SHALLOW GROUND-WATER FLOW, WATER LEVELS, AND QUALITY OF WATER, 1980-84, COWLES UNIT, INDIANA DUNES NATIONAL LAKESHORE

By David A. Cohen and Robert J. Shedlock

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(INTERNATIONAL SYSTEM) UNITS

Multiply inch-pound unit	By	To obtain Metric units
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
foot per day (ft/d)	0.3048	meter per day (m/d)

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ABSTRACT

The Cowles Unit of Indiana Dunes National Lakeshore in Porter County, northwest Indiana, contains a broad dune-beach complex along the southern shoreline of Lake Michigan and a large wetland, called the Great Marsh, that occupies the lowland between the shoreline dunes and an older dune-beach complex farther inland. These lacustrine sediments form a surficial aquifer that extends from the Lake Michigan shoreline to the northern edge of the Lake Border moraine.

Water levels and water quality in the surficial aquifer were monitored from 1977 to 1984 near settling ponds on adjacent industrial property at the western end of the Cowles Unit. Seepage from the settling ponds from 1967 to 1980 created a water-table mound that extended north into the shoreline dune complex and caused perennial flooding of several intradunal lowlands on National Lakeshore property. Since 1980, when the settling-pond bottoms were sealed, these intradunal lowlands contained standing water only during periods of high snowmelt or rainfall.

Water-level declines following the cessation of seepage ranged from 6 feet at the easternmost settling pond to nearly 14 feet at the westernmost pond. No general pattern of water-table decline was observed in the Great Marsh or in the shoreline dune complex at distances greater than approximately 3,000 feet east or north of the settling ponds.

Since the settling ponds were sealed, the concentration of boron has decreased while concentrations of cadmium, arsenic, zinc, and molybdenum in shallow ground water downgradient of the ponds show no definite trends in time. Arsenic, boron and molybdenum have remained at concentrations above those of shallow ground water in areas unaffected by settling-pond seepage.

INTRODUCTION

Location

The Indiana Dunes National Lakeshore, hereafter called the Lakeshore, extends along the south shoreline of Lake Michigan from the west end of Michigan City to the east end of Gary (fig. 1). The Lakeshore was established in 1966 and is divided into nine units, six of which are within two miles of Lake Michigan and three of which are isolated preserves several miles inland. The Cowles Unit (fig. 2) extends from the Lake Michigan shoreline south to U.S. Highway 12. It is bordered on the east by Indiana Dunes State Park and other Lakeshore property and on the west by an industrial area which includes a coal-fired electrical plant, two steel mills and the Port of Indiana (figs. 1 & 2). The Cowles Unit contains the western section of the Great Marsh (fig. 3), the largest interdunal wetland at the lakeshore. Cowles Bog, (fig. 2) a national natural landmark, is a 56-acre tract at the western end of the Great Marsh near the industrial complex. Cowles Bog has a raised peat mound and an unusual plant community (Hendrickson and Wilcox, 1979). Its proximity to the industrial complex has made it an area of concern to the Park Service.

Background

The Cowles Unit is bordered on the west by an electric power generating facility. From 1967 to 1980 the facility used several unlined ponds (fig. 2) for settling fly-ash from two coal-fired generating units. Seepage from these ponds, estimated at 2 Mgal/d by Meyer and Tucci (1979), created a ground-water mound that extended into Lakeshore property and caused several lowlands within a dune field north of the settling ponds to be flooded year-round. From 1973 to 1981 the company attempted to construct a nuclear power plant immediately west of their existing coal-fired plant. The effects of dewatering the excavation for the nuclear plant foundation was also an issue of concern to the National Park Service. Four previous studies, Marie (1976), Meyer and Tucci (1979), Gillies and Lapham (1980), and Hardy (1981), assessed actual and projected impacts of these activities on the water resources in adjacent park-lands. In late 1979 the facility discontinued use of the easternmost settling pond which was dewatered, dredged and back-filled with sand. In 1980 and 1981 the remaining settling ponds were sealed and in late summer 1981, after construction of the nuclear power plant was abandoned, the foundation excavation was back-filled with sand.

Purpose and Scope

The purpose of this report is to present 1) a detailed discussion of shallow ground-water flow in the Cowles Unit, and 2) describe changes in the flow system and water levels, and 3) describe changes in quality of ground water that have resulted from the decline of the seepage mound.

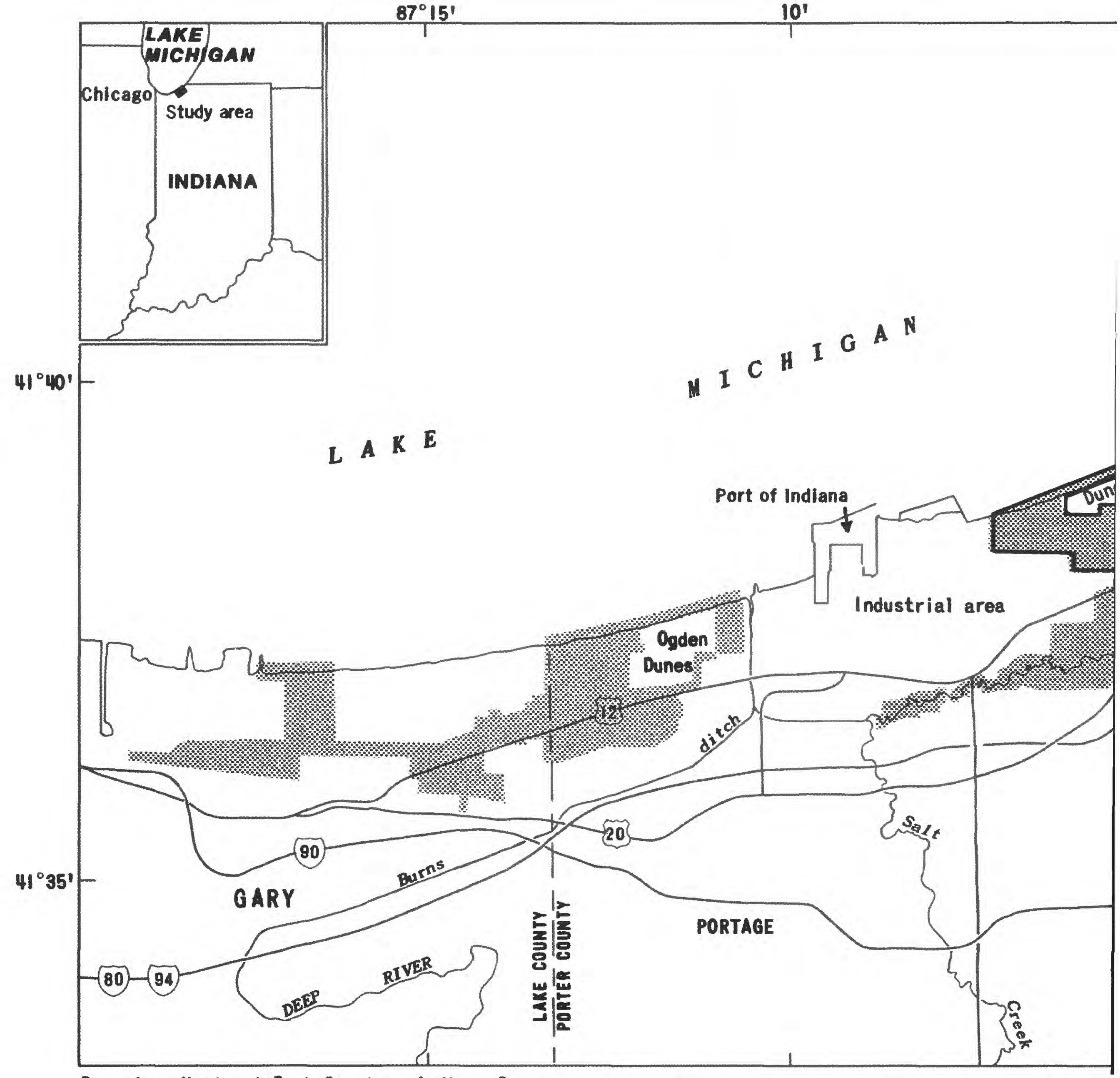
Water levels in approximately 45 observation wells were used to prepare water-table maps for February 1980, during settling-pond seepage, and April 1983, approximately two years after cessation of seepage. Samples from selected wells were collected quarterly to monitor changes in water quality downgradient from the ponds. The samples were analyzed for boron, molybdenum, arsenic, cadmium and zinc. These elements were chosen because of their toxicity to plants.

Hydrogeologic Setting

The study area contains two major dune-beach complexes (fig. 3) formed when ancestral levels of Lake Michigan were higher than the modern mean level of 578 feet above sea level. These complexes have been mostly stabilized by vegetation and extend across the study area roughly parallel to the modern shoreline. The southern dune-beach complex (Calumet-Glenwood dune complex) was deposited on the north flank of the Lake Border moraine which forms an upland south of the Cowles Unit. The northern dune-beach complex (shoreline dune complex) is much broader and extends from the modern shoreline to the Great Marsh, the large wetland in the lowland between the two dune complexes. The shoreline complex contains smaller lowlands, some of which are wetlands. Furthermore, nearly all of the industrial area west of the Cowles Unit was part of the shoreline dune complex before the area was developed.

