HYDROGEOLOGY OF, GROUND-WATER WITHDRAWALS FROM, AND SALTWATER INTRUSION IN THE SHALLOW AQUIFER SYSTEM OF CAPE MAY COUNTY, NEW JERSEY

By Paul F. Schuster and Mary C. Hill

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
gallon (gal)	3.785	liter
foot per day (ft/d)	0.3048	meter per day
million gallons per day (Mgal/d)	0.04381	cubic meter per second
gallon per minute per foot [(gal/min)/ft]	0.2070	liter per second per meter
foot squared per day (ft^2/d)	0.09290	meter squared per day

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

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ABSTRACT

Ground water is the major source of freshwater supply in southern Cape May County, New Jersey. Withdrawals from the shallow aquifers provide about 50 percent of the freshwater used in the county. These withdrawals increased about 66 percent from 1956 to 1986, from 4.22 to 7.00 million gallons per day. Development of the shallow aquifers has modified the direction of ground-water flow, resulting in the contamination of many wells with saltwater. Prior to the development of southern Cape May County, ground water beneath the center of Cape May peninsula moved upward from the Cohansey aquifer to the estuarine sand aquifer and horizontally to the Delaware Bay and Atlantic Ocean, thus maintaining a substantial reservoir of fresh ground water beneath the peninsula. Water levels in the unconfined Holly Beach water-bearing zone did not change significantly from 1958 to 1987, but withdrawals of up to 7.00 million gallons per day caused heads in the confined Cohansey aquifer and estuarine sand aquifers to decline to as much as 24 feet below sea level, allowing saltwater to intrude into these aquifers. Chloride concentrations as high as 850 milligrams per liter have been measured in wells used for freshwater supply. A comparison between lines of equal chloride concentration in 1958 and 1983-87 indicates that saltwater has intruded into the estuarine sand and Cohansey aquifers and is migrating landward in the Cohansey aquifer in the southern and western parts of the peninsula.

INTRODUCTION

Withdrawals from shallow aquifers provide about 50 percent of the freshwater used in Cape May County. These withdrawals increased 66 percent from 1956 to 1986, from 4.22 to 7.00 Mgal/d (Zapecza and others, 1987). Development of the aquifer system caused the intrusion of saltwater into the aquifers. The resulting increased chloride concentrations have caused the water in some domestic and public-supply wells to become nonpotable (Gill, 1962a; Schaefer, 1983; David Rutherford, Cape May County Planning Board, written commun., 1987; W.D. Jones, U.S. Geological Survey, written commun., 1987). In response to concerns about seawater intrusion and to improve understanding of shallow-flow-system geohydrology, the U.S. Geological Survey (USGS), in cooperation with the City of Cape May, City of Wildwood, and Township of Lower Municipal Utilities Authority, undertook the present study.

Purpose and Scope

This report describes the hydrogeology of the shallow aquifers of Cape May County, New Jersey, and vicinity, including the hydrogeologic framework, the hydraulic properties of the aquifers and confining units, and ground-water flow. Ground-water withdrawals from, and saltwater intrusion in, the shallow aquifer system also are documented.

The report includes a discussion of previous investigations of the geology and ground-water resources of Cape May County and vicinity, and presents data collected from March through July 1987 as part of the current study. These data include--

(1) results of drilling and geophysical logging of two wells, conducted to define more accurately the hydrogeologic framework of the area;

(2) water levels measured in 30 wells to refine the knowledge of the ground-water flow patterns in the shallow aquifers; and

(3) results of analyses of ground water from 22 wells for tritium and chloride, made to determine the age of the water and the extent of saltwater intrusion in the aquifer system.

Description of Study Area

The study area is a 1,752-mi^2 area at the southern tip of New Jersey in the Atlantic Coastal Plain physiographic province (pl. 1). It includes nearly all of Cape May County and parts of Cumberland and Atlantic Counties, the State of Delaware, the Delaware Bay, and the Atlantic Ocean. Although the focus of this report is southern Cape May County, a larger study area was chosen to ensure that all factors affecting the hydrology of southern Cape May County would be considered.

Cape May County comprises 263 mi^2 and consists of low-lying, gently rolling plains with low, tidally influenced, marshy areas along the Delaware Bay and the Atlantic Ocean. Much of the mainland area consists of swamps. The northwestern part of the county is nearly level, with a maximum altitude of 60 ft above sea level. The southern part of the county consists of a low, sandy peninsula with altitudes that range from 0 to 30 ft above sea level. Well-developed barrier beaches along the Atlantic Ocean are separated from the mainland by extensive tidal flats.

The physiography of Cumberland and Atlantic Counties within the study area is similar to that of Cape May County. The bathymetry of the Delaware Bay and Atlantic Ocean in the study area and the topography of Cape May County and vicinity are shown on plate 2. The bathymetry of the Delaware Bay is irregular, ranging from 0 to 92 ft below sea level. Features include linear sand shoals, tidal channels, and a broad, irregular sill at the bay mouth. The bathymetry of the Atlantic Ocean is more regular, sloping first steeply and then more gradually to the east from the coast.

Previous Studies and Ongoing Data Collection

Gill's (1962a) comprehensive study of the ground-water resources of Cape May County includes (1) a summary of significant reports prior to 1962; (2) a detailed description of the aquifer system, including aquifer and confining-unit thicknesses and certain hydrologic properties; and (3) contour maps of potentiometric surfaces of, and chloride concentrations in, major aquifers. Several reports prepared by consultants consider the water resources of individual towns or other limited areas (Roy F. Weston, Inc., 1967, 1980; Geraghty and Miller, 1971) and include much of the same information contained in Gill (1962a). A study conducted by the USGS in the

Bidwell Ditch Basin near Cape May Court House (pl. 1) provided results of a 3-day aquifer test and permeability tests of confining-unit material (J.G. Rooney, U.S. Geological Survey, written commun., 1968).

Eckel and Walker (1986) show tabular potentiometric-surface data for the Cohansey aquifer in Cape May County in 1978 and 1983, and contour maps for 1983. Walker (1983) shows potentiometric-surface data and contours for 1978. These data document the decline in hydraulic heads over the 5-year period. Schaefer (1983) presents a contour map of chloride concentrations in the Cohansey aquifer at the southern tip of Cape May County, showing the increase in concentrations from 1958 to 1977. Transmissivities of most of the major aquifers in Cape May County were calculated from a numerical model of the New Jersey Coastal Plain ground-water system, which was developed as part of the USGS Regional Aquifer System Analysis (RASA) program (Martin, 1990).

Ongoing data-collection efforts by the USGS and the Cape May County Planning Board include the USGS's Saltwater Intrusion Monitoring Network. As part of this program, chloride concentrations in major aquifers of the New Jersey Coastal Plain are measured annually, during late summer. Approximately 40 of the 225 wells measured are in Cape May County. (The number of wells sampled varies). As of 1987, the Cape May County Planning Board measured chloride concentrations in nine wells near Villas (pl. 1) semiannually (winter and summer).

Approach and Methods

In the first phase of this study, data on hydrogeology, water levels, and chloride concentrations in the study area were inventoried and compiled. The second phase of the study included limited data collection. During spring 1987, three potentiometers and five drive-points (temporary potentiometers) were installed. Chloride concentrations, ground-water levels, and tritium concentrations were measured in these and selected additional wells throughout the county. In the study's third phase, all available data were combined to describe the hydrogeology of the shallow aquifers in Cape May County and the surrounding area, including the hydrogeologic framework, hydraulic properties of the aquifers and confining units, and ground-water flow, and to document ground-water withdrawals from, and chloride concentrations in, the aquifers. Southern Cape May County and parts of the study area where ground-water withdrawals are large and saltwater intrusion is extensive were studied most intensively; other parts of the study area were considered in less detail.

Previously published contour maps and sections that define the hydrogeologic framework of Cape May County (Gill, 1962a, figs. 2 and 4-7) were updated and extended to encompass the study area by using data from a variety of sources, including Zapecza (1989), Trapp (1992), Knebel and Circe (1988), Williams and others (1985), G.N. Paulachok (U.S. Geological Survey, written commun., 1987), I. Walker and H.E. Gill (U.S. Geological Survey, written commun., 1965), and Richards and Harbison (1944). Well-record information and geologic data from wells in Cape May County and the surrounding area used to define the hydrogeologic framework of the shallow aquifer system are listed in tables 1 and 2. Updated structure-contour maps were developed from these sources by using computer contouring software.

Table 1.--Partial records of wells used to construct hydrogeologic maps of the shallow aquifer system in Cape May County and vicinity

[Latitude and longitude in degrees, minutes, and seconds (391821 is 39° 18' 21''); dashes (--) indicate data not available or not applicable; USGS, U.S. Geological Survey; BORO, Borough; TWP, Township; WD, Water Department]

USGS unique well number	Well location Latitude	Well location Longitude	Local well identifier	Municipality
1-369	391905	743128	LONGPORT WD 3	LONGPORT BORO
1-578	391826	743709	USGS JOBS POINT	SOMERS POINT CITY
9-001	390420	744435	AVALON WD 4-48/NEW 2	AVALON BORO
9-002	390420	744435	AVALON WD 2R-71/NEW 7	AVALON BORO
9-009	390622	744250	13TH ST AND 2ND AVE	AVALON BORO
9-013	385613	745457	CAPE MAY CITY WD TH 10	CAPE MAY CITY
9-015	385625	745710	SUNSET BLVD 1 MI EAST OF DEL BAY	LOWER TWP
9-019	385557	745738	CAPE MAY PT WD LIGHTHOUSE 1	CAPE MAY POINT BORO
9-021	385631	745741	CAPE MAY PT WD SUNSET 2	CAPE MAY POINT BORO
9-024	385804	745742	USGS HIGBEE 2	LOWER TWP
9-030	385650	745310	USGS TEST 6	CAPE MAY CITY
9-033	385650	745535	CAPE MAY CITY WD BROADWAY 2	LOWER TWP
9-048	385748	745533	USGS CANAL 5	LOWER TWP
9-052	385851	745715	LOWER TWP MUA 1	LOWER TWP
9-054	385905	745625	LOWER TWP MUA 2	LOWER TWP
9-066	390135	745349	WILDWOOD WD RIO GRANDE 22	MIDDLE TWP
9-071	390138	745348	WILDWOOD WD RIO GRANDE 23	MIDDLE TWP
9-080	390213	745056	USGS CAPE MAY 42CC	MIDDLE TWP
9-086	390331	744604	STONE HARBOR WD 1	MIDDLE TWP
9-089	390425	745446	USGS OYSTER LAB 4	MIDDLE TWP
9-093	390525	744851	NJ WATER COMPANY NEPTUNUS TH1	MIDDLE TWP
9-094	390525	744851	NJ WATER COMPANY NEPTUNUS TW-19	MIDDLE TWP
9-099	390611	744838	USGS COUNTY PARK T8	MIDDLE TWP
9-110	391604	743539	NJ WATER COMPANY OCEAN CITY 12	OCEAN CITY
9-115	391636	743428	OCEAN AVE AND 9TH STREET	OCEAN CITY
9-117	391642	743447	NJ WATER COMPANY SHORE DIV 10	OCEAN CITY
9-118	391644	743447	OCEAN CITY WTRS 10TH AND HAVEN	OCEAN CITY
9-119	391647	743442	OCEAN CITY WTRS 9TH AND HAVEN	OCEAN CITY
9-126	390747	744241	SEA ISLE CITY WD 5	SEA ISLE CITY
9-127	390847	744200	SEA ISLE CITY WD 4	SEA ISLE CITY
9-129	390926	744131	SEA ISLE CITY WD 2	SEA ISLE CITY
9-132	390301	744545	STONE HARBOR WD 4	STONE HARBOR BORO
9-140	391422	744041	US AIR FORCE PALERMO 1	UPPER TWP
9-148	391707	743756	ATLANTIC CITY ELECTRIC LAYNE 4	UPPER TWP
9-149	391814	744954	MORRIS APRIL BROS	UPPER TWP
9-150	385607	745556	USGS WEST CAPE MAY COUNTY 1	WEST CAPE MAY BORO
9-153	385932	744851	WWD1	WILDWOOD CITY
9-158	385823	745023	WILDWOOD WD OLD WELL	WILDWOOD CREST BORO
9-159	385830	745021	WILDWOOD WD 35	WILDWOOD CREST BORO
9-166	390351	744504	STONE HARBOR WD 5	STONE HARBOR BORO
9-177	390642	744248	WONDER ICE COMPANY ABANDONED	AVALON BORO
9-178	385643	745803	NW MAGNESITE STEAM PLT	LOWER TWP
9-187	390218	745609	CAPE MAY F35	LOWER TWP
9-188	390215	745440	CAPE MAY F36	MIDDLE TWP
9-189	390211	745457	CAPE MAY F-37	MIDDLE TWP
9-190	390211	745457	CAPE MAY F-40	MIDDLE TWP
9-207	391121	745114	JAKES LANDING -1	DENNIS TWP
9-208	390212	745557	BSR-6	LOWER TWP
9-210	385946	745725	CAPE MAY C1	LOWER TWP
9-213	390128	745639	CAPE MAY F41	LOWER TWP
9-214	390050	745659	CAPE MAY F44	LOWER TWP
9-312	385828	745457	OLD SEASHORE ROAD 1	LOWER TWP
9-313	390726	745329	REEDS BEACH BAY FRONT	MIDDLE TWP
9-314	385930	744852	RECHARGE 3	WILDWOOD CITY
11-115	391109	745642	MOORES BEACH, LEWIS TOMLINSON	MAURICE RIVER TWP
11-116	391118	745705	MOORES BEACH FIRE DEPT	MAURICE RIVER TWP
99-005	390615	745245	1 MI NORTH OF DIAS CRK DEL BAY	MIDDLE TWP
99-008	391401	745220	BELLEPLAIN ST FOREST	DENNIS TWP
99-010	390035	744735	WEST SPRUCE ST NORTH WILDWOOD	NORTH WILDWOOD
99-013	391432	744847	WOODBINE WC CENTER OF WOODBINE BORO	WOODBINE BORO

Table 2.--Altitudes used to define the top or base of the major hydrogeologic units in Cape May County and vicinity

[See pls. 3 through 8 for well locations; values are in feet above or below (-) sea level; ABS indicates the unit is absent or its presence cannot be determined from available information; dashes (--) indicate data not available; USGS, U.S. Geological Survey]

