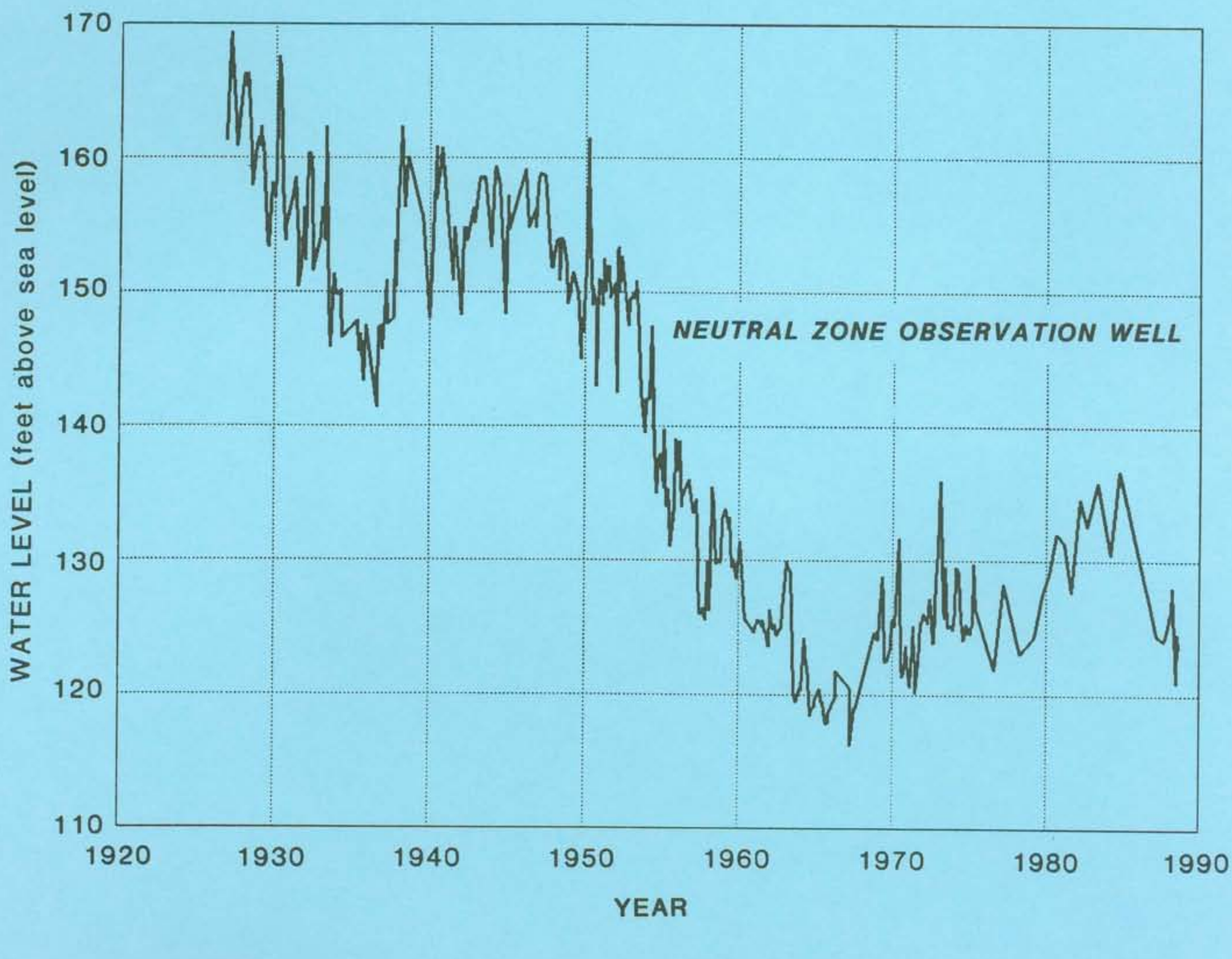
New Jersey Geological Survey
Open-File Report 88-4

Plan of Study for the Central Passaic River Basin Hydrogeologic Investigation



Department of Environmental Protection - Division of Water Resources

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Plan of Study for the Central Passaic River Basin Hydrogeologic Investigation

by
Jeffrey L. Hoffman

New Jersey Department of Environmental Protection
Division of Water Resources
Geological Survey
CN-029
Trenton, New Jersey 08625

1989

CONVERSION FACTORS

For the convenience of readers who prefer to use metric (International System) units rather than the inch-pound units in this report, values may be converted using the following factors:

Multiply inch-pound units	by	to obtain metric unit
inch (in.)	25.40	millimeter (mm)
foot (ft.)	0.3048	meter (m)
mile (mi.)	1.609	kilometer (km)
foot per second (ft/s)	0.3048	meter per second (m/s)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
million gallons per day (Mgal/d)	0.04382	cubic meters per second (m^3/s)
square foot (ft^2)	0.09290	square meter (m^2)

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Plan of Study for the Central Passaic River Basin Hydrogeologic Investigation

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ABSTRACT

The New Jersey Geological Survey, in cooperation with the United States Geological Survey, has planned a 5-year study to collect and interpret the information needed to effectively manage the ground-water resources of the Central Passaic River Basin. This study will define the geology, bedrock topography, ground-water pumpage, water levels and hydrogeochemistry of the area. A three-dimensional computer model will be developed to simulate ground-water flow and predict ground-water response to changes in pumpage.

The Central Passaic River Basin is located in northeastern New Jersey. It is composed primarily of southeastern Morris and western Essex Counties, but includes small parts of Somerset, Union and Passaic Counties. It is bounded on the west by the Ramapo fault and on the north, east, and south by the Watchung Mountains. The Passaic River flows through the area, eventually discharging to Newark Bay. The Ramapo, Pequannock, Wanaque, and Pompton Rivers are tributaries to the Passaic River in the study area.

Two aquifer systems supply ground water in the Central Passaic River Basin. Quaternary sediments of glacial and postglacial origin fill stream channels in the bedrock and form the buried-valley aquifer system. The bedrock aquifer system is comprised of sedimentary and igneous units of the Brunswick Group of the Newark Supergroup.

The Central Passaic River Basin has experienced significant pumping since withdrawals began around the turn of this century. Water-level declines of 80 feet have been measured in areas of heavy pumpage. Expected population increases will probably increase stresses on ground-water supplies. Additional wells must be located so as to minimize effects on prior ground-water users.

This report describes the goals, methods, work plans, time frame and planned outputs of the study. The New Jersey Geological Survey will perform hydrogeological and geophysical investigations and will develop the computer model. The United States Geological Survey, Water Resources Division (West Trenton Office) will investigate ground-water chemistry and streamflow. This study, which is being funded by the New Jersey 1981 Water Supply Bond Act, is scheduled for completion in 1991.

INTRODUCTION

In 1981 New Jersey voters authorized the $350-million Water Supply Bond Act of 1981 (New Jersey Department of Environmental Protection, 1980). The act was intended to fund the rehabilitation and improvement of the water-supply facilities of New Jersey and assure the availability of safe, adequate and reliable water supplies. Monies from this fund have been used for ground-water studies of the Atlantic City, Camden and South River areas (Leahy and others, 1987). The 1981 Water Bond is also funding a study of the ground-water resources of the Central Passaic River Basin.

This Plan of Study report serves as a brief review of the hydrogeologic setting, ground-water-supply problems and previous ground-water studies in the Central Passaic River Basin (CPRB). It also is a general description of the goals, time frame and proposed outputs of the current 1981 Water Bond study.

The Passaic River and its tributaries drain roughly 930 square miles in northeastern New Jersey and southern New York (fig. 1). The Passaic River Basin is divided into three sections:

the Highland Area, Central Basin, and Lower Valley (U.S. Army Corps of Engineers, 1987).

The CPRB is bounded on the west and northwest by the Ramapo Fault and on the northeast, east, and south by the Watchung Mountains (fig. 2). It is largely located in southeastern Morris and western Essex Counties but also includes small parts of Passaic, Somerset, and Union Counties (fig. 3). The CPRB includes all or parts of 38 municipalities (table 1). The Whippany, Rockaway, Ramapo, Wanaque, Pequannock and Pompton Rivers are major tributaries which join the mainstem Passaic River in the Central Basin (fig. 4).