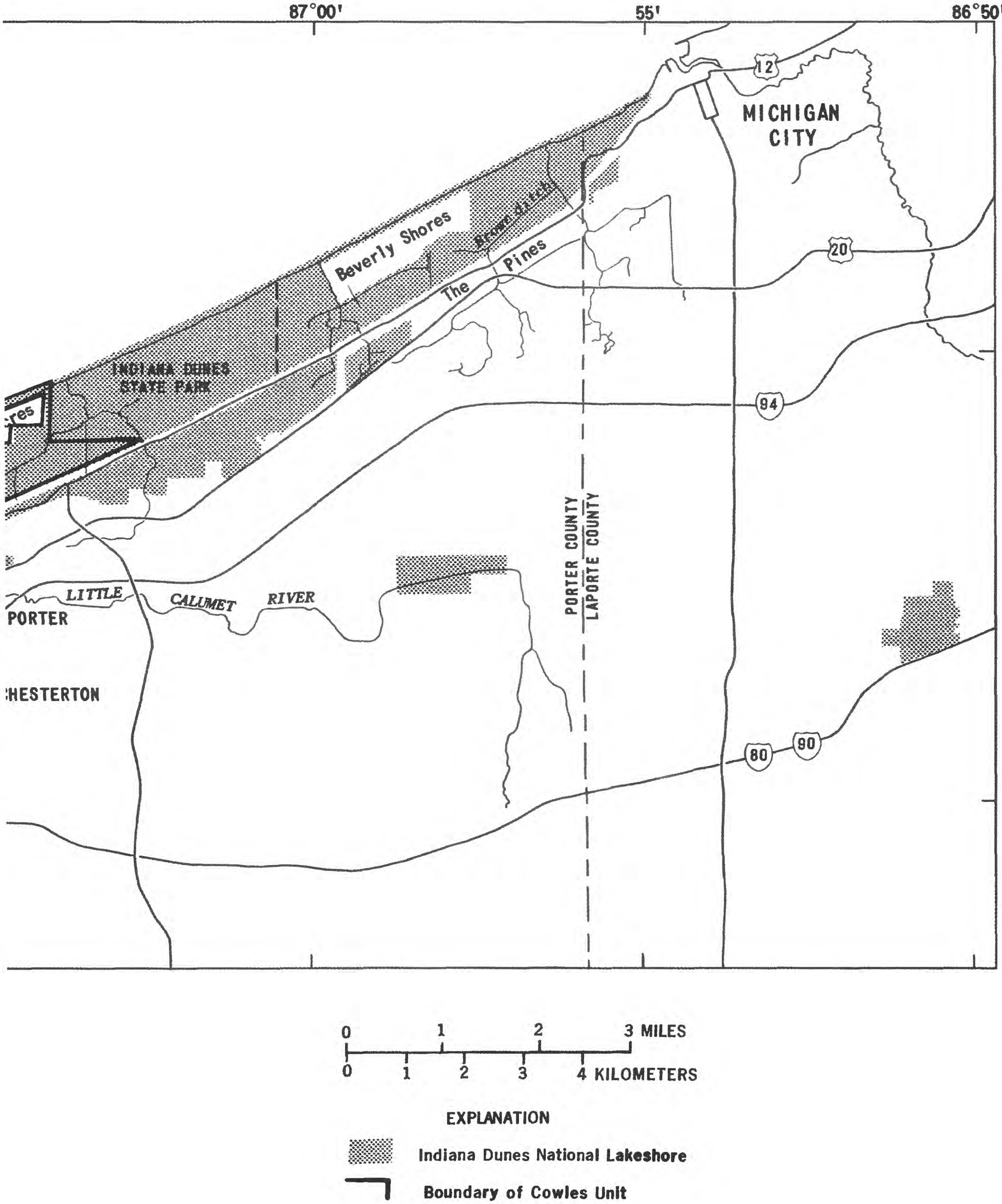
The lacustrine, dune, and beach sediments in this area form a surficial aquifer that extends from the northern edge of the Lake Border moraine to Lake Michigan. In the wetlands, the sands are overlain by marl and various organic deposits including peat, muck, and mixtures of peat and sand. The saturated thickness of the surficial aquifer ranges from approximately 35 feet under parts of the shoreline complex to 0 feet along the northern edge of the Lake Border moraine. Hydraulic conductivities reported by Rosenshein and Hunn (1968) and Meyer and Tucci (1979) ranged from 20 ft/day to 167 ft/day. Calculations using specific capacity data from 18 wells yielded values ranging from 27 ft/day to 96 ft/day. The variability in values of hydraulic conductivity results from the variability in the sediments and bedding structures in the surficial aquifer (Thompson, 1985).

In the eastern two-thirds of the Cowles Unit the surficial aquifer is underlain by a till sheet that is the subsurface extension of the Lake Border moraine (fig. 4). Below the till sheet is a confined sand aquifer that discharges upward into the surficial aquifer through a breach in the till in the Cowles Bog area (Shedlock, 1983). The subtill aquifer pinches out north



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

Figure 1.-- Indiana Dunes National Lakeshore.


87°00'
55'
86°50'
12
MICHIGAN CITY
Beverly Shores
The Pines
20
INDIANA DUNES STATE PARK
94
PORTER COUNTY
LAPORTE COUNTY
LITTLE CALUMET RIVER
PORTER
80
90
0 1 2 3 MILES
0 1 2 3 4 KILOMETERS
EXPLANATION
Indiana Dunes National Lakeshore
Boundary of Cowles Unit

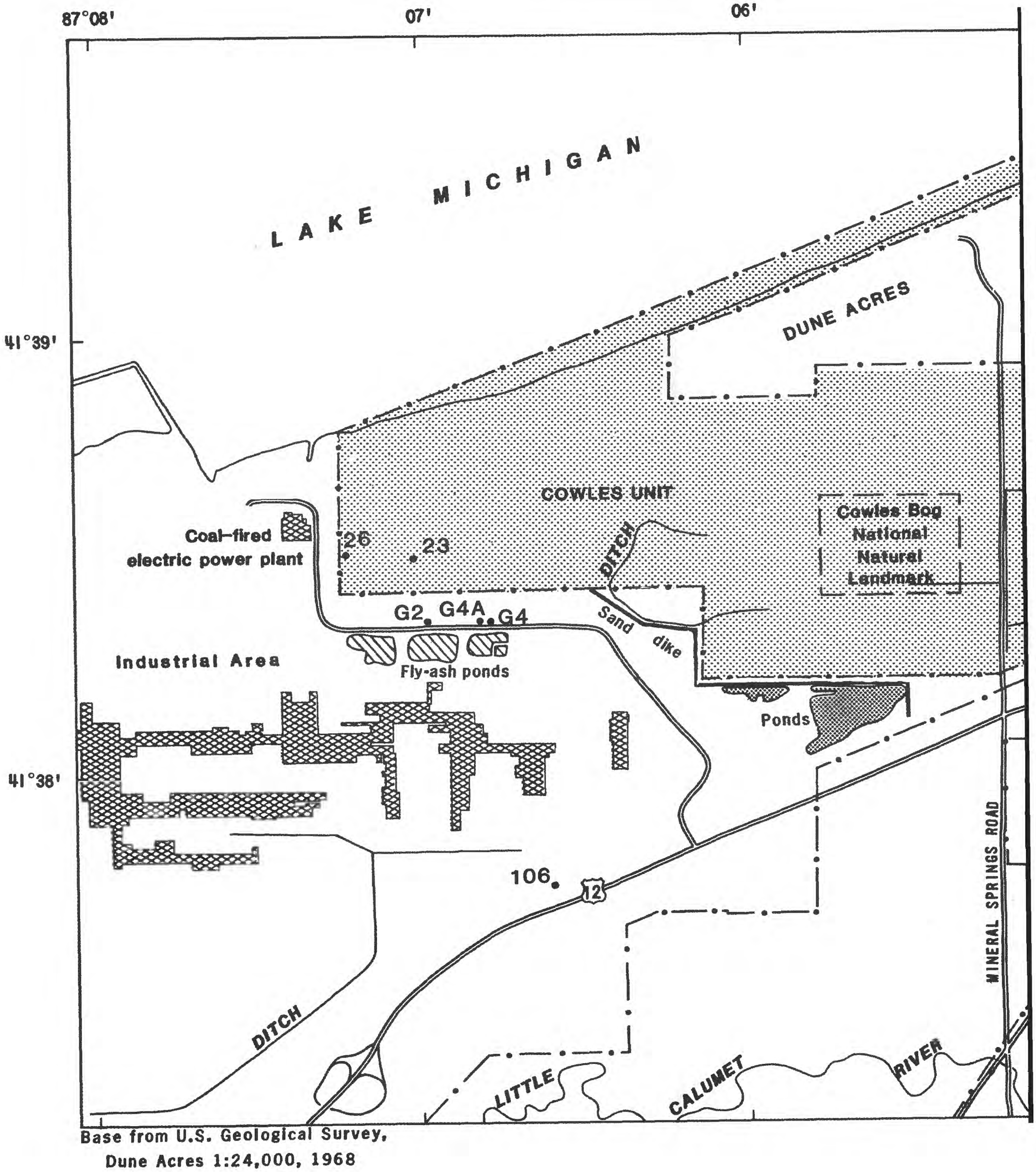
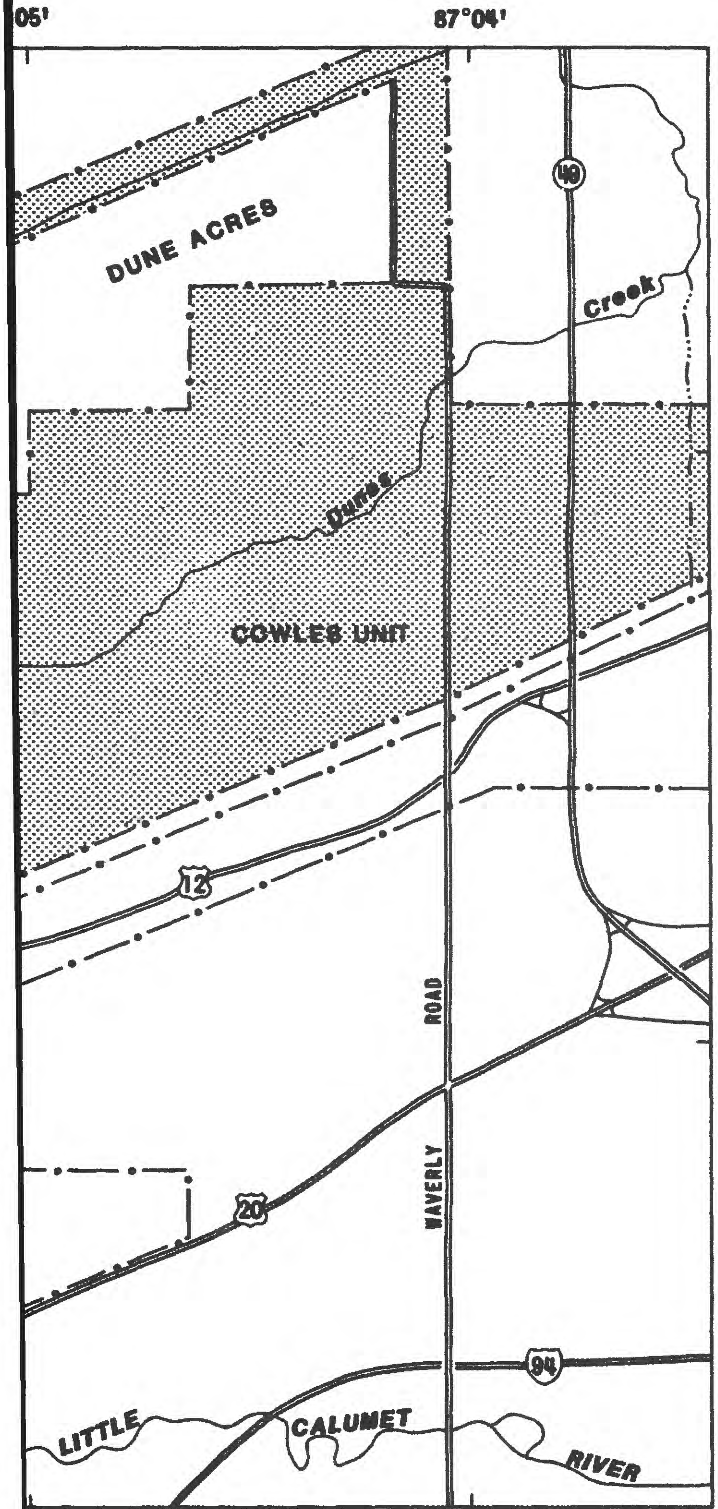


