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SOUTHERN LAKE MICHIGAN COASTAL EROSION STUDY WORKSHOP

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Edited by

Folger, D. W., Colman, S. M., and Barnes, P. W.

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CONTENTS

FIGURES

APPENDIX

INTRODUCTION

The Southern Lake Michigan Coastal Erosion Study was initiated in 1988 as a result of damage to the shoreline related to the high lake levels of the mid-1980's. The purpose of the study is to develop a better understand of the processes that cause erosion and flooding of the Illinois-Indiana shorelines, and of the mechanisms and frequency of lake level fluctuations, and to develop better models to predict the extent, and speed of coastal retreat.

The study is about half-way through its allotted five years. Most field work for the Framework and Lake Level phases has been completed; field work for the third phase, Processes, is now underway.

Framework studies show that glacial till overlying bedrock commonly ranges from 0 to 20 m thick along the Illinois shore and 20-40 m thick along the Indiana shore. Offshore a patchy veneer of sand and gravel covers the till. Sidescan-sonar records are still being analyzed; they will provide surficial sediment distribution maps in five areas along the Illinois and Indiana shoreline where more detailed studies of processes will be carried out.

The volume of sand that lies in the nearshore area has not been adequately assessed. In part, this is because the thickness of sediment in the transition zone from lake to beach is difficult to measure acoustically, and time consuming and labor intensive to measure by coring or probing. Enough information is available to suggest that Ground Penetrating Radar (GPR) might be an appropriate tool to evaluate the sand thickness. Experiments will be carried out in the fall of 1990 to test the feasibility of GPR to fill this important gap in our knowledge. This is a critical element of study because of the role that the sand wedge plays in protecting the bluffs and the nearshore clay substrate from erosion by waves, currents, and ice, and in providing material for recreational beaches.

Cores collected as part of the Lake Level studies reveal that little sand apparently is transported from the shoreline to the deep areas of the lake. Modern lake muds approach closest to the Illinois shore off Waukegan but do not appear to be covering till off Chicago closer to shore than about 20 km. Detailed studies of the deep water sediments are beginning to unravel the relation of depositional and erosional events to climatic variations. These data will contribute to understanding the mechanism and chronology of lake level changes. Onshore studies of beach ridges in Illinois Beach State Park, Indiana Dunes, and Two Rivers, Wisconsin reveal the patterns of lake level fluctuations as much as 5500 years BP. These are being combined with more regional studies of the lakeshore in an effort to establish the relationship between the uplift history of the basin following deglaciation and the range of lake level fluctuations.

A submerged forest, recently discovered in 25 m of water about 25 km off Chicago, will provide valuable new information concerning lake level changes. We will survey the forest in 1990. If similar stands of trees on the lake floor at different water depths can be found, the lake level history curve can be greatly refined.

Process studies already are showing that ice along the shoreline is a significant agent of sediment erosion and transport. The ice acts both as a rafter of sediment and as a temporary sea wall that focuses lakebed erosion along the margins of the ice ridges.

Compilations of aerial photography along the Illinois shoreline reveal that the 50-yr retreat for all bluff segments is 10.9 m or a mean rate of 0.22 m/yr. In contrast, near a marina site that is under construction at Illinois Beach State Park, erosion rates along a beach scarp accelerated to 2 m/month before the area could be stabilized.

Detailed nearshore studies at Fort Sheridan show significant variability of bedforms and sediment inshore of 15 meters water depth. A deposit of probable glacial sediment is expected to affect bed stability and erodability. Examination of gravel motion under oscillatory flow on beaches suggests that coarse sediment on beaches can move during smaller waves and storms than predicted with existing models; therefore, new models are being developed. Estimates of littoral drift transport have been made using infilling rates behind shore-normal jetties, constructed in 1933, at the mouth of the Chicago River which suggest mean annual transport rates of 75×10^3 m^3/yr from north to south.

