SHALLOW GROUND-WATER FLOW AND DRAINAGE CHARACTERISTICS OF THE BROWN DITCH BASIN NEAR THE EAST UNIT, INDIANA DUNES NATIONAL LAKESHORE, INDIANA, 1982

By Robert J. Shedlock and William E. Harkness

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WILLIAM P. CLARK, Secretary

GEOLOGICAL SURVEY

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ILLUSTRATIONS

ILLUSTRATIONS--Conutinued

FACTORS FOR CONVERTING INCH-POUND UNITS USED IN THIS REPORT TO THE INTERNATIONAL SYSTEM OF UNITS (SI)

Multiply inch-pound units	By	To obtain SI units
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
cubic foot per second (ft^3/s)	28.32	liter per second (L/s)
square foot per day (ft^2/d)	0.0929	square meter per day (m^2/d)
foot per day (ft/d)	0.3048	meter per day (m/d)

DATUM

National Geodetic Vertical Datum of 1929 (NGVD OF 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "mean sea level." NGVD of 1929 is referred to as sea level in this report.

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ABSTRACT

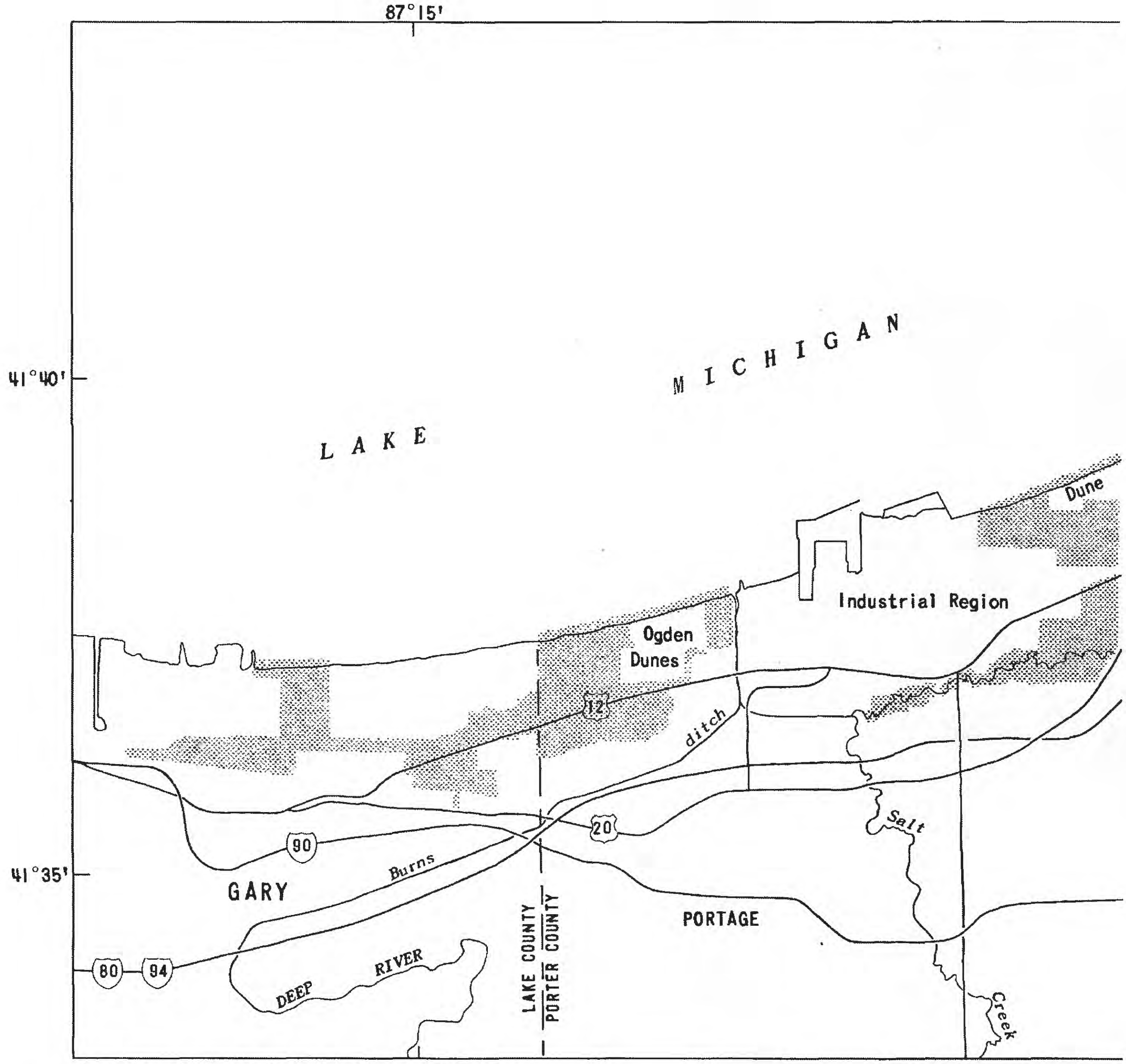
Brown ditch consists of several segments that drain wetlands between dune ridges near the East Unit of Indiana Dunes National Lakeshore in Porter County, Indiana, west of Michigan City. The dune ridges were formed during higher stages of Lake Michigan in the Pleistocene and Recent Epochs. Surficial lacustrine sands deposited during these older lake stages form a water-table aquifer that provides perennial base flow to the ditch.

The northwest-trending reach of the ditch immediately upstream from the lakeshore and the upstream east arm south of the adjacent town, The Pines, were dredged in the summer of 1983. Profiles established before the dredging in July and August 1982, showed the average streambed slope of the ditch in the lakeshore (0.19 percent) to be six times that of the upstream east arm (0.03 percent) at that time. The ditch contains debris and vegetation in the reach in the lakeshore but seems to convey all the base flow it receives there. In contrast, before the dredging the upstream east reach contained several ponded sections where flow was sluggish.

Water-table declines for hypothetical reconstructions of the ditch were estimated by using a digital model to compute changes in the boundary component of the water-table head. Dredging to eliminate high points to form uniformly graded streambed and stage profiles in the upstream east arm could lower the water table in The Pines 0.2 to 2.0 feet. Dredging to lower the ditch stage in the lakeshore by 0.5 to 1.0 foot would cause additional water-table decline of less than 0.5 foot in The Pines. However, dredging in both the lakeshore and the upstream east arm could lower the water table by nearly 1.0 foot within the lakeshore.

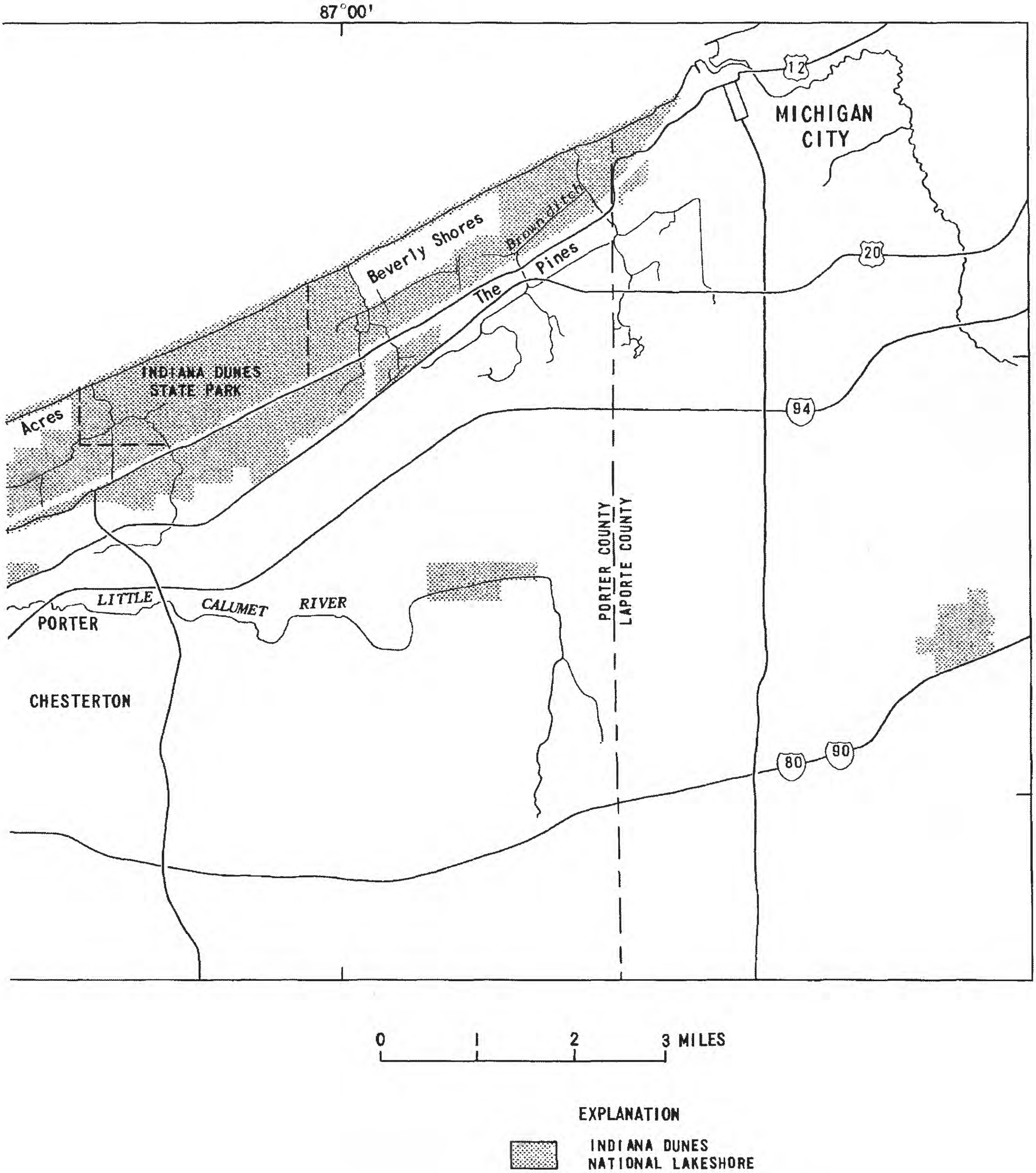
INTRODUCTION

Indiana Dunes National Lakeshore (the lakeshore) extends from the west end of Michigan City to the east end of Gary in an urban-industrial setting along the shoreline of Lake Michigan in northwest Indiana (fig. 1). The lakeshore, created in 1966, is divided into nine land units. Six of these units are within 2 mi of the Lake Michigan shoreline, and three of the units are isolated



Base from National Park Service, Indiana Dunes National Lakeshore, Lake, LaPorte, and Porter Counties, Indiana

Figure 1.-- Indiana Dunes National Lakeshore.


87°00'
MICHIGAN CITY
12
20
94
80
90
Beverly Shores
Brown Ditch
The Pines
INDIANA DUNES STATE PARK
Acres
PORTER COUNTY
LAPORTE COUNTY
LITTLE CALUMET RIVER
PORTER
CHESTERTON
0 1 2 3 MILES
EXPLANATION
INDIANA DUNES NATIONAL LAKESHORE

preserves several miles inland. Several small residential communities are along and within the lakeshore boundaries. A 4-square mile industrial region north of Burns Harbor, Indiana, separates the West Unit from the other land units of the lakeshore to the east.

The U.S. Geological Survey, in cooperation with the National Park Service, has been studying flow and water quality in the glacial-drift aquifer system in the lakeshore since 1973. Previous studies include, Marie (1976), Arihood (1975), Meyer and Tucci (1979), Gillies and Lapham (1980), and Hardy (1981). Except for Arihood (1975), which was a lakeshore-wide assessment of water quality, the studies begun before 1979 involved only the Cowles Unit (fig. 1). In 1979, a study was begun on the hydrogeology of the entire lakeshore, with the exception of a few of the isolated inland units. Test holes were drilled to bedrock, and piezometers were installed across the lakeshore to define the glacial-drift aquifer system. One of the major goals of the hydrogeology study is to improve the understanding of the relation between the ground-water system and the extensive interdunal wetlands in the lakeshore. In roughly the eastern one-third of the lakeshore, these interdunal wetlands are partially drained by ditch systems, whose construction began around the turn of the century. The Brown ditch system is a legal drain under the jurisdiction of the drainage board of Porter County.

In 1982, the town of The Pines asked the county drainage board to clean Brown ditch, which runs through the east end of the lakeshore. The Pines, which borders the East Unit of the lakeshore (fig. 1), proposed the dredging because basements in some residences were flooded with several feet of water during springtime. The Pines town board has contended that the ditch is clogged within the lakeshore and is inhibiting drainage in the town.

The dredging proposal prompted the National Park Service to ask the Geological Survey to investigate the relation between Brown ditch and the shallow aquifer system in the lakeshore and adjacent areas. The purpose of this study is to determine (1) whether surface drainage in Brown ditch is being significantly controlled or obstructed, and (2) the effects on the water table of lowering the stage of the ditch in the lakeshore and in The Pines.

In the summer of 1983, while this report was in review, two segments of the ditch upstream from the lakeshore were dredged. The first was the northwest-trending reach in the cut through the Calumet dune complex (fig. 2), and the second was the upstream east arm of the ditch south of The Pines. The data and discussion presented in this report are for conditions observed before the dredging.

GEOHYDROLOGIC SETTING

Geomorphology and Drainage Boundaries

The area near the eastern end of the lakeshore (fig. 2) contains three distinct ridges of sand dunes that were deposited when the ancestral form of Lake Michigan (Lake Chicago) stood at several major stages during the Pleistocene and Recent Epochs (Bretz, 1951). Most of the beaches and offshore slopes of these major lake stages have been preserved in the lakeshore area. The Glenwood dune ridge, the oldest and furthest inland, was formed when the mean stage of Lake Chicago was 640 ft. The next set of dunes to the north, the Calumet dune ridge, was formed when the mean stage of Lake Chicago was 620 ft. The set of dunes along the modern shoreline consists of dune and beach deposits from several ancient lake stages, as well as the modern sediments, and are referred to here as the shoreline dune ridge. The stages that built this ridge ranged from 605 to 580 ft (the approximate mean level of the modern lake).

The lowlands between the major dune-ridge complexes represent the offshore slopes of the major stages of Lake Chicago. These lowlands are primarily wetlands that have been partially drained by the ditch systems. The surficial sediments in these lowlands are peat, muck, and sand. The lowland between the shoreline dune ridge and the Calumet dune ridge is called the Great Marsh (fig. 2). The lowland between the Calumet dune ridge and the Glenwood dune ridge has no recognized name but is called the Calumet-Glenwood wetland in this report.

The ditch systems and the drainage boundary of the Brown ditch basin are illustrated in figure 3. Brown ditch is a tributary to Kintzele ditch and primarily drains the east ends of both the Great Marsh and the Calumet-Glenwood wetland. The ditch also receives a minor amount of drainage from the Lake Border Moraine, immediately south of the Glenwood dune ridge. The drainage area for Brown ditch is about 4.7 mi^2; 1.0 mi^2 is within the lakeshore. Brown ditch empties into Kintzele ditch in the lakeshore. A short distance from this confluence, Kintzele ditch drains into Lake Michigan in a channel that was cut through the shoreline dune ridge.