Figure 2.-- Cowles Unit, Indiana Dunes National Lakeshore, and surrounding area.



EXPLANATION

Pond used for settling fly-ash, 1967 to 1980

Cowles Unit, IDNL

Boundary of Indiana Dunes National Lakeshore (IDNL)

Sand dike

G4 U.S. Geological Survey observation well and designation

0 1 MILE
0 1 KILOMETER

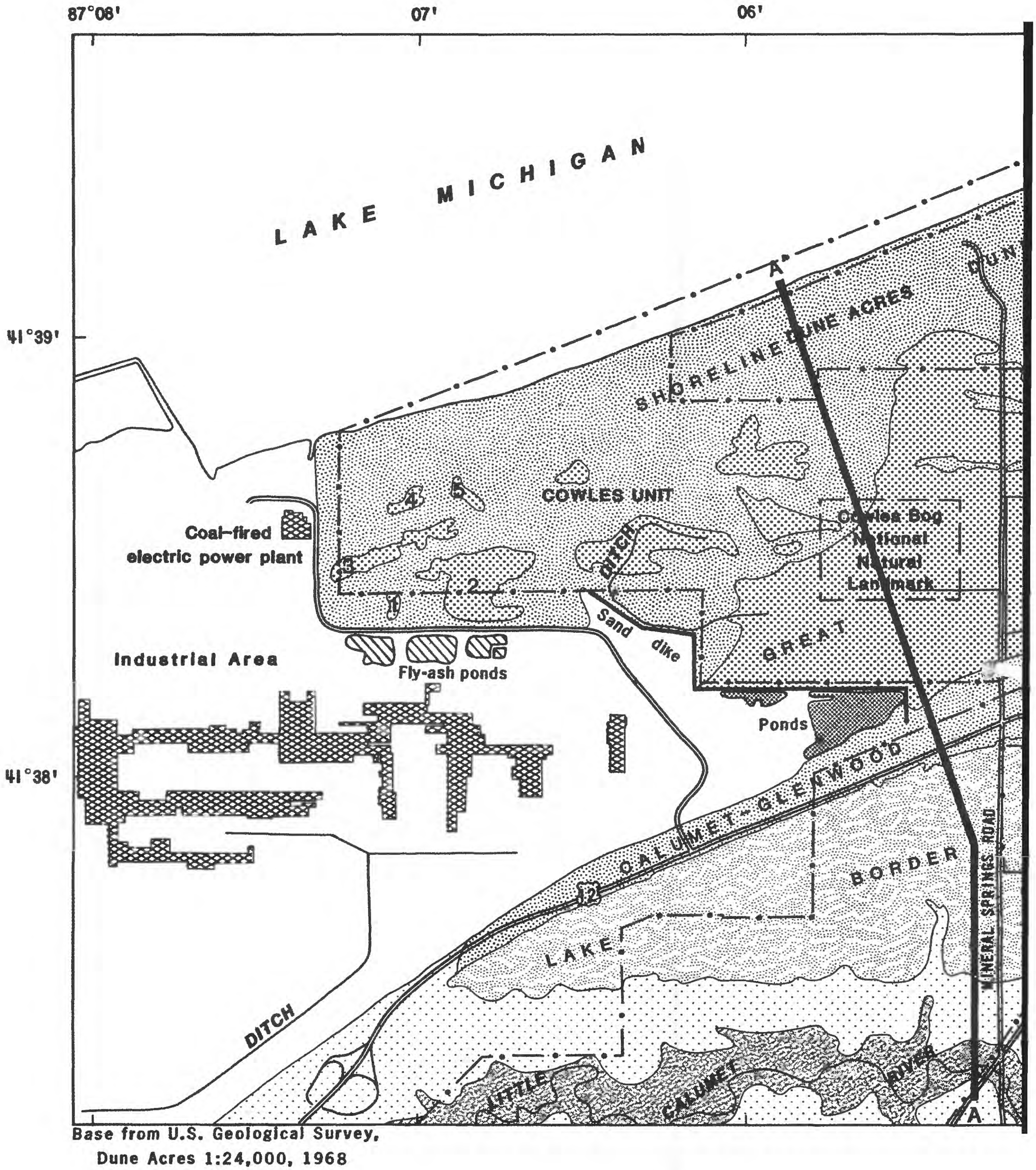
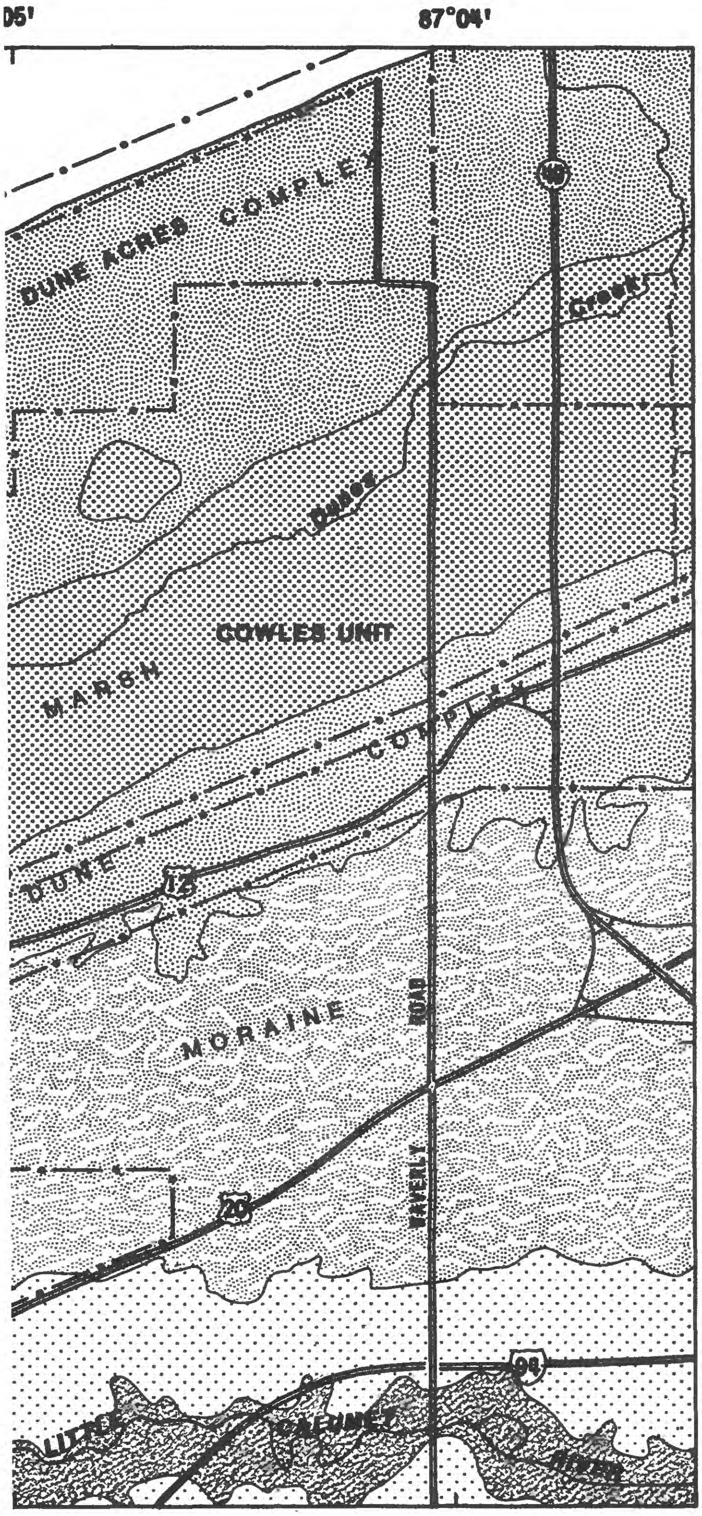


Figure 3.-- Geomorphic features and surficial geology of the Cowles Unit and surrounding area.