Two aquifer systems supply ground water in the Central Passaic River Basin: the bedrock aquifer system and the buried-valley aquifer system.

The bedrock aquifer system underlies the entire study area. Bedrock crops out primarily around the border of the study area. Generally, however, it is overlain by sediments. The maximum known thickness of sediments, under the Great Piece Meadows, is 160 feet (Nichols, 1968a). The bedrock aquifer system produces significant volumes of ground water. It is, however, very variable in yield. A good well is usually located by trial and error.

The buried-valley aquifer system consists of unconsolidated sediments deposited during and after the last glacial period. The water-bearing unit can be over 100 feet thick (Geraghty & Miller, Inc., 1976). This aquifer system is extremely productive but is confined to the major preglacial valleys (fig. 5).

Use of the CPRB's ground-water resources began in the late 1800s (Thompson, 1932) and has increased significantly since then. Ground water is most heavily utilized in the mid-section of the CPRB, in southeastern Morris and western Essex Counties south of the confluence of the Passaic and Pompton Rivers and north of the Great Swamp (fig. 2). Pumpage from the buried-valley aquifer system here was 26.56 million gallons per day (mgd) in 1986 (table 2).

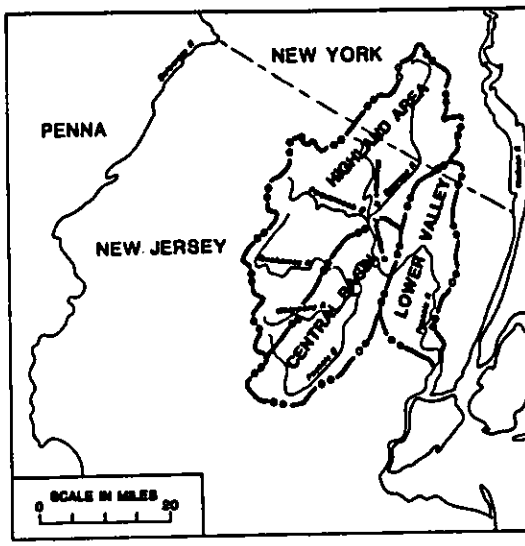

Figure 1. Location of the Passaic River drainage basin in New Jersey and New York. Adapted from U.S. Army Corps of Engineers (1987).

Table 1. Townships and counties wholly or partially in the Central Passaic River Basin

Essex County
- Caldwell Borough
- Essex Fells Borough
- Fairfield Borough
- Livingston Township
- Millburn Township
- North Cadwell Borough
- Roseland Borough
- West Caldwell Borough

Morris County
- Boonton Town
- Chatham Borough
- Chatham Township
- East Hanover Township
- Florham Park Borough
- Hanover Township
- Harding Township
- Kinnelon Borough
- Lincoln Park Borough
- Madison Borough
- Montville Township
- Morris Plains Borough
- Morristown Town
- Morris Township
- Mountain Lakes Borough
- Parsippany-Troy Hills Twp.
- Passaic Township
- Pequannock Township
- Riverdale Borough

Passaic County
- Little Falls Twp
- Pompton Lakes Borough
- Totowa Borough
- Wayne Township

Somerset County
- Bernardsville Borough
- Bernards Township
- Far Hills Borough
- Warren Township

Union County
- Berkeley Heights Twp.
- New Providence Borough
- Summit City

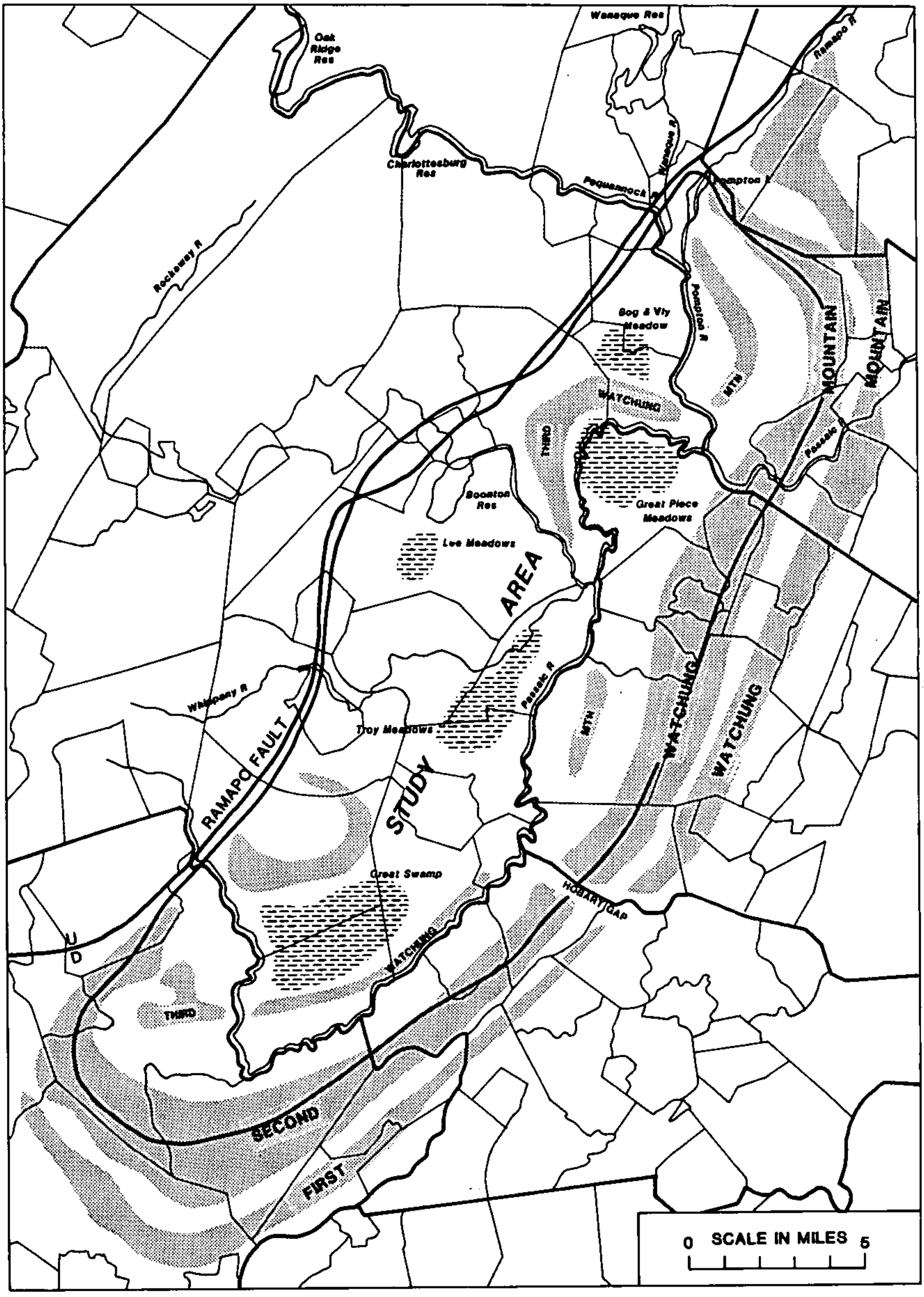

Figure 2. Major geographical features of the Central Passaic River Basin. Geology from Olsen (1980).