WORKSHOP AGENDA

TUESDAY

February 6, 1990

Introductory Comments

0830 Coastal Studies Overview -A. H. Sallenger

0840 Southern Lake Michigan Project-D. W. Folger

Review of Work Accomplished

GEOLOGIC FRAMEWORK & GIS

0900 Bedrock surface and thickness of overlying sediment-D. S. Foster

0920 Sidescan-sonar images of Indiana Shoals & transect areas-D. W. Folger

0940 GIS development-C. F. Polloni

1000 Coffee Break

1020 Discussion

LAKE LEVEL CHANGE

1100 Introduction-S. M. Colman

1110 Seismic stratigraphy-D. S. Foster

1130 Sedimentation rates and paleoclimate-S. M. Colman

1200 Lunch

1300 Discussion

1320 Illinois State Park beach ridge chronology-A. K. Hansel

1340 Indiana beach ridge chronology-T. A. Thompson

1400 Wisconsin beach ridge chronology-E. R. Dott

1420 Discussion

1440 Lake Levels and paleoclimate northern Lake Michigan-C. E. Larsen

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1500 Coffee Break

1520 1986 Storm deposits and land forms-R. E. Hunter

1540 Relict forest off Chicago-M. J. Chrzastowski

1600 Summary

1620 Summary Discussion

1700 Adjourn

WEDNESDAY

February 7, 1990

NEARSHORE PROCESSES

0830 Introduction-P. W. Barnes

0840 Ice Processes-P. W. Barnes & E. W. Kempema

0900 Nearshore zone off Fort Sheridan-J. S. Booth

0920 Bluff stability north of Chicago-R. W. Jibson

0940 Discussion

1000 Coffee Break

1020 Wave, current, sediment interaction at Gillson State Park-J. W. Haines

1040 Littoral sediment transport and erosion rates North Point Marina-M. J. Chrzastowski

1100 Long term littoral trends-M. J. Chrzastowski

1120 Coastal changes northern Indiana-W. L. Wood

1140 Discussion

1200 Lunch

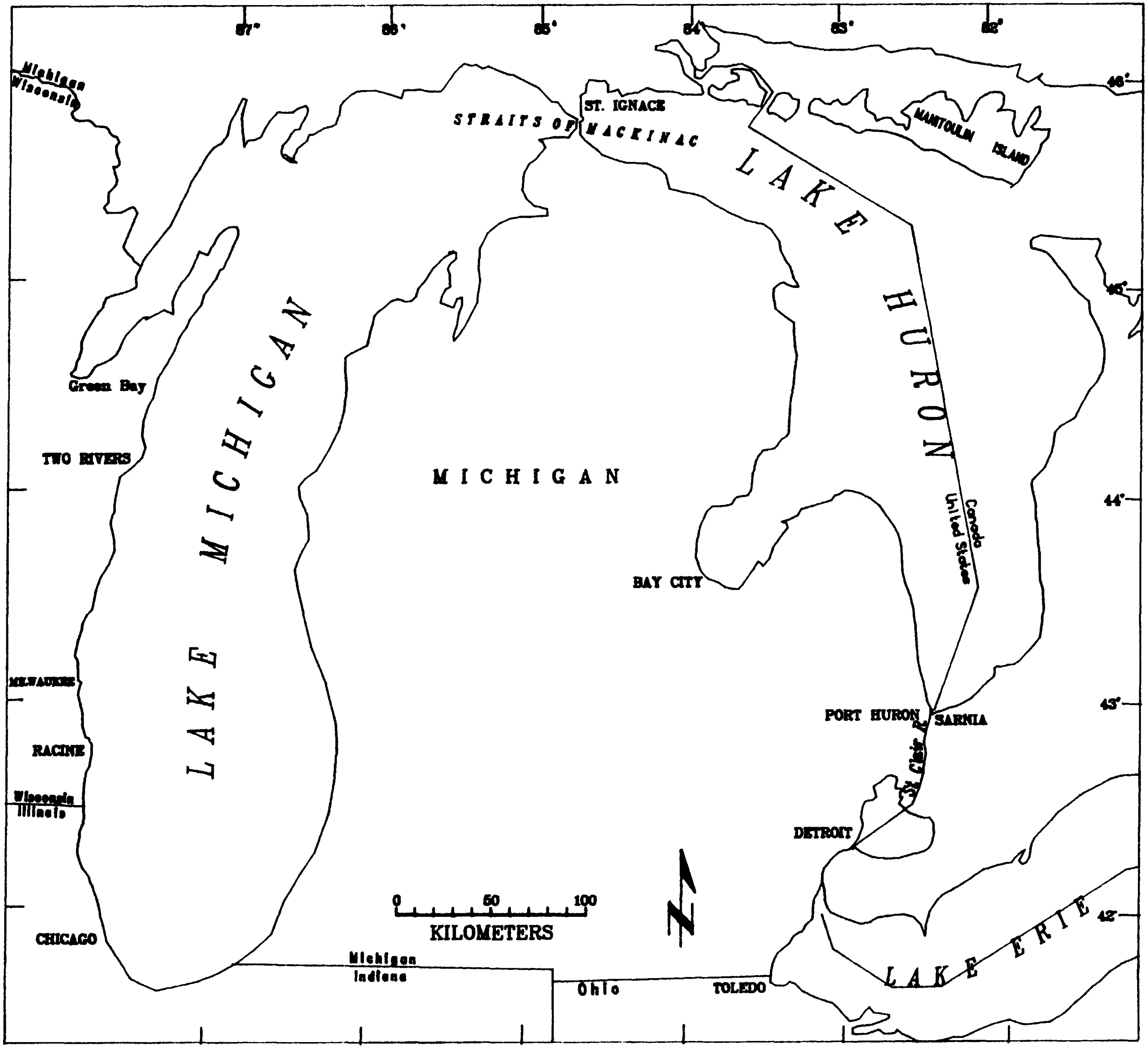
Plans for Future Work

1300 Framework-Discussion leader-D. W. Folger

1320 Lake Level-Discussion leader-S. M. Colman

1340 Processes-Discussion leader-P. W. Barnes

1500 Adjourn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LAKE HURON
LAKE MICHIGAN
Green Bay
TWO RIVERS
MICHIGAN
Canada
United States
BAY CITY
MILWAUKEE
RACINE
Wisconsin
Illinois
PORT HURON
SARNIA
St. Clair R.
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KILOMETERS
CHICAGO
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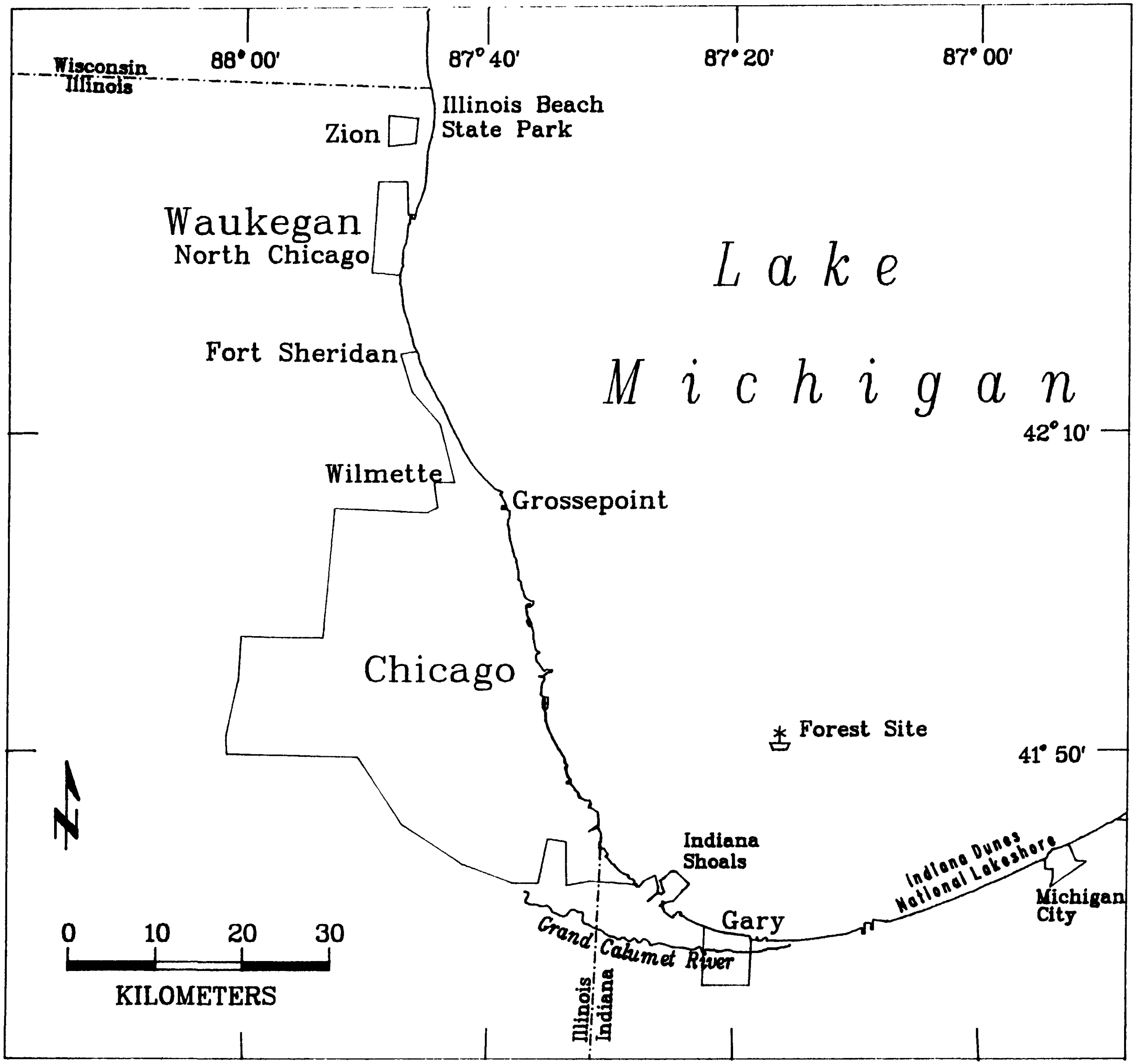
Ohio
TOLEDO
LAKE ERIE

Figure 1a.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Grossepoint
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Figure 1b.

ABSTRACTS

Framework

NEAR-SHORE SEISMIC STRATIGRAPHIC FRAMEWORK OF SOUTHERN LAKE MICHIGAN

Foster, D. S., and Folger, D. W., U. S. Geological Survey, Woods Hole, MA 02543

High-resolution seismic-reflection profiles, sidescan sonar, bathymetry, and sediment grab samples were collected along 650 km of track lines off the Illinois and Indiana shoreline from Wisconsin to Michigan. Twenty-five 18-to 20-km-long transects were run at right angles to the shoreline to define the distribution of bedrock, till, and postglacial lake deposits as well as the character of the lake floor.

Boomer-type seismic profiles penetrated till and commonly reached the bedrock surface. The Wadsworth Till Member occurs throughout the study area, and another till unit (Haeger?) is often beneath Wadsworth Till. Typically, the till is 0 to 20 m thick along the Illinois near-shore zone. Thicker deposits occur in bedrock valleys off Chicago and Fort Sheridan, Ill. The till is generally 20 to 40 m thick along the Indiana near-shore area. Approximately 50 m of till is found off Michigan City, Indiana. The acoustic impedance contrast between the till and the underlying Niagaran Dolomite (Silurian) is highly variable, an indication that the physical characteristics of the tills overlying bedrock, such as density or composition, are also highly variable.

Higher frequency seismic profiles (3.5 kHz) define the stratigraphy of the upper few meters of sediment. The postglacial lake deposits of the Lake Michigan Formation extend from the deep lake into the near-shore zone off Waukegan, Ill., and off Michigan City, Ind. The Lake Michigan Formation is absent over much of the remainder of the near-shore area. Combined analysis of 3.5-kHz seismic profiles, sidescan-sonar images, and surface-sediment texture show that Wadsworth Till is exposed at the lake floor or is overlain by a patchy veneer of sand and gravel. Bathymetric profiles identify several shoals in the near-shore zone. These features may be locally constructed entirely of sand, of till, or of till with a cap of sand.

SIDESCAN-SONAR MOSAICS, SOUTHERN LAKE MICHIGAN

Folger, D. W.[1], Schlee, J. S.[1], Polloni, C. F.[1], Foster, D.S.[1], Risch, J. S.[2], Chrzastowski, M. J.[3], and Thompson, T. A.[4], [1]U.S.G.S., Woods Hole, MA 02543, [2]Dept. of Geosciences, University of Wisconsin-Milwaukee, Milwaukee, WI 53201, [3]Illinois State Geological Survey, 615 Peabody Dr., Champaign, IL 61820, [4]Indiana Geological Survey, 611 N. Walnut Grove, Bloomington, IN 47405

As part of an effort to assess in detail the physiographic and sedimentologic characteristics of the nearshore bottom of southern Lake Michigan, five surveys were conducted off the Illinois and Indiana shorelines aboard R/V Miami River in 1988 and R/V Neptune in 1989 with a Klein Model 531 sidescan sonar[1], ORE 3.5 kHz seismic profiler, and Odem 200 kHz echo sounder. Lines were positioned with a Miniranger Falcon IV System. At Fort Sheridan, Wilmette, and Grosse Pointe lighthouse five lines were run offshore for a distance of 5-6 km at a line spacing of 150 m. The most extensive survey lies in the Indiana Shoals area off East Chicago, Indiana where 47 sidescan-sonar lines (180 line-km) were run over a 20 km^2 area at a line spacing of 50 m. Approximately 50 line-km of 3.5 kHz of high resolution seismic reflection data were also collected in the area. In the southernmost area five lines were run from Indiana Dunes National Lakeshore for 10 km offshore at 150-m spacing.

