STRIBUTION OF CHLORIDE CONCENTRATIONS
THE PRINCIPAL AQUIFERS OF THE
W JERSEY COASTAL PLAIN, 1977-81

F. L. Schaefer

S. GEOLOGICAL SURVEY

ter-Resources Investigations Report 83-4061

epared in cooperation with the NEW JERSEY
PARTMENT OF ENVIRONMENTAL PROTECTION,
VISION OF WATER RESOURCES

Trenton, New Jersey

1983

UNITED STATES DEPARTMENT OF THE INTERIOR

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FACTORS FOR CONVERTING INCH-POUND UNITS TO METRIC UNITS

For those readers who prefer to use metric units rather than inch-pound units, the conversion factors for the terms used in this report are listed below:

Multiply inch-pound unit	By	To obtain metric unit
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
gallon (gal)	0.003785	cubic meter (m^3)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)

DISTRIBUTION OF CHLORIDE CONCENTRATIONS IN THE PRINCIPAL AQUIFERS OF THE NEW JERSEY COASTAL PLAIN, 1977-81

By F. L. Schaefer

ABSTRACT

The U.S. Geological Survey maintains a saltwater monitoring network in New Jersey to document and evaluate the movement of saline water into freshwater aquifers that serve as sources of water supply. This report delineates areas in the Coastal Plain where existing or potential saltwater intrusion exists.

During the 1977 water year, chloride concentrations were measured in samples from 202 wells, screened in 13 different aquifers or aquifer systems in Middlesex, Monmouth, Ocean, Atlantic, Cape May, Cumberland, Salem, and Gloucester Counties. These data, complemented by data collected prior and subsequent to 1977, indicate that freshwater aquifers in parts of seven counties are contaminated by saline water.

Encroachment of saltwater into freshwater aquifers in the Sayreville area of Middlesex County and in the lower peninsula of Cape May County has been reported for about 40 years and is now more extensive. Many production wells have been abandoned in both areas. In some existing production wells, chloride concentrations currently are approaching the 250 mg/L potable water standard. Several other areas are experiencing limited saltwater intrusion. These include the Keyport-Union Beach area in Monmouth County, areas adjacent to the Delaware estuary in Gloucester and Salem Counties, and at Point Pleasant Beach and Seaside Heights in Ocean County. The continuing updip movement of saline water in the heavily used aquifers in the Potomac-Raritan-Magothy aquifer system is also threatening existing freshwater supplies in the interior areas of Gloucester and Salem Counties. At Clayton Borough in Gloucester County and at Woodstown Borough in Salem County, chloride concentrations from wells currently vary between 140 and 195 mg/L.

Saltwater intrusion has resulted from extensive ground-water withdrawals. The resultant freshwater head declines have caused reversals in the natural hydraulic gradients permitting inland movement of saline water from adjacent saltwater bodies.

INTRODUCTION

Purpose and Scope

The usability of ground water in the Coastal Plain of New Jersey was described by Seaber (1963, p. 5) as follows:

> The usability of the ground water of the Coastal Plain of New Jersey depends primarily on its chemical quality. In near-shore areas, actual or potential salt-water contamination of ground water is of paramount importance, and chloride concentration is an excellent index of the extent and degree of contamination. High chloride concentrations, in themselves, do not necessarily prove actively advancing salt-water encroachment. They may represent a natural static condition common in shallow deposits bordering saline creeks, bays, and marshes. In the deeper formations, the occurrence of saline ground water may represent residual water trapped in the sediments. Salt-water encroachment in these areas can be proved only by periodic sampling which shows an increase in chloride concentration with time. It is difficult to establish limits of chloride concentration that can be used to indicate salt-water encroachment, because encroachment is indicated by changes in chloride content and not by actual concentration. However, water containing less than 10 ppm (parts per million) of chloride generally indicates no encroachment.

The U.S. Geological Survey, in cooperation with the New Jersey Department of Environmental Protection, Division of Water Resources, maintains a network of wells to monitor the movement of saltwater into the freshwater aquifers of the New Jersey Coastal Plain. The periodic sampling of wells was established in the 1940's for most areas of the Coastal Plain where the possibility of saltwater contamination was suspected. The sampling program was revised in 1958 and continues to the present. Chloride concentrations in samples are used as indicators of saltwater. This report discusses the chloride data only as it relates to saltwater intrusion or contamination of the ground water. Results of the chloride sampling are presented through water year 1981, with primary emphasis on the comprehensive sampling of 1977.

Data Collection and Presentation

In 1977, there were about 430 wells in the saltwater monitoring network in the eight Coastal Plain counties covered in this report. The counties are Middlesex, Monmouth, Ocean, Altantic, Cape May, Cumberland, Salem, and Gloucester. The majority of wells, approximately 400, are large capacity (300 to 1,000 gal/min) production wells. Because of their high yield and relative constant pumping, these wells draw from a large volume of the aquifer and provide the most representative water samples for analysis. In areas where no large production wells exist, water samples are collected from lower-yielding domestic wells. Observation wells or unused wells are sampled if no pumping wells are available.

Water samples from large production wells were collected from a tap in the discharge line near the wellhead. With some domestic wells, it was not possible to collect samples from the discharge line before it entered a pressure tank. These samples were collected after the water passed through the tank. All water samples, however, were collected before the water had passed through a water softener or other treatment process. A portable submersible pump was used to sample observation wells and unused wells.

Prior to sampling all wells were pumped until the casings were flushed and the water temperature had stabilized. Thus, the water sample came directly from the aquifer. Two samples were collected from each well. The first was used for field determinations of pH and specific conductance and the second was forwarded to the U.S. Geological Survey National Water Quality Laboratory in Doraville, Georgia for chloride analysis.

Data collected in 1977 were the most comprehensive to date (1981), especially in areas of significant saltwater intrusion such as the Sayreville area of Middlesex County, the Keyport-Union Beach areas of Monmouth County, and the Cape May City area of Cape May County. Most of the interpretations that follow are based upon the 1977 survey. However, the graphs of chloride concentrations depicting the concentration trends with time (figs. 4, 6, 9, 12, and 15) include data through the 1981 water year. Also, the text describing chloride concentration for each county includes any significant changes since 1977.

During the 1977 water year, 202 wells in the saltwater monitoring network were sampled in the eight counties in the Coastal Plain covered in this report. The locations of these wells are shown on individual maps for each county (figs. 2, 7, 8, 10, 11, 14, 17, and 18). A total of 266 water samples were collected and analyzed for temperature, pH, specific conductance, and chloride concentration. Tables 2-9 contain selected well records and chloride analyses by county. The water temperature, pH, and specific conductance data, which are not included in this report, were published in the annual series of U.S. Geological Survey Water-Data Reports for water years 1977 through 1981.

The Study Area

The study area of this report is located entirely within the Coastal Plain physiographic province (fig. 1). A Fall Line, which extends northeast along the Delaware River and through Mercer and Middlesex Counties, separates the Coastal Plain from the Appalachian Highlands province to the north.

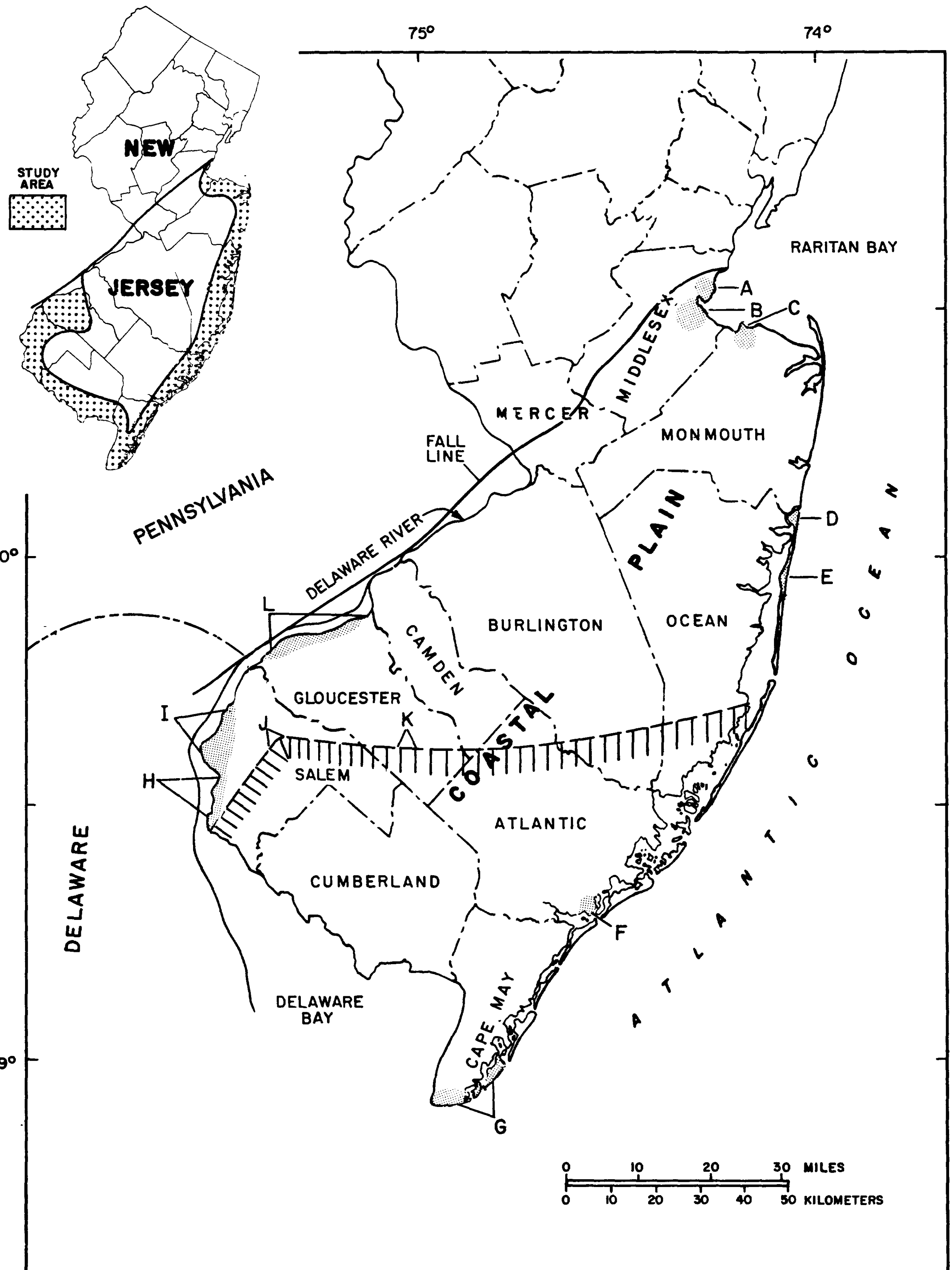


Figure 1.--Location of study area and areas of significant saltwater

EXPLANATION

Areas of saltwater intrusion in principal aquifers. Letter identifies locations listed below.

Area	Location	County	Aquifer affected
A	Perth Amboy City and Woodbridge Township	Middlesex	Farrington aquifer
B	Sayreville Borough and South Amboy City	Middlesex	Farrington and Old Bridge aquifers
C	Keyport and Union Beach Boroughs	Monmouth	Old Bridge aquifer
D	Point Pleasant Beach Borough	Ocean	Kirkwood-Cohansey aquifer system
E	Seaside Heights Borough	Ocean	Kirkwood-Cohansey aquifer system
F	Somers Point City	Atlantic	Kirkwood-Cohansey aquifer system
G	Cape May City and surrounding areas	Cape May	Cohansey Sand
H	Salem City and surrounding areas	Salem	Wenonah-Mount Laurel aquifer
I	Areas between Penns Grove and Salem City	Salem	Potomac-Raritan-Magothy aquifer system
J	Woodstown Borough and surrounding areas	Salem	Potomac-Raritan-Magothy aquifer system
K	Clayton Borough and surrounding areas	Gloucester	Potomac-Raritan-Magothy aquifer system
L	Areas between Paulsboro and Gibbstown	Gloucester	Potomac-Raritan-Magothy aquifer system

Line of 250-milligrams-per-liter chloride concentration near the top of the Potomac-Raritan-Magothy aquifer system (from Luzier, 1980, p.6). South and east of this line, chloride concentrations increase.

intrusion in the principal aquifers of the New Jersey Coastal Plain.

The Coastal Plain of New Jersey covers about 4,000 mi^2. More than half of this land area is below an altitude of 50 ft above sea level. The study area is largely surrounded by brackish or saltwater and is bounded by Raritan Bay on the north, the Atlantic Ocean on the east, Delaware Bay on the south, and the Delaware River on the west. A detailed description of the Coastal Plain physiographic province appears in Parker and others (1964, p. 41-42).

Previous Studies

Numerous studies have been made of existing or potential saltwater intrusion in the New Jersey Coastal Plain since the 1920's. Many of the studies and ensuing reports were restricted to limited areas, such as a county or a part of the county.

Barksdale (1937) indicated the potential for saltwater intrusion in the Farrington aquifer in Sayreville, Middlesex County. A later study by Barksdale and others (1943) concluded that saltwater intrusion was in evidence in the Farrington aquifer in several areas along the Raritan River between the South River and Raritan Bay. This report also indicated that overpumpage of the Old Bridge aquifer could induce saltwater into this aquifer, and suggested that a tidal dam could be constructed on the South River or its tributaries to prevent such contamination. Appel (1962) investigated the extent of saltwater intrusion in both the Farrington and Old Bridge aquifers in Middlesex County and indicated measures that could be considered to retard saltwater encroachment into these aquifers.

Hasan and others (1969) studied the Old Bridge aquifer in the vicinity of the South River and recommended a pumped storage diversion project instead of a tidal dam to increase the yield of this aquifer. Schaefer and Walker (1981) reported on saltwater intrusion in the Old Bridge aquifer in Keyport and Union Beach Boroughs in northern Monmouth County. Anderson and Appel (1969), in their ground-water study of Ocean County, noted the existence of saline water in the Potomac-Raritan-Magothy aquifer system in the southern part of the County. This report also indicated a potential for saltwater intrusion in other aquifers, especially the Englishtown and Atlantic City 800-foot sand aquifers along the barrier beaches in Ocean County. Thompson (1928) discussed the ground-water supplies in the Atlantic City areas of Atlantic County, including the problem of potential saltwater intrusion in the Atlantic City 800-foot sand. In 1936, a supplementary report was published on the Atlantic City area (Barksdale and others, 1936). This study concentrated on the saltwater intrusion problem in the shallow aquifers underlying the tidal marshes in the area of the Atlantic City Water Works at Pleasantville. In addition, this study focused on the extent of pumpage from the Atlantic City 800-foot sand and the danger of saltwater intrusion into this important aquifer. Chemical analyses presented in Clark and others (1968) show high chlorides (9,000 to 13,000 mg/L) from three wells tapping the Kirkwood-Cohansey aquifer system in Atlantic County, one in Somers Point and two in Atlantic City. Gill (1962) discussed the existing and potential danger of saltwater intrusion in all the principal aquifers of Cape May County. Rooney (1971) and Nemickas and Carswell (1976) discussed saltwater intrusion in aquifers in Cumberland County. Rosenau and others (1969), in their study of Salem County, evaluated saltwater intrusion in the Vincentown, Wenonah-Mount Laurel, and Englishtown aquifers in the vicinity of Salem City. The report also noted the incidence of saline water intrusion into the Potomac-Raritan-Magothy aquifer system from the Delaware River from Pennsville northward to Penns Grove. The authors also expressed concern about the consequences of the continual updip movement of highly saline water within this aquifer system from the southeast. In Gloucester County, Hardt and Hilton (1969) documented that saltwater intrusion had occurred in the Potomac-Raritan-Magothy aquifer system in areas in proximity to the Delaware River from Gibbstown northward to Paulsboro. The report also referred to the potential problem associated with the northward migration of saline water within this aquifer system, especially in Clayton Borough and Harrison Township (Mullica Hill).

Several regional studies have been conducted which in part dealt with saltwater intrusion in aquifers of the Coastal Plain. Barksdale and others (1958) discussed and evaluated the present and the potential for additional saltwater encroachment in the Potomac-Raritan-Magothy aquifer system in the southern part of the Coastal Plain. This report was one of the first to stress the importance of maintaining adequate freshwater flow in the Delaware River to protect the Potomac-Raritan-Magothy aquifer system from more widespread saltwater encroachment. Luzier (1980) augmented the above work in terms of the documentation of saltwater intrusion and proposed artificial recharge as an alternate means of retarding the migration of saline water northward within the Potomac-Raritan-Magothy aquifer system. Seaber (1963) presented basic chloride and well data for all aquifers throughout the Coastal Plain of New Jersey. This work contains 8,957 chloride analyses from 884 wells sampled from 1923 to 1961.

Walker (1983) provides water-level data and potentiometric surface maps for the major aquifers of the New Jersey Coastal Plain. The maps show cones of depression in many aquifers that are of major significance to the movement of saltwater. Vowinkel and Foster (1981, p. 22-28) contains information on ground-water withdrawals from the major Coastal Plain aquifers for 1956-78. Ground-water withdrawals by county and aquifer for 1978 also are presented.

Acknowledgments

The author gratefully acknowledges the assistance of public and industrial water-supply officials and private individuals who permitted access to their wells for sampling and provided information about their wells.

THE GROUND-WATER SYSTEM

The New Jersey Coastal Plain is underlain by a wedge-shaped mass of unconsolidated marine, marginal marine, and nonmarine deposits of clay, silt, sand, and gravel. The sediments range in age from Cretaceous to Holocene and lie unconformably on the pre-Cretaceous bedrock consisting chiefly of Precambrian and lower Paleozoic rocks. The total thickness of the Coastal Plain sediments ranges from a featheredge along the Fall Line to a thickness of about 6,500 ft at the extreme southern part of Cape May County. The Tertiary and Cretaceous sediments, in general, strike northeast-southwest and dip gently to the southeast from 10 to 60 ft/mi. The overlying Quaternary deposits, where present, are essentially flatlying. The stratigraphic and hydrologic characteristics of the geologic units are given in table 1. The outcrops of the geologic formations and a fence diagram of the Coastal Plain are shown in Parker and others (1964, plates 5 and 6, respectively).

