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TASK VII - WATERSHED MANAGEMENT

GROUNDWATER MANAGEMENT APPENDICES

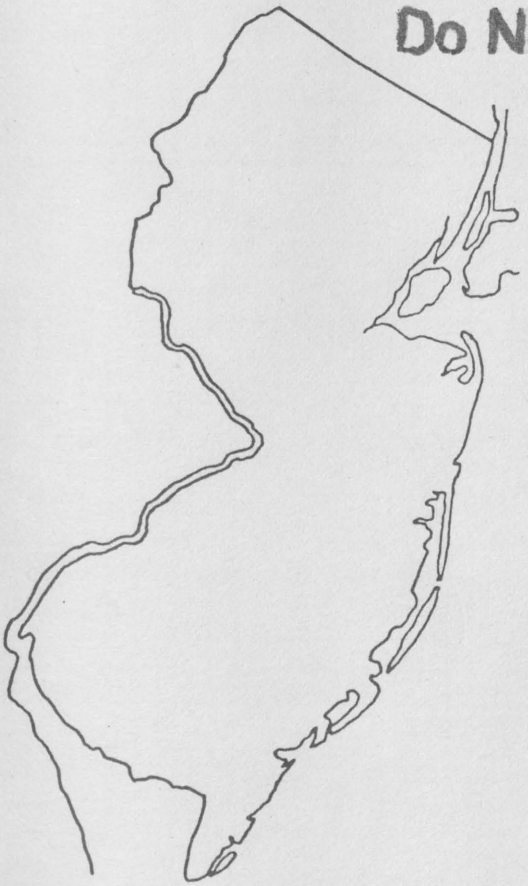
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FOR

THE NEW JERSEY STATEWIDE WATER SUPPLY PLAN

JUNE, 1980



STATE OF NEW JERSEY
DEPARTMENT OF ENVIRONMENTAL PROTECTION
DIVISION OF WATER RESOURCES

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GROUND-WATER MANAGEMENT

APPENDIX A

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CONTENTS

Page

APPENDIX A: HYDROGEOLOGY OF NEW JERSEY

INTRODUCTION . . . . . A 1

HYDROGEOLOGY OF THE COASTAL PLAIN . . . . . A 2

POTOMAC GROUP AND MAGOTHY-RARITAN FORMATIONS . . . . A 5
ENGLISHTOWN FORMATION. A13
MT. LAUREL SAND AND WENONAH FORMATION. A17
KIRKWOOD FORMATION A19
COHANSEY SAND. A23

REFERENCES. A26

GROUND-WATER AVAILABILITY IN THE NEW JERSEY COASTAL PLAIN A27

INTRODUCTION A27
POTOMAC-MAGOTHY-RARITAN SYSTEM A28
MT. LAUREL SAND AND WENONAH FORMATION. A31
ENGLISHTOWN FORMATION. A33
KIRKWOOD FORMATION A35
COHANSEY SAND. A39

REFERENCES. A43

HYDROGEOLOGY OF THE TRIASSIC LOWLANDS A44

BERGEN COUNTY. A44
Hydrogeology. A44
ESSEX COUNTY A47
Hydrogeology. A47
HUDSON COUNTY. A48
Hydrogeology. A48
MIDDLESEX COUNTY A49
Hydrogeology. A49
PASSAIC COUNTY A51
Hydrogeology. A51

CONTENTS (Cont'd.)

	Page
UNION COUNTY	A53
Hydrogeology	A53
REFERENCES	A55
GROUND-WATER AVAILABILITY IN THE TRIASSIC LOWLANDS	A56
RECHARGE AND POTENTIAL YIELD	A56
BERGEN COUNTY	A66
Ground-Water Development	A66
Recharge and Potential Ground-Water Availability	A67
ESSEX COUNTY	A72
Ground-Water Development	A72
Recharge and Potential Ground-Water Availability	A74
HUDSON COUNTY	A74
Ground-Water Development	A74
Recharge and Potential Ground-Water Availability	A75
MIDDLESEX COUNTY	A75
Ground-Water Development	A75
Recharge and Potential Ground-Water Availability	A76
PASSAIC COUNTY	A77
Ground-Water Development	A77
Recharge and Potential Ground-Water Availability	A77
UNION COUNTY	A79
Ground-Water Development	A79
Recharge and Potential Ground-Water Availability	A79
REFERENCES	A81

CONTENTS (Cont'd.)

	Page
HYDROGEOLOGY OF THE HIGHLANDS PROVINCE	A 82
HUNTERDON COUNTY	A 82
Hydrogeology	A 82
Precambrian Rocks	A 84
Cambro-Ordovician Rocks	A 85
Triassic Rocks	A 86
Quaternary Deposits	A 89
MERCER COUNTY	A 90
Hydrogeology	A 90
Precambrian Rocks	A 91
Cambrian Rocks	A 91
Triassic Rocks	A 91
Quaternary Rocks	A 94
MORRIS COUNTY	A 94
Hydrogeology	A 94
Precambrian Rocks	A 95
Cambrian Rocks	A 96
Cambro-Ordovician Rocks	A 96
Silurian Rocks	A 97
Triassic Rocks	A 97
Quaternary Deposits	A 99
SOMERSET COUNTY	A100
Hydrogeology	A100
Precambrian Rocks	A100
Triassic Rocks	A100
Quaternary Deposits	A101
SUSSEX COUNTY	A102
Hydrogeology	A102
Precambrian Rocks	A103
Cambro-Ordovician Rocks	A103
Silurian Rocks	A105
Quaternary Deposits	A106

CONTENTS (Cont'd.)

	Page
WARREN COUNTY	A106
Hydrogeology	A106
Precambrian Rocks	A107
Cambro-Ordovician Rocks	A108
Ordovician Rocks	A109
REFERENCES	A111
GROUND-WATER AVAILABILITY IN THE HIGHLANDS PROVINCE	A112
HUNTERDON COUNTY	A112
Ground-Water Development	A112
Recharge and Potential Ground-Water Availability	A113
MERCER COUNTY	A114
Ground-Water Development	A114
Recharge and Potential Ground-Water Availability	A115
MORRIS COUNTY	A116
Ground-Water Development	A116
Recharge and Potential Ground-Water Availability	A117
SOMERSET COUNTY	A119
Ground-Water Development	A119
Recharge and Potential Ground-Water Availability	A120
SUSSEX COUNTY	A121
Ground-Water Development	A121
Recharge and Potential Ground-Water Availability	A122
WARREN COUNTY	A123
Ground-Water Development	A123
Recharge and Potential Ground-Water Availability	A124

CONTENTS (Cont'd.)

	Page
REFERENCES	A127
SALT-WATER INTRUSION	A128
NEW JERSEY COASTAL PLAIN AQUIFERS	A139
Potomac-Magothy-Raritan Aquifer System	A139
Mount Laurel and Wenonah Formations	A140
Kirkwood Aquifer	A140
Cohansey Sand	A141
AREAS AFFECTED BY SALT-WATER INTRUSION	A142
Newark-Passaic River	A142
Sayreville-Raritan River	A143
Farrington Sand	A145
Old Bridge Sand	A150
Keyport-Union Beach	A151
Atlantic City Region	A152
Cape May County	A157
AQUIFERS AFFECTED BY SALT-WATER INTRUSION	A159
Holly Beach Water-Bearing Zone	A159
Estuarine Sand	A160
Cohansey Sand	A160
Potomac-Magothy-Raritan Aquifer System	A163
REFERENCES	A167
REGIONS WHERE THE GROUND-WATER RESERVOIR IS STRESSED BY PUMPING	A170
COHANSEY SAND	A170
KIRKWOOD FORMATION	A171
MOUNT LAUREL SAND AND WENONAH FORMATION	A176
ENGLISHTOWN FORMATION	A176
POTOMAC-MAGOTHY-RARITAN SYSTEM	A184
OTHER AQUIFERS	A190
REFERENCES	A191
EFFECT OF GROUND-WATER PUMPAGE ON SURFACE WATER IN LOW STREAMFLOW PROBLEM AREAS	A192

CONTENTS (Cont'd.)

	Page
FACTORS AFFECTING STREAMFLOW	A192
EXISTING PROBLEM AREAS	A196
Passaic River Basin	A196
Ramapo River Sub-Basin	A196
Rockaway River Sub-Basin	A197
Saddle River Sub-Basin	A199
POTENTIAL PROBLEM AREAS	A199
Passaic River Basin	A200
Whippany River Sub-Basin	A200
Upper Passaic Sub-Basin	A200
Lower Passaic Sub-Basin	A201
IMPROVED RESOURCE MANAGEMENT IN LOW FLOW AREAS	A201
REFERENCES	A202

FIGURES

		Page
1.	Structure Contours on the Top of the Bedrock Surface	A 3
2.	Thickness Contours of the Magothy-Raritan Formations and Potomac Group	A 6
3.	Structure Contours on the Top of the Magothy Formation	A 7
4.	Cross Section D-D'	A 8
5.	Cross Section E-E'	A 9
6.	Cross Section F-F'	A 10
7.	Cross Section G-G'	A 11
8.	Cross Section H-H'	A 12
9.	Structure Contours on the Top of the Englishtown Formationn	A 15
10.	Aggregate Sand Thickness Contours of the Englishtown Formation	A 16
11.	Thickness Contours of the Mount Laurel Sand and Wenonah Formation	A 18
12.	Structure Contours on the Top of the Mount Laurel Sand	A 20
13.	Structure Contours on the Top of the Kirkwood Formation	A 21
14.	Thickness Contours of the Cohansey Sand and Overlying Deposits of Quaternary Age	A 24
15.	Public Supply Pumpage From the Kirkwood Formation	A 37
16.	Unconsolidated Sediments in Northern New Jersey	A 46
17.	Estimated Average Recharge to Rocks in Northern New Jersey	A 57
18.	Reported Ground-Water Pumpage in 1976 by County	A 58
19.	Extent of Sewered and Unsewered Areas	A 65
20.	Industrial Pumpage by Township for Northern New Jersey, 1976	A 69
21.	1976 Public Water Supply Service Areas and Pumpage in Northern New Jersey	A 70
22.	Industrial Grandfather Rights by Township for Northern New Jersey, 1976	A 73
23.	Principal Geologic Regions	A 83
24.	Schematic Vertical Cross Section Showing Fresh Water and Sea Water Circulation within a Transition Zone	A133
25.	Cross Section of New Jersey Continental Margin Showing Zone of Diffusion	A135
26.	Occurrence of Salty Water in the New Jersey Coastal Plain	A138

FIGURES (Cont'd.)

		Page
27.	Salt-Water Intrusion in the Newark Area.	A144
28.	Historical Advance of Salt-Water Encroachment in the Farrington Sand	A147
29.	Chloride Trends in Farrington Observation Wells at Hercules and National Lead Plant Sites and in the Perth Amboy Wells	A149
30.	Chloride Trends in Union Beach Water-Supply Wells, Monmouth County	A153
31.	Profiles of the Piezometric Surface for the Lower Kirkwood Aquifer, Cape May and Atlantic Counties	A156
32.	Isochlors for the Cohansey Sand in the Cape May City Area During August 1976	A161
33.	Chloride Trends in Wells Tapping Cohansey Sand in the Cape May City Area	A162
34.	Hydrographs of Observation Wells in the Kirkwood Formation	A173
35.	Generalized Potentiometric Surface of the Kirkwood Formation	A175
36.	Generalized Potentiometric Surface of the Mount Laurel Sand and Wenonah Formation.	A177
37.	Altitude of the Potentiometric Surface in the Englishtown Aquifer about 1900 in Monmouth and Northern Ocean and Burlington Counties	A179
38.	Altitude of the Potentiometric Surface in the Englishtown Aquifer in January 1959 in Monmouth and Northern Ocean and Burlington Counties . . .	A180
39.	Generalized Potentiometric Surface of the Englishtown Formation.	A181
40.	Hydrographs of Observation Wells in the Englishtown Formation.	A183
41.	Generalized Potentiometric Surface of the Magothy-Raritan Formations and Potomac Group . . .	A185
42.	Hydrographs of Observation Wells in the Potomac-Magothy-Raritan Aquifer System	A187

TABLES

		Page
1.	Stratigraphic Units in the Northern Coastal Plain of New Jersey.	A 4
2.	Available Recharge from Precipitation on Outcrop Area in Atlantic Coastal Plain	A 30
3.	Ground-Water Use and Available Recharge in Northern New Jersey.	A 62

APPENDIX A
HYDROGEOLOGY OF NEW JERSEY

INTRODUCTION

This section describes the hydrogeology and ground-water development possibilities in New Jersey. The state is divided into three physiographic provinces: Coastal Plain, Triassic Lowlands, and Triassic Highlands. In the northern half of the state, ground-water availability and use are given by aquifer for each county; in the Coastal Plain portion of New Jersey, this information is given by aquifer for the region as a whole. Locations where the aquifer is overstressed by present pumpage are pointed out.

A history of salt-water intrusion is included, stating the extent of intrusion by aquifer, the areas most seriously affected, and the magnitude of the problem statewide. Finally, the general relationship between ground-water withdrawal and streamflow is presented, followed by a discussion of those areas where low flow problems are or would be aggravated by ground-water withdrawal.

HYDROGEOLOGY OF THE COASTAL PLAIN

The New Jersey portion of the Atlantic Coastal Plain physiographic province covers nearly 5,000 square miles and includes all or part of five major drainage basins: Raritan, Delaware, Delaware Bay, Atlantic Coastal, and Rahway. The Coastal Plain is underlain by a generally southeasterly dipping and thickening sequence of unconsolidated sediments which lie unconformably upon a floor of predominantly crystalline rock. This bedrock floor dips generally between 80 and 100 feet per mile to the southeast and is over 6,000 feet below sea level beneath the Cape May peninsula (see Figure 1).

The formations outcrop in a series of belts roughly parallel to the Fall Line, which separates the Piedmont and Coastal Plain provinces. The oldest sediments, those of the Potomac Group and Magothy-Raritan Formations, outcrop adjacent to the Delaware River. Each successively younger formation outcrops further downdip and, because the formations thicken seaward, the dip of the formations decreases.

Table 1 is a generalized stratigraphic column for the Coastal Plain formations. The major hydrogeologic units are discussed in some detail, while the confining units, which have no potential for development, are mentioned only as they relate stratigraphically to the major units. The minor water-bearing formations have been omitted from the discussion but

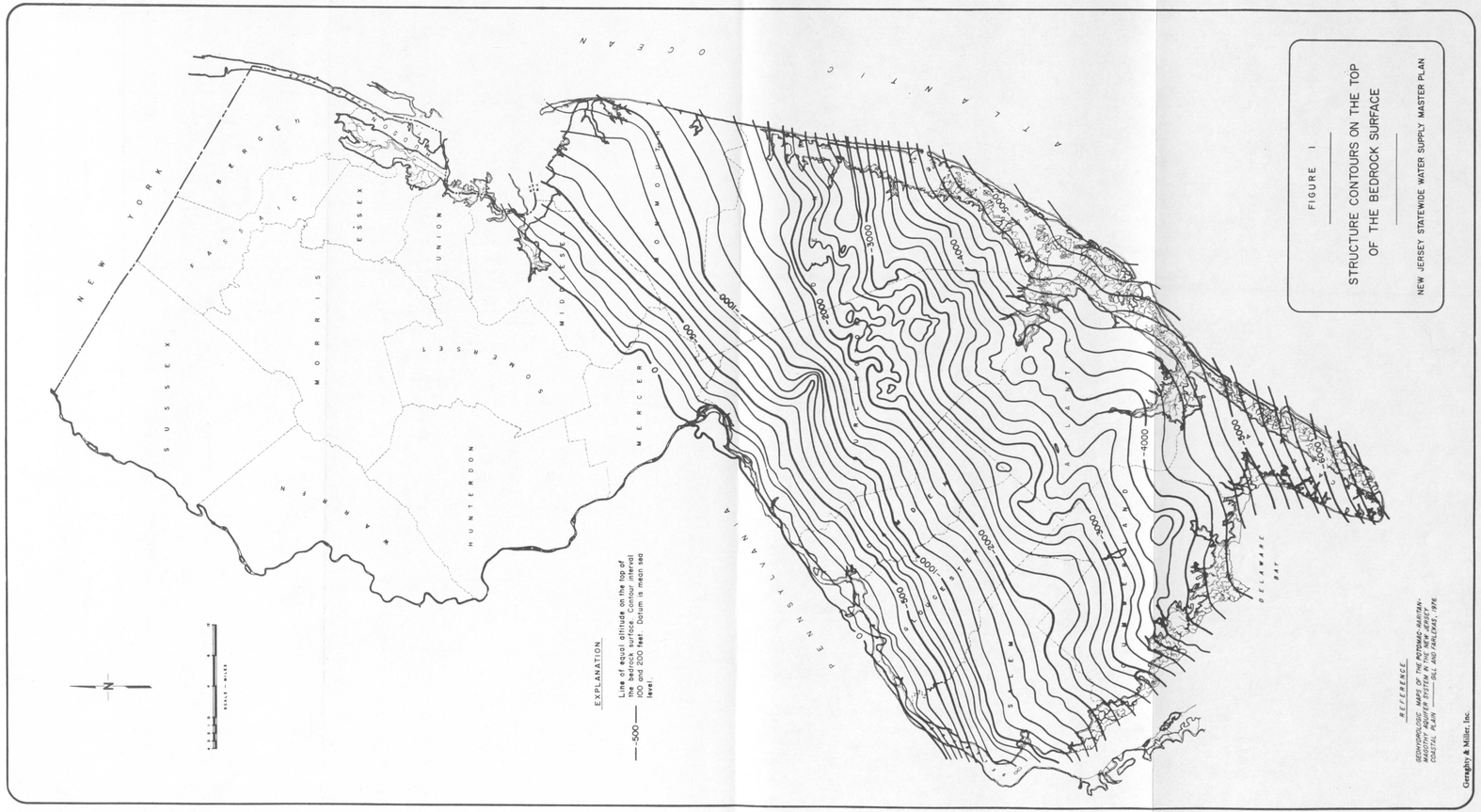


Table 1.--Stratigraphic units in the northern Coastal Plain of New Jersey[1/]

Erathem	System	Series	Subdivision		Lithology
Cenozoic	Quaternary	Holocene	Alluvial deposits		Gray mixture of clay, silt, organic material, sand, and gravel.
			Eolian deposits		Light gray, well sorted quartz sands.
		Pleistocene	Columbia Gp	Cape May Formation	Yellow to brown to gray, medium to coarse-grained quartzose sand.
				Pensauken Formation	Yellow to brown, medium to coarse-grained quartzose sand.
				Bridgeton Formation	White to brown, fine to very coarse quartzose sand and gravel, fairly well sorted and subangular.
	Tertiary	Plio-cene(?) and Mio-cene(?)	Cohansey Sand		Yellowish orange, fine to coarse quartzose sand and fine gravel, somewhat micaceous, contains lenses of silt and clay.
		Miocene	Kirkwood Formation		Light olive gray, glauconitic, slightly micaceous, very fine to fine quartzose sand.
		Eocene	Rancocas Gp	Manasquan Formation	Olive gray, clayey, quartzose, glauconitic, silty sand.
		Paleocene		Vincentown Formation	Light brown to gray, very fine, calcareous, micaceous, sand and silt.
				Hornerstown Sand	Dark green glauconitic sand and clay.
Mesozoic	Cretaceous	Upper Cretaceous	Monmouth Gp	Red Bank Sand	Dark to light gray, fine to coarse-grained, clayey, lignitic sand.
				Navesink Formation	Dark green to black glauconitic sand and clay.
				Mount Laurel Sand	Light gray, fine to coarse-grained quartz sand.
			Matawan Group	Wenonah Formation	Dark gray, poorly sorted, very micaceous, silty, fine quartz sand.
				Marshalltown Formation	Dark gray, micaceous, silty glauconite sand.
				Englishtown Formation	Massive dark-colored silty sand.
				Woodbury Clay	Grayish-black massive micaceous clayey silt.
				Merchantville Formation	Dark gray to grayish-black micaceous clay to clayey silt with beds and lenses of glauconite sand.
			Magothy Formation		Alternating clays, silts, sands, and gravel.
			Raritan Formation		
		Lower Cretaceous	Potomac Group		
	Pre-Cretaceous	Pre-Cretaceous consolidated rocks and Wissahickon Formation (Precambrian to Lower Ordovician).			Schist and gneiss.

1/ Modified after Farlekas, Nemickas, and Gill, 1973, table 2.

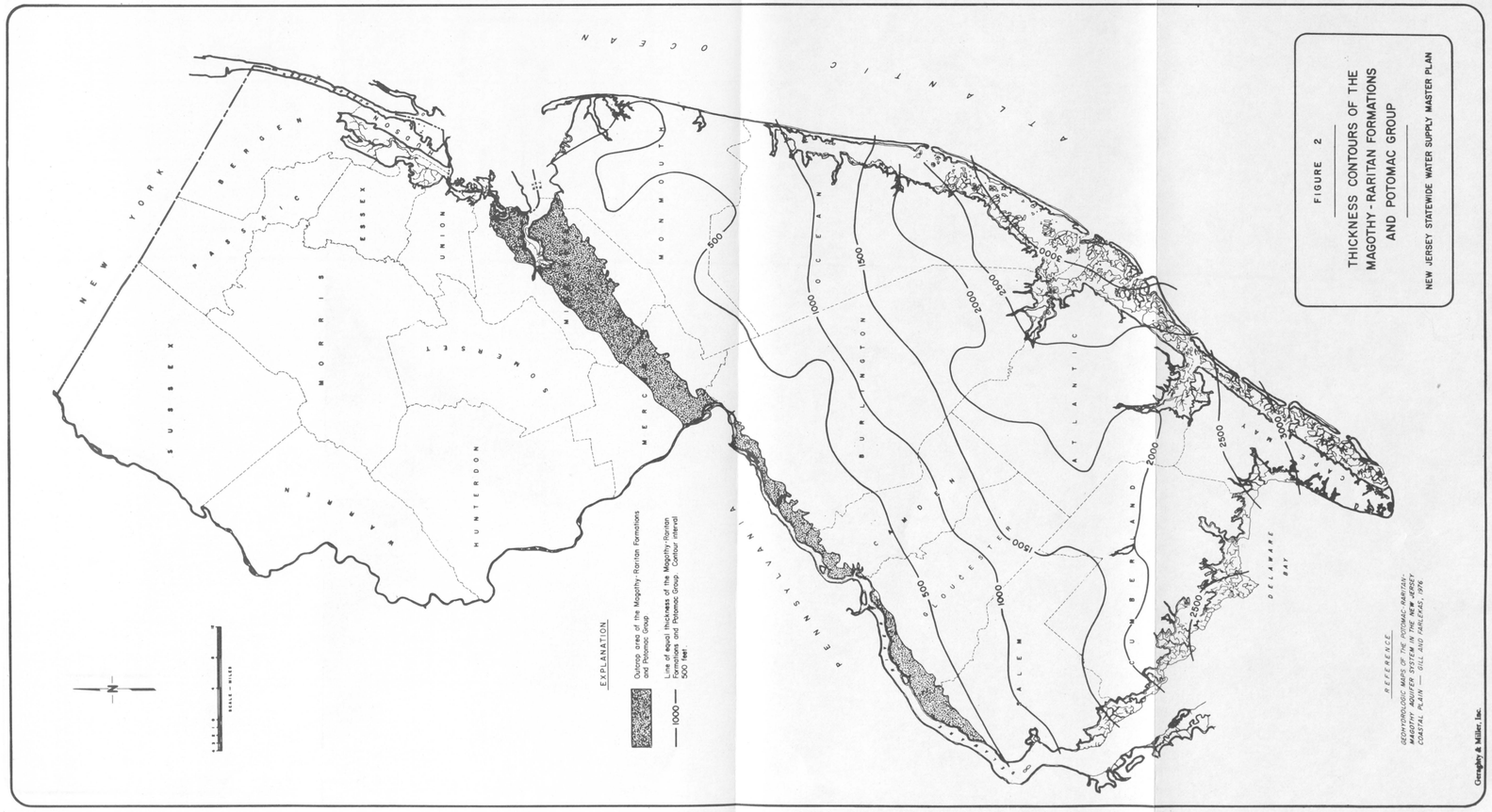
Source: Nemickas, 1976.

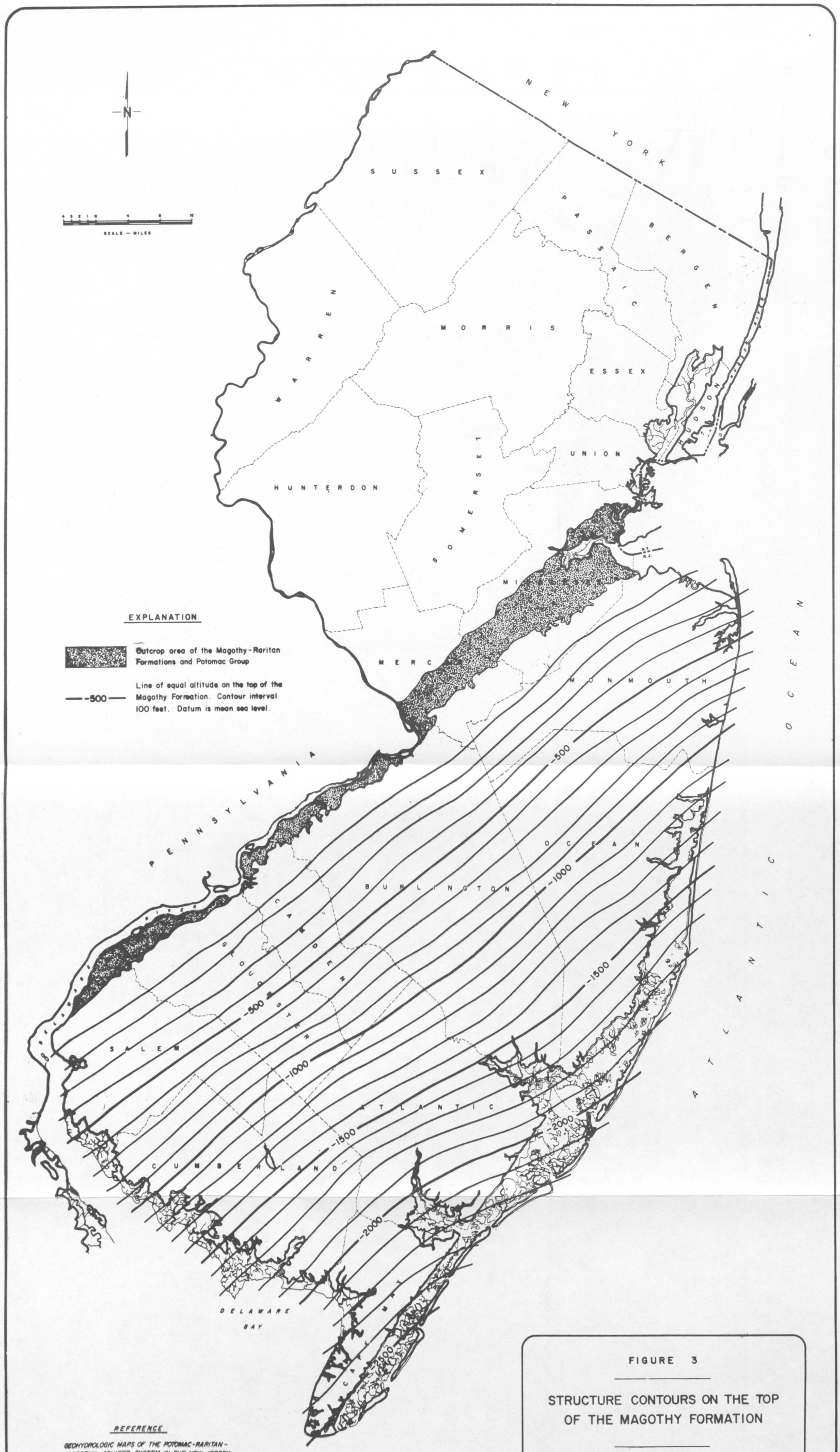
are included in the stratigraphic column.

