, Figure 1-5 illustrates the shore erosion pattern that occurred south (downdrift) of the southern end of the riprap while the stone was still emergent during 1989. Figure 1-6 shows the erosion that occurred landward of the riprap during 1990 once the stone subsided sufficiently for waves to overtop it.

Bathymetric conditions 1990 - 1992

By summer 1990, some sections of the riprap had subsided sufficiently such that a bathymetric survey could be conducted with a shallow-draft boat crossing over the submerged stone along its southern part (Appendix A; Map A-4). Subsequent surveys in 1991 and 1992 could cross along all five lines of the ISGS survey net that intercept the riprap area (Profiles 37 through 41). These surveys documented continued lowering of the riprap and the erosion of the adjacent lake-bottom.

As of 1992, minimum depth over the submerged riprap was 0 to 2 ft LWD adjacent to the south breakwater. The submerged flank of the south breakwater supported the riprap and limited the degree of riprap subsidence in this area. Toward the south, away from breakwater support, the minimum depth contour was 3 ft LWD (Appendix A; Map A-6). An enclosed depression with a maximum depth contour of 7 ft LWD was located between the submerged riprap and the shoreline. On the east (lakeward) side of the submerged riprap, the 1992 survey documented a rather steep profile descending from 5 ft LWD to 10 ft LWD in a minimum distance of 65 ft (1:13 slope).

Bathymetric conditions 1995

As of summer 1995, the lake-bottom depression on the landward side of the submerged riprap had increased to a maximum depth between 9 and 10 ft LWD (Fig. 2-14). The depression thus deepened by at least 2 ft between 1992 and 1995. On the east side of the riprap, the 1995 lake bottom descended from 5 ft LWD to 10 ft LWD at an average slope of about 1:16. This reduction in slope since 1992 is related to a decrease in the elevation of the submerged riprap. Adjacent to the south breakwater, the minimum depth recorded across the submerged riprap remained at 0 to 2 ft LWD, the same as recorded in 1992. Here the riprap has apparently subsided as far as possible over the submerged flank of the south breakwater. Away from the influence of the south breakwater, the minimum-depth contour is generally 5 ft LWD, although a contour of 3 ft LWD persists along the southern part of the submerged stone. The area enclosed by the 5 ft LWD contour has had 2 ft of subsidence since 1992. The area of 3-ft minimum depth had a similar depth in 1992 and thus represents a localized area of stability. Other than the two stable areas, the 1992-1995 comparison generally documents continued subsidence over this three-year interval.

Figure 2-16 View of the riprap looking south from the south breakwater in October 1989. Note the variety of stone sizes and shapes. For comparison with the photograph in Figure 2-17, note the position and height above water of the concrete block supporting an upright steel pole, at left center with black arrow (Photo date October 4, 1989).

Figure 2-17 Same view of the riprap six months later in April 1990 showing the degree of riprap subsidence and landward erosion (Photo date April 13, 1990).

Magnitudes and rates of riprap settling

Comparison of the bathymetric profile data across the submerged riprap for 1991, 1992, and 1995 documents the magnitudes and rates of settling of the riprap and erosion of the adjacent lake bottom. As previously noted, data exist for five profile lines across the riprap (ISGS profiles 37 through 41; Appendix C). There is some uncertainty in the measurements of riprap settling made from profile comparisons because slight differences in position of the survey boat in different years can cause measurements to be made to different rocks or different parts of the same rock. These profiles also include the bathymetric data for 1990 which was collected prior to the riprap subsiding below water level.

Along all profile lines, during the four years 1991-1995, the crest elevation of the riprap settled between 1 and 3 ft. This gives an average annual rate of settling of 0.5 ft/yr. Along two of the five lines (profiles 37 and 39), the annual rate of settling from 1992 to 1995 slowed compared to 1991-1992. Along two of the lines (profiles 38 and 41), the rate of change from 1992 to 1995 increased compared to 1991-1992. Thus, varied conditions appear to occur with different parts of the riprap showing either decreasing or increasing rates of settling. Whether these trends are real or an artifact of survey-boat positioning and slight inaccuracies in the data collection is uncertain.

The important observation is that most of the riprap continues to subside. As of 1995, this riprap had yet to reach an equilibrium lake-bottom elevation. The settling of the submerged riprap does not involve the stone sinking into the lake-bottom sediment. The settling is a response to a widespread lowering of the lake bottom caused by the net erosion of lake-bottom sand (see South Parking Area Nearshore; Fig. 2-15). As of 1995, the base of the submerged riprap is at about 8 to 9 ft LWD. Considering past changes across the nearshore at the fan delta, erosion has been active to at least 15 ft LWD. Thus, if the erosion process continues, the submerged riprap has the potential to subside several more feet.

Influence of the submerged riprap on lake-bottom changes

Comparison of bathymetric data from 1989 through 1995 shows that the nearshore adjacent to the south breakwater and south parking area continues to deepen. Continued lakebed erosion is marked by the progressive landward migration of individual bathymetric contours. Annual changes in the position of the 10-ft LWD contour provide a useful reference for this persistent nearshore erosion (Fig. 2-18). The submerged riprap functions as a lake-bottom hard point, and it has retarded the rate of landward contour migration along most of the nearshore opposite the south parking area. This is indicated in Figure 2-18 by the relative position of the annual 10-ft LWD contours, and is also illustrated in Figure 2-14 which shows 1995 bathymetry. If the 8-

through 10-ft LWD contours in Figure 2-14 are followed northward along the south breakwater, and southward along the south parking area, the lakeward contour deflection is apparent along the submerged riprap.

If the submerged riprap were absent, water depths greater than those now observed (1995) would likely occur adjacent to the northern part of the south parking area. As a result of this deeper water close to shore, shore defense placed along the lakeward side of the south parking area would have been subjected to greater wave energy and increased rates of undermining and failure. The conclusion is that the submerged riprap has benefited the efforts to control erosion at the south parking area, but these benefits have been progressively diminishing as the riprap continues to subside.

A concern is that the submerged riprap has contributed to the wave-induced erosion landward of the riprap and the development of the erosional trough between the riprap and the shore. As the riprap has been subsiding, this erosional feature has become deeper. This deepening could be detrimental to the adjacent revetment. A similar erosional trough could be expected to occur landward of a submerged reef proposed to be built lakeward of the south parking area (see the following discussion and Appendix D).

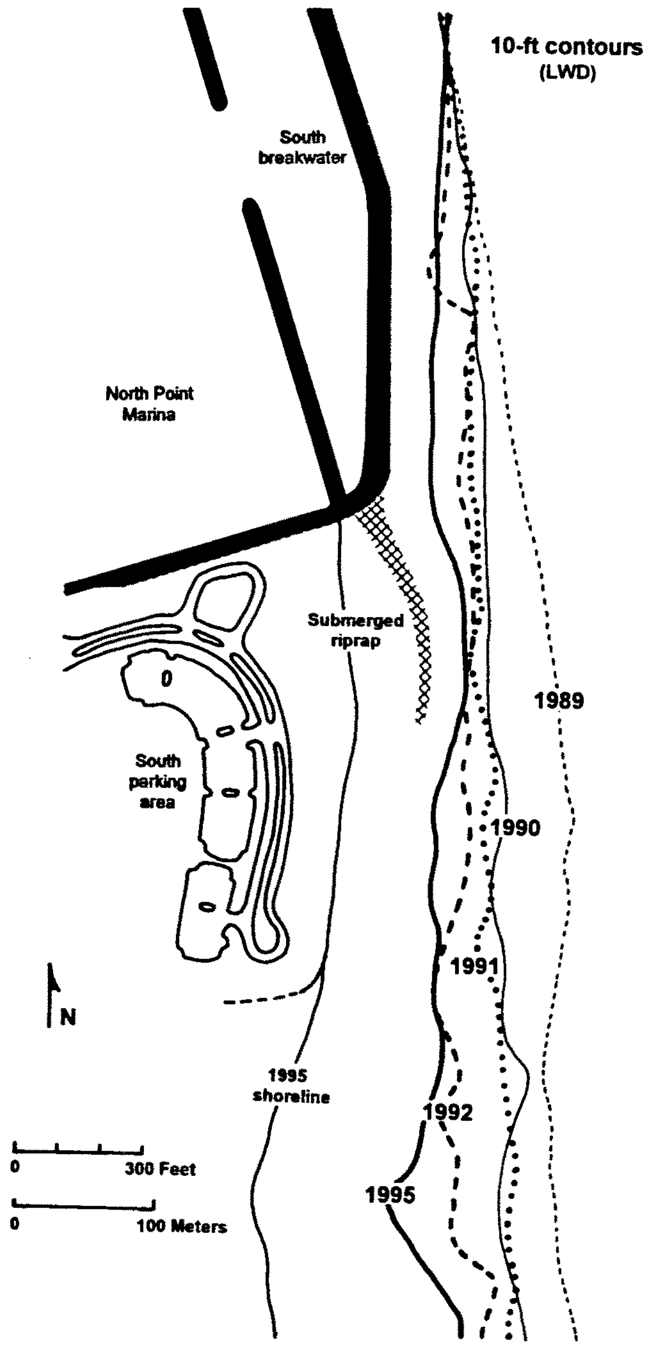


Figure 2-18 Comparison of the position of the 10-ft LWD contour lakeward of the south parking area between 1989 and 1995. The 10-ft contour is used here as an indicator of profile steepening and the amount of landward contour migration with time. The submerged riprap has slowed contour recession lakeward of the northern part of the south parking area.

VIII South Parking Area Proposed Shore Protection

As of late autumn 1995, a project plan is being reviewed by federal and state permitting agencies for the construction of erosion protection for the south parking area. This proposed project involves building a stone revetment along the existing shore, and building a submerged "reef" in the nearshore to trip waves and reduce wave energy impacting the stone revetment (Patrick Engineering Inc., 1995). The reef will be a rubble-mound structure that will rest on the existing lake-bottom sand. However, a segment of the reef will rest on some of the submerged riprap. The ongoing lake-bottom erosion at the south parking area in this area (Fig. 2-15) could lead to undermining of the reef and consequent subsidence of the reef stone. This may necessitate intermittent addition of stone to the reef to restore minimum design depths along the reef crest.

Detailed discussion of the coastal processes and the project engineering are beyond the scope of this report. Appendix D contains maps that show the location of the proposed reef superimposed on the local 1995 bathymetry, and the reef superimposed on the local 1992-1995 lake-bottom changes. Refraction of waves around the southern end of the reef may cause accentuated erosion in the shallow nearshore south of the parking area.

IX Volumetric Analysis of Sand Beneath the South Parking Area

Background

In the original NPM project plans, all sediment dredged from the marina basin and discharged to form the fan delta was intended to serve as a sand reservoir and feeder beach for the downdrift state park beaches and nearshore (Moffatt & Nichol Engineers, 1986). However, a change in project plans resulted in using the landward half of the fan delta as a parking area. To halt shoreline recession that could threaten these parking facilities, a concrete-cube revetment was constructed in November 1989 along the southern part of the fan-delta shoreline. This was subsequently extended northward to the south breakwater in December 1990, and later fortified with additional riprap. Thus, since 1989, a significant volume of sand and gravel initially intended as a feeder beach has been "locked up" landward of this shore defense and beneath the south parking area. Questions persist concerning the volume of this sand and gravel. A spatial analysis was conducted to compute this volume.

Methods

An isopach map was produced by comparing the topography and bathymetry that existed in the south parking area in 1989 with that existing in 1987 prior to the addition of sediment dredged from the marina basin. Producing a map of the pre-construction setting required merging bathymetric data collected by ISGS in 1987 with 1985 topographic data compiled by Abrams Aerial Survey Co. (Mapping 1985; Sheet 19662). The topographic data, referenced to NGVD 1929, were converted to LWD (see Table 1-2 for conversion factors). For the post-construction map, ISGS bathymetric data and south parking area topographic data were available for 1989. In addition, data were obtained from a topographic map of the south parking area prepared by Patrick Engineering, Inc. (1993).

The boundaries for the volume calculation were as follows:

- Northern boundary — The NPM south breakwater
- Western boundary — The vegetation line to the west of the parking area (approx. Easting 643,500). Photographic comparisons indicate no significant change in this line pre- and post-construction. An arbitrary boundary on the northwest is a line drawn from the landward limit of the south breakwater toward the south-southwest to the nearest point along the vegetation line.
- Southern boundary — An east-west line corresponding to the southern limit of the concrete-cube revetment (approx. Northing 2,117,850).
- Eastern boundary — A north-south line along the concrete-cube revetment on the lakeward side of the parking area (approx. Easting 644,200).

Superposition of the pre- and post-construction topography and bathymetry enabled construction of a sand (and gravel) isopach map. From this map, areas within contours were measured and multiplied by the mid-contour value to determine volume.

Results of volume analysis

Figure 2-19 shows the sand isopach map for the south parking area. In east-west cross section, this sand body is thinnest along the western margin where it lies atop the beach that existed prior to construction, and thickest along the line of the concrete-cube revetment where the sand body rests atop the former lake bottom. The maximum thickness is between 23 and 24 ft.

The volume estimate is 295,100 cu yds. This volume includes a correction (subtraction) of 5500 cu yds which is a volume estimate for the flank of the south breakwater lying beneath the sand pile. The 295,100 cu yds of sand (and gravel) has volume components both above and below the LWD plane. Comparison of the bathymetric data between 1987 (pre-construction) and 1989 (initial construction of the concrete-cube revetment) indicates that the volume below the LWD plane totals 54,200 cu yds. Thus, of the total 295,100 cu yds of marina-dredged sand beneath the south parking area, 18 percent is below the LWD plane, and 82 percent is above.

The best available estimate for the total volume dredged from the marina basin is approximately 1.5 million cu yds. The majority of this volume was discharged to the fan delta; a lesser volume was placed into a sand stockpile that resides to the west of the south parking area. For simplicity, 1.5 million cu yds is a volume commonly used for the contribution to the fan delta. Using this estimate, the volume of sediment residing within the area landward of the concrete-cube revetment accounts for about 20 percent of the volume initially discharged to the fan delta. The remaining 80 percent was distributed lakeward of the line of the cube revetment. Although some of this sand still resides across the nearshore, much has been eroded and transported downdrift. These percentages can be more precisely determined once the marina basin total dredge volume is computed, and once the volume of the western sand stockpile is determined.

At present, the best estimate of the "natural-state" littoral transport rate along the Illinois coast between the WI-IL state line and Waukegan Harbor is 90,000 cu yds/yr (U.S. Army Corps of Engineers, 1953, Table 11, p. 39). Thus, if the sand "locked up" within the NPM south parking area were available to supply this littoral transport (and assuming no contributions from updrift), the volume present would be sufficient to supply the littoral system in its natural state for 3.3 years (295,100 cu yds divided by 90,000 cu yds/yr). As discussed in a subsequent section (see Regional Coastal Monitoring), a preliminary sediment budget derived as part of this report indicates a minimum littoral transport rate of about 68,400 cu yds/yr. If the sand reservoir beneath the south parking area was eroded at this more conservative rate, the sand reservoir would last 4.3 years, again assuming no influx of sediment from updrift.

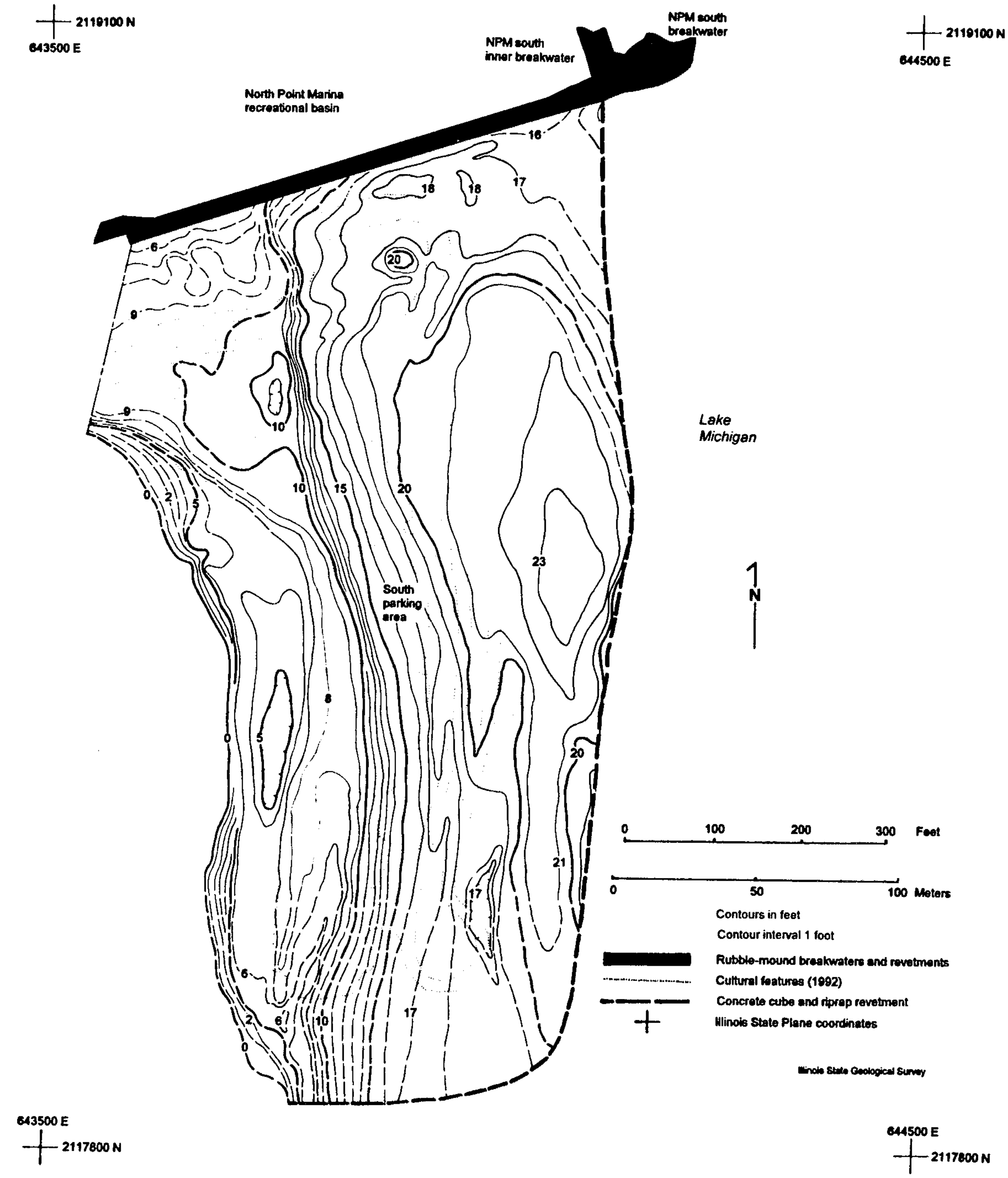


Figure 2-19 Isopach map of the NPM south parking area showing thickness of sand (and gravel) beneath the parking area that was derived from dredging the marina basin in 1987-1988.

X Breakwater Conditions

Engineering background

The north and south outer breakwaters are classified as "rubble-mound" breakwaters consisting of alternate layers of different sized quarry stone. The surficial stone of the breakwaters consists of 2- to 10-ton dolomite quarry blocks. Although the north and south breakwaters superficially appear to be of uniform design, a total of ten different cross-sectional designs (A through H, J and K) occur along twelve different segments of the breakwaters. These different designs consist of variations in stone size, crest elevation, and toe characteristics. Variations were engineered for the anticipated maximum wave energies that could impact different segments of the breakwaters.

The layer of base stones for the north and south breakwaters rests on either the beach or lake bottom that existed at the time of construction in 1987 and 1988. For the north breakwater, the landward end is built on former beach which had a maximum elevation of about + 7 ft LWD. The base elevation progressively decreases eastward to a maximum depth of about 14.5 ft LWD at the lakeward end of the breakwater near the marina entrance. The landward end of the south breakwater is also built on the 1987 beach which had a maximum elevation of about + 7 ft LWD. The base elevation decreases eastward to a maximum of about 11 to 12 ft LWD along the north-south segment of the south breakwater just south of the marina entrance. For most segments of both breakwaters, the design crest elevation is +11.9 ft LWD (590 ft MSL 1929). The exception is the middle section of the south breakwater which has a design elevation of +13.9 ft LWD (592 ft MSL 1929).

Construction of the outer breakwaters began in spring 1987 and was completed by autumn 1988. Thus, as of summer 1995, these structures are 7 to 8 years old. In a time frame of one or more decades, shifting and settling of stone can be expected for such massive structures. However, the observations discussed below suggest that some shifting and settling has occurred in excess of that expected for structures of this age.

North breakwater

The possibility of lake-bottom erosion along the base of the north breakwater was noted even before the breakwaters were constructed, and is discussed by Moffatt & Nichol, Engineers (1986, p. 86-87) in a report on potential coastal impacts near the marina. The reason for concern is that the north breakwater is subject to the direct impact of northeasterly waves which are the highest-energy waves along this coast. Two primary factors are potentially capable of causing scour along the toe of the north breakwater. These are:

1) Incident and breakwater-reflected waves could increase shear stresses on the lakebed and thereby induce erosion.

2) Increased current velocities could result when northeasterly waves induce set-up in the North Beach nearshore area, and the resultant southward flow of water around the breakwater occurs at velocities capable of eroding the lake bottom.

Significant lake-bottom erosion adjacent to the north breakwater may undermine the breakwater and cause differential settling of the breakwater stone.

Documented lake-bottom erosion adjacent to the north breakwater Bathymetric data indicate the development of an elongate lake-bottom depression generally trending NW-SE along the northeast-facing lakeward side of the north breakwater. First documented in 1988, this feature can be seen in the bathymetric maps included in Appendix A (Maps A-2, A-4, A-5, and A-6) and in the 1995 bathymetry along the north breakwater (Fig. 2-5). Table 2-5 summarizes the lake-bottom changes recorded from 1988 through 1995.

Table 2-5 Summary characteristics of the lake-bottom depression adjacent to the north breakwater (1988-1995).

	1988	1989	1990	1991	1992	1995
Distance from north breakwater (ft) [1]	150	200	70	100	90	40
Maximum depth of depression (ft LWD) [2]	16	15	13	16	16	11
Minimum closed contour depth (ft LWD) [3]	15	n/a [6]	13	16	15 [7]	n/a [6]
Depression relief (ft) [4]	2	1	2	3	6	2
Depression length (ft) [5]	280	300	600	650	650	850
Reference Appendix map (or Figure)	A-2	A-3	A-4	A-5	A-6	(2-5)

[1] Distance is measured orthogonal to the lakeward face of the breakwater from the waterline.
[2] Depth is based on the deepest contour that defines the depression. The north breakwater base elevation adjacent to the depression lies between 10 and 13.5 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 lake-bottom depression adjacent to the north breakwater is a dynamic feature. The general NW-SE orientation of the feature has been fairly constant, but the depression has varied in width, length, maximum depth, and distance lakeward of the breakwater. Between 1988 and 1995, the depression grew in length from 280 ft to 850 ft (Table 2-5) and moved closer to the north breakwater. The base elevation of the north breakwater in the vicinity of the depression is 10 to 13.5 ft LWD. When the depression reached its maximum recorded depth of about 16.5 ft LWD in 1988, 1991, and 1992, it was up to 3.5 ft below the base elevation of the nearby segment of breakwater.

Figure 2-20 shows a cross section of the north breakwater and the adjacent depression for the six years that the depression appeared on bathymetric data. This particular line of section illustrates the worst-case conditions in 1991 and 1992 when the base of the depression was 3.5 ft below the base of the breakwater and within 60 ft of the breakwater.

1990 diver inspection In a cooperative effort with the ISGS in August 1990, U.S. Geological Survey (USGS) divers made a reconnaissance SCUBA inspection of the lakeward edge of the extended toe of the north breakwater to determine if erosion was causing stone instability (Circe and Blackwood, 1991). Near the inner daymarker, they observed evidence of voids beneath some of the breakwater stone suggesting a winnowing of sand. Appendix E contains text and an illustration from this diver survey.

1995 observations No above-water evidence of stone shifting or settling along the north breakwater was apparent at any time during ISGS field studies at NPM through 1992. During field work in summer 1995, however, an apparent sag in the breakwater crest was observed along the northeast-facing section between the inner and outer daymarkers. The location of the sag corresponds with the segment of the breakwater that is adjacent to the lake-bottom depression previously discussed.

Figures 2-21A and 2-21B are views from the south breakwater looking northward to the north breakwater. Figure 2-21A provides an overview; Figure 2-21B is a closer view centered on the area of maximum sag. In this closer view, the photo has been composed to use the distant lake-level horizon as a reference. This horizon is visible in the area of sag, but is below the crest of the breakwater on either side of the sag. An additional, less extensive area of possible differential settling occurs to the right (eastward) of these two views.

The amount of apparent vertical settling on the north breakwater is unknown at this time. Data were not collected as of this report to determine differences between existing crest elevations and those at the completion of breakwater construction. Also, no early post-construction photographs have been recovered to make photographic comparisons with present conditions. A visual estimate is that the maximum displacement in the central sag is 1.5 to 2 ft. To accurately determine the degree and extent of settling, a detailed survey is recommended to compare existing breakwater elevations with early post-construction data.

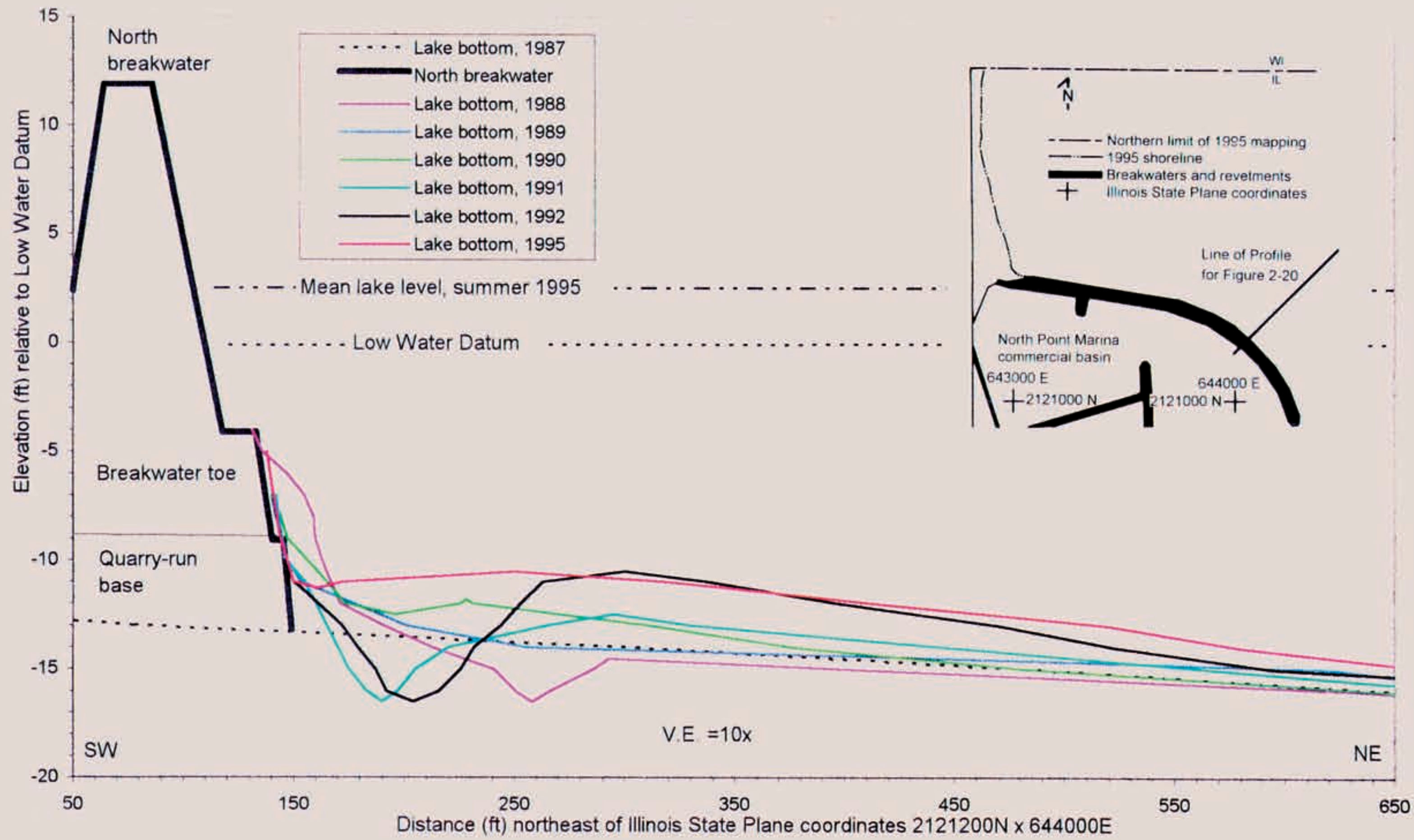


Figure 2-20 Cross section showing the relationship between the marina north breakwater and the adjacent lake-bottom depression.

Figure 2-21A View looking north toward the north breakwater "sag" from the north end of the south breakwater. The extent of a sag in the crest can be seen by comparing the breakwater crest against the horizon. The sag is located between the inner and outer daymarkers (not visible in the photo) (Photo date July 18, 1995).

Figure 2-21B Closer view of north breakwater "sag" looking north from the south breakwater. Photo is centered on the area of sag. The extent of sag is indicated by the horizon that can be seen in the distance where the crest elevation has decreased. Note two adult persons at left for scale (Photo date July 18, 1995).