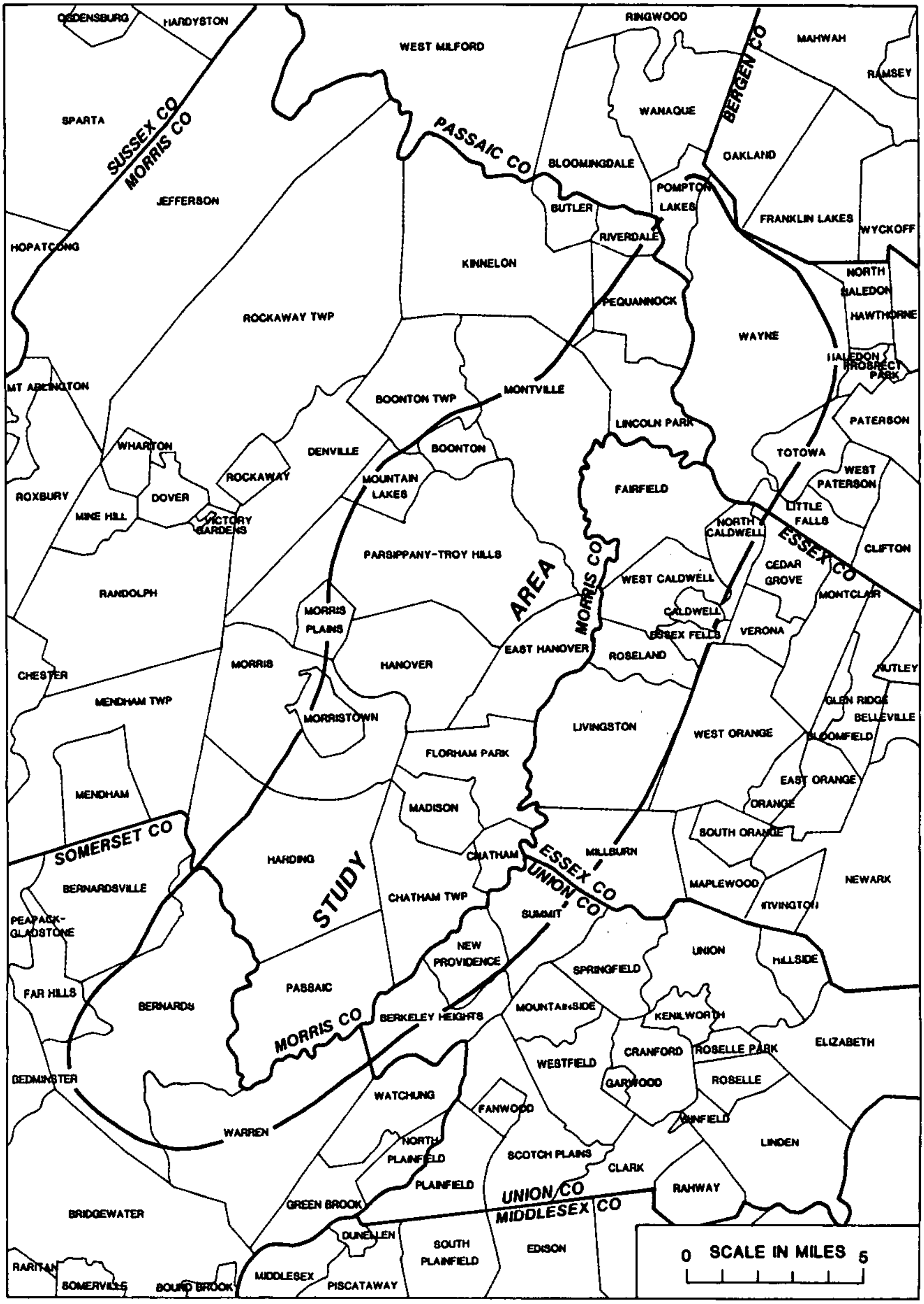

Figure 3. Political divisions of the Central Passaic River Basin and surrounding areas.

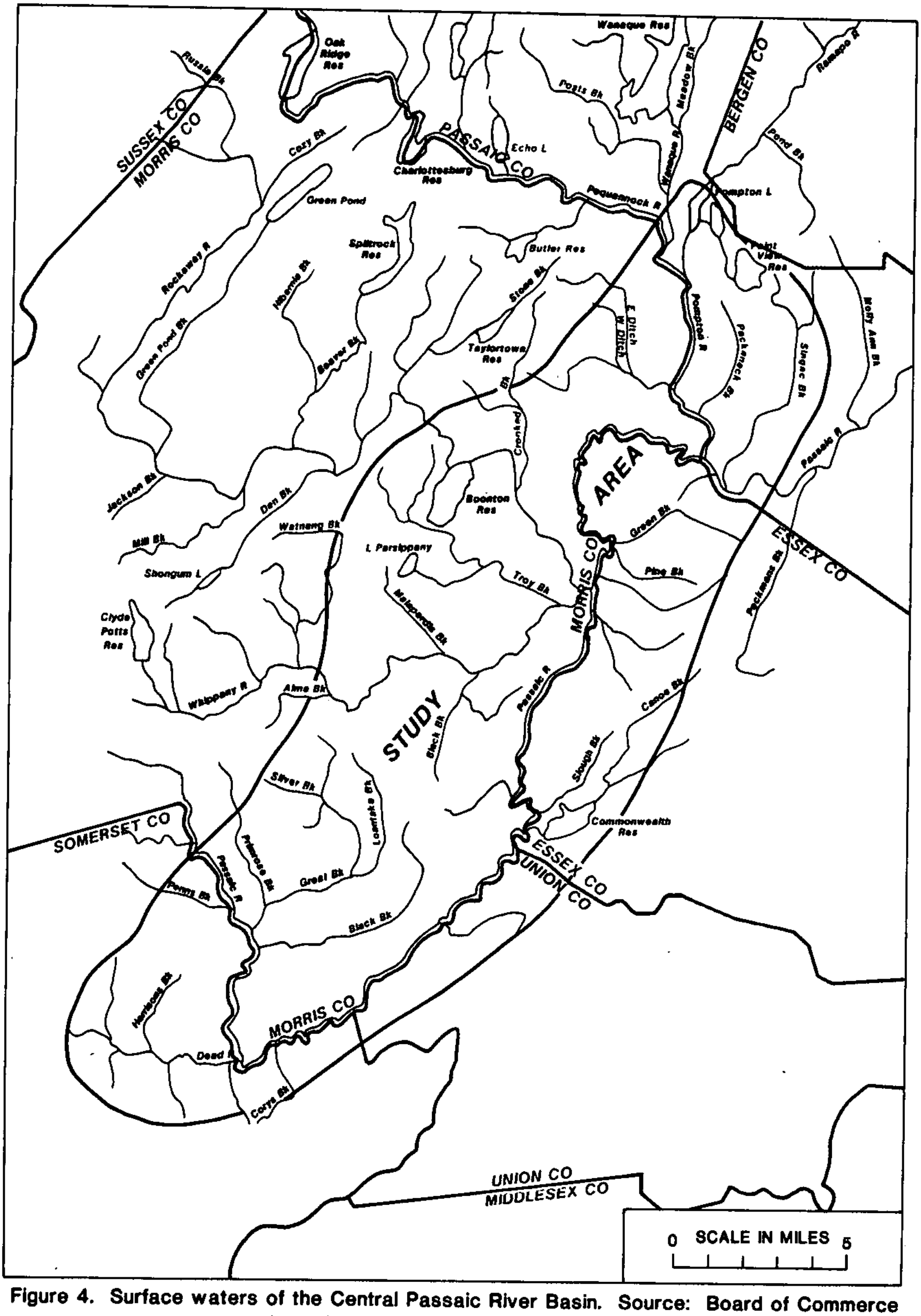

Figure 4. Surface waters of the Central Passaic River Basin. Source: Board of Commerce and Navagation (1932).