EXPLANATION

Alluvium

Dune and beach sand

Paludal deposits-- Peat, muck, and mixtures of peat and sand. Number is designation of intradunal lowland basins

Till

Glacial-lacustrine sand, silt, and clay

A——A' Line of geologic section shown in figure 4

0 1 MILE
0 1 KILOMETER

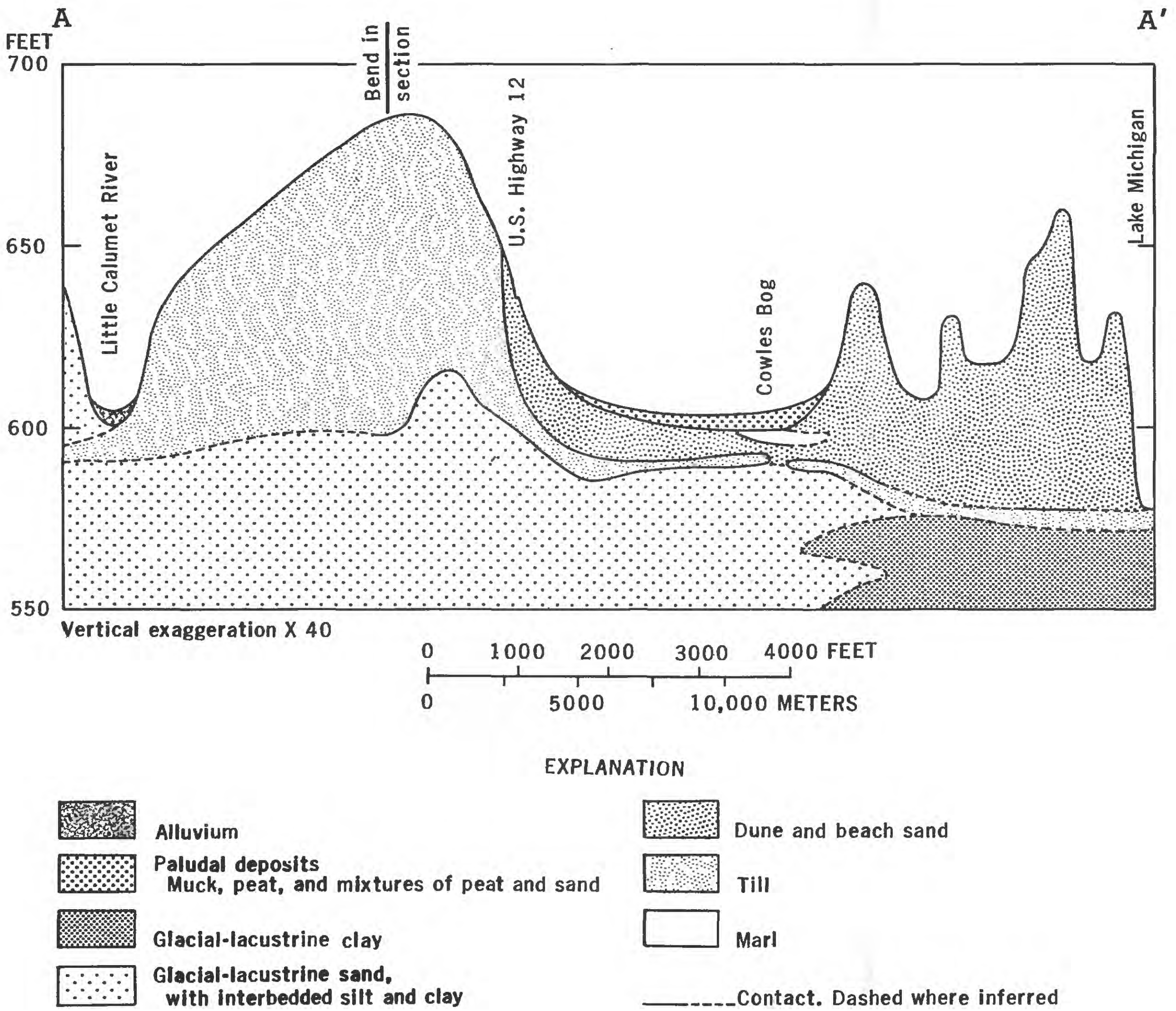


Figure 4.-- Generalized geologic section A-A'.

and west of the Great Marsh beneath the shoreline dune complex. At the west end of the Cowles Unit the till sheet dips deeper into the subsurface and, in part of this area, the uppermost confining layer is a calcareous lacustrine clay with plant and shell fragments. Sands below this clay form a local confined aquifer layer in the industrial area.

A network of ditches was constructed in the early 1900's to drain the Great Marsh near Cowles Bog (Cook and Jackson, 1978). The ditches drain east into Dunes Creek, a natural wetland stream that discharges into Lake Michigan. The channels of these ditches have not been cleaned or dredged for many years, but flow can be seen in many of them after snowmelt or moderate rainfall. The crest of the Lake Border moraine is a major drainage divide for the study area. North of the divide surface flow is to Dunes Creek in the east half of the study area and to a ditch system in the industrial area in the west half. South of the crest of the moraine drainage is to the Little Calumet River which parallels the south margin of the moraine.

SHALLOW GROUND-WATER FLOW, 1980-84

Figures 5 and 6 are water-table maps of the surficial aquifer for periods before and after the sealing of the fly-ash settling ponds, respectively. Comparison of the two maps shows that shallow ground-water flow differs significantly for the two time periods only in the industrial area and the west end of the Cowles Unit. In the east half of the study area, flow is from water-table highs in the dune-beach complexes to Dunes Creek and its tributary ditches in the Great Marsh and to Lake Michigan north of the water-table divide in the shoreline dune complex. The only exception to this is around the raised peat mound at Cowles Bog (fig. 2) where upwelling through a breach in the till has created a water-table mound and a local pattern of radial flow away from the peat mound. In the western one-half of the study area, shallow ground water discharges to the ditch system in the industrial area and drains to the west into the Little Calumet River.

In addition to the water-table divide in the shoreline dune complex, there is also a water-table divide near the east end of the industrial area just southwest of the sand dike (fig. 2). This divide runs along the flexures in the 610-foot contour (figures 5 and 6) and generally constitutes the drainage divide between the Dunes Creek basin to the east and the basin of the ditch system in the industrial area to the west. Although this east-west divide is near the ponded area behind the raised sand dike, Cook and Jackson (1978) present evidence that suggests this divide existed before the industrial area was developed. They report an east-west drainage ditch that traversed this area in the early 1900's. Water in this ditch was reported to flow both east to Dunes Creek at some reaches and west to the Little Calumet River at others, a condition which suggests the presence of a ground-water divide. Ponding behind the dike has probably shifted the southern part of this divide slightly eastward. The dike, constructed in 1971 as a containment wall for future fly-ash fill, impounded flow in several ditches that drained northward. Ponded water south of the dike is generally 3 feet higher than surface water elevations immediately north in the Great Marsh.

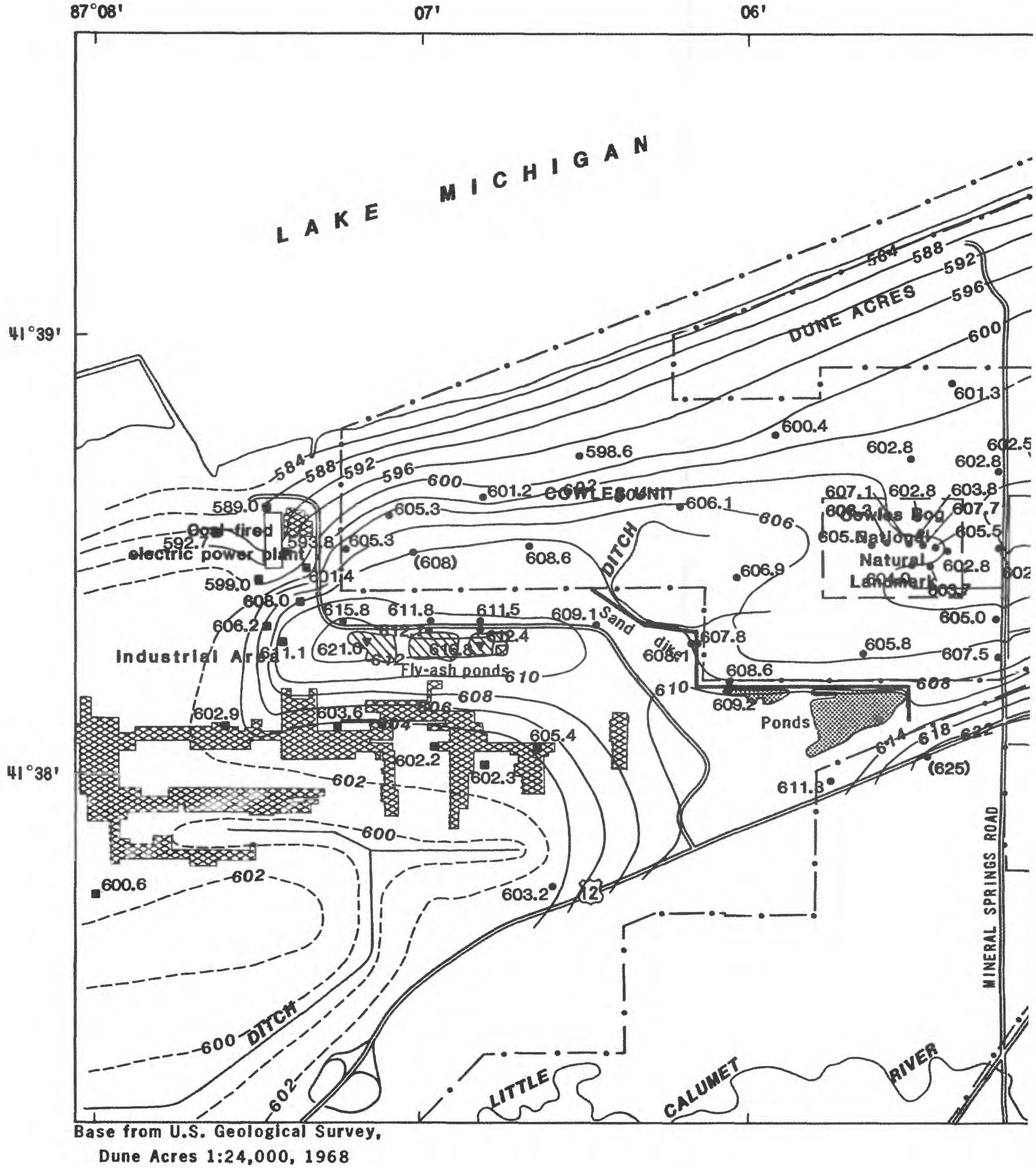
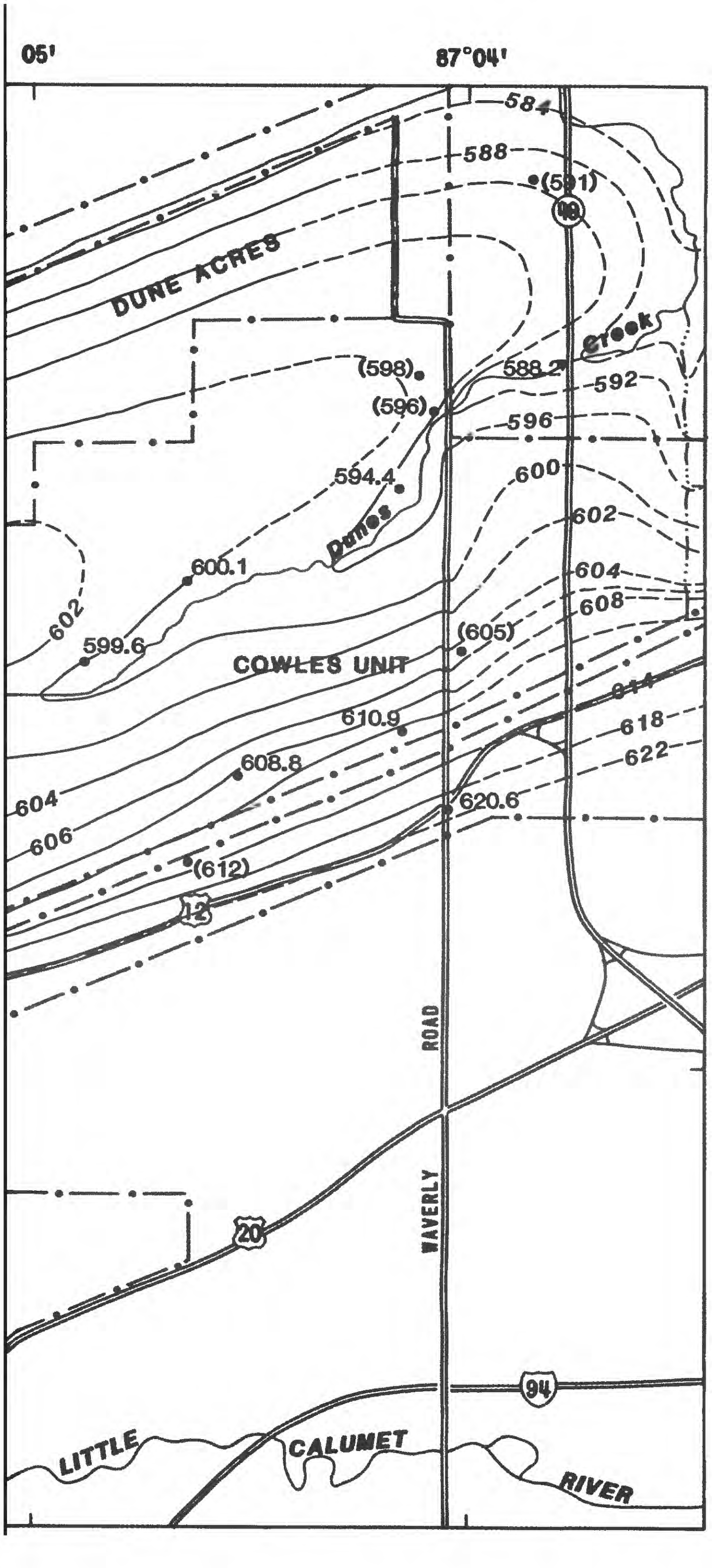