	Altitude				
USGS unique well number[1]	Land surface	Top of estuarine clay confining unit	Top of estuarine sand aquifer	Base of Pleistocene deposits	Base of Cohansey aquifer
9-001	5	ABS	ABS	-90	--
9-002	5	--	--	--	-367
9-009	10	ABS	ABS	-90	--
9-013	10	-30	-75	-99	-315
9-015	13	-37	-59	-83	--
9-019	6	-50	-104	--	-286
9-021	13	-35	-55	-79	--
9-024	9	-35	-91	-126	-241
9-030	11	-29	-81	-149	--
9-033	12	-30	-73	-128	-295
9-048	17.48	-29	-134	-152	--
9-052	18	-26	-118	--	--
9-054	14	-30	-106	--	--
9-060	12	-51	-133	--	-268
9-066	8	--	--	--	-247
9-071	8	-40	-79	-129	--
9-080	13.67	-30	-86	-101	--
9-086	8	-30	-88	-104	--
9-089	7.37	-28	-56	-82	-202
9-093	17	--	--	--	-264
9-094	6	-54	-62	-128	--
9-098	18.5	-41	--	--	--
9-099	10.73	-47	-81	-111	--
9-110	7	--	--	--	-280
9-115	10	--	--	--	--
9-117	5	ABS	ABS	-128	--
9-119	8	ABS	ABS	-112	--
9-126	7	ABS	ABS	-108	-324
9-127	7	ABS	ABS	-112	--
9-129	7	ABS	ABS	-146	--
9-132	10	ABS	ABS	-109	-377
9-140	15	ABS	ABS	-63	--
9-148	9	--	--	--	-281
9-149	20	ABS	ABS	-40	-145
9-150	6.6	-37	-72	-86	--
9-153	8	-70	-127	-171	--
9-158	9	-53	-111	-210	--
9-159	8	--	--	--	-337
9-166	7	--	--	--	-340
9-177	5	--	--	--	-346
9-178	10	-31	-53	--	--
9-185	15	-48	-78	-155	-255
9-187	10	-30	-46	-102	--
9-188	10	-44	-70	-115	--
9-207	10.48	ABS	--	--	--
9-208	6.92	-40	-69	--	--
9-210	11.03	-62	-119	-140	--
9-213	12.23	-45	-77	-128	--
9-214	19.86	-53	-96	-124	--
11-115	4	ABS	-5	-106	-165
99-005	7	-52	-67	-112	--
99-006			ABS	-90	--
99-008	38	ABS	ABS	-20	--
99-009			ABS	-40	--
99-010	8	-44	-104	-124	--
99-011	17	-43	-133	--	--
99-012	14	-40	-82	--	--
99-013	40	ABS	ABS	-20	--
99-015	--	-31	-53	--	--
99-016	--	-30	--	--	--

Table 2.--Altitudes used to define the top or base of the major hydrogeologic units in Cape May County and vicinity--Continued

USGS unique well number[1]	Altitude: Land surface	Top of estuarine clay confining unit	Top of estuarine sand aquifer	Base of Pleistocene deposits	Base of Cohansey aquifer
99-017	--	-30	--	--	--
99-018	--	-30	--	--	--
99-019	--	-54	--	--	--
99-020	--	-43	-133	--	--
99-023	--	-35	--	--	--
99-024	--	-62	--	--	--
99-025	--	-50	--	--	--
99-026	--	-44	--	--	--
99-027	--	-43	--	--	--
99-028	--	-46	--	--	--
99-029	--	-57	--	--	--
99-030	--	-56	--	--	--
99-031	--	-71	--	--	--
99-032	--	-48	--	--	--
99-033	--	-40	--	--	--
99-034	--	-41	--	--	--
99-036	--	-30	-45	--	--
99-037	--	--	-45	--	--
99-038	--	--	-75	--	--
99-039	--	--	-117	--	--
99-040	--	--	-114	--	--
99-041	--	--	-116	--	--
99-042	--	--	-128	--	--
99-043	--	--	-133	--	--
99-044	--	--	-110	--	--
99-045	--	--	-82	--	--
99-046	--	--	-125	--	--
99-047	--	--	-78	--	--
99-048	--	--	-82	--	--
99-049	--	--	--	-70	--
99-050	--	--	--	-85	--
99-051	--	--	--	-177	--
99-052	--	--	--	-164	--
99-053	--	--	--	-210	--
99-054	--	--	--	-210	--
99-055	--	--	--	-129	--
99-056	--	--	--	-129	--
99-057	--	--	--	-128	--
99-058	--	--	--	-135	--
99-059	--	--	--	-128	--
99-178	--	--	-53	--	--

[1] Well numbers that begin with "99" are not USGS unique well numbers, but are arbitrary numbers assigned to wells for which geologic data are found in Gill (1962a, figs. 4, 6, and 7). Most of these wells are not included in table 1 because well records are not available.

Sufficient data were available to locate accurately the base of Pleistocene deposits and the Cohansey aquifer in many parts of the study area, but data for offshore areas were limited, consisting of information from only two wells offshore from Atlantic City, several miles outside the study area. Where available data were inadequate, the altitudes of the base of the Pleistocene deposits and the base of the Cohansey aquifer were estimated by extending the structure contours from areas with more detailed coverage, and by correlating them with similar information from locations outside the study area.

Few data were available to define the altitudes of the tops of the estuarine clay confining unit and the estuarine sand aquifer offshore (pls. 3 and 4). The locations of structure contours were estimated by using abundant onshore data, limited offshore data, the topography and bathymetry maps shown on plate 2, and the structure-contour map of the base of the Pleistocene deposits shown on plate 5. The onshore structure contours shown on plates 3 and 4 were developed from well data (table 2). The estuarine clay confining unit and the estuarine sand aquifer are absent in northern Cape May County (table 3; pls. 3 and 4). Analysis of the contours in southern Cape May County indicates that the material between land surface (the topography or bathymetry) and the base of the Pleistocene deposits generally is evenly distributed among the Holly Beach water-bearing zone, the estuarine clay confining unit, and the estuarine sand aquifer. Geophysical data of Williams and others (1985) indicate that all three units are found seaward from southern Cape May County, and data from Richards and Harbison (1944) indicate that all three units are found beneath the Delaware Bay. These data were insufficient, however, to define the relative thicknesses of the three units. The offshore contours shown on plates 3 and 4 were developed by assuming that one-third of the thickness of the material above the base of the estuarine sand aquifer can be attributed to each of the three units. The resulting structure contours, although approximate at best, are consistent with all available data.

Well-Numbering System

Gill (1962a, 1962b), the Cape May County Planning Board, and the USGS each use a distinct well-numbering system to identify wells in Cape May County. Wells listed in Gill (1962a; 1962b) are grouped by aquifer and are numbered sequentially starting at the southern tip of the county (Gill, 1962a, p. 6). Wells monitored by the Cape May County Planning Board that are located in the Cox Hall Creek Basin begin with "C"; those located in the Fishing Creek Basin begin with "F" (pl. 1). An identifying number follows the letter to form the well number. All wells used in this study have been inventoried by the USGS and have been assigned a 6-digit number that is used for identification in this report. (All three well-numbering systems are included in table 6, further on in the report, to facilitate cross-referencing this report with other works.)

Acknowledgments

The authors express their appreciation to members of the Cape May County Planning Board and personnel of the New Jersey Department of Environmental Protection for their cooperation and assistance. Special thanks are extended to David Rutherford of the Cape May County Planning Board for his assistance with data collection.

Table 3.--Relation of geologic and hydrogeologic units in the shallow aquifer system in Cape May County

[Modified from Zapecza, 1989, table 2]

<table>
<tr><th rowspan="2">System</th><th rowspan="2">Series</th><th colspan="2">Northern Cape May County</th><th colspan="2">Peninsular Cape May County</th></tr>
<tr><th>Geologic unit</th><th>Hydrogeologic unit</th><th>Geologic unit</th><th>Hydrogeologic unit</th></tr>
<tr><td rowspan="5">Quaternary</td><td rowspan="2">Holocene</td><td rowspan="2">Beach and dune deposits</td><td rowspan="6">Holly Beach water-bearing zone</td><td>Beach and dune deposits</td><td rowspan="3">Holly Beach water-bearing zone</td></tr>
<tr><td>Intertidal sands</td></tr>
<tr><td rowspan="3">Pleistocene</td><td rowspan="3">Cape May Formation</td><td rowspan="3">Cape May Formation</td></tr>
<tr><td>Estuarine clay confining unit</td></tr>
<tr><td rowspan="2">Estuarine sand aquifer</td></tr>
<tr><td rowspan="4">Tertiary</td><td rowspan="4">Miocene</td><td>Bridgeton Formation</td><td rowspan="4">Cohansey Sand</td></tr>
<tr><td rowspan="2">Cohansey Sand</td><td>Confining unit</td><td>Confining unit</td></tr>
<tr><td rowspan="2">Cohansey aquifer</td><td rowspan="2">Cohansey aquifer</td></tr>
<tr><td>Kirkwood Formation</td></tr>
</table>

HYDROGEOLOGY

The Coastal Plain sediments in Cape May County are similar to sediments elsewhere in the New Jersey Coastal Plain in that they (1) consist of unconsolidated to partly consolidated marine, marginal-marine, and nonmarine clays, silts, sands, and gravels; (2) are Tertiary and Cretaceous in age; (3) generally strike northeast; and (4) dip gently to the southeast at 10 to 60 ft/mi. The Coastal Plain sediments in Cape May County are from 4,200 to 6,700 ft thick. Overlying Quaternary deposits are 0 to 65 ft thick and are essentially flat-lying (Zapecza, 1989). Generalized stratigraphic sections of geologic and hydrogeologic units in the shallow aquifer system in the northern and peninsular parts of Cape May County are shown in table 3.

Framework

The major aquifers in the study area are, from top to bottom: (1) the Holly Beach water-bearing zone, which is composed of Quaternary beach and dune deposits, intertidal sands, the Cape May Formation, and the Bridgeton Formation; (2) the estuarine sand aquifer of the Cape May Formation; (3) the Cohansey aquifer of the Cohansey sand; and (4) the Rio Grande water-bearing zone and the Atlantic City 800-foot sand of the Kirkwood Formation (table 3). The Holly Beach water-bearing zone is an unconfined (water-table) aquifer. The estuarine sand aquifer is confined in the southern (peninsular) part of the county and is absent in the northern part. The Cohansey aquifer is confined in the southern part of the study area and unconfined in some sections in the northern part.

The two most extensive and effective confining units in the study area are in the Kirkwood Formation. Other less extensive confining units are found within the Cohansey Sand and Cape May Formation. The most significant of these is the estuarine clay facies of the Cape May Formation, which overlies the estuarine sand aquifer in the southern part of the study area. Another confining unit separates the estuarine sand aquifer from the underlying Cohansey aquifer.

The shallow aquifers in Cape May County referred to in this report are those above the upper confining unit of the Kirkwood Formation. Little leakage occurs through this unit (Gill, 1962a; Martin, 1990), which provides a well-defined lower boundary for the shallow aquifers throughout Cape May County. Although this confining unit pinches out in the northwestern corner of the study area, this location is more than 15 mi from southern Cape May County, the area of primary interest, so that the hydrologic effects of the pinchout in the study area probably are small.

Holly Beach Water-Bearing Zone

The Holly Beach water-bearing zone is composed of Holocene beach and dune deposits, intertidal sands, and the Cape May and Bridgeton Formations. It extends from land surface (pl. 2) to a depth that ranges from 17 to 71 ft below sea level (table 2; pl. 3) in Cape May County. The water table generally is between 0 and 15 ft below land surface (Gill, 1962a). This unit ranges in thickness from 9 ft at well 11-115 to 78 ft at well 9-153 (table 2). In the northern part of the county, where the estuarine clay confining unit is absent, the Holly Beach water-bearing zone is underlain by the confining unit that overlies the Cohansey aquifer; in the southern part of the county, it is underlain conformably by the estuarine clay confining unit (pl. 3).

Estuarine Clay Confining Unit

The estuarine clay confining unit, composed of the estuarine clay facies of the Cape May Formation, is found only in the southern part of the study area and pinches out on a line roughly parallel to the Dennis Township-Middle Township border (Gill, 1962a; J.G. Rooney, U.S. Geological Survey, written commun., 1968) (pls. 1 and 3). It does not crop out in Cape May County. The top of this unit ranges in altitude from 17 to 71 ft below sea level (pl. 3); its base ranges in altitude from 5 to 134 ft below sea level. Its thickness ranges from 0 ft in northern Cape May County to 105 ft at well 9-048 (Gill, 1962a; Gill, 1962b). As indicated on plates 3 and 4, the unit probably is thicker offshore to the southeast and thinner toward the northwest, beneath the Delaware Bay. The estuarine clay confining unit is underlain conformably by the estuarine sand aquifer (pl. 4).

Estuarine Sand Aquifer

The estuarine sand aquifer is composed of the estuarine sand facies of the Cape May Formation, which are Pleistocene channel-fill deposits. In the study area, the estuarine sand aquifer is found only in the southern part of Cape May County and in the area of Moores Beach, Cumberland County (pl. 1); it does not crop out in Cape May County. Well data indicate that the altitude of the top of the estuarine sand aquifer ranges from 5 to 134 ft below sea level (pl. 4), and the altitude of its base ranges from 20 to 210 ft below sea level (pl. 5). Its thickness averages about 30 ft, ranging from 0 ft in northern Cape May County to 101 ft at well 11-115 where it is thickest along the channels eroded into the underlying Cohansey aquifer (Gill, 1962a; Gill, 1962b). These channel-fill deposits, which extend from Reeds Beach to North Wildwood and Villas to Wildwood Crest (pl. 1), are evident in the contour map of the base of the Pleistocene deposits shown on plate 5. The estuarine sand aquifer is underlain conformably by the locally leaky confining unit above the Cohansey aquifer (pl. 6).

Confining Unit at the top of the Cohansey aquifer

The Cohansey Sand can be divided into two hydrogeologic units--the upper unit, which is composed of fine-grained material, and the lower unit, which is the Cohansey aquifer.

Gill (1962a) described a clay beneath the estuarine sand facies that he interpreted as the boundary between the Miocene and Pleistocene deposits in Cape May County. He hypothesized that this clay, where present, forms a leaky confining unit between the estuarine sand aquifer and the underlying Cohansey aquifer. The thickness of this unit is variable, with measured values ranging from 0 to 68 ft (pl. 6). Plates 5 and 6 show that the confining unit thickens to the east and tends to be thin or absent where the base of the Pleistocene deposits is found at relatively higher elevations.

Parts of Gill's (1962a) interpretation of the lithology in the northwest-central part of Cape May County have been modified as a result of more recent work. Gill (1962a) identified a sand unit above a clay 4 mi north of Reeds Beach (pl. 1) as part of the estuarine sand aquifer, and the clay as the boundary between the Miocene and Pleistocene deposits. On the basis of the color and compaction of augered material, however, W.L. Newell (U.S. Geological Survey, written commun., 1987) determined the sand to be Miocene in age, and hypothesized that the Cohansey Sand in Cape May County is part of a deltaic sequence that originates northwest of the county. This recent interpretation indicates that clays in the Cohansey Sand probably are equivalent to clays that crop out northwest of Cape May County, and that the fine material at the top of the Cohansey Sand probably is continuous throughout large areas in Cape May County. The continuity of this confining unit could have a significant effect on vertical hydraulic conductivity.

Although Newell's work (W.L. Newell, U.S. Geological Survey, written commun., 1987) indicates that the clay deposits identified by Gill (1962a) may form a confining unit that is more continuous than that shown on plate 6, his thickness interpretations are otherwise largely consistent with those of Gill, which are used here.

Cohansey Aquifer

The Cohansey aquifer is composed primarily of the Cohansey Sand, which is Miocene in age. The Cohansey Sand is found throughout Cape May County, but may be absent in some parts of the Delaware Bay as a result of incision by the ancient Delaware River, which may have caused complete erosion of the unit in places (pl. 7). In some areas in the northeastern part of Cape May County (wells 9-126, 9-132, and 9-177), a sand member of the Kirkwood Formation is found between the Cohansey aquifer and the underlying confining unit, and functions as part of the Cohansey aquifer.