Aquifer System and Ground-Water Flow Patterns

In the study of the glacial-drift aquifer system in the lakeshore and surrounding area, the Geological Survey drilled 52 test holes to bedrock. One or more piezometers were installed at most of the test-hole sites. In addition, about 50 shallow piezometers were installed in the surficial aquifer by using an auger rig or by hand-driving well points at sites inaccessible to vehicles, such as in the wetlands. The hydrogeologic information presented in this paper

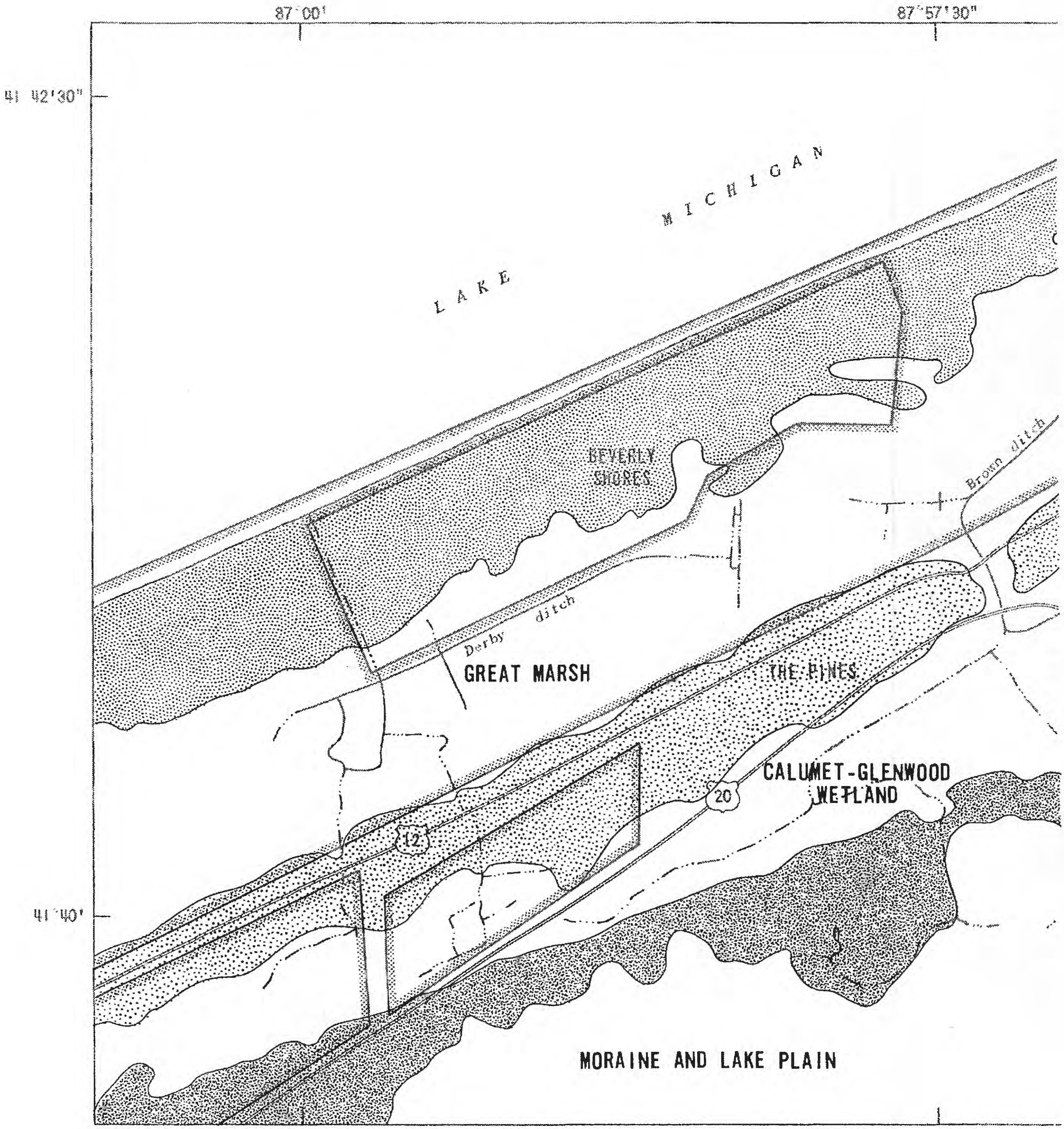
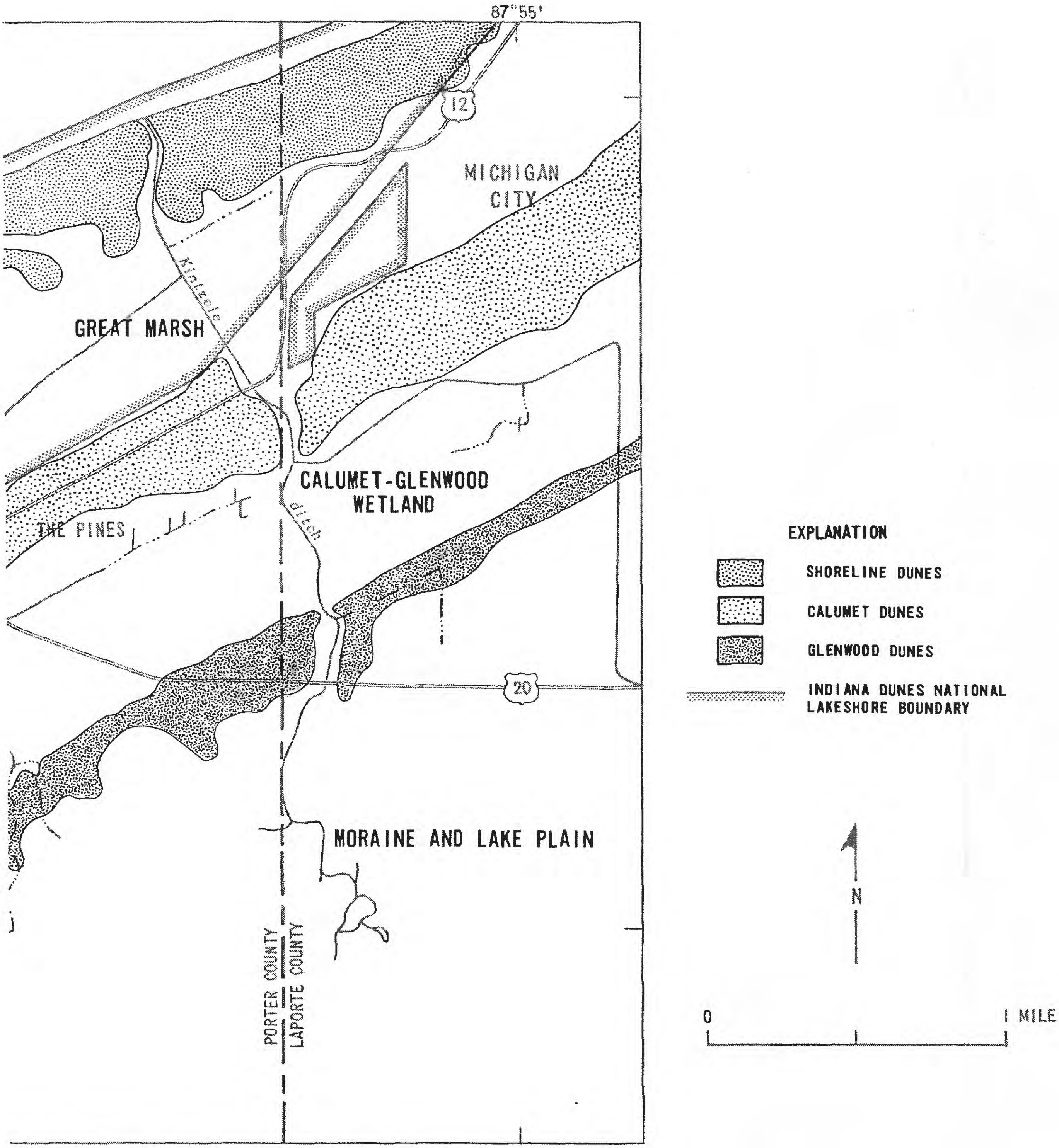


Figure 2.-- Dune ridges, ditches, and interdunal wetlands at east end of the Indiana Dunes National Lakeshore.



87°55'
12
MICHIGAN CITY
GREAT MARSH
Kintzele
CALUMET-GLENWOOD WETLAND
ditch
THE PINES
20
MORAINE AND LAKE PLAIN
PORTER COUNTY
LAPORTE COUNTY
EXPLANATION
SHORELINE DUNES
CALUMET DUNES
GLENWOOD DUNES
INDIANA DUNES NATIONAL LAKESHORE BOUNDARY
N
0
1 MILE

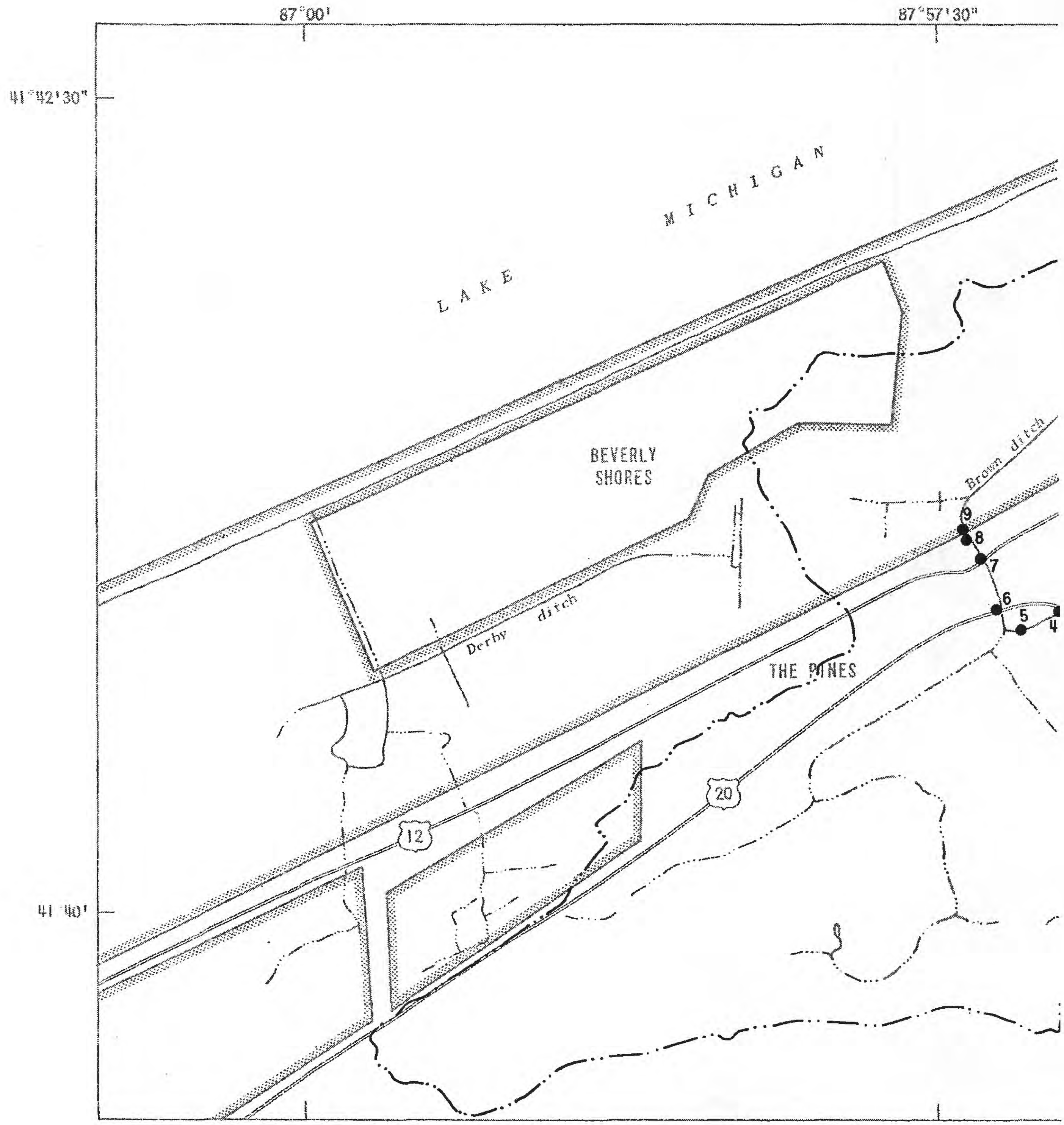
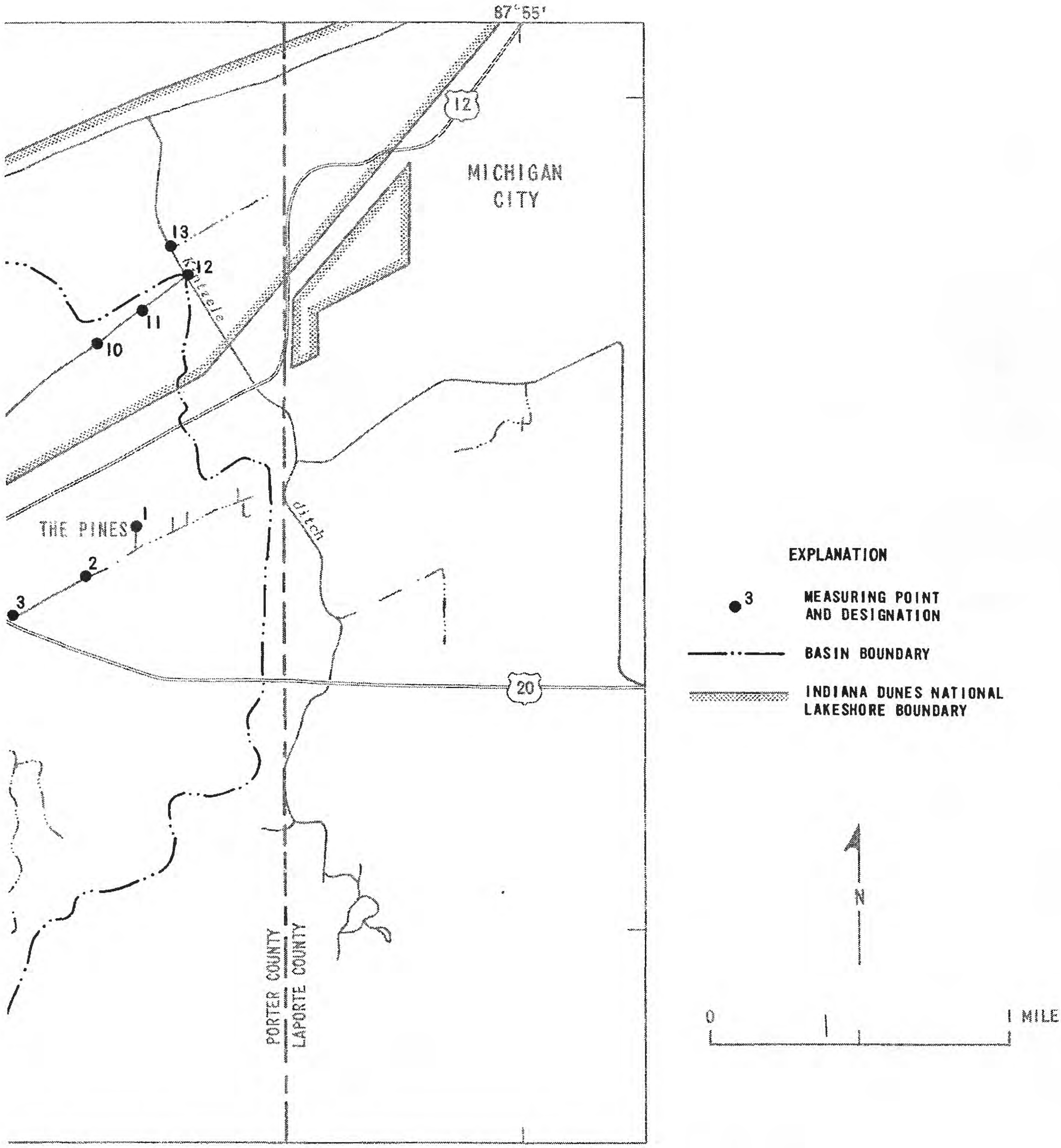


Figure 3.-- Brown ditch drainage basin.


87°55'
12
MICHIGAN CITY
13
12
Kintzele
11
10
ditch
THE PINES
1
2
3
20
PORTER COUNTY
LAPORTE COUNTY
EXPLANATION
3 MEASURING POINT AND DESIGNATION
BASIN BOUNDARY
INDIANA DUNES NATIONAL LAKESHORE BOUNDARY
N
0
1 MILE

is based on potentiometric, lithologic, and hydraulic data from the eastern part of this network of piezometers and test holes. In addition, six test wells in The Pines and soil cores and hand-driven wells at six sites in the lakeshore were installed in November 1982.