Table 1.--Stratigraphic and hydrologic characteristics of geologic units of the New Jersey Coastal Plain

(Modified from Walker, 1983, p.7)

SYSTEM	GEOLOGIC UNIT	LITHOLOGY	HYDROLOGIC CHARACTERISTICS
Quaternary	Alluvial deposits	Sand, silt, and black mud.	Locally may yield small quantities of water to shallow wells.
	Beach sand and gravel	Sand, quartz, light-colored, medium grained, pebbly.	
	Cape May Formation	Sand, quartz, light-colored, heterogeneous, clayey, pebbly, glauconitic.	Thicker sands are capable of yielding large quantities of water.
Tertiary	Pensauken Formation		
	Bridgeton Formation		
	Beacon Hill Gravel	Gravel, quartz, light-colored, sandy.	No known wells tap this formation.
	Cohansey Sand	Sand, quartz, light-colored, medium to coarse-grained, pebbly; local clay beds.	A major aquifer. Ground-water occurs generally under water-table conditions. In Cape May County, the aquifer is under artesian conditions. Inland from the coast and in the northern part of Ocean County, the Cohansey Sand is in hydraulic connection with the Kirkwood Formation, forming the unconfined Kirkwood-Cohansey aquifer system.
	Kirkwood Formation	Sand, quartz, gray to tan, very fine- to medium-grained, micaceous, and dark-colored diatomaceous clay.	Includes a major and minor artesian aquifer near the coast. The major aquifer is the Atlantic City 800-foot sand. The minor aquifer is the Rio Grande water-bearing zone or upper aquifer. The Kirkwood Formation includes up to three confining layers near the coast. Inland from the coast and in the northern part of Ocean County, the Kirkwood Formation is hydraulically connected to the unconfined Cohansey Sand, forming the unconfined Kirkwood-Cohansey aquifer system.
	Piney Point Formation	Sand, quartz and glauconitic, fine- to coarse-grained.	Minor aquifer in New Jersey. Greatest thickness in Cumberland County.
	Shark River Marl	Sand, quartz and glauconite, gray, brown, and green, fine- to coarse-grained, clayey, and green silty and sandy clay.	Locally may yield small quantities of water to wells.
	Manasquan Formation		Locally may yield small to moderate quantities of water to wells.
	Vincentown Formation	Sand, quartz, gray and green, fine- to coarse-grained, glauconitic, and brown clayey, very fossiliferous, glauconite and quartz calcarenite.	Locally may yield small to moderate quantities of water to wells.
	Hornerstown Sand	Sand, glauconite, green, medium- to coarse-grained, clayey.	Locally may yield small quantities of water to wells.
Cretaceous	Tinton Sand	Sand, quartz, and glauconite, brown and gray, fine- to coarse-grained, clayey, micaceous.	No known wells tap this sand.
	Red Bank Sand		Yields small quantities of water to wells in Monmouth County.
	Navesink Formation	Sand, glauconite, and quartz, green, black, and brown, medium- to coarse-grained, clayey.	Locally may yield small quantities of water to wells.
	Mount Laurel Sand	Sand, quartz, brown and gray, fine- to coarse-grained, glauconitic.	A major aquifer in the northern part of the Coastal Plain. A sand unit within the two formations forms the Wenonah-Mount Laurel aquifer.
	Wenonah Formation	Sand, quartz, gray and brown, very fine- to fine-grained, glauconitic, micaceous.	
	Marshalltown Formation	Sand, quartz and glauconite, gray and black, very fine to medium-grained, very clayey.	Leaky confining bed.
	Englishtown Formation	Sand, quartz, tan and gray, fine- to medium-grained; local clay beds.	A major aquifer in the northern part of the Coastal Plain, the Englishtown aquifer consists of two sand units in Ocean and Monmouth Counties.
	Woodbury Clay	Clay, gray and black, micaceous.	The two formations form the Merchantville-Woodbury confining unit, a major confining layer throughout the New Jersey Coastal Plain. Locally the Merchantville may contain a thin water-bearing sand.
	Merchantville Formation	Clay, gray and black, micaceous, glauconitic, silty; locally very fine-grained quartz and glauconitic sand.	
	Magothy Formation	Sand, quartz, light-gray, fine-grained, and dark-gray lignitic clay.	Potomac-Raritan-Magothy aquifer system: Upper aquifer referred to as Old Bridge aquifer in the northern Coastal Plain.
	Raritan Formation	Sand, quartz, light-gray, fine- to coarse-grained, pebbly, arkosic, red, white, and variegated clay.	Major confining layer. Middle aquifer referred to as the Farrington aquifer in the northern Coastal Plain is combined with sands of the Potomac Group forming a large lower aquifer, as used in this report.
	Potomac Group	Alternating clay, silt, sand, and gravel.	
Pre-Cretaceous	Pre-Cretaceous basement	Precambrian and lower Paleozoic crystalline rocks, metamorphic schist and gneiss; locally Triassic basalt, sandstone, and shale	Except along Fall Line, no wells obtain water from these consolidated rocks.

The principal aquifers of the New Jersey Coastal Plain are the Potomac-Raritan-Magothy aquifer system (Potomac Group, Raritan and Magothy Formations), Englishtown aquifer (in the Englishtown Formation), Wenonah-Mount Laurel aquifer (in the Wenonah Formation and Mount Laurel Sand), aquifers within the Kirkwood Formation, and Cohansey Sand. Minor aquifers are found within the Red Bank Sand, the Vincentown, Manasquan, and Piney Point Formations, and the Cape May Formation in Cape May County. Separate aquifers, the Farrington and Old Bridge (in the Farrington Sand Member of the Raritan Formation and the Old Bridge Sand Member of the Magothy Formation) have been defined within the Potomac-Raritan-Magothy aquifer system in the northern part of the Coastal Plain (Barksdale and others, 1943; Farlekas, 1979). The Kirkwood Formation contains two artesian aquifers along the New Jersey coast. The principal artesian aquifer is the lower aquifer and is known as the Atlantic City 800-foot sand (Thompson, 1928, p. 35-119; Barksdale and others, 1936, p. 91-125). The upper artesian aquifer is referred to as the Rio Grande water-bearing zone and is primarily utilized in Cape May County (Gill, 1962, p. 17-18). The major unconfined aquifer within the New Jersey Coastal Plain is known as the Kirkwood-Cohansey aquifer system. It is composed of hydraulically connected sediments of the Kirkwood Formation, Cohansey Sand, and overlying surficial deposits. In Cape May County the Cohansey Sand is under artesian conditions.

CHLORIDE CONCENTRATIONS IN GROUND WATER IN THE COASTAL PLAIN OF NEW JERSEY

Figure 1 shows locations of significant saltwater intrusion in the principal Coastal Plain aquifers. The following sections are county by county descriptions of chloride concentrations in ground water.

Middlesex County

All wells sampled are screened in either the Old Bridge aquifer or the underlying Farrington aquifer. In 1977, 57 samples were collected from 40 wells. Twelve of these wells tap the Old Bridge and 28 tap the Farrington. Well records and chloride analyses are shown in table 2, and the well locations are shown in figure 2.

The movement of saltwater into the Farrington aquifer in areas near the Raritan and South Rivers has been documented for about 40 years (Barksdale and others, 1943; Appel, 1962; Hasan and others, 1969). Data collected during 1977 indicate a continued increase in chloride concentrations south of the Raritan River in Sayreville Borough, South Amboy City, and in adjacent areas of Old Bridge Township. The distribution of chloride concentrations in 1977 is shown on figure 3. The direction of ground-water movement indicated in figure 3 is based on the potentiometric surface of the Farrington aquifer in November, 1973 (Farlekas, 1979, p. 17).

Saltwater in the Farrington aquifer continues to move south and southeast through large areas in Sayreville Borough and South Amboy City. In the summer of 1977, Sayreville WD well M (map No. 352) and the nearby Perth Amboy WD well 2 (map No. 197) yielded chloride concentrations of 100 mg/L and 49 mg/L, respectively. Historical data from Perth Amboy WD well 2, which has been sampled frequently during the past 20 years, show evidence of saltwater intrusion beginning about 1970 (fig. 4).

There were indications about 1977 that saltwater was moving southwestward toward the South River WD well field. This is indicated by slowly increasing chloride concentration in South River WD well 2 (map No. 434, see fig. 4), and by samples from two other wells (fig. 3) north of the borough well field, South River 2 obs. (map No. 439) and Thomas and Chadwick 1 (map No. 440). These two wells contained chloride concentrations of 12 mg/L and 16 mg/L, respectively. A third well, DuhSay 4 obs. (map No. 365), on the eastern shore of South River, 0.5 mi from the borough well field, had a chloride concentration of 520 mg/L.

Increased chloride concentrations in 1977 were also found at the E.I. duPont well field in Sayreville. A September, 1977 sample from duPont well 3 (map No. 393) contained 47 mg/L. The previous recorded maximum was 8.1 mg/L in September, 1973. Two samples in 1977 from the Duhernal Water System 60F well (map No. 425) located nearby yielded chloride concentrations of 535 and 680 mg/L. In 1974, chloride concentration from this well was about

Table 2.--Well records and chloride analyses from saltwater monitoring network wells in Middlesex County, 1977 water year

[Geologic unit (aquifer): 211ODBG - Old Bridge aquifer; 211FRNG - Farrington aquifer]

MAP* NO.	LOCAL NAME AND WELL NUMBER	LATITUDE	LONGITUDE	GEOLOGIC UNIT	ELEVATION OF LAND SURFACE ABOVE NGVD OF 1929 (FT)	SCREENED INTERVAL (FT)	DATE OF SAMPLE	CHLORIDE (MG/L AS CL)
135	OLD BRIDGE TWP MUA-BRN 2	40 23 45	74 18 38	211ODBG	95	190-250	JAN 5, 1977	2.7
192	PERTH AMBOY WD 3	40 25 35	74 20 14	211ODBG	15	48- 68	AUG 18, 1977	31
193	PERTH AMBOY WD 4	40 25 36	74 20 12	211ODBG	15	51- 66	APR 6, 1977	51
				211ODBG	15	51- 66	AUG 18, 1977	55
195	PERTH AMBOY WD 5	40 25 37	74 20 02	211ODBG	15	50- 80	AUG 18, 1977	12
196	PERTH AMBOY WD 1A	40 25 37	74 20 20	211FRNG	20	201-261	APR 6, 1977	4.8
				211FRNG	20	201-261	AUG 18, 1977	6.3
197	PERTH AMBOY WD 2	40 25 43	74 20 10	211FRNG	20	205-260	APR 6, 1977	9.0
				211FRNG	20	205-260	JULY 6, 1977	49
				211FRNG	20	205-260	AUG 18, 1977	42
434	SOUTH RIVER BORO WD 2	40 25 56	74 21 41	211FRNG	20	173-198	AUG 18, 1977	7.2
432	SOUTH RIVER BORO WD 4-75	40 25 57	74 21 38	211FRNG	20	149-179	AUG 18, 1977	6.1
438	SOUTH RIVER BORO WD 5-77	40 25 59	74 21 42	211FRNG	20	132-182	AUG 31, 1977	7.0
346	SAYREVILLE BORO WD B	40 26 04	74 20 04	211ODBG	27	71- 81	APR 6, 1977	63
				211ODBG	27	71- 81	SEPT 30, 1977	130
352	SAYREVILLE BORO WD M	40 26 09	74 19 52	211FRNG	35	225-278	SEPT 30, 1977	100
355	SAYREVILLE BORO WD A	40 26 14	74 19 50	211ODBG	30	72- 82	SEPT 30, 1977	85
365	DUHSAY 4 OBS**	40 26 33	74 21 20	211FRNG	6	148-160	NOV 30, 1977	520
368	SAYREVILLE BORO WD I	40 26 26	74 19 36	211ODBG	58	83- 94	APR 6, 1977	13
				211ODBG	58	83- 94	SEPT 30, 1977	12
371	HERCULES INC 5	40 26 38	74 20 22	211FRNG	48	183-228	JULY 6, 1977	950
439	S. RIVER BORO WD 2 OBS**	40 26 33	74 22 00	211FRNG	21	121-126	NOV 30, 1977	12
440	THOMAS AND CHADWICK 1	40 26 47	74 22 27	211FRNG	21	167-195	SEPT 29, 1977	16
376	HERCULES INC 3	40 26 49	74 20 25	211FRNG	45	180-220	JULY 6, 1977	850
380	HERCULES INC 2	40 26 59	74 20 20	211FRNG	52	184-237	JULY 6, 1977	370
205	OLD BRIDGE TWP MUA-LH 1	40 27 00	74 14 59	211ODBG	60	193-213	JAN 5, 1977	3.9
				211ODBG	60	193-213	AUG 18, 1977	4.2
206	OLD BRIDGE TWP MUA-LH 2	40 27 00	74 14 59	211FRNG	60	360-395	AUG 18, 1977	3.3
383	EI duPONT-PARLIN 8A	40 27 03	74 18 59	211ODBG	93	97-116	SEPT 30, 1977	17
384	HERCULES INC 1R	40 27 05	74 20 23	211FRNG	59	170-225	JULY 6, 1977	200
386	EI duPONT-PARLIN 6	40 27 01	74 19 17	211FRNG	103	253-314	SEPT 30, 1977	1.1
389	EI duPONT-PARLIN 5	40 27 10	74 19 10	211FRNG	118	257-305	SEPT 30, 1977	17
392	EI duPONT-PARLIN 1	40 27 15	74 19 24	211FRNG	104	237-286	APR 6, 1977	6.0
				211FRNG	104	237-286	SEPT 30, 1977	7.5
393	EI duPONT-PARLIN 3	40 27 15	74 19 32	211FRNG	91	246-284	SEPT 30, 1977	47
401	SAYREVILLE BORO WD P	40 27 44	74 16 28	211FRNG	40	254-288	SEPT 30, 1977	2.2
403	SAYREVILLE BORO WD Q-73	40 27 45	74 16 31	211ODBG	40	78-136	JAN 4, 1977	4.0
				211ODBG	40	78-136	SEPT 30, 1977	16
411	SOUTH AMBOY CITY WD 8	40 28 22	74 16 30	211FRNG	10	210-234	NOV 16, 1976	4.2
413	SOUTH AMBOY CITY WD 9	40 28 24	74 16 31	211ODBG	10	33- 48	NOV 16, 1976	15
				211ODBG	10	33- 48	AUG 18, 1977	15
414	SOUTH AMBOY CITY WD 10	40 28 25	74 16 32	211ODBG	10	39- 49	JAN 4, 1977	17
				211OBDG	10	39- 49	AUG 18, 1977	18
415	NL INDUSTRIES 4	40 28 31	74 18 15	211FRNG	109	220-251	APR 6, 1977	4.7
418	NL INDUSTRIES 3	40 28 42	74 18 11	211FRNG	120	240-270	APR 6, 1977	7.6
430	JERSEY CENT P&L-WERNER 7	40 29 23	74 16 51	211FRNG	10	135-165	NOV 16, 1976	377
				211FRNG	10	135-165	SEPT 29, 1977	710
425	DUHERNAL WS 60F	40 27 29	74 19 38	211FRNG	149	282-287	APR 6, 1977	535
				211FRNG	149	282-287	SEPT 30, 1977	680
255	CARBORUNDUM CO 1	40 30 46	74 18 27	211FRNG	15	57- 67	NOV 16, 1976	13
				211FRNG	15	57- 67	SEPT 29, 1977	12
263	CHEVRON OIL CO 2	40 32 00	74 16 20	211FRNG	45	96-106	NOV 16, 1976	8.7
				211FRNG	45	96-106	SEPT 29, 1977	9.2
473	HAAGEN DAZS INC	40 32 33	74 16 33	211FRNG	30	39- 59	NOV 16, 1976	82
				211FRNG	30	39- 59	SEPT 29, 1977	240
478	AMERICAN CYANAMID CO 2A	40 32 36	74 16 16	211FRNG	9	45- 60	NOV 16, 1976	76
				211FRNG	9	45- 60	SEPT 29, 1977	110

*Well locations shown in figure 2.
**Sampled in 1978 water year.

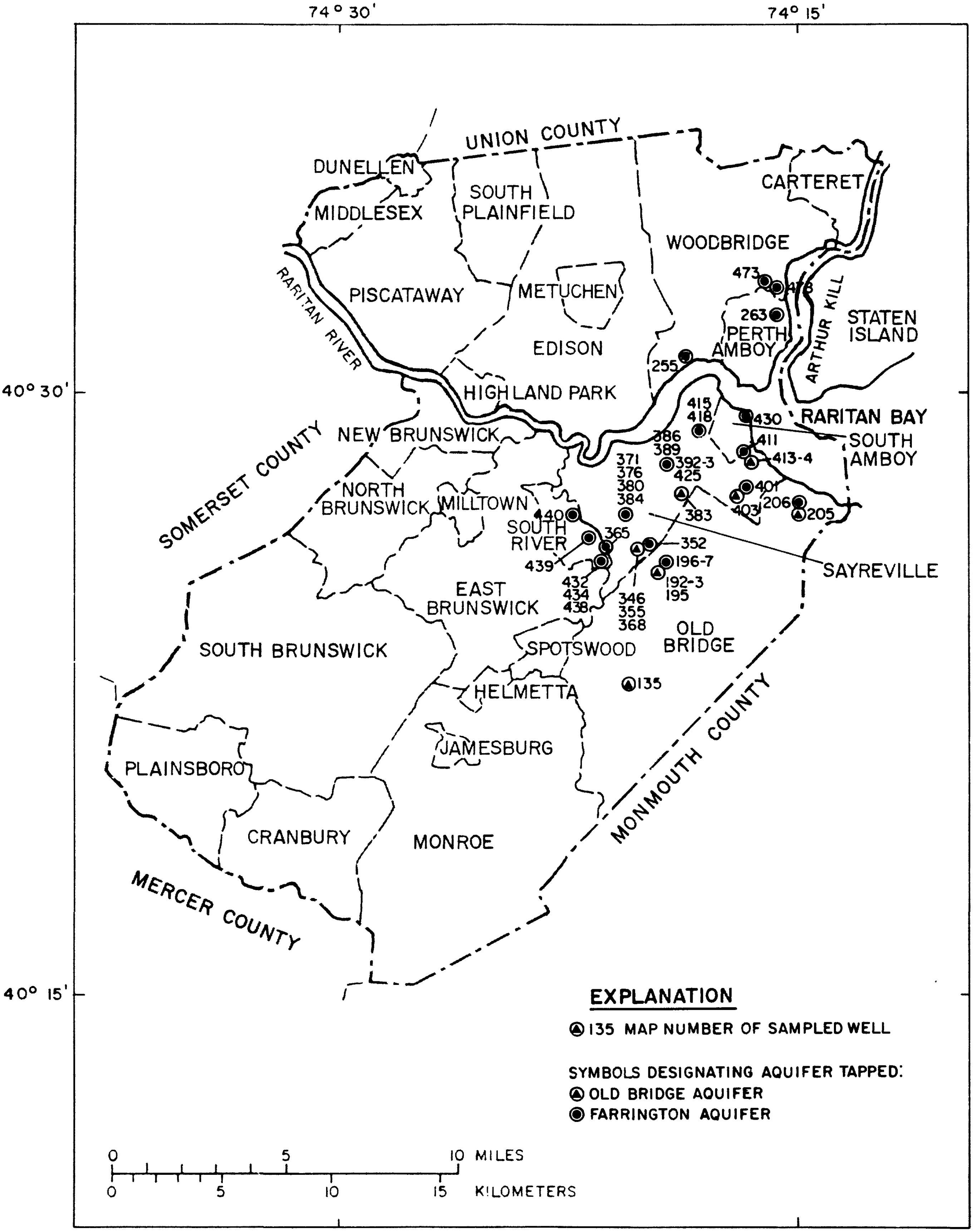


Figure 2.--Location of saltwater monitoring network wells in Middlesex County.

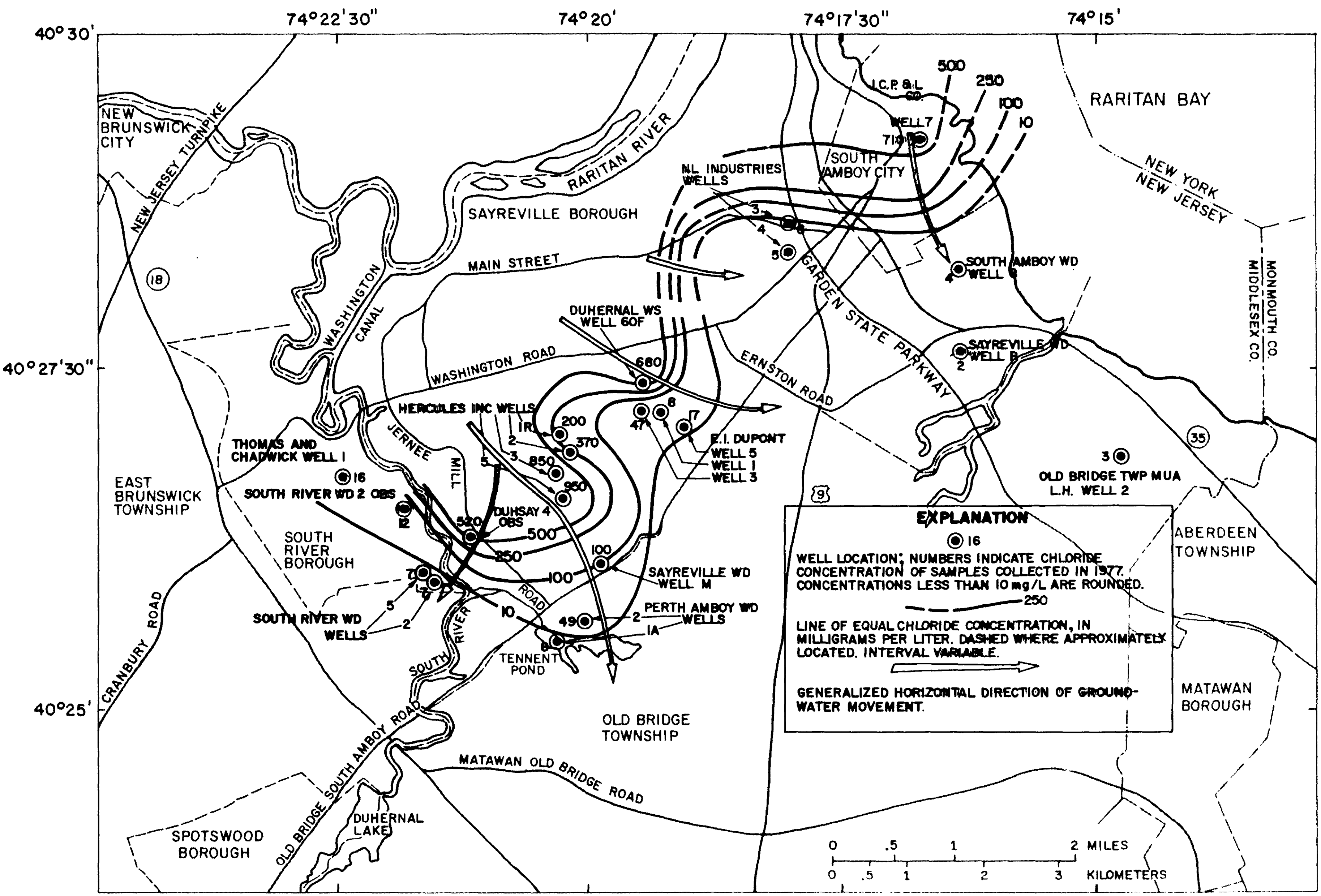


Figure 3.--Map of the Sayreville area, Middlesex County, showing well locations, chloride concentrations, and ground-water movement in the Farrington aquifer, 1977.

