LAB 16

SEYMOUR HAZARDOUS WASTE SITE I: HYDROGEOLOGIC SETTING

OVERVIEW: This series of three integrated lab exercises will provide you with a detailed knowledge of a hydrogeologic environment typical of much of the central and eastern United States. Although the hazardous nature of the site is not typical, it is, unfortunately, not rare. The exercises in these labs are typical of studies that would be conducted initially at such a site when faced with a problem of groundwater contamination.

PURPOSE: Establish the basic hydrogeology of the site by interpreting borehole data.

OBJECTIVES: Learn to work with typical geologic logs to derive subsurface information.

Make a structure contour map of the bedrock surface.

Construct two geologic cross sections to show three-dimensional variations in lithology.

Use these products to interpret and describe the hydrogeology of the site.

INTRODUCTION

Seymour Recycling Corporation operated a solvent-recovery and solvent-recycling plant at Seymour, Indiana, from 1970 to 1979. In 1979, the corporation went into bankruptcy and abandoned the location, leaving 98 large tanks and approximately 50,000 drums of organic chemicals on the site. For the next four years, an unknown amount of liquid synthetic organic compounds leaked into the soil from deteriorating drums before they were all removed in 1983. A substantial amount of these organic compounds percolated into the aquifer and threatened private water-supply wells north of the site and at least one municipal well less than a quarter of a mile to the northeast.

Site Geology

The Seymour hazardous waste site is in south central Indiana (Fig. 16.1). The general geology in this area consists of a blanket of unconsolidated periglacial deposits overlying shale bedrock. The unconsolidated sediments consist of alluvium of glacial sluiceway origin and lacustrine silts and clays. The shale bedrock is impermeable.

Hydrogeologic Maps and Sections

One of the most important methods of displaying and interpreting hydrogeologic data is through the use of maps and cross sections. These graphical representations of data also provide a way for the hydrogeologist to present information and conclusions to a nongeologist.

The information used to make cross sections and hydrogeologic maps comes chiefly from wells. When a well is drilled or a soil boring is made, a descriptive log of the strata encountered is usually made. The log is sometimes made by the well driller, in which case it is referred to as a driller's log. Because the educational level and understanding of geology varies widely from one driller to another, the quality of their well logs also varies. In most instances, a geologic log made by a geologist will provide more reliable information. Geophysical logs made using various borehole techniques may also be used to discover the nature of subsurface formations.

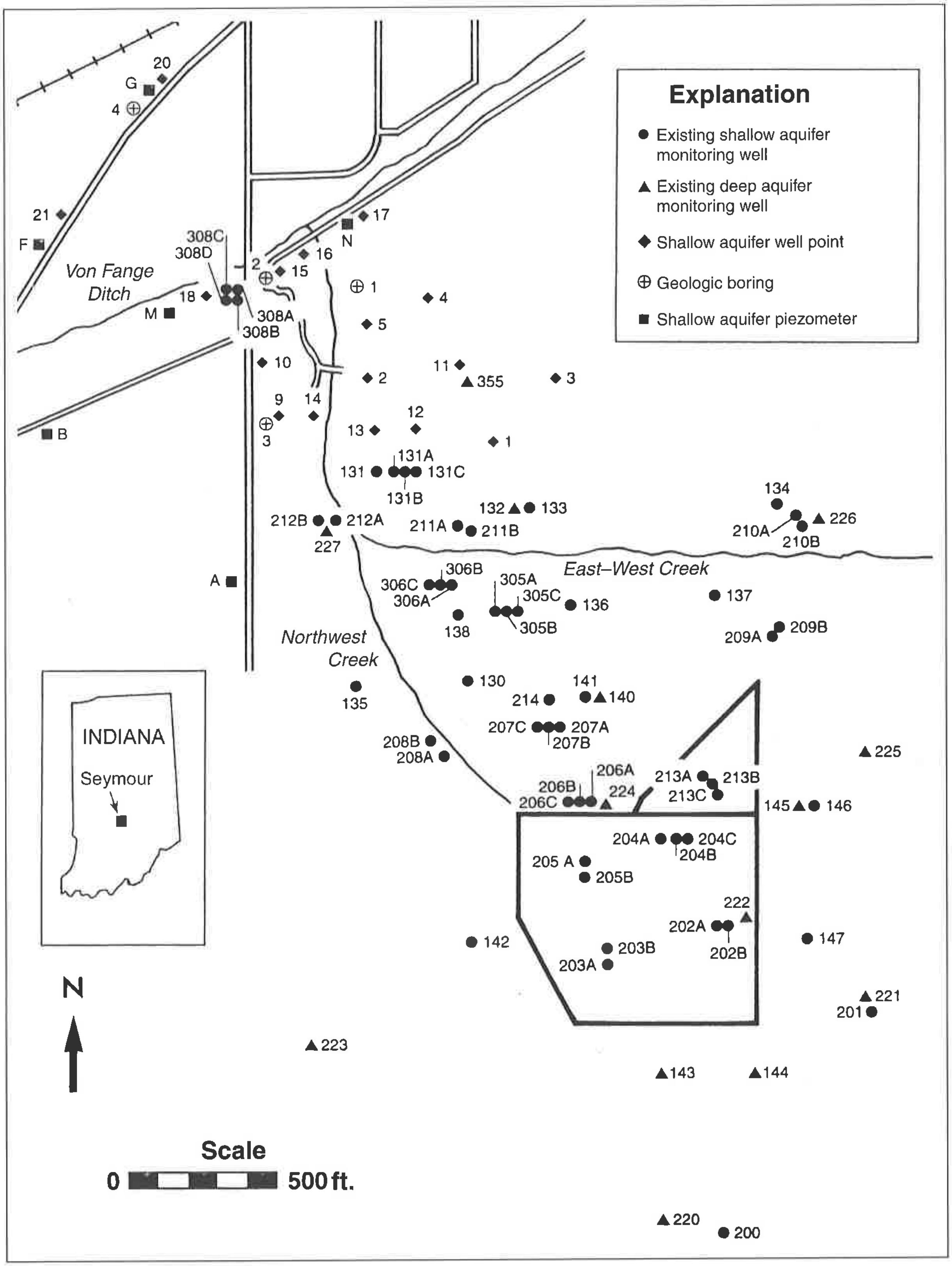

Figure 16.1—Location of Seymour Recycling Corporation site (heavy outline) at Seymour, IN (inset map).

