WATER-QUALITY RECONNAISSANCE OF THE PERIMETER OF THE ROLLING KNOLL LANDFILL NEAR GREEN VILLAGE, NEW JERSEY, AND ELECTROMAGNETIC SURVEY OF THE PARTS OF THE LANDFILL WITHIN THE GREAT SWAMP NATIONAL WILDLIFE REFUGE, 1989

By Kenneth S. Turner, Mark A. Hardy, and Robert J. Tapper

U.S. GEOLOGICAL SURVEY

Open-File Report 92-153

Prepared on behalf of the

U.S. FISH AND WILDLIFE SERVICE

West Trenton, New Jersey
1993

U.S. DEPARTMENT OF THE INTERIOR

BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information write to:

District Chief
U.S. Geological Survey
Mountain View Office Park
810 Bear Tavern Road, Suite 206
West Trenton, NJ 08628

Copies of this report can be purchased from:

U.S. Geological Survey
Books and Open-File Reports Section
Federal Center
Box 25425
Denver, CO 80225

CONTENTS

ILLUSTRATIONS

TABLES

TABLES--Continued

CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

Multiply	By	To obtain
foot (ft)	0.3048	meter
acre	4,047	square meter
micrograms per liter (μg/L)	1,000	milligrams per liter
millimhos per meter (mmhos/m)	1.0	millisiemens per meter
micrometer (μm)	0.000001	meters

Abbreviated water-quality unit used in this report:

μg/kg, micrograms per kilogram

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum 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.

WATER-QUALITY RECONNAISSANCE OF THE PERIMETER OF THE ROLLING KNOLL LANDFILL NEAR GREEN VILLAGE, NEW JERSEY, AND ELECTROMAGNETIC SURVEY OF THE PARTS OF THE LANDFILL WITHIN THE GREAT SWAMP NATIONAL WILDLIFE REFUGE, 1989

By Kenneth S. Turner, Mark A. Hardy, and Robert J. Tapper

ABSTRACT

A water-quality reconnaissance of surface water and shallow ground water at the perimeter of the former Rolling Knoll landfill near Green Village, New Jersey, and an electromagnetic survey of the parts of the landfill within the Great Swamp National Wildlife Refuge were conducted during 1989. Results of the water-quality reconnaissance indicate that cadmium, lead, silver, and zinc were present in surface water and ground water adjacent to the Rolling Knoll landfill, although the concentrations of these constituents did not exceed New Jersey drinking-water regulations for these constituents. Concentrations of dissolved iron varied from 64 to 57,000 micrograms per liter; of the surface-water and ground-water samples collected, two-thirds exceeded New Jersey secondary drinking-water regulations. Several organic compounds were detected and were tentatively identified as pharmaceuticals or related compounds. Organic compounds were detected in surface water on the southern and western sides of the landfill, and polycyclic aromatic compounds, insecticides, and polychlorinated biphenyls were detected in samples of stream-bottom materials in Loantaka Brook. Trace elements (other than lead) generally were present in concentrations greater than background levels only in samples of surface water and ground water collected east and south of the landfill. Lead was detected in samples of surface water and ground water collected east and south of the landfill and in samples from two surface-water sample sites in the western and southwestern parts of the study area, near Loantaka Brook.

Results of the electromagnetic survey were consistent with the lithologic descriptions of cores collected from hand-augered holes around the perimeter of the landfill. On the basis of the results of the water-quality analyses and the distribution of sands and clays inferred from the results of the electromagnetic survey, sites were identified at which installation of observation wells would allow for monitoring of the possible effects of the landfill on water quality in the area.

INTRODUCTION

The U.S. Fish and Wildlife Service manages the Great Swamp National Wildlife Refuge, which includes part of the former Rolling Knoll landfill near Green Village in Morris County, New Jersey. The landfill was used for disposal of domestic wastes, pharmaceuticals, and possibly industrial wastes from the 1930's to 1968. About 30 acres of the 140-acre landfill lie within the Wilderness Area of the Refuge. The area of the Great Swamp, the Wilderness Area, and the location of the Rolling Knoll landfill are shown in figure 1. The U.S. Fish and Wildlife Service, as a caretaker of Federal lands, is responsible for the maintenance and well-being of the lands and associated flora and fauna in the Great Swamp National Wildlife Refuge. Results of previous studies have shown that the Rolling Knoll landfill has the potential to affect water quality in the surrounding Great Swamp wetlands (NUS Corporation, 1985; U.S. Fish and Wildlife Service, 1991). Therefore, the U.S. Fish and Wildlife Service entered into a cooperative agreement with the U.S. Geological Survey (USGS) to investigate the effects of the landfill on the geohydrology of the surrounding part of the Great Swamp National Wildlife Refuge. The study consists of three phases--a reconnaissance of surface-water and shallow ground-water quality, ground-water levels, and electromagnetic conductivity in the area surrounding the landfill; selection of borehole sites, borehole drilling, and ground-water-well installation; and ground-water-quality monitoring. This report addresses the first phase of the study.

Purpose and Scope

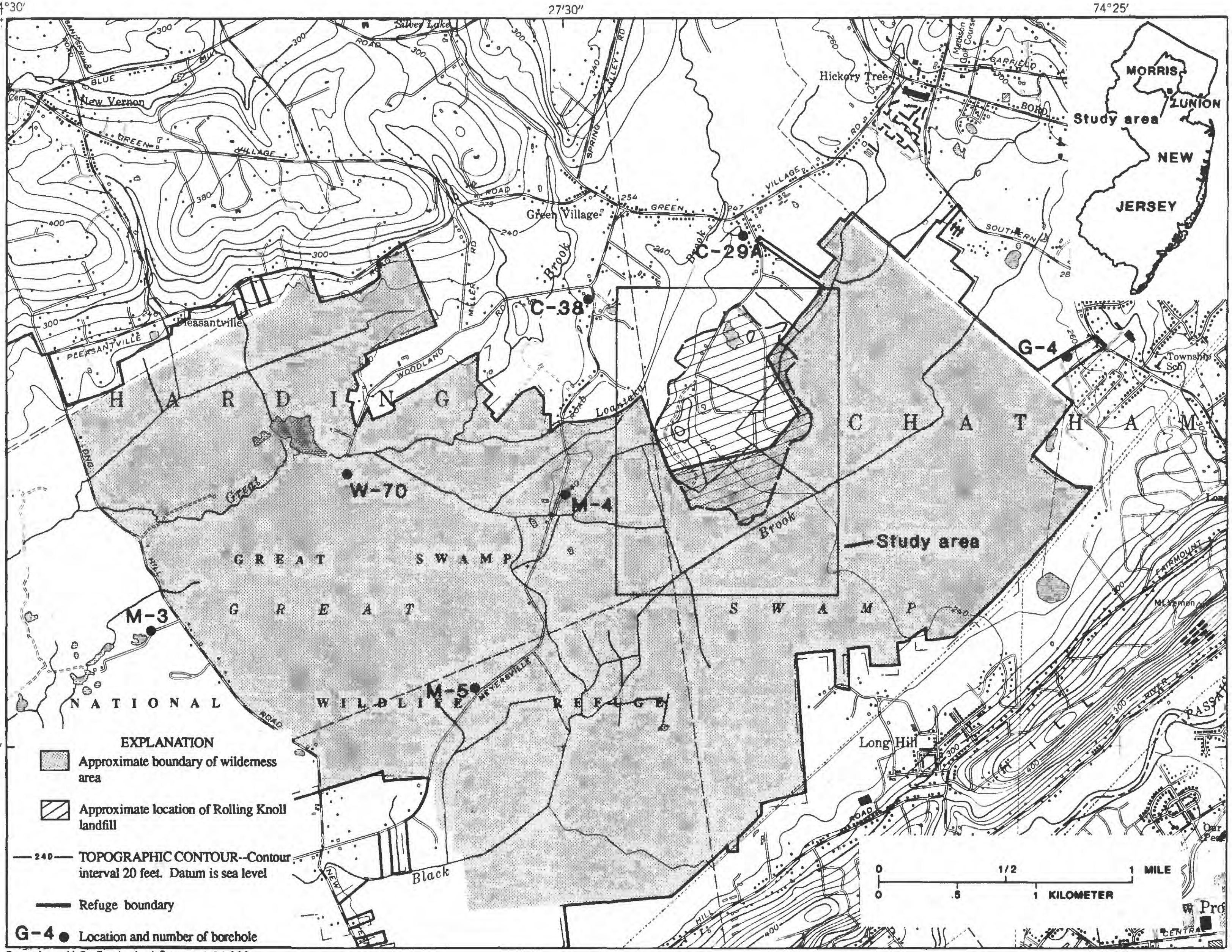
This report presents results of (1) a water-quality reconnaissance of 21 ground-water and surface-water sites around the perimeter of the Rolling Knoll landfill and (2) an electromagnetic survey of the parts of the landfill within the Great Swamp National Wildlife Refuge.

Concentrations of major ions, trace elements, volatile organic compounds, and methylene chloride-extractable compounds were determined, and the presence of additional organic compounds was identified. Bottom sediments from Loantaka Brook were analyzed for the presence of metals.

Results of the electromagnetic survey of 284 sites were used to (1) determine the areal extent of the landfill within the Refuge and (2) locate regions at the edge of the landfill at which the installation of ground-water-observation wells would facilitate monitoring of water quality in the area.

Physical Setting

The Great Swamp Wildlife Refuge is in the southern part of Morris County in north-central New Jersey. Most of the Refuge has low relief and altitudes range from 220 to 240 ft (Minard, 1967). The Rolling Knoll landfill is located adjacent to, and partly within, the Wilderness Area of the Great Swamp Wildlife Refuge. The swamp area lies in the western part of the former glacial Lake Passaic and is bounded on three sides by hills and ridges of gneiss and basalt and on the northern side by terminal moraine (Minard, 1967).



Base from U.S. Geological Survey 1:24,000 quadrangle, Chatham, 1955

Figure 1.--Location of the study area and the surrounding terrain.

The landfill forms an elevated mound that slopes gradually to the swamp. Knolls, which are elevated dry islands of silt, sand, and gravel, are located at the eastern and southern edges of the landfill. The knolls are covered with deciduous trees, whereas the wet areas between the knolls are vegetated mostly with common reed (Phragmites sp.) and common cattail (Typha latifolia).

Geohydrology of the Great Swamp

Figure 2 shows geologic and hydrologic conditions along a generalized section through the Great Swamp. Muck of variable thickness underlies the swamplands. Beneath the muck are relatively impermeable beds of clay and silt, which are as much as 100 ft thick in places (Minard, 1967). The clay and silt confine the underlying sand and gravel aquifer, which mantles the bedrock (Vecchioli and others, 1962).

The sand and gravel aquifer underlying the lakebed clay and silt receives recharge at its edges, where it is exposed at the surface. Because the recharge area is higher than the surface of the swamp, an artesian head that is several feet higher than land surface is present in the part of the aquifer that lies beneath the thick confining layer of the lakebed (Vecchioli and others, 1962). As a result, water from the aquifer flows upward through the confining unit into the swamp, where it dissipates by evapotranspiration or is carried off as streamflow (Minard, 1967). Swamps in this region can be considered to be areas of discharge for the regional ground-water body. The amount of water discharged probably is small, however, because the permeability of the confining unit is low compared to that of the aquifer (Vecchioli and others, 1962).

Geohydrology of the Landfill

In order to assess the possible effects of the landfill on the underlying aquifer, the thickness of the lakebed clay and silt at the landfill site needs to be known. Although no records of deep boreholes in the landfill area have been found, logs of several boreholes near the landfill are available. The locations of several boreholes near the landfill area are shown in figure 1; table 1 lists the reported thickness of the lakebed clay and silt at those sites. These borehole logs (available from the State of New Jersey Office of Water Allocation, Trenton, New Jersey; USGS well files, West Trenton, New Jersey; and the U.S. Army Corps of Engineers, New York City, New York) indicate that the lakebed clay and silt probably is sufficiently thick to prevent the presence of the landfill from significantly affecting the quality of water in the underlying aquifer, even if ground water in the clay and silt did not flow upward.

Information on sedimentary deposits that overlie the lakebed clay at the landfill was obtained from a geologic map that predates the landfill (Salisbury and Peet, 1896), a soil survey of Morris County (Eby, 1976), and logs of shallow boreholes augered at the landfill in 1986 (Diane Trube, NUS Corporation, written commun., 1986). These data indicate that the eastern part of the landfill is directly underlain by organic deposits (muck and peat), whereas the western part is directly underlain by intermixed and interbedded sand, gravel, silt, and clay.