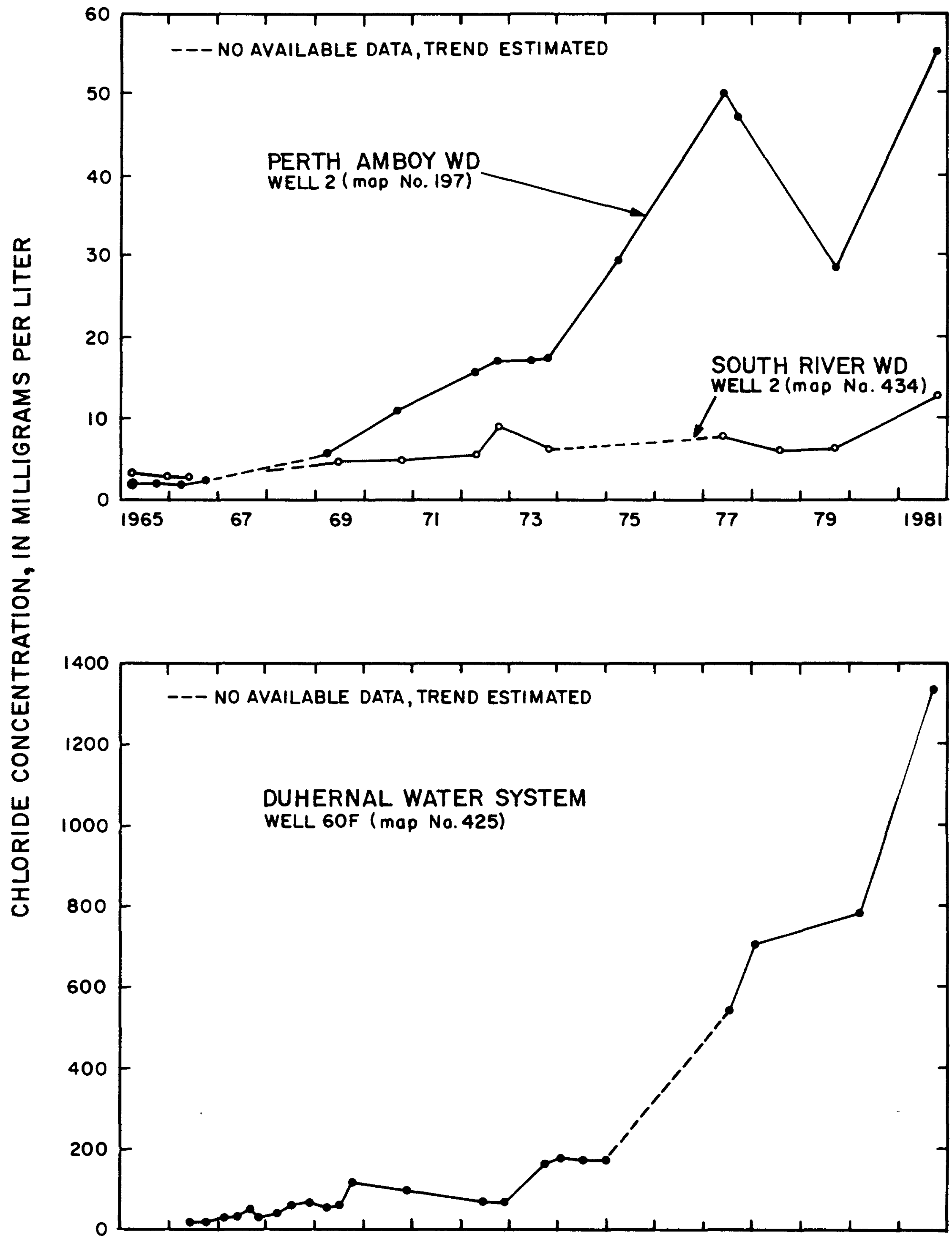


Figure 4.--Chloride concentrations from selected wells tapping the Farrington aquifer in the Sayreville area, Middlesex County, 1965-81.

130 mg/L (fig. 4). In the vicinity of the Garden State Parkway, wells sampled at the NL Industries, South Amboy City WD, and Sayreville Borough WD-Morgan well fields do not show significant upward trends. However, the Jersey Central Power and Light Co. (J.C.P. and L. Co.) Werner well 7 (map No. 430) located to the northeast (fig. 3) had a chloride concentration of 710 mg/L in September 1977, compared to 377 mg/L in November 1976.

Since 1977, chloride concentrations have continued to increase in many of the wells in the Farrington aquifer shown in figure 3. The following comparison of 1977, 1979, and 1981 data illustrates this upward trend:

Well name	Chloride concentration, in milligrams per liter	
	1977	1981
Perth Amboy WD 1A	6.3	32
Perth Amboy WD 2	49	54
South River Boro WD 2	7.2	12
South River Boro WD 5-77	7.0	12
South River Boro WD 2 obs.	12	26
Sayreville Boro WD M	100	190*
Thomas and Chadwick 1	16	42*
EI duPont - Parlin 1	7.5	45
EI duPont - Parlin 3	47	96
Duhernal Water System 60F	680	1,300
NL Industries 3	7.6	55*

*Sampled in 1979.

These data suggest an additional 0.2 to 0.4 mi inland migration of the freshwater-saltwater transition zone as compared to 1977.

North of Raritan River in Perth Amboy City and Woodbridge Township, chloride concentrations from four wells tapping the Farrington ranged from 8.7 to 240 mg/L. The maximum of record for the Haagen Dazs Inc. well (map No. 473, formerly owned by Swift and Company) is 240 mg/L; the previous recorded maximum was 96 mg/L in September, 1972. The data from the other three wells (map Nos. 255, 263, 478), however, are comparable to past records. The source of high chloride concentration in this area is believed to be a result of either surface contamination from industrial wastes, sporadic tidal flooding, or saltwater intrusion from the Arthur Kill. Data collected subsequent to 1977 do not indicate significant changes in chloride distribution in the Farrington aquifer in this area.

Twelve wells tapping the Old Bridge aquifer in the Sayreville area were sampled in 1977. Several show concentrations in excess of 10 mg/L (fig. 5). The Old Bridge aquifer is vulnerable to saltwater intrusion from South River and its tributaries and from Raritan Bay. The aquifer is relatively shallow in and near the outcrop area and, therefore, very susceptible to contamination from vertical leakage from the surface in the vicinity of the outcrop. Poor waste-disposal practices and accidental spills of pollutants have been considered the cause of the water-quality problems, including elevated chlorides, in some areas of the Old Bridge aquifer (Hasan and others, 1969, p. 11).

Figure 6 illustrates the trends in chloride concentration from wells tapping the Old Bridge aquifer at the Perth Amboy WD and Sayreville WD well fields. Most of the wells sampled at these two well fields have yielded chloride concentrations in excess of 10 mg/L in recent years, and wells nearest to South River and its tidal tributaries generally had the highest salinities in 1977-81. A comprehensive investigation is required to determine the source of these high chloride concentrations.

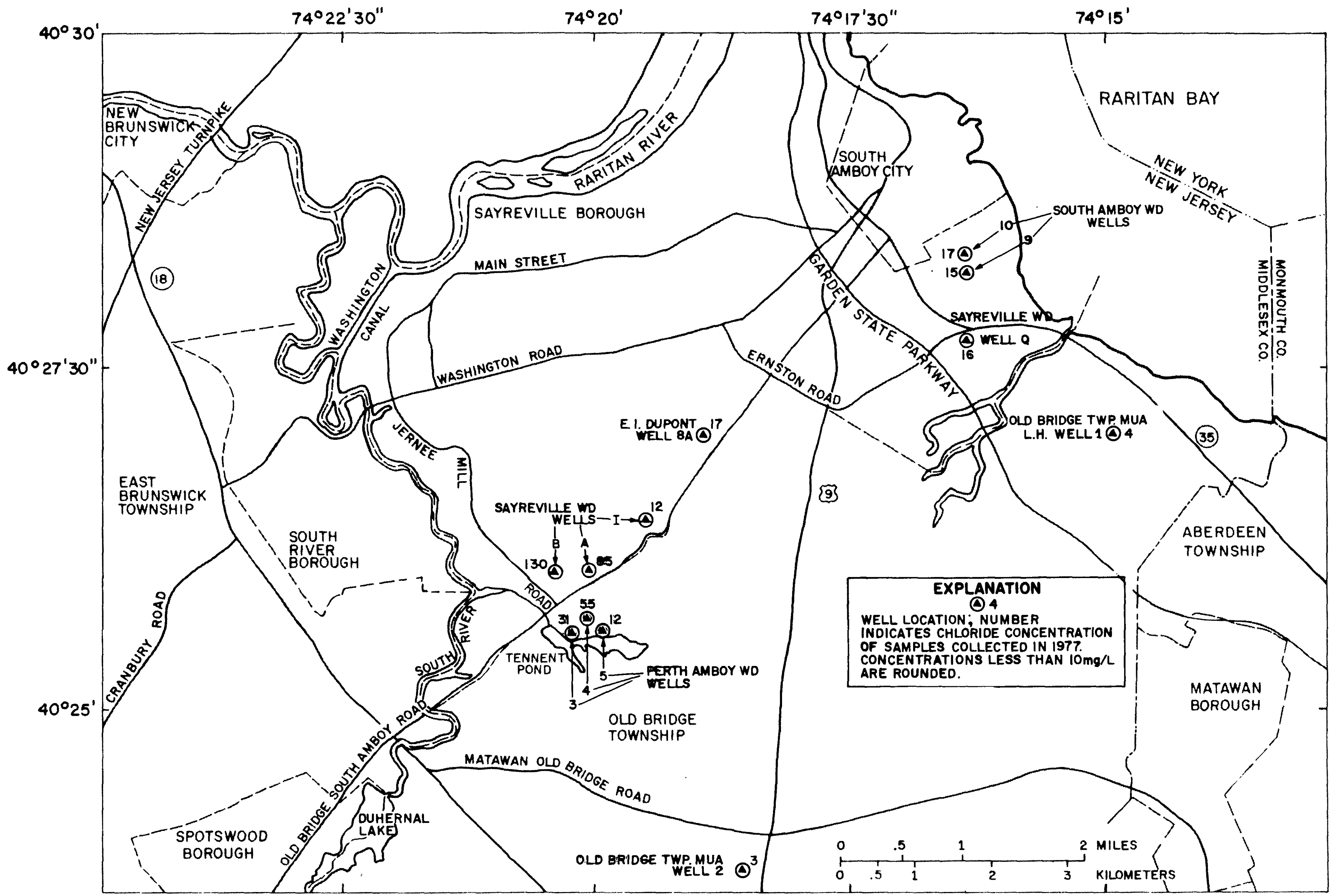


Figure 5.--Map of the Sayreville area, Middlesex County, showing well locations and chloride concentrations from wells tapping the Old Bridge aquifer, 1977.

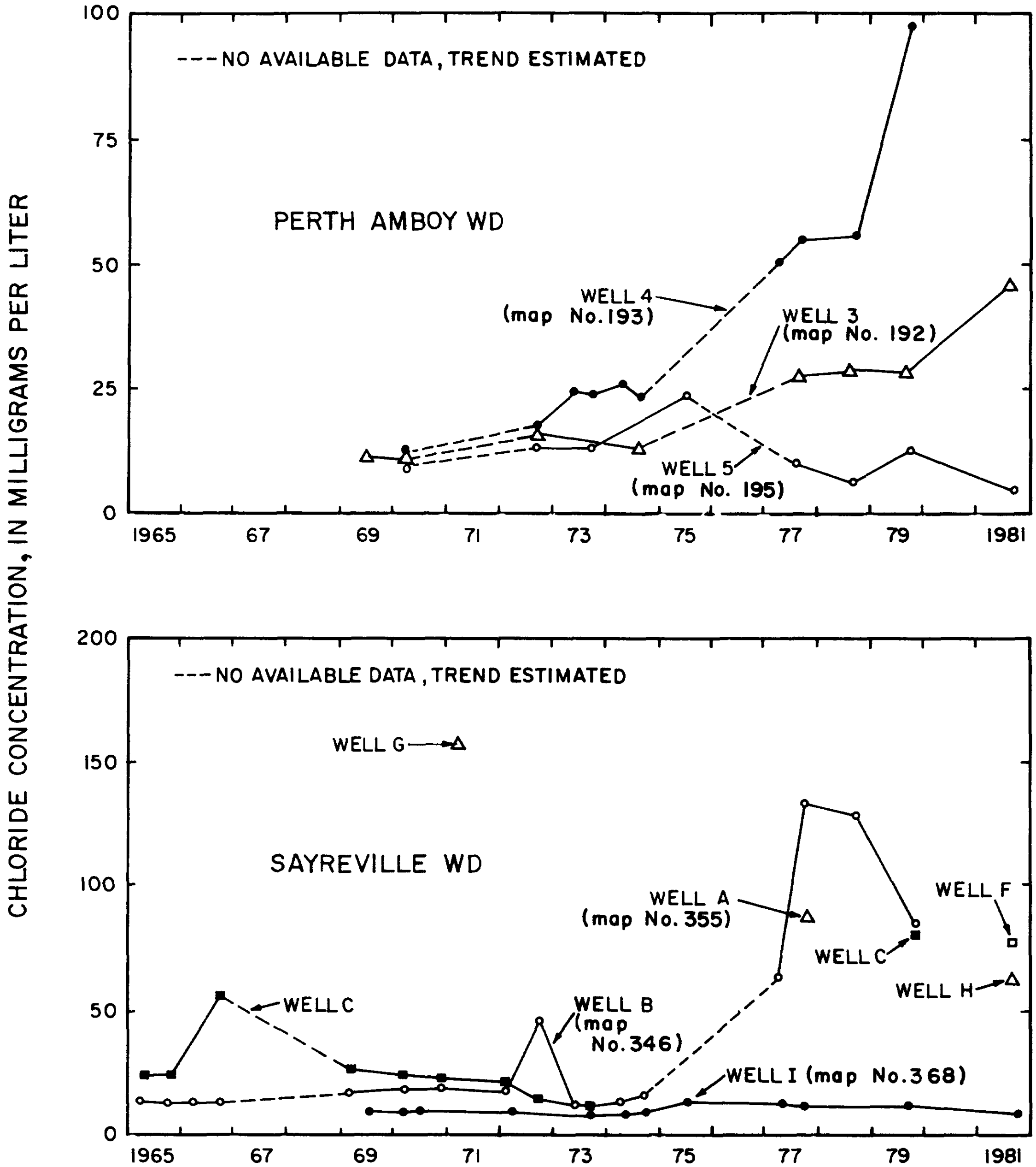


Figure 6.--Chloride concentrations from selected wells tapping the Old Bridge aquifer in the Sayreville area, Middlesex County, 1965-81.

Monmouth County

Seventy-nine samples were collected from 50 wells near Raritan Bay and along the Atlantic Coast. These wells tap the Farrington and Old Bridge aquifers, the Englishtown aquifer, the Wenonah-Mount Laurel aquifer, and the Kirkwood-Cohansey aquifer system. Well records and chloride analyses are shown in table 3, and the well locations are shown in figure 7.

The most significant finding is the increasing salinity from wells tapping the Old Bridge aquifer in Keyport and Union Beach Boroughs. Schaefer and Walker (1981) describes the source, areal extent, and reasons for intrusion of saltwater. The following is a summary of some of the major findings:

1. An analysis of the changes in freshwater head and chloride concentration indicate that saline water has moved into the Old Bridge aquifer from the Old Bridge outcrop submerged beneath Raritan Bay.

2. The saline water reached some of the coastal wells at Keyport and Union Beach in significant amounts by 1972-73.

3. Data from 1950 to 1968 indicate that the background chloride concentrations in the Old Bridge aquifer were generally less than 5 mg/L. However, by 1977 chloride concentration had increased to more than 600 mg/L at one well in the Union Beach WD well field and 98 mg/L at one well in Keyport (Infern-o-therm Co. map No. 208).

4. By January 1977, withdrawals from the Old Bridge aquifer had lowered the hydraulic head in the center of the cone of depression to 45 ft below sea level.

5. The rate of ground-water movement was about 400 ft/yr in January 1977. The primary direction of movement was from Raritan Bay to the southeast toward the center of the cone of depression in Hazlet Township.

The original Keyport well field near Raritan Bay was abandoned in May 1976. All of the wells tap the Old Bridge aquifer. Only wells 5 (map No. 202) and 6 were in use during 1975-76. Wells 1 and 4 (map No. 206) were abandoned in 1965 and 1974, respectively. Since 1977, these four wells were sampled using portable submersible pumps. Between 1977 and 1981, chlorides from all four wells have not changed significantly (about 40-100 mg/L). This is probably due to the cessation of pumping. Although the concentration of chloride at the well field has not changed since 1977, the variation in chlorides between individual wells has changed. The cause or significance of this is not known at present. Keyport well 7 (map No. 197), drilled in 1976, is about 1 mi south of the original well field near the southern Keyport Borough boundary. Samples collected from well 7 from 1976 to 1981 have yielded low chlorides between 1.5 and 2.6 mg/L.