Windblown sand from the three major dune ridges, their associated beach and offshore sands, and organic deposits in the interdunal wetlands form a water-table aquifer throughout the lakeshore. This aquifer is part of the Calumet aquifer described by Hartke and others (1975) but is called the surficial aquifer in this paper to distinguish it from deeper confined aquifers in the glacial drift.

An estimate of the average hydraulic conductivity of the surficial aquifer, 50 ft/d, was obtained from specific-capacity tests in 18 Geological Survey observation wells in the lakeshore, by a method in Theis (1963, p. 332-336). In the Brown ditch basin, the saturated thickness of the aquifer generally ranges from 2 ft in the channel of the reach of the ditch in the lakeshore to 25 ft in the adjacent dune ridges. The surficial aquifer rests on lacustrine clay that is underlain by till. Buried lacustrine sands and lenses of sand and gravel in the till form confined aquifers of variable thickness and areal extent in the lakeshore. In the Brown ditch basin, the total thickness of unconsolidated sediments generally ranges from 100 ft in the lowlands to 300 ft in the shoreline dune ridge. The bedrock below the drift is shale of Devonian and Mississippian age.

Potentiometric data in the network of observation wells show that regional ground-water flow in the lakeshore area is toward Lake Michigan, which is a major discharge zone for both the glacial drift and the bedrock aquifer systems. Because of this regional flow system, there is a strong component of upward flow in the middle and lower levels of the drift. Most wells screened in the lower levels of the drift in the lakeshore flow at the surface and have water levels 30 to 50 ft above the mean stage of Lake Michigan (580-ft altitude). In contrast, water in the surficial aquifer circulates in smaller cells because of ground-water discharge to the ditch systems and streams and because of the low saturated thickness (10 to 30 ft in most of the lakeshore).

HYDROLOGY OF THE BROWN DITCH BASIN

Channel Slope and Base Streamflow in Brown Ditch

Brown ditch has two main east-west arms in the Calumet-Glenwood wetland. These arms flow in opposite directions toward a single channel that flows north through a manmade cut in the Calumet dune ridge and then east through the lakeshore into Kintzele ditch (fig. 2). The altitudes of the water surface and the streambed were determined during base flow in July and August 1982 for the reach of the ditch system between points 1 and 13 in figure 3. This reach includes the east arm of the ditch in the Calumet-Glenwood wetland, the north-south reach that cuts through the Calumet dune ridge, the eastward flowing main channel of the ditch in the lakeshore and a short section of Kintzele ditch that is in the proposed dredging project.

The profile of this reach in figure 4 is based on measurements at the points designated in figure 3. Stages at points 1 through 5 were determined August 25,1982, and stages at points 6 through 13 were determined July 15,1982. The stage at point 6 on August 25 was only 0.14 ft lower than it was on July 15. Thus, the stage profile should be virtually the same for both dates. The streambed profile can be separated into three reaches on the basis of slope. The steepest of the three is the reach in the lakeshore between points 9 and 12. In this reach, the streambed altitude decreased 13.1 ft in 7050 ft, a slope of 0.186 percent. The next reach is between point 9 at the lakeshore boundary and point 5, at the bridge at U.S. Highway 20. In this reach, streambed altitude decreased 2.52 ft in 2,400 ft, a slope of 0.105 percent. From point 5 to point 1 streambed altitude decreased 1.14 ft in 4,010 ft, a slope of 0.028 percent.

Discharge was measured during base flow conditions on July 16, 1982. Flow increased from 0.79 ft^3/s at point 6 at the U.S. Highway 20 bridge to 1.41 ft^3/s at point 11 in the lakeshore. The increase was probably caused by ground-water seepage and inflow from shallow tributary ditches not shown on the map but discernible on aerial photographs.

The ditch was inspected on July 16 and August 25 to 26, 1982. Although the channel contains vegetation and fallen trees, very few reaches within the lakeshore contain ponded water. In contrast, water was ponded in several reaches south of the lakeshore boundary and upstream from point 8. One of the ponded reaches was the section between point 7 at U.S. Highway 12 and point 6 at U.S. Highway 20. Another ponded reach was a section a few hundred ft upstream and downstream from point 3. A third ponded reach was the section on both sides of the culvert at point 2. At point 3 the water was 1.5 ft deep, and at point 2 it was 3.0 ft deep on August 25, 1982. Depths of water in Brown ditch in the lakeshore were generally less than 1.0 ft, which suggests that base flow in the ditch before dredging was more sluggish in the upstream reaches than in the lakeshore.

The channel of Brown ditch was deeper and better defined in the lakeshore than in the upstream east arm (before dredging), where channel boundaries were, indistinct in places. Eighty-five ft north of point 9, the cross-sectional area of the ditch is 107 ft^2 (fig. 5) at bankfull stage (altitude 608.5 ft). Approximately 20 percent of this cross-sectional area is under water during base flow as typified by the November 24, 1982 conditions shown in figure 5. Downstream from where this section was measured, the cross-sectional area of the channel gradually increases. Thus, in the lakeshore, the ditch easily conveys base flow and has ample cross-sectional area for higher flows. Although the ditch is not gaged, no evidence was found of previous flows above bankfull stage near point 9 during an inspection of the ditch on August 26, 1982.

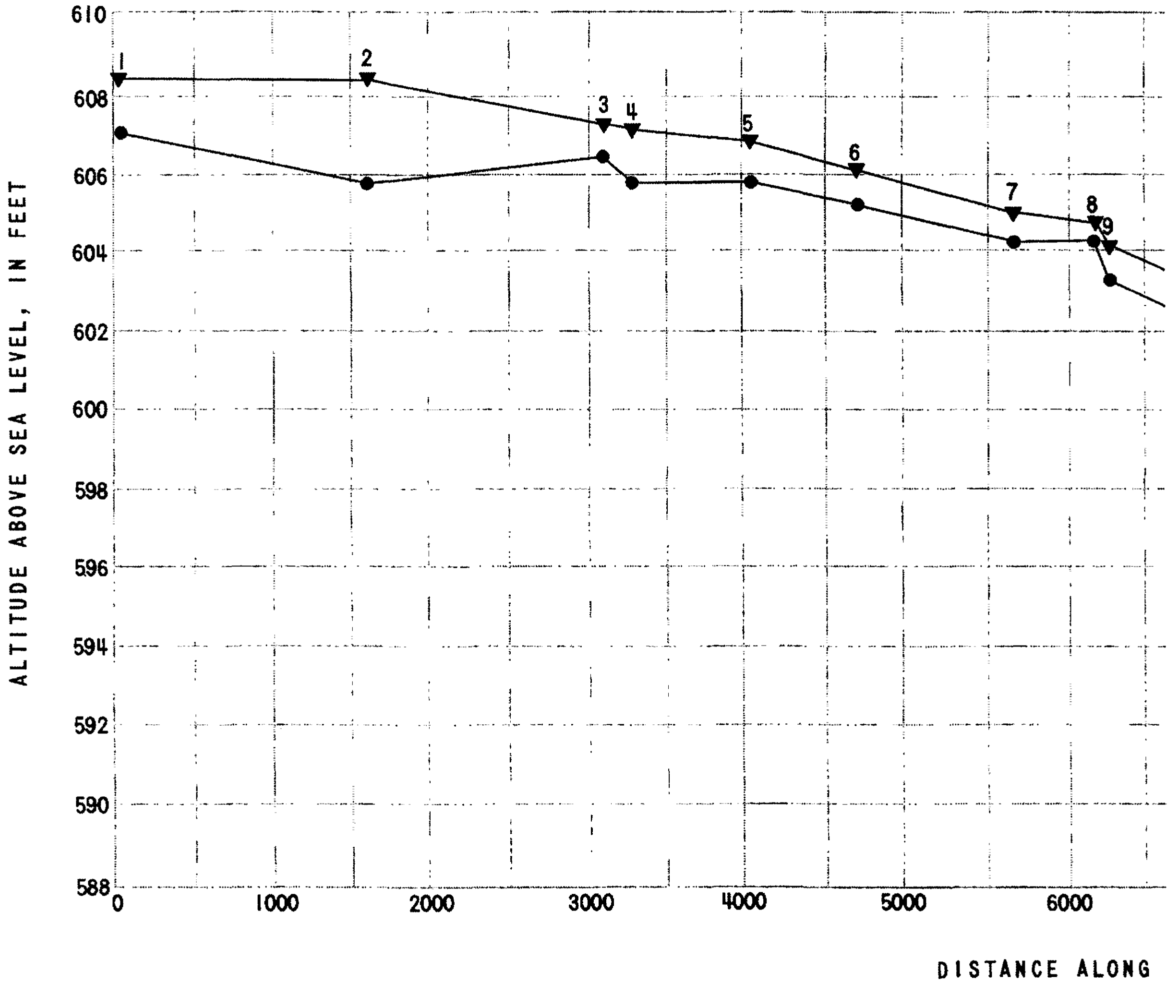
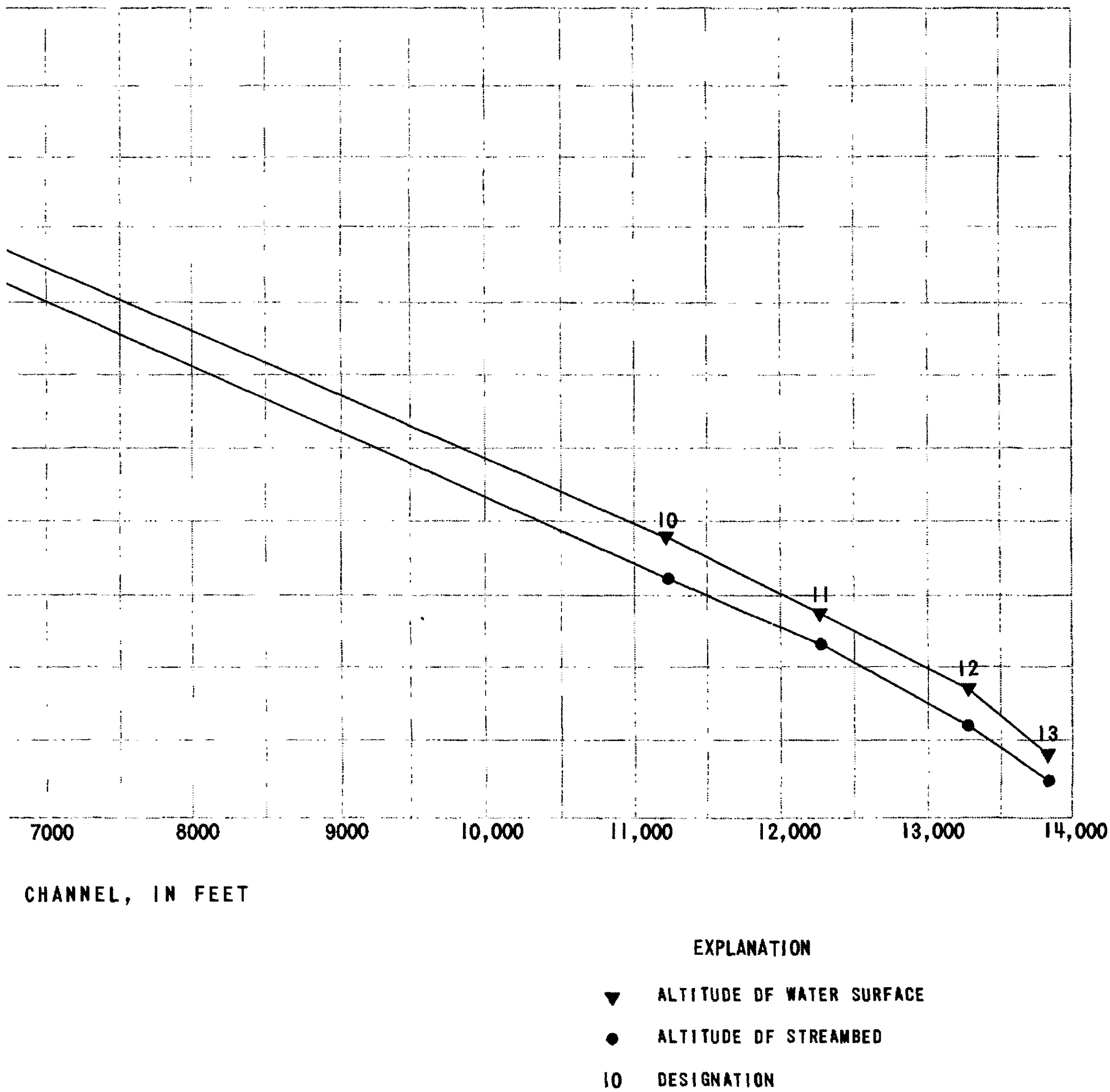


Figure 4.-- Profiles of streambed and stage in part of the



Brown ditch system, August 25-26, 1982.