Zapecza (1989, pl. 23) defined the base of this unit in onshore and nearshore areas of Cape May County through interpretation of geophysical well logs. The base of the Cohansey aquifer, shown on plate 7, was extended to parts of the study area where few data are available by extending the structure contours of Zapecza's (1989) maps and and correlating them with offshore geologic data from the area east of Atlantic City (G.N. Paulachok, U.S. Geological Survey, written commun., 1987), and with onshore geologic data from the State of Delaware (Trapp, 1992).

In the northwestern and north-central parts of the county, the Cohansey Sand is overlain by the Miocene Bridgeton Formation (Gill, 1962a; Owens and Minard, 1979). Within the study area, the altitude of the top of the Cohansey aquifer ranges from 20 to 210 ft below sea level (pl. 5); the altitude of its base ranges from 145 to 377 ft below sea level (pl. 7); and its thickness averages about 166 ft, ranging from 59 ft at well 11-115 to 268 ft at well 9-132 (Zapecza, 1989; Gill, 1962b). The aquifer probably is thicker beneath the Atlantic Ocean to the east. The Cohansey aquifer is underlain unconformably by the upper confining unit of the aquifers in the Kirkwood Formation (Gill, 1962a).

Lithology and Hydraulic Properties of Aquifers and Confining Units

Selected hydraulic properties of each hydrogeologic unit in the shallow aquifer system are summarized in table 4.

Holly Beach Water-Bearing Zone

The unconfined Holly Beach water-bearing zone is the uppermost aquifer in Cape May County. In the southern part of the county, this aquifer is composed of intertidal sands and marine sands of the Cape May Formation; in the offshore areas, it is composed of marine sands and beach and dune deposits; in the northwestern part of the county, it is composed of the Bridgeton Formation; and in the northeastern part of the county, it is composed of beach and dune deposits and marine sands (Gill, 1962a). Because of this variation in depositional environments, the texture of the Holly Beach water-bearing zone is variable. The intertidal sands are fine to coarse, with thin units of fine gravel in many areas; the marine sands are medium to coarse; and the beach and dune deposits are composed of fine to medium sand. The Bridgeton Formation consists of coarse to medium sand with abundant silt and clay (Gill, 1962b).

Little work has been done to determine the hydraulic properties of the Holly Beach water-bearing zone. Based on the specific capacities of wells, Gill (1962a) estimated the transmissivity of this aquifer to be about 2,000 ft^2/d. Results of a numerical model of the New Jersey Coastal Plain aquifer system calibrated by Martin (1990) indicate that the transmissivity ranges from 5,200 to 7,800 ft^2/d.

Estuarine Clay Confining Unit

The estuarine clay confining unit (pl. 3) is composed mostly of silty blue clay with interspersed lenses of sand and gravel less than 10 ft thick and is locally leaky (Gill, 1962a, 1962b). Results of permeameter tests reported by J.G. Rooney (U.S. Geological Survey, written commun., 1968) indicate that the vertical hydraulic conductivity of undisturbed samples of the estuarine clay confining unit in the Bidwell Creek Basin (pl. 1) is between 0.01 and 0.04 ft/d. Rooney also reported, however, that the estuarine clay is unusually sandy in this area, so that the confining unit probably is less permeable in other parts of the study area.

Tritium concentrations were measured in ground-water samples from the Holly Beach water-bearing zone and the estuarine sand and Cohansey aquifers in order to evaluate the effectiveness of the estuarine clay as a confining unit. Naturally occurring tritium has been shown to be useful in dating ground water (Stewart and Farnsworth, 1968), but the testing of nuclear devices that began in 1952 has produced tritium in the atmosphere in amounts sufficient to mask natural levels completely. Therefore, tritium levels are used here only to distinguish between water that was last exposed to the atmosphere before and since 1952.

Locations of two hydrogeologic sections (A-A′ and B-B′) through the shallow aquifer system of Cape May County are shown on plate 8; concentrations of tritium measured in ground water along section A-A′ and

Table 4.--Summary of ranges of hydraulic properties for each hydrogeologic unit in the shallow aquifer system of Cape May County

[Dashes (--) indicate data not available; (gal/min)/ft, gallons per minute per foot; ft^2/d, feet squared per day; ft/d, feet per day]

Hydrogeologic unit	Specific capacity ((gal/min)/ft)	Transmissivity (ft^2/d)	Vertical hydraulic conductivity (ft/d)	Horizontal hydraulic conductivity (ft/d)	Storage coefficient
Holly Beach water-bearing zone	0.67-21.5 [a]	2,000 [a] 5,200-7,800 [b]	--	--	--
Estuarine clay confining unit	--	--	0.01-0.04 [c]	--	--
Estuarine sand aquifer	1.5-22 [a]	2,700-5,300 [a] 9,200-11,400 [c]	--	156-286 [c]	0.00043-0.00073 [c]
Confining unit at top of Cohansey aquifer	--	--	0.008-0.05 [a]	--	--
Cohansey aquifer	--	3,600-7,200 [a] 8,000-11,700 [b]	--	53-146 [a]	0.00012-0.0003 [a]

[a] Gill, 1962a

[b] Martin, 1990

[c] J.G. Rooney, U.S. Geological Survey, written commun., 1968

water levels measured at selected wells along sections A-A′ and B-B′ are shown on plate 9. Water levels along section A-A′ show the drawdown produced by withdrawals at the Rio Grande well field (pl. 1).

Tritium concentrations in the two confined aquifers were less than one tritium unit (TU), indicating that "old" (pre-1952) water is present. Thus, as of 1987, this water has not been exposed to the atmosphere for at least 35 years. Tritium concentrations in the Holly Beach water-bearing zone were elevated, however, indicating that this water is more recent. Although the water-level contours on plate 9a show a downward gradient through the estuarine clay confining unit, tritium concentrations indicate that the vertical hydraulic conductivity of the estuarine clay confining unit in the vicinity of section A-A′ significantly retards the downward movement of ground water, even in areas of heavy withdrawals such as those surrounding the Rio Grande well field.

The distance that ground water would be expected to travel downward through the estuarine clay confining unit near wells 9-189 and 9-190 from 1966 to April 1987 can be calculated from the measured water levels at wells 9-189 (pl. 9a and fig. 1b) and 9-190 (pl. 9a) by assuming that hydraulic heads measured at wells 9-190 and 9-189 approximately equal the heads at the top and bottom, respectively, of the estuarine clay confining unit. On the basis of the tritium data, this calculated distance is less than the 20-ft thickness of the confining unit; a larger calculated value would indicate that the estimated vertical hydraulic conductivity of the confining unit is larger than the actual value. By using Darcy's Law, and ignoring the effects of storage in the confining unit, the distance traveled can be calculated as

$$D = t \frac{K_v}{n} \frac{(h_1 - h_2)}{L},$$

where D is distance traveled along a flow line, in feet;

t is time of travel (22 years);

K_v is vertical hydraulic conductivity of the confining unit, in feet per day;

n is effective porosity;

h_1 and h_2 are hydraulic heads above and below the confining unit, respectively, in feet; and

L is confining-unit thickness (20 ft).

In April 1987, h_1, as measured at well 9-190 (pl. 9a), was 3.11 ft. As discussed in the following section, hydraulic heads in the Holly Beach water-bearing zone did not change significantly from 1957 to April 1987. Therefore, this value is applicable for 1966 to April 1987. A value of h_1 equal to 3 ft is used in the calculation. Figure 1 shows that the water level at well 9-189 varied from -0.5 to -12.5 ft from 1966 to 1987, with yearly fluctuations of about 9 ft. This variation complicates the determination of h_2. One approach is to use a high value for h_2 so that $(h_1 - h_2)$ is a conservative estimate of the difference in head from the top to

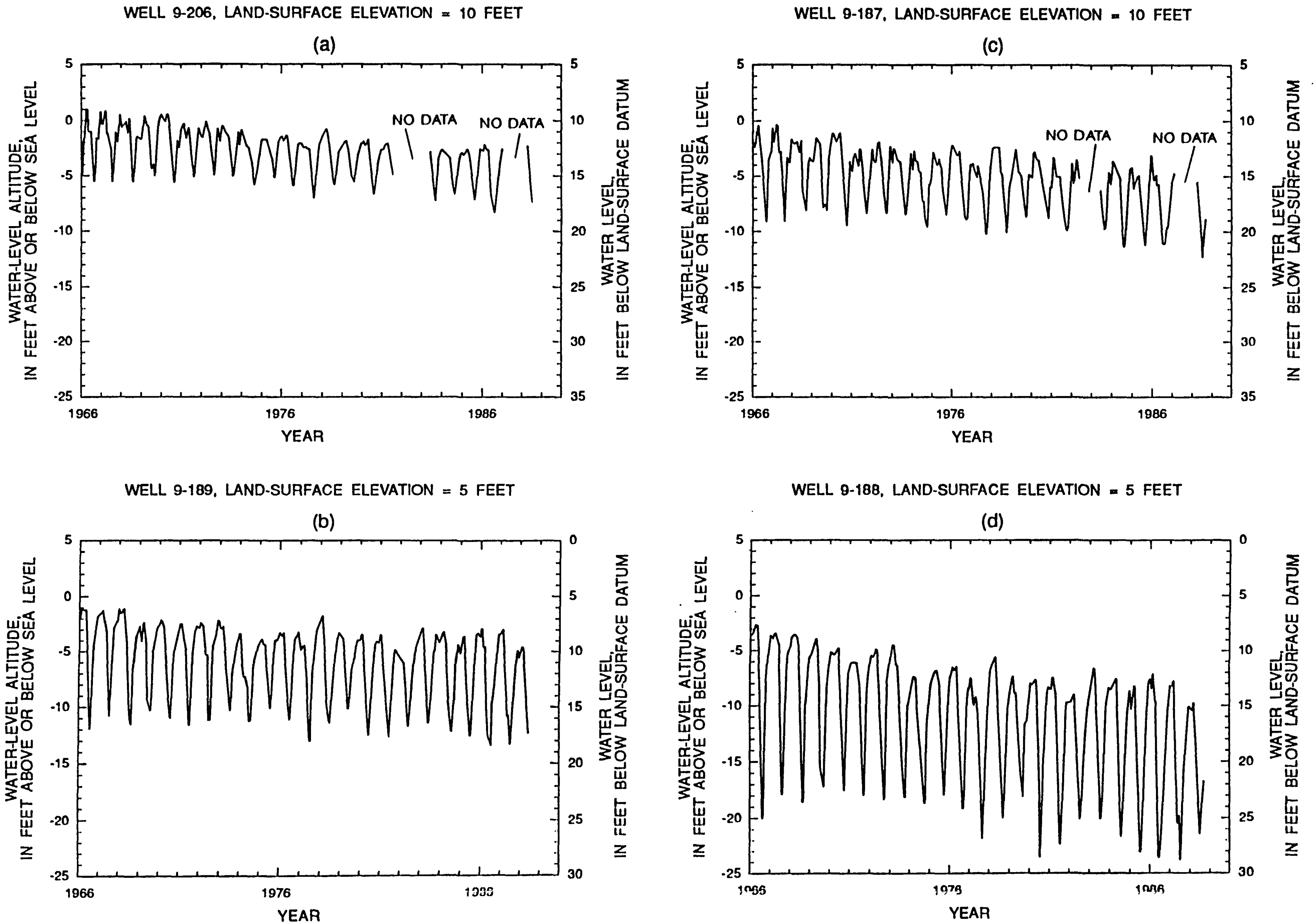

Figure 1. Water levels in four wells in Cape May County, New Jersey, 1966-87.

the bottom of the confining unit. This approach results in a smaller calculated distance, D, than would be calculated by using a more precise approximation of h_1-h_2. This approach is adopted here, and a value of h_2 equal to 0.0 ft is used in the calculation.

By assuming that n equals 0.15 and using the K_v value of 0.02 ft/d (based on the data presented in the previous section of this report), D can be calculated as

$$D = (22 \text{ years} \times \frac{365.25 \text{ days}}{1 \text{ year}}) \quad \frac{0.02 \text{ ft/d}}{0.15} \quad \frac{3 \text{ ft}}{20 \text{ ft}} = 161 \text{ ft.}$$

The calculated value is much larger than the 20-ft thickness of the confining unit, indicating that either (1) the approximate porosity value used in the calculation is lower than the actual volume, and (or) (2) the estimated value of vertical hydraulic conductivity is higher than the actual value. The porosity probably does not exceed 0.5, which would yield a value of D equal to 48 ft. Thus, the estimated value of K_v, 0.02 ft/d, is at least twice the actual effective value, and a more realistic estimate of the vertical hydraulic conductivity of the estuarine clay confining unit is 0.01 ft/d or less.

Estuarine Sand Aquifer

The estuarine sand aquifer commonly consists of poorly sorted silty clay, coarse sand, and fine gravel, but permeable, clean, coarse sand and gravel also are found, especially in the channels of ancient tributaries (pl. 5; Gill, 1962a, fig. 4 and p. 55). Sediments in the ancient tributary channel that extends from Reeds Beach to North Wildwood (pl. 1) are coarser than those found in the main channel to the south (Gill, 1962a).

Measurements of specific capacity in wells in the tributary deposits of the estuarine sand aquifer range from 18 to 22 (gal/min)/ft; specific capacities in the main channel range from 8.8 to 10 (gal/min)/ft (Gill, 1962a). Estimates of the transmissivity of the estuarine sand aquifer derived by using these values range from 2,700 to 5,300 ft^2/d (Gill, 1962a); this range is similar to the range of transmissivities reported for the Holly Beach water-bearing zone. Results of an aquifer test conducted by J.G. Rooney (U.S. Geological Survey, written commun., 1968) indicated that the transmissivity of the estuarine sand aquifer near the Bidwell Creek area (pl. 1) of Cape May County was between 9,200 and 11,400 ft^2/d, the horizontal hydraulic conductivity was between 152 and 286 ft/d, and the storage coefficient was between 0.00043 and 0.00073. The higher transmissivity range derived by Rooney probably is indicative of the coarse sediments deposited in the ancient tributary channel extending from Reeds Beach to North Wildwood (pl. 1).

Confining Unit at the top of the Cohansey Aquifer

The only hydraulic-property data available for the confining unit above the Cohansey aquifer are based on analyses reported by Gill (1962a) of two disturbed samples collected with a bailer. The samples are from 117 to 118.5 ft below sea level in well 9-089, and from 115 to 117 ft below sea level in well 9-150. The vertical hydraulic conductivities of these samples measured by means of laboratory permeameter tests were 0.008 ft/d and 0.05

ft/d, respectively. Although these values are similar to those determined for the estuarine clay confining unit, the possible discontinuity of the clay lenses discussed previously would increase the effective vertical hydraulic conductivity of this confining unit.

Cohansey Aquifer

Cohansey aquifer materials range in size from almost pure clay to coarse sand and fine gravel (Gill, 1962b). Several discontinuous clay wedges up to 70 ft thick also are found in the Cohansey aquifer at the southern tip of the county (Gill, 1962a).