Table 3.--Well records and chloride analyses from saltwater monitoring network wells in Monmouth County, 1977 water year

[Geologic unit (aquifer): 121CKKD - Kirkwood-Cohansey aquifer system; 211MLRW - Wenonah-Mount Laurel aquifer; 211EGLS - Englishtown aquifer; 211ODBG - Old Bridge aquifer; 211FRNG - Farrington aquifer]

MAP* NO.	LOCAL NAME AND WELL NUMBER	LATITUDE	LONGITUDE	GEOLOGIC UNIT	ELEVATION OF LAND SURFACE ABOVE NGVD OF 1929 (FT)	SCREENED INTERVAL (FT)	DATE OF SAMPLE	CHLORIDE (MG/L AS CL)
29	BRIELLE BORO WD 1	40 06 44	74 03 44	121CKKD	33	130- 150	JULY 27, 1977	8.0
233	MANASQUAN BORO WD 6	40 07 10	74 03 29	121CKKD	10	- 180	JULY 27, 1977	9.5
234	MANASQUAN BORO WD 3	40 07 12	74 03 28	121CKKD	15	118**	JULY 27, 1977	14
235	MANASQUAN BORO WD 2R	40 07 12	74 03 28	121CKKD	21	103- 118	JULY 27, 1977	14
236	MANASQUAN BORO WD 1R	40 07 13	74 03 29	121CKKD	15	98- 116	JULY 27, 1977	11
237	MANASQUAN BORO WD 5	40 07 14	74 03 29	121CKKD	15	97- 117	JULY 27, 1977	11
464	SEA GIRT BORO WD 6	40 08 01	74 02 31	121CKKD	21	80- 130	JULY 27, 1977	11
470	SEA GIRT BORO WD 2	40 08 02	74 02 28	121CKKD	21	159**	JULY 27, 1977	9.8
374	SEA GIRT BORO WD 5	40 08 04	74 02 27	211EGLS	20	660- 710	JULY 27, 1977	0.5
383	SPRING LAKE BORO WD 1	40 08 49	74 02 07	211EGLS	15	631- 711	JULY 27, 1977	0.6
386	SPRING LAKE BORO WD 4	40 09 52	74 01 49	211EGLS	10	600- 670	JULY 27, 1977	1.2
18	BELMAR BORO WD 2-ELEC	40 10 38	74 01 46	211EGLS	20	581**	JULY 28, 1977	2.8
13	AVON-BY-THE-SEA WD 4	40 11 37	74 01 21	211ODBG	29	1105-1165	JULY 28, 1977	2.0
14	AVON-BY-THE-SEA WD 1	40 11 38	74 01 25	211MLRW	28	424- 504	JULY 28, 1977	2.8
336	MON CON WC-OCEAN GROVE 21	40 12 16	74 01 08	211MLRW	20	395- 430	JULY 28, 1977	3.5
1	ALLENHURST BORO WD 4	40 14 01	74 00 25	211EGLS	10	525- 565	JULY 28, 1977	2.2
358	RED BANK BORO WD 1B-50	40 20 47	74 04 20	211ODBG	40	637- 687	AUG 3, 1977	7.2
190	KEANSBURG BORO MUA 4	40 26 21	74 07 38	211ODBG	10	280- 340	OCT 20, 1976	3.4
				211ODBG	10	280- 340	AUG 31, 1977	2.0
288	MATAWAN TWP MUA 3	40 23 59	74 12 35	211ODBG	94	345- 425	JAN 5, 1977	2.3
117	HIGHLANDS BORO WD 4-73	40 24 01	73 59 20	211ODBG	20	630- 680	AUG 3, 1977	2.4
295	MATAWAN BORO WD 2	40 24 27	74 13 48	211ODBG	20	228- 258	OCT 21, 1976	4.3
				211ODBG	20	228- 258	JAN 4, 1977	2.8
6	ATL HIGHLANDS BORO WD 1	40 24 37	74 02 36	211ODBG	20	519- 582	JAN 13, 1977	3.1
8	ATL HIGHLANDS BORO WD 3	40 24 41	74 02 33	211ODBG	20	547- 572	JAN 13, 1977	6.0
				211ODBG	20	547- 572	AUG 31, 1977	0.2
9	ATL HIGHLANDS BORO WD 2	40 24 41	74 02 34	211EGLS	15	180- 200	JAN 13, 1977	6.6
				211EGLS	15	180- 200	AUG 31, 1977	6.0
153	W KEANSBURG WC-HOLMDEL 4	40 24 43	74 10 10	211FRNG	65	635- 690	OCT 20, 1976	4.3
				211FRNG	65	635- 690	AUG 31, 1977	0.4
154	W KEANSBURG WC-HOLMDEL 3	40 24 45	74 10 19	211ODBG	73	400- 430	JAN 6, 1977	0.4
				211ODBG	73	400- 430	AUG 31, 1977	2.8
314	ENGR PRECISION CAST CO	40 25 00	74 08 11	211ODBG	20	354- 364	JAN 13, 1977	2.1
284	MATAWAN BORO WD 3	40 25 15	74 14 50	211ODBG	90	231- 271	OCT 21, 1976	6.2
				211ODBG	90	231- 271	JAN 5, 1977	4.4
				211ODBG	90	231- 271	SEPT 1, 1977	3.9
195	KEANSBURG BORO MUA 5A	40 26 21	74 07 43	211ODBG	10	290- 350	OCT 20, 1976	4.0
				211ODBG	10	290- 350	JAN 7, 1977	1.8
				211ODBG	10	290- 350	AUG 31, 1977	4.0
111	W KEANSBURG WC-HAZLET 1	40 25 33	74 09 32	211ODBG	59	327- 366	OCT 20, 1976	3.3
				211ODBG	59	327- 366	JAN 6, 1977	1.8
				211ODBG	59	327- 366	AUG 31, 1977	3.0
112	W KEANSBURG WC-HAZLET 2	40 25 37	74 09 33	211ODBG	44	312- 352	OCT 20, 1976	2.4
				211ODBG	44	312- 352	AUG 31, 1977	2.0
197	KEYPORT BORO WD 7	40 25 35	74 12 14	211ODBG	35	304- 354	OCT 20, 1976	2.6
316	SANDY HOOK SP OBS 1	40 25 36	73 59 05	211ODBG	11	371- 391	SEPT 7, 1977	2.2
199	KERR GLASS CO	40 25 42	74 12 20	211ODBG	20	285- 315	JAN 5, 1977	2.0
294	MATAWAN BORO WD 1	40 24 27	74 13 45	211ODBG	30	210- 235	OCT 21, 1976	3.3
				211ODBG	30	210- 235	SEPT 1, 1977	0.7
317	SEA COAST PRODUCTS 1	40 26 12	74 05 11	211ODBG	10	420**	MAR 31, 1977	6.3
				211ODBG	10	420**	AUG 31, 1977	9.3
201	LEX LUCAS	40 26 15	74 10 55	211ODBG	20	250- 282	APR 20, 1977	3.1
299	MATAWAN TWP WD-LAYNE 2	40 26 04	74 14 17	211FRNG	70	422- 457	OCT 21, 1976	5.5
				211FRNG	70	422- 457	SEPT 1, 1977	2.9
191	KEANSBURG BORO MUA 6-68	40 26 20	74 07 42	211ODBG	10	302- 362	OCT 20, 1976	3.6
				211ODBG	10	302- 362	AUG 31, 1977	4.6
202	KEYPORT BORO WD 5	40 26 24	74 11 45	211ODBG	10	204- 261	OCT 20, 1976	9.0
206	KEYPORT BORO WD 4	40 26 26	74 11 42	211ODBG	14	225- 285	MAR 30, 1977	7.3
196	KEANSBURG BORO MUA 3	40 26 28	74 07 44	211ODBG	12	308- 348	OCT 20, 1976	3.3
				211ODBG	12	308- 348	JAN 7, 1977	2.0
				211ODBG	12	308- 348	AUG 31, 1977	0.4
208	INFERN-O-THERM CO	40 26 30	74 11 29	211ODBG	15	300**	MAR 31, 1977	98

Table 3.--Well records and chloride analyses from saltwater monitoring network wells in Monmouth County, 1977 water year--Continued

MAP* NO.	LOCAL NAME AND WELL NUMBER	LATITUDE	LONGITUDE	GEOLOGIC UNIT	ELEVATION OF LAND SURFACE ABOVE NGVD OF 1929 (FT)	SCREENED INTERVAL (FT)	DATE OF SAMPLE	CHLORIDE (MG/L AS CL)
419	UNION BEACH BORO WD 1-62	40 26 32	74 10 49	211ODBG	10	235- 285	OCT 21, 1976	194
				211ODBG	10	235- 285	JAN 6, 1977	198
				211ODBG	10	235- 285	MAR 30, 1977	224
				211ODBG	10	235- 285	APR 20, 1977	232
				211ODBG	10	235- 285	AUG 15, 1977	260
				211ODBG	10	235- 285	SEPT 1, 1977	250
453	UNION BEACH BORO WD 3-77	40 26 32	74 10 51	211FRNG	10	480- 532	SEPT 1, 1977	4.3
420	UNION BEACH BORO WD 2-69	40 26 34	74 10 52	211ODBG	10	262- 289	OCT 21, 1976	401
				211ODBG	10	262- 289	MAR 30, 1977	660
424	INT FLAVOR FRAG 2	40 26 41	74 09 11	211ODBG	10	302- 326	OCT 20, 1976	3.3
				211ODBG	10	302- 326	JAN 6, 1977	2.2
				211ODBG	10	302- 326	SEPT 1, 1977	0.2
423	INT FLAVOR FRAG 1	40 26 41	74 09 19	211ODBG	10	298- 328	OCT 20, 1976	2.3
				211ODBG	10	298- 328	JAN 6, 1977	2.8
				211ODBG	10	298- 328	SEPT 1, 1977	1.0
320	NPS-SANDY HOOK 5A-70	40 27 05	73 59 59	211FRNG	10	838- 878	SEPT 1, 1977	7.0
321	NPS-SANDY HOOK 4	40 27 06	73 59 52	211ODBG	15	332- 486	SEPT 1, 1977	42

*Well locations shown in figure 7.
**Total depth of well.

At Union Beach, well 2-69 (map No. 420) was sampled in October 1979 and in October 1981, and the chloride concentrations were 950 and 1,400 mg/L, respectively. These concentrations are the highest of record for the two wells in the Old Bridge aquifer at Union Beach (wells 2-69 and 1-62), even though both wells have not been pumped except for monitoring, since late 1977 or early 1978. The increasing chlorides at the Union Beach well field indicate a continuing movement of high chloride water in the Old Bridge aquifer to the southeast. Starting in 1977, Union Beach used the well tapping the Farrington aquifer, well 3-77 (map No. 453), for their total water supply. In this area of Monmouth County, the Farrington aquifer has not experienced saltwater intrusion.

As of 1981, elevated chlorides were not measured in any wells in the Old Bridge aquifer in areas surrounding the Keyport and Union Beach well fields except for the following. Samples collected from a well owned by the Keansburg Amusement Park Co. located in the extreme northern tip of Keansburg Borough, about 1,000 ft from Raritan Bay, contained elevated concentrations of chloride. This well (screened interval 200-250 ft) was unknown to us prior to 1978, consequently, no data is shown in either table 3 or figure 7. However, samples collected in September or October in 1978, 1979, and 1981 yielded 18, 20, and 38 mg/L of chloride, respectively (all above the background level of 5 mg/L). Wells owned by the Keansburg MUA, located 1.2 mi south of the Amusement

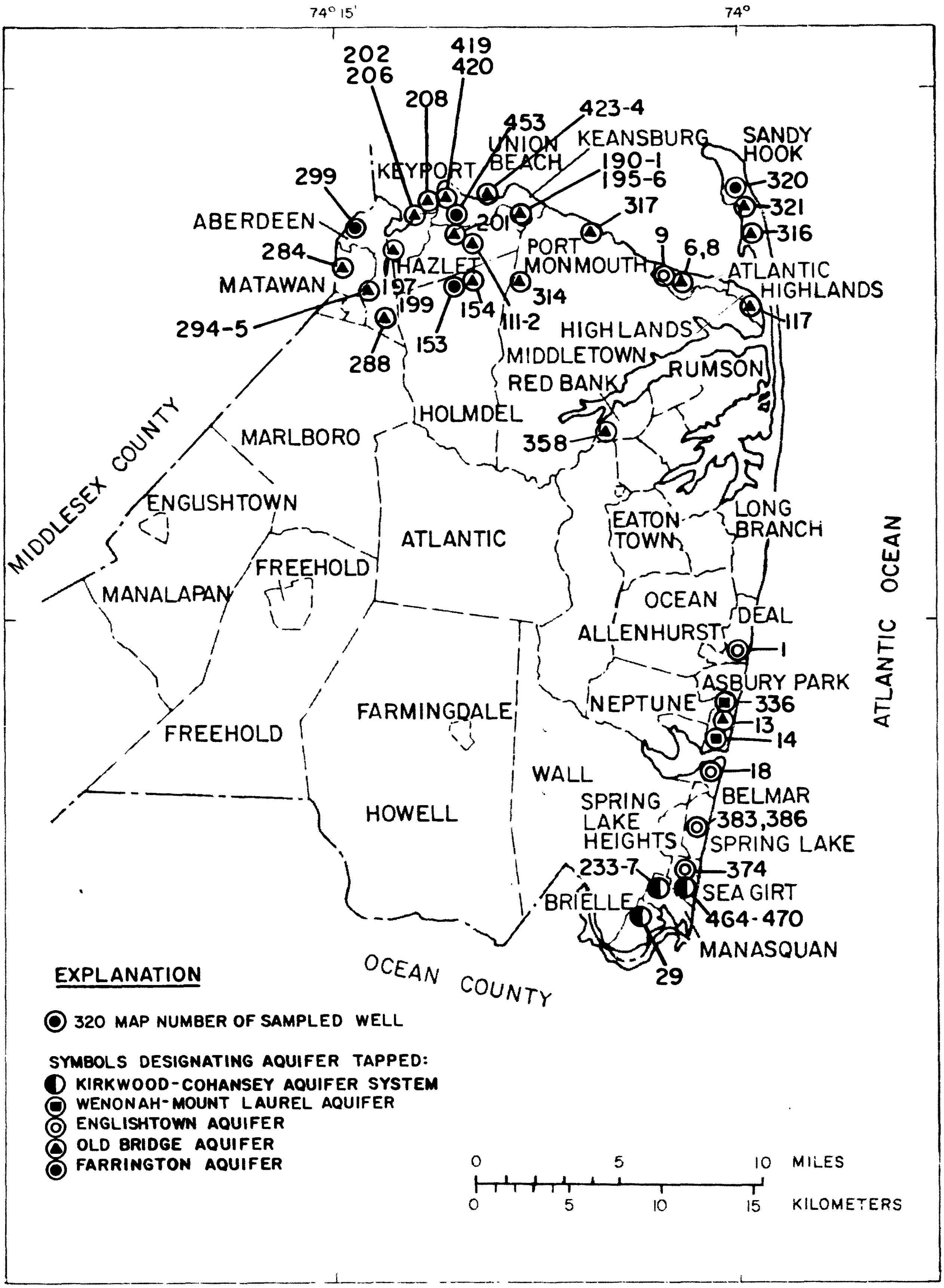


Figure 7.--Location of saltwater monitoring network wells in Monmouth County.

Company well, also yielded elevated chloride concentrations in 1980-81. Chlorides from two of the four Keansburg MUA wells, 4 and 6-68 (map Nos. 190, 191), were 26 mg/L and 18 mg/L, respectively, in September 1981. Prior to 1980, chlorides from these wells varied between 1 and 5 mg/L. The source or significance of these elevated chlorides is not known at this time.

The 1977 analyses of water samples from wells along Raritan Bay east of Keansburg at Port Monmouth, from Atlantic Highlands and Highlands Boroughs, and at Sandy Hook ranged from about 1.0 to 9.0 mg/L. The NPS-Sandy Hook well 4 (map No. 321) yielded a higher chloride concentration of 42 mg/L in 1977. The range in concentration from 1948-77 was from 6.0 mg/L in 1956 to 68 mg/L in 1968. This Sandy Hook well taps a shallow zone within the Potomac-Raritan-Magothy aquifer system. Minard (1969, plate 1) indicates that Holocene beach sands directly overlie the Magothy Formation approximately 2 mi north of the NPS-Sandy Hook well 4. Because the beach sands are in direct contact with Raritan Bay and the Atlantic Ocean, the source of the high chloride may be offshore. This area of northern Monmouth County adjacent to the bays and ocean is especially susceptible to saltwater intrusion.

Along the Atlantic Coast in Monmouth County, 16 wells were sampled from Allenhurst southward to Brielle. Chloride concentrations from wells tapping the Old Bridge, Englishtown, and Wenonah-Mount Laurel aquifers ranged from 0.5 to 3.5 mg/L. The highest chloride concentrations (8-14 mg/L) were from eight wells tapping the Kirkwood-Cohansey aquifer system at Sea Girt, Manasquan, and Brielle Boroughs. A review of past records indicates no significant change in chlorides.

Ocean County

Twenty-six wells screened in the Potomac-Raritan-Magothy aquifer system, the Englishtown and Wenonah-Mount Laurel aquifers, the aquifer in the Manasquan Formation, the Atlantic City 800-foot sand in the Kirkwood Formation, and the Kirkwood-Cohansey aquifer system were sampled during 1977. Well records and chloride analyses are shown in table 4, and the well locations are shown in figure 8. Results from the 1977-81 sampling and from past records indicate no significant change in chloride concentration in most wells. The two exceptions are wells tapping the Kirkwood-Cohansey aquifer system at Point Pleasant Beach and at Seaside Heights Boroughs.

The intrusion of saline water into the Kirkwood-Cohansey aquifer system at Point Pleasant Beach was documented in 1972 (Donsky, written communication, 1972). Since that time saline water has been detected in samples from both wells 9 and 10 (map Nos. 521, 523, fig. 9). Well 10 is the northernmost well in the three-well system. Well 9 is about 1,800 ft south of well 10. Chloride concentrations from samples collected since the mid-1970's generally have exceeded 100 mg/L, and an increasing trend with time is evident. The reason for the decrease in chloride from Well 9 in 1981 is not known, but it is probably of little consequence. As of 1979, the chloride concentration from well 11 (map No. 579) was 13 mg/L and has not increased significantly. Well 11 is about 2,500 ft south of well 9.

Seaside Heights currently has three wells tapping the Kirkwood-Cohansey aquifer system and one tapping the aquifer in the Manasquan Formation. The historical record for the latter well does not indicate an upward trend in chloride concentration. However, samples from two of the three wells in the Kirkwood-Cohansey aquifer system, 1R and 3 (map Nos. 538, 539), do show a substantial rise in chloride especially since 1977 (fig. 9). These three wells are located on the bay side of the island, separated by approximately 2,000 ft.

At both Point Pleasant Beach and Seaside Heights, increases in chloride are probably attributable to saltwater, under pumping influence, entering the water-table aquifer near Barnegat Bay and/or the ocean and infiltrating downward into the hydraulically connected Kirkwood-Cohansey aquifer system.

Table 4.--Well records and chloride analyses from saltwater monitoring network wells in Ocean County, 1977 water year

[Geologic unit (aquifer): 121CKKD - Kirkwood-Cohansey aquifer system; 122KRKDL - Kirkwood Formation, Atlantic City 800-foot sand; 124MNSQ - Manasquan aquifer; 211EGLS - Englishtown aquifer; 211MRPA - Potomac-Raritan-Magothy aquifer system]

MAP* NO.	LOCAL NAME AND WELL NUMBER	LATITUDE	LONGITUDE	GEOLOGIC UNIT	ELEVATION OF LAND SURFACE ABOVE NGVD OF 1929 (FT)	SCREENED INTERVAL (FT)	DATE OF SAMPLE	CHLORIDE (MG/L AS CL)
9	BEACH HAVEN BORO WD 8	39 33 46	74 14 30	122KRKDL	5	572- 656	JULY 12, 1977	5.9
549	SHIP BOTTOM BORO WD 5-74	39 38 48	74 10 53	122KRKDL	5	528- 588	JULY 12, 1977	4.5
567	BARNEGAT WC 4-75	39 45 20	74 13 17	121CKKD	25	141- 163	JULY 12, 1977	7.0
4	BARNEGAT LIGHT BORO WD 2	39 45 24	74 06 32	124MNSQ	7	593- 646	JULY 12, 1977	2.6
512	OCEAN TWP MUA 1-60	39 47 44	74 11 29	121CKKD	10	140- 160	JULY 12, 1977	6.0
513	GARDEN STATE PKWY 1 OBS	39 47 42	74 14 20	121CKKD	50	18- 21	JAN 20, 1977	8.9
613	BERKELEY WC-PINEWALL	39 52 48	74 10 11	121CKKD	45	200**	JULY 21, 1977	7.5
23	SHORE WATER CO 2	39 54 23	74 04 59	124MNSQ	10	495- 527	JULY 13, 1977	2.1
540	SEASIDE PARK BORO WD 3	39 54 51	74 05 02	124MNSQ	4	459- 503	JULY 13, 1977	1.3
612	BERKELEY WC-BAYVILLE	39 54 54	74 09 06	121CKKD	20	90**	JULY 21, 1977	12
13	BEACHWOOD BORO WD 4	39 55 30	74 12 21	121CKKD	60	67- 97	JULY 12, 1977	9.3
508	OCEAN GATE BORO WD 3	39 55 28	74 08 26	121CKKD	7	133- 153	JULY 21, 1977	7.1
543	SEASIDE PARK BORO WD 5	39 56 07	74 04 43	124MNSQ	5	383- 425	JULY 13, 1977	2.4
538	SEASIDE HTS BORO WD 1R	39 56 36	74 04 39	121CKKD	5	144- 175	JULY 13, 1977	37
539	SEASIDE HTS BORO WD 3	39 56 43	74 04 43	121CKKD	4	146- 156	JULY 13, 1977	15
453	LAVALLETTE BORO WD 4	39 58 08	74 04 16	211MRPA	5	1358-1515	JULY 13, 1977	2.1
454	LAVALLETTE BORO WD 2	39 58 08	74 04 21	211EGLS	5	1009-1136	JULY 13, 1977	3.4
80	OCEAN CO COLLEGE 2-70	40 00 05	74 09 37	121CKKD	15	66- 80	JULY 13, 1977	9.3
614	TOMS R WC-SILVERTON 1-56	40 00 20	74 07 29	121CKKD	6	209- 236	JULY 13, 1977	5.6
504	OCEAN CO WC-MANTOLOKING 7	40 02 10	74 03 10	211MRPA	10	1263-1369	JULY 14, 1977	2.2
6	OCEAN CO WC BAYHEAD 6	40 04 05	74 02 44	211EGLS	10	778- 818	JULY 14, 1977	2.0
524	PT PLEASANT BORO WD 7	40 04 09	74 04 06	211MRPA	15	1183-1219	JULY 14, 1977	1.8
553	PT PLEASANT BORO WD 4	40 05 01	74 04 55	121CKKD	13	45- 75	JULY 14, 1977	5.3
579	PT PLEAS BEACH BORO WD 11	40 05 12	74 02 51	121CKKD	10	130- 143	JULY 14, 1977	13
521	PT PLEAS BEACH BORO WD 9	40 05 36	74 02 52	121CKKD	11	96- 131	JULY 14, 1977	130
523	PT PLEAS BEACH BORO WD 10	40 05 51	74 02 43	121CKKD	10	86- 130	JULY 21, 1977	110

*Well locations shown in figure 8.
**Total depth of well.