South breakwater

The middle section of the south breakwater was constructed with a crest elevation 2 ft higher than both the more northern and southern sections (*i.e.*, 592 ft MSL compared to 590 ft MSL). Thus, even if the breakwater has not settled, there is a perception of differential settling on either side of this higher segment. However, some settling of stone has been suspected since at least 1992 along a segment at the southern end of the breakwater (landward of the inner daymarker; C. Price, NPM Harbormaster, pers. comm.).

1995 observations Figure 2-22 shows an area of discontinuity in crest elevation at a location about 360 ft north of the inner daymarker. Pipe for the ongoing hydraulic dredging of the marina is visible in the photo and provides a useful indicator of irregularities in the breakwater crest elevation. This particular site of stone displacement is the most severe observed anywhere on the south breakwater. Estimated settlement is 1 to 1.5 ft.

Figure 2-22 View showing localized subsidence of capstones along the middle section of the south breakwater. Discharge pipe for hydraulic dredging lies along the breakwater crest. This sag is located about 360 ft north of the inner daymarker which is visible in the distance. Note colored 1-ft increment bands on the prism pole for scale (Photo date July 18, 1995).

Possible causes of breakwater differential settling

Additional observations and survey data are needed before the magnitude and causes of any differential settling can be determined. Where apparent settling has occurred, the stone along both the lakeward and landward sides of both the north and south breakwaters shows no apparent outward displacement. Thus, the settling is uniform across the width of the breakwater. The possible factors contributing to the settlement are: 1) compaction of sediment beneath the breakwaters; 2) shifting, settling, and/or winnowing of quarry-run stone at the base of the breakwaters; or 3) winnowing of lakebed sand from beneath the breakwaters.

A cause and effect relationship may exist between the apparent sag in the north breakwater and the nearby lake-bottom depression. Since the depression has at times had a maximum depth below the base of the breakwater, the depression may have been associated with processes that removed sand from beneath the breakwater.

ILLINOIS BEACH STATE PARK / NORTH UNIT

General Statement

Studies in 1995 within the limits of the North Unit of Illinois Beach State Park (IBSP) focused on its northern part. The area studied consisted of approximately 3000 ft of shore between the NPM south parking area and the headland formed by the steel-sheetpile shore defense at the north end of Camp Logan. This segment of the North Unit was also studied by ISGS between 1987 and 1992 as part of annual bathymetric mapping in the vicinity of NPM.

Three geographic names are used in this discussion of the IBSP North Unit. These names were adapted by ISGS to assist in identifying geographic areas and are defined as follows:

North Unit nourishment stockpile: This refers to the beach area immediately south of the NPM south parking area where sand has been placed for beach nourishment since 1990. The nourishment stockpile lies between the south parking area and the mouth of Dead Dog Creek (Fig. 2-1).

Spring Bluff beach: This refers to the beach area extending from the mouth of Dead Dog Creek to the north side of the Camp Logan headland. The name is derived from the former community of Spring Bluff that existed along this lakefront area prior to the 1980s.

Camp Logan headland: This refers to the sheetpile-protected shoreline protrusion at Camp Logan. The name does not refer to a specific place along this shoreline promontory, but is a general name for the area.

1995 studies at IBSP North Unit are discussed under the following headings:

I Dispersion of 1994 Beach Nourishment
II Monitoring of 1995 Beach Nourishment
III Spring Bluff Nearshore
IV Spring Bluff Shoreline Changes Since Marina Construction
V Model for Spring Bluff Shoreline Recession

I Dispersion of 1994 Beach Nourishment

In September 1994, 32,000 cu yds of new sediment was added to the North Unit nourishment stockpile. This 1994 nourishment was a moderately sorted, angular, fine gravel ("pea gravel") from an inland quarry. Based on visual comparison with grain-size charts, the grain size ranged from 2 to 15 mm. The median grain size was approximately 6 mm. This nourishment was coarser than the medium to coarse sand previously supplied to the nourishment stockpile. Most of that pre-existing sand (and gravel) came from the 1987-1988 dredging of the marina basin, but some was also supplied in 1990 from dredging at Prairie Harbor Yacht Club on the Wisconsin side of the WI-IL state line.

The distinctive size and angularity of the 1994 nourishment gravel allows it to be readily identified along the downdrift beaches. In July 1995, the downdrift leading edge of this material could be identified 2800 ft to the south at the Camp Logan headland. Here the pea gravel dominated much of the beach. The steel-sheetpile on the north side of the headland had acted as a partial barrier to southward transport of this material. Some pea gravel was present as a progressively decreasing fraction of the beach sand population at sites to the south of the Camp Logan headland, but the bulk of the pea gravel was on the updrift side of the structure. Because the headland did not totally block southward transport of the gravel, and because the dispersion of the gravel in the nearshore was not monitored, the downdrift leading edge of the gravel on the beach represents a minimum dispersion distance.

The downdrift dispersion distance results in a minimum transport rate of 2800 ft in 10 months or 3350 ft/yr (0.6 mi/yr) for the pea gravel. This is a useful reference number for ongoing nourishment projects as a means of estimating expected rates of dispersion. This minimum rate of 0.6 mi/yr applies to moderately sorted pea gravel moving along the beach by swash and backwash; transport rates may be higher in the shallow nearshore in the zone of plunging waves. Finer-grained nourishment, such as that supplied to the North and South Units in July 1995, would be expected to move downdrift at a rate exceeding 0.6 mi/yr.

II. Monitoring of 1995 Beach Nourishment

Nourishment characteristics and emplacement

Between July 15 and July 27, 1995, new nourishment was added to the North Unit stockpile. This sediment was a moderately to poorly sorted fine to medium sand. Granules and pebbles comprised no more than 10 percent of the sediment. Some clay-silt clasts were present as a minor component. The total volume added was 20,000 cu yds. The nourishment was placed such that the contribution was about 40 cu yds per shoreline foot of the nourishment stockpile. Based on a comparison of ISGS profile surveys before and after the nourishment was supplied, the 1995 nourishment increased the stockpile area from 8200 sq yds (June 1995) to 11,400 sq yds (July 1995).

The nounshment material was obtained from storage stockpiles at the Commonwealth Edison Waukegan Generating Station (Fig. 1-2). The sediment was originally derived from maintenance dredging of that facility's intake and discharge channels and cooling basin prior to spring 1995. The material was trucked to the North Unit nounshment site and dumped along the lakeward flanks of the existing stockpile. The final stage of distributing the new material involved grading the top surface to an average slope of approximately 1:14 so that the lakeward edge of the stockpile ranged from 1 to 4 ft above lake level. This grading was done in part for public safety to minimize high scarps along the lakeward edge of the stockpile.

Monitoring scheme

In June 1995, ISGS established a monitoring scheme consisting of a series of four east-west profiles at 100-ft spacings across the existing stockpile where the new material was to be added. These lines were extended into the shallow nearshore. Survey points were also collected around the perimeter of the stockpile and along the scarp crest for comparison with future scarp positions. The June 1995 survey provided documentation of the topography and geometry prior to the 1995 nourishment. Surveys were repeated in late July 1995 to document conditions immediately after the nourishment operations. Subsequent surveys were done on a monthly basis through November 1995.

Monitoring observations (July - November 1995)

As the nourishment was supplied and distributed, some regrading of the pre-existing nourishment stockpile occurred. Lakeward displacement of the local shoreline thus resulted from both the addition of nourishment and the "skimming off" of some pre-existing sediment that was pushed lakeward. As a result of the regrading, the southern part of stockpile was lowered by 0.5 to 2 ft compared to its elevation prior to the addition of the July 1995 nourishment.

Erosion along the lakeward margin of the stockpile began immediately following completion of the nourishment operations. The resulting scarp and shoreline recession were minimal, however, compared to the changes that occurred during a storm of September 7 and 8 which was the first major storm event to impact this new stockpile. Nearshore waves reached heights of 6 to 8 ft. The two-day duration of high waves exacerbated the shore erosion. Through the remainder of 1995, no storm occurred with comparable wave energy. Data collected during the September 7-8 storm event document the erosional impact of this single event.

Appendix F shows data for the four profiles across the stockpile between late June and early November 1995. Along all profiles, most of the landward shift of the nourishment profile occurred during the storm of September 7-8. The September 8 scarp position was located 40 to 70 ft landward of its location on July 28. Figure 2-23 shows map-view positions of the scarp crest prior to and following the addition of the 1995 nourishment. By September 8, much of the scarp crest had retreated landward to its approximate location prior to the addition of the 1995 nourishment. Just north of Profile 48, severe erosion brought the scarp crest landward of the pre-nourishment position. The profiles in Appendix F indicate that as the stockpile eroded, most of the sand accumulated on the lake bottom at depths less than 5 ft LWD. Thus little, if any, nourishment sand was lost to deep water. The nourishment was being dispersed downdrift in a narrow band within 250 ft of the shoreline.

By November 1995, all of the July 1995 nourishment (20,000 cu yds) had been dispersed from the stockpile. Essentially, it was the single September storm that was responsible for this dispersion.

A principal factor influencing erosion patterns and rates along the North Unit stockpile is an elongate distribution or "apron" of boulders and cobbles on the beach along the northern part of the nourishment stockpile. The boulders and cobbles extend southward as far as Profile 49. This rock apron is the product of southward dispersion of different generations of shore-defense materials from the NPM south parking area since 1989. The rock armors the shore and prevents the northern part of the stockpile from eroding as rapidly as would occur otherwise. The influence of this rock armoring can be seen in Figure 2-23 where the nourishment stockpile has its maximum width between the concrete cube revetment and Profile 48. The stockpile has its minimum width along the first segment of unarmored shore between Profiles 49 and 50.

Nourishment in December 1995

Additional sand totaling 33,000 cu yds was placed at the North Unit nourishment site starting in mid-December 1995 and continuing until early January 1996. The nourishment sand was obtained from the stockpile at the Waukegan Generating Station as was done in July 1995. Unlike the work of July, this December/January nourishment included placement of sand into numerous embayed erosional areas along the landward side of the revetment protecting the south parking area. These erosional features on the landward side of the revetment had been present since at least spring 1995. Data concerning the dispersion of this December/January nourishment will be included in the report for 1996 (Year-2) study findings.

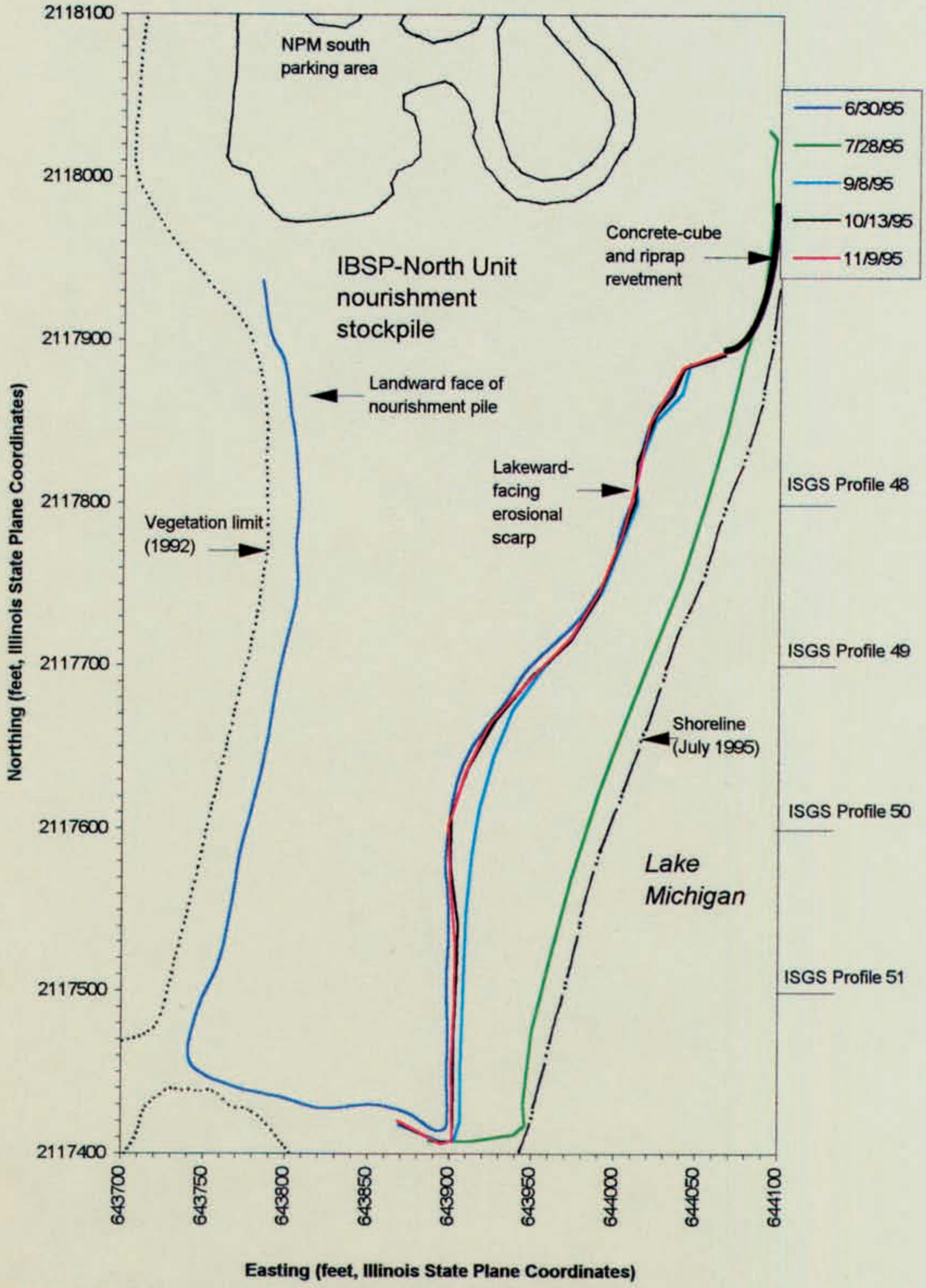


Figure 2-23 Map summary of changes to the North Unit nourishment stockpile between June and November 1995. The June 30 scarp position was surveyed prior to nourishment; the July 28 data show maximum lakeward extent of the stockpile nourishment.

III Spring Bluff Nearshore

The Spring Bluff nearshore is here defined as the area lying between a line projected east of the east-west trending section of Dead Dog Creek and the Camp Logan headland, located about 2600 ft to the south. These limits correspond to ISGS profiles 52 and 78, respectively. The northern limit for this reach was chosen in consideration of a proposal to construct a submerged breakwater (or reef) to defend the NPM south parking area (Appendix D). For comparison of 1995 bathymetric data and future data, it is advantageous to establish this limit south of the proposed construction area.

Figure 2-24 shows 1995 bathymetry for the Spring Bluff nearshore, and Fig. 2-25 shows lake-bottom elevation changes based on comparison of 1992 and 1995 bathymetry. Table 2-6 summarizes volumetric changes.

1995 Bathymetry (Figure 2-24)

The major feature in the Spring Bluff nearshore is a bar-trough pair that occurs within 250 ft of the shoreline (Fig. 2-24). Minimum depths along the bar are approximately 3.5 ft LWD. The relief across this bar-trough pair increases from approximately 1 ft in the north to 4 ft adjacent to the Camp Logan headland. Submerged ruins of former concrete bulkheads and other shore structures within 100 ft of the shoreline in the northern part of the nearshore cause localized bathymetric irregularities. Elsewhere, a regular pattern of bathymetric contours suggests a sand-covered lake bottom. The steepest lake-bottom slopes occur adjacent to the shoreline, as shown on Figure 2-24 by the closely spaced contours. Depths 100 ft lakeward of the shoreline range from 3 ft LWD in the north to 7.5 ft LWD in the south.

1992-1995 lake-bottom changes (Figure 2-25)

The Spring Bluff nearshore was net erosional between 1992 and 1995 (Fig 2-25; Table 2-6). The net volumetric change of -61,800 cu yds yielded a three-year average lake-bottom erosion rate of 20,600 cu yds/yr (Table 2-6).

Accretion Maximum accretion occurred within 300 ft of the 1995 shoreline and was associated with the nearshore bar. A bar was present along this shore prior to the marina construction as documented in the 1987 bathymetry (Appendix A; Map A-1). Beginning with the southward dispersion of dredged sediment in 1988, the bar became a more prominent feature, and it has persisted as a prominent feature in all subsequent surveys (Appendix A; Maps A-2 to A-6). The 1992-1995 bar accretion relates to continued southward dispersion of sediment from the North Unit nourishment stockpile, as well as to a landward shift of the bar-trough pair which caused infilling of the trough present in 1992 (Appendix A; Map A-6). Figure 2-25 documents the continued dynamic behavior of the Spring Bluff nearshore since construction of the marina. As shown by the lake-bottom change maps in Appendix B, the Spring Bluff nearshore had a dynamic history of accretion and erosion between 1988 and 1992. This resulted from continued adjustment to the input of sediment from the North Unit nourishment stockpile combined with a persistent trend of shoreline recession. The 1992-1995 changes are the most recent changes in this continuing trend.

Localized accretional areas occurred in water depths of 14 ft and 18 ft LWD. These were associated with infilling of northeast-trending bathymetric depressions that were present on the 1992 lake bottom.

Erosion Maximum erosion occurred in a narrow linear band lying approximately 100 ft lakeward of the 1995 shoreline and landward of the bar. In this band, average lake-bottom erosion was about 2 ft, with a localized maximum of more than 6 ft (Fig 2-25). The erosion is directly related to landward migration of the 0-ft LWD isobath between 1992 and 1995. This landward migration averaged about 50 ft. Lakeward of the bar, lake-bottom erosion and accretion were generally on the order of 1 ft or less. However, along the southern half of the nearshore reach, a narrow erosional band, marked by erosion from 3 to more than 6 ft, relates to landward migration of the 1992 bar-trough pair.

Considering the 1992-1995 nearshore erosion per shoreline foot, the Spring Bluff nearshore (-8 cu yds/yr/shoreline ft) was two times greater than that at the NPM south breakwater (-4 cu yds/yr/shoreline ft; Table 2-3), and 1.6 times greater than that at the south parking area (-5 cu yds/yr/shoreline ft; Table 2-4). Between 1992 and 1995, the Spring Bluff nearshore was the area of most extensive and rapid erosion between the WI-IL state line and the Camp Logan headland.

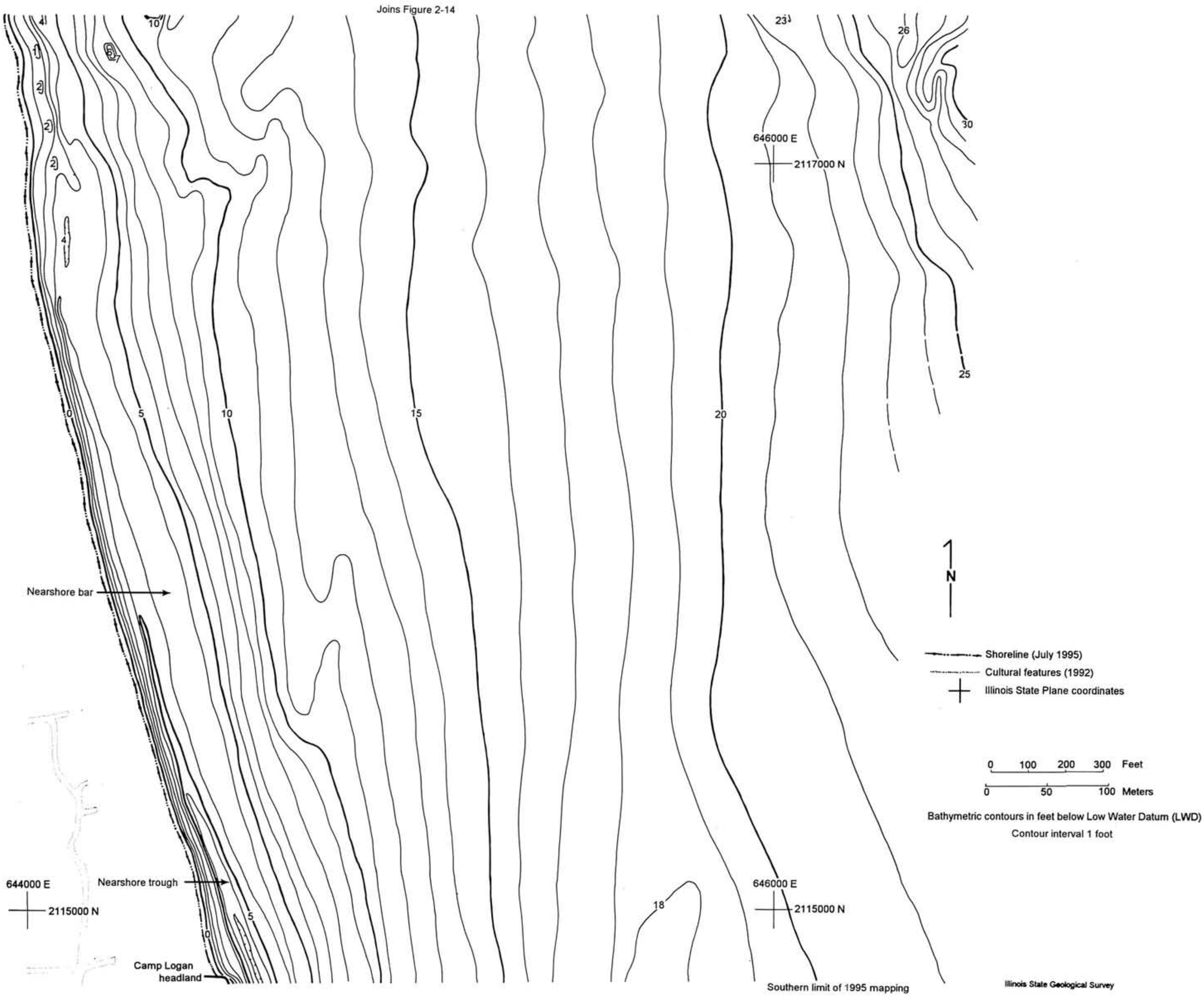


Figure 2-24 1995 bathymetry of the Spring Bluff nearshore. Bathymetric data were being collected during the early stage of the July 1995 nourishment and no major dispersion had yet occurred into this map area.

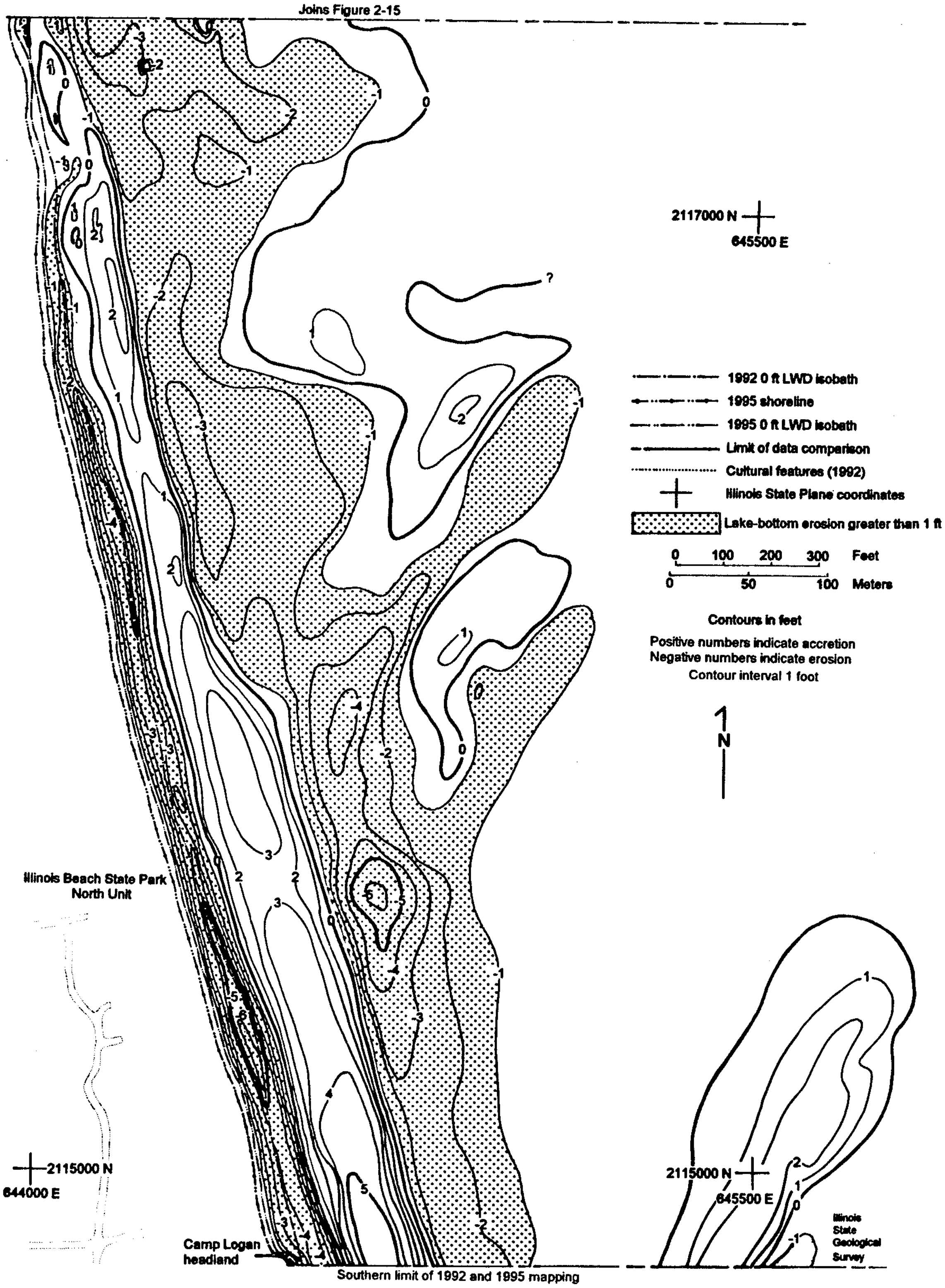


Figure 2-25 Isopach map of 1992-1995 lake-bottom changes in the Spring Bluff nearshore. The 1995 bathymetry was collected prior to dispersion of the 1995 beach nourishment and thus does not reflect input from this nourishment.

Table 2-6 Summary of erosion and accretion volumes in the Spring Bluff nearshore.[1]						
	1987-88	1988-89	1989-90	1990-91	1991-92	1992-95[2]
Accretion (+) cu yds	134,000	40,600	41,800	40,100	14,900	35,600
Erosion (-) cu yds	2,200	67,400	79,100	39,400	97,500	97,400
Annual net change (cu yds/yr)[3]	+131,800	-26,800	-37,300	+700	-82,600	-20,600
Normalized annual net change (cu yds/yr/shoreline ft)[4]	+51	-10	-14	0	-32	-8

[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; erosion and accretion volumes are for the three-year summation and annual net change is a three-year average. Total net change for 1992-1995 equals -61,800.
[3] Net accretion is indicated by a positive number and net erosion is indicated by a negative number.
[4] Shoreline distance (2600 ft) is based on measurement along a north-south line bounded to the north and south by the defined limits of the nearshore reach. Numbers are rounded to the nearest whole number. Net accretion is indicated by a positive number and net erosion is indicated by a negative number.

Summary of 1987-1995 nearshore changes

The major erosional and accretional areas between 1987 and 1995 occurred in the shallow nearshore within about 300 to 500 ft of the shoreline. The net, eight-year lake-bottom change across the Spring Bluff nearshore was erosion totaling 76,000 cu yds (Table 2-6). The record of annual sediment gain and loss from this nearshore area has been complex due to the influence of updrift beach nourishment. Table 2-6 summarizes these annual nearshore changes.

In the interval 1987-1988, the Spring Bluff nearshore had a net gain of sediment. This resulted from the influx of sediment from the north derived from the discharge and downdrift dispersion of sediment dredged from the marina basin. During the following two years (1988 to 1990), net erosion dominated across the nearshore. However, the area was still receiving considerable input of sediment from erosion occurring to the north along the nearshore and emergent part of the fan delta. Some of this sediment was temporarily deposited across the Spring Bluff nearshore, but the majority was apparently transported southward beyond the Camp Logan headland. From 1988 to 1990, the annual loss of nearshore sediment was nearly twice the annual gain. Thus, net erosion removed a volume of sediment greater than that gained between 1987 and 1988.

In the interval 1990-1991, the erosion and accretion were nearly balanced at about 40,000 cu yds each. At this time there was a reduced input of sediment supply from updrift because shore protection had been placed along the fan delta shoreline in 1989. The near balance of gain and loss is also partly due to beach nourishment at the North Unit nourishment site. In late summer 1990, approximately 150,000 cu yds of sand was stockpiled at the nourishment site. Erosion into this stockpile would have provided a considerable influx of sediment to the Spring Bluff nearshore during the 1990-1991 interval.

The 1991-1992 interval documents net erosion of 82,600 cu yds/yr. This is the most severe annual rate of net erosion documented for this nearshore. This severe erosion can be attributed to a diminished sediment supply from updrift because of reduced erosion at the fan delta combined with depletion of much of the 1990 beach nourishment.

In the 1992-1995 interval, the three-year average net change was erosion of 20,600 cu yds/yr. During this interval, 32,000 cu yds of beach nourishment was supplied in 1994, and this likely reduced the rate of net erosion that might otherwise have occurred. An additional 20,000 cu yds of nourishment was added to the stockpile in 1995, but little of this was yet dispersed at the time of the 1995 bathymetric survey, and thus it does not contribute significantly to the 1992-1995 accretion.

