GROUND-WATER QUALITY IN THE CENTRAL PART OF THE PASSAIC RIVER BASIN, NORTHEASTERN NEW JERSEY, 1959-88

By Teresa S. Czarnik and Jane Kozinski

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
square mile (mi^2)	2.590	square kilometer

Multiply	By	To obtain
	Mass	
microgram (µg)	3.527×10^{-8}	ounce, avoirdupois
milligram (mg)	3.527×10^{-5}	ounce, avoirdupois
	Volume	
milliliter (mL)	0.03382	ounce, fluid
liter (L)	33.82	ounce, fluid
	Temperature-conversion formula	
degree Celsius (°C)	$°F = 1.8 \times °C + 32$	degree Fahrenheit (°F)

Sea Level: In this report "sea level" refers to the National Geodetic Vertical Dataum of 1929--a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

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ABSTRACT

Water samples collected from 71 wells in the central part of the Passaic River basin in northeastern New Jersey during 1959-88 were analyzed for selected inorganic and organic constituents to characterize the regional ground-water quality. Water samples were collected from three principal aquifer groups--glacial sediments, sedimentary bedrock, and igneous bedrock. The glacial sediments consist of mixed glaciolacustrine and fluvial deposits; bedrock consists of continental sediments and basalts of the Newark Supergroup.

Calcium and bicarbonate were the predominant ions in the ground water in the study area. Concentrations of dissolved solids, iron, manganese, and sulfate exceeded U.S. Environmental Protection Agency (USEPA) secondary drinking-water regulations in water from some wells. The most frequently detected organic compounds were benzene, tetrachloroethylene, and trichloroethylene. No regulated inorganic constituents were detected in the ground water at concentrations greater than USEPA primary drinking-water regulations.

Ground-water samples from the study area were chemically dilute (median dissolved-solids concentration, 239 mg/L (milligrams per liter)) and slightly basic (median pH, 7.89). Ground-water samples were generally of the calcium bicarbonate type. The water quality was generally uniform throughout the aquifer systems and, for the most part, could not be readily distinguished on the basis of aquifer type.

Water from aquifers in igneous bedrock contained more oxygen (dissolved-oxygen concentration, 4.2 mg/L) than that from either the aquifers in glacial sediments or those in sedimentary bedrock (dissolved-oxygen concentrations, 2.5 and 2.9 mg/L, respectively). Concentrations of barium, magnesium, strontium, sodium, and sulfate tended to be higher in water from sedimentary bedrock than in water from either the igneous bedrock or glacial sediments, possibly because of dissolution of sulfate-containing and carbonate minerals in the matrix of sedimentary-bedrock aquifers. Ground water enriched in sulfate relative to the other common ions also was enriched in calcium and strontium. Although such enrichment may be the result of mineral dissolution, other sources of sulfate enrichment could be recharge by ground water enriched with sulfate from the decay of organic matter in overlying swamplands, and (or) recharge by ground water contaminated with sulfate from human activities.

A statistical correlation exists for water samples from the sedimentary bedrock between the ranks of sulfate concentration and the altitude of the deepest opening of the well. This correlation may indicate that, in some parts of the aquifer, little mixing occurs with dilute ground water from zones of recharge.

Tritium was detected in all but two ground-water samples, indicating that most of the ground water in the study area is more recent than the large-scale nuclear-bomb testing that began in 1953. The two samples in which tritium was not detected were collected from areas in which the aquifer is confined by clay layers and (or) the ground-water flow is restricted by the configuration of the nearby basalt units. Tritium was detected, however, in water samples from other wells open to confined parts of the aquifers in sedimentary bedrock.

INTRODUCTION

Population growth in the central part of the Passaic River basin has adversely affected the quantity and quality of ground-water supplies there (U.S. Army Corps of Engineers, 1987, p. 41). Increased ground-water withdrawals in the area have led to water-level declines and well interference (Hoffman, 1989a, p. 7). Concerns about the quality of ground water have resulted in the closure of certain public and private water-supply wells and the imposition of withdrawal restrictions for some wells in some areas (Oudijk, 1987). In response to these concerns and to the New Jersey Water Supply Bond Act of 1981 (Hoffman, 1989a), a multiphase hydrogeologic investigation of the central Passaic River basin was undertaken by the U.S. Geological Survey (USGS) in cooperation with the New Jersey Department of Environmental Protection and Energy to determine the geology, bedrock topography, ground-water use, water levels, and quality of water in the study area. This report documents the results of the water-quality phase of the investigation.

Purpose and Scope

This report characterizes the quality of ground water in the central part of the Passaic River basin, describes differences in water chemistry among three aquifer types, and identifies regional trends in water chemistry on the basis of results of chemical analyses of ground-water samples collected from 71 wells during 1959-88. Results of chemical analyses of ground water for common ions, trace elements, purgeable organic compounds (POC's), and tritium, and a statistical summary of these data, are provided. Regional trends in ground-water quality are illustrated on maps. The age of the ground water also is discussed.

Previous Investigations

Hoffman (1989a and b) summarized the hydrogeology of the central Passaic River basin and described the goals, schedules, and proposed products of the 1981 Water Bond study of the Passaic River basin. Reports on the hydrogeology and quality of ground water in Essex County (Nichols, 1968), Morris County (Gill and Vecchioli, 1965), Passaic County (Carswell and Rooney, 1976), and Union County (Nemickas, 1976) include parts of the study area. Geologic formations and structures of the Newark Quadrangle were mapped by Lyttle and Epstein (1987).

The inorganic chemistry of ground water in the Newark Basin was described by Szabo and others (1989). The geologic sources of and effects of ground-water geochemistry on naturally occurring radionuclides were reported by Zapecza and Szabo (1987) and Szabo and Zapecza (1987 and 1988).

Well-numbering System

The New Jersey District of the USGS uses a six-digit well-numbering system. The first two digits of the well number are the county code. The county codes used in this report are 13 (Essex County), 27 (Morris County), 31 (Passaic County), 35 (Somerset County), and 39 (Union County). The last four digits of the well number indicates the sequence in which the well was inventoried by the USGS. For example, New Jersey well number 35-100 indicates the 100th well inventoried in Somerset County.

Acknowledgments

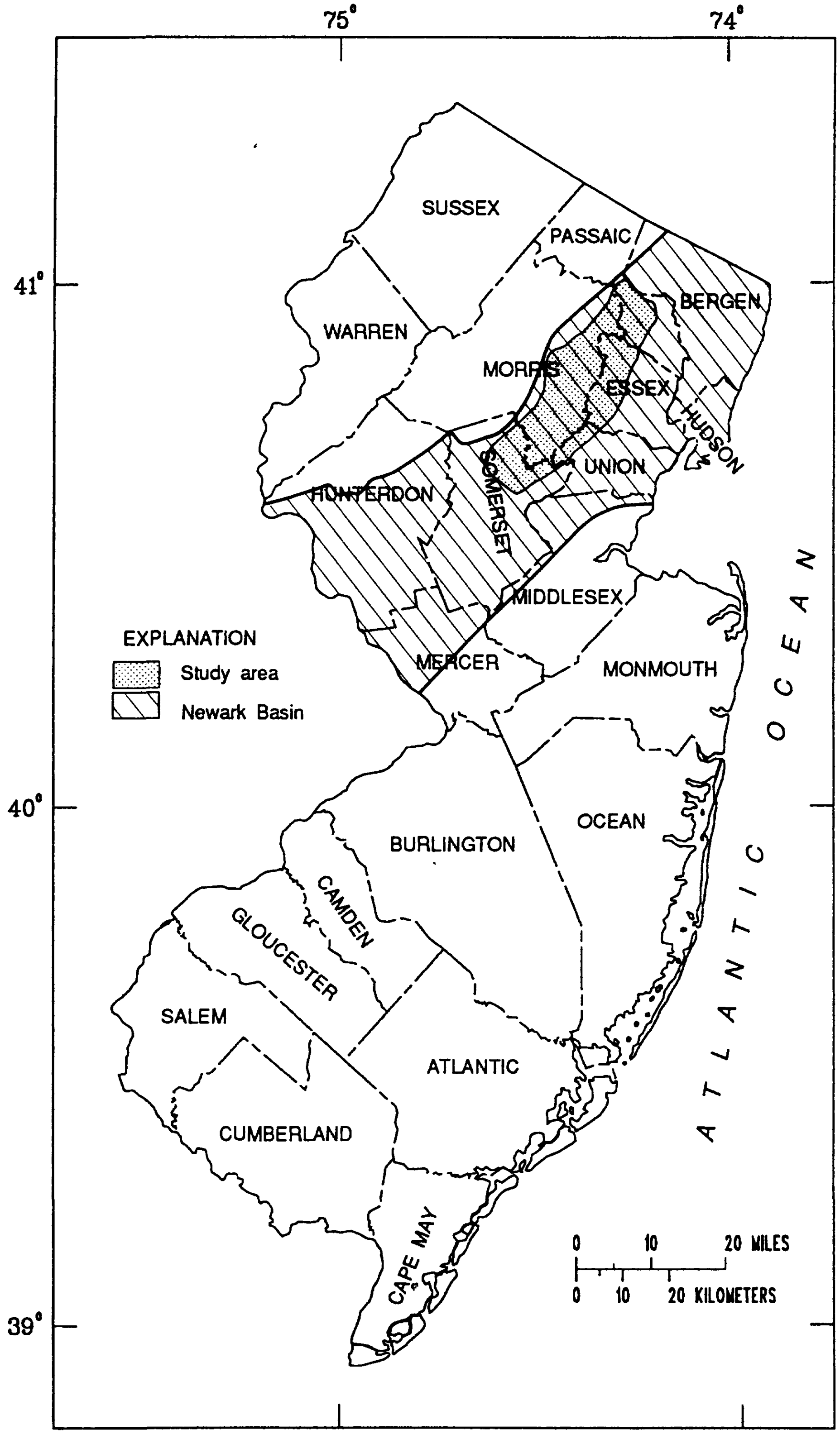
The cooperation and contributions of the project coordinator, Jeffrey L. Hoffman of the New Jersey Department of Environmental Protection and Energy, are gratefully acknowledged. Appreciation also is extended to the well owners who provided access to their wells for sampling purposes and to those well owners who provided information about their wells.

DESCRIPTION OF STUDY AREA

The study area (fig. 1) is in the drainage basin of the Passaic River (fig. 2). The Passaic River drainage basin is divided into three sections on the basis of topographic and hydrologic characteristics (fig. 2): the highland area, the central basin, and the lower valley (U.S. Army Corps of Engineers, 1987). The study area includes all of the central basin and parts of the highland area and lower valley. The topographic features of the central Passaic River basin include gently rolling hills and abrupt ridges of the Watchung Mountains (Carswell and Rooney, 1976, p. 6; Nichols, 1968, p. 3) (fig. 3). The study area is bounded on the west by the Ramapo Fault and on the northeast, east, and south by the extent of the outcrop area of the Preakness Basalt (fig. 4). The study area includes parts of Bergen, Essex, Morris, Passaic, Somerset, and Union Counties (fig. 1).

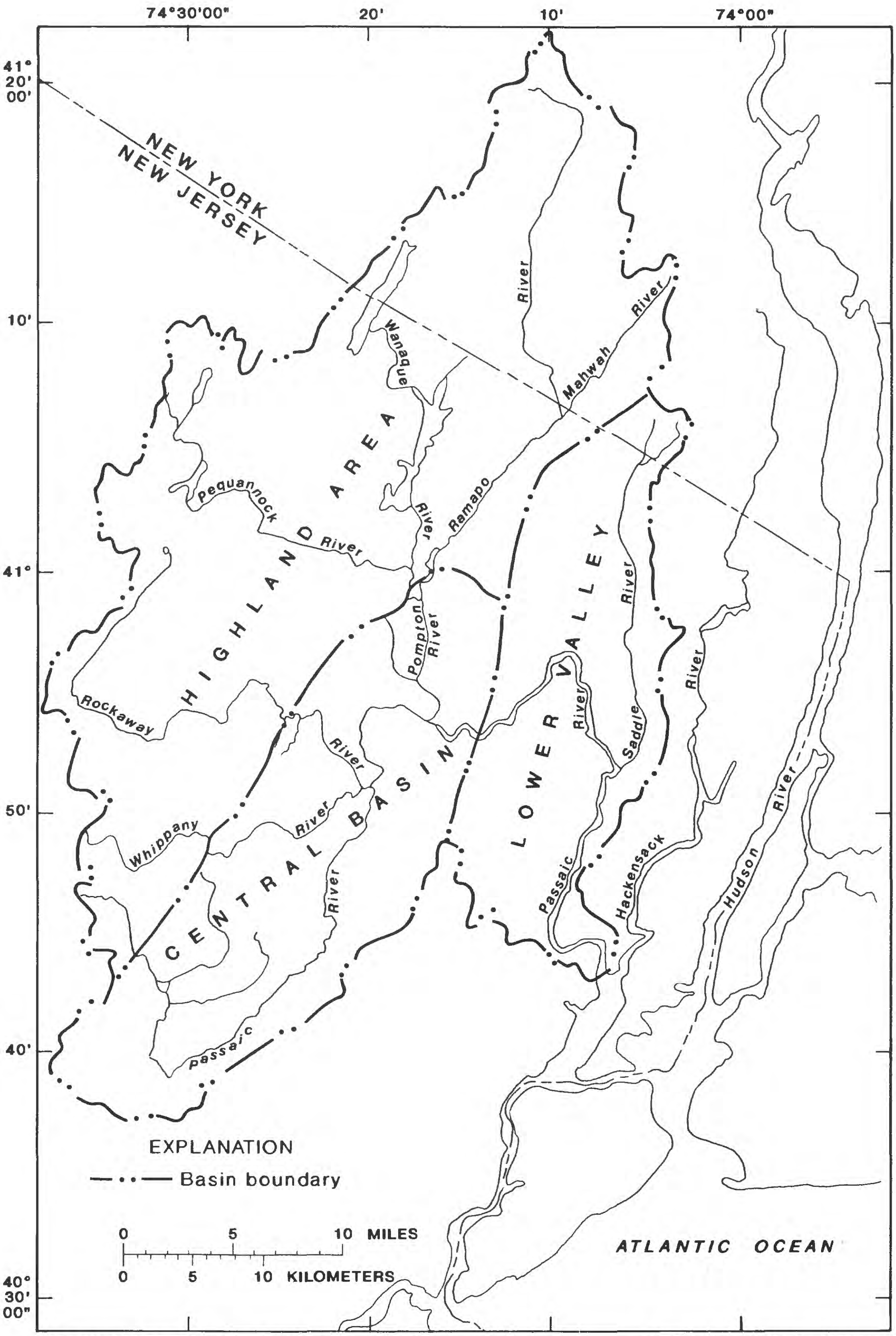
Geology

The study area is in the Newark Basin, a geologic basin that coincides with the Piedmont physiographic province in New Jersey (fig. 1). The study area consists of geologic units and formations of the Newark Supergroup, a thick sequence of continental sediments and basaltic lava flows of Mesozoic age (table 1). The Newark Basin is a fault-block basin formed as a result of extension and continental rifting during the Mesozoic Era (Faust, 1975, p. A1). The rifting produced alternating periods of intense volcanism and uplift of surrounding highlands with subsequent erosion and deposition (Van Houten, 1980, p. 268; Manspeizer, 1980, fig. 4). The three major geologic units of the Newark Supergroup in the study area are the Upper Triassic Stockton and Lockatong Formations, the Upper Triassic and Lower Jurassic interlayered basalt flows and clastic sedimentary rocks of the Brunswick Group, and a Lower Jurassic conglomerate unit (table 1). These formations and lithologic units form the bedrock of the study area. The bedrock is overlain by unconsolidated Quaternary sediments (table 1) and is underlain by Precambrian and Paleozoic metamorphic basement rocks.



Base from U.S. Geological Survey digital data, 1:2,000,000, 1972 Universal Transverse Mercator projection, Zone 18

Figure 1.--Location of the Newark Basin and study area.



Base adapted from U.S. Army Corps Engineers, 1987

Modified from Hoffman, 1989a, p.2

Figure 2.--Location of the Passaic River drainage basin in New Jersey and New York.

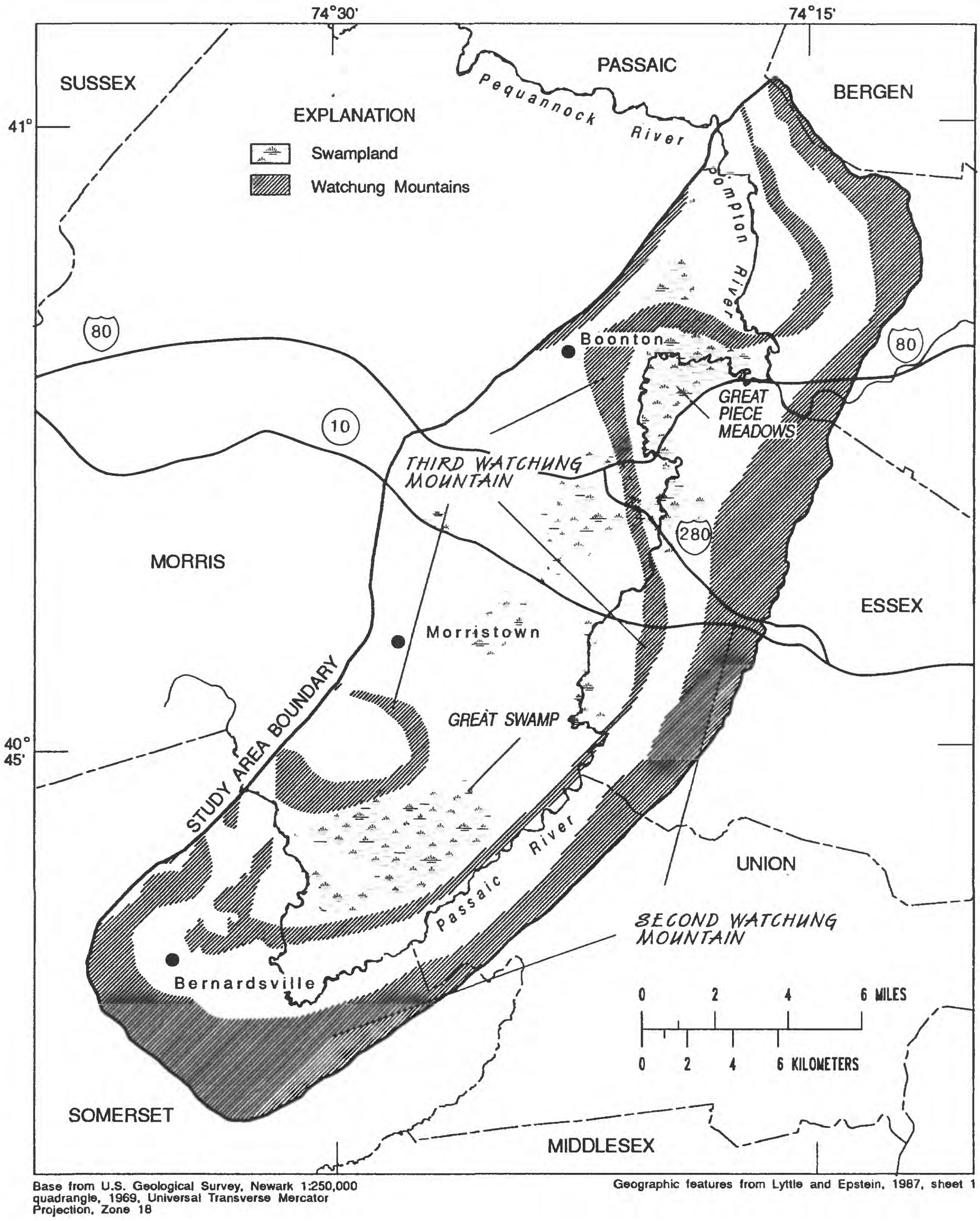
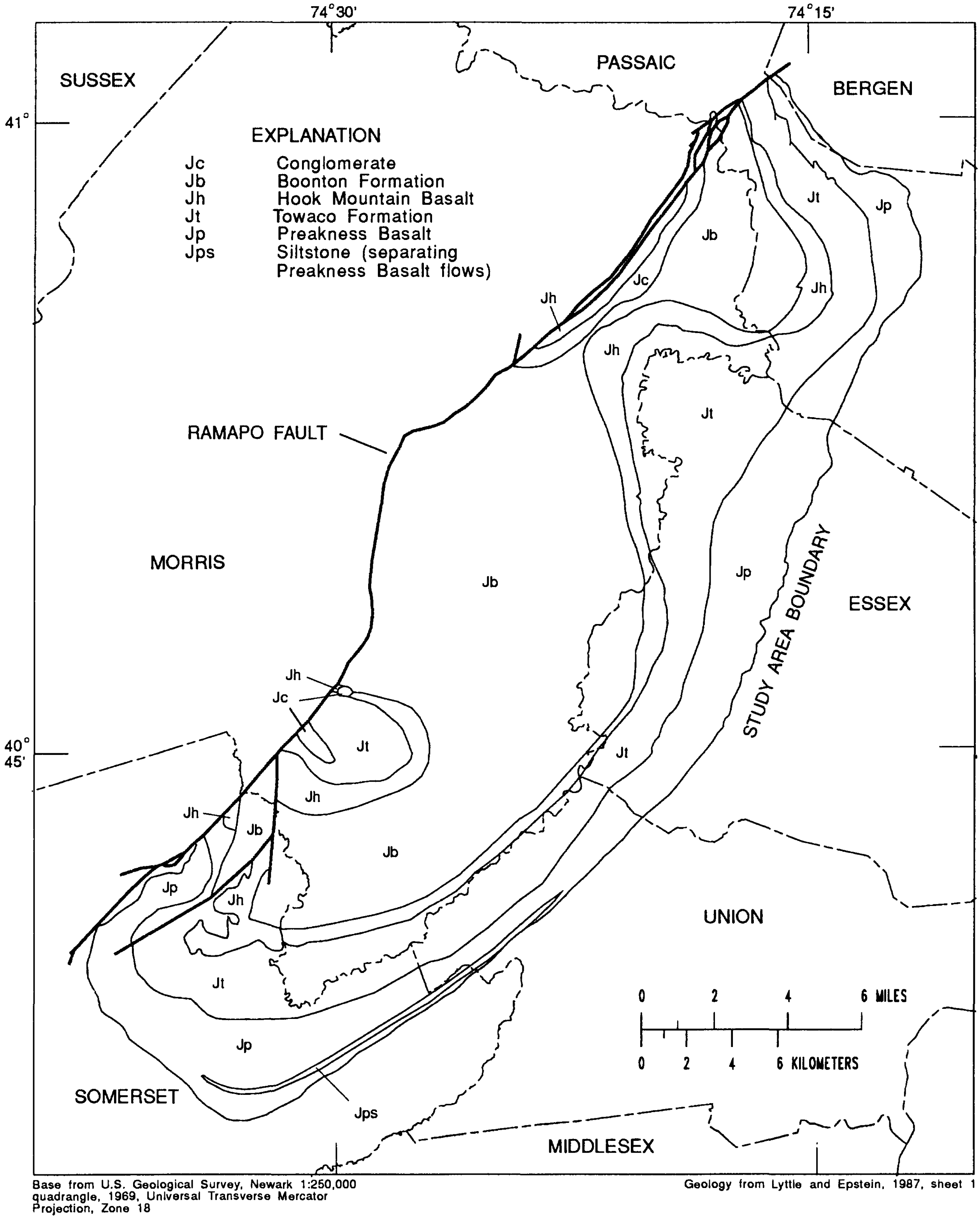


Figure 3.--Physiographic and geographic features of the study area.



Base from U.S. Geological Survey, Newark 1:250,000 quadrangle, 1969, Universal Transverse Mercator Projection, Zone 18

Geology from Lyttle and Epstein, 1987, sheet 1

Figure 4.--Bedrock geology of the study area.

Table 1.--Stratigraphy of the Newark Supergroup and Quaternary sediments in the study area

[Modified from Froelich and Robinson, 1988, and Lyttle and Epstein, 1987]

Era	Period	Series	Basin	Formation or lithologic unit		Lithology
Cenozoic		Holocene		Alluvium		Sand, silt, and mud
				Eolian deposits		Sand
		Pleistocene		Unstratified drift		Clay, sand, and gravel
				Stratified drift		Sand and gravel
				Unconformity		
Mesozoic	Jurassic	Lower Jurassic	Newark Super-group	Conglomerate		Conglomerate and conglomeratic sandstone
				Brunswick Group	Boonton Formation	Sandstone, siltstone, dolomitic siltstone, and minor evaporitic beds
					Hook Mountain Basalt	Basaltic lava sheets
					Towaco Formation	Sandstone, siltstone, conglomerate, and calcareous siltstone
					Preakness Basalt	Basaltic lava sheets
					Feltville Formation	Siltstone, sandstone, and carbonate
					Orange Mountain Basalt	Basaltic lava sheets intercalated with volcanoclastic units
	Triassic	Upper Triassic			Passaic Formation	Mudstone, siltstone, and sandstone
				Lockatong Formation		Mudstone, siltstone, and carbonate
				Stockton Formation		Arkosic sandstone, siltstone, and conglomerate

The Ramapo Fault, a northeast-southwest-trending normal fault (Carswell and Rooney, 1976, p. 14), forms the western boundary of the study area (fig. 4). The sedimentary and igneous rocks of the Newark Basin in the study area are in a monoclinal structure (Carswell and Rooney, 1976, p. 14; Gill and Vecchioli, 1965, p. 13) in which the strata dip gently to the northwest.

