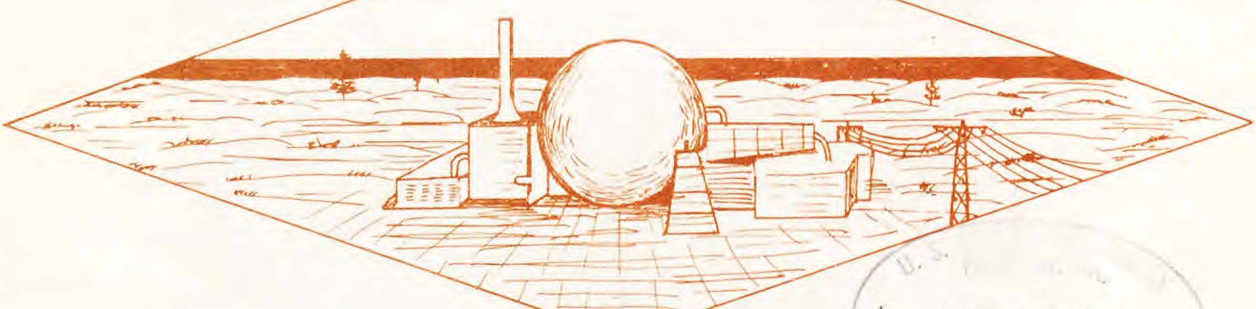
Model analysis of effects on water levels at Indiana Dunes National Lakeshore caused by construction dewatering

Prepared in cooperation with the
National Park Service



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July 1976

UNITED STATES DEPARTMENT OF THE INTERIOR

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CONTENTS

ILLUSTRATIONS

ILLUSTRATIONS--Continued

TABLE

FACTORS FOR CONVERTING ENGLISH UNITS TO INTERNATIONAL SYSTEM (SI) UNITS

Multiply English unit	By	To obtain SI unit
inches (in)	25.4	millimetres (mm)
feet (ft)	.3048	metres (m)
miles (mi)	1.609	kilometres (km)
acres	.4047	square hectometres (hm^2)
square miles (mi^2)	2.590	square kilometres (km^2)
cubic yards (yd^3)	.7646	cubic metres (m^3)
inches per year (in/yr)	25.4	millimetres per year (mm/yr)
hydraulic conductivity, feet per day (ft/d)	.3048	hydraulic conductivity, metres per day (m/d)

MODEL ANALYSIS OF EFFECTS ON WATER LEVELS AT INDIANA DUNES NATIONAL LAKESHORE CAUSED BY CONSTRUCTION DEWATERING

By James R. Marie

ABSTRACT

Two computer models were developed to investigate possible hydrologic effects within the Indiana Dunes National Lakeshore caused by planned dewatering at the adjacent Bailly Nuclear Generator construction site. The dewatering, which is scheduled to last for about 18 months, would cause ground-water levels to be drawn down 20 to 30 feet (6 to 9 metres) to an elevation of 4 ft (1.2 m) below Lake Michigan datum under the approximately 7-acre (2.8-square hectometre) construction site, which is about 800 ft (245 m) west of the Lakeshore property. The results of this study have been used by the National Park Service to help evaluate the environmental impact of the dewatering, particularly the effects on the ecosystem of the lakeshore.

The aquifer underlying the area is about 50 ft (15 m) thick and is composed of fine sand with layers of medium sand and gravel. All natural ponds in the area are separated from the aquifer by a low-permeability layer of silty organic muck and clay that ranges from about 1 to 4 ft (0.3 to 1.2 m) in thickness. This pond-bottom material acts only to retard the flow of water either to or from the aquifer beneath the ponds, depending upon the relative head in the pond and the aquifer. Elsewhere, the aquifer is under water-table conditions.

The model analysis indicates that the planned dewatering would cause a drawdown of about 4 ft (1.2 m) under the westernmost pond of the Lakeshore and that this drawdown would cause the pond to go almost dry--less than 0.5 ft (0.15 m) of water remaining in about 1 percent of the pond--under average conditions during the 18-month dewatering period. When water levels are below average, as during late July and early August 1974, the pond would go dry in about 5 1/2 months. However, the pond may not have to go completely dry to damage the ecosystem. If the National Park Service's independent study determines the minimum pond level at which ecosystem damage would be minimized, the models developed in this study could be used to predict the hydrologic conditions necessary to maintain that level.

INTRODUCTION

In September 1974, the National Park Service asked the U.S. Geological Survey to investigate the possible effects on the hydrologic system in the Indiana Dunes National Lakeshore of planned dewatering at the NIPSCO's (Northern Indiana Public Service Company) Bailly Nuclear No. 1 construction site, which adjoins the National Lakeshore on the west (fig. 1). According to the plans of NIPSCO, ground-water levels would be lowered to and held at an elevation of 4 ft (1.2 m) below the Lake Michigan datum of 578.5 ft (176.3 m) above mean sea level for about 18 months during the early stage of construction. There was some general concern that the dewatering, if it occurs, might cause adverse effects on the environment of the Lakeshore, particularly on the ecosystem.

The purpose of this report is to present the results of the investigation, which included (1) monitoring and documenting ground-water levels and interdunal pond-water levels before and during construction at Bailly Nuclear No. 1 and (2) developing a model of the area that could be used to indicate hydrologic response to the planned dewatering.

On September 16, 1974, a meeting was held at the Lakeshore headquarters among representatives of the National Park Service, NIPSCO, and the Geological Survey to discuss the planned dewatering. NIPSCO had made an intensive study of the Bailly site and furnished the Geological Survey with geologic logs of test borings, geologic sections of the property, grain-size analyses, and ground-water and pond levels. The company also provided access to the Bailly site and allowed test borings and observation wells to be completed on their property. Without this generous cooperation, the study could not have been completed.

Other hydrologic data available for the area are contained mainly in reports by Rosenshein (1962) and Rosenshein and Hunn (1968).

This report describes the pond- and ground-water level monitoring, presents the data used and assumptions made to simulate the hydrologic system, and discusses the results of the simulations.

HYDROGEOLOGIC SETTING

The Bailly site is underlain by Pleistocene and Holocene sediments (fig. 2) that average 180 ft (55 m) in thickness. The upper 50 ft (15 m), which is the aquifer, is composed primarily of gray to tan fine sand but contains zones of medium sand and gravel (fig. 3). The lower 130 ft (40 m) is primarily a silty clay but contains interspersed, thin beds of silty sand. Throughout the study area, these sediments are underlain by the Antrim shale of Devonian Age (Schneider and Keller, 1970).

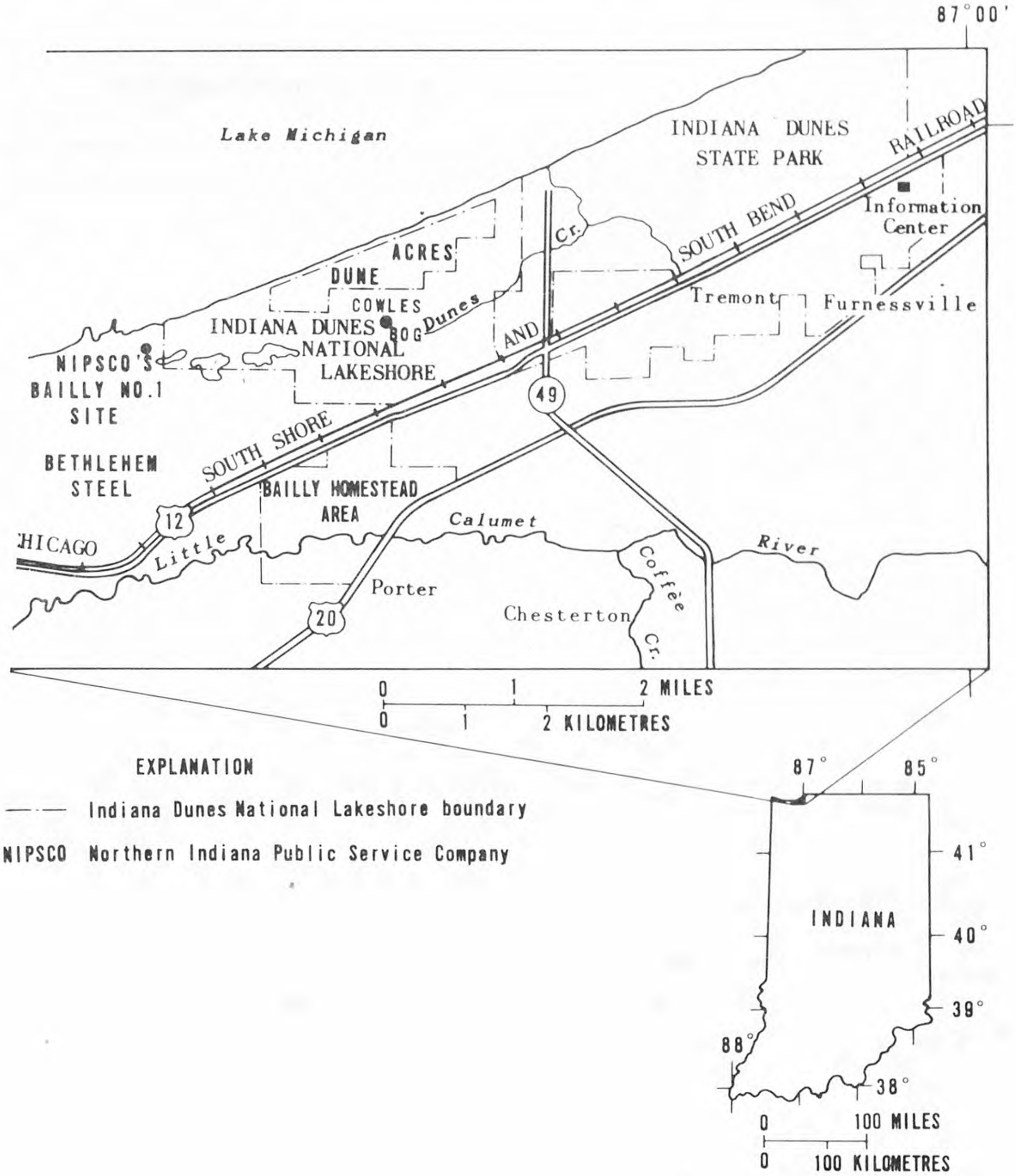
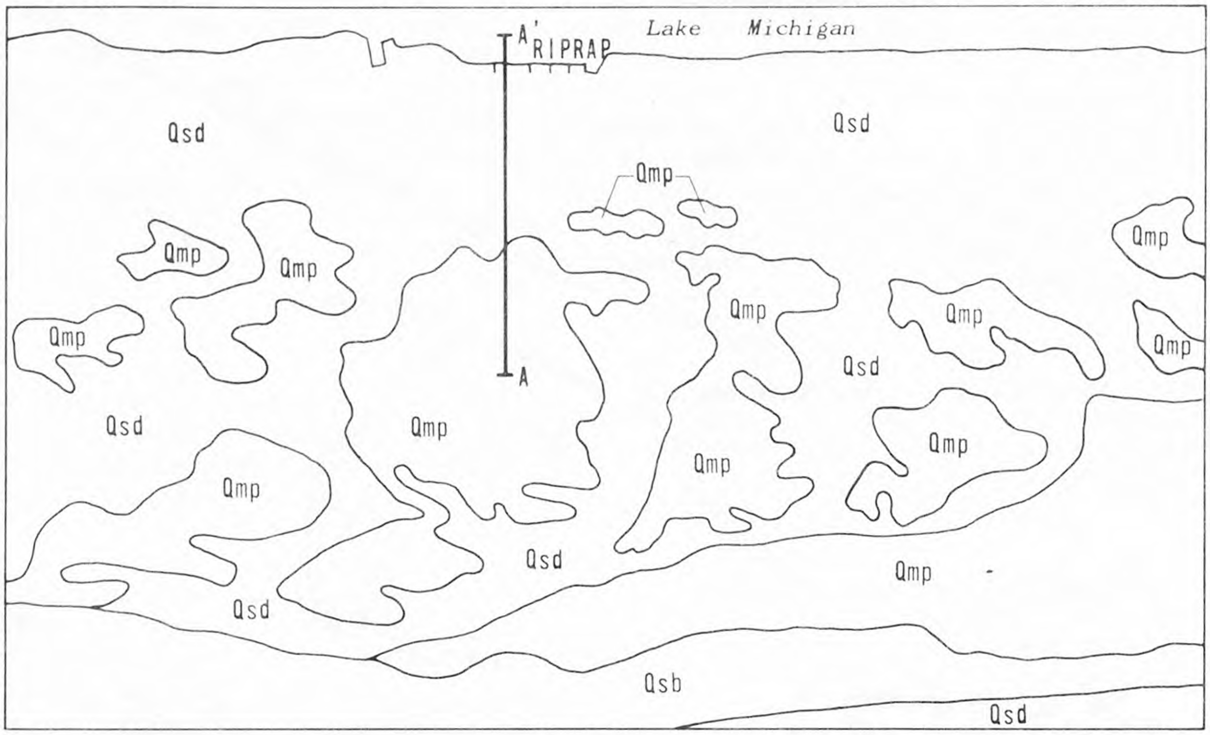


Figure 1.-- Location of the study area.