The important conclusion drawn from this eight-year record along the Spring Bluff nearshore is that, summing all annual changes from 1987 to 1995, the nearshore had a net loss of 76,000 cu yds. In general, the nearshore lakeward of the 1995 12 ft LWD contour is about 1 ft deeper than it was in 1987, while between the 7 and 12 ft LWD contours there has been 2 to 3 ft of erosion. Closer to shore, the comparison is complicated by the relative positioning of bar-trough pair from year to year. However, landward of the 1995 bar, lake-bottom elevations are generally 0.5 to 2 ft lower than they were in 1987. Thus, despite all the inputs from updrift erosion and dispersion of sediment from the North Unit nourishment stockpile, net erosion has prevailed across the Spring Bluff nearshore. The sediment supply from the nourishment stockpile is contributing to a reduction in the rate of shoreline recession and nearshore erosion. This sediment supply, however, is insufficient to produce a balanced sediment budget and thus eliminate net erosion in the nearshore and net shoreline recession.

IV Spring Bluff Shoreline Changes Since Marina Construction

Extreme and rapid shoreline changes have occurred between the marina and Camp Logan since marina construction. Initially there was extensive beach and nearshore accretion due to discharge of sediment dredged from the marina basin (Appendix B; Maps B-1 and B-2). Subsequently, there was extensive beach and nearshore erosion as this sediment was transported further southward and there was no appreciable supply from updrift to offset or diminish a net loss (Appendix B; Maps B-3 through B-5).

Because of concerns for the conservation of dunes and the natural setting along this segment of the North Unit, questions have been raised by park users concerning the degree to which erosion has adversely affected this shore since marina construction. Park users observing shoreline changes in the years since the marina was constructed have been able to witness extreme and rapid shoreline erosion, particularly between 1989 and 1990. As discussed in the previous section, net erosion has occurred since 1989. However, a possible misconception is that there has been a loss of beach area compared to what existed prior to marina construction. Comparison of map data and ground and aerial photography document that although substantial erosion has occurred, as of 1995 there still remains a net gain of beach width compared with 1987. The following discussion focuses on the data that document this net gain.

Shoreline changes (Figure 2-26A)

Figure 2-26A compares shorelines between the NPM south breakwater and the Camp Logan headland. Annual shorelines are shown for 1987 through 1992, and a 1995 shoreline documents most recent conditions. All shorelines are based on mapping by the ISGS while doing annual bathymetric surveys. Some of the differences in shoreline position result from differences in lake level, but because a steep slope characterizes much of the lower beach and shallow nearshore, the shoreline changes primarily reflect lateral accretion and erosion.

Comparing the 1987 shoreline with subsequent shorelines, the maximum lakeward shoreline position occurred in 1989 along the fan delta about 300-400 ft south of the south breakwater. Some erosion of this shoreline had already occurred by the time of shoreline mapping by ISGS in June 1989. Thus, the most lakeward shoreline position occurred sometime prior to this mapping, probably in late fall 1988 when dredging was completed. The hook-like feature in the 1989 shoreline (Fig. 2-26A) results from the erosion that was then ongoing beyond the southern limit of riprap protection (also see Fig. 1-5). The stability of the shoreline lakeward of the south parking area since 1990 results from the shore defense placed here in 1989 and expanded in 1990.

Within the North Unit, the most lakeward shoreline occurred in 1989 at the marina/state park boundary. 1989 corresponded to the time of maximum beach width and most lakeward position of the shoreline between the south breakwater and a point about two thirds the distance to the Camp Logan headland. In contrast, along the southern 1500 ft of Spring Bluff shoreline, maximum beach width occurred in 1990 (Fig. 2-26A). The one-year difference apparently reflects the time needed for the locus of sand accretion to move southward along the beach.

Although shoreline recession has been the general rule since 1989, the shoreline position has not yet reached landward of its 1987 position. The nearest approach occurs just south of the marina/park boundary where the 1987 and 1995 shorelines plot 45 ft apart (Fig. 2-26A). To emphasize that this beach area maintains a net gain compared to 1987, a stipple pattern has been added landward of the 1987 shoreline. No subsequent shoreline crosses into this stippled area.

Between the marina/state park boundary and the Camp Logan headland, between 1987 and 1989, marina-related accretion added 13 acres of beach area. As of 1995, 5 acres of this accretion remains. Thus there has been a persistent net erosion since 1989, but the beach maintains a net gain. The average rate of loss between 1989 and 1995 has been approximately 1.3 acres/yr.

Zero contour changes

Figure 2-26B shows the zero-ft LWD contours for 1987 through 1992, and for 1995. The advantage of comparing the zero contours is that these are elevations relative to a datum that is independent of lake level. Changes in the position of the zero-ft LWD contour solely reflect accretion or erosion. The 1987 lake level was higher than average, and thus comparing the zero contours makes use of a common datum.

Opposite the south parking area, the maximum lakeward position of the 0-ft LWD contour occurred in 1989 when it was about 525 ft lakeward of the 1987 location (measured perpendicular to the 1987 zero contour). Since 1991 the 0-ft LWD contour has been positioned along the line of shore defense that protects the south parking area.

South of the marina/park boundary, the maximum lakeward position of the 0-ft LWD contour occurred in 1988 about midway between the marina/park boundary and the Camp Logan headland. This was apparently caused by the early southward dispersion of dredge discharge, and by the initial placement of the discharge pipes at the southern end of the discharge area (Moffatt & Nichol Engineers, 1990). Closer to the marina/park boundary, the 1989 0-ft LWD contour occupied the most lakeward position (Fig. 2-26B).

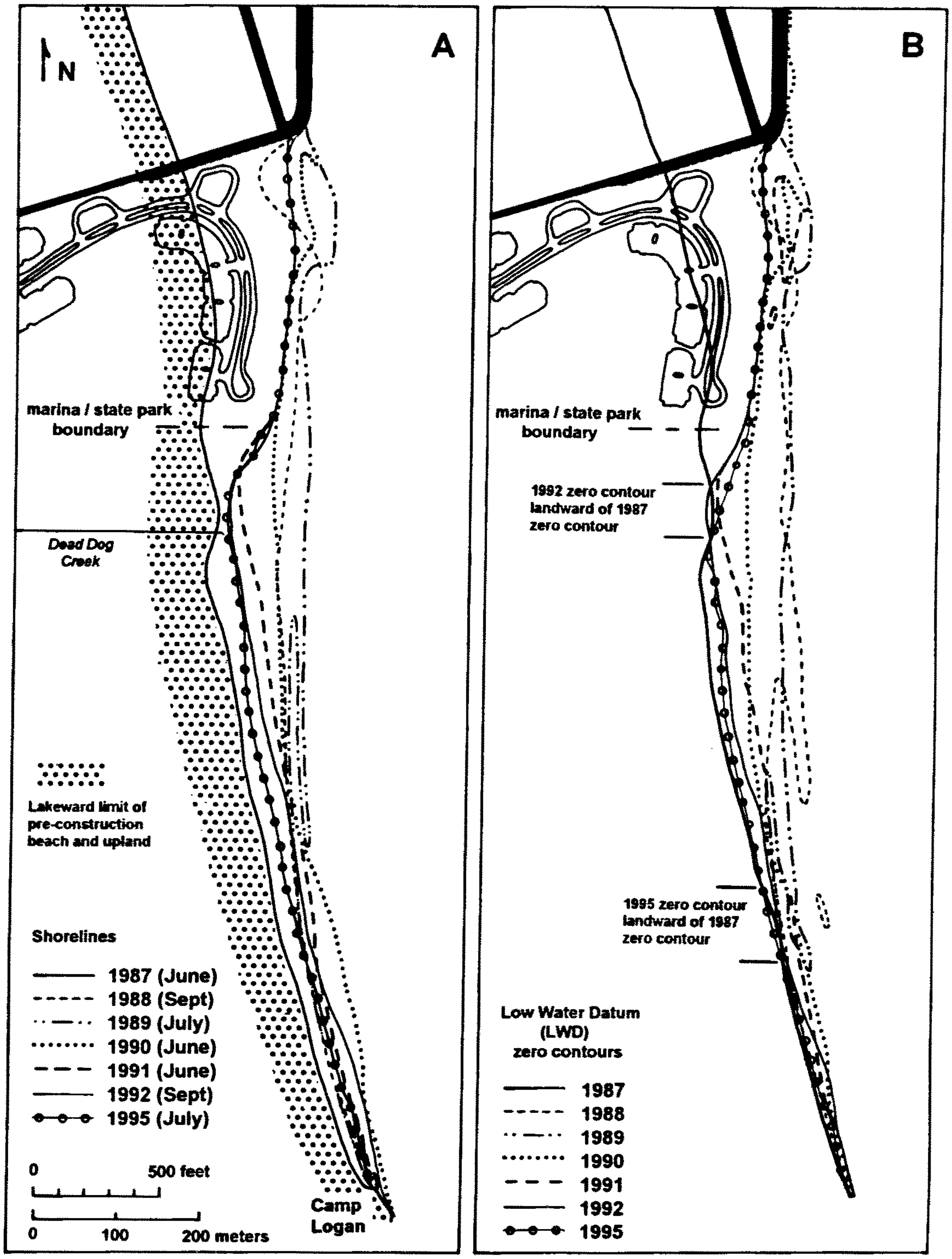


Figure 2-26 Maps showing 1987-1995 changes in position of the shoreline (A) and the Low Water Datum (LWD) zero-depth contour (B) between the North Point Marina south breakwater and the Camp Logan headland.

From 1990 through 1992, landward recession of the zero contour occurred along most of the nearshore. However, the nearshore immediately updrift of the Camp Logan headland continued to accrete and the 0-ft LWD contour moved lakeward as pulses of sediment were transported along the nearshore from updrift erosion.

Unlike the shoreline comparisons, there has been an intercept of the pre- and post-construction 0-ft LWD contours (Fig. 2-26B). The 1992 zero contour crosses landward of the 1987 zero contour along a 200-ft segment of nearshore located 250 ft south of the marina/park boundary. The 1995 zero contour also crosses the 1987 zero contour, along 300 ft of nearshore centered about 1150 ft north of the Camp Logan headland (Fig. 2-26B).

Factors influencing beach area and shoreline position

As previously discussed, the Spring Bluff nearshore had net erosion between 1987 and 1995 (Table 2-6). In contrast, comparing 1987 and 1995 shorelines (Fig. 2-26A) indicates that the Spring Bluff beach maintains a net gain. Updrift beach nourishment has been the prime factor in this gain. The initial addition of sand occurred between 1988 and 1989 from the southward dispersion of fan-delta sand from updrift (Fig. 2-26A). Subsequent updrift nourishment occurred in 1990 (150,000 cu yds), 1994 (32,000 cu yds), and July 1995 (20,000 cu yds). Southward dispersion of the 1990 nourishment was probably responsible for beach expansion at the south end of Spring Bluff between 1991 and 1992. Southward dispersion of the lesser volume of 1994 nourishment had the localized effect of slowing the change in shoreline position between 1992 and 1995 at the north end of Spring Bluff. Additional nourishment supplied in December 1995 postdates this map comparison.

An interesting factor responsible for reducing shoreline recession rates is the presence of ruins of former concrete bulkheads and other shore defense that presently reside in the nearshore. These ruins are in shallow water located in the northern part of the Spring Bluff nearshore. These structures were buried prior to 1990 by the accretion of sand resulting from the marina dredging. Shoreline recession and nearshore erosion first exposed parts of the ruins in 1990. Since that time nearshore erosion has exposed the entire assembly of ruins. These structures influence nearshore wave dynamics such that shoreline recession has decreased landward of the structures compared to areas immediately updrift or downdrift (Fig. 2-27). In effect, the ruins are acting as a submerged breakwater that is reduces the available wave energy impacting the shore.

The fact that a net gain in area still exists for Spring Bluff beach as of 1995 should not diminish concerns for beach erosion along this reach. All of the Spring Bluff shoreline and nearshore data clearly indicate net erosion. Within the near future, shoreline recession will eliminate most of the beach area that was gained since 1987. Beach nourishment volumes that have been added to this shore have been insufficient to negate the net erosion. In terms of shoreline recession, this is the most seriously eroding reach of shoreline in the study area. The following section discusses a model for shoreline erosion trends at Spring Bluff and the adjacent NPM south parking area.

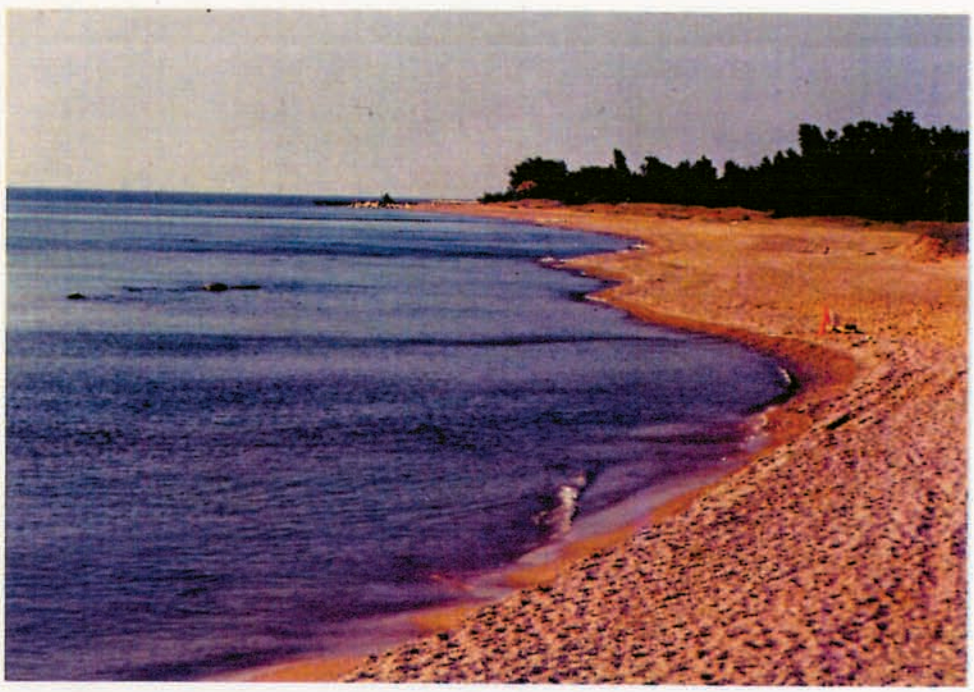


Figure 2-27 View showing the influence of submerged nearshore ruins on shoreline configuration just south of the marina/state park boundary. The view is southward toward the Camp Logan headland in the distance. Location of the nearshore ruins is indicated by one rock protruding above water level. Note the lakeward perturbation of the shoreline opposite the ruins which are acting like an offshore breakwater (Photo date July 17, 1995).

VI Model for Shoreline Recession at Spring Bluff Beach

Between 1988 and 1995, shoreline recession along the Spring Bluff beach was greatest just south of the marina/park boundary and minimal at the Camp Logan headland (Fig. 2-26A). The concrete cube and riprap revetment at the south parking area and the steel sheetpile at the Camp Logan headland act as "hard points" that anchor the shoreline at these two locations. The maximum amount of shoreline recession near the marina/park boundary is coincident with the first occurrence of undefended shoreline south of the marina.

If erosion was allowed to continue unimpeded, the ultimate extent of shoreline recession along this reach of shore can be estimated using established models of sandy coastline development between hard points. In map view, the ultimate shoreline configuration will be a concave-lakeward "hook" or "half-heart" shape approximating a logarithmic spiral. This type of shoreline configuration is technically referred to as a "logarithmic-spiral" shoreline, or simply a "log-spiral" shoreline (Schwartz, 1982).

Log-spiral embayments develop along sandy coasts between hard points such as rocky headlands or coastal structures. The predominant (strongest) waves approaching the coast are responsible for initially forming and then maintaining the log-spiral shape. The more oblique the approach of the incoming predominant waves, the better the capability of the waves to create this shape. For the Illinois shore, the predominant waves are from the northeast quadrant. The obliquely approaching waves refract around the updrift hard point and erode the shore into the log-spiral shape. The distance between the updrift and downdrift hard points determines how far landward the embayment extends. The idealized log-spiral shape occurs when all wave fronts ultimately approach the beach parallel to the shoreline. As a result, there is little or no lateral movement of beach sediment, and a stable shoreline configuration develops and is maintained. An excellent example of a log-spiral shoreline developed between 1988 and 1989 opposite the south parking area (Fig. 1-5). In the case of the south parking area, the southern end of the riprap along the fan delta acted as the updrift hard point around which northerly waves refracted to erode the fan delta beach and create a hook-shape shoreline in plan view (Terpstra and Chrzastowski, 1992).

Figure 2-28 schematically illustrates three potential shoreline configurations along the reach between the NPM south breakwater and the Camp Logan headland. In all three models, the Camp Logan headland forms the southern (downdrift) hard point; shorelines would converge towards this headland. Shoreline "A" would develop if the updrift hard point was the NPM south breakwater, and if the south parking area and associated shore defense were absent. Shoreline "B" would develop if the updrift hard point was the south end of the concrete-cube revetment built to protect the south parking area. Shoreline "C" would develop if the updrift hard point was the boulder and cobble armor that presently extends downdrift from the south parking area revetment. This rock debris has a low crest elevation that would allow wave over-topping and it would thus be a poorly defined hard point for wave refraction. However, this feature is used to illustrate that a reduction in the distance between the updrift and downdrift hard points reduces the maximum landward position of the log- spiral shoreline.

The erosional shorelines in Figure 2-28 are schematic. To accurately construct potential shoreline configurations would require a rigorous mathematical analysis to determine and quantify the parameters of the log-spiral equation for this shoreline reach. The distribution of rock and debris in the nearshore would complicate quantifying the influence of wave dynamics and the actual erosion/accretion patterns. These obstructions would cause the ultimate shoreline configuration to be a variation on an ideal log-spiral shape.

Figure 2-28 illustrates that all three potential shorelines would extend landward of the present vegetation line and reach into forested wetlands. Shorelines "B" and "C" are the models most applicable to the Spring Bluff beach assuming that the south parking area will remain a defended shore. Along shoreline "B," erosion would move the shoreline as much as 350 ft landward of the vegetation line; along shoreline "C," erosion would move the shoreline as much as 200 ft landward of this line. Comparing the locations of log-spiral shorelines "B" and "C" to the location of the vegetation line, the potential erosion of forested wetlands (excluding beach) would amount to about 15.5 acres for shoreline "B" and 7.4 acres for shoreline "C".

Development of log-spiral configurations occurs at several scales and would not be limited to this segment of the state park. The log-spiral configuration represents an ultimate equilibrium shoreline configuration that would develop between many of the hard points along the shoreline between the state line and Waukegan Harbor if the erosional process was allowed to proceed naturally. Once a fully developed log-spiral shoreline is attained, the shoreline is in a dynamic equilibrium with wave dynamics, sediment supply, and lake level. If no major changes occur in these three conditions, ideally, no further erosion will occur.

Two important conclusions relate to this model for shoreline recession:

1) Shoreline defense at the NPM south parking area is beneficial to the erosion control between the marina and Camp Logan. This shoreline defense acts as the updrift headland and reduces the length of erodible downdrift shore to the Camp Logan headland. Since the length of undefended shore is reduced, the maximum potential landward erosion is reduced. This is illustrated by comparing shorelines "A "and "B" in Figure 2-28.
2) A strategy for further reducing erosion between the marina and Camp Logan would be to construct one or more headlands along this reach. By having one or more closely spaced headlands, the principal benefit is a reduction in the maximum landward extent of erosion as well as in the total area of erosion.

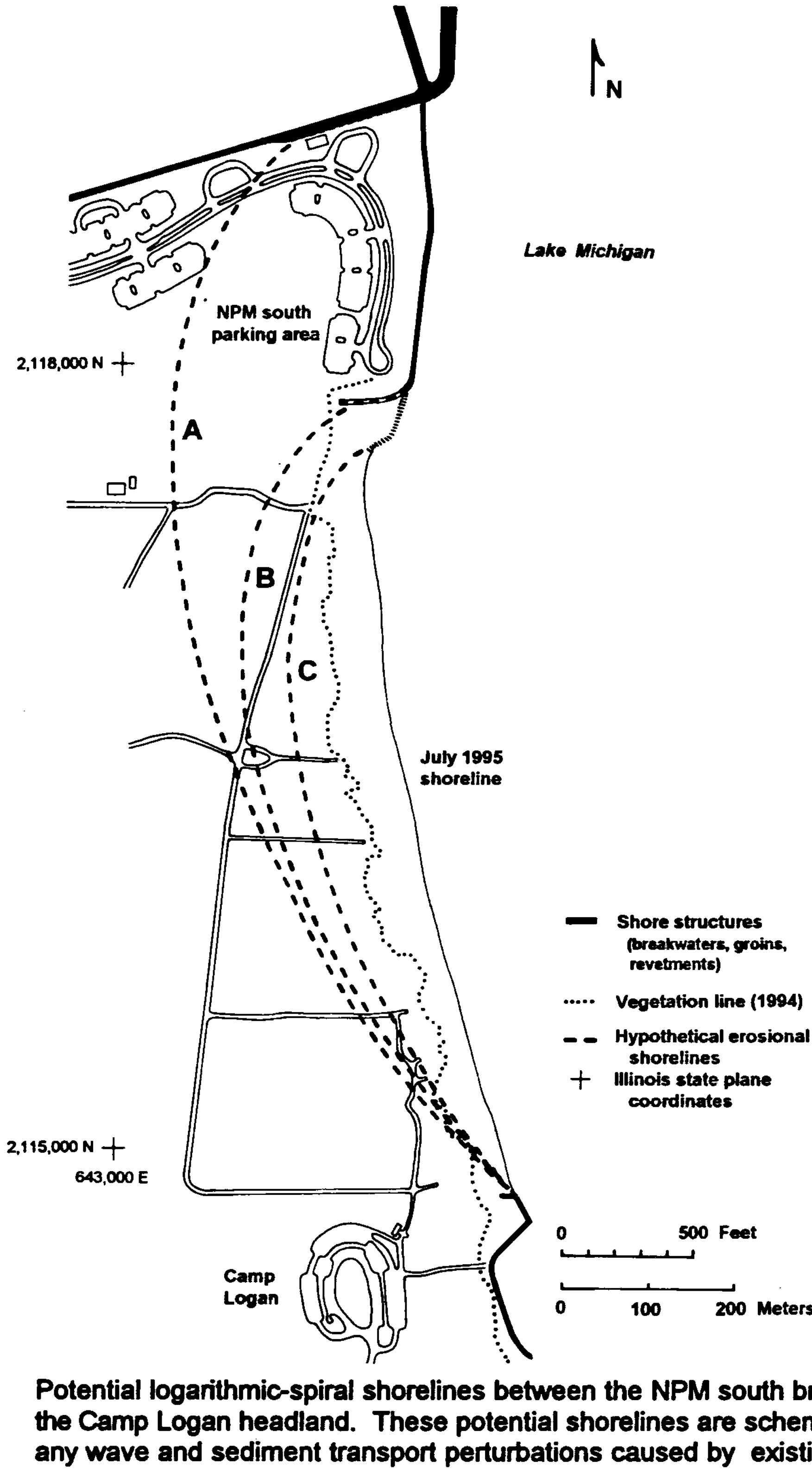


Figure 2-28 Potential logarithmic-spiral shorelines between the NPM south breakwater and the Camp Logan headland. These potential shorelines are schematic, ignoring any wave and sediment transport perturbations caused by existing structures and debris in the nearshore. Shoreline "A" assumes the absence of the south parking area and its associated shore defense.

ILLINOIS BEACH STATE PARK / SOUTH UNIT

General Statement

The focus of study in the South Unit during 1995 was monitoring the dispersion of beach nourishment placed at the north end of the unit.

Monitoring of 1995 Beach Nourishment

Nourishment characteristics and emplacement

Between June 19 and July 14, 1995, 24,000 cu yds of nourishment was placed along the shore at the north end of the South Unit. This nourishment extended from the southern end of the steel sheetpile that extends into the South Unit from the property of the Zion Nuclear Power Plant, southward to the concrete boat ramp at the south bathhouse (Fig. 2-29). This nourishment consisted of moderately- to poorly-sorted fine to medium sand, identical to that supplied to the North Unit in July 1995, and similarly derived from maintenance dredging at Waukegan Generating Station. This nourishment was placed lakeward of riprap that lined most of this 2400-ft reach of shoreline. In contrast to the North Unit site, the South Unit nourishment site had a greater linear extent along the shore and a lower crest elevation. The nourishment amounted to 10 cu yds/shoreline ft, or 25 percent of the normalized volume placed at the North Unit.

The nourishment material was trucked to the site and distributed along the shore such that the surface elevation was similar to that of the shore access road (elevation 11 to 12 ft LWD; Appendix G). The top surface of the nourishment stockpile initially had a slope of 1:50 and had elevations ranging from 12 ft LWD on the landward edge to 7 ft LWD along the lakeward edge Maximum lakeward extent of the stockpile (120 ft from the shore access road) occurred near the north bathhouse where the toe of the fill was coincident with pre-existing steel sheetpile. The minimum lakeward extent of the stockpile (45 ft) occurred just north of the south bathhouse boat ramp. The approximate maximum thickness of the nourishment was 10 ft based on a comparison of pre- and post-nourishment profiles (Appendix G). The addition of the nourishment initially moved the shoreline lakeward by as much as 25 ft. In early August, the southern half of the nourishment pile was graded along its lakeward face to a slope of 1:8 with a 2 to 6 ft scarp at the shoreline. This action was taken for public safety.

Monitoring scheme

ISGS began monitoring the nourishment stockpile in late June as nourishment was being emplaced near the north bathhouse. Monitoring continued on a monthly basis through November. The data collection involved repeated topographic and shallow-wading surveys, and mapping of survey points along the scarp crest to document changes in the lakeward extent of the stockpile (Fig. 2-30). Three profile lines were established and are referred to as North Bathhouse (NBH), Grass Knoll (GK), and South Bathhouse (SBH) profiles (Fig. 2-29). These profiles extended from the access road into the shallow nearshore. The southernmost profile, South Bathhouse (SBH), extended along the concrete boat ramp immediately east of the bathhouse and did not cross the nourishment stockpile. The profile location was chosen to monitor nearshore changes immediately downdrift of the nourishment.

Monitoring observations (July - November 1995)

Appendix G contains the profile comparisons along the three profile lines. Figure 2-30A and 2-30B are a record of the scarp recession. Figures 2-31 and 2-32 provide photographic documentation of the rapid changes that occurred at the nourishment site.

The South Unit nourishment stockpile was dispersed more rapidly than its counterpart in the North Unit. This stockpile was more vulnerable to wave action since the sand was placed along a narrow beach, and the elongate north-south geometry maximized exposure to waves. Between the end of June and mid-August, wave-induced erosion moved a significant volume of sand from the stockpile into the shallow nearshore (depths of +1 ft to -3 ft LWD). Much of this nearshore accretion was within a low-relief bar located approximately 15 ft offshore (Appendix G). Nearshore accretion up to 2 ft at the South Bathhouse profile documents southward transport of the nourishment sand in the nearshore. All three profiles illustrate that between June and mid-August the lake-bottom changes were confined to a narrow zone close to shore at depths generally less than 3.5 ft LWD.

As was the case for the nourishment at the North Unit, the storm of September 7-8, 1995 resulted in the highest rates of beach and nearshore change observed during the 1995 monitoring. Between August 9 and September 8, the scarp crest at the North Bathhouse and Grass Knoll locations retreated approximately 25 ft and 15 ft, respectively. Most of this retreat is attributed to the storm of September 7-8. This single storm event caused erosion along the entire length of the nourishment stockpile with recession rates up to two orders of magnitude greater than those recorded between late June and early August.

In addition to causing substantial erosion of the nourishment stockpile, the September storm also caused erosion in the shallow nearshore. Just over 2 ft of vertical erosion was recorded in the shallow nearshore along both the Grass Knoll profile and the South Bathhouse profile. Thus, sand that had been in temporary storage in the shallow nearshore from the July and August erosion was removed during the high-wave energy conditions of the September storm. Some sand was moved into deeper water to accumulate along a bar located about 50 ft offshore. This sand was subsequently transported downdrift as demonstrated by the data for October 12 along the South Bathhouse profile (Appendix G).

By November 1995, all that remained of the 1995 nourishment stockpile was a veneer of sand generally no more than about 2 ft thick between the access road and the preexisting riprap. Along the entire length of the nourishment stockpile, erosion had reached landward to the line of riprap. Thus, by November, the South Unit nourishment stockpile had essentially contributed all of its sand to the littoral stream. By November some percentage of this sand likely still resided in the nearshore lakeward of the nourishment site; some percentage had been transported downdrift.