Structure contour maps are contour maps of the surface of specific geologic units. The most common example is the bedrock contour map. The elevation of the unit at each control point is marked on a map. In some instances, the control point may indicate that the unit is known to be deeper than an indicated value, but the exact elevation is not known. Typically, the geologist will know the surface elevation of the control point, and from a well log showing the depth to the geologic unit, the elevation of the unit can be determined.

Geologic cross sections are constructed from information obtained from well logs and outcrops. Cross sections go from one control point to the next, generally following in the same direction, but not necessarily in a straight line. The distance from one control point to the next is measured on a map, and this constitutes the horizontal distance between wells on the cross section. At each control point, the well log is constructed in a vertical direction, typically with the scale in the vertical dimension much larger than the horizontal scale.

PROCEDURES

Structure Contour Map of Bedrock

1. Make a structure contour map of the bedrock surface on the site base map, Figure 16.2 on page 125.

   Data will come from the geologic logs and from some of the temporary well points. Datum for all elevations is mean sea level, and all measurements of elevation and depth are in feet.

   Use a contour interval of 2 ft.

2. Briefly describe the bedrock topography.

Geologic Cross Sections

3. Using the information in the borehole geologic logs, make two geologic cross sections.

   Cross section 1—a northeast-looking section from GB2 to GB3 to 227 to 224 to 222 to 221.

   Cross section 2—a northwest-looking section from 223 to 224 to 209 to 226.

   Show the two lines of section on Figure 16.1.

   Horizontal scale: 1 in = 500 ft; vertical scale: 1 in = 20 ft; vertical exaggeration: 25.

Hydrogeologic Interpretation

4. Using your map and sections together, consider whether or not the paleotopography was significant—that is, did it appear to influence the Quaternary sedimentation?

5. Interpreting your cross sections, describe the hydrostratigraphy of the site.

   To facilitate your interpretation, consider these questions:

   How many units are there, or does the number vary within the site?

   Is there one aquifer, or is there more than one?

   Does the geometry of the aquifer(s) change within the site?

   If there may be more than one aquifer, how do you think they might relate? Would they be clearly separated by a good confining layer, or might there be flow between them?

6. On your cross sections, outline the hydrostratigraphic units, using a different line symbol or line weight, and label the units.

GEOLOGIC LOGS OF BORINGS
SEYMOUR HAZARDOUS WASTE SITE[1]

GB-1	GE (ground elevation) 562
0–6	fine silty, clayey sand (SM-SC)[1]
6–56	medium to coarse sand (SP)
56–58	silt (ML)

GB-2	GE 562
0–7	clay and silty sand (SM-CL)
7–70	fine to medium sand (SP)
70	shale bedrock

GB-3	GE 565
0–7	fine silty sand (SM)
7–60	fine to coarse sand (SP)
60–61	clay and silt (ML-CL)

GB-4	GE 566
0–7	fine to medium sand, silty (SM)
7–68	sand, medium to coarse (SP)
68–70	shale bedrock

209	GE 564.2
0–6.5	silty sand to sandy clay (SM-SC)
6.5–39.5	medium to coarse sand, clean (SP)
39.5–41	silt (ML)

220	GE 573.2
0–5.8	medium to fine sand, silty (SM-SP)
5.8–9.4	silt with fine sand (ML)
9.4–20.3	medium sand, slightly silty (SM-SP)
20.3–68	interbedded silt and clayey silt (ML-CL) with occasional fine sand layers (SM)
68–81	coarse to fine sand, some gravel (SM-SP)
81–81.5	red shale bedrock

221	GE 569.8
0–10.5	fine to medium sand, silty to clayey (SC-SP)
10.5–33	coarse to fine sand (SP-SM)
33–55.5	interbedded silt, clayey silt and sandy clay (ML-CL)
55.5–65	coarse to fine sand (SP)
65–76.6	gravel to fine sand (GW-GM)
76.6–77.1	red shale bedrock

222	GE 568.0
0–3	artificial fill
3–19.5	fine to medium sand, silty to clayey (SC-SP)
19.5–22	silt with clay (ML-CL)
22–26	fine sand (SM)
26–51.5	silt with trace of clay (ML-CL)
51.5–63.5	medium sand (SM)
63.5–73.5	medium gravel to sand (GP)
73.5–74	red shale bedrock

223	GE 570.5
0–9	sandy, silty clay (SC)
9–18.5	medium sand, slightly silty (SP)
18.5–68.5	interbedded silt and clayey silt (ML-CL)
68.5–79.5	medium to coarse sand and gravel (SP-GP)
79.5–80	shale bedrock

224	GE 564.5
0–5	fine to medium sand, silty (SM)
5–15.7	coarse to fine sand, slightly silty (SM-SP)
15.7–18	silt (ML)
18–39.5	fine to medium sand, slightly silty (SM-SP)
39.5–65.5	interbedded silt (ML) and clayey silt (ML-CL)
65.5–69.5	medium to coarse sand (SP)
69.5–70	shale bedrock

[1]Parenthetic annotations are soil designations in the commonly used Unified Soil Classification System (USCS), a system based on grain size, sorting, and plasticity (U.S. Army Engineer Waterways Experiment Station, 1960). The system is described in any basic textbook on geotechnical engineering.