Figure 5.-- Water-table altitude, February 1980.



EXPLANATION

—604— Altitude of water table. Contour intervals 2 and 4 feet. Dashed where approximate. Datum is sea level

• U.S. Geological Survey observation well

■ Industrial observation well

▼ Surface-water measurement site

608.8 Water-level altitude in feet above sea level

(612) Estimated water-level altitude in feet above sea level

▯ Foundation excavation

0 1 MILE

0 1 KILOMETER

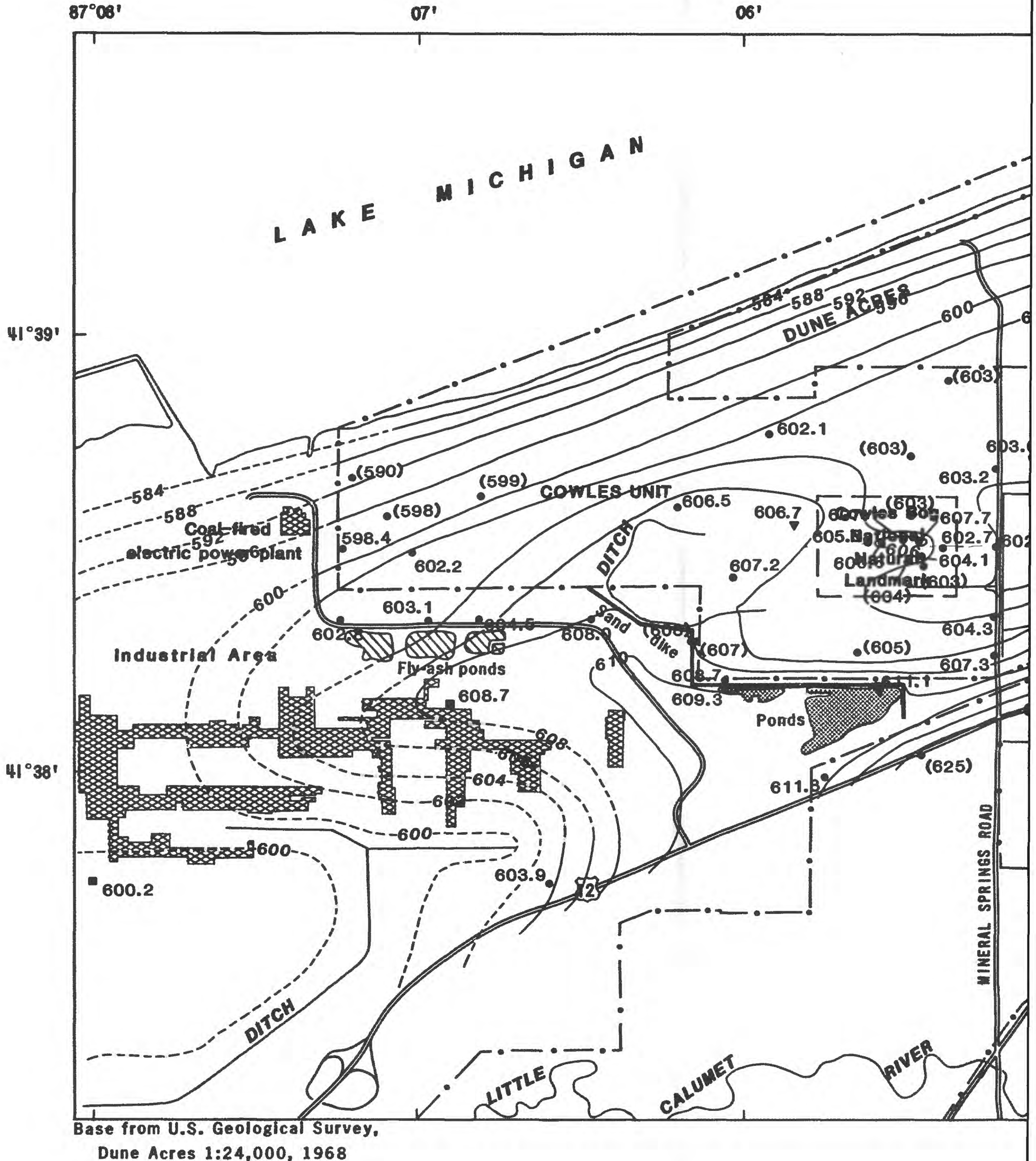
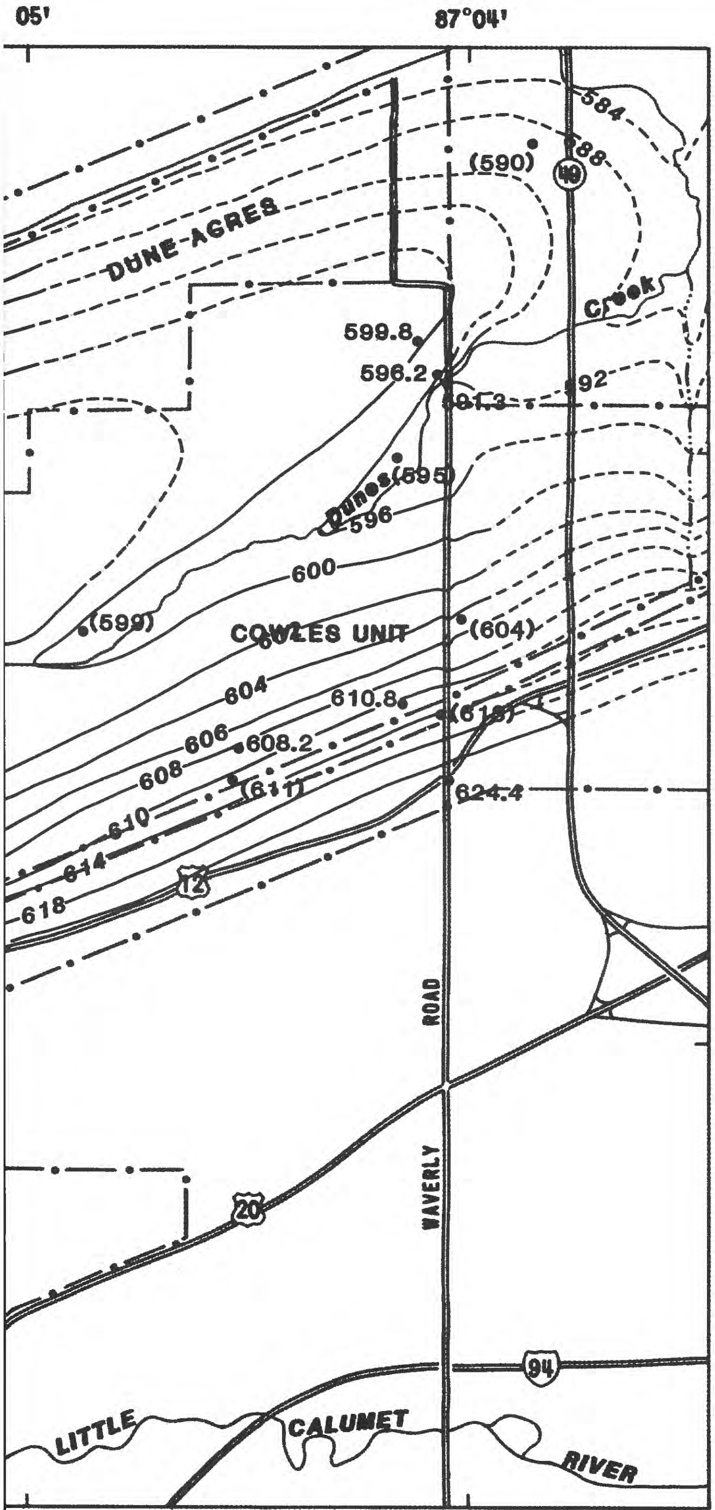


Figure 6.– Water-table altitude, April 1983.