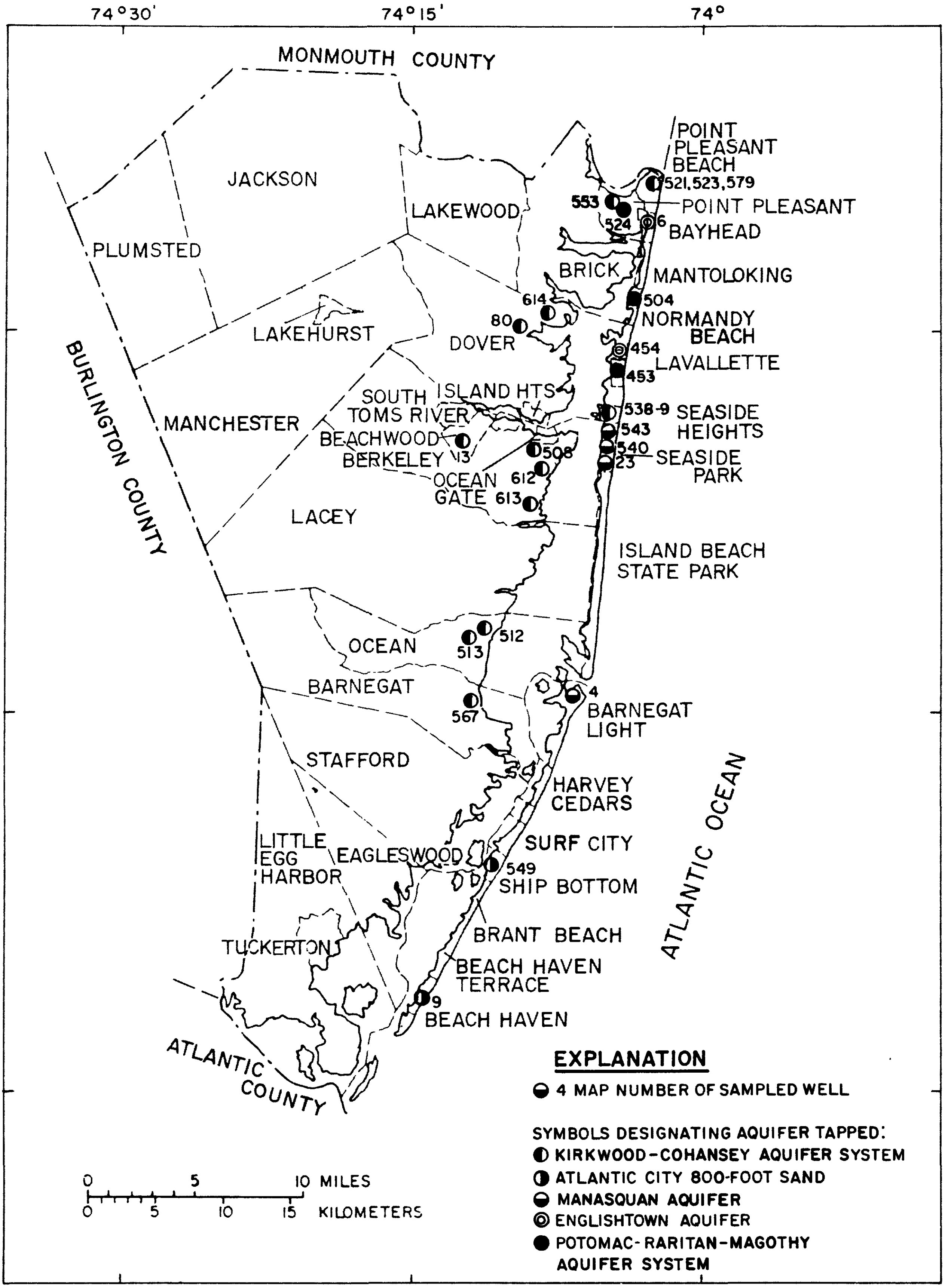


Figure 8.--Location of saltwater monitoring network wells in Ocean County.

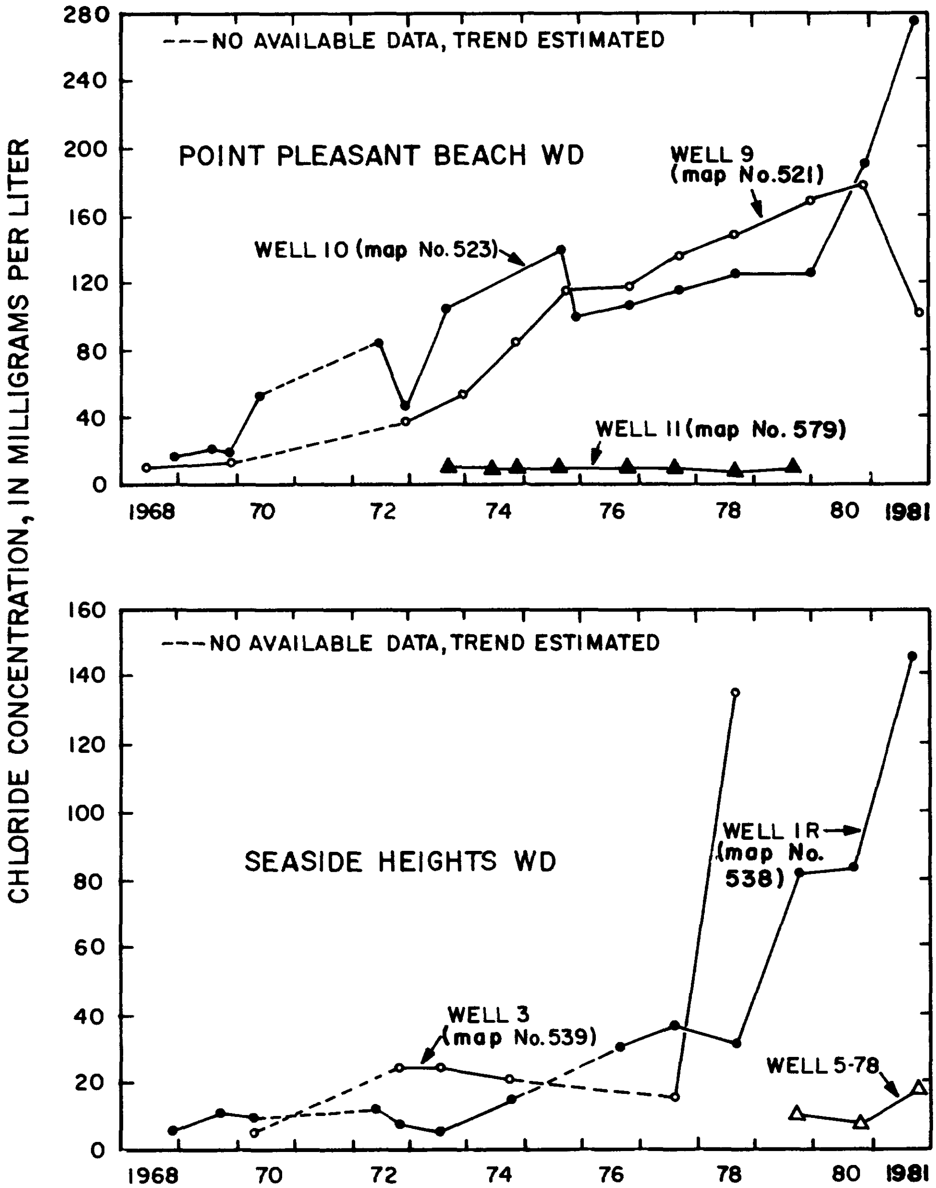


Figure 9.--Chloride concentrations from selected wells tapping the Kirkwood-Cohansey aquifer system at Point Pleasant Beach and Seaside Heights Boroughs, Ocean County, 1968-81.

Atlantic County

Twelve wells in Atlantic County were sampled in 1977. The well records and chloride analyses are shown in table 5, and the well locations are shown in figure 10. Data collected since 1977 in Atlantic County do not indicate any significant changes in the distribution of chlorides.

In Absecon, Pleasantville, and Somers Point, eight wells screened in the Kirkwood-Cohansey aquifer system were sampled in 1977, and the chloride analyses from seven of the wells (7.0 to 19 mg/L) are consistent with the historical record which shows no definite trend. The exception is a single well at Somers Point, NJWC-Atlantic Co.-Groveland (map No. 590). Somers Point is surrounded on three sides by tidal streams and Great Egg Harbor Bay. The well yielded a chloride concentration of 110 mg/L. This well has been affected by saltwater intrusion since 1969. This recent value, however, does not represent a sharply rising trend. Data supplied by the water company indicate chloride concentration from the Groveland well varied between 100 and 150 mg/L during 1969-77. Because of the high chloride concentration, this well has been pumped only during times of peak demand.

Chlorides in three wells tapping the Atlantic City 800-foot sand within the Kirkwood Formation at Ventnor City, Atlantic City, and Brigantine ranged from 3.3 to 11 mg/L and showed no change from long-term records.

The chloride concentration (54 mg/L) from the Marlborough-Blenheim well 3 (map No. 21) in Atlantic City is higher than nearby wells, but is within the range of chlorides recorded since the first sampling in 1934. From 1934 to 1954, chlorides ranged from 67 to 118 mg/L. The maximum concentration since the well was rebuilt in 1954 was 86 mg/L in 1972. It is believed that these elevated chlorides resulted primarily from leakage from the nearby Marlborough-Blenheim well 2 that was reported sealed in 1938. Furthermore, the structural integrity of well 3 has been suspect because an inner casing and new screen was installed in October 1954.

Since the 1930's other wells near the Marlborough-Blenheim Hotel have yielded higher than normal chlorides--greater than about 20 mg/L. Among these were Shelburne Hotel wells 1 and 2, Traymore Hotel wells 1 and 2, and the Dennis Hotel well. Barksdale and others (1936, table 5) lists 30 privately owned wells tapping the 800-foot sand in Atlantic City. By the early 1970's, the number was reduced to about 10 operable wells.

Table 5.--Well records and chloride analyses from saltwater monitoring network wells in Atlantic County, 1977 water year

[Geologic unit (aquifer): 121CKKD - Kirkwood-Cohansey aquifer system; 122KRKDL - Kirkwood Formation, Atlantic City 800-foot sand]

MAP* NO.	LOCAL NAME AND WELL NUMBER	LATITUDE	LONGITUDE	GEOLOGIC UNIT	ELEVATION OF LAND SURFACE ABOVE NGVD OF 1929 (FT)	SCREENED INTERVAL (FT)	DATE OF SAMPLE	CHLORIDE (MG/L AS CL)
582	NJWC-ATL CO-DOBBS AVE	39 19 05	74 36 31	121CKKD	20	79- 99	JULY 20, 1977	17
583	NJWC-ATL CO- 2 -5TH ST	39 19 08	74 36 02	121CKKD	32	78-118	JULY 20, 1977	17
590	NJWC-ATL CO-GROVELAND	39 19 24	74 35 49	121CKKD	19	129-159	JULY 20, 1977	110
353	NJWC-ATL CO-KIRKLIN AVE	39 20 01	74 35 22	121CKKD	20	56- 71	JULY 20, 1977	18
599	VENTNOR CITY WD 7	39 20 32	74 28 59	122KRKDL	8	800-830	JULY 20, 1977	6.4
362	NJWC-ATL CO-OAK AVE	39 21 19	74 34 24	121CKKD	15	96-165	JULY 20, 1977	19
21	MARLBOROUGH-BLENHEIM 3	39 21 23	74 26 00	122KRKDL	5	765-823	JULY 20, 1977	54
30	CHALFONTE HOTEL-NEW	39 21 32	74 26 22	122KRKDL	8	797-837	JULY 20, 1977	11
549	NJWC-ATL CO-MILL ROAD	39 21 58	74 33 17	121CKKD	20	117-152	JULY 20, 1977	14
558	NJWC-ATL CO-WOODLAND AVE	39 23 33	74 31 44	121CKKD	50	127-157	JULY 20, 1977	10
42	BRIGANTINE CITY WD 2-29	39 24 56	74 21 22	122KRKDL	12	718-778	JULY 20, 1977	3.3
13	NJWC-ATL CO-ABSECON 1	39 25 51	74 30 23	121CKKD	30	177-205	JULY 20, 1977	7.9

*Well locations shown in figure 10.

The high chloride water was believed to be local contamination resulting from breaks in well casings or failures of plugs or packers installed between casing segments (Thompson, 1928, p. 98-99). Structural failures of this type could permit saline water to leak downward inside the well casings when the wells were not in use. The Cohansey Sand which overlies the Kirkwood Formation is known to contain brackish water at Atlantic City (Thompson, 1928, p. 16; Barksdale and others, 1936, p. 6; Clark and others, 1968, p. 13). Chloride concentrations from samples of suspect wells typically ranged from several hundred to over 1,000 mg/L. Due to a lack of information, it is not known which wells leaked the salty water and which were affected by the residual water from the leaky wells. To date, however, there is no evidence in the Atlantic City area of lateral saltwater intrusion in the 800-foot sand from a seaward direction. Nevertheless, the probability of this occurrence is as significant today as it was in the 1930's. (See Barksdale and others, 1936, p. 117-125.)

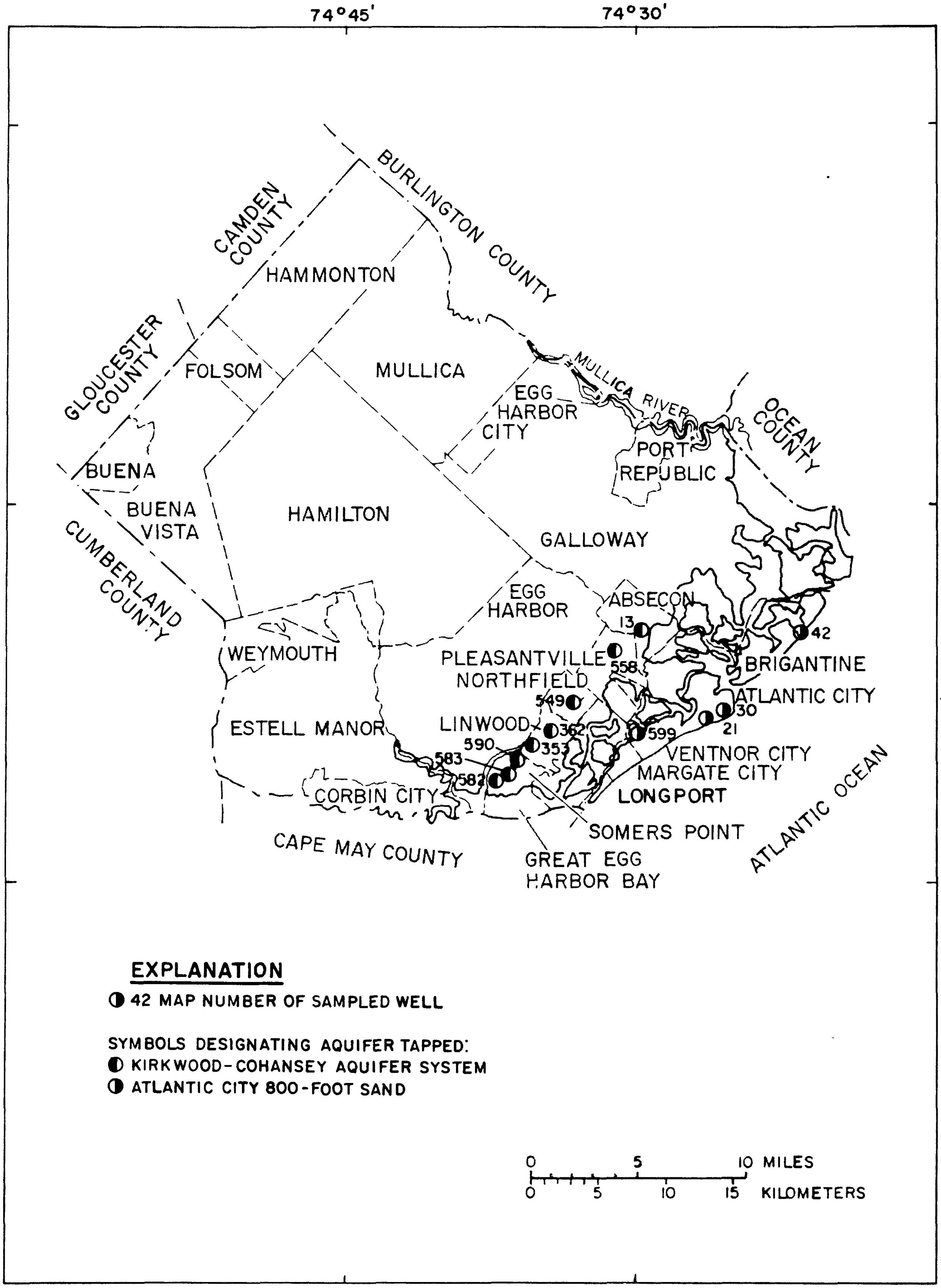


Figure 10.--Location of saltwater monitoring network wells in Atlantic County.

Cape May County

Samples were collected from 24 wells in Cape May County in 1977. Two wells tap aquifers in the Cape May Formation, 14 tap the Cohansey Sand, 7, the Atlantic City 800-foot sand within the Kirkwood Formation, and 1, the Rio Grande water-bearing zone within the Kirkwood. The Cohansey Sand in Cape May County is an artesian aquifer. Well records and chloride analyses are shown in table 6, and the well locations are shown in figure 11.