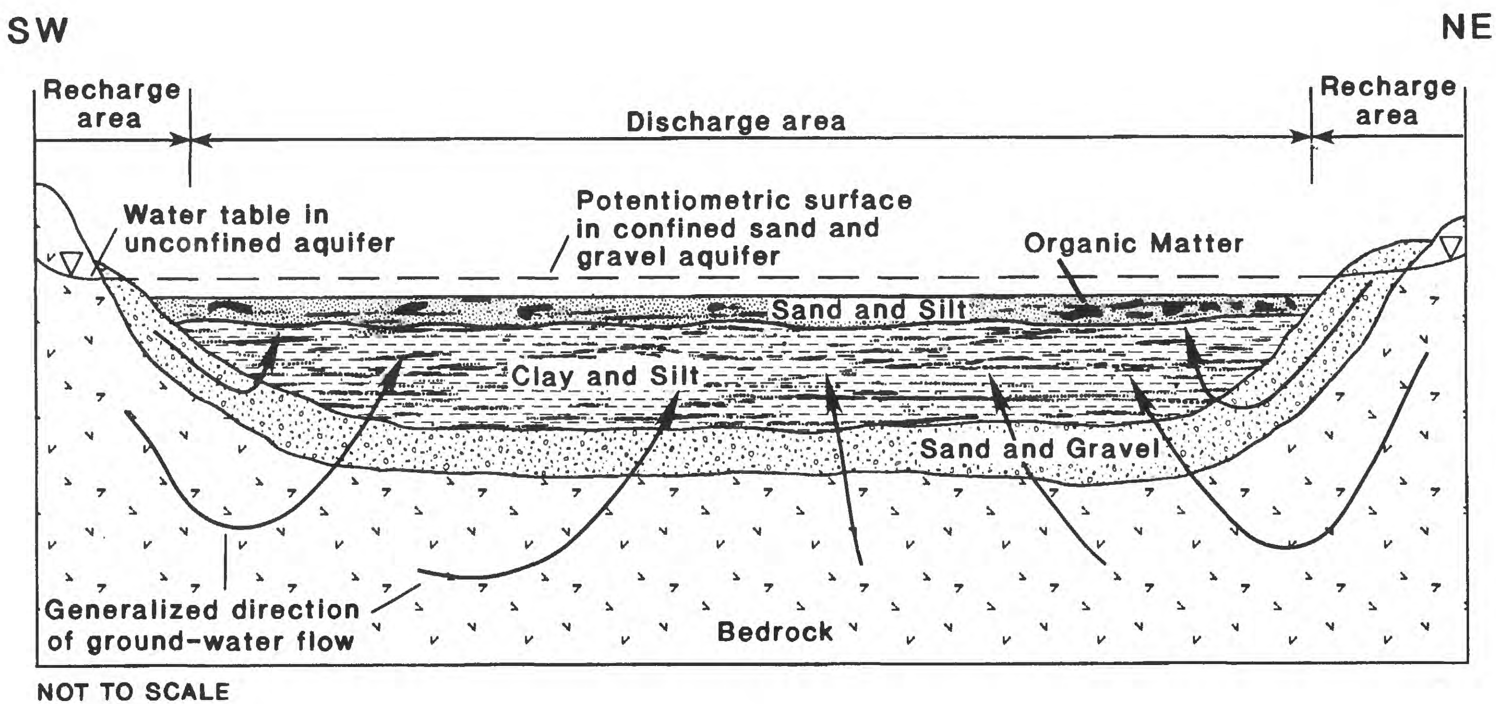


Figure 2.--Generalized schematic diagram showing the hydrogeologic framework and ground-water-flow directions in the Great Swamp, New Jersey. (Modified from Vecchioli and others, 1962, fig. 2.)

Table 1.--Thickness of clay and silt underlying the Great Swamp at selected boreholes

[Data from Diane Trube (NUS Corporation, written commun., 1986)]

Well number (shown in fig. 1)	Reported thickness of clay and silt (feet)
C-29A	74
C-38	72
G-4	122*
G-5	80
M-3	80
M-4	62
M-5	70
W-70	71

*** At well G-4, near the eastern edge of the swamp, the reported thickness of clay and silt of 122 feet includes two interlayered beds of sandy materials that have thicknesses of 25 and 30 feet.**

Figure 3 represents a conceptual model of the hydrologic regime in the landfill area. Precipitation falling on elevated areas moves through the unsaturated-zone materials and flows along the surface of the relatively impermeable clay layers to the nearest stream. Two major surface-water discharge areas probably carry precipitation and subsurface flow from the landfill into the swamp. The first, on the eastern side of the landfill, flows to the east and away from the landfill toward a tributary of Black Brook. The second, on the southern side of the landfill, flows to the west across and away from the landfill toward Loantaka Brook. Both streams flow year-round.

Acknowledgments

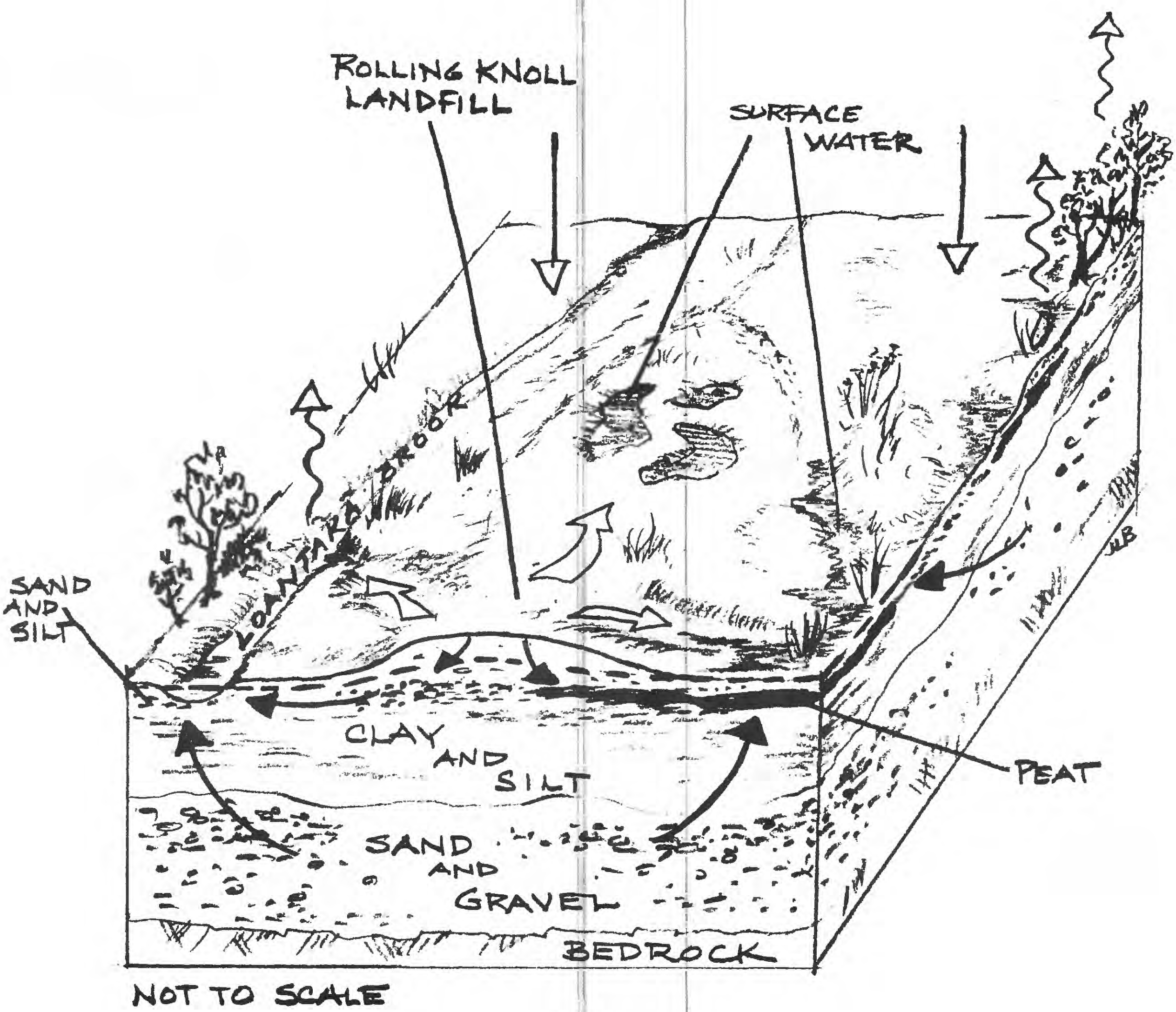
The authors thank Robert Miele for allowing access to the study area. The efforts of William Koch, Michael Chezik, and Craig Moore of the U.S. Fish and Wildlife Service in obtaining access to the site for USGS equipment and personnel, providing technical assistance and liaison among various agencies and individuals, and assistance in field operations, is gratefully acknowledged.

METHODS OF INVESTIGATION

Determination of Water Quality

A water-quality reconnaissance of surface and shallow ground water was conducted around the perimeter of the Rolling Knoll landfill. Fifteen sample sites were chosen (A through N, plus site B-C) which encircle the landfill (fig. 4). Surface-water samples were collected from 14 of the sites; site E was inaccessible. Water samples also were collected from four sites along Loantaka Brook. Identification numbers and site descriptions are given in Appendix 1. Ground-water samples were collected from three sites (A, B-C, and F) where water levels measured with a minipiezometer in conjunction with a water manometer indicated that ground water was moving upward, toward the surface. Ground-water samples were collected from a minipiezometer at a depth of approximately 5 ft below land surface. A portable peristaltic pump was used to develop the piezometer and to extract ground-water samples. Samples were collected, processed, and preserved according to methods described in Wood (1976).

Water samples were analyzed for the dissolved trace elements barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, molybdenum, nickel, silver, strontium, vanadium, zinc, and lithium. Samples also were analyzed for major ions, nutrients, volatile organic compounds, and methylene chloride-extractable organic compounds, such as chrysene, anthracene, benzoapyrene, parachlorometacresol, 2,4,6-trichlorophenol, and dimethylphthalate. The methylene chloride-extractable compounds were determined by means of gas chromatography with flame-ionization detector (GC/FID). Selected samples were chosen for additional analysis by means of gas chromatography/mass spectrometry (GC/MS), and a library search was performed to identify additional organic compounds. (GC/FID analysis is a relatively efficient method for screening samples for organic compounds before electing to analyze samples by means of more costly GC/MS methods.



EXPLANATION

- Precipitation
- Evapotranspiration
- Surface runoff
- Subsurface and ground-water flow
- Water table

Figure 3.--Conceptual diagram of the hydrologic regime of the Rolling Knoll landfill area.

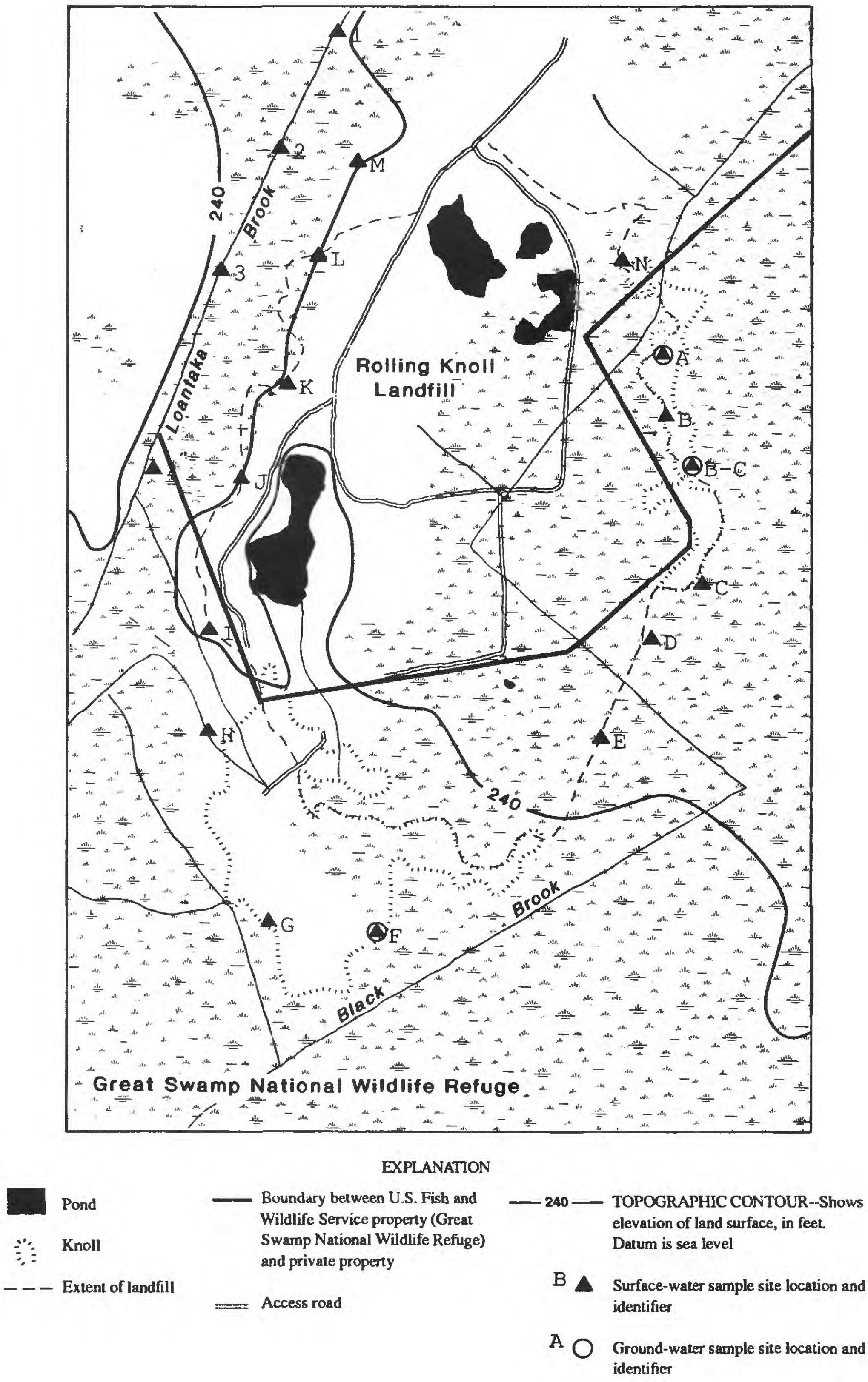


Figure 4.--Locations of water-quality sample sites at the Rolling Knoll landfill.

