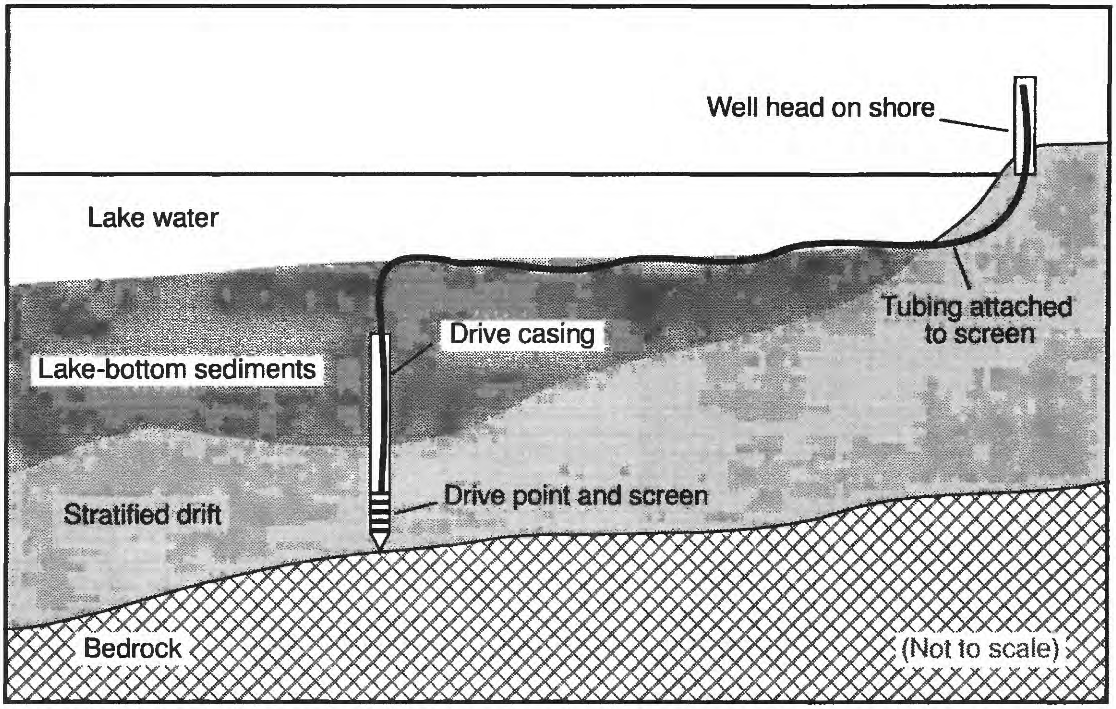
Design of Monitor Wells, Hydrogeology, and Ground-Water Quality beneath Country Pond, Kingston, New Hampshire

U.S. GEOLOGICAL SURVEY
Open-File Report 95-465



Prepared in cooperation with

U.S. ENVIRONMENTAL PROTECTION AGENCY REGION I
WASTE MANAGEMENT DIVISION

and the

NEW HAMPSHIRE DEPARTMENT OF ENVIRONMENTAL SERVICES
WASTE MANAGEMENT DIVISION

U.S. DEPARTMENT OF THE INTERIOR
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U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

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CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATIONS

Multiply	By	To Obtain
acre	4,047	square meter
foot (ft)	0.3048	meter
inch (in)	25.4	millimeter
mile (mi)	1.609	kilometer
gallon (gal)	3.785	liter
gallons per minute (gal/min)	0.06309	liter per second
square foot (ft^2)	929.0	square centimeter
square mile (mi^2)	2.590	square kilometer

Temperature in degrees Fahrenheit (^{o}F) can be converted to degrees Celsius (^{o}C) as follows: $^{o}C = 5/9\ (^{o}F - 32)$.

Sea Level: In this report "sea level" refers to the 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 Sea Level Datum of 1929.

Abbreviated Water-Quality and Geophysical Units Used in Report

In this report, the concentration of a chemical in water is expressed in milligrams per liter (mg/L) or micrograms per liter (µg/L). Milligrams per liter is a unit expressing the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water; 1,000 µg/L is equivalent to 1 mg/L.

Specific conductance of water is expressed in microsiemens per centimeter at 25 degrees Celsius (µS/cm). This unit is equivalent to micromhos per centimeter at 25 degrees Celsius (µmho/cm), formerly used by the U.S. Geological Survey.

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ABSTRACT

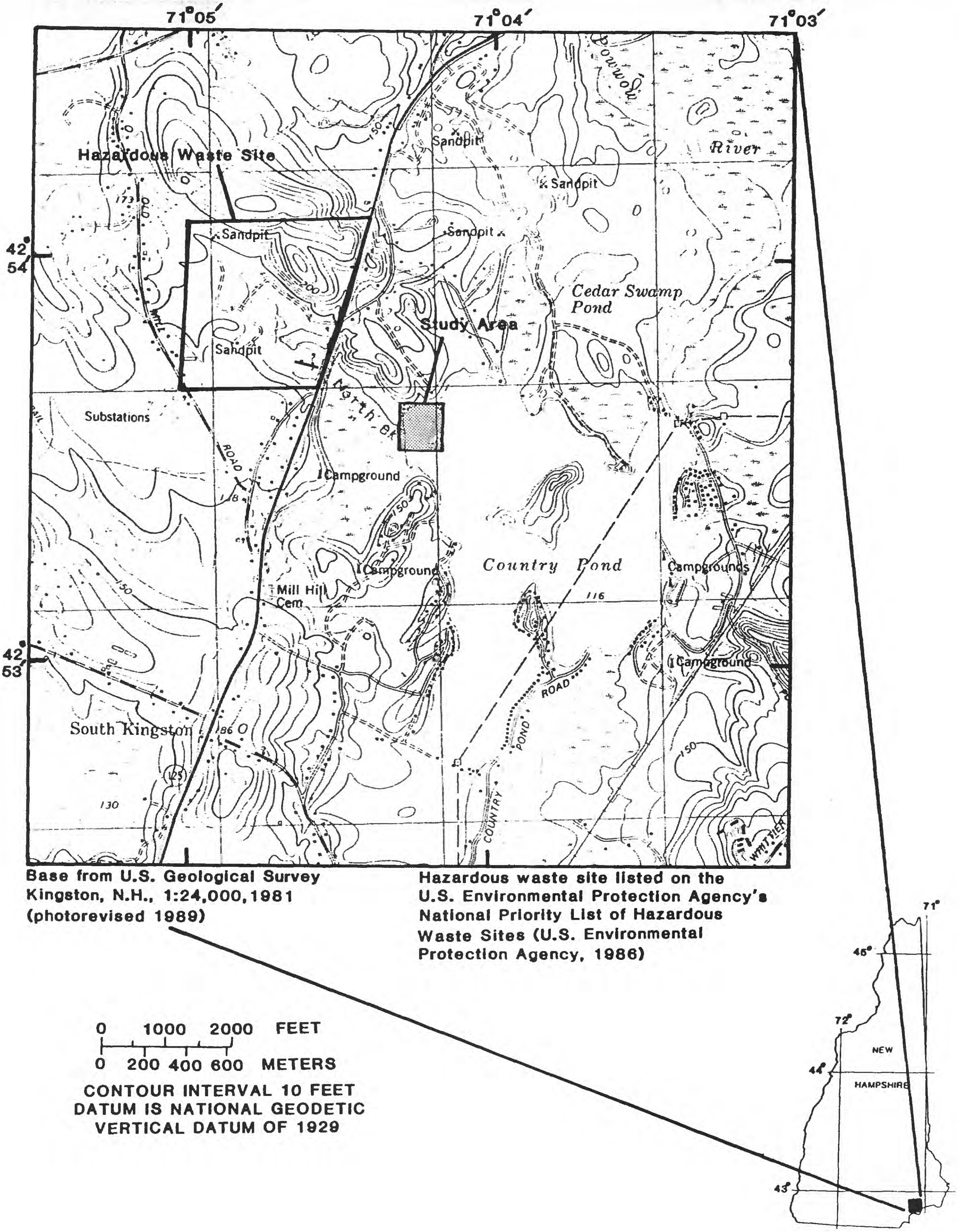
Ten monitor wells were installed in May 1993 in stratified-drift sediments to collect data on the hydrogeology and ground-water quality beneath Country Pond, a lake in Kingston, New Hampshire. The monitor wells were installed 14 to 48 feet beneath the lake surface in stratified-drift sediments that were up to 42 feet thick. The stratified drift is overlain by up to 35 feet of fine-grained, predominantly organic, lake-bottom sediment. The potentiometric head in the stratified drift was at or above the lake surface and up to 0.8 foot above the lake surface at one location.