Stockton and Lockatong Formations

The Stockton Formation is a sedimentary formation of arkosic siltstone, sandstone, and conglomerate that was deposited during the late Triassic Period in fluvial and marginal lacustrine environments (Van Houten, 1969). Typical arkosic sandstone of the Stockton Formation is about 50 to 70 percent quartz and about 15 to 40 percent feldspar (albite-oligoclase and potassium-feldspar), and contains minor amounts of chert, lithic fragments, biotite, and muscovite (Van Houten, 1969, p. 321). The Stockton Formation unconformably overlies Precambrian and Paleozoic basement rocks (Zapecza and Szabo, 1987, p. 51).

The Lockatong Formation consists of gray and black siltstone, calcareous siltstone, mudstone, and sandstone deposited during the late Triassic Period in a lacustrine environment (Van Houten, 1969, p. 321; Olsen, 1980, p. 352). The sedimentary rocks of the Lockatong Formation contain sodium- and potassium-feldspar, illite, muscovite, chlorite, calcite, and some quartz (Van Houten, 1969, p. 322). The Lockatong Formation conformably overlies or interfingers with the Stockton Formation (Zapecza and Szabo, 1987, p. 54).

Brunswick Group

The Brunswick Group, a part of the Newark Supergroup, is a series of intercalated sedimentary and igneous rock formations of Upper Triassic to Lower Jurassic age (table 1). The Brunswick Group consists of the following formations and lithologic units, from oldest to youngest: the Passaic Formation, Orange Mountain Basalt, Feltville Formation, Preakness Basalt, Towaco Formation, Hook Mountain Basalt, and Boonton Formation. Within the study area, the Passaic Formation, Orange Mountain Basalt, and Feltville Formation are present in the subsurface but do not crop out (fig. 4).

Sedimentary rock formations of the Brunswick Group

The sedimentary rock formations of the Brunswick Group are interbedded, reddish-brown to gray and black shale, sandstone, siltstone, and conglomerate. These formations were deposited in lacustrine environments (Olsen, 1980, p. 352). All of the formations contain some impure limestone or calcareous siltstone beds, and the Boonton Formation contains dolomitic siltstone (Lyttle and Epstein, 1987). Minerals present in these rocks include illite, quartz, sodium-feldspar, chlorite, and potassium-feldspar (Herpers and Barksdale, 1951, p. 37, 48, and 49; Lyttle and Epstein, 1987; Nemickas, 1976, p. 11; Van Houten, 1965, p. 829 and 833-840). Hematite, calcite, dolomite, pyrite, gypsum, and muscovite are present in small amounts. Glauberite and halite also may be present. Little work has been done, however, to characterize in detail the mineral assemblages in the sedimentary rocks in the study area.

Igneous rock formations of the Brunswick Group

The igneous rock formations of the Brunswick Group within the study area are the Preakness Basalt and the Hook Mountain Basalt (fig. 4). These formations form topographic ridges known as the Watchung Mountains (fig. 3); the Preakness Basalt forms the Second Watchung Mountain, and the Hook Mountain Basalt forms the Third Watchung Mountain (Lyttle and Epstein, 1987). Hook Mountain and Long Hill are part of the Third Watchung Mountain (Nemickas, 1976, p. 11). The basalt ridges of the Watchung Mountains trend northeast-southwest, reflecting the strike of the sedimentary formations of the Brunswick Group (Nichols, 1968, p. 6). The eastern sides of the basalt ridges are steep escarpments, but the western sides slope gently (Nemickas, 1976, p. 4). The Watchung Mountains extend from Bergen County through Passaic, Morris, Essex, and Union Counties and terminate in Somerset County (fig. 3).

The Preakness and Hook Mountain Basalts are extensive basalt sheets extruded during the accumulation and consolidation of the Brunswick Group sediments (Nemickas, 1976, p. 11; Manspeizer, 1980). Individual lava flows typically are topped with scoriaceous zones; vesicles, pillows, and basaltic breccia are common characteristics of these basalts (Lyttle and Epstein, 1987; Manspeizer, 1980). Sandstone and siltstone beds of fluvial origin separate some of the individual basalt flows of the Preakness Basalt (Fedosh and Smoot, 1988, p. 22). The Preakness and Hook Mountain Basalts are tholeiitic basalts composed of plagioclase feldspars, pyroxenes (pigeonite and augite), and iron and titanium oxides (Lyttle and Epstein, 1987; Puffer, 1988).

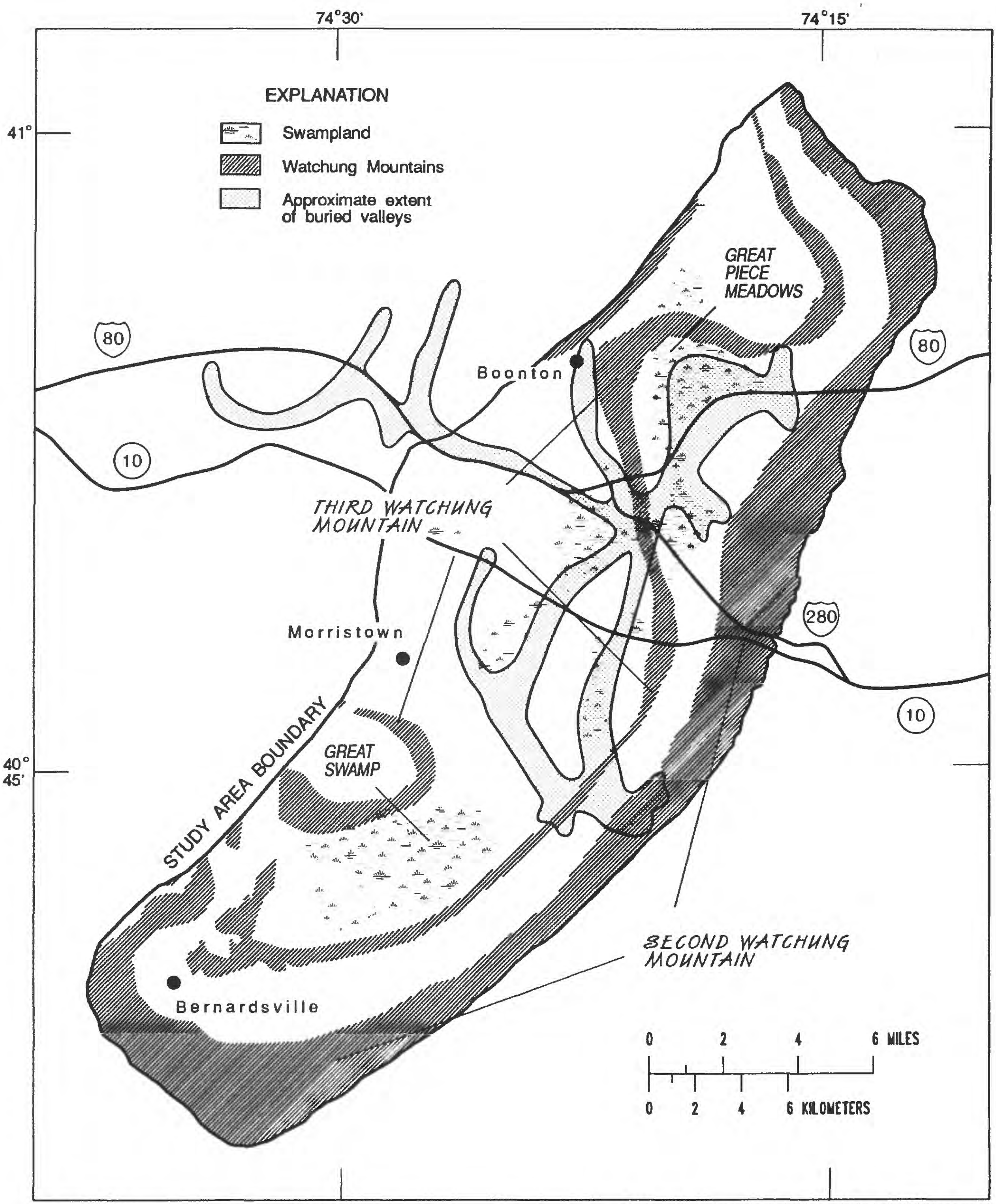
Lower Jurassic Conglomerate

A Lower Jurassic conglomerate of unknown thickness overlies the Boonton Formation, Hook Mountain Basalt, and the Towaco Formation (Lyttle and Epstein, 1987). The conglomerate borders the Ramapo Fault (fig. 4) and is composed of clasts of quartz, sandstone, conglomerate, granite, metamorphic rocks, limestone, and basalt (Lyttle and Epstein, 1987).

Unconsolidated Quaternary Sediments

The Quaternary deposits in the study area include sediments of Pleistocene and Holocene age (Nemickas, 1976, p. 12; Nichols, 1968, p. 6). The Pleistocene deposits, primarily of Wisconsin age, consist of both unstratified and stratified drift. Terminal-moraine deposits (end moraines) and ground-moraine deposits (till) are the primary constituents of the unstratified drift (Gill and Vecchioli, 1965, p. 24; Nemickas, 1976, p. 11 and 12; Nichols, 1968, p. 6). The stratified-drift deposits are glaciolacustrine or glaciofluvial in origin. Stratified-drift deposits consist of clay, silt, sand, and gravel (Gill and Vecchioli, 1965, p. 13; Nemickas, 1976, p. 11; Nichols, 1968, p. 20).

The Pleistocene deposits fill bedrock valleys (fig. 5) which were cut by streams before the Wisconsin glaciation (Carswell and Rooney, 1976, p. 12; Gill and Vecchioli, 1965, p. 15 and 25; Nemickas, 1976, p. 25; Nichols, 1968, p. 20 and 25, fig. 11; Meisler, 1976, pl. 1). Results of recent investigations indicate that the buried bedrock valleys are stream channels that were overdeepened during glaciation (Hoffman and Stone, 1991, p. 45; Stone and others, 1989, p. 69; J.L. Hoffman, New Jersey Department of



Base from U.S. Geological Survey, Newark 1:250,000 quadrangle, 1989, Universal Transverse Mercator Projection, Zone 18

Geographic features from Lyttle and Epstein, 1987, sheet 1

Figure 5.--Buried valleys in the study area and surrounding area. (Modified from Hoffman, 1989a, p. 6)

Environmental Protection and Energy, written commun., 1991). Depositional episodes in the bedrock valleys include a pre-Wisconsin period of glaciolacustrine deposition, a subsequent fluvial depositional episode resulting from glacial retreat, and a period of glaciolacustrine deposition (J.L. Hoffman, New Jersey Department of Environmental Protection and Energy, written commun., 1991). These depositional episodes produced a sequence of silty sediments overlain by better-sorted sands and gravels, which in turn are overlain by silty sediments (Stone and others, 1989, p. 69). Glacial till overlies most of the unconsolidated glacial deposits as well as the bedrock (Meisler, 1976, p. 8).

The Holocene sediments are lacustrine and fluvial in origin (Gill and Vecchioli, 1965, p. 13). They include swamp deposits and alluvium (Carswell and Rooney, 1976, p. 13; Nemickas, 1976, p. 12).

Hydrology

The three principal aquifer types considered in this report are unconsolidated stratified drift, sedimentary rocks of the Newark Supergroup, and igneous rocks of the Newark Supergroup (table 1). The degree of hydraulic connection between strata within a formation or between formations in the study area is not known because the hydrologic units have not been clearly defined (Carswell and Rooney, 1976, p. 15). In this report, however, water-bearing zones in stratified drift are referred to as aquifers in glacial sediments (the "buried-valley aquifer system" of Hoffman (1989a and b)). Similarly, the water-bearing zones in the Newark Supergroup are referred to as aquifers in either sedimentary or igneous bedrock (the "bedrock aquifers" of Hoffman (1989a and b)). Although the aquifers in sedimentary and igneous rock are intercalated stratigraphically, they are treated separately for purposes of geochemical discussion.

Aquifers in Glacial Sediments

The aquifers in glacial sediments are characterized by primary porosity because the water is present in the intergranular openings of the stratified drift deposits (Carswell and Rooney, 1976, p. 14). The yield of ground water from the sand and gravel that make up aquifers in glacial sediments is substantial where these deposits are horizontally and vertically extensive (Nemickas, 1976, p. 26; Nichols, 1968, p. 20).

The aquifers in glacial sediments are confined, semiconfined, or unconfined. The unconfined aquifers are not covered by clay or silt confining units and typically consist of coarse sand and gravel deposits that are generally less than 30-ft thick and are of limited geographic extent (Nemickas, 1976, p. 26; Nichols, 1968, p. 20). The unconfined aquifers receive recharge from precipitation in areas where they crop out (fig. 6) (Gill and Vecchioli, 1965, p. 25; Nemickas, 1976, p. 26; Nichols, 1968, p. 20).

The confined aquifers are covered locally by clay, silt, or glacial till and consist of coarse sand and gravel deposited in ancient stream valleys (Gill and Vecchioli, 1965, p. 25; Nemickas, 1976, p. 26; Nichols, 1968, p. 20;

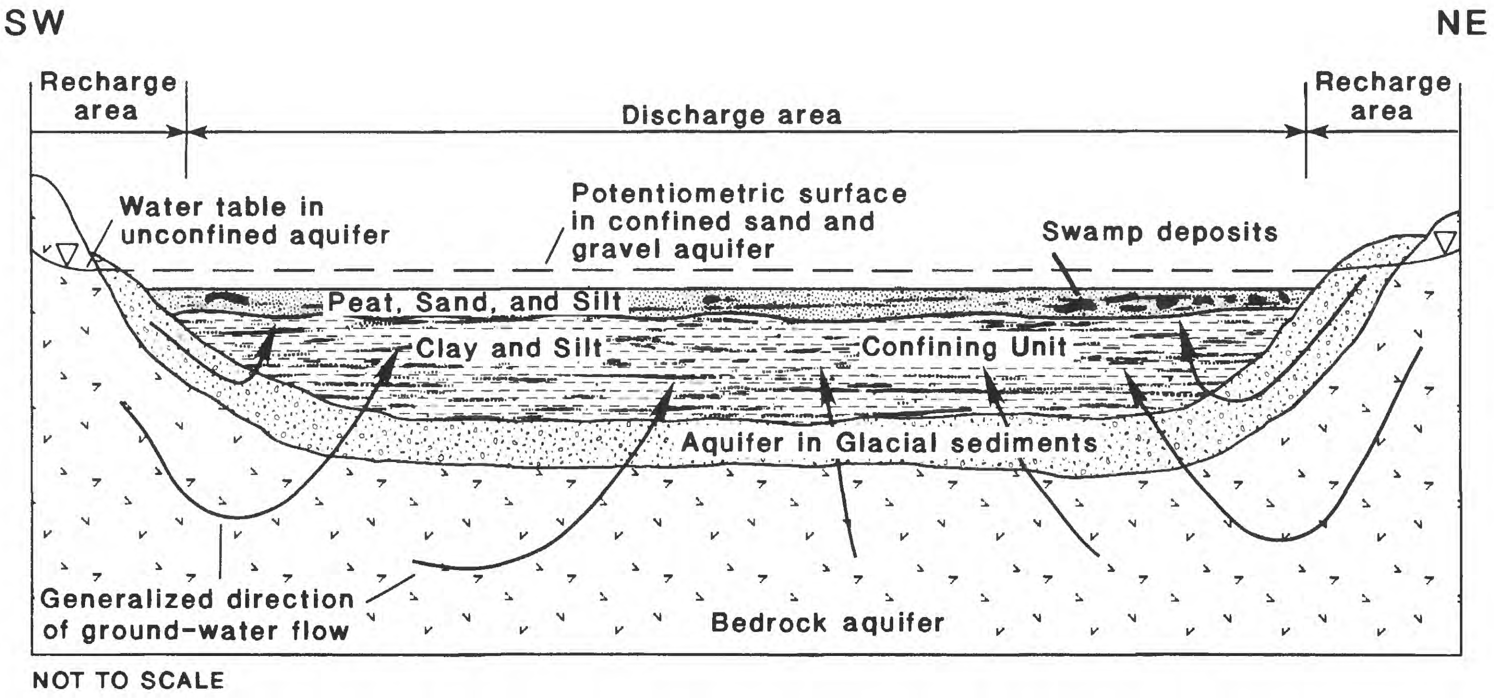


Figure 6.--Generalized hydrogeologic section through Great Swamp in the southern part of the study area. (Modified from Vecchioli and others, 1962.)

Meisler, 1976, p. 9). The extent of these buried valleys (fig. 5), and thus the extent of these confined and semiconfined aquifers, is poorly known (Nichols, 1968, p. 20). The confined and semiconfined aquifers in glacial sediments are recharged either by leakage from overlying confining units or by lateral and upward components of flow from adjacent and underlying bedrock (fig. 6) (Gill and Vecchioli, 1965, p. 25).

The aquifers in the glacial sediments in Morris and Essex Counties are confined, but are hydraulically connected to the underlying bedrock aquifer in the Newark Supergroup. The aquifers in the southern parts of the buried valleys are confined by sediments of the glacial terminal moraine, but are hydraulically connected to an outcrop area of sand and gravel deposits located on the southern side of the terminal moraine deposits (J.L. Hoffman, New Jersey Department of Environmental Protection and Energy, written commun., 1991). This outcrop area may be a recharge zone for the confined and semiconfined aquifers in the sand and gravel deposits (J.L. Hoffman, New Jersey Department of Environmental Protection and Energy, written commun., 1991).

The aquifers in glacial sediments are the most extensively used source of ground water in Morris County (Gill and Vecchioli, 1965, p. 24 and 26). In Passaic County, however, the glacial aquifers are only of local importance as a water-supply source (Carswell and Rooney, 1976, p. 1). These aquifers are the primary sources of water supply in western Essex County (J.L. Hoffman, New Jersey Department of Environmental Protection and Energy, written commun., 1991). In Union County, the aquifers in glacial sediments consist of relatively thin deposits which yield only limited quantities of water (Nemickas, 1976, p. 25, 26, and 32; Nichols, 1968, p. 20).

Aquifers in Sedimentary Bedrock

The shale and sandstone in the aquifers in sedimentary bedrock are characterized by both primary and secondary porosity. The secondary porosity is present as joints in the bedrock (fractures along which no appreciable movement has occurred), cleavage, and bedding planes (Carswell and Rooney, 1976, p. 14; Gill and Vecchioli, 1965, p. 23; Nichols, 1968, p. 9). The major joint sets of the sedimentary formations of the Brunswick Group strike parallel and transverse to the strike of the beds, approximately N. 45° E. and N. 75° W. The planar orientation of joints and fractures in homogeneous bedrock is uniform, and the major joint sets dip vertically (Carswell and Rooney, 1976, p. 14). The number of joints and fractures and the amount of separation between joints and between fractures decrease with depth (Nemickas, 1976, p. 19).

The sedimentary formations are anisotropic with regard to water-bearing properties as a result of the variable lithology of the strata (Nemickas, 1976, p. 20; Nichols, 1968, p. 11). Aquifers and confining units are defined by bedding within each sedimentary formation of the Brunswick Group, and hydraulic connection between the aquifers is poor (Carswell and Rooney, 1976, p. 15). As a result of the poor hydraulic connection, ground water from most high-yield wells is pumped from several water-bearing zones (Nichols, 1968, p. 10).

The aquifers in sedimentary bedrock can be either unconfined or confined. The confined aquifers are present in low-lying areas where the bedrock is overlain by silty and clay-rich unconsolidated deposits, whereas the unconfined aquifers generally are present in areas of higher elevation where unconsolidated deposits are absent (Gill and Vecchioli, 1965, p. 23).

The aquifers in sedimentary bedrock are the most extensively used sources of ground water in the southeastern part of Passaic County (Carswell and Rooney, 1976, p. 1); these aquifers also are the main sources of ground water in Essex and Union Counties (Nemickas, 1976, p. 19 and 34; Nichols, 1968, p. 10). Although the aquifers in sedimentary bedrock are "generally capable of sustaining moderate to large yields" to wells in Morris County (Gill and Vecchioli, 1965, p. 23), the glacial deposits are the primary source of ground water in that county (Gill and Vecchioli, 1965, p. 35).

Aquifers in Igneous Bedrock

Ground water in the igneous bedrock formations of the Brunswick Group is present in vesicles, joints, fractures, and faults (Carswell and Rooney, 1976, p. 14; Gill and Vecchioli, 1965, p. 16; Nemickas, 1976, p. 32). Compared to the aquifers in sedimentary bedrock, the aquifers in igneous bedrock generally are leaky confining layers (Carswell and Rooney, 1976, p. 15). These aquifers have low to moderate yield (Nichols, 1968, p. 10) because of limited capacities to store and transmit water (Gill and Vecchioli, 1965, p. 23; Nemickas, 1976, p. 21). The aquifers in igneous bedrock, used mainly for domestic water supplies (Carswell and Rooney, 1976, p. 19), are of minor importance as a source of ground water in the study area (Nemickas, 1976, p. 34).

METHODS OF INVESTIGATION

In order to determine the quality of ground water in the study area, water samples were collected from 40 wells during August 10, 1987-June 9, 1988. Results of chemical analyses of these samples and of samples collected from 31 additional wells during the period February 24, 1959, through August 9, 1987, were evaluated statistically to determine differences in water quality among aquifers and to identify regional trends in water quality.

Sampling Network and Collection of Samples

Initially, selection of wells for the sampling network was based on two criteria: (1) known depth to top of open interval, and (2) uniform distribution by location and aquifer. The second criterion could not be met, however, because the locations of aquifers in glacial sediments were constrained by the underlying bedrock topography and because few wells are open to the aquifers in igneous bedrock, which do not yield large quantities of water. Where possible, well clusters (several wells located in the same vicinity, each penetrating a different water-bearing geologic unit) were included in the network to permit assessment of differences in ground-water quality among the aquifers studied.

Wells within about 1 mi of a documented source of ground-water contamination were excluded from the network because the objective of the study was to describe the ambient water quality in the study area. Samples from three wells in the sampling network (wells 13-59, 13-72, and 13-73) (fig. 7) contained sodium, chloride, or nitrate in concentrations that indicated runoff of road salt or leaching from septic systems. Results of these analyses are reported in appendixes 1 and 2 but were excluded from statistical analyses. Wells 27-196 and 27-1114 are open to more than one type of aquifer (sedimentary and igneous bedrock) and, thus, do not yield water representative of any one aquifer type; therefore, results of analyses of water from these wells were eliminated from the data set used in the statistical analyses but are reported in appendix 3.

Well 35-8 is screened at the boundary between glacial sediments and weathered sedimentary bedrock. Thus, this well probably does not yield water that is representative of either aquifers in sedimentary bedrock or aquifers in glacial sediments. Results of analyses of water from this well were not included in figures or used in the statistical analysis, but are reported in appendix 1.

Of the 71 wells in the data set, 43 are screened in aquifers in glacial sediments, 19 are open to aquifers in sedimentary bedrock, 7 are open to aquifers in igneous bedrock, and 2 are open to aquifers in both sedimentary and igneous bedrock (fig. 7 and table 2). The data set includes publicly and privately owned production wells and observation wells.

For all wells sampled during 1987-88, ground-water samples were collected only after the field-measured characteristics of the water (dissolved-oxygen concentration, pH, specific conductance, and temperature) stabilized (two consecutive measurements within 5 percent of each other) and after at least three well volumes were pumped. For production wells, untreated ground water was collected from sampling spigots or other outlets. For observation wells with a diameter greater than 4 in., a 4-in. submersible electric pump was used to purge the well before sampling, and a 2-in. Fultz[1] electric submersible pump was used to collect the sample. For observation wells with diameters from 2 to 4 in., a Fultz pump was used to purge the well and to collect the sample. Observation wells with casings with an inside diameter of less than 2 in. were sampled with a peristaltic pump. Alkalinity was determined in the field by incremental titration immediately after sampling. Ground-water samples collected for this study were collected, filtered, and preserved according to accepted USGS procedures (Wershaw and others, 1987; Wood, 1981).