POTOMAC GROUP AND MAGOTHY-RARITAN FORMATIONS

The Potomac Group and Magothy-Raritan Formations, which lie unconformably on bedrock, are the oldest, thickest, and most extensive units and are found throughout the entire New Jersey portion of the Coastal Plain. They range in combined thickness from a feather edge along their outcrop adjacent to the Delaware River to nearly 3,000 feet in the Atlantic City area, and to over 3,000 feet beneath Cape May peninsula (see Figure 2). These formations are overlain by the Merchantville Clay and Woodbury Formation, which together form a thick and extensive confining unit throughout much of the Coastal Plain. The top of the Magothy dips uniformly to the southeast at about 45 feet per mile and in eastern Atlantic County is over 2,000 feet below sea level (see Figures 3 through 8).

In their outcrop, the Potomac Group and Raritan Formation consist of medium- to coarse-grained light colored quartzose sands and fine-grained gravel and light colored clays. The sands, gravels, and clays occur as discontinuous layers and lenses, with the sands and gravels generally predominating and being more continuous than the clays. The Magothy Formation in outcrop is typically composed of dark gray and black clays alternating with fine-grained micaceous quartz sand.





REFERENCE

GEOHYDROLOGIC MAPS OF THE POTOMAC-RARITAN-MAGOTHY AQUIFER SYSTEM IN THE NEW JERSEY COASTAL PLAIN — GILL AND FARLEKAS, 1976.

FIGURE 3

STRUCTURE CONTOURS ON THE TOP OF THE MAGOTHY FORMATION

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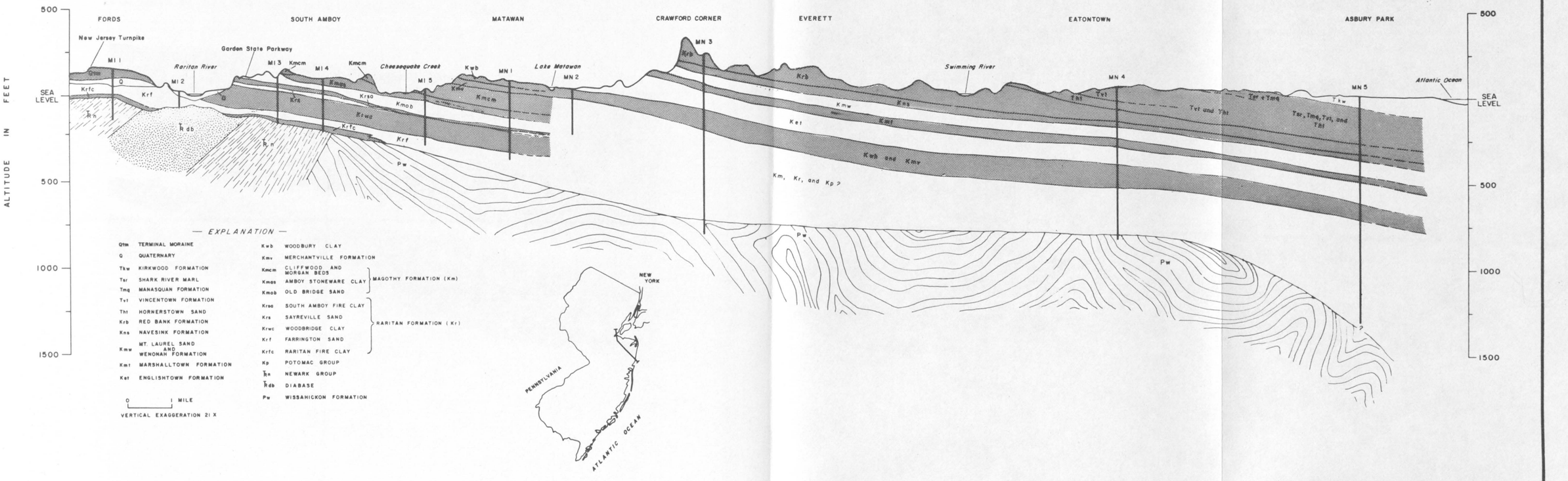


FIGURE 4

CROSS SECTION D-D'

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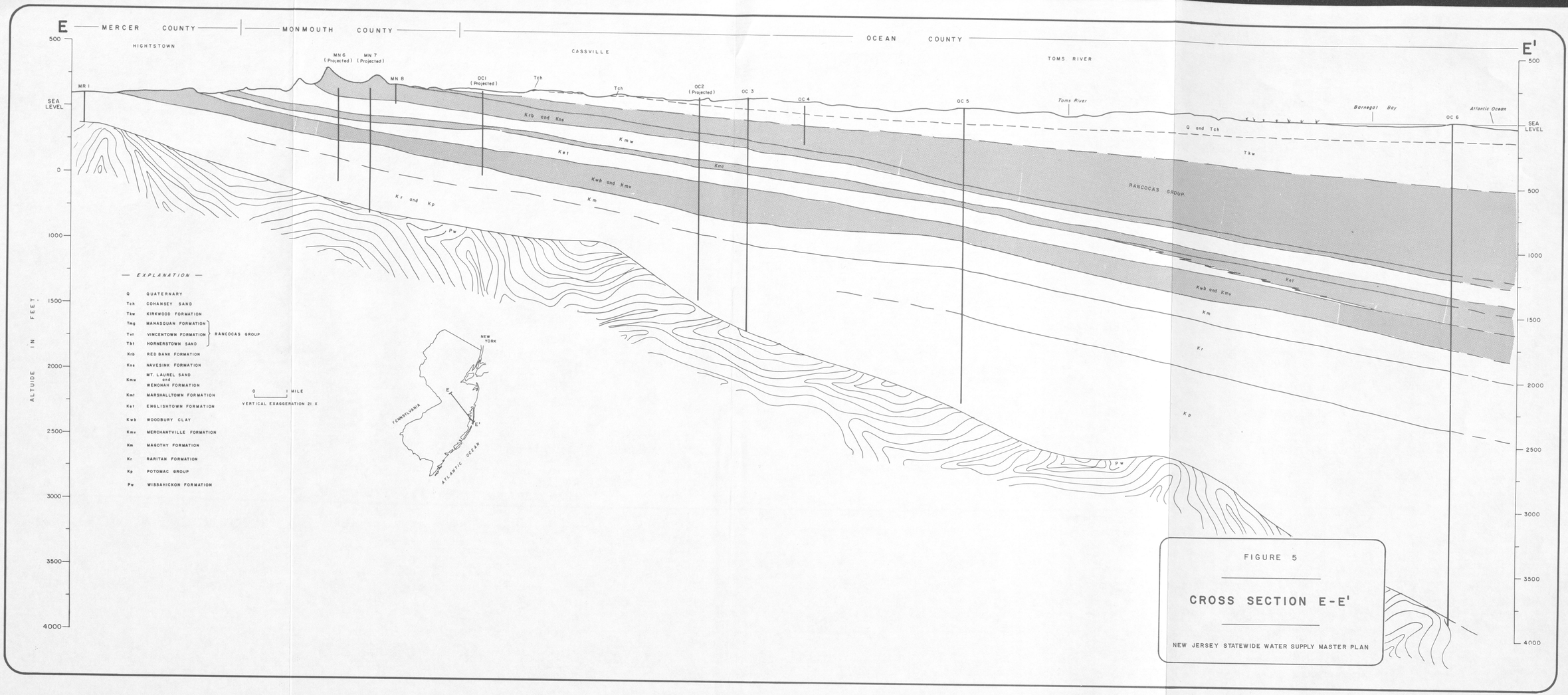


FIGURE 5

CROSS SECTION E-E'

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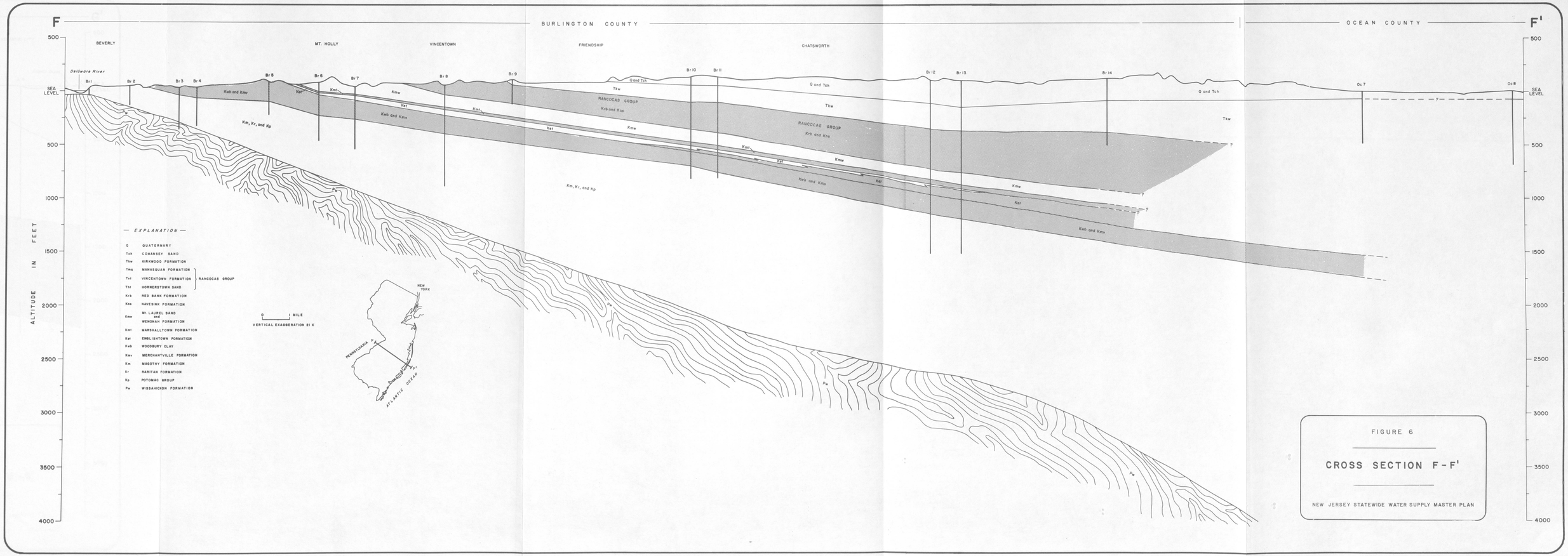


FIGURE 6

CROSS SECTION F-F'

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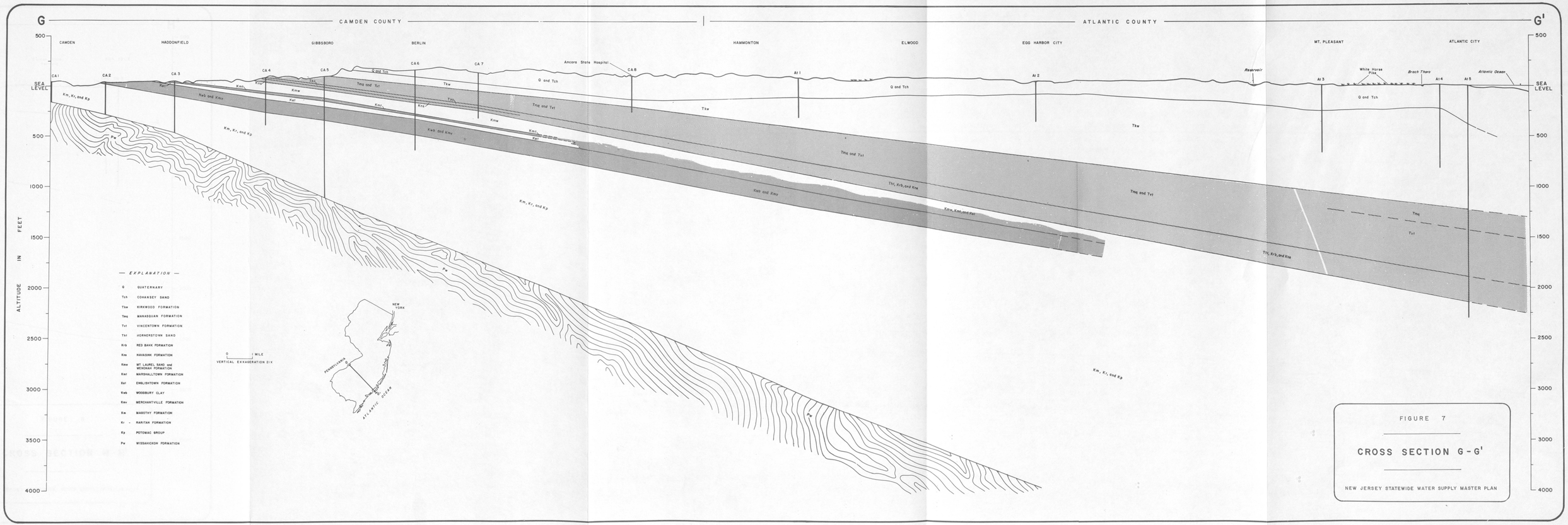


FIGURE 7

CROSS SECTION G-G'

NEW JERSEY STATEWIDE WATER SUPPLY MASTER PLAN

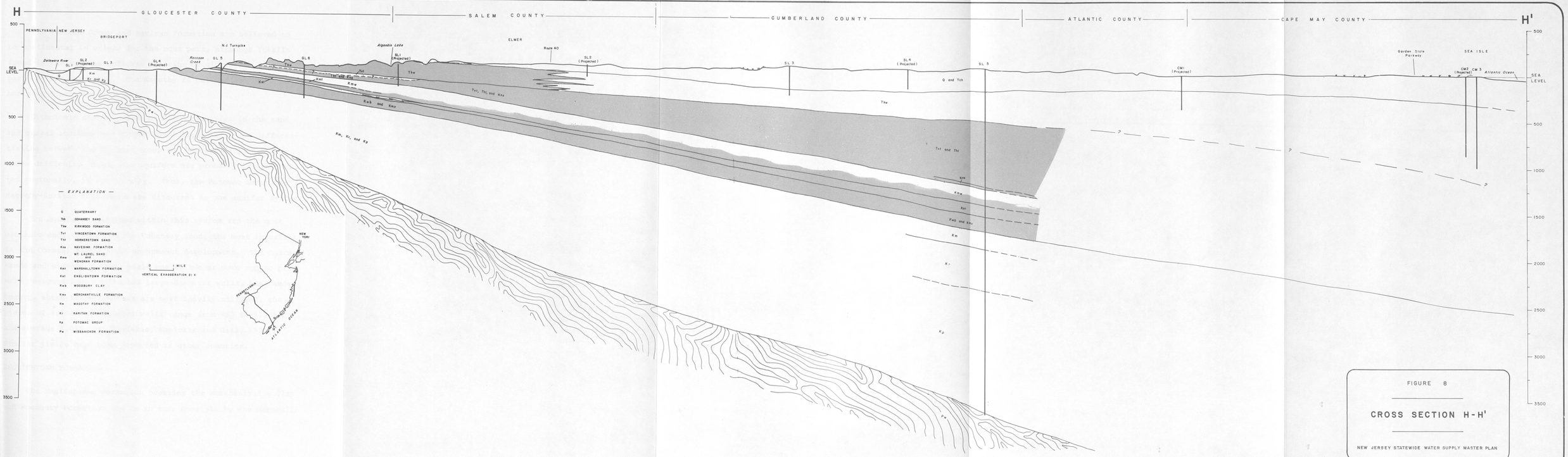


FIGURE 8

CROSS SECTION H-H'

NEW JERSEY STATEWIDE WATER SUPPLY MASTER PLAN

The Potomac Group and Raritan Formation are believed to be continental in origin for the most part, although fossils found in the Raritan indicate a marine origin for at least part of this formation. The Magothy is believed to be of both marine and non-marine origin.

Lithologic changes, such as discontinuities in the sand and gravel aquifers and clayey confining units, make differentiating between the Potomac Group and Magothy-Raritan Formations difficult. Also, the aquifers are probably interconnected regionally, if not locally. Thus, the Potomac Group and Magothy-Raritan Formations are discussed as one aquifer system.

The aquifers contained within this system are the most prolific and, except for the Cohansey Sand, the most important in the Coastal Plain based on present development. The coarse sands and gravels readily yield one to two or more mgd to properly designed and constructed large-diameter wells. In Camden County, where these aquifers are most heavily utilized, the yields of 106 large-diameter wells range from 455 to 1,900 gpm and average 1,085 gpm (Farlekas, Nemickas and Gill, 1976). Similar yields have been reported in other counties.

ENGLISHTOWN FORMATION

The Englishtown Formation overlies the Merchantville Clay and Woodbury Formation and is in turn overlain by the Marshall-

town Formation, a thin confining unit. The Englishtown ranges in thickness along its outcrop from 140 feet near Raritan Bay to 50 feet at Trenton; downdip its thickness is over 200 feet in the Toms River area. The formation dips uniformly to the southeast at about 40 feet per mile. In its area of greatest development, along the coast in Monmouth and Ocean Counties, it is some 600 feet below sea level (Figure 9).

Figure 10, depicting the aggregate sand thickness of the Englishtown Formation, shows the approximate areal extent of the aquifer portion of this formation. In Monmouth County, the northern half of Ocean County, and the northeast corner of Burlington County, this aquifer ranges from 40 to 140 feet thick. In the southern third of Ocean, Burlington, and Camden Counties, the sand facies of the Englishtown Formation is not found; instead clay and silt comprise the unit (see Figures 5 and 6). In Middlesex, Mercer, Gloucester, and Salem Counties, insufficient data were available to define the aquifer's thickness, but the aquifer in these areas is probably very thin. It is unlikely that the Englishtown aquifer exists elsewhere in the Coastal Plain.

The Englishtown Formation is most permeable and therefore, most highly developed in Monmouth and northeast Ocean Counties, especially along the coast. To the south and southwest, the formation thins and a facies change occurs, as the sand con-

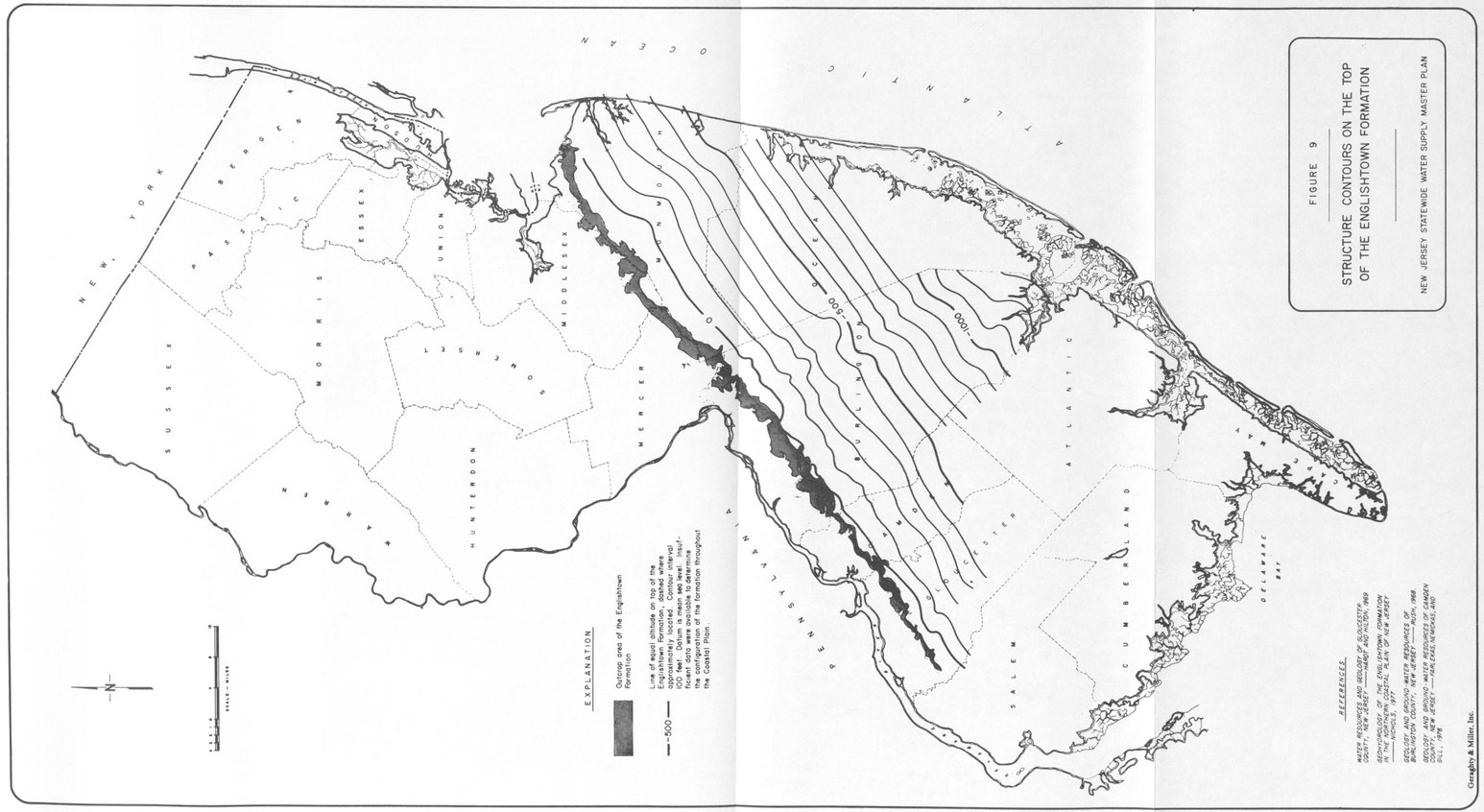
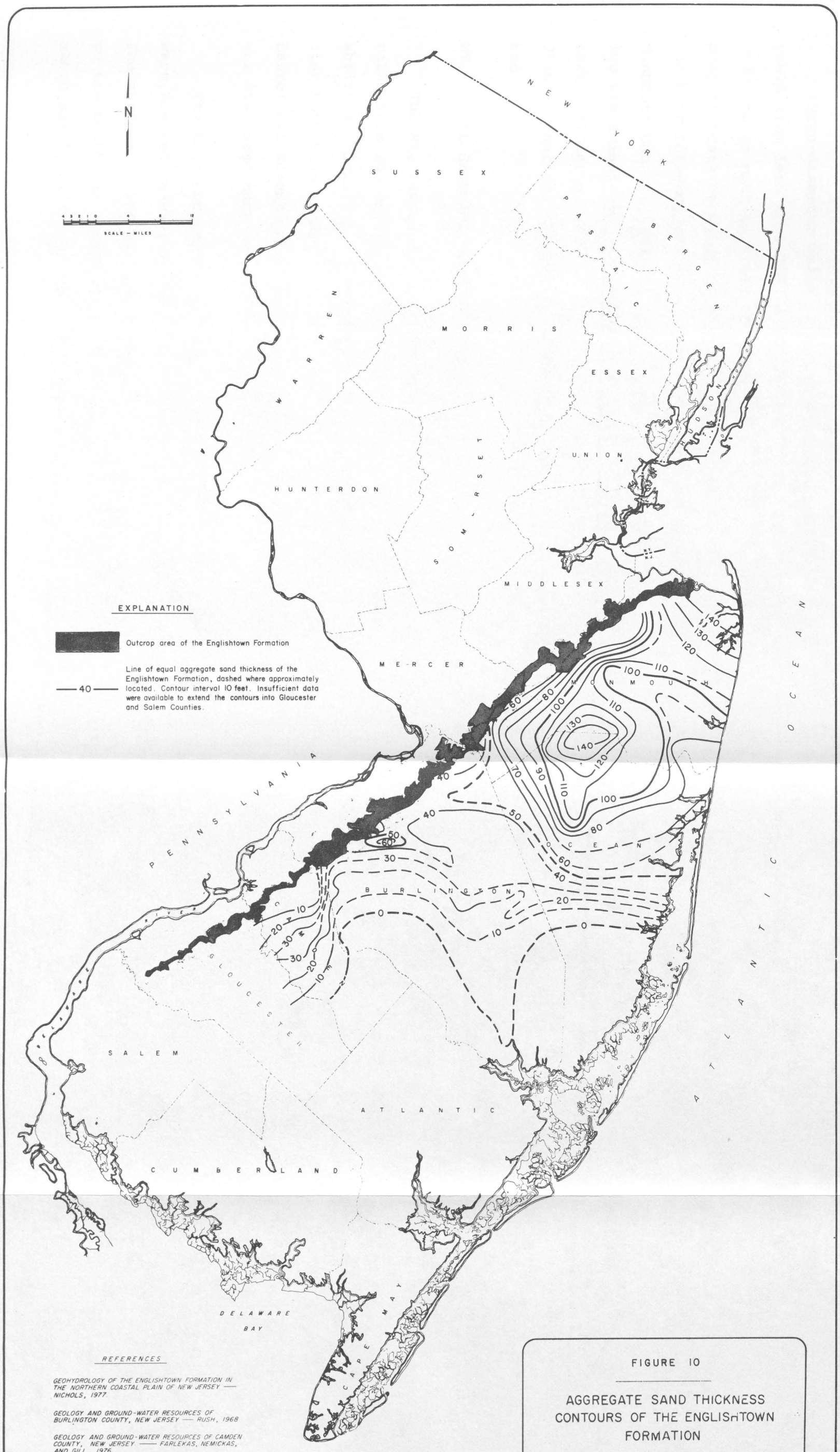


FIGURE 9

STRUCTURE CONTOURS ON THE TOP OF THE ENGLISHTOWN FORMATION

NEW JERSEY STATEWIDE WATER SUPPLY MASTER PLAN

397-9



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GEOHYDROLOGY OF THE ENGLISHTOWN FORMATION IN THE NORTHERN COASTAL PLAIN OF NEW JERSEY — NICHOLS, 1977.