By using a computer, results of GC/MS analysis can be compared with the results of GC/MS analyses of thousands of chemicals in a software "library" in order to identify unknown sample constituents.) Chromatograph groupings with similar characteristics were identified on the basis of GC/FID results. Ground-water samples from sites A and B-C and surface-water samples from sites B, C, H, I, and L were selected to represent the groupings for GC/MS analysis.

Bottom materials were collected from Loantaka Brook and the silt-clay (less than 63 micrometers) fraction was analyzed for trace elements. The silt-clay fractions were used so that results could be compared among sites. Bottom materials collected at Loantaka Brook sites 1 and 4 were analyzed at the USGS National Water Quality Laboratory (NWQL) in Lakewood, Colo., for organochlorine, organophosphorus, and phenoxy acid compounds; recoverable organic materials; and total metals by means of complete digestion-solubilization. Additional analyses were performed on water samples from sites 1 and 4 for total inorganic carbon, total organic carbon, and total cyanide. Analyses of samples for inorganic constituents by the NWQL followed procedures described by Fishman and Friedman (1989). Procedures used for analysis of samples for organic substances are described by Wershaw and others (1983).

Measurement of Electromagnetic Conductivity

An electromagnetic survey was conducted to determine the areal extent of the landfill within the Refuge and to aid in selection of observation-well sites by identifying the presence of hydraulically conductive earth materials (sands). The electromagnetic method is used to measure the apparent electromagnetic conductivity of the soil. A transmitter coil induces eddy-current loops in the earth. The eddy currents generate an electromagnetic field that is proportional to the electrical conductivity of the sediment and ground water. A receiver coil intercepts part of each electromagnetic field and produces a meter deflection indicative of the apparent electromagnetic conductivity of the earth materials through which the field passes. The electromagnetic method can be used in conjunction with geologic information to indicate sites of electromagnetically conductive materials, such as clays, and electromagnetically resistive materials, such as sands. Areas of low electromagnetic conductivity where sands are present are well-suited for the installation of ground-water-observation wells. In addition, landfill materials, which likely would be more heterogeneous than geologic materials, could be expected to show substantial variability in conductivity over short distances. Conductivity values greatly exceeding those expected for clays probably indicate the presence of buried metallic objects.

The electromagnetic survey was conducted by using a Geonics[1] EM-31 Non-Contacting Terrain Conductivity Meter operated in the horizontal-dipole configuration. The EM-31 is a portable instrument with a intercoil spacing of 3.66 meters (12.01 ft) and has an effective exploration depth of 6 meters

---

[1]Use of trade names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

(19.69 ft). The EM-31 was chosen for use in the study because it can be easily transported and operated in dense vegetation and flooded areas. The survey was conducted in a grid pattern composed of 50-ft stations along lines separated by 200 ft. The survey was conducted only on accessible parts of the Great Swamp National Wildlife Refuge property adjacent to the Rolling Knoll landfill.

The electromagnetic survey was supplemented by the collection of hand-augered core samples at sites A, B, B-C, C, D, and F to determine near-surface lithologic characteristics. The results of the core-sample analyses were used to confirm the presence of hydraulically conductive and nonconductive materials (sands and clays, respectively).

WATER QUALITY

Results of chemical analyses of surface- and ground-water samples collected from the perimeter of the Rolling Knoll landfill and from Loantaka Brook are listed in table 2 at the end of the report. Summary statistics for the water quality around the landfill and in Loantaka Brook are presented in tables 3 and 4, respectively. New Jersey Department of Environmental Protection and Energy water-quality regulations are listed in table 5. The New Jersey Surface-Water Quality Standard for Freshwater 2-Nontrout Category 1 Waters (FW2-NT (C1)) is the standard by which quality of water in Loantaka Brook was measured.

Major Ions and Physical and Chemical Properties

The Stiff diagrams in figure 5 show the relative concentrations of major ions in surface water at the 14 surface-water sample sites and 3 ground-water sample sites (A, B-C, and F) around the landfill and at the 4 sample sites in Loantaka Brook. The width of a Stiff diagram is an approximate indication of the total ionic content of the water.

Surface water and ground water near the landfill were determined to be predominantly a calcium bicarbonate type (fig. 5). Concentrations of sodium in, and specific conductance, pH, and alkalinity of, surface-water samples were highest on the eastern (sites A through D) and southern (sites F through H) sides of the landfill. Median values of sodium concentration, field specific conductance, pH, and alkalinity (as bicarbonate[2]) for the water samples from the four sites on the eastern side were 7.5 mg/L, 388 μS/cm, 7.2, and 165 mg/L, respectively; median values for the water samples from the three sites on the southern side were 8.5 mg/L, 350 μS/cm, 7.2, and 195 mg/L, respectively.

---

[2]Bicarbonate alkalinity concentrations are calculated from field measurements of alkalinity (expressed as mg/L of equivalent calcium carbonate) by dividing the field alkalinity value by 0.8202 (Hem, 1985, p. 57).

Table 3.--Statistical summary of selected water-quality data for ground-water and surface-water samples collected from the perimeter of the Rolling Knoll landfill

[All constituents are dissolved; concentrations are in milligrams per liter; specific conductance is in microsiemens per centimeter at 25 degrees Celsius; <, less than]

Water-quality characteristic or constituent	Number of samples	Minimum	Median	Maximum
FIELD MEASUREMENTS				
pH	17	6.10	6.90	7.50
Specific conductance	17	56	270	900
COMMON CONSTITUENTS				
Calcium	17	5.1	43	160
Magnesium	17	1.6	7.9	48
Sodium	17	2.3	7.1	81
Potassium	17	.6	4.3	27
Chloride	17	1.9	7.7	11
Sulfate	17	<1	6.0	28
Fluoride	17	.07	.1	.2
Silica	17	1.6	7.3	31
Alkalinity, as $CaCO_3$	17	10	127	442
TRACE ELEMENTS				
Barium	17	.023	.09	.45
Beryllium	17	<.0005	<.005	<.005
Cadmium	17	<.001	<.001	.005
Chromium	17	<.005	<.005	<.005
Copper	17	<.01	<.01	.02
Iron	17	.064	.95	57
Lead	17	<.01	<.01	.02
Manganese	17	.016	.045	1.4
Silver	17	<.001	<.001	.002
Strontium	17	.02	.17	.27
Zinc	17	.004	.012	.1
Lithium	17	<.004	.005	.29

Table 4.--Summary of selected water-quality data for samples of bottom material collected from Loantaka Brook

[All constituents are dissolved; concentrations are in milligrams per liter; specific conductance is in microsiemens per centimeter at 25 degrees Celsius; <, less than]

Water-quality characteristic or constituent	Site 1	Site 2	Site 3	Site 4
FIELD MEASUREMENTS				
pH	7.40	7.40	7.40	7.40
Specific conductance	557	550	552	607
COMMON CONSTITUENTS				
Calcium	37	36	36	41
Magnesium	13	13	13	15
Sodium	49	47	48	55
Potassium	4.6	4.5	4.6	5.1
Chloride	72	72	72	82
Sulfate	40	41	40	49
Fluoride	.1	.1	.1	.1
Silica	16	16	15	17
Alkalinity, as $CaCO_3$	79	75	74	120
TRACE ELEMENTS				
Barium	.032	.029	.030	.034
Beryllium	<.0005	<.0005	<.0005	<.0005
Cadmium	<.001	<.001	<.001	<.001
Chromium	<.005	<.005	<.005	<.005
Copper	<.01	<.01	<.01	.02
Iron	.11	.13	.12	.068
Lead	<.001	<.001	<.001	<.001
Manganese	.11	.11	.11	.079
Silver	<.001	<.001	<.001	<.001
Strontium	.15	.14	.14	.16
Zinc	.17	.009	.12	.15
Lithium	<.004	<.004	<.004	<.004

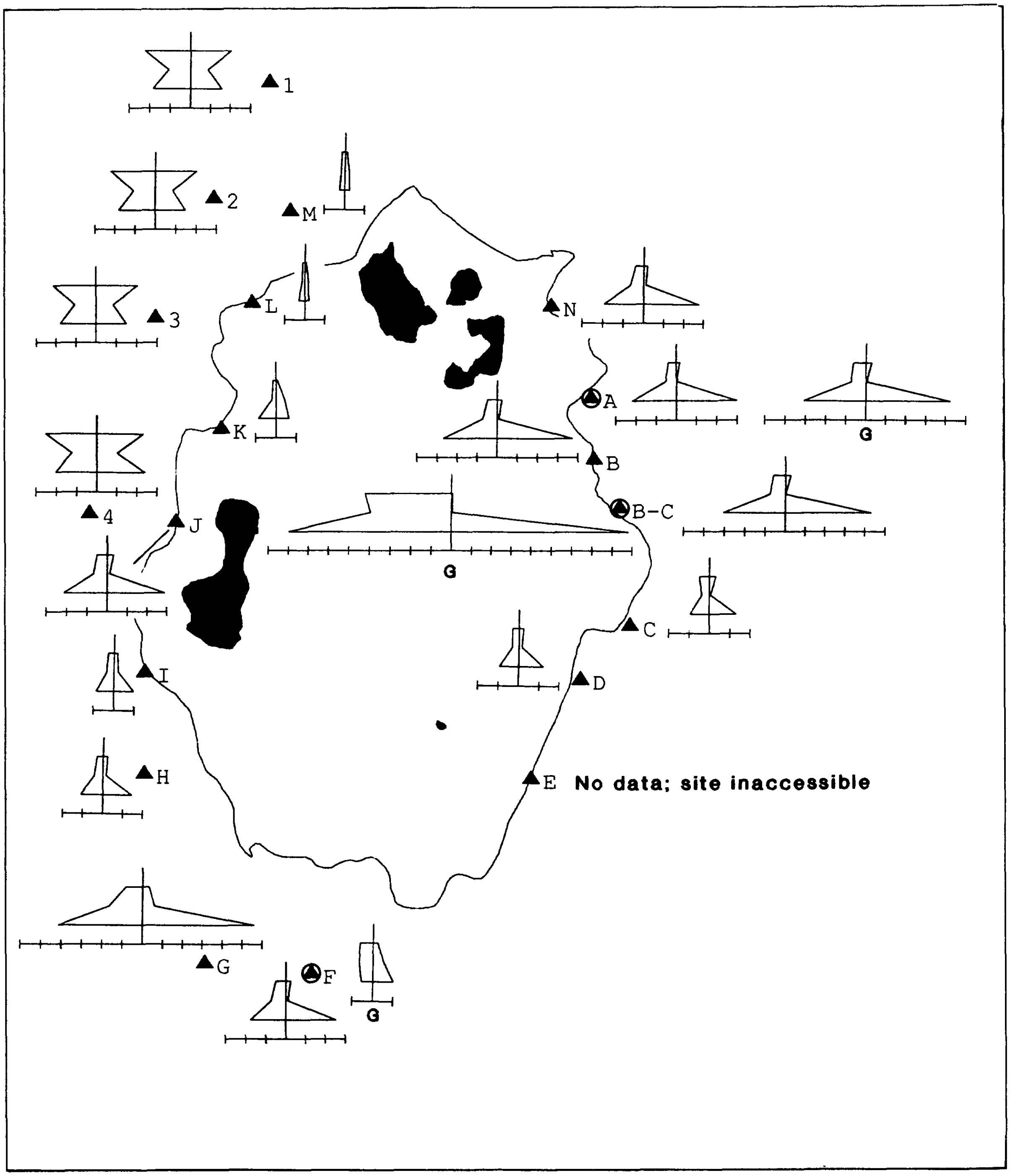
Table 5.--New Jersey Department of Environmental Protection and Energy water-quality regulations

[Concentrations are in milligrams per liter except where otherwise indicated; NJDEPE, New Jersey Department of Environmental Protection and Energy; --, no data]

Constituent or characteristic	NJDEPE maximum contaminant level[1]	NJDEPE secondary maximum contaminant level[1]	New Jersey surface-water quality standard for classification as non-trout waters, category 1 (FW2-NT (C1))[2]
INORGANIC:			
Arsenic	0.05	--	0.05
Barium	1.0	--	1.0
Cadmium	.01	--	.01
Chloride	--	250	--
Chromium	.05	--	.05
Color	--	10 color units	--
Copper	--	1	--
Corrosivity	--	Within ±1.0 of the optimum pH as determined by the Langlier index	--
Dissolved solids	--	500	500
Fluoride	4	--	--
Foaming agents	--	.5	--
Iron	--	.3	--
Lead	.05	--	.05
Manganese	--	.05	--
Mercury	.002	--	.002
Nitrate-nitrogen	10	--	--
Odor	--	3 Threshold odor number	--
pH	--	6.5 - 8.5	6.5 - 8.5
Selenium	.01	--	.01
Silver	.05	--	.05
Sulfate	--	250	--
Zinc	--	5	--
ORGANIC:			
Endrin	.0002	--	.0000023
Lindane	.004	--	.00008
Methoxychlor	.1	--	--
Toxaphene	.005	--	.013
2,4-D	.1	--	--
Silvex (2,4,5 -TP)	.01	--	--
Trihalomethanes	.1	--	--
Benzene	.001	--	--
Carbon tetrachloride	.002	--	--
Chlordane	.0005	--	.0000043
Chlorobenzene	.004	--	--
Orthodichlorobenzene	.6	--	--
Metadichlorobenzene	.6	--	--
Paradichlorobenzene	.075	--	--
1,2-Dichloroethane	.002	--	--
1,1-Dichloroethlyene	.002	--	--
1,2 Dichloroethylene, cis and trans	.01	--	--
Methylene chloride	.002	--	--
Polychlorinated biphenyls, total	.0005	--	.000014
Tetrachloroethlyene	.001	--	--
Trichlorobenzene(s)	.008	--	--
1,1,1-Trichloroethane	.026	--	--
Trichloroethylene	.001	--	--
Vinyl chloride	.002	--	--
Xylene (s)	.044	--	--
Total volatile organic compounds	.05	--	--

[1] New Jersey Register (1989)

[2] New Jersey Department of Environmental Protection (1989)



EXPLANATION

Stiff Diagram

NA+K CL+F
MG SO4
CA HCO3+CO3
1.0 1.0
Milliequivalents

Stiff diagram

Pond

Extent of landfill

B ▲ Surface-water sample site location and identifier

A ○ Ground-water sample site location and identifier

NOTE: All diagrams represent surface water, except those labelled "G" for ground water.