Ten aquifer tests conducted in the Cohansey aquifer and laboratory determinations of the physical properties of 22 core samples from the aquifer (Gill, 1962a, tables 5 and 6) were used to estimate its hydraulic properties. Based on the results of these tests, the average transmissivity of the Cohansey aquifer north of Cape May Canal is about 7,200 ft^2/d, which is higher than that of both the Holly Beach water-bearing zone and the estuarine sand aquifer. The average horizontal hydraulic conductivity of the Cohansey aquifer north of the canal is about 146 ft/d, and the average storage coefficient is about 0.0003; both of these values are lower than the corresponding values for the estuarine sand aquifer. South of the canal, where the aquifer material is finer, transmissivity ranges from 3,600 to 6,000 ft^2/d, horizontal hydraulic conductivity ranges from 53 to 94 ft/d, and the storage coefficient ranges from 0.00012 to 0.00013. The estimates of hydraulic conductivity were calculated by using "effective aquifer thicknesses" (Gill, 1962a), which represent the length of the well screen or the thickness of the coarsest layer shown in the driller's log. Effective aquifer thicknesses generally are less than the full thickness of the aquifer.

In Martin's (1990) calibrated numerical model, the transmissivity of the Cohansey aquifer ranged from 8,000 to 11,700 ft^2/d--values greater than those previously reported. In the simulated system, however, the Cohansey aquifer was combined with the estuarine sand aquifer, resulting in a higher transmissivity than expected.

Ground-Water Flow

The flow of ground water within and between the aquifers of the shallow aquifer system of Cape May County has been affected by pumpage. Historical and recent (1987) measurements of hydraulic head were compared to determine the direction and magnitude of these changes.

Holly Beach Water-Bearing Zone

The unconfined Holly Beach water-bearing zone receives recharge directly from precipitation. The absence of streams at higher elevations in Cape May County indicates that surficial deposits are highly permeable, promoting infiltration of water into the ground-water system.

A comparison between water levels measured in 1957 (Gill, 1962a) and those measured by the USGS in the same wells during the 1980's indicates that water levels in the unconfined Holly Beach water-bearing zone have not changed significantly since 1957. Annual high and low water-table maps (Gill, 1962a, figs. 46 and 47) and the sections shown on plate 9 (a and b) indicate that ground water moves from high-elevation recharge areas in the northwestern part of the county and along the center of the Cape May peninsula to points of discharge along streams or directly to the ocean or bay. Measured water levels (Gill, 1962a) are consistent with simulated water levels presented by Martin (1990, fig. 51).

Estuarine Sand Aquifer

Before extensive development of the Cohansey aquifer in Cape May County, water moved upward from the Cohansey aquifer to the estuarine sand aquifer (Gill, 1962a). Hydrographs shown in figure 1 (a and b) indicate that water levels in the estuarine sand aquifer near the Rio Grande well field (pl. 1) declined 2 to 3 ft from 1966 to 1986, and remain below sea level even in winter, when ground-water withdrawals are lowest. Locally, the vertical gradient has reversed, so that water moves from the estuarine sand aquifer into the Cohansey aquifer. Plate 9 and previously published maps of the potentiometric surface in the estuarine sand aquifer (Gill, 1962a, figs. 43 and 44) indicate that freshwater recharges the aquifer principally through downward leakage from the overlying Holly Beach water-bearing zone. According to Gill (1962a), downward leakage is greatest where the overlying estuarine clay confining unit is sandy and (or) thin. As discussed previously, the low tritium concentrations measured in the estuarine sand aquifer indicate that the estuarine clay confining unit impedes the downward flow of water throughout the area surrounding the Rio Grande well field.

Cohansey Aquifer

Maps of the potentiometric surface of the Cohansey aquifer in September 1957 and January 1958 (Gill, 1962a, figs. 30 and 31) indicate that the principal recharge area in northern Cape May County is near Belleplain (pl. 1), where the Cohansey aquifer is overlain by the surficial sands and gravels of the Bridgeton Formation. Ground water moves from a local ground-water high north and west toward the Maurice and Tuckahoe Rivers (pl. 1) and south and east toward the Delaware Bay, the Atlantic Ocean, and southern Cape May County. The outcrop areas of the Cohansey aquifer, located in Cumberland and Atlantic Counties (pl. 7), are relatively small, and ground water in these areas tends to flow away from Cape May County toward the north, south, and west (Roy F. Weston, Inc., 1967). Hydrogeologic sections shown on plate 9 are consistent with results of Gill's (1962a) analysis, which indicate that the Cohansey aquifer in the southern part of Cape May County is recharged by vertical leakage from the overlying estuarine sand aquifer.

The predevelopment potentiometric surface of the Cohansey aquifer shows a ridge of high heads that extends down the Cape May peninsula from Dennis Township to Cape May City (pl. 1; Gill, 1962a, fig. 32), indicating that ground water in the southern part of Cape May County moved horizontally south, east, and west from the center of the peninsula. Static water levels in wells drilled on the Cape May peninsula in about 1900 were 8 ft above sea level (Gill, 1962a), indicating that ground water moved upward from the Cohansey aquifer to overlying units. Because few historical data are available, however, this hypothesis is unconfirmed. The hydrographs shown in figure 1 (c and d) indicate that water levels declined from 1966 to 1987. Extensive development of the Cohansey aquifer in southern Cape May County has caused a local reversal of both the horizontal and vertical ground-water flow. A map of the potentiometric surface of the Cohansey aquifer in 1983 (Eckel and Walker, 1986, fig. 11) shows a deep cone of depression centered at Cape May City. Plate 9 indicates that water now (1987) moves horizontally from areas beneath the Atlantic Ocean and the Delaware Bay toward the pumped wells and downward from the overlying estuarine sand aquifer.

GROUND-WATER WITHDRAWALS

Ground-water withdrawals from the shallow aquifer system in Cape May County account for about 50 percent of the freshwater used in the county. Ground-water-withdrawal and -recharge data for the shallow aquifers of Cape May County for 1918-86 are shown in table 5 and plotted in figure 2. These data are from records submitted to the New Jersey Department of Environmental Protection by water companies and include withdrawals for public-supply. industrial, and agricultural water use from the shallow aquifers in Cape May County. Before and during 1956, the water companies reported only total withdrawals; since 1956, the data have been reported by individual well.

Ground-water withdrawals in Cape May County vary seasonally. During summer, increased tourism and irrigation result in increased water demands. To meet these demands, three times as much water is withdrawn from the shallow aquifer system in summer than in winter. Figure 3 shows the increase in monthly ground-water withdrawals from the estuarine sand and Cohansey aquifers during summer 1986.

In 1986, an average of 7.00 Mgal/d was withdrawn from the shallow aquifers. About 88 percent of the water was used for public supply, of which about 66 percent was withdrawn at the City of Wildwood's Rio Grande well field (fig. 4). About 9 percent of all the ground water withdrawn from the shallow aquifers in 1986 was used for industrial purposes, and about 3 percent was used for agriculture. Although some residents of Cape May County derive their water from domestic wells, the amount of these withdrawals and their effect on the ground-water system are unknown.

Most of the remaining freshwater used in Cape May County currently (1987) is withdrawn from the aquifers in the Kirkwood Formation. In 1985, the average withdrawal from these aquifers (7.44 Mgal/d) was nearly equal to withdrawals from the shallow aquifer system. Most of the wells that tap the aquifers in the Kirkwood Formation are located in the barrier-island areas of Cape May County.

Holly Beach Water-Bearing Zone

The Holly Beach water-bearing zone is a potentially productive aquifer that historically has been the least used aquifer in Cape May County (Gill, 1962a). Ground water withdrawn from the Holly Beach water-bearing zone was pumped from two wells at the Rio Grande well field (fig. 4) for public supply. Ground-water withdrawals from this aquifer increased from 0.03

Table 5.--Historical ground-water-withdrawal[1] and -recharge data for the shallow aquifers in Cape May County, 1918-86

[Values are in millon gallons per day; HLBC, Holly Beach water-bearing zone; ESRNS, Estuarine sand aquifer; CNSY, Cohansey aquifer[2]; dashes (--) indicate data not available]

Year	Withdrawals[3] HLBC	Withdrawals[3] ESRNS	Withdrawals[3] CNSY	Recharge[4] CNSY
1918	--	--	1.49	0
1919	--	--	1.39	0
1920	--	--	1.32	0
1921	--	--	1.20	0
1922	--	--	1.29	0
1923	--	--	1.39	0
1924	--	--	1.32	0
1925	--	--	1.40	0
1926	.03	--	1.67	0
1927	.02	--	1.63	0
1928	.02	--	1.53	0
1929	.05	--	1.73	0
1930	.04	--	1.76	0
1931	.04	--	1.86	0
1932	.04	--	1.85	0
1933	.05	--	2.02	0
1934	.04	--	1.86	0
1935	.05	--	1.60	0
1936	.06	--	1.65	0
1937	.05	--	1.69	0
1938	.05	--	1.54	0
1939	.05	--	1.66	0
1940	.05	--	1.58	0
1941	.05	--	1.76	0
1942	.04	--	1.76	0
1943	.04	--	1.93	0
1944	.05	--	1.84	0
1945	.05	--	1.90	0
1946	.06	--	1.82	0
1947	.06	--	1.96	0
1948	.07	--	1.99	0
1949	.07	--	2.17	0
1950	.08	--	2.02	0
1951	.10	--	2.38	0
1952	.08	--	2.43	0
1953	.09	--	2.64	0
1954	.10	--	2.52	0
1955	.10	--	2.63	0
1956	.10	.45	3.67	0
1957	.10	.48	4.21	0
1958	.11	.42	4.20	0
1959	.12	.48	4.26	0
1960	.13	.57	4.24	0
1961	.14	.48	4.64	0
1962	.16	.53	4.72	0
1963	.17	.55	5.20	0
1964	.20	.57	5.27	0
1965	.20	.57	4.70	0
1966	.19	.58	5.24	0
1967	.10	.58	4.53	--
1968	.03	.59	4.65	.27
1969	.12	.52	5.07	.25
1970	.12	.64	5.19	.33
1971	.10	.50	5.09	.21
1972	.08	.59	4.95	.20
1973	.06	.44	5.58	.22
1974	.07	.44	6.17	.23
1975	.12	.51	5.33	.21
1976	.16	.41	5.93	.21
1977	.15	.28	6.34	.10
1978	.16	.39	6.22	.16
1979	.17	.45	6.43	.18
1980	.21	.49	6.58	.15

Table 5.--Historical ground-water-withdrawal[1] and -recharge data for the shallow aquifers in Cape May County, 1918-86--Continued

Year	Withdrawals[3] HLBC	ESRNS	CNSY	Recharge[4] CNSY
1981	0.25	.44	6.16	.19
1982	.25	.48	6.36	.43
1983	.25	.44	6.16	.31
1984	.13	.44	5.26	.35
1985	.0	.47	5.97	.24
1986	.0	.39	6.61	.51

1 Withdrawal data include water used for public-supply, industrial, and agricultural purposes in Cape May County.

2 Described as the Kirkwood-Cohansey aquifer system in Zapecza (1989) and Zapecza and others (1987).

3 Sources of withdrawal data: Zapecza and others (1987), U.S. Geological Survey State Water Use System; and New Jersey Department of Environmental Protection and Energy.

4 Source of recharge data: New Jersey Department of Environmental Protection.

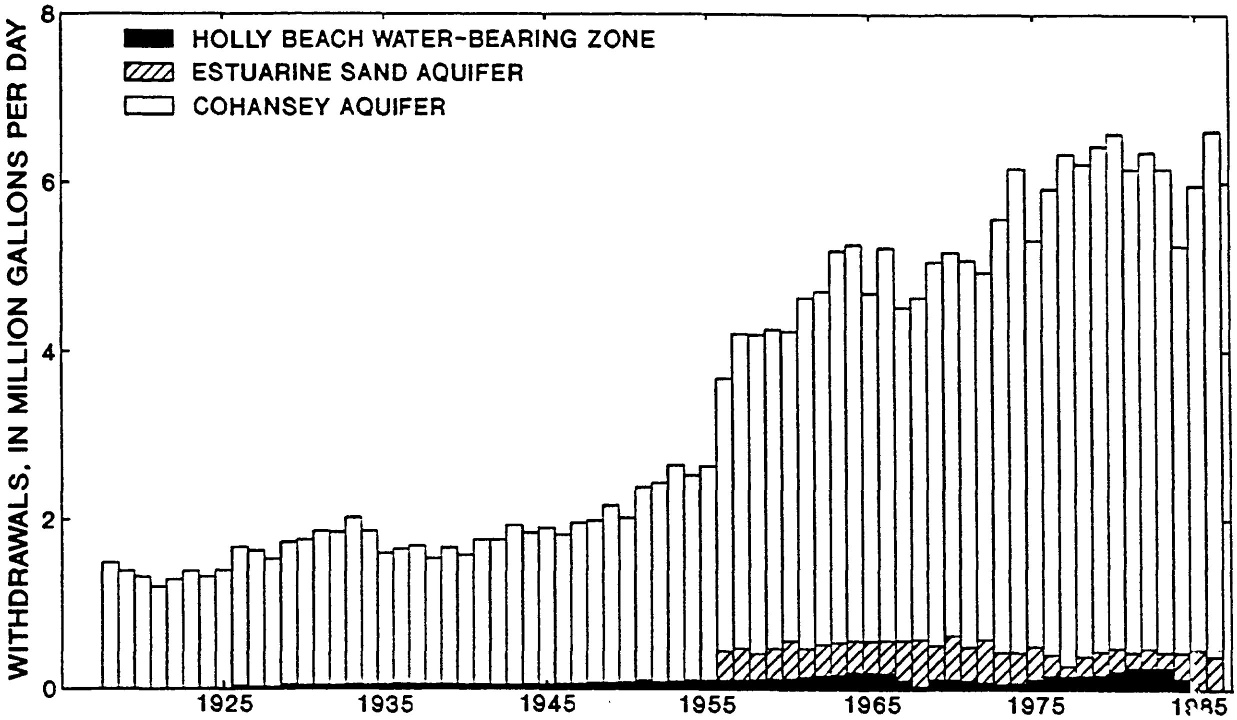

Figure 2. Historical ground-water withdrawals from the shallow aquifers in Cape May County, New Jersey, 1918-86.