Water-quality analyses detected numerous volatile organic compounds in the ground water, including chloroethane, benzene, dichlorobenzenes, and 1,1-dichloroethane, at maximum concentrations of 110, 43, 54, and 92 micrograms per liter, respectively. The maximum concentration of total volatile organic compounds detected in ground water from a monitor well was 550 micrograms per liter in November 1993. Ground-water samples with concentrations of volatile organic compounds above background levels also had elevated specific conductances indicating the presence of other non-organic contaminants. Water-quality analyses indicate that a plume of contaminated ground water extends at least 300 feet in a northeast direction beneath the lake.

INTRODUCTION

Country Pond, a 280-acre lake in Kingston, New Hampshire, is 1/4 mi downgradient from a hazardous-waste U.S. Environmental Protection Agency (USEPA) Superfund site (fig. 1). The lake is a recreational resource for the area and is bordered by homes and seasonal camps that use onsite wells for water supply. The extent and migration of ground-water contamination towards the lake is a concern for local residents and those using the lake for recreational activities. The U.S. Geological Survey (USGS), in cooperation with the USEPA, Waste Management Division, Region I, and the New Hampshire Department of Environmental Services (NHDES), installed 10 monitor wells during May 1993 for periodic water-level measurements and ground-water-quality sampling at permanent locations.

Previous investigations (Stekl, 1994; Paul Lincoln, New Hampshire Department of Environmental Services, personal commun., 1994) detected total volatile organic compounds (VOC's) in the ground water immediately beneath the lake at concentrations up to 1,300 µg/L. Wells installed during previous



Base from U.S. Geological Survey Kingston, N.H., 1:24,000, 1981 (photorevised 1989)

Hazardous waste site listed on the U.S. Environmental Protection Agency's National Priority List of Hazardous Waste Sites (U.S. Environmental Protection Agency, 1986)

CONTOUR INTERVAL 10 FEET
DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

Figure 1. Location of the study area in Kingston, New Hampshire.

investigations to sample ground water beneath the lake were removed after sampling to avoid being a hazard to recreation on the lake (Stekl, 1994).

Purpose and Scope

The purpose of this report is to describe the procedures used to install monitor wells beneath a lake and the data collected during installation, the results of water-quality sampling in May 1993, and the hydrogeology of the stratified-drift aquifer beneath Country Pond in Kingston, New Hampshire. The study was limited to Country Pond and the stratified-drift aquifer underlying the lake.

Description of the Study Area

The study area encompasses about 14 acres (fig. 1) on the northwestern part of Country Pond, including the surrounding shoreline. Country Pond is a glacial kettle lake in an extensive outwash plain (Stekl and Flanagan, 1992). Outwash deposits and ice-contact deposits are exposed on the northwest shore of the lake.

Surface water flows into the study area through North Brook (fig. 1), which flows along the north side of a waste site and drains a wetland adjacent to the lake. Surface water flows from Country Pond to Powwow River northeast of the lake. The water-level altitude of Country Pond is controlled by a dam on Powwow River and ranges from 114 to 117 ft above sea level (Goldberg-Zoino and Associates, 1986). The water level of the lake is regulated at about 116 ft throughout spring and summer and is lowered about 2 ft during late fall and winter. The depth of water in the study area is generally less than 5 ft within 100 ft of the shoreline, and up to 10 ft deep further from the shoreline.

Previous Investigations

Ground-water contamination was detected in the stratified-drift deposits and underlying bedrock at a hazardous-waste site 1,500 ft upgradient of Country Pond (fig. 1). Previous investigations by Goldberg-Zoino and Associates (1986) and Ecology and Environment, Inc. (1982) were concerned with the nature and extent of contamination associated with the waste site and in the wetland southeast of the waste site. A previous study by the USGS (Stekl, 1994), in cooperation with the USEPA and the NHDES, focused on concentrations of VOC's in the water from the stratified-drift aquifer beneath the lake.

Contaminated ground water from the waste site flows through the stratified-drift aquifer beneath the wetland and Country Pond. North Brook has been identified as an area of elevated sediment and surface-water contamination (Arthur D. Little, Inc., 1991). The contaminants found downgradient of the site are primarily VOC's, polychlorinated biphenyls (PCB's), arsenic, and nickel. The VOC's found in the aquifer beneath Country Pond include dichloroethane, trans-dichloroethylene, tetrachloroethylene, acetone, methyl ethyl ketone, methyl isobutyl ketone, ethyl benzene, toluene, xylenes, vinyl chloride, and tetrahydrofuran (Stekl, 1994).

Stekl (1994) provides information on 30 temporary wells and ground-water quality in the study area during 1987, 1988, and 1991. In 1987, 11 wells extending above the lake surface were left in place to provide a sampling point. The wells were removed in the spring of 1988 after being damaged by winter ice. Wells installed in 1988 and 1991 were driven into the glacial sediments beneath the lake. Ground-water heads and well yields were measured and water-quality samples were collected from those 11 wells. Later wells in glacial sediments (1988 and 1991) were removed immediately after sampling to prevent interference with recreational uses of the lake. Stekl (1994) indicated that contamination in the stratified-drift aquifer beneath the lake generally increased with depth.

Acknowledgments

The author wishes to thank Paul Lincoln of the New Hampshire Department of Environmental Services for his assistance with this study and in sampling wells. Thanks are also extended to individuals who granted U.S. Geological Survey personnel access to their property.