EXPLANATION

—614—	Altitude of water table. Contour intervals 2 and 4 feet. Dashed where approximate. Datum is sea level
●	U.S. Geological Survey observation well
■	Industrial observation well
▼	Surface-water measurement site
608.2	Water-level altitude in feet above sea level
(604)	Estimated water-level altitude in feet above sea level

Sealing the settling ponds has changed shallow ground-water flow in two main respects. First, comparison of figures 5 and 6 shows that before the ponds were sealed the seepage mound below the ponds acted as a north-south flow divide in the industrial area. This divide has moved to the south since the ponds were sealed. Second, dissipation of the seepage mound has lowered water levels beneath the settling ponds and in the Cowles Unit just north of the settling ponds.

WATER-LEVEL CHANGES BEFORE AND AFTER SETTLING-POND SEEPAGE

Settling-pond seepage from 1967 to 1980 raised ground-water levels in adjacent Park Service lands. As seen in aerial photographs from 1938 to 1967, intradunal, lowland basins 1, 2 and 3, north of the settling ponds (fig. 3), contained some standing water, probably during periods of high rainfall or snowmelt (Hendrickson, W. H., Indiana Dunes National Lakeshore, written commun., 1978). Beginning in 1967, settling-pond seepage began raising the water table above the bottom elevations of these basins, causing perennial flooding. Aerial photographs and utility company records show basins 1 and 2 as being perennially flooded from 1967 to 1969, and basins 1 through 5 as being perennially flooded from 1969 to mid-1980.

Pond sealing in 1980 and 1981 consisted of dewatering a pond, removing any accumulated fly-ash, and lining the pond with a one-foot thick layer of clay and a 0.12 in. thick PVC liner. Sealing of the ponds halted seepage, and dewatering during sealing operations hastened the decay of the seepage mound. Hydrographs for wells G2 and 26 (fig. 7) show sharp declines of about 10 ft in the spring of 1980 that correspond to the beginning of pond-sealing operations. Water-level declines following pond sealing (fig. 8) were greatest near the westernmost settling pond indicating that more seepage occurred at that end of the settling pond area than at the east end. No water-level declines greater than those expected from seasonal fluctuations are apparent in the Great Marsh or in the shoreline dune complex at distances greater than approximately 3,000 feet east or north of the settling ponds.

Quarterly water-level observations from mid-1980 through 1983 and aerial photographs from May 1984 showed intradunal basins 1 through 5 as being dry all of the time with the exception of occasional standing water in basin 2.

CHANGES IN GROUND-WATER QUALITY, 1980-84

The quality of shallow ground water near the settling ponds was extensively investigated by Hardy (1981) from September 1976 to May 1978, a period before the ponds were sealed. Hardy described a plume of leachate in the shallow ground water on Lakeshore property immediately north of the settling ponds. The plume had higher concentrations of calcium, sulfate, potassium, and some trace constituents (boron, cadmium, fluoride, iron, manganese,

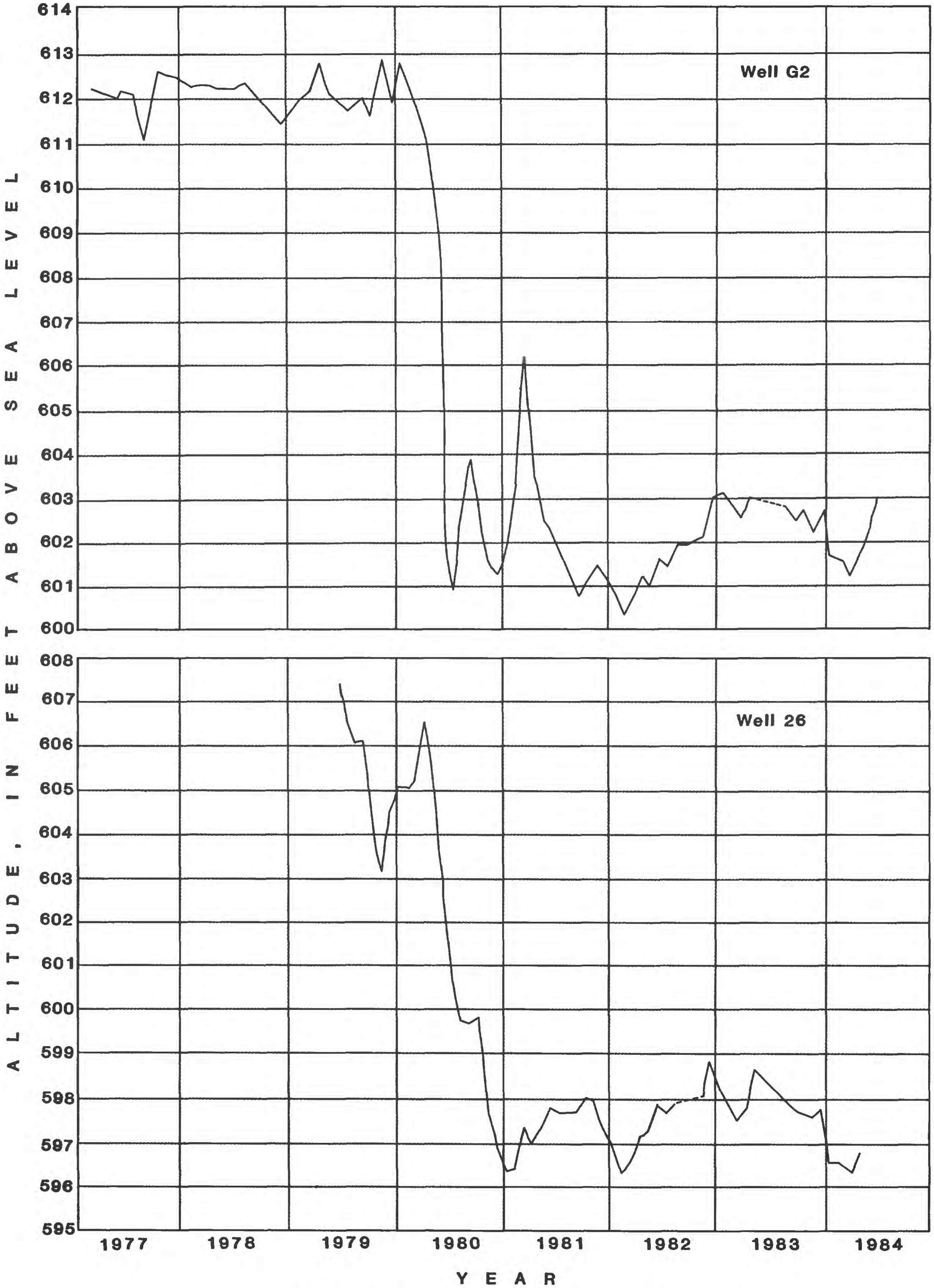


Figure 7.-- Hydrographs for wells G2 and 26.