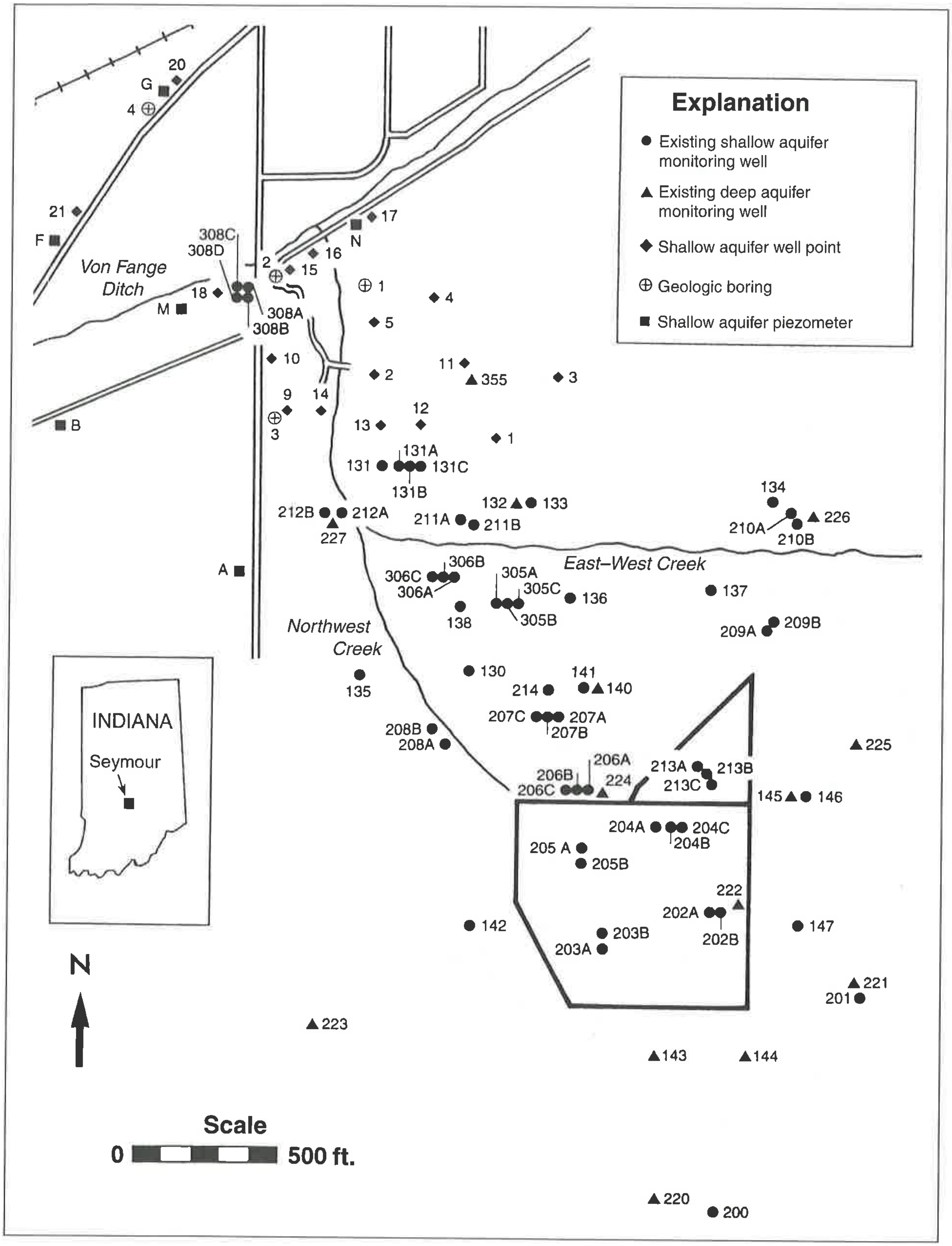

Figure 16.2—Bedrock structure contour map, Seymour hazardous waste site (contour interval 2 ft).

225	**GE 565.8**
0–6.5	sandy clay (SC)
6.5–43	medium to coarse sand (SP)
43–64.5	interbedded silt (ML) and silty clay (ML-CL)
64.5–77.5	medium to coarse sand with gravel (SP-GP)
77.5–78	shale bedrock

226	**GE 564.9**
0–6.5	silty to clayey sand (SM-SC)
6.5–37.2	medium sand, trace of silt (SP)
37.2–54	sandy, silty clay (CL) interbedded with silt (ML)
54–57	sand with silt (SM-SP)
57–74.5	medium to coarse sand with gravel (SP-GP)
74.5	shale bedrock

227	**GE 562.6**
0–6.5	artificial fill
6.5–9	medium to coarse silty sand (SM)
9–16.5	medium sand to medium gravel (SP-GP)
16.5–25.5	coarse to medium sand, slightly silty (SM-SP)
25.5–27	sandy clay (SC)
27–36	medium to fine sand (SP)
36–66.2	clay, plastic (CH) to clayey silt (CL-ML)
66.2–67.5	medium gravel to fine sand (GP-SP)
67.5–68	bedrock

BEDROCK SURFACE ELEVATIONS FROM TEMPORARY WELL POINTS

Well Point Number	Elevation	Bedrock Elevation
10	566.0	494.0
15	562.3	492.3
16	561.8	492.8
17	562.3	488.8
18	559.8	494
20	564	496
21	558.7	493.2

LAB 17

SEYMOUR HAZARDOUS WASTE SITE II: GROUNDWATER FLOW

OVERVIEW: This is the second in a series of three integrated lab exercises that will familiarize you with a hydrogeologic environment typical of much of the central and eastern United States. The exercises in these labs are typical of studies that would be conducted initially at such a site when faced with a problem of groundwater contamination.

PURPOSE: Determine groundwater flow at the Seymour hazardous waste site.

OBJECTIVES: Determine the number and type of aquifers at the site.

Establish the nature and extent of a hydrostratigraphic unit by making an isopach map.

Map the potential distribution in the aquifer(s), and determine groundwater flow directions.

HYDROGEOLOGIC MAPS

The water level measured in a well is a measure of the hydraulic head (or potential) in the aquifer at the screened zone of the well. Wells that set screens into more than one hydrostratigraphic unit have a water level that reflects the combination of the water levels of the different screened zones; the data from such wells are difficult to use. Wells in unconfined aquifers show the position of the water table. Wells screened into confined aquifers indicate the position of the potentiometric surface. Clusters of several wells at the same location, but screened at different depths, can show the vertical component of groundwater movement.