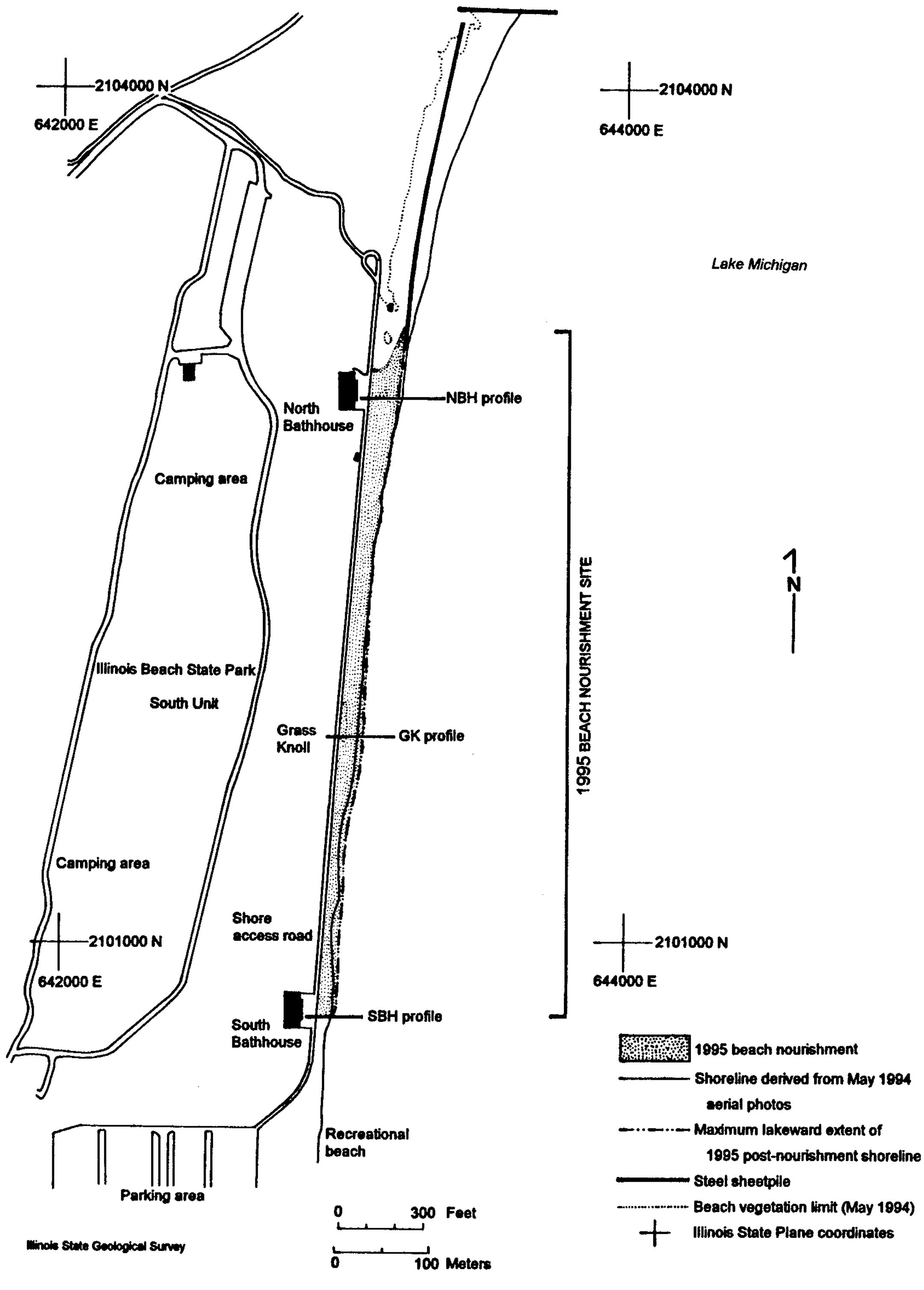


Figure 2-29 Location of the 1995 beach nourishment site in the Illinois Beach State Park South Unit.

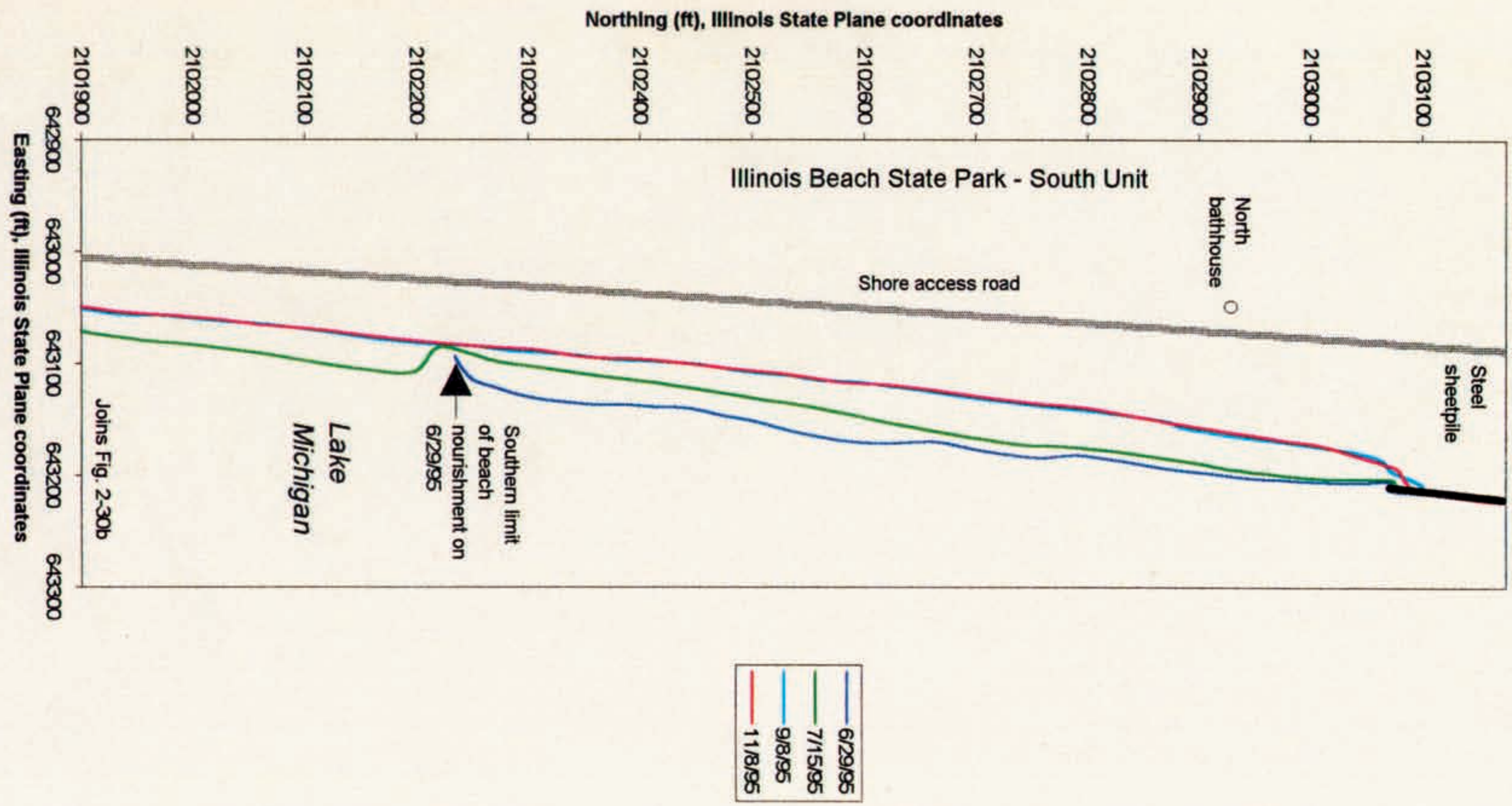


Figure 2-30A Map summary of changes to the northern half of the South Unit nourishment stockpile between June and December 1995. The June 29 survey was conducted while the beach nourishment was being supplied and distributed.

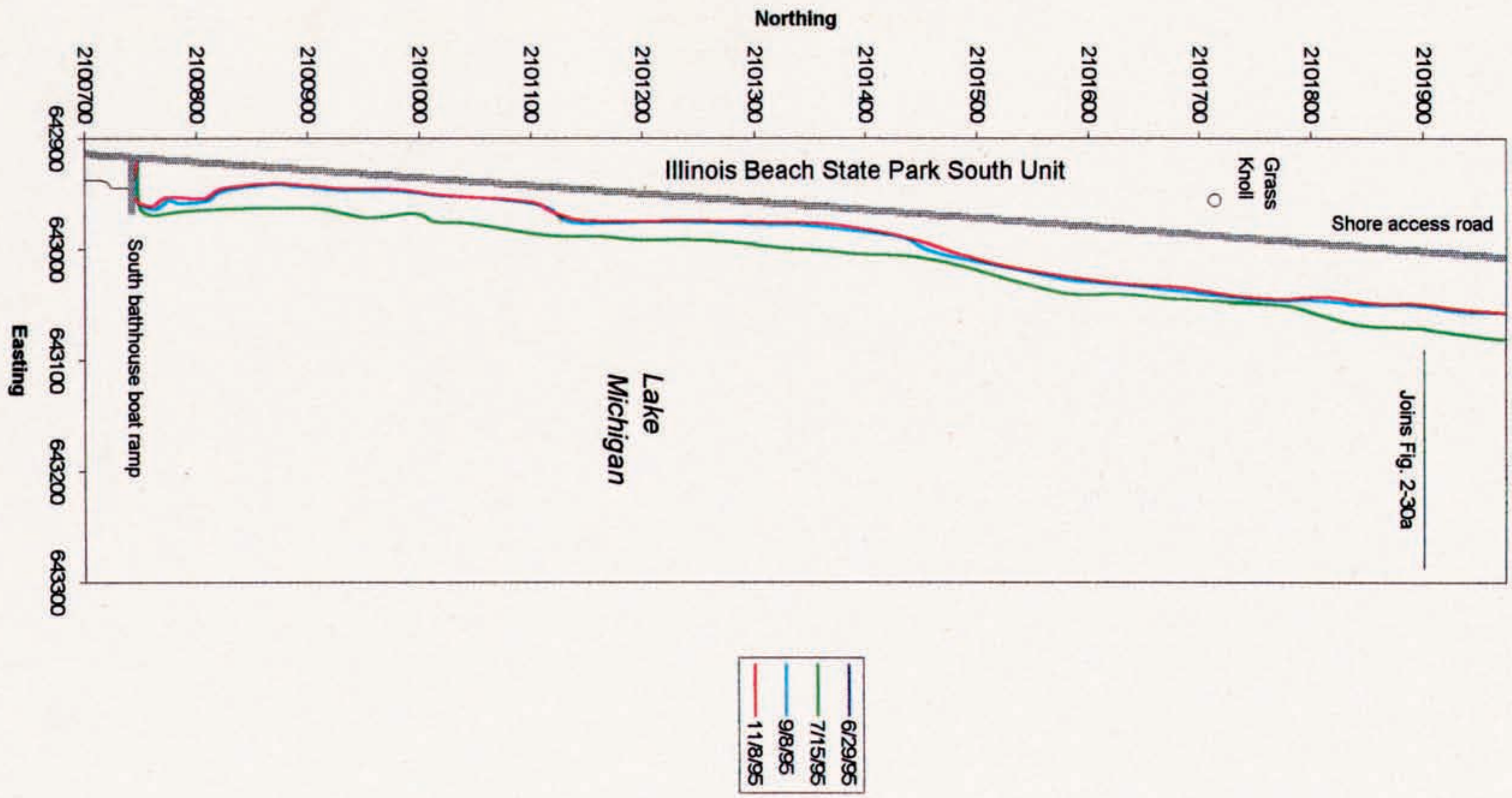


Figure 2-30B Map summary of changes to the southern half of the South Unit nourishment stockpile between June and December 1995. The June 29 survey was conducted while the beach nourishment was being supplied and distributed.

Figure 2-31 View looking southward along the South Unit nourishment site three days before completion of the June/July 1995 nourishment. Photograph is taken from the steel sheetpile (lower left) that defends the north end of the South Unit shoreline. Approximately 10 ft of recession has already occurred (Photo date July 11, 1995).

Figure 2-32 Same view as Figure 2-31 showing what remained of the South Unit nourishment stockpile in November 1995. The scarp crest has receded approximately 35 ft compared to the photo in Figure 2-31 to re-expose the riprap that defends this reach of shore (Photo date November 8, 1995).

REGIONAL COASTAL MONITORING

General

The coastal monitoring at North Point Marina and Illinois Beach State Park is designed to address erosion and coastal-management concerns specific to these individual coastal segments. To adequately evaluate the gain, loss, and transport of littoral sediment along these two coastal segments, it is necessary to examine coastal processes from a regional perspective. Ideally, this regional emphasis involves examination of a complete coastal system or compartment bounded by littoral-transport barriers. The WI-IL state line is a political boundary important to coastal management, but also corresponds to a partial littoral-transport barrier caused by the intercept, dredging and removal of sediment at Prairie Harbor Yacht Club. The jetties and entrance channel at Waukegan Harbor form a partial to near-total barrier to net southerly littoral transport, and thus mark the terminal point for a large percentage of the sediment transported southward along the marina and state park nearshore. Thus, the coastal reach from the state line to Waukegan Harbor is appropriately treated as a regional coastal compartment having an origin (sediment crossing the state line), a littoral sediment transport pathway, and a terminus (sediment trapped at Waukegan Harbor).

Beach and Nearshore Profile Scheme

The profile scheme to be used in this study to evaluate regional long-term changes to the beaches and nearshore will rely on a series of 22 beach and nearshore profile lines spaced from 1700 to 2200 ft apart along the shore. The scheme is shown in Appendix H. The eight primary lines (Range Lines 1-8) are at locations first established by the U.S. Lake Survey in 1872-73. These range lines were subsequently reoccupied on several occasions in the early to mid-1900s by federal and state agencies (U.S. Army Corps of Engineers, 1951; Illinois Division of Waterways, 1954; Illinois State Geological Survey, 1988). Reports by these agencies contain profile data and profile comparisons with previous years. A series of 14 new intermediate or "secondary" range lines (Appendix H; alpha-numeric line designations) will be established by ISGS for this study to provide more detailed coverage. The objective of collecting profile data using this scheme is to compare present-day profiles with the historical data to evaluate long-term erosion and accretion trends.

Profile data were not collected using this range-line scheme during 1995. Field work focused on determining the X-Y coordinates of the range-line origins and on establishing these points along the marina and state park shore. The profiles will be run in 1996.

Compilation of Dredge Records

The volume of sediment dredged from harbors or trapped updrift of coastal barriers is a valuable data source for the development of coastal sediment budgets. In 1995, data were compiled for dredging at the Commonwealth Edison Waukegan Generating Station near the south end of the study area, and at Waukegan Harbor which forms the south end of the study area.

Waukegan Generating Station

Dredge records for the Waukegan Generating Station are available for a 37-year period from 1958 through 1995 (Table 2-7). During this time dredging was done, on average, every two years. The dredging was confined to the cooling pond and to the water intake-discharge channels along the jetty to its lakeward end (approx. 8 ft LWD). Entrapment in the dredge areas represents a fraction of the local littoral transport because sand and gravel can readily bypass the facility. The dredge volumes thus provide a minimum estimate of littoral transport. The 32-year record from 1958 to 1990 is used here because a temporal equivalent dredge record is available for Waukegan Harbor. Between 1958 and 1990, the total dredge volume at Waukegan Generating Station was 1,207,100 cu yds. This is a 32-year average of 37,700 cu yds/yr.

Table 2-7 Dredge volumes for Commonwealth Edison Waukegan Generating Station 1958-1995.[1,2]

Calendar year	Dredge volume	Calendar year	Dredge volume
1958	120,000	1979	47,000 / 90,000[3]
1961	125,000	1981	20,000
1963	50,000	1983	42,000
1965	100,000	1986	102,700
1968/69	120,000	1987	50,700 / 92,700[3]
1972	100,000	1988	7,000
1973	103,000	1990	35,500
1976	78,700	1992	114,000[4]
1977	105,500	1995	100,000[4]

[1] Volumes are rounded to the nearest one hundred cu yds.
[2] Volumes were provided by T.B Platt, Regulatory Compliance Engineer, Commonwealth Edison.
[3] Records show two possible dredge volumes. The lesser volume is used in the summation of dredge volumes.
[4] Volumes were accurately determined from stockpile surveys following placement.

Waukegan Harbor

The jetties, shore-attached breakwater, and the deep-water entrance channel combine to make Waukegan Harbor the largest barrier to littoral transport on the northern Illinois coast, and one of the largest littoral transport barriers in the Great Lakes Region. Dredging to maintain a harbor at Waukegan spans a 105-year period from 1889 to 1994 (Chrzastowski and Trask, 1995). Prior to 1977, and again in 1982, sediment dredged from the harbor was discharged into deep water about 2.5 miles lakeward of the harbor entrance. First in 1977, and consistently since 1984, material dredged has been discharged into a nearshore disposal area about three-quarters of a mile south of the harbor.

Table 2-8 summarizes the dredge records for Waukegan Harbor from 1958 through 1994. In general, dredging at Waukegan Harbor occurred every one or 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.

The dredge data from 1958 through 1990 are of interest since the time period corresponds in duration to the 32-year record at Waukegan Generating Station (Table 2-7). The summation of dredge volumes from 1958 through 1990 is 981,473 cu yds. For this 32-year record, an average of 30,700 cu yds/yr was thus captured by the Waukegan Harbor entrance channel.

Table 2-8 Dredge volumes for Waukegan Harbor 1958-1994.[1]			
Fiscal year	Dredge volume[2]	Fiscal year	Dredge volume[2]
1958	108,200	1976	34,691
1960	12,629	1977	130,000
1961	39,900	1982	85,396
1963	47,191	1984-1985	81,000
1964	50,812	1985	26,180
1965	41,279	1988	100,996
1966	49,370	1990	49,513
1967	32,491	1991	79,482
1969	33,456	1993	66,597
1974	~10,000	1994	44,879
1975	~48,369		

[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 1958 to 1975 are for federal fiscal years July through June; dates from 1976 to 1994 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.

Regional Littoral Sediment Budget

A considerable amount of data yet needs to be collected and evaluated to provide a littoral sediment budget for this coast that is better than a first approximation. Subsequent annual reports will continue to refine the budget analysis. For ongoing coastal management, it is valuable to summarize the budget as it is presently understood.

The budget presented here primarily considers average trends over the past three years (1992-1995). This time frame is used since the sediment budget data are derived primarily from 1992-1995 bathymetric comparisons. Four components of the overall budget can be approximated with some certainty. These are:

1) the minimum volume of littoral sediment moving south across the WI-IL state line
2) the minimum volume of littoral sediment moving south past the Camp Logan headland
3) the volume contribution from beach nourishment
4) the minimum volume of littoral sediment in transport at the south end of the IBSP South Unit

1) Sediment volume crossing the state line

The volume of littoral sediment crossing the state line can be estimated based on the accretion volumes documented by bathymetric changes. Three distinct areas of accretion can be attributed to a sediment supply moving south across the state line.

North Beach/north breakwater nearshore accretion The NPM north breakwater acts as a partial barrier to the southward transport of littoral sediment. The nearshore updrift of the north breakwater has been an area of persistent sediment entrapment since the breakwater was constructed (Figs. 2-6 and 2-7). Between 1992 and 1995, the net accretion in this nearshore area was 31,000 cu yds which is an average net accretion rate of 10,300 cu yds/yr (Table 2-1).

Marina entrance accretion The 1992-1995 bathymetric comparison identifies an accretional wedge along the lakeward side of the north breakwater and extending into the marina entrance. This is a pathway for sediment to bypass the breakwater and contribute to accretion within the marina basin. Accretion within the marina basin is widespread and has been ongoing since the time of construction. Bathymetric comparisons suggest that at least in the early post-construction history, some of this sediment supply came from the south (Appendix B; Maps B-2, B-3). For the limited marina entrance accretion data for the past three years (Fig. 2-10), it is not known what percentage was derived from either the north or south. Within this area, net accretion between 1992 and 1995 was 9,200 cu yds. If it is conservatively assumed that half of this accretion was supplied by sediment bypassing the north breakwater, the component from the north was 4,600 cu yds. This is an average annual contribution of 1,500 cu yds/yr from a source area updrift of the marina entrance.

Nearshore accretion lakeward of the marina entrance The 1992-1995 bathymetric comparison documents an accretional lobe lakeward of the marina entrance. This lobe has an orientation and configuration suggesting that it was supplied by sediment bypassing the north breakwater (Fig. 2-13). The volume of this accretional feature is 7,200 cu yds. Assuming this accretion does represent a supply of sediment that originated updrift of the north breakwater, the updrift contribution over the past three years is 2,400 cu yds/yr.

The summation of the annual accretion volumes updrift of the north breakwater (10,300 cu yds/yr), accretion in the marina entrance from updrift sources (1,500 cu yds/yr), and accretion in the nearshore lakeward of the marina entrance (2,400 cu yds/yr) yields a total annual accretion rate of 14,200 cu yds/yr. This is a minimum estimate for the annual volume moving south across the state line. What is not known is the volume of sediment coming across the state line and continuing in southward transport past the north breakwater and marina entrance. This sediment that bypasses the marina supplies the nearshore downdrift of the marina.

2) Littoral transport rate past the Camp Logan headland

Comparison of 1992-1995 bathymetric data across the nearshore from the NPM marina entrance to the Camp Logan headland documents that net erosion dominates (Figs. 2-13; 2-15; and 2-25). This erosion is an important contribution to the littoral sediment volume in transport past the Camp Logan headland. Net erosion averaged 6,600 cu yds/yr in the south breakwater nearshore (Table 2-3), 10,600 cu yds/yr in the south parking area nearshore (Table 2-4), and 20,600 cu yds/yr in the Spring Bluff nearshore (Table 2-6). The summation is 37,800 cu yds/yr. This is a minimum estimate since it does not account for the unknown volume of sediment that may be bypassing the marina and continuing southward past Camp Logan. Also, the estimate is based solely on nearshore changes and does not consider sediment volumes above LWD.

3) Contribution from beach nourishment

Beach nourishment along the IBSP North Unit and South Unit has been sporadic and has fluctuated significantly in annual volume. Thus, to asses how nourishment contributes to the budget, it is necessary to average the nourishment over as long a time frame as possible. Using data prior to 1992 is problematic because of the large influx of nourishment from dredging of the marina basin in 1987-1988, and from the stockpiling of sediment derived from dredging at Prairie Harbor Yacht Club in 1990. Between 1992 and November 1995, nourishment at the North Unit totaled 52,000 cu yds (32,000 cu yds, 1994; 20,000 cu yds, July 1995); nourishment at the South Unit had a minimum volume of 24,000 cu yds (July 1995; additional nourishment data needs to be compiled). These 1992-1995 nourishment data combined with nourishment data over the next two to three years will have greater application to the budget.

4) Minimum littoral transport rate at south end of IBSP

The dredge data (1958-1990) for Waukegan Generating Station and Waukegan Harbor can be summed to provide a long-term minimum estimate of littoral transport at the south end of the IBSP South Unit. A long-term average is advantageous in applying the dredge data because this minimizes influence caused by short-term perturbations in dredge volumes and dredge frequency. For a 32-year dredge record for these two sites (1958-1990; Tables 2-7 and 2-8), the combined average dredge volume is 68,400 cu yds/yr. A minimum of 68,400 cu yds/yr is therefore in transport at the south end of the South Unit.

Budget overview

Figure 2-33 provides a graphical summary of the littoral sediment budget. The following are key components of the budget.

- Littoral sediment is moving south across the WI-IL state line at a minimum rate of 14,200 cu yds/yr. This sediment supply contributes to accretion on the updrift side of the NPM north breakwater, within the marina basin, and lakeward of the marina entrance. The principal accretion area has been updrift of the north breakwater which forms a partial barrier to southward littoral transport. Accretion updrift of the breakwater averaged 10,300 cu yds/yr between 1992 and 1995.

- It is not known what volume of sediment coming south across the state line bypasses the marina.

- Between 1992 and 1995, net erosion dominated across the nearshore from near the marina entrance southward to the Camp Logan headland. The net erosion volume across this reach was 37,800 cu yds/yr. This provides a minimum estimate for the sediment in transport past the Camp Logan headland.

- Between 1992 and 1995, beach nourishment updrift of the Camp Logan headland totaled 52,000 cu yds, or about 17,000 cu yds/yr. As of 1995, much of this sediment, and particularly the 1995 nourishment, is apparently still in residence updrift of Camp Logan. Ultimately this volume will add to the volume in transport past the Camp Logan headland.

- The nearshore between the state line and the Camp Logan headland can be divided into a northern net accretional zone from the state line to the marina entrance (minimum net accretion of 14,200 cu yds/yr), and a southern net erosional zone from the marina entrance to the Camp Logan headland (minimum net erosion 37,800 cu yds/yr). The downdrift net erosion exceeds the updrift net accretion by a factor of at least 2.5.

- This study has not yet evaluated data between the Camp Logan headland and the northern half of the IBSP South Unit, but past studies have documented that net erosion predominates along this reach (U. S. Army Corps of Engineers, 1953; State of Illinois, Division of Waterways, 1958; Tetra Tech, Inc., 1980). A minimum of 37,800 cu yds/yr enters the updrift end of this reach at the Camp Logan headland. Beach and nearshore erosion along the reach add to the littoral transport volume. Beach nourishment at the northern end of the South Unit (24,000 cu yds during 1995) also adds to the volume.

- Previous studies have documented that along the beach and nearshore between the state park lodge and the mouth of Dead River, a transition occurs in long-term coastal processes. Net erosion dominates to the north of the lodge and net accretion or a stable shore dominates to the south of Dead River.

- The first major sediment trap encountered south of Dead River is at the cooling water channels and basin at the Commonwealth Edison Waukegan Generating Station. Entrapment here reduces the littoral transport volume by 37,700 cu yds/yr.

- The Waukegan Harbor entrance channel is the next downdrift entrapment area, and a partial to near-total barrier to continued southward transport. Entrapment here reduces the littoral transport volume by an additional 30,700 cu yds/yr. An unknown volume of sediment bypasses the harbor entrance and is possibly deflected offshore.

- The beach and nearshore between the Commonwealth Edison Waukegan Generating Station and Waukegan Harbor is stable or accretional. The 30,700 cu yds/yr entrapped at Waukegan Harbor is sediment that bypassed the Commonwealth Edison facility. Summing the dredge volumes from Commonwealth Edison (37,700 cu yds/yr) and Waukegan Harbor (30,700 cu yds/yr) provides a minimum estimate for the supply approaching the Commonwealth Edison facility from updrift. The proximity of the state park means that this is also a minimum estimate for the littoral transport along the southern end of the IBSP South Unit. This minimum transport volume at the south end of the IBSP South Unit is 68,400 cu yds/yr.

Several conclusions result from this preliminary sediment budget:

1) A sediment supply is coming south across the state line, but the marina is acting as a partial barrier to the southward transport of a component of this sediment. At this time the volume bypassing the marina is not known and the percentage of entrapment and bypass can not be determined.

2) The beach and nearshore between the marina and Camp Logan headland is a major net erosional area that is providing much of the littoral sediment supply for the rest of the coastal reach south to Waukegan Harbor. The term "erosion hot spot" is commonly used to identify coastal areas of severe and persistent erosion. This reach between the marina and Camp Logan headland is such a setting.

3) The estimated minimum littoral sediment transport at the south end of the IBSP South Unit suggests that the "carrying capacity" of the littoral system along this shore is at least 68,400 cu yds/yr. If the potential exists for such a volume to be in transport between the marina and the Camp Logan headland, then a minimum of 68,400 cu yds/yr of nourishment would be needed south of the marina to produce a balanced sediment budget and thus have no net loss of littoral sediment.

4) The "natural state" littoral transport along this reach was computed by the U.S. Army Corps of Engineers (1953) to be 90,000 cu yds/yr, based on rates of shore erosion and accretion against barriers to littoral drift. The minimum estimate of 68,400 cu yds/yr presented here will likely be revised upwards as additional data are evaluated in future reports of this four-year study.

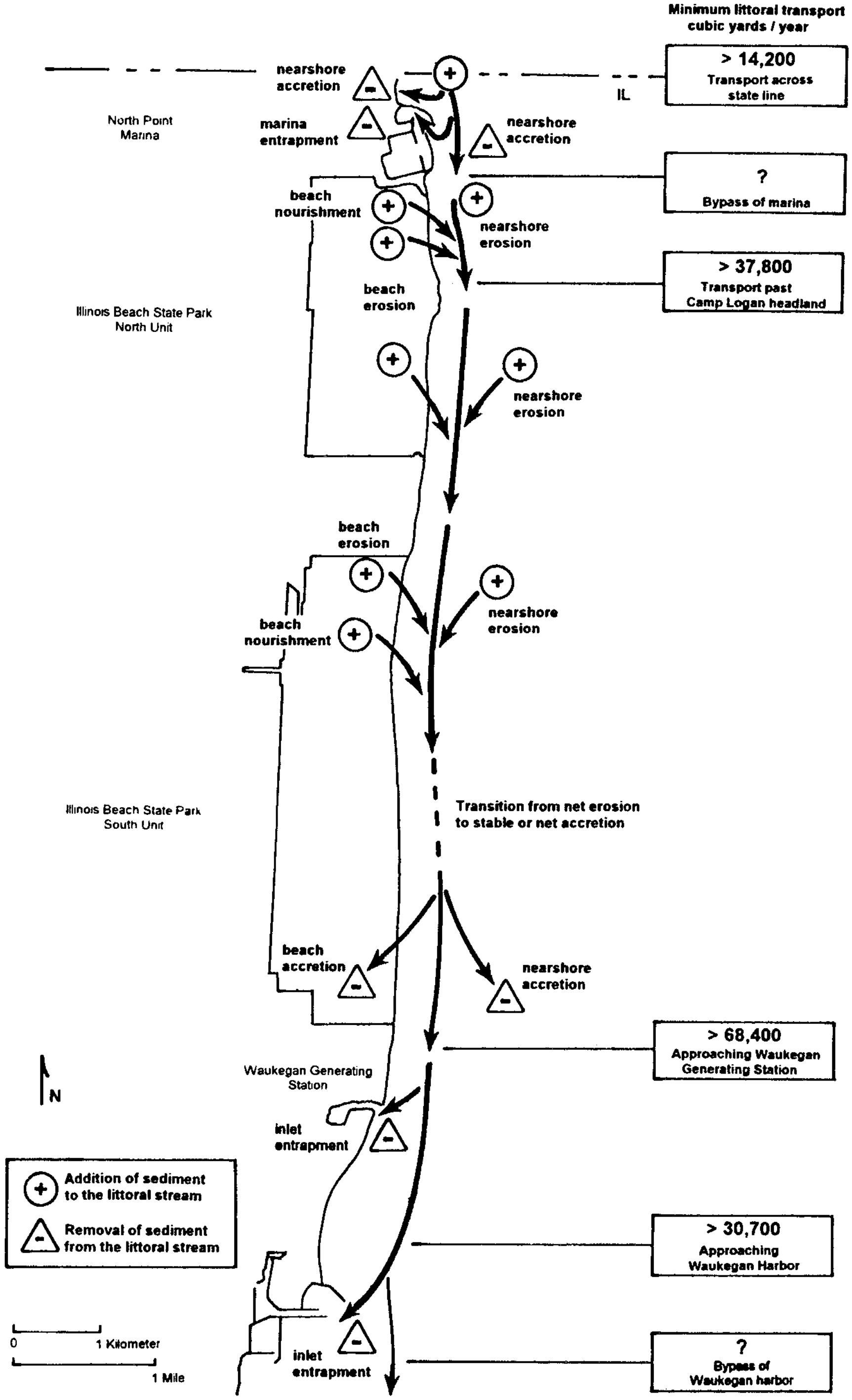


Figure 2-33 Preliminary graphical littoral sediment budget between the WI-IL state line and Waukegan Harbor. The budget relies on data from bathymetric comparisons in the marina vicinity between 1992 and 1995, and dredge records at the south end of the study area between 1958 and 1990. All volumes are minimum estimates.