Figure 5.--Stiff diagrams of the relative concentrations of major ions in samples of ground water and surface water collected from the perimeter of the Rolling Knoll landfill and from Loantaka Brook.

Median sodium concentration (4.6 mg/L), specific conductance (138 µS/cm), pH (6.6), and alkalinity (60.0 mg/L) were lowest in surface-water samples from the western side of the landfill (sites I through M). Median specific conductance (300 µS/cm) and pH (7.4) were significantly higher in samples from site J than in samples from the other sites on the western side of the landfill. This indicates that runoff from the landfill near site J affects the quality of wetland water. Because elevated specific conductance, pH, and sodium and bicarbonate concentrations were greater than background levels, the presence of the landfill appears to have a greater effect on surface water on the eastern and southern sides of the landfill than on surface water on the western side.

Water collected from Loantaka Brook was determined to be a mixed type; sodium and calcium were the major cations and bicarbonate and chloride were the major anions (fig. 5). The pH of each of the four samples from the brook was 7.4 and the field specific conductance varied only from 550 to 607 µS/cm, with a mean of 566.5 µS/cm and a median of 554.5 µS/cm. Sodium concentrations in the samples ranged from 47 to 55 mg/L, calcium concentrations ranged from 36 to 41 mg/L, chloride concentrations ranged from 72 to 82 mg/L, and bicarbonate concentrations ranged from 90.2 to 146.2 mg/L. Concentrations of virtually all major ions were greater at site 4, which is west of site J, than at sites 1, 2, and 3. Whether the presence of dissolved solids in higher concentrations in the sample from site 4 is indicative of effects of landfill runoff is unknown; no contaminants present at site 4 can be attributed conclusively to landfill runoff.

The pH of ground-water samples generally was lower than that of surface-water samples, including those from Loantaka Brook; pH ranged from 6.1 to 6.9 and the median was 6.8. Field specific conductances of ground-water samples from sites A and B-C, on the eastern side of the landfill, were substantially higher (420 and 900 µS/cm, respectively) than that of the sample from site F, on the southern side (192 µS/cm). Concentrations of calcium, magnesium, sodium, and potassium in the ground-water sample from site B-C were elevated compared to those in samples from the other two ground-water sites (A and F) (see table 2), and the bicarbonate concentration also was greater at site B-C (539 mg/L). Concentrations of these ions in ground water at site B-C were substantially greater than those in the surface-water sample from site B-C.

Minor Constituents and Trace Elements

The greatest concentrations of iron and the trace elements cadmium, lead, silver, and zinc generally were found in samples of surface water from the eastern and southern sides of the landfill. Lead was detected in surface-water samples from sites A, H, and M and in ground-water samples from sites A, B-C, and F, whereas cadmium was detected in surface-water samples collected at sites A and D and in ground-water samples collected at sites A, B-C, and F. These findings are generally consistent with the distribution and concentrations of major ions shown in figure 5. Iron hydroxide precipitate was most evident in samples of surface water from the eastern and southern edges of the landfill, indicating that landfill leachate may reach the swamp in these areas.

With the exception of the surface-water samples collected at sites G, J, and N, the concentrations of dissolved iron in all water samples collected from the perimeter of the landfill exceeded the NJDEPE secondary maximum contaminant level[3] (SMCL) of 0.3 mg/L (New Jersey Register, 1989). Concentrations of dissolved iron and manganese in ground-water samples from sites A and B-C were elevated compared to those in the other samples; the highest concentration of iron was 57 mg/L in ground water from site B-C. The elevated concentrations of iron and manganese in ground water at sites A and B-C could be the result of reducing conditions in landfill leachate and indicate that conditions might be conducive to the transport of other trace elements in the ground water. The presence of lead in the surface-water sample from site M (20 μg/L) was inconsistent with the direction of possible contamination inferred from the distribution of major ions. Many broken batteries are present on the landfill surface near site M and may be a source of the lead in the water on that side of the landfill. Although metals other than iron and manganese were detected in several water samples, none of those determined was present in a concentration that exceeded a State surface-water-quality standard (New Jersey Department of Environmental Protection, 1989) or primary or secondary drinking-water regulation (New Jersey Register, 1989).

Concentrations of most trace elements in samples of water from Loantaka Brook were less than the detection limits. Although zinc, strontium, manganese, barium, and iron were detected at all sample sites, none of these elements was detected in a concentration that exceeded a New Jersey surface-water quality standard (New Jersey Department of Environmental Protection, 1989) or drinking-water regulation (New Jersey Register, 1989). Samples of bottom material from Loantaka Brook also were analyzed for trace elements. Results of these analyses indicate no substantial enrichment of most trace elements at the downstream site (site 4) relative to the upstream site (site 1), which is north of the landfill. Concentrations of manganese, copper, and lead were slightly higher in sediment at site 4 than in sediment at site 1. Results of the analyses of bottom sediments for metals are listed in table 6.

Organic Compounds

Ground-water and surface-water samples from all sampled sites were analyzed semiquantitatively for 32 volatile organic compounds (VOC's) at the New Jersey District laboratory in West Trenton, New Jersey, by using gas-chromatography methods with a photo-ionization detector and a Hall conductivity detector in series (Kammer and Gibs, 1989). Surface-water samples from sites B, H, and M were sent to the NWQL for analysis for VOC's by means of GC/MS. Some discrepancies were noted between results of

---

[3]Contaminants covered by secondary drinking-water regulations, otherwise known as secondary maximum contaminant levels (SMCLs), are those which may adversely affect the aesthetic quality of drinking water, such as taste, odor, color, and appearance, and which thereby may deter public acceptance of drinking water provided by public-water systems. Secondary regulations represent "reasonable" goals for drinking-water quality. They are intended as guidelines and are not enforceable (Shelton, undated, p. 22).

Table 6.--Summary of results of analyses of bottom-material samples[1] from Loantaka Brook

[Concentrations are for total recoverable metals, in micrograms per gram; <, less than; NF, Not Found]

Water-quality constituent	Loantaka Brook Site 1	Loantaka Brook Site 4
Aluminum	60,900	62,100
Arsenic	<10	<10
Barium	399	400
Beryllium	2	2
Bismuth	<10	<10
Boron	NF	NF
Cadmium	<2	<2
Calcium	7,400	7,400
Cerium	79	78
Chromium	63	66
Cobalt	15	16
Copper	36	50
Europium	<2	<2
Gallium	15	16
Germanium	NF	NF
Gold	<8	<8
Holmium	<4	<4
Iron	27,900	30,200
Lanthanum	42	43
Lithium	30	32
Lead	63	73
Potassium	15,700	14,900
Magnesium	6,400	6,200
Manganese	450	671
Molybdenum	<2	<2
Neodymium	39	41
Nickel	25	27
Niobium	10	8
Phosphorus	800	1,400
Scandium	13	14
Silver	<2	<2
Sodium	14,800	13,600
Strontium	114	111
Tantalum	<40	<40
Thorium	9	9
Tin	40	10
Titanium	3,300	3,700
Uranium	<100	<100
Vanadium	78	80
Tungsten	NF	NF
Ytterbium	3	3
Yttrium	28	31
Zinc	121	165
Zirconium	NF	NF

[1] Samples consisted of stream-bottom materials that passed through a 63-micrometer sieve.

analyses performed by the two laboratories. Generally, results of the analyses performed at the New Jersey District laboratory indicate the presence of small amounts of VOC's in samples from the southern and western sides of the landfill, whereas results of the analyses performed at the NWQL indicate no detectable quantities of these compounds, possibly because the sample-holding times at the NWQL were much longer than those at the New Jersey District laboratory. The sites at which VOC's were detected typically did not coincide with those at which large concentrations of major ions or trace elements were found. Results of the analyses for VOC's are presented in tables 2 and 7. None of the VOC's detected was present in a concentration greater than the applicable New Jersey maximum contaminant level[4] (MCL) (New Jersey Register, 1989).

Five surface-water and two ground-water samples were analyzed by means of GC/MS for methylene-chloride extractable compounds. Compounds tentatively identified in these seven samples from the GC/MS library search are presented in tables 8 and 9. Data on the presence and concentration of tentatively identified organic compounds (TIOC's) in this report are based on comparisons of sample spectra with library spectra, followed by visual examination by GC/MS analysts at the NWQL. TIOC data have not been confirmed by direct comparison with reference standards; therefore, identification of the compounds is tentative and reported concentrations are semiquantitative. Several of the compounds were tentatively identified as pharmaceuticals or compounds related to pharmaceuticals. These compounds were found primarily in water samples collected on the eastern and southern sides of the landfill; the GC/FID analysis indicated these compounds were not present at other sites around the landfill. Two of the tentatively identified compounds, meprobamate and phenobarbital, are Class IV Drug Enforcement Administration Controlled Substances. When the samples were reanalyzed, the molecular formulas of two tentatively identified compounds (6e-diol 2-methyl-2-propyl dicarbamate (meprobamate) and 3-ethyl-3-phenyl 2,6-piperidinetione) were found to be consistent with the results of "high-resolution" GC/MS analyses.

Results of GC/MS analyses showed the presence of 10 polycyclic aromatic compounds in bottom materials at sites 1 and 4 in Loantaka Brook. Four compounds classified as insecticides also were found in the analyzed bottom materials--chlordane, DDD, DDE, and dieldrin. Polychlorinated biphenyls also were found in bottom materials at sites 1 and 4 in concentrations of 2 $\mu g/kg$. Results of normalization of these data to concentrations of organic carbon generally indicate that concentrations of six of the polycyclic aromatic hydrocarbons and two of the insecticides were present in greater concentrations in bottom materials collected at site 4 than in bottom materials collected at site 1.

---

[4] A maximum contaminant level (MCL) is the highest amount of a specific contaminant allowed in the water delivered to any customer of a public-water system. The maximum contaminant level is the primary water-quality regulation enforced by the USEPA (Shelton, undated, p. 4). New Jersey MCL's generally are the same as the USEPA MCL's.