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GEOLOGY AND GROUND-WATER RESOURCES OF CAMDEN COUNTY, NEW JERSEY — FARLEKAS, NEMICKAS, AND GILL, 1976.

FIGURE 10

AGGREGATE SAND THICKNESS CONTOURS OF THE ENGLISHTOWN FORMATION

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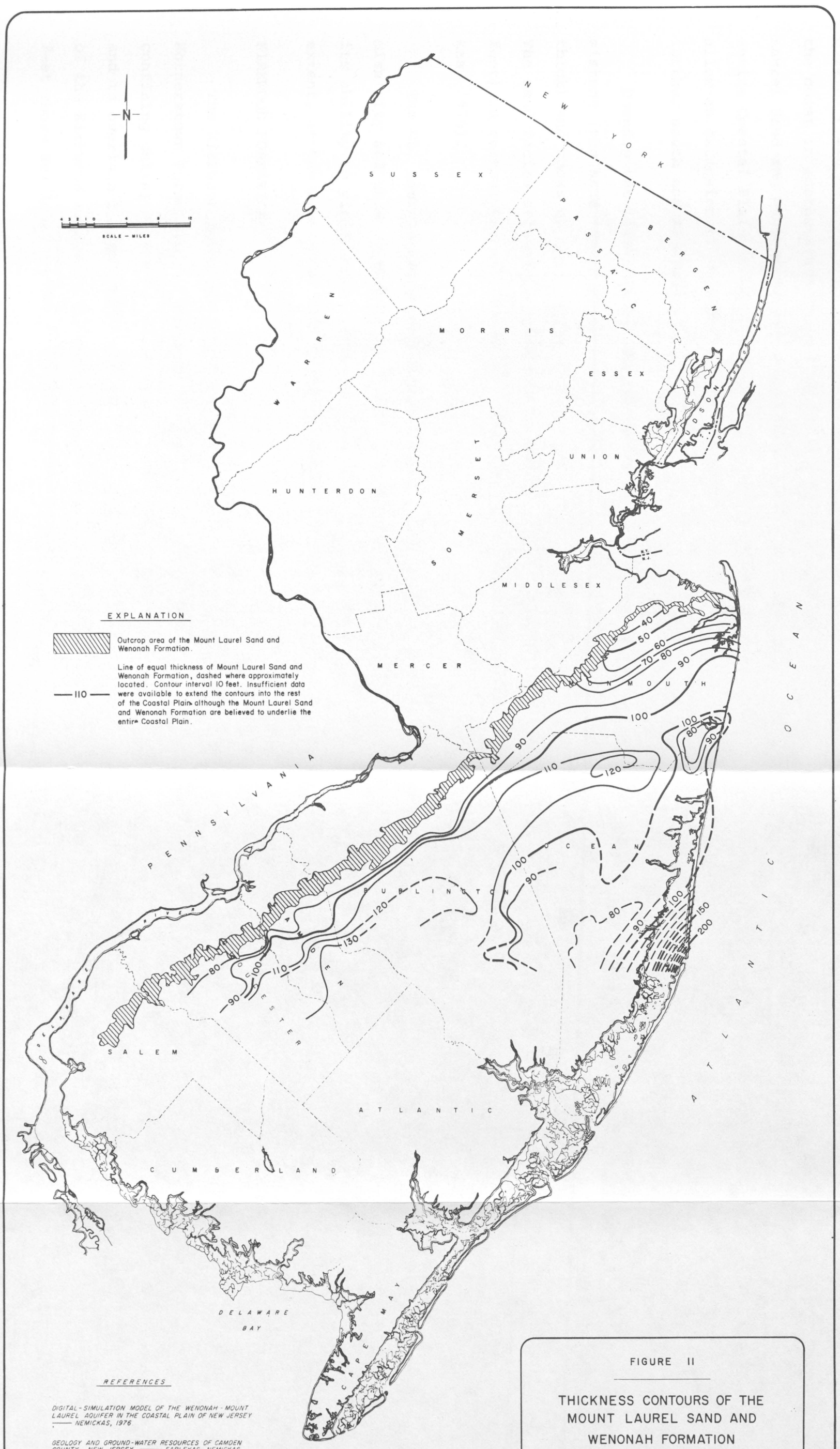
tent decreases and clay and silt increase.

Large-diameter wells in the Englishtown usually range in yield from less than 200 to 500 gpm with only a few wells yielding as much as 1,000 gpm (Nichols, 1977). Results of two pumping tests on wells screened in the Englishtown Formation, one near Lakewood in Ocean County and one near Allenwood in Monmouth County, indicate that the aquifer has a relatively low transmissivity in Monmouth County, northern Ocean, northeast Burlington, central Camden, and extreme southeastern Middlesex Counties. Elsewhere it can be considered a confining bed.

MT. LAUREL SAND AND WENONAH FORMATION

The Mt. Laurel Sand and the Wenonah Formation are separated from the underlying Englishtown Formation by the Marshalltown Formation (confining unit) and overlain by the Navesink Formation (generally a confining unit). Because the Mt. Laurel and Wenonah function hydraulically as one aquifer, they are discussed here as a single unit.

The unit outcrops from Raritan Bay southwestward to Delaware Bay and reaches a thickness of over 200 feet (Figure 11). The surface of the Mt. Laurel Sand dips about 40 feet per mile to the southeast, ranging in elevation from over 100 feet above sea level at its outcrop in the northern end of the



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DIGITAL-SIMULATION MODEL OF THE WENONAH-MOUNT LAUREL AQUIFER IN THE COASTAL PLAIN OF NEW JERSEY —— NEMICKAS, 1976.

GEOLOGY AND GROUND-WATER RESOURCES OF CAMDEN COUNTY, NEW JERSEY —— FARLEKAS, NEMICKAS, AND GILL, 1976.

DELAWARE VALLEY REGIONAL PLANNING COMMISSION 208 AREA-WIDE WASTE TREATMENT MANAGEMENT PLANNING - DESCRIPTION OF GROUND-WATER SYSTEM —— GERAGHTY AND MILLER, INC., 1976.

FIGURE II

THICKNESS CONTOURS OF THE MOUNT LAUREL SAND AND WENONAH FORMATION

NEW JERSEY STATEWIDE WATER SUPPLY MASTER PLAN

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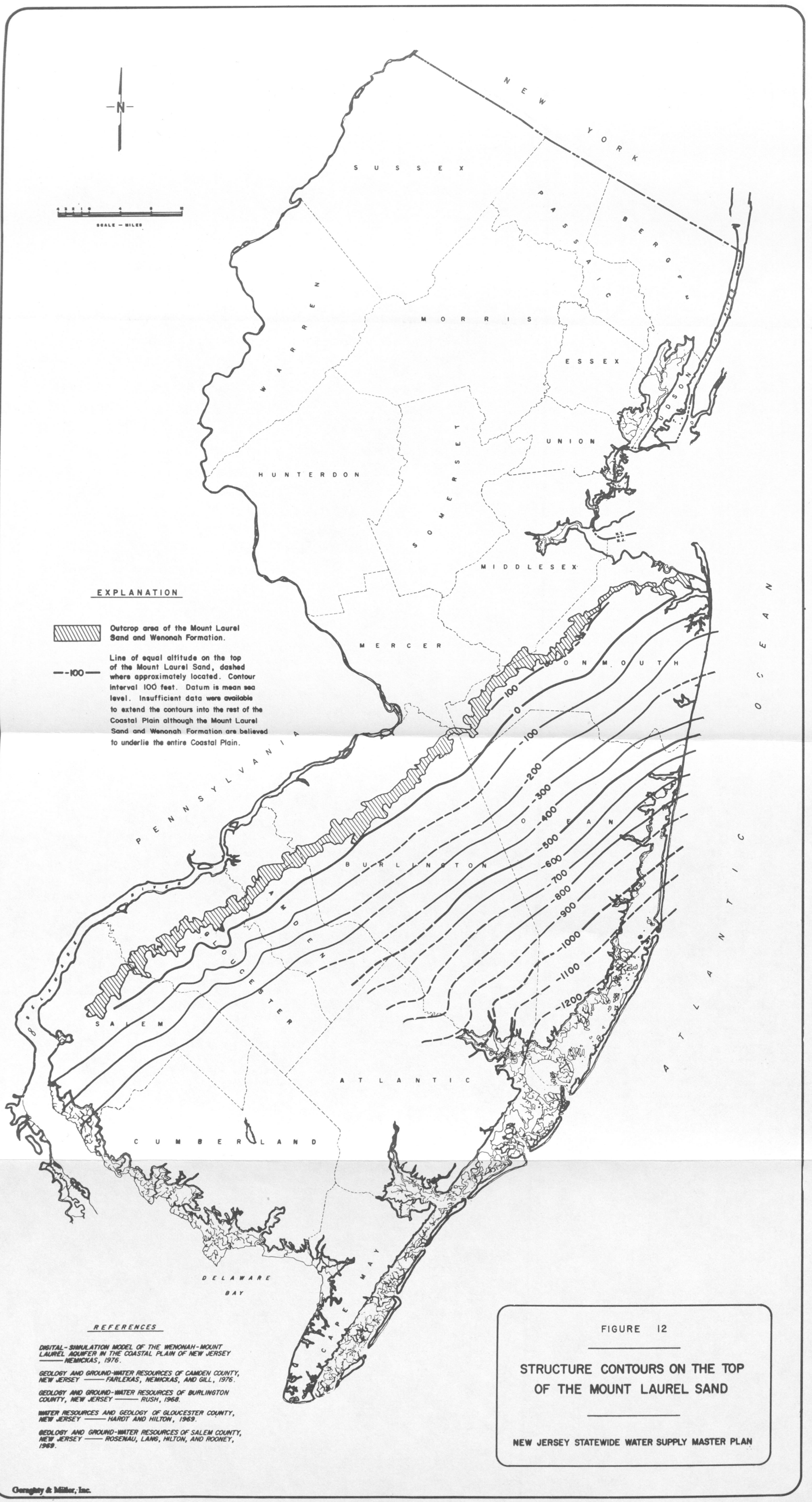
Coastal Plain to more than 1,200 feet below sea level beneath the coast in southeastern Ocean County (Figure 12). The Mt. Laurel Sand and Wenonah Formation are believed to underlie the entire Coastal Plain although insufficient well data exist to allow an extension of the contours on Figures 11 and 12 any further south and southwest.

Downdip the lithology of the formation remains fairly consistent (the sand facies is generally between 50 and 100 feet thick) and shows no progressive thinning away from the outcrop. The sand facies attains its greatest thickness (more than 115 feet) in central Camden, Gloucester, and Salem Counties (Nemickas, 1976).

The Mt. Laurel-Wenonah has generally low values of transmissivity and thus is similar to the Englishtown Formation in its ability to yield water. However, because of its greater extent, it has more potential for development.

KIRKWOOD FORMATION

The Kirkwood Formation overlies the Manasquan Formation, Hornerstown Formation, or Navesink Formation (all generally confining units) depending on location in the Coastal Plain, and is overlain by the Cohansey Sand. The irregular surface of the Kirkwood ranges in elevation (Figure 13) from over 100 feet above sea level in its outcrop area to 300 feet below sea



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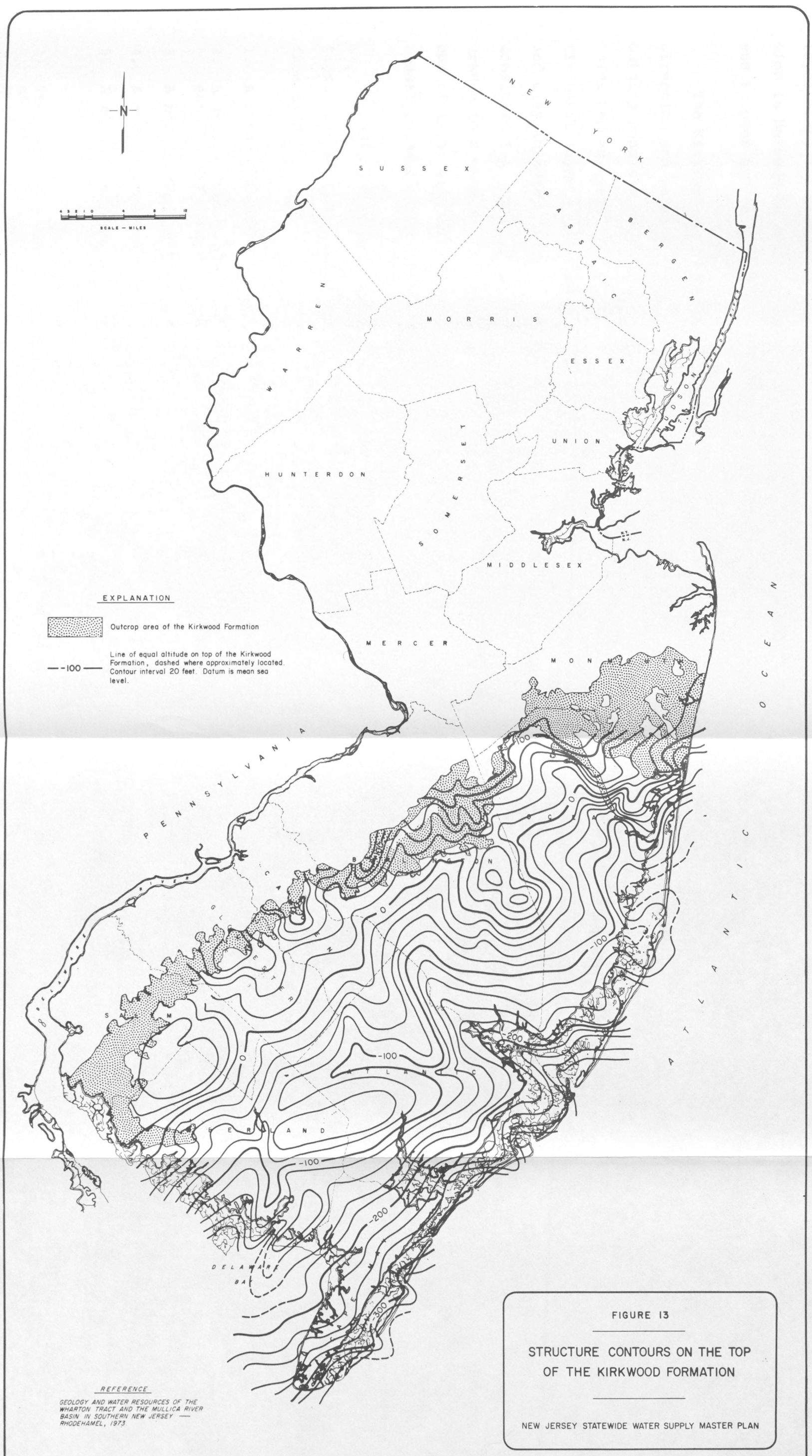
GEOLOGY AND GROUND-WATER RESOURCES OF SALEM COUNTY, NEW JERSEY —— ROSENAU, LANG, HILTON, AND ROONEY, 1969.

FIGURE 12

STRUCTURE CONTOURS ON THE TOP OF THE MOUNT LAUREL SAND

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REFERENCE

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FIGURE 13

STRUCTURE CONTOURS ON THE TOP OF THE KIRKWOOD FORMATION

NEW JERSEY STATEWIDE WATER SUPPLY MASTER PLAN

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level along the eastern edge of Cape May peninsula. The formation is between 50 and 100 feet thick at its outcrop and thickens to over 800 feet in the Atlantic City area (Figure 7).

The Kirkwood is of variable lithology, in both a downdip direction and parallel to its outcrop. In Salem County, its outcrop consists of a lower member that is a dark-colored, thick-bedded, very fine micaceous sand with a pebbly glauconitic basal layer 2 to 4 feet thick and an upper member of silt and clay (Minard, 1965). In Burlington County the Kirkwood consists of a lower member of brownish-black clayey silt that grades to a very fine-grained quartz sand, and a thicker member of light gray to light yellow-orange fine-grained sand. Fossil evidence indicates a marine origin for this formation.

Downdip and along the coast in Cape May County, five distinct facies of the Kirkwood have been recognized and are, from oldest to youngest, as follows:

1. A tough brown basal clay.
2. A gray medium-to-coarse sand (Atlantic City "800-foot sand" [1]) or lower aquifer).
3. A blue silty diatomaceous clay.
4. A medium-to-coarse sand (Rio Grande zone or upper aquifer).
5. A blue diatomaceous clay.

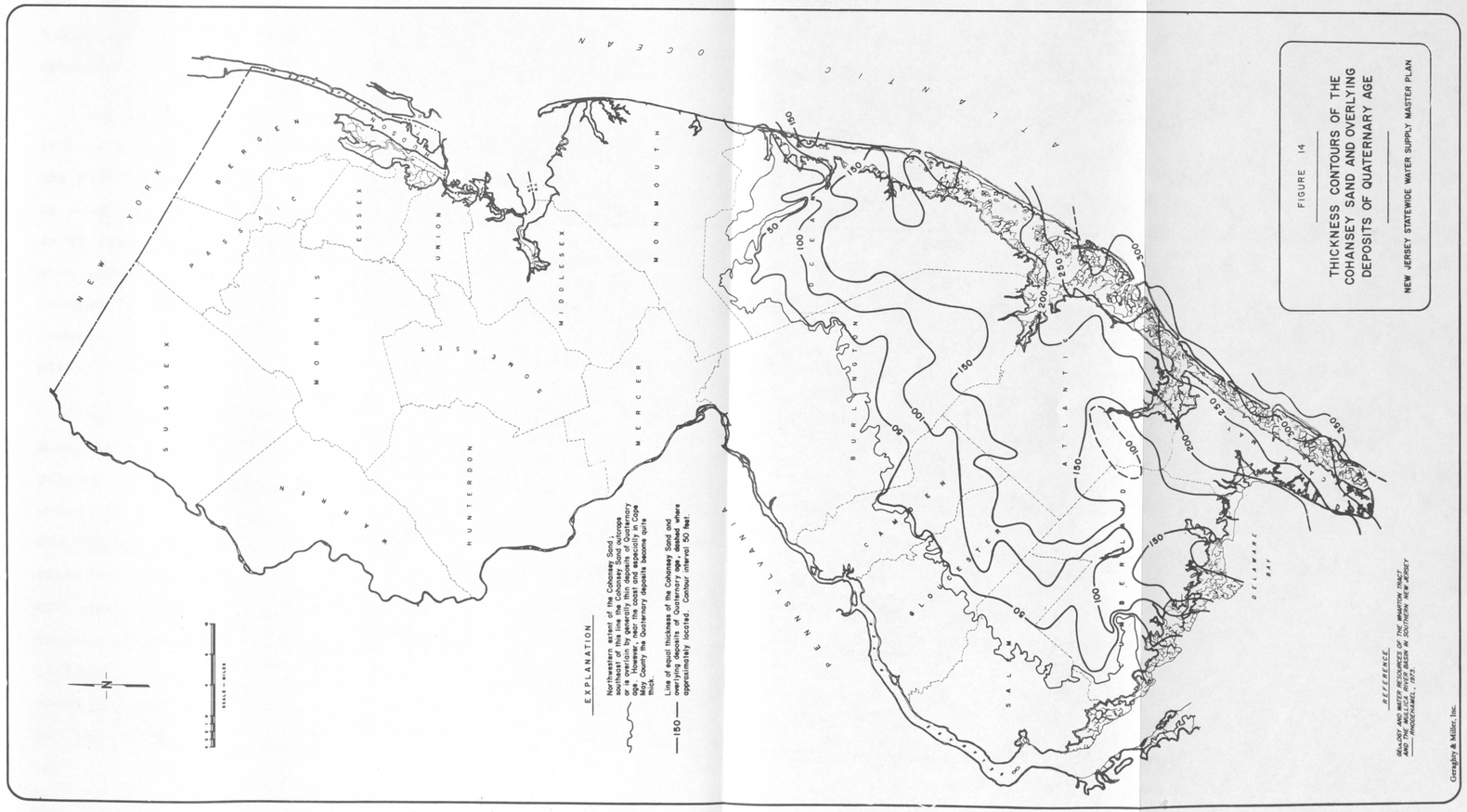
1) The "800-foot sand" is so named because that is the depth at which it was typically found in the Atlantic City area where it was first developed.

The lower aquifer ("800-foot sand") can be traced continuously from the Cape May peninsula as far north as Barnegat Light (southern Ocean County) and from there discontinuously to Point Pleasant (northeastern Ocean County), whereas the upper aquifer (Rio Grande) occurs only in Cape May and Cumberland Counties. The "800-foot sand" is most permeable and most highly developed in an area centered around Atlantic City. The permeability of this unit decreases sharply away from Atlantic City. Results of pumping tests indicate that water in the lower Kirkwood is under confined conditions and that the formation is highly productive in places. The Rio Grande zone is not as productive as the lower aquifer.

Yields of wells tapping the Kirkwood range from 10 to 50 gpm for domestic wells in its outcrop area to 1,200 gpm for public supply and industrial wells located near Atlantic City, where the aquifer's permeability is highest. In Atlantic County, the median yield of 27 public supply and industrial wells tapping this unit is 700 gpm (Clark and others, 1968).

COHANSEY SAND

The Cohansey Sand outcrops over an area of some 2,300 square miles located almost entirely within the Pine Barrens region. The combined thickness of the Cohansey Sand and overlying Pleistocene deposits ranges from less than 50 feet to 300 feet (Figure 14) and averages about 100 feet. For the



most part, it outcrops or is overlain by a thin veneer of Pleistocene deposits. However, in Cape May County the Pleistocene deposits may have a thickness of 200 feet.

The Cohansey Sand typically consists of fine- to coarse-grained quartzose sand with lenses of gravel that are usually one foot thick or less. Discontinuous lenses of clay generally occur in the upper part of the formation and may be as much as 25 feet thick. The presence of certain distinct lithologies and sedimentary structures and the lack of fossils or glauconite in the Cohansey Sand, indicate a transitional environment of deposition that ranges from stream and fluvial plain to beach and near-shore environments.

Aquifer tests conducted on wells tapping the Cohansey at more than ten sites indicate a wide range of transmissivity values. Generally, the lower values occur to the northwest, where the formation thins, and in southern Cape May County. The higher values occur in the central part of the Coastal Plain and downdip to the southeast where the formation thickens, specifically in Cumberland County and the Mullica River basin. It should be possible to construct wells capable of yielding 500 to 1,000 gpm or more in most of these areas, where the aquifer compares favorably with the Magothy-Raritan-Potomac system in its ability to yield water.

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GROUND-WATER AVAILABILITY IN THE NEW JERSEY COASTAL PLAIN

INTRODUCTION

All naturally occurring fresh ground water in the unconsolidated formations of the Coastal Plain is ultimately derived from precipitation, which over the long term averages 44 inches per year, or slightly over 2 mgd per square mile. Evapotranspiration losses of 50 percent leave one mgd per square mile, or approximately 5 bgd as recharge to the entire Coastal Plain. Most of this is eventually discharged through streams as base flow. In the Coastal Plain, it has been estimated (Anderson and Appel, 1969; Lang, 1961; and Rhodehamel, 1970) that ground-water discharge accounts for between 67 and 89 percent of streamflow in the region. If 75 percent of this discharge to streams could be withdrawn by wells, an additional 3.75 bgd of ground water would potentially be available for development. A comparison of this amount to the 440 mgd withdrawn from the Coastal Plain in 1976 shows that only a small portion of available recharge has been utilized.

In the following sections, ground-water availability in the five major hydrogeologic units of the Coastal Plain is discussed, taking into account recharge, discharge, present development, and water-level trends.

POTOMAC-MAGOTHY-RARITAN SYSTEM

The Potomac-Magothy-Raritan aquifer system is the most extensively developed of all the Coastal Plain aquifers. Estimated pumpage from it was over 240 mgd in 1976, and took place mostly in the outcrop area and a short distance downdip of it, between Old Bridge (Middlesex County) and the Gloucester-Salem County line.

Recharge to this aquifer system is derived from precipitation on its outcrop area, induced infiltration (primarily from the Delaware River), and leakage through overlying confining beds. Discharge occurs as base flow to streams in the outcrop area, vertical leakage to subjacent aquifers with lower heads, submarine underflow that maintains the fresh-water/salt-water interface, and artificial discharge through wells.

It has been well documented (Barksdale and others, 1958; Greenman and others, 1961) that in many places along the Delaware River, especially between Trenton and Camden, a large amount of the water pumped from the Potomac-Magothy-Raritan system is induced from the river. A pumping test at the Morro Phillips tract in Camden showed that, after two years of operation, 90 percent of the water produced from a well near the river would be induced river water.

A computer model developed by the USGS and modified by the Army Corps of Engineers showed that approximately 47 percent of the water pumped from the aquifer system between Trenton and Salem is induced infiltration, 31 percent is leakage from overlying aquifers, 17 percent is from precipitation on the outcrop area, and 5 percent is underflow from the northeast and southeast. It is apparent that precipitation on the outcrop area contributes water but is not a major source overall. Any evaluation of the potential for future development based solely on precipitation recharge would be inaccurate. Potentially, 320 mgd of recharge from precipitation on the outcrop is available to this aquifer system (Table 2).