PART 3: STUDY APPLICATIONS AND SUMMARY

RECOMMENDATIONS

North Point Marina

1) Planning for future maintenance dredging at North Point Marina should consider the possibility of dredging the North Beach bar and the adjacent nearshore. Accretion in this area has established a pathway for sand that comes across the state line to move southward, bypass the north breakwater, and feed into the marina entrance. If this bypass is not interrupted, it may result in increased rates of shoaling within the marina entrance. Removal of sediment from the North Beach bar and adjacent nearshore will create a depositional sink capable of storing several years of new accretion before the bypass pathway is re-established. However, any dredging on the updrift side of the north breakwater should not approach the toe of the north breakwater. To avoid any potential stability problems along the north breakwater as a result of nearby dredging, the best option may be to dredge a catchment basin on the Illinois side of the state line that would trap littoral sediment and be dredged periodically.

2) Planning for the proposed construction of a submerged reef (*i.e.*, submerged breakwater) to protect the south parking area needs to include provisions for post-construction monitoring. The primary concern is the crest elevation of the reef. The lake bottom on which this proposed structure would be built is presently eroding, and erosion will continue after the structure is built. This erosion could cause shifting and settling of the reef stone which would lower the crest elevation. As the crest elevation is lowered, the structure will become less effective in reducing incoming wave energy. Monitoring of the structure will determine if and when additional stone may be needed.

3) A bathymetric survey is warranted for the entire marina basin to compare present depths with construction depths. Accretion has been identified for some time at the marina entrance and in the channel leading to the recreational basin. This study documents that between 1992 and 1995 about 1 ft of accretion occurred just inside the marina entrance, over 3 ft of accretion occurred locally at the approach to the commercial basin, and up to 6 ft of accretion occurred related to the northward advance of a shoal area on the north tip of the south breakwater. A thorough, basin-wide survey is needed to fully assess the accretion trends.

4) A survey is warranted to compare present crest elevations along the north and south breakwaters with the "as built" crest elevations that existed soon after construction. The

possibility exists that subsidence has occurred along several segments of both breakwaters. A systematic monitoring of reference points on selected stones is recommended to determine changes in location and elevation. A diver survey of underwater conditions is recommended.

North Unit / Illinois Beach State Park

1) If it is desirable to maintain beach width in the Spring Bluff area, then either structural measures (*i.e.*, breakwaters, artificial headlands, etc.) or a commitment for continued beach nourishment must be considered. No significant sediment supply reaches this shore from updrift. Without maintaining a nourishment program, severe shoreline recession will continue.

2) As of 1995, the best estimate for the nourishment volume needed at the updrift end of Spring Bluff beach to create a balanced sediment budget is 68,400 cu yds/yr. This should be considered a minimum estimate and a preliminary estimate that will be refined with the collection of additional annual data. An annual nourishment volume at the North Unit nourishment site of less than 68,400 cu yds/yr will slow the rate of both shoreline recession and nearshore erosion, but net erosion will persist.

3) Long-term coastal management options should be considered for the shore between the marina/state park boundary and the Camp Logan headland. If beach nourishment is continued, without an increase in the annual nourishment volume, loss of beach area will continue. If the beach is allowed to erode into an equilibrium shape, provision must be made for some erosion extending landward of the existing vegetation line. Construction of shore structures are an option. Offshore structures could be built to reduce incoming wave energy and reduce erosion. One or more constructed headlands could be built to allow the shore to erode into a series of arcuate embayments. The closer the spacing of the constructed headlands, the more the maximum landward extent of shoreline recession will be reduced.

South Unit / Illinois Beach State Park

1) The South Unit nourishment site used in 1995 has the advantage of easy access for truck delivery of nourishment, but the site places restrictions on the width and height of the nourishment stockpile and results in a stockpile that is vulnerable to rapid erosion even in moderate wave conditions. Most importantly, because of its location, this nourishment site benefits a shorter reach of the DNR shoreline. If a given volume of nourishment is to be divided between the North and South Unit nourishment sites, a 60/40 or 75/25 split would be prudent with the major contribution going to the North Unit. With time, the benefits from this North Unit nourishment will translate downdrift to the South Unit beaches and nearshore.

SUMMARY OF YEAR-1 KEY FINDINGS

The primary goal of this four-year study is to develop a sediment budget for the beaches and nearshore along the coast at North Point Marina and Illinois Beach State Park. Achieving this goal will provide the scientific basis for designing and implementing beach nourishment, shore defense, and other coastal management strategies for the long-term conservation of the area's coastal resources. A minimum of four years of data collection and analysis is needed before a thorough sediment budget can be developed. In the interim, data collected on an annual basis has value for ongoing coastal management concerns. Following is a summary of the major findings resulting from the first-year data collection and synthesis.

North Point Marina

Overall Erosion/Accretion Trends

1) Comparison of 1992 and 1995 bathymetric data indicates that during these three years, the lake bottom in the marina vicinity was divided into two distinct net accretional areas, and one extensive net erosional area. Net lake-bottom accretion dominated between the state line and the north breakwater, and in the marina entrance. Net lake-bottom erosion dominated from the marina entrance southward to the south parking area, and beyond. The most severe lake-bottom erosion between the state line and the marina/state park boundary occurred opposite the south parking area.

North Beach

1) The shoreline position and total beach area at North Beach have been fairly constant since the marina was constructed. However, persistent accretion has occurred in the shallow nearshore and in association with the development of a nearshore bar. The erosion/accretion record from 1992 to 1995 for the nearshore between the state line and the north breakwater indicates that, on average, net accretion occurred at a rate of 10,300 cu yds/yr.

Marina Entrance

1) Bathymetric data obtained by ISGS is limited within the marina basin, but available data in the marina entrance area document that there has been persistent sediment entrapment since early post-construction. A major accretion feature is a broad shoal area built around the north tip of the south breakwater. Between 1992 and 1995, lateral accretion extended the shoal northward about 60 ft and resulted in up to 6 ft of vertical accretion. Vertical accretion of 1 to 3 ft occurred in the approach to the commercial basin. The three-year average accretion rate for the marina entrance was 3,100 cu

yds/yr. Bathymetric comparisons suggest that, between 1992 and 1995, one of the sources of sediment coming into the marina was from the north by way of bypass around the north breakwater. Additional sediment may have originated in erosion areas south of the marina entrance.

South Parking Area

1) A spatial analysis was performed to determine the volume of sand and gravel beneath the south parking area that was derived from 1987-1988 dredging of the marina basin. This volume is 295,100 cu yds. Because of shore defense at the south parking area, this sediment is being prevented from ever re-entering littoral transport. Based on an estimated total dredge volume of 1.5 million cubic yards, the 295,100 cu yds beneath the parking area represents about 20 percent of the total volume dredged from the marina basin. If this volume was available for addition to the littoral transport stream, it would be adequate to supply sediment to the nearshore for about 3 to 4 years. If this sediment had not been protected, and if no other nourishment had been added to the area, this sand reservoir would likely have been depleted by 1995.

2) Between 1992 and 1995, lake-bottom erosion was pervasive across the nearshore opposite the south parking area. The most severe erosion was concentrated close to shore at depths less than 12 ft LWD. Most vertical erosion was in the range of 1 to 2 ft, with a maximum of 5 ft. In 1995, about 80 percent of the lake bottom landward of 12 ft LWD had been eroded to depths greater than those present in 1992. Between the shoreline and 400 ft offshore, erosion had lowered the lake bottom at an average rate of 0.25 ft/yr.

Submerged Riprap

1) Comparison of 1991 and 1995 bathymetric data in the vicinity of the submerged riprap indicate that, in general, this rock has been a beneficial feature contributing to reduced lake-bottom erosion lakeward of the south parking area. However, the interaction of waves with this submerged riprap has contributed to localized erosion between the riprap and the shore resulting in a trough-like depression. Most of the riprap continued to subside between 1992 and 1995 as erosion lowered the surrounding lake bottom. As of 1995, elevation of the riprap crest is 0 to 2 ft LWD in the north where it rests on the slope of the south breakwater, and 3 to 5 ft LWD to the south where it rests on sand. The submerged riprap remains a navigational hazard for any vessel with a draft exceeding about 2 ft.

Breakwaters

1) Visual inspection of the north and south outer breakwaters suggests that localized

sagging has occurred. One of the most pronounced sags occurs along the north breakwater where it faces northeast, which is the direction of predominant wave approach. A lake-bottom depression has been a dynamic feature along the base of this breakwater since 1988, and may relate to a winnowing of sand from beneath the structure. In 1991 and 1992, this depression was 3.5 ft below the base elevation of the breakwater.

Illinois Beach State Park / North Unit

Overall Erosion/Accretion Trends

1) Bathymetric data collected in 1995 extended from the marina/park boundary to the Camp Logan headland. Comparison of 1992 and 1995 data indicates net erosion dominated across the lake bottom during these three years. Net shoreline recession also occurred, but the 1995 shoreline is still lakeward of the 1987 (pre-construction) shoreline.

Beach Nourishment

1) In September 1994, 34,000 cu yds of fine gravel ("pea gravel") was placed at the North Unit nourishment stockpile. The majority of this material had been dispersed southward by summer 1995. The leading edge of this dispersion indicates that this material moved downdrift along the beach at a minimum annual rate of about 0.6 mile/yr. This provides a minimum estimate for transport of fine gravel moving along the beach. More rapid transport would occur for sand such as the nourishment placed here in July 1995.

2) Nourishment totaling 20,000 cu yds of fine to medium sand was placed at the North Unit nourishment stockpile in July 1995. Wave action had dispersed most of this nourishment by November 1995. A single storm on September 7-8 accounted for nearly all of the dispersion. Nearshore profile data indicate that, once the sand was eroded from the stockpile, it moved downdrift in a narrow band within about 250 ft of the shoreline. Thus the nourishment was residing in the shallow nearshore as intended and not being dispersed or lost into offshore areas.

Shoreline Changes

1) Shorelines between the marina/park boundary and the Camp Logan headland were compared for 1987 through 1995. The 0-ft LWD contours were also compared. As of 1995, this reach still has a net gain in beach area compared to 1987 (prior to marina construction). This is a result of the large volume of sand added to the area by southward dispersion of dredged material between 1987 and 1989. Since shoreline recession resumed in 1989, the 13-acre net gain in beach area between 1987 and 1989

has been reduced to 5 acres as of 1995. Between 1989 and 1995, the average rate of loss in beach area was approximately 1.3 acres/yr.

Illinois Beach State Park / South Unit

Beach Nourishment

1) In June and July 1995, beach nourishment totaling 24,000 cu yds of fine to medium sand was placed along 2,400 ft of riprap-defended shore at the north end of the South Unit. The storm of September 7-8 removed all but a remnant of the stockpile. By the end of November, dispersion was essentially complete. As was the case in the North Unit, the sand dispersion occurred in a narrow band in the shallow nearshore.

Regional Coastal Monitoring

Preliminary Sediment Budget

1) A minimum estimate of 14,200 cu yds/yr can be made for the volume of littoral sand moving southward across the WI-IL state line between 1992 and 1995. This estimate is based on the summation of annual net accretion in the North Beach nearshore (10,300 cu yds/yr), a conservative estimate for the accretion in the marina entrance derived from bypass of the north breakwater (1,500 cu yds/yr), and accretion in a nearshore feature lakeward of the south breakwater (2,400 cu yds/yr). This is a minimum estimate since it is not known how much littoral sediment bypasses the marina. The volume crossing the state line would be greater if not for the dredging and updrift disposal of sand that is captured in the entrance channel to Prairie Harbor Yacht Club.

2) The summation of net erosional volumes for 1992 to 1995 across the nearshore between the North Point Marina entrance and the Camp Logan headland provides a minimum littoral transport rate of 37,800 cu yds/yr passing the Camp Logan headland.

3) Dredge records compiled for 1958 through 1990 from the Commonwealth Edison Waukegan Generating Station and Waukegan Harbor provide a minimum littoral transport rate estimate of 68,400 cu yds/yr at the south end of the IBSP South Unit.

4) If the wave energy along this entire coastal reach is sufficient to transport a minimum littoral sediment volume of 68,400 cu yds/yr, the annual nourishment supplied to the North Unit needs to be a minimum of 68,400 cu yds/yr to create a balanced sediment budget along the North Unit nearshore.

ACKNOWLEDGMENTS

Logistical support during field studies was provided by numerous members of the staff at North Point Marina and Illinois Beach State Park. Special thanks are due to Jim LaBelle, General Manager at North Point Marina, Charles Price, Harbormaster at North Point Marina, and Robert Grosso, Site Superintendent at Illinois Beach State Park. For contributions to much of the 1987 through 1992 North Point Marina data collection and maps presented in this report, special recognition is due to Paul Terpstra, Christine Fucciolo, and Christopher Rompot of the Illinois State Geological Survey (ISGS). Field studies at North Point Marina between 1988 and 1992 were part of a cooperative study focusing on coastal erosion in southern Lake Michigan funded by the U.S. Geological Survey Center for Coastal Geology. Technical assistance in 1995 field studies and in the compilation of map data were provided by Douglas Mulvey of the ISGS.

Special appreciation is extended to T. B. Platt, Regulatory Compliance Engineer at the Commonwealth Edison Waukegan Generating Station, who provided data on dredging at the station.

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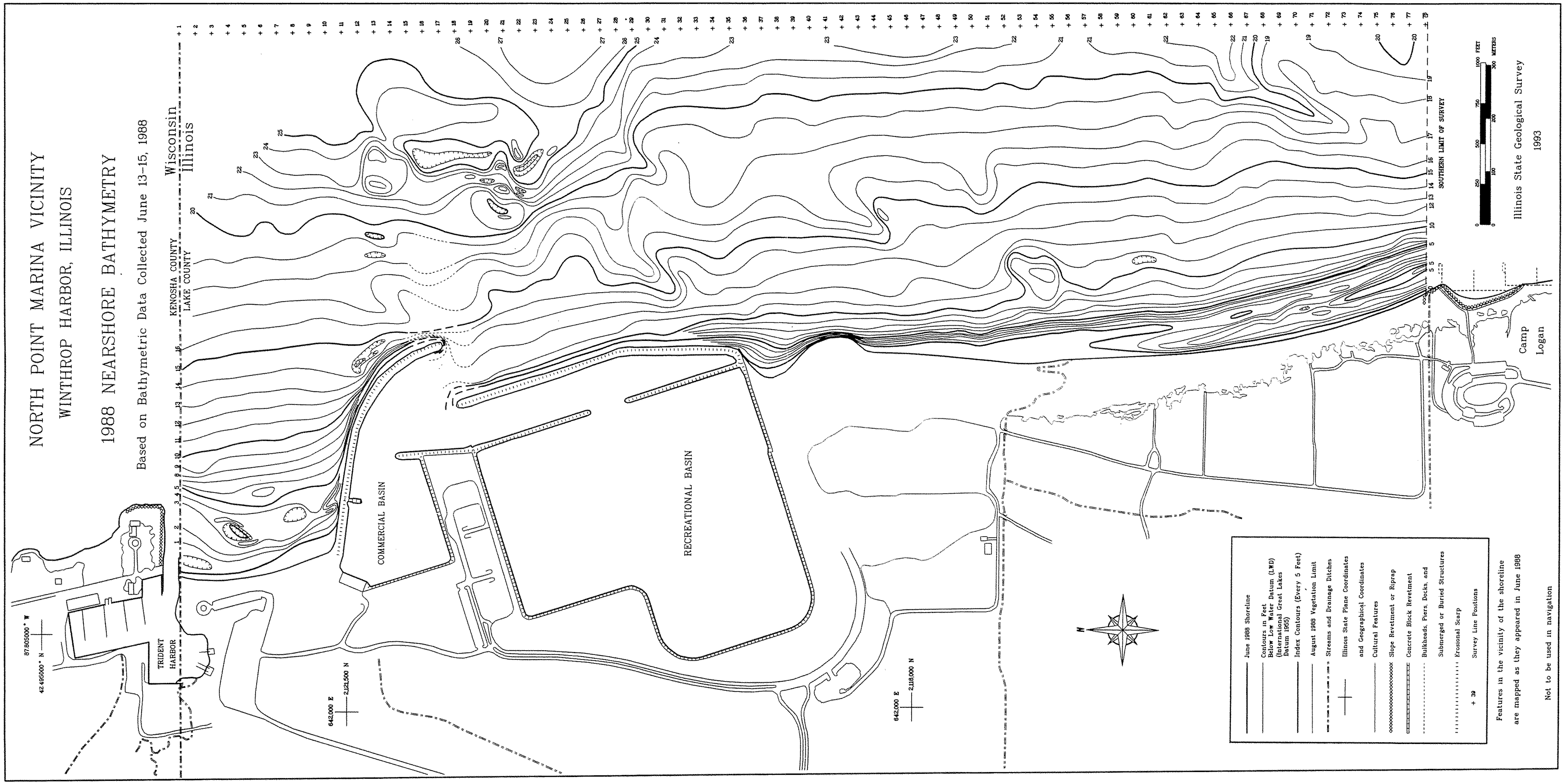
APPENDIX A
Annual Bathymetric Contour Maps of North Point Marina Vicinity
1987 - 1992

The series of six annual bathymetric maps of Appendix A are based on fathometer surveys completed by the ISGS. Mapping in 1987 was funded through State of Illinois expenditures related to construction of North Point Marina. Mapping in 1988 through 1992 was funded in part through a cooperative study with the U.S. Geological Survey, examining coastal erosion in southern Lake Michigan. The 1987 bathymetric map documents the pre-construction nearshore bathymetry.

All contours are in feet referenced to Low Water Datum (LWD). Contours are based on east-west fathometer profiles. Profile locations and numbers are shown on the right margin of each map. These maps were plotted using the ARC/INFO Geographic Information System (GIS) at the ISGS.

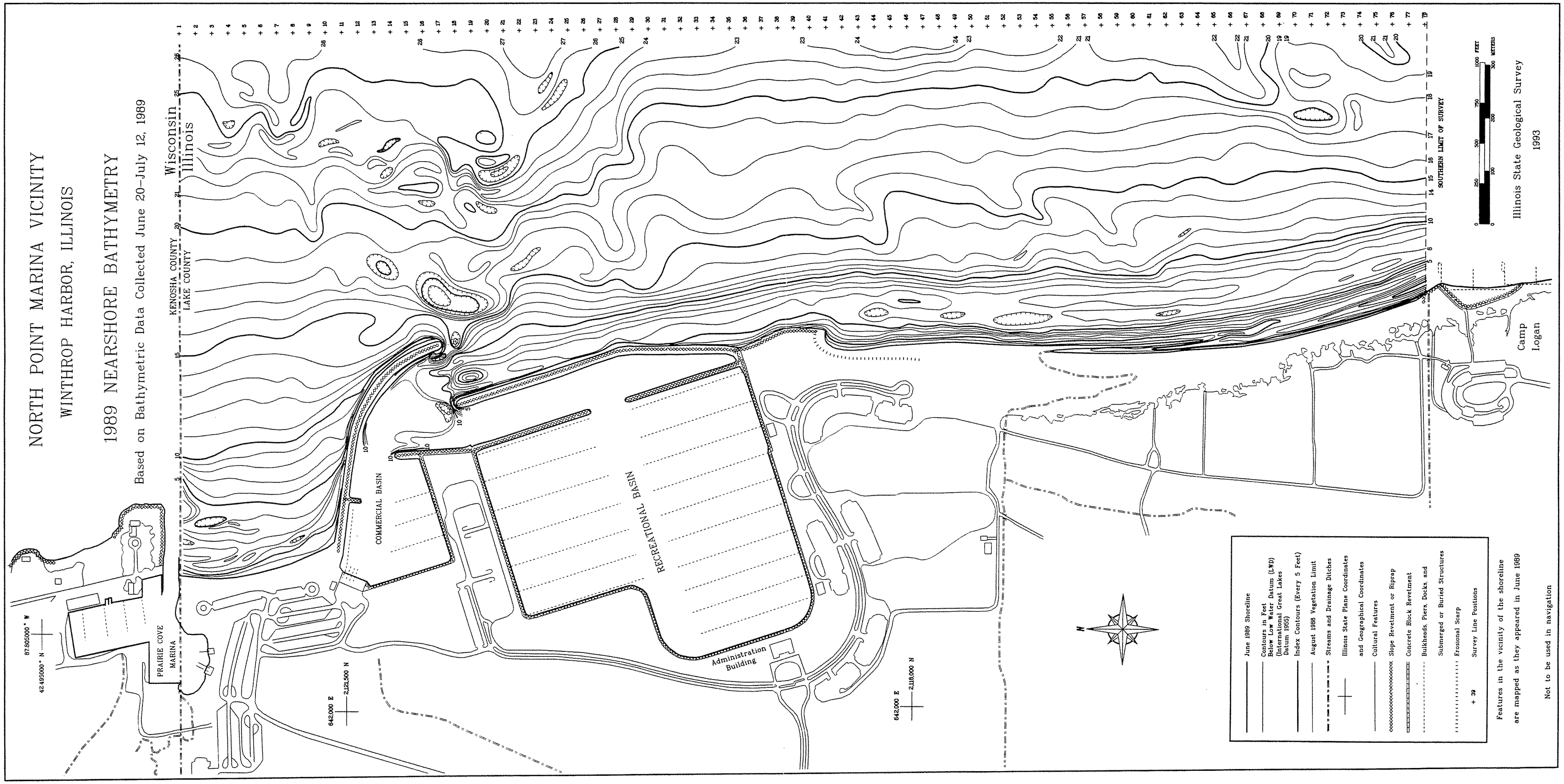

NORTH POINT MARINA VICINITY
WINTHROP HARBOR, ILLINOIS
1987 NEARSHORE BATHYMETRY
Based on Bathymetric Data Collected May 27–29, 1987
Wisconsin
Illinois
KENOSHA COUNTY
LAKE COUNTY
Not surveyed
in 1987
TRIDENT
MARINA
MAIN STREET
SOUTHERN LIMIT OF SURVEY
Camp
Logan
Illinois State Geological Survey
1993
May 1987 Shoreline
Contours in Feet Below Low Water Datum (LWD) (International Great Lakes Datum 1955)
Index Contours (Every 5 Feet)
August 1988 Vegetation Limit
Streams and Drainage Ditches
Illinois State Plane Coordinates and Geographical Coordinates
Cultural Features
Slope Revetment or Riprap
Concrete Block Revetment
Bulkheads, Piers, Docks, and Submerged or Buried Structures
Erosional Scarp
Survey Line Positions
Features in the vicinity of the shoreline are mapped as they appeared in May 1987
Not to be used in navigation

Map A-1



NORTH POINT MARINA VICINITY
WINTHROP HARBOR, ILLINOIS
1988 NEARSHORE BATHYMETRY
Based on Bathymetric Data Collected June 13-15, 1988
Wisconsin
Illinois
KENOSHA COUNTY
LAKE COUNTY
COMMERCIAL BASIN
RECREATIONAL BASIN
TRIDENT HARBOR
Camp Logan
SOUTHERN LIMIT OF SURVEY
Illinois State Geological Survey
1993
June 1988 Shoreline
Contours in Feet Below Low Water Datum (LWD) (International Great Lakes Datum 1955)
Index Contours (Every 5 Feet)
August 1988 Vegetation Limit
Streams and Drainage Ditches
Illinois State Plane Coordinates and Geographical Coordinates
Cultural Features
Slope Revetment or Riprap
Concrete Block Revetment
Bulkheads, Piers, Docks, and Submerged or Buried Structures
Erosional Scarp
Survey Line Positions
Features in the vicinity of the shoreline are mapped as they appeared in June 1988
Not to be used in navigation

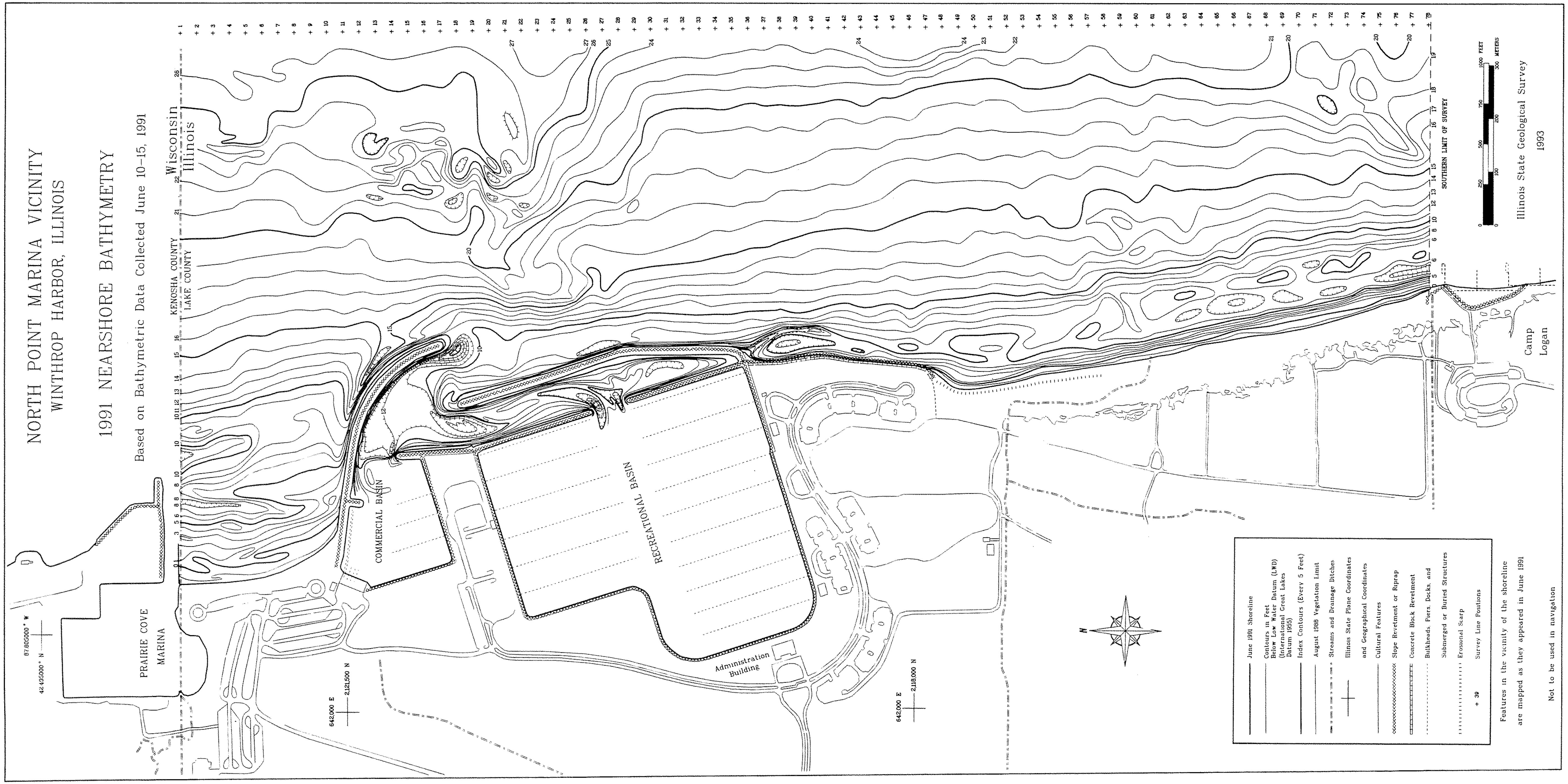
Map A-2


NORTH POINT MARINA VICINITY
WINTHROP HARBOR, ILLINOIS
1989 NEARSHORE BATHYMETRY
Based on Bathymetric Data Collected June 20–July 12, 1989
Wisconsin
Illinois
KENOSHA COUNTY
LAKE COUNTY
SOUTHERN LIMIT OF SURVEY
COMMERCIAL BASIN
RECREATIONAL BASIN
Administration Building
PRAIRIE COVE MARINA
Camp Logan
Illinois State Geological Survey
1993
June 1989 Shoreline
Contours in Feet Below Low Water Datum (LWD) (International Great Lakes Datum 1955)
Index Contours (Every 5 Feet)
August 1988 Vegetation Limit
Streams and Drainage Ditches
Illinois State Plane Coordinates and Geographical Coordinates
Cultural Features
Slope Revetment or Riprap
Concrete Block Revetment
Bulkheads, Piers, Docks, and Submerged or Buried Structures
Erosional Scarp
Survey Line Positions
Features in the vicinity of the shoreline are mapped as they appeared in June 1989
Not to be used in navigation