DESIGN OF MONITOR WELLS

The design of monitor wells for use below the bottom of Country Pond includes consideration of installation, water-level measurements, and water-quality sampling. The monitor-well network was designed and installed to meet the following requirements:

1. It must provide permanent access for periodic monitoring of water quality and water levels in the stratified-drift aquifer beneath the lake;
2. It must not be a hazard to recreational activities on the lake, such as boating and swimming;
3. It must provide year-round access without being damaged by ice.

Monitor wells were installed in a pattern similar to previous investigations to take advantage of previously determined depths to bedrock to avoid damaging the drive points during installation, and to compare newly collected data with previously collected water-quality data. Monitor wells were driven from a raft into the unconsolidated sediments below the lake as shown in figure 2. One-foot long, 1-in. inside-diameter, #400 mesh stainless-steel drive-point screens were attached to steel casing and driven beneath the lake. Polyethylene tubing was attached to a fitting on top of the screen inside the casing. This arrangement isolated the screened intake area from the upper casing and the lake water. The well was driven by a mechanical or weight-drop hammer suspended by a tripod on the raft. The top of the steel well casing was driven to the lake-bottom surface, or some depth below it, as listed in table 1, and was uncoupled from the drive casing. The tubing was either capped and sunk in place on the lake bottom or extended to the shore.

The tubing attached to the monitor well was set into the lake bottom as it was laid out to the desired location on shore. The head in the monitor well, measured in a well housing on shore, indicates the head in the aquifer at a point beneath the lake.

Monitor wells were driven to the base of the stratified drift, just above the till or bedrock surface, as indicated by previous drilling refusal depths (Stekl, 1994). Stekl (1994) found that wells installed in lake-bottom sediments or in till would not yield water because of the low permeability of these sediments. The thickness of the lake-bottom sediments and stratified drift, if refusal was encountered, were measured during monitor-well installation. Monitor wells could be manually pushed through the lake-bottom sediments; a weight drop or mechanical hammer was required to drive the monitor wells through the stratified drift. The thickness of the lake-bottom sediments was readily determined by noting the force required to drive the monitor wells.

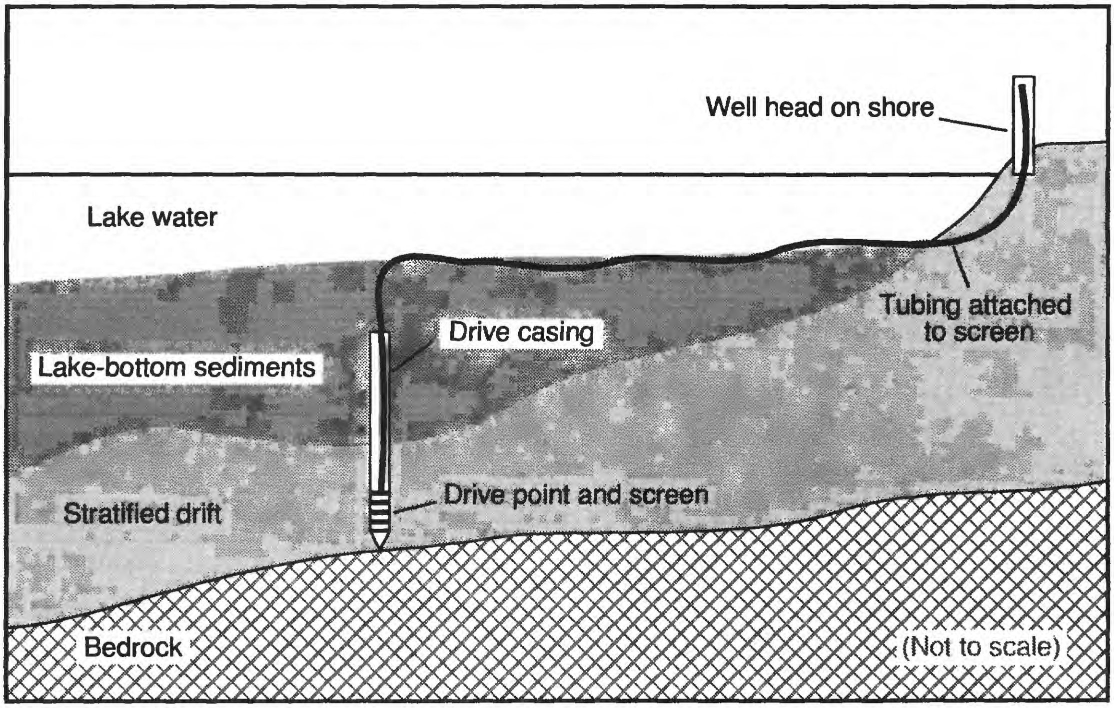


Figure 2. Typical monitor-well design and installation beneath Country Pond, Kingston, New Hampshire.

Table 1. Description of monitor wells installed and hydrogeologic conditions in Country Pond, Kingston, New Hampshire, May 1993

[ft, foot; < , indicates less than; >, indicates greater than; LTS, length of tubing to sampling point; A1, A2, indicate monitor-well position relative to wells installed by Stekl (1994); -,less than zero]

Monitor well number	Casing length (ft)	Top of casing above or below lake bottom (ft)	Water depth (ft)	Point below water surface (ft)	Thickness of lake-bottom sediment (ft)	Thickness of stratified drift (ft)	Notes
P-1	14	<-1	4	19	1	>14	A1, difficult driving, 100 ft LTS
P-2	22	-4	3	30	5	>22	A2, 140 ft LTS
P-3	35	-4	2	42	26	>14	A3, 60 ft LTS
P-4	10	<1	3	14	2	>9	AB1, difficult driving, 90 ft LTS
P-5	28	-18	4	48	35	>9	AB2, tubing sunk in place
P-6	24	1	5	25	8	12	AB3, possible refusal at 25 ft, tubing sunk in place
P-7	12	0	4	17	1	13	B1, 140 ft LTS
P-8	33	1	7	40	15	>18	B2, tubing sunk in place
P-9	21	-9	9	43	29	>3	B3, tubing sunk in place
P-10	28	1	9	37	10	18	C2, refusal at 37 ft, tubing sunk in place

The monitor wells were installed at the locations shown in figure 3. At monitor wells P-5, P-6, P-8, P-9, and P-10, the polyethylene sampling tubing was sunk in place for retrieval at a later date. At monitor wells close to shore (less than 200 ft), the tubing was extended to the shoreline. This approach has been used by Welsh and Lee (1989) for head measurement and water sampling in a similar setting. The sampling tubing for P-8 was damaged shortly after installation and no data were collected at that site.

Potentiometric-head gradients between the aquifer and the lake were determined by measuring the difference between the water level in the tubing and the level of the lake surface before water-quality samples were taken. Where the tubing had been submerged on the lake bottom, the tubing was held at a constant height above the water surface until the head in the tubing stabilized.