At Indiana Shoals the nearshore area is characterized by polygons with sharp angles between sides--shapes atypical of naturally occurring bottom features. The polygons probably were caused by extensive dredging carried out in the early part of the century for fill along the Chicago waterfront. Farther offshore, irregular, low, north-trending ridges are present that are typical of large areas of the bottom of southern Lake Michigan. This area is mainly covered by a thin, discontinuous sheet of gravelly sand, whereas the areas inside the polygons are mainly floored by sand and clay.

[1] Use of trade names is for identification only and does not constitute endorsement by the U. S. Geological Survey.

STATUS OF GIS DEVELOPMENT, SOUTHERN LAKE MICHIGAN

Polloni, C. F., Foster, D. S., and Folger, D. W., U. S. Geological Survey, Woods Hole, MA 02543

The Southern Lake Michigan Coastal Erosion Study is being carried out by a diverse group of Federal, State, and university researchers who need to communicate and exchange data. Until now, this exchange has been done informally. As the study proceeds into its final 3 years and as the database takes shape, it is important to input data into a networked Geographic Information System (GIS) that is accessible to most participants.

Geographic Information Systems that are presently being evaluated are ARC-INFO, INTERGRAPH, and SPANS. ARC-INFO is operational at the Illinois State Geological Survey, INTERGRAPH at the Michigan Department of Natural Resources, and SPANS at Environment Canada. The U. S. Army Corps of Engineers is preparing to set up INTERGRAPH. The strength of ARC-INFO lies mainly in its mapping and publication capabilities; INTERGRAPH appears to have more powerful database and exchange capabilities; SPANS is particularly strong as an analytical tool and, in addition, is PC-based. To deal with vector, raster, and tabular data being acquired in the Southern Lake Michigan Coastal Erosion Study, a combination of at least two (and perhaps all three) of the systems may be necessary.

SEISMIC STRATIGRAPHY OF GLACIAL, PROGLACIAL, AND LACUSTRINE DEPOSITS FROM LAKE MICHIGAN

Foster, D. S., and Colman, S. M., U.S. Geological Survey, Woods Hole, MA 02543

High-resolution seismic-reflection profiles from lake Michigan reveal seismic sequences and facies that portray the glacial and postglacial history of the basin. Facies analysis delineates till, ice-contact drift, outwash, glaciolacustrine, and nonglacial lacustrine deposits. Cores were examined to verify interpretations of the seismic data.

Acoustically massive seismic units that contain scattered reflections are interpreted to be tills. The stratigraphy and geometry of the till units suggest that the late Wisconsinan Lake Michigan lobe readvanced at least three times during the overall deglaciation of the basin. At their southern limits, tills form wedges or moraines that pinch out or grade into stratified sublacustrine outwash. In the deep basins, stratified seismic units that have moderately continuous internal reflections are intercalated with the till units. The stratified units are interpreted to be ice-proximal lacustrine deposits of the Equality Formation. Shoreward, reflectors in the Equality Formation become discontinuous and weak, and eventually the unit becomes acoustically massive, similar to till. This change in seismic facies suggests that the Equality Formation was deposited soon after the till, close to the retreating glacier.

Two distinct seismic sequences lie above the Equality Formation. The lower sequence has continuous internal reflections that drape the Equality Formation. The unit is thickest and most acoustically transparent in the deep basins, whereas on the basin slopes, it is thinner and has strong, continuous reflections. The upper sequence is acoustically transparent or contains weak, continuous reflections. Along the eastern slope, the upper sequence is as much as 18 m thick, but it is only a few meters thick in the deep basins and the western slope. The boundary between the upper and lower sequences appears as a continuous reflection that truncates the lower unit on the basin slopes and can be traced to the deep basins where the two units are conformable. This reflection is associated with the unconformity that formed during the Chippewa lowstand and subsequent transgression. Cores show that the unconformity separates the lower glaciolacustrine red mud from the upper postglacial gray mud of the Lake Michigan Formation. The thickness and distribution of postglacial deposits mapped from the seismic data indicate asymmetric accumulation. Previously published core descriptions and an isopach map support this interpretation. The distribution of postglacial deposits also probably reflects the sediment dynamics within the lake. Rates of erosion, transport, deposition, and reworking of sediments in the lake are not well known, especially in the deep basins. Postglacial depositional patterns are probably influenced by bottom currents in Lake Michigan.

HOLOCENE SEDIMENTATION RATES AND PALEOCLIMATIC EVIDENCE FROM CORES IN SOUTHERN LAKE MICHIGAN

Colman, S. M., and Foster, D. S., U. S. Geological Survey, Woods Hole, MA 02543

A multidisciplinary study of new cores from the southern basin of Lake Michigan have provided new information about the nature and causes of Holocene lake-level fluctuations. Preliminary results from these lithostratigraphic, micropaleontologic, stable-isotope, radiocarbon (accelerator-mass spectrometer, AMS), and magnetic studies suggest that the material in these cores can be interpreted in terms of both isostatically and climatically induced changes in lake level. Pollen and diatom preservation in the cores is poor, which hinders comparisons with local and regional vegetation records. However, we have obtained the first AMS ^{14}C ages for Great Lakes bottom sediments. These ages, from several different carbon and carbonate fractions, provide basin-wide correlations and help resolve the longstanding problem of anomalously old ages that result from detrital organic matter in Great Lakes sediments.

Several cores contain a distinct unconformity associated with the abrupt fall in lake level that occurred about 10 ka when the isostatically depressed North Bay outlet was uncovered by the retreating Laurentide ice sheet. Below the unconformity, ostracode assemblages imply cold water with very low total dissolved solids (TDS). Mollusk shells from this interval have ^{18}O (PDB) values of less than -11. Just above the unconformity, shallow water ostracode and mollusk species appear, and the assemblages suggest warmer, low-TDS water. Above this zone, a second interval with ^{18}O values less than 11 occurs. These data suggest that two influxes of cold, isotopically light meltwater from Laurentide ice entered the lake near the Holocene-Pleistocene boundary. These influxes, which occurred shortly before 10 ka and between 9 and 10 ka, were separated by a period during which the lake was warmer, shallower, but still very low in dissolved solids.

Middle Holocene mollusk shells are mostly deep-water species that have ^{18}O values ranging from -2 to -4; they appear to trend toward lighter values in the late Holocene. The ostracode assemblages and the stable isotopes suggest changes that are climatically controlled, including fluctuating water levels and increasing dissolved solids, though the water remained relatively dilute (TDS<300 mg/l). A dramatic reduction in ostracode abundances during the late Holocene is due to either (1) decreased dissolved oxygen in the bottom waters, associated with increased algal productivity in the epilimnion, or (2) slow sedimentation rates, which result in dissolution of the ostracode shells.

^{14}C AGES ON LATE HOLOCENE PEAT ACCUMULATION IN BEACH-RIDGE SWALES AT ILLINOIS BEACH STATE PARK

Hansel, A. K., Chrzastowski, M. J., Riggs, M. H., Miller, M. V., and Follmer, L. R., Illinois State Geological Survey, 615 E. Peabody Dr., Champaign, IL, 61820

A study of 102 vibracores from ridges and swales in the southward-prograding, beach-ridge complex at Illinois Beach State Park near Zion, Illinois has provided new information on the late Holocene record of lake-level fluctuation in Lake Michigan. Results indicate that at this locality, which has undergone a complex depositional history, ^{14}C ages of basal peat and organic silt from swales do not provide close age control on the time of formation of the lakeward beach ridge as we had assumed in our research design. Instead, the ^{14}C age estimates of peat and organic sediment from the bases of swales appear to cluster about two time intervals, one from about 2500 to 2200 years BP and a second from about 1600 to 1000 years BP. We interpret these clusters to represent times when the water table rose to intersect the base of interridge swales, resulting in marsh development and peat accumulation. This new age control on water table-fluctuation in the beach-ridge complex may provide an indirect measure of the timing of water-level fluctuations in Lake Michigan. Combined with additional age control on basal swale sedimentation from other sites around Lake Michigan, it should provide further insight into the late Holocene record of lake level fluctuation.

In historic times many of the youngest and more-lakeward swales in the beach-ridge complex appear to have been dominated by eolian sedimentation rather than organic matter accretion, which leads us to suspect that in some cases a considerable time lag (on the order of hundreds of years?) may exist between the formation of a new beach ridge and the accumulation of organics in the adjacent swale.