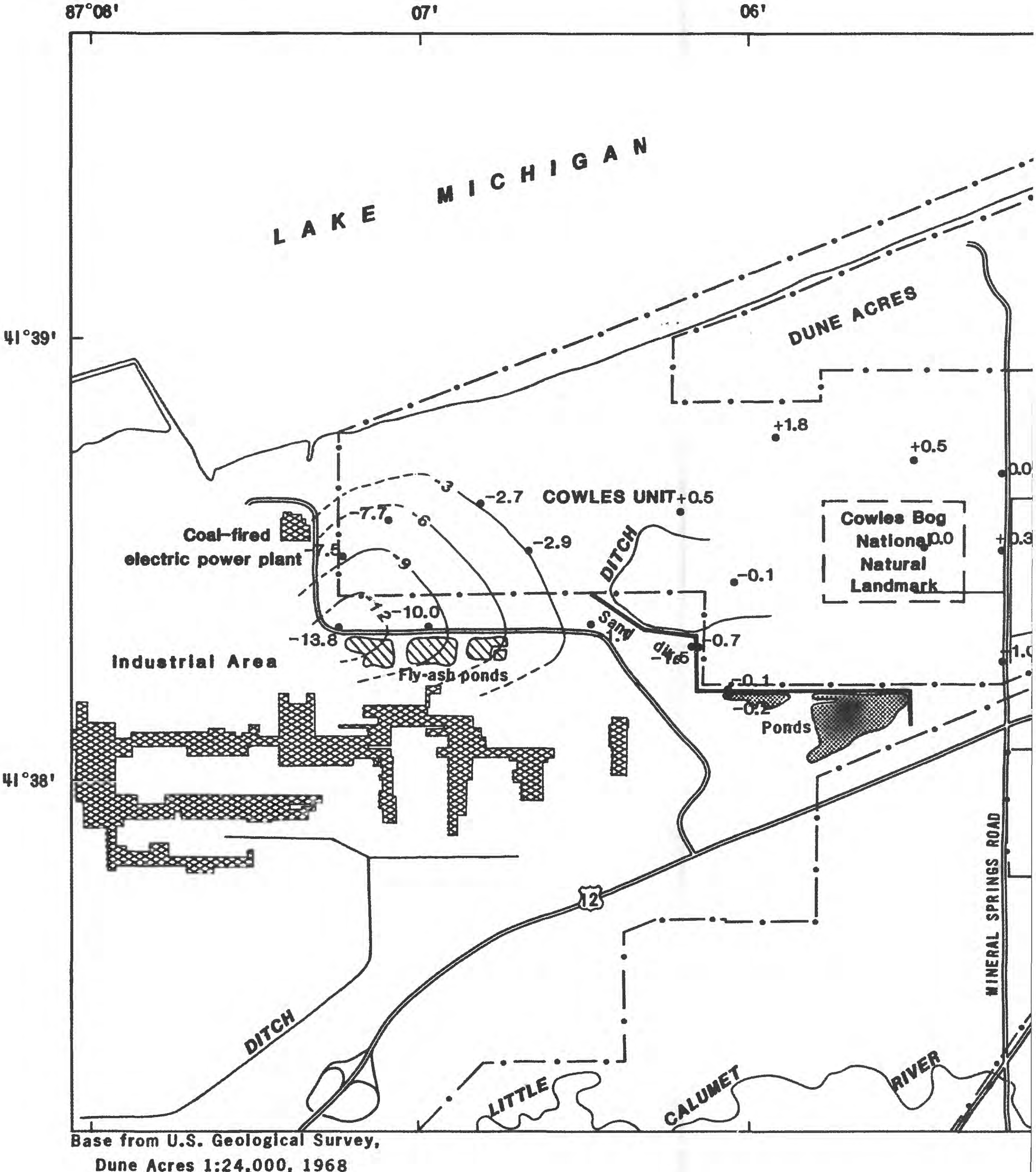
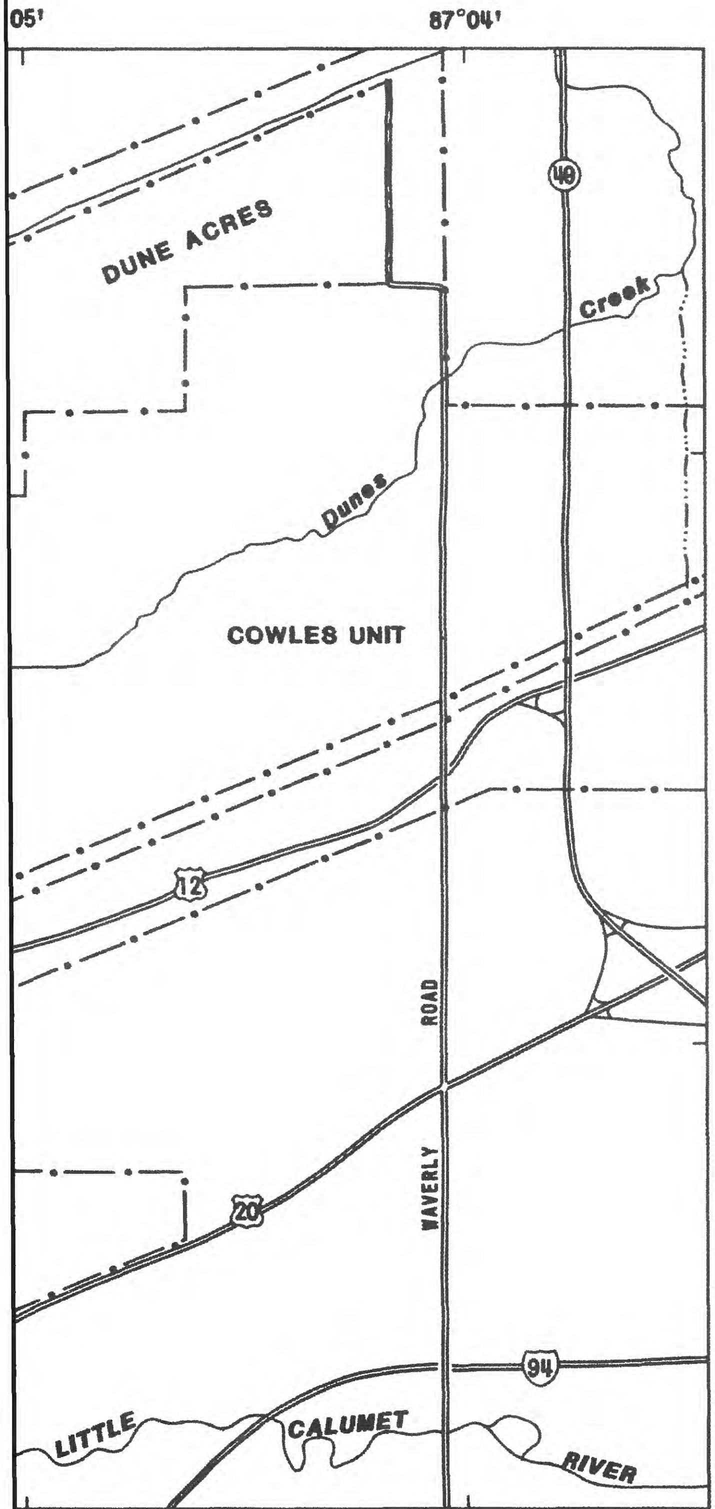


Figure 8.– Changes in water-table altitude, February 1980 to July 1982.



EXPLANATION

—-6— Line of equal change in water-table altitude. Interval 3 feet. Dashed where approximate

• U.S. Geological Survey well

-10.0 Change in water level

0 — 1 MILE

0 — 1 KILOMETER

molybdenum, nickel, zinc, arsenic, and strontium) than shallow ground water outside the area of the plume. To monitor concentration changes as the seepage mound declined after the settling ponds were sealed, samples were collected from selected wells and analyzed for these elements in February, May and August of 1981.

Beginning in October 1981 a more modest monitoring program was begun. Samples were collected in spring and fall from 3 wells north of the ponds and analyzed for arsenic, boron, cadmium, molybdenum and zinc. These elements were chosen because of their potential toxicity to plants and because, during at least one sampling, the concentrations of all except arsenic exceeded maximum concentration limits recommended by the U.S. Environmental Protection Agency or the National Academy of Engineering (Hardy, 1981, p. 31). Specific conductance, pH, and temperature were measured in the field. Analysis for the major ions was discontinued as enrichment of these constituents was not considered a threat to the parkland biota.

Analysis of samples collected from February 1981 through October 1984 (table 1) indicate that concentrations of cadmium have remained constant while concentrations of boron, molybdenum, zinc and arsenic downgradient of the settling ponds have decreased, although at different rates for each element at different sites. However, the concentrations of boron, molybdenum and arsenic have not decreased below background levels based on mean concentrations as computed from 11 samples collected in 1976 through 1978 at well 106, away from the flow path of settling-pond seepage (Hardy, 1981). For example, boron concentrations in well G2 (fig. 9) show a rapid decline immediately after completion of sealing operations in 1981 followed by a more gradual decline. Boron concentrations at well G4 declined more gradually than at well G2 and concentrations at well 23 show no significant change over the period of record. Arsenic concentrations at all 3 wells showed no significant changes and remained above background levels.

Molybdenum concentrations at wells G4 and 23 (fig. 10) show no apparent change over the period of record. However, molybdenum concentrations at well G2 have fluctuated appreciably. Although the transient behavior of metal concentrations in fly-ash leachate has been documented by Theis and others (1978) and Jennings (1983), the changes in molybdenum concentrations at well G2 cannot be readily explained in terms of their models and observations. Local flow reversals which occurred immediately south of the settling ponds during dissipation of the seepage mound may have contributed to these fluctuations, however no similar fluctuations in the concentration of other elements were observed.

Nonetheless, concentrations of boron, molybdenum, and arsenic in wells G2, G4 and 23 are higher than those in wells outside the area of influence of the seepage mound. These higher concentrations probably indicate that these constituents have been either sorbed or precipitated on the aquifer materials during the seepage and are now being leached back into the ground water.

Table 1.--Concentrations of arsenic, boron, cadmium, molybdenum and zinc in water samples from selected wells, 1981-84

[Concentrations are in micrograms per liter; NS, not sampled; NA, no analysis; <, less than]

	Well G2					Well G4					Well 23				
Collection date	Arsenic	Boron	Cad-mium	Molyb-denum	Zinc	Arsenic	Boron	Cad-mium	Molyb-denum	Zinc	Arsenic	Boron	Cad-mium	Molyb-denum	Zinc
02/19/81	6	13,000	<1	190	30	3	2,900	2	15	30	3	630	2	41	10
05/20/81	2	11,000	<1	71	20	1	3,000	2	34	90	1	730	<1	23	8
08/26/81	2	6,100	1	950	<10	2	2,400	31	80	70	2	1,000	1	28	40
04/20/82	4	3,800	1	300	10	NS	NS	NS	NS	NS	3	960	<1	22	20
10/28/82	8	1,900	<1	1,400	30	NS	NS	NS	NS	NS	3	990	<1	28	20
04/26/83	6	2,100	1	550	<10	NS	NS	NS	NS	NS	2	890	1	17	10
10/25/83	5	1,400	1	360	10	2	410	1	70	270	1	750	1	32	<10
05/01/84	11	1,300	2	310	<10	3	290	77	70	5,000	2	720	2	41	<10
10/23/84	2	610	1	NA	10	2	220	230	63	2,800	3	380	1	55	<10