Preliminary results from the Corps' maximum yield analysis give an indication of the future potential for this unit. Several population growth rates were assumed for the tri-county area, and pumpage from the Potomac-Magothy-Raritan of slightly over 140 mgd (1973) was increased proportionately. At a 2 percent growth rate, a withdrawal rate of approximately 365 mgd would be reached by 2020 with no currently (1973) pumping wells being dewatered. Later computer runs by the Corps will attempt to redistribute the present pumpage centers to determine the maximum yield obtainable in this area.

In general, the potential for further development of this aquifer system is relatively large. As discussed above, the Delaware River provides significant recharge to the aquifer system, and as the average discharge (64 years of record) of the river at Trenton is over 7,500 mgd, present withdrawals

Table 2. Available Recharge From Precipitation on Outcrop Area in Atlantic Coastal Plain (mgd).

County	Potomac-Magothy-Raritan	Englishtown	Mt. Laurel-Wenonah	Kirkwood	Cohansey
Middlesex	154 a)	39 a)	2	-	-
Monmouth	154 a)	39 a)	26	-	-
Mercer	50	11	-	-	-
Ocean	-	-	-	-	-
Burlington	48	54	41	-	-
Camden	21	7	14	-	-
Gloucester	32	11	26	-	-
Atlantic	-	-	-	-	-
Salem	19	-	18	-	-
Cumberland	-	-	-	-	-
Cape May	-	-	-	-	-
Rounded Total:	320	120	130	150-200 b)	2,500

GRAND TOTAL: 3,200 or 3.2 billion gallons

Note: Based on the equation: available recharge = aquifer outcrop area in square miles x recharge rate per square mile.

Assumptions: Recharge rate as follows -

Potomac-Magothy-Raritan	1.00 mgd - Barksdale (1958)
Englishtown	0.85 mgd - Rush (1968)
Mt. Laurel-Wenonah	0.85 mgd - Rush (1968)
Cohansey	1.07 mgd - Rhodehamel (1970)

a) Total for Monmouth and Middlesex Counties.
b) From Gill (1962).

are only a fraction of this amount. In fact, not even the 320 mgd of potential recharge from precipitation on the outcrop is presently utilized.

To allow maximum development of this system, wells must be properly located. The present well locations and patterns of pumping are not ideal, as most pumpage is confined to a relatively small area. Thus, water-level declines are concentrated rather than distributed uniformly.

In summary, based on available data, increased supplies can be withdrawan from the Potomac-Magothy-Raritan aquifer system for many years to come. In order to maximize these supplies, future withdrawals should be made in the relatively underdeveloped portions of the aquifer system with pumping centers distributed as evenly as possible. Artificial recharging ponds located in the outcrop areas of the aquifer system can increase yields there significantly. Efforts to induce more recharge from the Delaware River should continue. Quality rather than quantity considerations may become more critical due to industrialization on the outcrop area.

MT. LAUREL SAND AND WENONAH FORMATION

The aquifer in this unit is the least developed of the major formations in the Coastal Plain. Slightly over 3 mgd were withdrawn from it in 1976.

The total recharge available to the Mt. Laurel Sand/ Wenonah Formation outcrop area is about 130 mgd (Table 2). However, very little of this amount travels downdip to the confined parts of the aquifer. It has been estimated (Nichols, 1977) that only 1.5 mgd was directly recharged to the confined part of the aquifer from the outcrop area in 1970. Because of existing hydraulic gradients, most of the water falling on the outcrop is also discharged in the outcrop area. According to a digital model of the Mt. Laurel-Wenonah aquifer (Nemickas, 1976), no change in the hydraulic gradient near the outcrop is predicted for the near future.

Although precipitation on the outcrop does contribute significant recharge to this aquifer, the percentage of water available from precipitation that is being utilized is extremely small. Based on the drawdowns that have occurred, it is unlikely that a significant portion of this recharge could ever be utilized by existing wells in their present locations.

Downdip, in southeast Monmouth and northeast Ocean Counties, the Mt. Laurel-Wenonah contributes significant quantities of water to the Englishtown Formation through vertical leakage. On the basis of its importance as a source of recharge to the underlying Englishtown, no additional withdrawals should be considered from the aquifer in this area. Future development of the Mt. Laurel-Wenonah should be in the outcrop area or a short distance downdip of the outcrop in order to use the 130 mgd of available recharge. The aquifer would have to be developed by adequately spaced shallow wells to reduce interference. Because development at the outcrop reduces streamflow, optimum ground-water potential depends on the minimum streamflow desired. If, as for the Cohansey Sand, 43 percent of the potentially developable water is left for streamflow, then about 75 mgd would be available for development in the outcrop area of the Mt. Laurel-Wenonah. Further downdip, in the southern Coastal Plain, development of the aquifer would probably lead to sharply declining water levels as have occurred in the north. Although little data on the aquifer in the southern Coastal Plain are available, development in the outcrop area should result in substantial additional supplies, with more or less stable water levels.

ENGLISHTOWN FORMATION

The Englishtown is quite similar in present and potential development to the Mt. Laurel-Wenonah. The available recharge from precipitation on the outcrop is about 120 mgd (Table 2). Estimated pumpage from the Englishtown was over 12 mgd in 1976, nearly all in southeastern Monmouth and northeastern Ocean Counties. Like the Mt. Laurel-Wenonah, the outcrop area of the Englishtown can readily absorb precipitation and the overall transmissivity of the formation is low.

The generalized potentiometric surface of the Englishtown

aquifer is similar to that of the Mt. Laurel-Wenonah. The area of depressed water levels is in the same general location and heads in the Englishtown are lower, which provides the gradient for leakage into it from the Mt. Laurel-Wenonah.

Potentiometric highs occur a short distance downdip of the outcrop and create a ground-water divide with water flowing from the divide to the northwest and southeast. Water moving to the northwest eventually discharges to streams in the outcrop area as does precipitation falling there, which is prevented from flowing toward the coast by the prevailing hydraulic gradients.

A computer model of the Englishtown in the northern Coastal Plain (Nichols, 1977) simulated the historical decline of the water levels in this aquifer between 1959 and 1970. During that period, 31.2 billion gallons of water were pumped from the aquifer. Six percent came from storage in the aquifer, 27 percent was derived from storage in the underlying confining unit (Woodbury Clay-Merchantville Formation), 33 percent was derived from storage in the overlying confining unit (Marshalltown Formation), and 34 percent came from leakage through the Marshalltown Formation derived from the overlying Mt. Laurel-Wenonah Formation.

Water-level declines in this aquifer can be expected to continue for the foreseeable future at the same or an increased rate. It is unlikely that much if any of the available recharge in the outcrop area can be utilized with present well locations. As with the Mt. Laurel-Wenonah, due to the relatively large water-level declines compared to the amount of pumpage, no additional withdrawals should be planned for this aquifer along the coast. Future development should be limited to its outcrop area and a short distance downdip of the outcrop, specifically in Monmouth, Burlington, and Ocean Counties. The Englishtown is more limited in extent than the Mt. Laurel-Wenonah, and it is estimated that about 50 mgd can be developed from the Englishtown. Wells would have to be properly spaced to reduce interference effects and obtain the maximum possible yield.

KIRKWOOD FORMATION

After the Potomac-Magothy-Raritan system and the Cohansey Sand, the Kirkwood Formation is the most heavily developed aquifer in the Coastal Plain. Estimated pumpage was almost 25 mgd in 1976, nearly all along the shore and barrier beaches in Atlantic, Ocean, and Cape May Counties. During the summer tourist season, pumpage can be three to four times the winter pumpage.

Examination of the potentiometric surface of the Kirkwood Formation indicates a cone of depression around the Atlantic City area and extending southwestward to Cape May County. A

hydraulic gradient exists from the Kirkwood outcrop area to the center of the cone, and precipitation falling on the outcrop could be transmitted to the coast. However, vertical leakage from overlying and underlying confining units has been shown to be a significant source of recharge to confined aquifers in the Coastal Plain. The Kirkwood overlies a relatively thick sequence of clayey confining beds along the coast and thick clay units are also present within the formation itself. Release of water from these zones in the formation is likely to be more significant than recharge derived from the outcrop area.

Examination of Figure 15 shows total public supply pumpage from the Kirkwood has increased from 1970 to 1975, but pumpage in Atlantic County decreased during this time, and in Cape May, the pumpage increased only slightly. The large increase in Ocean County pumpage is the reason for the overall increase; since the early 1960's, pumpage in Ocean County has increased at a much greater rate than in the other two counties. Therefore, it appears that water levels have remained unchanged in Atlantic and Cape May Counties because the pumpage here has not changed appreciably since 1970, but water levels may be declining in Ocean County in response to increased pumpage there. It is significant that, while public supply pumpage has increased by nearly 300 percent from 1935 to 1970, water levels along the coast between Atlantic City and Wild-

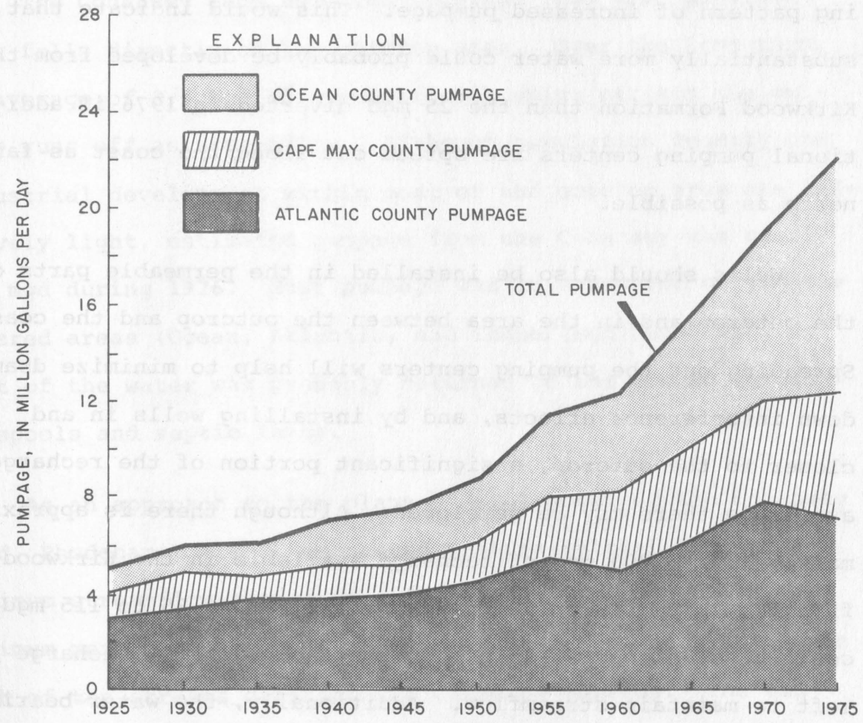


FIGURE 15

PUBLIC SUPPLY PUMPAGE FROM THE KIRKWOOD FORMATION

NEW JERSEY STATEWIDE WATER-SUPPLY MASTER PLAN

wood have remained essentially unchanged because of the shifting pattern of increased pumpage. This would indicate that substantially more water could probably be developed from the Kirkwood Formation than the 25 mgd diverted in 1976 if additional pumping centers are spread out along the coast as far north as possible.

Wells should also be installed in the permeable parts of the outcrop and in the area between the outcrop and the coast. Spreading out the pumping centers will help to minimize drawdown interference effects, and by installing wells in and closer to the outcrop, a significant portion of the recharge available there may be developed. Although there is approximately 150 to 200 mgd of recharge available in the Kirkwood from precipitation on the outcrop, only about 85 to 115 mgd could be developed if 43 percent of the available recharge is left to maintain streamflow. Additionally, the water-bearing properties of the formation between the outcrop and the coast are relatively unknown; although pumping centers may be spread out in the future, relatively high yield wells may only be possible along the coast. Test drilling and pumping, and perhaps computer simulation, should be undertaken to better define the formation's potential yield. The ultimate yield may be controlled by the movement of the fresh-water/salt-water interface which, except in Cape May County, lies some distance offshore.

COHANSEY SAND

The Cohansey Sand receives recharge from precipitation that falls directly on its outcrop area. Over the long term, an average of 2.5 bgd of precipitation which strikes the outcrop runs off as streamflow. Although population density and industrial development within most of the outcrop area are relatively light, estimated pumpage from the Cohansey was nearly 100 mgd during 1976. Most pumpage was in unsewered or lightly sewered areas (Ocean, Atlantic, and Cumberland Counties), so most of the water was probably returned to the ground through cesspools and septic tanks.

As an approach to the planned development of the Cohansey Sand, Rhodehamel (1970) suggested that an initial limit for minimum streamflow should be established. For example, the minimum mean discharge for 30 consecutive days was measured in each of ten streams draining the Cohansey outcrop. The ten means were averaged for each year studied, with the values weighted according to each basin's area. Thus, minimum streamflow draining the outcrop was computed to be equivalent to 0.46 mgd per square mile. When this value (0.46) was subtracted from the average mean flow for the streams (1.07 mgd per square mile), 0.61 mgd per square mile remained. Over the outcrop area of the Cohansey, this would amount to some 1.4 bgd that could be developed while still assuring a minimum streamflow.

In order to develop this 1.4 bgd, or a significant portion thereof, several factors must be considered. First of all, along the northwest edge of the formation, the sand is too thin to allow development of substantial supplies. Along the coast, especially in Cape May County and near Atlantic City, the threat of salt-water intrusion exists. Therefore, production wells should be installed toward the interior of the outcrop area in the center of the Pine Barrens near such rivers as the Mullica and Great Egg Harbor. Pumping from wells installed along these streams could induce much of their flow (the amount that is surplus over the established minimum) to re-enter the Cohansey Sand and be withdrawn by wells as needed.

A pumping test run adjacent to the Mullica River (Rhodehamel, 1973) revealed a poor hydraulic connection between the river and aquifer which was attributed to a thin, relatively impermeable bog iron deposit in the river bed. A good hydraulic connection between the Cohansey and the rivers draining it will have to be maintained, possibly through dredging operations, for induced river infiltration to be effective.

The 1.4 bgd of potentially developable water is an annual average and variations in the overall pumping rate must be made to compensate for seasonal fluctuations in streamflow. When runoff rates are high, the wells can be pumped in excess

of the average rate of 1.4 bgd. For low flow periods, however, when little pumping can take place adjacent to streams, pumpage must be from interstream areas where water will be removed primarily from storage, with little effect on streamflow. The recoverable water contained in storage in the Cohansey Sand has been estimated (Rhodehamel, 1970) at nearly 11 trillion gallons; therefore, tapping this huge reservoir during low flow periods should present no problems, especially since most of the water removed will be replenished by precipitation during the winter and early spring.

As demand is often greatest during low flow periods (summer and fall), some of the water that was pumped in excess of 1.4 bgd during high flow periods may have to be recharged in these interstream areas to allow for subsequent withdrawal during peak demands.

A joint study by biologists and engineers was undertaken to determine the maximum amount of water that could be withdrawn from the Mullica River basin through the conjunctive use of surface and ground water, without causing undue environmental impacts (Granstrom, Nieswand, and Ahmed, 1973; and Durand, Granstrom, and Rudolph, 1974). The marine ecosystems in the Great Bay estuary (into which the Mullica flows) were studied over an 11-year period, including the drought of the 1960's, to establish a salinity level that would result in minimal ad-

verse effect on biological communities in the estuary. The minimum streamflow necessary to maintain this level was then established. A digital model developed for the basin's aquifer/stream system indicated that a maximum withdrawal of 118 mgd of ground and surface waters could be made and still maintain the minimum streamflow. This would be the average withdrawal rate; during some months there would be excess streamflow. Calculations showed the excess would average out to 35 mgd over the course of a year. Recharging this to make it available for later use would increase the basin yield to 153 mgd. Although similar models of other basins may be needed to determine the applicability of this technique, extrapolation of these initial findings to the entire outcrop area indicates that a total of 670 mgd could be developed conjunctively (ground and surface waters) from the Cohansey Sand with minimal adverse environmental results. It appears feasible to induce river infiltration during high flow periods and then withdraw the entire 670 mgd from wells.

The potential for development of substantial supplies from the Cohansey Sand is great, with a range from 670 mgd to 1.4 bgd indicated. The limit on development would probably not be based on the aquifer's ability to store, transmit, or yield water, but on other restrictions such as maintaining minimum streamflow or preserving aquatic communities.

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HYDROGEOLOGY OF THE TRIASSIC LOWLANDS

BERGEN COUNTY

Hydrogeology

Bergen County lies almost entirely within the Triassic Lowlands, which is composed of Triassic age rocks referred to as the Newark Group. The northwest corner of the county is part of the Highlands province, which consists of Precambrian rocks, primarily gneiss. Shallow deposits of stratified and unstratified glacial drift, as well as reworked valley-fill deposits, exist throughout both provinces. All three of these units are significant with regard to water supply. The sedimentary rocks of the Newark Group are by far the most extensive; the valley fill and stratified drift deposits are much less extensive but nevertheless are also important.

The sedimentary rocks of the Newark Group are composed of reddish-brown arkosic sandstone, mudstone, siltstone, congomerate, and dark gray argillite. About 80 percent of the county is underlain by these. Associated with the sedimentary rocks are igneous rocks, principally diabase and basalt, which form the ridges of the Watchung Mountains (basalt) and the resistant escarpment of the Palisades (diabase). Ground water in appreciable quantities is found mainly in the sedimentary rocks.

In Bergen County, the Newark Group is represented by the Brunswick Formation. In general, the principal water-bearing zones of the Brunswick Formation range from 200 to 600 feet in depth. The median industrial or municipal supply well is 260 feet deep and yields 100 gpm (Carswell, 1976). In the Ramapo basin, the probable well depth necessary to obtain a maximum yield from the Brunswick Formation is between 300 and 400 feet (Vecchioli and Miller, 1973). Local variations in the lithology of deposits overlying the Brunswick is another factor that determines well yield. In the lower Hackensack River basin, for instance, wells located on the flanks of the meadows have much greater yields than those centrally located (Carswell, 1976). This may be due to increased ground-water recharge from coarse-grained unconsolidated deposits overlying the Brunswick on the flanks, as opposed to the poorly permeable lake beds overlying the rocks in the center.

Unconsolidated deposits in Bergen County generally consist of either till or stratified drift. These deposits are generally thickest in the valleys and thin or absent in upland areas. Data are not available to define the saturated thickness of the upland drift in all areas. The extent of known deposits of significant thickness is shown in Figure 16. In the Hackensack River basin, the most significant unconsolidated deposits are those underlying the Hackensack Meadows. (The Meadows lie in both Hudson and Bergen Counties.) Here, as much as

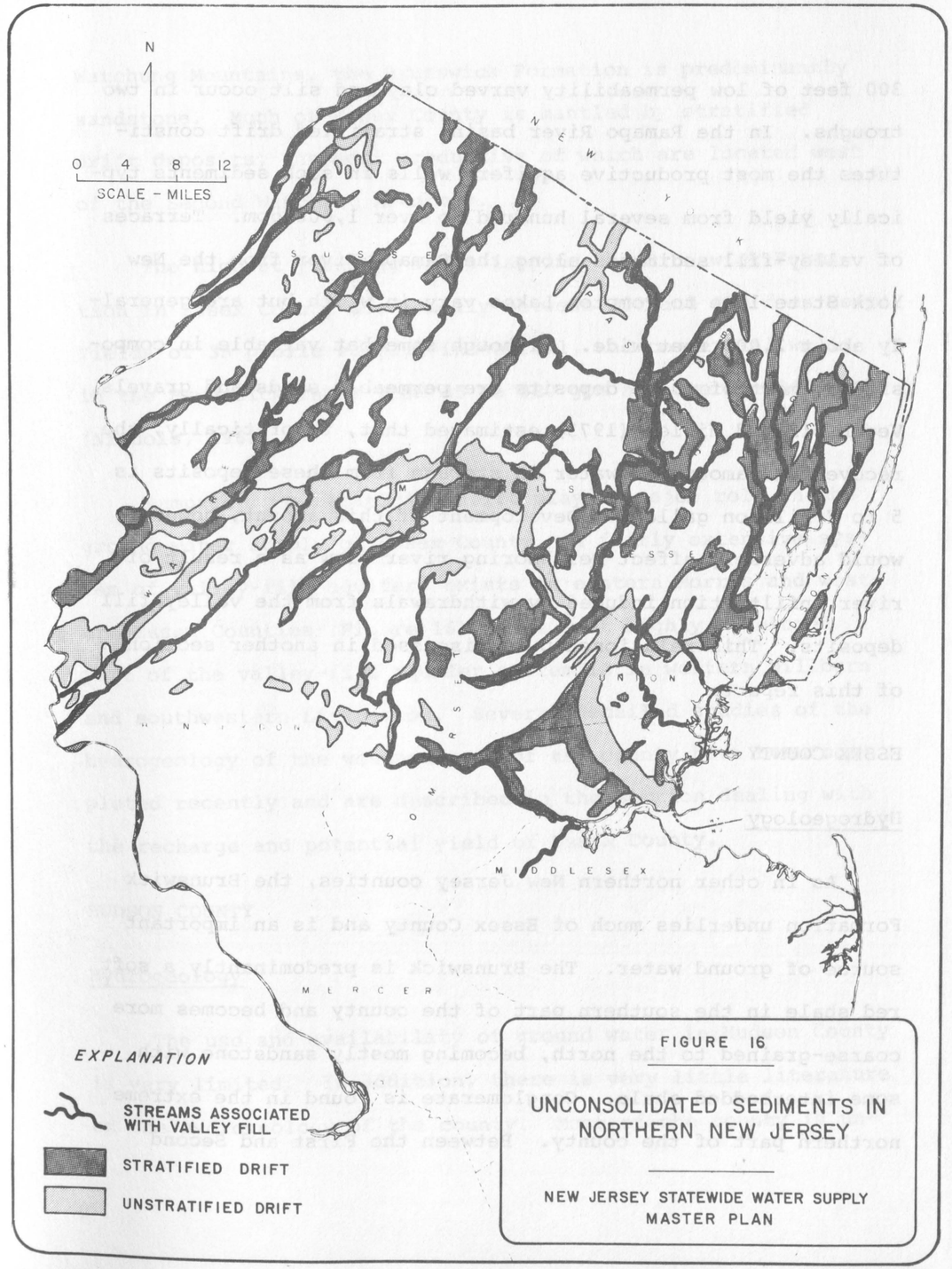


FIGURE 16

UNCONSOLIDATED SEDIMENTS IN NORTHERN NEW JERSEY

NEW JERSEY STATEWIDE WATER SUPPLY MASTER PLAN

300 feet of low permeability varved clay and silt occur in two troughs. In the Ramapo River basin, stratified drift constitutes the most productive aquifer; wells in such sediments typically yield from several hundred to over 1,000 gpm. Terraces of valley-fill sediments along the Ramapo River from the New York State line to Pompton Lakes vary in width but are generally about 2,000 feet wide. Although somewhat variable in composition, most of these deposits are permeable sands and gravels. Vecchioli and Miller (1973) estimated that, theoretically, the recoverable amount of water in storage from these deposits is 5 to 7 billion gallons. Development of this amount, however, would adversely affect neighboring river flow as a result of river infiltration induced by withdrawals from the valley-fill deposits. This relationship is discussed in another section of this report.

ESSEX COUNTY

Hydrogeology

As in other northern New Jersey counties, the Brunswick Formation underlies much of Essex County and is an important source of ground water. The Brunswick is predominantly a soft red shale in the southern part of the county and becomes more coarse-grained to the north, becoming mostly sandstone with some interbedded shale. Conglomerate is found in the extreme northern part of the county. Between the First and Second

Watchung Mountains, the Brunswick Formation is predominantly sandstone. Much of Essex County is mantled by stratified drift deposits, the most productive of which are located west of the Second Watchung Mountain.

The highest yielding wells tapping the Brunswick Formation in Essex County are usually between 300 and 400 feet deep. Yields of 35 public supply, industrial, and commercial wells in the Brunswick range from 35 to 820 gpm and average 364 gpm (Nichols, 1968).

Pumpage from stratified drift plays a major role in the ground-water supply of Essex County. A fairly extensive system of valley-fill aquifers exists in eastern Morris and western Essex Counties (Figure 16). The most highly developed part of the valley-fill aquifer system is in western Millburn and southwestern Livingston. Several detailed studies of the hydrogeology of the western part of the county have been completed recently and are described in the section dealing with the recharge and potential yield of Essex County.

HUDSON COUNTY

Hydrogeology

The use and availability of ground water in Hudson County is very limited. In addition, there is very little literature on the hydrogeology of the county. Most of the county is un-

derlain by a diabase known as the Palisades Sill, which yields only small to moderate amounts of ground water to wells. The Stockton Formation, the Manhattan Schist and a small deposit of serpentine are the other bedrock units in Hudson County.

The Hackensack Meadows, described under Bergen County, cover the northwestern part of the county. Stratified drift deposits of varved silt and clay occur in two north-south trending troughs which parallel the sides of the meadow basin. The eastern trough extends from the Newark area north to North Bergen. Coarse sand and gravel deposits underlie the till and lake beds in places. There is also a narrow band of sand and gravel between the eastern trough and the Palisades Sill. Wells tapping this sand and gravel near North Bergen yield more than 300 gpm where they are in hydraulic connection with the Hackensack River (Carswell, 1976).

MIDDLESEX COUNTY

Hydrogeology

Middlesex County lies in two physiographic provinces, the Piedmont or Lowlands province, made up of Triassic age rocks, and the Coastal Plain, underlain by Cretaceous age unconsolidated deposits. This section deals only with rocks in the Piedmont province; hydrogeology of the Coastal Plain is discussed in the section with that title. The Triassic rocks are

found northwest of a line drawn roughly from Plainsboro to Carteret. Rocks of the Newark Group make up most of this area, with the Brunswick Formation accounting for over 80 percent of the surficial bedrock.

In the southwest part of the county, diabase has intruded in the form of steeply dipping dikes and relatively flat sills. The largest of these is a diabase sill which is now exposed to the north in Bergen Hill and the Palisades, to the east on Staten Island, and to the west in Rocky Hill. Between these latter two exposures, it is buried beneath a mantle of Cretaceous and Pleistocene sediments. In general, this diabase is suitable only for domestic wells and other small supply needs.