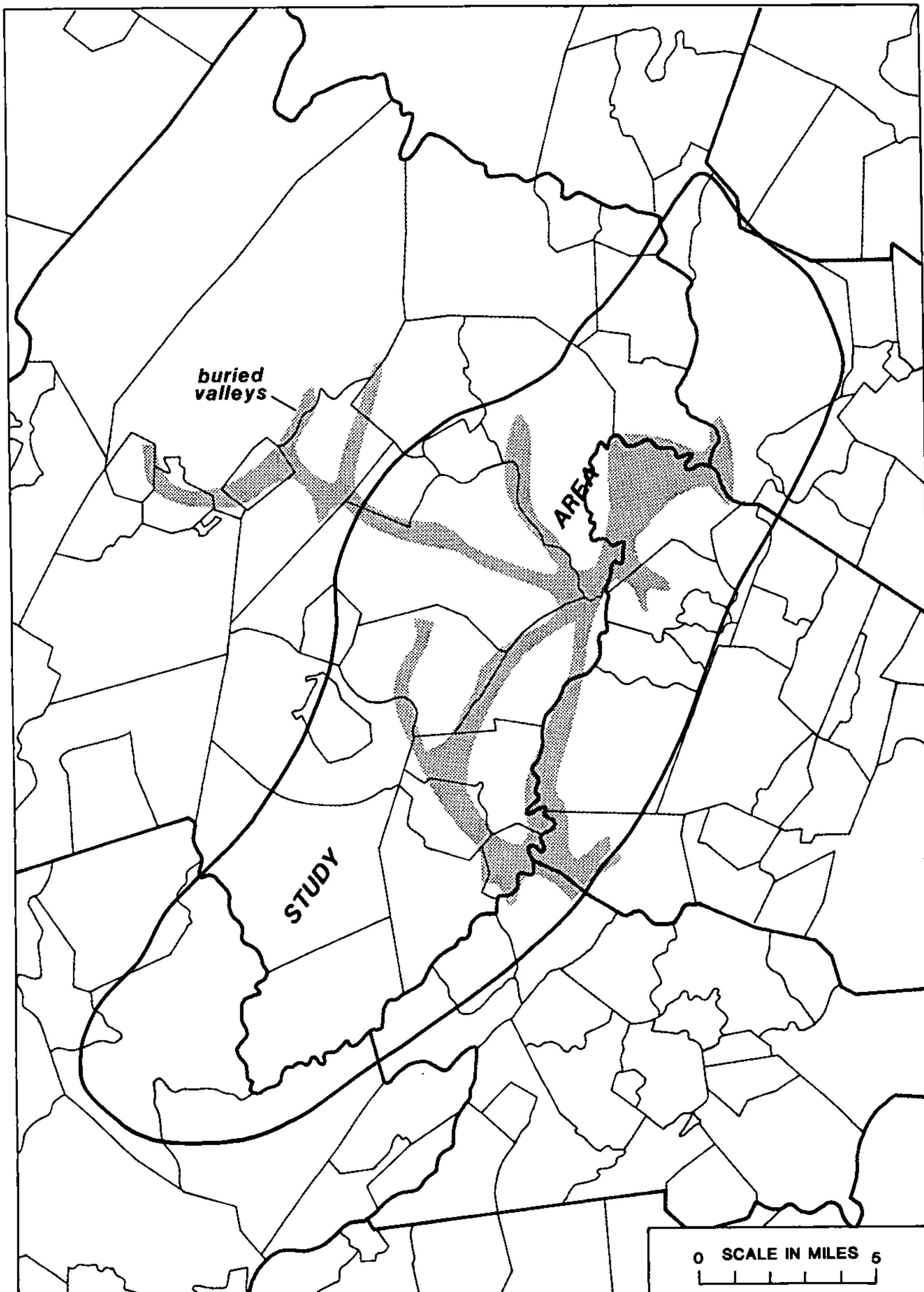

Figure 5. Buried valleys in the Central Passaic River Basin. Data compiled from Meisler (1976), van Abs (1986), and files of New Jersey Geological Survey.

Declining ground-water levels have necessitated deepening of wells or reduction of pumping rates in western Essex County (Geraghty & Miller, Inc., 1976). Interference effects among pumping wells have become an important limitation to use of the ground-water resources of the area. The greatest problems have occurred in western Essex County, bordering the Passaic River just east of Chatham. Here the East Orange Water Department and the New Jersey-American Water Company (formerly the Commonwealth Water Company) have been pumping water since the turn of the century at several well fields. Table 3 shows pumpage rates for East Orange and New Jersey-American since 1900. Situated between the two purveyors is the Neutral Zone monitoring well, so called as it was drilled as the result of litigation between the two purveyors (David Miller, Geraghty & Miller, Inc., oral communication, 1988). Figure 6 displays water levels from this well. The water level before pumpage began is estimated to have been at an elevation of roughly 210 feet above sea level (Geraghty & Miller, Inc., 1976).

Expected increases in the population of the CPRB will increase the need for water (table 4). If previous trends continue, increased demands will be met, at least partially, using ground-water sources. New wells must be located with care, using all available hydrogeologic information, to minimize adverse impact upon existing users.

Surface water supplies a significant part of the water demand (table 5). For the five counties in which the study area lies, surface water supplies roughly 75 percent of the total water demand. Specific data for the CPRB are not available.

An additional constraint on the aquifer system in the CPRB is ground-water pollution at more than 60 sites (Britton, 1984). Contamination has forced the closing of some public and private supply wells and may require placing certain areas off-limits to pumping[1]. Pollution threatens ground-water supplies in the unconsolidated and bedrock aquifers, and reduces the number of sites available for additional water-supply wells. This study does not specifically address ground-water contamination at individual sites. However, the results will provide a general view of geochemical characteristics of ground-water in the CPRB and provide the necessary regional data for site-specific investigations of water quality.

Table 2. Summary of pumpage by major ground-water users in southeastern Morris and western Essex Counties, 1900-1985

time span (years)	average pumpage (mgd)	source
1900-29	5.17	Meisler, 1976
1930-45	8.98	"
1946-52	12.47	"
1953-59	16.93	"
1960-65	22.39	"
1966-68	22.51	"
1969-71	26.11	"
1972-73	28.46	Meisler, 1986[1]
1974-76	28.12	Hoffman, 1986[2]
1977-79	29.94	"
1980	30.75	"
1981-84	28.42	"
1985	26.56	"

[1] Harold Meisler, USGS, written communication, 1986

[2] Hoffman, J.L., 1986, An update of a computer model of the Pleistocene valley fill aquifer in southwestern Essex and southeastern Morris Counties, New Jersey: unpublished manuscript report on file with the New Jersey Geological Survey, Trenton, N.J., 40p.

The overall goal of this study is to enhance efficient management of the ground-water resources of the Central Passaic River Basin. To do this it is necessary to first identify and quantify those factors which govern ground-water flow, quality, and quantity. Flow paths will be delineated. An investigation of ground-water chemistry will indicate natural quality limitations to ground-water use. A computer model will be developed to predict the effects of additional pumping. The model will be also used, if feasible, to determine optimal well locations.

The study is to last five years. A review of previous studies will be followed by geological, hydrogeological, and geophysical field investigations. Analysis of field data will help define the

[1] Oudijk, Gil., 1987, Ground-water contamination and the delineation of a well-restriction area in East Hanover Township, Morris County, New Jersey: unpublished technical memorandum on file with the New Jersey Geological Survey, Trenton, NJ, 49 p.