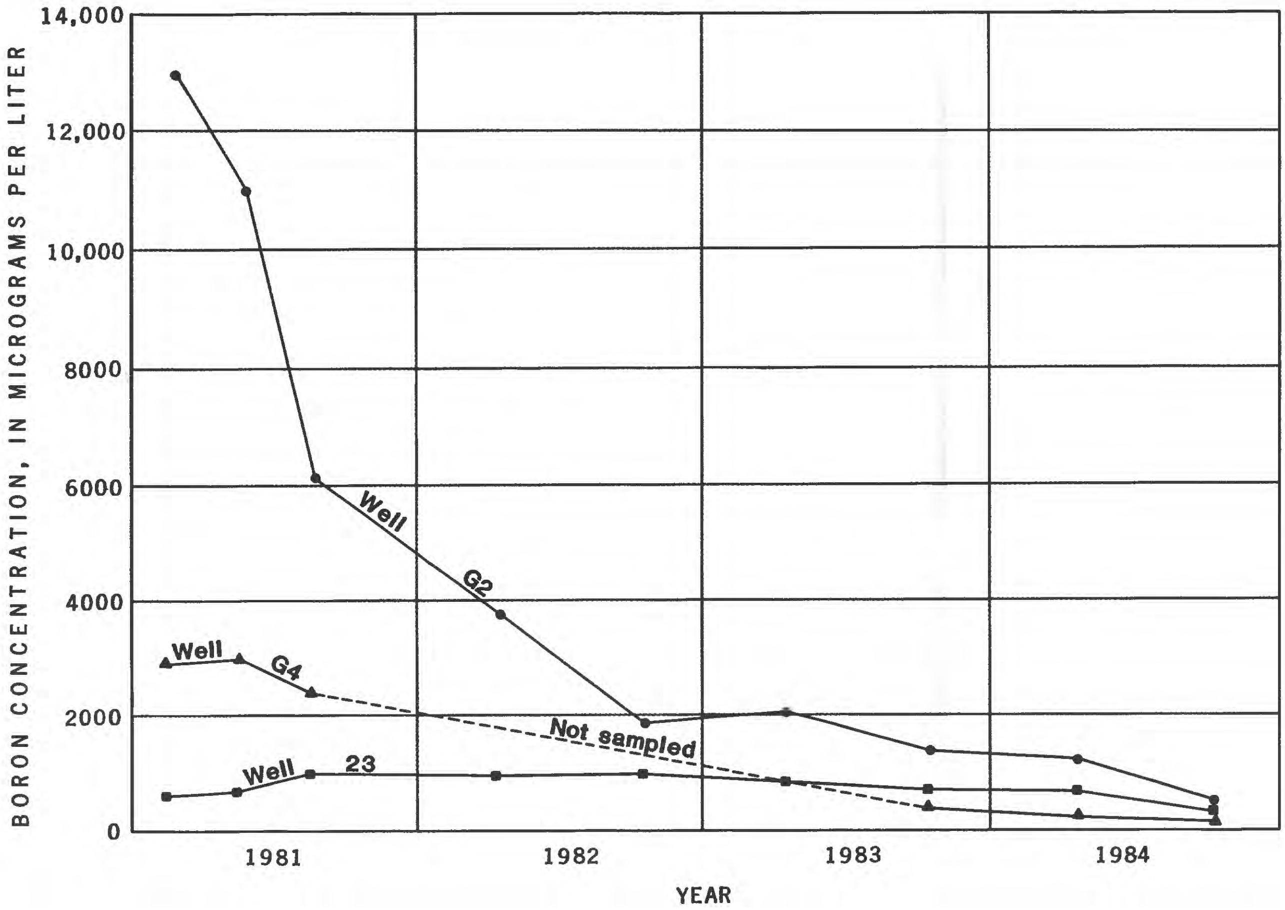


Figure 9.-- Boron concentrations in water from selected wells, 1981-84.

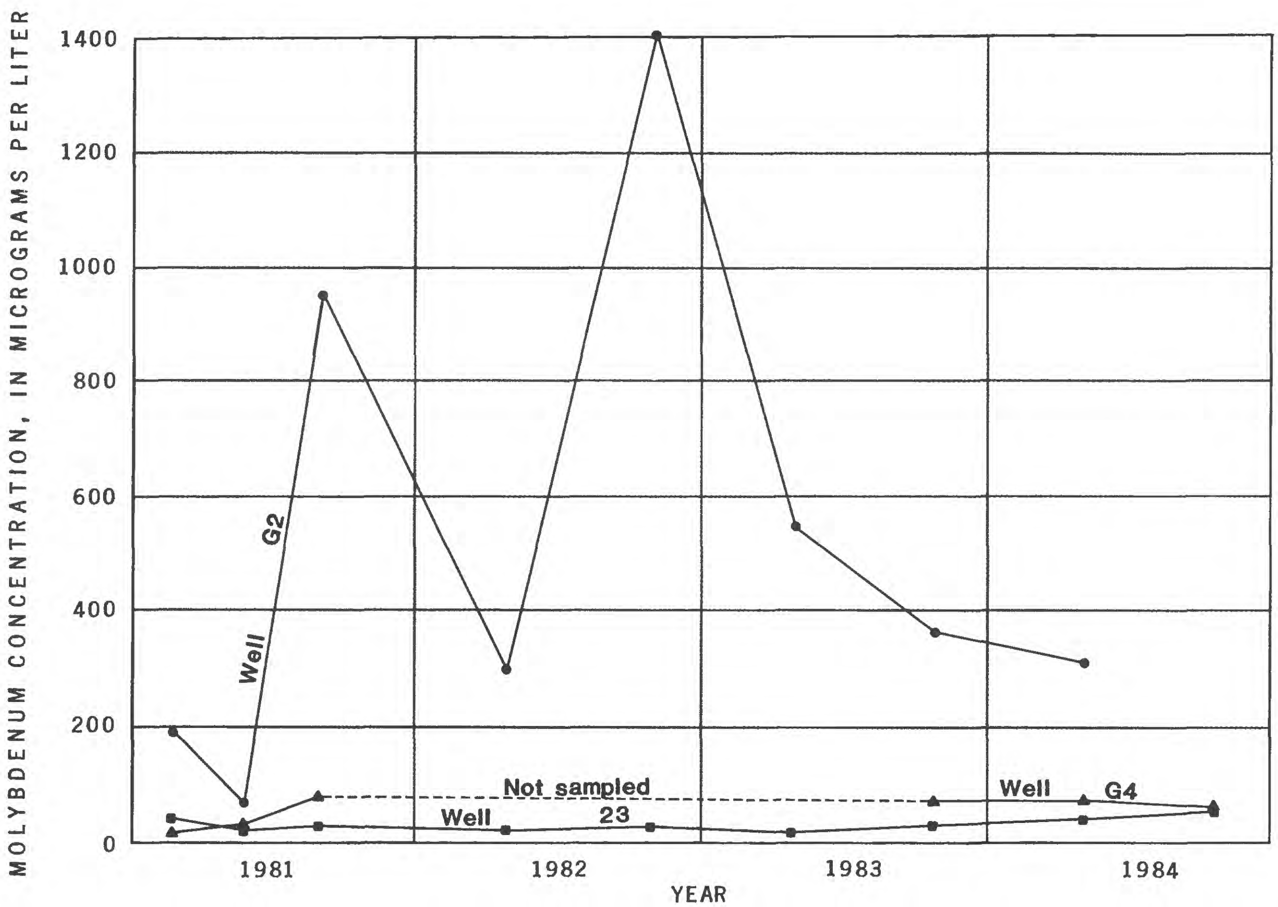


Figure 10.– Molybdenum concentrations in water from selected wells, 1981-84.

SUMMARY AND CONCLUSIONS

The surficial aquifer in the Cowles Unit of Indiana Dunes National Lakeshore comprises dune, beach and lacustrine sands which are overlain by several feet of peat and muck in wetland areas. Shallow ground water in the eastern half of the Cowles Unit flows to Dunes Creek and its tributaries in the Great Marsh from water-table highs in surrounding dune complexes. Shallow ground water discharges to Lake Michigan north of the water-table divide in the shoreline dune complex. In the western half of the Cowles Unit, ground water south of this divide flows to a ditch system in the industrial area which drains westward to the Little Calumet River.

Seepage from nearby industrial settling ponds constructed in 1967 raised water levels in the surrounding area and caused perennial flooding of several lowlands in the Cowles Unit north of the ponds. Decline and dissipation of the seepage mound after the pond bottoms were sealed in 1980-81 lowered water levels near the settling ponds by 6 to 14 feet. The extent of the seepage mound in the Cowles Unit was limited to an area within approximately 3,000 feet of the settling ponds and indicates that seepage from the settling ponds prior to sealing had no apparent effect on water levels in the Great Marsh.

Although the concentration of boron in shallow ground water downgradient of the ponds has decreased since the settling ponds were sealed, the concentrations of arsenic and molybdenum show no consistent trends in time. However, the concentrations of all these constituents have remained above background levels, which suggests that they had previously sorbed or precipitated onto aquifer materials and are now being leached back into the ground water.

REFERENCES CITED

Cook, S. G., and Jackson, R. S., 1978, The Bailly Area of Porter County, The final report of a geohistorical study undertaken on behalf of the Indiana Dunes National Lakeshore: Robert Jackson and Associates, 110 p.

Gillies, D. G., and Lapham, W. W., 1980, Reassessment of the effects of construction dewatering on ground-water levels in the Cowles Unit, Indiana Dunes National Lakeshore, Indiana, supplement to WRI 78-138: U.S. Geological Survey Open-File Report 80-1105, 50 p.

Hardy, M. A., 1981, Effects of coal fly-ash disposal on water in and around the Indiana Dunes National Lakeshore, Indiana: U.S. Geological Survey Water-Resources Investigations 81-16, 64 p.

Hendrickson, W. H., and Wilcox, D. A., 1979, Relationships between some physical properties and the vegetation found in Cowles Bog National Natural Landmark, Indiana: Proceedings of the Second Conference on Scientific Research in the National Parks 5:642-666.

Jennings, A. A., 1983, Groundwater Solute Transport Modeling: 1983 Indiana Water Resources Association Symposium Proceedings.

Marie, J. R., 1976, Model analysis of effects on water levels at Indiana Dunes National Lakeshore caused by construction dewatering: U.S. Geological Survey Water-Resources Investigations 76-82, 32 p.

Meyer, William, and Tucci, Patrick, 1979, Effects of seepage from fly-ash settling ponds and construction dewatering on ground-water levels in the Cowles Unit, Indiana Dunes National Lakeshore, Indiana: U.S. Geological Survey Water-Resources Investigations 78-138, 95 p.

Rosenshein, J. S., and Hunn, J. D., 1968, Geohydrology and ground-water potential of Porter and LaPorte Counties, Indiana: Indiana Department of Conservation, Division of Water Resources Bulletin 32, 22 p.

Shedlock, R. S., 1983, Hydrogeology of Indiana Dunes National Lakeshore--A National Park in an Urban-Industrial Setting: Abstracts with Programs, Geological Society of America, Annual Meeting, vol. 15, no. 6, p. 685.

Theis, T. L., Westrick, J. D., Hsu, C. L., and Marley J. J., 1978, Field investigation of trace metals in groundwater from fly ash Disposal: Journal of Water Pollution Control Federation, vol. 50, no. 11, p. 2457-2469.

Thompson, T. A., 1985, Lake pleistocene lacustrine sediments of the Cowles Bog area, Indiana Dunes National Lakeshore: Abstracts with programs, Geological Society of America, vol. 17, p. 329.

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