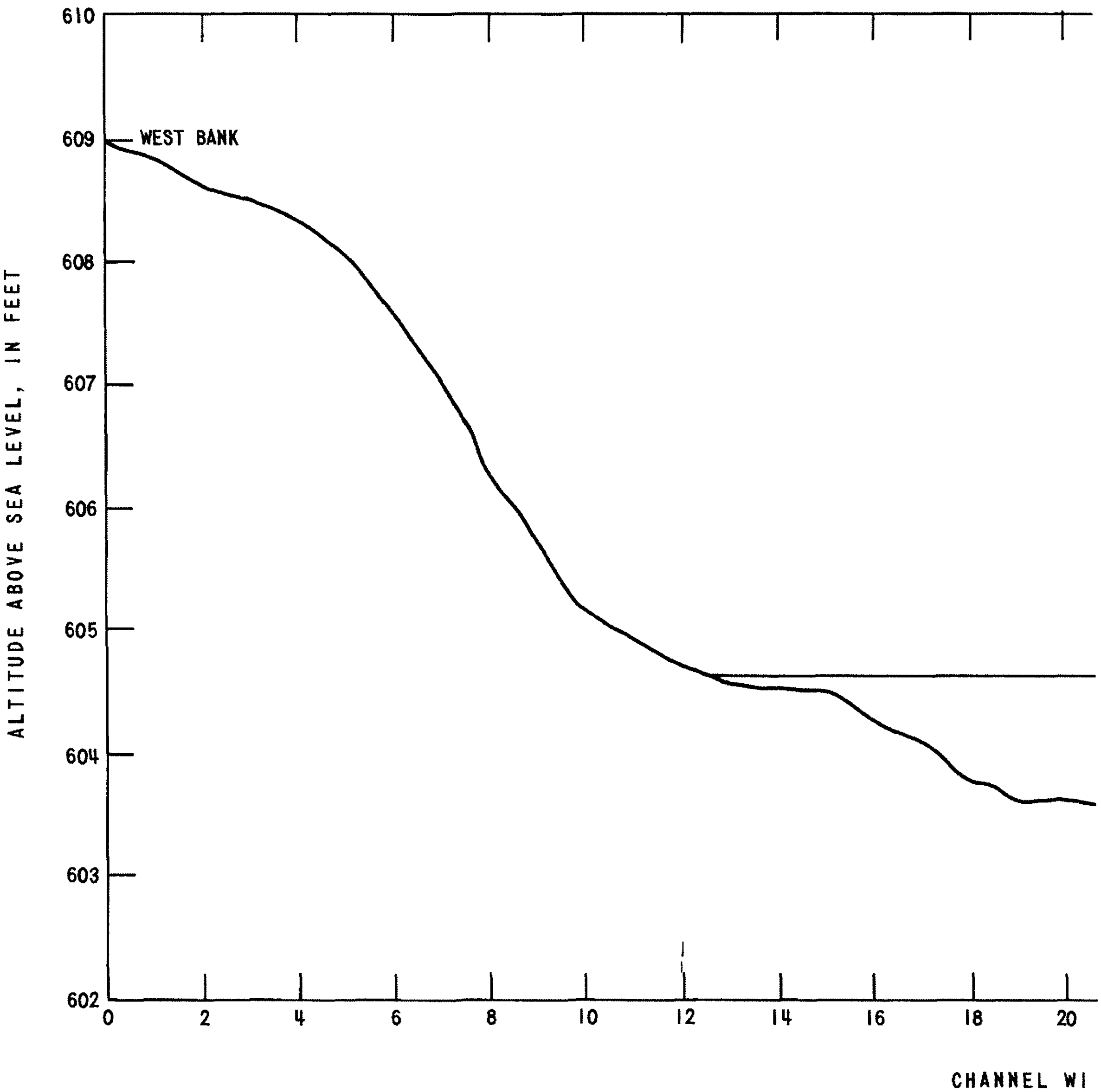
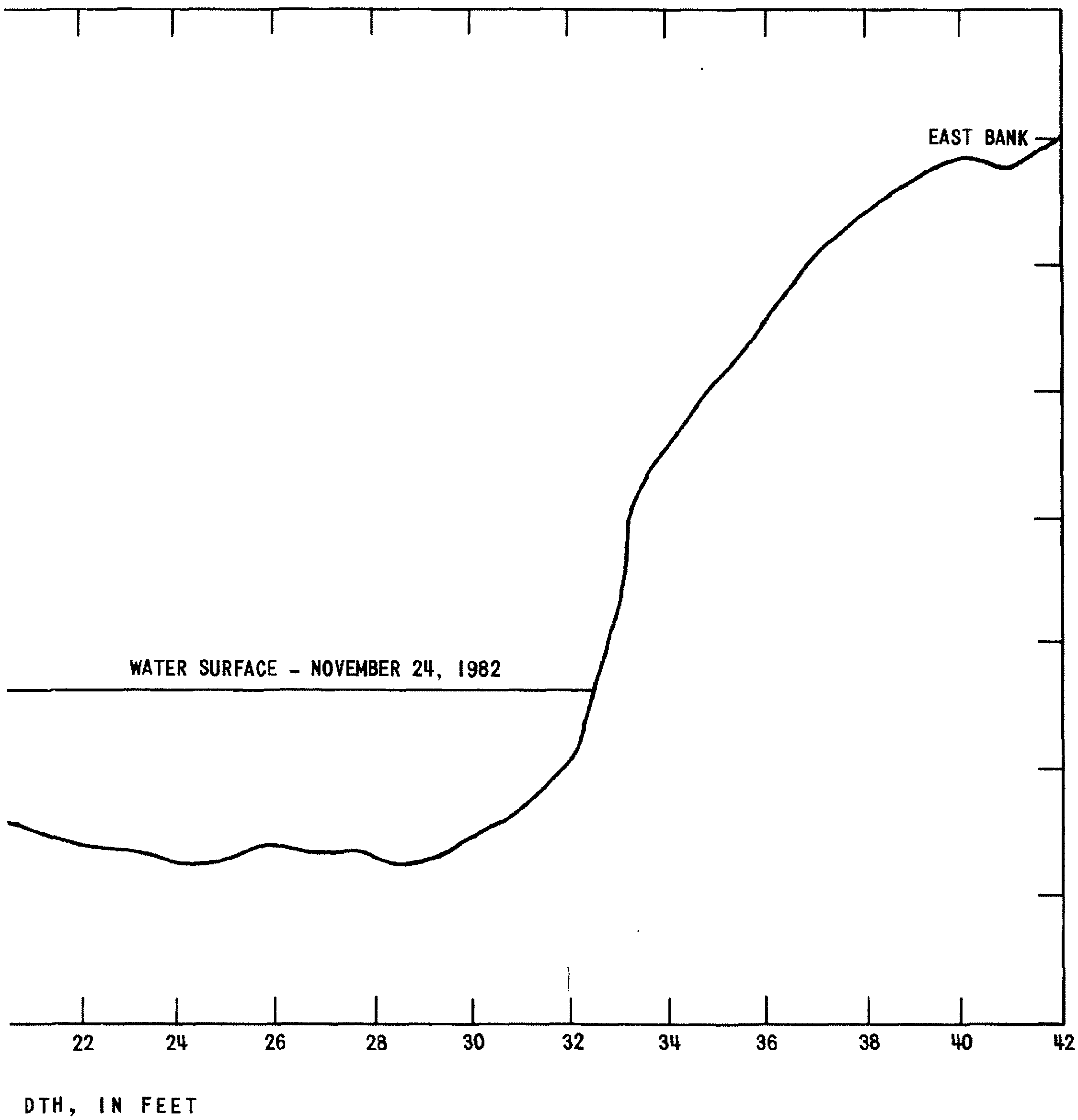


Figure 5.-- Cross section of Brown ditch at



boundary of Indiana Dunes National Lakeshore.

Shallow Ground-Water Flow in the Brown Ditch Basin

Shallow ground-water flow in the Brown ditch basin is to the channels of the ditch system from water-table mounds of low relief beneath the dune ridges as shown by the map of the water table on August 5, 1982, in figure 6. Additional data on shallow ground-water flow and the hydraulic connection between the ditch and the surficial aquifer were obtained along two transects perpendicular to the ditch. Test holes were drilled and piezometers were installed along transect A-A' in The Pines, and drive points were installed and soil cores taken along transect B-B' in the lakeshore (fig. 6).

The water-table profile for November 18, 1982, and the near surface stratigraphy in The Pines and in the Calumet-Glenwood wetland to the south are depicted in the cross-section in figure 7 along transect A-A' in figure 6. In the section, the slope of the water table on the south side of the ditch roughly parallels the ground surface and exceeds the slope north of the ditch in The Pines where the water table is virtually flat. The land south of the ditch in the Calumet-Glenwood wetland represents the offshore slope of the Glenwood stage of Lake Chicago. The low relief of the water-table mound beneath The Pines in the Calumet dune ridge is depicted by the profile. The difference between the altitude of the water-table divide in The Pines and the altitude of the water surface in Brown ditch to the south was only 2.4 ft on November 18, 1982.

Section A-A' also illustrates that the bottom of the east arm of Brown ditch in the Calumet-Glenwood wetland was not cut into the sand aquifer before dredging and that the water table was above the contact between the sand and the organic layer in the wetland. The stratigraphy shown for section A-A' is not necessarily representative of the Calumet-Glenwood wetland because the test holes were drilled along a road constructed of coal ash. The ditch bottom sediments were identified as organic deposits, probably muck, during a field inspection at several points in the east arm of Brown ditch. Furthermore, the many areas of standing water in the east part of the Calumet-Glenwood wetland are evidence that the surficial organic sediments were not effectively drained by this reach of the ditch before the dredging.

The geohydrologic section along transect B-B' in the Great Marsh in the lakeshore is shown in figure 8. The water levels shown were measured on November 18, 1982. As in the Calumet-Glenwood wetland, the slope of the water table south of Brown ditch in the Great Marsh roughly parallels the ground surface, which is the offshore slope of another level of Lake Chicago, the Calumet stage. North of Brown ditch the water table in the Great Marsh is virtually flat. In contrast to conditions before dredging in the Calumet-Glenwood wetland, Brown ditch is incised into the sand aquifer in the Great Marsh. Thus, the water table is generally below the contact between the sand and the organic deposits in the Great Marsh in the Brown ditch basin.

The geohydrologic sections and the water-table map suggest no relation between the condition of the ditch in the lakeshore and the apparent high water-table conditions in The Pines. The water table decreases in altitude by more than 10 ft between the water-table divide in The Pines and the eastward flowing part of the ditch in the lakeshore.

SIMULATION OF WATER-TABLE DECLINES

Model Construction

Steady-state water-table declines caused by lowering the stage of Brown ditch were simulated by using the two-dimensional finite-difference model of Trescott and others (1976). The model was used to compute the boundary component of the water-table head described by Reed and Bedinger (1961). In this concept, the water-table head is separated into boundary and accretionary components. The boundary component is determined by stream and lake stages and the areal shape of the aquifer. The accretionary component is determined by the shape of the aquifer and by vertical gains or losses attributed to processes such as areal recharge, evapotranspiration, and vertical leakage through underlying aquitards.

For changes in surface-water stages that have a negligible effect on the accretionary component in coupled stream-aquifer or lake-aquifer systems, the change in the water table is equivalent to the change in the boundary component. Thus, if one has a reasonable knowledge of the hydraulic characteristics of an aquifer, then water-table changes caused by changes in surface-water stages can be simulated as changes in the boundary component of head.

In the simulations, the surficial aquifer was assumed to be homogenous and isotropic and was assigned a uniform hydraulic conductivity. The ditches were assumed to be constant-head boundaries and changes in stage along the ditch system were simulated by changing the values of the constant heads.

The surficial aquifer departs from these ideal conditions in that the ditches are not unlimited sources of water as simulated by the constant-heads and where the water table is above the sand in the organic layer, the aquifer is not homogenous and its hydraulic conductivity is probably less than the average for the underlying sand. However, these two nonidealities probably yield errors of opposing direction that tend to minimize the total error for simulated changes in ditch stage of a few feet or less.

The boundary of the model area, the variable grid-spacing, and the locations of the constant-head grid blocks are shown in figure 9. The grid blocks in the Brown and Kintzele ditch basins are 500 ft square. Most of the blocks in the Derby ditch basin are 500 ft by 1,000 ft. A transition zone of three

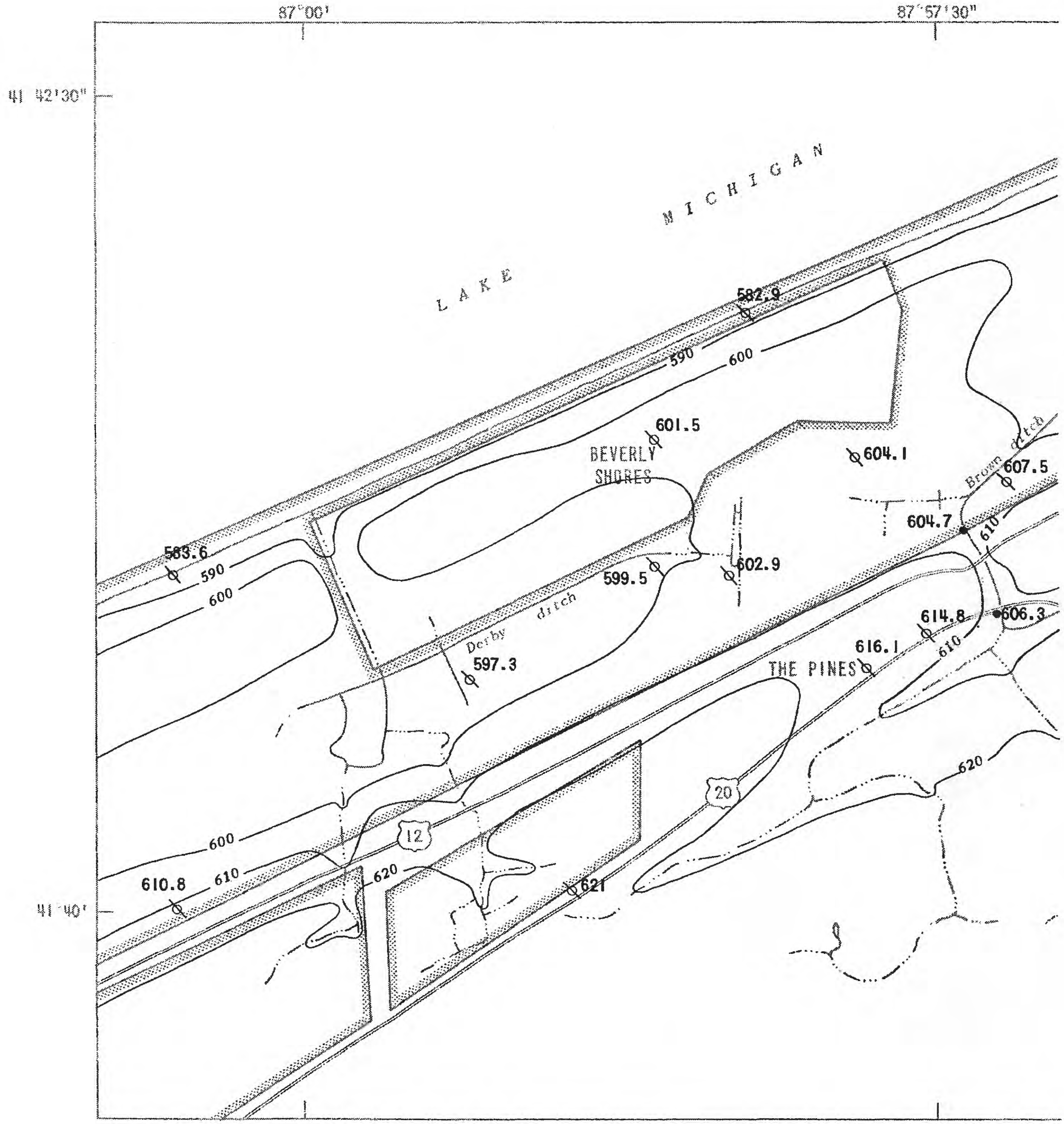
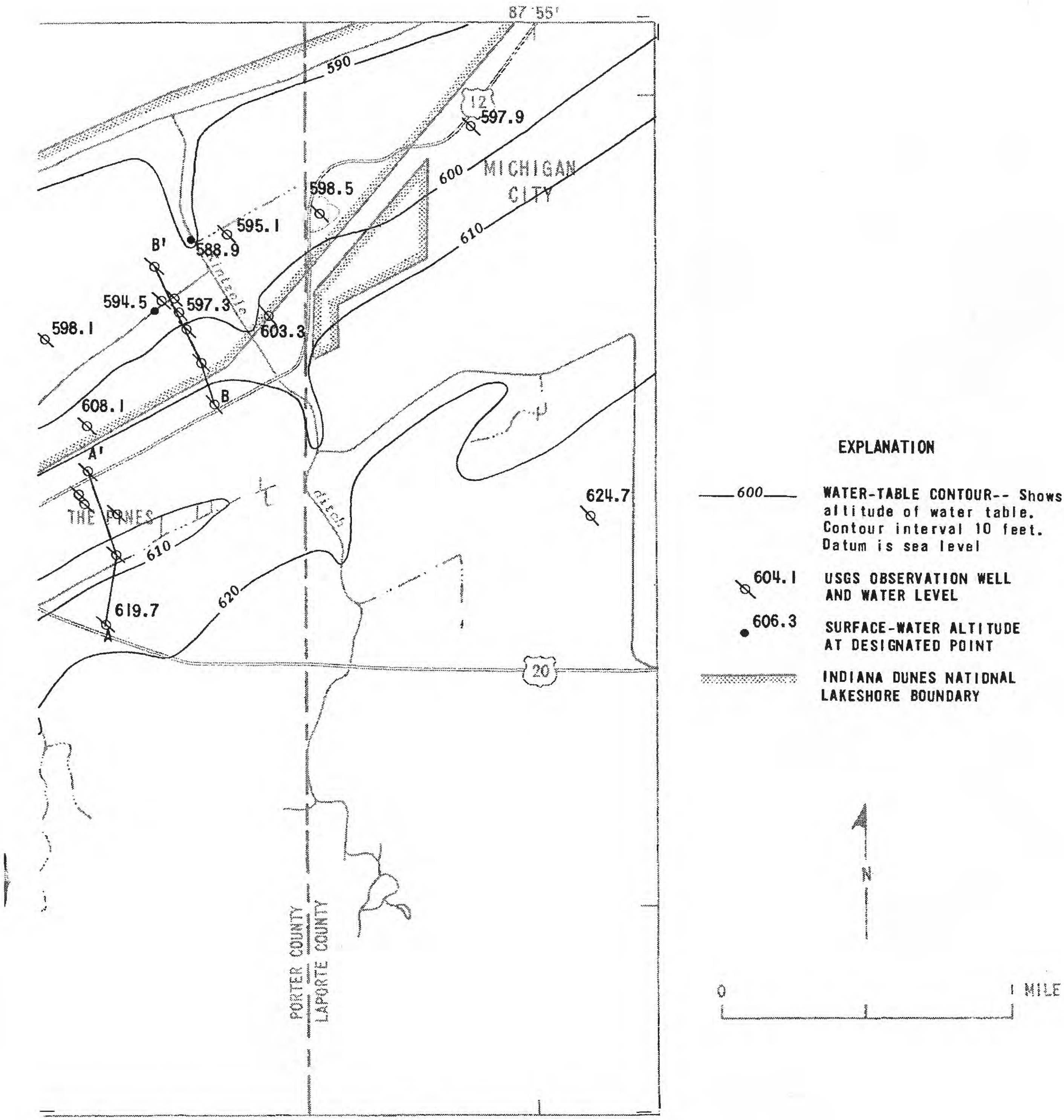


Figure 6.-- Water-table altitude in the Brown ditch basin and surrounding area, August 5, 1982.