A mantle of stratified and unstratified drift exists in the northern part of the county (Figure 16). The outwash plain found between Metuchen, Plainfield, and East Bound Brook covers about 16 square miles. The stratified drift is 10 to 60 feet thick on the eastern edge of the plain near the adjacent moraine (Middlesex County Planning Board, 1974). These sediments are important because of both the water they yield and the water they transmit to underlying bedrock aquifers.

The chances of locating high yield wells in the Brunswick Formation are greater where ground-water recharge is enhanced by overlying sand and gravel. In Middlesex County, the total area in which the rocks of the Newark Group are covered by rel-

atively impermeable younger materials is about 35 square miles. Some high yield wells have been developed in Newark Group rocks that are covered by permeable drift or by the Cape May or Pensauken Formations. Two areas in which Newark Group rocks are overlain by permeable deposits are between the Raritan River and the terminal moraine and in the southwestern corner of the county (Barksdale et al., 1943).

PASSAIC COUNTY

Hydrogeology

Passaic County is shaped like a bent hourglass with the area above the neck lying in the Highland province, and the area below the neck lying in the Lowland province. The Highlands are composed of crystalline rocks of Precambrian age, an outlier of Paleozoic sedimentary rocks, and a small fault-bounded wedge of black shale near Pompton Lakes. The Precambrian rocks are characteristically gneissic, granitoid, foliated and structurally complex. The gneisses are cut by northeast trending faults which parallel the regional strike of the rock units, and by transverse (east-west) trending faults (Carswell and Rooney, 1976). These rocks are the major source of ground water for domestic supplies in the northwestern two-thirds of the county.

Paleozoic rocks underlie a 2- to 3.5-mile wide belt trending northeast from the Pequannock River to the New York State line. These consist of the Hardyston Quartzite, Kittatinny Limestone, Green Pond Conglomerate, Longwood Shale, Decker Limestone, Kanouse Sandstone, Cornwell Shale, Bellvale Sandstone, and Skunnemunk Conglomerate. As with the Precambrian rocks, yields from the Paleozoic sedimentary rocks are usually adequate only for domestic supplies. Some of the units, such as the Kanouse Sandstone, Green Pond Conglomerate, and Hardyston Quartzite, are locally friable and may yield significant quantities of water to properly located wells (Carswell and Rooney, 1976). Yields of wells tapping the Paleozoic rocks range from less than 1 to 35 gpm, with a median of about 10 gpm.

Triassic sedimentary rocks make up most of the bedrock surface found in the Lowland province and also yield the largest ground-water supplies. Yields of 91 public supply and industrial wells range from 20 to 510 gpm. Wells over 300 feet deep and greater than 8 inches in diameter have a median yield of 230 gpm. Carswell and Rooney (1976) report that most of the high yielding wells are located in or on the flanks of preglacial valleys containing thicker unconsolidated deposits, an environment where recharge to the rock units is greater.

The Watchung Basalt also underlies a substantial portion of the Lowland province in Passaic County. However, its poten-

tial yield is much less than that of the Brunswick Formation. The basalt is used primarily for domestic supplies.

Stratified drift and valley-fill deposits are locally important sources of ground water in Passaic County (Figure 16). The thickness of much of the drift deposits has not been extensively explored; most of the wells in these sediments are between 50 and 125 feet deep. The median yield of public supply and industrial wells is 130 gpm (Carswell and Rooney, 1976).

UNION COUNTY

Hydrogeology

The Brunswick Formation is the major aquifer and underlies most of Union County. Basalt underlies the western portion of the county and is of lesser importance. Unconsolidated glacial deposits mantle much of the bedrock. Where these deposits are of significant thickness and are stratified and sorted, they are important aquifers.

The greatest yields from the Brunswick in Union County are from wells between 200 and 600 feet in depth. The average yield of 109 public supply, industrial, and commercial wells is 310 gpm; yields range from 23 to 870 gpm (Nemickas, 1976). As in other counties, many of the higher yielding wells occur where the Brunswick is overlain by relatively thick, permeable unconsolidated deposits which tend to increase the amount of

ground-water recharge to the rock below.

Ground water in the Watchung Basalt is found as a result of secondary permeability from fractures and joints. Well yields are generally small to moderate.

Unconsolidated stratified glacial drift deposits which occur as valley fill are locally important sources of ground water in Union County. The general distribution of some of the more extensive deposits is shown in Figure 16. The most important are located in the Kenilworth-Newark, Summit, Union, and Rahway valleys. The thickness of sand and gravel sediments generally ranges from 50 to 200 feet (Nemickas, 1976). Reported yields from 11 wells in the stratified drift ranges from 180 to 690 gpm and average 394 gpm.

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GROUND-WATER AVAILABILITY IN THE TRIASSIC LOWLANDS

RECHARGE AND POTENTIAL YIELD

A major objective of this report is to identify areas which are presently being stressed by ground-water pumpage to the point where water levels are declining and there is a threat to the future usefulness of the resource. At the same time, an attempt is made to determine which areas may have potential for additional ground-water supply. In general, long-term records of water-level flucutations in northern New Jersey are sparse. In the absence of representative water-level data, areas of potential problems can be delineated by comparing the estimated recharge to the region with ground-water pumpage (Figures 17 and 18, respectively). In addition, county reports and river basin studies were reviewed.

The amount of recharge to the ground-water system by precipitation is highly variable and depends on the nature of unconsolidated surficial deposits, the lithology of surficial rock units, topography of the land surface, structural features such as fractures and joints, and a number of other factors. For purposes of this report, average recharge values are used for regional analysis. Estimates of recharge to various rock types have been cited in the literature for all areas in the state (N. J. Geological Survey, 1974). On Figure 17, rock types with the same or similar average recharge rates

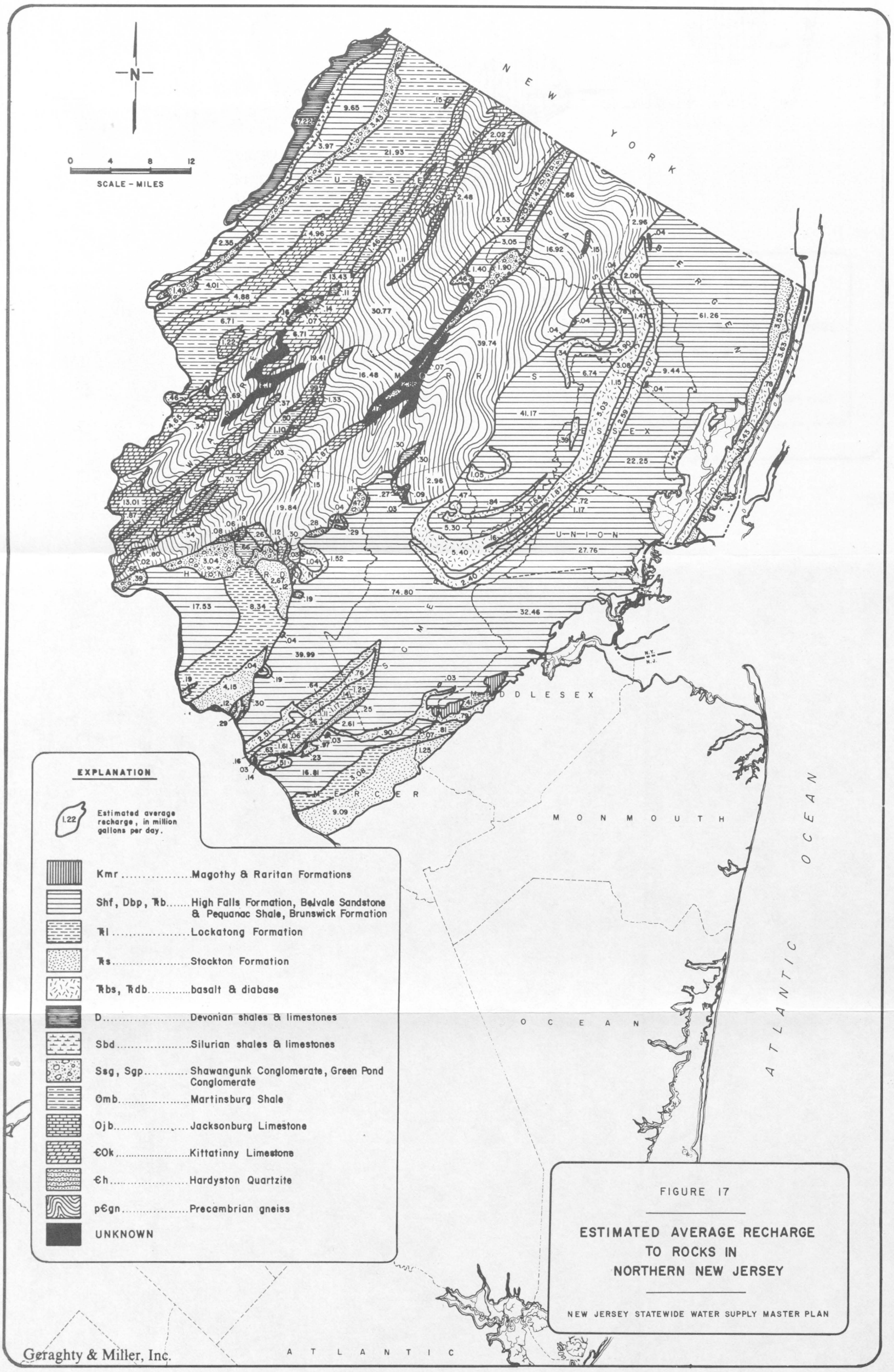
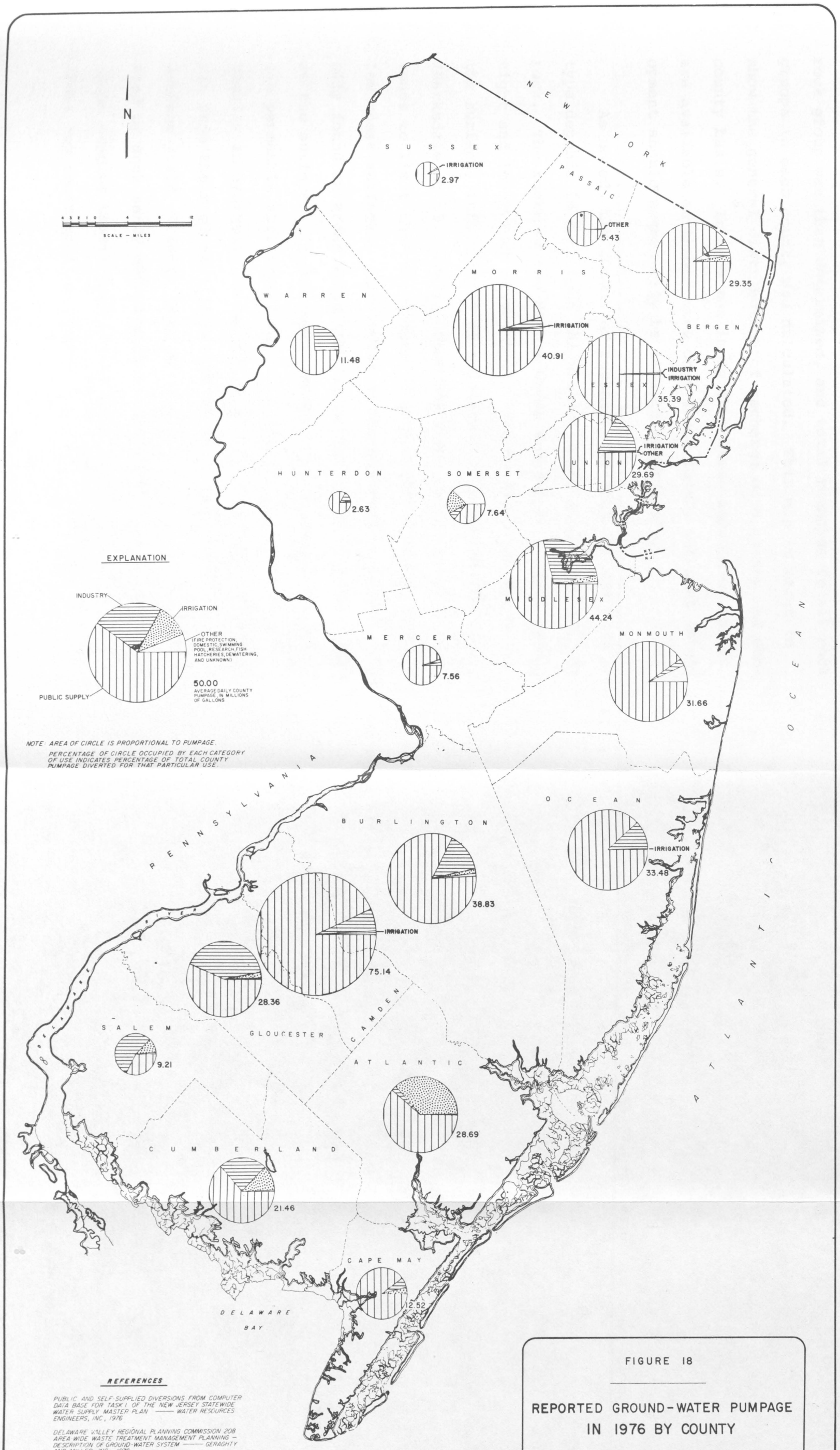


FIGURE 17

ESTIMATED AVERAGE RECHARGE TO ROCKS IN NORTHERN NEW JERSEY

NEW JERSEY STATEWIDE WATER SUPPLY MASTER PLAN

Geraghty & Miller, Inc.



REFERENCES

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MIDDLESEX COUNTY 208 AREA WIDE WASTE TREATMENT MANAGEMENT PLANNING – DESCRIPTION OF GROUND-WATER SYSTEM ——— GERAGHTY AND MILLER, INC, 1976

FIGURE 18

REPORTED GROUND-WATER PUMPAGE IN 1976 BY COUNTY

NEW JERSEY STATEWIDE WATER SUPPLY MASTER PLAN

Geraghty & Miller, Inc.

were grouped together and mapped. The area of each distinct rock group was then determined, and total recharge to all rock groups in each county was calculated. This map is meant to show the general distribution of recharge on a county and sub-county basis. It does not imply that these amounts of water are available at these rates on a local level, nor that development should necessarily be limited accordingly.

As noted, the amount of recharge reaching any one rock type depends in part upon the nature of the soil overlying the rock. The rocks of the Newark Group weather to a relatively tight and impervious clayey soil. Where this soil occurs at the surface, infiltration is relatively low and runoff high (Barksdale et al., 1943). Such low permeability surface cover tends to limit the circulation of ground water in the rocks below these surfaces. Rock wells of large capacity are not usually found in areas where residual soils or glacial till occur at the surface. In contrast, Newark Group rocks which underlie permeable striatified drift or valley-fill deposits are usually in hydraulic connection with these deposits and benefit from their greater infiltration and storage capacity. The average yield of wells tapping Newark Group rocks that are covered by such sandy deposits is perhaps five times greater than those tapping Newark Group rocks covered by soil derived from their own decomposition (Barksdale et al., 1943).

Areas overlain by unconsolidated drift deposits or valley-fill sediments are shown on Figure 16. The nature, extent, and present use of these deposits are discussed in the text by county. Although limited in extent, in many places they serve as important aquifers. Recharge rates to these sand and gravel deposits may be as high as one mgd per square mile. These higher rates are not included in the regional estimates, however, because full development of valley-fill deposits will result in reduced streamflow in those streams hydraulically connected to the sediments. This relationship is discussed in detail elsewhere. Since many streams in New Jersey are utilized as a source of drinking water supply and much of their flow is already allocated, decisions regarding greatly increased pumpage from alluvial deposits must be made on an individual basis. Therefore, the recharge analysis shown on Figure 17 does not differentiate recharge rates for stratified drift and valley fill.

The general availability of ground water and the problems resulting from withdrawing excess amounts are usually discussed in terms of the safe yield of the reservoir. Most of the comprehensive plans prepared in recent years have attempted to estimate the safe ground-water yield of each county. Unfortunately, the safe yield concept has been inadequately defined in many cases. In this study, safe yield is defined as the greatest amount of ground water that can be used consumptively without causing undesirable effects. Depending on the area, undesirable effects can include reduced streamflow, lowered lake levels, or dewatered shallow wells. Most reports equate the safe yield with the pumpage which will approach but not exceed the average recharge rate for the study area. Although maintaining pumpage below the average recharge rate will not result in an indefinite loss of ground water from storage, it will result in a temporary loss of storage and water levels which will decline until a new equilibrium elevation is reached. In this study, maximum potential yield is the amount of ground-water pumpage which is equivalent to the recharge rate for a given area. The safe yield is some number less than the maximum potential yield and depends on the hydrologic and environmental considerations of a particular area.

Ground-water use and recharge are shown on Table 3. Use data were taken from Water Resources Engineers' printouts and the files of the Bureau of Water Policy and Supply. The column entitled "Total Reported Pumpage" lists the amount actually withdrawn by companies holding diversion permits. The "Total Estimated Pumpage" column was calculated from agricultural statistics and housing characteristics. The next heading shows how much ground water could be pumped if holders of grandfather rights used 100 percent of their alloted amount (round-the-clock pumping). Full usage of these rights was assumed because the actual amount is unreported. The "Total"

Table 3. Ground-Water Use and Available Recharge in Northern New Jersey (mgd).

County	Total Reported Pumpage		Total Estimated Pumpage		Grandfather Rights Unreported	Total Potential Use	Recharge Undeveloped Normal	Recharge Developed Normal	Balance
	Public Supply	Industrial	Agricultural Unreported	Domestic Unreported					
Bergen	26.94	2.41	0.53	2.47	24.77	57.12	71.52	48.63	+ 14.40
Essex	35.22	0.17	0.12	0.57	16.53	52.61	37.94	19.64	- 14.67
Hudson	0	0	0	0.05	4.37	4.42	7.08	3.66	+ 2.66
Hunterdon	2.17	0.46	0.18	4.33	9.1	16.24	109.36	99.39	+ 93.12
Mercer	2.63	0.75	0.56	2.99	0.79	7.72	36.17	31.19	+ 28.45
Middlesex	5.32	2.14	0.66	2.93	17.68	28.73	32.88	21.22	+ 4.15
Morris	39.03	1.88	0.38	7.10	31.09	79.48	111.43	96.26	+ 31.95
Passaic	5.4	0.03	0.05	2.69	8.84	17.01	46.86	27.46	+ 29.85
Somerset	2.75	4.89	0.09	5.51	7.6	20.84	95.94	86.81	+ 75.10
Sussex	2.65	0.28	0.04	3.5	18.6	25.07	97.54	92.04	+ 72.47
Union	24.66	5.03	0.06	0.16	21.96	51.87	33.49	19.85	- 18.38
Warren	8.5	2.98	0.81	2.45	10.75	25.49	73.98	0	+ 48.49

column is the sum of the actual public and industrial pumpage, the estimated agricultural and domestic pumpage, and the grandfather rights. "Recharge-Undeveloped-Normal" refers to the recharge that would be available in a year of normal precipitation if the county was undeveloped. The next column is the amount of recharge in a year of normal precipitation under developed land-use conditions. The column entitled "Balance" is the "Recharge-Undeveloped-Normal" amount minus the "Total" amount, indicating how much ground water is theoretically still available for withdrawal. Essex and Union Counties appear to have exceeded the available recharge.

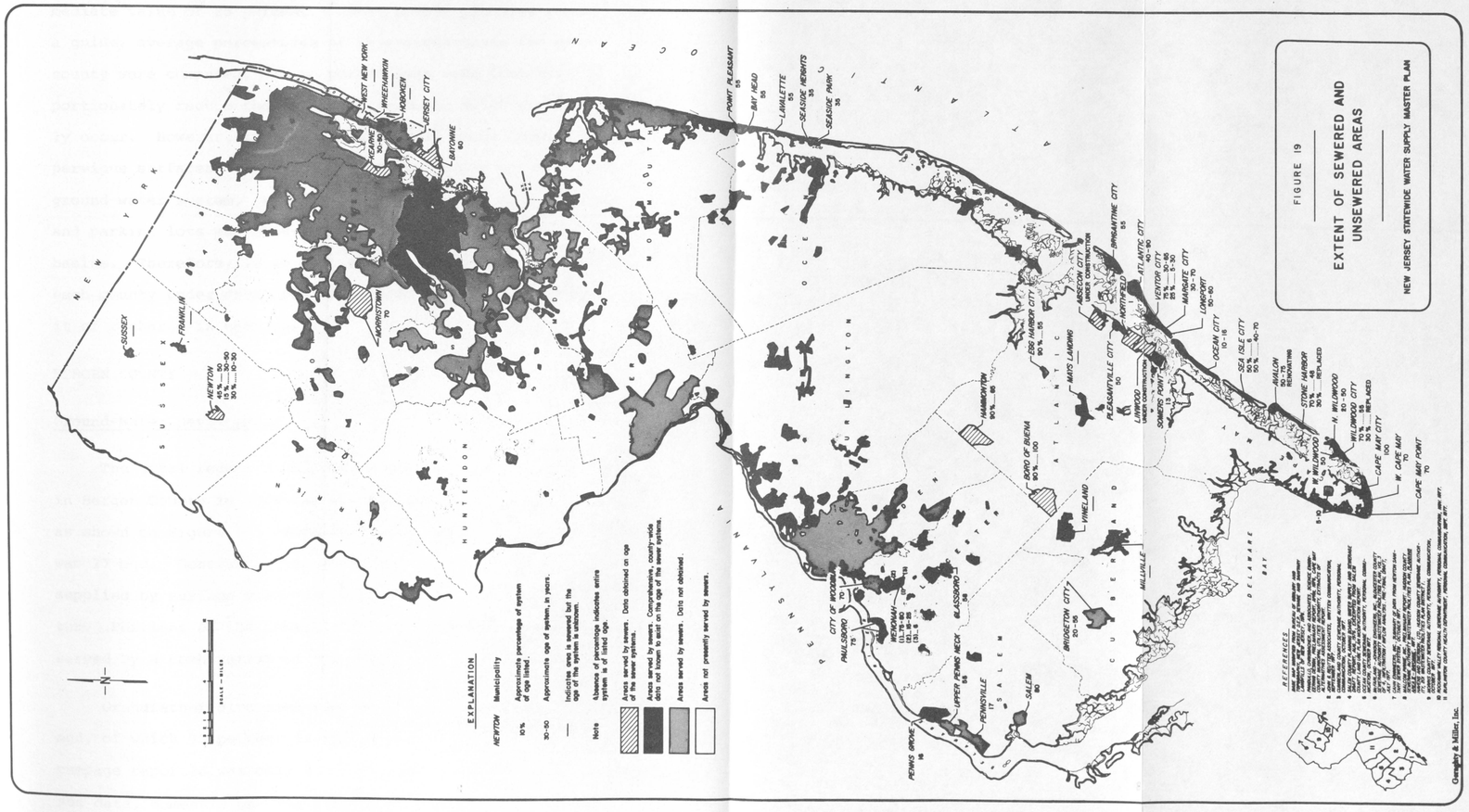
A major problem in determining areas which are being either over- or under-utilized as sources of ground-water supply is the present system of grandfather rights in New Jersey. These rights represent a significant percentage of the total pumpage for most counties (Table 3). Since these users are not required to report actual pumpage, there is no way of knowing what portion of their alloted amount is being pumped.

For instance, in the northern and western portions of Middlesex County where pumpage is from rock aquifers, the reported self-supplied pumpage is 2.1 mgd and the grandfather diversion is 17.7 mgd. On a county-wide basis, full utilization of this latter diversion, in addition to that reported, would exceed the estimated maximum potential yield for the county. However, if only a small percentage of the grandfather rights

is actually utilized, there may be potential for developing additional supply.

Another complicating factor is the consumptive use of ground water. In this report, the safe yield and the maximum potential yield are considered in terms of consumptive use. This means the water is not returned to the ground-water system in the same area from which it was removed. The use of on-lot domestic septic systems is one way water can be used and returned to the system. Another way is by the recharge of industrial process or cooling waters to recharge basins. Waste water discharged to sewers, which eventually discharge to surface waters, is assumed to be used consumptively. Public supply use is typically consumptive, and domestic use is usually nonconsumptive. On a geographical basis, comparison of Figures 18 and 19 provides an idea of the distribution of consumptive versus nonconsumptive use. Unfortunately, without a detailed analysis there is no way to determine how many industries discharge to sewers as opposed to basins.

Discrepancies between estimated and actual recharge rates can occur in areas which are developed and have a portion of their land area covered by impervious surfaces. Stankowski (1974) developed estimates of the percentages of impervious land areas associated with various land-use categories. For instance, in single-family residential areas, the amount of impervious surface ranges from 12 to 40 percent, with an inter-



mediate value of 25 percent. Using county planning reports as a guide, average percentages of impervious areas for each county were computed. These percentages were then used to proportionately reduce the estimated recharge which would naturally occur. However, in most cases not all water landing on impervious surfaces is prevented from eventually entering the ground-water system. Much of the storm runoff from streets and parking lots may be drained to nearby dry wells or storm basins. Therefore, it is felt that recharge estimates for each county under developed conditions represent the lower limit of recharge in each case.

BERGEN COUNTY

Ground-Water Development

The total reported and allocated ground-water diversion in Bergen County in 1976 was approximately 57 mgd, distributed as shown on Figure 18. Reported public supply pumpage in 1976 was 27 mgd. Generally, the eastern section of the county is supplied by surface water and the western section by ground water. Portions of the central and southwestern sections are served by a combination of the two.

Grandfather diversion rights in Bergen County total 22.7 mgd, of which 90 percent is industrial. In 1976, industrial pumpage reported was only 2.4 mgd. On the basis of 1970 census data, domestic on-site pumpage is estimated to be about

2.5 mgd. Agricultural pumpage is approximately 0.5 mgd.

In many cases, wells are located in alluvial deposits where possible, because of the generally higher yields. In the Ramapo River basin, about 75 percent of the total pumpage is obtained from the stratified drift even though it only represents a small percentage of the total area of the basin (Vecchioli and Miller, 1973). Wells in the valley-fill deposits are the main source of supply for the Township of Mahwah and the only source of supply for the Borough of Oakland.