Following are two additional types of hydrogeologic maps that are made.

Isopach maps show the thickness of a particular geologic unit. They are constructed by finding the thickness of the unit at each of the control points, either outcrops or well logs. The thickness at each control point is located on a map, and a contour map is constructed on the basis of the hydrostratigraphic unit thickness.

Potentiometric surface maps show the distribution of head, or potential, throughout an aquifer. They are made by plotting the locations of wells on a base map, and water levels, measured within a short period of time, are plotted at the well locations. For confined aquifers, the potentiometric surface is contoured from water levels in wells screened in the same aquifer, and contour lines may be drawn without regard to the influence of surface hydrologic features.

For unconfined aquifers, the potentiometric surface is the water table. Water levels are measured within a short period of time (within a few days, with no major precipitation during the measurement period). Streams, lakes, and rivers that might be linked to the water table are also mapped, and contours must be drawn keeping in mind how these surface water features may impact the water table.

PROCEDURES

Define Aquifers

1. In the last lab, you made an interpretation of the hydrostratigraphy of the site. Did you suggest there is one or two aquifers? If more than one, were the aquifers part of the same flow system—that is, are they hydraulically connected—or are there two independent flow systems?

2. If you could measure standing water levels in two wells side by side, one open at depth and the other only shallow, how would this information help you answer this question?

   (a) If the two levels were exactly the same, what would you infer?

   (b) If the level in the deep well were higher, what would you infer?

3. Return to the cross sections you made in the last lab, and plot on them the water levels recorded April 8, 1990, in each of the deep wells (Water Levels in Deep Wells, April 8, 1990 [p. 132]). Use a red line to connect the water levels. Note that for GB-2 at the northwest end of the section, you can use data from 308-D nearby. Similarly, you can get information from shallow wells that were drilled and monitored next to each of the deep wells. Referring to the site map, you can see at the northwest end, for example, 308-A, a shallow well, is adjacent to 308-D.

   Plot data from Water Levels in Shallow Wells, April 8, 1990 (p. 134), on the cross sections also, using blue for these measurements.

   Considering the relationship of the upper potentiometric surface to the stratigraphy, is the upper aquifer confined, unconfined, or semiconfined?

4. Describe and interpret the relationship of the two potentiometric lines.

Construct an Isopach Map of the Confining Layer

1. Once you have established the relationship of the upper and lower aquifers and your cross section 1 shows some limitation to the separateness of these aquifers, it would be instructive to determine the three-dimensional nature of the confining layer. In addition to the geologic logs, some information is available from a temporary well point program (p. 132). Using both of these data sources, construct an isopach map for the confining layer on the site base map, Figure 17.1.

2. Describe the geometry of the confining layer, and suggest an explanation for it.

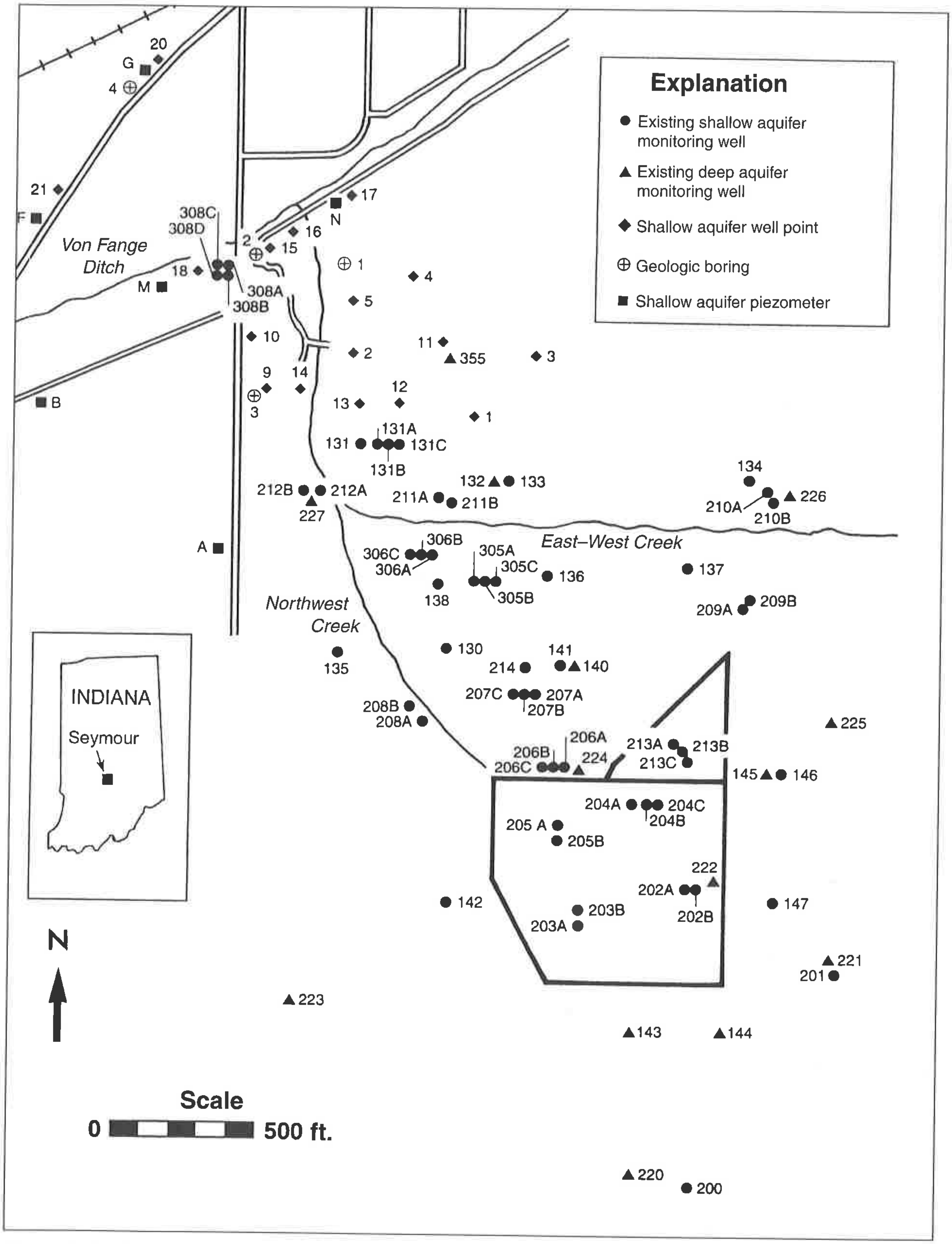

Figure 17.1—Isopach map of the confining layer, Seymour hazardous waste site (contour interval, 5 ft).