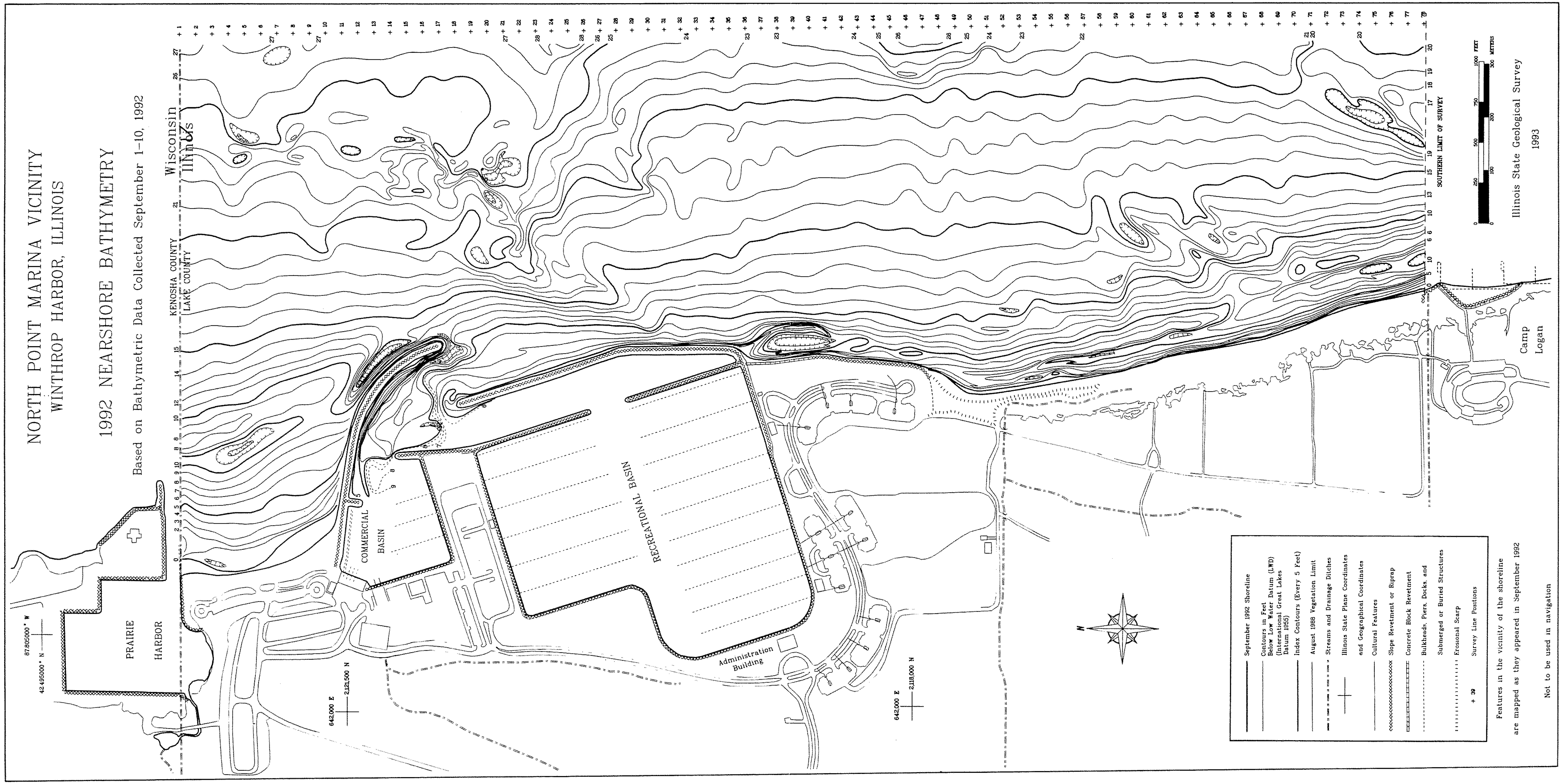
Map A-3

NORTH POINT MARINA VICINITY
WINTHROP HARBOR, ILLINOIS
1990 NEARSHORE BATHYMETRY
Based on Bathymetric Data Collected June 5-8, 1990
Wisconsin
Illinois
KENOSHA COUNTY
LAKE COUNTY
SOUTHERN LIMIT OF SURVEY
PRAIRIE COVE MARINA
COMMERCIAL BASIN
RECREATIONAL BASIN
Administration Building
Camp Logan
87.805000° W
42.495000° N
642,000 E
2,121,500 N
2,118,000 N
FEET
METERS
June 1990 Shoreline
Contours in Feet Below Low Water Datum (LWD) (International Great Lakes Datum 1955)
Index Contours (Every 5 Feet)
August 1988 Vegetation Limit
Streams and Drainage Ditches
Illinois State Plane Coordinates and Geographical Coordinates
Cultural Features
Slope Revetment or Riprap
Concrete Block Revetment
Bulkheads, Piers, Docks, and Submerged or Buried Structures
Erosional Scarp
+ 39 Survey Line Positions
Features in the vicinity of the shoreline are mapped as they appeared in June 1990
Not to be used in navigation
Illinois State Geological Survey
1993

Map A-4


NORTH POINT MARINA VICINITY
WINTHROP HARBOR, ILLINOIS
1991 NEARSHORE BATHYMETRY
Based on Bathymetric Data Collected June 10–15, 1991
Wisconsin
Illinois
KENOSHA COUNTY
LAKE COUNTY
COMMERCIAL BASIN
RECREATIONAL BASIN
Administration Building
PRAIRIE COVE MARINA
Camp Logan
SOUTHERN LIMIT OF SURVEY
Illinois State Geological Survey
1993
June 1991 Shoreline
Contours in Feet Below Low Water Datum (LWD) (International Great Lakes Datum 1955)
Index Contours (Every 5 Feet)
August 1988 Vegetation Limit
Streams and Drainage Ditches
Illinois State Plane Coordinates and Geographical Coordinates
Cultural Features
Slope Revetment or Riprap
Concrete Block Revetment
Bulkheads, Piers, Docks, and Submerged or Buried Structures
Erosional Scarp
Survey Line Positions
Features in the vicinity of the shoreline are mapped as they appeared in June 1991
Not to be used in navigation

Map A-5


NORTH POINT MARINA VICINITY
WINTHROP HARBOR, ILLINOIS
1992 NEARSHORE BATHYMETRY
Based on Bathymetric Data Collected September 1–10, 1992
Wisconsin
Illinois
KENOSHA COUNTY
LAKE COUNTY
PRAIRIE HARBOR
COMMERCIAL BASIN
RECREATIONAL BASIN
Administration Building
Camp Logan
SOUTHERN LIMIT OF SURVEY
FEET
METERS
Illinois State Geological Survey
1993
September 1992 Shoreline
Contours in Feet Below Low Water Datum (LWD) (International Great Lakes Datum 1955)
Index Contours (Every 5 Feet)
August 1988 Vegetation Limit
Streams and Drainage Ditches
Illinois State Plane Coordinates and Geographical Coordinates
Cultural Features
Slope Revetment or Riprap
Concrete Block Revetment
Bulkheads, Piers, Docks, and Submerged or Buried Structures
Erosional Scarp
Survey Line Positions
Features in the vicinity of the shoreline are mapped as they appeared in September 1992
Not to be used in navigation
42.495000° N
87.805000° W
642,000 E
2,121,500 N
2,118,000 N

Map A-6

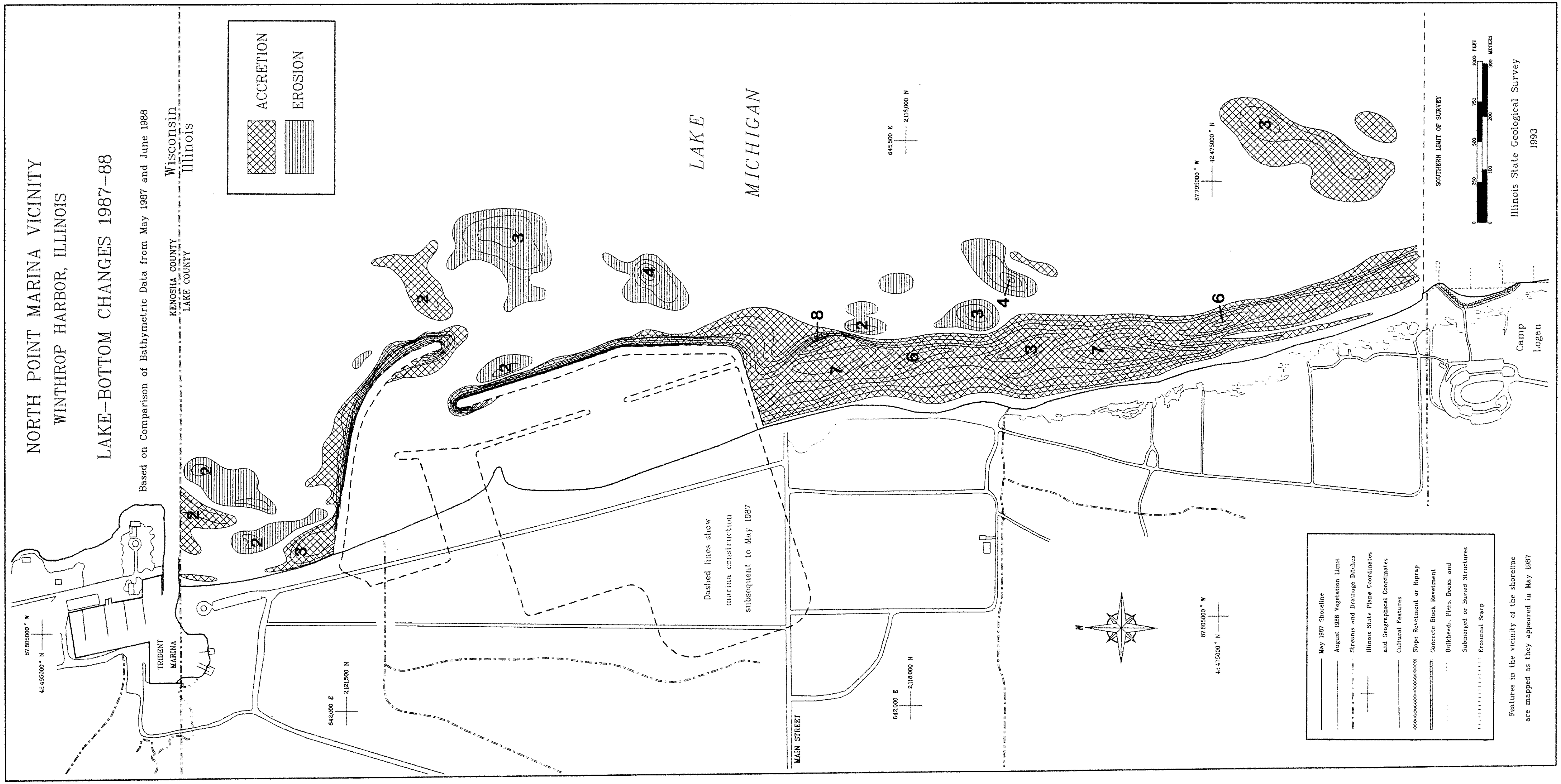
APPENDIX B
Annual Lake-Bottom Change Maps for North Point Marina Vicinity
1987 - 1992

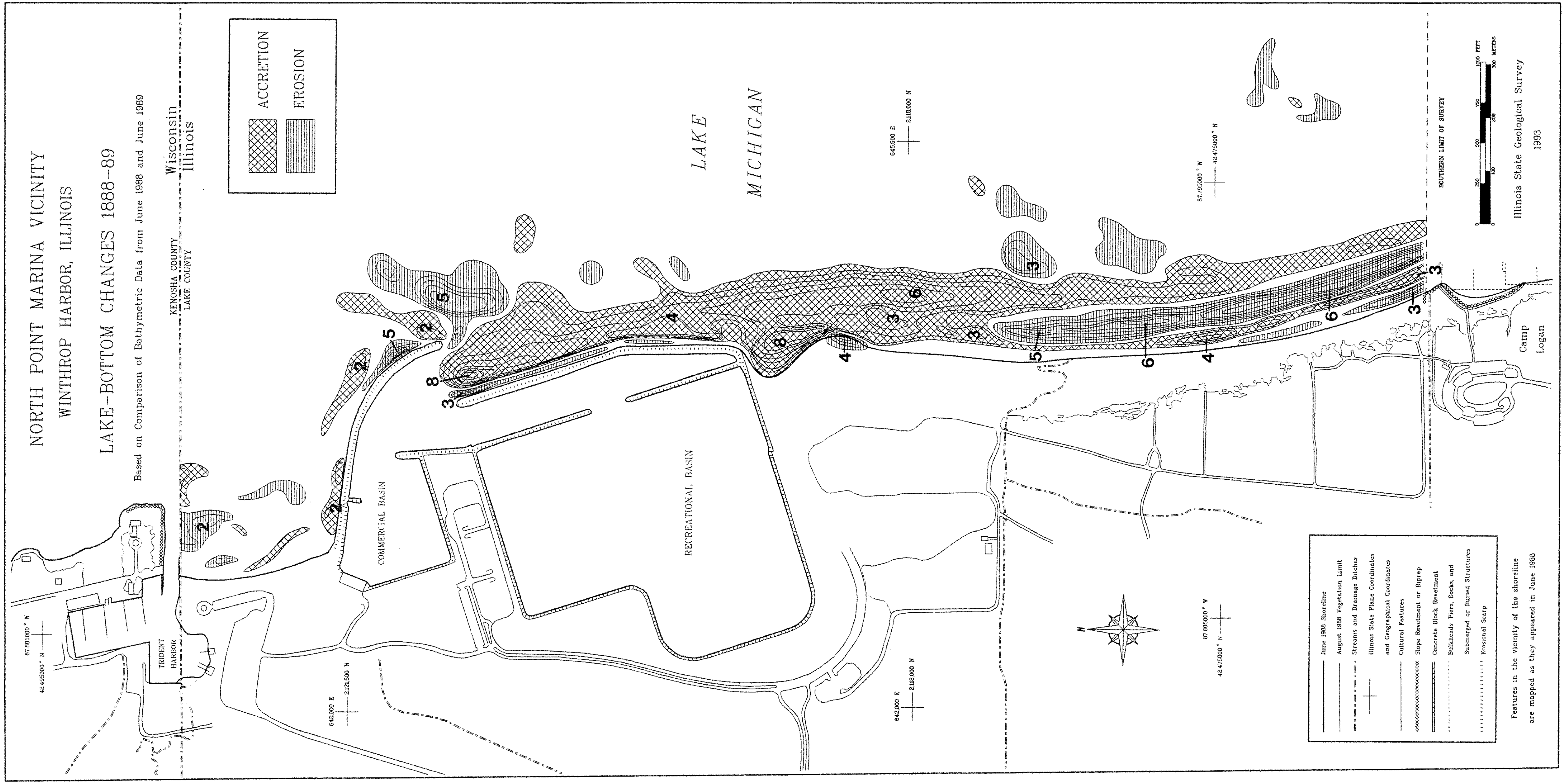
The series of five annual lake-bottom change maps of Appendix B are based on comparison of bathymetry recorded in the successive bathymetric maps presented in Appendix A. Erosion and accretion areas are distinguished by different map patterns. Only areas of lake-bottom change greater than 1 foot are shown. Contours are in 1-foot increments. The maximum contour value is shown as a reference in the map areas where congested or numerous contours prevent good contour resolution. The table below summarizes major lake-bottom changes depicted on each map.

Summary of annual lake-bottom changes in the vicinity of North Point Marina (1987-1992).

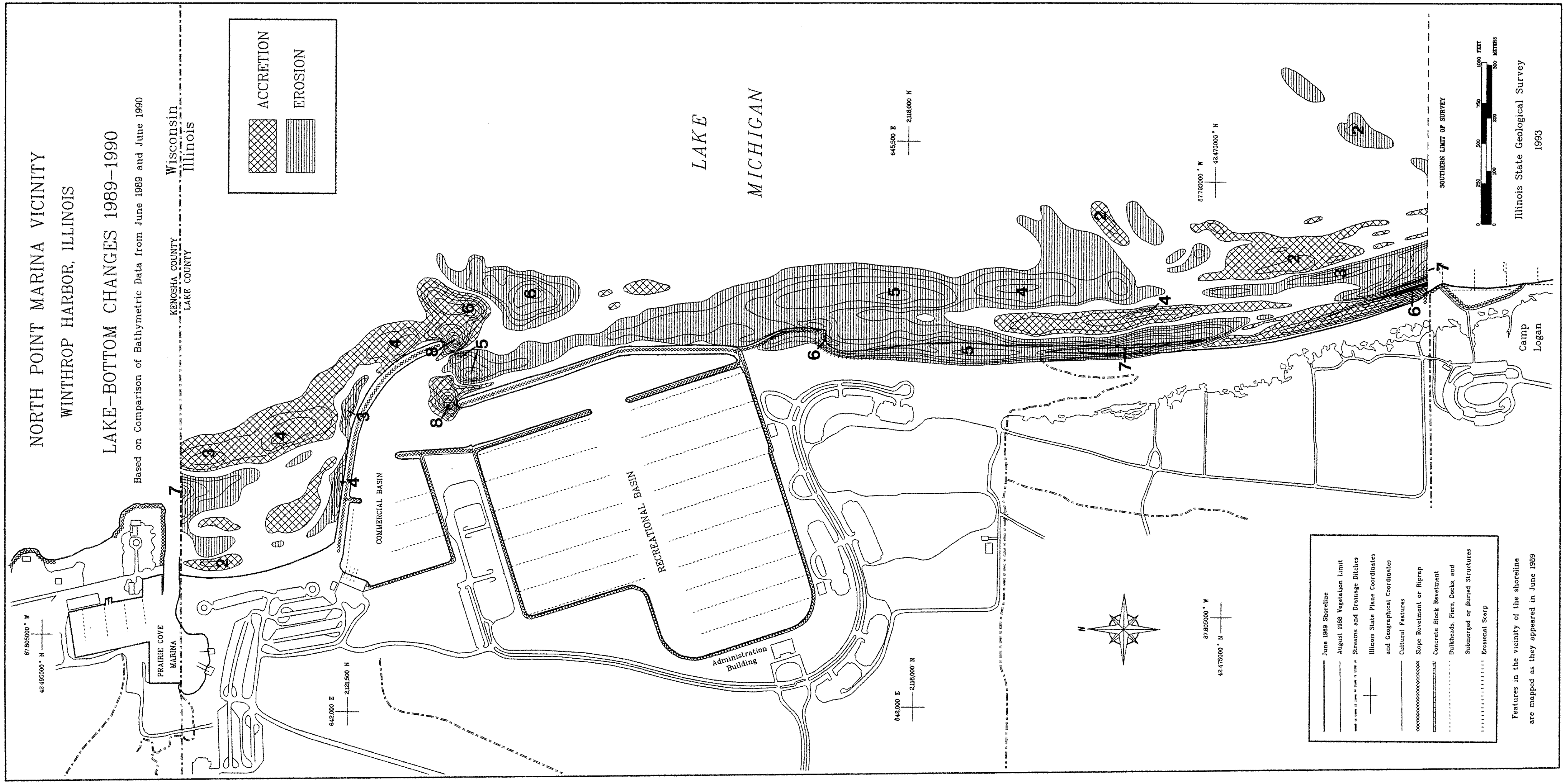
1987-1988	**Map B-1**
Overview	This interval spans from the initiation of basin dredging to the advanced stage of breakwater construction. This interval captures earliest lake-bottom changes associated with marina construction.
Erosion	Maximum erosion contours were 3 and 4 ft in patchy areas lakeward of the south breakwater. This erosion was possibly a localized lake-bottom adjustment to the breakwater construction.
Accretion	Accretion extended along the nearshore from the south side of the marina to Camp Logan. The maximum accretion contour was 8 ft at the fan delta.
Net change	Accretion
1988-1989	**Map B-2**
Overview	The prominent lake-bottom change was an accretional band extending from the marina entrance to Camp Logan. This resulted from both northward and southward dispersion of sediment from the fan delta.
Erosion	A maximum erosion contour of 6 ft occurred along the state park North Unit. This relates to lateral shift of the axis of a nearshore bar. A 5 ft erosion contour occurred adjacent to the northeastern side of the north breakwater. This erosion is suggestive of wave-induced scour along the breakwater toe.
Accretion	Maximum accretion contours of 8 ft occurred at the fan delta and marina entrance.
Net change	Accretion

1989-1990	**Map B-3**
Overview	Erosion dominated between 1989 and 1990. This was also the interval of greatest erosion in the initial six years (1987-1992) of data collection. Discharge of dredge material to the fan delta ceased in 1988; the nearshore was rapidly eroding by 1990. Some erosion was rapid and severe due to the instability of the discharged dredged sediments and steep and unstable underwater slopes.
Erosion	Maximum erosion contours of 6 and 7 ft occurred in the shallow nearshore downdrift of the fan delta.
Accretion	Two major accretion areas occurred. One related to development of the North Beach bar extending from the WI-IL state line to just south of the southern end of the north breakwater. The other occurred in the marina entrance adjacent to the north end of the south breakwater.
Net change	Erosion
1990-1991	**Map B-4**
Overview	Both accretion and erosion occurred between the state line and the north breakwater. This is interpreted as a response to both new sediment coming across the state line and redistribution of existing sediment. Between the marina and Camp Logan, changes were less extensive and less extreme compared to 1989-1990. Beach nourishment placed south of the south parking area in 1990 was a sediment source that likely alleviated erosional trends across the nearshore.
Erosion	A maximum erosion contour of 6 ft occurred landward of the submerged riprap. This area had been above lake level in 1989, but as the riprap subsided, erosion occurred landward of this riprap. A 5 ft erosion contour occurred off the northeast side of the north breakwater and also off the breakwater's southern end. Erosion also occurred along the shoreline and shallow nearshore south of the south parking area.
Accretion	Accretion off the southern end of the north breakwater corresponded to infilling of an erosional area that was present in the 1989-1990 comparison. Between the south parking area and Camp Logan, accretion occurred in a series of nearshore bars.
Net change	Erosion
1991-1992	**Map B-5**
Overview	Changes between the state line and the north breakwater were less pronounced in 1991-1992 compared to 1990-1991. The 1991-1992 erosion lakeward of the south parking area was less severe than in 1990-1991, but south of the parking area the erosion was more widespread and severe.
Erosion	Erosion dominated between the marina south parking area and Camp Logan. A nearly continuous band of erosion occurred in the shallow nearshore where maximum erosion contours were 6 ft.
Accretion	Both erosion and accretion occurred near the marina entrance, but accretion dominated. A maximum accretion contour of 7 ft occurred west of the north end of the south breakwater.
Net change	Erosion

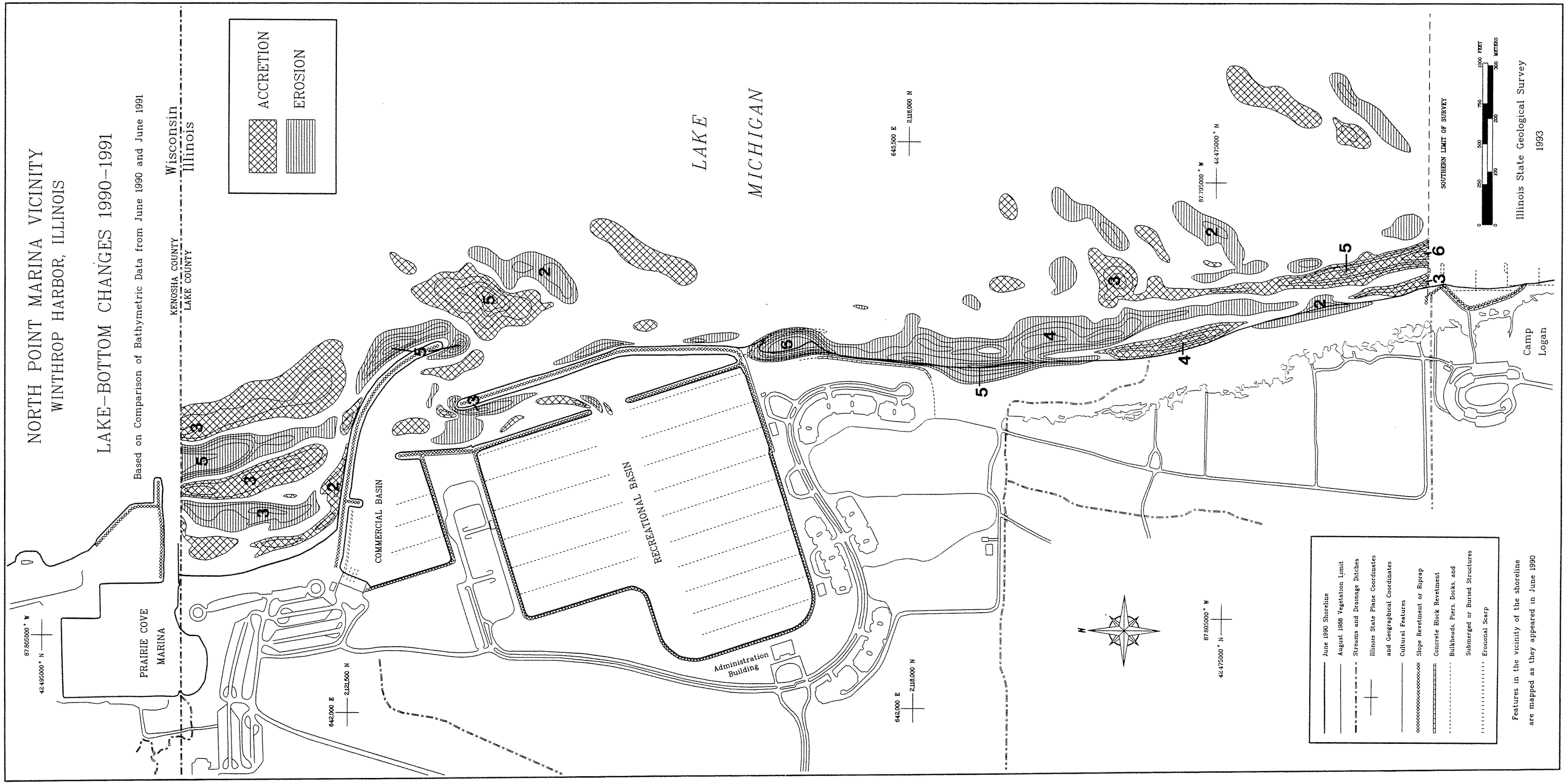

NORTH POINT MARINA VICINITY
WINTHROP HARBOR, ILLINOIS
LAKE-BOTTOM CHANGES 1987–88
Based on Comparison of Bathymetric Data from May 1987 and June 1988
ACCRETION
EROSION
Wisconsin
Illinois
KENOSHA COUNTY
LAKE COUNTY
LAKE MICHIGAN
TRIDENT MARINA
Dashed lines show marina construction subsequent to May 1987
MAIN STREET
Camp Logan
SOUTHERN LIMIT OF SURVEY
FEET
METERS
Illinois State Geological Survey
1993
N
May 1987 Shoreline
August 1988 Vegetation Limit
Streams and Drainage Ditches
Illinois State Plane Coordinates and Geographical Coordinates
Cultural Features
Slope Revetment or Riprap
Concrete Block Revetment
Bulkheads, Piers, Docks and Submerged or Buried Structures
Erosional Scarp
Features in the vicinity of the shoreline are mapped as they appeared in May 1987
642,000 E
2,121,500 N
2,118,000 N
645,500 E
87.805000° W
42.495000° N
87.795000° W
42.475000° N


NORTH POINT MARINA VICINITY
WINTHROP HARBOR, ILLINOIS
LAKE-BOTTOM CHANGES 1888-89
Based on Comparison of Bathymetric Data from June 1988 and June 1989
Wisconsin
Illinois
KENOSHA COUNTY
LAKE COUNTY
ACCRETION
EROSION
LAKE MICHIGAN
COMMERCIAL BASIN
RECREATIONAL BASIN
TRIDENT HARBOR
SOUTHERN LIMIT OF SURVEY
Camp Logan
Illinois State Geological Survey
1993
June 1988 Shoreline
August 1988 Vegetation Limit
Streams and Drainage Ditches
Illinois State Plane Coordinates and Geographical Coordinates
Cultural Features
Slope Revetment or Riprap
Concrete Block Revetment
Bulkheads, Piers, Docks, and Submerged or Buried Structures
Erosional Scarp
Features in the vicinity of the shoreline are mapped as they appeared in June 1988