(Geology modified from Schneider and Keller, 1970.)

EXPLANATION

Holocene	Qmp	Muck, peat and marl
Pleistocene and Holocene	Qsd	Dune deposits, sand and some fine gravel
	Qsb	Beach and shoreline deposits, sand and gravel

N

0 1000 2000 FEET

0 300 600 METRES

A ____ A' Line of geologic section shown on figure 3

Figure 2.--Surfical geology of the study area.

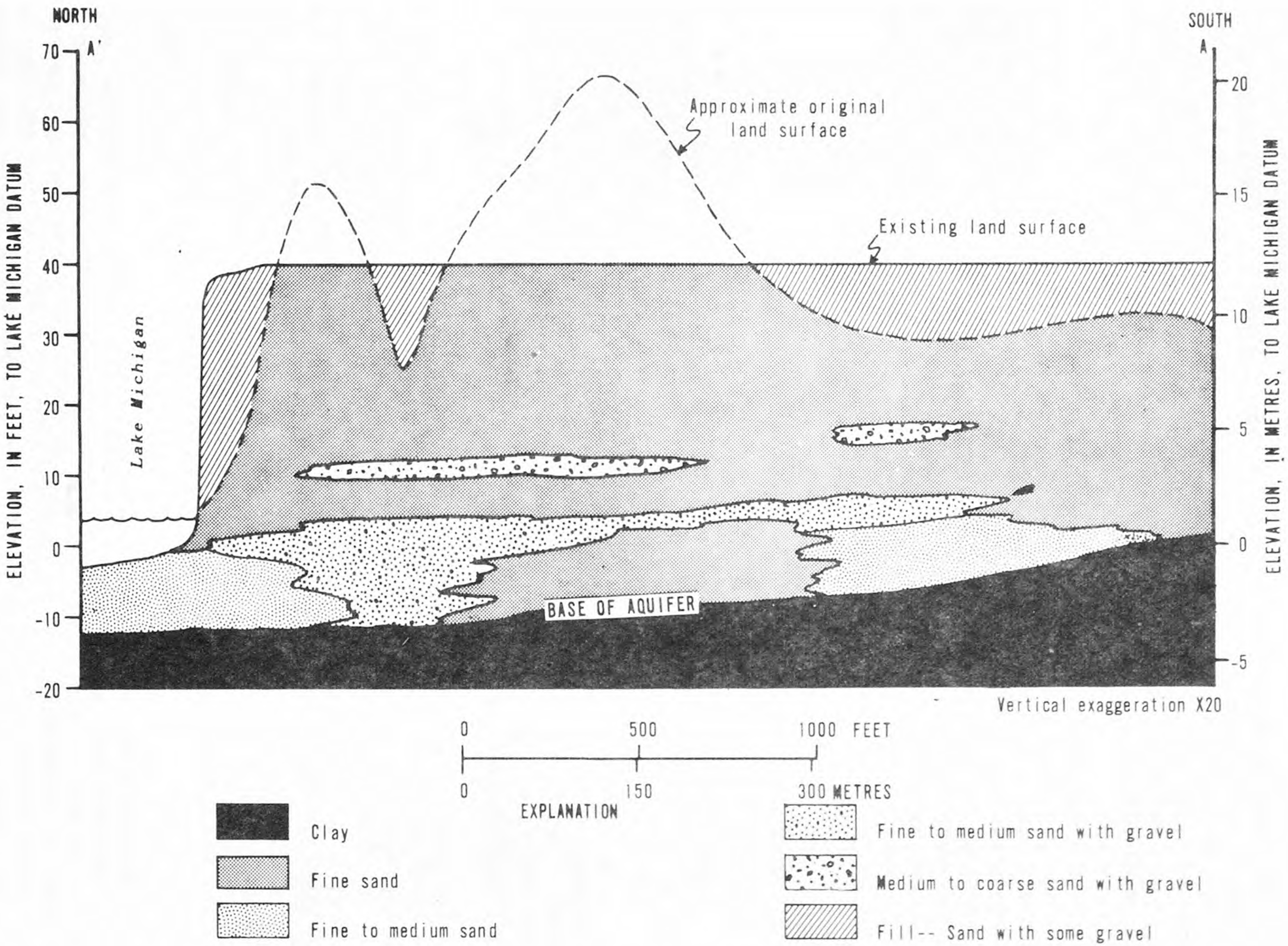


Figure 3.-- Idealized geologic section of the construction site.

All natural ponds are separated from the aquifer by a low-permeability layer of silty organic muck and clay that ranges from about 1 to 4 ft (0.3 to 1.2 m) in thickness. This pond-bottom material acts only to retard the flow of water either to or from the aquifer beneath the ponds, depending upon the relative heads in the pond and the aquifer. Elsewhere, the aquifer is under water-table conditions.

Under natural conditions, all water flowing through the hydrologic system originates as precipitation. The average annual precipitation on the study area is 37 in or 940 mm (National Oceanic and Atmospheric Administration, 1974). Of this amount, an average of 9.2 in (234 mm) is estimated to infiltrate into the ground-water reservoir. Water in the ground-water reservoir generally moves to the north-northwest toward Lake Michigan and eventually discharges into the lake. This natural flow system is in dynamic equilibrium.

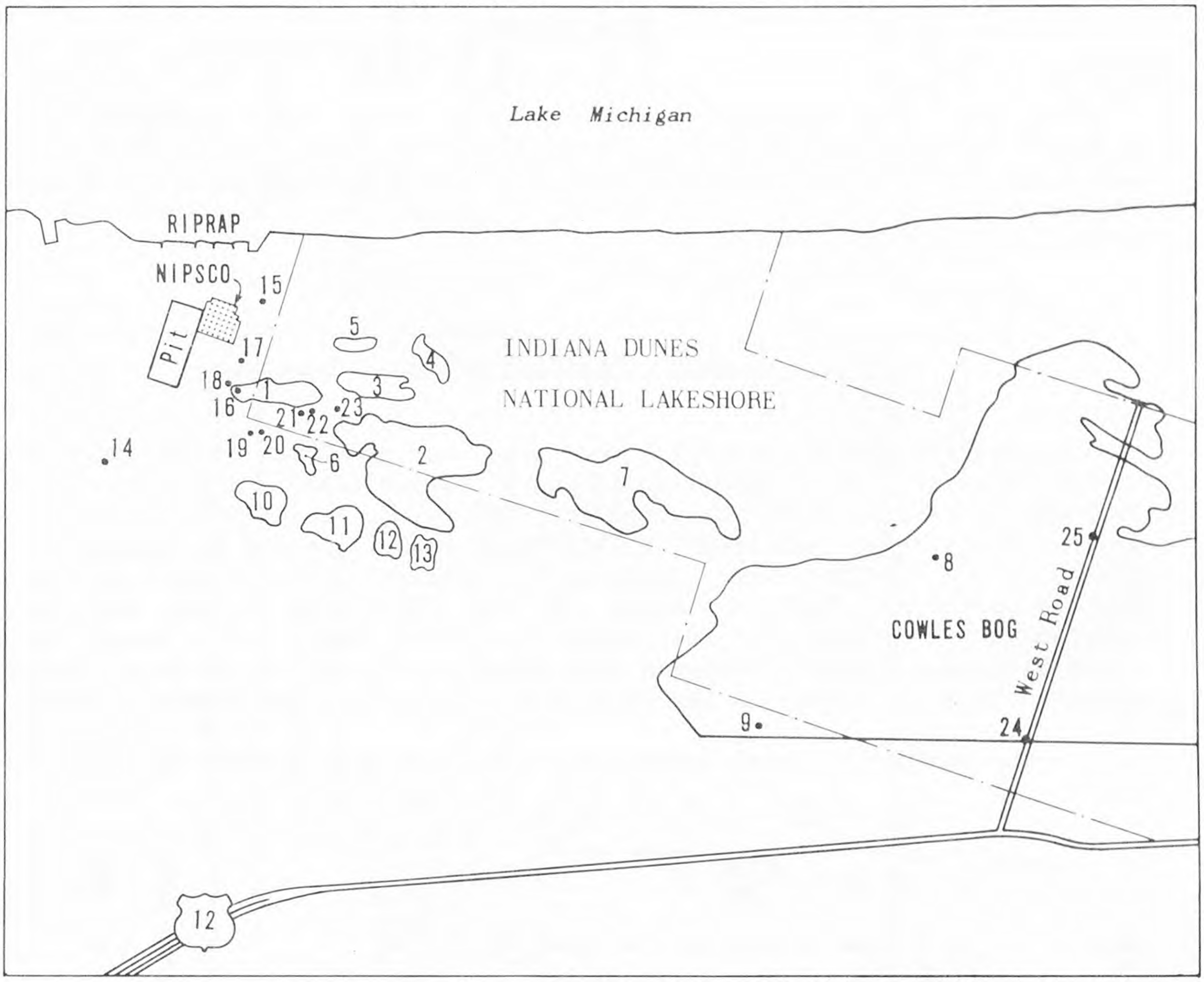
MONITORING PROGRAM IN THE AREA

In preparation for construction, NIPSCO began a monitoring program in March 1972 by recording water levels in interdunal ponds 1 and 2 and in ash pond 13 (fig. 4). In October and November 1973, the program was expanded to include monitoring interdunal ponds 3 through 7, ash ponds 10 through 12, site 9 in Cowles Bog, and observation wells 14, 15, 17, and 18. In March 1974, site 8 in Cowles Bog was added; in May 1974, observation well 16 was added. All sites are being monitored at the present time (June 1975). Daily precipitation records and Lake Michigan water levels are available for the period March 1972 to the present.

The Geological Survey installed two observation wells (19 and 20) and two staff gages in interdunal pond 2 in October 1974. The Survey's program was expanded in April and May 1975 to include observation wells 21 through 25. The Survey's monitoring program will continue until the construction dewatering is completed in order to provide data to verify the digital model developed through this study and to document water-level changes.

SIMULATION OF THE HYDROLOGIC SYSTEM BY DIGITAL MODEL

To determine the effects of dewatering at the Bailly construction site, a digital-computer model was developed for the hydrologic system in the area. This model incorporates all that is known about the geologic setting, the physical boundaries, the hydrologic characteristics of the aquifer, and the interrelations of the interdunal and ash ponds and the aquifer system. The next five sections describe the digital model and the physical conditions that control the hydrologic system during dewatering.



EXPLANATION

.14	Observation well and number
(3)	Pond and number
—·—	Indiana Dunes National Lakeshore Boundary
NIPSCO	Northern Indiana Public Service Company

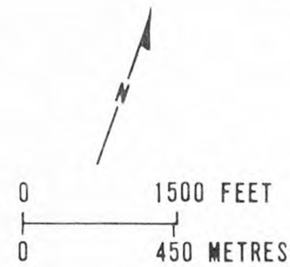


Figure 4.-- Location of monitoring sites.

Area Modeled

The area for which the ground-water flow was simulated is a 3.36-mi^2 (8.71-km^2) rectangle 12,500 ft (3,810 m) long, northeast-southwest and 7,500 ft (2,300 m) wide (fig. 5). The model configuration has 50 nodes on the long sides of the rectangle and 30 nodes on the others. All the nodes are 250 ft (76.2 m) on a side.

Model Characteristics

The aquifer system underlying the area was simulated by the two-dimensional, digital-computer model developed by Pinder (1970) and later revised by Trescott (1973) and P. C. Trescott and G. F. Pinder (written commun., 1975). Water-level declines in interdunal pond 1, caused by lowered water levels in the aquifer, were simulated by a digital-computer model developed by the author and Mark A. Ayers of the Geological Survey and later substantially revised by the author. This model is based on a Crank-Nicholson finite difference approximation of pond water-level decline provided by S. P. Larson of the Geological Survey (written commun., 1975).

In the pond model, pond water-level change is approximated by:

$$h_{t+\Delta t} = \frac{Nh_t - \left(\frac{K'\Delta t}{2M'}\right)\left(2\Sigma_1^N b_i - Nh_t\right)}{N\left[1 + \left(\frac{K'\Delta t}{2M'}\right)\right]}$$

where: $h_{t+\Delta t}$ = head in pond at new time, L

N = number of nodes in the pond

h_t = beginning head in pond, L

K' = hydraulic conductivity of pond-bottom material, LT^{-1}

Δt = increment of time, T

M' = thickness of pond-bottom material, L

b_i = head in aquifer below pond, L.

The time (Δt) required for a specific change in pond-water level is defined by:

$$\Delta t = \frac{N(2M')(h_{t+\Delta t} - h_t)}{K'[2\Sigma_1^N b_i - N(h_{t+\Delta t} + h_t)]}$$

These equations are incorporated in the computer program outlined by the flow chart shown on figure 6.