Ground-water and surface-water samples were collected on May 21 and 27, and November 2, 1993, and analyzed by the NHDES. Water samples were withdrawn from the tubing by use of a peristaltic pump. Specific conductance and temperature of the pumped water were measured during pumping and the results were compared to measurements of lake water to confirm that water samples were from the aquifer and that the sampling tubing was intact. Ground-water samples were analyzed for the 42 VOC's listed in table 2.

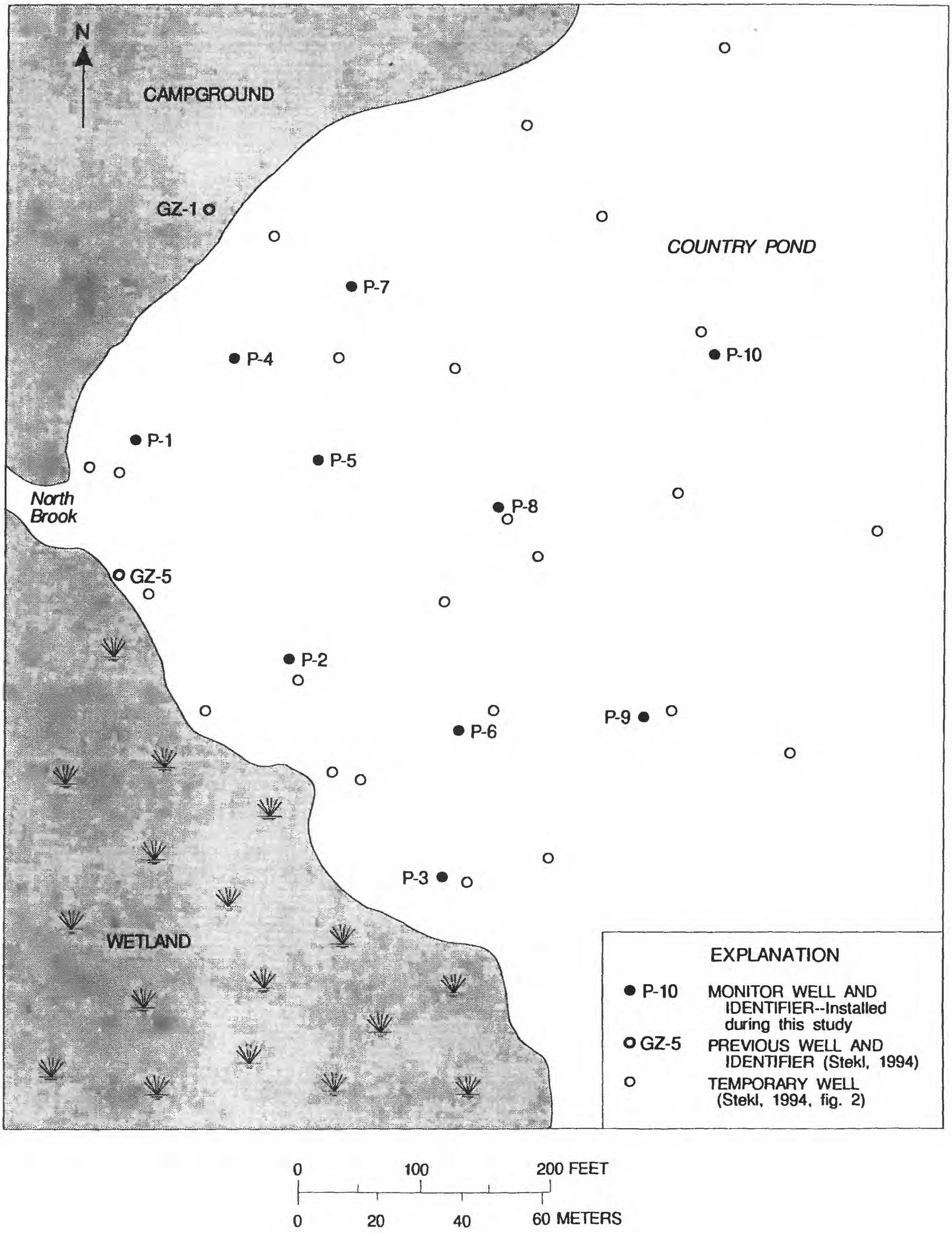


Figure 3. Location of monitor and temporary wells in Country Pond, Kingston, New Hampshire.

Table 2. Summary of the detection limits of volatile organic compounds tested in the water samples from Country Pond, Kingston, New Hampshire

[µg/L, micrograms per liter]

Analyte	Detection limit (µg/L)	Analyte	Detection limit (µg/L)
Acetone	20.0	t-1,3-Dichloropropene	2.0
Benzene	1.0	Diethyl ether	2.0
Bromoform	1.0	Ethane, dichloro, trifluor	4.0-20.0
Bromomethane	1.0	Ethyl benzene	1.0
Carbon disulfide	1.0	2-Hexanone	4.0
Carbon tetrachloride	1.0	Methylene chloride	2.0
Chlorobenzene	1.0	Methyl ethyl ketone	20.0
Chlorodibromomethane	1.0	Methyl isobutyl ketone	2.0
Chloroethane	1.0	Methyl-t-butyl ether	1.0
2-Chloroethylvinyl ether	20.0	Styrene	1.0
Chloroform	1.0	1,1,2,2-Tetrachloroethane	1.0
Chloromethane	1.0	Tetrachloroethylene	1.0
Cyclohexane	1.0	Tetrahydrofuran	10.0
Dichlorobenzenes	2.0	Toluene	1.0
Dichlorobromomethane	1.0	1,1,1-Trichloroethane	1.0
1,1-Dichloroethane	1.0	1,1,2-Trichloroethane	1.0
1,2-Dichloroethane	1.0	Trichloroethylene	1.0
1,1-Dichloroethylene	1.0	Trichlorofluoromethane	1.0
c&t-1,2-Dichloroethylene	1.0	Vinyl acetate	4.0
1,2-Dichloropropane	2.0	Vinyl chloride	1.0
c-1,3-Dichloropropene	2.0	Xylenes (Total)	1.0

HYDROGEOLOGY

Hydrogeology of the study area consists of fine-grained lake-bottom sediments and stratified drift overlying till or bedrock. The thickness and extent of these sediments are determined by use of information from previous investigations (primarily Stekl, 1994) and from information collected for this study. The thickness of these sediments is inferred from the depth to well refusal (driven wells discussed in this study do not penetrate till or bedrock). The combined thickness of lake-bottom sediments and stratified drift overlying till and bedrock beneath the lake ranges from 11 to 61 ft. Throughout most of the study area, the sediments overlying till or bedrock are 20 to 40 ft thick and increase in thickness from northwest to southeast (fig. 4). Maximum sediment thickness exceeds 60 ft at one point adjacent to the wetland (fig. 4). Glacial till commonly is present beneath stratified-drift deposits in this region (Stekl and Flanagan, 1992); however, the extent and continuity of till beneath Country Pond is unknown.