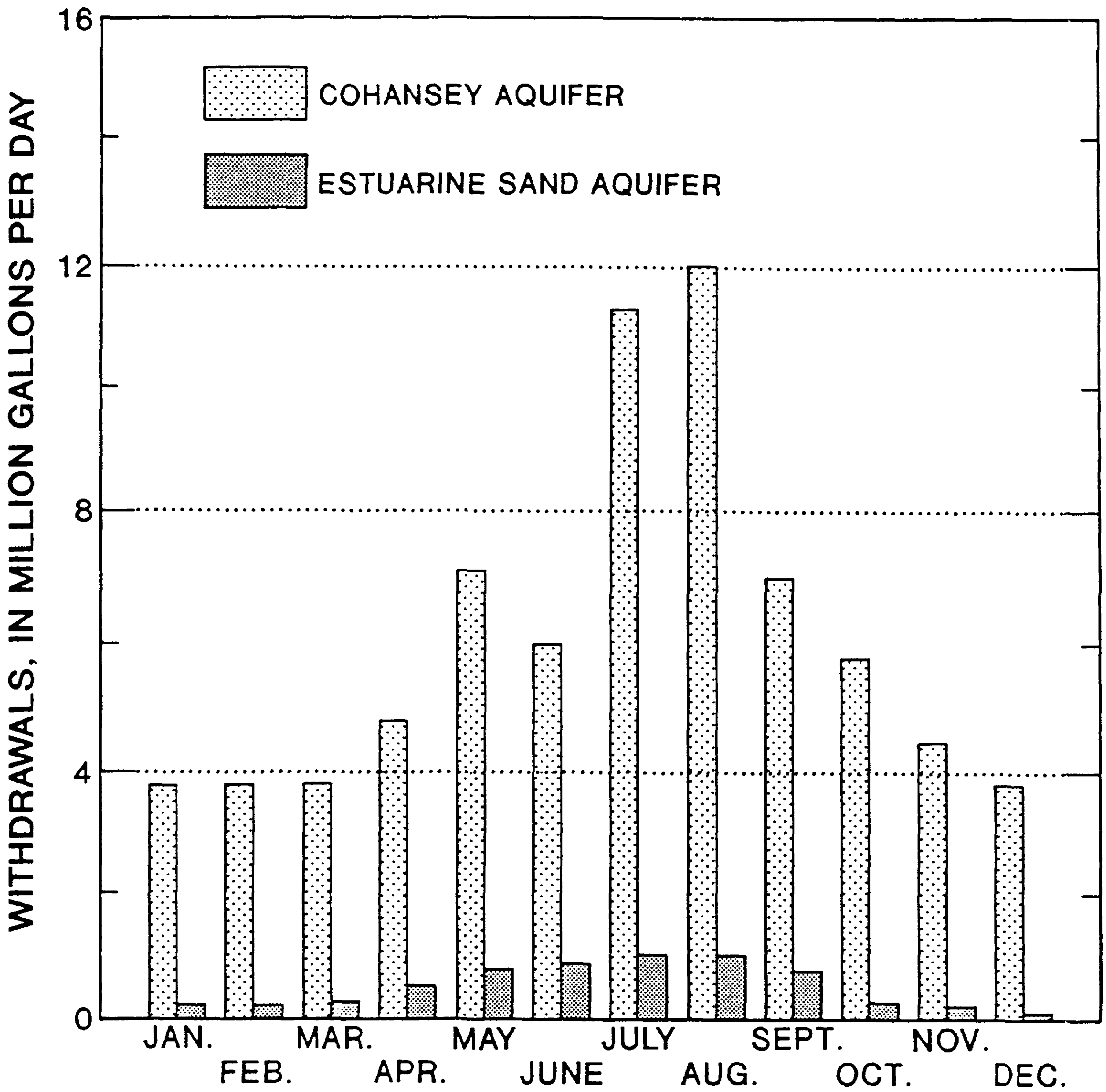

Figure 3. Monthly ground-water withdrawals from the estuarine sand and Cohansey aquifers in Cape May County, New Jersey, 1986.

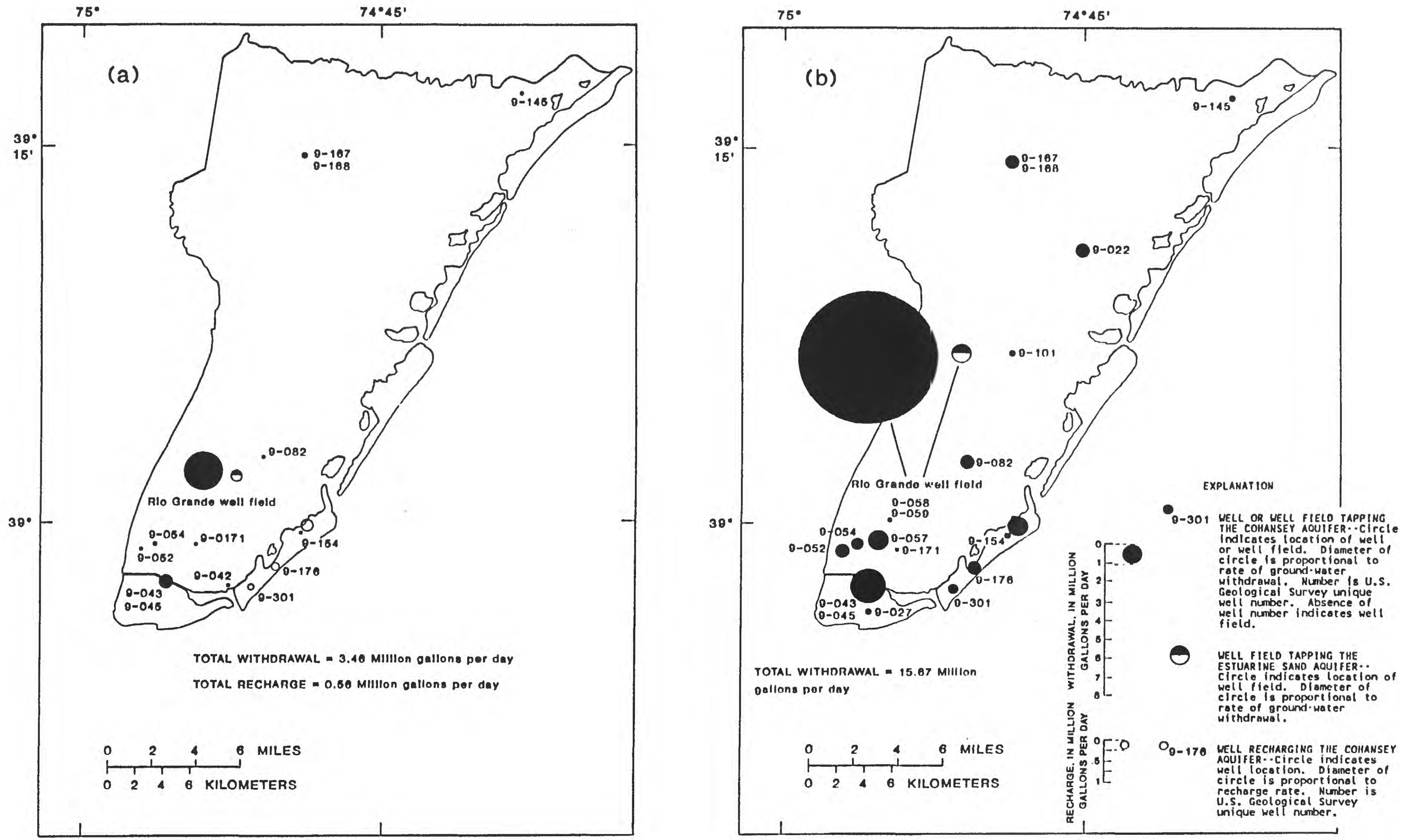

Figure 4. Major public supply wells and well fields, and reported recharge to or withdrawal from the shallow aquifers of Cape May County, New Jersey, 1986, during (a) low water consumption (winter months) and (b) peak water consumption (summer months).

Mgal/d in 1926 to 0.25 Mgal/d in 1983, but decreased to near zero in 1985 and 1986 as a result of local contamination of ground water caused by a gasoline spill at the Rio Grande well field. No public suppliers currently (1987) report withdrawals from the Holly Beach water-bearing zone.

Estuarine Sand Aquifer

All ground water currently (1987) withdrawn from the estuarine sand aquifer for public water use is from Wildwood's Rio Grande well field (fig. 4). Withdrawals have fluctuated no more than 0.4 Mgal/d since 1956 (fig. 2, table 5). Monthly withdrawals are greatest in summer (fig. 3).

Ground water was withdrawn from the estuarine sand aquifer in the Villas area (pl. 1) through many domestic wells during summer 1957; these withdrawals reached a combined maximum of 1 to 2 Mgal/d (Gill, 1962a). Ground-water withdrawals from the estuarine sand aquifer for domestic use probably have increased throughout southern Cape May County in response to the increase in population since 1957 (David Rutherford, Cape May County Planning Board, oral commun., 1987).

Cohansey Aquifer

The Cohansey Sand is the most productive and most extensively pumped aquifer in the shallow aquifer system. Total reported ground-water withdrawals increased from about 1.49 Mgal/d in 1918 to 6.61 Mgal/d in 1986 (fig. 2, table 5). Monthly withdrawals usually are greatest from May through September (fig. 3). (Withdrawals shown for May in figure 3 are exceptionally large as a result of increased pumpage during Memorial Day weekend (Robert Beebee, Wildwood Water Department, oral commun., 1987).) Locations of ground-water wells and well fields and withdrawals for 1986 are shown in figure 4. Withdrawals are concentrated in the southern part of Cape May County.

The Wildwood Water Department operates four recharge wells on the barrier islands of Cape May County; three of these wells are screened in the Cohansey aquifer (fig. 4) and one is screened in the Atlantic City 800-foot sand. In winter, water is withdrawn at the Rio Grande well field and is transported through a pipeline to these recharge wells. In summer, a period of increased water use, these wells are pumped to meet water-supply needs in Wildwood. Table 5 shows annual-average recharge rates for 1968-86.

SALTWATER INTRUSION

Chloride concentrations in samples from selected wells in the shallow aquifer system of Cape May County have been monitored since 1939. Gill (1962a) documented lateral saltwater intrusion into the Cohansey aquifer south of Cape May Canal. The USGS (through the Saltwater Intrusion Monitoring Network) and the Cape May County Planning Board have monitored observation and production wells since 1962 in order to document increases in chloride concentrations in the southern part of the county (Schaefer, 1983; Epstein, 1986). Several production wells that yield water containing chloride concentrations as high as 850 mg/L (milligrams per liter) have been abandoned, and many existing observation wells currently (1987) yield water approaching the Federal 250-mg/L drinking-water regulation for chloride

(U.S. Environmental Protection Agency, 1986). Wells inventoried by the USGS at which chloride concentrations have been measured are listed in table 6, and their locations are shown on plate 8; chloride-concentration data from these wells are listed in the appendix at the end of this report. Lines of equal chloride concentration in the estuarine sand aquifer in 1986-87 are shown on plates 10 and 12; lines of equal chloride concentration in the Cohansey aquifer in 1983-87 are shown on plates 11 and 12. (The sections shown on plate 12 are the same as those shown on plate 9). These maps and sections show the extent of migration of saltwater into the shallow aquifers of Cape May County from 1958 to 1983-87.

Holly Beach Water-Bearing Zone

The Holly Beach water-bearing zone is hydrologically connected to the Delaware Bay, the Atlantic Ocean, and many estuaries and tidal streams. It is dissected by the Cape May Canal at the southern tip of Cape May County and is underlain by the estuarine clay confining unit. Saltwater intrusion into this aquifer has occurred where water levels are too low to prevent the advance of saltwater (Gill, 1962a). A comparison between chloride concentrations measured in samples from wells screened in the Holly Beach water-bearing zone in 1987 and those reported by Gill (1962a, fig. 50) indicate that little additional landward movement of saltwater has occurred since 1958. Plate 12a indicates that chloride concentrations are largest near saltwater bodies, whereas chloride concentrations in the center of the Cape May peninsula are as small as 17 mg/L.

Estuarine Sand Aquifer

Chloride concentrations have been measured in samples from only a few wells screened in the estuarine sand aquifer. Most of these wells are located along the Delaware Bay in the Villas area (pl. 10) and have been monitored by the Cape May County Planning Board.

Plate 12 (a and b) shows lines of equal chloride concentration for sections A-A' and B-B'. On plate 12a, chloride concentrations are greatest near the coasts and decrease landward. The estuarine sand aquifer contains lenses of coarse sand and gravel (Gill, 1962b) which probably promote rapid infiltration of saltwater when freshwater heads are below sea level. This infiltration most likely is the cause of the elevated chloride concentrations in the estuarine sand aquifer at Villas along the Delaware Bay (pl. 12a). Figure 5 shows historical chloride concentrations for selected wells; figure 5e shows that annual averages of inland chloride concentrations have remained below 20 mg/L. The chloride concentrations are greatest near the coasts, and also are elevated in the center of Cape May peninsula. The elevated chloride concentrations in the center are the result of saltwater migration from the south (perpendicular to section B-B') and possibly from the Cape May Canal (pl. 10).

Plate 10 shows a comparison of lines of equal chloride concentration in 1986-87 to those developed for 1958 (Gill, 1962a, fig. 45). The lines of equal chloride concentration shown on plates 10 and 12 indicate that saltwater has intruded the estuarine sand aquifer at the western and southern edges of the peninsula.

Table 6. -- Partial records of wells sampled for chloride concentrations in the shallow aquifers of Cape May County

[Latitude and longitude in degrees, minutes, and seconds (385612 is 38° 56' 12"); dashes (--) indicate data not available or not applicable; USGS, U.S. Geological Survey; BORO, Borough; TWP, Township; HLBC, Holly Beach water-bearing zone; ESRNS, estuarine sand aquifer; CNSY, Cohansey aquifer; CPMY, Cape May Formation; CKKD, Kirkwood-Cohansey aquifer system]

Well-identification number[1]			Well location						
USGS unique well number	Well number in Gill (1962a)	Cape May County Planning Board well number	Latitude	Longitude	Municipality	Local well identifer	Altitude of land surface (feet)	Screened interval (feet below land surface)	Aquifer
9-011	11Cr	--	385612	745457	CAPE MAY CITY	CMCWD 1 OBS	7.28	281-321	CNSY
9-012	--	--	385613	745457	CAPE MAY CITY	COLUMBIA 1	10	[3] 395	CNSY
9-014	10Cr	--	385615	745509	CAPE MAY CITY	LAFAYETTE 2	12	282-322	CNSY
9-017	12Cr	--	385651	745310	CAPE MAY CITY	USCG 1	11	292-322	CNSY
9-018	14Cr	--	385652	745327	CAPE MAY CITY	USCG 2	11	295-325	CNSY
9-019	1Kc	--	385557	745738	CAPE MAY POINT BORO	LIGHTHOUSE 1	6	[3] 592	CNSY
9-020	--	--	385616	745800	CAPE MAY POINT BORO	TRAFFIC CIRCLE	9.12	15- 20	HLBC
[2] 9-021	5Cc	--	385631	745741	CAPE MAY POINT BORO	SUNSET 2	13	250-280	CNSY
9-027	7Cr	--	385643	745533	LOWER TWP	CMCWD 3	7	277-306	CNSY
9-028	3Cr	--	385641	745749	LOWER TWP	NW MAG 2	10	235-265	CNSY
9-029	2Cr	--	385640	745805	LOWER TWP	NW MAG 1	10	296-321	CNSY
9-036	--	--	385701	745528	LOWER TWP	CMCWD 2	10	[3] 282	CNSY
9-041	19Cc	--	385722	745241	LOWER TWP	SNOW 2	10	280-320	CNSY
9-043	--	--	385724	745521	LOWER TWP	CMCWD 5	15	[3] 276	CNSY
9-044	18Cc	--	385725	745257	LOWER TWP	SNOW 1	5	270-278	CNSY
[2] 9-048	16Cr	--	385748	745533	LOWER TWP	CANAL 5	17.48	242-252	CNSY
9-049	1Cc	--	385804	745742	LOWER TWP	HIGBEE BEACH 3	6	241-250	CNSY
[2] 9-052	15Cr	--	385851	745715	LOWER TWP	LTMUA 1	18	241-262	CNSY
[2] 9-054	--	--	385905	745625	LOWER TWP	LTMUA 2	14	212-247	CNSY
9-057	--	--	385919	745518	LOWER TWP	LTMUA 3	20	262-303	CNSY
9-060	24Cr	--	390056	745426	LOWER TWP	AIRPORT T7	13.11	242-257	CNSY
9-064	35Cc	--	390128	745339	MIDDLE TWP	RIO GRANDE 32	8	226-250	CNSY
9-065	--	--	390130	745350	MIDDLE TWP	RIO GRANDE 34	12	172-242	CNSY
9-068	32Cr	--	390135	745358	MIDDLE TWP	RIO GRANDE 28	8	209-244	CNSY
9-069	--	--	390136	745342	MIDDLE TWP	RIO GRANDE 33	9	[3] 250	CNSY
9-070	--	--	390137	745352	MIDDLE TWP	RIO GRANDE 36	10	48- 63	HLBC
9-072	26Esr	--	390138	745350	MIDDLE TWP	RIO GRANDE 31	10	108-135	ESRNS
9-074	34Cc	--	390139	745349	MIDDLE TWP	RIO GRANDE 29	8	191-231	CNSY
9-075	--	--	390140	745348	MIDDLE TWP	RIO GRANDE 37	10	40- 60	CPMY
9-078	--	--	390149	745354	MIDDLE TWP	RIO GRANDE 30	9	229-250	CNSY
[2] 9-080	42Cc	--	390213	745056	MIDDLE TWP	CAPE MAY 42CC	13.67	242-252	CNSY
[2] 9-089	46Cc	--	390425	745446	MIDDLE TWP	OYSTER LAB 4	7.37	197-210	CNSY
[2] 9-099	49Cr	--	390611	744838	MIDDLE TWP	COUNTY PK T8	10.73	214-230	CNSY
9-104	37Cc	--	390020	744736	NORTH WILDWOOD CITY	BLOCK-CONSTRUC	5	290-307	CNSY
9-105	40Cc	--	390058	744748	NORTH WILDWOOD CITY	SEWAGE PLANT	8	255-263	CNSY
[2] 9-150	6Cc	--	385607	745556	WEST CAPE MAY BORO	WCM 1	6.60	283-293	CNSY
9-154	28Cc	--	385932	744851	WILDWOOD CITY	WWD 2	10	293-354	CNSY
9-155	--	--	385933	744953	WILDWOOD CLAM CO	3-1971	5	311-331	CNSY
[2] 9-159	--	--	385830	745021	WILDWOOD CREST BORO	WWD 35	8	249-360	CNSY
[2] 9-187	--	F35	390218	745609	LOWER TWP	CAPE MAY F35	10	184-190	CNSY