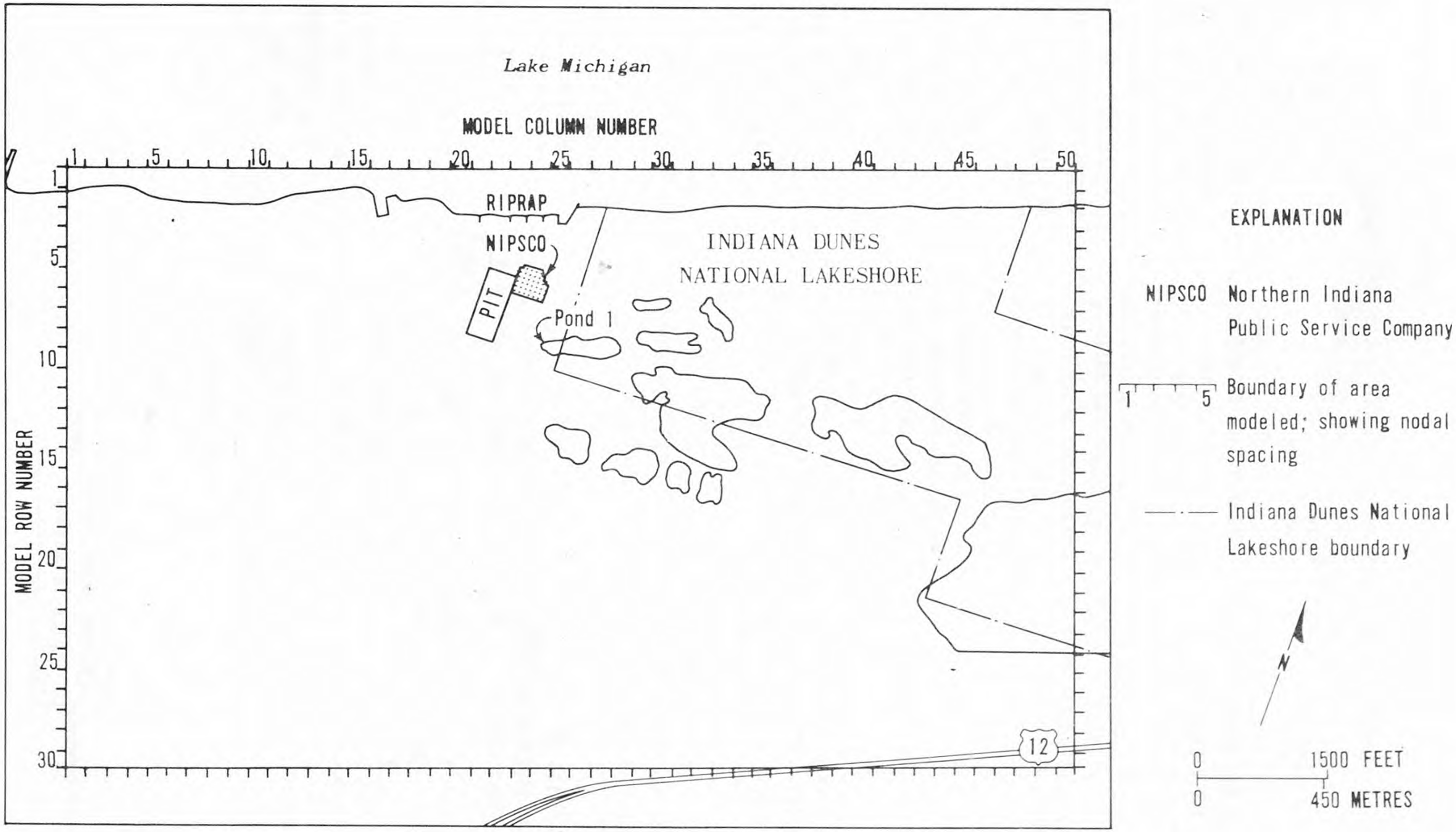


Figure 5.-- Area modeled

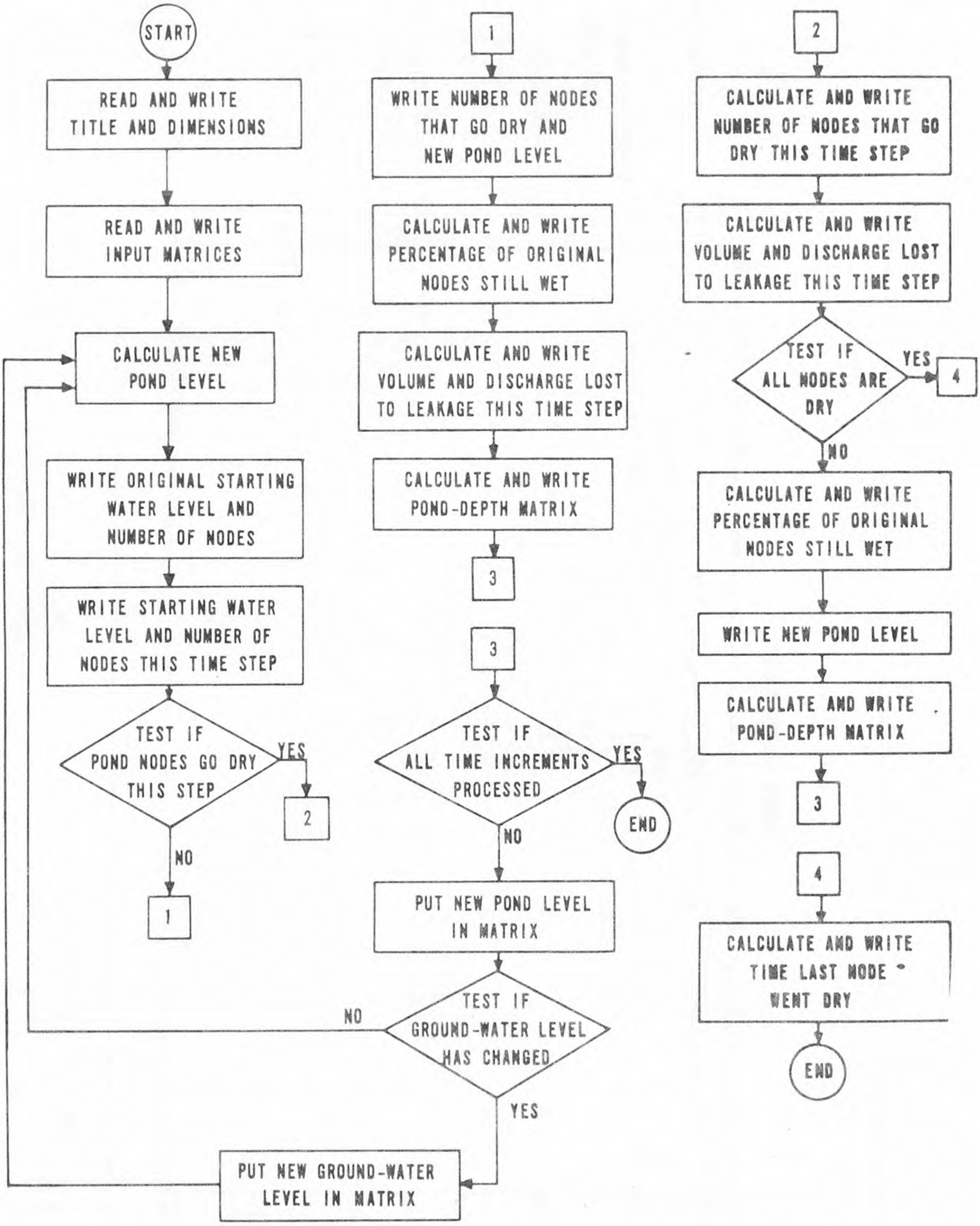


Figure 6.-- Flow chart for pond model.

Input data for the program are:

1. Starting water level in the pond, in feet above datum.
2. Area of each pond node, in square feet.
3. Number of pond nodes at starting water level.
4. Thickness of pond-bottom impeding zone, in feet.
5. Hydraulic conductivity of impeding zone, in feet per second.
6. Time increments specified for solution of pond-level decline, in seconds.
7. A matrix defining pond nodes.
8. A matrix defining pond-bottom elevation, in feet above datum.
9. A matrix defining ground-water level at each node, in feet above datum. A separate matrix is required for each time-step for which the ground-water level is changed.

Output from the program consists of the following information:

1. Original starting water level in the pond, in feet above datum.
2. Original number of pond nodes.
3. Starting water level in pond, in feet above datum, and number of pond nodes for each time-step during simulation.
4. Water level in pond, in feet above datum, at end of each time-step.
5. Areas of pond (model nodes) that went dry during each time-step.
6. Percentage of original pond area containing water at end of each step.
7. Volume of water, in cubic feet, and average discharge, in cubic feet per second, change during each time-step.
8. Pond depth map, in feet per node, for each time-step.
9. Time, in days, pond went dry, if applicable.

Hydraulic Coefficients and Boundary Conditions

In setting up the model of the aquifer, the hydraulic conductivity used was based on geologic data provided by NIPSCO and on data contained in reports by Rosenshein (1962) and Rosenshein and Hunn (1968). The distribution of hydraulic conductivity varies along each column, as shown on figure 7, but is constant along each row. This distribution is valid within the construction site and, because of lack of data, was assumed to extend without change through the modeled area. Specific-yield and storage-coefficient values used are discussed in a later section (Transient Conditions Modeled) of this report.

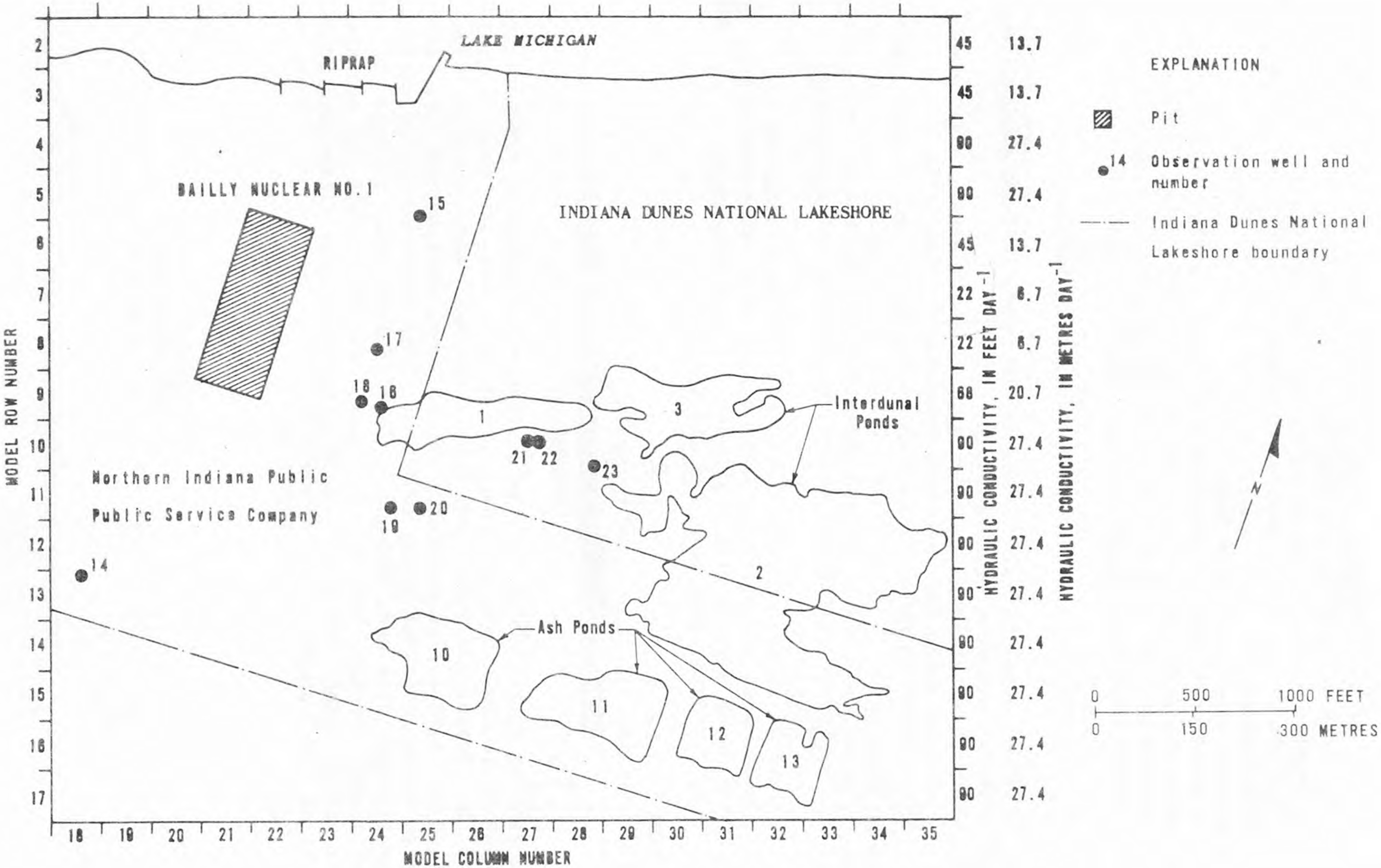


Figure 7.-- The central 0.65 mi^2 (1.7 km^2) of the area modeled.