Water Levels

The potentiometric heads, or heads, in the stratified-drift aquifer at the monitor wells were measured relative to the lake surface (table 2). As there was no datum from which to measure the lake-surface altitude: water-level data was used to determine vertical-head gradients between the lake and the aquifer. Heads in the stratified-drift deposits beneath the lake in May and November 1993 were equivalent to

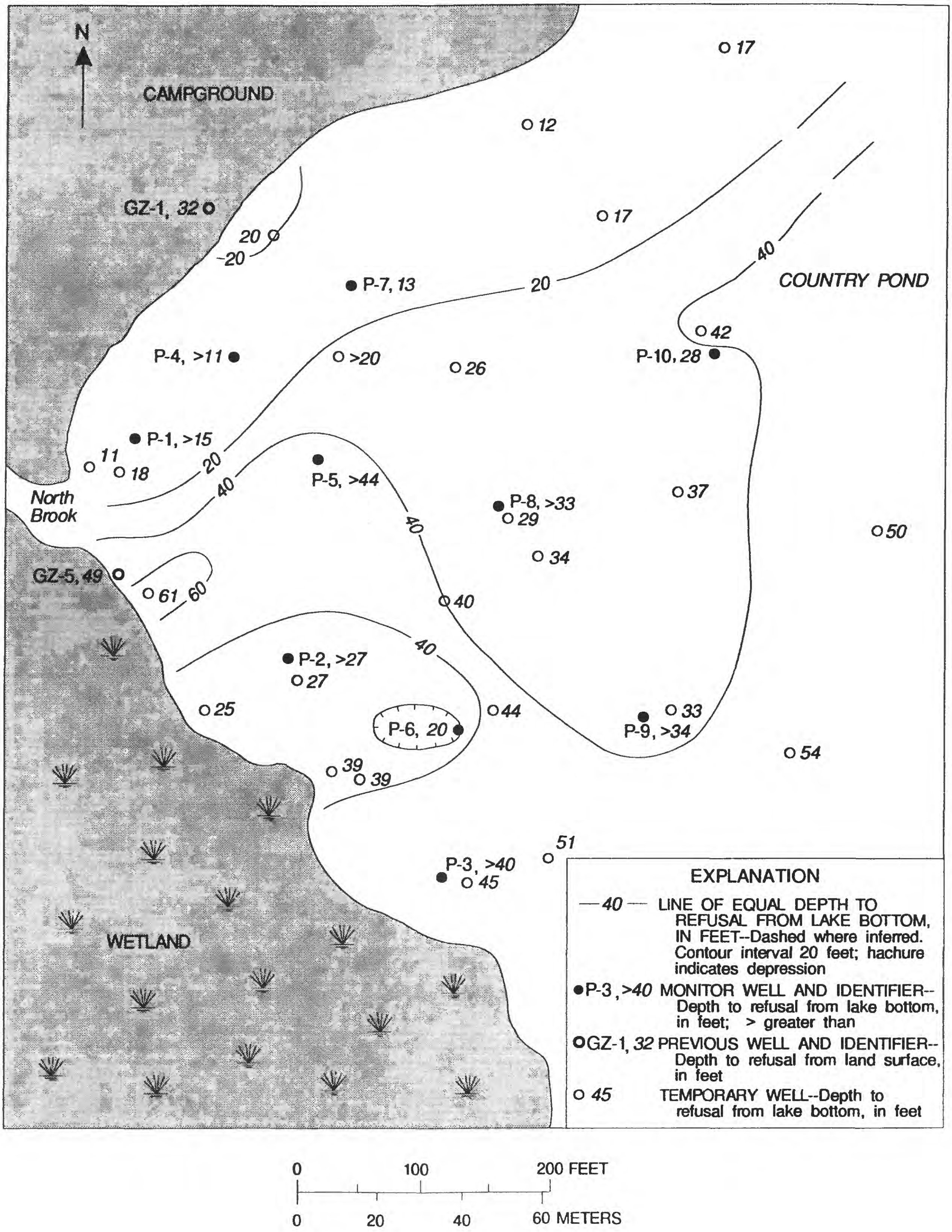


Figure 4. Depth to refusal benearth the bottom of Country Pond, Kingston, New Hampshire.

or slightly above the lake level, indicating an upward-head gradient consistent with the findings of Stekl (1994). The largest upward-head gradient (0.8 ft) was measured at monitor well P-4 on November 2, 1993 (table 3).

Lake-Bottom Sediments

Lake-bottom sediments consist of recent (Holocene), very fine-grained sediment and organic materials that settled out of the lake water. The sediments are unconsolidated and easily disturbed.

The thickness of lake-bottom sediments ranges from zero at the northern shoreline to 35 ft at monitor well P-5 and to about 30 ft at the southeastern edge of the study area (table 1, fig. 5). The bottom sediments are flat-lying; however, their thickness varies depending on the topography of the underlying stratified drift.

Stratified Drift

Stratified drift, including silt, sand, cobbles and gravel, overlie till or bedrock. The thickness of these deposits was determined from the difference between the base of lake-bottom sediments and the driven-well refusal depth. The thickness of stratified-drift deposits varies with location from 8 to 42 ft but generally is 15 to 25 ft (fig. 6). The area of 40-ft thick stratified drift was measured at the northwest corner of the lake adjacent to the wetland (Stekl, 1994).

Deltaic coarse-grained sand, gravel, and cobbles are exposed at the lake's northern shoreline and extend approximately 100 to 200 ft to the south beneath the lake. The stratified drift surrounding the study area are glaciomarine deltaic deposits deposited in shallow marine water (Koteff and Moore, 1994). At the southern end of the study area, glacial sediments beneath the lake consist of medium to fine-grained sand and silt. The yield of monitor wells installed in this material ranged from 0 to 60 gal/min (Stekl, 1994).

WATER QUALITY

Several water-quality samples that were collected from nine monitor wells and one lake site on May 21 and 27, and November 2, 1993, contained VOC's (table 4). The specific conductance and temperature of ground water and the concentrations of VOC's were similar in the May and November samples. Monitor wells with the highest total concentration of VOC content (sum of analytes) in May 1993 (table 4) were

Table 3. Potentiometric heads above the surface of Country Pond, Kingston, New Hampshire, May and November 1993

[--, indicates no data]

Monitor well number	Depth of monitor well point below water surface (feet)	Potentiometric head above the surface of Country Pond (feet)	
		May 27	November 2
P-1	19	--	--
P-2	30	0.1	--
P-3	42	.2	0.1
P-4	14	.1	.8
P-5	48	.1	.1
P-6	25	.1	--
P-7	17	.0	--
P-8	40	--	--
P-9	43	.1	--
P-10	37	.0	--