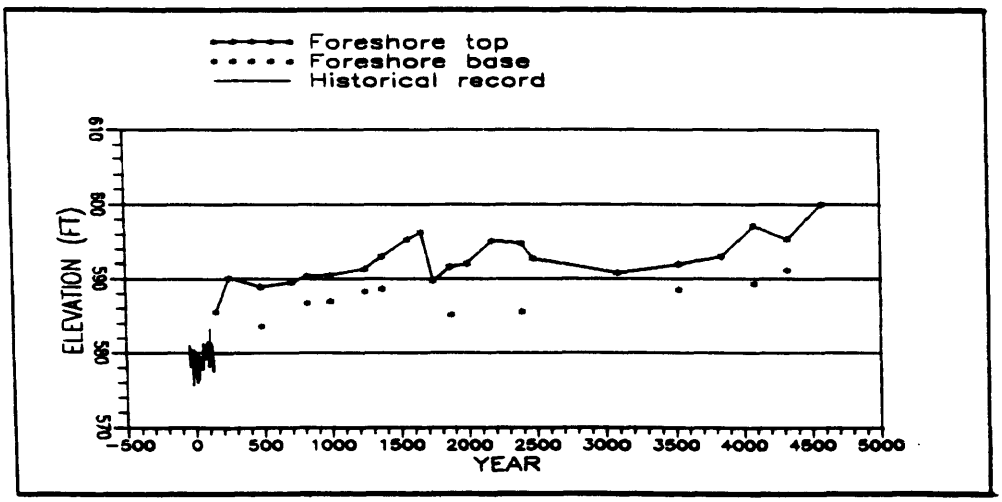
PRELIMINARY ASSESSMENT LATE HOLOCENE LAKE-LEVEL VARIATION IN LAKE MICHIGAN

Thompson, T. A., Indiana Geological Survey, 611 North Walnut Grove, Bloomington, IN 47405

The southern shore of Lake Michigan was a sediment sink throughout the late Holocene. This sediment accumulated in a 32-km long 9-km wide, and 15-m thick wedge of beach/dune ridge, called the Toleston Beach, that arcs across northwestern Indiana. The ridges within the Toleston Beach are records of past lake-level fluctuations in the Lake Michigan basin, recording about 5500 years of lake level.

Vibracores from the lakeward margin of about 50 ridges and radiocarbon dates on peat and organic sand from the base of wetlands between ridges were collected to construct a curve of late Holocene lake-level variation. This curve is useful in defining the upward physical limits of lake level and indicates patterns of past lake-level fluctuation.

In the Miller Woods area of the Indiana Dunes National lakeshore, a long-term and large-scale lake-level change is preserved. Beach ridges were formed about every 150 years, and the elevations of foreshore deposits indicate a long-term drop in the upper limit of lake level of about 2 m. Perturbations (rise in lake level) from this long-term fall occurred 300, 1600, 2300, and possibly 4100 years ago. These highs are consistent with the pattern of late Holocene lake-level variation by Larsen (1985).



STRATIGRAPHY AND LAKE LEVEL INTERPRETATION OF A HOLOCENE AGE BEACH RIDGE COMPLEX AT TWO RIVERS, WISCONSIN ON THE NORTHWEST SHORE OF LAKE MICHIGAN

Dott, Eric C., Department of Geology and Geophysics, University of Wisconsin, Madison, WI 53706

A beach ridge complex of up to 30 low, subparallel dune-capped ridges, ranging from 1.5 to 8 m high, occurs along the northwest shore of Lake Michigan at Two Rivers, Wisconsin. Holocene-aged lake deposits at the Two Rivers site form a progradational sequence of accumulated beach and shoreface sand deposits. These deposits provide a history of Holocene lake levels. Three high lake shorelines (Glenwood, Calumet, and Nipissing), that occur inland and above the beach ridge complex, were also mapped in the study area. A poorly defined Glenwood shoreline and terrace are interpreted to occur between 210 m and 198 m (690-650 ft) elevation. The Glenwood terrace and shoreline deposits do not appear to extend onto the Two Rivers till surface north or east of the Twin Rivers lowland. Calumet level shoreline deposits are interbedded with the Two Rivers end moraine, and a Calumet level terrace is also cut into the crest of the Two Rivers moraine above the town of Two Rivers between 195 m and 187.5 m, (640-615 ft) elevation. Nipissing level wave-cut scarps, or low discontinuous elongate beach and dune ridges between 188 m and 178 m (617-584 ft), occur at the western edge of the beach ridge complex.

The sedimentary and stratigraphic characteristics of the lake deposits at Two Rivers are interpreted using subsurface data from 42 shallow vibracores and 10 auger bore holes collected along two east-west transects. Eight realignments of the beach ridge lineation pattern mapped from airphotographs coincide with lakeward dipping erosional unconformities. Coarse-grained, foreshore beach deposits identified in the cores indicate the elevation of past lake levels. Twelve radiocarbon dates, ranging from 6,100 +/- 90 BP to present, were obtained from basal peat collected from swales, from Molash swamp, or from detrital wood from transgressive sand deposits underlying the ridge complex. The radiocarbon dates were used to date past shorelines as well as lake transgressions and regressions.

The site has been a location of net sediment accumulation through the Holocene, with sediments derived from glacial deposits in the Twin Rivers drainage and along the lake shoreline. Prehistoric lake levels (starting about 3,000 years ago) have risen no more than 1.7 m above the historic (1860-1989) mean lake elevation, of 176.3 m, at the Two Rivers site. By comparison, maximum levels for 1860 to 1989 did not exceed 0.99 m above the 176.3 m elevation.

ISOSTATIC UPLIFT RATES AND THE RECONSTRUCTION OF LAKE LEVEL CHANGES IN THE LAKE MICHIGAN-HURON BASINS

Larsen, C. E., U. S. Geological Survey, National Center, Reston, VA 22092

The reconstruction of past lake level fluctuations in the Great Lakes relies on detailed interpretation of the present altitudes and attitudes of coastal landforms and stratigraphy. Facies relationships between nearshore sediments (plunge-point coarse-grained deposits) and lower shoreface sediments (swash-backwash zone deposits) help to define the approximate position of a contemporaneous water plane. The height of beach ridges above their contemporaneous water planes indicates the amount of run-up during moderate to extreme wave regimes. The water levels reconstructed from landforms are broadly comparable to those observed in coastal process studies and

verified by historic lake level and wave records.

The reconstruction of lake level changes that occurred prior to detailed historic records is complicated by differential isostatic uplift of the Great Lakes region. Northern parts of the basin are rising more rapidly than southern parts. As a result, the northern Lake Michigan-Huron basin has receding shorelines north of the controlling outlet of Lake Huron at Port Huron, Mich., and southern Lake Michigan, which is south of the more rapidly rising outlet, has transgressing shorelines.

The short-term hydrologic record of lake level change from 1900-present is used to determine public policy related to the Great Lakes. Researchers using these data rely on stochastic analyses of the magnitude and frequency of short-term events to develop engineering design criteria. Long-term high or low lake level episodes, on the order of centuries, also occurred prior to recorded history. These appear to have been related to abrupt climate or environmental changes that are commonly preserved in the geologic record. It is difficult to reconcile the different scales of lake-level change so that the magnitude of long-term events may be taken into account. Therefore, separating the uplift and climate-related lake level components contained in the coastal geomorphic record is important to gain an accurate understanding of the paleohydrological changes in the lake system. Long-term lake level changes in the geologic record can be integrated with the short-term hydrological data sets. Both long-term and short-term fluctuations are represented in the geologic record, but they may be confused during analysis because a contemporaneous datum plane necessary for differentiation is lacking. Thus, it is difficult to ascertain whether past fluctuations recorded by landforms are short term i.e., +/- 0.75 m of the historic mean level, similar to fluctuations represented in the historic record from 1900 to present, or whether such short term changes are superimposed on persistently high or low long-term periods with greater ranges in level.

For Lake Michigan-Huron, the historic mean lake level has been controlled by the flow rate of the St. Clair River. Data show that the same outlet has controlled the lake system for at least 4000 years; therefore, the flow rate can be assumed to have controlled the prehistoric mean level as well. Similarly, difference in historic mean lake level measured at various gauge sites around the basin and relative to the datum mean lake level at the outlet, are used to demonstrate differential vertical movement over the lake basin. Concomitantly, prehistoric uplift measured at the outlet is also relative to a contemporaneous mean level. Thus, an uplift curve calculated for the outlet region approximates the changing position of the mean level through time. Such a curve becomes a composite datum for reconstructing prehistoric changes throughout the lake basin.