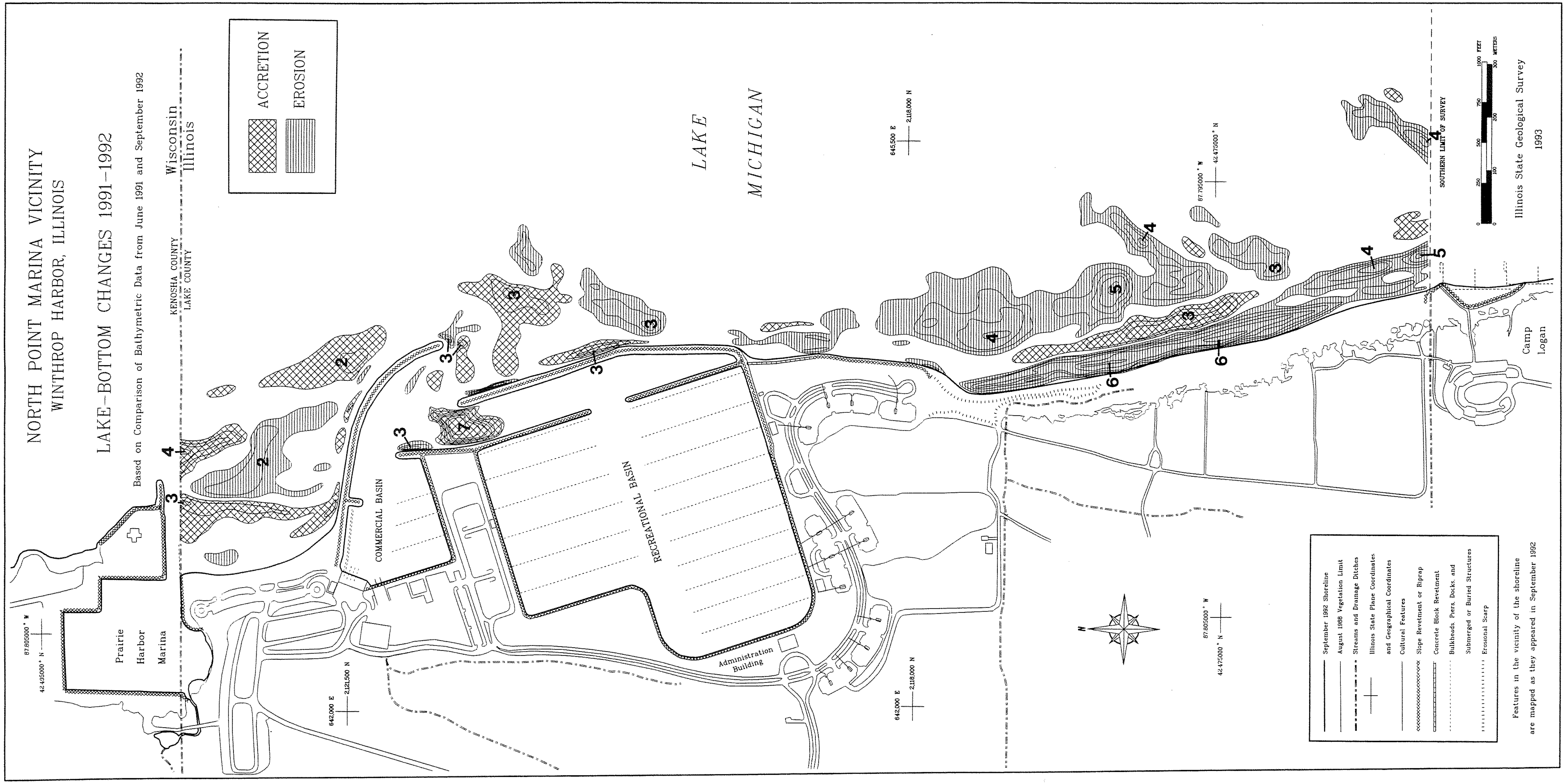
Map B-2


NORTH POINT MARINA VICINITY
WINTHROP HARBOR, ILLINOIS
LAKE-BOTTOM CHANGES 1989-1990
Based on Comparison of Bathymetric Data from June 1989 and June 1990
ACCRETION
EROSION
Wisconsin
Illinois
KENOSHA COUNTY
LAKE COUNTY
LAKE MICHIGAN
COMMERCIAL BASIN
RECREATIONAL BASIN
Administration Building
PRAIRIE COVE MARINA
Camp Logan
SOUTHERN LIMIT OF SURVEY
Illinois State Geological Survey
1993
June 1989 Shoreline
August 1988 Vegetation Limit
Streams and Drainage Ditches
Illinois State Plane Coordinates and Geographical Coordinates
Cultural Features
Slope Revetment or Riprap
Concrete Block Revetment
Bulkheads, Piers, Docks, and Submerged or Buried Structures
Erosional Scarp
Features in the vicinity of the shoreline are mapped as they appeared in June 1989

Map B-3


NORTH POINT MARINA VICINITY
WINTHROP HARBOR, ILLINOIS
LAKE–BOTTOM CHANGES 1990–1991
Based on Comparison of Bathymetric Data from June 1990 and June 1991
ACCRETION
EROSION
Wisconsin
Illinois
KENOSHA COUNTY
LAKE COUNTY
LAKE
MICHIGAN
PRAIRIE COVE
MARINA
COMMERCIAL BASIN
RECREATIONAL BASIN
Administration
Building
Camp
Logan
SOUTHERN LIMIT OF SURVEY
Illinois State Geological Survey
1993
June 1990 Shoreline
August 1988 Vegetation Limit
Streams and Drainage Ditches
Illinois State Plane Coordinates
and Geographical Coordinates
Cultural Features
Slope Revetment or Riprap
Concrete Block Revetment
Bulkheads, Piers, Docks, and
Submerged or Buried Structures
Erosional Scarp
Features in the vicinity of the shoreline
are mapped as they appeared in June 1990

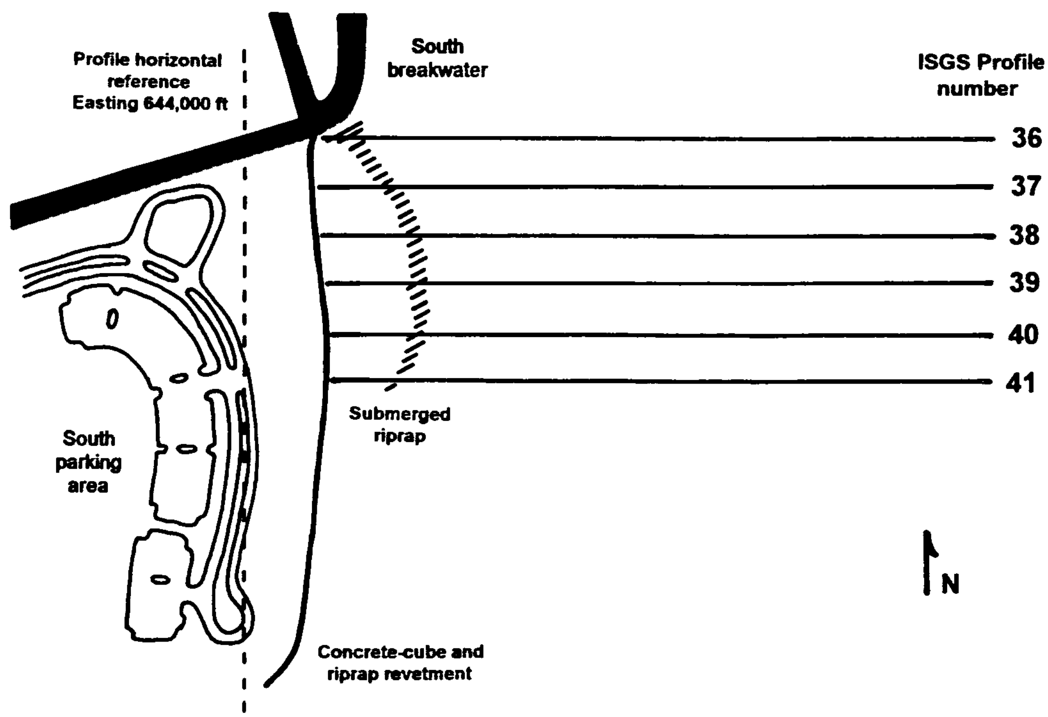
Map B-4


NORTH POINT MARINA VICINITY
WINTHROP HARBOR, ILLINOIS
LAKE-BOTTOM CHANGES 1991-1992
Based on Comparison of Bathymetric Data from June 1991 and September 1992
ACCRETION
EROSION
Wisconsin
Illinois
KENOSHA COUNTY
LAKE COUNTY
LAKE
MICHIGAN
COMMERCIAL BASIN
RECREATIONAL BASIN
Administration Building
Prairie Harbor Marina
Camp Logan
SOUTHERN LIMIT OF SURVEY
645,500 E
2,118,000 N
642,000 E
2,121,500 N
2,118,000 N
87.795000° W
42.475000° N
87.805000° W
42.495000° N
87.805000° W
42.475000° N
FEET
METERS
Illinois State Geological Survey
1993
September 1992 Shoreline
August 1998 Vegetation Limit
Streams and Drainage Ditches
Illinois State Plane Coordinates and Geographical Coordinates
Cultural Features
Slope Revetment or Riprap
Concrete Block Revetment
Bulkheads, Piers, Docks, and Submerged or Buried Structures
Erosional Scarp
Features in the vicinity of the shoreline are mapped as they appeared in September 1992

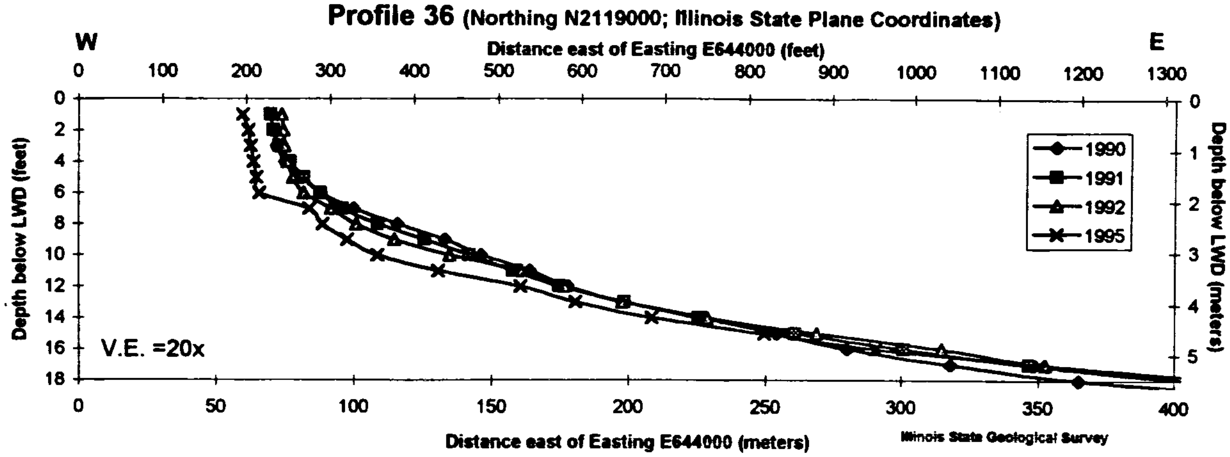
Map B-5

APPENDIX C
Profiles across the submerged riprap 1990 - 1995

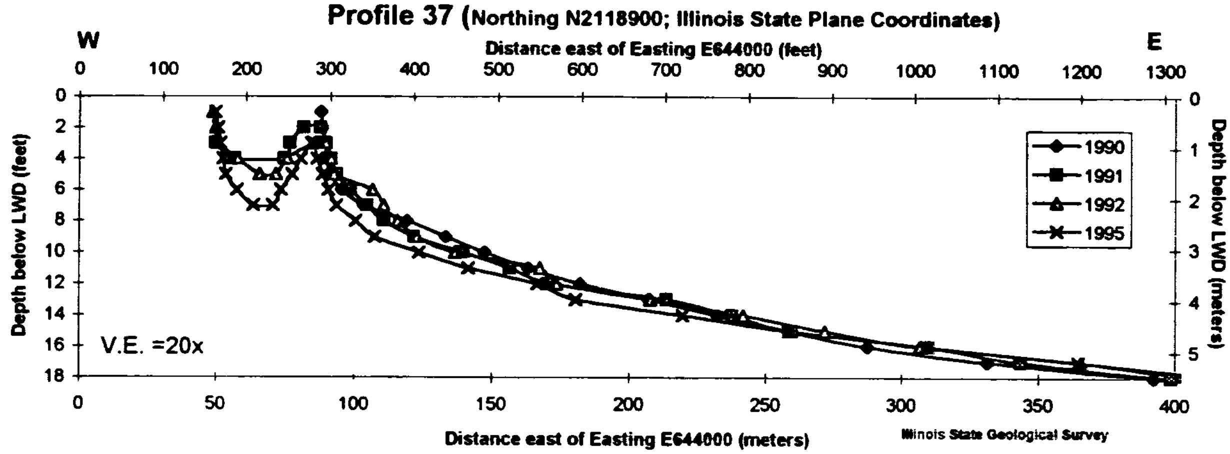
The five profiles (Profiles 36 through 41) are based on fathometer data. The index map below shows the location of the five profiles. All five profiles show that the net lake-bottom change is erosion, and this has consistently occurred above 15 ft LWD. The 1990 profiles have their landward end against the riprap which was then still emergent. By the time of the 1991 survey, sufficient subsidence had occurred for fathometer data to be collected across the riprap.



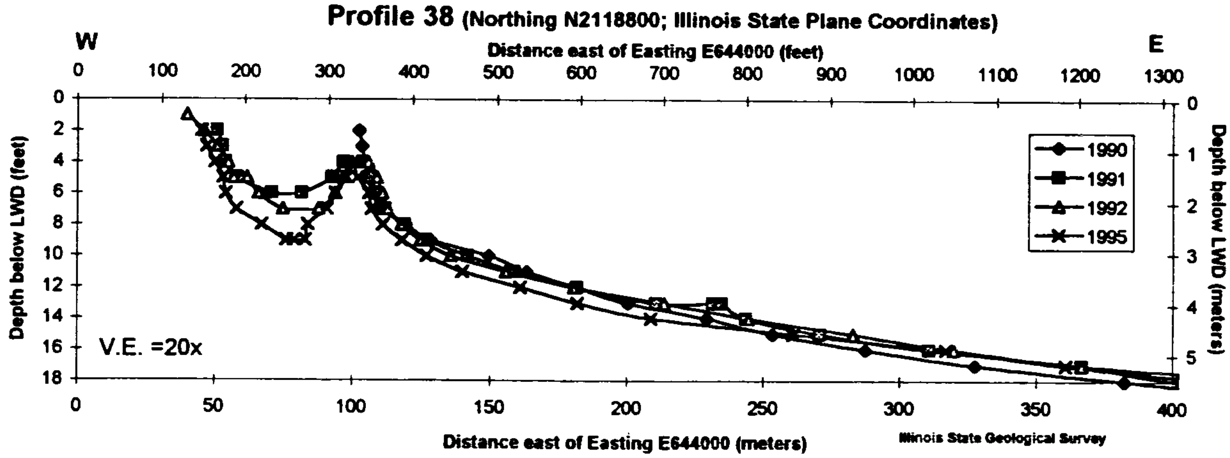
Profile 36 (Northing N2119000; Illinois State Plane Coordinates)

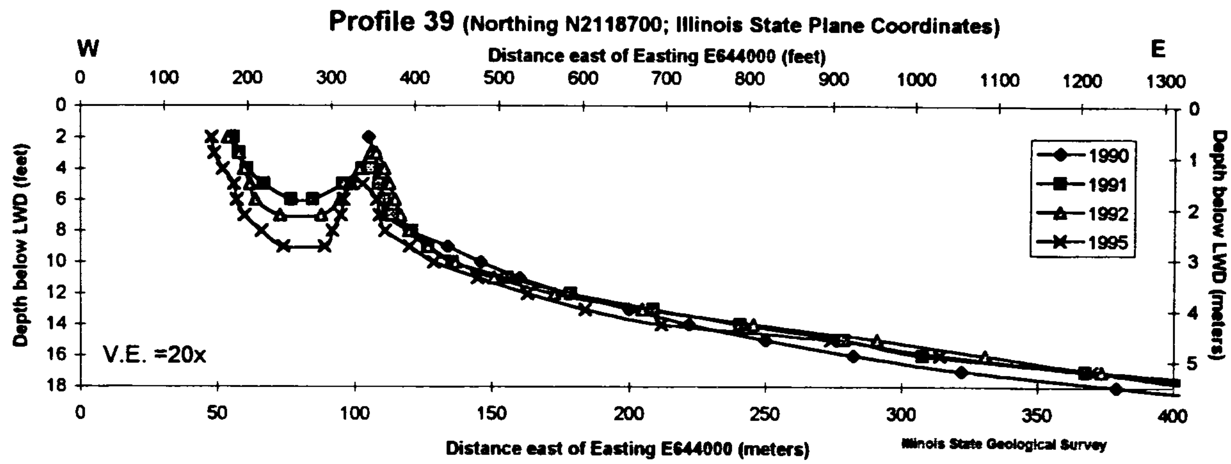


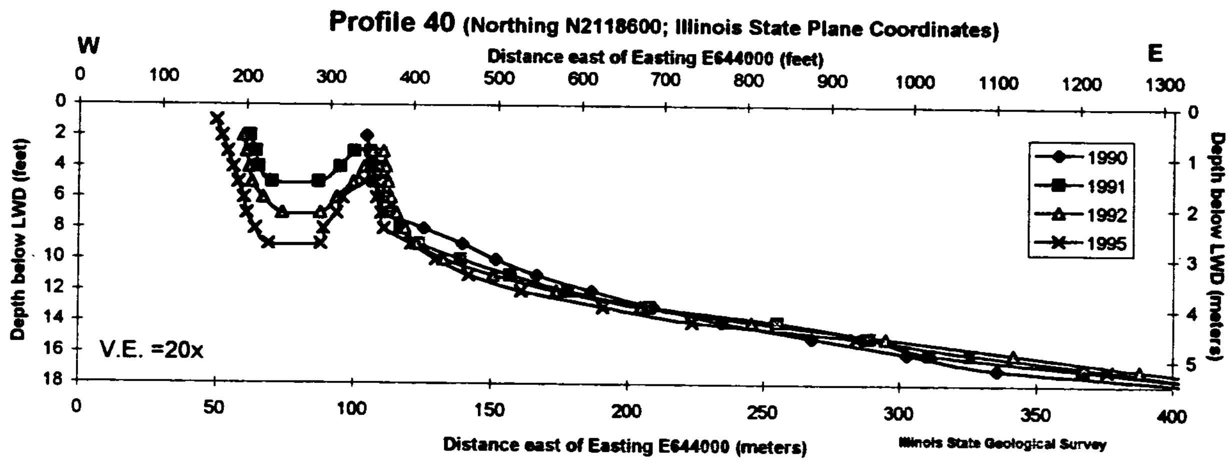
Profile 37 (Northing N2118900; Illinois State Plane Coordinates)

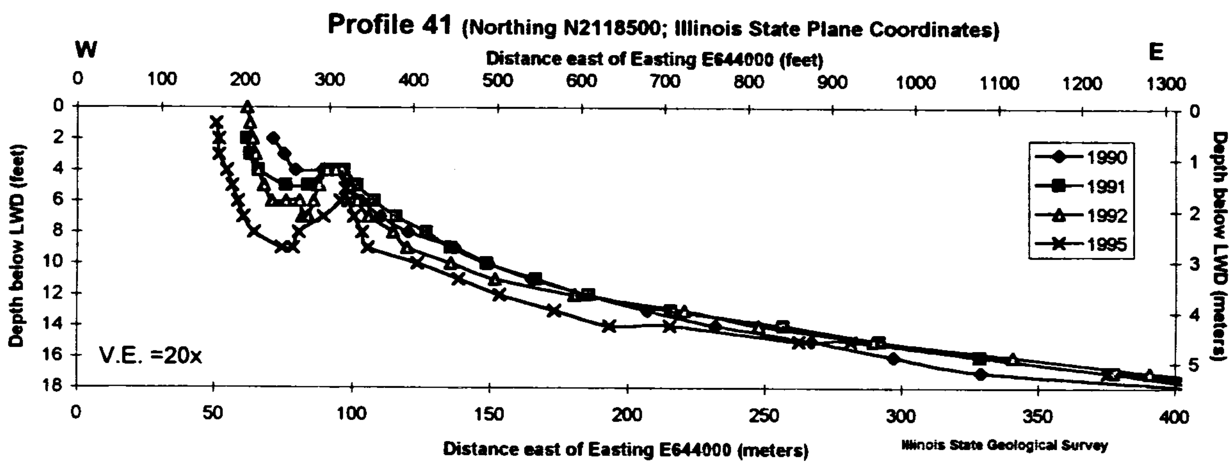


Profile 38 (Northing N2118800; Illinois State Plane Coordinates)




Profile 39 (Northing N2118700; Illinois State Plane Coordinates)
W
E
Distance east of Easting E644000 (feet)
Depth below LWD (feet)
Depth below LWD (meters)
1990
1991
1992
1995
V.E. =20x
Distance east of Easting E644000 (meters)
Illinois State Geological Survey


Profile 40 (Northing N2118600; Illinois State Plane Coordinates)
W
E
Distance east of Easting E644000 (feet)
Depth below LWD (feet)
Depth below LWD (meters)
1990
1991
1992
1995
V.E. =20x
Distance east of Easting E644000 (meters)
Illinois State Geological Survey


Profile 41 (Northing N2118500; Illinois State Plane Coordinates)
W
E
Distance east of Easting E644000 (feet)
Depth below LWD (feet)
Depth below LWD (meters)
1990
1991
1992
1995
V.E. =20x
Distance east of Easting E644000 (meters)
Illinois State Geological Survey

APPENDIX D
Maps related to proposed shore defense at the NPM south parking area

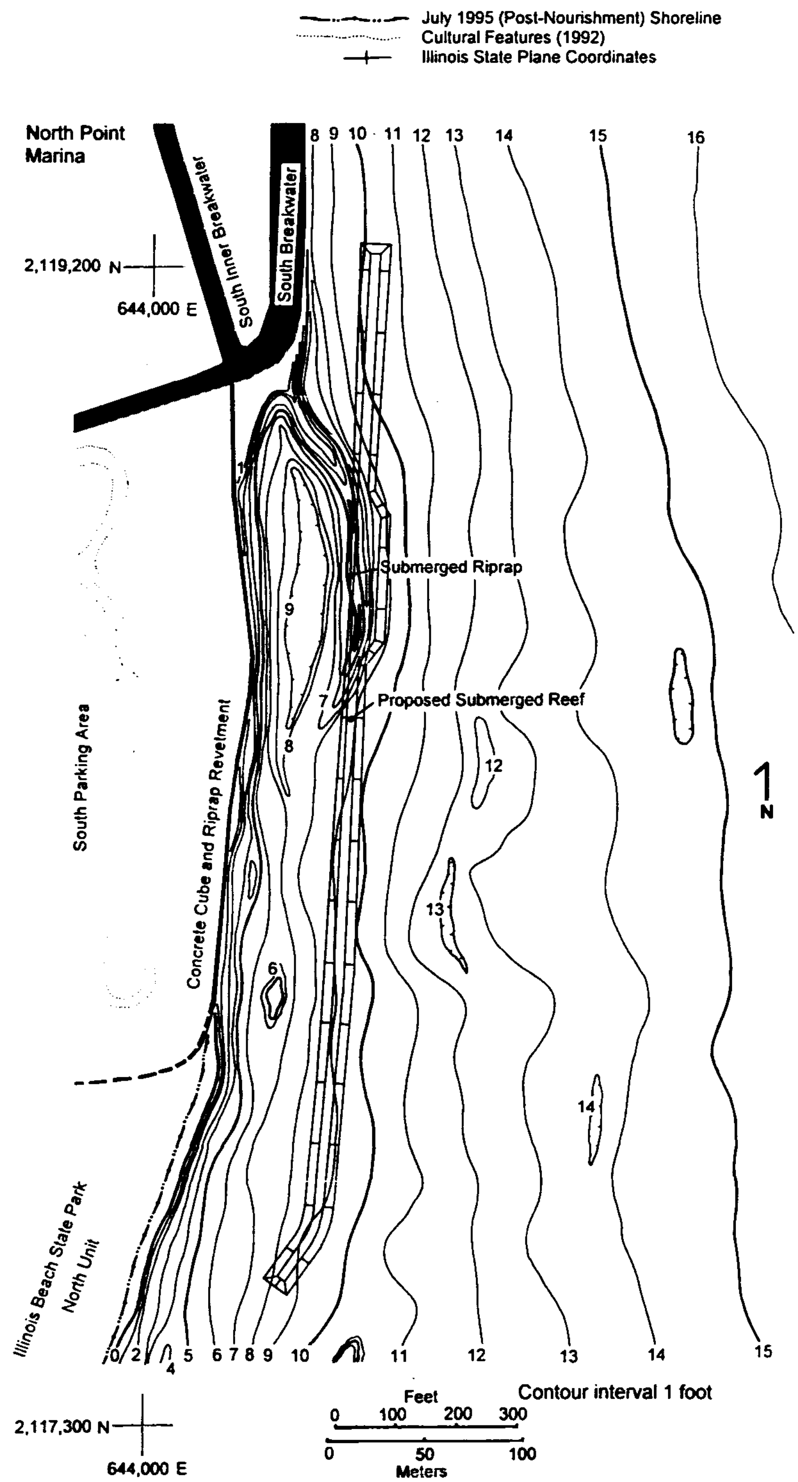
Maps D-1 and D-2 relate to plans for proposed shore defense at the south parking area. A new revetment along the shore is proposed in conjunction with a submerged, nearshore reef. Map D-1 shows the proposed location of the reef superimposed on the local 1995 bathymetry. Map D-2 shows the location of the reef superimposed on an isopach map of 1992-1995 lake-bottom changes.

Project plans for the reef were obtained from Patrick Engineering, Inc. (1995).

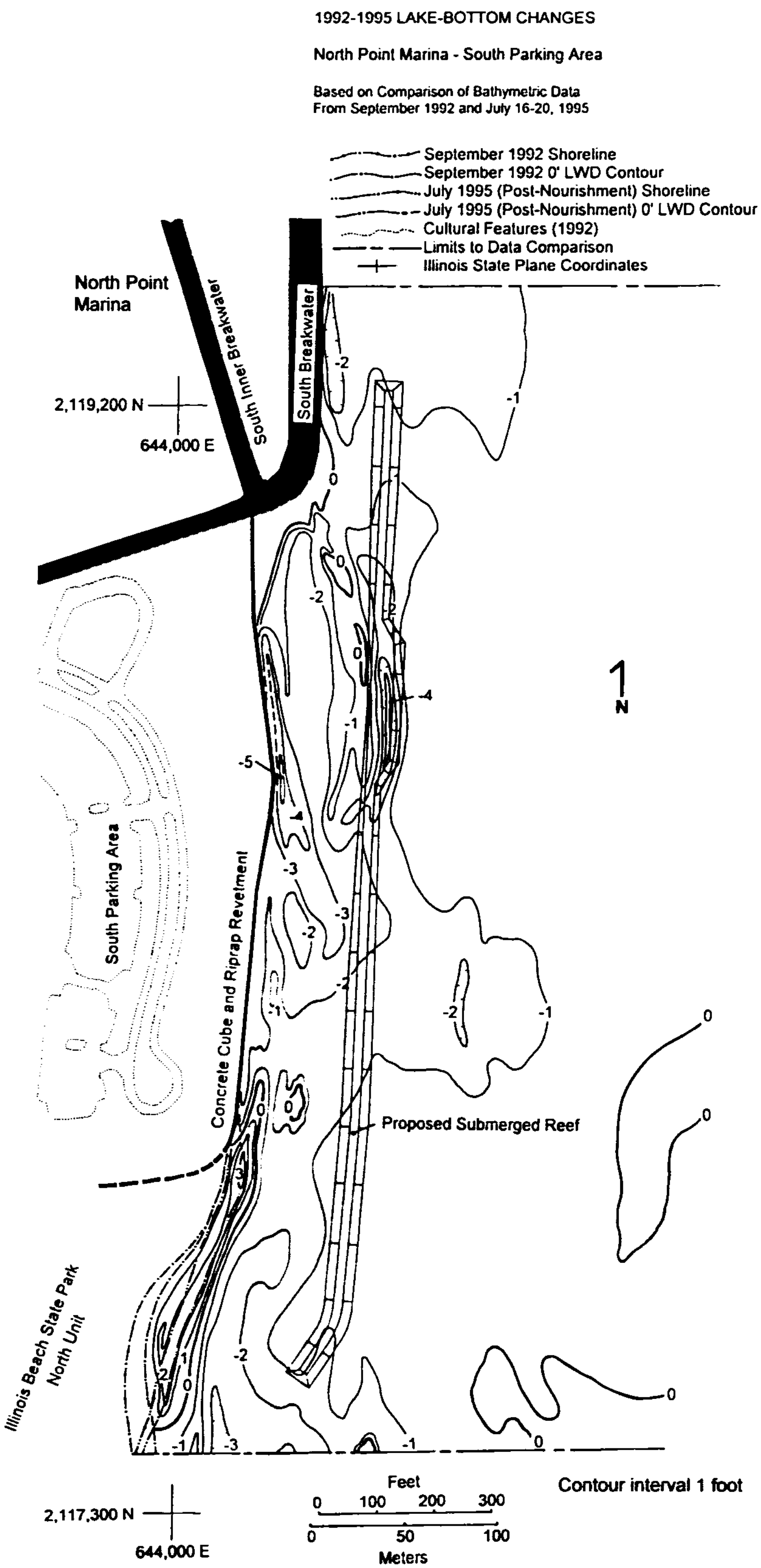
1995 NEARSHORE BATHYMETRY

North Point Marina - South Parking Area

Based on Bathymetric Data Collected July 16-20, 1995



Map D-1



1992-1995 LAKE-BOTTOM CHANGES
North Point Marina - South Parking Area
Based on Comparison of Bathymetric Data
From September 1992 and July 16-20, 1995
September 1992 Shoreline
September 1992 0' LWD Contour
July 1995 (Post-Nourishment) Shoreline
July 1995 (Post-Nourishment) 0' LWD Contour
Cultural Features (1992)
Limits to Data Comparison
Illinois State Plane Coordinates
North Point Marina
South Inner Breakwater
South Breakwater
2,119,200 N
644,000 E
South Parking Area
Concrete Cube and Riprap Revetment
Proposed Submerged Reef
Illinois Beach State Park North Unit
N
2,117,300 N
644,000 E
Feet
0 100 200 300
0 50 100
Meters
Contour interval 1 foot

Map D-2

APPENDIX E
Diver report from 1990 survey along the NPM north breakwater

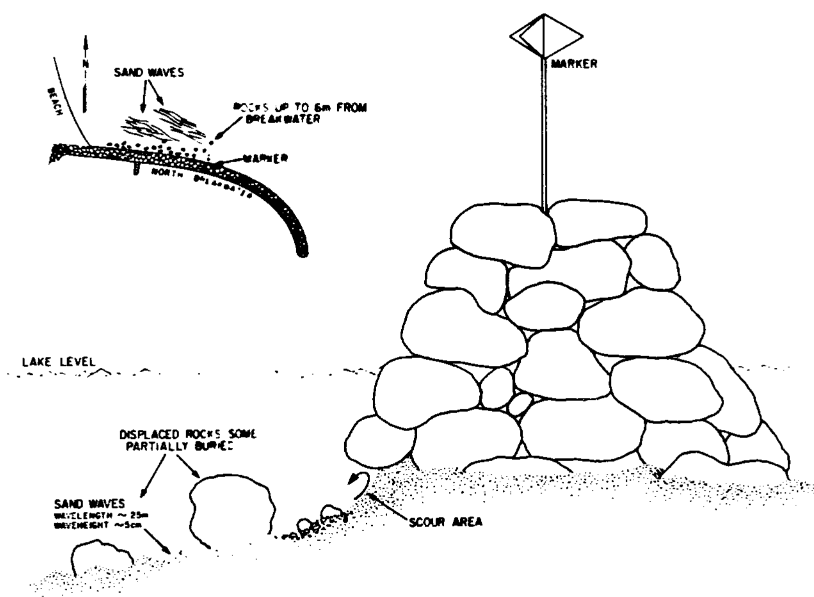
The following text and illustration are taken from:
U.S. Geological Survey Open File Report 91-327
Underwater Observations of Breakwaters at North Point Marina, Winthrop Harbor, Illinois
by
Ronald Circe and Dann Blackwood
1991

Dive Site Number 1: Lakeward Side of North Breakwater
Sand waves were observed in water depths of 1 to 2 meters. The sand waves had heights of about 5 cm and lengths of about 250 cm. The field of sand waves extended lakeward of the breakwater to a distance of 6 meters. Using an underwater compass, it was noted that the crests of the sand waves were oriented in a NW-SE direction (Fig. 1).