The lateral boundaries of the model were treated in two ways. The boundary defined by Lake Michigan was modeled as a constant-head boundary, with the head at the level observed for Lake Michigan. The lake level can be varied in the model to correspond to any level that may be observed during actual dewatering. The other boundaries of the model area were treated as impermeable (no flow across the boundary in either direction) and were established at an arbitrary distance far enough from the site that drawdown at the boundary would be insignificant--in most cases less than 0.3 ft (0.09 m).

The model used is two-dimensional (all flow is in the horizontal plane with no vertical flow components). This assumption was made because there is only one aquifer at the dewatering site. Further, all water-level data provided by NIPSCO and used to calibrate the model were observed in wells having screens longer than half the saturated thickness of the aquifer and, consequently, represent the integrated head in the aquifer at that site. No reliable data are available on the hydraulic characteristics of the thick silty clay unit that underlies the aquifer throughout the area, and it was assumed that no water leaks through or from this unit.

The bottom of the aquifer at the site was defined by borings furnished by NIPSCO. The configuration of the bottom of the aquifer, as modeled, is shown on figure 8.

Figure 8 also shows the ground-water and Lake Michigan levels observed on February 5, 1974. These levels were used as one set of input conditions for the model discussed in the next section of the report.

Vertical hydraulic conductivity for the silty organic muck and clay layer observed in the bottom of each interdunal pond was estimated to be:

$$8 \times 10^{-3} \text{ ft/d } (2.4 \times 10^{-3} \text{ m/d})$$

This value was derived using (1) the physical characteristics of the muck layer, (2) an analytical solution for pond draining provided by S. P. Larson of the Geological Survey (written commun., 1975), and (3) NIPSCO's ground-water and pond-level data. The estimate is also based on the assumption that the bottom material of the pond has a uniform thickness of 1 ft (0.3 m). The derived value was applied to all interdunal and ash-pond nodes for the central part of the aquifer model shown on figure 9. This value was also used at all nodes in the pond model depicted on figure 10.

The configuration of pond 1 used in the pond model is based on data obtained from pond 1 on January 20, 1975, when the pond was frozen. (See fig. 10.) The top of the ice cover was at elevation 26.0 ft (7.92 m) above Lake Michigan datum. Pond depths were measured through holes cut in the ice; pond bottom-material samples and thicknesses were obtained with an auger. The silty organic muck, which makes up the pond bottoms, was observed at every sampling point in and around all the ponds. The shoreline of pond 1 was estimated from traverses plotted on a base map.

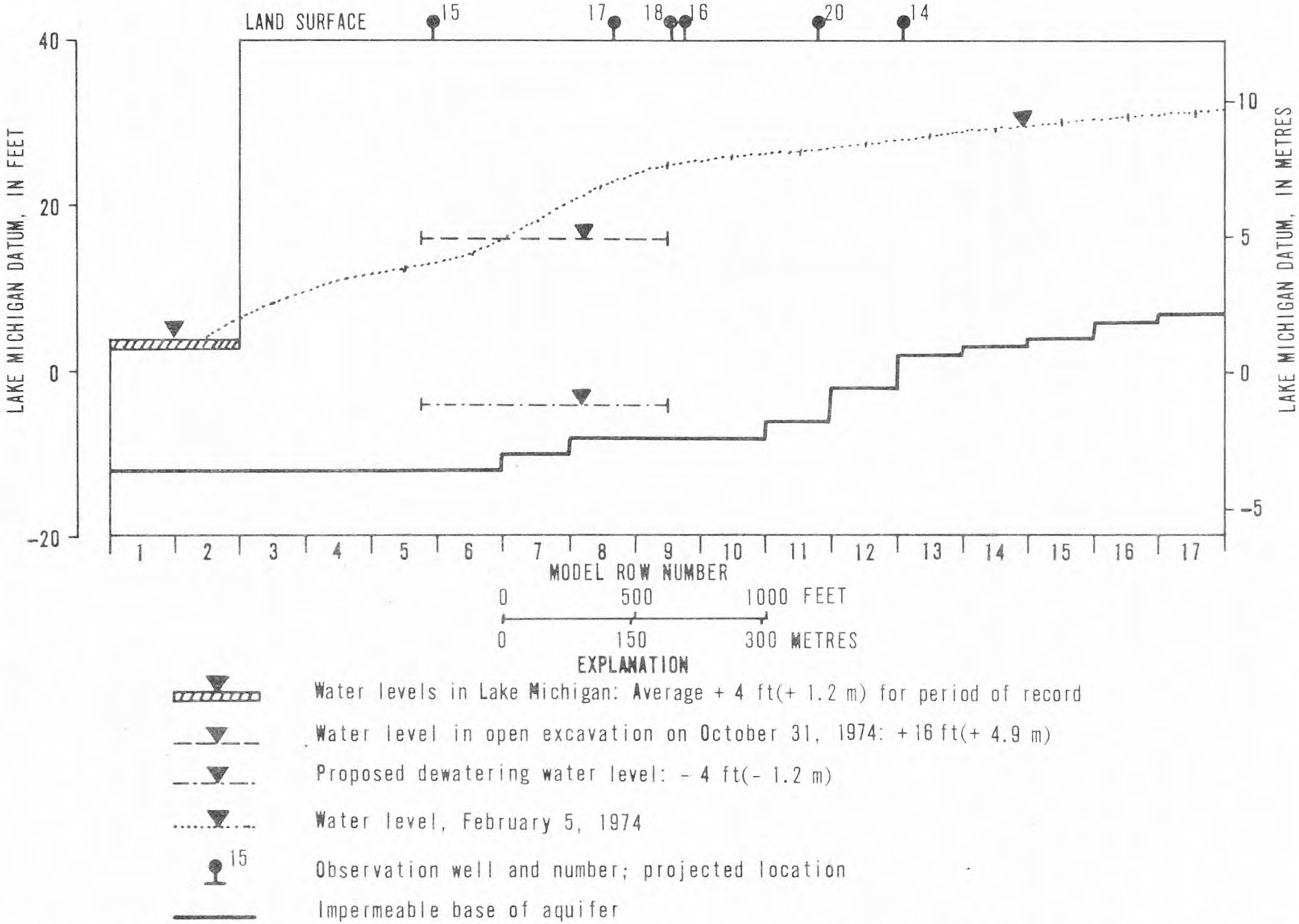


Figure 8.-- Section along column 22 of the model showing modeled conditions and configuration.

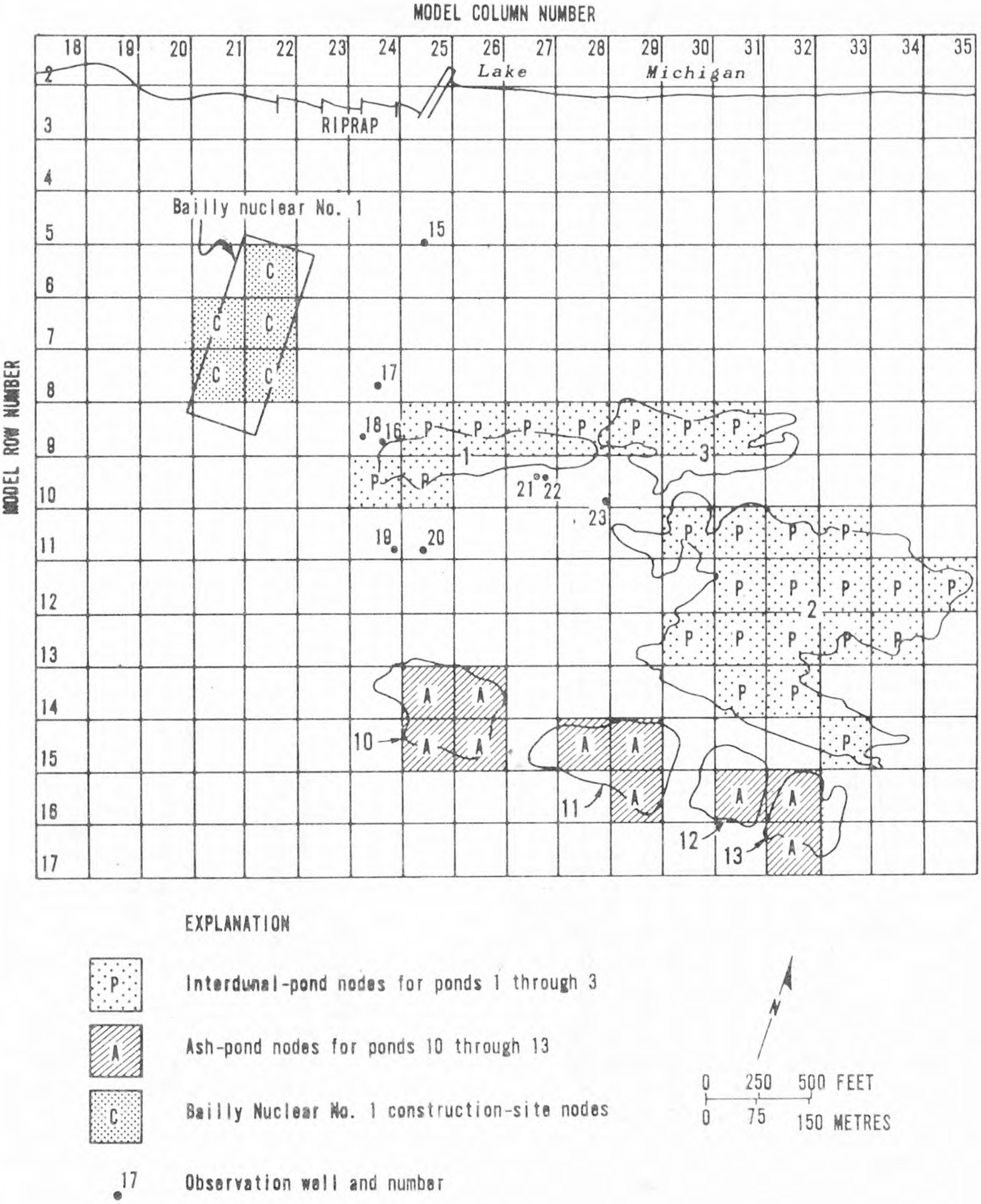


Figure 9.-- Construction-site, interdunal-pond, and ash-pond nodes within the central 0.65 mi^2 (1.7 km^2) of the area modeled.

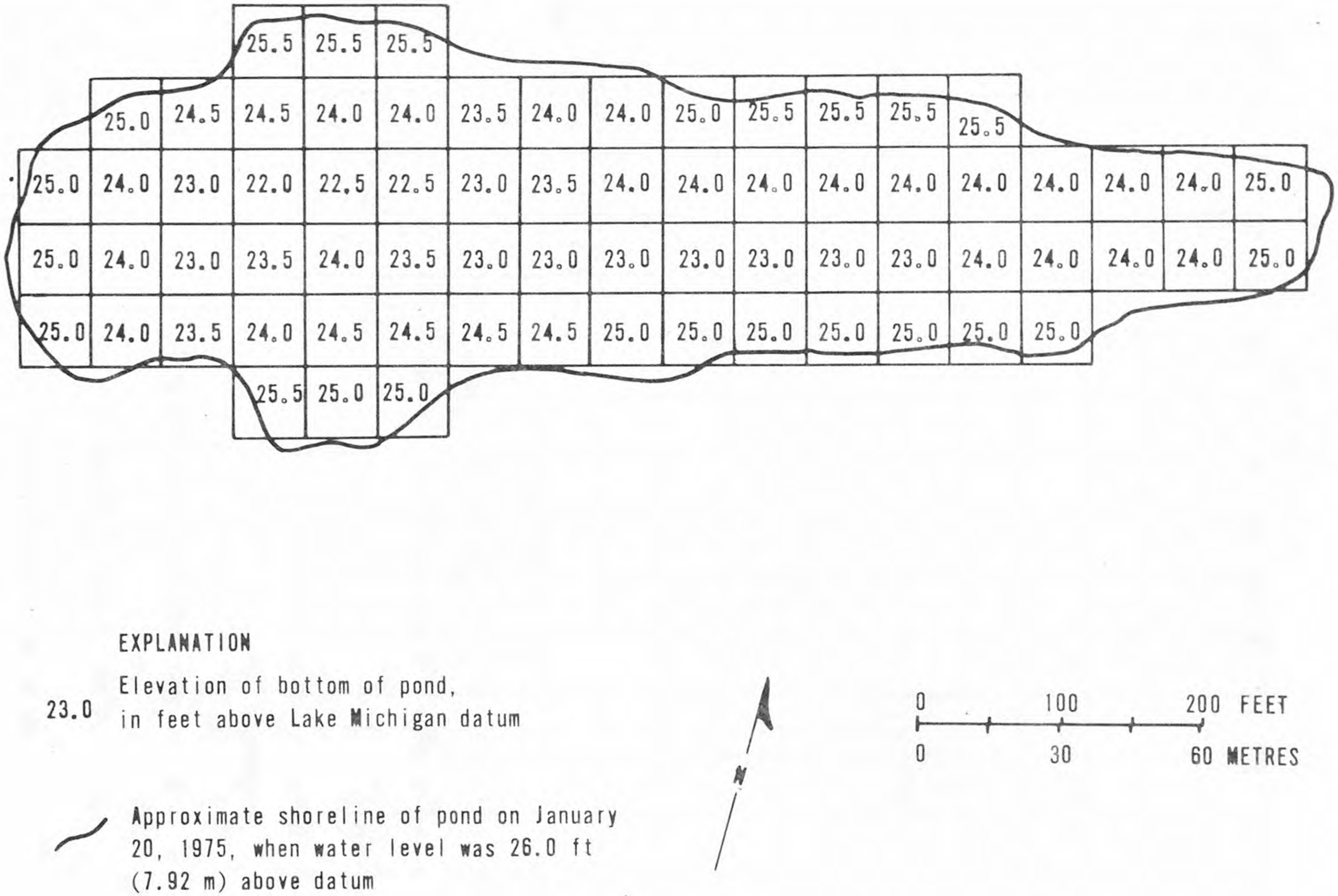


Figure 10.-- Shoreline and nodal network for pond 1.