Cumulative uplift curves for the lake basin have been calculated from the measured historic vertical movement and the heights of the key late Holocene Nipissing and Algoma terraces relative to the outlet control at Port Huron. A datum curve for Port Huron is described by a simple exponential function $\log y = 0.00034x - 1.0746$ with a half-time constant of 886 years. The total uplift of this region was about 2.5 m over the past 4,300 years and 0.09 m of this uplift occurred over the past century. Stations examined north of a zero isobase, which passes through Port Huron, display curves that have slopes equal to that of the datum curve. An uplift curve for each station intersects the plotted amount of historic uplift at that site. The altitude of the Nipissing and Algoma terraces are consistent for each calculated curve. This association shows continuity between past and present uplift and indicates that the pattern of historic uplift can be used a model to reconstruct the range of past levels.

Stations in Lake Michigan south of the zero isobase experienced submergence relative to the uplift of the outlet. The south shore of Lake Michigan had an overall rise in level of 2.5 m over 4300 years; the rise in level decreased exponentially to 0.09 m during the past century. At the opposite extreme, at the Mackinac Straits, vertical uplift relative to the outlet is 8 m, 0.15 m of which occurred during the past century.

The calculated curve for each station represents the approximate contemporaneous position of the mean water plane through time. This association is important in reconstructing the upper range of prehistoric lake level stands because the curve becomes a contemporaneous datum relative to the outlet and is simultaneously adjusted for vertical movement. Former water level positions, preserved stratigraphically or geomorphically, can be viewed relative to their contemporaneous mean level. Hence, the range of prehistoric water level changes with respect to their contemporaneous means can be compared directly to the mean calculated from historic data. The historic mean level of Lake Michigan-Huron has been permanently lowered by 0.5 m due to engineered channel changes. Nonetheless, the range of water level variation, historic or prehistoric, varies relative to a mean, past or present. This reconstruction is of practical value because past geologic events can be compared directly to the magnitude and frequency of measured historic events without correction for channel changes.

The reconstructed water level record of the past several centuries provides an example. At the Mackinac Straits archeological sites preserve records of dated lakeshore stratigraphy. Beach features dated to 1830's high lake levels suggest that the levels were 0.72 m above the long term mean and comparable to the range of the high levels of 1986 relative to the 1900 to 1989 mean. At the Marquette Mission site (occupied 1670-1705) in St. Ignace, Michigan, the stratigraphy shows a contemporaneous water level 1.1 m above the mean. By contrast, stratigraphy dated to about the year 1600 A. D. at the Beyer Site in St. Ignace shows a range 1.7 m above the long term mean. When viewed in perspective, steadily decreasing upper ranges from the 17th through 19th centuries are evidence for an episode of high levels greater than twice the range recorded by historic records. During this period, lake levels apparently fell in response to long-term climate-related changes in the region.

COASTAL DEPOSITIONAL AND EROSIONAL EFFECTS OF 1985-1987 HIGH LAKE LEVELS IN LAKE MICHIGAN

Hunter, R. E., Reiss, T. E., Chin, J. L., Anima, R. J., U. S. Geological Survey, Menlo Park, CA 94025

The drop in lake level following the 1986-1986 period of very high levels in Lake Michigan provided a unique opportunity for investigating the depositional and erosional effects of a high stand in a large lake. The principal effects of wave action at the shoreline were (1) the cutting of an erosional scarp where the beach is backed by a bluff or dune ridge and (2) the building of a beach ridge where the beach is backed by low, flat land and where the beach material is gravel. High-stand features were surveyed and trenched at 17 sites around the lake. Elevations of the features were measured relative to local lake level and converted to elevations relative to the International Great Lakes Datum with an estimated error of not more than 0.1 m.

Although the bases of scarps cut during the high stand have in most places been buried by slumped bluff material, beach sand, and windblown sand, four scarp bases (shoreline angles) were uncovered by trenching. Where the scarp was cut into deposits formed by the building out of the shoreline during the last few centuries, the erosional surface formed during the latest high stand could be recognized adjacent to the scarp but could not be easily recognized farther out on the beach, where the erosional surface was nearly parallel to underlying and overlying beach stratification. At eight study sites, beach ridges were formed or preexisting ridges were moved landward or otherwise modified by wave action during the high stand. The beach ridges are characterized internally by cross-bedding formed by wave overwash. The study site at Gary, Indiana, is unique in having a dune ridge built by wind action following the high stand.

The scarp bases uncovered by trenching ranged in elevation from 177.5 to 178.5 m, whereas the beach-ridge crests ranged from 177.8 to 179.7 m. Because all of these features were formed by storm waves at the time of the high stand, their elevations are higher than the highest monthly level (177.28 m in October, 1986) reached by Lake Michigan during the 1985-1987 period of high lake levels, The beach-ridge crests are higher than the scarp bases because the beach ridge crests mark nearly the maximum possible height of wave runup, whereas the scarps were formed at places where the waves were reflected seaward before achieving their maximum possible runup. The variations in beach-ridge height are correlated with variations in storm-wave height in different parts of the lake.

DISCOVERY AND RADIOCARBON DATING OF TREE STUMPS IN GROWTH POSITION THE FLOOR OF SOUTHERN LAKE MICHIGAN

Chrzastowski, M. J.[1], Pranschke, F. A.[2], and Shabica, C. W.[2]
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In June, 1989, tree stumps were identified on the floor of southern Lake Michigan by salvage operators using sidescan-sonar in search of shipwrecks. The site covers at least 2 hectares (20 X 10^3 m^2) and is located about 23 km northeast of Calumet Harbor, Illinois (approximate latitude 41^o 49.9'N; longitude 87^o 17.2'W) where water is 24 to 26 m deep (152 to 150 m above mean sea level). Diver inspection and video documentation indicate that at least 16 stumps in growth position range from 15-30 cm in diameter and protrude as much as 1.2 m above the lake floor. Some trunks and limbs also rest on the lake floor. The morphology of the lake bottom consists of ridges and troughs with an amplitude of about 0.5 m. Bottom sediments comprise silt and very fine sand with localized concentrations of pebbles and cobbles. Wood from a sampled stump has been identified as oak. The excellent preservation of the wood suggests that the site has been continuously submerged since it was drowned.

Radiocarbon dating for the wood sample gives age estimates of 8,120 $\pm$ 100 yBP (ISGS-2036) and 8,380 $\pm$ 100 yBP (BETA-34357). The radiocarbon age and the elevation of the site presents some questions concerning the relationship to the lake-level history. If the drowning of the trees resulted from a transgression from the 74 m above MSL Chippewa low in the southern basin to the 184 m MSL Nipissing high, then the ancestral Lake Michigan reached an elevation of 152 to 150 m about 8000 years ago. This is 1-2,000 years earlier than previously thought. Alternatively, the trees could have been drowned about 8,000 years ago by a lake that was located well above the Chippewa lake that then occupied the southern basin. This lake might have persisted until it was overtaken by the Nipissing transgression and became part of the ancestral Lake Michigan. Additional study of the site is planned to address these and other questions concerning the transgression history and the factors that contributed to preservation of the stumps.

SEDIMENT CONTENT AND BEACH PROFILE MODIFICATION BY ICE ALONG COAST OF SOUTHERN LAKE MICHIGAN

Barnes P. W.[1], Reimnitz, Erk[1], Weber, W. S. [1],
and Kempema, E. W.[2], [1]U.S. Geological Survey, 345 Middlefield Road, Menlo Park, CA 94025, [2] School of Oceanography University of Washington, Seattle, WA 9815

Lake ice is present along the coast of southern Lake Michigan for 2 to 4 months per year. Its presence corresponds to periods of high wave energy associated with winter storms. The coastal ice regime in February 1989, consisted of an ice foot at the shoreline built of ice and sediment where the subaerial beach is exposed to freezing temperatures and wave swash. Immediately lakeward of the ice foot, were a series of one or more grounded ice ridges often, but not always, separated by ice-filled lagoons.

The wave-built ice ridges are parallel to the coast and composed of adjoining ice cones (volcanoes) with steep lakeward slopes and more gentle shoreward slopes. Most of those observed were about a meter high but some reached heights of 5 to 7 m. Most ridges were restricted to within 25 m of the coast along the western and southern shores in Illinois and Indiana, but extended out to about 100 m along the southeastern shore.

Sediment content of the ice in February, 1989, ranged from less than 0.01 g/L to 866 g/L, the latter being a ball-shaped mass that rolled along the lake bed. Apart from ice balls, sediment contents were highest in ice foot samples, where average concentrations were nearly 40 g/L; sediment concentrations were least (0.003g/L) in the drift ice lakeward of the ridges. Conservative estimates suggest that total longshore transport by ice rafting may be as high as 3×10^3 tons per day.