Boulders from the rubble-mound breakwater were observed as far as 6 meters lakeward of the breakwater. These displaced rocks were first thought to have moved relative to the breakwater. After reviewing copies of the blueprints for construction of the breakwater, it is possible that these rocks are in, or close to, their intended location.

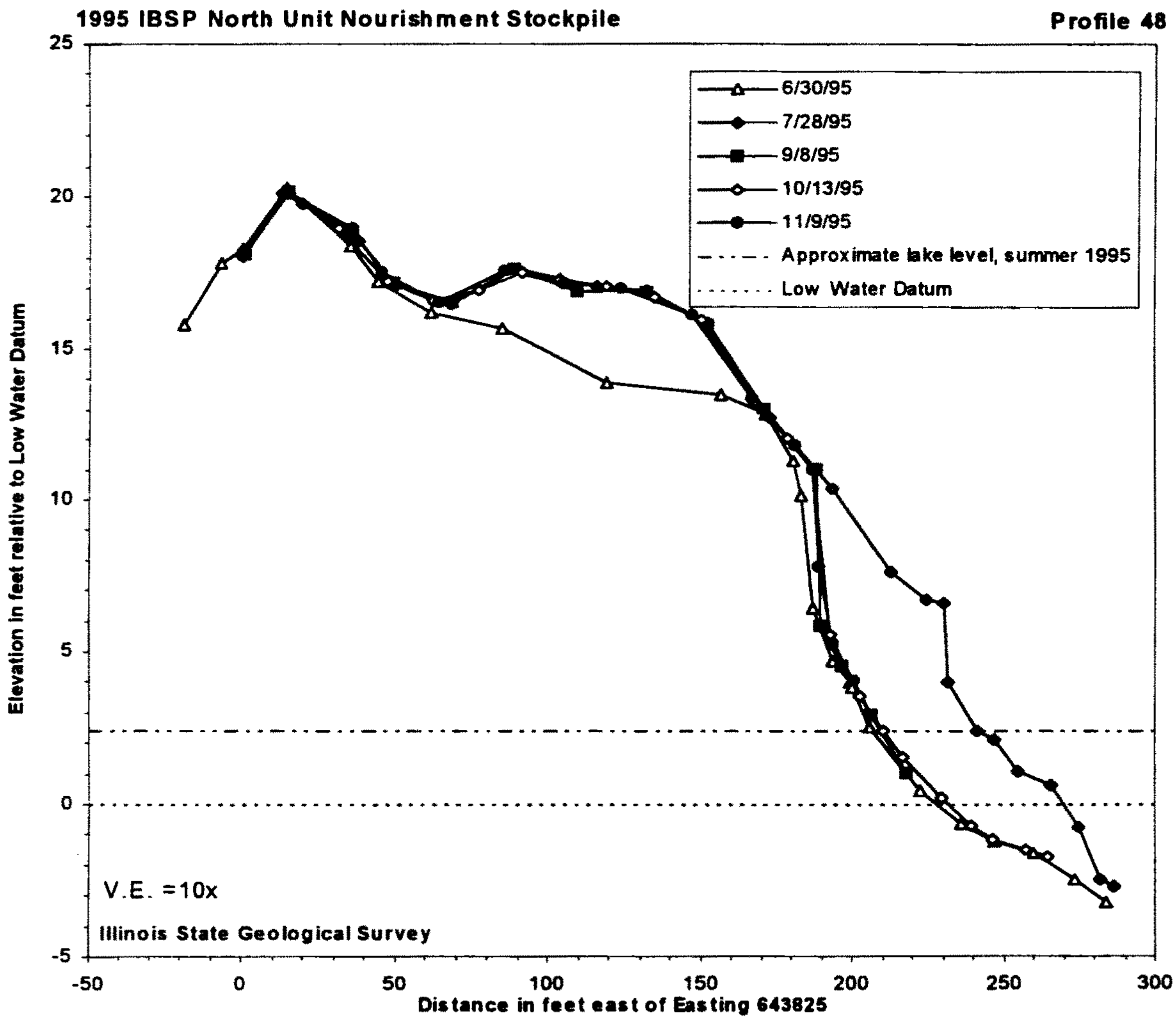
Sediment at the base of the breakwater was generally well-sorted, fine sand, but pebbles and cobbles (up to 20 cm in diameter) were also present. These pebble/cobble beds were typically confined to a 1-meter wide zone adjacent to the breakwater. Evidence of scouring was seen along the entire base of the breakwater within the area of observation. Figure 1 shows a diagrammatic cross-section of the North Breakwater with the sand waves, possible displaced rocks, and the scour area.

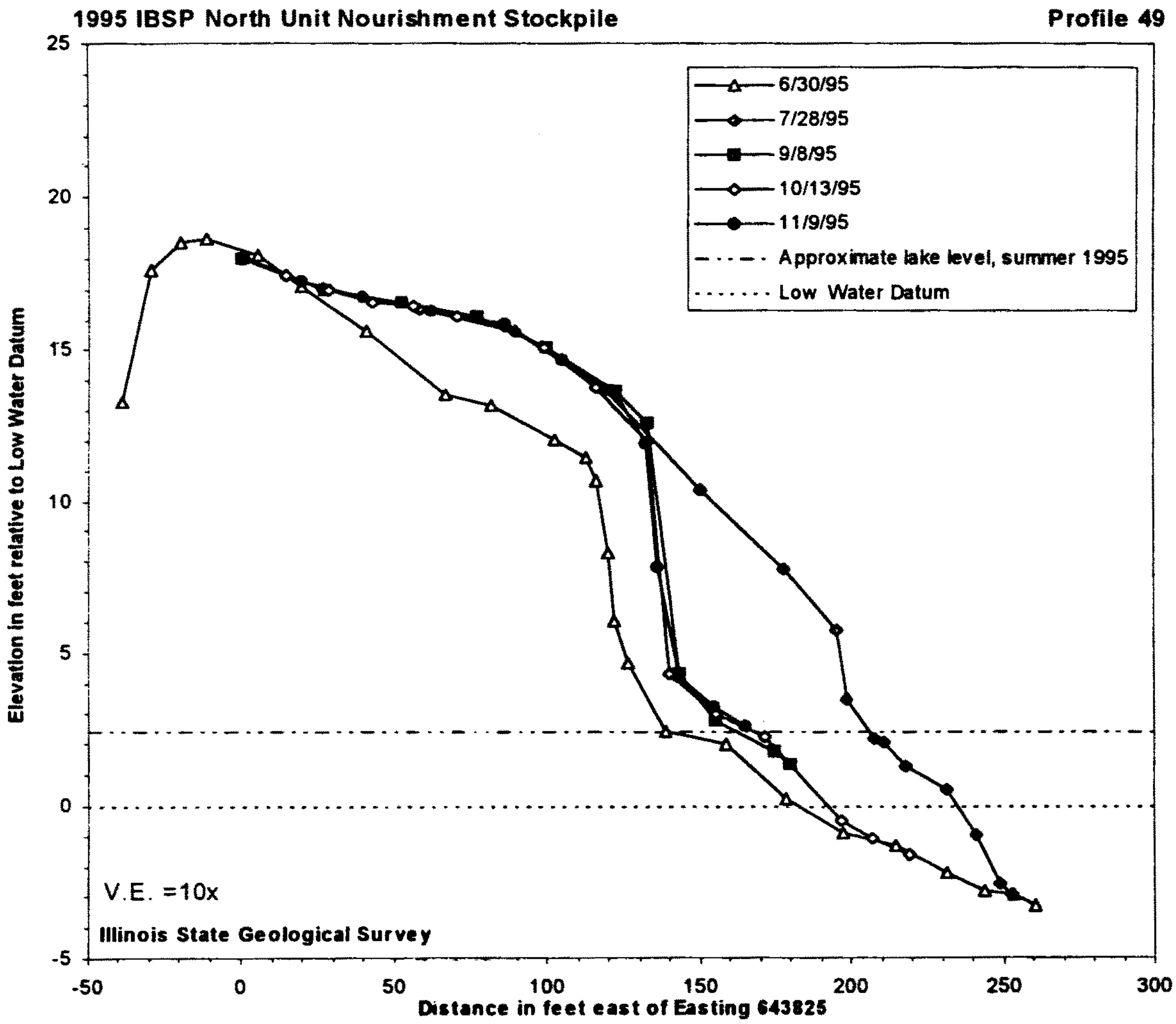
Due to limited visibility, no underwater photographs were taken at this site.

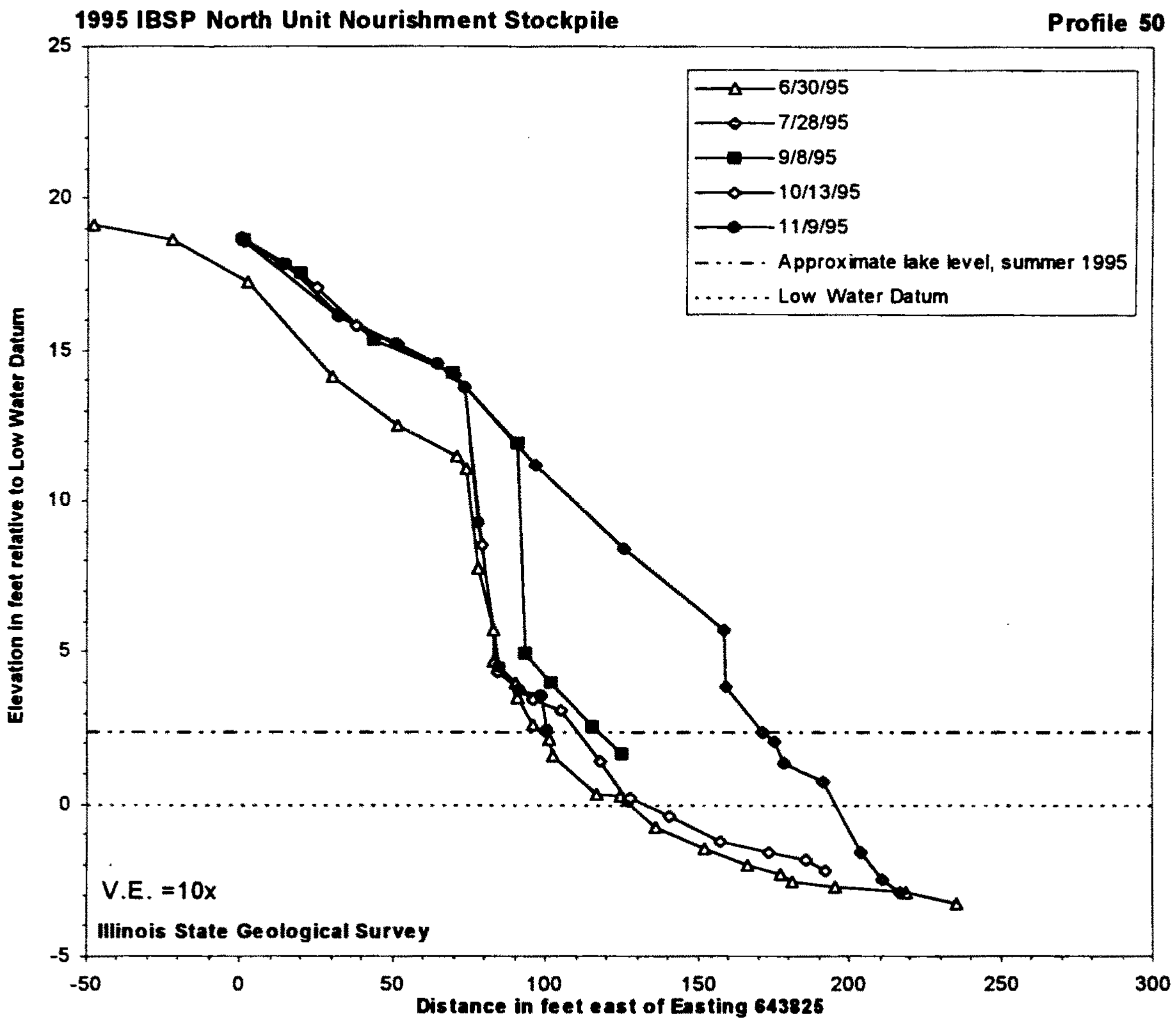


Appendix E / Figure 1 (from Circe and Blackwood, 1991)

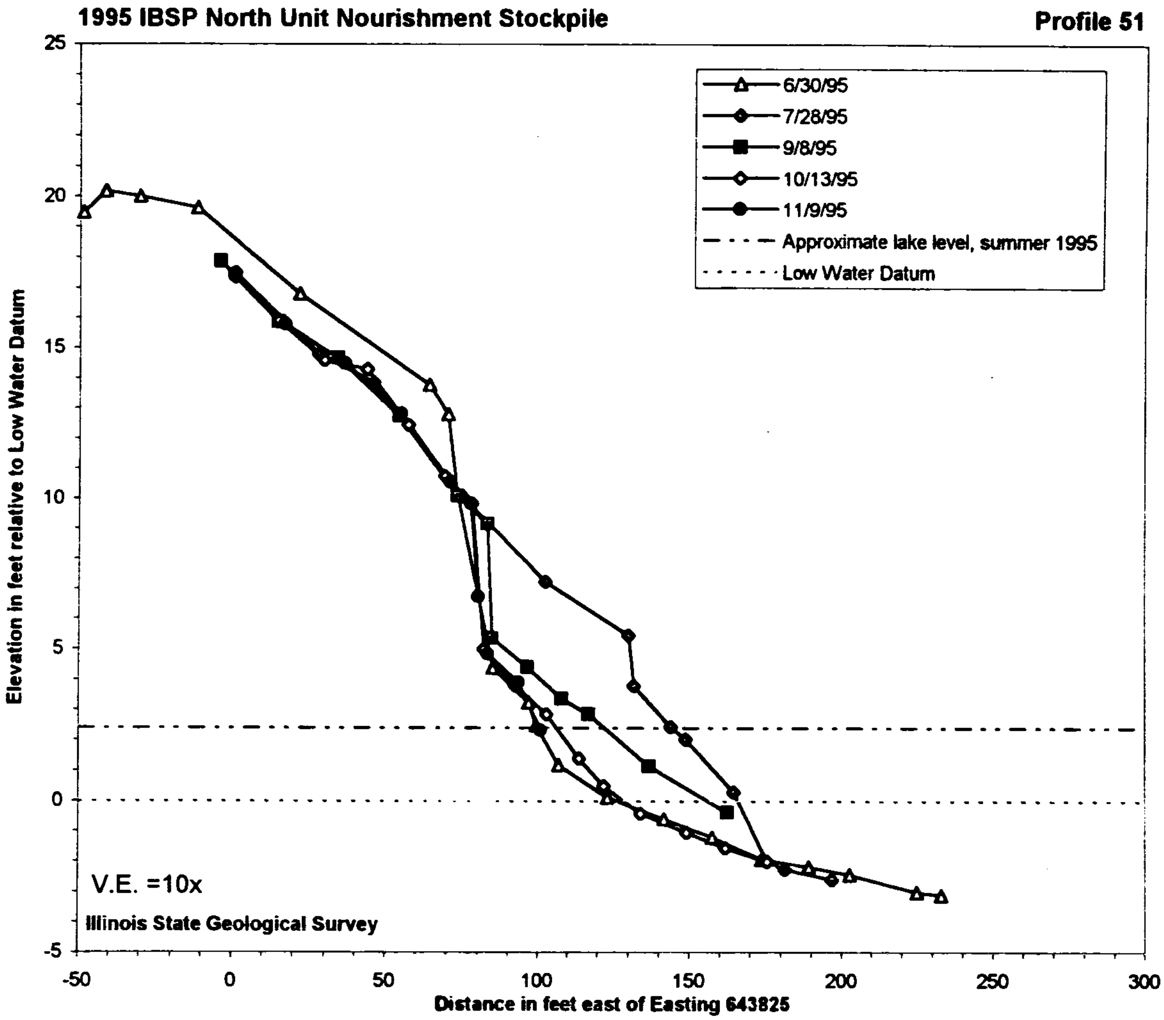
APPENDIX F
Profiles across the 1995 nourishment stockpile at IBSP North Unit



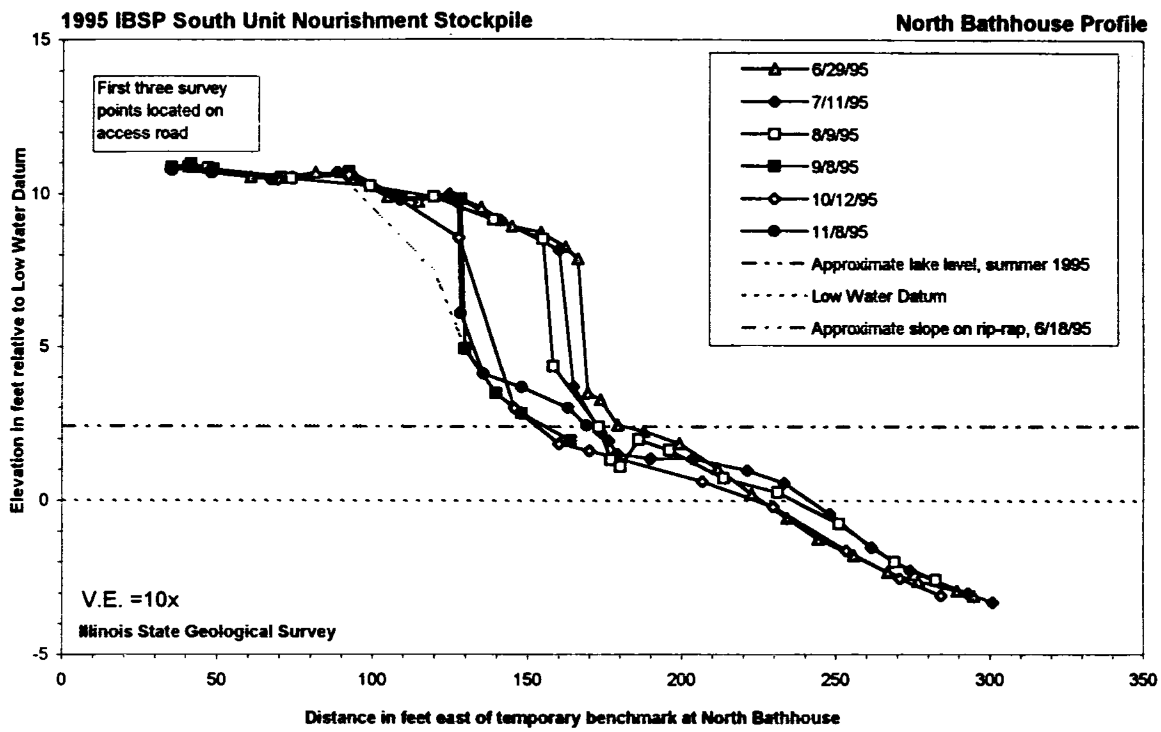

1995 IBSP North Unit Nourishment Stockpile
Profile 49
6/30/95
7/28/95
9/8/95
10/13/95
11/9/95
Approximate lake level, summer 1995
Low Water Datum
V.E. =10x
Illinois State Geological Survey
Elevation in feet relative to Low Water Datum
Distance in feet east of Easting 643825
25
20
15
10
5
0
-5
-50
0
50
100
150
200
250
300

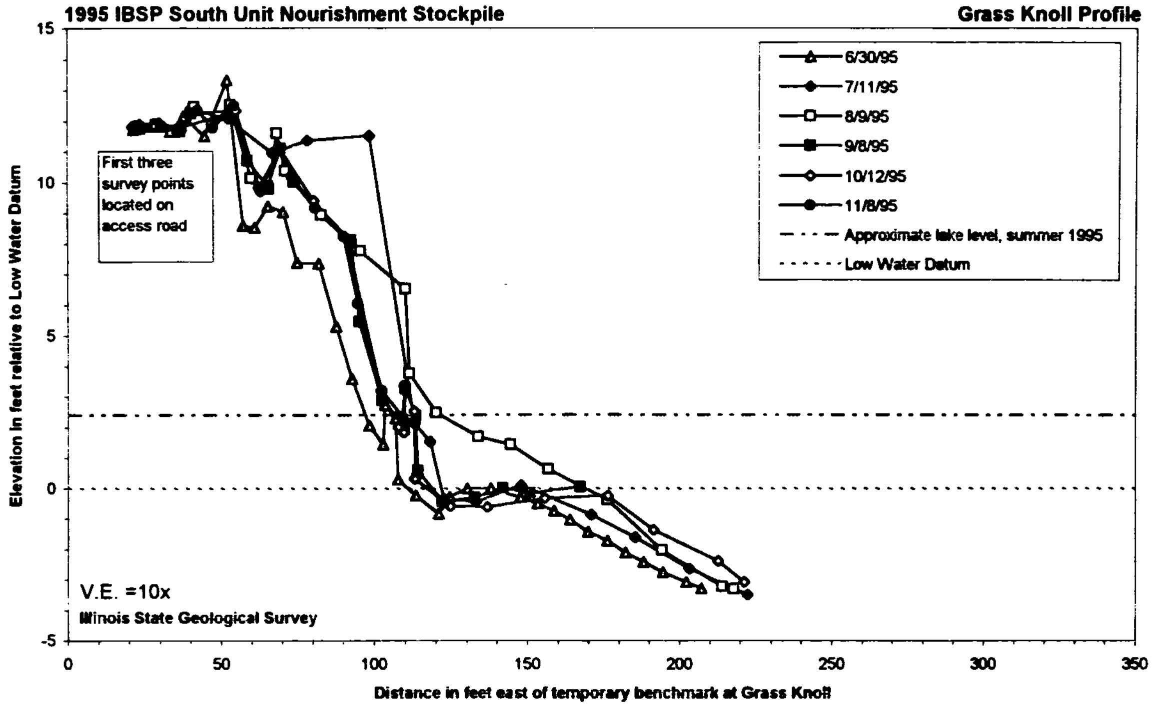


1995 IBSP North Unit Nourishment Stockpile
Profile 50
6/30/95
7/28/95
9/8/95
10/13/95
11/9/95
Approximate lake level, summer 1995
Low Water Datum
V.E. =10x
Illinois State Geological Survey
Elevation in feet relative to Low Water Datum
Distance in feet east of Easting 643825
25
20
15
10
5
0
-5
-50
0
50
100
150
200
250
300

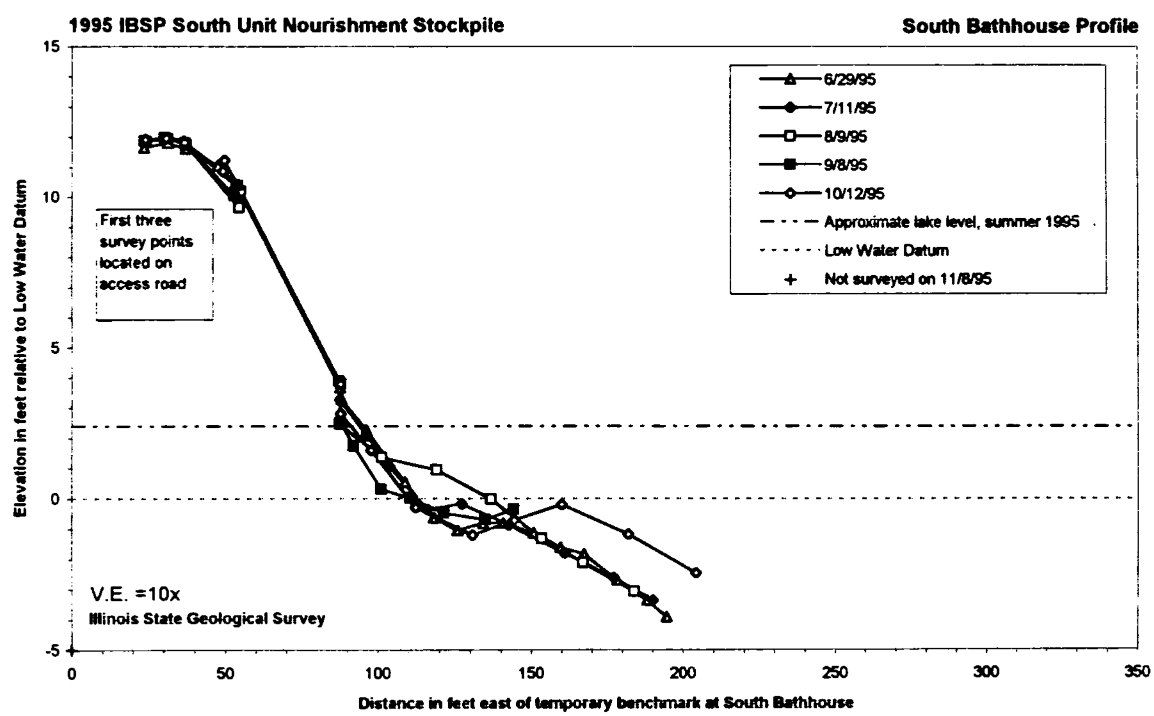

1995 IBSP North Unit Nourishment Stockpile
Profile 51
6/30/95
7/28/95
9/8/95
10/13/95
11/9/95
Approximate lake level, summer 1995
Low Water Datum
V.E. =10x
Illinois State Geological Survey
Elevation in feet relative to Low Water Datum
Distance in feet east of Easting 643825
25
20
15
10
5
0
-5
-50
0
50
100
150
200
250
300

APPENDIX G
Profiles across the 1995 nourishment stockpile at IBSP South Unit





1995 IBSP South Unit Nourishment Stockpile
Grass Knoll Profile
6/30/95
7/11/95
8/9/95
9/8/95
10/12/95
11/8/95
Approximate lake level, summer 1995
Low Water Datum
First three survey points located on access road
V.E. =10x
Illinois State Geological Survey
Elevation in feet relative to Low Water Datum
Distance in feet east of temporary benchmark at Grass Knoll
15
10
5
0
-5
0
50
100
150
200
250
300
350



1995 IBSP South Unit Nourishment Stockpile
South Bathhouse Profile
6/29/95
7/11/95
8/9/95
9/8/95
10/12/95
Approximate lake level, summer 1995
Low Water Datum
Not surveyed on 11/8/95
First three survey points located on access road
V.E. =10x
Illinois State Geological Survey
Elevation in feet relative to Low Water Datum
Distance in feet east of temporary benchmark at South Bathhouse
15
10
5
0
-5
0
50
100
150
200
250
300
350

APPENDIX H
Regional scheme for nearshore profiling from WI-IL state line to Waukegan Harbor