Chemical Analysis of Samples

The constituents for which the ground-water samples were analyzed are listed in table 3. Chemical constituents reported as dissolved were measured in ground-water samples that were passed through a 0.45-micrometer membrane filter. Concentrations of major cations, anions, nutrients, and trace elements in ground-water samples were determined at the USGS National Water-Quality Laboratory (NWQL) in Lakewood, Colorado, according to the methods described in Fishman and Friedman (1989). Concentrations of aluminum, barium, beryllium, boron, cadmium, cobalt, copper, iron, lead, lithium, magnesium, manganese, molybdenum, nickel, silica, silver, sodium, vanadium, and zinc were

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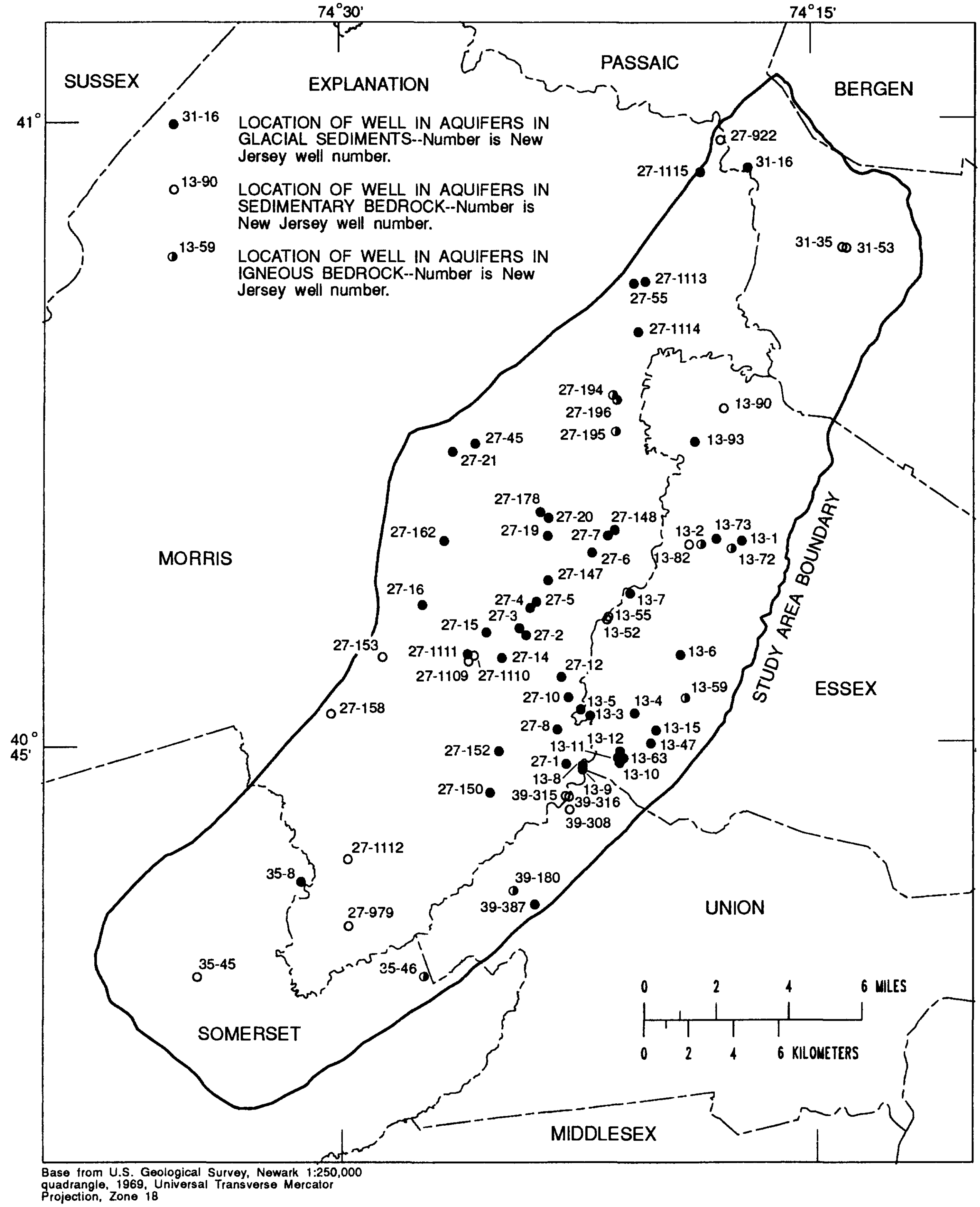
[1] The use of brand or firm names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.



Base from U.S. Geological Survey, Newark 1:250,000 quadrangle, 1969, Universal Transverse Mercator Projection, Zone 18

Figure 7.--Ground-water-sampling network.

Table 2.--Records of wells sampled

[WD, Water Department; WC, Water Company; CC, Country Club; Twp, Township; MUA, Municipal Utilities Authority; Bd of Ed, Board of Education; *, multiple screens; --, information not available]

New Jersey well number	Well owner	Local well name or number	Municipality	Latitude	Longitude
AQUIFERS IN GLACIAL SEDIMENTS					
13- 1	Essex Fells WD	EFWD 1A	Essex Fells Boro	404953	741715
13- 3	East Orange WD	Dickinson 3	Livingston Twp	404540	742205
13- 5	East Orange WD	Dickinson 1	Livingston Twp	404549	742222
13- 7	Livingston Twp WD	LWD 5	Livingston Twp	404837	742048
13- 8	NJ American WC	CWC 50	Millburn Twp	404427	742222
13- 9	NJ American WC	CWC 51	Millburn Twp	404430	742222
13- 10	NJ American WC	CWC 46	Millburn Twp	404432	742111
13- 11	NJ American WC	CWC E	Millburn Twp	404439	742114
13- 12	NJ American WC	CWC K5	Millburn Twp	404450	742111
13- 15	East Orange WD	EOWD H	Millburn Twp	404519	742001
13- 47	East Orange WD	Canoe Brook 1	Millburn Twp	404501	742011
13- 63	NJ American WC	CWC K2	Millburn Twp	404438	742105
13- 73	Essex Fells WD	EFWD 7	Essex Fells Boro	404948	741754
13- 93	Fairfield WD	Fairfield 4	Fairfield Boro	405216	741848
27- 1	U.S. Geological Survey	Recreation Fld Obs	Chatham Boro	404432	742252
27- 2	U.S. Geological Survey	W B Driver 1	East Hanover Twp	404738	742406
27- 3	U.S. Geological Survey	W B Driver 2 Obs	East Hanover Twp	404748	742419
27- 4	U.S. Geological Survey	Clemens	East Hanover Twp	404816	742359
27- 5	U.S. Geological Survey	Sandoz Chem Co Obs	East Hanover Twp	404826	742347
27- 6	U.S. Geological Survey	Green Acres Obs	East Hanover Twp	404937	742200
27- 7	U.S. Geological Survey	Homestead	East Hanover Twp	405001	742130
27- 8	U.S. Geological Survey	Greenhouse	Florham Park Boro	404522	742307
27- 10	U.S. Geological Survey	Braidburn Club	Florham Park Boro	404609	742246
27- 12	U.S. Geological Survey	Briarwood School Obs	Florham Park Boro	404639	742300
27- 14	U.S. Geological Survey	ESSO Six Inch Obs	Florham Park Boro	404705	742452
27- 15	Morristown Airport	Test 2 Obs	Hanover Twp	404743	742522
27- 16	U.S. Geological Survey	Morris Treat 2	Hanover Twp	404822	742724
27- 19	U.S. Geological Survey	Troy Meadows 2	Parsip-Troy Hills Twp	405002	742324
27- 20	U.S. Geological Survey	Troy Meadows 1 Obs	Parsip-Troy Hills Twp	405027	742323
27- 21	U.S. Geological Survey	INTERPCE QEP 1	Parsip-Troy Hills Twp	405204	742624
27- 45	Parsippany-Troy Hills WD	PTHWD 17	Parsip-Troy Hills Twp	405216	742541
27- 55	Montville Twp MUA	Indian Lane 1	Montville Twp	405605	742038
27- 147	East Hanover Twp WD	EHTWD 2	East Hanover Twp	404856	742325
27- 148	East Hanover Twp WD	EHTWD 5	East Hanover Twp	405009	742117
27- 150	U.S. Geological Survey	Great Swamp 4 Obs	Chatham Twp	404349	742516
27- 152	U.S. Geological Survey	Niles Park 1 Obs	Madison Boro	404450	742459
27- 162	SouthEastern Morris County MUA	Wing Well	Hanover Twp	404955	742641
27- 178	Parsippany-Troy Hills WD	PTHWD 8-3	Parsip-Troy Hills Twp	405035	742337
27-1111	St Elizabeth Sisters of Charity	Convent 3	Florham Park Boro	404709	742544
27-1113	Montville Township MUA	Indian Lane 3/Montvi 6	Montville Twp	405608	742017
27-1115	Pequannock Township	Pequannock WD 2	Pequannock Twp	405844	741831
31- 16	Pompton Lakes Boro MUA	Lincoln Ave 2	Pompton Lakes Boro	405850	741701
[3]35- 8	U.S. Geological Survey	GS TH 6	Bernards Twp	404142	743116
39- 387	NJ Bell Telephone Laboratories Co	Bell Labs MW2	Berkeley Heights Twp	404107	742353

Table 2.--Records of wells sampled--Continued

Altitude of land surface (feet)	Depth to top of open interval(s) (feet below land surface)	Depth to bottom of open interval(s) (feet below land surface)	Diameter of of open interval or screen (inches)	Year completed	Use of site[1]	Use of water[2]	New Jersey permit number	New Jersey well number
AQUIFERS IN GLACIAL SEDIMENTS								
334	43	94*	16	1927	W	P	--	13- 1
180	81	133	14	1955	W	P	25-07101	13- 3
173	88	130	14		W	P	25-07099	13- 5
170		90	25	1960	W	P	--	13- 7
175	88	118	12	1955	W	P	25-04872	13- 8
180	84	124	12		W	P	25-04872	13- 9
190	119	157	12	1954	W	P	--	13- 10
180	129	139	12	1949	W	P	--	13- 11
180		134	25	1932	W	P	--	13- 12
193	82	112	16	1958	W	P	26-01712	13- 15
190	88	108	16	1930	W	P	--	13- 47
180	53	134*	25	1925	W	P	--	13- 63
257	72	92	10	1941	W	P	--	13- 73
170	86	101	10	1966	W	P	--	13- 93
219	140	150	6	1967	O	U	25-14164	27- 1
182	60	70	6	1966	O	U	--	27- 2
178	99	108	6	1966	O	U	--	27- 3
175	100	110	6	1966	O	U	--	27- 4
188	113	123	6	1965	O	U	--	27- 5
181	94	104	6	1966	O	U	--	27- 6
190	62	72	6	1967	O	U	--	27- 7
167	63	73	6	1966	O	U	25-14146	27- 8
176	105	115	6	1966	O	U	25-14147	27- 10
198	100	110	6	1967	O	U	25-14149	27- 12
176	110	120	6	1967	O	U	25-14150	27- 14
181	51	62	6	1960	O	U	--	27- 15
260	76	85	6	1967	O	U	--	27- 16
177	71	81	8	1966	O	U	--	27- 19
192	79	89	6	1965	O	U	--	27- 20
318	191	213	6	1966	O	U	--	27- 21
310	116	136	12	1975	W	P	25-18849	27- 45
190	202	242	12	1974	W	P	22-13497	27- 55
190	85	115	12	1967	W	P	25-14205	27- 147
190	65	84	12	1972	W	P	25-18267	27- 148
250	110	112	1	1981	O	U	--	27- 150
360	170	172	1	1981	O	U	--	27- 152
280	88	118	17	1948	W	P	25-00048	27- 162
180	40	70	12	1963	W	P	25-00036	27- 178
200	99	109	8	1920	O	U	--	27-1111
200	175	200	16	1984	W	P		27-1113
220	171	196	12	1969	W	P		27-1115
170	133	153	12	1969	W	P	23-05454	31- 16
230	68	70	--	1981	O	U	--	35- 8
460	22	52	4	1981	O	U	25-22477	39- 387

Table 2.--Records of wells sampled--Continued

New Jersey well number	Well owner	Local well name or number	Municipality	Latitude	Longitude
		AQUIFERS IN SEDIMENTARY BEDROCK			
13- 4	East Orange WD	Slough Brook 3	Livingston Twp	404543	742041
13- 6	Livingston Twp WD	LTWD Pool 4	Livingston Twp	404708	741913
13- 52	Livingston Twp WD	LTWD 7	Livingston Twp	404757	742135
13- 55	Livingston Twp WD	LTWD 9	Livingston Twp	404802	742130
13- 82	Essex Fells WD	EFWD 17	Roseland Boro	404948	741833
13- 90	Fairfield WD	Hollywood 6	Fairfield Boro	405315	741739
27- 153	Southeastern Morris County MUA	Lidgerwood 5	Morristown Town	404707	742839
27- 158	Southeastern Morris County MUA	Sand Springs	Harding Twp	404545	743018
27- 922	Riverdale Boro	Main Supply 1	Riverdale Boro	405929	741754
27- 979	Passaic Township	Stirling Lake	Passaic Twp	404038	742946
27-1109	St. Elizabeth College	St. Elizabeth Main	Florham Park Boro	404700	742556
27-1110	St. Elizabeth Sisters of Charity	Convent 2	Florham Park Boro	404709	742544
27-1112	US Fish and Wildlife	Great Swamp NWR HQ	Harding Twp	404212	742947
31- 35	Preakness Hills Country Club	Tower 2	Wayne Twp	405655	741403
31- 53	Preakness Hills Country Club	Preakness Hills CC 3	Wayne Twp	405653	741352
35- 45	Bernards Twp Sewage Authority	Bernards Twp STP	Bernards Twp	403925	743435
[4]39- 308	CIBA Pharmaceutical	CIBA 10	Summit City	404324	742245
39- 315	CIBA Pharmaceutical	CIBA 6	Summit City	404341	742248
39- 316	CIBA Pharmaceutical	CIBA 4	Summit City	404342	742242
		AQUIFERS IN IGNEOUS BEDROCK			
[5]13- 2	Essex Fells WD	EFWD 8	Essex Fells Boro	404956	741803
13- 59	East Orange WD	Canoe Brook 6	Livingston Twp	404607	741910
13- 72	Essex Fells WD	EFWD 6	Essex Fells Boro	404942	741739
27- 194	Montville Twp MUA	Montvale 2-Westminster	Montville Twp	405326	742119
27- 195	Montville Twp MUA	MTMUA 1	Montville Twp	405229	742111
27- 196	Montville Twp MUA	Montvale 3-Lee Ct.	Montville Twp	405319	742109
27-1114	Montville Twp Bd of Ed	Montville Bd of Ed	Montville Twp	405500	742029
35- 46	Gordner, Ward or Van Wert, Fred	Gordner 1	Warren Twp	403927	742727
39- 180	Fablok, Inc	Spring Ind 1	New Providence Boro	404132	742435

Table 2.--Records of wells sampled--Continued

Altitude of land surface (feet)	Depth to top of open interval(s) (feet below land surface)	Depth to bottom of open interval(s) (feet below land surface)	Diameter of of open interval or screen (inches)	Year completed	Use of site[1]	Use of water[2]	New Jersey permit number	New Jersey well number
				AQUIFERS IN SEDIMENTARY BEDROCK				
182	125	176	--	1927	W	P	--	13- 4
285	38	291	10	1955	W	R	26-01240	13- 6
180	70	301	12	1965	W	P	25-12755	13- 52
180	38	405	--	1974	W	P	25-16551	13- 55
210	117	450	14	1978	W	P	26-04743	13- 82
170	90	200	10	1969	W	P	26-04269	13- 90
300	68	265	--	1967	W	P	25-14520	27- 153
300	36	94	--	1942	W	P	25-02502	27- 158
200	106	184	12	1959	W	P	23-02497	27- 922
245	40	500	8	1955	W	P	25-04545	27- 979
270	177	300	10		W	T	25-22434	27-1109
200	157	588	6	1920	O	U	--	27-1110
230	50	200	--	1980	W	T	--	27-1112
290	40	561	8	1949	W	C	43-00048	31- 35
255	40	342	8	1966	W	A	23-04756	31- 53
230	32	107	8	1963	W		25-11357	35- 45
230	199	719	10	1958	W	N	25-07298	39- 308
220	36	600	8	1947	W	N	--	39- 315
210	41	600	10	1940	W	N	--	39- 316
				AQUIFERS IN IGNEOUS BEDROCK				
244	110	423	10	1942	W	P	--	13- 2
230	89	172	--	1977	W	P	--	13- 59
330	65	565	--	1933	W	P	--	13- 72
290	--	350	--	1965	W	P	25-06387	27- 194
190	60	290	--	1957	W	P	--	27- 195
300	19	293	8	1966	W	P	25-13895	27- 196
400	20	413	6	1964	W	T	--	27-1114
400	50	222	--	1981	W	H	25-22318	35- 46
230	49	200	8	1962	W	N	25-10333	39- 180

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[1] O, observation; W, withdrawal; C, standby.

[2] P, public supply; U, unused; R, recreation; N, industrial; C, commercial; I, irrigation; T, institutional; A, air conditioning; H, domestic.

[3] Well 35-8 is screened in sediment at boundary between sedimentary bedrock and glacial sediments.

[4] Well 39-308 passes through basalt from 710 to 719 feet below land surface.

[5] Well 13-2 passes through sandstone from 106 to 120 feet below land surface.

Table 3.--Physical and chemical characteristics and inorganic and organic constituents determined in ground-water samples[1]

Physical and chemical characteristics

Alkalinity, field, water, whole, fixed-end-point titration
Barometric pressure
Bicarbonate, field
pH, field
Oxygen, dissolved, field

Specific conductance, field
Water temperature

Inorganic constituents

Common ions and silica

Calcium
Chloride
Fluoride
Magnesium
Potassium

Silica
Sodium
Sulfate

Trace elements

Aluminum
Antimony
Arsenic
Barium
Beryllium

Boron
Bromide
Cadmium
Chromium
Chromium, hexavalent

Cobalt
Copper
Iodide
Iron
Lead

Lithium
Manganese
Mercury
Molybdenum
Nickel

Selenium
Silver
Strontium
Vanadium
Zinc

Nutrients

Nitrogen, ammonia
Nitrogen, ammonia + organic
Nitrogen, nitrite
Nitrogen, nitrite + nitrate
Phosphorus

Miscellaneous

Cyanide (dissolved)
Tritium (total)

Organic constituents (total)

Dichlorobromomethane
Carbon tetrachloride
1,2-Dichloroethane (Ethylene dichloride)
Bromoform (Tribromomethane)
Chlorodibromomethane

Chloroform (Trichloromethane)
Toluene
Benzene
Chlorobenzene
Chloroethane

Ethylbenzene
Methyl bromide
Methyl chloride
Methylene chloride (Dichloromethane)
Tetrachloroethylene

Trichlorofluoromethane
1,1-Dichloroethane
1,1-Dichloroethylene
1,1,1-Trichloroethene (Methylchloroform)
1,1,2-Trichloroethane

1,1,2,2-Tetrachloroethane
1,2-Dichlorobenzene (o-Dichlorobenzene)
1,2-Dichloropropane
1,2-Transdichloroethylene
1,3-Dichloropropane

1,3-Dichlorobenzene (m-Dichlorobenzene)
1,4-Dichlorobenzene (p-Dichlorobenzene)
2-Chloroethylvinyl ether
Dichlorodifluoromethane
trans 1,3-Dichloropropene

cis 1,3-Dichloropropene
1,2-Dibromoethylene
Vinyl chloride
Trichloroethylene
Styrene

Xylene, water, whole, total recoverable

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[1] Not all samples were analyzed for all constituents.

determined by means of atomic-emission spectroscopy; concentrations of chloride, sulfate, inorganic phosphorus, and nitrogen species were determined by means of colorimetric methods; concentrations of fluoride were determined by means of electrometric methods; concentrations of arsenic, calcium, chromium, hexavalent chromium, mercury, potassium, and strontium were determined by means of atomic-absorption spectroscopy; and concentrations of dissolved and total solids were determined by means of gravimetric methods.

Water samples from 36 wells were scanned for 36 POC's at the USGS New Jersey District laboratory according to the methods of Kammer and Gibs (1989). For samples in which POC's were found at concentrations greater than the reporting limit of 0.8 μg/L (micrograms per liter), duplicate samples were sent to the NWQL for analysis by means of gas chromatography-mass spectroscopy.

Concentrations of tritium in most samples were determined by means of direct gas proportional counting (Ostlund and Dorsey, 1977). The reporting limit for this method is 10 pCi/L (picocuries per liter). Tritium concentrations were determined by means of a liquid scintillation method with a reporting limit of 26 pCi/L for samples from wells 27-1110 and 27-1111 (method modified from U.S. Geological Survey, 1977). If the concentration of tritium determined by means of direct gas proportional counting or liquid scintillation was within 10 pCi/L of the reporting limit of either method, then tritium concentration was determined in a sequential sample by means of electrolytic enrichment-liquid scintillation (wells 13-63, 27-150, 27-979, 27-1112, 31-16, and 35-8) (apps. 1 and 3) (method modified from U.S. Geological Survey, 1977).

Quality Assurance and Quality Control

The internal quality-control program of the NWQL is described by Friedman and Erdmann (1982). Samples spiked at the NWQL were analyzed to determine percent recovery. Standard samples also were sent "blind" to that laboratory for analysis.

Multiple ground-water samples were collected sequentially from wells 13-63, 13-73, and 27-1114 (app. 1,2 and 3) as an external check on laboratory precision and accuracy. These samples were submitted blind to the NWQL for analysis for common ions, metals, tritium, and purgeable organic compounds. Sequential samples from wells 13-63 and 27-1114 were analyzed by Environmental Testing and Certification Laboratory (hereafter called the contract laboratory) to verify the results of the analyses performed at the NWQL.

Ion balances were computed for each chemical analysis to identify questionable data. If the difference between the cation charge and the anion charge exceeded 6 percent, the sample was submitted to the NWQL for reanalysis of selected or all common ions.

Data Analysis

The results of the inorganic and organic chemical analyses were compared to State and Federal primary and secondary drinking-water regulations (U.S. Environmental Protection Agency, 1988a, 1988b; New Jersey Administrative Code, 1990a, 1990b), and were summarized by using descriptive statistics. For wells sampled more than once, the analysis representing the most recent sampling event was used in the statistical analysis. The 25th, 50th (median), and 75th percentile concentrations were calculated for selected inorganic constituents in ground-water samples from each of the three major aquifer types and for the complete data set. Boxplots showing the concentrations of selected constituents were generated to compare the distributions of these constituents among the aquifer types.

Regional trends in water quality were assessed by plotting Stiff diagrams of results of the chemical analyses on maps of the study area. A Stiff diagram is a graph of the concentration of four cations (calcium, magnesium, and the sum of potassium and sodium) on parallel left horizontal axes against the concentration of three anions (chloride, bicarbonate, and sulfate) on parallel right horizontal axes. All concentrations are in milliequivalents per liter. Points on the graph are connected with straight lines, and the resulting patterns are useful in comparing the ionic compositions of ground-water samples. The shapes of Stiff diagrams are not affected by dilution.

The common-ion chemistry of the ground-water samples was plotted on trilinear diagrams to classify the samples by hydrogeochemical facies (Back, 1966) and to identify differences in ground-water quality (fig. 8). The chemical constituents included in trilinear diagrams are sodium, potassium, calcium, magnesium, chloride, sulfate, and bicarbonate (fig. 8). Concentrations of cations (in milliequivalents per liter) are represented on the cation triangle as percentages of the total concentration of cations. The three sides of the cation triangle show sodium plus potassium, calcium, and magnesium as a percentage of total cations; the sides of the anion triangle show chloride, sulfate, and bicarbonate as a percentage of total anions. Because the trilinear diagrams represent ion concentrations as percentages of total concentrations, concentrations cannot be determined from them. Of the 38 ground-water analysis results plotted on trilinear diagrams, 20 represent water from aquifers in glacial sediments, 15 represent water from aquifers in sedimentary bedrock, and 3 represent water from aquifers in igneous bedrock.

GROUND-WATER QUALITY

Results of chemical analyses for inorganic constituents are presented in appendixes 1 and 3. Results of analyses for POC's are presented in appendix 2.

Results of Quality-Assurance Analyses

Comparison of the results of chemical analyses of the sequential samples showed that the precision and accuracy of the analyses done at the NWQL were acceptable. Concentrations of the inorganic constituents determined in the sequential samples were within accepted precision limits (Feltz and Anthony, 1985). Although the reporting limits for the analyses done at the contract laboratory generally were higher than those for the analyses done at the NWQL,

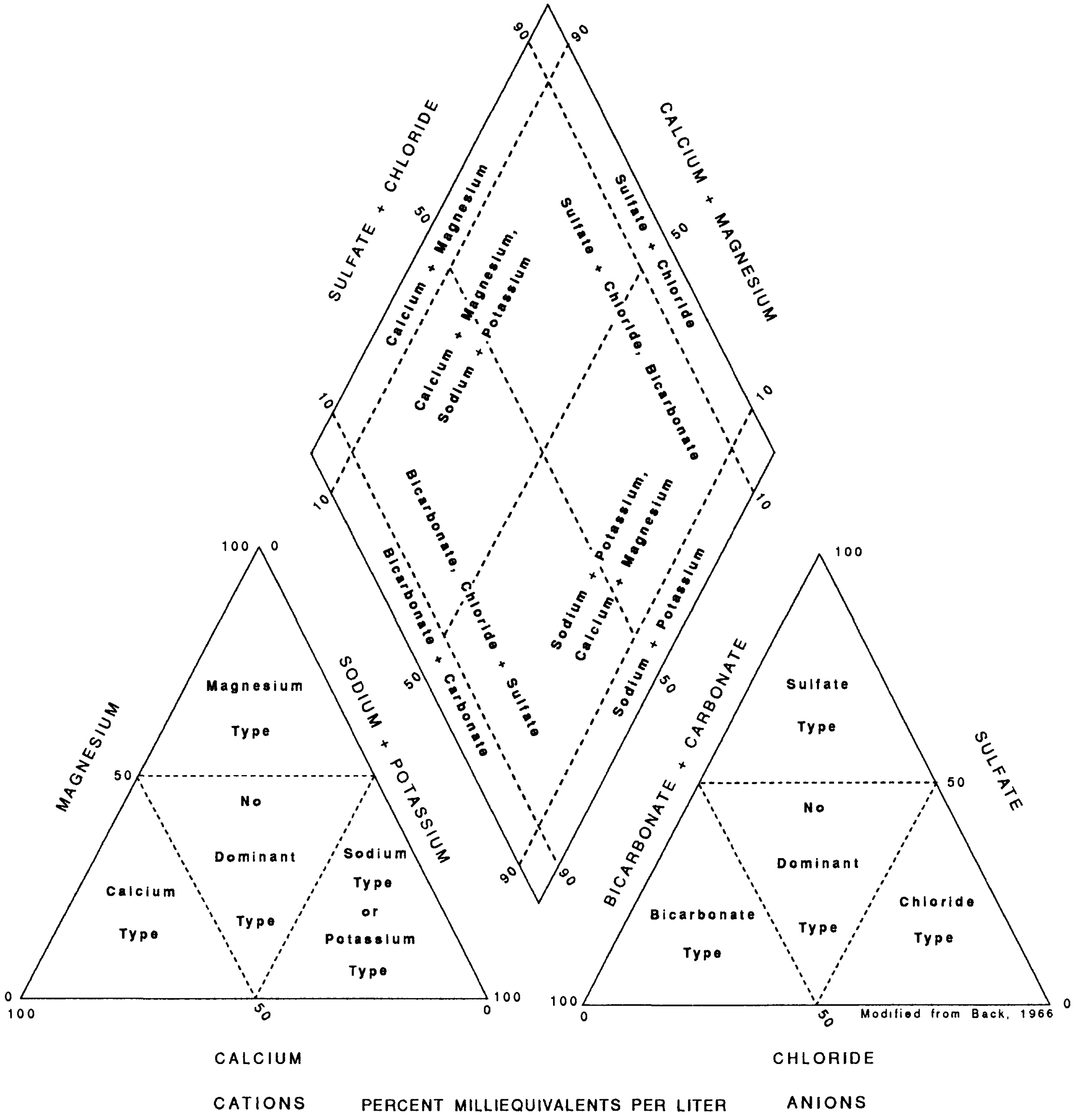


Figure 8.--Trilinear diagram for classifying water types.

the results of the chemical analyses done at the contract laboratory are consistent with those done at the NWQL. Results of the analyses of sequential samples from wells 13-63 and 13-73 for organic constituents (app. 2) also were within suggested precision limits, where such limits exist (Feltz and Anthony, 1985).