87°55'
590
12
597.9
600
MICHIGAN
CITY
598.5
595.1
610
B'
588.9
594.5
597.3
598.1
603.3
608.1
B
A'
THE PINES
610
624.7
619.7
A
620
20
PORTER COUNTY
LAPORTE COUNTY
EXPLANATION
600
WATER-TABLE CONTOUR-- Shows altitude of water table. Contour interval 10 feet. Datum is sea level
604.1
USGS OBSERVATION WELL AND WATER LEVEL
606.3
SURFACE-WATER ALTITUDE AT DESIGNATED POINT
INDIANA DUNES NATIONAL LAKESHORE BOUNDARY
N
0
1 MILE

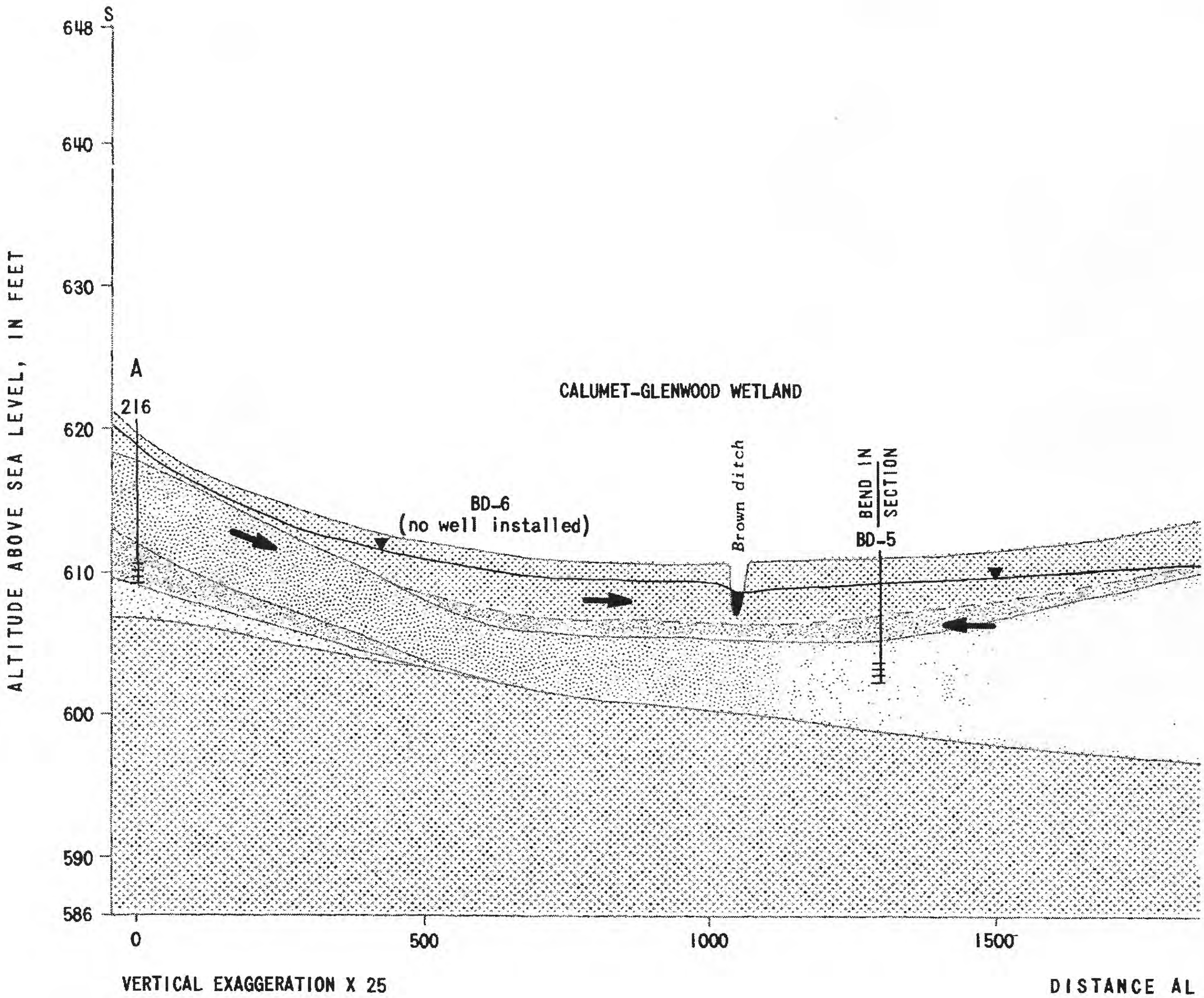
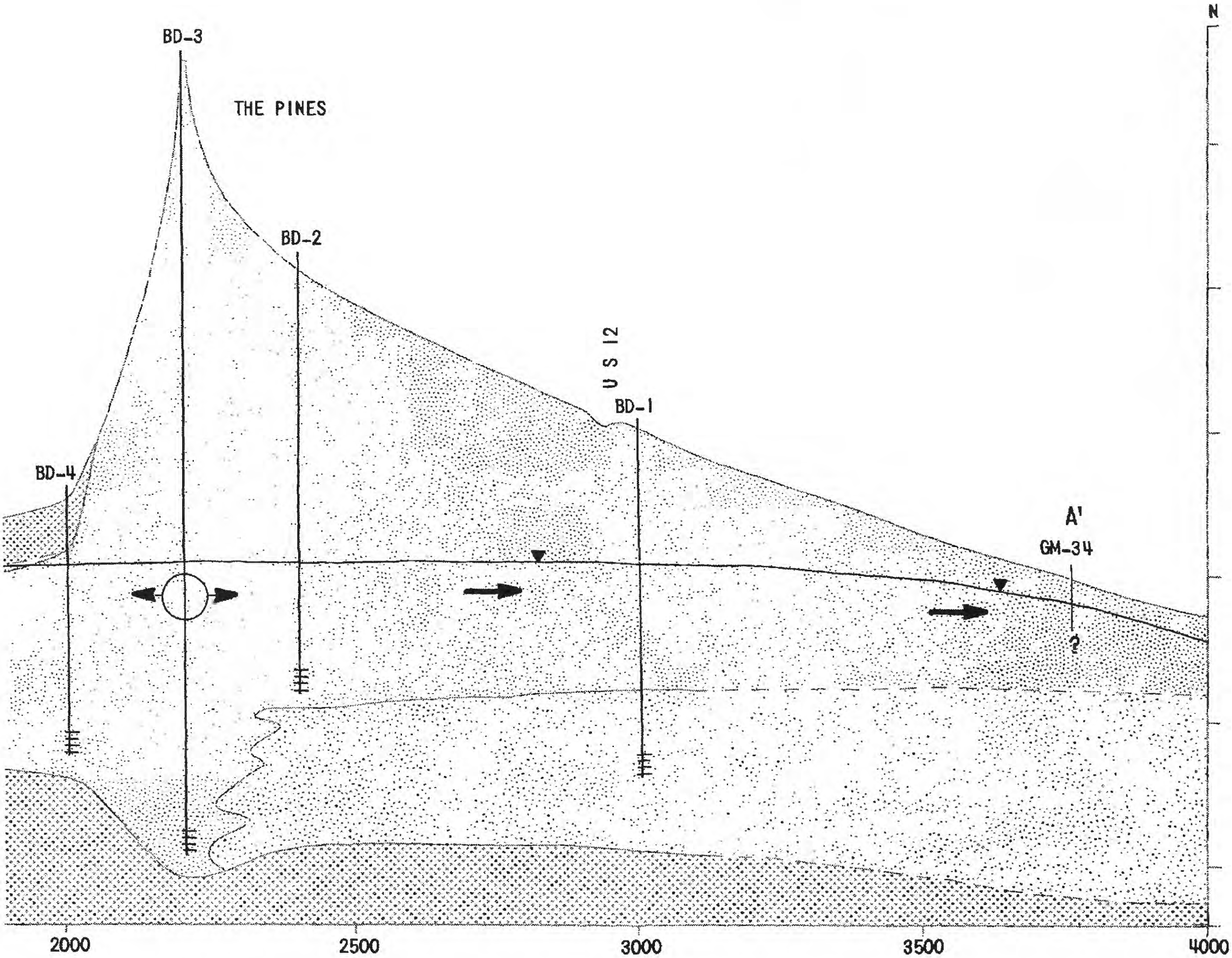
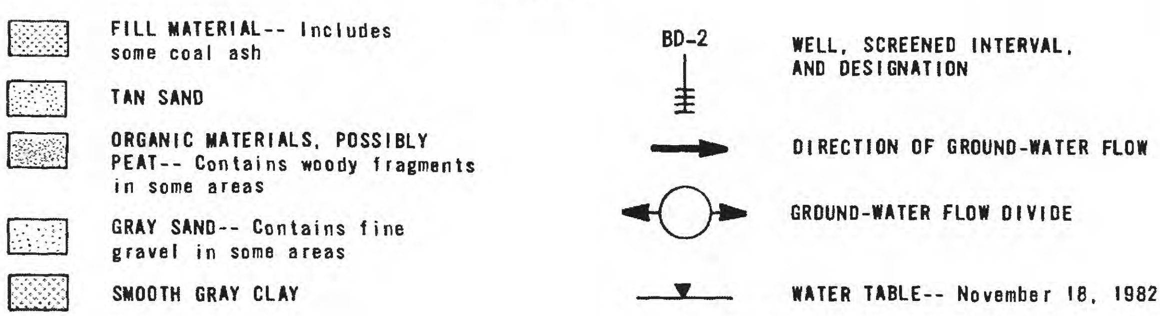


Figure 7.-- Geohydrologic section of surficial aquifer in the Pines and the Calumet-Glenwood wetland, November 18, 1982.



ONG TRANSECT, IN FEET

EXPLANATION



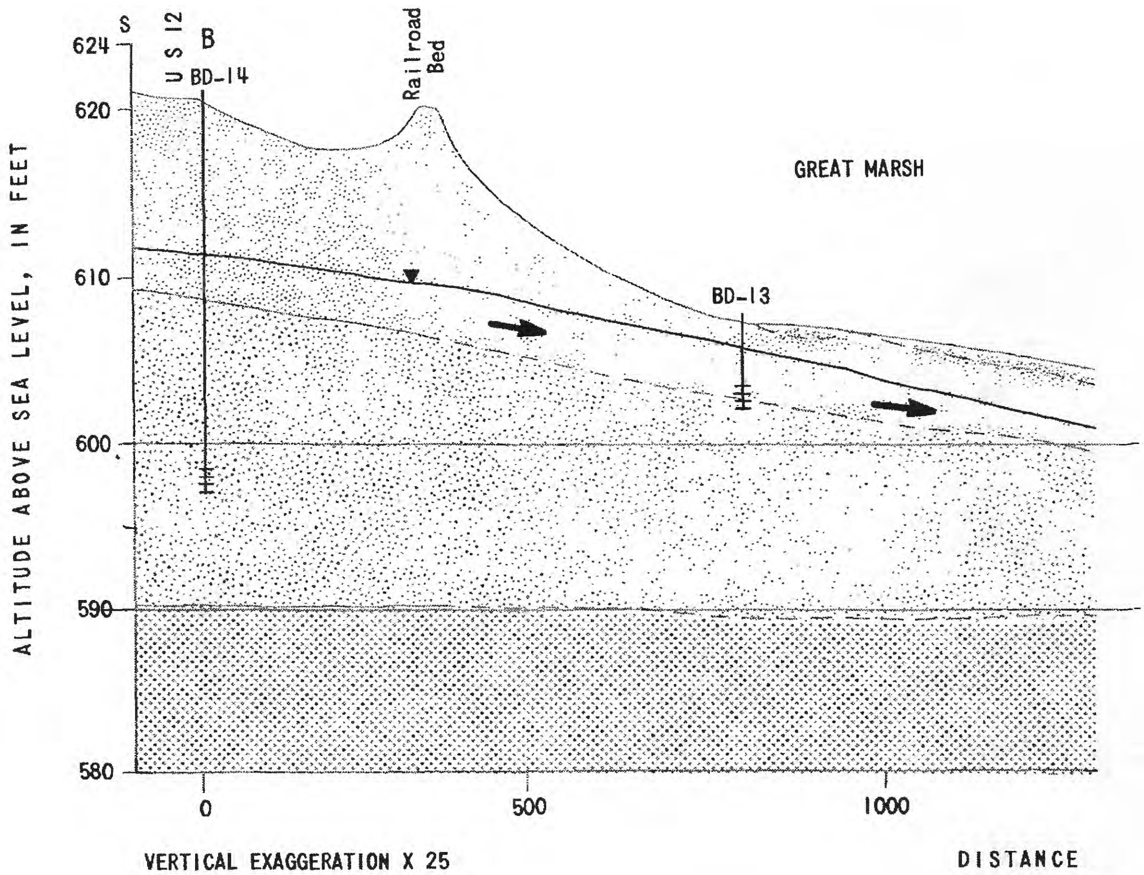
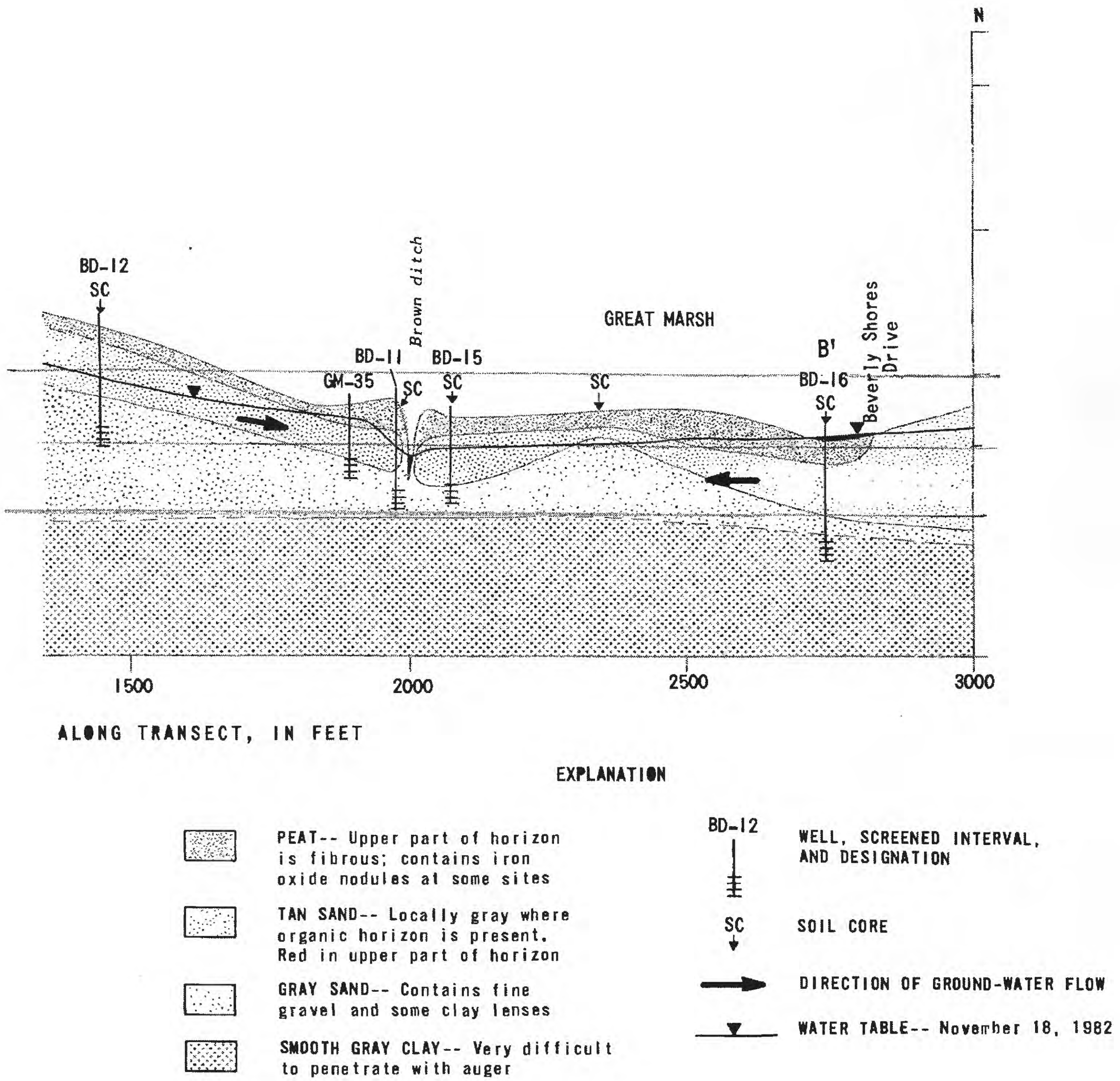


Figure 8.-- Geohydrologic section of surficial aquifer in the Great Marsh at east end of Indiana Dunes National Lakeshore, November 18, 1982.