Table 6.--Well records and chloride analyses from saltwater monitoring network wells in Cape May County, 1977 water year

[Geologic unit (aquifer): 112CPMY - Cape May Formation, undifferentiated; 112ESRNS - Cape May Formation, estuarine sand facies; 121CNSY - Cohansey Sand; 122KRKDU - Kirkwood Formation, Rio Grande water-bearing zone; 122KRKDL - Kirkwood Formation, Atlantic City 800-foot sand]

MAP* NO.	LOCAL NAME AND WELL NUMBER	LATITUDE	LONGITUDE	GEOLOGIC UNIT	ELEVATION OF LAND SURFACE ABOVE NGVD OF 1929 (FT)	SCREENED INTERVAL (FT)	DATE OF SAMPLE	CHLORIDE (MG/L AS CL)
150	WEST CAPE MAY 1 OBS	38 56 07	74 55 52	121CNSY	7	283-293	SEPT 15, 1977	490
11	CAPE MAY CITY WD COL 1	38 56 13	74 54 57	121CNSY	11	281-321	SEPT 15, 1977	850
27	CAPE MAY CITY WD 1	38 56 43	74 55 33	121CNSY	12	277-306	AUG 31, 1977	140
28	HARBESON-WALKER REF CO 2	38 56 43	74 57 55	121CNSY	10	235-265	AUG 31, 1977	196
29	HARBESON-WALKER REF CO 1	38 56 45	74 58 03	121CNSY	10	296-321	AUG 31, 1977	270
17	US COAST GUARD 1	38 56 50	74 53 11	121CNSY	11	292-322	AUG 31, 1977	45
36	CAPE MAY CITY WD 2	38 57 01	74 55 28	121CNSY	12	174-282	AUG 31, 1977	40
43	CAPE MAY CITY WD 3	38 57 24	74 55 21	121CNSY	15	-276	AUG 31, 1977	22
49	HIGBEE BEACH 3 OBS	38 58 04	74 57 42	121CNSY	6	240-250	SEPT 16, 1977	16
52	LOWER TWP MUA 1	38 58 53	74 57 12	121CNSY	18	241-262	AUG 31, 1977	14
54	LOWER TWP MUA 2	38 59 05	74 56 25	121CNSY	12	212-247	AUG 31, 1977	13
154	WILDWOOD WD PINE 2	38 59 32	74 48 51	121CNSY	10	304-354	SEPT 1, 1977	120
67	WILDWOOD WD RIO GRANDE 38	39 01 35	74 53 52	122KRKDU	10	461-590	AUG 31, 1977	30
70	WILDWOOD WD RIO GRANDE 36	39 01 37	74 53 52	112CPMY	9	48- 63	AUG 31, 1977	26
72	WILDWOOD WD RIO GRANDE 31	39 01 38	74 53 50	112ESRNS	10	108-135	AUG 31, 1977	13
74	WILDWOOD WD RIO GRANDE 29	39 01 39	74 53 49	121CNSY	8	191-231	AUG 31, 1977	12
132	STONE HARBOR WD 4	39 03 01	74 45 45	122KRKDL	10	830-880	SEPT 1, 1977	31
89	OYSTER LAB 4 OBS	39 04 25	74 54 46	121CNSY	7	195-210	SEPT 16, 1977	10
4	AVALON BORO WD 6-68	39 05 28	74 43 38	122KRKDL	10	880-920	SEPT 1, 1977	46
5	AVALON BORO WD 8-76	39 05 45	74 43 26	122KRKDL	8	784-839	SEPT 1, 1977	13
129	SEA ISLE CITY WD 2	39 09 26	74 41 31	122KRKDL	7	744-861	SEPT 1, 1977	14
136	ARAMINGO WC 1	39 11 52	74 39 27	122KRKDL	7	802-834	SEPT 1, 1977	14
106	NJWC-OCEAN CITY DIST 7	39 13 43	74 37 55	122KRKDL	8	760-810	SEPT 1, 1977	12
125	NJWC-OCEAN CITY DIST 11	39 17 26	74 33 52	122KRKDL	10	747-797	SEPT 1, 1977	7.2

*Well locations shown in figure 11.

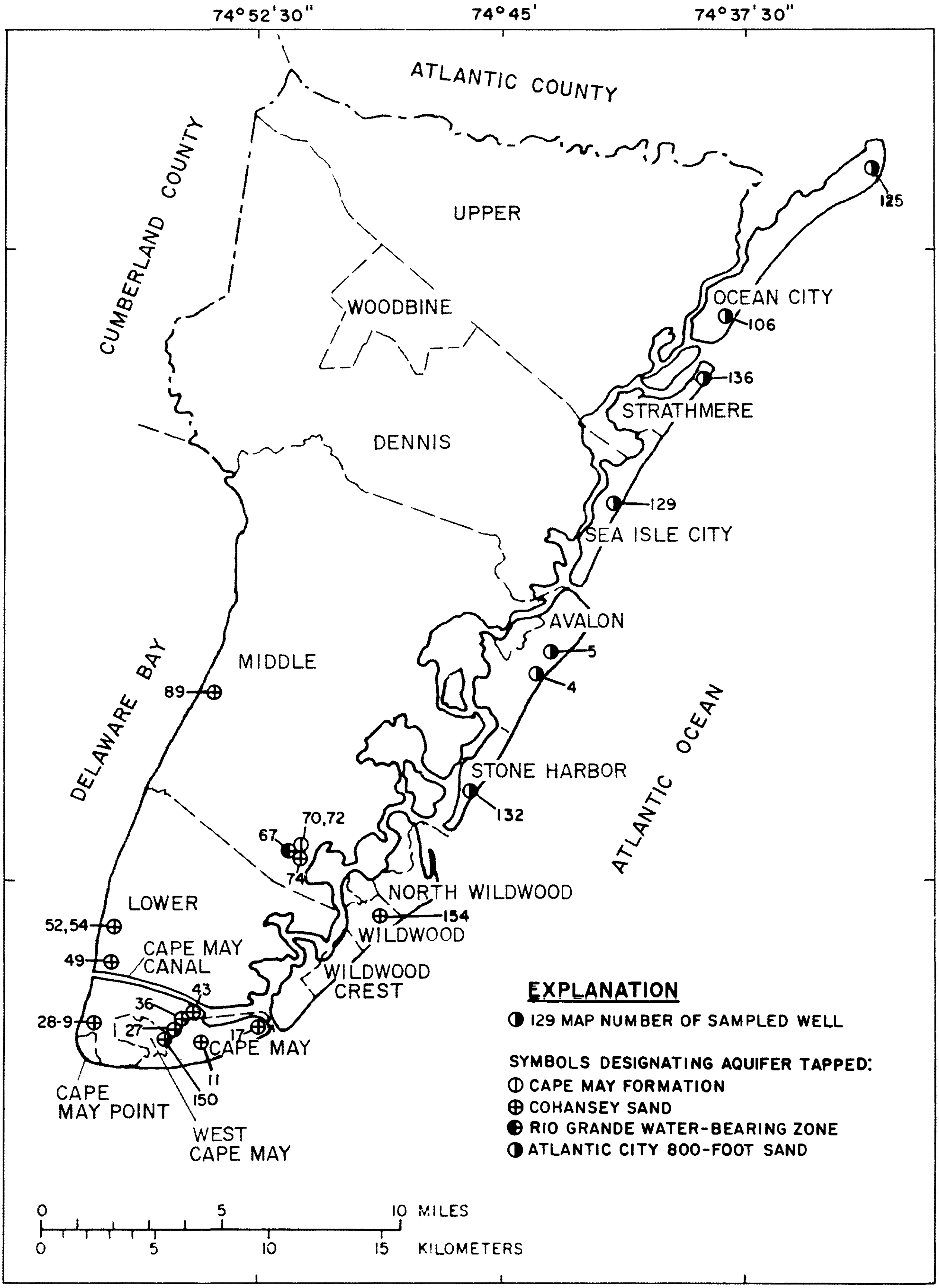


Figure 11.--Location of saltwater monitoring network wells in Cape May County.

High chloride concentrations from wells in the Cohansey Sand in the lower peninsula indicate a serious salinity problem. Lateral saltwater intrusion into the Cohansey south of the Cape May Canal, first documented by Gill (1962), has continued and chloride concentrations have risen substantially in the operational wells in the coastal areas. Chloride concentrations from two wells, Cape May City WD 1 (map No. 27) and Harbeson-Walker Refractories Co. 2 (map No. 28), are shown in figure 12. In contrast, the other two city wells (Cape May City WD 2 and 3) shown in figure 12, further to the north in Lower Township, had lower concentrations. Increased chloride concentrations in the monitoring wells indicate that saline water is moving further inland toward Cape May City WD wells 2 and 3 (map Nos. 36, 43). The increasing trend in chloride in the WD 2 well is of major significance. Chloride concentrations in samples collected from well 2 in 1981 were 65 mg/L, compared to 40 mg/L in 1977 and 19 mg/L in 1973. These two wells are about 2,000 and 4,000 feet, respectively, north of well 1, and they provide the public water supply (1.2 Mgal/d in 1980) for the entire area south of Cape May Canal, including the U.S. Coast Guard base.

The areal extent of saline water intrusion in the Cohansey Sand in the Cape May City area is shown for 1958 and 1977 in figure 13. An estimate of the inland movement of saline water since 1958 can be made by comparing the positions of the 50 and 500 mg/L isochlors for the two years. The net movement between the old and new city well fields was about 2,500 ft during the 20-year period. The difference in shape of the isochlors for 1958 and 1977 is due largely to changes in the distribution of withdrawals. Through the mid 1960's, 6 to 8 production wells were withdrawing water regularly in Cape May City, West Cape May, and Cape May Point. By 1977, all but two of these had been abandoned. The only wells in regular use in 1977 were the Harbeson-Walker Refractories Co. wells 1 and 2. Increases in chloride concentration in two observation wells, West Cape May 1 obs. (map No. 150) and Cape May City WD Col. (Columbia Avenue) 1 (map No. 11) were as follows:

Well name	Chloride concentration, in milligrams per liter			
	Previous sampling			
	1957	1964	1965	1977
West Cape May 1 obs.	--	--	220	490
Cape May City WD Col. 1	--	690	--	850
Higbee Beach 3 obs.	16	--	--	16

See figures 11 and 13 for their locations. The Higbee Beach well (map No. 49), north of the Canal, has not shown significant change in chloride concentration in recent years.

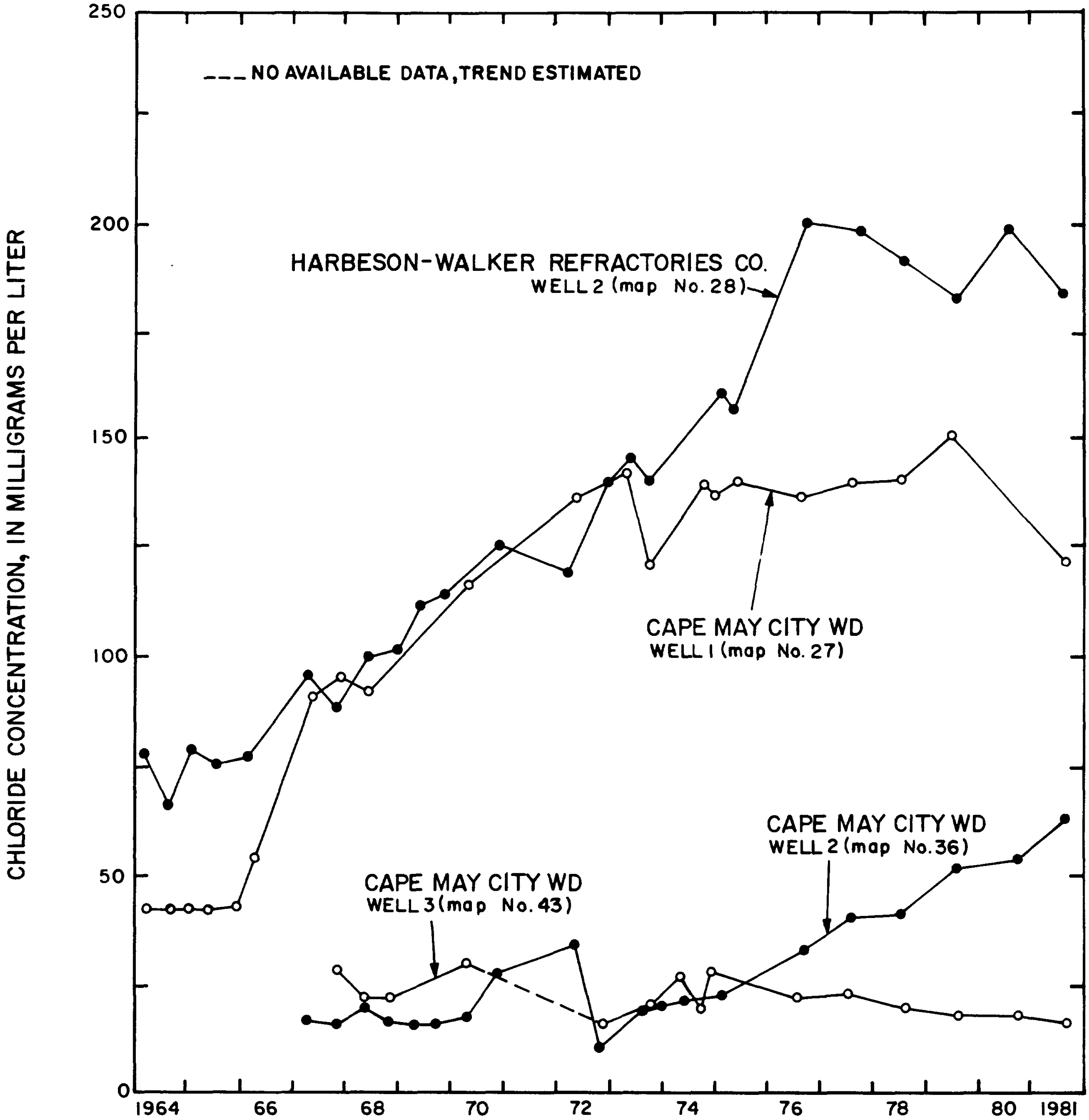
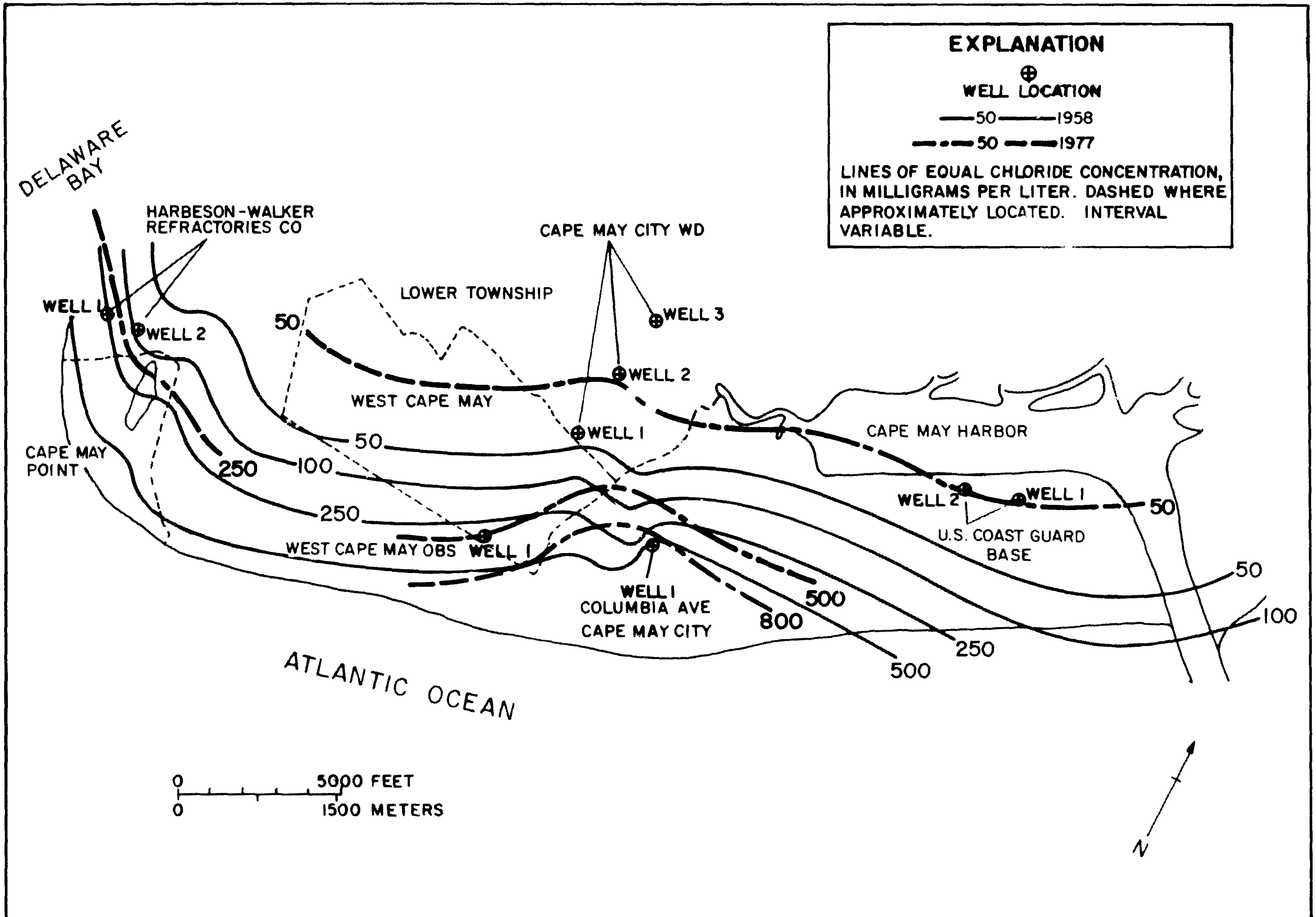


Figure 12.--Chloride concentrations from wells tapping the Cohansey Sand in the Cape May City area, Cape May County, 1964-81.



Base and 1958 isochlors modified from Gill, 1962.

Figure 13.--Isochlors for the Cohansey Sand in the Cape May City area, 1958 and 1977.

The salinity problem in the Cohansey Sand in the lower peninsula is especially significant because there is no alternative freshwater source in the area. The water in both the Rio Grande water-bearing zone and the Atlantic City 800-foot sand within the Kirkwood Formation in this area is more saline than in the Cohansey Sand (Gill, 1962, p. 99, 103, and 107). To obtain potable ground water, it would be necessary for Cape May City to either establish a new well field north of the canal in Lower Township, or purchase water from another supplier in that same area.

No significant increases in chloride concentration are indicated elsewhere in Cape May County through 1981. Samples from wells in Lower and Middle Townships ranged from 10 to 30 mg/L and are similar to previously recorded data. Chloride concentrations from wells in the Atlantic City 800-foot sand within the Kirkwood Formation along the barrier beach islands from Stone Harbor north to Ocean City ranged from 7.2 to 46 mg/L, with the higher concentrations at Stone Harbor and Avalon. There has not been a significant change in concentration at these two municipalities during the past 20 years. However, the proximity of relatively high chloride concentrations (more than 250 mg/L) in the 800-foot sand at Wildwood City as recently as 1971 indicates that the Stone Harbor and Avalon areas are susceptible to saltwater intrusion. The freshwater-saltwater transition zone in the 800-foot sand was defined by Gill (1962, p. 103) based on chloride data collected through 1957. The present delineation of this transition zone is not known because there are no existing wells in the 800-foot sand south of Stone Harbor. (See Gill, 1962, p. 96-109.)

Cumberland County

Five wells were sampled for chloride in the 1977 water year; two tap the unconfined Kirkwood-Cohansey aquifer system and three tap the Piney Point aquifer. Well records and chloride analyses are shown in table 7, and the well locations are shown in figure 14. Chloride ranged from 4.5 to 6.5 mg/L for the wells in the Kirkwood-Cohansey aquifer system and from 68 to 81 mg/L for wells tapping the Piney Point. These concentrations are similar to previous concentrations, and upward trends are not evident. However, chlorides in the Piney Point aquifer are significantly higher than natural background levels (20 mg/L or less) in the other Coastal Plain aquifers.

Table 7.--Well records and chloride analyses from saltwater monitoring network wells in Cumberland County, 1977 water year

[Geologic unit (aquifer): 121CKKD - Kirkwood-Cohansey aquifer system; 124PNPN - Piney Point aquifer]

MAP* NO.	LOCAL NAME AND WELL NUMBER	LATITUDE	LONGITUDE	GEOLOGIC UNIT	ELEVATION OF LAND SURFACE ABOVE NGVD OF 1929 (FT)	SCREENED INTERVAL (FT)	DATE OF SAMPLE	CHLORIDE (MG/L AS CL)
123	NJDIA LEESBURG SP FARM 1	39 13 56	74 57 51	121CKKD	13	248-268	JULY 21, 1977	4.5
52	FORTESCUE REALTY 4	39 14 20	75 10 23	121CKKD	8	283-303	JULY 21, 1977	6.5
56	MONEY ISLAND MARINA 1	39 17 04	75 14 15	124PNPN	4	350-370	JULY 21, 1977	77
92	BAY PT ROD & GUN CLUB 2	39 17 46	75 15 10	124PNPN	5	397-417	JULY 21, 1977	81
61	SEA BREEZE TAVERN 2	39 19 26	75 19 21	124PNPN	4	281-354	JULY 21, 1977	68

*Well locations shown in figure 14.