Recharge to the aquifer comes from three sources: (1) infiltration from precipitation, (2) leakage from the interdunal ponds, and (3) leakage from NIPSCO's four ash-settling ponds, which receive process water that is pumped from Lake Michigan. All sources were included in the model. Infiltration directly from precipitation is a model option and was applied at various uniform rates on all nodes except those depicting the interdunal ponds, the ash-settling ponds, and Cowles Bog. The quantity of leakage to and from the ponds and Cowles Bog was defined by the model, using the areal and vertical head relationships observed in the various water bodies and the underlying aquifer and the vertical hydraulic conductivity value assigned to the pond-bottom material.

Steady-State Conditions

Water levels observed on February 5 and August 1, 1974, were selected to test the digital model under steady-state conditions. The February 5 date was selected because ground-water levels were at or near the highest observed for the period of record. Further, precipitation data correlated with water levels suggest that this period is near the long-term average water-level conditions for the area. The August 1 date was selected because water levels were at or near their lowest for the period of record prior to excavation at the construction site.

To simulate steady-state conditions, all observed water levels--both surface and underground--were used as input and control points for the model. A precipitation-infiltration rate (estimated) of 9.2 in/yr (234 mm/yr) was applied for February, and 8.4 in/yr (213 mm/yr) was applied for August. Figure 11 shows the ground-water levels generated by the model for both February 5 and August 1, 1974. Table 1 shows the observed and model-generated values and the differences between them for both dates. All differences are 0.2 ft (0.06 m) or less, except that for well 14 on February 5, which is 0.5 ft (0.15 m).

Model simulation of observed values to this accuracy is considered a calibration of the model for steady-state conditions.

Considerable controversy has arisen over the possible effects on the hydrology of the Bailly area caused by NIPSCO's excavation of a large pit at the construction site. Consequently, the next step in modeling was to simulate the effects of this pit.

Prior to excavation, the ground at the site was fairly level and at an elevation of about 40 ft (12.2 m) above Lake Michigan datum. No dewatering was done during the excavation.

The pit was started on August 13, 1974, and work was stopped on October 4, 1974, when water flowing into the pit became a problem. During this time, 211,400 yd^3 (161,600 m^3) of sand was excavated, creating a pit about 700 ft (213 m) long, 300 ft (90 m) wide, and 27 ft (8.2 m) deep. On October

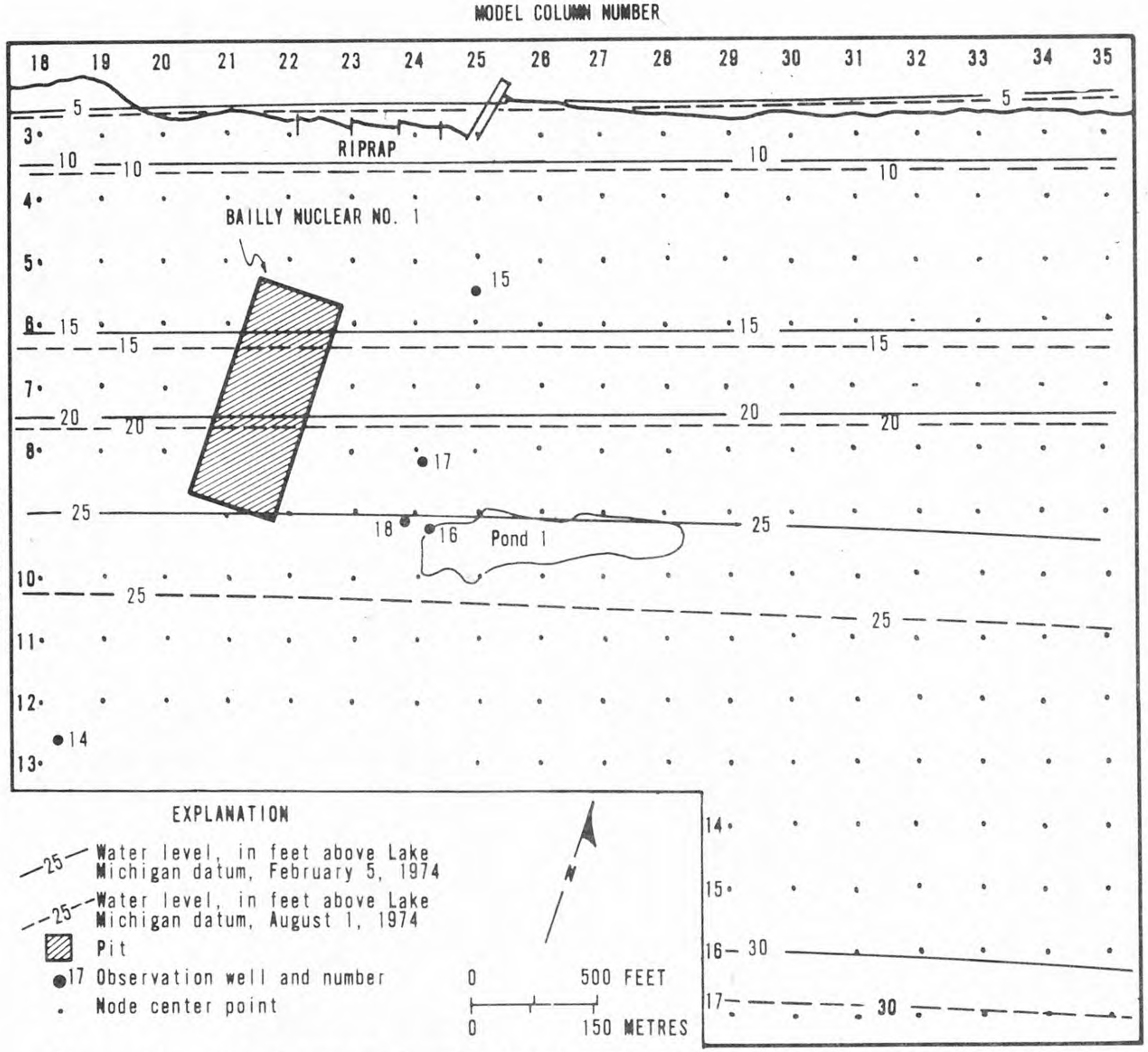


Figure 11.-- Model-generated water-level contours for February 5 and August 1, 1974.

4, water in the pit stood at an elevation of 14 ft (4.3 m) above Lake Michigan datum. The water level in the pit rose to 16 ft (4.9 m) above datum by November 15 and to 16.4 ft (5.0 m) above datum by January 1, 1975 (description of excavation from W. J. Miller and J. W. Dunn, oral commun., 1975).

Considering that the water level in the pit had virtually stabilized at 16.0 ft (4.9 m) above datum in 4 1/2 months, this value was selected, and the model was programmed to show the steady-state effects caused by the pit. For this simulation, the assumed average water-level conditions (February 5, 1974) were used as input for the model. Figure 12 shows the model-generated effects. The model indicates that under average conditions at steady state the drawdown beneath the west end of pond 1 will be almost 2 ft (0.6 m).

Table 1.--Comparison of observed and model-generated water levels for NIPSCO's observation wells

	February 5, 1974			August 1, 1974		
Well	Observed	Model	Difference	Observed	Model	Difference
14	27.6	28.1	+0.5	26.7	26.8	+0.1
15	13.4	13.5	+ .1	12.8	12.9	+ .1
17	22.6	22.8	+ .2	21.3	21.4	+ .1
18	25.2	25.0	- .2	23.7	23.8	+ .1

Note: All water levels are in feet above Lake Michigan datum. No data are available for well 16 on February 5; consequently, well 16 was not used in this comparison.

The model was then programmed to simulate dewatering of the construction site using a conventional well-point system to lower the water level to the design elevation of 4 ft (1.2 m) below Lake Michigan datum. Again, assumed average water-level conditions (February 5, 1974) were used as input. During dewatering, NIPSCO plans to pump enough water to reach the design water level in as short a time as practical and then to pump only enough water to maintain the design water level (W. J. Miller and J. W. Dunn, oral commun., 1975). Consequently, the dewatering simulation was made much in the same manner by holding the water level constant at the design elevation in the construction area and allowing the withdrawal of water from the site to vary with time, as needed to maintain this water level. Figure 13 shows the model-generated steady-state effect. According to the model, the ground-water level beneath the west end of pond 1 (node 10-24) would be 22.1 ft (6.74 m) above datum--a drawdown of about 4 ft (1.2 m) under average conditions.

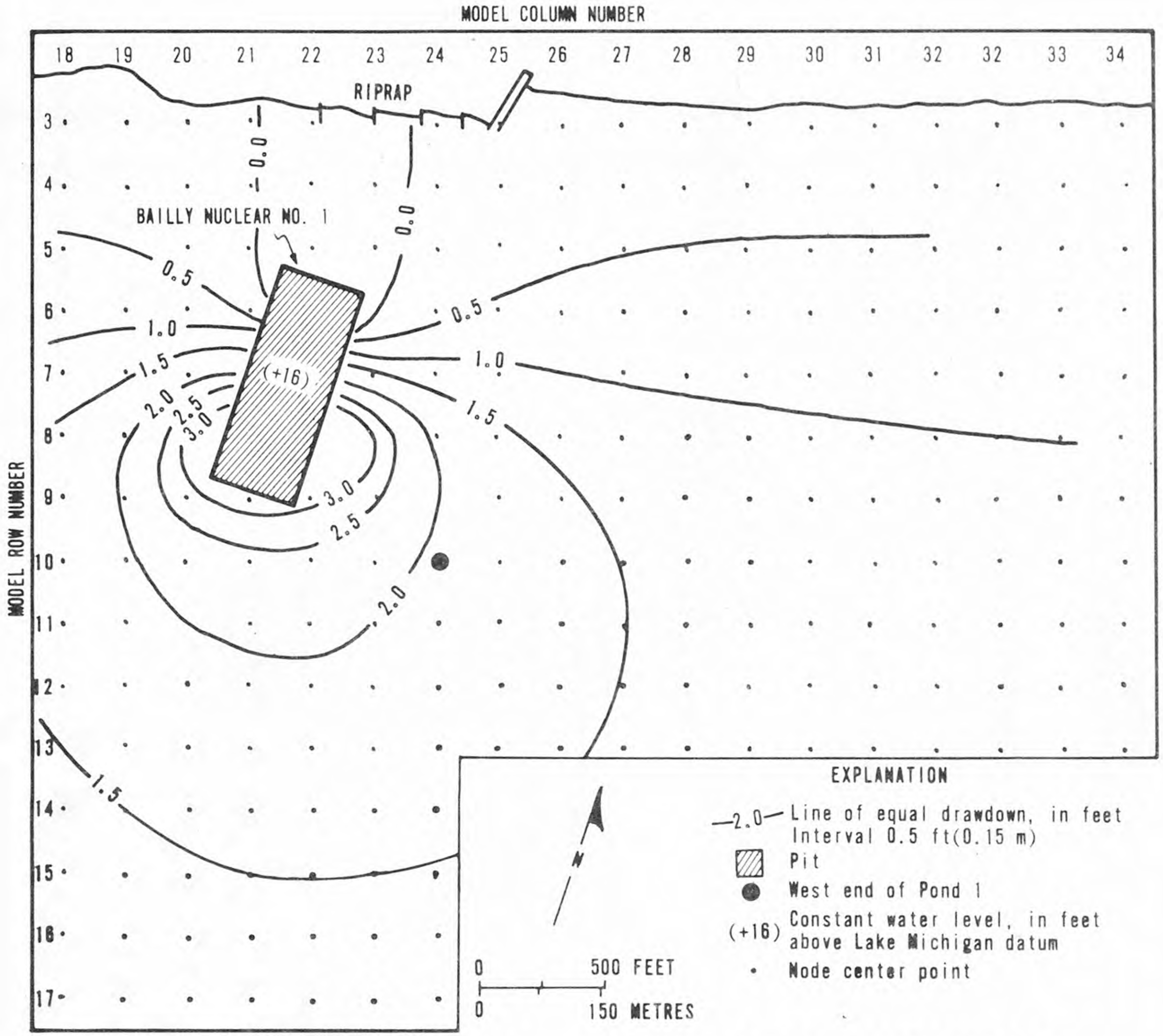


Figure 12.-- Model-derived drawdown caused by open pit under steady-state conditions and average (9.2 in or 230 mm) effective recharge.