Table 6. -- Partial records of wells sampled for chloride concentrations in the shallow aquifers of Cape May County

Well-identification number[1]									
USGS unique well number	Well number in Gill (1962a)	Cape May County Planning Board well number	Well location		Municipality	Local well identifer	Altitude of land surface (feet)	Screened interval (feet below land surface)	Aquifer
			Latitude	Longitude					
[2] 9-188	--	F36	390215	745440	MIDDLE TWP	CAPE MAY F36	10	229-233	CNSY
9-189	--	F37	390215	745440	MIDDLE TWP	CAPE MAY F37	5	83- 87	ESRNS
9-190	--	F40	390215	745440	MIDDLE TWP	CAPE MAY F40	5	22- 31	HLBC
9-191	--	--	390219	745611	LOWER TWP	FISHING CREEK HB-1	10	14- 17	HLBC
9-192	40Esc	--	390425	745446	MIDDLE TWP	RUTGERS OYSTER LAB	7	64- 71	ESRNS
9-193	--	--	390523	745327	MIDDLE TWP	REEDS BEACH SMOKEY	5	84- 87	ESRNS
9-195	--	--	390219	745608	LOWER TWP	FC-1 DRIVEPOINT	8.48	15- 17	HLBC
9-196	--	--	390219	745608	LOWER TWP	FC-2 DRIVEPOINT	8.48	25- 27	HLBC
9-197	--	--	390219	745608	LOWER TWP	FC-3 DRIVEPOINT	8.48	46- 48	HLBC
9-198	--	--	390212	745557	LOWER TWP	BSR-1 DRIVEPOINT	6.85	10- 12	HLBC
9-199	--	--	390212	745557	LOWER TWP	BSR-2 DRIVEPOINT	6.85	20- 22	HLBC
9-200	--	--	390212	745557	LOWER TWP	BSR-3 DRIVEPOINT	6.85	28- 30	HLBC
9-201	--	--	390212	745557	LOWER TWP	BSR-4 DRIVEPOINT	6.85	39- 41	HLBC
9-202	--	--	390212	745557	LOWER TWP	BSR-5 DRIVEPOINT	6.85	54- 56	HLBC
9-203	--	--	390738	745330	MIDDLE TWP	RB-1 DRIVEPOINT	10	10- 12	HLBC
9-204	--	--	390738	745330	MIDDLE TWP	RB-2 DRIVEPOINT	10	40- 42	HLBC
9-205	--	--	390738	745330	MIDDLE TWP	RB-3 DRIVEPOINT	10	50- 52	HLBC
9-206	--	F7	390218	745609	LOWER TWP	CAPE MAY F7	10	108-112	ESRNS
[2] 9-208	--	--	390212	745557	LOWER TWP	BSR-6	6.92	9[illegible]-108	ESRNS
9-209	--	--	385656	745422	CAPE MAY CITY	COLD SPRING PACK 1	5	90-110	ESRNS
[2] 9-210	--	C1	385946	745725	LOWER TWP	CAPE MAY C1	11.03	216-221	CKKD
9-212	--	C3	385946	745725	LOWER TWP	CAPE MAY C3	11.41	45- 50	HLBC
[2] 9-213	--	F41	390128	745639	LOWER TWP	CAPE MAY F41	12.23	203-208	CKKD
[2] 9-214	--	F44	390050	745659	LOWER TWP	CAPE MAY F44	19.86	205-210	CKKD
9-215	--	F45	390050	745659	LOWER TWP	CAPE MAY F45	20.23	120-125	ESRNS
9-216	--	F46	390050	745659	LOWER TWP	CAPE MAY F46	20.62	45- 50	HLBC
9-217	--	F42	390128	745639	LOWER TWP	CAPE MAY F42	13.17	95-100	ESRNS
9-218	--	F43	390128	745639	LOWER TWP	CAPE MAY F43	12.76	46- 50	HLBC

[1] Three well-identification numbering systems have been widely used in Cape May County; all are reported here to facilitate comparison between this and other reports. Elsewhere in this report, only the U.S. Geological Survey unique well number is reported.

[2] Also listed in table 2.

[3] Only well depth available.

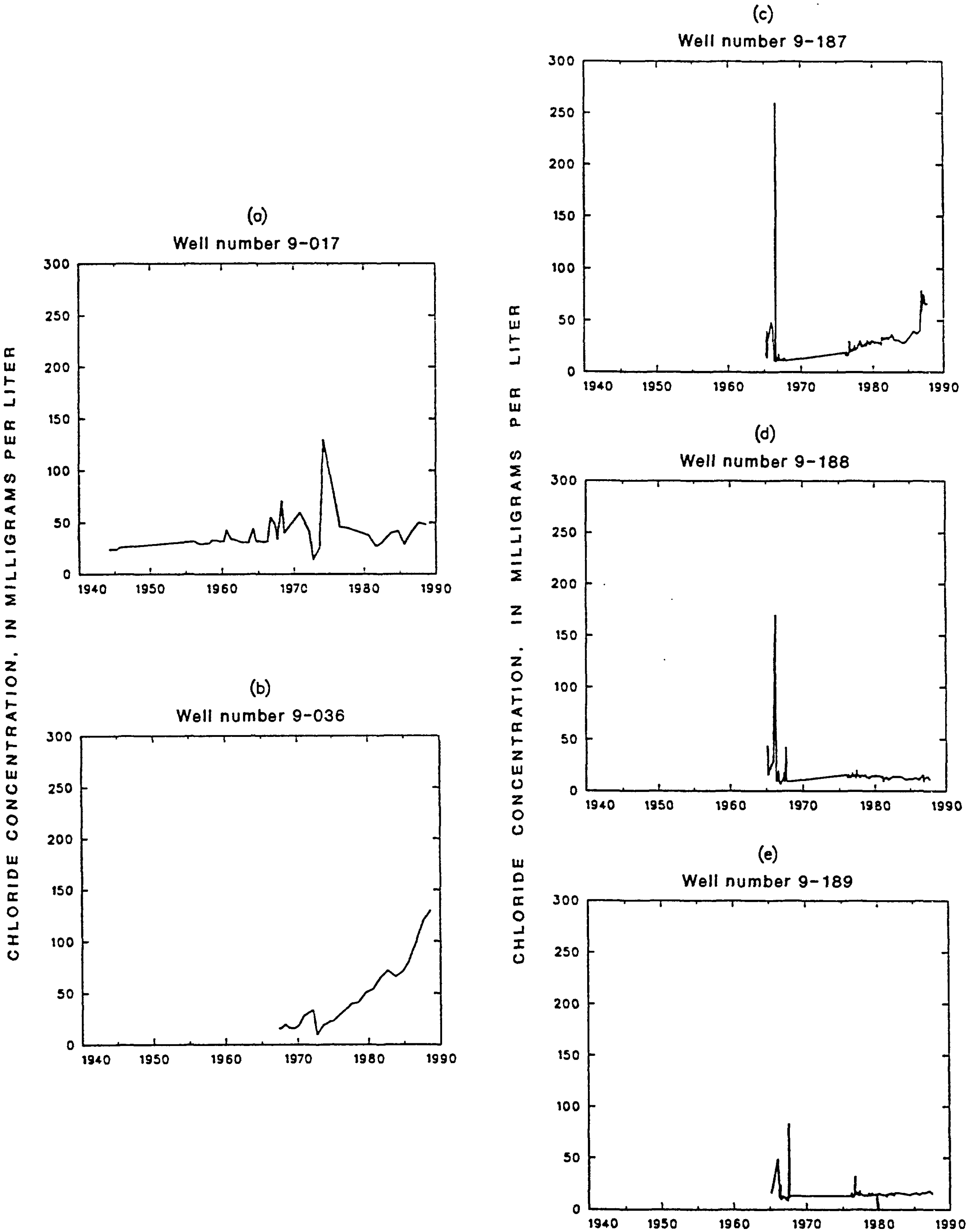

Figure 5. Historical chloride concentrations for selected wells in Cape May County, New Jersey.

Cohansey Aquifer

Spatial trends in chloride concentrations in the Cohansey aquifer are similar to those found in the estuarine sand aquifer. Lines of equal chloride concentration in 1984-87 compared to those developed by Gill for 1958 (1962a) are shown on plate 11. These contours and the graphs of chloride concentrations shown in figures 5a, 5b, and 5c indicate that saltwater is migrating landward in the Cohansey aquifer in the western and southern parts of the peninsula. Figure 5d indicates that annual medians of inland chloride concentrations have remained below 20 mg/L.

SUMMARY AND CONCLUSIONS

Ground water is the major source of freshwater supply in southern Cape May County, New Jersey. Nearly 50 percent of the freshwater supply for the county is withdrawn from the shallow aquifer system, resulting in the contamination of many ground-water wells due to saltwater intrusion. From top to bottom, the shallow aquifer system of Cape May County consists of the unconfined Holly Beach water-bearing zone; the estuarine clay confining unit; the confined estuarine sand aquifer; a leaky, discontinuous confining unit at the top of the Cohansey aquifer; and the confined Cohansey aquifer. Previously published data indicate that the transmissivity of the Holly Beach water-bearing zone ranges from 2,000 to 7,800 ft^2/d; the transmissivity of the estuarine sand aquifer ranges from 2,700 to 11,400 ft^2/d; and the transmissivity of the Cohansey aquifer ranges from 3,600 to 11,700 ft^2/d. The vertical hydraulic conductivities of the estuarine clay confining unit and the confining unit at the top of the Cohansey aquifer range from 0.01 to 0.04 ft/d and from 0.008 to 0.05 ft/d, respectively. The horizontal hydraulic conductivities of the estuarine sand and Cohansey aquifers range from 156 to 286 ft/d and from 53 to 146 ft/d, respectively.

Before southern Cape May County was developed, ground water moved upward from the Cohansey aquifer to the estuarine sand aquifer and horizontally from the center of Cape May peninsula to the Delaware Bay and Atlantic Ocean. Extensive development of the Cohansey aquifer has reversed the hydraulic gradients locally, so that water moves vertically down from the estuarine sand aquifer and horizontally from the Delaware Bay and Atlantic Ocean toward pumped wells. Tritium concentrations indicate that the estuarine clay confining unit significantly impedes the movement of ground water.

In response to increased population in Cape May County, ground-water withdrawals have increased 66 percent since 1956. In 1986, ground-water withdrawals from the shallow aquifer system averaged about 7.00 Mgal/d. Ground-water withdrawals in Cape May County are seasonal; three times as much water is withdrawn in summer as in winter.

Maps that show a comparison of lines of equal chloride concentrations in different years, graphs showing variations in chloride concentrations with time, and sections through the Cape May peninsula that show lines of equal chloride concentration indicate that saltwater has intruded the estuarine sand and Cohansey aquifers and is migrating landward in the Cohansey aquifer in the western and southern parts of Cape May County.