Show the Groundwater Flow in the Upper Aquifer

1. Construct a map of the potentiometric surface of the upper aquifer on Figure 17.2, using a contour interval of 1 ft. With blue arrows, draw sufficient flow lines to show the groundwater flow throughout the site.

2. One could use this map to estimate actual travel paths of groundwater. For example, where would you expect groundwater to flow from the area of well 204? Draw a green flow line from 204B to the Von Fange Ditch. Where along the ditch (nearest which well) would you expect this flow to occur?

3. Where does recharge to this aquifer probably occur?

Show the Groundwater Flow in the Lower Aquifer

1. Construct a map of the potentiometric surface of the lower aquifer on Figure 17.3 on page 133, using a contour interval of 1 ft. With red arrows, draw sufficient flow lines to show the groundwater flow throughout the site.

2. Where does recharge probably occur?

3. Compare the heads from the two potentiometric maps north of the Von Fange Ditch. What do you think is happening in this area?

Summary of Hydrogeology

Summarize, in a few paragraphs, the hydrogeology of the site, making reference to your maps and sections.

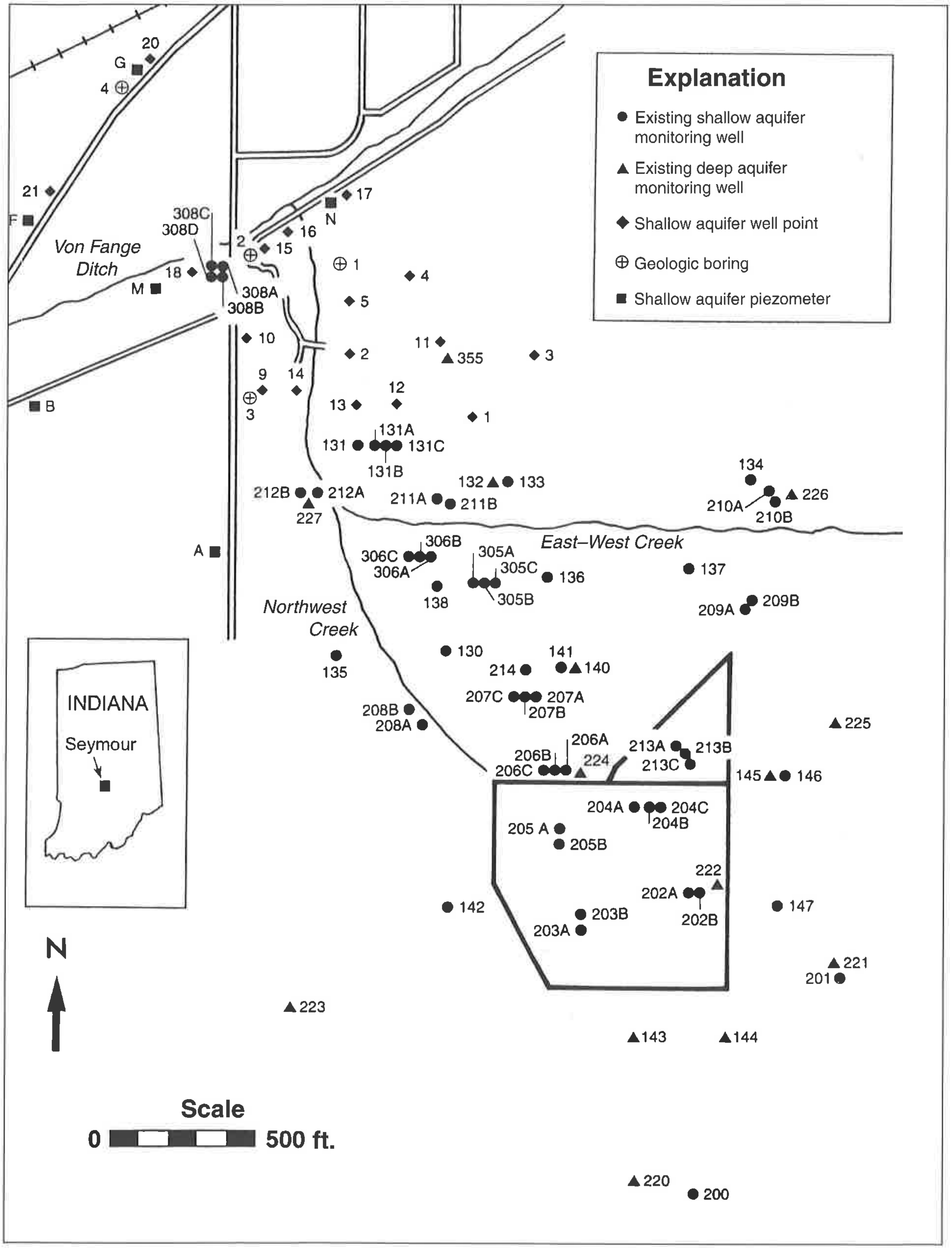

Figure 17.2—Potentiometric surface and groundwater flow in the upper aquifer (contour interval, 1 ft).