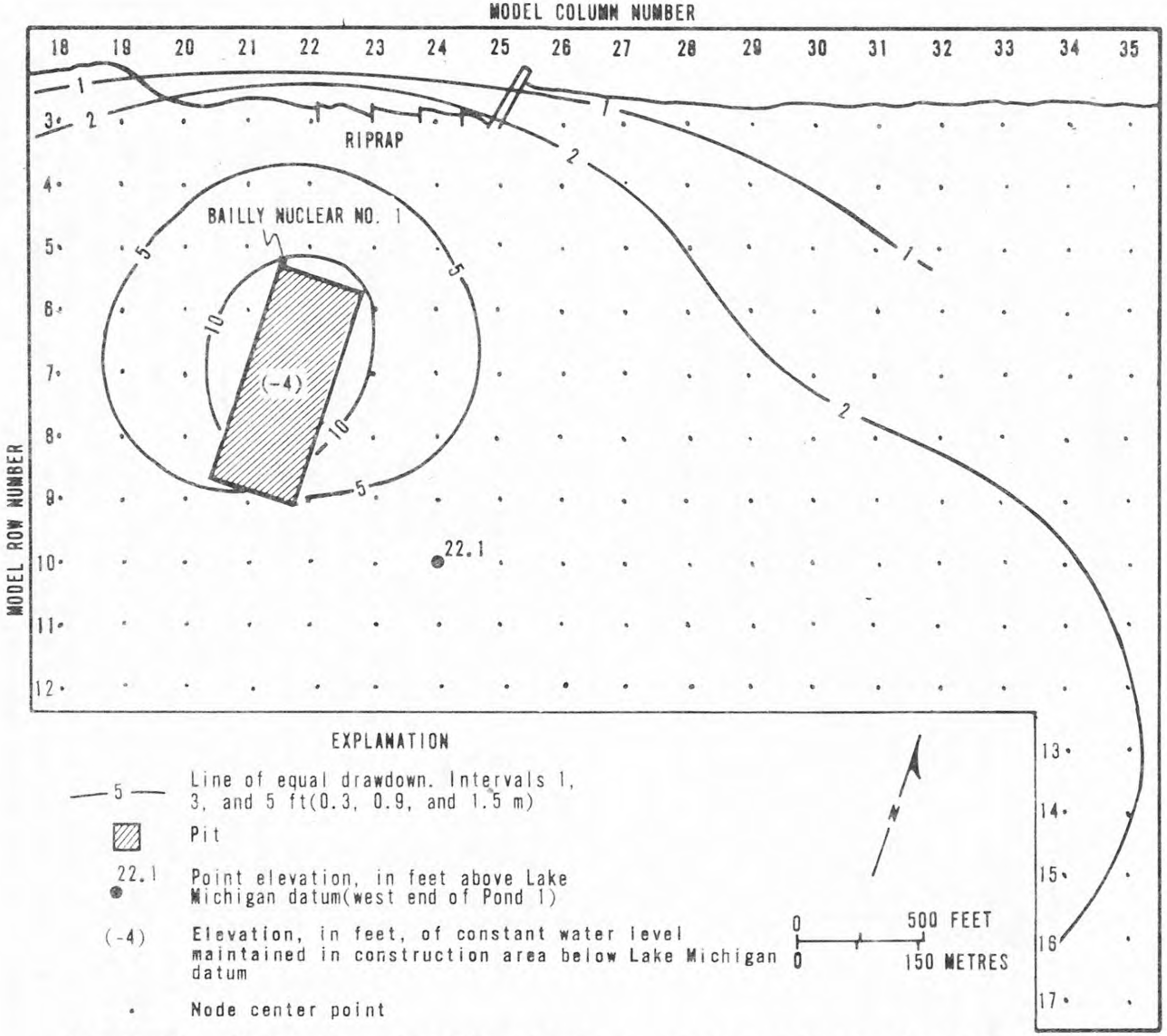


Figure 13.-- Model-derived drawdown caused by dewatering the construction site to 4 ft(1.2 m) below datum under steady-state conditions and average effective recharge.

Because the water level at the construction site is expected to be maintained at the dewatering elevation for about 18 months, the model was used to determine the effect of a relatively dry period, such as the observed conditions of August 1, 1974. Figure 14 shows this effect. The model indicates that the ground-water level under the west end of pond 1 would be 20.8 ft (6.34 m) above datum, or a drawdown of about 4 ft (1.2 m) below the August 1, 1974, water level. The water level of 20.8 ft (6.34 m) represents a decline of about 5 ft (1.5 m) below the average water level of February 5, 1974.

Transient Conditions

In order to predict the hydrologic effects, with time, resulting from dewatering at the construction site, a value for both specific yield and storage coefficient must be assigned to the aquifer model. This is necessary because, under initial conditions, the ground-water level under some of the ponds is above the bottom of the pond; that is, the ground water is semiconfined beneath the low-permeability, pond-bottom layer. This condition is simulated by assigning the artesian storage coefficient to these areas of the model. Elsewhere, the aquifer is under water-table conditions, and a specific-yield value must be assigned. Further, as the water levels decline during dewatering, some of the areas that were initially under semiconfined conditions will possibly convert to water-table conditions. This conversion from artesian to water-table conditions is effectively simulated by the model.

No aquifer test has been made at the Bailly site to define the values of specific yield and storage coefficient accurately. However, values for specific yield generally range from 0.1 to 0.3, and the storage coefficient may be estimated by multiplying the thickness of the confined zone, in feet, times specific storage of 10^{-6}/ft (metres times 3.28 x 10^{-5}/m). Two values of specific yield were selected. The first (0.13) is the best estimate based on all available data. The second (0.2) is the commonly selected average value for specific yield. Storage coefficient below each of the confining layers of the pond bottoms was estimated by multiplying the thickness times the specific storage, as stated above. The values for specific yield were programmed into the model, and two separate runs were made to determine how sensitive the model was to these differences in specific yield. Figure 15 shows the differences in drawdown after 158 days and 540 days under average (February 5, 1974) conditions, as determined by using the two values of specific yield. The greatest difference in the model-generated drawdown is slightly more than 0.4 ft (0.1 m) at 158 days and 0.3 ft (0.1 m) at 540 days. These differences are slight, and, for all practical purposes, are negligible. In any case, verification of specific yield will require acceptable modeling of drawdown caused by pumping in the construction area, which has not been started. In the discussion of all transient runs of the model that follows, the specific yield programmed into the model is the best-estimate value of 0.13.

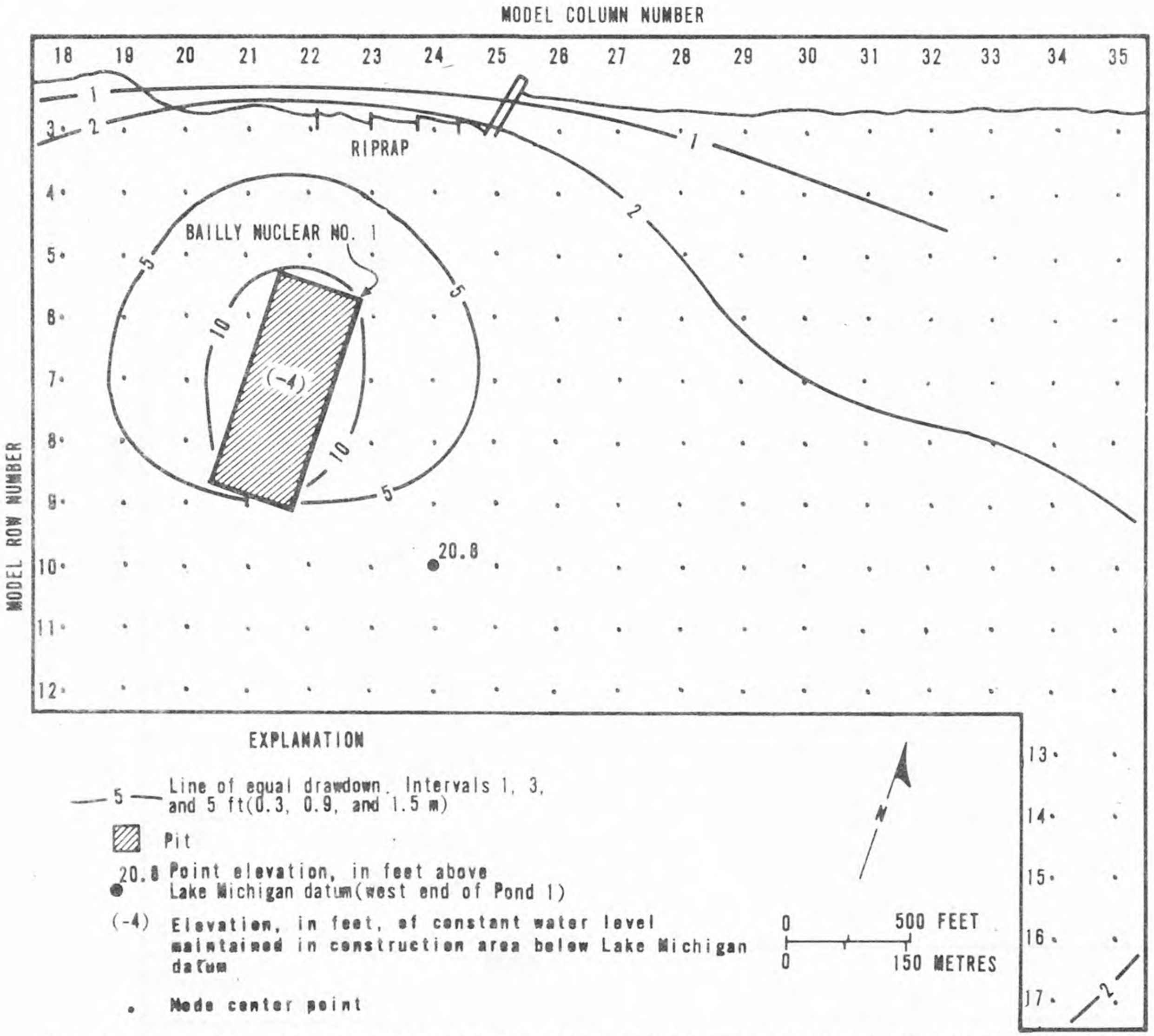


Figure 14.-- Model-derived drawdown caused by dewatering the construction site to 4 ft (1.2 m) below datum under steady-state conditions and 8.4 in(210 mm)/yr effective recharge, August 1. 1974.