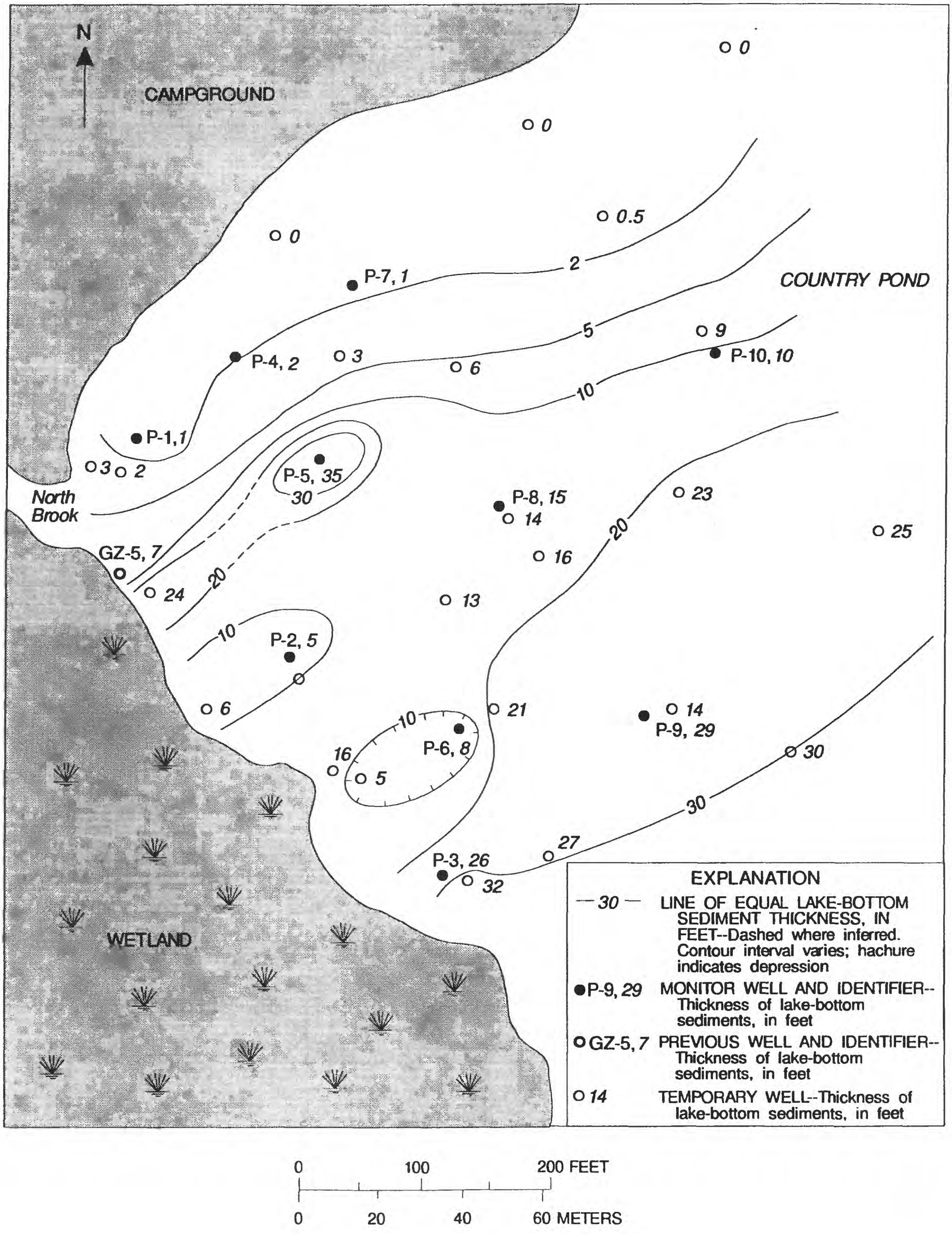


Figure 5. Thickness of lake-bottom sediments beneath Country Pond, Kingston, New Hampshire.

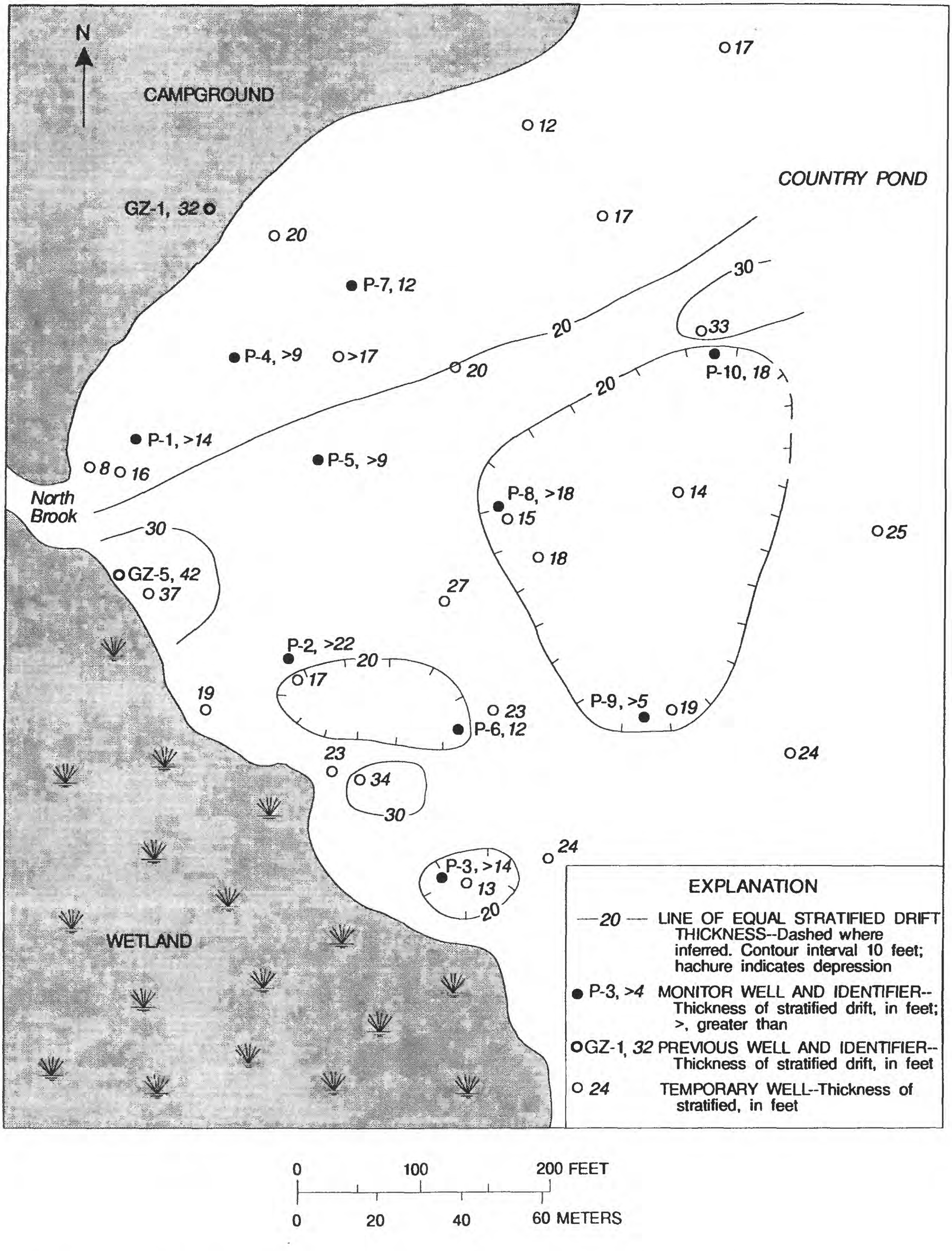


Figure 6. Thickness of stratified drift beneath Country Pond, Kingston, New Hampshire.