Recharge and Potential Ground-Water Availability

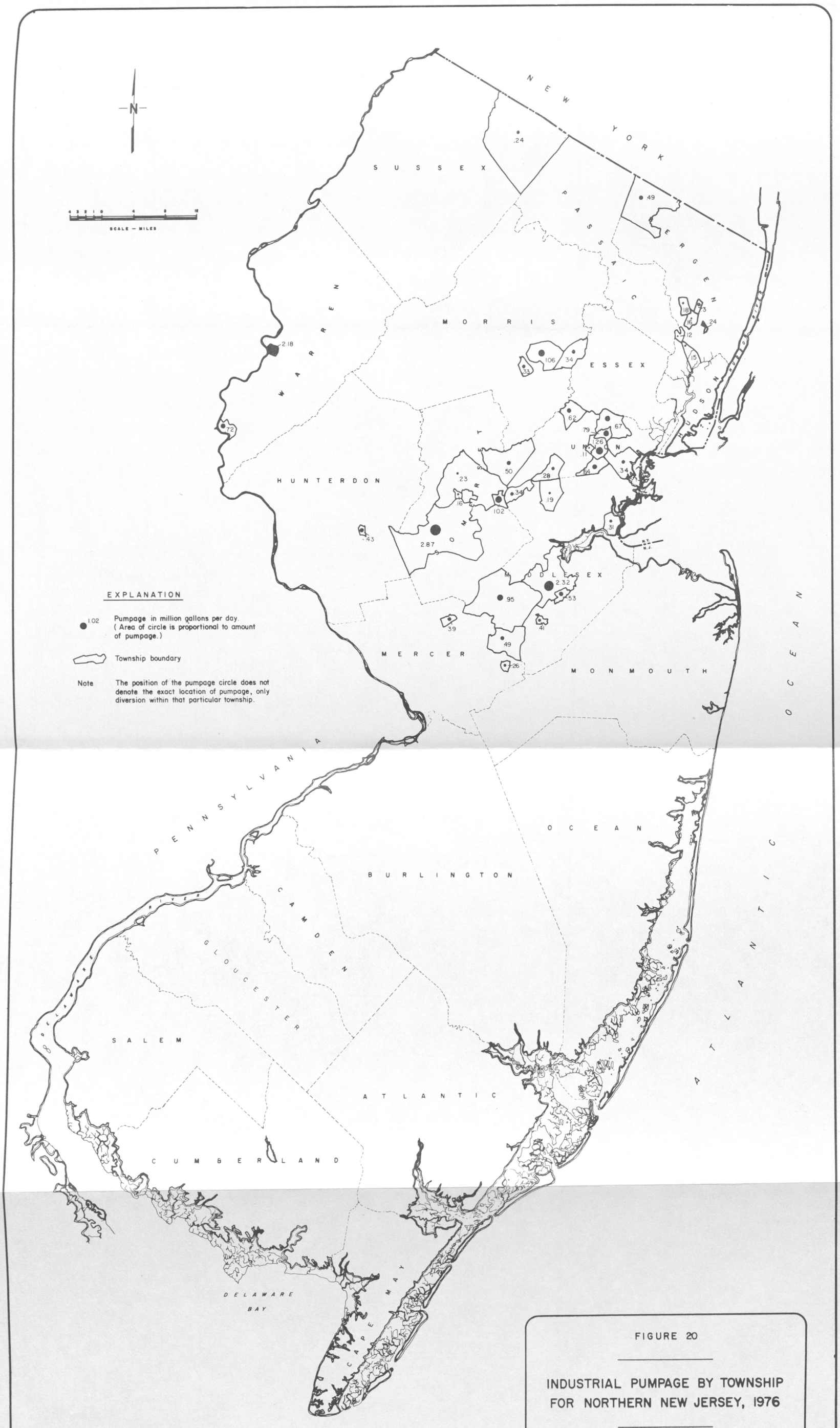
There have been a number of studies in recent years which have estimated the potential safe yield of the county, assuming full development of all the aquifers. These estimates range from 70 to 100 mgd (Elam and Popoff, 1970). Additional evaluation of the maximum potential yield has also been accomplished in this investigation. This was done by approximating the total recharge to the rock aquifers using average recharge rates.

It is estimated that recharge in the county as a whole during a normal year would be about 72 mgd and about 46 mgd during a dry year, assuming the county were completely undeveloped. Using the method described previously for evaluating recharge in developed areas, recharge is estimated to be about

49 mgd and 32 mgd during normal and dry years, respectively. This assumes no return of storm runoff from impervious surfaces to the ground. The recharge analysis does not take into account higher yields which may be available locally from valley-fill or stratified drift deposits. In addition, the use of artificial recharge or low flow augmentation is not considered. Use of these measures may increase the yield in certain areas.

Industrial (based on grandfather rights) and public supply pumpage is concentrated in a broad north-south band in the center of the county (Figures 20 and 21). Most of the southern and central parts of the county are sewered (Figure 19). Public supply pumpage is used consumptively except in the extreme northern section of the county. The percentage of industrial pumpage used consumptively is unknown. Undoubtedly many of the industries along the Passaic and Saddle Rivers discharge to the rivers and the water is essentially lost from the ground-water system.

Previous reports on a sub-county scale indicate that in the Hackensack River basin, future development of the ground-water supplies in the upper part of the basin is restricted because such development would decrease surface-water flow used for supply (Carswell, 1976). Utilization of surface-water in the Hackensack River basin above Oradell Reservoir is reported-



EXPLANATION

● 1.02 Pumpage in million gallons per day. (Area of circle is proportional to amount of pumpage.)

Township boundary

Note The position of the pumpage circle does not denote the exact location of pumpage, only diversion within that particular township.

REFERENCE

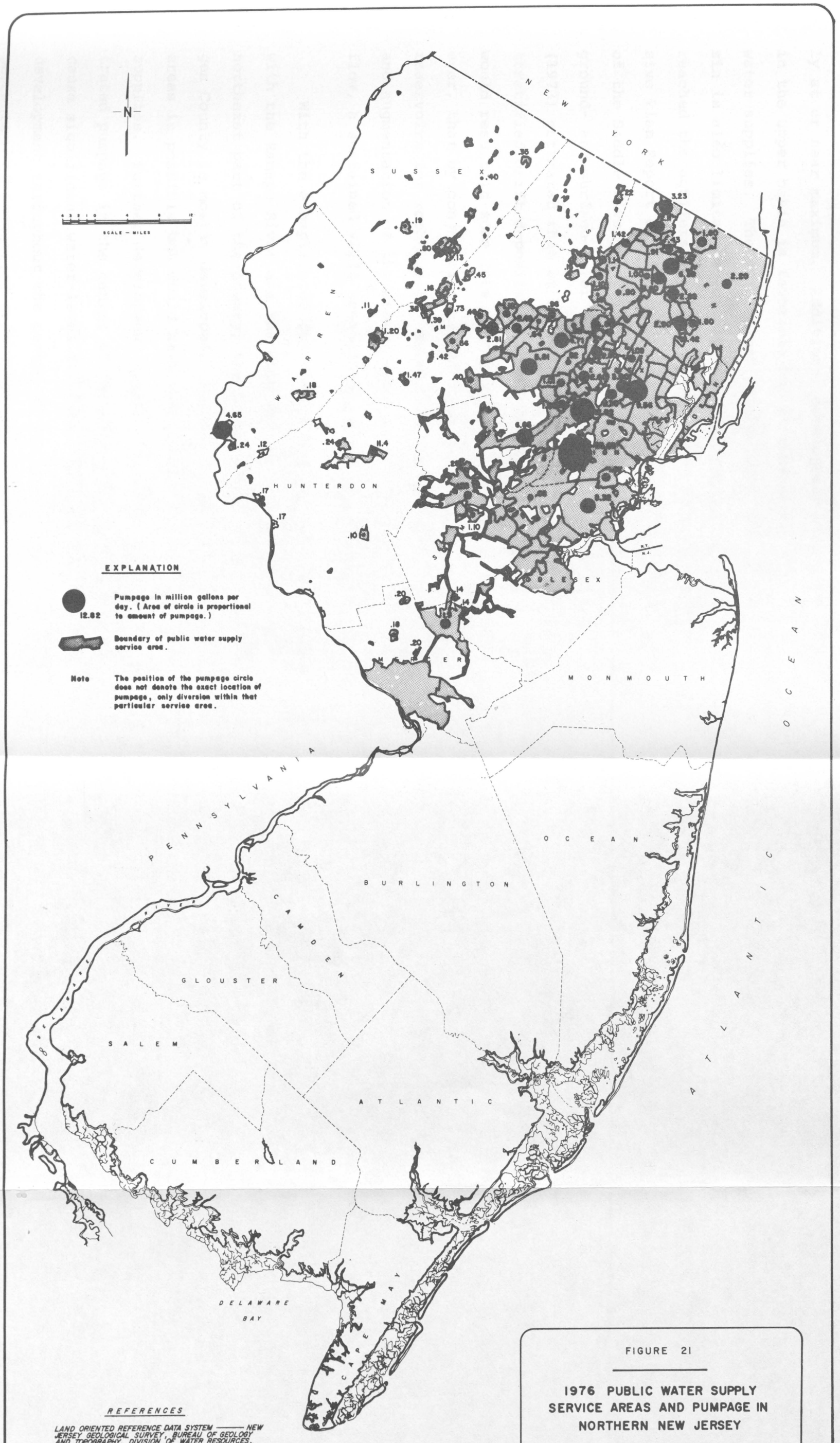
DIVERSION PERMIT FILE, 1976, ALLOCATIONS BRANCH, BUREAU OF WATER SUPPLY PLANNING AND MANAGEMENT, NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION, UNPUBLISHED DATA COMPILED BY WATER RESOURCES ENGINEERS, 1977.

FIGURE 20

INDUSTRIAL PUMPAGE BY TOWNSHIP FOR NORTHERN NEW JERSEY, 1976

NEW JERSEY STATEWIDE WATER SUPPLY MASTER PLAN

Geraghty & Miller, Inc.



REFERENCES

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FIGURE 21

1976 PUBLIC WATER SUPPLY SERVICE AREAS AND PUMPAGE IN NORTHERN NEW JERSEY

NEW JERSEY STATEWIDE WATER SUPPLY MASTER PLAN

Geraghty & Miller, Inc.

ly at or near maximum. Additional development of ground water in the upper basin is favorable but at some cost to surface-water supplies. The development of the lower part of the basin is also limited because contaminated surface water has reached the aquifers (Carswell, 1976). The County Comprehensive Plan Report of 1970 indicates that the future development of the Saddle River basin is restricted because of present ground- and surface-water diversions. Vecchioli and Miller (1973) estimated that at least 11 mgd could be developed from stratified drift deposits along the Ramapo River but that this would result in some loss in streamflow. They indicate, however, that by conjunctive use of stratified drift and surface reservoirs for recharge of the aquifers during high streamflow, and augmentation of the stream with ground water during low flow, a sustained yield greater than 25 mgd could be developed.

With the exception of the valley-fill deposits associated with the Ramapo River and the rock and drift aquifers in the northeast part of the county, the ground-water resource of Bergen County is mostly developed. Further pumpage in these two areas is possible but would have some impact on surface-water supplies. Further development within the broad band of concentrated pumpage in the center of the county would be likely to cause significant water-level declines. The opportunity for development throughout the county is largely dependent on the percentage of industrial grandfather rights currently being

used. Table 3 illustrates how the total county pumpage would vary depending on the percentages of grandfather diversion which might be utilized.

ESSEX COUNTY

Ground-Water Development

The total allocated ground-water diversion for Essex County in 1976 was approximately 53 mgd. The reported and estimated pumpage was as follows: public supply, 35.2 mgd; self-supplied industrial, 0.2 mgd; agricultural, 0.1 mgd; and domestic, 0.6 mgd (see Table 3). The remaining 16.5 mgd is the total grandfather rights, of which industrial rights comprise 10.9 mgd.

As can be seen from the ratio between domestic and public supply, almost the entire population of the county is served by public water utilities. Eighty-one percent of public-supply pumpage was from stratified drift deposits, primarily in the western portion of the county (Nichols, 1968).

There was no individual industrial pumpage over 0.1 mgd reported in 1976. Almost all industrial pumpage is under grandfather rights, which are concentrated in the Newark area (Figure 22).

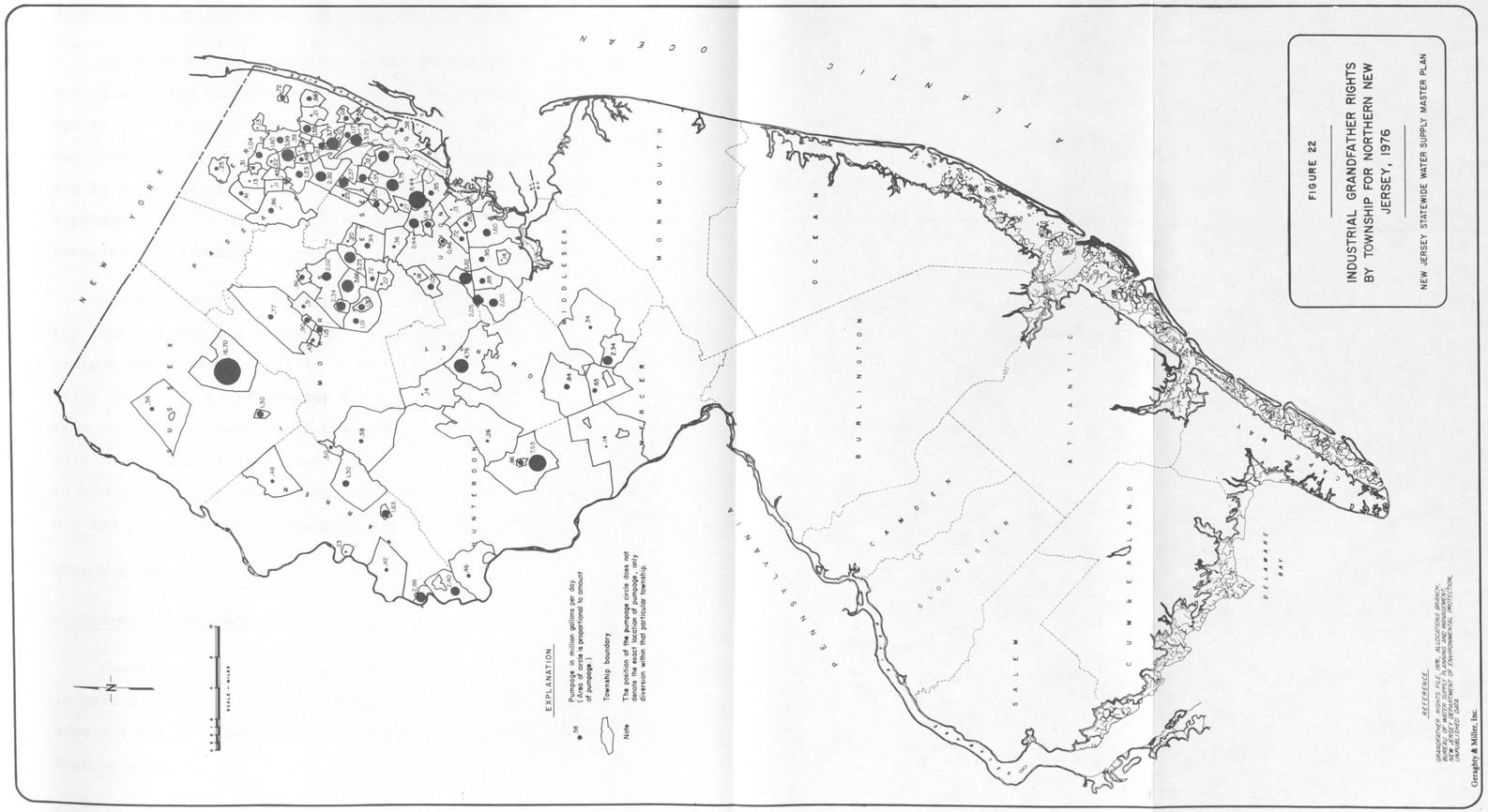


FIGURE 22

INDUSTRIAL GRANDFATHER RIGHTS BY TOWNSHIP FOR NORTHERN NEW JERSEY, 1976

NEW JERSEY STATEWIDE WATER SUPPLY MASTER PLAN

Recharge and Potential Ground-Water Availability

In Essex County, recharge to the ground-water system under essentially undeveloped conditions is estimated to be 38 mgd in years of normal precipitation and 25 mgd in dry years. For developed land, the estimates would be approximately 20 and 13 mgd, respectively. The recharge values for normal precipitation, 20 to 38 mgd, represent a practical range for long-term, regional planning purposes.

Table 3 shows that present allocated rights to ground water (grandfather and diversions combined) exceed the estimated maximum potential yield. If industrial grandfather rights are fully utilized, total pumpage would be about 53 mgd. Utilization of 70 or 35 percent of the grandfather rights would result in pumpage of approximately 48 or 42 mgd. Essex County is almost entirely sewered and therefore nearly all public supply and probably much industrial use is consumptive.

HUDSON COUNTY

Ground-Water Development

There was no reported public-supply or industrial pumpage in Hudson County in 1976. Industrial grandfather rights of some 4.4 mgd have been granted, primarily for the Hackensack Meadows area.

Recharge and Potential Ground-Water Availability

Recharge under normal precipitation and undeveloped land conditions is about 7 mgd; under developed conditions, it is estimated to be about 3.7 mgd. Recharge during dry years for undeveloped and developed conditions is approximately 4.8 and 2.5 mgd, respectively.

Water quality is an important constraint on ground-water development in Hudson County. The chemical quality of ground water in the unconsolidated deposits in the Hackensack Meadows is influenced by the quality of water in the Hackensack River; sometimes the meadows are flooded by the river as a result of tides. Heavy pumping at Hackensack and near North Bergen has induced infiltration of poor quality river water into the sand and gravel aquifers (Carswell, 1976). High concentrations of chloride make the water in the lower Hackensack unsuitable for municipal and most industrial processes.

MIDDLESEX COUNTY

Ground-Water Development

The total reported and estimated pumpage and allocated rights for Middlesex County in 1976 was 25 mgd. Of this, public-supply pumpage accounted for only 1.6 mgd, nearly all in the northern part of the county. This small amount is the result of the Middlesex Water Company's conversion from ground-

to surface-water use after 1969. In that year, ground-water pumpage was 13.4 mgd in Middlesex County.

Industrial pumpage reported under diversion applications was only 2.1 mgd in 1976. Pumpage allocated under grandfather rights is 17.7 mgd and is concentrated mostly in the northeast portion of the county. Domestic and agricultural pumpage amounted to an estimated 2.9 and 0.7 mgd, respectively.

Recharge and Potential Ground-Water Development

The annual recharge to Triassic age rocks in northwestern Middlesex County under undeveloped conditions and normal precipitation is estimated to be about 36 mgd. In years with low precipitation, the amount might be as low as 21 mgd. Under developed conditions, recharge would be about 21 and 13 mgd in years of normal and low precipitation, respectively. An amount between 21 and 36 mgd is considered practical for withdrawal from the Triassic rocks in Middlesex County.

Full utilization of grandfather rights in addition to 1976 reported public and industrial pumpage amounts to a total ground-water diversion of 25 mgd (see Table 3). Utilization of 70 and 35 percent of industrial grandfather rights would reduce the total diversion to 19.7 and 13.5 mgd, respectively.

Most pumpage is concentrated in the north-northeastern part of Middlesex County, which is sewered. It is likely that

water-level declines have occurred in areas near heavy industrial pumpage. Unfortunately, there are no data available to evaluate these water-level declines. If industrial pumpage under grandfather rights is not fully utilized, there may be the potential for additional ground-water development in the northwestern part of the county.

PASSAIC COUNTY

Ground-Water Development

The role of ground water in the overall water supply of Passaic County is small; much smaller than in other northern counties. Carswell and Rooney (1976) estimated that only 5 to 10 percent of the county's total demand is drawn from ground-water sources. The total reported ground-water pumpage for public supply in 1976 was 5.4 mgd. Most of this pumpage is from the northwestern portion of the county (Figure 21).

Industrial pumpage under diversion permits is insignificant (Figure 20). Allocated industrial grandfather rights amount to 8.8 mgd and are in the southern half of the county (Figure 22). Domestic pumpage, estimated to be about 2.7 mgd, occurs almost entirely in the northern half of the county.

Recharge and Potential Ground-Water Development

The estimated recharge, with normal annual precipitation

and undeveloped land-use conditions, is about 47 mgd in Passaic County (Table 3). In years of below normal precipitation this figure would be about 29 mgd. Under present conditions of development, annual recharge under normal and low precipitation conditions could be as low as 27 and 17 mgd, respectively.

In the county as a whole, pumpage is much lower than the practical range of 27 to 47 mgd that probably could be developed. Even if industrial grandfather rights were fully utilized, total pumpage in the county would only be about 30 mgd. The distribution of pumpage, however, is such that almost all of the ground-water diversion is in the southern half of the county. There may be local problems at present or in the future in the valley-fill aquifers of the Pompton and Wanaque Rivers, but this has not been documented. Much of this water is used consumptively since almost the entire southern portion of the county is sewered. As in other northern New Jersey counties, the high degree of urbanization in the southern part of Passaic County makes ground-water development difficult.

Development of the ground-water resources of the northern part of the county is limited by the generally low yields of the rock aquifers. Further exploration of the valley-fill and stratified drift deposits may result in new sources of ground water on a local level.

UNION COUNTY

Ground-Water Development

The combined total of actual pumpage and allocated rights to ground water in Union County in 1976 was 51.9 mgd (Table 3). Ground-water pumpage for public supply was reported to be 24.7 mgd, distributed as shown in Figure 21. Industrial grandfather rights in the county total 20 mgd while actual industrial diversion under the permit system was 5 mgd. Much of the industrial pumpage occurs near the Rahway and Elizabeth Rivers. Domestic pumpage is estimated at less than 0.2 mgd.

Public supply wells primarily tap the Brunswick Formation, although stratified drift deposits are important in some areas. On a county-wide basis there is much less reliance on these aquifers than in Essex County. Public supply pumpage from unconsolidated sediments is concentrated in the extreme northern and southern parts of the county.

Recharge and Potential Ground-Water Availability

Estimated recharge under undeveloped conditions is approximately 28 mgd in years of normal precipitation and 18 mgd in drought years. Taking urban and suburban development into consideration, recharge could be as low as 17 and 11 mgd in years of normal and low precipitation, respectively. For purposes of this report, a range of 17 to 28 mgd is considered as a

practical maximum potential yield for Union County.

Using the values in Table 3, it is apparent that present pumpage exceeds the range of the maximum potential yield. Under all three assumed percentages (100, 70, 35) of grandfather rights' utilization, pumpage exceeds natural recharge. Union County is almost entirely sewered (Figure 19) and therefore essentially all public supply pumpage is used consumptively. The regional analysis of recharge indicates that there may be serious problems of ground-water overdraft. Specific case histories of serious water-level declines do not exist in the literature, and the water-level monitoring system in the county is not adequate to identify such problems if they exist.

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HYDROGEOLOGY OF THE HIGHLANDS

HUNTERDON COUNTY

Hydrogeology

Hunterdon County is located within both the Highlands and the Triassic Lowlands physiographic provinces (Figure 23). The Triassic Lowlands include the Raritan Valley lowland and the Hunterdon Plateau and occupy the southern two-thirds of the county. The plateau slopes to the southeast and is predominantly underlain by dense argillite and hard shale, while further east the Raritan Valley forms a low rolling plain underlain by shale and sandstone with occasional ridges composed of resistant igneous rock rising several hundred feet above the surrounding plain.

The Highlands province, which occupies the remaining northern third of the county, is characterized by flat-topped ridges and rounded hills consisting of metamorphosed Precambrian rocks at elevations several hundred feet above the neighboring lowlands. The ridges exhibit a northeast-southwest alignment and are separated by deep and narrow valleys containing folded and faulted limestones and shales of Paleozoic age. Distinct differences in elevation define the boundary between the Lowlands and the Highlands except in western Hunterdon, where the latter adjoins the Hunterdon Plateau. In addition,

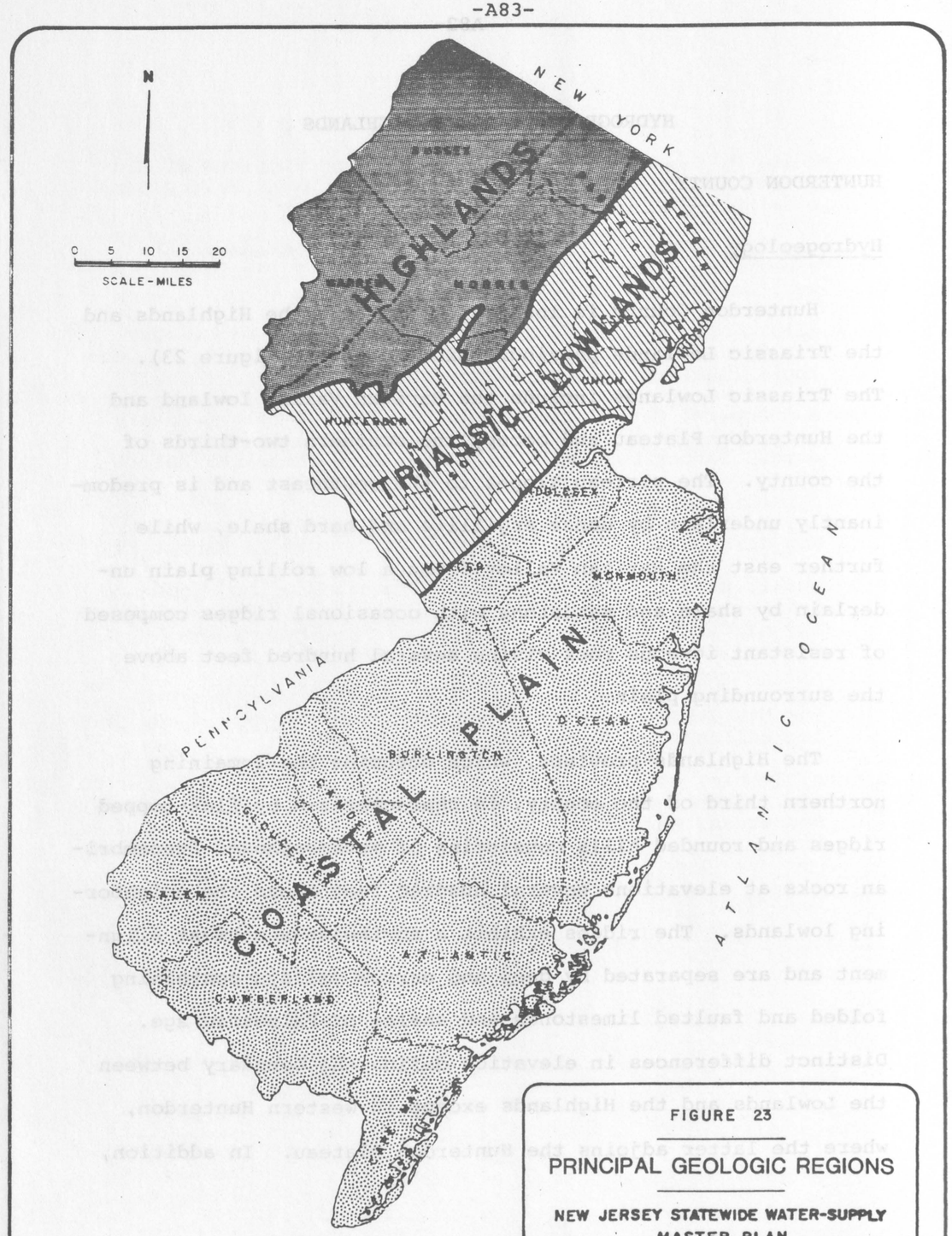


FIGURE 23

PRINCIPAL GEOLOGIC REGIONS

NEW JERSEY STATEWIDE WATER-SUPPLY MASTER PLAN

Paleozoic and Precambrian crystalline rocks, similar to those underlying the formations of the Triassic basin in Hunterdon County, outcrop at several places along this boundary, suggesting that they are part of a foothill belt which occupied the edge of the basin. Sediments deposited in this region were thin and subsequently underwent rapid erosion at the basin's edge, exposing the underlying crystalline formations.