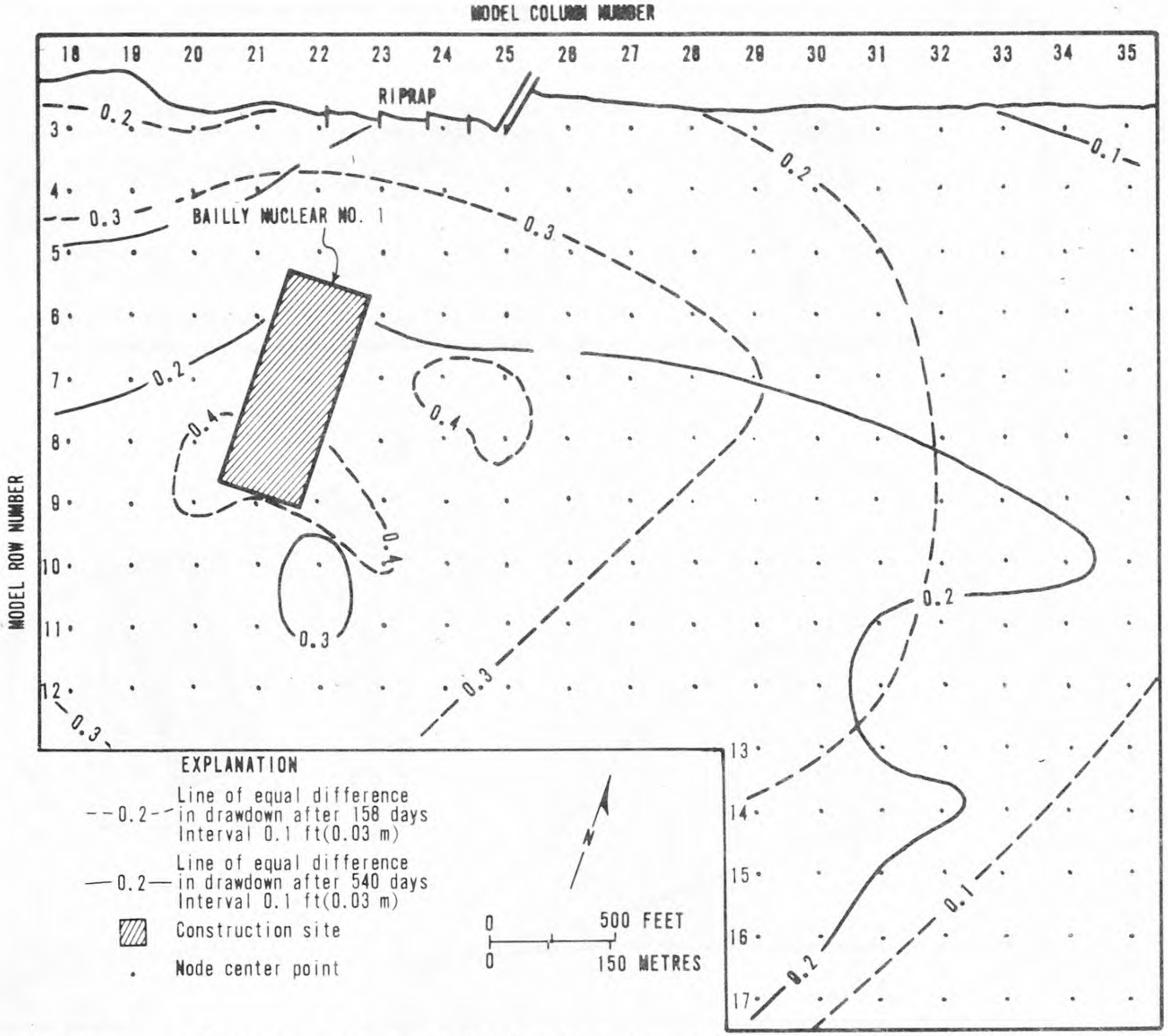


Figure 15.-- Differences in drawdown produced by the model using specific yield values of 0.13 and 0.20 after dewatering the construction site for 158 days and 540 days.

The final simulation using the aquifer model was to determine the hydrologic effects, with time, of dewatering both with and without the preexisting open pit. Answers were needed to the following questions: 1) How much additional drawdown would be caused under the ponds if the dewatering were started with the lowered water levels caused by the pit as compared to the nonlowered levels had the pit not been dug? and 2) Would this additional drawdown cause the ponds to go dry significantly sooner and stay dry longer, thus causing possibly more ecological damage to the National Lakeshore? It was necessary, therefore, to evaluate differences in hydraulic conditions caused during dewatering by the existing stabilized lowered water levels in the pit. (See fig. 12.)

The differences shown by the model in ground-water levels caused with and without the influence of the pit are shown on figures 16 and 17 after dewatering for 104 and 540 days. At 104 days, the ground-water level under the west end of pond 1 would be 1 ft (0.3 m) deeper when influenced by the pit than it would be without the pit's influence. (See fig. 15.) At 540 days, the water level would be 0.6 ft (0.2 m) deeper. (See fig. 16.) The effects of these additional drawdowns caused by the pit are being evaluated by the National Park Service.

The validity of the pond model was tested using the water-level data provided by NIPSCO for the periods May 24, 1974, to August 1, 1974 (70 days) and October 27, 1973, to September 8, 1974 (317 days). The 70-day test period was selected because it represented a typical set of observed conditions--a relatively constant ground-water level during the early part and a rapid decline during the late part of the period. This phenomenon was repeated three times during the period of record. The 317-day period was selected because it was the longest during which hydrologic conditions in the area were relatively stable.

At the beginning of the 70-day test, the water level in pond 1 was 27.86 ft (8.49 m) above datum and in well 18 was 24.62 ft (7.50 m). At the beginning of the 317-day test, the water level in pond 1 was 27.73 ft (8.45 m) and in well 18 was 25.21 ft (7.68 m).

The first test period (70 days) was divided into 7 equal intervals, and the second test period (317 days) was divided into 10 equal intervals. The average water level for well 18, which is immediately west of pond 1, was then determined for each interval for both test periods. These water levels were assumed to represent the average ground-water level under pond 1 for the respective test periods. This assumption seems valid because the water-level contours shown on figure 11 for the verified ground-water model are virtually parallel to the axis of pond 1 and extend through well 18. The water level observed in pond 1 at the beginning of each test period and the ground-water levels for that period were entered into the pond model, and two separate runs were made to evaluate the model.

The observed pond level at the end of the 70-day test period (August 1) was 26.34 ft (8.03 m). The model-produced pond level was 26.30 ft (8.02 m), or a difference of 0.04 ft (0.01 m). The observed pond level at the end of

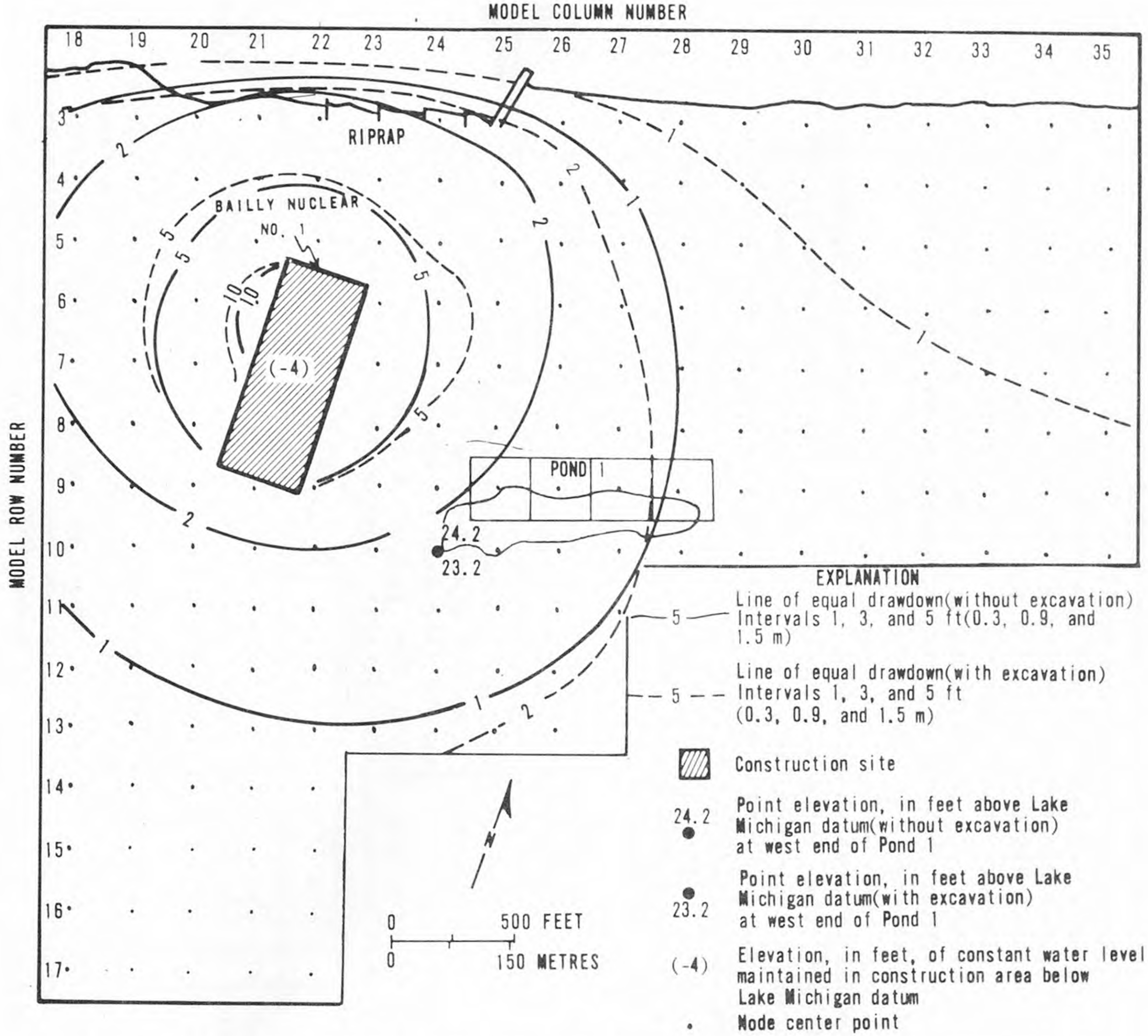


Figure 16.-- Model-derived drawdown caused by dewatering the construction site to 4 ft(1.2 m) below datum for 104 days under average water-level conditions with and without open pit.

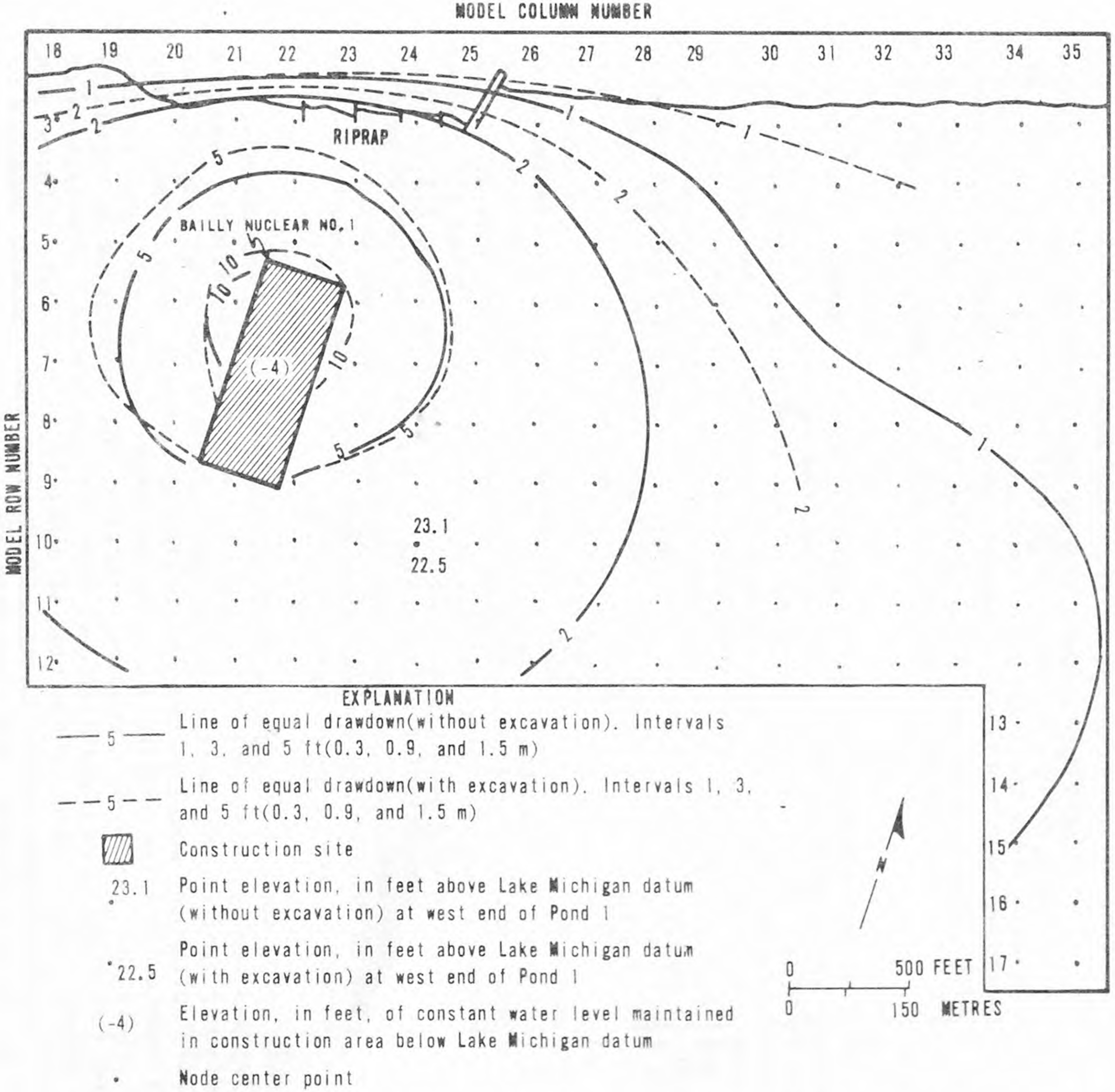


Figure 17.-- Model-derived drawdown caused by dewatering the construction site to 4 ft (1.2 m) below datum for 540 days under average water-level conditions with and without open pit.

the 317-day test period (September 8) was 25.03 ft (7.63 m). The model-produced water level was 24.80 ft (7.56 m), or a difference of 0.23 ft (0.07 m). These differences are considered acceptable and, consequently, a verification of the pond model.