Table 4. Results of water-quality analyses of ground and surface water, Country Pond, Kingston,

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; VOC's, volatile organic compounds; µg/L, ns, not sampled]

Monitor well or surface water sample	Date collected	Specific conductance (µS/cm)	Temperature (°C)	Total VOC's	Acetone (µg/L)	Benzene (µg/L)	Chlorobenzene (µg/L)	Chloroethane (µg/L)	Chloromethane (µg/L)	Cyclohexane (µg/L)
P-1	05-27-93	71	15.8	--	--	--	--	--	--	--
	11-02-93	92	10.2	--	--	--	--	--	--	--
P-2	05-21-93	ns	ns	1	--	--	--	--	--	--
	11-02-93	345	7.5	1	--	--	--	--	--	--
P-3	05-21-93	265	16.0	6	--	--	--	--	2.1	--
				4	--	--	--	--	--	--
	11-02-93	279	8.1	12	--	--	--	--	--	--
P-4	05-27-93	606	ns	397	43.0	23.0	9.6	96.0	--	--
	11-02-93	492	11	550	--	22.0	11.0	110.0	--	--
P-5	05-21-93	ns	ns	151	--	9.0	18.0	11.0	--	--
	11-02-93	648	9.9	148	--	8.3	17.0	17.0	--	1.1
P-6	05-21-93	ns	ns	2	--	--	--	1.1	--	--
P-7	05-21-93	600	ns	201	--	26.0	15.0	86.0	--	--
	11-02-93	950	10.7	403	--	43.0	25.0	180.0	--	--
P-9	05-21-93	ns	ns	1	--	--	--	--	--	--
P-10	05-27-93	240	ns	1	--	--	--	--	--	--
Lake water	05-21-93	125	18.9	33	--	--	--	--	--	--
	11-02-93	147	8.2	ns	ns	ns	ns	ns	ns	ns

micrograms per liter; <, indicates identified as present less than detection limit; --, not present or below detection limit;

Dichloro-benzenes (µg/L)	1,1-Di-chloro-ethane (µg/L)	1,2-Di-chloro-ethane (µg/L)	c&t-1,2-Di-chloro-ethylene (µg/L)	Diethyl ether (µg/L)	Ethane, dichloro, trifluoro (µg/L)	Ethyl-benzene (µg/L)	Methyl-ene chloride (µg/L)	Methyl-t-butyl ether (µg/L)	Tetra-hydro-furan (µg/L)	Toluene (µg/L)	Vinyl chloride (µg/L)	Xylenes (total) (µg/L)
--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	1.2	--	--
--	1.3	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	1.2	--	2.4	--	--
--	--	--	--	--	--	--	--	1.2	--	2.5	--	--
--	--	--	--	--	--	--	--	1.5	--	11.0	--	--
18.0	92.0	5.5	--	20.0	<8	--	--	--	87.0	3.0	--	--
28.0	15.0	6.0	--	18.0	<8	--	--	--	340.0	--	--	--
43.0	29.0	4.7	2.0	6.5	<4	8.3	4.4	--	11.0	1.8	--	2.6
40.0	31.0	4.5	2.3	6.1	<4	6.5	--	--	10.0	--	2.7	1.9
--	1.1	--	--	--	--	--	--	--	--	--	--	--
22.0	--	--	--	18.0	<20	34.0	--	--	--	--	--	--
54.0	--	--	--	32.0	<20	63.0	--	--	--	6.4	--	--
--	--	--	--	--	--	--	--	--	--	1.1	--	--
--	--	--	--	--	--	--	--	--	--	[1]1.5	--	--
--	--	--	--	--	--	--	--	--	33.0	--	--	--
ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

[1] Possibly a lab contamination.

P-4 (397 µg/L), P-7 (201 µg/L), and P-5 (151 µg/L). The contaminants most frequently detected in May and November 1993 were chloroethane, benzene, dichlorobenzenes, and 1,1-dichloroethane; maximum concentrations were 110, 43, 54, and 92 µg/L, respectively (table 4).

VOC's found at the monitor wells in the southern part of the study area (P-2, P-3, P-6, and P-9) (table 4, fig. 7) were at or near detection limits. At monitor wells P-3 and P-4, VOC's were detected at concentrations slightly above detection limits (table 4). A lake-water sample contained tetrahydrofuran at a concentration of 33 µg/L (table 4). No other VOC's were detected in lake water; however, the lake water was only sampled at one location near well P-5.

Tetrahydrofuran was detected in ground water beneath the lake at a concentration of 1,190 µg/L near P-1 in 1988 and at 400 and 300 µg/L near P-4 in 1991 by Stekl (1994). Tetrahydrofuran was detected in ground water at concentrations of 87 and 340 µg/L at P-4 and at 11 µg/L at P-5 (table 4) in 1993 during this study. The concentrations of tetrahydrofuran found at P-4 in 1993 may represent a similar or slight decrease in the concentration found near P-4 in 1988 by Stekl (1994).

VOC's or other indications of contamination were not detected in water samples from P-1 during this study in 1993. The difference between concentrations of tetrahydrofuran found in water samples taken near P-1 in 1988 and 1993 is most likely a result of P-1 being 30 to 40 ft northeast of previous monitor-well locations in this part of the study area (Stekl, 1994; well A-1, fig. 2). This difference indicates that uncontaminated ground water probably is recharging the northwestern part of the study area from the north and diluting the VOC's. The low specific conductance of ground water at P-1 (71 and 92 µS/cm) supports this observation.

The water samples with the greatest concentrations of total VOC's (P-4, 550 µg/L; P-5, 151 µg/L and P-7, 403 µg/L), also had elevated specific conductances ranging from 492 to 950 µS/cm. These results indicate that ground water from wells P-4, P-5, and P-7 also may contain inorganic contaminants. Lake water had specific conductances (125 and 147 µS/cm) that were lower than the well water but higher than the specific conductance of uncontaminated ground water (71 and 92 µS/cm) from P-1 (table 4).

The extent of the contaminant plume in the stratified drift beneath the lake, indicated by the amount of total VOC's at each monitor well in May 1993, is shown in figure 7. Investigations west of the study area, beneath the wetlands, have detected concentrations of total VOC's at over 1,000 µg/L (Paul Lincoln, New Hampshire Department of Environmental Services, written commun., 1994). Contaminated ground water, from the hazardous-waste site 1,500 ft west of the lake, most likely flows east beneath the wetland and through the stratified drift beneath the lake. High concentrations of VOC's were found at monitor wells P-4, P-5, and P-7, whereas VOC's were not detected at either P-1 (table 4) or observation well GZ-1 (Paul Lincoln, New Hampshire Department of Environmental Services, written commun., 1994). The VOC contamination extends at least 300 ft in a northeast direction beneath the lake, from North Brook at the northwest corner of the lake towards monitor well P-7 (fig. 7). VOC's were detected by Stekl (1994) in ground water 150 ft northeast of monitor well P-7.