NEARSHORE ZONE OF LAKE MICHIGAN OFF LAKE FOREST, ILLINOIS: PRELIMINARY RESULTS OF BATHYMETRIC AND GRAIN SIZE DISTRIBUTION CURVES

Booth, J. S., and Winters, W. J., U. S. Geological Survey, Woods Hole, MA 02543

The nearshore zone immediately north of Fort Sheridan, Illinois is being investigated to determine possible relationships between lake bed characteristics and observed differences in the rate of shoreline retreat. The initial field work consisted of a bathymetric survey of a corridor approximately 0.8 km wide (shore-parallel) by up to 8 km long (shore normal) and grab sampling (32 stations). Grain size analyses (sieves and settling tube for coarse fraction; coulter counter for fine fraction) were performed on each sample.

Results of the bathymetric survey show that the lake floor is morphologically complex. Specifically, a representative profile (lakeward direction) contains the following features or characteristics: (a) one or two broad mounds of low relief adjacent to the foreshore zone, (b) a zone of narrow ridges and troughs having about 1 meter of relief, (c) another mound (in 7-8 m of water), (d) a second zone of low ridges and troughs, (e) a 2-km-wide zone of hummocky terrain often distinguished by twin ridges that rise up to 4 m above the surrounding lake floor, and (f) a conspicuous ramp about 7 km offshore. There are apparent differences in the shallow water morphologies of the northern and southern sections of lake floor. For example, in about 7 m of water, rough terrain in the northern section gradually changes to smooth or mounded terrain in the southern section.

A general trend toward a hard clay lake bed in deeper water (>6m) seems to be present: the presence of sand (typically "very fine"), at least in appreciable quantities, appears to be restricted to shallower depths and to within 500 to 800 m of the shore. The sand is too fine to be used for beach nourishment in the local area. Shells and ash particles are present in many samples.

SUMMARY OF RESEARCH ON RETREAT OF COASTAL BLUFFS ALONG THE LAKE MICHIGAN SHORELINE IN ILLINOIS AND SOUTHERN WISCONSIN

Jibson R. W., Staude, J.M., and Reinhardt, Juergen, U. S. Geological Survey, National Center, 12201 Sunrise Valley Dr., Reston, VA 22092

A fundamental objective of this study is to determine the spatial and temporal variability in the rates at which coastal bluffs are receding along the Lake Michigan shoreline. We developed a 50-yr record of bluff retreat by comparing locations of features on the oldest available airphotos, taken in 1937, with those from airphotos taken in 1987. Maximum 50-yr amounts of retreat range from 20-30 m, which corresponds to 0.4 to 0.6-m/yr. The calculated mean 50-yr retreat for all bluff segments for which data are available is 10.9 m, which corresponds to a mean rate of 0.22 m/yr. Cone penetration testing (CPT) at 14 locations between Winnetka and North Chicago reveal throughout most of the area that man-made fills or organic soils extend from the ground surface to about 0.2 to 1.5 m depth. Below this surface layer, a stiff, desiccated, silty to sandy clay crust extends to depths of 2.4 to 5.5 m. Below this crust are two silty-clay till units, separated by thinner silty-sand layers. The upper till is uniformly stiff; the lower till is somewhat weaker. Studies of bluff recession along the southern Wisconsin shoreline which is primarily undeveloped and freely eroding provide a valuable comparison to the Illinois bluffs, which are heavily developed.

CROSS-SHORE SEDIMENT TRANSPORT IN SOUTHERN LAKE MICHIGAN

Haines, J. W., U.S.G.S. Center for Coastal Geology, 600 4th St. South, St. Petersburg, FL 33701

Preliminary results of the Southern Lake Michigan Coastal Erosion Study indicate that the western shore of the lake is characterized by a narrow offshore body of sand. While the thickness of the sand body is unknown, its offshore extent appears to be limited to 6-8 m water depth. This lens of sand is the material available for transport in the nearshore region. Given the probable small volume of this reservoir it is important to address the significance of the potential removal of sand from the system. This will be the focus of planned field work at Gillson Park, Wilmette, Illinois.

Cross-shore transport may permanently remove sediment from the beach/nearshore zone, whereas sand transported to the deeper basin may not accumulate in deposits which can be economically recovered.

During the field experiment we will simultaneously measure hydrodynamic variables and suspended sediment concentration using electromagnetic current meters, pressure sensors, and optical backscatter sensors. Estimates of the cross-shore sediment flux will be made near the offshore limit of the nearshore sand lens. The resulting data will provide an assessment of the rates and mechanisms (e. g. rip currents, undertow, reflected waves) of sand transport offshore normal to the shoreline.

Two special concerns will be addressed by this study:

- The small nearshore sand thickness results in a profile which is to some degree controlled by the shape of the underlying till. The response of the nearshore sediments to wind and waves will be largely controlled by this topography. We will investigate this control and create models of profile evolution and sediment transport. Relatively short-term fluctuations in sediment availability may be associated with changes in lake level which cause variations in rates of bluff erosion. Changes in the volume of sand available may substantially alter the nearshore profile and the rate of sediment transport both alongshore and offshore.

- Evidence from deep basin cores suggests that little sand-sized material is reaching deep water areas (S. Colman, pers. comm.). Our observations, and the resulting physical models, should provide an independent estimate of the deep water accumulation. This will require careful consideration of the potential geographic and temporal variability in the flux of sediment offshore.

The limited amount of sand in the nearshore zone suggests that the southern Lake Michigan coast is in a rather delicate balance. Small changes in the rates of sediment loss may have dramatic effects on the nearshore area. It appears that the flux of sediment offshore to the deep basin is small. We will attempt to verify this observation and determine if the potential for increased offshore sediment transport exists.

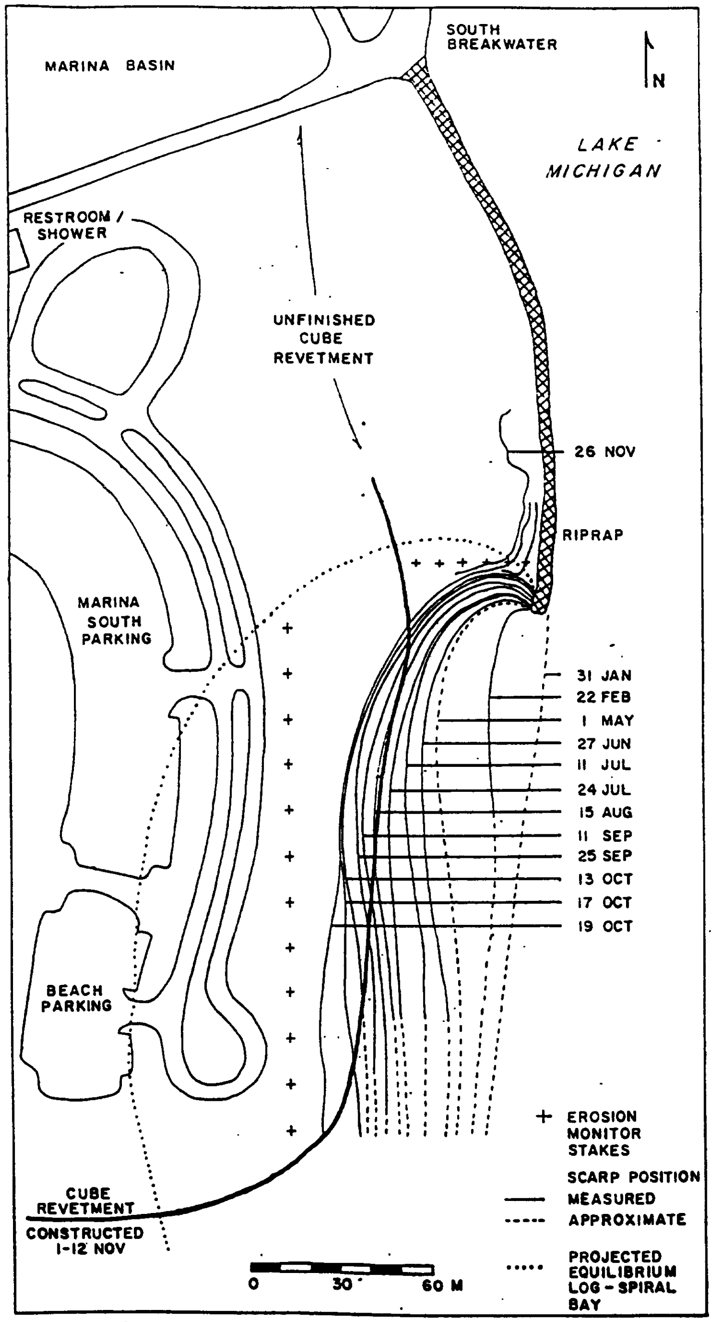
COASTAL GEOMORPHIC CHANGES DURING 1988-89 AT NORTH POINT MARINA, WINTHROP HARBOR, ILLINOIS

Chrzastowski, M. J., and Terpstra, P. D. , Illinois State Geological Survey, 615 E. Peabody Dr., Champaign, IL 61820

North Point Marina is a 1500-boat marina built by the State of Illinois in the North Unit of Illinois Beach State Park. The 1987-88 marina construction required building shore-attached, rubble-mound breakwaters and hydraulic dredging of an estimated 1.2 million m^3 of gravelly sand to form the marina basin. Since 1988, the Illinois State Geological Survey has monitored coastal-geomorphic changes at the marina with bathymetric surveys, beach surveys, ground and aerial photography.