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APPENDIX

Chloride concentrations in ground water from selected wells in the shallow aquifers of Cape May County

[* indicates data from Cape May County Planning Board (David Rutherford, Cape May County Planning Board, written commun., 1987); all other data from the U.S. Geological Survey Saltwater Intrusion Monitoring Network (Walter Jones, U.S. Geological Survey, written commun., 1987); where more than one measurement is available for the month indicated, the average value is shown; USGS, U.S. Geological Survey]

USGS unique well number	Date of sample collection	Chloride concentration (milligrams per liter)
9-011	09/1986	910
9-012	08/1961	570
	09/1962	36
	04/1963	560
	04/1964	690
	03/1972	140
	09/1977	850
9-014	08/1961	220
	04/1962	150
	09/1962	240
	04/1963	160
	08/1963	270
	04/1964	120
	09/1964	300
9-017	04/1944	24
	03/1945	24
	08/1945	26
	04/1956	32
	08/1956	30
	04/1957	29
	08/1957	30
	04/1958	30
	09/1958	33
	04/1959	33
	09/1959	32
	04/1960	32
	08/1960	43
	04/1961	34
	08/1961	34
	09/1962	31
	08/1963	31
	04/1964	44
	09/1964	32
	04/1965	32
	08/1965	31
	04/1966	32
	09/1966	55
	05/1967	48
	09/1967	34
	03/1968	71
	08/1968	40
	11/1970	60
	03/1972	42
	09/1972	14
	09/1973	26
	04/1974	130
	08/1976	46
	08/1977	45
	08/1980	38
	08/1981	27
	09/1982	32
	10/1983	40
	10/1984	42
	08/1985	29
	08/1986	41
9-018	04/1944	18
	03/1945	21
	08/1945	22
	04/1956	20
	08/1956	20
9-018 cont.	04/1957	20
	08/1957	19
	04/1958	20
	09/1958	20
	04/1959	22
	09/1959	21
	04/1960	20
	08/1960	21
	04/1961	21
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	04/1966	20
	09/1966	23
	09/1967	26
	03/1968	24
	08/1968	29
	08/1969	26
	11/1970	26
	09/1972	21
	09/1973	40
	01/1975	30
	05/1975	30
	08/1976	32
	07/1978	30
	08/1979	28
	08/1980	28
	08/1981	36
	09/1982	41
	10/1983	30
	10/1984	30
	08/1985	36
	08/1986	32
9-019	09/1943	560
	08/1945	560
	08/1948	550
	04/1949	520
	08/1949	570
	04/1950	570
	08/1950	570
	03/1951	560
	08/1951	560
	04/1952	500
	09/1952	550
	04/1953	560
	09/1953	560
	04/1954	520
	09/1954	610
	03/1955	560
	08/1955	560
	04/1956	570
	08/1956	540
	04/1957	570
	04/1958	560
	09/1958	560
	04/1959	550
	09/1959	570
	04/1960	560
9-019 cont.	04/1961	560
	08/1961	560
	04/1962	590
	09/1962	480
	04/1963	580
	08/1963	570
	04/1964	590
	09/1964	570
	04/1965	560
	08/1965	560
	03/1969	570
	03/1970	570
9-020	03/1978	68
	09/1986	110
9-021	08/1961	140
	04/1962	160
	09/1962	150
	04/1963	180
	08/1963	180
	04/1964	190
	09/1964	180
	04/1965	190
	08/1965	180
	04/1966	180
	09/1966	190
	05/1967	200
	09/1967	200
	03/1968	210
	08/1968	220
	02/1969	220
	07/1969	220
	03/1970	230
	11/1970	250
	03/1972	250
9-027	08/1961	34
	04/1962	37
	09/1962	600
	04/1963	38
	08/1963	38
	04/1964	42
	09/1964	42
	04/1965	42
	08/1965	42
	04/1966	42
	09/1966	54
	05/1967	92
	09/1967	95
	03/1968	92
	03/1970	120
	03/1972	140
	09/1972	69
	05/1973	140
	09/1973	120
	08/1974	140
	01/1975	140
	05/1975	140
	08/1976	140
	08/1977	140
	07/1978	140
	08/1979	150
	08/1981	120
	09/1982	52
	10/1983	100

APPENDIX--Continued

Chloride concentrations in ground water from selected wells in the shallow aquifers of Cape May County

USGS unique well number	Date of sample collection	Chloride concentration (milligrams per liter)
9-027 cont.	10/1984	75
	08/1985	130
	08/1986	150
9-028	04/1954	79
	09/1954	76
	03/1955	73
	08/1955	59
	04/1959	68
	09/1959	63
	04/1960	62
	08/1960	60
	04/1961	61
	08/1961	59
	04/1962	61
	09/1962	250
	04/1963	60
	08/1963	64
	04/1964	78
	09/1964	66
	04/1965	78
	08/1965	75
	04/1966	76
	09/1966	90
	05/1967	96
	09/1967	88
	03/1968	100
	08/1968	100
	02/1969	110
	07/1969	110
	11/1970	120
	03/1972	120
	09/1972	140
	05/1973	140
	09/1973	140
	04/1974	150
	08/1974	160
	01/1975	160
	05/1975	160
	08/1976	200
	08/1977	200
	07/1978	190
	08/1979	180
	08/1980	200
	08/1981	180
	09/1982	210
	10/1983	220
9-029	09/1954	270
	08/1955	260
	04/1956	260
	08/1956	240
	04/1957	240
	08/1957	240
	04/1958	240
	09/1958	380
	04/1959	240
	09/1959	250
	04/1960	250
	08/1960	300
	04/1961	250
	08/1961	240
	04/1962	250
	09/1962	260
	04/1963	260
	08/1963	410
	04/1964	420
	09/1964	250
9-029 cont.	04/1965	240
	08/1965	240
	04/1966	250
	09/1966	250
	05/1967	260
	09/1967	230
	03/1968	250
	08/1968	300
	02/1969	260
	07/1969	250
	03/1970	260
	11/1970	260
	03/1972	250
	09/1972	260
	05/1973	250
	09/1973	290
	04/1974	250
	08/1974	380
	01/1975	340
	05/1975	250
	08/1976	260
	08/1977	270
	07/1978	260
	08/1979	200
9-036	05/1967	16
	09/1967	16
	03/1968	20
	08/1968	17
	02/1969	16
	07/1969	16
	03/1970	19
	11/1970	28
	03/1972	34
	09/1972	10
	09/1973	19
	04/1974	21
	08/1974	23
	01/1975	23
	08/1976	33
	08/1977	40
	07/1978	41
	08/1979	51
	08/1980	54
	08/1981	65
	09/1982	72
	10/1983	66
	10/1984	71
	08/1985	80
	08/1986	100
9-041	09/1958	17
	04/1959	18
	09/1959	16
	04/1960	30
	07/1960	18
	08/1960	16
	04/1961	31
	08/1961	16
	04/1962	20
	09/1962	48
	04/1963	16
	08/1963	17
	04/1964	38
	09/1964	16
	04/1965	16
	08/1965	16
	04/1966	16
	09/1966	18
	11/1970	18
9-041 cont.	08/1981	27
	09/1982	30
	08/1985	29
	08/1986	34
9-043	09/1967	28
	03/1968	20
	08/1968	21
	03/1970	30
	11/1970	28
	03/1972	19
	09/1972	12
	09/1973	18
	04/1974	27
	08/1974	18
	01/1975	28
	08/1976	21
	08/1977	22
	07/1978	19
	08/1979	18
	08/1980	17
	08/1981	15
	09/1982	20
	10/1984	22
	08/1985	19
	08/1986	18
9-044	10/1983	22
	10/1984	20
9-048	06/1957	16
	08/1961	17
	08/1963	16
	04/1964	17
	09/1964	16
	04/1965	16
	09/1985	15
9-049	09/1977	16
	09/1985	15
9-052	01/1957	20
	04/1958	22
	09/1958	20
	04/1959	20
	09/1959	20
	04/1960	19
	08/1960	18
	04/1961	18
	08/1961	17
	04/1962	18
	09/1962	18
	04/1963	16
	08/1963	16
	04/1964	14
	04/1965	14
	08/1965	16
	04/1966	16
	09/1966	18
	05/1967	15
	03/1969	14
	08/1969	18
	03/1970	16
	11/1970	20
	03/1972	17
	09/1972	7
	09/1973	13
	08/1974	14
	08/1976	13
	08/1977	14
	07/1978	13

APPENDIX--Continued

Chloride concentrations in ground water from selected wells in the shallow aquifers of Cape May County

USGS unique well number	Date of sample collection	Chloride concentration (milligrams per liter)
9-052 cont.	08/1979	11
	08/1980	13
	08/1981	8
	10/1983	11
	08/1985	11
	08/1957	9
	08/1986	12
9-054	11/1970	18
	03/1972	16
	09/1972	8
	05/1973	14
	09/1973	14
	04/1974	16
	08/1974	15
	05/1975	16
	08/1977	13
	07/1978	13
	08/1979	16
	08/1981	10
	09/1982	15
	10/1983	14
	10/1984	14
	08/1985	13
	08/1986	13
9-057	08/1976	9
	08/1980	7
	09/1982	8
	10/1984	12
	08/1985	8
	08/1986	16
9-060	09/1985	10
9-064	11/1970	14
	07/1973	10
9-065	11/1970	16
	07/1973	13
9-068	11/1970	14
	07/1973	12
	08/1974	12
	01/1975	11
	08/1976	11
9-069	11/1970	14
	10/1984	12
	08/1986	10
9-070	09/1967	26
	08/1968	35
	11/1970	30
	03/1972	16
	09/1972	23
	05/1973	14
	07/1973	19
	09/1973	27
	08/1974	32
	01/1975	18
	05/1975	16
	08/1976	30
	08/1977	26
	08/1978	23
	08/1979	21
	08/1980	22
	08/1981	22
	09/1982	27
	10/1983	27
	10/1984	29
9-072	04/1954	13
	09/1954	12
	09/1967	13
	03/1968	13
	08/1968	12
	11/1970	10
	03/1972	10
	09/1972	14
	07/1973	13
	09/1973	12
	08/1974	13
	01/1975	12
	08/1976	13
	08/1977	13
	08/1978	13
	08/1979	11
	08/1980	12
	08/1981	9
	09/1982	12
	10/1983	11
	10/1984	12
	08/1985	11
	08/1986	11
9-074	11/1970	14
	09/1972	12
	05/1973	12
	07/1973	12
	09/1973	11
	08/1977	12
	08/1978	10
	09/1979	10
	08/1980	11
	08/1981	10
	09/1982	11
	10/1983	13
	10/1984	12
	08/1985	12
9-075	08/1968	22
	11/1970	20
	09/1972	18
	07/1973	34
	09/1973	21
9-078	09/1953	5
	04/1954	25
	09/1954	12
	03/1955	10
	08/1955	12
	04/1956	14
	08/1956	11
	10/1956	10
	04/1957	10
	08/1957	10
	08/1963	11
	04/1964	10
	09/1964	11
	08/1965	10
	04/1966	10
	09/1966	12
	09/1967	12
	08/1968	11
	03/1970	12
	11/1970	14
	07/1973	12
9-080	08/1985	10
9-089	08/1957	9
	08/1961	9
	04/1962	9
	09/1962	10
	04/1963	9
	08/1963	9
	04/1964	9
	09/1964	9
	04/1965	9
	09/1977	10
	09/1985	9
	05/1987	34
9-099	09/1984	2
9-104	10/1952	140
	04/1953	150
	09/1953	78
	04/1954	150
	09/1954	160
	03/1955	160
	08/1955	160
	04/1956	160
	08/1956	160
	04/1957	160
	08/1957	170
	04/1958	160
	09/1958	170
	04/1959	160
	09/1959	160
	04/1960	160
	08/1960	150
	08/1961	160
	04/1962	160
	09/1962	170
	04/1963	160
	08/1963	160
9-105	04/1953	510
	09/1953	79
	09/1954	560
	03/1955	560
	08/1955	590
	04/1956	600
	08/1956	600
	08/1957	610
	04/1958	540
	09/1958	610
	09/1959	610
	04/1960	610
	08/1960	620
	08/1961	640
	04/1962	680
	09/1962	660
	04/1963	690
	08/1963	680
	04/1964	650
	09/1964	610
	04/1965	600
	08/1965	580
	04/1966	590
	09/1966	600
	05/1967	600
	09/1967	580
	03/1968	600
	08/1968	600
	07/1969	610
	03/1970	600

Chloride concentrations in ground water from selected wells in the shallow aquifers of Cape May County

USGS unique well number	Date of sample collection	Chloride concentration (milligrams per liter)
9-150	03/1945	190
	08/1945	14
	09/1946	17
	08/1948	15
	04/1949	15
	08/1949	16
	06/1950	160
	07/1950	210
	08/1950	180
	03/1951	11
	08/1951	13
	09/1952	18
	04/1953	12
	09/1953	7
	04/1954	15
	09/1954	16
	03/1955	16
	08/1955	16
	04/1956	20
	05/1957	50
	06/1957	270
	10/1957	340
	08/1961	120
	04/1962	2,600
	09/1962	860
	04/1963	460
	08/1963	360
	04/1964	400
	09/1964	350
	04/1965	220
	09/1977	490
	09/1985	470
9-154	04/1939	98
	08/1939	84
	08/1940	92
	05/1941	88
	09/1941	89
	04/1942	92
	10/1942	92
	04/1943	100
	04/1944	110
	09/1944	98
	03/1945	100
	08/1945	100
	04/1946	110
	09/1946	110
	04/1947	100
	04/1948	97
	08/1948	100
	04/1949	99
	08/1949	110
	04/1950	100
	08/1950	110
	03/1951	120
	08/1951	110
	04/1952	69
	09/1952	100
	04/1953	88
	09/1953	130
	04/1954	87
	09/1954	110
	03/1955	78
	08/1955	110
	08/1956	100
	04/1957	96
	08/1957	75
	04/1958	82
9-154 cont.	09/1958	97
	04/1959	96
	09/1959	100
	04/1960	97
	08/1960	95
	04/1961	96
	08/1961	98
	04/1962	98
	09/1962	93
	04/1963	96
	08/1963	100
	09/1964	100
	04/1965	80
	08/1965	100
	04/1966	90
	09/1966	110
	05/1967	76
	09/1967	95
	03/1968	64
	08/1968	110
	02/1969	110
	07/1969	110
	03/1970	100
	11/1970	120
	03/1972	110
	09/1972	120
	05/1973	110
	09/1973	110
	04/1974	120
	08/1974	120
	01/1975	120
	05/1975	120
	08/1976	120
	09/1977	120
	08/1978	120
	08/1979	110
	08/1980	120
	08/1981	100
	09/1982	53
	10/1983	93
	08/1985	110
	08/1986	130
9-159	08/1968	50
	11/1970	16
9-187*	04/1965	16
	05/1965	27
	06/1965	30
	12/1965	48
	02/1966	44
	05/1966	12
	06/1966	11
	08/1966	10
	10/1966	12
	11/1966	11
	12/1966	18
	01/1967	12
	04/1967	11
	06/1967	12
	07/1967	11
	08/1967	11
	09/1967	14
	10/1967	11
	06/1968	10
	10/1969	12
	07/1970	11
	08/1970	11
9-187*cont.	10/1970	12
	01/1971	24
	02/1971	15
	03/1971	22
	04/1971	18
	06/1971	14
	09/1971	15
	10/1971	15
	11/1971	16
	12/1971	18
	01/1972	15
	02/1972	18
	03/1972	16
	04/1972	14
	05/1972	12
	06/1972	14
	08/1972	14
	09/1972	13
	10/1972	13
	11/1972	13
	12/1972	13
	01/1973	12
	02/1973	12
	03/1973	12
	04/1973	12
	05/1973	8
	06/1973	13
	07/1973	12
	08/1973	13
	09/1973	14
	10/1973	14
	11/1973	17
	12/1973	13
	01/1974	13
	02/1974	12
	03/1974	13
	04/1974	10
	05/1974	15
	06/1974	14
	07/1974	10
	08/1974	13
	10/1974	15
	12/1974	14
	01/1975	15
	02/1975	17
	03/1975	22
	04/1975	15
	05/1975	15
	06/1975	15
	07/1975	15
	08/1975	15
	09/1975	16
	11/1975	18
	12/1975	16
	01/1976	19
	02/1976	19
	03/1976	16
	04/1976	20
	05/1976	16
	06/1976	16
	07/1976	16
	08/1976	19
	09/1976	30
	10/1976	19
	11/1976	21
	12/1976	22
	01/1977	21

APPENDIX--Continued

Chloride concentrations in ground water from selected wells in the shallow aquifers of Cape May County