Relations of Constituent Concentrations to Drinking-Water Regulations

Some dissolved inorganic and organic constituents are regulated by both Federal and State drinking-water standards (U.S. Environmental Protection Agency, 1988a and 1988b; New Jersey Administrative Code, 1990a and 1990b). Because New Jersey drinking-water regulations (New Jersey Administrative Code, 1990a and 1990b) for the constituents and characteristics considered in this report are identical to U.S. Environmental Protection Agency (USEPA) regulations (U.S. Environmental Protection Agency, 1988a, for organic compounds, and 1988b, for inorganic constituents), all references to drinking-water regulations in this report are to USEPA regulations. These regulations include maximum contaminant levels (MCL's) and secondary maximum contaminant levels (SMCL's). The MCL is the maximum concentration of a regulated constituent allowable in public drinking water. MCL's are enforceable drinking-water standards based on health criteria. Other chemical constituents are subject to SMCL's, the recommended maximum concentrations in public drinking water. SMCL's are based on acceptable aesthetic and taste characteristics. MCL's and SMCL's for organic and inorganic constituents in drinking water are given in tables 4 and 5.

Concentrations of the regulated inorganic constituents determined in ground-water samples from wells in the study area were below the respective MCL's (app. 1 and 3). Concentrations of dissolved solids, iron, manganese, and sulfate generally were below the SMCL's, but concentrations of dissolved solids exceeded the SMCL of 500 mg/L in three ground-water samples from wells open to aquifers in sedimentary bedrock (wells 13-90, 27-1112, and 39-315). The SMCL's for iron (300 μg/L), manganese (50 μg/L), and sulfate (250 mg/L) were exceeded in samples from one, four, and three wells, respectively, that are open to the sedimentary bedrock (app. 3). In samples from wells open to glacial sediments, water from 3 wells exceeded the SMCL for iron, and water from 14 wells exceeded the SMCL for manganese (app. 1).

Concentrations of iron, manganese, and sulfate above the SMCL's can be attributed to the dissolution of minerals in the aquifer matrix that contain iron, manganese, and sulfur. Iron and manganese hydroxides are found naturally in the bedrock aquifer material (Turner-Peterson, 1980), and iron-rich minerals commonly are present in basalts of the Newark Basin. Sources of sulfur in the bedrock aquifer material are iron sulfide or manganese sulfide minerals and other ore minerals. Sulfate minerals, such as gypsum, probably were common precipitate minerals in the lacustrine environments in the ancient rift basin.

POC's are rare in ambient ground water in the central part of the Passaic River basin. The POC's detected in concentrations greater than the MCL's were benzene, tetrachloroethylene, and trichloroethylene (app. 2). Concentrations

Table 4.--Maximum contaminant levels for selected organic compounds

Organic compound	Maximum contaminant level[1] (parts per billion)[2]
Benzene	1
Carbon tetrachloride	2
Chlordane	.5
Chlorobenzene	4
1,2-Dichlorobenzene	600
1,3-Dichlorobenzene	600
1,4-Dichlorobenzene	75
1,2-Dichloroethane	2
1,1-Dichloroethylene	2
1,2-Dichloroethylene (cis and trans)	10
Methylene chloride	2
Tetrachloroethylene	1
1,1,1-Trichloroethane	26
Trichloroethylene	1
Vinyl chloride	2
Xylenes	44

[1] U.S. Environmental Protection Agency, 1988a; New Jersey Administrative Code, 1990a.

[2] Parts per billion is approximately equivalent to micrograms per liter.

Table 5.--Statistical summary of pH of, and concentrations of selected constituents in, ground-water samples, 1966-88

[All, aquifers in glacial sediments, sedimentary bedrock, and igneous bedrock combined; Glacial, aquifers in glacial sediments; Sedimentary, aquifers in sedimentary bedrock; Igneous, aquifers in igneous bedrock. Concentrations are in milligrams per liter (mg/L) unless otherwide indicated. USEPA, U.S. Environmental Protection Agency; µg/L, micrograms per liter; ° C, degrees Celsius; --, no regulation; <, less than]

Constituent or characteristic	USEPA drinking-water regulation	Aquifer type(s)	Number of wells sampled	25th Percentile	Median	75th Percentile
PHYSICAL AND CHEMICAL CHARACTERISTICS						
Bicarbonate (as HCO_3^-)	--	All	40	122	160	192
		Glacial	21	151	172	201
		Sedimentary	15	106	138	160
		Igneous	4	81	173	193
Dissolved oxygen (mg/L)	--	All	36	.1	2.8	5.0
		Glacial	19	<.1	2.5	4.5
		Sedimentary	13	1.1	2.9	6.5
		Igneous	4	2.3	4.2	4.9
pH	[1]6.5 - 8.5	All	65	7.60	7.89	8.10
		Glacial	41	7.70	7.90	8.00
		Sedimentary	19	7.48	7.89	8.25
		Igneous	5	7.50	7.70	8.18
Solids, residue on evaporation at 180° C	[1]500	All	66	202	239	300
		Glacial	42	193	240	300
		Sedimentary	19	220	236	309
		Igneous	5	180	215	303
COMMON IONS AND SILICA						
Calcium	--	All	66	32	44	54
		Glacial	42	31	46	56
		Sedimentary	19	32	41	49
		Igneous	5	31	51	61
Chloride	[1]250	All	66	8.8	15	23
		Glacial	42	7.4	11	21
		Sedimentary	19	14	16	32
		Igneous	5	13	19	31
Magnesium	--	All	66	12	15	19
		Glacial	42	12	14	18
		Sedimentary	19	14	18	22
		Igneous	5	4.5	11	18
Potassium	--	All	66	.6	.8	1
		Glacial	42	.6	.9	1
		Sedimentary	19	.8	.8	1.2
		Igneous	5	.4	.4	.7
Silica	--	All	68	19	22	25
		Glacial	42	19	21	24
		Sedimentary	19	19	23	25
		Igneous	5	27	34	39
Sodium	--	All	66	9.5	13	19
		Glacial	42	8.2	12	17
		Sedimentary	19	11	14	43
		Igneous	5	9.4	9.8	14
Sulfate	[1]250	All	66	29	36	61
		Glacial	42	29	39	65
		Sedimentary	19	29	43	88
		Igneous	5	29	32	36

Table 5.--Statistical summary of pH of, and concentrations of selected constituents in, ground-water samples, 1966-88--Continued

Constituent or characteristic	USEPA drinking-water regulation	Aquifer type(s)	Number of wells sampled	25th Percentile	Median	75th Percentile
		NUTRIENTS				
Nitrite and nitrate (as N)	[2]10	All	38	<.10	1.0	2.1
		Glacial	20	.11	.5	1.5
		Sedimentary	14	<.10	1.1	2.2
		Igneous	4	.48	1.9	2.2
Phosphorous	--	All	36	<0.010	0.035	0.070
		Glacial	18	.025	.065	.083
		Sedimentary	14	<.010	.030	.040
		Igneous	4	<.010	<.010	.028
		TRACE ELEMENTS				
Barium (µg/L)	[3]2,000	All	31	11	35	110
		Glacial	16	9.5	16	34
		Sedimentary	12	42	71	132
		Igneous	3	<1	2.0	130
Boron	--	All	31	40	100	240
		Glacial	16	40	130	238
		Sedimentary	12	43	90	273
		Igneous	3	30	100	1200
Bromide	--	All	31	.043	.063	.081
		Glacial	16	.045	.059	.088
		Sedimentary	12	.032	.053	.078
		Igneous	3	.048	.071	.120
Iron (µg/L)	[1]300	All	66	<3	13	78
		Glacial	42	5.8	40	103
		Sedimentary	19	<3	3	9
		Igneous	5	<3	<3	48
Manganese (µg/L)	[1]50	All	66	<1	3	58
		Glacial	42	<1	9.7	100
		Sedimentary	19	<1	<1	30
		Igneous	5	<1	<1	6.5
Strontium (µg/L)	--	All	31	120	170	240
		Glacial	16	99	135	195
		Sedimentary	12	175	225	530
		Igneous	3	77	130	150

[1] Secondary drinking-water regulation (U.S. Environmental Protection Agency, 1988b; New Jersey Register, 1987).

[2] Primary drinking-water regulation (U.S. Environmental Protection Agency, 1988a; New Jersey Register, 1987).

[3] Primary drinking-water regulation (U.S. Environmental Protection Agency, 1991).

of benzene exceeded the MCL (1 µg/L) in a sample from well 27-147 (1.9 µg/L), which is screened in glacial sediments. Concentrations of tetrachloroethlyene were greater than the MCL (1 µg/L) in samples from two wells open to sedimentary bedrock (wells 13-52 and 35-45) and one well open to igneous bedrock (well 39-180) (app. 2). Concentrations of trichloroethylene were much greater than the MCL of 1 µg/L in water from wells 27-147 (37 µg/L) and 13-73 (31 and 34 µg/L), which are screened in glacial sediments, and in water from wells 13-55 (18 µg/L), 13-52 (1.7 µg/L), and 13-82 (2.2 µg/L), which are open to sedimentary bedrock. Benzene is a fractional component of fuel oil, and trichloroethylene and tetrachloroethylene are common industrial solvents.

Statistical Summary of Water-Quality Data

A descriptive statistical summary of pH values and of concentrations of dissolved oxygen, bicarbonate, and inorganic chemical constituents is presented in table 5. The median concentration of dissolved solids (239 mg/L) indicates that ground water in the central part of the Passaic River basin is dilute freshwater (less than 1,000 mg/L dissolved solids) (Freeze and Cherry, 1979, p. 84), although locally the ground water may be brackish (maximum dissolved-solids concentration 1,400 mg/L, well 27-1112). Median concentrations of dissolved solids in ground water from the three aquifer types (glacial sediments, sedimentary bedrock, and igneous bedrock) were similar (240, 236, and 215 mg/L, respectively). The ground water was slightly basic (median pH for water from all aquifers was 7.89); pH was lowest in ground water from igneous bedrock (7.70), but varied little among the three aquifer types (table 5). Concentrations of dissolved oxygen in the ground water generally were low (median for all aquifers was 2.8 mg/L), but were as high as 8.0 mg/L (in water from well 27-1111). Median concentrations of dissolved oxygen in ground water from glacial sediments (2.5 mg/L) and sedimentary bedrock (2.9 mg/L) were lower than those in ground water from igneous bedrock (4.2 mg/L), perhaps because oxygen is consumed by the reduction of organic matter in the glacial sediments and sedimentary bedrock. In addition, the median dissolved-oxygen concentration may be high in ground water from aquifers in igneous bedrock because the wells open to igneous bedrock are located at topographic ridges that probably are recharge zones.

Water samples from aquifers in sedimentary bedrock contained higher concentrations of some cations (barium, magnesium, sodium, and strontium) and sulfate than water samples from aquifers in either glacial sediments or igneous bedrock (figs. 9 and 10). The median concentration of barium in water from aquifers in glacial sediments (16 µg/L) was lower than that in ground water from aquifers in either sedimentary or igneous bedrock (71 µg/L and 2.0 µg/L, respectively). In addition, the range of barium concentrations in water samples from glacial sediments was much smaller (25th percentile, 9.5 µg/L; 75th percentile, 34 µg/L) than that in water samples from either sedimentary (25th percentile, 42 µg/L; 75th percentile, 132 µg/L) or igneous bedrock (25th percentile, <1 µg/L; 75th percentile, 130 µg/L) (fig. 9). The median concentration of strontium in water from sedimentary bedrock was higher (225 µg/L) than that in water from either igneous bedrock (130 µg/L) or glacial sediments (135 µg/L) (fig. 9). Because of the small number of water samples collected from aquifers in igneous bedrock, it is impossible to determine whether the differences in median concentrations are statistically

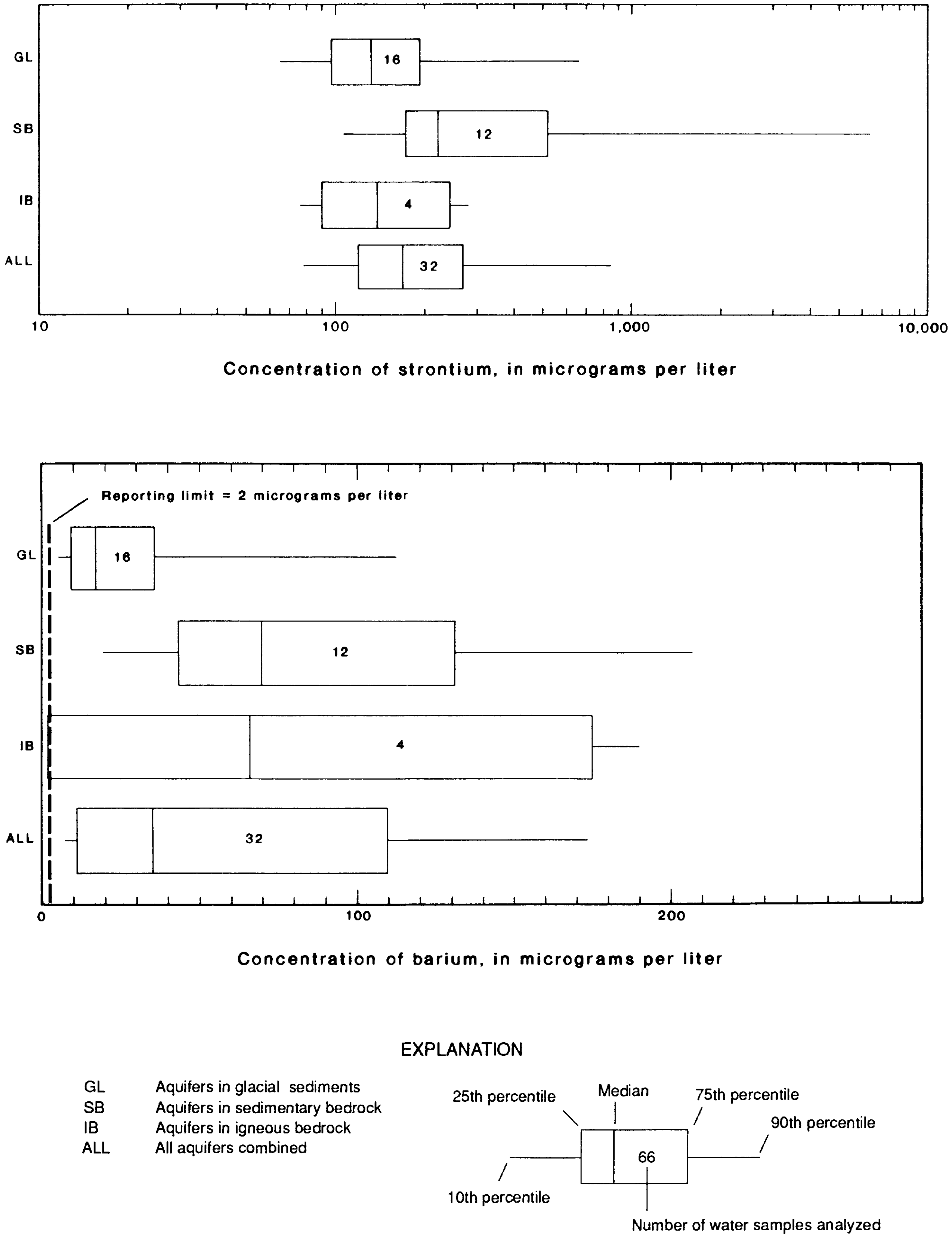


Figure 9.--Concentrations of barium and strontium in water samples from all three aquifer types, aquifers in glacial sediments, aquifers in sedimentary bedrock, and aquifers in igneous bedrock in the central part of the Passaic River basin, New Jersey, 1959-88.

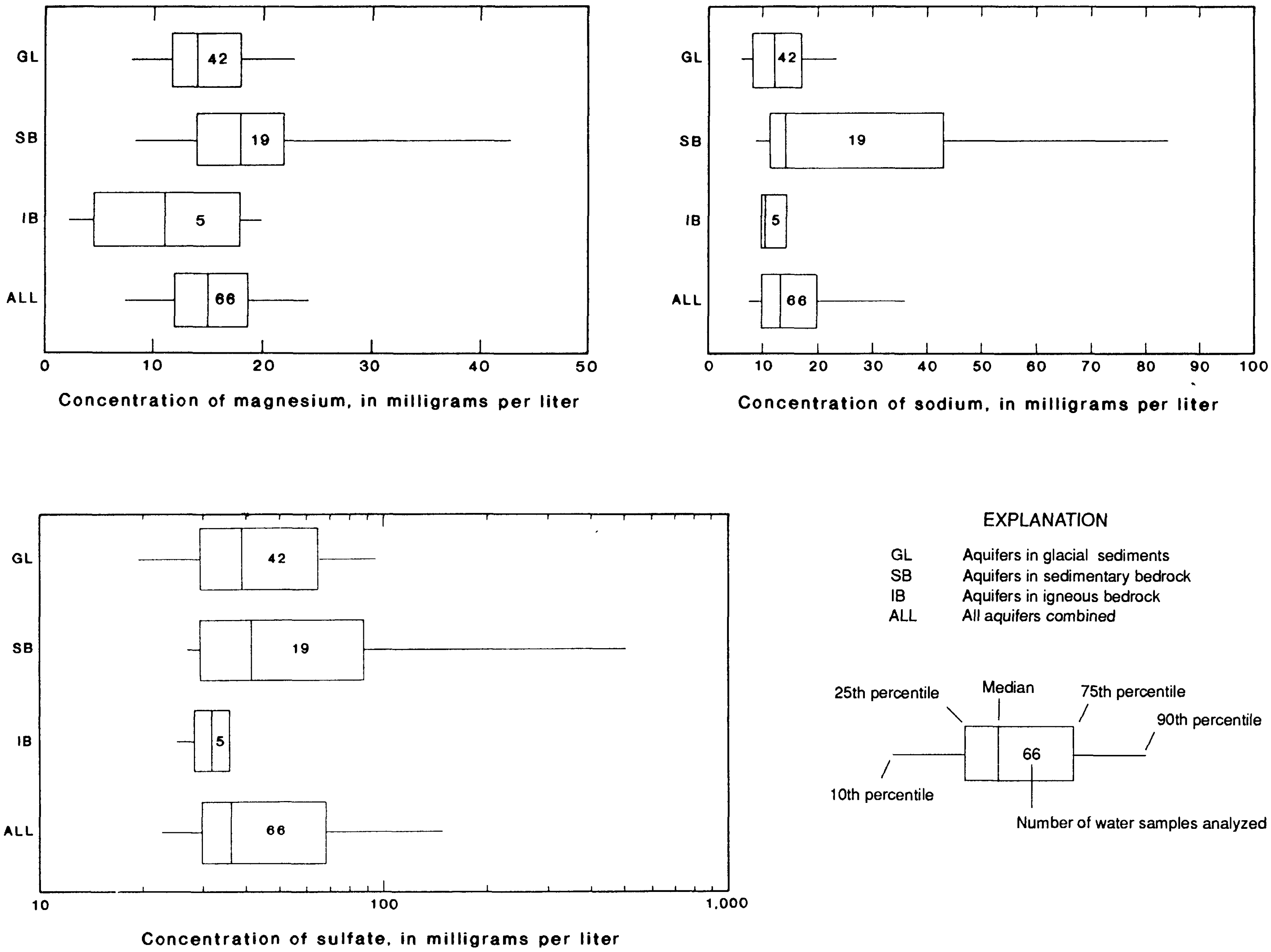


Figure 10.--Concentrations of magnesium, sodium, and sulfate in water samples from all three aquifer types, aquifers in glacial sediments, aquifers in sedimentary bedrock, and aquifers in igneous bedrock in the central part of the Passaic River basin, New Jersey, 1959-88.

significant. The boxplot patterns in figure 9 indicate, however, that concentrations of barium and strontium tended to be highest in water samples from aquifers in sedimentary bedrock.

High concentrations of barium and strontium in water samples from aquifers in sedimentary bedrock may be attributable to dissolution of barium- and strontium-bearing carbonate minerals that precipitated during or following deposition of the sedimentary bedrock. Barium and strontium are common minor components of carbonate minerals, such as calcite and dolomite, that probably were precipitate minerals in the ancient lakes of the Newark Basin. The sedimentary bedrock of the Newark Supergroup contains carbonate-rich beds. As the carbonate minerals in the sedimentary bedrock dissolve, the water in the sedimentary bedrock can become enriched in these ions. If the aquifers in sedimentary bedrock and igneous bedrock are hydraulically connected, ground water in the igneous bedrock can become enriched in these elements as well.

Concentrations of iron and manganese are probably controlled by the concentration of dissolved oxygen. Median concentrations of iron and manganese were much higher in water samples from aquifers in glacial sediments (40 μg/L and 9.7 μg/L, respectively) than in water samples from either aquifers in sedimentary (3 μg/L and <1 μg/L, respectively) or igneous (<3 μg/L and <1 μg/L, respectively) bedrock (table 5). Water samples from aquifers in glacial sediments contained lower concentrations of dissolved oxygen than water samples from the other two aquifer types (table 5). The observed distribution of iron and manganese may be attributable to the fact that the solubilities of iron and manganese increase with decreasing concentrations of dissolved oxygen.

Regional Trends

Water-quality data were plotted on trilinear diagrams to investigate regional trends in ground-water quality. The trilinear diagrams are useful in identifying hydrochemical facies, and especially, in determining whether the aquifer types can be distinguished from each other on the basis of hydrochemical facies. The major ion chemistry for 20 water samples from aquifers in glacial sediments, 15 water samples from aquifers in sedimentary bedrock, and 3 water samples from aquifers in igneous bedrock is represented in figures 11, 12, and 13, respectively.

Calcium was the predominant cation and bicarbonate was the predominant anion in water from aquifers in glacial sediments. Generally, water from these aquifers was a calcium bicarbonate type (fig. 11). Magnesium and sulfate tended to be the next most prominent ions, followed by sodium and chloride. Two samples that did not fall in this category (from wells 31-16 and 27-150) were enriched in sodium relative to calcium. (See app. 1.) This sodium enrichment probably is not a result of contamination by road salt because no corresponding enrichment in chloride relative to the other anions was found in these samples. The sample from well 13-93 was enriched in sulfate and chloride relative to bicarbonate, and thus deviated from the typical chemical composition of ground water from the aquifers in glacial sediments (fig. 11).

Calcium was the predominant cation in the water from aquifers in sedimentary bedrock; bicarbonate was the predominant anion (fig. 12). Generally, dominance of ions in water from these aquifers, in order of decreasing concentration, was calcium, magnesium, sodium, and bicarbonate, sulfate, chloride; however, chloride was more abundant than sulfate in water from wells 13-82, 13-90, 27-1112, and 31-35.

Two water samples from aquifers in sedimentary bedrock (from wells 13-90 and 27-1112) were enriched in sulfate relative to the other anions and were slightly enriched in calcium and magnesium relative to sodium (fig. 12). Concentrations of sulfate in these samples (480 and 850 mg/L, respectively) (app. 2) exceeded the SMCL of 250 mg/L. The water sample from well 39-315 (not shown in fig. 12 because bicarbonate was not determined) also contained high concentrations of sulfate (505 mg/L) relative to chloride (18 mg/L) and higher concentrations of calcium (134 mg/L) relative to other cations (app. 2).

Elevated concentrations of sulfate in these two ground-water samples could be attributed to either natural processes or human activities. A natural source of sulfate could be the dissolution of sulfate-bearing minerals (such as gypsum, a calcium sulfate mineral) in the aquifer material. If the elevated sulfate concentrations were a result of anthropogenic contamination (for example, leachate from point sources such as landfills, and (or) spills of sulfate-containing chemicals), concentrations of other major cations (such as sodium and potassium) and other anions (such as chloride and bicarbonate) might be expected to be elevated as well, and a preferential enrichment of sulfate and calcium would not be evident. Generally, concentrations of calcium, magnesium, potassium, and sodium in water samples from wells 13-90, 27-1112, and 39-315 were greater than the median concentrations in water samples from this aquifer (see app. 2). (The exception was the concentration of potassium in well 27-1112). Chloride concentrations were near the median for this aquifer, however, in water samples from two of these three wells (13-90 and 39-315) (app. 2). No point sources of anthropogenic contamination are known to exist near these wells. Another source of elevated sulfate concentrations could be sulfate from acidic precipitation, which is retained in wetland areas. The cause of the enrichment of these samples in sulfate, calcium, and magnesium cannot be determined conclusively from available information.