The pond model was then programmed to simulate the effects of the dewatering on pond 1. The ground-water levels beneath pond 1, generated by the aquifer model for various times after dewatering began, were used as input for the program. The decline in pond level due to dewatering both with and without the effects of the open pit was examined. The results from these model runs are shown on figure 18. The model indicates that the pond would not go completely dry under average conditions during the planned 540-day dewatering period, either with or without the effects of the pit. However, in both cases the pond would have less than 0.55 ft (0.17 m) of water remaining and would be reduced to about 1 percent of its original area. With less than average recharge (August 1, 1974), the pond would go dry in 170 days when influenced by the pit and in 310 days without the pit's influence.

The pond may not have to go completely dry to damage the National Lakeshore environment. Figure 19 shows the sequence and the particular water level at which different areas of the pond go dry. This figure, in conjunction with figure 18, can be used to estimate the area and the depth of pond 1 at a given time after dewatering begins. For example, even though the pond does not go completely dry under average conditions and without the effect of the open pit, the model indicates that pond 1 would have a water level of 25.70 ft (7.83 m) above Lake Michigan datum after 120 days of pumping and 23.13 ft (7.05 m) above datum after 360 days of pumping. (See fig. 18.) From figure 19 it can be seen that the pond has not decreased significantly in area after 120 days, but after 360 days it has decreased to about 20 percent of its original area. On the other hand, with the effects of the pit, which would be the more realistic condition when dewatering begins because the pit does exist, the model shows, after 120 days of pumping under average conditions, that the pond would be about 2.2 ft (0.67 m) deep at its deepest point and would be decreased to less than 60 percent of it's original area. After 360 days of pumping, the pond would be about 0.6 ft (0.2 m) deep at its deepest point and again would be reduced to less than 4 percent of its original area.

Many other sets of conditions, both naturally occurring and manmade, can be imposed on either or both models to simulate conditions observed immediately before or during dewatering. Probably the most significant natural influence would be the variability of recharge with time. This study examined only an average and a low recharge period to show results that could be expected. However, varying the recharge as it actually occurs, or might occur, would produce more precise results. Simulations of this nature could be made at the time of dewatering to predict effects due to whatever conditions exist then. Simulating even the most probable of these conditions, beyond what has been done, is outside the scope of this project and would be clearly hypothetical at this time.

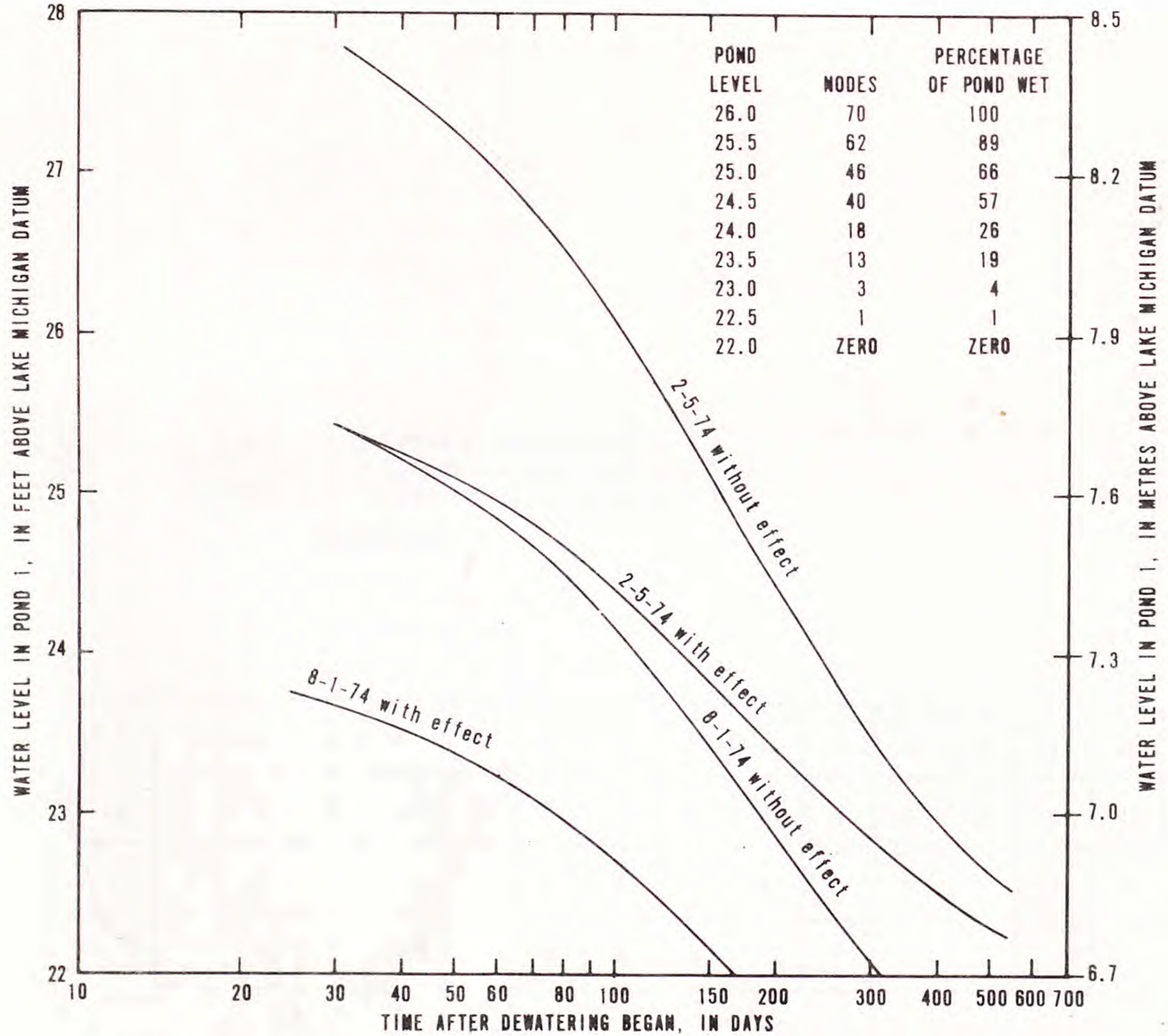


Figure 18.-- Lowering of water level in pond 1 caused by dewatering with and without the effects of the open pit at construction site for average (February 5, 1974) and below average(August 1, 1974) water-level conditions.

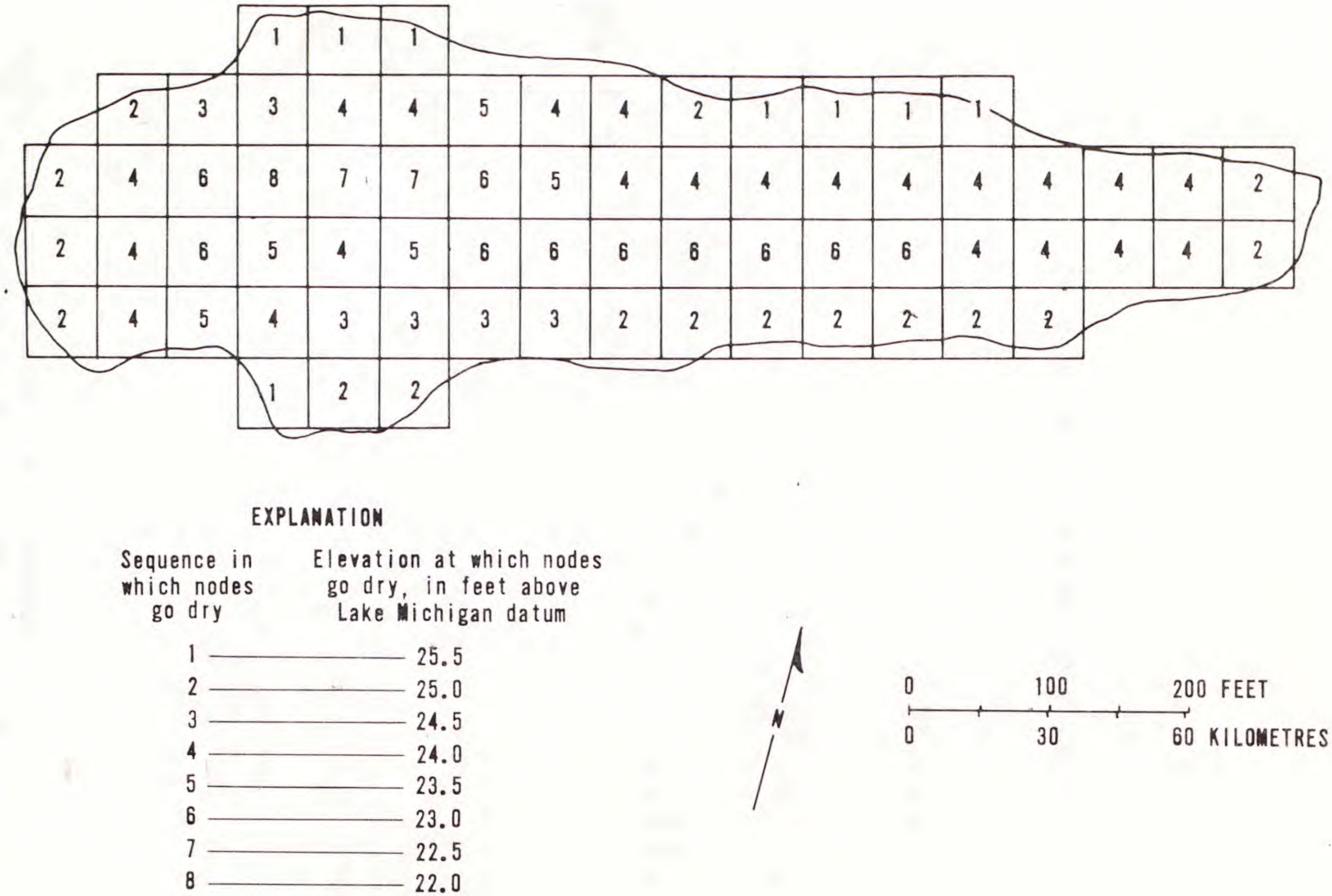


Figure 19.-- Sequence and water levels at which areas of the pond go dry.

SUMMARY AND CONCLUSIONS

The results of the steady-state simulations indicate that the drawdown caused by conventional dewatering methods at the Bailly Nuclear Generator construction site would be about 4 ft (1.2 m) under the west end of pond 1, which is on the west side of the Indiana Dunes National Lakeshore. Assuming average conditions (similar to those of February 5, 1974), this would mean a ground-water elevation of 22.1 ft (6.74 m) above Lake Michigan datum. Under drier conditions (August 1, 1974), a ground-water elevation of 20.8 ft (6.34 m) would be produced. Simulations under transient-flow conditions show that, after 104 days of dewatering under average conditions and with the influence of the open pit, the water level would be at an elevation of 23.2 ft (7.07 m). After 540 days, the planned length of time for dewatering, the elevation of the water level would be 22.5 ft (6.86 m). The model does not indicate that pond 1 would go completely dry within the 540 days. However, the pond would have less than 0.5 ft (0.2 m) of water remaining and would be reduced to about 1 percent of its original area. With less-than-average recharge (similar to conditions defined for August 1, 1974), the model shows that pond 1 would go dry in 170 days. However, pond 1 may not have to go completely dry to damage the ecosystem in this part of the National Lakeshore. Any minimum pond water level determined by the National Park Service to be critical in order to minimize environmental damage could be predicted, under the assumed conditions, by applying the data on figure 18. The area of and the depth of water remaining in the pond could then be estimated by examining the model results shown on figure 19.

The models on which these predictions are based incorporate all that is presently known of the hydrology of the construction area. However, no allowance was made in the models for possible leakage from or through the thick silty clay zone that underlies the area. This was necessitated because no data were available to allow reliable estimates to be made concerning this zone. Also, the specific yield used in the model has not been verified. However, sensitivity tests were made using different values for specific yield. These tests show that only slight differences in drawdown would result from relatively large differences in specific yield.

Many other sets of conditions, both naturally occurring and manmade, can be imposed on either or both models to simulate actual conditions at the time of dewatering. Simulations of this nature could be made at that time to predict the effects of dewatering under actual conditions.

Currently, it is planned to continue the National Park Service and the U.S. Geological Survey cooperative water-level monitoring until the construction dewatering is completed, both to verify the transient model and to document water-level changes.

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