Comparison of 1988 and 1989 bathymetric surveys indicate that during the first year following marina construction, accretion accounted for the greatest lake-bottom change. The sediment supply was from dredge discharge and erosion at a dredge-spoil fan-delta built on the south (downdrift) side of the marina. Drift reversals transported an estimated 110,000 m^3 accretionary wedge along the south breakwater and into the marina entrance.

Southward longshore sediment transport resulted in the development of a series of prominent nearshore bars. Areas of lake-bottom erosion primarily corresponded to loss or migration of these nearshore bars. Erosion that threatened marina facilities occurred along the shore of the fan-delta. In January, 1989, riprap was placed along the northern half of this 1- to 4.5-m scarp into a logarithmic spiral planform typical of crenulate-shaped bays. Between late January and October 19 when shore defense was added, maximum shoreline recession was approximately 61 m. Monitoring between June 27 and October 19 documented mean scarp recession of 2 m/month near the riprap terminus increasing to 17 m/month at a point about 150 m to the south. The fan-delta recession documents the potential rapid erosion rates of undefended gravelly sand lakefill elsewhere on the Illinois shore.

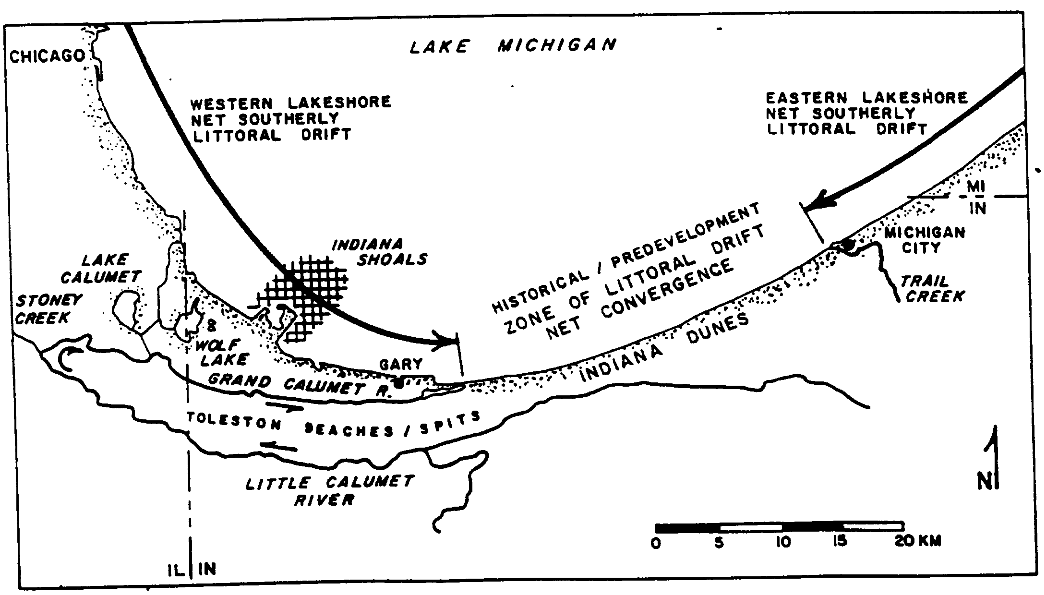


Partial record of 1989 scarp positions.

SOUTHERN LAKE MICHIGAN COASTAL EROSION STUDIES OF 1989 PROCESS STUDIES

Chrzastowski, M. J., Illinois State Geological Survey, 615 E. Peabody Dr., Champaign, IL 61820

This study summarizes the late Wisconsinan and Holocene littoral-drift patterns and coastal evolution in southern Lake Michigan. It provides at least three new perspectives on littoral-drift processes along the south lakeshore. First, as determined from historical shoreline maps of the Michigan City vicinity, the zone of net drift convergence prior to urban shore development was a well-defined 31.4-km reach between the eastward- deflected stream-mouth of the Grand Calumet River in east Gary and westward-deflected stream-mouth of Trail Creek at Michigan City. Apparently the significance of the stream-mouth deflection of the Grand Calumet River previously was not recognized as a means to define this net drift convergence. Second, two distinct sediment sinks existed on the south shore. One was the beach ridge accretion area to the west of east Gary which represents accretion that smoothed the shoreline; the other was the Indiana Dunes which corresponded to the zone of drift convergence. The sediment sink at Indiana Dunes emphasizes the importance of the beach-to-dune transport process in the analysis of sediment budgets along this coast. Nearly all littoral sediment supplied to this shore is medium sand or finer which is a size that can be moved by eolian transport. This explains why this drift convergence is not marked by progradational features such as one or more cuspate forelands or cuspate spits. Third, over the past 3-4,000 years, the 6- to 10-m deep bathymetric high known as Indiana Shoals has not been related to any convergence and offshore deflection of littoral drift, nor have these shoals been of any consequence to regional drift patterns. The shoal area would be significant to littoral transport processes at lake levels lower than present. At lake levels 6- to 10-m lower than present, the shoal area likely corresponded to the net-drift convergence on the south lakeshore. During the past 3-4,000 years, however, littoral drift terminated south and east of the Indiana shoals.



Select coastal-geographic features of the southern lakeshore related to the littoral drift history over the past 3-4,000 years.

MODELING BEACH AND NEARSHORE PROFILE RESPONSE TO LAKE LEVEL CHANGE AND STORM WAVE FORCING

Wood, W. L., Great Lakes Coastal Research Laboratory, School or Civil Engineering, Purdue University, West Lafayette, Indiana 47907

The primary purpose of this proposed research is to develop a coastal response model for predicting beach and nearshore profile adjustment to lake-level change and storm wave forcing. This model is to be developed in both a quasi-deterministic (eigenfunction recomposition) and stochastic framework. A need for this study exists because at this time there is no adequate beach erosion prediction model for dealing with the characteristic time scale of lake-level variation. In addition, models developed for predicting beach erosion response to ocean storm events lack verification for Great Lakes coasts. In fact, these ocean storm response models may not be directly applicable to the Great Lakes because of the difference in wave characteristics associated with lake storms. Wood and Weishar (1984) and Wood (1986) showed that maximum variability of the total profile was directly related to mean annual lake-level variation and that profile response to shorter time scales of lake-level change was less consistent. This is why the approach proposed for this study is, first, to establish a model which represents the "average annual" profile response to long-term lake-level variation. The second step of the model development will use Monte Carlo simulation techniques to superimpose storm wave forcing effects on the "average annual" profile form.

An "average annual" equilibrium profile has recently been determined from a data base of coastal profiles from southern Lake Michigan. The form of the equilibrium profile is

$$h=Ax^{2/3}$$

where h is water depth, x is distance offshore, and A is a scale parameter between 0.05 and 0.20. The characterizing shape parameter 2/3 is, interestingly, in agreement with that found for ocean coasts. Determination of this equilibrium profile form did not consider submarine bar positions. A methodology to deal with submarine bar position, on the equilibrium profile, is proposed, based on the fundamental concept of superposition of component segments of beach and offshore profile to form a recomposition of temporally distinct elements. This recomposition scheme is developed from principal component analysis applied to beach and offshore profiles.

Two analysis methodologies will be applied to the southern Lake Michigan data set. The first method will be to compare variation in the scale parameter "A" (equation above) for each profile, to available sediment volume and to profile distance from each cell boundary. Since the only source of new sediment within each isolated cell is the dune-bluff, it can be hypothesized that profiles more distant from a cell boundary may be more likely to attain the "characteristic" equilibrium shape. The second method will be to apply empirical eigenfunction analysis to a temporal set of bathymetric data arrayed in a longshore coordinate system.