SUPPLEMENTARY CONFINING LAYER DATA FROM TEMPORARY WELL POINTS			
Well Point	**Ground Elevation**	**Bedrock Elevation**	**Top of Confining Layer Elevation**
1	552	not encountered	502
2	561.7	not encountered	501.7
3	563.1	not encountered	503.1
4	562.7	not encountered	503.7
5	560.9	not encountered	503.9
9	565.5	not encountered	505.5
10	566.0	494.0	506.0
11	562.7	not encountered	501.7
12	562.2	not encountered	503.2
13	562.4	not encountered	507.4
14	562.2	not encountered	507.2
15	562.3	492.3	not found
16	561.8	492.8	not found
17	562.3	488.8	not found
18	559.8	494	not found
20	564	496	not found
21	558.7	493.2	not found

WATER LEVELS IN DEEP WELLS April 8, 1990	
Well	**Water-Level Elevation**
132	556.80
140	556.65
145	556.49
220	551.59
221	550.69
222	551.15
223	550.82
224	556.32
225	556.64
226	556.91
227	555.34
308D	555.43
355	556.62

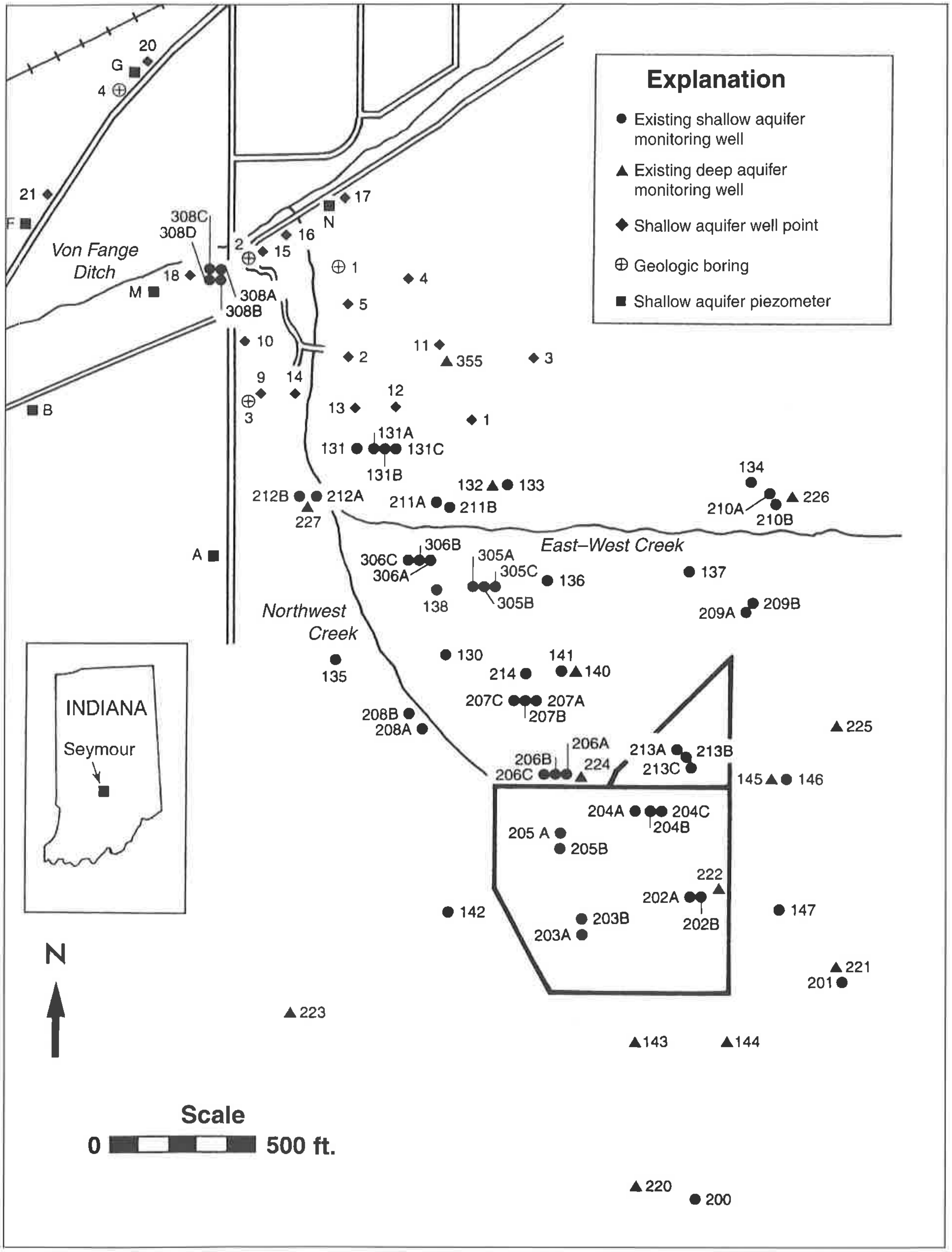

Figure 17.3—Potentiometric surface and groundwater flow in the lower aquifer (contour interval, 1 ft).

WATER LEVELS IN SHALLOW WELLS April 8, 1990	
Well	**Water-Level Elevation**
131	556.40
133	557.37
134	558.55
135	557.50
136	558.04
137	559.01
138	557.79
141	558.79
142	560.18
144	563.67
146	560.31
147	561.15
200	570.11
201	561.75
202A	559.80
203A	560.80
204A	559.78
205A	559.82
206A	559.16
207A	558.46
208A	558.43
209A	559.08
210A	558.72
211A	557.04
212A	556.78
213A	559.41
305A	557.73
306A	556.54
308A	555.43
A	557.92
B	554.83
F	554.22
G	554.77
M	555.03
N	557.10

LAB 18

SEYMOUR HAZARDOUS WASTE SITE III: GROUNDWATER CONTAMINATION

OVERVIEW: This is the third in the series of three integrated lab exercises that will familiarize you with a hydrogeologic environment typical of much of the central and eastern United States. The exercises in these labs are typical of studies that would be conducted initially at such a site when faced with a problem of groundwater contamination.

PURPOSE: Determine groundwater contamination at the Seymour hazardous waste site.