N
BD-12
SC
Brown ditch
GREAT MARSH
BD-11
GM-35
SC
BD-15
SC
SC
B'
BD-16
SC
Beverly Shores Drive
1500
2000
2500
3000
ALONG TRANSECT, IN FEET
EXPLANATION
PEAT-- Upper part of horizon is fibrous; contains iron oxide nodules at some sites
TAN SAND-- Locally gray where organic horizon is present. Red in upper part of horizon
GRAY SAND-- Contains fine gravel and some clay lenses
SMOOTH GRAY CLAY-- Very difficult to penetrate with auger
BD-12
WELL, SCREENED INTERVAL, AND DESIGNATION
SC
SOIL CORE
DIRECTION OF GROUND-WATER FLOW
WATER TABLE-- November 18, 1982

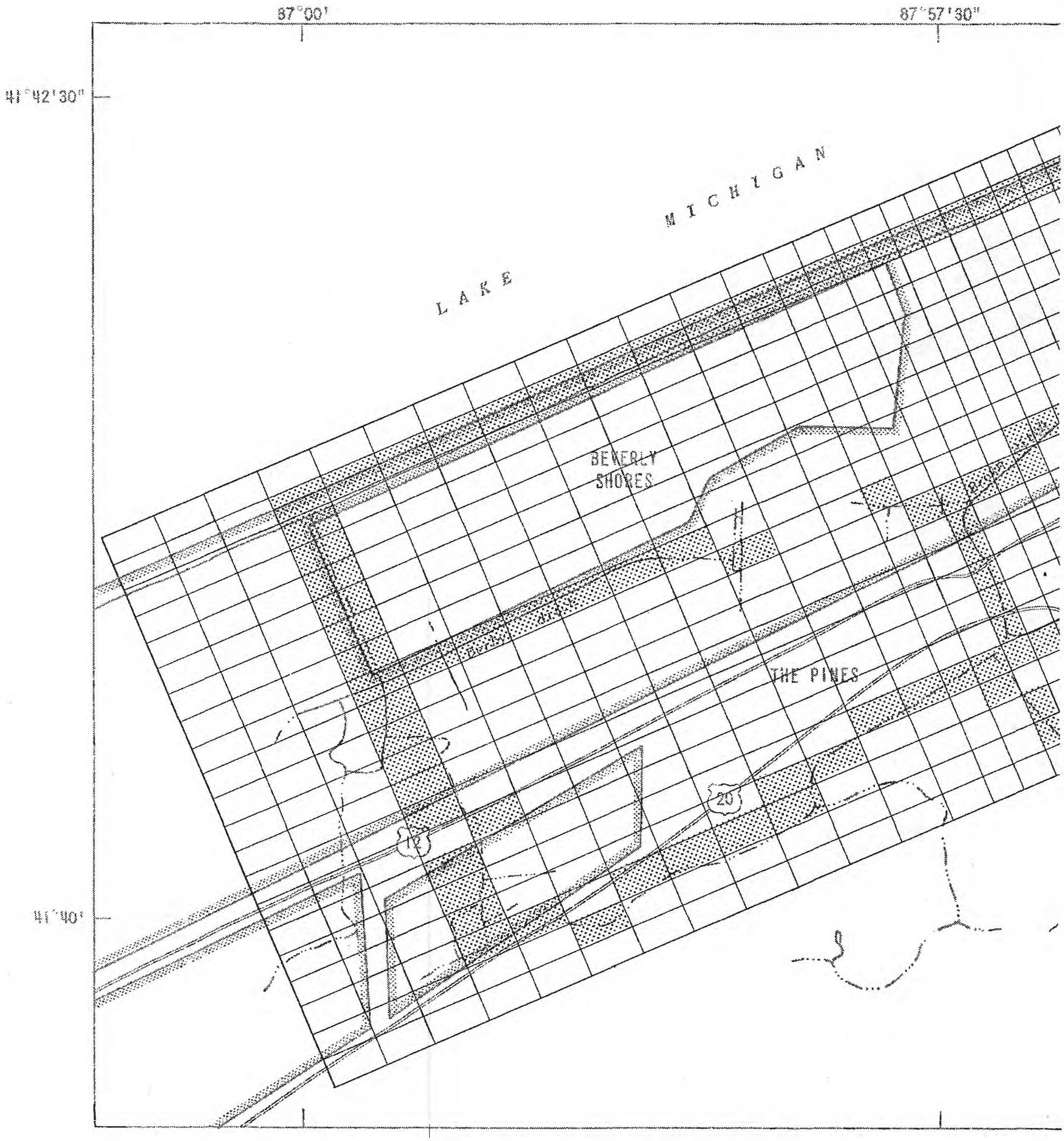
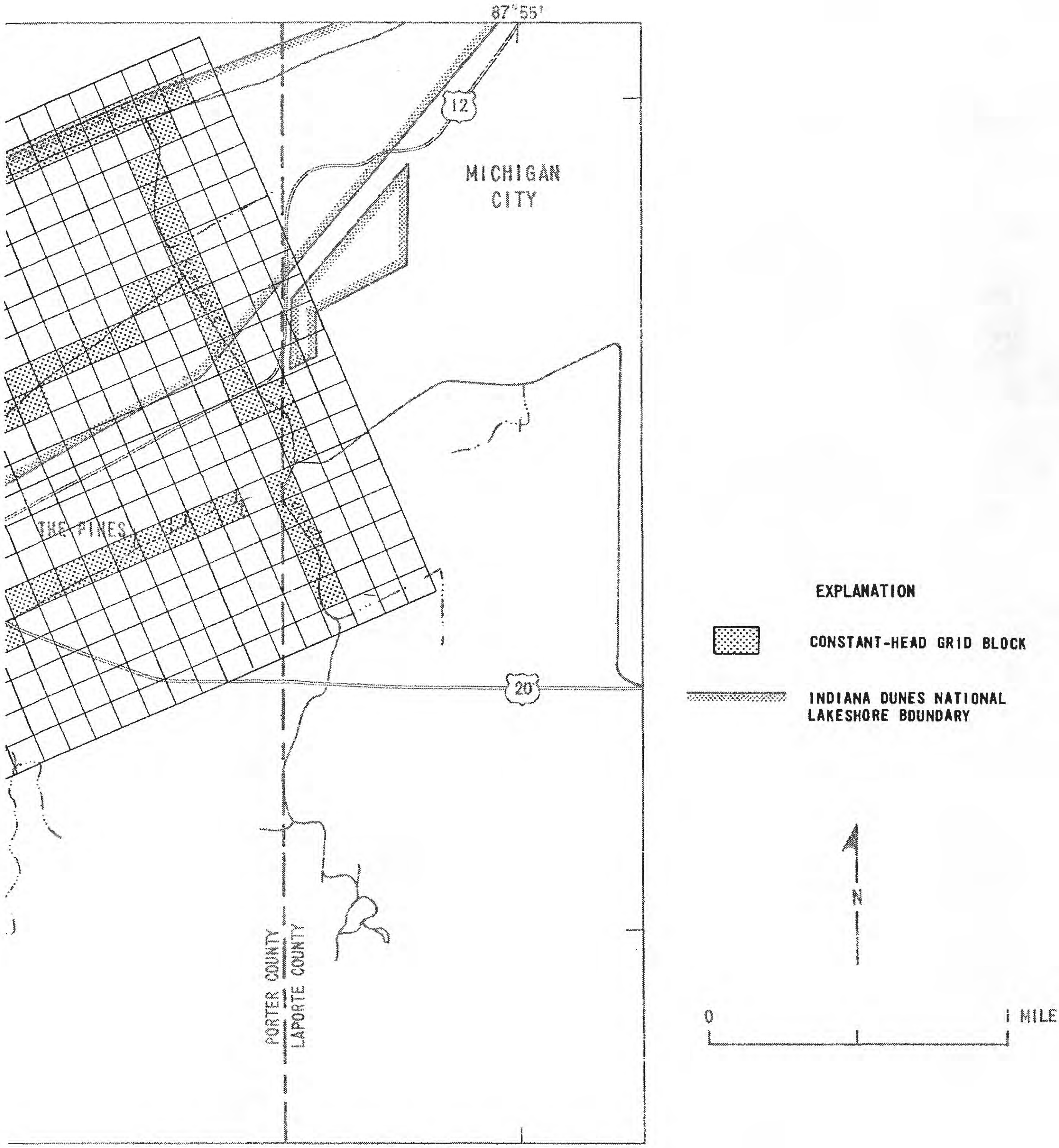


Figure 9.-- Finite-difference model grid for Brown, Kintzele, and Derby ditch basins.


87°55'
12
MICHIGAN
CITY
THE PINES
20
PORTER COUNTY
LAPORTE COUNTY
EXPLANATION
CONSTANT-HEAD GRID BLOCK
INDIANA DUNES NATIONAL
LAKESHORE BOUNDARY
N
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columns having respective lengths of 800, 600, and 600 ft separates the 500 ft long grid blocks from those that are 1,000 ft long. No changes in the Derby ditch basin were simulated but this basin was included in the model because of the possibility of future study there.

The south, east, and west borders of the model were simulated as no-flow boundaries by assigning a hydraulic conductivity of zero to the exterior grid blocks. The north border of the model, representing Lake Michigan, was simulated as a constant-head boundary by assigning all grid blocks in the first interior row a constant head of 580 ft above sea level, the approximate mean level of the lake.

The hydraulic conductivity assigned to all interior grid blocks was 50 ft/d, an average estimated from specific capacity tests in 18 wells in the surficial aquifer at the lakeshore. A variable matrix of the bottom altitude of the aquifer, based on data from several test-holes in the area, was used in the model. As a result, the saturated thickness in the model varied as a function of the bottom altitude and the boundary component of the water-table head.

Grid blocks crossed by ditches were assigned constant heads estimated from points on the measured profile (fig. 4) in the Brown ditch basin or from the topographic map for the Derby and upper Kintzele ditch basins.

The boundary component of head was obtained by allowing the model to solve for heads in the aquifer with the constant-head grid blocks as the only sources and sinks. The resulting computed array of heads was used as the initial head array in the model experiments. In this manner, the model-generated map for the difference between initial and computed heads represents changes in the boundary component that are equivalent to water-table declines caused by simulated changes in the stage of the ditch.

Model Experiments

The National Park Service asked the Geological Survey to simulate steady-state water-table declines for two hypothetical reconstructions of Brown ditch: (1) dredging to clean debris and eliminate high points to form uniformly graded streambed and stage profiles in a reach from a point 200 ft within the lakeshore to point 2 (fig. 4) in the upstream east arm south of The Pines and (2) dredging both in the lakeshore as originally planned by the county drainage board and upstream of the lakeshore as described above.

For the first experiment, a streambed profile was synthesized (fig. 10) by drawing a straight line on the existing profile between the streambed at point 2 and the streambed at a point in the lakeshore 235 feet downstream from point 9. A stage profile was then synthesized by assuming the water surface to be 0.5 ft above the synthetic streambed profile.

The synthetic stage profile (fig. 11) was simulated in the model, and the corresponding water-table declines are shown in figure 12. The declines in The Pines range from less than 0.2 ft to 2.0 ft. The declines in the lakeshore from this simulation are less than 0.5 ft.

For the second experiment the ditch stage profile was synthesized in three segments (fig. 11). The upstream segment was virtually the same as the synthetic stage profile used in the first experiment upstream of point 8. Between point 8 and a point 10,000 ft downstream, the ditch stage was lowered 1.0 ft from the values used to simulate the real profile. From the latter point to the end of the profile the ditch stage was lowered 0.5 ft. The 1.0- and 0.5-ft increments were generalized from the difference between stage and streambed profiles in the plans of the Porter County Drainage Board.

The water-table declines for the second experiment are shown as solid contour lines in figure 13. For the sake of comparison, selected segments of the contours for the first experiment, where there was virtually no change in the ditch stage profile in the lakeshore, are shown as dotted contour lines. On the basis of the difference between these two sets of contour lines, the maximum additional water-table decline in The Pines that can be acheived by lowering the stage profile of Brown ditch in the lakeshore is estimated to be less than 0.5 ft. However, the simulated ditch stage profile in this model experiment could cause water-table declines of about 1.0 ft in the lakeshore between the north edge of The Pines and Brown ditch.

SUMMARY

Profiles of the Brown ditch system at the east end of Indiana Dunes National Lakeshore and in the adjacent town, The Pines, show that the slope of the streambed of the ditch in the lakeshore was six times that of the upstream east arm of the ditch south of The Pines before the latter was dredged in July 1983. The lakeshore reach of the ditch is incised into the sand aquifer, but in the upstream east arm the ditch was not cut below the organic layer of the surrounding wetland before the dredging. The channel in the lakeshore contains vegetation and fallen trees but seems to be conveying all the base flow that it receives and has ample cross-sectional area to convey greater flows. In contrast, before the dredging the channel was not as deep and well defined in the upstream east arm where, in some sections, water was ponded and flow was sluggish.

Ground-water flow in the surficial aquifer is toward the ditches from water-table mounds of low relief beneath the dune ridges. The water table near the eastward flowing section of the ditch in the lakeshore was more than 10 ft lower than the water-table divide in The Pines in August 1982. No relation between the condition of the ditch in the lakeshore and the apparent high water-table conditions in The Pines is suggested by the ground-water flow pattern or the water-table gradient between The Pines and the lakeshore.