Total concentrations of VOC's greater than 900 µg/L in 1988 near wells P-1 and P-2 and greater than 600 µg/L in 1991 near wells P-2 and P-4 were detected by Stekl (1994). The maximum total concentration of VOC's detected in ground water during this study was 550 µg/L at monitor well P-4 in November 1993 (table 4). It is uncertain whether this decrease represents a trend of improving ground-water quality or is the result of the different sampling point locations.

Uncontaminated ground-water discharges to the lake from stratified drift northwest of the lake, as indicated by heads above the lake surface and the presence of uncontaminated water at monitor wells GZ-1 (Stekl, 1994) and P-1 (tables 2 and 4). A large upward-head gradient was measured at monitor well P-4 (table 2), where several VOC's are present (table 4) and confining lake-bottom sediments are thin (table 1, fig. 5). Contaminated ground water probably discharges to the lake at this location.

SUMMARY AND CONCLUSIONS

Ten monitor wells were installed in 1993 in Country Pond, in Kingston, New Hampshire to determine hydrogeology and ground-water quality beneath the lake. The monitor wells were driven to

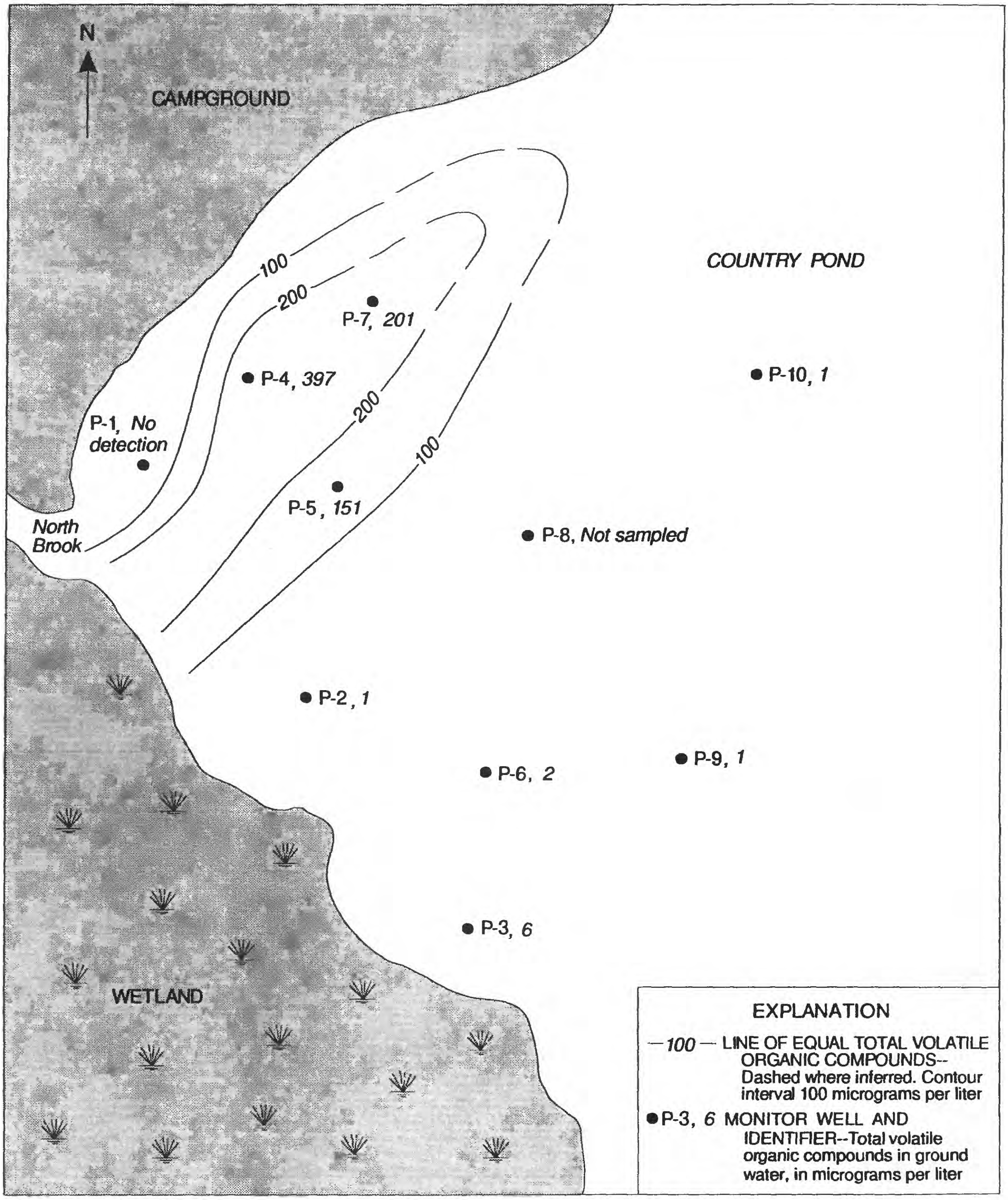


Figure 7. Distribution of total volatile organic compounds in ground water beneathCountry Pond, Kingston, New Hampshire, May 1993.

depths between 14 and 48 ft below the lake surface into stratified-drift sediments. Polyethylene sample tubing was extended from the wells to the shore where the wells were less than 200 ft to the shoreline. Elsewhere, sample tubing was left in place on the lake bottom. Heads in the stratified-drift aquifer beneath the lake ranged from 0.0 to 0.8 ft above the lake surface.

Water depths in the lake ranged from 4 to 9 ft in the study area. The lake bottom consisted of fine-grained, predominantly organic sediment that ranged from less than 1 to 35 ft in thickness. Beneath the lake-bottom sediments, stratified drift is about 15 to 25 ft thick. The stratified-drift sediments are 42 ft thick beneath the lake adjacent to a wetland.

The most frequently detected VOC's in ground water beneath Country Pond were chloroethane, benzene, dichlorobenzenes, and 1,1-dichloroethane at maximum concentrations of 110, 43, 54, and 92 µg/L, respectively. Tetrahydrofuran was detected in the lake water at 33 µg/L, near monitor well P-5, and up to 340 µg/L at monitor well P-4. Water samples from four monitor wells had concentrations of VOC's that were near the detection limits. The maximum total concentration of VOC detected during this study was 550 µg/L, which is less than the maximum total concentration of VOC's detected in 1988 (over 900 µg/L) and in 1991 (over 600 µg/L).

Water-quality samples indicate that a plume of contaminated ground water extends northeastward at least 300 ft beneath the lake from near North Brook at the northwest corner of the study area. Ground water with relatively high concentrations of VOC's also had elevated specific conductances (492 to 950 µS/cm) suggesting that inorganic contaminants also were present. The location of the greatest concentration of contaminants (monitor well P-4) also has the greatest upward-head gradient (0.8 ft) and only a thin layer (1.5 ft) of fine-grained, lake-bottom sediments. It is possible that ground-water contaminants are discharging to the lake at this site.

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