OBJECTIVES: Map the extent of groundwater contamination at the site.

Compare actual path of contaminant flow with your earlier estimate.

Estimate the nature and extent of future aquifer contamination.

Explore possible mitigation and remediation procedures.

Groundwater Contamination

Some of the wells in and around the Seymour Recycling Corporation site were sampled within a seven-month period in 1984–1985. Most of these wells were resampled again in 1989–1990, along with a series of well points that were put in to take additional samples. The samples were analyzed for organic compounds, using gas chromatography and mass spectroscopy. Analytical results for one of these compounds, tetrahydrofuran, are tabulated on the next page.

1. Using data from the earlier survey, construct a map showing the plume of contamination due to tetrahydrofuran on Figure 18.1, page 137. Use equal-concentration lines (contour lines) of 10, 50, 100, 500, 1000, 5000, 10,000, and 50,000 $\mu g/L$.

   Describe the distribution of the tetrahydrofuran. Is it what you would have anticipated?

   Based on the results from this first survey, where would you like additional information?

TETRAHYDROFURAN IN GROUNDWATER AT Seymour Hazardous Waste Site

	Tetrahydrofuran, μg/L	
Well	**1984–1985**	**1989–1990**
131C	—	3100
133	—	ND-50[1]
136	—	290
141	—	2200
143	—	ND-5
145	—	ND-5
200	ND	—
201	ND	—
202A	30,000	6000
203A	9000	2500
204B	20,000	37,000
205A	10,000	ND-1000
206A	12,000	6200
207A	52,000	5900
208	30	—
209A	ND	ND-10
210	ND	—
211A	530	5700
212A	ND	ND-10
213A	7000	ND-10
214	—	2100
305B		2200
306C		9800
WP-1		2000
WP-2		2
WP-3		ND
WP-4		2
WP-8		ND
WP-9		ND
WP-10		ND
WP-11		ND
WP-12		15
WP-13		12
WP-14		6
WP-15		5
WP-16		ND
WP-17		ND
WP-18		17
WP-20		ND
WP-21		ND

Note: [1]ND = none detected, unknown detection limit; ND-50 = none detected, 50 μg/L detection limit; — = no report; WP = well point.

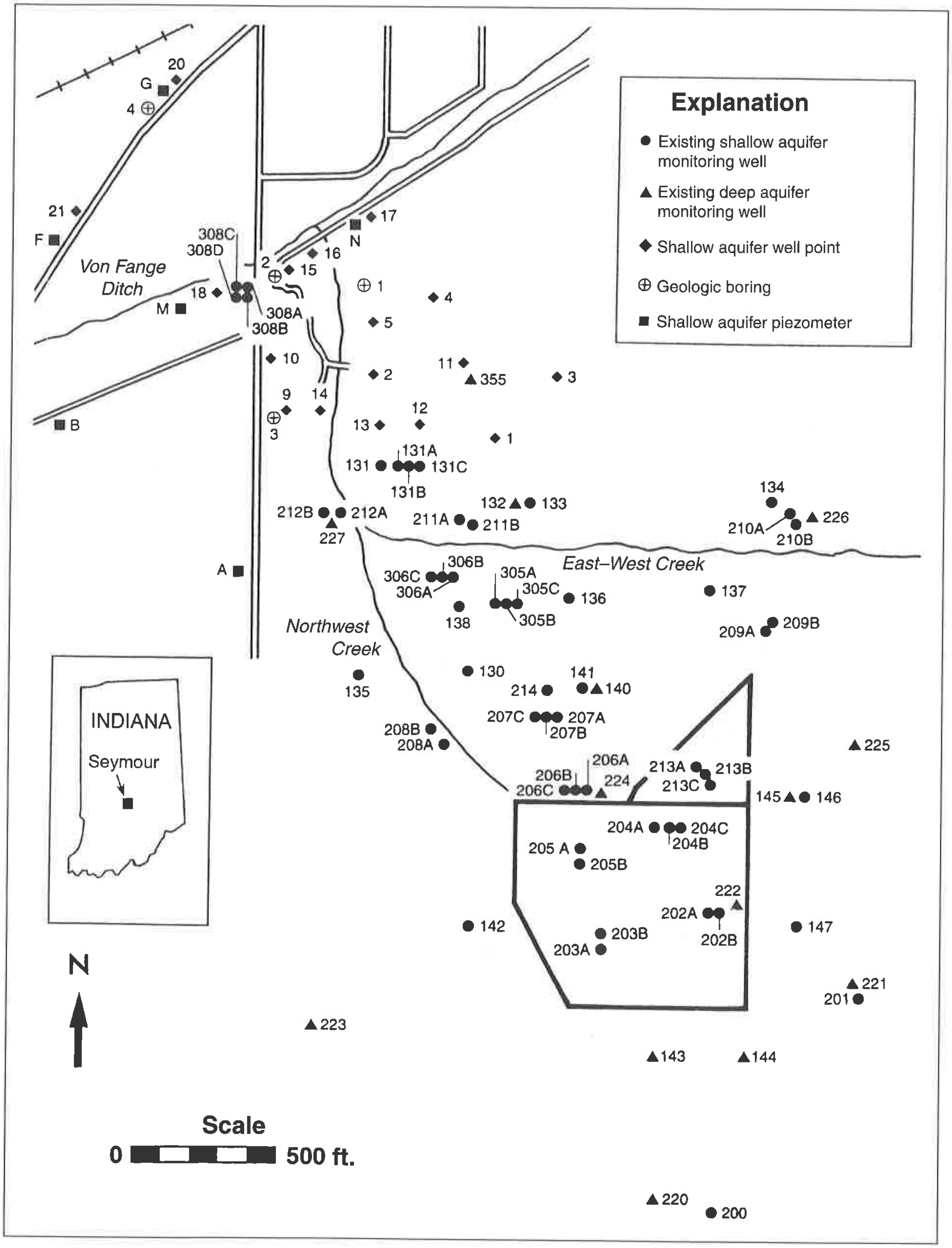

Figure 18.1—Map of tetrahydrofuran concentration (μg/L), Seymour hazardous waste site, 1984–1985.