Precambrian Rocks -

Precambrian rocks of highly complex igneous and metamorphic origin are located in northern Hunterdon County; they underlie slightly more than 20 percent of the entire county (Figure 17) and trend northeast-southwest. These crystalline rocks form the "basement" or oldest known rock formations and are of unknown thickness. The presence of numerous major folds and faults within the Precambrian rocks provides a record of the past compressional forces, which, acting over long periods of time, served to metamorphose all the sedimentary deposits once present. In addition to these compressional forces, subsequent igneous intrusions occurred along the northeast-southwest alignment of the major folds and faults, resulting in an extremely complex geological region.

The water-bearing characteristics of the Precambrian rocks are primarily dependent upon the effects of weathering and the degree of fracturing. Unweathered crystalline rocks

have virtually no permeability and serve as a very poor water source, while weathered rock may yield as much as 65 gpm to domestic wells if derived from loosely cemented quartz grains.

The reported yields of over 200 domestic wells tapping the partially weathered Precambrian rock average 14 gpm. Industrial and public supply well yields are relatively low; the average of 26 such wells in the county is 64 gpm and only a few supply more than 100 gpm (Kasabach, 1966).

Cambro-Ordovician Rocks -

Kittatinny Limestone - The Kittatinny Limestone is composed of a dolomitic limestone containing thin beds of chert, shale, and sandstone. It outcrops in northern Hunterdon County and conformably overlies the Hardyston quartzite throughout its extent covering about 4 percent of the county. The thickness of the formation is unknown but estimates ranging from 2,500 to 3,000 feet are believed reasonable.

The Kittatinny Limestone has almost no primary permeability; joints and fractures provide its water-bearing capabilities. In addition, the carbonate composition of the limestone readily allows the formation of solution channels and large cavities by weathering. Wells drilled in such areas have a good chance of yielding large quantities of water. Conversely, wells drilled into dense, predominantly unfractured and undissolved limestone will exhibit low yields.

Domestic well yields from the Kittatinny Limestone average approximately 20 gpm and exhibit a range from less than 1 to 50 gpm. Industrial wells tapping the limestone typically yield 400 gpm and may yield as much as 1,500 gpm (Kasabach, 1966).

Triassic Rocks -

Border Conglomerates - The Border Conglomerates are composed of either well rounded quartzite and hard sandstone pebbles or limestone fragments. These conglomerates underlie about 30 square miles or 6 percent of Hunterdon County in an intermittent narrow band along the northwest edge of the Triassic basin (Figure 17). Their water-bearing properties are characterized by domestic well yields ranging from less than 1 to 90 gpm and averaging 15 gpm.

Stockton Formation - The Stockton Formation is primarily a fine-grained siliceous sandstone interbedded with red shales and conglomerate. Some sandstone beds may be traced over several miles, reaching a maximum thickness of 5,000 feet along the Delaware River (Williard, 1959). The formation underlies about 6 percent of the county and outcrops in the southwest along the Delaware River and in the north in Delaware Township (Figure 17). The sandstone beds comprise a large part of the southern and eastern slopes of the Hunterdon Plateau and frequently overlie Precambrian and lower Paleozoic formations unconformably.

The formation serves as the most prolific consolidated aquifer within Hunterdon County with domestic wells yielding as much as 70 gpm and typically averaging 20 gpm. Only 9 percent of all the domestic wells inventoried by Kasabach (1966) yielded 5 gpm or less, reflecting favorable conditions for water availability from the Stockton Formation. Very limited data on industrial withdrawals indicate average yields of 100 gpm.

Lockatong Formation - The Lockatong Formation is predominantly composed of argillite with small amounts of mudstone and carbonaceous or calcareous shale present. The formation outcrops in a large belt which extends northeast from the Delaware River in southern Kingwood Township to southern Alexandria and Bethlehem Townships in north-central Hunterdon County. This main belt, together with a second outcrop belt extending across the extreme southern portion of the county from southwest to northeast, underlies about 14 percent of the county.

The water-yielding capacity of the Lockatong Formation is among the poorest of all the consolidated rock aquifers in the state. Although domestic well yields average about 12 gpm, more than 50 percent of all such wells yielded 7 gpm or less and more than 35 percent less than 5 gpm. A limited number of industrial well yields average about 65 gpm. It is believed that the reported yields from the industrial wells may be atypically high due to their location in areas of extensive fracturing (Kasabach, 1966).

Brunswick Shale - The Brunswick Shale consists of argillaceous shale with local beds of fine-grained sandstone and siltstone. The formation underlies about 37 percent of Hunterdon County and outcrops in two major belts. The western belt trends northeast from the Delaware River in Kingwood Township and terminates in northern Alexandria and Holland Townships, while the eastern belt extends northeast from Lambertville in a widening belt until it crosses into Somerset County (Figure 17).

The formation is one of the most important consolidated aquifers within the county, supporting a majority of the wells. This reliance upon the Brunswick results from its large areal extent which encompasses the most densely populated areas of the county. The shale beds comprising the formation are highly fractured and contain numerous closely spaced joints, which result in relatively high values for secondary permeability. Yields for domestic wells tapping the formation average about 10 gpm and range as high as 100 gpm. Of over 500 domestic wells, more than 50 percent yielded 15 gpm or more (Kasabach, 1966). Public supply and industrial wells tapping the Brunswick Shale are reported to range in yield from 15 to 765 gpm and average about 280 gpm. More than 50 percent of the 48

wells inventoried exceeded 240 gpm with fewer than 20 percent yielding less than 100 gpm.

Basalt and Diabase - Basalt and diabase are dense ingneous rocks, similar in composition and distinguished principally by texture, with diabase being coarser. These rocks exhibit the highest resistance to weathering of all the Triassic rocks and form local topographically high regions where they outcrop. Such outcrops cover approximately 6 percent of Hunterdon County.

The water-yielding capacity of these rocks is low, a result of their lack of primary permeability and extreme resistance to weathering. Wells that derive water from these rocks are usually found to tap a weathered zone. Yields average 8 gpm and range as high as 55 gpm. In regions where weathered zones are absent or contain no water, the chances of obtaining an adequate water supply are almost nil. Work done by Kasabach (1966) indicates that more than 50 percent of all domestic wells in these rocks yield 5 gpm or less. No industrial or public supply wells tap these rocks.

Quaternary Deposits -

The Quaternary deposits discontinuously scattered throughout Hunterdon County are of glacial origin and are either unstratified till or stratified outwash. The latter, composed

of poorly sorted sand and gravel, predominates within the county and is nearly continuous along the Delaware River and much of the Musconetcong River (Figure 16).

These outwash deposits are an excellent source of water in areas where they fill eroded valleys and have an appreciable saturated thickness. When these deposits are hydraulically connected to a surface-water body, induced infiltration permits industrial withdrawals ranging from 533 to 940 gpm and averaging 773 gpm. Yields for domestic wells tapping these deposits range from 10 to 40 gpm and average about 25 gpm (Kasabach, 1966).

MERCER COUNTY

Hydrogeology

Mercer County is located within both the Triassic Lowlands and the Coastal Plain physiographic province (Figure 23). The Triassic Lowlands province, which occupies the northwestern 60 percent of the county, is underlain by crystalline rocks of Precambrian and Paleozoic age and by Triassic shale, argillite, sandstone, and diabase. These rocks have undergone extensive erosion, to the degree that they are almost as low topographically as the adjoining unconsolidated rocks of the Coastal Plain province. (The Coastal Plain province within the county is discussed at length elsewhere.)

Precambrian Rocks -

Complex Precambrian rocks, metamorphic in nature and primarily composed of granitic gneiss, outcrop in a very small area of west-central Mercer County (Figure 17). The rocks are highly fractured with numerous joints. They exhibit little or no primary porosity in an unweathered condition, with almost all water being retained in fractures and joints. The extent of such fracturing and jointing typically decreases with increasing depth and the effects of weathering generally do not extend deeper than about 300 feet. The Precambrian rocks are a poor prospect as a potential water source. They have little or no capacity for storing or yielding water and underlie only a very small segment of the county.

Cambrian Rocks -

Hardyston Quartzite - The Hardyston Quartzite consists of fine- to coarse-grained quartzite interbedded with conglomerate, feldspar, and some slate. The formation outcrops in the vicinity of Trenton where it attains a thickness of about 400 feet. Water-bearing properties of the Hardyston Quartzite in this region are very similar to those of the Precambrian rocks just discussed.

Triassic Rocks -

Stockton Formation - The Stockton Formation consists of

sequential beds of micaceous feldspathic sandstone, arkosic conglomerate, fine-grained sandstone and soft shale which indicate recurrent and rapidly changing conditions of sedimentation. The formation has undergone extensive faulting and jointing. It outcrops in Mercer County in two belts, one running east-west and one northeast-southwest (Figure 17).

The Stockton Formation serves as the most reliable source of ground water from consolidated rock in the northern portion of Mercer County, partially as a result of its high susceptibility to weathering. The beds of the formation are generally a source of moderate to large supplies of water, especially where they are hydraulically connected to surface-water bodies or saturated overlying deposits of high permeability. Reported yields from domestic wells range from 1 to 60 gpm and average approximately 22 gpm, while industrial well yields average about 150 gpm and may yield as much as 1,000 gpm (Widmer, 1965; Vecchioli and Palmer, 1962).

Lockatong Formation - The Lockatong Formation is predominantly composed of dark and light shale, massive argillite, and thin layers of calcareous shale. The formation weathers to a dense clay soil and ranges in thickness from 1,800 to 3,600 feet throughout the northern 15 percent of the county (Figure 17).

The formation is an extremely poor source of water, infe-

rior to even the crystalline rocks. Yields from domestic wells average only about 8 gpm and more than 50 percent yield 5 gpm or less. Industrial well yields are reported to average 31 gpm. Yields of 20 gpm or less were obtained from 50 percent of all the industrial wells drilled (Widmer, 1965).

Brunswick Shale - In Mercer County the Brunswick Shale consists of fine-grained, thin-bedded, argillaceous shale with hard, fine-grained sandstone and siltstone locally present. The formation outcrops in a 4-mile wide belt across northern Mercer County and in a small belt just north of the Hopewell Fault (Figure 17).

The Brunswick Shale effectively supplies small to moderate quantities of water to wells from fractures and joints within its weathered zone. It yields from 8 to over 650 gpm and averages 150 gpm in industrial wells. Domestic wells produce an average of 13 gpm, over a range of less than 1 to 60 gpm (Widmer, 1965). Higher sustained yields may occur in areas where the Brunswick Shale is in hydraulic contact with surface-water bodies.

Diabase - The Rock Hill, Pennington Mountain and Baldpate Mountain ridges found in Mercer County are diabase, a highly weather-resistant, coarse-grained igneous rock consisting of plagioclase and augite. These ridges mark the outcrop area of the diabase and constitute approximately 4 percent of the county's total area.

The diabase rocks are the poorest source of water in Mercer County since they possess virtually no primary permeability and they are extremely resistant to weathering. Yields of wells in these rocks range from less than 1 gpm to as high as 100 gpm and average about 7 gpm (Widmer, 1965). Yields from the diabase approach 100 gpm when a well intersects a fault or large joint opening but these structures are not common. In fact only about 10 percent of all domestic wells in these rocks yield 10 gpm or more. There are no industrial wells reported which tap the diabase rocks in Mercer County.

Quaternary Rocks -

Quaternary deposits of stratified drift occur in and around the Trenton area and along the Delaware River in northern Mercer County (Figure 16). These deposits, which include beds of clay, sand, and gravel, attain a maximum thickness of some 30 feet. As a result of this limited extent, the drift deposits are not considered a major aquifer within the northern portions of the county and typically yield only small to moderate supplies of water to shallow farm or domestic wells.

MORRIS COUNTY

Hydrogeology

Morris County contains portions of both the Triassic Lowlands and Appalachian Highlands physiographic provinces. The

Lowlands occupy the southeastern part of the county, comprising some 30 percent of its total area, and are characterized by rounded hills and ridges averaging about 300 feet in elevation. The Highlands province, which covers the remaining northwestern 70 percent of the county, consists of principally northeast to southwest trending, rounded or flat topped ridges averaging about 1,000 feet in height and occasionally exceeding 1,300 feet. These ridges are typically separated by narrow and deep valleys.

Precambrian Rocks -

Approximately 65 percent of Morris County is underlain by Precambrian crystalline rocks. These rocks predominate in the northwestern section of the county and consist of gneisses, schists, and crystalline limestone which exhibit similar water-bearing properties.

The gneisses include hornblende, pyroxene, biotite, and feldspar while the limestone (Franklin Limestone) is generally a coarse crystalline marble rich in calcite. Characteristically the gneisses are found in thick and extensive beds striking northeast and dipping to the southeast while the limestone occurs locally as isolated outcrops within the gneiss (Figure 17).

The Precambrian rocks serve as the only source of ground

water from consolidated formations for most of the northwestern 65 percent of the county. In this region, industrial wells yield from 4 to 400 gpm and average approximately 85 gpm. Where high yields are reported, the wells most likely tap zones of major faulting.

Cambrian Rocks -

Hardyston Quartzite - In Morris County the Hardyston Quartzite consists of arkosic quartzite containing small amounts of conglomerate. Its outcrop is limited to three small bands that trend southwest to northeast (Figure 17). These outcrops total less than 5 percent of the county's area. In general, the quartzite of the formation serves as a poor aquifer, capable of yielding only 15 gpm or less.

Cambro-Ordovician Rocks -

Kittatinny Limestone - The Kittatinny Limestone is principally composed of massively bedded magnesian limestone containing small beds of chert and shale. It underlies between 5 and 10 percent of the county, outcropping in three narrow belts which extend in a northeasterly direction from the county's southwestern and south-central borders (Figure 17).

The limestone beds of the Kittatinny Formation serve as the best source of water from Paleozoic rocks in Morris County. They are extremely susceptible to weathering which frequently

produces large and extensive cavities or solution channels within the limestone. Industrial wells tapping such cavities reportedly yield as much as 400 gpm, while overall withdrawal rates for the Kittatinny average about 220 gpm (Gill and Vecchioli, 1965).

Silurian Rocks -

Green Pond Conglomerate - The Green Pond Conglomerate underlies about 4 percent of Morris County, outcropping in a narrow belt which extends to the northeast from the central portion of the county (Figure 17). The formation is composed of a coarse quartz conglomerate interbedded with sandstone.

The water-bearing characteristics of the conglomerate beds vary substantially from place to place. In the absence of cementing material, well yields averaging 200 gpm have been reported (Gill and Vecchioli, 1965). However, such yields are atypically high and do not reflect the generally poor water-yielding capability of the well-cemented conglomerate beds throughout their outcrop area.

Triassic Rocks -

Brunswick Formation - The Brunswick Formation is principally composed of interbedded shales, sandstones and conglomerates 6,000 to 8,000 feet thick. These deposits underlie the eastern 35 percent of the county where they are pierced by

three small bands of weather resistant basalt (Figure 17). The formation dips gently to the northwest and exhibits a generally monoclinal structure.

The Brunswick Formation is the major source of water supply for southeastern Morris County. Highest well yields are obtained from a zone 200 to 500 feet deep. Shallower wells will generally yield less because joints and fractures are filled by weathering debris, while wells drilled deeper than 500 feet will encounter fewer and less extensive water-supplying fractures. Yields of industrial wells tapping the Brunswick shale and sandstone range from 4 to 650 gpm and average about 140 gpm.

Basalt - Basalts of Triassic age occur as three sandwiched sheets within the Brunswick Formation and as such underlie a broad area of eastern Morris County. Outcrops of this basaltic rock pierce the overlying shale and sandstone in three belts all derived from the uppermost basalt sheet (Figure 17). These outcrops occur in northern, southern, and extreme southeastern Morris County, occupying less than 5 percent of the county.

The basaltic rocks provide small supplies that rarely exceed 50 gpm. Although these rocks consistently yield water when tapped, their low permeability prevents them from being considered as a major water supply source in the area.

Quaternary Deposits -

The Quaternary deposits which overlie the bedrock formations throughout much of Morris County may be classified as representative of a terminal moraine, a ground moraine, or stratified drift. The water-yielding ability of both the terminal and ground moraines is virtually negligible. Conversely, the stratified drift deposits, consisting of coarse sand and gravel, accounted for close to 80 percent, or some 24 mgd, of the total ground-water withdrawals made within the county in 1960.

The drift deposits closely parallel the distribution of surface-water bodies and are most developed along the Rockaway River in east-central Morris County. The public supplies of Wharton, Rockaway, Boonton, Dover, and Mountain Lakes are largely diverted from the drift deposits.

As noted, the Quaternary deposits are among the most productive aquifers in Morris County. Reported yields for over 125 commercial, public supply, and industrial wells tapping the stratified drift deposits range from 20 to 2,200 gpm and average about 500 gpm (Gill and Vecchioli, 1965).

SOMERSET COUNTY

Hydrogeology

Nearly all of Somerset County is situated in the Triassic Lowlands and is characterized by low rolling hills, wide valleys and two distinct ridge systems, the Sourland and Watchung Mountains (Figure 17). Only the extreme northeastern portion of the county is located in the Highlands physiographic province.

Precambrian Rocks -

The Precambrian rocks found within Somerset County are metamorphic and consist mainly of granitic gneiss containing small amounts of quartz, hornblende and/or pyroxene. These rocks are confined to the northernmost regions of the county where they underlie 5 percent of its total area (Figure 17). Characteristically dense, these crystalline rocks exhibit a lack of cracks and fissures and are not a major source of water. The average yield of domestic wells tapping these rocks is 12 gpm.

Triassic Rocks -

Brunswick Shale - The Brunswick shale underlies about 75 percent of Somerset County and consists of argillaceous shale with local beds of fine-grained sandstone and siltstone. Over-

all, the Brunswick shale is the most productive aquifer in Somerset County. The major water-yielding zone exists from the surface to a depth of 300 feet. Domestic wells that tap this zone yield an average of 25 gpm.

Basalt and Diabase - Basalt and diabase (commonly referred to as "traprock") underlie less than 20 percent of Somerset County, comprising the Watchung, Sourland, and Rocky Hill Mountains, respectively (Figure 17). These dense igneous rocks are very similar in composition but diabase can be distinguished by its coarser texture. The high density of these traprocks accounts for their extreme resistance to weathering.

Basalt and diabase are the poorest source of ground water within Somerset County. This stems from their lack of both primary and secondary permeability. Successful domestic wells have reported average yields of less than 10 gpm and more than 50 percent of such wells yield less than 5 gpm.

Quaternary Deposits -

Quaternary deposits of stratified drift are present throughout much of northern Somerset County (Figure 16). Their thickness tends to vary considerably and has not yet been precisely mapped. In addition, little is known regarding the current utilization of these deposits to meet domestic and/or industrial needs within the county. Thus, an accurate evaluation concerning the importance and future water supply potential of these deposits is not possible until more detailed information becomes available.

SUSSEX COUNTY

Hydrogeology

Sussex County is located within the Highlands and the Valley and Ridge physiographic provinces. The Valley and Ridge province, comprising the northernmost 65 percent of the county, is further divided into the Kittatinny Ridge and the Kittatinny Valley sub-provinces. The Kittatinny Ridge sub-province occupies the area between the Delaware River, the New York State line, and the eastern flank of the Kittatinny Valley and is characterized by the double crests of the mountains which rise 450 to 600 feet above the valley floor. The Kittatinny Valley sub-province, approximately 10 miles wide, is bounded by the Kittatinny Mountains to the northwest, the Highlands province to the east, and the New York State line to the north. The Paulins Kill and Wallkill Rivers drain its length.

The Highlands province is located immediately to the southeast of the Kittatinny Valley and primarily consists of several flat-topped ridges separated by narrow, steep-walled valleys underlain by dolomites, limestones, and shales.

Precambrian Rocks -

Gneisses and Franklin Limestone - Complex igneous and metamorphic gneisses along with coarse crystalline limestone containing magnesium and pyroxene (Franklin Limestone), represent the Precambrian rocks in Sussex County. These rocks outcrop in the east-southeastern 30 percent of the county (Figure 17). The Franklin Limestone, which extends southwestward into this outcrop area from the county's northeastern border, accounts for about 7 percent of the Precambrian rock.

The Precambrian gneisses provide a reliable source of water for domestic use. Yields from 1,000 domestic wells average about 10 gpm with 45 percent of the wells yielding 5 gpm or less. A survey of industrial wells tapping these Precambrian rocks reported yields averaging 157 gpm (Miller, 1974).

The Franklin Limestone is a very dense rock in its unweathered state and can support large withdrawals only where extensive solution cavities have been formed. Yields from 160 domestic wells tapping the limestone average 15 gpm (Miller, 1974). Only two industrial wells, yielding 80 and 800 gpm, have been reported.

Cambro-Ordovician Rocks -

Kittatinny Limestone - The Kittatinny Limestone is predominantly a fine- to coarse-grained dolomitic limestone containing small beds of chert and calcareous sandstone. The Kittatinny outcrops in an extensive band running southwest to northeast through the eastern portion of the county and in several smaller areas scattered to the northeast and southwest (Figure 17).

Ground water within the Kittatinny Formation occurs in joints, fractures, and solution cavities, the latter contributing the most significant quantities. Faults and joints which generally provide substantial quantities of water in consolidated, non-porous rocks are frequently sealed or too tight to accomplish this within the limestone beds of the Kittatinny. Most successful domestic wells intersect cavities that are between 50 and 300 feet below land surface. The average yield for domestic wells is 15 gpm, but 35 percent of these wells yield 5 gpm or less while only 15 percent yield between 15 and 25 gpm. Reported yields from over 30 industrial wells range from 15 to 815 gpm and average about 160 gpm. Of these, more than 40 percent yield less than 100 gpm and only 9 percent yield in excess of 300 gpm (Miller, 1974).

Martinsburg Formation - In Sussex County, the Martinsburg Formation consists of an intensely faulted sequence of shale, slate, sandstone, and calcareous siltstone which rests unconformably on the Jacksonburg Limestone. These units underlie some 30 percent of the county (Figure 17).

The Martinsburg Formation is a poor source of water as a result of its virtual lack of primary permeability and its subsequent dependence upon fractures and joints to produce significant supplies. In general, these fractures and joints are most common from 50 to 300 feet below land surface. In this zone, reported yields of over 900 domestic wells averaged about 10 gpm and ranged as high as 120 gpm. However, more than 45 percent of such wells yielded 5 gpm or less while only 1 percent yielded over 100 gpm (Miller, 1974). As a possible result of its low water-yielding ability, the number of industrial wells tapping the formation is insufficient for evaluation.

Silurian Rocks -

High Falls Formation - The High Falls Formation, which attains a maximum thickness of about 2,300 feet in Sussex County, is predominantly composed of sandstone, shales, and small quantities of pea conglomerate. The formation outcrops in a broad belt running from the county's southwestern border to its northeastern border (Figure 17), and covers about 9 percent of Sussex's total area.

The sandstone and conglomerate beds of the High Falls Formation are an adequate water source for domestic needs, yielding as much as 60 gpm and averaging 17 gpm. There is no record of any industrial well tapping the formation.

Quaternary Deposits -

The Quaternary deposits within Sussex County consist primarily of river silt and stratified drift in the valley, kames and kame terraces, along with till in the recessional and terminal moraines. While saturated, coarse, stratified drift deposits usually serve as an excellent source of water, till with its low permeability does not. The distribution of the deposits (Figure 16) generally reflects the existing surface-water drainage network. Large withdrawals may be sustained by stratified drift deposits which are hydraulically connected to streams.

The average yield of some 120 domestic wells tapping the stratified drift deposits is about 20 gpm and ranges from less than one to 75 gpm. Only 23 percent of these wells yielded less than 5 gpm while more than 40 percent supplied in excess of 15 gpm. Yields for 13 industrial wells tapping these deposits range from 6 to 942 gpm and average about 250 gpm (Miller, 1974).

WARREN COUNTY

Hydrogeology

Warren County, located in northwestern New Jersey, is located in the Highlands and the Valley and Ridge physiographic provinces (Figure 23). The Valley and Ridge province occupies

the northern half of the county, cutting across it in a northwesterly direction. It is characterized by the Kittatinny Mountain ridge and the adjacent valleys. The ridge system consists of weather-resistant quartz and conglomerate while the valleys on either side are composed of less resistant limestone and shales.