Table 7.--Summary of results of semiquantitative analyses for volatile organic compounds in ground-water and surface-water samples collected from the perimeter of the Rolling Knoll landfill

[Concentrations are in micrograms per liter; µg/L, micrograms per liter; *, found in laboratory water blank in similar concentrations; <, less than; all analyses performed at the New Jersey District laboratory in West Trenton, New Jersey]

Site name and source of water	Dichlorobromomethane, total	Carbontetrachloride, total	1,2-Dichloroethane, total	Bromoform, total	Chlorodibromomethane, total	Chloroform, total	Toluene, total	Benzene, total
Site A Surface	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Site A Ground	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Site B Surface	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Site B-C Surface	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Site B-C Ground	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Site C Surface	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Site D Surface	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Site F Surface	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Site F Ground	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Site G Surface	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Site H Surface	<.2	<.2	.2-1.0	<.2	<.2	<.2	<.2	<.2
Site I Surface	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Site J Surface	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Site K Surface	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Site L Surface	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Site M Surface	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Site N Surface	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Site 1 Loantaka Brook	<.2	<.2	<.2	<.2	<.2	.2-1.0	<.2	<.2
Site 2 Loantaka Brook	<.2	<.2	<.2	<.2	<.2	.2-1.0	<.2	<.2
Site 3 Loantaka Brook	<.2	<.2	<.2	<.2	<.2	.2-1.0	<.2	<.2
Site 4 Loantaka Brook	<.2	<.2	<.2	<.2	<.2	.2-1.0	<.2	<.2

Site name and source of water	Chlorobenzene, total	Chloroethane, total	Ethylbenzene, total	Methylbromide, total	Methylene chloride, total	Tetrachloroethylene, total	Trichlorofluoromethane, total
Site A Surface	<.2	<.2	<.2	<.2	<.2*	<.2	<.2
Site A Ground	<.2	<.2	<.2	<.2	.2-1.0*	<.2	<.2
Site B Surface	<.2	<.2	<.2	<.2	1.0-3.0*	<.2	<.2
Site B-C Surface	<.2	<.2	<.2	<.2	.2-1.0*	<.2	<.2
Site B-C Ground	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Site C Surface	<.2	<.2	<.2	<.2	.2-1.0*	<.2	<.2
Site D Surface	<.2	<.2	<.2	<.2	.2-1.0*	<.2	<.2
Site F Surface	<.2	<.2	<.2	<.2	1.0-3.0*	<.2	<.2
Site F Ground	<.2	<.2	<.2	<.2	.2-1.0*	<.2	<.2
Site G Surface	<.2	<.2	<.2	<.2	.2-1.0*	<.2	<.2
Site H Surface	<.2	<.2	<.2	<.2	1.0-3.0*	<.2	<.2
Site I Surface	<.2	<.2	<.2	<.2	1.0-3.0*	<.2	<.2
Site J Surface	<.2	<.2	<.2	<.2	.2-1.0*	<.2	<.2
Site K Surface	<.2	.2-1.0	<.2	<.2	.2-1.0*	<.2	<.2
Site L Surface	<.2	<.2	<.2	<.2	1.0-3.0*	<.2	<.2
Site M Surface	<.2	.2-1.0	<.2	<.2	1.0-3.0*	<.2	<.2
Site N Surface	<.2	<.2	<.2	<.2	.2-1.0*	<.2	<.2
Site 1 Loantaka Brook	<.2	<.2	<.2	<.2	.2-1.0*	<.2	<.2
Site 2 Loantaka Brook	<.2	<.2	<.2	<.2	.2-1.0*	<.2	<.2
Site 3 Loantaka Brook	<.2	<.2	<.2	<.2	.2-1.0*	<.2	<.2
Site 4 Loantaka Brook	<.2	<.2	<.2	<.2	.2-1.0*	<.2	<.2

Table 7.--Summary of results of semiquantitative analyses for volatile organic compounds in ground-water and surface-water samples collected from the perimeter of the Rolling Knoll landfill--Continued

Site name and source of water	1,1,2-Tri-chloro-ethane, total	1,1,2,2,Tetra-chloro-ethane, total	1,2-Di-chloro-benzene, total	1,2-Di-chloro-propane, total	1,2-Transdi-chloro-ethyl-ene, total	Cis-1,3-di-chloro-propene, total	1,3-Di-chloro-benzene, total	1,4-Di-chloro-benzene, total
Site A Surface	<.2	<.2	<.2	<.2	<.2*	<.2	<.2	<.2
Site A Ground	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Site B Surface	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Site B-C Surface	<.2	<.2	<.2	<.2	<.2*	<.2	<.2	<.2
Site B-C Ground	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Site C Surface	<.2	<.2	<.2	<.2	<.2*	<.2	<.2	<.2
Site D Surface	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Site F Surface	<.2	<.2	<.2	<.2	.2-1.0*	<.2	<.2	<.2
Site F Ground	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Site G Surface	<.2	<.2	<.2	<.2	<.2*	<.2	<.2	<.2
Site H Surface	<.2	<.2	<.2	<.2	.2-1.0*	<.2	<.2	<.2
Site I Surface	<.2	<.2	<.2	<.2	.2-1.0*	<.2	<.2	<.2
Site J Surface	<.2	<.2	<.2	<.2	<.2*	<.2	<.2	<.2
Site K Surface	<.2	<.2	<.2	<.2	<.2*	<.2	<.2	<.2
Site L Surface	<.2	<.2	<.2	<.2	.2-1.0*	<.2	<.2	<.2
Site M Surface	<.2	<.2	<.2	<.2	.2-1.0*	<.2	<.2	<.2
Site N Surface	<.2	<.2	<.2	<.2	<.2*	<.2	<.2	<.2
Site 1 Loantaka Brook	<.2	<.2	.2-1.0	<.2	<.2	<.2	<.2	<.2
Site 2 Loantaka Brook	<.2	<.2	.2-1.0	<.2	<.2	<.2	<.2	<.2
Site 3 Loantaka Brook	<.2	<.2	.2-1.0	<.2	<.2	<.2	<.2	<.2
Site 4 Loantaka Brook	<.2	<.2	.2-1.0	<.2	<.2	<.2	<.2	<.2

Site name and source of water	1,1-Di-chloro-ethane, total	1,1-Di-chloro-ethyl-ene, total	1,1,1-Tri-chloro-ethane, total	Cis-1,3-di-chloro-propene, total	Vinyl chlo-ride, total	Tri-chloro-ethyl-ene, total	2-Chloro-ethyl-vinyl-ether, total
Site A Surface	<.2	<.2	<.2	<.2	<.2	<.2*	<.2
Site A Ground	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Site B Surface	<.2	<.2	<.2	<.2	<.2	<.2*	<.2
Site B-C Surface	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Site B-C Ground	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Site C Surface	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Site D Surface	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Site F Surface	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Site F Ground	<.2	<.2	<.2	<.2	<.2	<.2*	<.2
Site G Surface	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Site H Surface	<.2	<.2	<.2	<.2	<.2	<.2*	<.2
Site I Surface	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Site J Surface	<.2	<.2	<.2	<.2	<.2	<.2*	<.2
Site K Surface	<.2	<.2	<.2	<.2	<.2	<.2*	<.2
Site L Surface	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Site M Surface	<.2	<.2	<.2	<.2	<.2	<.2*	<.2
Site N Surface	<.2	<.2	<.2	<.2	<.2	<.2*	<.2
Site 1 Loantaka Brook	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Site 2 Loantaka Brook	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Site 3 Loantaka Brook	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Site 4 Loantaka Brook	<.2	<.2	<.2	<.2	<.2	<.2	<.2

Table 8.--Estimated concentrations of organic compounds tentatively identified[1] by means of gas chromatography/mass spectrometry of surface-water and ground-water samples

[Concentrations are in micrograms per liter; site locations shown in figure 2; NI, not identified; SW, surface water; GW, ground water; **, molecular formula found to be consistent with results of high-resolution gas chromatography/mass spectrometry]

Compound	Site A GW	Site B SW	Site B-C GW	Site C SW	Site H SW	Site I SW	Site L SW
Nonanal	NI	NI	0.6	0.2	NI	NI	5.0
Carisoprodol	3.0	2.0	1.0	NI	NI	NI	NI
Mebutamate	NI	2.0	NI	NI	NI	NI	NI
6e-diol, 2-methyl-2-propyl, dicarbamate (meprobamate) **	.9	2.0	.7	NI	20.0	4.0	NI
2,6-Piperidinedione, 3-ethyl-3-phenyl **	10.0	30.0	NI	2.0	20.0	1.0	NI
Phenobarbital	NI	.3	NI	NI	.5	NI	NI
Phenobarbital metabolite	NI	NI	NI	NI	.4	NI	NI
5-Allyl-5(1-methylbutl) barbituric acid	NI	NI	NI	NI	.4	NI	NI
Benzothiozole	.3	.3	.3	NI	NI	NI	NI
Benzenesulfonamide, n-ethyl-4-methyl	.4	.5	.5	NI	NI	NI	NI
Benzamide, 2,6-dichloro	1.0	NI	2.0	.3	NI	NI	NI
1,2-Benzenedicarboxylic acid, dipropyl ester	NI	6.0	NI	NI	NI	NI	NI
2(3H)-Benzothiazolone	NI	.9	NI	NI	NI	NI	NI
Benzene, ethoxymethyl	NI	NI	NI	NI	.6	NI	NI
1H-benzimidazole, 5-chloro-2-methyl	NI	NI	NI	NI	.4	NI	NI
1,3-Isobenzofurandione	NI	NI	NI	NI	NI	NI	.4
Naphthalene, 2-ethyl	NI	NI	NI	NI	NI	.1	NI
Phenol, 2,4-dimethyl	NI	NI	NI	NI	.3	NI	NI
Phenol, 3-(1,1-dimethyl)	NI	.2	NI	NI	NI	NI	NI
Tetradecanoic acid	NI	NI	NI	2.0	NI	NI	NI
1-Hexanol, 2-ethyl	NI	NI	NI	NI	NI	NI	.8
Sulfur (S8)	NI	NI	2.0	NI	NI	NI	NI
Hexanedioic acid, dioctyl ester	NI	NI	NI	.8	NI	NI	NI
Phosphoric acid, triethyl ester	NI	.2	NI	NI	NI	NI	NI

[1] Reported concentration generally accurate to one order of magnitude.

Table 9.--Type and number of unidentified peaks in chromatographs produced by means of gas chromatography/mass spectrometry of surface-water and ground-water samples

[A, unknown; B, nitrogen-containing; C, alkene/cycloalkane; D, organic acid; E, alkane; F, monochlorinated alkyl benzene; SW, surface water; GW, ground water]

	Unidentified peaks in analysis chromatographs						
	Site B SW	Site A GW	Site B-C GW	Site C SW	Site H SW	Site I SW	Site L SW
Total unidentified	3	31	6	7	17	3	7
Types and number in each analysis	A2 C1	A 4 C15 E12	A4 B1 C1	A5 D2	A14 C 1 E 1 F 1	A2 C1	A1 C4

ELECTROMAGNETIC SURVEY

The distribution of apparent-conductivity values determined near the eastern and southern edges of the landfill are presented in figure 6. The high apparent-electrical-conductivity values indicate the presence of the laterally extensive, electrically conductive glacial-lake clay deposit discussed by Minard (1967).

Apparent-conductivity values measured near the perimeter of the landfill range from 1.7 to 76 mS/m. These values are interpreted with respect to the hydrogeology, presence of landfill materials, and water quality at the site as indicated below.

Apparent conductivity (in millisiemens per meter)	Type of earth materials
less than 15	Electrically nonconductive materials (sands) and (or) water table greater than 4 ft below land surface.
15-30	Electrically conductive materials (clays) and (or) contaminated ground water.
23-30	Typical background values for swamp materials.
greater than 30	Interference from metallic objects.

Background apparent conductivities, measured at the stations farthest to the south and east of the landfill (F and G), ranged from 23 to 30 mS/m. Apparent-conductivity values were highly variable (1.7 to 76.0 mS/m) over landfill material within the Refuge, on the eastern and southern sides of the landfill. Interference from metallic objects is most likely the cause of this extreme variability. The depth to the water table also affected apparent-conductivity measurements at the measurement stations. Apparent conductivities decreased dramatically over the knolls as the depth to the water table increased.

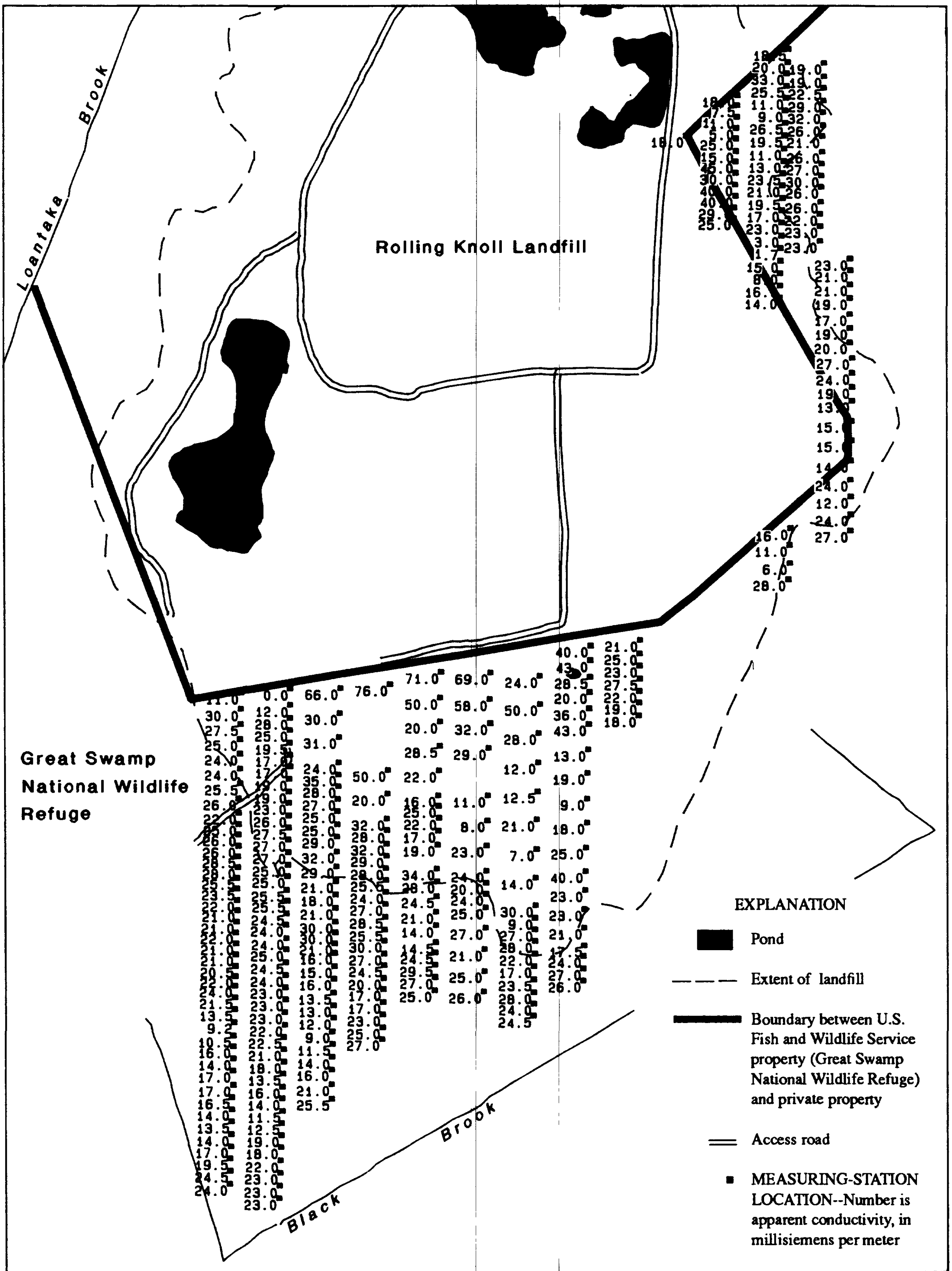


Figure 6.--Distribution of apparent-conductivity values measured near the perimeter of the Rolling Knoll landfill.