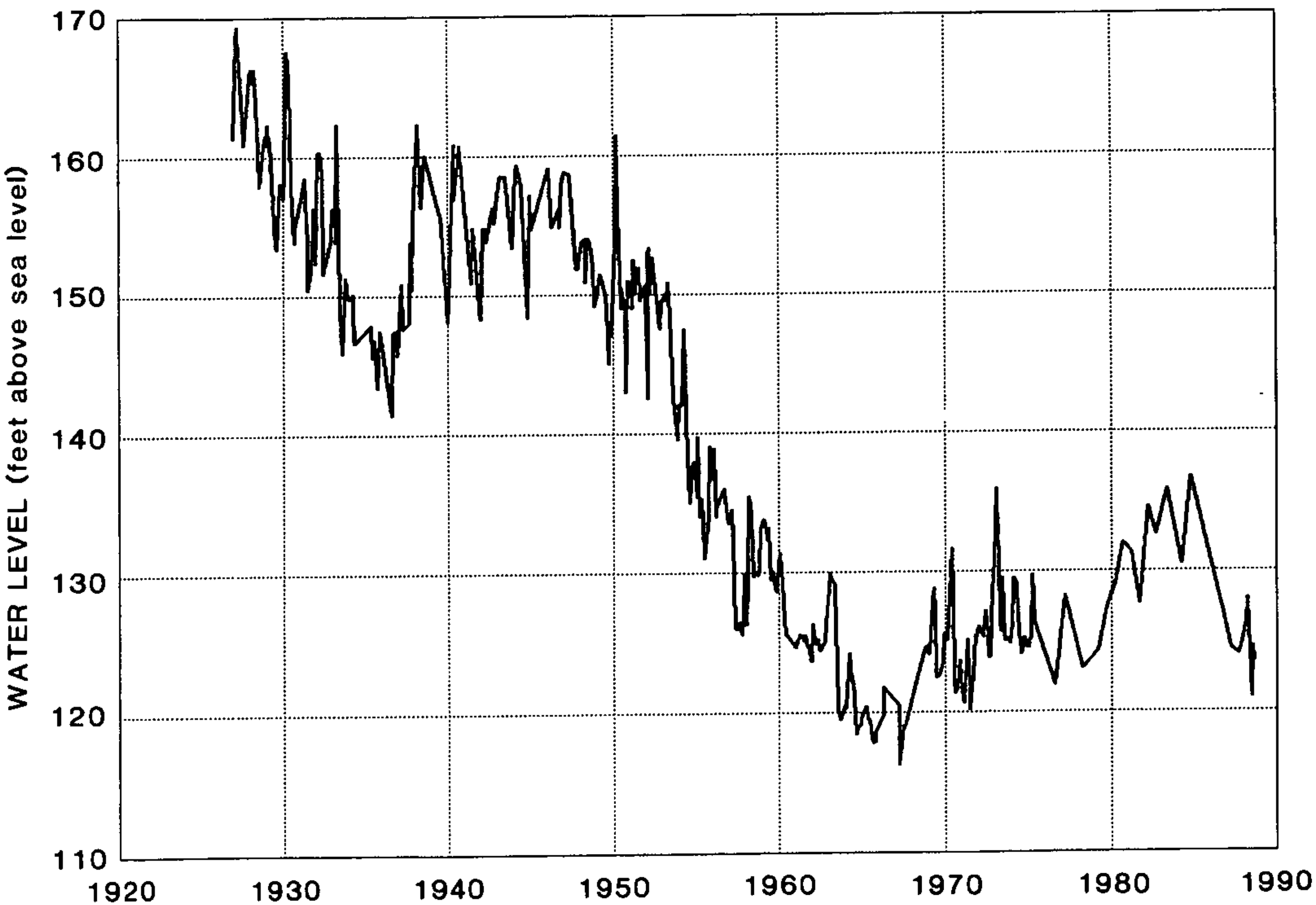

Figure 6. Hydrograph of the Neutral Zone observation well, 1926–1988. Source: Files of the New Jersey Geological Survey and U.S. Geological Survey. (U.S.G.S. Well ID 13-0014) Land surface elevation = 179'.

Table 3. Withdrawals of ground water by East Orange Water Department and New Jersey-American Water Company, 1900-1985

Time span (years)	East Orange	New Jersey-American	sum	source
1900-29	2.39	2.26	4.65	Meisler, 1976
1930-45	5.06	2.58	7.65	"
1946-52	6.06	3.88	9.94	"
1953-59	6.85	6.89	13.73	"
1960-65	6.96	9.58	16.54	"
1966-68	7.53	8.32	15.85	"
1969-71	8.15	8.75	16.89	"
1972-73	8.68	9.22	17.90	Meisler, 1986[1]
1974-76	9.16	8.30	17.46	Hoffman, 1986[2]
1977-79	9.30	8.71	18.01	"
1980	9.97	8.80	18.77	"
1981-84	9.13	7.09	16.22	"
1985	9.37	4.95	14.33	"

[1] Harold Meisler, USGS, written communication, 1986
[2] Hoffman, J.L., 1986, An update of a computer model of the Pleistocene valley fill aquifer in southwestern Essex and southeastern Morris Counties, New Jersey: unpublished manuscript report on file with the New Jersey Geological Survey, Trenton, N.J., 40p.

Table 4. Historical and Projected Population, by county

Year	County				
	Essex	Morris	Passaic	Somerset	Union
1900	359,053	65,156	155,202	32,948	99,353
1910	512,886	74,704	215,902	38,820	140,107
1920	652,089	82,694	259,174	47,991	200,157
1930	833,513	110,445	302,129	65,132	305,209
1940	837,340	125,732	309,353	74,390	328,344
1950	905,949	164,371	337,093	99,052	398,138
1960	923,545	261,620	406,618	143,913	504,255
1970	932,526	383,454	460,782	198,372	543,116
1980	851,304	407,630	447,585	203,129	504,094
1990	816,200	447,100	465,000	227,700	520,600
2000	795,500	510,500	469,100	261,200	539,700

Sources: Trenton Evening Times, 1963; New Jersey Department of Labor, 1985.

Table 5. Withdrawal of ground and surface water in northeastern New Jersey, 1975, by county

County	Ground water		Surface Water		Total
	mgd	percent	mgd	percent	mgd
Essex	35.37	20.9	133.59	79.1	168.96
Morris	28.78	87.9	3.97	12.1	32.75
Passaic	5.28	6.5	75.38	93.5	80.66
Somerset	1.46	44.6	1.81	55.4	3.27
Union	28.62	23.4	93.56	76.6	122.18
Total	99.51	24.4	308.31	75.6	407.82

Source: New Jersey Department of Environmental Protection, 1980 hydrogeological characteristics of the CPRB. A ground-water model will be set up based on collected data and calibrated using measured water levels. The model will then be used to predict the effects of additional pumping in the study area.

HYDROGEOLOGIC SETTING

The Central Passaic River Basin (CPRB) is underlain by two principal hydrogeologic systems: the bedrock aquifer system and the buried-valley aquifer system. The geology of each system is a major factor in determining ground-water flow and water availability.

Bedrock aquifer system

Bedrock in the study area consists of interbedded sedimentary and igneous rocks of Jurassic age (Lyttle and Epstein, 1987). Figure 7 is a generalized map of the bedrock geology.

The bedrock units in the area are part of the Newark Supergroup (Lyttle and Epstein, 1987). They are, from bottom to top, the Orange Mountain Basalt, Feltville Formation, Preakness Basalt, Towaco Formation, Hook Mountain Basalt and Boonton Formation (table 6). The Boonton and Towaco Formations interfinger with an unnamed conglomerate in places on the western edge of the study area. Thickness and extent of the conglomerate are poorly defined.

An older classification of the local bedrock units combines the Hook Mountain, Preakness, and Orange Mountain' Basalts together as the Watchung Basalts (Lewis and Kummel, 1912). The Boonton, Towaco, and Feltville Formations, as well as the Passaic Formation (which underlies the Orange Mountain Basalt and is outside of the study area) are grouped into the Brunswick Formation. While this older usage is less precise it is still almost universally used by well drillers, local officials and currently available data sources.

The sedimentary units (the Boonton, Towaco, Feltville and Passaic Formations) of the Brunswick Group are primarily made up of clastic rocks ranging from claystone to conglomerate. Deposition occurred in lakes and streams within a closed terrestrial basin. Cyclical expansion and contraction of the hypersaline lakes provided changing depositional environments. After consolidation, regional tectonic stresses fractured the sedimentary rocks, forming distinct joint sets.

The igneous units (Hook Mountain, Preakness, and Orange Mountain Basalts) consist of basalt extruded at the land surface by volcanic activity. Tilting and folding of the sediments and sheets of basalt followed by erosion of the softer sedimentary rocks resulted in the long, curvilinear Watchung Mountains.

The amount of hydrogeologic data available does not justify investigating the sedimentary units of the Brunswick Group separately. The individual units are not known to differ sufficiently to require separate hydrogeologic consideration. The igneous units of the Brunswick Group likewise are similar enough to justify treating them similarly. Accordingly, the bedrock aquifer system is subdivided into only two kinds of units, sedimentary and igneous (table 7). Detailed work beyond the scope of this project might disclose differences in the hydraulic properties of individual units in the Brunswick Group.

Ground water in the bedrock is mainly stored in and transmitted through openings formed after rock consolidation. These openings include weathered bedding planes in addition to fractures and joints formed by folding and faulting. The basalts may contain some voids caused by gas bubbles entrapped during cooling from a molten state to rock. The upper layers of the basalt flows may be highly vesicular and yield appreciable volumes of water.