2. Using data from the later survey, construct a map showing the plume of contamination due to tetrahydrofuran on Figure 18.2. Use equal-concentration lines (contour lines) of 10, 50, 100, 500, 1000, 5000, 10,000, and 50,000 μg/L.

   Describe the distribution of the tetrahydrofuran.

   What information can you interpret from these two maps combined?

3. Using your maps, estimate where the main source of the tetrahydrofuran contamination occurred, and show the general path of groundwater flow from this point as traced by the tetrahydrofuran.

4. How does this path compare with your earlier estimated path of groundwater flow? Refer back to your work in Lab 17 under *Groundwater Flow in Upper Aquifer*, and to the green flow line you drew on the map in Figure 17.2.

5. We don't know for sure if the tetrahydrofuran contamination occurred at a single point or over some finite area. Assuming that it was a point source at or near well 204, would you expect the contaminant to be restricted to a single flow line?

6. What mechanisms might operate to disperse the contaminants from a line into a plume?

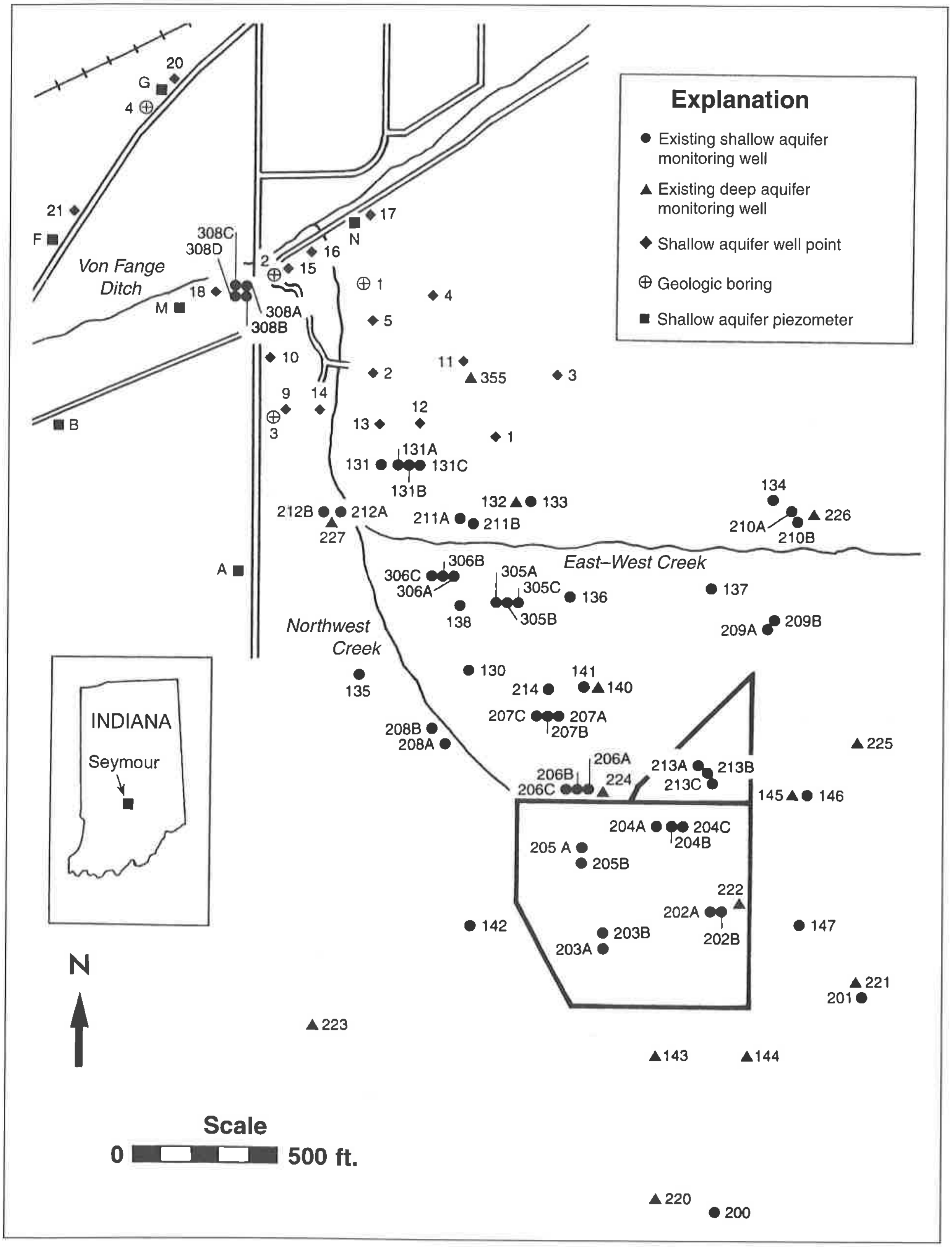

Figure 18.2—Map of tetrahydrofuran concentration (μg/L), Seymour hazardous waste site, 1989–1990.

Future Contamination

1. Would the removal of all the contaminated soil at the site solve the problem? Explain your answer.

2. All the wells in and around the site are being monitored. Might contaminants eventually show up in well 209A? Well 212A? Well 201? What would determine if this occurs?

3. Do you think contaminants might move from the upper shallow aquifer to the deeper aquifer?

4. Assuming contamination of the deeper aquifer is possible, describe the path you think contaminants might follow from the upper to the lower aquifer. Where would you expect the contaminants to appear first in the lower aquifer—that is, in which wells would you expect the first tetrahydrofuran to be detected?

Mitigation/Remediation

1. How might the problem at this site be diminished?

2. How might the problem at this site be solved?

Summary

Write a brief summary of groundwater contamination at the Seymour Recycling Corporation site.

Review

Read the case history of the Seymour site (Fetter, 2001, pp. 428–436). Realizing that you have only limited data, discuss any significant differences between your evaluation of the site and that described by Fetter.