Table 10.--Lithologic descriptions of hand-augered core samples

Sample site	Depth interval (in feet)	Lithology
A	0.5 - 1.0	Organic, some clay
A	1.0 - 4.0	Sand, tan, some silt and clay
A	4.0 - 6.5	Sand, grey, some silt
B	0.0 - 5.5	Clay, tan, with iron concretions, very little sand, fairly dry inside core
B	5.5 - 6.5	Clay, very dense
B-C	0.0 - 0.5	Organic, black, peat with some fibers
B-C	0.5 - 1.0	Clay, sandy, dark brown
B-C	1.0 - 2.0	Clay, sandy, dark brown
B-C	2.0 - 4.0	Sand, some silt
B-C	4.0 - 5.0	Sand, dark, some silt
B-C	5.0 - 7.0	Sand, grey and loose
B-C	7.0 - 8.0	Sand, grey, clay present
C	0.0 - 4.0	Organic
D	0.0 - 7.0	Organic, peat, fibrous to humic, fairly impermeable (dry inside core)
D	7.0 - 8.0	Clay, very dense, grey
F	0.0 - 1.0	Organic, peat, fibrous, some sandy silt
F	1.0 - 2.0	Sand, clayey
F	2.0 - 5.0	Sand, brown, permeable
N		No cores collected; lithology appears to be impermeable material (probably dense clay)

Apparent-conductivity values measured at stations at sites A, B-C, and F were lower than those measured at adjacent stations, indicating the presence of materials with low electrical conductivity, such as sands. Measurements made near sample sites A, B-C, and F ranged from 11 to 17 mS/m. Because the sample sites are located within a few feet of the water table, these low apparent-conductivity values most likely indicate the presence of sands and silts at these sites.

The apparent-conductivities measured at these sample sites are consistent with the lithologic data obtained from core-sample analysis (table 10). Results of analysis of the hand-augered core samples also indicate that permeable sand was present at sites A, B-C, and F. At sites B and D, however, a dense, relatively impermeable clay was detected. Compacted, relatively impermeable peat was present at site C from the surface to a depth of 4 ft. Low apparent-conductivity values, together with the presence of sands in core samples and elevated concentrations of dissolved solids in samples of ground water and surface water, indicate that installation and periodic sampling of observation wells at sites A, B-C, and F would be likely to allow early detection of any possible effects of the Rolling Knoll landfill on the quality of ground water underlying and discharging to the adjacent Great Swamp National Wildlife Refuge.

SUMMARY AND CONCLUSIONS

A water-quality reconnaissance of 21 ground-water and surface-water sites around the perimeter of the Rolling Knoll landfill and an electromagnetic survey of the parts of the landfill within the Great Swamp National Wildlife Refuge were conducted in 1989. Samples of surface water and ground water were analyzed for major ions, dissolved trace elements, volatile organic compounds, and methylene chloride-extractable organic compounds. The methylene chloride-extractable compounds were analyzed by means of gas chromatography with flame-ionization detector, and selected samples were chosen for analysis by means of gas chromatography/mass spectrometry to identify or tentatively identify additional organic compounds.

Results of the water-quality reconnaissance showed that cadmium, lead, silver, and zinc were present in surface water and ground water adjacent to the landfill. Concentrations of dissolved iron and manganese were variable near the perimeter of the landfill but generally exceeded secondary drinking-water regulations. Several organic compounds were tentatively identified by means of gas chromatography/mass spectroscopy as pharmaceuticals or compounds related to pharmaceuticals. Results of analyses of bottom materials from Loantaka Brook showed the presence of polycyclic aromatic compounds, insecticides, and polychlorinated biphenyls; the source of these compounds is unknown. Organic compounds were found in ground water and surface water on the southern and western sides of the landfill. In contrast, ground water and surface water enriched primarily with trace elements (other than lead) was found only east and south of the landfill. Lead was detected not only in samples of surface water and ground water collected east and south of the landfill but also in samples from two surface-water sites in the western and southwestern parts of the study area, near Loantoka Brook. Broken batteries on the western side of the landfill may be a source of lead in surface water in the western and southwestern parts of the study area. Elevated specific conductance, pH, and sodium and bicarbonate concentrations in surface water on the eastern and southern sides of the landfill indicate that the landfill appears to have a greater effect on surface water there than on surface water on the western side.

Inspection of cores collected from hand-augered holes at several water-quality sites verified the presence of clay beneath the landfill and Refuge; sands capable of conducting landfill leachate were present at the eastern and southern edges of the landfill. Results of the electromagnetic survey were consistent with the lithology of the samples. Installation and periodic sampling of observation wells at sites A, B-C, and F located at the eastern and southern edges of the landfill probably would allow early detection of any possible effects of the landfill on the quality of ground water underlying and discharging to the adjacent Refuge.

REFERENCES CITED

Eby, C.F., 1976, Soil survey of Morris County, New Jersey: U.S. Soil Conservation Service, 111 p., 39 sheets.

Fishman, Marvin J., and Friedman, Linda C., 1989, Methods for determination of inorganic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. A1, 545 p.

Hem, J.D., 1985, Study and interpretation of the chemical characteristics of natural water: U.S. Geological Survey Water Supply Paper 2254, 263 p.

Kammer, J.A., and Gibs, Jacob, 1989, An analytical technique for screening purgeable volatile organic compounds in water: U.S. Geological Survey Open-File Report 89-53, 13 p.

Minard, J.P., 1967, Summary report on the geology and mineral resources of the Great Swamp National Wildlife Refuge: New Jersey Geological Survey Bulletin 1260-D,E, 14 p.

New Jersey Department of Environmental Protection, 1989, N.J.A.C. 7:9-4.1 et seq., Trenton, New Jersey, 118 p.

New Jersey Register, 1989, v. 21, no. 54, January 3, 1989.

NUS Corporation, 1985, Final draft site inspection report and hazardous ranking system model, Green Village Disposal: Unpublished consultant's report prepared for the U.S. Environmental Protection Agency, 8 sections.

Salisbury, R.D., and Peet, C.E., 1896, A preliminary map of the surface formations of the valley of the Passaic with the county eastward to Newark and southward to the Raritan River, <u>in</u> Geological Survey of New Jersey, 1894: Annual Report of the State Geologist, scale 1:63,360.

Shelton, T.B., undated, Interpreting drinking water quality analysis: What do the numbers mean?: New Brunswick, N.J., Rutgers Cooperative Extension, 46 p.

U.S. Fish and Wildlife Service, 1991, Contaminants in fish and sediments of Great Swamp National Wildlife Refuge: Technical Assistance Report, Morris County, N.J., 22 p., 5 app.

Vecchioli, John, Gill, H.E., and Lang, S.M., 1962, Hydrologic role of the Great Swamp and other marshland in Upper Passaic River basin: Journal of the American Water Works Association, v. 54, no. 6, p. 695-701.

Wershaw, R.L., Fishman, M.J., Grabbe, R.R., and Lowe, L.E., eds., 1983, Methods for the determination of organic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. A3, 173 p.

Wood, W.W., 1976, Guidelines for collection and field analysis of ground-water samples for selected unstable constituents: U.S. Geological Survey Techniques of Water-Resources Investigations book 1, chap. D-2, 24 p.

GLOSSARY

Apparent conductivity is a measure of the ease with which a material transmits electric current. The measurement is made without physically contacting the material that is measured. The inverse of apparent conductivity is apparent resistivity.

Current is a flow of electricity, measured in amperes.

Dissolved is that portion of a material in a representative water sample that passes through a 0.45-micrometer membrane filter. This is a convenient operational definition used by Federal agencies that collect and analyze water samples. Determinations of dissolved constituents are made on subsamples of the filtrate.

Gas chromatography is a separation process in which a multicomponent fluid phase (carrier gas plus sample) moves past a stationary condensed (solid) phase referred to as a column. Molecules of the moving sample undergo many successive adsorptions and desorptions. Each component has a different value of the ratio of time spent adsorbed on the solid to time spent in solution; hence the components travel at different rates through the column and are separated. Sensors, such as a Hall[1] conductivity detector, flame-ionization detector, and mass spectrometer, are used to detect sample components as they leave the column.

Horizontal dipole is a pair of magnetic poles that are parallel with the Earth's surface.

Intercoil spacing is the distance between the transmitter and receiver coil for an electromagnetic measurement.

Micrograms per liter (μg/L) is a unit that expresses the concentration of a chemical constituent in solution as weight (micrograms) of solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to one milligram per liter.

Milligrams per liter (mg/L) is a unit that expresses the concentration of a chemical constituent in solution as weight per unit volume of water.

Minipiezometer is an instrument that is inserted into the ground to measure hydraulic head and used to collect shallow ground-water samples.

Non-contacting terrain conductivity meter is an instrument that uses electromagnetic energy to measure the apparent conductivity of sediments and ground water.

---

[1] Use of trade names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

Stiff diagrams use three or four parallel horizontal axes extending on each side of a vertical axis whose value is zero. Concentrations of three or four cations can be plotted, one on each axis, to the left of zero; likewise, concentrations of three or four anions can be plotted, one on each axis, to the right of zero. The units of concentration are milliequivalents per liter. The resulting points are connected to give an irregular polygonal shape or pattern. The Stiff diagram is a relatively distinctive method of showing differences and similarities in water composition, with the width of the pattern being an approximate indication of total ionic content.

Volatile organic compounds (VOC's) are a group of organic substances that can be stripped from a water sample by the injection of an inert gas prior to analysis by means of gas chromatography. By definition, these compounds are less than 2 percent soluble in water and have boiling points below 150 degrees Celsius.

Water table is the upper surface of water (at atmospheric pressure) in an unconfined aquifer. It is the level at which water stands in wells that penetrate the uppermost part of an unconfined aquifer.