USGS unique well number	Date of sample collection	Chloride concentration (milligrams per liter)
9-187*cont.	02/1977	20
	03/1977	23
	04/1977	21
	05/1977	26
	06/1977	21
	07/1977	22
	08/1977	22
	09/1977	23
	10/1977	23
	11/1977	26
	12/1977	27
	03/1978	30
	04/1978	30
	05/1978	24
	06/1978	25
	07/1978	26
	08/1978	25
	09/1978	26
	12/1978	28
	01/1979	30
	03/1979	31
	04/1979	30
	05/1979	30
	07/1979	27
	08/1979	27
	09/1979	29
	10/1979	32
	11/1979	30
	01/1980	30
	02/1980	30
	03/1980	28
	04/1980	30
	09/1980	29
	10/1980	28
	11/1980	28
	12/1980	30
	01/1981	29
	03/1981	26
	04/1981	34
	07/1981	34
	08/1981	34
	09/1981	32
	10/1981	34
	11/1981	33
	12/1981	34
	03/1982	32
	04/1982	33
	05/1982	34
	07/1982	35
	09/1982	37
	02/1983	31
	08/1983	31
	04/1984	28
	09/1984	30
	04/1985	35
	10/1985	40
	03/1986	37
	08/1986	40
	11/1986	60
	05/1987	66
9-188*	04/1965	16
	05/1965	20
	07/1965	21
	12/1965	29
	02/1966	44
	04/1966	171
	05/1966	13
9-188*cont.	06/1966	10
	07/1966	14
	08/1966	15
	09/1966	10
	10/1966	8
	11/1966	8
	12/1966	7
	01/1967	10
	04/1967	11
	06/1967	18
	07/1967	11
	08/1967	42
	09/1967	13
	10/1967	9
	06/1968	13
	11/1969	10
	05/1970	12
	08/1970	11
	12/1970	16
	01/1971	15
	02/1971	10
	04/1971	17
	06/1971	16
	09/1971	14
	10/1971	15
	11/1971	14
	12/1971	16
	01/1972	16
	02/1972	20
	03/1972	15
	04/1972	15
	05/1972	13
	06/1972	15
	08/1972	14
	09/1972	13
	10/1972	13
	11/1972	13
	12/1972	16
	01/1973	12
	02/1973	12
	03/1973	12
	04/1973	12
	05/1973	8
	06/1973	13
	07/1973	13
	08/1973	13
	09/1973	14
	10/1973	13
	11/1973	15
	12/1973	13
	01/1974	11
	02/1974	12
	03/1974	12
	05/1974	15
	06/1974	14
	07/1974	11
	08/1974	12
	10/1974	15
	12/1974	11
	01/1975	11
	02/1975	14
	03/1975	13
	04/1975	16
	05/1975	14
	06/1975	14
	07/1975	15
	08/1975	15
9-188*cont.	09/1975	15
	11/1975	16
	12/1975	12
	01/1976	16
	02/1976	14
	03/1976	13
	04/1976	16
	05/1976	13
	06/1976	14
	07/1976	14
	08/1976	14
	09/1976	16
	10/1976	18
	11/1976	14
	12/1976	16
	01/1977	16
	02/1977	14
	03/1977	14
	04/1977	12
	05/1977	20
	06/1977	15
	07/1977	16
	08/1977	15
	09/1977	15
	10/1977	14
	11/1977	13
	12/1977	15
	04/1978	15
	05/1978	15
	06/1978	15
	07/1978	15
	08/1978	16
	09/1978	14
	12/1978	14
	01/1979	13
	03/1979	12
	04/1979	14
	05/1979	14
	07/1979	15
	08/1979	15
	09/1979	15
	10/1979	14
	01/1980	15
	02/1980	16
	03/1980	14
	05/1980	15
	06/1980	14
	09/1980	15
	10/1980	14
	11/1980	14
	12/1980	14
	01/1981	15
	03/1981	10
	04/1981	13
	06/1981	14
	07/1981	12
	08/1981	14
	09/1981	14
	10/1981	14
	11/1981	11
	12/1981	12
	03/1982	13
	04/1982	13
	05/1982	13
	06/1982	14
	07/1982	15
	09/1982	14

Chloride concentrations in ground water from selected wells in the shallow aquifers of Cape May County

USGS unique well number	Date of sample collection	Chloride concentration (milligrams per liter)
9-188*cont.	09/1983	14
	06/1984	11
	09/1984	12
	04/1985	12
	10/1985	14
	03/1986	11
	08/1986	16
	11/1986	10
	05/1987	14
9-189*	04/1965	16
	02/1966	49
	05/1966	13
	06/1966	12
	08/1966	10
	10/1966	13
	11/1966	13
	12/1966	11
	01/1967	12
	04/1967	9
	06/1967	12
	07/1967	9
	09/1967	11
	10/1967	13
	06/1968	11
	08/1968	13
	08/1969	13
	09/1969	13
	10/1969	11
	11/1969	11
	07/1970	12
	08/1970	17
	01/1971	13
	04/1971	14
	06/1971	20
	09/1971	14
	10/1971	15
	11/1971	12
	12/1971	20
	01/1972	14
	02/1972	17
	03/1972	15
	04/1972	15
	05/1972	13
	06/1972	15
	08/1972	14
	09/1972	13
	10/1972	13
	11/1972	15
	12/1972	13
	01/1973	12
	02/1973	12
	03/1973	12
	04/1973	12
	05/1973	8
	06/1973	13
	07/1973	12
	08/1973	13
	09/1973	14
	10/1973	14
	11/1973	15
	12/1973	13
	01/1974	12
	02/1974	11
	03/1974	12
	04/1974	12
	05/1974	15
	06/1974	14
9-189*cont.	07/1974	10
	08/1974	12
	10/1974	15
	12/1974	11
	01/1975	12
	02/1975	12
	03/1975	13
	04/1975	13
	05/1975	14
	06/1975	14
	07/1975	13
	08/1975	15
	09/1975	13
	11/1975	14
	12/1975	14
	01/1976	13
	02/1976	13
	03/1976	12
	04/1976	16
	05/1976	12
	06/1976	12
	07/1976	12
	08/1976	14
	09/1976	32
	10/1976	14
	11/1976	15
	12/1976	16
	01/1977	16
	02/1977	14
	03/1977	15
	04/1977	13
	05/1977	18
	06/1977	14
	07/1977	14
	08/1977	15
	09/1977	14
	10/1977	14
	11/1977	14
	12/1977	13
	04/1978	14
	05/1978	14
	06/1978	14
	07/1978	14
	08/1978	16
	09/1978	14
	12/1978	14
	01/1979	16
	03/1979	14
	04/1979	14
	05/1979	14
	07/1979	14
	08/1979	15
	09/1979	14
	10/1979	15
	11/1979	15
	01/1980	15
	02/1980	16
	03/1980	14
	05/1980	16
	06/1980	14
	09/1980	14
	10/1980	14
	11/1980	14
	12/1980	14
	01/1981	14
	03/1981	12
	04/1981	15
9-189*cont.	06/1981	14
	07/1981	15
	08/1981	16
	09/1981	16
	10/1981	16
	11/1981	14
	12/1981	16
	03/1982	14
	04/1982	15
	05/1982	16
	06/1982	16
	07/1982	16
	09/1982	16
	09/1983	15
	06/1984	14
	09/1984	16
	04/1985	16
	10/1985	14
	03/1986	16
	08/1986	16
	05/1987	16
9-190	05/1987	17
9-191	05/1987	130
9-192	05/1987	170
9-193	05/1987	28
9-195	05/1987	95
9-196	05/1987	370
9-197	05/1987	330
9-198	05/1987	38
9-199	05/1987	19
9-200	05/1987	30
9-201	05/1987	19
9-202	05/1987	330
9-203	05/1987	6,300
9-204	05/1987	2,700
9-205	05/1987	1,600
9-206*	01/1965	443
	02/1965	434
	03/1965	365
	04/1965	435
	05/1965	426
	06/1965	435
	12/1965	414
	02/1966	421
	03/1966	368
	04/1966	368
	05/1966	480
	07/1966	360
	08/1966	360
	10/1966	470
	12/1966	440
	01/1967	440
	04/1967	480
	06/1967	460
	07/1967	410
	08/1967	490

APPENDIX--Continued

Chloride concentrations in ground water from selected wells in the shallow aquifers of Cape May County

USGS unique well number	Date of sample collection	Chloride concentration (milligrams per liter)
9-206*cont.	09/1967	450
	10/1967	450
	08/1968	464
	10/1969	440
	11/1969	350
	07/1970	420
	08/1970	420
	10/1970	400
	12/1970	420
	01/1971	420
	02/1971	410
	04/1971	400
	06/1971	430
	09/1971	420
	10/1971	408
	11/1971	440
	12/1971	408
	01/1972	970
	03/1972	420
	04/1972	410
	05/1972	430
	06/1972	423
	08/1972	410
	09/1972	420
	10/1972	420
	11/1972	430
	12/1972	410
	01/1973	420
	02/1973	420
	03/1973	420
	04/1973	420
	05/1973	440
	06/1973	410
	07/1973	420
	08/1973	410
	09/1973	420
	10/1973	410
	11/1973	410
	12/1973	400
	01/1974	400
	02/1974	380
	03/1974	400
	04/1974	400
	05/1974	420
	06/1974	410
	07/1974	350
	08/1974	400
	10/1974	370
	12/1974	380
	02/1975	380
	03/1975	380
	04/1975	370
	05/1975	390
	06/1975	380
	07/1975	400
	08/1975	340
	09/1975	360
	11/1975	360
	01/1976	740
	02/1976	340
	03/1976	340
	04/1976	330
	05/1976	320
	06/1976	320
	07/1976	140
	08/1976	330
	09/1976	330
9-206*cont.	10/1976	320
	11/1976	340
	12/1976	300
	01/1977	320
	02/1977	320
	03/1977	320
	04/1977	300
	05/1977	300
	07/1977	300
	08/1977	300
	09/1977	270
	10/1977	300
	11/1977	300
	12/1977	300
	03/1978	290
	04/1978	290
	05/1978	290
	06/1978	280
	07/1978	290
	08/1978	290
	12/1978	300
	01/1979	300
	03/1979	300
	04/1979	300
	05/1979	300
	07/1979	300
	08/1979	300
	09/1979	310
	10/1979	300
	01/1980	310
	02/1980	300
	03/1980	310
	04/1980	300
	05/1980	310
	06/1980	310
	09/1980	300
	10/1980	300
	11/1980	310
	12/1980	340
	01/1981	300
	03/1981	330
	04/1981	320
	07/1981	320
	08/1981	320
	09/1981	320
	10/1981	320
	11/1981	320
	12/1981	320
	03/1982	320
	05/1982	320
	07/1982	340
	09/1982	330
	02/1983	330
	10/1984	330
	04/1985	330
	10/1985	330
	03/1986	330
	08/1986	330
	03/1987	340
9-208	08/1987	530
9-209	08/1987	120
9-210*	02/1966	69
	03/1966	74
	04/1966	44
	06/1966	17
	10/1966	14
9-210*cont.	11/1966	15
	12/1966	15
	04/1977	21
	07/1977	20
	08/1977	20
	11/1977	19
	05/1978	21
	07/1978	20
	09/1978	19
	12/1978	23
	06/1979	18
	10/1979	19
	11/1979	19
	04/1980	25
	06/1980	18
	08/1980	21
	09/1980	18
	11/1980	18
	04/1981	24
	08/1981	20
	09/1981	19
	03/1982	19
	07/1982	20
	08/1983	18
	04/1984	18
	09/1984	15
	04/1985	16
	03/1986	16
	08/1986	19
9-212*	02/1966	2,700
	03/1966	2,700
	04/1966	3,400
	06/1966	3,100
	10/1966	2,700
	11/1966	2,900
	12/1966	2,800
	04/1977	1,700
	07/1977	1,700
	08/1977	1,700
	11/1977	1,700
	05/1978	1,900
	07/1978	1,900
	09/1978	1,700
	12/1978	1,700
	10/1979	1,800
	11/1979	1,500
	04/1980	1,700
	06/1980	1,800
	08/1980	1,800
	09/1980	1,700
	11/1980	1,900
	04/1981	1,700
	09/1981	1,800
	03/1982	1,800
	09/1982	1,800
	02/1983	1,800
	08/1983	1,800
	04/1984	1,800
	09/1984	1,700
	04/1985	1,800
	03/1986	1,700
	08/1986	1,700
9-213*	05/1966	12
	06/1966	13
	10/1966	11
	11/1966	11
	12/1966	10

APPENDIX--Continued

Chloride concentrations in ground water from selected wells in the shallow aquifers of Cape May County

USGS unique well number	Date of sample collection	Chloride concentration (milligrams per liter)
9-213*cont.	04/1977	9
	07/1977	10
	08/1977	10
	11/1977	12
	05/1978	12
	07/1978	10
	09/1978	9
	12/1978	11
	10/1979	10
	11/1979	10
	04/1980	11
	06/1980	8
	08/1980	8
	09/1980	12
	11/1980	10
	04/1981	9
	08/1981	8
	09/1981	10
	03/1982	11
	07/1982	10
	09/1982	10
9-214*	02/1966	69
	03/1966	74
	04/1966	74
	06/1966	30
	08/1966	22
	10/1966	22
	11/1966	16
	12/1966	19
	04/1977	11
	07/1977	14
	08/1977	14
	11/1977	14
	05/1978	16
	07/1978	15
	09/1978	14
	12/1978	14
	10/1979	16
	11/1979	16
	04/1980	15
	06/1980	16
	07/1978	55
	09/1978	55
	08/1980	14
	09/1980	14
	11/1980	16
	04/1981	16
	08/1981	15
	09/1981	22
	03/1982	23
	09/1982	26
	02/1983	26
	08/1983	19
9-214*cont.	04/1984	8
	09/1984	18
	03/1986	21
	08/1986	22
9-215*	02/1966	34
	03/1966	49
	04/1966	49
	06/1966	26
	10/1966	12
	11/1966	15
	12/1966	12
	04/1977	9
	07/1977	9
	08/1977	9
	11/1977	9
	05/1978	9
	07/1978	9
	09/1978	8
	12/1978	8
	10/1979	9
	11/1979	8
	04/1980	9
	06/1980	7
	08/1980	7
	09/1980	7
	11/1980	8
	04/1981	8
	08/1981	7
	09/1981	8
	03/1982	9
	07/1982	8
	09/1982	9
	02/1983	10
	08/1983	6
	04/1984	20
	09/1984	8
	04/1985	10
	10/1985	10
	03/1986	8
	08/1986	10
9-216*	02/1966	49
	03/1966	59
	04/1966	74
	06/1966	20
	10/1966	13
	11/1966	13
	12/1966	12
	04/1977	14
	07/1977	15
	08/1977	17
	11/1977	11
	05/1978	16
	07/1978	12
9-216*cont.	09/1978	14
	12/1978	12
	10/1979	18
	11/1979	16
	06/1980	16
	08/1980	17
	09/1980	15
	11/1980	25
	04/1981	18
	08/1981	18
	09/1981	19
	03/1982	17
	07/1982	19
	09/1982	18
	02/1983	18
	08/1983	17
	04/1984	18
	09/1984	118
	04/1985	30
	10/1985	18
9-217*	02/1966	39
	03/1966	49
	04/1966	49
	05/1966	40
	06/1966	55
	07/1966	33
	10/1966	46
	11/1966	52
	04/1977	56
	07/1977	49
	08/1977	53
	11/1977	49
	05/1978	51
	12/1978	57
	10/1979	57
	11/1979	54
9-218*	02/1966	1,400
	03/1966	1,400
	04/1966	1,500
	07/1966	1,400
	10/1966	1,700
	11/1966	1,800
	12/1966	1,800
	04/1977	1,100
	07/1977	1,100
	08/1977	940
	11/1977	820
	05/1978	1,500
	07/1978	880
	09/1978	1,200
	12/1978	680