Calcium was the predominant cation and bicarbonate was the predominant anion in water samples from wells open only to aquifers in igneous bedrock (fig. 13). Water from these aquifers can not be characterized further because of the small number of analyses (three); however, the limited constituent-concentration data indicate that magnesium and chloride generally were the next most-dominant ions.

Generally, the chemistry of the ground water was relatively uniform throughout the study area and could not be distinguished readily on the basis of aquifer type (figs. 11-13). Calcium was the predominant cation in water from each aquifer sampled, followed by magnesium, and sodium plus potassium.

Index number	New Jersey well number
1	27- 12
2	27- 15
3	27- 20
4	13- 47
5	27- 1113
6	27- 55
7	13- 93
8	13- 63
9	13- 9
10	31- 16
11	27- 147
12	27- 148
13	27- 1115
14	27- 178
15	27- 45
16	27- 162
17	27- 150
18	27- 152
19	27- 1111
20	39- 387

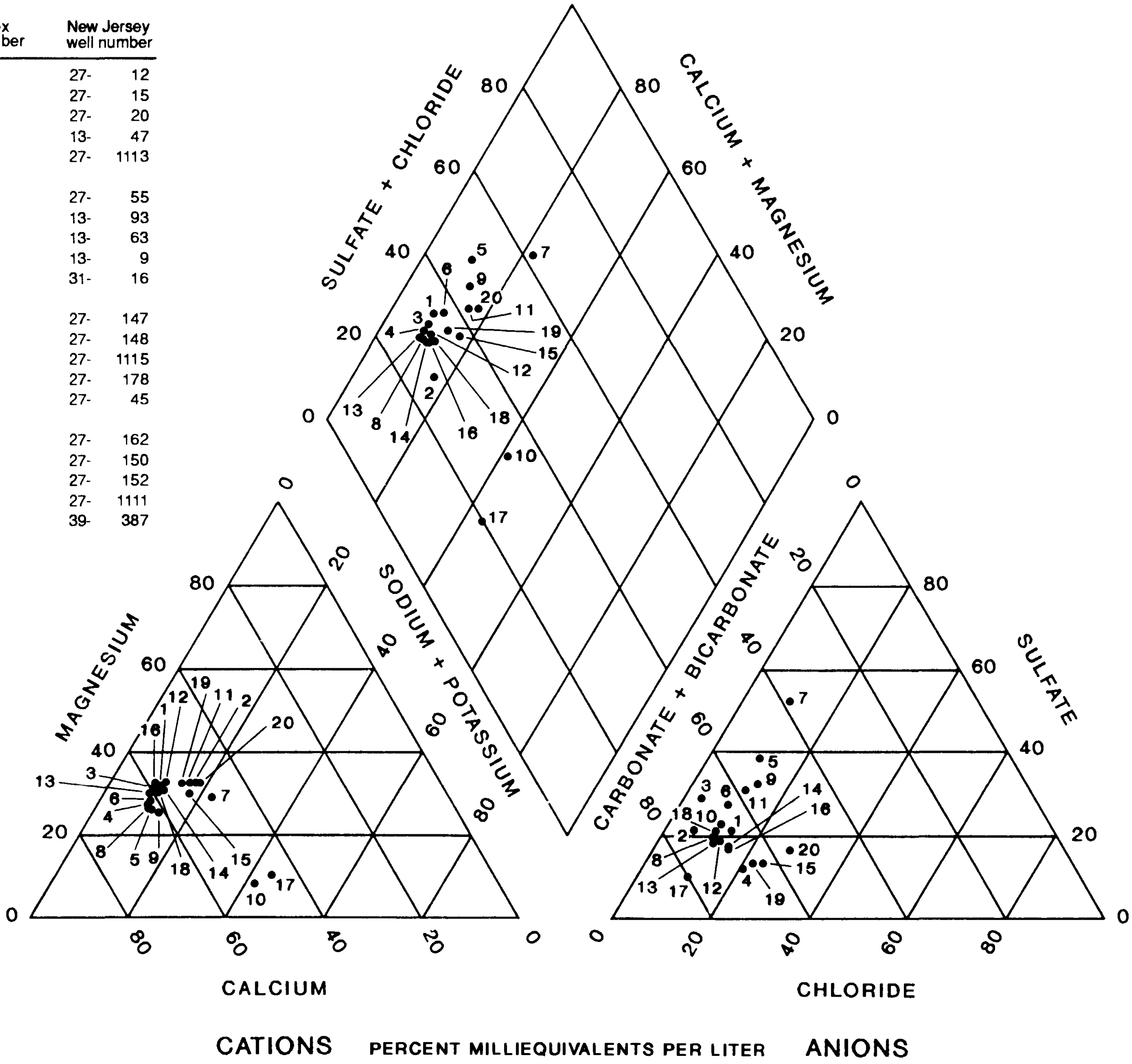
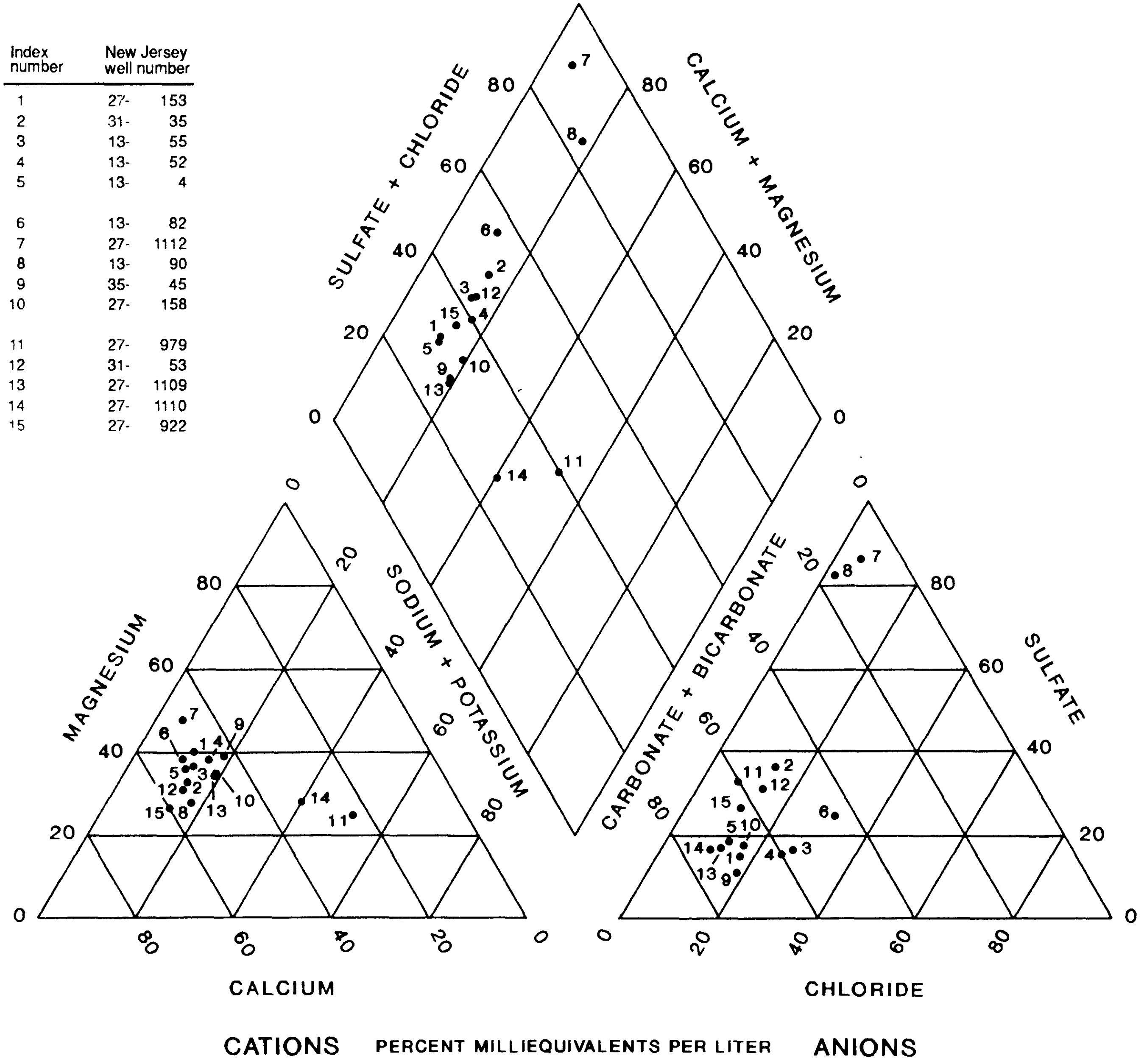
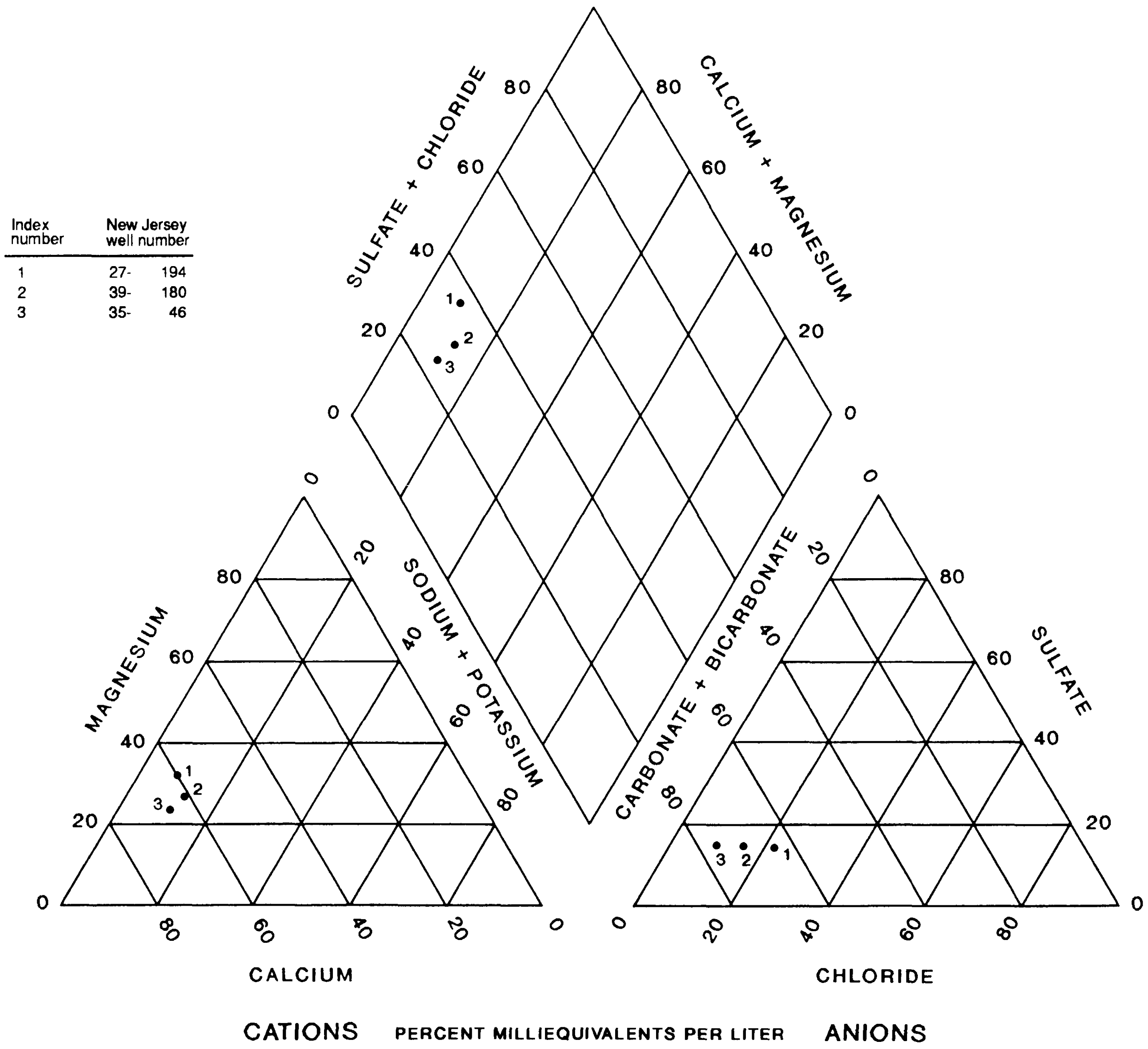


Figure 11.--Trilinear diagram showing relative amounts of major ions in water from aquifers in glacial sediments in the central part of the Passaic River basin, New Jersey, 1987-88.



Index number	New Jersey well number
1	27- 153
2	31- 35
3	13- 55
4	13- 52
5	13- 4
6	13- 82
7	27- 1112
8	13- 90
9	35- 45
10	27- 158
11	27- 979
12	31- 53
13	27- 1109
14	27- 1110
15	27- 922

Figure 12.--Trilinear diagram showing relative amounts of major ions in water from aquifers in sedimentary bedrock in the central part of the Passaic River basin, New Jersey, 1987-88.



Index number	New Jersey well number
1	27- 194
2	39- 180
3	35- 46

Figure 13.--Trilinear diagram showing relative amounts of major ions in water from aquifers in igneous bedrock in the central part of the Passaic River basin, New Jersey, 1987-88.

In the majority of water samples, the predominant anions, in order of decreasing abundance, were bicarbonate, sulfate, and chloride. Chloride ions were more abundant than sulfate ions in 11 of the 38 ground-water samples, however. The overall uniformity of water chemistry among the aquifer types indicates that, despite the differences in aquifer-matrix compositions, the ground water in the three aquifer types has evolved to similar major-ion chemical compositions. Mixing of ground water among the three aquifers as a result of their hydraulic connections would tend to lessen the chemical distinctions among the ground waters from the different aquifers.

Stiff diagrams were generated to represent the results of the 38 analyses that were plotted on the trilinear diagrams. Stiff diagrams were plotted on well-location maps for each of the three aquifer types: aquifers in glacial sediments (fig. 14), aquifers in sedimentary bedrock (fig. 15), and aquifers in igneous bedrock (fig. 16). Clusters of Stiff diagrams of approximately the same size and of similar shape on a map indicate that the ionic strength and ionic composition of the water are similar throughout the region where the corresponding wells are clustered.

Stiff diagrams representing the major-ion chemistry of the water samples from aquifers in glacial sediments (fig. 14) generally are similar to each other and represent a calcium bicarbonate water type. The exceptions are the diagrams for the samples from wells 13-93, 27-150, 31-16, and 39-387. No regional variation in the ionic concentration of the ground water can be detected from this map although some samples are dilute compared to the majority (for example, those from wells 39-387 and 27-150). These slight differences are probably a result of local variations in the composition of the aquifer matrix or in ground-water flow and do not represent a regional trend. For example, the concentration of sulfate in the water sample from well 13-93 is greater than the median sulfate concentrations in water samples from the aquifer system and from aquifers in glacial sediments. (See table 5 and app. 1.) Well 13-93 is southeast of Great Piece Meadows (fig. 3); the swamp area of the Meadows and the area around well 13-93 are characterized by downward hydraulic gradients (J.L. Hoffman, New Jersey Department of Environmental Protection and Energy, oral commun., 1991). Decay of sulfur-containing organic matter in the swamp may result in increased sulfate concentrations in the ground water. Although this well is screened from 86 to 101 ft below land surface and a confining layer of clay is present above the screened interval, sulfate-rich water from Great Piece Meadows may have leached downward from the swamp and affected the quality of water in this area. This scenario is plausible, particularly if the well is in an area where the confining unit thins and pinches out; however, the thickness and continuity of the clay layer are not well known (J.L. Hoffman, New Jersey Department of Environmental Protection and Energy, oral commun., 1991).

Alternatively, the relatively high sulfate concentration in the water sample from well 13-93 could be attributed to the dissolution of sulfate-bearing minerals. Concentrations of calcium and strontium in this sample (68 mg/L and 1,000 μg/L, respectively) are greater than the 75th-percentile values for the concentrations of these ions in the water samples from aquifers in glacial sediments (table 5 and app. 1). The association of elevated concentrations of sulfate with elevated concentrations of calcium and strontium is consistent with mineral dissolution as the source of elevated sulfate concentration.

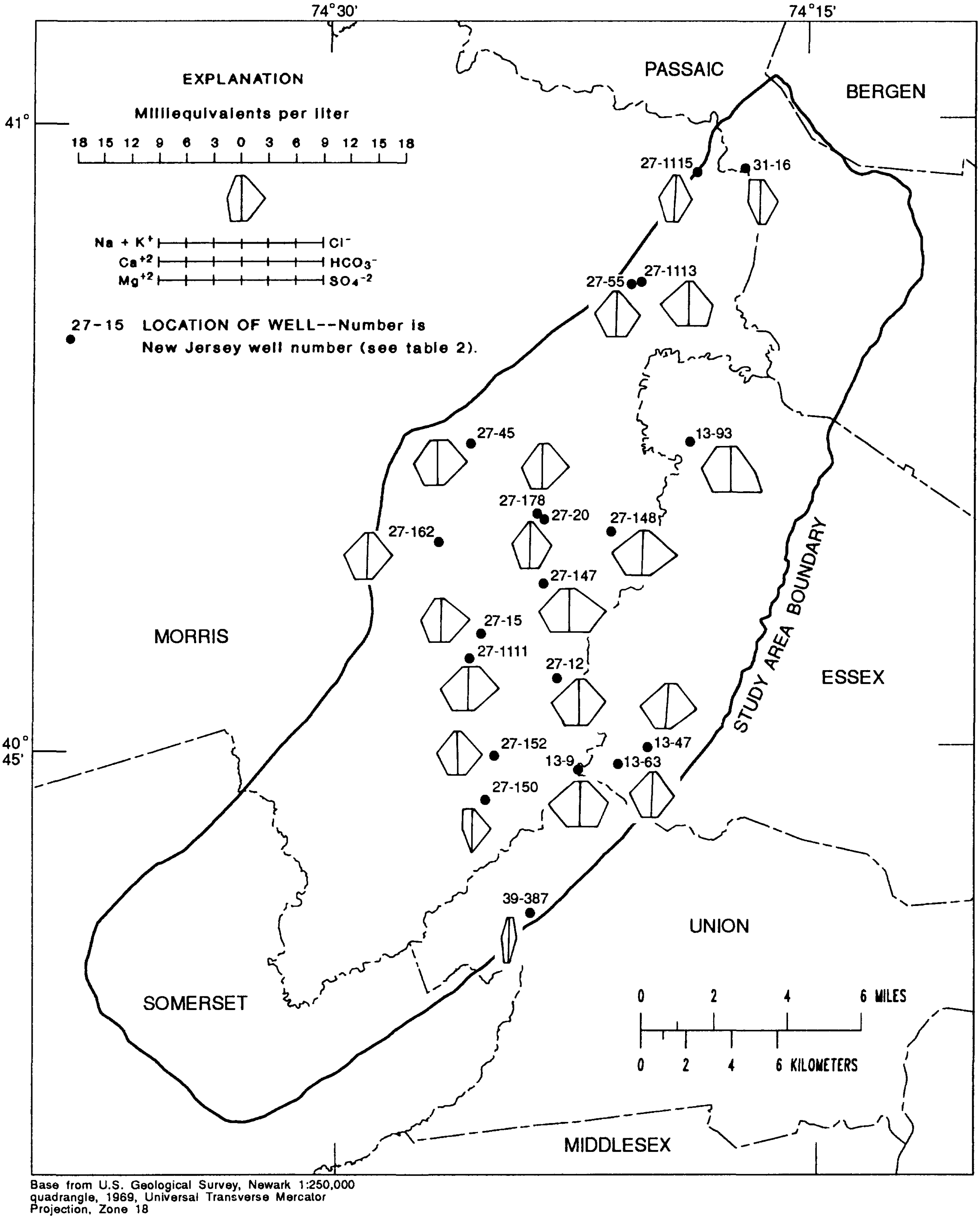
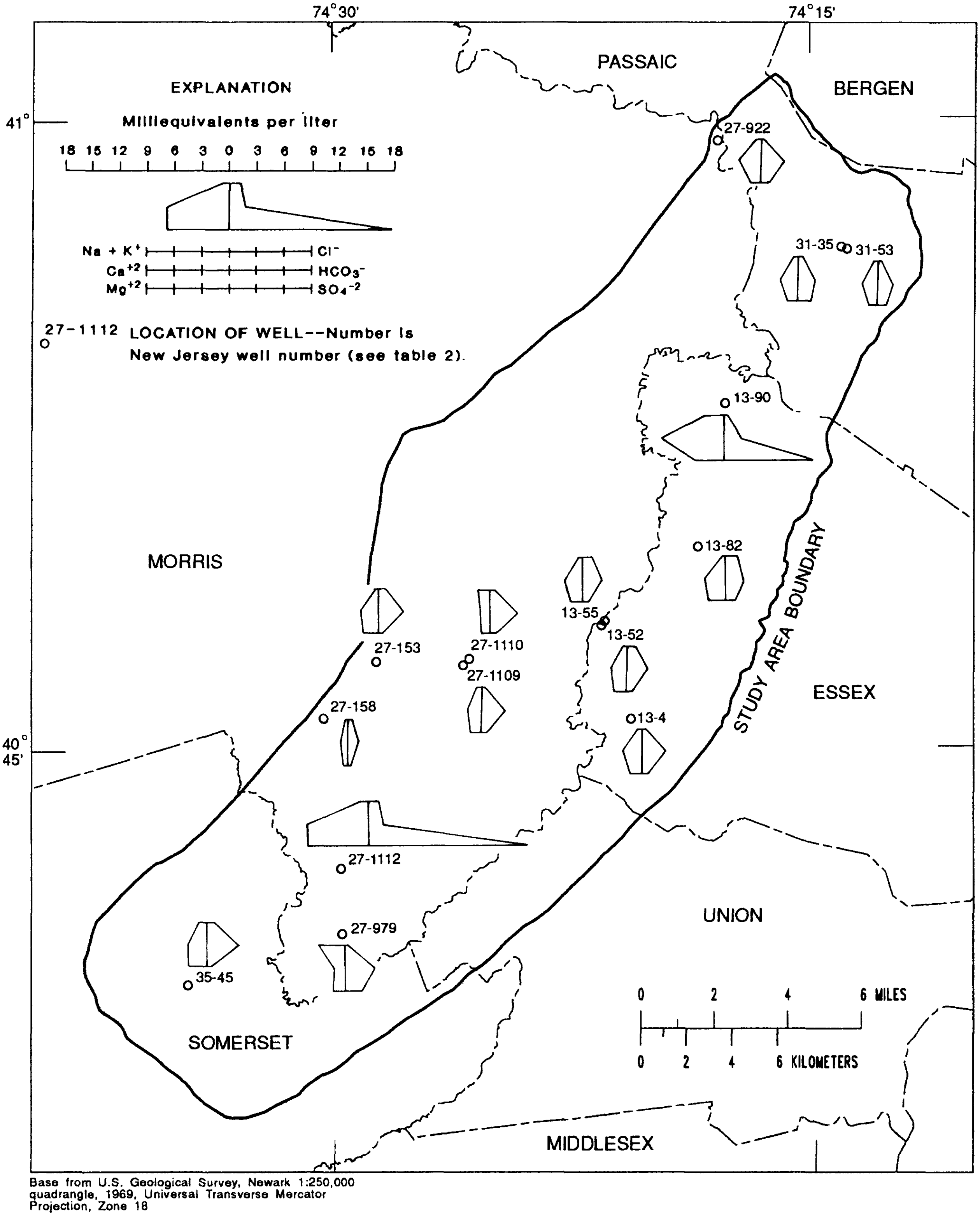
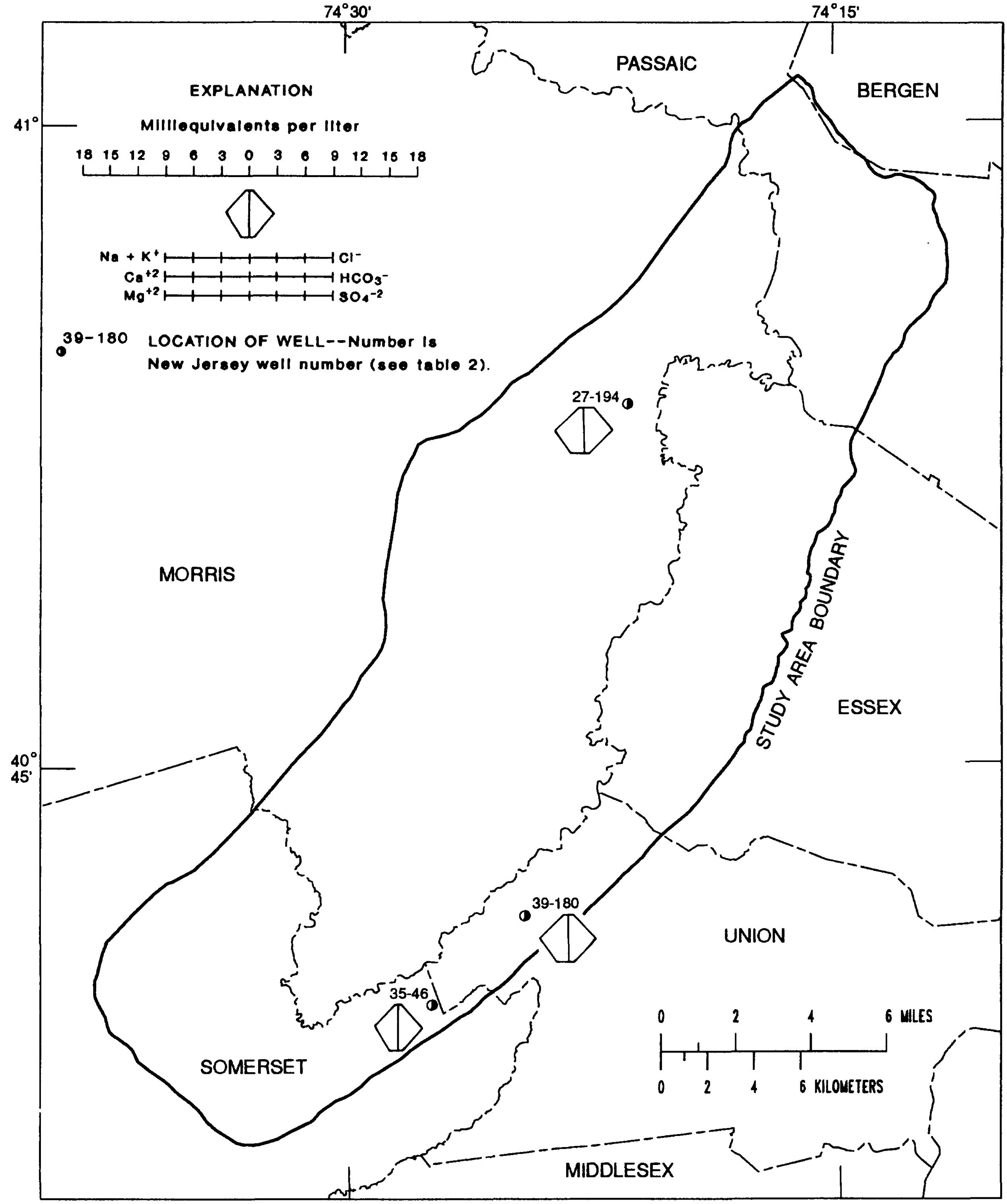


Figure 14.--Map showing Stiff diagrams representing major-ion chemistry of water samples from aquifers in glacial sediments in the central part of the Passaic River basin, New Jersey, 1959-88.