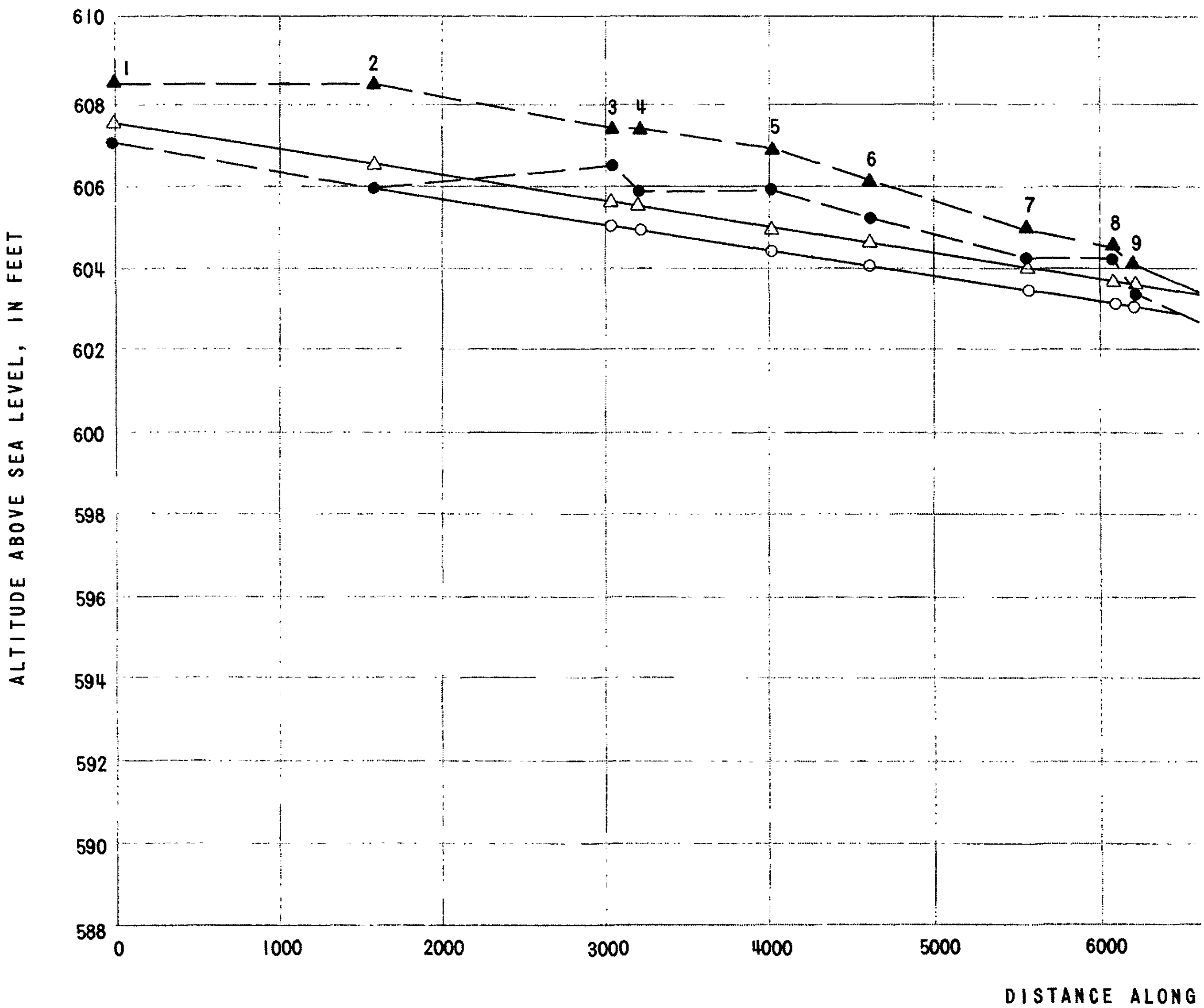
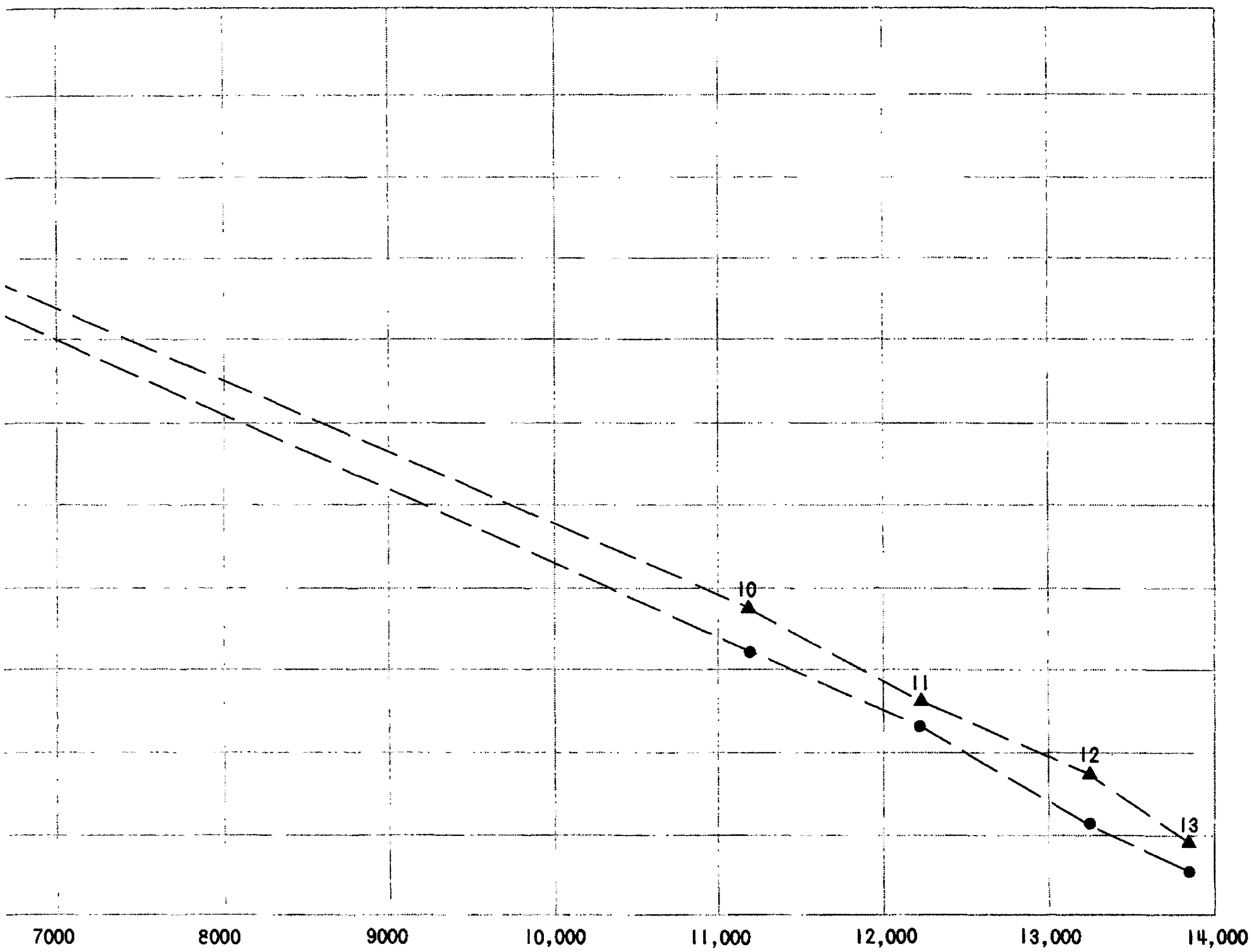


Figure 10.-- Actual and synthetic profiles of stage and streambed altitudes in part of the Brown ditch system.



CHANNEL, IN FEET

EXPLANATION

STAGE PROFILE OF BROWN DITCH--August 25 to 26, 1982

STREAMBED PROFILE OF BROWN DITCH--August 25 to 26, 1982

SYNTHETIC STAGE PROFILE-- Resulting from hypothetical dredging of upstream east arm of Brown ditch

SYNTHETIC STREAMBED PROFILE-- Resulting from hypothetical dredging of upstream east arm of Brown ditch

2 DESIGNATION

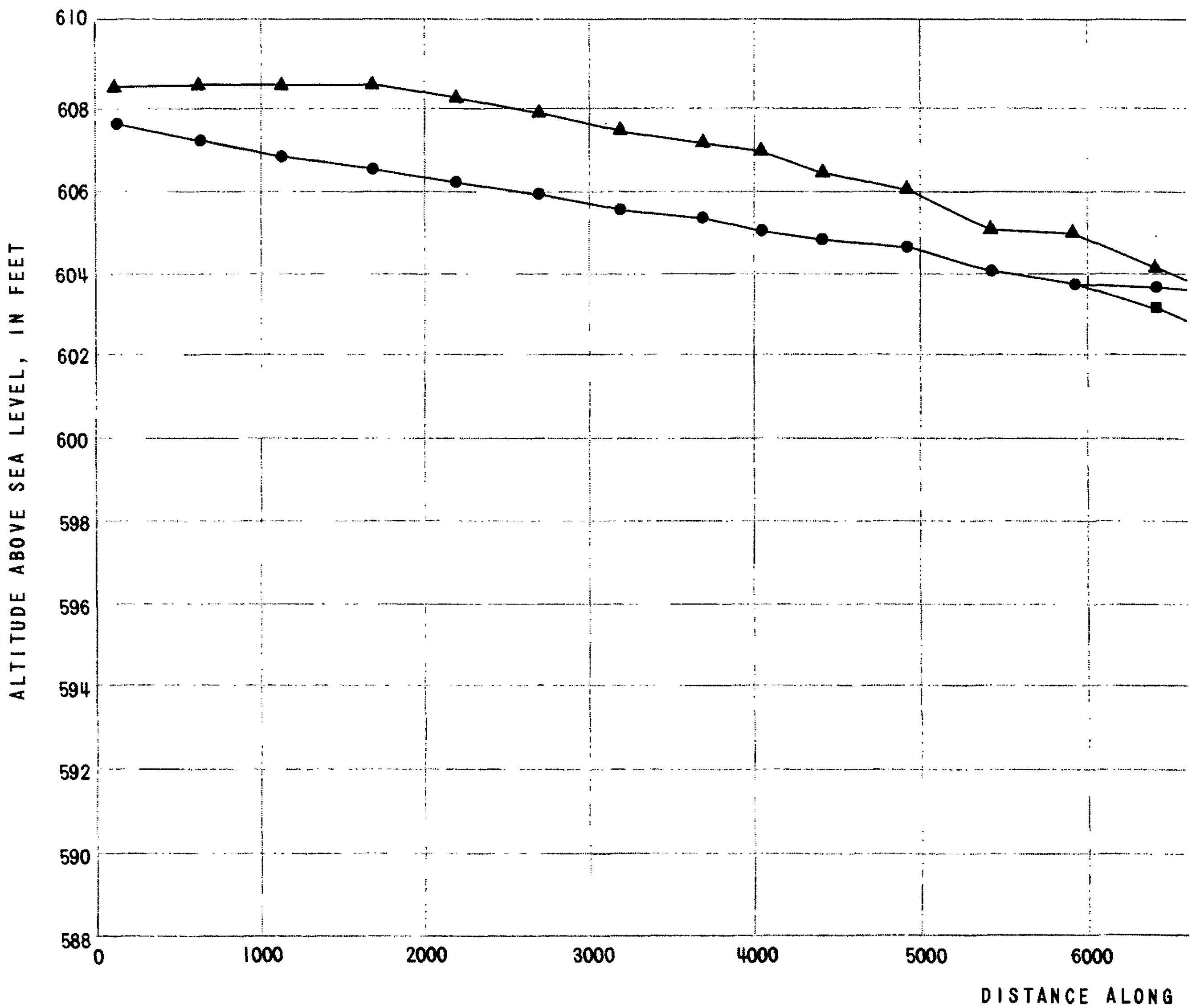
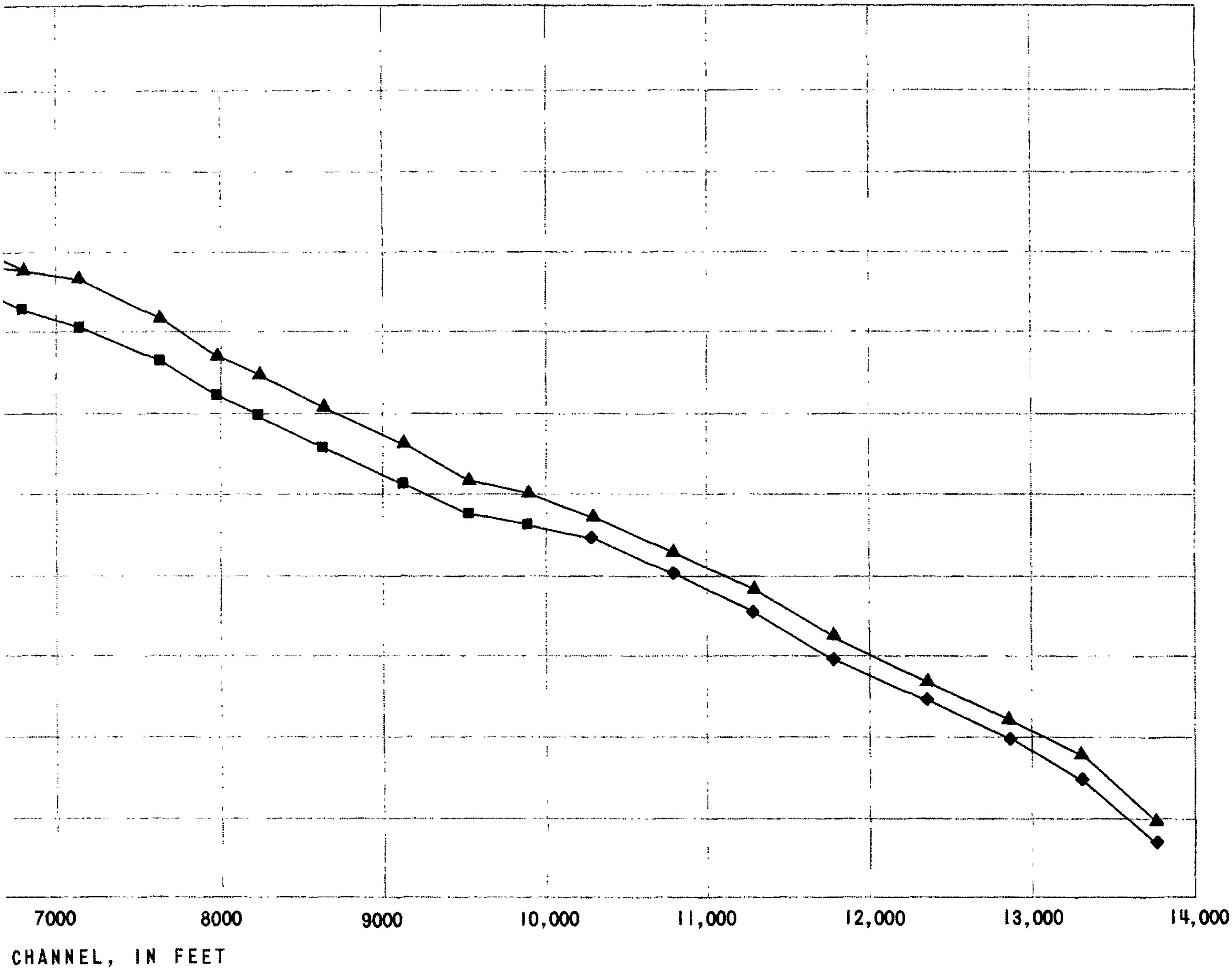


Figure 11.-- Simulated Brown ditch stage profiles in boundary-component computation and model experiments.