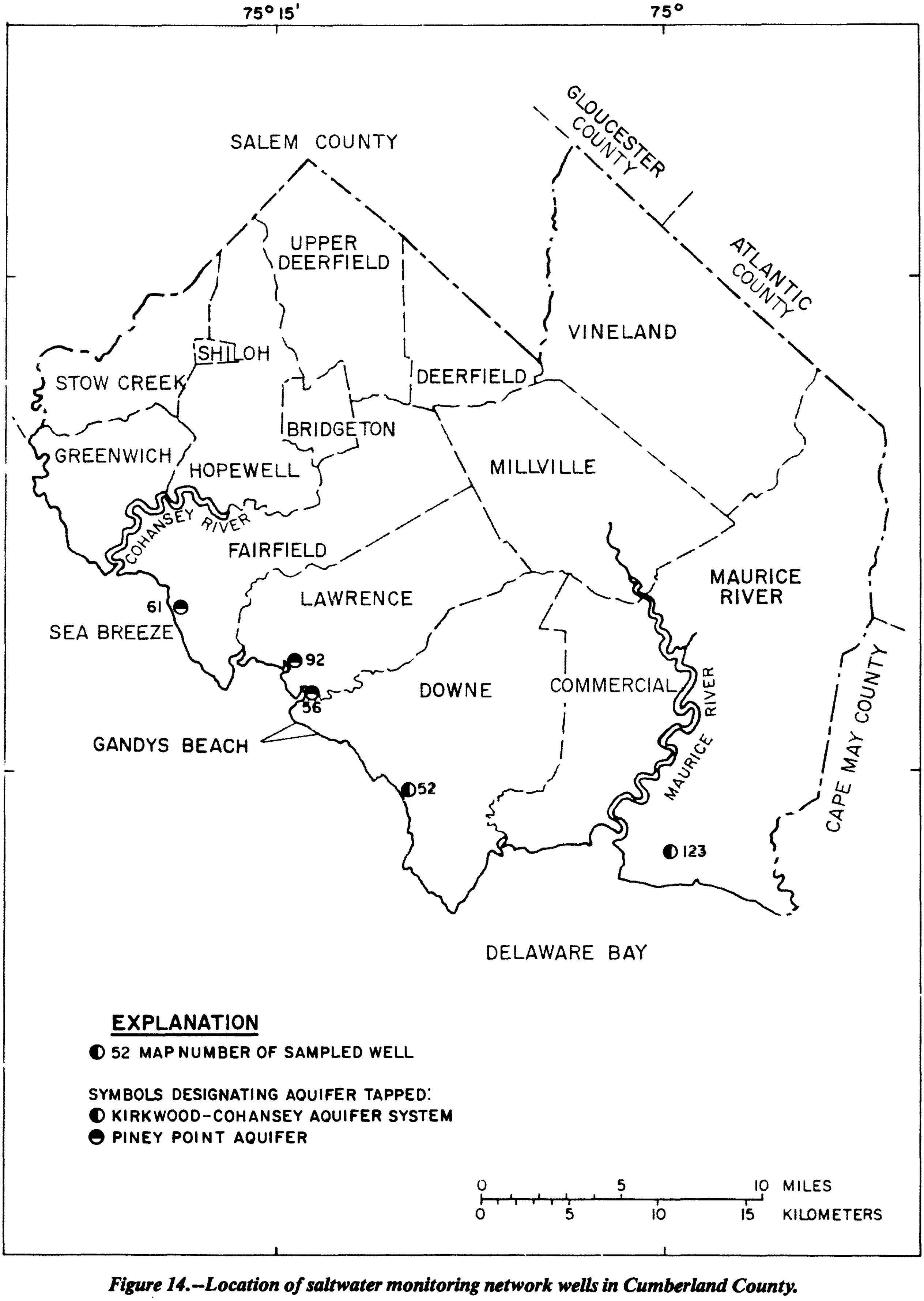


Figure 14.--Location of saltwater monitoring network wells in Cumberland County.

At Gandys Beach, some samples collected subsequent to 1977 from wells tapping the Piney Point aquifer have yielded excessively high chlorides. This aquifer is used for domestic and semipublic water supply in coastal communities from Gandys Beach northward to Sea Breeze. Long-term records from 1963 to 1981 for all communities except Gandys Beach show that chlorides have varied between 55 and 85 mg/L, and no trends are evident. At Gandys Beach, three wells sampled from 1978-81 show chlorides with above background levels:

Well name or owner	Screened interval, in feet	Chloride concentration, in milligrams per liter			
		1978	1979	1980	1981
M. Gandys Beach	378-402	830	900	930	1000
G. Stanger	440*	220	220	--	200
H. Myers	399-409	--	55	91	140
R. Gondolf	405-425	--	60	--	--

*Total depth of well.

The M. Gandys Beach well, yielding the highest chlorides, was constructed about 1945. Graphs of chloride concentrations from this well and other nearby wells at Gandys Beach and at Money Island Marina are shown in figure 15 and the well locations are shown in figure 16. The elevated chlorides from the M. Gandys Beach well, about 500 to 1,000 mg/L, were first detected in 1973-74, and noted again in higher concentrations from 1978 to 1981. Abnormally high chlorides also were measured in 1978-81 in the G. Stanger and H. Myers wells, about 100 ft south and 300 ft west, respectively, from the M. Gandys Beach well (fig. 16). Another well at Gandys Beach owned by R. Gondolf and located about 1,500 ft west of the M. Gandys Beach well was sampled only in 1979 (not shown in fig. 15). This sample had a chloride concentration of 60 mg/L, which is comparable to long-term records from other wells. Figure 15 also contains chloride data for the Money Island Marina 1 well located about 1 mi north of the M. Gandys Beach well. Since 1963, chlorides from this well varied between about 70 and 85 mg/L with no evident trends.

The source of the relatively high chlorides in the Piney Point aquifer near Delaware Bay can not be substantiated at present. Nemickas and Carswell (1976) suggest two possible causes. First, a freshwater-saltwater transition zone may exist within the Piney Point aquifer near the wells in question. The second possibility is vertical leakage of high chloride water from Delaware Bay through the overlying Kirkwood Formation.

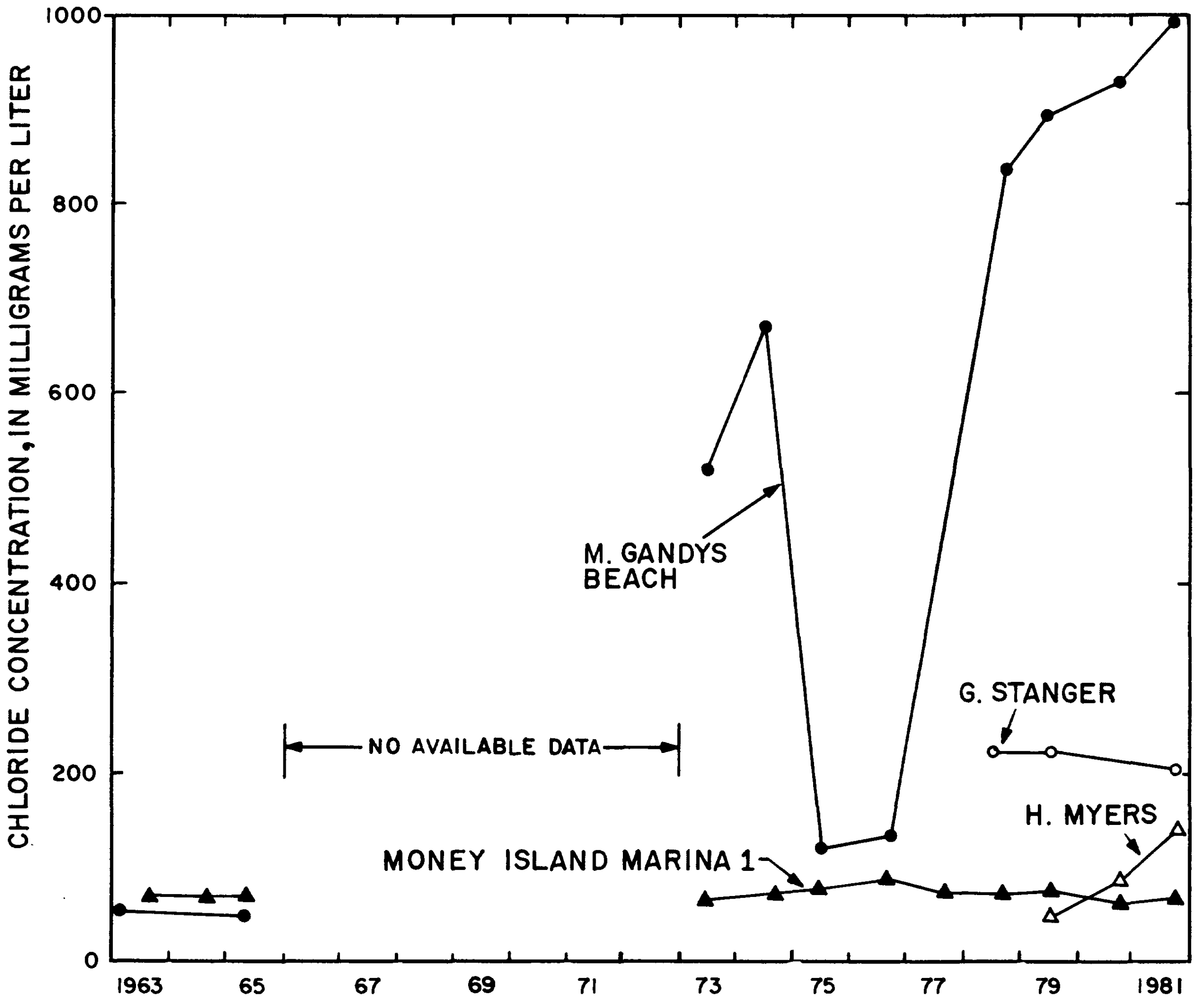


Figure 15.--Chloride concentrations from selected wells tapping the Piney Point aquifer in the Gandys Beach area, Cumberland County, 1963-81.

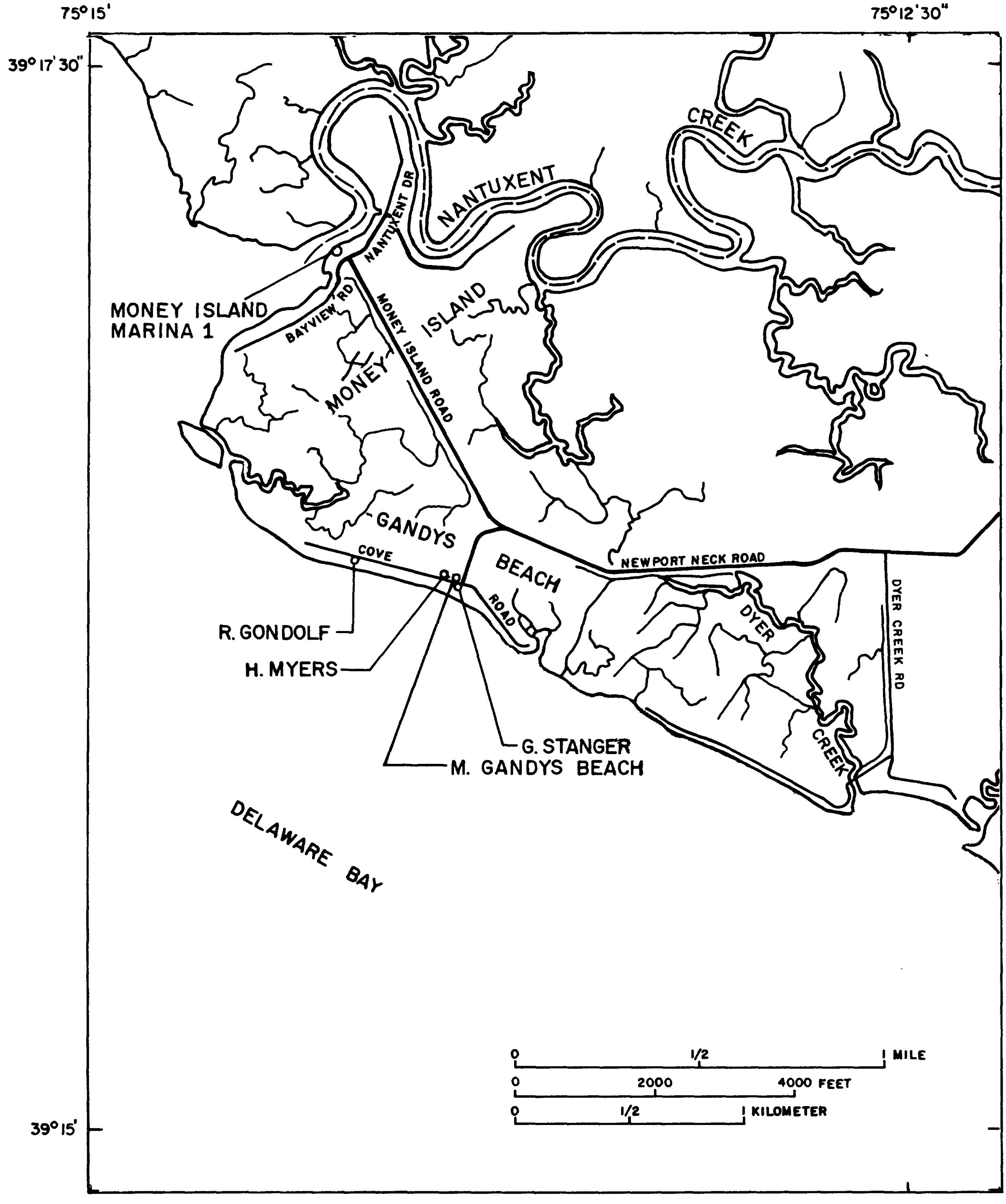


Figure 16.--Location of saltwater monitoring network wells in the Gandys Beach area of Cumberland County.

Abnormally high chlorides near the M. Gandys Beach well also may have resulted from a casing break in that well. If the casing failed, it probably failed fairly close to land surface where the water-table aquifer contains corrosive saltwater. Thus, the salty water may be entering the well bore and mixing with water from the Piney Point aquifer. Several factors support this. Based on conversations with the present owner and several users of the well water, the quality of water from this well has deteriorated in recent years. Not only have chloride and total dissolved solids increased, the hardness of the water has increased. This deterioration in quality was a major reason many customers decided to have new wells drilled. Also, when the well was sampled in 1978, 1979, and 1980, the pH of the water was lower than in most previous samplings, indicating a possible mixing of waters of different quality. The recent increases in chloride in the nearby Stanger and Myers wells and the age of the M. Gandys Beach well (37 years old) also support this theory.

A comprehensive study is needed to determine the exact cause and areal extent of the high chlorides in the Piney Point aquifer in Cumberland County.

Salem County

Samples were collected from 24 wells in Salem County during the 1977 water year. Well records and chloride analyses are shown in table 8, and the well locations are shown in figure 17. Eighteen of these wells are screened within the Potomac-Raritan-Magothy aquifer system. Thirteen of the eighteen wells are within 1.5 mi of the Delaware River in areas subject to induced recharge from the river. Chloride concentrations of 23 samples from these 13 wells ranged from 8.4 to 210 mg/L, and most are consistent with

Table 8.--Well records and chloride analyses from saltwater monitoring network wells in Salem County, 1977 water year

[Geologic unit (aquifer): 211MLRW - Wenonah-Mount Laurel aquifer; 211MRPA - Potomac-Raritan-Magothy aquifer system]

MAP* NO.	LOCAL NAME AND WELL NUMBER	LATITUDE	LONGITUDE	GEOLOGIC UNIT	ELEVATION OF LAND SURFACE ABOVE NGVD OF 1929 (FT)	SCREENED INTERVAL (FT)	DATE OF SAMPLE	CHLORIDE (MG/L AS CL)
34	SALEM NUCLEAR GEN STA 1	39 27 42	75 32 00	211MLRW	20	248-298	OCT 7, 1976	36
35	SALEM NUCLEAR GEN STA 2	39 27 44	75 32 05	211MLRW	20	230-280	OCT 7, 1976	114
32	SALEM NUCLEAR GEN STA 3	39 27 40	75 32 02	211MLRW	20	243-293	OCT 7, 1976	30
364	SALEM NUCLEAR GEN STA 5	39 27 43	75 31 58	211MRPA	20	765-840	OCT 7, 1976	18
33	L ALLOWAY CR ELEM SCH 1	39 27 51	75 24 41	211MLRW	10	340**	SEPT 27, 1977	45
241	SALEM CITY WD-QUINTON ML	39 32 53	75 24 25	211MLRW	7	248**	OCT 7, 1976	14
				211MLRW	7	248**	SEPT 27, 1977	17
249	SALEM CITY WD-KEASB CR 2	39 33 42	75 27 18	211MLRW	5	110-157	OCT 7, 1976	54
				211MLRW	5	110-157	SEPT 27, 1977	26
107	NJ DEP-FORT MOTT SP 1	39 36 20	75 33 10	211MRPA	8	300-320	OCT 6, 1976	102
				211MRPA	8	300-320	SEPT 22, 1977	98
108	VETS ADMIN-FINNS POINT	39 36 41	75 33 22	211MRPA	7	282-319	OCT 6, 1976	140
				211MRPA	7	282-319	SEPT 22, 1977	130
112	PENNSVILLE TWP WD 4	39 37 54	75 31 48	211MRPA	10	117-137	OCT 5, 1976	11
				211MRPA	10	117-137	SEPT 22, 1977	12
354	WOODSTOWN BORO WD 2	39 39 04	75 19 46	211MRPA	45	670-705	OCT 7, 1976	195
				211MRPA	45	670-705	SEPT 27, 1977	180
362	WOODSTOWN BORO WD 3	39 39 27	75 19 27	211MRPA	60	692-712	OCT 7, 1976	182
				211MRPA	60	692-712	SEPT 27, 1977	190
163	RICHMAN ICE CREAM 1	39 39 28	75 21 47	211MRPA	25	455-475	OCT 7, 1976	22
				211MRPA	25	455-475	SEPT 27, 1977	24
164	RICHMAN ICE CREAM 2	39 39 28	75 21 47	211MRPA	20	418-446	SEPT 27, 1977	50
117	PENNSVILLE TWP WD 3	39 39 54	75 30 13	211MRPA	7	87-102	OCT 5, 1976	8.4
				211MRPA	7	87-102	SEPT 22, 1977	10
118	PENNSVILLE TWP WD 1	39 39 58	75 30 45	211MRPA	8	213-238	OCT 5, 1976	65
				211MRPA	8	213-238	SEPT 22, 1977	67
119	PENNSVILLE TWP WD 2	39 40 09	75 30 43	211MRPA	7	210-230	OCT 5, 1976	108
				211MRPA	7	210-230	SEPT 22, 1977	110
122	ATLANTIC CITY ELECTRIC 3R	39 40 46	75 30 22	211MRPA	10	165-235	SEPT 22, 1977	49
123	ATLANTIC CITY ELECTRIC 2	39 40 47	75 30 27	211MRPA	20	158-234	SEPT 22, 1977	76
125	ATLANTIC CITY ELECTRIC 5	39 40 50	75 30 30	211MRPA	15	149-219	OCT 6, 1976	62
				211MRPA	15	149-219	SEPT 22, 1977	54
127	ATLANTIC CITY ELECTRIC 6	39 41 00	75 30 30	211MRPA	15	158-188	SEPT 22, 1977	110
137	EI duPONT-DRINKWATER 8	39 41 12	75 30 28	211MRPA	14	317-361	OCT 6, 1976	64
				211MRPA	14	317-361	SEPT 22, 1977	70
345	PENNS GROVE WC 2B	39 42 47	75 27 14	211MRPA	19	45- 60	OCT 6, 1976	15
346	PENNS GROVE WC-LAYNE 1	39 42 56	75 27 18	211MRPA	19	317-357	OCT 6, 1976	199
				211MRPA	19	317-357	SEPT 22, 1977	210

*Well locations shown in figure 17.
**Total depth of well.