Base from U.S. Geological Survey, Newark 1:250,000 quadrangle, 1969, Universal Transverse Mercator Projection, Zone 18

Figure 15.--Map showing Stiff diagrams representing major-ion chemistry of water samples from aquifers in sedimentary bedrock in the central part of the Passaic River basin, New Jersey, 1959-88.



Base from U.S. Geological Survey, Newark 1:250,000 quadrangle, 1969, Universal Transverse Mercator Projection, Zone 18

Figure 16.--Map showing Stiff diagrams representing major-ion chemistry of water samples from aquifers in igneous bedrock in the central part of the Passaic River basin, New Jersey, 1959-88.

The map of Stiff diagrams representing the water samples from aquifers in sedimentary bedrock demonstrates that water quality varied little regionally (fig. 15). Most of the diagrams illustrate the calcium bicarbonate composition of the ground water. The diagrams for the water samples from wells 13-90 and 27-1112, however, show that these samples are not a calcium bicarbonate type water and reflect sulfate enrichment of the ground water and relatively high concentrations of total ions. Both wells are in or near a swamp (fig. 2 and fig. 15). The aquifers in sedimentary bedrock are confined by thick clay layers that underlie both Great Swamp, near well 27-1112, and Great Piece Meadows, near well 13-90. If the confining units are discontinuous or leaky, downward hydraulic gradients could induce recharge of sulfate-rich water from above; however, the elevated concentrations of sulfate in the samples from wells 13-90 and 27-1112, like that in the sample from well 13-93, are associated with relatively high concentrations of other cations (strontium, calcium, lithium, and vanadium). This association may indicate dissolution of sulfate-bearing minerals.

The three Stiff diagrams representing the results of analyses of the water samples from aquifers in igneous bedrock are all similarly shaped (fig. 16). This indicates that the ground water is dominated by calcium and bicarbonate ions. The number of data points is insufficient to determine whether the ground-water quality varies within the study area.

Relation of Water Quality to Depth

In Passaic County, the concentration of dissolved solids in ground water from the aquifers in sedimentary bedrock is inversely related to the altitude of the top of the well (that is, land surface) (Carswell and Rooney, 1976, p. 23). Water from the aquifers in sedimentary bedrock is thought to be more heavily mineralized near the discharge zones, most of which are at the lowest altitudes, than elsewhere, and with depth (Carswell and Rooney, 1976, p. 23). There is some evidence of a positive relation between well depth and sulfate concentration in ground water from the Brunswick Formation in Union County (Nemickas, 1976, p. 32).

In this study, no relation was found between the concentration of dissolved solids in water samples from the entire aquifer system or from any of the three aquifer types and either the elevation of land surface or the altitude of the bottom of the open interval of the well. Concentrations of sulfate in ground-water samples from aquifers in sedimentary bedrock, however, were inversely related to the altitude of the bottom of the open interval of the well (fig. 17), but this relation is not significant. The correlation coefficient is 0.018 for 19 pairs of data, but the correlation coefficient for the ranked values is -0.462. The correlation is stronger (correlation coefficient -0.690) when the sulfate-concentration data for wells 21-1112 and 13-90 are eliminated from the data set. Water from these wells may be affected by the leaching of sulfate-rich waters from overlying swamps, and thus may not be representative of ambient ground water.

This analysis of the limited data set indicates that the altitude of the bottom of the open interval of the well has some effect on the sulfate concentration in ground water from the aquifers in sedimentary bedrock. Carswell and Rooney (1976) attributed this relation to increased mineralization of ground water with depth. Sulfate concentrations may be elevated in parts of the aquifer system where the ground water is not affected

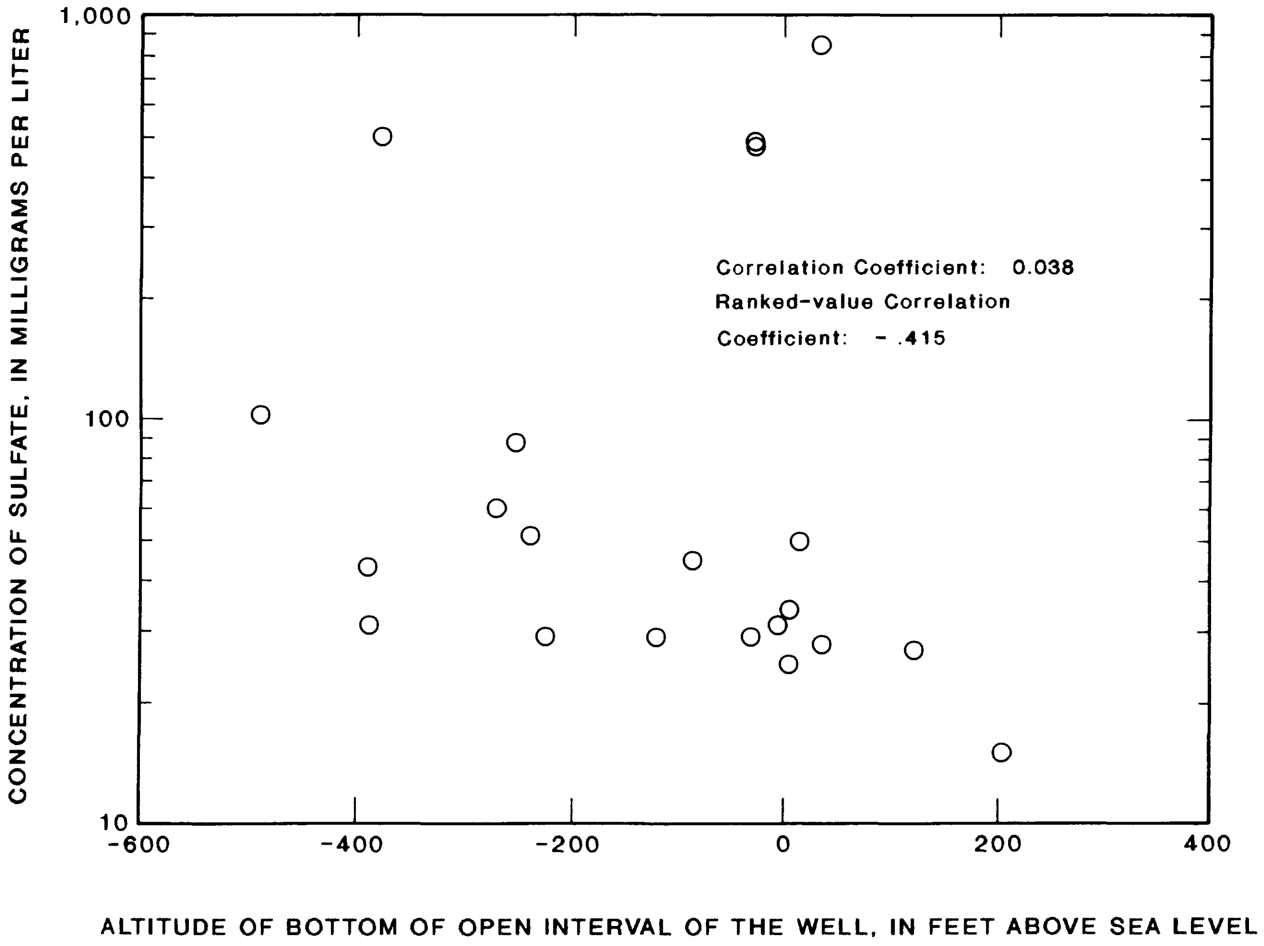


Figure 17.--Relation between the concentration of sulfate and the altitude of the bottom of the open interval of the well for water samples from aquifers in sedimentary bedrock in the central part of the Passaic River basin, New Jersey, 1987-88.

by mixing with dilute water from the recharge zones, or the aquifer matrix may be more sulfate-rich at low altitudes than at high altitudes. No correlation between sulfate concentration and altitude of the bottom of the open interval of the well is indicated for water samples from the aquifers in glacial sediments or in igneous bedrock.

Relative Age of Ground Water

Concentrations of tritium were determined in ground-water samples from 35 wells: 20 screened in glacial sediments, 12 open to sedimentary bedrock, and 3 open to igneous bedrock (app. 1). Tritium was detected in concentrations greater than the reporting limits of 10 pCi/L (University of Miami, 1987, unpublished description of sampling and analytical procedures on file at the U.S. Geological Survey office in West Trenton, N.J.) and 26 pCi/L (U.S. Geological Survey, 1977) in water samples from every well except wells 27-1112 and 35-8 (app. 1). Sequential samples of water from these wells were analyzed for tritium to a reporting limit of 2.5 pCi/L; the tritium concentration in both samples was less than the reporting limit (app. 1). The results of the analyses of the sequential samples from well 27-979 for tritium did not agree (<10 pCi/L and 12 pCi/L), but the degree of error associated with the analysis is approximately +/- 1.8 pCi/L. For the purposes of the following discussion, tritium is considered to have been undetected in well 27-979.

Generally, the presence of tritium in concentrations greater than the reporting limit indicates that the ground water is younger than 1953, the year when large-scale nuclear-bomb testing began (Freeze and Cherry, 1979, p. 136-137). Most of the ground water in the study area is, thus, younger than 1953.

The three samples that did not contain detectable concentrations of tritium were from the Great Swamp and its vicinity (figs. 3 and 6); well 27-979 is east of Third Watchung Mountain (Long Hill), well 27-1112 is west of Long Hill, and well 35-8 is south of Long Hill. Wells 27-979 and 27-1112 are north of a meander loop of the Passaic River, a section where the river's course changes direction from southwest to north; well 35-8 is just south of this loop (fig. 3). In addition, wells 27-979 and 27-1112 are open to aquifers in sedimentary bedrock that are confined by thick clay layers. Well 35-8 is screened in aquifers in semiconfined glacial sediments (unpublished data on file at the U.S. Geological Survey in West Trenton, N.J.) but, because the bottom of the screen is at the boundary of the sedimentary bedrock and glacial sediments, water from this well probably is from aquifers in sedimentary bedrock. Ground water may be relatively old in this area because flow has been restricted or is stagnant as a result of the overlying clay layers and the morphology of the surrounding basalt sheets. Tritium was detected in other wells open to confined parts of aquifers in sedimentary bedrock (wells 13-4, 13-90, and 39-308), indicating that confinement is not an effective impediment to mixing with more recent water in all parts of the aquifer system.

SUMMARY AND CONCLUSIONS

The quality of ground water in the central part of the Passaic River basin was evaluated on the basis of the results of chemical analyses of water samples collected from 71 wells in aquifers in unconsolidated glacial sediments, sedimentary bedrock, and igneous bedrock in the study area. Concentrations of inorganic constituents in most samples of ambient ground water from the study area did not exceed U.S. Environmental Protection Agency primary or secondary drinking-water regulations. No inorganic constituents were detected in concentrations greater than those specified in primary drinking-water regulations. Concentrations of dissolved solids, iron, manganese, and sulfate exceeded secondary drinking-water regulations, however. Each of these constituents is found naturally in the aquifer-system matrix. Some organic compounds were detected in the water, although the samples were collected only from wells that were more than 1 mi from known or suspected sources of contamination related to human activities. Benzene, tetrachloroethylene, and trichloroethylene were detected in concentrations greater than U.S. Environmental Protection Agency primary drinking-water regulations.

Ground-water samples from the study area were chemically dilute (median dissolved-solids concentration 239 mg/L), slightly basic (median pH 7.89), and generally low in dissolved oxygen (median 2.8 mg/L). Water samples from aquifers in igneous bedrock were slightly more oxygen-rich (4.2 mg/L) than samples from aquifers in glacial sediments (2.5 mg/L) or sedimentary bedrock (2.9 mg/L). The low concentrations of dissolved oxygen in water from glacial sediments and sedimentary bedrock could result from the oxygen-depleting decay of organic matter.

Median concentrations of barium, magnesium, sodium, strontium, and sulfate were greatest (71 μg/l, 18 mg/L, 14 mg/L, 225 μg/L, and 43 mg/L, respectively) in water samples from aquifers in sedimentary bedrock. This relation probably results from the dissolution of carbonate- and sulfate-containing minerals in the aquifer matrix. Median concentrations of iron, and phosphorus were highest in water samples from aquifers in glacial sediments (40 μg/L and 0.065 mg/L, respectively).

Calcium was the dominant cation and bicarbonate was the dominant anion in water samples from the aquifers in the study area. Most water samples were of the calcium bicarbonate type. Samples not of this type were enriched in either sodium or sulfate. Regional variation in ground-water quality is minimal, although some ground-water samples from areas near Great Swamp and Great Piece Meadows were enriched in sulfate. Sources of sulfate could be natural, derived from the dissolution of sulfate-bearing minerals in the aquifer matrix. Sulfate also could be contributed by sulfate-enriched acid precipitation, and decay of organic matter in swamps; however, the aquifers in these areas are believed to be confined by thick continuous confining units that would limit downward recharge.

Well depth and the concentrations of inorganic constituents did not appear to be related; however, sulfate concentrations in water samples from aquifers in sedimentary bedrock tended to be inversely related to the altitude of the bottom of the open interval of the well. The correlation coefficient for 17 pairs of ranked data (sulfate concentration and altitude) representing water samples from aquifers in sedimentary bedrock was -0.690. This relation indicates the presence at depth of zones in the aquifer where the aquifer matrix is enriched in sulfate relative to shallower parts of the aquifer, and (or) the presence of zones where little mixing of resident ground water with fresh, dilute water from the recharge zones occurs.

Tritium was detected in all but three ground-water samples (from wells 27-979, 27-1112 and 35-8). Results of analyses for tritium indicate that most ground water in the study area post-dates (see p. 13) 1953, but that some ground water is stagnant and has not mixed with post-1953 water.

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GLOSSARY

Aquifer. A geologic unit, a combination of geologic units, or part of a geologic unit that is saturated with water. Unconfined aquifers are those in which the pressure is similar to atmospheric pressure; in confined aquifers, ground water is under pressure greater than atmospheric.

Microgram per liter. A unit expressing the concentration of chemical constituents in solution as the mass (microgram) of solute per unit volume (liter) of water.

Milligram per liter (mg/L). A unit expressing the concentration of chemical constituents in solution as the mass (milligram) of solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to one milligram per liter.

Picocuries per liter (pCi/L). One trillionth (1 x 10(-12)) of the amount of radioactivity represented by a Curie (Ci). A Curie is the amount of radioactivity that yields 3.7 x 10(10) radioactive disintegrations per second. A picocurie yields 2.22 disintegrations per minute.

Porosity. The ratio of interstitial or void space within a rock or soil to its total volume. It may be expressed as a decimal fraction or as a percentage.

Reporting limit. For a given type of sample and analytical method, the lowest concentration at which quantification can be performed.

APPENDIXES

Appendix 1.-- Results of analyses for inorganic constituents in ground-water samples from aquifers in glacial sediments in the central part of the Passaic River basin, New Jersey, 1959-88

[mg/L, milligrams per liter; mm of Hg, millimeters of mercury; µS/cm, microsiemens per centimeter at 25 degees Celsius; dis, dissolved; deg C, degrees Celsius; µg/L, micrograms per liter; pCi/L, picocuries per liter; WD, Water Department; WC, Water Company; TWP, Township; MUA, Municipal Utilities Authority; --, no data; <, less than]

New Jersey well number	Well owner	Local well name or number	Sample-collection date	Barometric pressure (mm of Hg)	Alkalinity, field (mg/L as $CaCO_3$)	Bicarbonate (mg/L as HCO_3)	pH field (standard units)	Oxygen, dissolved field (mg/L)
13- 1	Essex Fells WD	EFWD 1A	09-01-66	--	--	--	8.10	--
13- 3	East Orange WD	DICKINSON 3	02-24-59	--	--	--	7.90	--
13- 5	East Orange WD	DICKINSON 1	08-18-66	--	--	--	7.50	--
13- 7	Livingston Twp WD	LWD 5	08-31-66	--	--	--	7.60	--
13- 8	N.J. American WC	CWC 50	08-19-66	--	--	--	8.10	--
13- 9	N.J. American WC	CWC 51	08-18-87	756	171	201	7.98	4.5
13- 10	N.J. American WC	CWC 46	08-19-66	--	--	--	7.60	--
13- 11	N.J. American WC	CWC E	02-24-59	--	--	--	7.90	--
13- 12	N.J. American WC	CWC K5	08-19-66	--	--	--	7.60	--
13- 15	East Orange WD	EOWD H	08-18-66	--	--	--	8.00	--
13- 47	East Orange WD	CANOE BROOK 1	08-11-87	758	171	209	7.99	2.4
13- 63	N.J. American WC	CWC K2	08-18-87	756	121	160	8.00	3.3
13- 63	N.J. American WC	CWC K2	08-18-87	756	121	160	8.00	3.3
13- 63	N.J. American WC	CWC K2	08-18-87	756	121	160	8.00	3.3
13- 63	N.J. American WC	CWC K2	08-18-87	756	121	160	8.00	3.3
13- 63*	N.J. American WC	CWC K2	08-18-87	--	--	--	--	--
13- 73	Essex Fells WD	EFWD 7	08-12-87	756	129	157	7.50	5.9
13- 73	Essex Fells WD	EFWD 7	08-12-87	756	129	157	7.50	5.9
13- 93	Fairfield WD	FAIRFIELD 4	08-14-87	765	129	157	8.02	.1
27- 1	U.S. Geological Survey	RECREATION FLD OBS	01-27-67	--	--	--	8.00	--
27- 2	U.S. Geological Survey	W B DRIVER 1	01-22-66	--	--	--	7.40	--
27- 3	U.S. Geological Survey	W B DRIVER 2 OBS	06-16-83	760	--	--	8.10	.1
27- 4	U.S. Geological Survey	CLEMENS OBS	05-17-66	--	--	--	7.80	--
27- 5	U.S. Geological Survey	SANDOZ CHEM CO OBS	12-28-65	--	--	--	7.50	--
27- 6	U.S. Geological Survey	GREEN ACRES OBS	12-09-66	--	--	--	7.80	--
27- 7	U.S. Geological Survey	HOMESTEAD	01-17-67	--	--	--	7.90	--
27- 8	U.S. Geological Survey	GREENHOUSE	12-14-66	--	--	--	7.90	--
27- 10	U.S. Geological Survey	BRAIDBURN CLUB	03-02-67	--	--	--	7.80	--
27- 12	U.S. Geological Survey	BRIARWOOD SCHL OBS	09-16-86	760	148	179	7.50	6.3
27- 14	U.S. Geological Survey	ESSO SIX INCH OBS	01-20-67	--	--	--	7.90	--
27- 15	Morristown Airport	TEST 2 OBS	09-17-86	760	166	201	8.30	.2
27- 16	U.S. Geological Survey	MORRIS TREAT 2	01-17-67	--	--	--	7.70	--
27- 19	U.S. Geological Survey	TROY MEADOWS 2	01-11-66	--	--	--	7.50	--
27- 20	U.S. Geological Survey	TROY MEADOWS 1 OBS	09-18-86	760	120	145	7.90	<.1
27- 21	U.S. Geological Survey	INTERPCE OEP 1	04-12-66	--	--	--	7.90	--
27- 45	Parsippany-Troy Hills WD	PTHWD 17	08-31-87	760	159	194	7.81	2.5
27- 55	Montville Twp MUA	INDIAN LANE 1	08-13-87	--	131	160	8.23	5.3
27- 147	East Hanover Twp WD	EHTWD 2	08-20-87	760	211	257	7.81	.0
27- 148	East Hanover Twp WD	EHTWD 5	08-20-87	760	195	238	7.78	.5
27- 150	U.S. Geological Survey	GREAT SWAMP 4 OBS	12-18-87	--	95	116	7.70	--
27- 150	U.S. Geological Survey	GREAT SWAMP 4 OBS	12-18-87	--	95	116	7.70	--
27- 152	U.S. Geological Survey	NILES PARK 1 OBS	12-19-87	--	141	172	--	--
27- 162	S.E. Morris County MUA	WING WELL	09-03-87	761	135	165	7.98	2.6
27- 178	Parsippany-Troy Hills MUA	PTHWD 8-3	08-31-87	760	142	173	7.88	4.2
27-1111	St Elizabeth Sisters	CONVENT 3	02-25-88	755	173	211	7.87	8.0
27-1113	Montville Twp MUA	INDIAN LANE 3/MONTVI 6	08-13-87	--	129	157	8.22	.1
27-1115	Pequannock Twp	PEQUANNOCK WD 2	08-28-87	760	101	123	8.15	6.6
31- 16	Pompton Lakes Boro MUA	LINCOLN AVE 2	08-19-87	758	99	121	8.42	.0
31- 16	Pompton Lakes Boro MUA	LINCOLN AVE 2	08-19-87	758	99	121	8.42	<.1
35- 8	U.S. Geological Survey	GS TH 6	12-03-87	755	105	128	8.16	2.1
35- 8	U.S. Geological Survey	GS TH 6	12-03-87	755	105	128	8.16	2.1
39- 387	NJ Bell Telephone Labs	BELL LABS MW2	06-09-88	746	45	55	6.72	3.9

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* Analysis was performed by Environmental Testing and Certification Laboratory. (Use of firm names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.)