Table 2.--Summary of results of chemical analyses of ground-water, surface-water, and bottom-material samples for physical characteristics, metals, major ions, and organic compounds

[Total, total recoverable constituent from water and suspended sediment; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; <, less than or below detection limit; µg/kg, micrograms per kilogram; bot.mat, bottom materials; NA, sample not analyzed for the indicated constituent]

Site name and source of water	Date of sampling	Specific conductance, field, (µS/cm)	pH, field (standard units)	Nitrogen, nitrite dissolved as N (mg/L)	Nitrogen, nitrate dissolved as N (mg/L)	Nitrogen, $NO_2 + NO_3$ dissolved as N (mg/L)	Phosphorus ortho, dissolved as P (mg/L)
				WATER-QUALITY CHARACTERISTICS			
Site A Surface	05-09-89	300	7.2	NA	NA	NA	NA
Site A Ground	05-19-89	420	6.8	NA	NA	NA	NA
Site B Surface	05-11-89	410	7.2	NA	NA	NA	NA
Site B-C Surface	05-09-89	440	7.2	NA	NA	NA	NA
Site B-C Ground	05-19-89	900	6.9	NA	NA	NA	NA
Site C Surface	05-09-89	175	7.3	NA	NA	NA	NA
Site D Surface	05-17-89	157	7.2	NA	NA	NA	NA
Site F Surface	05-11-89	270	7.2	NA	NA	NA	NA
Site F Ground	05-18-89	192	6.1	NA	NA	NA	NA
Site G Surface	05-11-89	625	7.5	NA	NA	NA	NA
Site H Surface	05-11-89	156	6.9	NA	NA	NA	NA
Site I Surface	05-11-89	140	6.7	NA	NA	NA	NA
Site J Surface	05-09-89	300	7.4	NA	NA	NA	NA
Site K Surface	05-09-89	127	6.5	NA	NA	NA	NA
Site L Surface	05-11-89	56	6.1	NA	<.01	NA	.05
Site M Surface	05-11-89	66	6.4	NA	<.01	NA	<.01
Site N Surface	05-09-89	310	6.9	NA	NA	NA	NA
Site 1 Loantaka Brook	06-07-89	557	7.4	<.01	NA	<.10	<.01
Site 2 Loantaka Brook	06-07-89	550	7.4	<.01	NA	<.10	.02
Site 3 Loantaka Brook	06-07-89	552	7.4	<.01	NA	<.10	<.01
Site 4 Loantaka Brook	06-07-89	607	7.4	<.01	NA	<.10	<.01

Site name and source of water	Specific conductance, lab (µS/cm)	Alkalinity[1] $CaCO_3$ (mg/L)	Calcium, dissolved (mg/L)	Magnesium, dissolved (mg/L)	Sodium, dissolved (mg/L)	Potassium, dissolved (mg/L)	Chloride, dissolved (mg/L)
Site A Surface	304	149	44	6.5	6.1	5.0	5.9
Site A Ground	417	212	62	9.1	8.6	10	10
Site B Surface	389	187	54	8.9	7.1	7.0	7.8
Site B-C Surface	435	216	61	9.3	9.0	8.0	9.5
Site B-C Ground	782	442	160	48	81	27	2.0
Site C Surface	172	66	19	4.4	9.5	3.0	11
Site D Surface	155	60	19	4.0	5.8	3.0	7.2
Site F Surface	284	127	35	8.9	8.1	5.9	8.9
Site F Ground	186	50	11	8.2	14	.3	8.1
Site G Surface	612	281	83	20	12	12	11
Site H Surface	178	72	22	5.3	5.4	2.7	7.7
Site I Surface	141	49	17	4.3	5.4	1.9	5.7
Site J Surface	313	145	43	8.3	9.2	4.3	11
Site K Surface	122	32	17	2.4	2.7	1.4	2.2
Site L Surface	54	10	5.9	1.6	2.3	.8	1.9
Site M Surface	62	12	5.1	2.3	3.3	.6	3.1
Site N Surface	301	139	39	7.9	6.3	5.2	6.2
Site 1 Loantaka Brook	557	79	37	13	49	4.6	72
Site 2 Loantaka Brook	546	75	36	13	47	4.5	72
Site 3 Loantaka Brook	551	74	36	13	48	4.6	72
Site 4 Loantaka Brook	618	120	41	15	55	5.1	82

Footnote at end of table.

Table 2.--Summary of results of chemical analyses of ground-water, surface-water, and bottom-material samples for physical characteristics, metals, major ions, and organic compounds--Continued

Site name and source of water	WATER-QUALITY CHARACTERISTICS--Continued						
	Sulfate, dissolved (mg/L)	Fluoride, dissolved (mg/L)	Silica, dissolved (mg/L)	Barium, dissolved (µg/L)	Beryllium, dissolved (µg/L)	Cadmium, dissolved (µg/L)	Chromium, dissolved (µg/L)
Site A Surface	<1.0	0.2	3.4	160	<0.5	2	<5
Site A Ground	2.0	.1	7.7	35	<.5	2	<5
Site B Surface	4.0	.1	9.1	170	<.5	<1	<5
Site B-C Surface	<1.0	.1	7.5	220	<.5	<1	<5
Site B-C Ground	2.0	.1	31	450	<.5	5	<5
Site C Surface	3.0	.1	3.0	59	<.5	<1	<5
Site D Surface	7.0	.1	5.0	71	<.5	1	<5
Site F Surface	5.0	.1	7.1	98	<.5	<1	<5
Site F Ground	25	.1	23	30	<.5	1	<5
Site G Surface	28	.1	8.4	250	<.5	<1	<5
Site H Surface	8.0	.1	7.3	62	<.5	<1	<5
Site I Surface	10	.1	7.0	44	<.5	<1	<5
Site J Surface	6.0	.1	1.6	90	<.5	<1	<5
Site K Surface	20	.1	13	50	<.5	<1	<5
Site L Surface	8.9	.07	9.4	25	<.5	<1	<5
Site M Surface	10	.1	10	23	<.5	<1	<5
Site N Surface	6.0	.2	8.4	140	<.5	<1	<5
Site 1 Loantaka Brook	41	.1	16	32	<.5	<1	<5
Site 2 Loantaka Brook	40	.1	16	29	<.5	<1	<5
Site 3 Loantaka Brook	41	.1	15	30	<.5	<1	<5
Site 4 Loantaka Brook	49	.1	17	34	<.5	<1	<5

Site name and source of water	Cobalt, dissolved (µg/L)	Copper, dissolved (µg/L)	Iron, dissolved (µg/L)	Lead, dissolved (µg/L)	Manganese, dissolved (µg/L)	Molybdenum, dissolved (µg/L)	Nickel, dissolved (µg/L)
Site A Surface	<3	<10	1,800	10	75	<10	<10
Site A Ground	<3	<10	6,200	10	1,100	<10	<10
Site B Surface	<3	<10	440	<10	96	<10	<10
Site B-C Surface	<3	<10	880	<10	410	<10	<10
Site B-C Ground	<3	<10	57,000	18	930	<10	<10
Site C Surface	<3	<10	2,600	<10	45	<10	<10
Site D Surface	<3	<10	1,000	<10	33	<10	<10
Site F Surface	<3	<10	570	<10	16	<10	<10
Site F Ground	6	20	2,500	10	220	<10	<10
Site G Surface	<3	<10	64	<10	33	<10	<10
Site H Surface	<3	30	950	20	48	<10	10
Site I Surface	<3	<10	440	<10	30	<10	<10
Site J Surface	<3	<10	140	<10	38	<10	<10
Site K Surface	<3	10	2,200	<10	43	<10	<10
Site L Surface	<3	<10	510	<10	21	<10	<10
Site M Surface	<3	<10	360	20	20	<10	<10
Site N Surface	<3	<10	270	<10	260	<10	<10
Site 1 Loantaka Brook	<3	<10	110	<10	110	20	<10
Site 2 Loantaka Brook	<3	<10	130	<10	110	<10	<10
Site 3 Loantaka Brook	<3	<10	120	<10	110	<10	<10
Site 4 Loantaka Brook	<3	20	68	<10	79	10	<10

Table 2.--Summary of results of chemical analyses of ground-water, surface-water, and bottom-material samples for physical characteristics, metals, major ions, and organic compounds--Continued

Site name and source of water	Silver, dissolved (μg/L)	Strontium, dissolved (μg/L)	Vanadium, dissolved (μg/L)	Zinc, dissolved (μg/L)	Lithium, dissolved (μg/L)	Bromide, dissolved (μg/L)
	WATER-QUALITY CHARACTERISTICS--Continued					
Site A Surface	2.0	210	<6	6	5	0.07
Site A Ground	1.0	280	<6	12	<4	.24
Site B Surface	<1.0	240	<6	5	5	<.01
Site B-C Surface	<1.0	260	<6	4	7	<.01
Site B-C Ground	<1.0	2,700	<60	63	290	.04
Site C Surface	<1.0	87	<6	5	<4	<.01
Site D Surface	<1.0	88	<6	6	<4	.07
Site F Surface	<1.0	170	<6	5	8	<.01
Site F Ground	1.0	44	<6	41	<4	.1
Site G Surface	<1.0	480	<6	11	38	.11
Site H Surface	<1.0	110	<6	52	6	.1
Site I Surface	<1.0	80	<6	17	<4	<.01
Site J Surface	<1.0	240	<6	14	13	<.01
Site K Surface	<1.0	78	<6	100	<4	<.01
Site L Surface	<1.0	22	<6	20	<4	<.01
Site M Surface	2.0	20	<6	16	<4	<.01
Site N Surface	<1.0	190	<6	6	5	<.01
Site 1 Loantaka Brook	<1.0	150	<6	17	<4	.05
Site 2 Loantaka Brook	<1.0	140	<6	9	<4	.05
Site 3 Loantaka Brook	<1.0	140	<6	12	<4	.04
Site 4 Loantaka Brook	<1.0	160	<6	15	<4	.03

Site name and source of water	Dichloro-bromomethane, total (μg/L)	Carbon tetrachloride total (μg/L)	1,2-Dichloro-ethane, total (μg/L)	Bromoform, total (μg/L)	Chlorodi-bromomethane, total (μg/L)	Chloroform, total (μg/L)	Toluene, total (μg/L)
	ORGANIC COMPOUNDS IN WATER						
Site A Ground	NA	NA	NA	NA	NA	NA	NA
Site B Surface	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Site B-C Ground	NA	NA	NA	NA	NA	NA	NA
Site C Surface	NA	NA	NA	NA	NA	NA	NA
Site H Surface	<.2	<.2	1.3	<.2	<.2	<.2	<.2
Site I Surface	NA	NA	NA	NA	NA	NA	NA
Site L Surface	NA	NA	NA	NA	NA	NA	NA
Site M Surface	<.2	<.2	<.2	<.2	<.2	<.2	<.2

Site name and source of water	Benzene, total (μg/L)	Acenaphth-ylene, total (μg/L)	Acenaph-thene, total (μg/L)	Anthra-cene, total (μg/L)	Benzo[b] fluoran-thene, total (μg/L)	Benzo[k] fluoran-thene, total (μg/L)	Benzo[a] pyrene, total (μg/L)	bis (2-Chloroethyl) ether, total (μg/L)
Site A Ground	NA	<5.0	<5.0	<5.0	<10.0	<10.0	<10.0	<5.0
Site B Surface	<2.0	<5.0	<5.0	<5.0	<10.0	<10.0	<10.0	<5.0
Site B-C Ground	NA	<5.0	<5.0	<5.0	<10.0	<10.0	<10.0	<5.0
Site C Surface	NA	<5.0	<5.0	<5.0	<10.0	<10.0	<10.0	<5.0
Site H Surface	<.2	<5.0	<5.0	<5.0	<10.0	<10.0	<10.0	<5.0
Site I Surface	NA	<5.0	<5.0	<5.0	<10.0	<10.0	<10.0	<5.0
Site L Surface	NA	<5.0	<5.0	<5.0	<10.0	<10.0	<10.0	<5.0
Site M Surface	<.2	NA	NA	NA	NA	NA	NA	NA

Table 2.--Summary of results of chemical analyses of ground-water, surface-water, and bottom-material samples for physical characteristics, metals, major ions, and organic compounds--Continued

Site name and source of water	bis (2-Chloroethoxy ether, total (µg/L)	bis (2-Chloro-isopropyl) ether, total (µg/L)	N-butyl benzyl phthalate, total (µg/L)	Chloro-benzene, total (µg/L)	Chloro-ethane, total (µg/L)	Chrysene, total (µg/L)	Di-ethyl phtha-late, total (µg/L)	Di-methyl phtha-late, total (µg/L)
	ORGANIC COMPOUNDS IN WATER--Continued							
Site A Ground	<5.0	<5.0	<5.0	NA	NA	<10.0	<5.0	<5.0
Site B Surface	<5.0	<5.0	<5.0	<2.0	<2.0	<10.0	<5.0	<5.0
Site B-C Ground	<5.0	<5.0	<5.0	NA	NA	<10.0	<5.0	<5.0
Site C Surface	<5.0	<5.0	<5.0	NA	NA	<10.0	<5.0	<5.0
Site H Surface	<5.0	<5.0	<5.0	<2.0	<2.0	<10.0	<5.0	<5.0
Site I Surface	<5.0	<5.0	<5.0	NA	NA	<10.0	<5.0	<5.0
Site L Surface	<5.0	<5.0	<5.0	NA	NA	<10.0	<5.0	<5.0
Site M Surface	NA	NA	NA	<.2	<.2	NA	NA	NA

Site Name and source of water	N-Nitro-sodimethyl-amine, total (µg/L)	Nitro-benzene, total (µg/L)	Parachloro-metacresol, total (µg/L)	Phenan-threne, total (µg/L)	Pyrene, total (µg/L)	Tetrachloro-ethylene, total (µg/L)	Trichloro-fluoromethane, total (µg/L)
Site A Ground	<5.0	<5.0	<30.0	<5.0	<5.0	NA	NA
Site B Surface	<5.0	<5.0	<30.0	<5.0	<5.0	<2.0	<2.0
Site B-C Ground	<5.0	<5.0	<30.0	<5.0	<5.0	NA	NA
Site C Surface	<5.0	<5.0	<30.0	<5.0	<5.0	NA	NA
Site H Surface	<5.0	<5.0	<30.0	<5.0	<5.0	<.2	<.2
Site I Surface	<5.0	<5.0	<30.0	<5.0	<5.0	NA	NA
Site L Surface	<5.0	<5.0	<30.0	<5.0	<5.0	NA	NA
Site M Surface	NA	NA	NA	NA	NA	<.2	<.2