Buried-Valley aquifer system

Unconsolidated glacial sediments overlie the bedrock in most places. Postglacial sediments, including gravel, sand, and swamp deposits, are a minor component overlying the glacial deposits.

The sand and gravel deposits are most productive where they are thickest. The thickest deposits generally occur in the preglacial valleys, where preglacial streams cut more deeply into

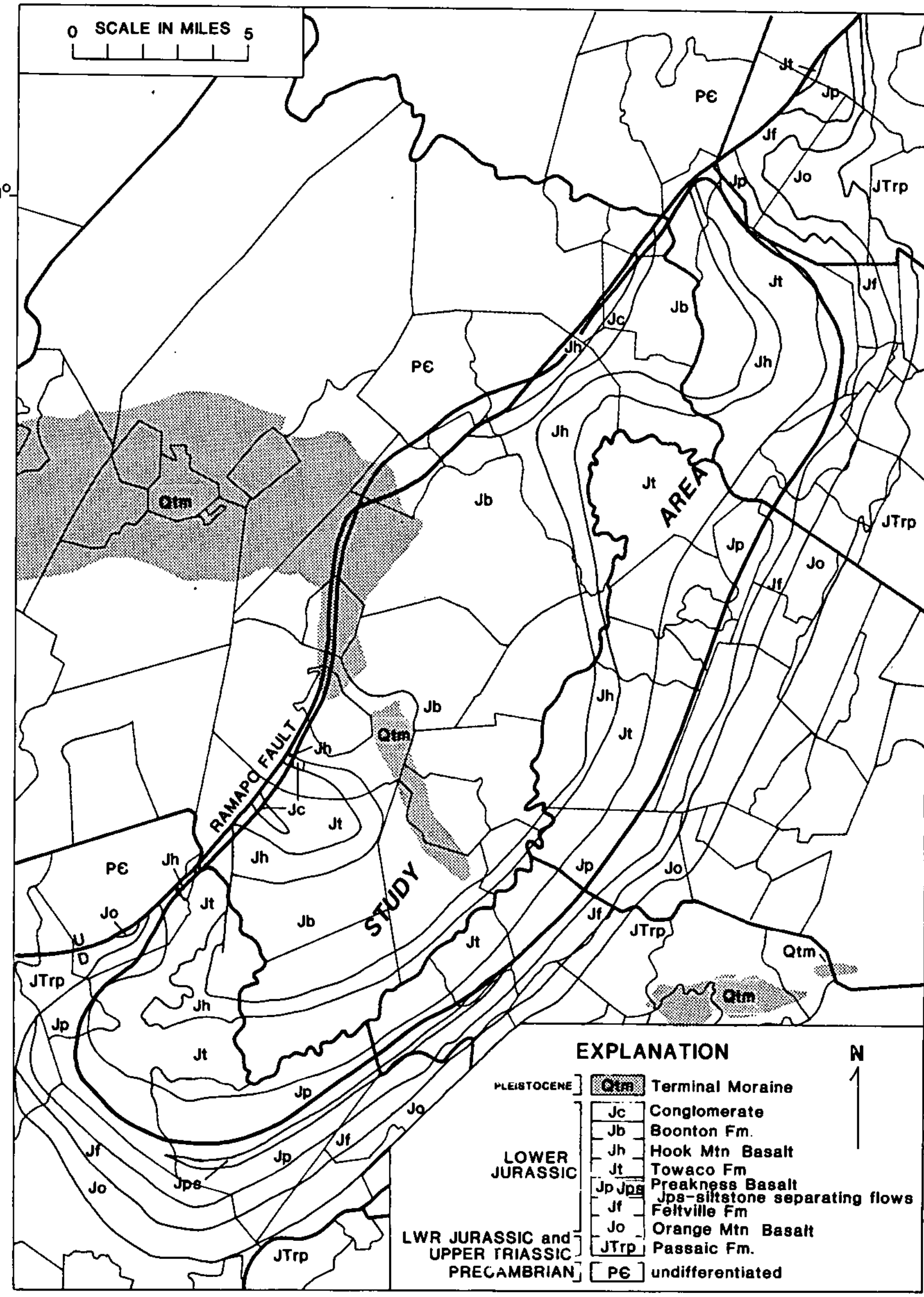

Figure 7. Generalized bedrock geology and terminal moraine. Bedrock geology south of 41° latitude modified from Lyttle and Epstein (1987), remainder from Houghton (personal communication, 1988). Terminal moraine from Lewis and Kummel (1912).

Table 6 Bedrock geologic column of the Central Passaic River Basin

Super-group	Group	Age[1]	Unit[1]	Estimated maximum thickness (feet)	Older usage[2]
			conglomerate	unknown	
			Boonton Formation	1,640	Brunswick Formation
			Hook Mountain Basalt	361	Third Watchung Basalt
		JURASSIC	Towaco Formation	1,115	Brunswick Formation
NEWARK SUPERGROUP	BRUNSWICK GROUP		Preakness Basalt	984	Second Watchung Basalt
			Feltville Formation	1,969	Brunswick Formation
			Orange Mountain Basalt	656	First Watchung Basalt
			Passaic Formation	8,760	Brunswick Formation
		TRIASSIC	Lockatong Formation	3,871	Lockatong Formation
			Stockton Formation	2,700	Stockton Formation

[1] Lyttle and Epstein, 1987

[2] Lewis and Kummel, 1912

Table 7. Hydrogeologic units in the Central Passaic River Basin

Unit	Lithology	Aquifer system
Stratified drift	Sand and gravel	Buried valley
Sedimentary units of the Brunswick Group	Siltstone, sandstone, shale and conglomerate	Bedrock
Igneous units of the Brunswick Group	Basalt	

the bedrock. These deposits constitute the 'buried-valley aquifers.' Outside the buried valleys, the sand and gravel deposits are usually thin or absent. Known buried-valleys are shown in figure 5.

A generalized geologic model of the buried-valley aquifer system assumes that the sediments were deposited primarily during the retreat of the latest (Wisconsinan) glaciers according to mechanisms described by Koteff and Pessl, (1981). A bottom layer of stratified glacial drift (primarily sand and gravel) directly overlies bedrock. In places this drift may be underlain or replaced by a layer of glacial till (poorly sorted sediments, commonly highly compacted). The stratified glacial drift is the most productive water-bearing unit in the buried-valley aquifer system. The stratified drift deposits may extend upward in places to crop out at the surface. Ground-water recharge to the buried-valley aquifer system may occur where the stratified drift crops out.

Overlying the stratified drift deposits are fine-grained sediments deposited in Glacial Lake Passaic (Reeds, 1933). These lake-bed deposits act as a confining unit for any underlying sand and gravel or bedrock. Lake-bed-deposit thickness may be as much as 100 feet (Reimer, 1984). The thickest and most continuous lake-bed deposits underlie the Great Swamp in the southern section of the Central Basin where the glacial lake persisted for the longest time (fig. 2). Where the lake was shallow, and in the interfluves between the buried valleys, the lake-bed deposits are thin or nonexistent.

Several significant swamps lie within the basin. The Great Swamp, Black Meadows, Troy Meadows, Lee Meadows, and Great Piece Meadows are areas where marsh deposits, peat, muck, and clay overlie the lake-bed sediments (fig. 2).

Overlying the lake-bed sediments along present streams are Holocene sediments of fluvial origin consisting of gravel, sand, silt, and clay. These fluvial materials supply domestic needs in places. The fluvial deposits are generally less than 50 feet thick and thus are not tapped by new wells because of state regulations governing minimum depth of wells.

[1]Hoffman, J. L., 1986, An update of a computer model of the Pleistocene valley fill aquifer in southwestern Essex and southeastern Morris Counties, New Jersey: unpublished manuscript report on file with the New Jersey Geological Survey, Trenton, NJ, 40 p.

Conceptual ground-water flow and availability

The conceptual model of Meisler (1976) for ground-water flow in the the bedrock aquifer assumes, under prepumpage conditions, recharge at higher elevations at the borders of the Basin. Ground water then flowed downward and laterally with discharge to the buried-valley aquifer system. Ground-water flow in the buried-valley aquifer system was both upwards towards the surface wetlands and down-valley, following the preglacial drainage of the bedrock valley towards the Hobart Gap (fig. 2). The Hobart Gap is assumed to be the pre-glacial surface water outlet through the Watchung Mountains (Kummel, 1933).