Appendix 1.--Results of analyses for inorganic constituents in ground-water samples from aquifers in glacial sediments in the central part of the Passaic River basin, New Jersey, 1959-88--Continued

New Jersey well number	Specific conductance, field (µS/cm)	Temperature water (deg C)	Calcium, dissolved (mg/L as Ca)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Magnesium, dissolved (mg/L as Mg)	Potassium, dissolved (mg/L as K)	Silica, dissolved (mg/L as SiO_2)	Sodium, dissolved (mg/L as Na)	Solids, residue at 180 deg C, dissolved (mg/L)	Sulfate, dissolved (mg/L as SO_4)
13- 1	358	11.1	42	28	0.0	16	0.5	27	7.2	265	40
13- 3	415	11.1	47	7.5	.0	18	.5	20	14	279	73
13- 5	433	--	52	9.4	.1	20	.8	19	13	309	78
13- 7	530	11.7	64	20	.0	23	1.1	22	16	408	88
13- 8	407	11.7	53	13	.0	14	.8	20	13	298	67
13- 9	520	13.4	72	27	.1	18	1.0	22	17	343	95
13- 10	368	11.7	40	11	.1	10	.4	20	23	240	47
13- 11	375	11.7	40	7.7	.0	13	.8	22	19	256	77
13- 12	358	12.2	44	10	.0	15	.8	21	12	240	40
13- 15	347	--	50	15	.0	13	1.8	25	3.6	256	32
13- 47	455	11.2	61	37	.1	16	.6	28	11	290	30
13- 63	345	11.8	51	16	.1	13	.6	24	9.7	232	35
13- 63	345	11.8	--	--	--	--	--	--	--	--	--
13- 63	345	11.8	52	16	.1	13	.6	24	9.7	235	35
13- 63	345	11.8	--	--	--	--	--	--	--	--	--
13- 63*	--	--	48	20	<.1	12	.6	24	9.3	--	30
13- 73	589	12.5	73	90	.1	24	.8	31	12	396	32
13- 73	589	12.5	--	--	--	--	--	--	--	--	--
13- 93	600	12.1	68	23	.2	24	1.2	21	35	419	170
27- 1	324	11.1	44	8.2	.0	12	.7	21	8	220	38
27- 2	262	10.0	25	6.2	.1	12	.8	17	12	158	23
27- 3	700	11.5	81	13	<.1	31	1.3	15	16	497	210
27- 4	294	10.6	26	7	.2	11	.6	17	16	180	34
27- 5	278	9.4	27	6.8	.1	11	.9	18	14	172	29
27- 6	321	10.6	38	7.1	.0	14	.6	25	8.2	220	29
27- 7	261	10.0	32	4.6	.0	12	.6	23	5.5	158	18
27- 8	455	11.1	54	10	.1	15	1.0	20	23	295	64
27- 10	329	10.6	21	8.2	.1	10	1.0	21	36	219	48
27- 12	466	12.0	59	21	<.1	19	.9	28	10	276	47
27- 14	268	10.6	28	5.5	.0	13	.6	16	10	167	22
27- 15	455	14.2	46	8.6	.2	18	1.2	29	17	328	47
27- 16	206	11.1	27	3.4	.1	6.3	.6	16	6.5	136	25
27- 19	321	10.0	37	3.2	.1	14	1.0	20	7.9	197	25
27- 20	331	10.5	42	4.4	.2	14	.8	17	7.4	204	49
27- 21	222	10.6	24	5	.1	9.5	.6	19	4.1	140	17
27- 45	477	11.4	55	43	.1	19	1.1	22	20	305	33
27- 55	357	11.9	51	14	.1	14	.8	21	9.8	241	55
27- 147	582	12.0	70	29	.1	27	1.2	26	23	390	110
27- 148	506	13.2	66	24	.1	23	1.2	25	15	328	50
27- 150	203	10.0	21	7.9	.7	3.1	1.0	11	23	216	12
27- 150	203	10.0	--	--	--	--	--	--	--	--	--
27- 152	324	10.0	46	15	.4	15	1.0	23	11	227	42
27- 162	384	11.5	54	21	.1	17	1.0	21	9.5	237	31
27- 178	378	11.1	49	22	.1	17	1.0	21	9.7	247	34
27-1111	507	11.4	64	41	--	22	1.0	25	16	322	34
27-1113	436	12.6	63	18	.1	16	1.1	23	11	287	94
27-1115	264	11.0	37	11	<.1	11	.7	16	5.5	166	25
31- 16	268	11.7	29	11	.6	3.2	1.0	13	27	168	32
31- 16	268	11.7	--	--	--	--	--	--	--	--	--
35- 8	256	10.8	23	9.3	.2	9.9	.8	15	18	168	26
35- 8	256	10.8	--	--	--	--	--	--	--	--	--
39- 387	195	12.7	18	16	.2	7.3	.5	48	7.2	155	13

Appendix 1.--Results of analyses for inorganic constituents in ground-water samples from aquifers in glacial sediments in the central part of the Passaic River basin, New Jersey, 1959-88--Continued

New Jersey well number	Aluminum, dissolved (µg/L as Al)	Antimony, dissolved (µg/L as Sb)	Arsenic dissolved (µg/L as As)	Barium, dissolved (µg/L as Ba)	Beryllium, dissolved (µg/L as Be)	Boron, dissolved (µg/L as B)	Bromide, dissolved (mg/L as Br)	Cadmium, dissolved (µg/L as Cd)	Chromium, dissolved (µg/L as Cr)	Chromium, hexavalent, dis. (µg/L as Cr)	Cobalt, dissolved (µg/L as Co)
13- 1	--	--	--	--	--	--	--	--	--	--	--
13- 3	--	--	--	--	--	--	--	--	--	--	--
13- 5	--	--	--	--	--	--	--	--	--	--	--
13- 7	--	--	--	--	--	--	--	--	--	--	--
13- 8	--	--	--	--	--	--	--	--	--	--	--
13- 9	<10	<1	2	18	<0.5	140	0.077	2	7	<1	<3
13- 10	--	--	--	--	--	--	--	--	--	--	--
13- 11	--	--	--	--	--	--	--	--	--	--	--
13- 12	--	--	--	--	--	--	--	--	--	--	--
13- 15	--	--	--	--	--	--	--	--	--	--	--
13- 47	<10	<1	<1	6	<.5	190	.091	<1	<5	2	<3
13- 63	<10	<1	1	38	<.5	120	.062	<1	<5	<1	<3
13- 63	--	--	--	--	--	--	--	--	--	--	--
13- 63	<10	<1	1	38	<.5	110	.064	<1	<5	<1	<3
13- 63	--	--	--	--	--	--	--	--	--	--	--
13- 63*	<64	<95	<83	36	<.51	--	--	<3.4	53	<10	<41
13- 73	<10	<1	<1	5	<.5	70	.10	<1	<5	<1	<3
13- 73	--		--	--	--	--	--	--	--	--	--
13- 93	<10	<1	2	32	<.5	570	.045	<1	<5	<1	<3
27- 1	--	--	--	--	--	--	--	--	--	--	--
27- 2	--	--	--	--	--	--	--	--	--	--	--
27- 3	30	--	1	--	--	--	--	<1	8	--	--
27- 4	--	--	--	--	--	--	--	--	--	--	--
27- 5	--	--	--	--	--	--	--	--	--	--	--
27- 6	--	--	--	--	--	--	--	--	--	--	--
27- 7	--	--	--	--	--	--	--	--	--	--	--
27- 8	--	--	--	--	--	--	--	--	--	--	--
27- 10	--	--	--	--	--	--	--	--	--	--	--
27- 12	<10	--	<1	--	--	--	--	<1	<1	--	--
27- 14	--	--	--	--	--	--	--	--	--	--	--
27- 15	20	--	4	--	--	--	--	<1	<1	--	--
27- 16	--	--	--	--	--	--	--	--	--	--	--
27- 19	--	--	--	--	--	--	--	--	--	--	--
27- 20	<10	--	<1	--	--	--	--	<1	<1	--	--
27- 21	--	--	--	--	--	--	--	--	--	--	--
27- 45	<10	<1	1	16	.6	50	.075	<1	<5	<10	<3
27- 55	<10	<1	3	110	<.5	240	.035	<1	<5	<1	<3
27- 147	<10	<1	2	35	<.5	230	.047	<1	<5	<1	<3
27- 148	<10	<1	1	17	<.5	100	.072	<1	<5	<1	<3
27- 150	570	1	2	21	<.5	300	.17	<1	<3	<1	<3
27- 150	--	--	--	--	--	--	--	--	--	--	--
27- 152	10	<1	1	15	<.5	40	.032	1	2	<1	<3
27- 162	<10	<1	1	14	1	20	.12	<1	<5	<1	<3
27- 178	<10	<1	1	9	.6	40	.055	<1	<5	<1	<3
27-1111	--	--	--	--	--	--	--	--	--	--	--
27-1113	<10	2	4	120	<.5	180	.049	<1	<5	<1	<3
27-1115	<10	<1	<1	6	<.5	20	.046	<1	<5	<1	<3
31- 16	<10	<1	3	11	<.5	550	.043	<1	<5	<1	<3
31- 16	--	--	--	--	--	--	--	--	--	--	--
35- 8	<10	1	2	60	<.5	120	.021	<1	<1	<1	<3
35- 8	--	--	--	--	--	--	--	--	--	--	--
39- 387	<10	<1	<1	3	<.5	10	.11	<1	1	1	2

Appendix 1.-- Results of analyses for inorganic constituents in ground-water samples from aquifers in glacial sediments in the central part of the Passaic River basin, New Jersey, 1959-88--Continued

New Jersey well number	Copper, dis-solved (µg/L as Cu)	Iodide, dis-solved (mg/L as I)	Iron, dis-solved (µg/L as Fe)	Lead, dis-solved (µg/L as Pb)	Lithium, dis-solved (µg/L as Li)	Manga-nese, dis-solved (µg/L as Mn)	Mercury, dis-solved (µg/L as Hg)	Molyb-denum, dis-solved (µg/L as Mo)	Nickel, dis-solved (µg/L as Ni)	Sele-nium, dis-solved (µg/L as Se)	Silver, dis-solved (µg/L as Ag)
13- 1	--	--	20	--	--	0	--	--	--	--	--
13- 3	--	--	30	--	--	0	--	--	--	--	--
13- 5	--	--	140	--	--	0	--	--	--	--	--
13- 7	--	--	120	--	--	0	--	--	--	--	--
13- 8	--	--	0	--	--	0	--	--	--	--	--
13- 9	<10	0.003	37	<10	<4	16	0.1	<10	<10	1	<1
13- 10	--	--	40	--	--	100	--	--	--	--	--
13- 11	--	--	50	--	--	0	--	--	--	--	--
13- 12	--	--	100	--	--	0	--	--	--	--	--
13- 15	--	--	30	--	--	0	--	--	--	--	--
13- 47	<10	.003	<3	<10	<4	<1	.2	<10	<10	<1	<1
13- 63	<10	.001	<3	<10	<4	<1	<.1	<10	<10	<1	<1
13- 63	--	--	--	--	--	--	--	--	--	--	--
13- 63	<10	.001	<3	<10	5	<1	<.1	<10	<10	<1	1
13- 63	--	--	--	--	--	--	--	--	--	--	--
13- 63*	<8.9	--	510	<77	--	9.3	<.24	<8.7	37	<81	<17
13- 73	<10	.004	3	10	<4	<1	.2	<10	<1	<1	<1
13- 73	--	--	--	--	--	--	--	--	--	--	--
13- 93	<10	.013	6	<10	8	100	<.1	<10	<10	<1	<1
27- 1	--	--	80	--	--	0	--	--	--	--	--
27- 2	--	--	80	--	--	150	--	--	--	--	--
27- 3	8	--	99	<1	--	410	.3	--	--	--	--
27- 4	--	--	0	--	--	220	--	--	--	--	--
27- 5	--	--	160	--	--	200	--	--	--	--	--
27- 6	--	--	40	--	--	0	--	--	--	--	--
27- 7	--	--	30	--	--	0	--	--	--	--	--
27- 8	--	--	70	--	--	140	--	--	--	--	--
27- 10	--	--	110	--	--	30	--	--	--	--	--
27- 12	4	--	50	<5	--	7	<.1	--	--	--	--
27- 14	--	--	60	--	--	0	--	--	--	--	--
27- 15	2	--	130	<5	--	97	<.1	--	--	--	--
27- 16	--	--	50	--	--	200	--	--	--	--	--
27- 19	--	--	130	--	--	150	--	--	--	--	--
27- 20	<1	--	870	<5	--	150	<.1	--	--	--	--
27- 21	--	--	190	--	--	0	--	--	--	--	--
27- 45	<10	.002	12	<10	<4	22	<.1	<10	<10	<1	<1
27- 55	<10	.003	4	<10	<4	70	<.1	<10	<10	<1	<1
27- 147	<10	.008	49	<10	<4	440	.1	<10	<10	<1	<1
27- 148	20	.008	36	<10	<4	39	.1	<10	<10	1	1
27- 150	20	.004	1,000	<10	4	71	<.1	<10	<10	<1	<1
27- 150	--	--	--	--	--	--	--	--	--	--	--
27- 152	<10	.003	23	<10	5	6	<.1	<10	<10	<1	<3
27- 162	<10	.001	<3	<10	<4	<1	<.1	<10	<10	1	1
27- 178	<10	.001	<3	<10	<4	<10	<.1	<10	<10	<1	<1
27-1111	--	--	5	--	--	<1	--	--	--	--	--
27-1113	<10	.004	4	<10	5	47	<.1	<10	<10	1	<1
27-1115	<10	<.001	<3	<10	4	<1	<.1	<10	<10	1	<1
31- 16	<10	.005	4	<10	<4	49	<.1	<10	--	<1	1
31- 16	--	--	--	--	--	--	--	--	--	--	--
35- 8	<10	.003	3	<10	8	140	<.1	<10	<10	<1	2
35- 8	--	--	--	--	--	--	--	--	--	--	--
39- 387	<10	.001	14	<5	<4	<1	<.1	<1	3	<1	--

Appendix 1.-- Results of analyses for inorganic constituents in ground-water samples from aquifers in glacial sediments in the central part of the Passaic River basin, New Jersey, 1959-88--Continued

New Jersey well number	Strontium, dissolved (µg/L as Sr)	Vanadium, dissolved (µg/L as V)	Zinc, dissolved (µg/L as Zn)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia + organic, dis. (mg/L as N)	Nitrogen, nitrite, dissolved (mg/L as N)	Nitrogen, NO_2+NO_3, dissolved (mg/L as N)	Phosphorous ortho, dissolved (mg/L as P)	Cyanide, dissolved (mg/L as CN)	Tritium, total (pCi/L)
13- 1	--	--	--	--	--	--	--	--	--	--
13- 3	--	--	--	--	--	--	--	--	--	--
13- 5	--	--	--	--	--	--	--	--	--	--
13- 7	--	--	--	--	--	--	--	--	--	--
13- 8	--	--	--	--	--	--	--	--	--	--
13- 9	210	<4	<3	<0.01	0.3	0.01	1.20	0.08	<0.01	74
13- 10	--	--	--	--	--	--	--	--	--	--
13- 11	--	--	--	--	--	--	--	--	--	--
13- 12	--	--	--	--	--	--	--	--	--	--
13- 15	--	--	--	--	--	--	--	--	--	--
13- 47	92	6	<3	<.01	<.2	<.01	.38	.04	<.01	83
13- 63	150	<5	4	<.01	<.2	<.01	1.30	.07	<.01	19
13- 63	--	--	--	--	--	--	--	--	--	43
13- 63	150	<5	11	<.01	<.2	<.01	1.30	.07	<.01	51
13- 63	--	--	--	--	--	--	--	--	--	36
13- 63*	160	<15	<20	--	--	--	--	--	--	--
13- 73	110	6	<3	<.01	.6	<.01	2.80	.02	<.01	80
13- 73	--	--	--	--	--	--	--	--	--	--
13- 93	1,000	<2	7	.02	.4	<.01	<.10	.06	<.01	22
27- 1	--	--	--	--	--	--	--	--	--	--
27- 2	--	--	--	--	--	--	--	--	--	--
27- 3	--	--	17	--	<.2	<.01	<.10	--	--	--
27- 4	--	--	--	--	--	--	--	--	--	--
27- 5	--	--	--	--	--	--	--	--	--	--
27- 6	--	--	--	--	--	--	--	--	--	--
27- 7	--	--	--	--	--	--	--	--	--	--
27- 8	--	--	--	--	--	--	--	--	--	--
27- 10	--	--	--	--	--	--	--	--	--	--
27- 12	--	--	10	.02	.4	<.01	3.20	.09	--	--
27- 14	--	--	--	--	--	--	--	--	--	--
27- 15	--	--	7	.04	<.2	<.01	<.10	--	--	--
27- 16	--	--	--	--	--	--	--	--	--	--
27- 19	--	--	--	--	--	--	--	--	--	--
27- 20	--	--	6	.08	<.2	<.01	<.10	.10	--	--
27- 21	--	--	--	--	--	--	--	--	--	--
27- 45	140	<2	6	<.01	.4	<.01	1.60	.04	<.01	99
27- 55	140	<2	<3	<.01	.3	<.01	.37	.01	<.01	93
27- 147	520	<2	4	.02	.3	.02	.12	.08	<.01	86
27- 148	200	<3	16	.08	.3	<.01	2.10	.07	<.01	54
27- 150	75	<2	340	.17	.2	<.01	.26	.11	<.01	13
27- 150	--	--	--	--	--	--	--	--	--	22
27- 152	120	<3	22	.02	<.2	<.01	2.20	.03	<.01	83
27- 162	130	<3	7	<.01	<.2	<.01	1.20	.08	<.01	77
27- 178	120	<4	9	<.01	.2	<.01	.70	.09	<.01	60
27-1111	--	--	--	--	--	--	--	--	--	120
27-1113	180	<5	4	<.01	.7	<.01	.16	<.01	<.01	54
27-1115	83	<1	7	<.01	<.2	<.01	.90	<.01	<.01	42
31- 16	120	<1	<3	<.01	.2	<.01	<.10	.03	<.01	16
31- 16	--	--	--	--	--	--	--	--	--	42
35- 8	190	<1	<3	<.01	<.2	<.01	<.10	.01	<.01	<10
35- 8	--	--	--	--	--	--	--	--	--	<2.5
39- 387	47	4	<3	<.01	<.2	<.01	2.30	<.01	<.01	95

Appendix 2.--Results of analyses for purgeable organic compounds in ground-water samples from aquifers in glacial sediments and sedimentary and igneous bedrock in the central part of the Passaic River basin, New Jersey, 1987-88

[µg/L, micrograms per liter; ND, not detected at a concentration greater than 0.8 µg/L by analysis in the New Jersey District laboratory of the U.S. Geological Survey; WC, Water Company; WD, Water Department; Twp, Township; MUA, Municipal Utilities Authority; CC, Country Club; tot.rec., total recoverable; <, less than]

New Jersey well number	Well owner	Local well name or number	Sample-collection date	Benzene, total (µg/L)	Bromoform, total (µg/L)	Carbon tetrachloride, total (µg/L)	Chlorobenzene, total (µg/L)
		AQUIFERS IN GLACIAL SEDIMENTS					
13- 9	NJ American WC	CWC 51	08-18-87	ND	ND	ND	ND
13- 47	East Orange WD	CANOE BROOK 1	08-11-87	ND	ND	ND	ND
13- 63	NJ American WC	CWC K2	08-18-87	<.20	<.20	<.20	<.20
13- 63	NJ American WC	CWC K2	08-18-87	<.20	<.20	<.20	<.20
13- 73	Essex Fells WD	EFWD 7	08-12-87	<.20	<.20	<.20	<.20
13- 73	Essex Fells WD	EFWD 7	08-12-87	<.20	<.20	<.20	<.20
13- 93	Fairfield WD	FAIRFIELD 4	08-14-87	<.20	<.20	<.20	<.20
27- 45	Parsippany - Troy Hills WD	PTHWD 17	08-31-87	<.20	<.20	<.20	<.20
27- 55	Montville Twp MUA	INDIAN LANE 1	08-13-87	ND	ND	ND	ND
27- 147	East Hanover Twp WD	EHTWD 2	08-20-87	1.9	<.20	<.20	<.20
27- 148	East Hanover Twp WD	EHTWD 5	08-20-87	<.20	<.20	<.20	<.20
27- 150	US Geological Survey	GREAT SWAMP 4 OBS	12-18-87	<.20	<.20	<.20	<.20
27- 152	US Geological Survey	NILES PARK 1 OBS	12-19-87	.30	<.20	<.20	<.20
27- 162	SE Morris County MUA	WING WELL	09-03-87	<.20	<.20	<.20	<.20
27- 178	Parsippany - Troy Hills WD	PTHWD 8-3	08-31-87	<.20	<.20	<.20	<.20
27-1111	St. Elizabeth Sisters	CONVENT 3	02-25-88	ND	ND	ND	ND
27-1113	Montville Twp MUA	INDIAN LANE 3/MONTVI 6	08-13-87	ND	ND	ND	ND
27-1115	Pequannock Twp	PEQUANNOCK WD 2	08-28-87	ND	ND	ND	ND
31- 16	Pompton Lakes Boro MUA	LINCOLN AVE 2	08-19-87	ND	ND	ND	ND
39- 387	NJ Bell Telephone	BELL LABS MW2	06-09-88	ND	ND	ND	ND
		AQUIFERS IN SEDIMENTARY BEDROCK					
13- 4	East Orange WD	SLOUGH BROOK 3	08-11-87	ND	ND	ND	ND
13- 52	Livingston Twp WD	LTWD 7	05-11-87	<.20	<.20	<.20	<.20
13- 52	Livingston Twp WD	LTWD 7	08-10-87	<.20	<.20	<.20	<.20
13- 55	Livingston Twp WD	LTWD 9	08-10-87	<.20	<.20	<.20	<.20
13- 82	Essex Fells WD	EFWD 17	08-12-87	<.20	<.20	<.20	<.20
13- 90	Fairfield WD	HOLLYWOOD 6	08-19-87	ND	ND	ND	ND
27- 158	SE Morris County MUA	SAND SPRINGS	09-01-87	ND	ND	ND	ND
27- 922	Riverdale Boro	MAIN SUPPLY 1	08-19-87	ND	ND	ND	ND
27- 979	Passaic Twp	STIRLING LAKE	09-01-87	ND	ND	ND	ND
27-1109	St. Elizabeth College	ST ELIZABETH MAIN	09-04-87	<.20	1.5	<.20	<.20
27-1110	St. Elizabeth Sisters	CONVENT 2	03-08-88	ND	ND	ND	ND
27-1112	US Fish and Wildlife	GREAT SWAMP NWR HQ	08-14-87	<.20	<.20	<.20	<.20
31- 35	Preakness Hills CC	TOWER 2	09-14-87	<.20	<.20	<.20	<.20
31- 53	Preakness Hills CC	PREAKNESS HILLS CC3	09-03-87	ND	ND	ND	ND
35- 45	Bernards Twp Sewage Authority	BERNARDS TWP STP	08-28-87	<.20	<.20	<.20	<.20
		AQUIFERS IN IGNEOUS BEDROCK					
27- 194	Montville Twp MUA	MONTVALE 2-WESTMINSTER	08-13-87	ND	ND	ND	ND
35- 46	Gordner or VanWert	GORDNER 1	09-16-87	ND	ND	ND	ND
39- 180	Fablock, Inc.	SPRING IND 1	09-16-87	<.20	<.20	<.20	<.20

Appendix 2.--Results of analyses for purgeable organic compounds in ground-water samples from aquifers in glacial sediments and sedimentary and igneous bedrock in the central part of the Passaic River basin, New Jersey, 1987-88--Continued

New Jersey well number	Chloro- di- bromo- methane, total (µg/L)	Chloro- ethane, total (µg/L)	2- Chloro- ethyl- vinyl ether, total (µg/L)	Chloro- form, total (µg/L)	cis 1,3-Di- chloro- propene, total (µg/L)	1,2- Dibromo ethyl- ene, total (µg/L)	1,2-Di- chloro- benzene, total (µg/L)	1,3-Di- chloro- benzene, total (µg/L)	1,4-Di- chloro- benzene, total (µg/L)	Di- chloro- bromo- methane, total (µg/L)	Di- chloro- di- fluoro- methane, total (µg/L)
AQUIFERS IN GLACIAL SEDIMENTS											
13- 9	ND	ND	ND	ND	ND	--	ND	ND	ND	ND	--
13- 47	ND	ND	ND	ND	ND	--	ND	ND	ND	ND	--
13- 63	<.20	<.20	<.20	<.20	<.20	<0.20	<.20	<.20	<.20	<.20	<0.20
13- 63	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
13- 73	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
13- 73	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
13- 93	<.20	1.3	<.20	.20	<.20	<.20	<.20	<.20	<.20	<.20	.20
27- 45	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
27- 55	ND	ND	ND	ND	ND	--	ND	ND	ND	ND	--
27- 147	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
27- 148	<.20	<.20	<.20	.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
27- 150	.20	<.20	<.20	5.1	<.20	<.20	<.20	<.20	<.20	.80	<.20
27- 152	.70	<.20	<.20	28	<.20	<.20	<.20	<.20	<.20	4.4	<.20
27- 162	<.20	<.20	<.20	.80	<.20	<.20	<.20	<.20	<.20	<.20	.20
27- 178	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
27-1111	ND	ND	ND	ND	ND	--	ND	ND	ND	ND	--
27-1113	ND	ND	ND	ND	ND	--	ND	ND	ND	ND	--
27-1115	ND	ND	ND	ND	ND	--	ND	ND	ND	ND	--
31- 16	ND	ND	ND	ND	ND	--	ND	ND	ND	ND	--
39- 387	ND	ND	ND	ND	ND	--	ND	ND	ND	ND	--
AQUIFERS IN SEDIMENTARY BEDROCK											
13- 4	ND	ND	ND	ND	ND	--	ND	ND	ND	ND	--
13- 52	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
13- 52	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
13- 55	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
13- 82	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
13- 90	ND	ND	ND	ND	ND	--	ND	ND	ND	ND	--
27- 158	ND	ND	ND	ND	ND	--	ND	ND	ND	ND	--
27- 922	ND	ND	ND	ND	ND	--	ND	ND	ND	ND	--
27- 979	ND	ND	ND	ND	ND	--	ND	ND	ND	ND	--
27-1109	2.4	<.20	<.20	.50	<.20	<.20	<.20	<.20	<.20	1.0	<.20
27-1110	ND	ND	ND	ND	ND	--	ND	ND	ND	ND	--
27-1112	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
31- 35	<.20	<.20	<.20	1.30	<.20	<.20	<.20	<.20	<.20	<.20	<.20
31- 53	ND	ND	ND	ND	ND	--	ND	ND	ND	ND	--
35- 45	<.20	<.20	<.20	.40	<.20	<.20	<.20	<.20	<.20	<.20	<.20
AQUIFERS IN IGNEOUS BEDROCK											
27- 194	ND	ND	ND	ND	ND	--	ND	ND	ND	ND	--
35- 46	ND	ND	ND	ND	ND	--	ND	ND	ND	ND	--
39- 180	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20

Appendix 2.--Results of analyses for purgeable organic compounds in ground-water samples from aquifers in glacial sediments and sedimentary and igneous bedrock in the central part of the Passaic River basin, New Jersey, 1987-88--Continued