EXPLANATION

SIMULATED DITCH STAGES

- ▲ Used to compute boundary component of water-table head
- ● From profile synthesized for hypothetical dredging and cleaning of Brown ditch between points 2 and 9 in figure 5; used in first and second model experiments
- ■ Lowered 1 foot from corresponding value used in boundary-component simulation; used in second model experiment
- ◆ Lowered 0.5 foot from corresponding value used in boundary-component simulation; used in second model experiment

STAGE PROFILES

- ▲—▲—▲ Boundary component computation
- ●—▲—▲ First model experiment
- ●—■—◆ Second model experiment

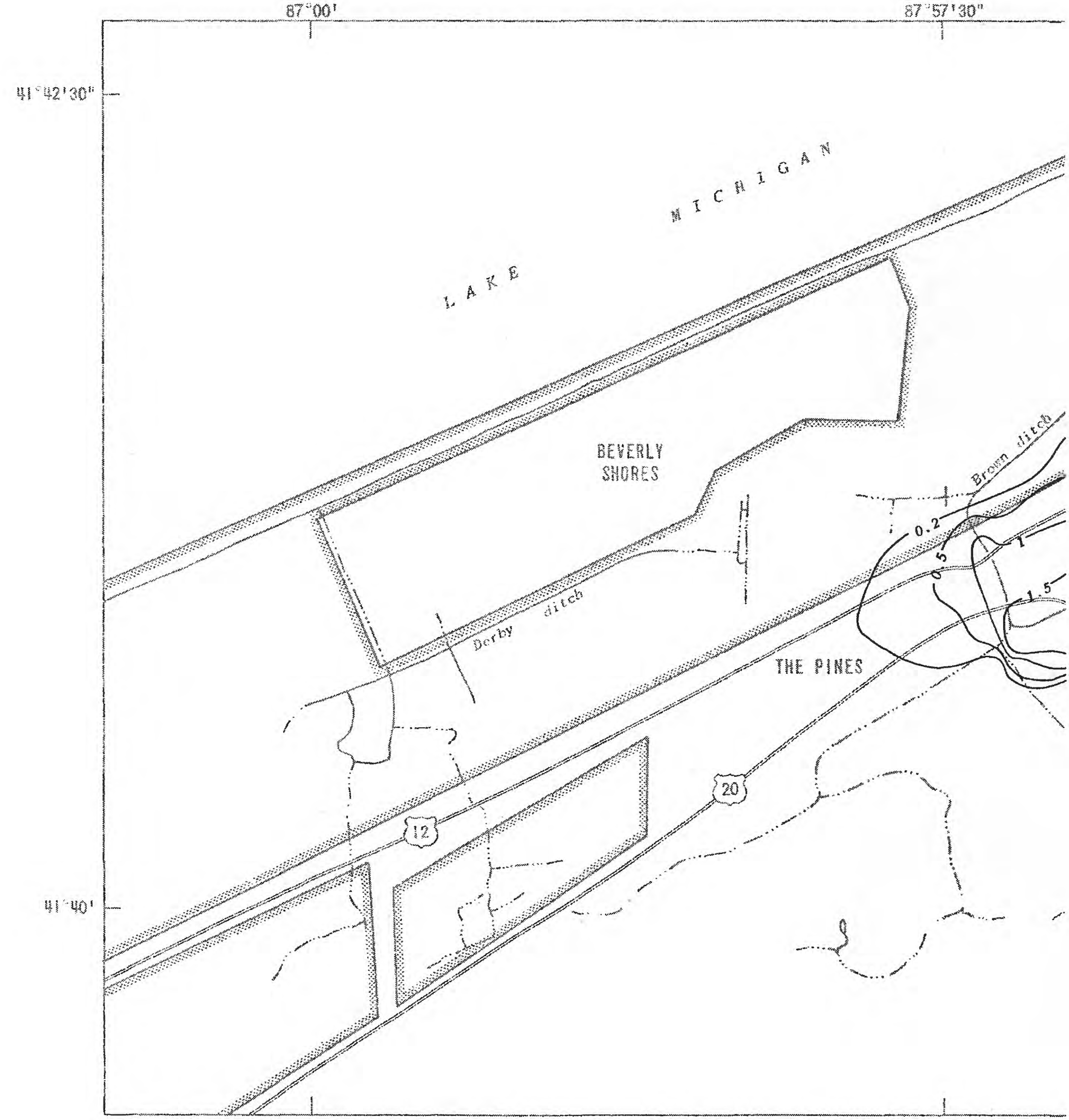
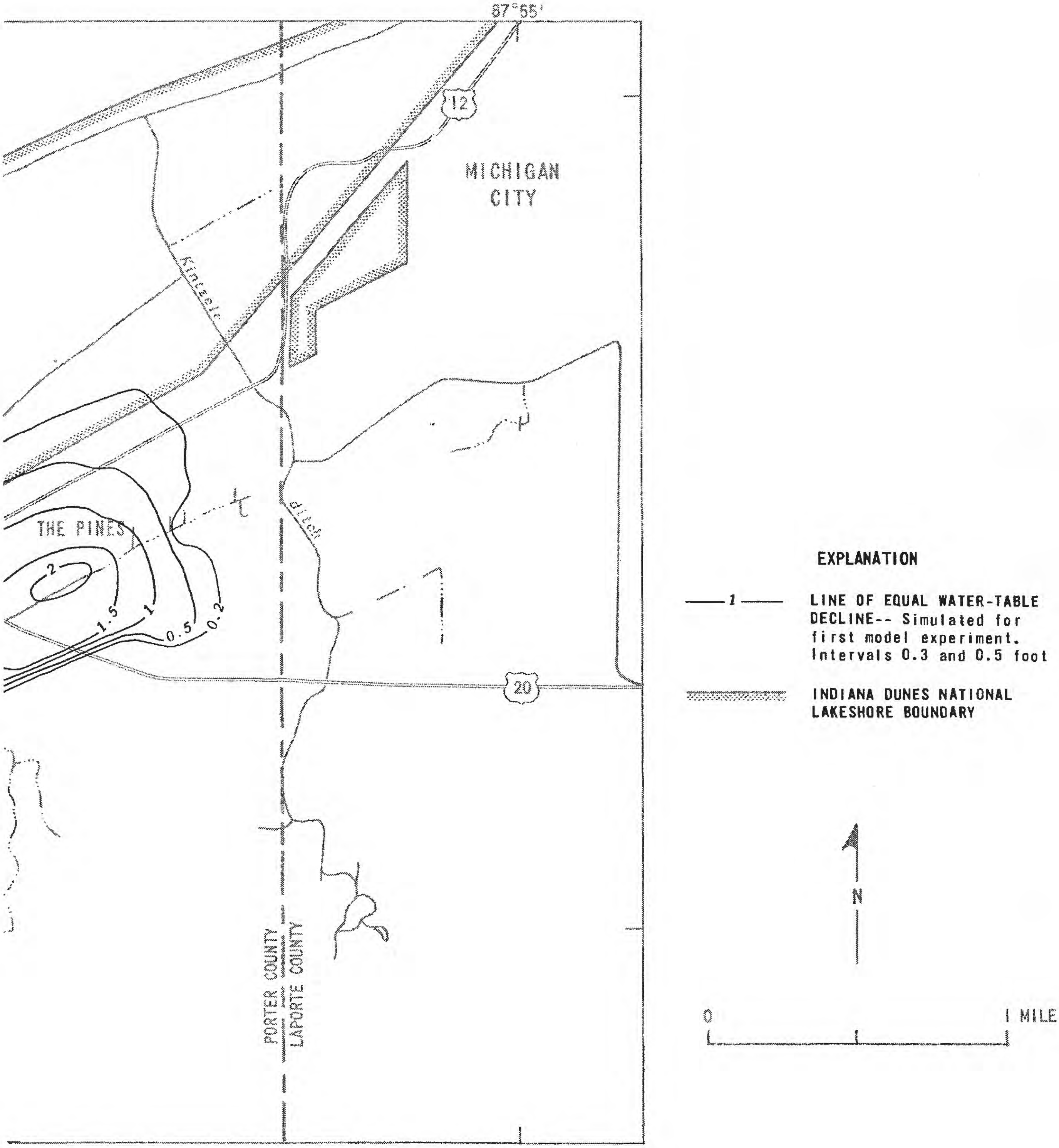


Figure 12.-- Simulated water-table decline for model experiment 1: hypothetical dredging of upstream east arm of Brown dítch.


87°55'
MICHIGAN CITY
12
Kintzele
Ditch
THE PINES
2
1.5
1
0.5
0.2
20
PORTER COUNTY
LAPORTE COUNTY
EXPLANATION
1
LINE OF EQUAL WATER-TABLE DECLINE-- Simulated for first model experiment. Intervals 0.3 and 0.5 foot
INDIANA DUNES NATIONAL LAKESHORE BOUNDARY
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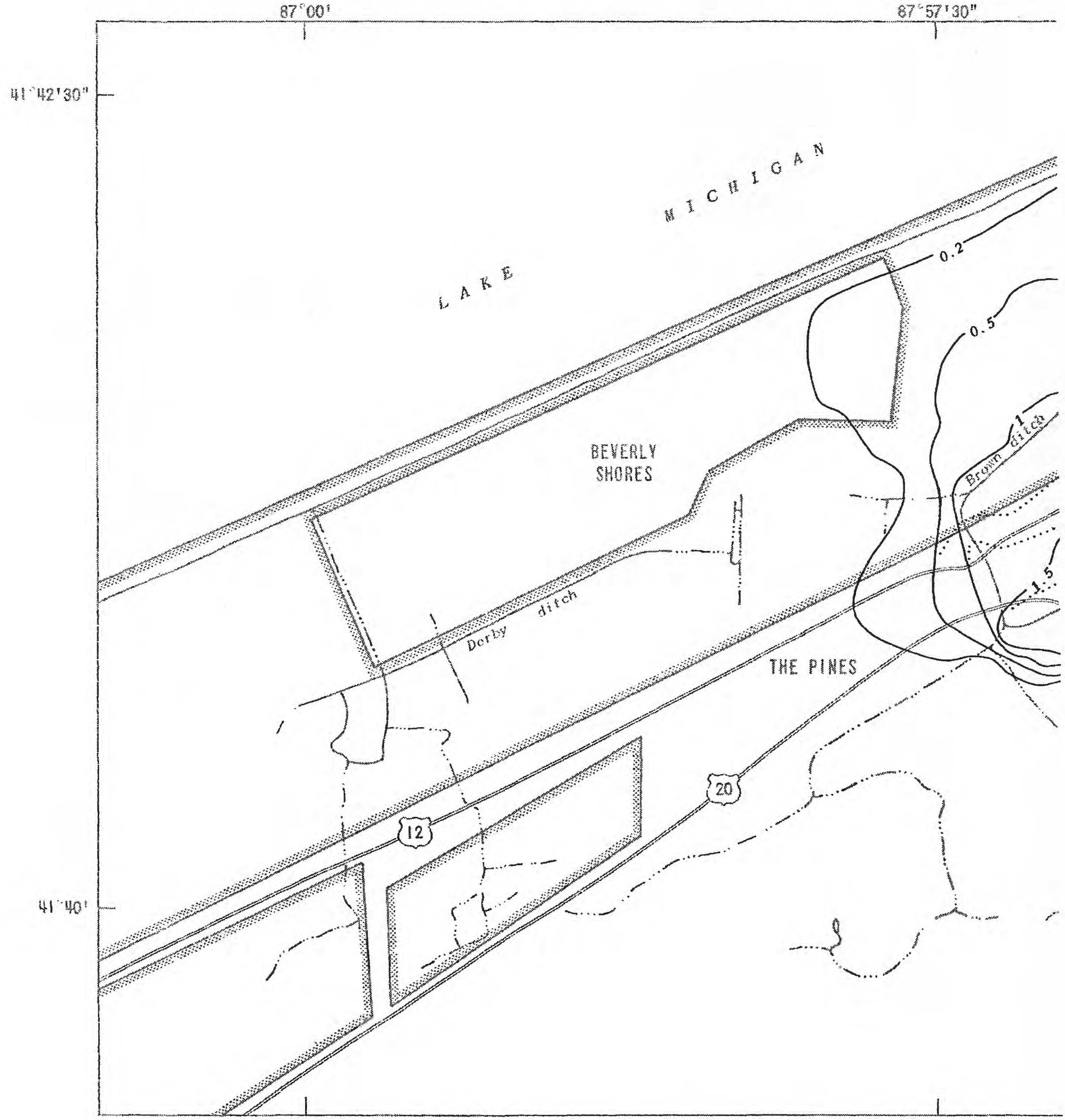
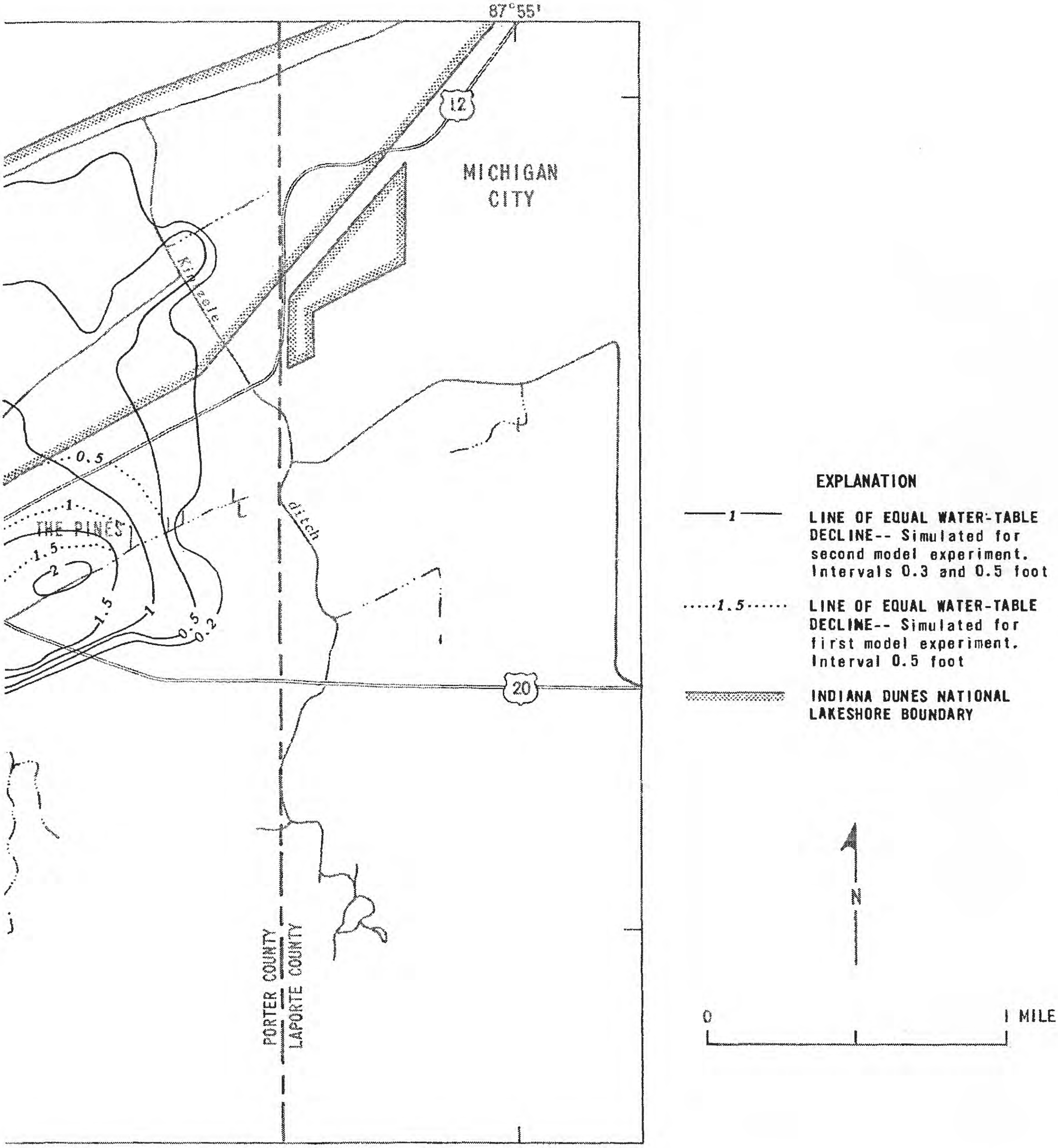


Figure 13.-- Simulated water-table decline for model experiment 2: hypothetical dredging of lakeshore reach and upstream east arm of Brown ditch.


87°55'
MICHIGAN CITY
12
20
THE PINES
Kintzele ditch
PORTER COUNTY
LAPORTE COUNTY
EXPLANATION
LINE OF EQUAL WATER-TABLE DECLINE-- Simulated for second model experiment. Intervals 0.3 and 0.5 foot
LINE OF EQUAL WATER-TABLE DECLINE-- Simulated for first model experiment. Interval 0.5 foot
INDIANA DUNES NATIONAL LAKESHORE BOUNDARY
N
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1 MILE

Water-table declines from hypothetical reconstructions of the ditch were estimated using a digital model to compute changes in the boundary component of the water-table head. Dredging to eliminate high points in the streambed and to form uniformly graded streambed and stage profiles in the upstream east arm of the ditch could lower the water table in The Pines 0.2 to 2.0 ft. Dredging to lower the ditch stage in the lakeshore by 0.5 to 1.0 ft would cause additional water-table decline of less than 0.5 ft in The Pines. However, dredging in both the lakeshore and in The Pines could lower the water table in parts of the lakeshore by nearly 1.0 ft.

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