Under prepumpage conditions ground water exited the CPRB in one of three ways: 1) upward flow to the surface, followed by evaporation and transpiration; 2) discharge to the Passaic River; or, 3) underground flow through Hobart Gap (fig. 2).

A fourth discharge route, out-of-basin diversion, now exists. A significant volume of ground water is withdrawn from the study area. Current pumpage by purveyors near the Hobart Gap in the CPRB probably intercepts much of the water in the buried-valley aquifer system that would otherwise travel toward or through Hobart Gap.

The middle section of the CPRB, south of Great Piece Meadows (fig. 2) and north of the terminal moraine (fig. 7), is currently the most heavily pumped area. Withdrawals from this area were roughly 26 (mgd) in 1985[1]. The greatest pumpage concentration is in Essex and Morris Counties just west of the Hobart Gap. The buried valley here is referred to as the Southern Millburn Buried Valley (Meisler, 1976). Ground-water withdrawals from the Southern Millburn Buried Valley were approximately 13.2 mgd in 1985.

Ground-water levels have dropped in response to the pumpage. In 1900, water levels in the buried-valley aquifer west of Hobart Gap (near the present pumping centers of the the New Jersey-American Water Company and the East Orange Water Department) were 10 to 20 feet above the land surface (Geraghty & Miller, Inc., 1976). An observation well in the Southern Millburn Buried Valley (the Neutral Zone observation well) has provided water-level data since 1925 (fig. 6). In 1987, water levels were roughly 50 feet below land surface.

The buried-valley aquifer system tends to be the preferred water supply where both systems are present. It is more productive than the bedrock aquifer system and closer to the surface.

The sedimentary units of the Brunswick Group supply some high yielding wells. High yields are associated with fracture zones which are commonly covered by overburden and thus difficult to locate. The basalt units of the Brunswick Group are minor contributors to the CPRB's ground-water resources as a result of their generally lower water yields (Nichols, 1968). Wells completed in the basalt generally yield small quantities of water at best, but moderately good yields in excess of 100 gallons per minute have been reported (Nichols, 1968b). It is suspected that the highest yielding basalt wells tap vesicular zones which can occur near the top of the units (Richard Dalton, 1988, N.J. Geological Survey, oral communication).

PREVIOUS STUDIES

Initial geologic work in the Central Passaic River Basin concentrated on identifying the extent of glaciation and Glacial Lake Passaic (Salisbury, 1892, 1893, 1895, 1902; Salisbury and Kummel, 1894a, 1894b, 1895; Kummel, 1933). The sedimentary and igneous rocks of the Central Basin were studied by Darton and others (1908), Banino, Markewicz, and Miller (1970); Faust (1974); Olsen (1980) and Van Houton (1969, 1980). Bedrock topography and thickness of overburden in the middle part of the Central Basin were delineated by Vecchioli and Nichols (1966), Vecchioli, Nichols, and Nemickas (1967), Nichols (1968a), and Nemickas (1974). Geology of the Great Swamp area was studied by Minard (1967) and Reimer (1984).

Many ground-water investigations have covered part of the CPRB as part of a larger study. Ground-water investigations on a county scale are available for Essex (Nichols, 1968b), Morris (Gill and Vecchioli, 1965), and Union (Nemickas, 1976) Counties. The ground-water resources of smaller areas entirely within the CPRB have also been investigated (Thompson, 1932; Vecchioli, 1963; Geraghty & Miller, 1976; Geonics, 1978, 1979a, 1979b).

Meisler (1976) developed a computer model to estimate the ground-water supply of the buried-valley aquifer system of southwestern Essex and southeastern Morris counties and made some estimates of sustained yield from these valleys. His model was calibrated against observed drawdowns, not actual water levels. This model did not explicitly consider water levels in the bedrock aquifer, nor did it include the entire Central Passaic River Basin. Meisler's model was later updated to include additional pumpage data[1].

The possible effect of dredging the Passaic River on vertical ground-water flow was investigated by Vecchioli and Gill (1962). The Great Swamp's effect on the flow of the Passaic River was investigated by Vecchioli, Gill and Lang (1962) and Miller (1965).

Several data compilations deal with the CPRB. Streamflow data are collected and published yearly by the US Geological Survey (for example, Bauersfeld and others, 1986). Britton (1984) listed ground-water-pollution sites in the CPRB investigated by the NJ Geological Survey. Van Abs (1986) summarized geological data available for the buried-valley aquifer system in the Upper and Central Passaic River Basins.

Studies currently (1988) underway by the New Jersey and United States Geological Surveys will provide useful information for this study. Projects include an investigation of the ground-water resources of the Lower Rockaway River Valley, bedrock contours of the Florham Park-East Hanover Region, and an updating of New Jersey's geologic map (Harper, 1987).

[1]Hoffman, J. L., 1986, An update of a computer model of the Pleistocene valley fill aquifer in southwestern Essex and southeastern Morris Counties, New Jersey: unpublished manuscript report on file with the New Jersey Geological Survey, Trenton, NJ, 40 p.

OBJECTIVES

The overall goal of this study is to increase understanding of the geology and hydrogeology of the Central Passaic River Basin to allow more effective ground-water resource management. To accomplish this the following objectives have been set:

A. Better delineate the buried-valley and bedrock aquifers. This will be done by defining the subsurface geology, thickness of the valley-fill deposits, and bedrock topography. Outputs will include detailed contour maps of unconsolidated-deposit thickness and bedrock topography, and a summary map delineating the buried valleys.

B. Define the ground-water flow systems in the buried-valley and bedrock-aquifer systems. Produce contour maps showing ground-water elevations in these two systems. Delineate regional recharge and discharge areas. Define ground-water/surface-water interactions and the roles of geology and pumpage in these interactions. Assess pumpage from the aquifer systems.

C. Analyze the chemical constitutants of the ground water and identify regional trends. Use any observed trends to help delineate flow paths. Use the hydrogeochemical data to characterize different types and sources of ground water. If possible, identify background ground-water quality in both aquifers.

D. Develop a digital model to accurately simulate ground-water flow in the buried-valley and bedrock aquifer systems. Use the model to investigate the ground-water flow system and its sensitivity to changes in pumpage and recharge. Use the model to predict the effects of increased pumpage on regional ground-water levels and flow paths. If possible, use the model to determine optimum well locations to maximize yield while minimizing detrimental effects.

APPROACH

The study will be performed by the N.J. Geological Survey (NJGS) and the U.S. Geological Survey (USGS), West Trenton. The NJGS will investigate the hydrogeologic setting and ground-water flow system. The USGS will investigate streamflow and hydrogeochemistry.

The following work outline is designed to fulfill the objectives described above.

A. Planning
   1. Develop detailed work plans.
   2. Coordinate plans between the Geological Surveys of New Jersey and the United States.
   3. Coordinate with other projects underway or planned which may provide useful information.

B. Geology
   1. Compile and review available data on the geological framework, define data gaps.
   2. Compile and review well logs.
   3. Drill test holes in data gap areas to define the bedrock surface.
   4. Develop a map of bedrock topography at 1:24,000 scale.
   5. Develop a map showing overburden thickness at 1:24,000 scale.

C. Hydrogeology
   1. Compile and review available data on hydrogeologic properties of the buried-valley and bedrock aquifers.
   2. Conduct aquifer tests to ascertain hydraulic conductivity and storage coefficients in selected areas.
   3. Investigate the vertical connections between the buried-valley and bedrock aquifers.
   4. Conduct a basin-wide water-level-measurement program to define heads in the two aquifers.
   5. Monitor selected wells on a long-term basis for trends in water levels.
   6. Develop a ground-water budget for the area, identify sources and sinks.
   7. Compile and review pumpage data.
   8. Estimate future pumpage based on growth estimates and anticipated ground-water demand.

9. Compile and review available streamflow data.
10. Measure streamflow at selected sites to investigate surface-water/ground-water interactions.