New Jersey well number	1,1-Dichloroethane, total (µg/L)	1,2-Dichloroethane, total (µg/L)	1,1-Dichloroethylene, total (µg/L)	1,2-Dichloropropane, total (µg/L)	cis- + trans-1,3-Dichloropropene, total (µg/L)	Methyl bromide, total (µg/L)	Ethylbenzene, total (µg/L)	Methyl chloride, total (µg/L)	Methylene chloride, total (µg/L)	Styrene, total (µg/L)	1,2-Transdichloroethylene, total (µg/L)
AQUIFERS IN GLACIAL SEDIMENTS											
13- 9	ND	ND	ND	ND	--	--	ND	--	ND	--	ND
13- 47	ND	ND	ND	ND	--	--	ND	--	ND	--	ND
13- 63	<.20	<.20	<.20	<.20	<0.20	<0.20	<.20	<0.20	<.20	<0.20	<.20
13- 63	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
13- 73	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	4.2
13- 73	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	2.2
13- 93	1.3	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
27- 45	.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
27- 55	ND	ND	ND	ND	--	--	ND	--	ND	--	ND
27- 147	.70	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	6.0
27- 148	<.20	<.20	.90	<.20	<.20	<.20	<.20	<.20	<.20	<.20	.60
27- 150	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
27- 152	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
27- 162	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
27- 178	.30	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
27-1111	ND	ND	ND	ND	--	--	ND	--	ND	--	ND
27-1113	ND	ND	ND	ND	--	--	ND	--	ND	--	ND
27-1115	ND	ND	ND	ND	--	--	ND	--	ND	--	ND
31- 16	ND	ND	ND	ND	--	--	ND	--	ND	--	ND
39- 387	ND	ND	ND	ND	--	--	ND	--	ND	--	ND
AQUIFERS IN SEDIMENTARY BEDROCK											
13- 4	ND	ND	ND	ND	--	--	ND	--	ND	--	ND
13- 52	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
13- 52	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	1.7
13- 55	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	2.4
13- 82	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	1.1
13- 90	ND	ND	ND	ND	--	--	ND	--	ND	--	ND
27- 158	ND	ND	ND	ND	--	--	ND	--	ND	--	ND
27- 922	ND	ND	ND	ND	--	--	ND	--	ND	--	ND
27- 979	ND	ND	ND	ND	--	--	ND	--	ND	--	ND
27-1109	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
27-1110	ND	ND	ND	ND	--	--	ND	--	ND	--	ND
27-1112	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
31- 35	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
31- 53	ND	ND	ND	ND	--	--	ND	--	ND	--	ND
35- 45	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	.40
AQUIFERS IN IGNEOUS BEDROCK											
27- 194	ND	ND	ND	ND	--	--	ND	--	ND	--	ND
35- 46	ND	ND	ND	ND	--	--	ND	--	ND	--	ND
39- 180	.30	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	.30

Appendix 2.--Results of analyses for purgeable organic compounds in ground-water samples from aquifers in glacial sediments and sedimentary and igneous bedrock in the central part of the Passaic River basin, New Jersey, 1987-88--Continued

New Jersey well number	trans-1,3-Dichloropropene, total (µg/L)	Tetrachloroethylene, total (µg/L)	1,1,2,2-Tetrachloroethane, total (µg/L)	Toluene, total (µg/L)	1,1,1-Trichloroethane, total (µg/L)	1,1,2-Trichloroethane, total (µg/L)	Trichloroethylene, total (µg/L)	Trichlorofluoromethane, total (µg/L)	Vinyl chloride, total (µg/L)	Xylene water, whole, tot. rec. (µg/L)
AQUIFERS IN GLACIAL SEDIMENTS										
13- 9	ND	ND	ND	ND	ND	ND	ND	--	ND	--
13- 47	ND	ND	ND	ND	ND	ND	ND	--	ND	--
13- 63	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<0.20	<.20	<0.20
13- 63	<.20	<.20	<.20	<.20	.40	<.20	<.20	<.20	<.20	<.20
13- 73	<.20	4.2	<.20	<.20	2.2	<.20	31	<.20	<.20	<.20
13- 73	<.20	4.2	<.20	<.20	2.6	<.20	34	<.20	<.20	<.20
13- 93	<.20	<.20	<.20	<.20	.90	<.20	<.20	<.20	<.20	<.20
27- 45	<.20	<.20	<.20	<.20	1.0	<.20	<.20	<.20	<.20	<.20
27- 55	ND	ND	ND	ND	ND	ND	ND	--	ND	--
27- 147	<.20	<.20	<.20	<.20	1.8	<.20	37.0	<.20	<.20	<.20
27- 148	<.20	<.20	<.20	<.20	.60	<.20	.9	<.20	<.20	<.20
27- 150	<.20	<.20	<.20	.90	<.20	<.20	<.20	<.20	<.20	<.20
27- 152	<.20	<.20	<.20	.50	<.20	<.20	<.20	<.20	<.20	<.20
27- 162	<.20	<.20	<.20	<.20	.50	<.20	.3	.90	<.20	<.20
27- 178	<.20	<.20	<.20	<.20	1.3	<.20	<.20	<.20	<.20	<.20
27-1111	ND	ND	ND	ND	ND	ND	ND	--	ND	--
27-1113	ND	ND	ND	ND	ND	ND	ND	--	ND	--
27-1115	ND	ND	ND	ND	ND	ND	ND	--	ND	--
31- 16	ND	ND	ND	ND	ND	ND	ND	--	ND	--
39- 387	ND	ND	ND	ND	ND	ND	ND	--	ND	--
AQUIFERS IN SEDIMENTARY BEDROCK										
13- 4	ND	ND	ND	ND	ND	ND	ND	--	ND	--
13- 52	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
13- 52	<.20	3.1	<.20	<.20	<.20	<.20	1.7	<.20	<.20	<.20
13- 55	<.20	.70	<.20	<.20	2.6	<.20	18	<.20	<.20	<.20
13- 82	<.20	<.20	<.20	<.20	<.20	<.20	2.2	<.20	<.20	<.20
13- 90	ND	ND	ND	ND	ND	ND	ND	--	ND	--
27- 158	ND	ND	ND	ND	ND	ND	ND	--	ND	--
27- 922	ND	ND	ND	ND	ND	ND	ND	--	ND	--
27- 979	ND	ND	ND	ND	ND	ND	ND	--	ND	--
27-1109	<.20	<.20	<.20	.40	<.20	<.20	.2	<.20	<.20	2.1
27-1110	ND	ND	ND	ND	ND	ND	ND	--	ND	--
27-1112	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
31- 35	<.20	.30	<.20	<.20	<.20	<.20	<.20	.40	<.20	<.20
31- 53	ND	ND	ND	ND	ND	ND	ND	--	ND	--
35- 45	<.20	1.7	<.20	<.20	<.20	<.20	.3	<.20	<.20	<.20
AQUIFERS IN IGNEOUS BEDROCK										
27- 194	ND	ND	ND	ND	ND	ND	ND	--	ND	--
35- 46	ND	ND	ND	ND	ND	ND	ND	--	ND	--
39- 180	<.20	4.3	<.20	<.20	.40	<.20	.2	<.20	<.20	<.20

Appendix 3.-- Results of analyses for inorganic constituents in ground-water samples from aquifers in sedimentary and igneous bedrock in the central part of the Passaic River basin, New Jersey, 1959-88

[mg/L, milligrams per liter; mm of Hg, millimeters of mercury; µS/cm, microsiemens per centimeter at 25 degrees Celsius; dis., dissolved; deg C, degrees Celsius; µg/L, micrograms per liter; pCi/L, picocuries per liter; WD, Water Department; WC, Water Company; MUA, Municipal Utilities Authority; Auth, Authority; Bd of Ed, Board of Education; CC, Country Club; Twp, Township; --, no data; <, less than]

New Jersey well rumber	Well owner	Local well name or number	Sample-collection date	Barometric pressure (mm of Hg)	Alkalinity, field (mg/L as $CaCO_3$)	Bicarbonate, field (mg/L as HCO_3)	pH (standard units)	Oxygen, dissolved (mg/L)
			AQUIFERS IN SEDIMENTARY BEDROCK					
13- 4	East Orange WD	SLOUGH BROOK 3	08-18-66	--	--	--	7.30	--
13- 4	East Orange WD	SLOUGH BROOK 3	08-11-87	758	131	160	7.99	2.9
13- 6	Livingston Twp WD	LTWD POOL 4	08-31-66	--	--	--	7.80	--
13- 52	Livingston Twp WD	LTWD 7	05-11-87	760	110	137	7.50	3.0
13- 52	Livingston Twp WD	LTWD 7	08-10-87	754	117	143	7.45	5.1
13- 55	Livingston Twp WD	LTWD 9	08-10-87	754	105	128	7.69	2.6
13- 82	Essex Fells WD	EFWD 17	08-12-87	756	97	118	8.12	5.0
13- 90	Fairfield WD	HOLLYWOOD 6	03-12-86	--	101	--	7.80	.4
13- 90	Fairfield WD	HOLLYWOOD 6	08-19-87	758	91	111	7.89	2.2
27- 153	SE Morris County MUA	LIDGERWOOD 5	04-21-87	--	142	162	7.30	6.6
27- 158	SE Morris County MUA	SAND SPRINGS	09-01-87	754	59	72	6.75	7.6
27- 922	Riverdale Boro	MAIN SUPPLY 1	08-19-87	758	127	155	8.25	.1
27- 979	Passaic Twp	STIRLING LAKE	09-01-87	754	169	206	8.12	.1
27- 979	Passaic Twp	STIRLING LAKE	09-01-87	754	169	206	8.12	.1
27-1109	St. Elizabeth College	ST ELIZABETH MAIN	09-04-87	766	129	157	7.48	--
27-1110	St. Elizabeth Sisters	CONVENT 2	03-08-88	765	143	174	8.60	--
27-1112	U.S. Fish and Wildlife	GREAT SWAMP NWR HQ	08-14-87	756	83	101	7.48	<.1
27-1112	U.S. Fish and Wildlife	GREAT SWAMP NWR HQ	08-14-87	756	83	101	7.48	<.1
27-1114	Montville Twp Bd of Ed	MONTVILLE BD OF ED	08-17-87	754	97	118	8.2	3.9
27-1114	Montville Twp Bd of Ed	MONTVILLE BD OF ED	08-17-87	754	97	118	8.20	3.9
27-1114*	Montville Twp Bd of Ed	MONTVILLE BD OF ED	08-17-87	--	--	--	--	--
31- 35	Preakness Hills CC	TOWER 2	09-14-87	755	88	106	7.60	6.7
31- 53	Preakness Hills CC	PREAKNESS HILLS CC3	09-03-87	761	84	102	8.14	6.3
35- 45	Bernards Twp Sewage Auth	BERNARDS TWP STP	08-28-87	760	179	218	7.80	2.3
39- 308	CIBA Pharmaceutical	CIBA 10	10-04-68	--	--	--	8.50	--
39- 315	CIBA Pharmaceutical	CIBA 6	10-04-68	--	--	--	8.40	--
39- 316	CIBA Pharmaceutical	CIBA 4	10-04-68	--	--	--	8.50	--
			AQUIFERS IN IGNEOUS BEDROCK					
13- 2	Essex Fells WD	EFWD 8	09-01-66	--	--	--	7.60	--
13- 59	East Orange WD	CANOE BROOK 6	08-11-87	758	115	140	8.10	4.2
13- 72	Essex Fells WD	EFWD 6	08-12-87	756	104	127	7.70	6.4
27- 194	Montville Twp MUA	MONTVALE 2-WESTMINSTER	08-13-87	764	152	185	7.70	4.0
27- 195	Montville Twp MUA	MTMUA 1	11-25-85	760	45	--	8.50	1.7
27- 196	Montville Twp MUA	Montvale 3-Lee Ct	05-05-88	755	149	180	7.4	3.0
35- 46	Gordner or Van Wert	GORDNER 1	09-16-87	760	131	160	7.85	5.0
39- 180	Fablock, Inc.	SPRING IND 1	09-16-87	760	161	196	7.39	4.4

Appendix 3.-- Results of analyses for inorganic constituents in ground-water samples from aquifers in sedimentary and igneous bedrock in the central part of the Passaic River basin, New Jersey, 1959-88--Continued

New Jersey well number	Specific conductance (µS/cm)	Temperature water (deg C)	Calcium, dissolved (mg/L as Ca)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Magnesium, dissolved (mg/L as Mg)	Potassium, dissolved (mg/L as K)	Silica, dissolved (mg/L as SiO_2)	Sodium, dissolved (mg/L as Na)	Solids, residue at 180 deg C, dissolved (mg/L)	Sulfate, dissolved (mg/L as SO_4)
AQUIFERS IN SEDIMENTARY BEDROCK											
13- 4	288	--	34	6.7	<0.1	13	0.7	24	8.7	191	25
13- 4	362	11.4	43	17	.1	18	.8	25	11	234	34
13- 6	306	12.8	32	13	.0	14	.7	23	8.7	220	31
13- 52	432	11.7	38	36	.1	18	.7	24	13	234	29
13- 52	378	12.0	36	35	.1	18	.9	24	14	250	29
13- 55	375	12.2	41	35	.2	18	.8	24	12	229	29
13- 82	451	12.4	49	49	.1	22	.9	25	11	283	52
13- 90	1,060	11.8	130	12	--	42	1.4	23	48	--	490
13- 90	1,020	12.1	140	11	.2	43	1.4	24	50	869	480
27- 153	398	11.5	42	23	<.1	21	1.3	15	11	227	28
27- 158	177	11.2	18	10	.1	8.2	.8	23	7.7	120	15
27- 922	370	12.3	52	15	.1	14	1.2	15	13	237	50
27- 979	499	13.6	26	15	.5	17	.7	20	68	309	88
27- 979	499	13.6	--	--	--	--	--	--	--	--	--
27-1109	303	12.0	33	15	.2	15	.9	17	15	192	29
27-1110	338	10.7	24	14	--	13	.6	20	35	218	31
27-1112	1,510	12.5	140	40	.2	86	.7	33	120	1,400	850
27-1112	1,510	12.5	--	--	--	--	--	--	--	--	--
27-1114	260	12.6	24	13	.1	15	.5	20	9.7	165	20
27-1114	260	12.6	25	13	.1	15	.6	21	9.7	170	21
27-1114*	--	--	24	14	.1	14	.5	22	9.5	--	20
31- 35	385	13.0	41	16	.2	15	.8	23	12	233	60
31- 53	286	12.5	35	14	.1	12	.8	23	10	196	45
35- 45	447	12.8	45	32	<.1	25	1.0	29	22	288	27
39- 308	530	15.0	45	18	.2	18	1.5	17	36	330	100
39- 315	1,210	15.0	130	18	.3	34	1.5	19	84	934	510
39- 316	379	15.0	18	6.5	.1	7.4	.8	27	43	236	43
AQUIFERS IN IGNEOUS BEDROCK											
13- 2	281	11.7	32	19	.0	6.9	.3	25	14	192	36
13- 59	461	11.1	46	54	.1	10	.3	30	35	310	37
13- 72	463	11.6	58	66	.1	16	.4	30	10	311	29
27- 194	468	13.0	62	37	.1	20	.4	28	9.5	317	32
27- 195	217	12.0	30	13	<.1	2.2	.4	38	9.8	168	36
27- 196	484	12.0	55	39	.1	20	6.7	27	7.7	303	35
35- 46	334	12.2	51	12	.1	11	1.0	34	9.3	215	25
39- 180	426	13.8	61	25	.1	16	.4	39	14	289	32

Appendix 3.--Results of analyses for inorganic constituents in ground-water samples from aquifers in sedimentary and igneous bedrock in the central part of the Passaic River basin, New Jersey, 1959-88--Continued

New Jersey well number	Aluminum, dissolved (µg/L as Al)	Antimony, dissolved (µg/L as Sb)	Arsenic, dissolved (µg/L as As)	Barium, dissolved (µg/L as Ba)	Beryllium, dissolved (µg/L as Be)	Boron, dissolved (µg/L as B)	Bromide dissolved (mg/L as Br)	Cadmium dissolved (µg/L as Cd)	Chromium, dissolved (µg/L as Cr)	Chromium, hexavalent, dis. (µg/L as Cr)	Cobalt, dissolved (µg/L as Co)
AQUIFERS IN SEDIMENTARY BEDROCK											
13- 4	--	--	--	--	--	--	--	--	--	--	--
13- 4	<10	<1	2	110	<0.5	40	0.081	<1	<5	<1	<3
13- 6	--	--	--	--	--	--	--	--	--	--	--
13- 52	1	--	<1	--	--	--	--	<1	<1	--	--
13- 52	<10	<1	<1	86	<.5	100	.072	<1	<5	2	<3
13- 55	<10	<1	<1	140	<.5	50	.062	<1	<5	<1	<3
13- 82	<10	<1	2	200	<.5	100	.086	<1	<5	<1	<3
13- 90	--	--	--	45	<.5	--	--	<1	--	--	<3
13- 90	<10	<1	7	41	<.5	890	.042	<1	<5	<1	<3
27- 153	<10	--	<1	--	--	--	--	1	<1	--	--
27- 158	<10	<1	<1	48	<.5	10	.032	<1	<5	<1	<3
27- 922	<10	<1	3	43	<.5	30	.043	<1	<5	<1	<3
27- 979	<10	1	7	55	<.5	320	.029	<1	<5	<1	<3
27- 979	--	--	--	--	--	--	--	--	--	--	--
27-1109	<10	<1	1	42	<.5	80	.013	<1	<5	<1	<3
27-1110	--	--	--	--	--	--	--	--	--	--	--
27-1112	<10	<1	2	10	.6	450	.080	<1	<5	<1	<3
27-1112	--	--	--	--	--	--	--	--	--	--	--
27-1114	<10	<1	3	190	<.5	670	.02	<1	<5	<1	<3
27-1114	<10	<1	3	19	<.5	670	.02	<1	<5	<1	<3
24-1114*	<64	<95	<83	190	<.51	605	.30	<3.4	<24	<10	<41
31- 35	<10	--	2	--	--	--	--	<1	2	--	--
31- 53	<10	1	4	110	.7	130	.069	<1	<5	<1	<3
35- 45	<10	<1	2	210	<.5	70	.033	<1	<5	<1	<3
39- 308	--	--	--	--	--	--	--	--	--	--	--
39- 315	--	--	--	--	--	--	--	--	--	--	--
39- 316	--	--	--	--	--	--	--	--	--	--	--
AQUIFERS IN IGNEOUS BEDROCK											
13- 2	--	--	--	--	--	--	--	--	--	--	--
13- 59	<10	<1	<1	<2	<.5	570	.097	<1	<5	<1	<3
13- 72	<10	<1	<1	<2	<.5	120	.076	<1	<5	1	<3
27- 194	<10	<1	<1	130	<.5	1200	.071	<1	<5	<1	<3
27- 195	<100	--	<1	--	<.5	--	--	<1	<10	--	--
27- 196	<10	--	2	--	--	--	--	<1	<1	--	--
35- 46	<10	<1	<1	<2	<.5	30	.048	<1	<5	<1	<3
39- 180	<10	<1	<1	<2	<.5	100	.12	<1	<5	<1	<3

Appendix 3.--Results of analyses for inorganic constituents in ground-water samples from aquifers in sedimentary and igneous bedrock in the central part of the Passaic River basin, New Jersey, 1959-88--Continued

New Jersey well number	Copper, dis-solved (µg/L AS Cu)	Iodide dis-solved (mg/L as I)	Iron, dis-solved (µg/L as Fe)	Lead, dis-solved (µg/L as Pb)	Lithium, dis-solved (µg/L as Li)	Manga-nese, dis-solved (µg/L as Mn)	Mercury, dis-solved (µg/L as Hg)	Molyb-denum, dis-solved (µg/L as Mo)	Nickel, dis-solved (µg/L as Ni)	Sele-nium, dis-solved (µg/L as Se)	Silver, dis-solved (µg/L as Ag)
AQUIFERS IN SEDIMENTARY BEDROCK											
13- 4	--	--	100	--	--	<1	--	--	--	--	--
13- 4	<10	0.002	<3	<10	<4	<1	<0.1	<10	<10	<1	1
13- 6	--	--	0	--	--	<1	--	--	--	--	--
13- 52	2	--	5	<5	--	<1	<.1	--	--	--	--
13- 52	<10	.006	<3	<10	<4	1	.2	<10	<10	<1	<1
13- 55	<10	.004	3	<10	<4	1	.2	<10	<10	<1	<1
13- 82	<10	.003	<3	10	6	<1	.2	<10	<10	<1	<1
13- 90	60	--	<3	<10	29	46	--	<10	--	--	--
13- 90	<10	.009	6	<10	21	51	<.1	<10	<10	<1	2
27- 153	<1	--	4	<5	--	<1	<.1	--	--	--	--
27- 158	<10	<.001	<10	<10	<4	<1	<.1	<10	<10	<1	<1
27- 922	<10	.010	6	10	<4	75	<.1	<10	<10	<1	2
27- 979	10	.003	77	<10	21	11	<.1	<10	<10	<1	<1
27- 979	--	--	--	--	--	--	--	--	--	--	--
27-1109	<10	<.001	<3	<10	<4	1	.3	<10	<10	1	<1
27-1110	--	--	<3	--	--	4	--	--	--	--	--
27-1112	<10	.029	410	<10	24	75	<.1	<10	<10	<1	<1
27-1112	--	--	--	--	--	--	--	--	--	--	--
27-1114	<10	<.001	<3	<10	7	<1	<.1	<10	<10	<1	<1
27-1114	<10	<.001	<3	<10	7	<1	<.1	<10	<10	<1	<1
[1]27-1114	<10	--	<160	<100	--	<1.2	<.24	<10	<9.5	<81	<17
31- 35	<1	--	9	<5	--	2	<.1	--	--	--	--
31- 53	<10	.001	<3	<10	6	<1	<.1	<10	<10	<1	<1
35- 45	<10	<.001	<3	<10	10	<1	<.1	<10	<10	<1	<1
39- 308	--	--	0	--	--	60	--	--	--	--	--
39- 315	--	--	10	--	--	30	--	--	--	--	--
39- 316	--	--	0	--	--	10	--	--	--	--	--
AQUIFERS IN IGNEOUS BEDROCK											
13- 2	--	--	90	--	--	0[2]	--	--	--	--	--
13- 59	<10	.003	<3	<10	<4	<1	.2	<10	<10	<1	1
13- 72	<10	.002	<3	<10	<4	<1	.2	<10	<10	<1	<1
27- 194	<10	.007	<3	<10	<4	<1	<.1	<10	<10	<1	2
27- 195	1	--	<3	<1	--	11	<.1	--	<1	<1	--
27- 196	<10	--	3	<10	--	<1	<.1	--	--	--	--
35- 46	<10	<.001	<3	<10	<4	<.1	<.1	<10	<10	<1	<1
39- 180	<10	.002	5	<10	<4	2	<.1	<10	<10	<1	<1

Appendix 3.-- Results of analyses for inorganic constituents in ground-water samples from aquifers in sedimentary and igneous bedrock in the central part of the Passaic River basin, New Jersey, 1959-88--Continued

New Jersey well Number	Strontium, dissolved (µg/L as Sr)	Vanadium, dissolved (µg/L as V)	Zinc, dissolved (µg/L as Zn)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia + organic, dis. (mg/L as N)	Nitrogen, nitrite, dissolved (mg/L as N)	Nitrogen, NO_2+NO_3, dissolved (mg/L as N)	Phosphorous ortho, dissolved (mg/L as P)	Tritium, total (pCi/L)	Cyanide, dissolved (mg/L as CN)
AQUIFERS IN SEDIMENTARY BEDROCK										
13- 4	--	--	--	--	--	--	--	--	--	--
13- 4	240	<3	7	<0.01	0.3	<0.01	0.72	0.04	54	<0.01
13- 6	--	--	--	--	--	--	--	--	--	--
13- 52	--	--	22	<.01	.3	<.01	1.10	.08	--	--
13- 52	190	<3	12	<.01	.3	<.01	1.10	.07	83	<.01
13- 55	500	<4	<3	<.01	.2	<.01	.80	.06	80	<.01
13- 82	--	<5	<3	<.01	.6	<.01	3.10	.02	51	<.01
13- 90	2,000	8	3	--	--	--	--	--	--	--
13- 90	2,100	11	<3	<.01	.2	<.01	<.10	<.01	54	<.01
27- 153	--	--	6	.01	.3	<.01	2.80	<.01	--	--
27- 158	82	<3	10	<.01	<.2	<.01	1.20	.04	58	<.01
27- 922	170	<1	<3	.02	<.2	<.01	<.10	.03	110	<.01
27- 979	540	<6	7	<.01	.4	<.01	1.60	.01	<10	<.01
27- 979	--	--	--	--	--	--	--	--	12	--
27-1109	170	6	4	<.01	<.2	<.01	<.10	.04	37	<.01
27-1110	--	--	--	--	--	--	--	--	--	--
27-1112	8,400	<1	8	.06	.5	<.01	<.10	<.01	<10	<.01
27-1112	--	--	--	--	--	--	--	--	<2.5	--
27-1114	280	9	110	.010	.40	<.01	.41	<.01	58	<.01
27-1114	280	9	120	<.01	<.2	<.01	.40	.01	51	<.01
[1]27-1114*	290	<15	130	--	--	--	--	--	--	--
31- 35	--	--	11	<.01	<.2	<.01	1.10	.04	--	--
31- 53	200	<5	<3	.01	.2	<.01	2.30	.03	42	<.01
35- 45	370	<6	5	<.01	.3	<.01	2.20	.02	58	<.01
39- 308	--	--	--	--	--	--	--	--	--	--
39- 315	--	--	--	--	--	--	--	--	--	--
39- 316	--	--	--	--	--	--	--	--	--	--
AQUIFERS IN IGNEOUS BEDROCK										
13- 2	--	--	--	--	--	--	--	--	--	--
13- 59	--	7	<3	.01	<.2	<.01	.49	.02	110	<.01
13- 72	--	9	<3	<.01	.2		1.80	.02	80	<.01
27- 194	--	6	29	<.01	.6	<.01	2.20	<.01	80	<.01
27- 195	--	--	6	<.01	<.2	<.01	<.10	.01	--	<.01
27- 196	--	--	46	<.01	<.2	<.01	2.10	<.01	--	--
35- 46	130	8	<3	<.01	<.2	<.01	2.10	.02	86	<.01
39- 180	77	14	79	<.01	<.2	<.01	1.60	.03	90	<.01

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[1] Analysis was performed by Environmental Testing and Certification Laboratory. (Use of firm names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.)

[2] Zero was used prior to < reporting limit; historically, the concentration of the lower reporting limit has decreased with time.