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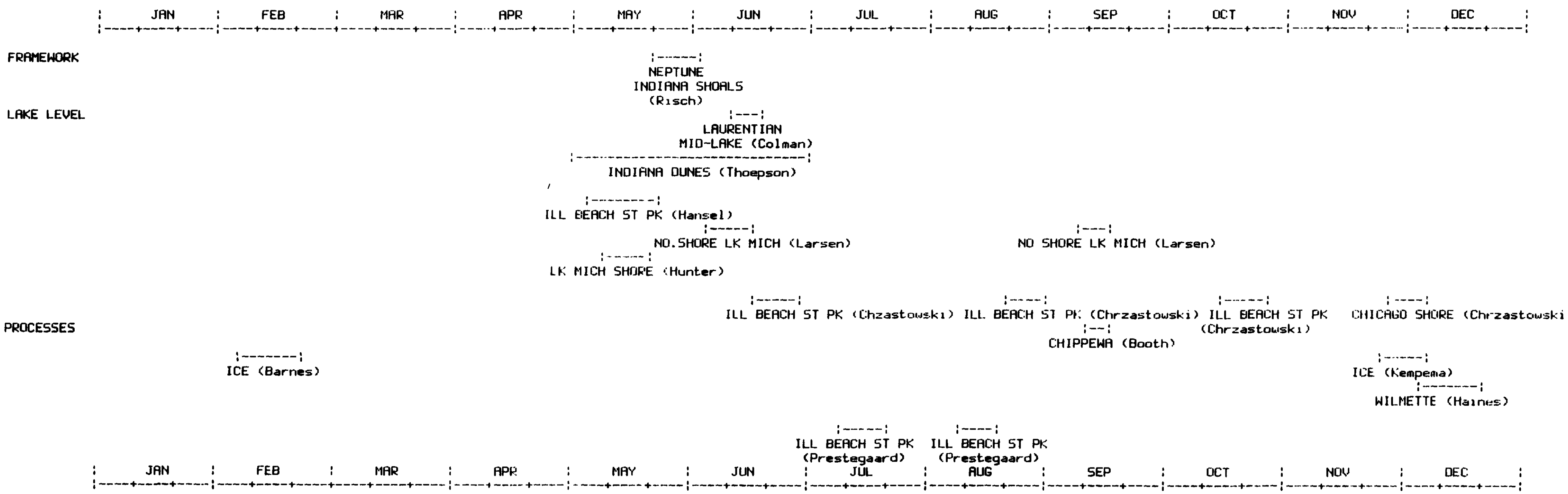
SOUTHERN LAKE MICHIGAN

CY 1989 Cruises & Field Work



APPENDIX A

SOUTHERN LAKE MICHIGAN

CY 1990 Cruises & Field Work

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
FRAMEWORK				SHORE STRUCT CHICAGO (Chrzastowski)	NEPTUNE SSS FOREST CHICAGO (Folger)			CORING NEARSHORE SAND WILMETTE AREA (Shabica)	GROUND PENETRATING RADAR TEST (Olhoeft-Folger)			
LAKE LEVEL			INDIANA DUNES (Thompson)		NEPTUNE SSS SELECTED FEATURES OFF WAUKEGAN (Colman)	NORTH SHORE SURVEY (Larsen)						
PROCESSES		ICE STUDIES SOUTHERN LK MICH (Barnes)		INDIANA DUNES SAND BUDGET (Olyphant)			CORING-ILL BEACH ST PK (Hansel)					INDIANA DUNES SAND BUDGET (Olyphant)
							EKDS (?) ILL BEACH ST PK (Booth)	INDIANA DUNES SAND BUDGET (Olyphant)				
			CROSS-SHORE-SED TRANSPORT WILMETTE (Haines)				NORTH POINT MARINA (Chrzastowski)		NORTH POINT MARINA (Chrzastowski)			
					RESURVEY HIGH WATER DEPOSITS (Hunter)							
				FT SHERIDAN BLUFFS (Jibson)								
		PROFILES-ILL BEACH ST PK (Prestegaard)		PROFILES ILL BEACH ST PK (Prestegaard)		PROFILES ILL BEACH ST PK (Prestegaard)						

APPENDIX B

SOUTHERN LAKE MICHIGAN

FRAMEWORK

Data Acquisition, Processing,
Compilation, & GIS Development

CY 1990

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 JAN                 FEB                MAR                  APRIL               MAY                 JUNE
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             SLM Wrkshp                  Symp                                   IAGLR
             St. Pete   +Submit 2        Toronto                                Windsor
                         Abs to IAGLR

FOSTER           Prep bathy, seis paper            Review
        --------------------------------->------------------>

SCHLEE        Complete MIPS processing
                Indiana Shoals data          Prep Indiana Shoals paper         Review
        --------------------------->------------------------------->------------------->

FOLGER          QMIPS processing SSS
                   transects            MIPS processing   Prep paper sed dist & physiogr charact           Review
            ----------------------->----------------->--------------------------------------->------------------>

POLLONI         Data assembly south Lk Mich GIS   Set up interactive displays ARC-INFO & SPANS          Integrate GIS with ISGS, MDNR, & CCIW
                ---------------------------->-------------------------------------------->----------------------------------------->

 JAN                 FEB                MAR                  APRIL               MAY                 JUNE
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APPENDIX C

SOUTHERN LAKE MICHIGAN

LAKE LEVEL

Data Acquisition, Processing,
& Compilation

CY 1990

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 :        JAN            :        FEB            :        MAR            :        APRIL          :        MAY            :        JUNE          :
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CHRZASTOWSKI

COLMAN      -----Prep paper on paleoclimate & sed rates core 9--------------------Review-------------------->
                                                         ----Prep paper on Holocene strat------------------>------------Review------------------>
            --------Sample cores for pollen and 14C----->  ----Sample and analyze for grain size---------->              ---Sample cores for ostracodes & C

FORESTER    ---------Complete ostracode analysis of GCC-4------------>------------------------Analyze ostracodes in PC-4------------------------------------>
            --------------Analyze & compile trace element data on shells--------------------------->

FOSTER      -------------------Prep paper & map on Holocene sed thickness---------------------------->------------Review---------->
            -------------------Split & desc cores---------------------->-Talk NEGSA-   -------------------------Compile seismic-refl data--------------------->

GOLDHABER   ----------Sample cores 4 & 6--------------->-----------------------------Analyze S and Fe chemistry------------------------------->---------Prep report-------->

HUNTER      ---------------Compile data on 1986 storm deposits---------------------->----------------------Prep paper on storm deposits------------------>------------Review--------->

LARSEN      ----------------Compile 1989 fld results------------------>----------------------Tree-ring analyses of inter-ridge and buried trees---------------------------->
                                    ---------------------Prepare uplift curves for southern basin----------------------------------->---------Compile high lake stand data---------->

REYNOLDS    --------------------Complete paleomag analyses cores 20 & 6----------------------------->-------------------Begin magn meas core 4------------------------------------>
                                                      --------Perform magn secular variation & dating analyses box cores 9,6,4-------------------------->---Prep report------>
```

APPENDIX D

SOUTHERN LAKE MICHIGAN

PROCESSES

Data Acquisition, Processing,
& Compilation

CY 1990

```
                 :        JAN                :       FEB             :        MAR              :       APRIL               :         MAY                :       JUNE              :
                 1       10        20        30 1       10        20  1       10        20      30 1      10        20       1       10        20        30 1       10        20       30
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                                                   ::
                                                Wrkshp-SP

                                                                     --------------------Prep paper on ice as seawall----------------------------------------------------->----------Review------------>
                -------Prep for fld wrk--------------->---Field Work------->
BARNES          -----Analysis of profiles & samples->----------Prep rpt/paper on 1989  obs coastal ice regime--------------------------->---------------Review------------>
REIMNITZ                                                              -----------------------------1990 Profile & ice analysis in lab----------------------------------------------------------------->
KEMPEMA                                                                                       ---------------Flume studies-sed entrainment--------------------------Prep paper------------->

                                                                                                      ------------Prep Open File of sed and profile data----------->

                ----------------------------------Bathymetric and textural analyses------------------------------->
BOOTH                                                                                                    -----------Prep paper on corridor off Ft.Sheridan----- ------------->-------Review-
                                                                                                                                                               ------Prep for fld wrk-------->

HAINES                             -------------Deployment prep------->------------Instrument deployment--------------------------->
                                                                                              ----------------------Quality control & bulk stats------------------------->
                                                                                                                              ---------Analysis of field data------------------------------>

HUNTER           --------------Analysis of profiles and trenches---------------------------------------------------------------------->
                                                                                                                            --Field wrk-->
                                                                                                  ------Prep pap on hist 1986 hi stand---------------------------------->-----Review----->

                 ----------Prep historical shoreline posit--------------->
JIBSON                                  -------------------Analyze historical  shoreline data------------------------------------------------->--------Prep paper rate bluff retreat----------
                                                                                 --Prep for fld-----------Field work------------>
                                                                                 --------------------Analysis coastal engineering geology-------------------------------------------------->
OLYPHANT,FRASER, THOMPSON                                                                                                                         :-------Field Work------------------------->

PRESTEGAARD      --Compl pap sed trans------->
                                                         :----->  Field work (profiles)                               :------>              Field work (profiles)                         :------>
                 ---------------------------------------------Laboratory and field data analysis------------------------------------------------------------------------------------------->

WOOD                                                                                                              :--------------------------Data Analysis------------------------------------>
```

APPENDIX E

APPENDIX F

LIST OF ATTENDEES

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