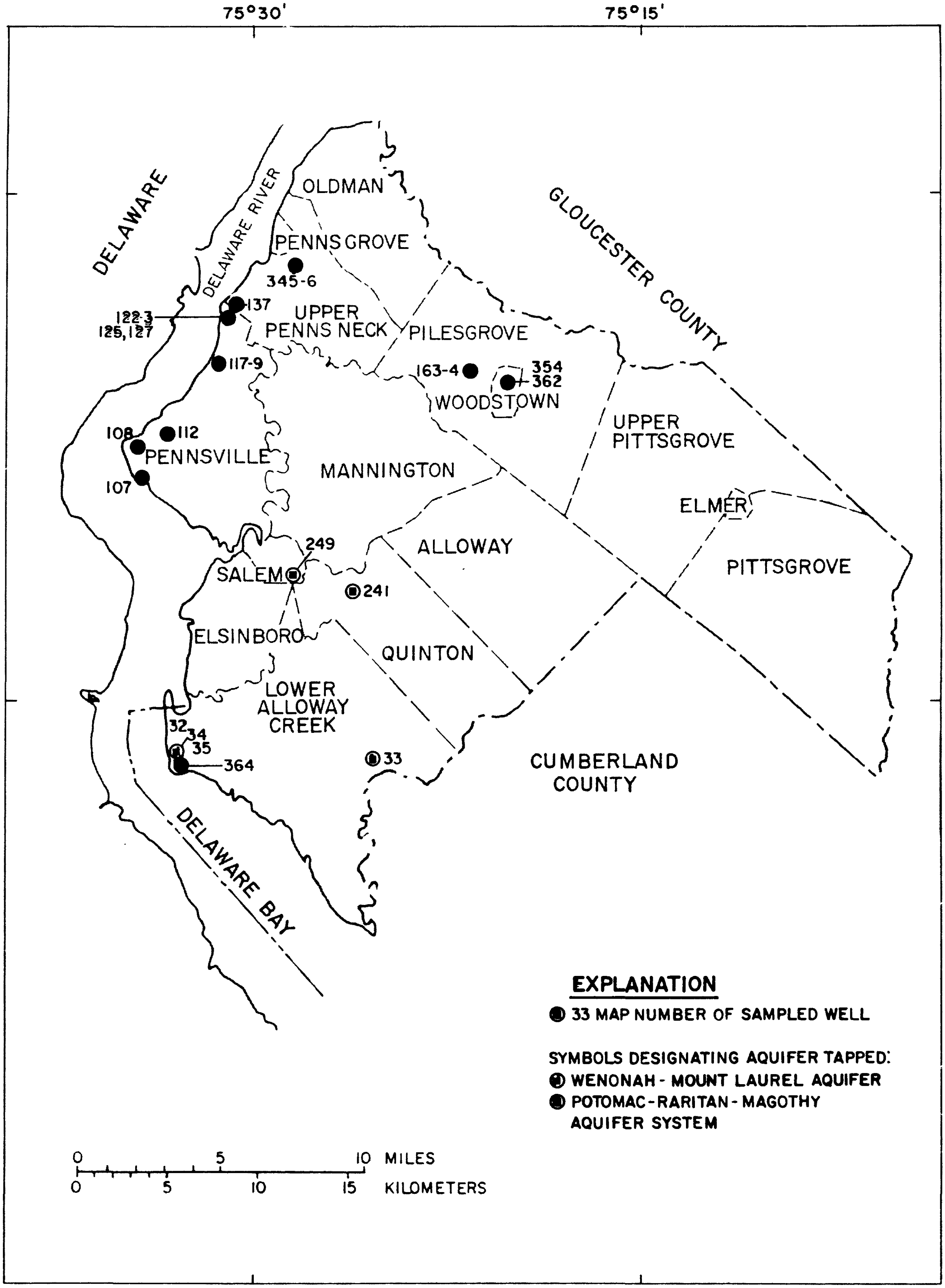


Figure 17.--Location of saltwater monitoring network wells in Salem County.

past records. However, five of these wells had record-high chloride concentrations (49-210 mg/L) in 1977. These include Penns Grove WC Layne 1, E.I. duPont Drinkwater 8, Atlantic City Electric Co. Deepwater 2 and 3R, and Pennsville Township WD 2 (map Nos. 346, 137, 123, 122, 119, respectively).

Chloride concentrations in seven samples from four wells tapping the Potomac-Raritan-Magothy aquifer system in the Woodstown area ranged from 22 to 195 mg/L. Concentrations from the two Woodstown Borough wells (180 and 195 mg/L) are now at record-high levels. In this region, the aquifer system is threatened by the lateral movement of highly saline water from the southeast (Barksdale and others, 1958). The approximate location of the freshwater-saltwater transition zone near the top of the aquifer system is shown in figure 1 (from Luzier, 1980, p. 6).

Chloride concentrations in six wells screened in the Wenonah-Mount Laurel aquifer in the southwestern part of the county ranged from 14 to 114 mg/L. The period of record for most of these wells is short and insufficient to determine trends. However, this aquifer is one of the most heavily used aquifers in the county, and continued surveillance is required to identify trends. The intrusion of saline water in this aquifer is believed to be a result of vertical leakage from the overlying water-table aquifers which are subject to tidal flooding (Rosenau and others, 1969, p. 43).

Since 1977, chloride concentrations have continued to increase in the wells tapping the Wenonah-Mount Laurel aquifer at the Salem Nuclear Generating Station in Lower Alloway Creek Township. The following comparison of 1977, 1979, and 1981 data illustrates this upward trend:

Well name	Chloride concentration, in milligrams per liter		
	1977	1979	1981
Salem Nuclear Generating Station			
Well 1	36	70	95
Well 2	114	210	250
Well 3	30	66	220

Except as noted above, data collected since 1977 do not indicate any significant changes in chloride distribution in Salem County.

Gloucester County

The well records and chloride analyses for wells sampled in Gloucester County are shown in table 9, and the well locations are shown in figure 18. Samples from 21 wells tapping aquifers within the Potomac-Raritan-Magothy aquifer system do not indicate any significant changes in chloride concentrations. Chloride concentrations from 8 wells along the Delaware estuary between Paulsboro and Bridgeport in Logan Township ranged from 14 to 177 mg/L. Some chloride concentrations are at or near maximums of record, but a few others have shown slight to moderate decreases during the past 5 to 10 years. This decline (up to 64 mg/L) is most notable in well water at the Mobil Oil Corp. facility in Paulsboro. The aquifer system throughout this area receives induced recharge from the river, in addition to contamination from vertical leakage from the surface (Hardt and Hilton, 1969, p. 13).

In the inland areas of the county, recent data from wells at Clayton, Glassboro, Pitman, and Mullica Hill (South Jersey Water Supply Co.) indicate gradually increasing salinities. The increases in chlorides ranged from about 10 to 20 mg/L between 1967 and 1977. Here, as in the northeastern part of Salem County, the Potomac-Raritan-Magothy aquifer system is threatened with the lateral movement updip of saline water from the southeast (Barksdale and others, 1958). Recent data, however, do not indicate increasing chloride concentrations at Swedesboro or in municipalities north of Pitman.

Data collected subsequent to 1977 do not indicate any noteworthy change in chloride distribution in Gloucester County.

Table 9. --Well records and chloride analyses from saltwater monitoring network wells in Gloucester County, 1977 water year

[Geologic unit (aquifer): 211MRPA - Potomac-Raritan-Magothy aquifer system]

MAP* NO.	LOCAL NAME AND WELL NUMBER	LATITUDE	LONGITUDE	GEOLOGIC UNIT	ELEVATION OF LAND SURFACE ABOVE NGVD OF 1929 (FT)	SCREENED INTERVAL (FT)	DATE OF SAMPLE	CHLORIDE (MG/L AS CL)
1	CLAYTON BORO WD 3	39 39 12	75 05 22	211MRPA	133	746-800	NOV 5, 1976	142
				211MRPA	133	746-800	SEPT 14, 1977	140
3	CLAYTON BORO WD 4	39 40 13	75 05 58	211MRPA	140	670-740	NOV 5, 1976	98
59	OWENS ILLINOIS 1	39 41 47	75 07 14	211MRPA	144	607-647	SEPT 14, 1977	65
60	GLASSBORO BORO WD 3	39 42 05	75 07 53	211MRPA	150	562-612	SEPT 14, 1977	68
225	PITMAN BORO WD P1	39 44 05	75 07 45	211MRPA	140	468-514	SEPT 14, 1977	44
130	SOUTH JERSEY WS CO 3	39 44 08	75 13 30	211MRPA	35	234-265	NOV 5, 1976	140
				211MRPA	35	234-265	SEPT 14, 1977	160
238	SWEDESBORO BORO WD 2	39 44 38	75 18 33	211MRPA	30	217-240	SEPT 16, 1977	62
6	WOODBURY WD-SEWELL 1A	39 46 27	75 08 13	211MRPA	20	271-312	SEPT 16, 1977	25
191	SEWELL WC 2	39 46 29	75 08 59	211MRPA	60	336-368	SEPT 16, 1977	29
194	MANTUA WC 3	39 47 32	75 10 36	211MRPA	10	230-265	SEPT 16, 1977	35
275	WENONAH BORO WD 2	39 47 51	75 09 12	211MRPA	30	270-310	SEPT 16, 1977	22
166	PENNS GROVE WC-BRIDGPT 2	39 47 55	75 21 08	211MRPA	20	65- 85	SEPT 21, 1977	14
72	EI duPONT REPAUNO 3	39 49 36	75 17 47	211MRPA	10	91-101	SEPT 21, 1977	140
79	EI duPONT REPAUNO 6	39 49 44	75 17 34	211MRPA	10	84-109	SEPT 21, 1977	130
331	WOODBURY WD RAILROAD 5	39 49 50	75 09 09	211MRPA	35	405-457	SEPT 16, 1977	27
94	MOBIL OIL-GREENWICH 44	39 49 58	75 15 12	211MRPA	20	116-136	SEPT 21, 1977	54
98	MOBIL OIL-GREENWICH 45	39 50 05	75 15 23	211MRPA	3	95-118	NOV 5, 1976	132
101	MOBIL OIL-GREENWICH 40	39 50 12	75 15 20	211MRPA	20	195-225	NOV 5, 1976	177
109	MOBIL OIL-GREENWICH 41	39 50 27	75 15 03	211MRPA	20	230-259	NOV 5, 1976	111
				211MRPA	20	230-259	SEPT 21, 1977	110
118	MOBIL OIL-GREENWICH 47	39 50 36	75 15 01	211MRPA	20	220-240	NOV 5, 1976	132
				211MRPA	20	220-240	SEPT 21, 1977	130
207	NATIONAL PARK BORO WD 2	39 51 56	75 10 53	211MRPA	30	241-282	SEPT 21, 1977	32

*Well locations shown in figure 18.

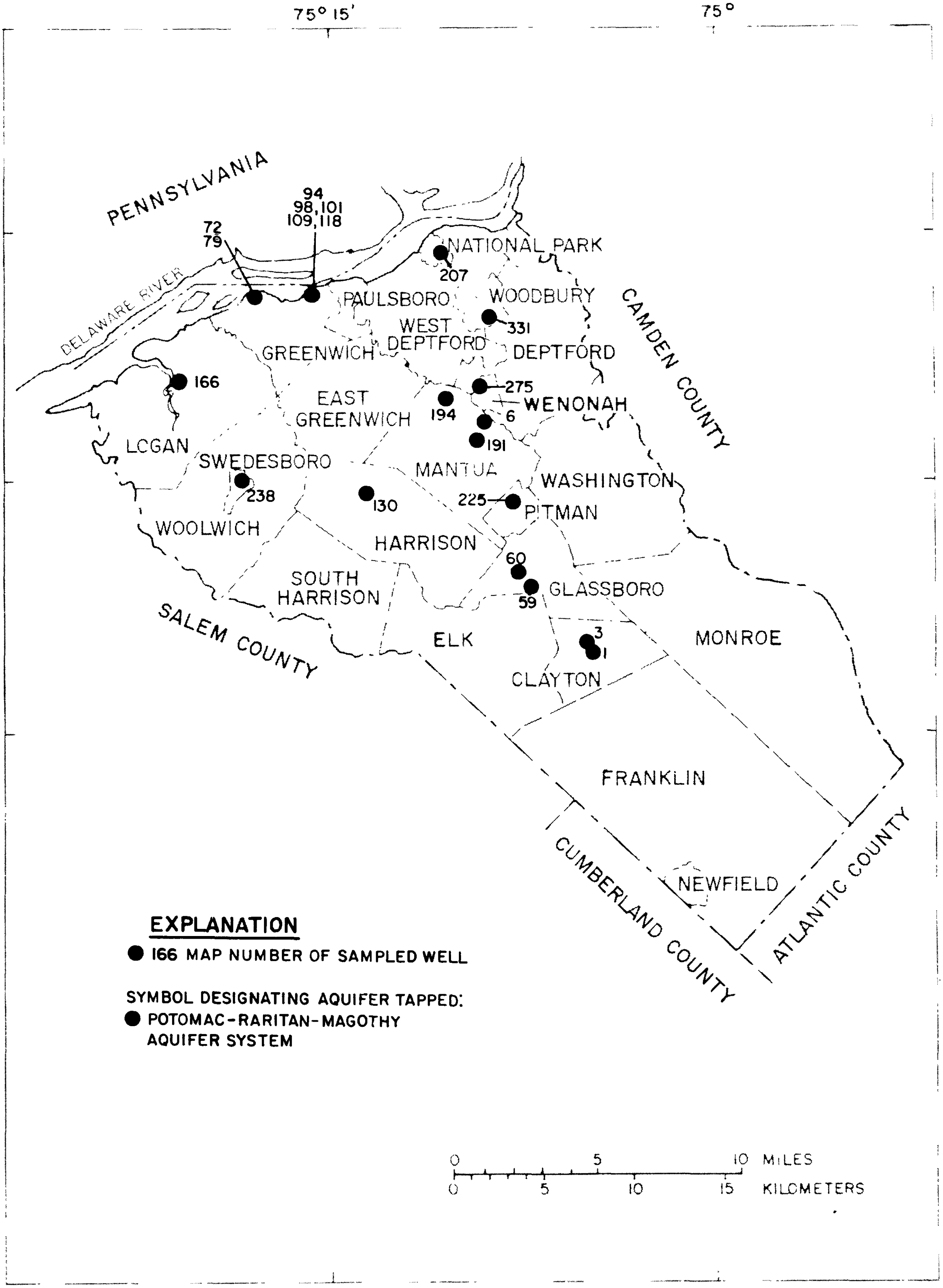


Figure 18.--Location of saltwater monitoring network wells in Gloucester County.

SUMMARY

During the 1977 water year, chloride concentrations were determined in samples from 202 wells, screened in 13 different aquifers in Middlesex, Monmouth, Ocean, Atlantic, Cape May, Cumberland, Salem, and Gloucester Counties. These data, complemented by data collected prior and subsequent to 1977, indicate that saline water is contaminating freshwater aquifers in parts of seven counties.

Encroachment of saltwater into freshwater aquifers in the Sayreville area of Middlesex County and in the lower peninsula of Cape May County has been reported for about 40 years and is now more extensive. Many production wells have been abandoned in both areas. In some existing production wells, chloride concentrations currently are approaching the 250 mg/L potable water standard.

The continual northward movement of saline water within the Potomac-Raritan-Magothy aquifer system toward pumping centers is threatening freshwater supplies. At Woodstown Borough in Salem County, chloride concentration was as high as 195 mg/L in 1977. In Gloucester County, 1977 chloride concentration in well water varied between 140 and 160 mg/L at Clayton Borough and at Harrison Township (Mullica Hill). Between 1977 and 1981, chloride concentrations did not change significantly in either of these areas.

Saltwater is also intruding into freshwater aquifers in other areas in the Coastal Plain, including the Keyport-Union Beach area in Monmouth County, Point Pleasant Beach and Seaside Heights Boroughs in Ocean County, Somers Point City in Atlantic County, and in areas adjacent to the Delaware estuary in Salem and Gloucester Counties.

Saltwater intrusion has resulted from extensive withdrawals of ground water. The resultant freshwater head declines have caused reversals in the natural hydraulic gradients permitting inland movement of saline water from adjacent saltwater bodies.

The downward leakage of saline water through damaged well casings has caused some local contamination of the Atlantic City 800-foot sand aquifer at Atlantic City. To date, however, there is no evidence in the Atlantic City area of the lateral intrusion of saltwater in the 800-foot sand from a seaward direction.

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GLOSSARY

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

Artesian aquifer. An aquifer containing water under sufficient pressure to rise above the top of the aquifer when penetrated by a well; also called confined aquifer.

Brackish water. Water intermediate in salinity between saltwater and freshwater.

Cone of depression. A depression produced in the water table or other potentiometric surface by the withdrawal of water from an aquifer; it is shaped like an inverted cone with its apex at the area of greatest concentration of pumping.

Confining bed. A body of relatively impermeable material stratigraphically adjacent to one or more aquifers. The hydraulic conductivity may range from nearly zero to some value distinctly lower than that of the aquifer.

Chloride. A major chemical constituent in seawater but a very minor constituent in freshwater. Chloride concentration is used as an indicator of saltwater in this report; see saltwater.

Discharge. The process by which water is depleted from an aquifer.

Estuary. The tidal part of a river where freshwater mixes with and dilutes saltwater.

Head, static. The height above a standard datum of the surface of a column of water (or other liquid) that can be supported by the static pressure at a given point. Head, when used alone, is understood to mean static head.

Hydraulic gradient. The change in static head per unit of distance in a given direction. If not specified, the direction generally is understood to be that of the maximum rate of decrease in head.

Induced recharge. Water which enters an aquifer from an adjacent surface-water body as a result of an established hydraulic gradient from the surface water toward pumping well(s).

Milligrams per liter (mg/L). A unit expressing the concentration of chemical constituents in solution as the mass (1 milligram = 1 X 10^{-3} gram) of solute per unit volume (liter) of water. One mg/L is approximately equal to 1 part per million (ppm) in aqueous solutions of low dissolved-solids concentration.

National Geodetic Vertical Datum of 1929 (NGVD of 1929) A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called mean sea level. NGVD of 1929 is referred to as sea level in this report.

Outcrop area. Regions where geologic units are exposed at or near the land surface.

Permeability. The ability of a rock or earth material to transmit water in response to head differences.

Potentiometric surface. A surface which represents the static head in an aquifer. The potentiometric surface is defined by the levels to which water will rise in tightly cased wells. See head, static.

Recharge. The process by which water enters an aquifer.

Saltwater. Water containing about 35,000 mg/L of dissolved solids including about 19,000 mg/L of chloride.

Saltwater intrusion. The movement of saltwater or brackish water into a freshwater aquifer due to the lowering of the freshwater head below sea level by pumping.

Screened interval (FT). The length of well screen through which water enters a well, in feet below land surface.

Transition (diffusion) zone. A zone of mixed water between fresh and salty ground water.

Total depth of well. The maximum depth in feet below land surface at which the well was originally finished. This depth may be slightly deeper than the bottom of the screened interval because many wells have a tailpiece or short length of casing installed below the well screen.

Water table. That surface in an unconfined ground-water body at which the pressure is atmospheric.

Water year. The twelve-month period, October 1 through September 30, designated by the calendar year in which it ends.

For brevity and ease of reading, abbreviations are used frequently in this report. The following list contains the most commonly used abbreviations with corresponding definitions:

Abbreviation	Definition
Boro	borough
Co	company
Corp	corporation
Dist	district
Inc	incorporated
MUA	municipal utilities authority
NGVD of 1929	National Geodetic Vertical Datum of 1929 (formerly, mean sea level datum)
NJDEP	New Jersey Department of Environmental Protection
NJWC	New Jersey Water Company
NPS	National Park Service
obs	observation (well)
Twp	township
WC	water company
WD	water department
WS	water system