Site name and source of water	Ethylbenzene, total (µg/L)	Fluoroanthene, total (µg/L)	Fluorene, total (µg/L)	Hexa-chlorocyclo-pentadiene, total (µg/L)	Hexa-chloroethane, total (µg/L)	Indeno (1,2,3-CD) pyrene, total (µg/L)	Isophorone, total (µg/L)
Site A Ground	NA	<5.0	<5.0	<5.0	<5.0	<10.0	<5.0
Site B Surface	<2.0	<5.0	<5.0	<5.0	<5.0	<10.0	<5.0
Site B-C Ground	NA	<5.0	<5.0	<5.0	<5.0	<10.0	<5.0
Site C Surface	NA	<5.0	<5.0	<5.0	<5.0	<10.0	<5.0
Site H Surface	<.2	<5.0	<5.0	<5.0	<5.0	<10.0	<5.0
Site I Surface	NA	<5.0	<5.0	<5.0	<5.0	<10.0	<5.0
Site L Surface	NA	<5.0	<5.0	<5.0	<5.0	<10.0	<5.0
Site M Surface	<.2	NA	NA	NA	NA	NA	NA

Site name and source of water	Methylbromide, total (µg/L)	Methyl-chloride, total (µg/L)	Methylene chloride, total (µg/L)	N-nitrosodi-n-propylamine, total (µg/L)	N-nitrosodi-phenylamine, total (µg/L)	1,1-Di-chloroethane, total (µg/L)	1,1-Di-chloro-ethylene, total (µg/L)
Site A Ground	NA	NA	NA	<5.0	<5.0	NA	NA
Site B Surface	<2.0	<2.0	<2.0	<5.0	<5.0	<2.0	<2.0
Site B-C Ground	NA	NA	NA	<5.0	<5.0	NA	NA
Site C Surface	NA	NA	NA	<5.0	<5.0	NA	NA
Site H Surface	<.2	<.2	<.2	<5.0	<5.0	<.2	<.2
Site I Surface	NA	NA	NA	<5.0	<5.0	NA	NA
Site L Surface	NA	NA	NA	<5.0	<5.0	NA	NA
Site M Surface	<.2	<.2	<.2	NA	NA	<.2	<.2

Table 2.--Summary of results of chemical analyses of ground-water, surface-water, and bottom-material samples for physical characteristics, metals, major ions, and organic compounds--Continued

ORGANIC COMPOUNDS IN WATER--Continued

Site name and source of water	1,1,1-Tri-chloroethane, total (µg/L)	1,1,2-Tri-chloroethane, total (µg/L)	1,1,2,2-Tetra-chloroethane, total (µg/L)	Benzo [ghi] perylene-1,12-benzoperylene total (µg/L)	Benzo [a] anthracene-1,2-benzanthracine, total (µg/L)	1,2-Di-chloro-benzene, total (µg/L)	1,2-Di-chloro-propane, total (µg/L)
Site A Ground	NA	NA	NA	<10.0	<5.0	<5.0	NA
Site B Surface	<2.0	<2.0	<2.0	<10.0	<5.0	<5.0	<2.0
Site B-C Ground	NA	NA	NA	<10.0	<5.0	<5.0	NA
Site C Surface	NA	NA	NA	<10.0	<5.0	<5.0	NA
Site H Surface	<.2	<.2	<.2	<10.0	<5.0	<5.0	<.2
Site I Surface	NA	NA	NA	<10.0	<5.0	<5.0	NA
Site L Surface	NA	NA	NA	<10.0	<5.0	<5.0	NA
Site M Surface	<.2	<.2	<.2	NA	NA	<.2	<.2

Site name and source of water	2,4-Di-nitrophenol, total (µg/L)	2,4,6-Tri-chlorophenol, total (µg/L)	2,6-Di-nitrotoluene, total (µg/L)	1,2-Transdi-chloroethene, total (µg/L)	1,2,4-trichloro-benzene, total (µg/L)	1,2,5,6-Dibenz-anthracene, total (µg/L)	1,3-Dichloro-propene, total (µg/L)
Site A Ground	<20.0	<20.0	<5.0	NA	<5.0	<10.0	NA
Site B Surface	<20.0	<20.0	<5.0	<2.0	<5.0	<10.0	<2.0
Site B-C Ground	<20.0	<20.0	<5.0	NA	<5.0	<10.0	NA
Site C Surface	<20.0	<20.0	<5.0	NA	<5.0	<10.0	NA
Site H Surface	<20.0	<20.0	<5.0	<.2	<5.0	<10.0	<.2
Site I Surface	<20.0	<20.0	<5.0	NA	<5.0	<10.0	NA
Site L Surface	<20.0	<20.0	<5.0	NA	<5.0	<10.0	NA
Site M Surface	NA	NA	NA	<.2	NA	NA	<.2

Local identifier	1,3-Di-chloro-benzene, total (µg/L)	1,4-Di-chloro-benzene, total (µg/L)	2-chloroethyl-vinylether, total (µg/L)	2-Chloro-naphthalene, total (µg/L)	Styrene, total (µg/L)	1,2-Di-bromoethane, water whole, total (µg/L)	Xylene, water whole total (µg/L)
Site A Ground	<5.0	<5.0	NA	<5.0	NA	NA	NA
Site B Surface	<5.0	<5.0	<2.0	<5.0	<2.0	<2.0	<2.0
Site B-C Ground	<5.0	<5.0	NA	<5.0	NA	NA	NA
Site C Surface	<5.0	<5.0	NA	<5.0	NA	NA	NA
Site H Surface	<5.0	<5.0	<.2	<5.0	<.2	<.2	<.2
Site I Surface	<5.0	<5.0	NA	<5.0	NA	NA	NA
Site L Surface	<5.0	<5.0	NA	<5.0	NA	NA	NA
Site M Surface	<.2	<.2	<.2	NA	<.2	<.2	<.2

Local identifier	2-Chloro-phenol, total (µg/L)	2-Nitro-phenol, total (µg/L)	Di-n-octyl phthalate, total (µg/L)	2,4-Di-chlorophenol, total (µg/L)	2,4-Di-methylphenol, total (µg/L)	2,4-Di-nitrotoluene, total (µg/L)	4-Bromophenyl phenyl ether, total (µg/L)
Site A Ground	<5.0	<5.0	<10.0	<5.0	<5.0	<5.0	<5.0
Site B Surface	<5.0	<5.0	<10.0	<5.0	<5.0	<5.0	<5.0
Site B-C Ground	<5.0	<5.0	<10.0	<5.0	<5.0	<5.0	<5.0
Site C Surface	<5.0	<5.0	<10.0	<5.0	<5.0	<5.0	<5.0
Site H Surface	<5.0	<5.0	<10.0	<5.0	<5.0	<5.0	<5.0
Site I Surface	<5.0	<5.0	<10.0	<5.0	<5.0	<5.0	<5.0
Site L Surface	<5.0	<5.0	<10.0	<5.0	<5.0	<5.0	<5.0
Site M Surface	NA	NA	NA	NA	NA	NA	NA

Table 2.--Summary of results of chemical analyses of ground-water, surface-water, and bottom-material samples for physical characteristics, metals, major ions, and organic compounds--Continued

ORGANIC COMPOUNDS IN BOTTOM MATERIALS--Continued

Site name	1,2-Dichlorobenzene, bot.mat (µg/kg)	1,2,4-Trichlorobenzene, bot.mat (µg/kg)	1,2,5,6-Dibenzanthracene, bot.mat (µg/kg)	1,3-Dichlorobenzene, bot.mat (µg/kg)	1,4-Dichlorobenzene, bot.mat (µg/kg)	2-Chloronaphthalene, bot.mat (µg/kg)
Site 1	<200	<200	<400	<200	<200	<200
Site 4	<200	<200	<400	<200	<200	<200

Site name	2-Chlorophenol, bot.mat (µg/kg)	2-Nitrophenol, bot.mat (µg/kg)	Di-n-octyl phthalate, bot.mat (µg/kg)	2,4-Dichlorophenol, bot.mat (µg/kg)	2,4-DP, in bot.mat (µg/kg)	2,4-Dinitrotoluene, bot.mat (µg/kg)
Site 1	<200	<200	<400	<200	<200	<200
Site 4	<200	<200	<400	<200	<200	<200

Site name	2,4-Dinitrophenol, bot.mat (µg/kg)	2,4,6-Trichlorophenol, bot.mat (µg/kg)	2,6-Dinitrotoluene bot.mat (µg/kg)	4-Bromophenyl phenyl ether, bot.mat (µg/kg)	4-Nitrophenol, bot.mat (µg/kg)	4,6-Dinitro-orthocresol, bot.mat (µg/kg)
Site 1	<600	<600	<200	<200	<600	<600
Site 4	<600	<600	<200	<200	<600	<600

Site name	Phenol (C6H-5OH), bot.mat (µg/kg)	Pentachlorophenol, bot.mat (µg/kg)	bis(2-ethyl hexyl) phthalate, bot.mat (µg/kg)	Di-n-butyl phthalate, bot.mat (µg/kg)	PCN, total in bot.mat (µg/kg)	Aldrin, total in bot.mat (µg/kg)
Site 1	<200	<600	<200	<200	<1.0	<.1
Site 4	<200	<600	<200	<200	<1.0	<.1

Site name	Lindane, total in bot.mat (µg/kg)	Chlordane, total in bot.mat (µg/kg)	DDD, total in bot.mat (µg/kg)	DDE, total in bot.mat (µg/kg)	DDT, total in bot.mat (µg/kg)	Dieldrin, total in bot.mat (µg/kg)
Site 1	<.1	8.0	1.8	2.5	<.1	.3
Site 4	<.1	<1.0	7.0	2.5	<.1	.2

Site name	Endosulfan, total in bot.mat (µg/kg)	Endrin, total in bot.mat (µg/kg)	Ethion, total in bot.mat (µg/kg)	Toxaphene, total in bot.mat (µg/kg)	Heptachlor, total in bot.mat (µg/kg)	Heptachlor epoxide, total in bot.mat (µg/kg)
Site 1	<.1	<.1	<.1	<10	<.1	<.1
Site 4	<.1	<.1	<.1	<10	<.1	<.1

Site name	Methoxychlor, total in bot.mat (µg/kg)	PCB, total in bot.mat (µg/kg)	Malathion, total in bot.mat (µg/kg)	Parathion, total in bot.mat (µg/kg)	Diazinon, total in bot.mat (µg/kg)	Methylparathion, total in bot.mat (µg/kg)
Site 1	<.1	2	<.1	<.1	.2	<.1
Site 4	<.1	2	<.1	<.1	.1	<.1

Site name	Hexachlorobenzene, total in bot.mat (µg/kg)	Hexachlorobutadiene, total in bot.mat (µg/kg)	2,4-D, total in bot.mat (µg/kg)	2,4,5-T, total in bot.mat (µg/kg)	Mirex, total in bot.mat (µg/kg)	Silvex, total in bot.mat (µg/kg)
Site 1	<200	<200	<.1	<.1	<.1	<.1
Site 4	<200	<200	<.1	<.1	<.1	<.1

Site name	Methyl thion, total in bot.mat (µg/kg)	Trithion, total in bot.mat (µg/kg)	Perthane, total in bot.mat (µg/kg)	Carbon, inorganic, total in bot.mat (µg/kg)	Carbon, organic plus inorganic, total in bot.mat (µg/kg)	Cyanide, total in bot.mat (µg/kg)
Site 1	<.1	<.1	<1.00	.1	12	<.5
Site 4	<.1	<.1	<1.00	<.1	7.9	<.5

[1] Alkalinity expressed as milligrams per liter can be converted to an equivalent concentration of HCO_3^- in milligrams per liter by dividing the former by 0.8202 (Hem, 1985, p. 57).

Appendix 1.--Site identification numbers and site descriptions for water-quality sites around the perimeter of the Rolling Knoll Landfill and along Loantaka Brook

Site name[1]	Site identification number	Site description
	Surface-water sites	
Site A Surface	404348074262700	Wetland site A at edge of landfill
Site B Surface	404344074262400	Wetland site B at edge of landfill
Site B-C Surface	404340074262400	Wetland site B-C at edge of landfill
Site C Surface	404337074262000	Wetland site C at edge of landfill
Site D Surface	404330074262700	Wetland site D at edge of landfill
Site E Surface[2]	404322074263100	Wetland site E at edge of landfill
Site F Surface	404319074263800	Wetland site F at edge of landfill
Site G Surface	404322074264900	Ditch site G at edge of landfill
Site H Surface	404326074270000	Wetland site H at edge of landfill
Site I Surface	404330074270300	Wetland site I at edge of landfill
Site J Surface	404340074270300	Wetland site J at edge of landfill
Site K Surface	404344074270000	Wetland site K at edge of landfill
Site L Surface	404351074265600	Wetland site L at edge of landfill
Site M Surface	404358074264900	Wetland site M at edge of landfill
Site N Surface	404355074263100	Wetland site N at edge of landfill
Site 1 Loantaka Brook	404406074265600	Loantaka Brook near Green Village
Site 2 Loantaka Brook	404358074270000	Loantaka Brook near Green Village
Site 3 Loantaka Brook	404351074270300	Loantaka Brook near Green Village
Site 4 Loantaka Brook	404344074270700	Loantaka Brook near Green Village
	Ground-water sites[3]	
Site A Ground	404348074262701	Piezometer site at edge of landfill
Site B-C Ground	404340074262401	Piezometer site at edge of landfill
Site F Ground	404319074263801	Piezometer site at edge of landfill

[1]Site locations are shown in figure 4.
[2]Site inaccessible and not sampled.
[3]New Jersey well numbers for sites A, B-C, and F are 271724, 271723, and 271722, respectively.

☆U.S. GOVERNMENT PRINTING OFFICE: 1993 - 711-591