D. Geophysics
1. Use seismic, gravity, and other appropriate geophysical techniques to define depth to bedrock at selected locations.
2. Use seismic, gravity, and other appropriate techniques to define thickness of the Buried-Valley Aquifer System at selected locations.

E. Hydrogeochemistry
1. Compile and review available water-quality data
2. Establish network of wells.
3. Collect and analyze samples to fill data gaps.
4. Develop graphics of geochemical properties.
5. Analyze data to help delineate ground-water flow paths.

F. Ground-water model
1. Set up parameter matrixes.
2. Calibrate model to prepumpage conditions.
3. Calibrate model with current pumping and head conditions.
4. Estimate future pumping distribution and predict resulting ground-water head distribution.

G. Data and interpretation reports
1. Compilation of well records from the Central Passaic River Basin
2. Ground-water withdrawals in the Central Passaic River Basin
3. Bedrock topography of the Central Passaic River Basin
4. Hydrogeology of the Central Passaic River Basin
5. A ground-water model of the Central Passaic River Basin
6. Miscellaneous data and interpretation reports to meet short-term needs

H. Future studies
1. Identify needs for detailed site studies

The planned sequence of activities is shown in table 8. This sequence may be altered or delayed if a shifting of resources is required to meet other commitments of the Department of Environmental Protection.

Table 8. Planned study sequence

Year 1
- A. Well data compilation
- B. Ground-water level
- C. Streamflow measurements
- D. Geology investigations
- E. Test drilling
- F. Geophysical investigations
- G. Synoptic water-level program
- H. Hydrogeochemistry measurements
- I. Report "Plan of Study for the Central Passaic River Basin Hydrogeologic Investigation"

Year 2
- A. Water-use inventory
- B. Geology investigations
- C. Test drilling
- D. Geophysical investigations
- E. Hydrogeochemical measurements
- F. Streamflow measurements
- G. Water budget determination
- H. Ground-water level measurements
- I. Report "Compilation of Well Data in the Central PassaicRiver Basin"
- J. Report "Ground-Water Withdrawals in the Central Passaic River Basin"

Year 3
- A. Ground-water model design and setup
- B. Ground-water level measurements
- C. Report "Bedrock Topography of the Central Passaic River Basin"

Year 4
- A. Ground-water-model utilization
- B. Ground-water level measurements
- C. Report "Hydrogeology of the Central Passaic River Basin"

Year 5
- A. Ground-water level measurements
- B. Report "A Ground-Water Model of the Central Passaic River Basin"

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GLOSSARY

Aquifer A formation, group of formations, or part of a formation that contains sufficient saturated and permeable material to yield significant quantities of water to wells and springs.

Basalt A fine-grained, dark-colored, extrusive igneous (volcanic) rock.

Bedding plane In sedimentary rocks, the plane dividing two strata of rock of the same or different lithology.

Bedrock A general term for consolidated rock.

Confined aquifer An aquifer in which ground water is confined under pressure that is significantly greater than atmospheric pressure.

Confining unit A layer of rock or sediment having very low hydraulic conductivity that hampers the movement of water into and out of an adjoining aquifer.

Conglomerate A sedimentary rock made up of pieces of other rocks which have been cemented together by a mineral substance, a fine- grained matrix, or by compaction.

Consolidated sediments Sediments which have been compressed and/or cemented together into a rock.

Digital model A representation of a physical situation based on a set of mathematical relationships and implemented on a digital computer which can be used to reproduce observed situations and predict changes if inputs change.

Dip The angle at which a layer, object or surface is inclined from the horizontal.

Electricial Conductivity The ability of a material to pass an electrical current. In geophysics, measurement of an induced electrical current leads to an estimation of a material's conductivity.

Extrusive rocks Rocks which were formed by molten lava cooling at the surface of the earth.

Fluvial Of or pertaining to a river or stream.

Gas vesicle A cavity of variable shape in a lava, formed by the entrapment of a gas bubble during solidification of the lava.

Gradient The amount by which a surface slopes or tilts from the horizontal.

Gravity technique A geophysical method in which minute varia tions in the earth's gravitational field are measured. These variations can indicate the differences in the distri bution of rock densities, hence the type of geological material, underneath the measurement point.

Ground water Water saturating soil, unconsolidated sediments or bedrock beneath the land surface.

Head see Head, hydraulic.

Head, hydraulic. The height above a standard datum of the surface of a column of water equivalent to the the static pressure and elevation at a given point.

Holocene An epoch of time extending from the end of the latest glacial period (roughly 10,000 years ago in North America) to the present.

Hydraulic conductivity A measurement of the ability of a material to transmit a fluid. Expressed in units of length per time (for example, feet per day or gallons per day per square foot). To be mathematicaly precise, it is the volume of water at the existing kinematic viscosity that will move in unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow.

Hydraulic gradient The amount by which the hydraulic head in an aquifer varies per unit distance in a specified distance at a given point. It is usually measured in the direction of maximum change.

Hypersaline water Water with a salinity substantially greater than that of typical sea water.

Interference effects The cumulative effects on ground-water level at a point due to two or more nearby pumping wells.

Intrusive rocks Rocks formed by molten lava cooling deep be neath the surface of the earth.

Igneous A rock or mineral that solidified from molten magma.

Interfluve area The area between streams, especially ridges or flat areas above and between stream channels.

Jurassic A geologic period of time extending from 190 to 135 million years ago. It was preceded by the Triassic period. Rocks deposited during this period are said to be Jurassic.

Moraine A mound, ridge, or other distinct accumulation normally of unsorted, unstratified glacial drift, predominantly till, deposited chiefly by direct action of glaciel ice.

Overburden The unconsolidated material above bedrock.

Permeability The property or capacity of a porous rock, sediment, or soil for transmitting a fluid. It is a property of the medium alone and independent of the nature of the fluid and of the force causing the movement. It is dependent upon the size, shape and degree of continuity of the pores in the medium.

Porosity The ratio of the open spaces (voids) in a material to total volume. It is the sum of the primary and secondary porosities.

Potentiometric surface The surface which represents the hydraulic head. If the hydraulic head varies with depth in an aquifer then a potentiometric surface is meaningful only if it describes the head along a particular specified surface or stratum in that aquifer.

Primary porosity The porosity of rock or other earth matrial developed at the time of its formation, which is chiefly intergranular void space (see secondary porosity).

Secondary features Features added to a rock or unit following original deposition or emplacement.

Secondary porosity Porosity added to rock or other earth material by weathering or deformation processes such as solution channeling or fracturing (see primary porosity).

Sedimentary A rock formed by the compaction or cementation of loose sediments.

Seismic technique Geophysical methods which measure, at land surface, the behavior of pressure waves originating at the surface that are reflected and refracted by underground layers.

Semiconfined aquifer An aquifer that is confined by a layer (or layers) of lower-permeability material through which recharge and discharge may occur.

Storage coefficient The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head.

Terminal moraine The end moraine that marks the farthest advance or maximum extent of a glacier. It is formed at a more or less stationary edge, or at a place marking the cessation of an important glacial advance.

Till Predominantly unsorted and unstratified glacial drift, deposited directly by a glacier without subsequent reworking by meltwater, and consisting of a heterogeneous mixture of clay, sand, gravel and boulders ranging widely in size and shape.

Transmissivity The hydraulic conductivity of an aquifer multiplied by its saturated thickness. Specifically, it is the rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient. It is expressed in units of square length per time (normally expressed, for example, as gallons per day per foot).

Triassic A period of time extending from 225 to 190 million years ago. It was followed by the Jurassic period. Rocks deposited during this period are said to be Triassic.

Unconfined aquifer An aquifer in which the hydraulic head is equivalent to atmospheric pressure.

Unconsolidated sediments Loose sediments which have not been compressed or cemented into a cohesive whole.

Water table The upper water surface in an unconfined aquifer.

Wisconsinan glacial stage The latest glacial episode in North America. It occurred roughly 70,000 to 8,000 years ago.

Plan of Study for the Central Passaic River Basin Hydrogeologic Investigation (New Jersey Geological Survey Open-File Report 88-4)