The Highlands province, which traverses the southern portion of the county in a similar northwesterly direction, can be identified by the presence of several flat-topped ridges and rounded hills formed when blocks of Precambrian gneiss were uplifted. The marked relief of these ridges results from their having greater erosional resistance than the adjoining shales and limestones.

Precambrian Rocks -

Rocks of Precambrian age underlie about 30 percent of Warren County and are predominantly complex igneous and metamorphic gneisses with some limestone (Franklin Limestone). The gneisses outcrop in a northeast-southwest belt which occupies most of southern Warren County and is interrupted in numerous and irregular areas by rocks of more recent age (Figure 17). Outcrops of the Franklin Limestone, on the other hand, are small in both number and area, occupying less than 1 percent of the county's total area.

The water-yielding capabilities of both the Precambrian limestone and gneisses are derived from joints, fractures, and solution cavities formed as a result of weathering. Within the crystalline gneisses, fractures and joints occur most often between 50 and 250 feet below land surface. Domestic wells intercepting the fracture system yield an average of 10 gpm; industrial wells open within this fracture zone yield an average of about 160 gpm (Miller, 1974). It should be noted that although the crystalline gneisses appear to be a reasonably dependable source of water, more than 45 percent of the domestic wells yield 5 gpm or less.

The limestone beds of the Franklin Formation can only be considered an aquifer where solution cavities have developed a secondary permeability in this otherwise very dense rock. Where these solution cavities are large and extensively interconnected, withdrawals exceeding 1,000 gpm may be sustained. Miller (1974) indicates that domestic yields from the formation range from less than 1 to 100 gpm and average about 15 gpm, with most of the water being withdrawn from a weathered zone extending between 50 and 300 feet below land surface.

Cambro-Ordovician Rocks -

Kittatinny Formation - The Kittatinny Formation outcrops in several bands running northeast to southwest through central and southern Warren County. It comprises about 36 per-

cent of the county (Figure 17). The formation is predominantly fine- to coarse-grained dolomitic limestone interbedded locally with shale and sandstone.

The Kittatinny is generally a poor source of water except where dissolution of its limestone beds, fractures and joints allows moderate withdrawals. Where dissolution has not occurred, faults, joints and fractures are typically tight and contain little water. Most wells tap solution cavities at depths between 50 and 300 feet. Domestic and industrial well yields average about 15 gpm and 160 gpm, respectively. However, 35 percent of all domestic wells tapping the formation yield 5 gpm or less while 41 percent of all industrial wells yield less than 100 gpm (Miller, 1974).

Ordovician Rocks -

Martinsburg Formation - In Warren County, the Martinsburg Formation is primarily a medium- to fine-grained sandstone with local lenses of shale and conglomerate underlain by banded shale and slate. The formation principally occurs as two large belts trending northeast to southwest in northern Warren County and as a third belt along the county's southwestern border (Figure 17). These outcrops comprise about 23 percent of the county's total area.

In general, the Martinsburg Formation is a poor source of

water in Warren County. The shale, slate, and sandstone beds of the formation possess little primary or secondary permeability; most water is found in tight, undeveloped joints and fractures. Approximately 80 percent of all the domestic wells tapping the formation yield 15 gpm or less. Industrial wells tapping the weathered zone of the Martinsburg Formation, which extends to a depth of about 200 feet, yield an average of 60 gpm (Miller, 1974).

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GROUND-WATER AVAILABILITY IN THE HIGHLANDS

HUNTERDON COUNTY

Ground-Water Development

The water supply requirements of Hunterdon County are met through the utilization of both surface- and ground-water resources. Northwestern portions of the county rely heavily on supplies from the Musconetcong and Delaware Rivers while ground-water sources accommodate most of the remaining areas.

Approximately 25 percent of all the public utilities use surface water, 40 percent rely on ground water and the remaining 35 percent use both. Public water systems, serving approximately 30 percent of the population, withdrew some 2.2 mgd of ground water in 1976. The distribution of these facilities and reported pumpage are shown in Figure 21.

In 1976, pumpage reported under issued diversion permits amounted to 9.5 mgd; that actually withdrawn under grandfather rights is unknown although 9.1 mgd is so allocated. The current distribution of actual withdrawals and allocated industrial grandfather rights is shown on Figures 20 and 22, respectively. Kasabach (1966) reports that in 1960, industrial use accounted for nearly 85 percent of the county's total pumpage.

Additional ground-water withdrawals in Hunterdon County are made to meet domestic and agricultural demands. In 1976,

domestic wells withdrew about 4.3 mgd, based on an inventory of on-site domestic supplies provided by 1970 census investigations. County-wide estimates of agricultural pumpage for 1976 amounted to only 0.2 mgd.

Recharge and Potential Ground-Water Availability

Previous ground-water withdrawal investigations have estimated the safe yield of Hunterdon County at about 160 mgd (Kasabach, 1966). An additional evaluation of potential yield has been undertaken for this study, to better quantify the water supply available. The average recharge values utilized are shown on Figure 17.

The total recharge to consolidated rock formations in Hunterdon County has been estimated at about 101 mgd. This is predicated upon undeveloped land conditions and average annual precipitation. During a dry year, the amount would be about 63 mgd. The effects of land development reduce the estimates to about 92 and 58 mgd for normal and dry years, respectively. These latter values are based on the assumption that storm water runoff from impermeable surfaces is not returned to the ground-water system. This analysis also does not take into account stratified drift deposits which may exhibit much higher recharge rates and thus allow greater withdrawals than consolidated deposits.

Under optimum recharge conditions, 101 mgd represents the

volume of water recharged to the system underlying the county or the maximum potential ground-water yield available. Table 3 compares this value to actual and potential water use in the county. This comparison indicates that even when the ground-water system is subjected to the maximum permitted pumpage, including that under grandfather rights, almost 85 mgd will still be available. Further examination of public supply and industrial pumpage, in conjunction with recharge patterns shown in Figure 17, fails to distinguish any problem areas in the county.

MERCER COUNTY

Ground-Water Development

Mercer County relies on both surface and ground water to meet its domestic, industrial, public, and agricultural water demands. Surface supplies account for approximately 30 mgd of the county's total usage and are principally derived from the Delaware River. The remaining needs are met by ground-water diversions which in 1976 totaled about 7.7 mgd, based on reported pumpage and that allocated under grandfather rights for the portion of Mercer within the Piedmont physiographic province. This is an increase of 34 percent over the 5.8 mgd reported withdrawn from the same area in 1958 (Vecchioli and Palmer, 1962).

Ground-water withdrawals in northern Mercer County (Piedmont province) primarily reflect the requirements of domestic and public water systems. The latter withdrew some 2.6 mgd in 1976, as shown on Figure 21.

Domestic water use represents the largest ground-water diversion in northern Mercer County, almost 3 mgd in 1976. This figure is based on an inventory of on-site domestic supplies provided by 1970 census investigations and per capita consumption estimates.

Industrial water use for the northern portion of the county was about 1.5 mgd in 1976, about equally divided between reported pumpage and grandfather rights. The distributions are shown in Figures 20 and 22, respectively. Agricultural requirements account for the remaining ground-water pumpage, an estimated 0.6 mgd for 1976.

Recharge and Potential Ground-Water Availability

An evaluation of the maximum potential ground-water yield for Mercer County was made using average recharge values (Figure 17). On this basis, the total recharge to the consolidated rock formations which underlie Mercer County north of the Fall Line is about 36 mgd, assuming undeveloped land conditions and average annual precipitation. Less than normal precipitation would reduce this value to approximately 25 mgd. Estimates of 31 and 22 mgd for normal and dry years, respectively, apply when the effects of land development are taken into account.

The maximum amount of recharge to the consolidated rock formations under optimum conditions, 36 mgd, was compared to actual and potential water use for northern Mercer County (Table 3). It was found that 28 mgd is available even when the system is subject to the current maximum allowable pumpage by all diverters. Comparing industrial and public supply pumpage to recharge patterns (Figure 17) indicates there are no significant areas where the ground-water system is presently being overstressed.

MORRIS COUNTY

Ground-Water Development

Ground water serves as the major source of public supply for Morris County despite the extensive development of surface water in the Passaic, Raritan, and Delaware River basins. These surface-water resources sustain the bulk of industrial water requirements.

Public water systems are principally located in the central and eastern portions of the county where the population concentrations are the heaviest. Ground-water withdrawals by these purveyors approached 39 mgd in 1976, an increase of 144 percent from the 16 mgd reportedly withdrawn in 1960 (Gill and

Vecchioli, 1965). The distribution of public water systems is shown on Figure 21.

Industrial water demands, based on actual reported pumpage plus total allocated grandfather rights, amounted to about 21 mgd in 1976 (Figures 20 and 22). However, the actual pumpage under grandfather rights is not known since reporting is not required.

Domestic and agricultural requirements, which comprise the remaining pumpage within the county, were an estimated 7.5 mgd in 1976. This represents an increase of 87 percent over the reported 4 mgd withdrawn in 1960 (Gill and Vecchioli, 1965). Domestic use comprised nearly all of the 1976 pumpage.

Recharge and Potential Ground-Water Availability

Previous ground-water availability investigations in Morris County have not quantitatively determined the maximum potential yield of the formations in this area. A qualitative study recommended development of stratified drift deposits and stated that the full potential of such deposits has not yet been realized. These deposits, as shown in Figure 16, will undoubtedly play an increasingly significant role in attempts to meet future needs. Comparing recharge to pumpage throughout the county would aid in the delineation of those water supply areas that are or may be under- or over-utilized. Such an

evaluation has been undertaken for consolidated rock units incorporating recharge values as shown on Figure 17.

Total recharge to the consolidated rock formations is estimated at 104 and 65 mgd, for normal and dry years, respectively, assuming undeveloped land conditions. The effects of development reduce the estimates to 89 and 56 mgd.

A comparison of recharge under optimum conditions to actual and potential water use for Morris County is shown in Table 3. This comparison indicates that even with full utilization of all allocated grandfather rights, some 25 mgd is still available.

At a local level, industrial and public supply pumpage together with the recharge values shown in Figure 17 indicate that withdrawals in the east-central portion of Morris County approach the calculated potential yield. However, this evaluation does not take into account extensive stratified drift deposits (Figure 16) which may provide considerable additional potential. In portions of Morris County where domestic needs are dependent upon ground water, the yield of the consolidated aquifers should be more than adequate.

SOMERSET COUNTY

Ground-Water Development

Surface- and ground-water resources are both utilized to meet the constantly increasing water supply requirements of Somerset County. Surface supplies are primarily obtained from the Neshanic, Raritan, and North Branch Rivers in the west, the Millstone River in the southeast and the Raritan River in central Somerset. A 1973 county inventory report estimates that by 1978, surface water will support roughly 80 percent of the county's public water demands and the remainder will be met by ground water.

The total ground-water pumpage in Somerset County for 1976, comprised of actual pumpage in conjunction with all grandfather rights, was 20.8 mgd. The largest component was self-supplied industrial use which totaled 10.6 mgd in 1976, comprised of pumpage reported under issued diversion permits (5.7 mgd) and that allocated under grandfather rights (4.9 mgd). Public supply withdrawals of ground water amounted to 2.8 mgd, distributed as shown on Figure 21.

Additional ground-water withdrawals in Somerset were made to meet domestic and agricultural requirements whose reported and/or calculated diversions in 1976 were 5.5 and 0.1 mgd, respectively. An additional 1.9 mgd may have been utilized under grandfather rights for the two categories.

Recharge and Potential Ground-Water Availability

Little has been done to quantitatively evaluate the maximum potential yield of the aquifers in Somerset County. The problem is illustrated by a Somerset County Planning Board investigation conducted in 1972 which reported a lack of knowledge on the part of the county's major public suppliers concerning the actual safe yield of their sources. Such an evaluation, a prerequisite to any discussion on potential ground-water development, was undertaken for this study.

The total recharge to consolidated rock formations underlying Somerset County, based on undeveloped land conditions, has been estimated at 89 mgd with average precipitation, and 57 mgd during a dry year. The effects of land development reduce these estimates to 81 and 51 mgd for normal and dry years, respectively. These latter values are conservative in that they do not take into account any recharge contribution from storm-water runoff. Also, the quantitative effect of valley-fill and stratified drift deposits on recharge has been avoided since they are typically of greatest importance when hydraulically connected to a nearby surface-water body. In these instances, however, the large-scale utilization of these deposits might ultimately be responsible for depleting such surface-water bodies.

The preceding 89 mgd, defined as the maximum potential

ground-water yield of the county, was compared with an inventory of actual and potential water use for all of Somerset (Table 3). Even under the maximum allowable pumpage, including full utilization of grandfather rights, nearly 69 mgd of ground water would still be available.

When comparing industrial and public supply pumpage with the recharge patterns shown in Figure 17, it becomes apparent that even on a local level there are no significant areas where the ground-water system is currently being overtaxed. The greatest localized consumption of about 6.2 mgd occurs in the central portion of the county where the underlying consolidated formations can supply in excess of 7.5 mgd.

SUSSEX COUNTY

Ground-Water Development

Sussex County, like many of the other counties already discussed, depends upon both surface and ground water to meet current needs. Of the major public supply systems, 14 percent obtain water from surface supplies, 67 percent use wells, and the remaining 19 percent, a combination of the two. These systems predominate in and around the larger towns and boroughs scattered throughout the county and withdraw much of their surface-water supplies from the Delaware, Paulins, and Wallkill Rivers. Rural areas depend principally upon domestic wells for supplies. The total of actual pumpage and allocated

grandfather rights in Sussex County for 1976 was 25 mgd.

Self-supplied industry is potentially the single largest diverter of ground water within the county, with 0.3 mgd of pumpage reported under issued diversion permits in 1976 and 18.6 mgd allocated under grandfather rights (Figures 20 and 22, respectively).

In 1976, public water system withdrawals of 2.7 mgd accounted for about 11 percent of the combined reported pumpage and allocated grandfather rights in Sussex County. This represents a 65 percent increase in the utilization of ground water by this category since 1967. The distribution of these withdrawals is shown in Figure 21.

The remaining ground-water pumpage within the county is primarily attributable to domestic use. In 1967 wells throughout the county removed slightly more than 1.5 mgd. An estimate of 3.5 mgd was computed for 1976, indicating a significant growth in rural population. Agricultural pumpage in 1976 was insignificant at less than 0.1 mgd.

Recharge and Potential Ground-Water Availability

It is estimated that the total recharge to consolidated rock formations underlying Sussex County is about 98 mgd with average annual precipitation and about 63 mgd during a dry year. Estimates of about 92 and 59 mgd for normal and dry

years, respectively, result when the effects of land development are considered.

The actual and potential water use for all of Sussex County (Table 3), subtracted from its total recharge of 98 mgd leaves some 70 mgd for future development. In addition, a reduction in industrial pumpage to 35 percent of that amount granted under grandfather rights would increase the total undeveloped ground water within the consolidated rock aquifers to almost 85 mgd.

Further evaluation of industrial and public supply pumpage versus recharge patterns (Figure 17) indicate that, for most of the county, consolidated rock aquifers are not being utilized to their maximum. An exception may exist in Sparta Township where the complete utilization of grandfather rights (16.7 mgd) would exceed the calculated recharge of less than 10 mgd for this area.

WARREN COUNTY

Ground-Water Development

Both surface and ground water sustain the water-use requirements of Warren County. Surface-water supplies are primarily obtained from the Paulins Kill River in north central Warren and the Musconetcong and Delaware Rivers which form the southeastern and northwestern borders of the county, respec-

tively. Large portions of these supplies are diverted by public water systems to support the needs of urbanized areas. In rural areas, domestic wells are the principal source of water supply. The total ground-water pumpage in Warren County for 1976, based on actual pumpage in conjunction with allocated grandfather rights, was 25.5 mgd.

Self-supplied industry represents the single largest ground-water diverter in the county, accounting for the withdrawal of some 12.8 mgd in 1976, based on 3 mgd reported under issued diversion permits and 9.8 mgd allocated under grandfather rights (Figures 20 and 22, respectively).

Public water systems withdrew some 8.5 mgd of ground water in 1976. Domestic and agricultural requirements constitute the bulk of the remaining pumpage within the county. In 1976 domestic wells withdrew about 2.5 mgd. Estimates of agricultural pumpage for 1976 amounted to 0.8 mgd.

Recharge and Potential Ground-Water Availability

There is a serious lack of information regarding the ground-water potential of Warren County. Without an adequate data base, the formulation of a water resource management policy is virtually impossible. This investigation has attempted to determine the maximum potential yield, as defined previously, and to evaluate pumpage versus recharge for the county as a whole.

The total recharge to consolidated rock formations underlying Warren County is estimated at about 74 mgd with average annual precipitation and 49 mgd during a dry year. The effects of land development on recharge cannot be quantified due to the absence of detailed county-wide land-use information. However, the county remains predominantly undeveloped and the influence of urbanization on recharge is assumed to be insignificant. Where major urban areas are present, as along the Delaware River, much of their water requirements are met by wells tapping the stratified drift adjoining the river. Where the river and these deposits are hydraulically connected, withdrawals may be comprised mostly of induced surface water, making recharge calculations for these areas unnecessary from this study's point of view.

Under optimum recharge conditions, 74 mgd represents potential ground-water yield available from the entire county. Table 3 compares this value with an inventory of the actual and potential water uses for Warren County.

The comparison indicates that a ground-water supply of approximately 49 mgd will remain when the maximum pumpage permitted, including grandfather rights, is used. Nearly 56 mgd would be available in the event that industrial sources utilized only 35 percent of grandfather rights allocated.

Evaluation of public supply and known and allocated in-

dustrial pumpage (Figures 20, 21, and 22) together with the recharge values shown in Figure 17, indicates that for most of the county, consolidated rock aquifers are not being utilized to their full potential. However, exceptions may exist in Phillipsburg and Belvidere Townships. The maximum allowable withdrawals by industry and public water systems for the Phillipsburg area have been inventoried at about 8.3 mgd while the maximum potential yield from the consolidated rocks in this area, based on recharge, has been estimated at some 6 mgd.

In Belvidere Township, the industrial pumpage of 2.4 mgd is estimated to be at least 0.5 mgd more than what is available for withdrawal from the underlying consolidated rocks in this area. In this case, the 0.5 mgd is probably obtained from stratified drift deposits adjoining the Delaware River (Figure 16). In Phillipsburg Township, however, such well-developed and extensive deposits are missing. In their place are unstratified deposits with typically poor water-yielding capabilities. Potential ground-water supply problems exist in the vicinity of Phillipsburg and should be examined in more detail. This area is one of the five sewered areas in the county (Figure 19). The area in and around Phillipsburg is of first concern, because the existence of sewers here may aggravate potential problems in that consumptive use of ground water is occurring.

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SALT-WATER INTRUSION

Sea-water encroachment in coastal areas is a direct consequence of increased ground-water withdrawal from wells. Under natural conditions, fresh ground water in coastal aquifers is continuously discharged to the ocean at, or seaward of, the coastline. Because of its greater density, salt water tends to form a wedge under the less dense fresh water. Under conditions of hydraulic equilibrium, the fresh-water/sea-water interface is essentially stationary, but, when the seaward flow of fresh ground water is decreased through pumping, sea water may move inland.

This section describes the history of sea-water intrusion in New Jersey and examines its environmental consequences, causal factors, and present extent in five coastal regions and along the Delaware River. The present monitoring procedures and possible control measures are also discussed.

The existence of salt-water intrusion into the coastal aquifers of New Jersey was noted during investigations carried out in the 1920's and 1930's. Thompson (1928) outlined the hydrology of the various aquifers in the Atlantic City area, and discussed potential salt-water encroachment in the 800-foot sand of the Kirkwood Formation. Barksdale, Sundstrom and Brunstein (1936) commented on ground-water supplies in the Atlantic City region and discussed the extent of salt-water en-

croachment in the Cohansey Sand beneath salt-water tidal marshes.

The danger of salt-water contamination of the No. 1 Sand (Farrington Sand) along the Raritan River in Middlesex County was noted by Barksdale in 1937, and was followed by a more detailed investigation of both the Farrington Sand and the Old Bridge Sand by Barksdale and others in 1943. The study of salt-water encroachment in these aquifers was updated by Appel in 1962 and by Geraghty & Miller, Inc. in 1976, as part of the Middlesex County 208 project.

Salt-water intrusion in the Newark area was first described by Herpers and Barksdale (1951) who noted that heavy industrial pumping along the Passaic River and Newark Bay led to saline river-water intrusion into the Brunswick Formation. Chloride analyses reported by Nichols (1968) in a report on the ground-water resources of Essex County indicate that additional salt-water encroachment has taken place.

In 1956, the U. S. Geological Survey and the New Jersey Division of Water Policy and Supply began a joint investigation of salt-water encroachment in Cape May County which was reported by Gill in 1959 and 1962. This work was updated by Geraghty & Miller, Inc. (1971) in 1970.

The presence of saline water in the aquifers of the Potomac Group and Raritan and Magothy Formations along the Delaware River was noted by Barksdale and others in 1958 as part of an examination of ground-water conditions in the Tri-State Region. In 1964, Parker and others identified the 250-mg/l isochlor in the Potomac-Magothy-Raritan, Kirkwood and Cohansey aquifers. Areas of potential salt-water encroachment in Camden County were described by Farlekas, Nemickas and Gill (1976). Ground-water pumpage, potentiometric levels and chloride concentrations of the Potomac-Magothy-Raritan aquifer system in Gloucester, Camden, and Burlington Counties were described in a report prepared by Geraghty & Miller, Inc. for the Delaware Valley Regional Planning Commission 208 Study.

In recent years, periodic sampling and chloride determinations have been carried out in numerous observation and public supply wells, and the U. S. Geological Survey has established a ground-water salinity monitoring network in Middlesex, Monmouth, Ocean, and Atlantic Counties.

A U. S. Geological Survey drilling and coring program conducted during 1976 on the continental shelf off New Jersey found relatively fresh water (salinity less than 3,000 mg/l) beneath the shelf some 60 nautical miles seaward of the coast. Water of about 1,000 mg/l salinity was found more than 7 nautical miles off Ocean County (Hathaway and others, 1976).

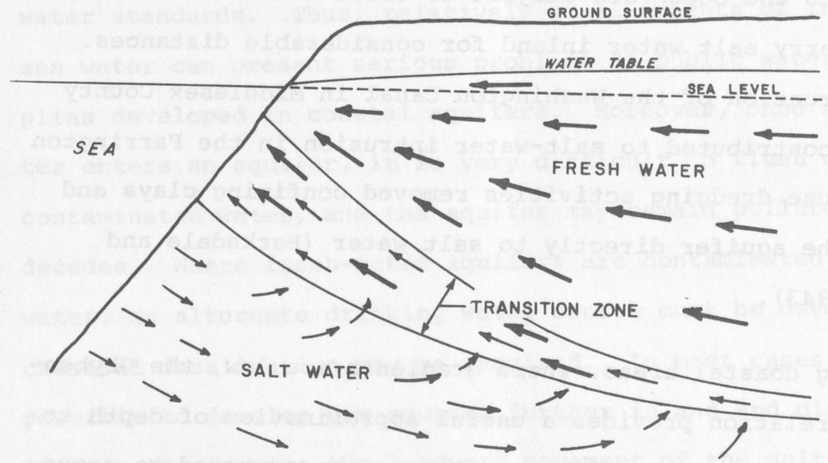
Because of the high salt content in sea water (19,000

mg/l chloride; 11,000 mg/l sodium), concentrations as low as 2 percent will make fresh water unusable in terms of U. S. Public Health Service and New Jersey Health Department drinking water standards. Thus, relatively small amounts of intruded sea water can present serious problems to public water supplies developed in coastal aquifers. Moreover, once saline water enters an aquifer, it is very difficult to flush out the contaminated water, and the aquifer may remain polluted for decades. Where fresh-water aquifers are contaminated by salt water, an alternate drinking water source must be developed or chemical desalination may be required. In most cases, it is possible to develop new sources further inland and distribute pumpage to minimize the landward movement of the salt-water front. It is also possible to implement a number of ground-water management techniques including artificial recharge and the interception of saline water through pumping troughs.

The general cause of sea-water encroachment in coastal aquifers is excessive pumping near the coast which lowers the water table or potentiometric surface. This reduces the hydraulic gradient and the flow of fresh ground water to the ocean. In several areas of New Jersey, pumpage has lowered the potentiometric surface to such an extent that the normal hydraulic gradient has reversed to the point where fresh-water outflow ceases and saline water moves into the aquifer along the salt-water contact.

Dredging in low-lying coastal areas may cause salt water to intrude into water-table aquifers as heads are reduced and fresh-water underflow to the ocean decreases. Channels that are open to the ocean are subject to tidal and storm action, and can carry salt water inland for considerable distances. The construction of the Washington Canal in Middlesex County may have contributed to salt-water intrusion in the Farrington Sand because dredging activities removed confining clays and exposed the aquifer directly to salt water (Barksdale and others, 1943).

Along coastal areas, where gradients are low, the Ghyben-Herzberg relation provides a useful approximation of depth to saline water. In general, sea water can be expected to occur near the coast at a depth that is roughly 40 times the height of fresh water above sea level. This distribution is known as the Ghyben-Herzberg relation, and involves the hydrostatic equilibrium between fluids of different density. The actual ground-water situation is dynamic because ground-water flow takes place near the coast, and the interface between fresh and salt water depends to a great extent on the hydraulic head in the aquifer. Moreover, the interface occupies a different position in each aquifer and, in thick aquifer zones, the salt-water body tends to wedge inland in the lower part of the aquifer (Figure 24).



SOURCE:

Meyer, C.F., 1973, POLLUTED GROUND WATER: SOME CAUSES, EFFECTS, CONTROLS, AND MONITORING, p.4-5.

FIGURE 24

SCHEMATIC VERTICAL CROSS SECTION SHOWING FRESH WATER AND SEA WATER CIRCULATION WITHIN A TRANSITION ZONE

NEW JERSEY STATEWIDE WATER SUPPLY MASTER PLAN

Salt-water intrusion can also result from the upward movement, or upconing, of saline water through aquifers or confining beds. Pumping from an aquifer underlain by saline water may lower the water table to a position below the potentiometric surface of a lower saline water zone. If the two aquifers are hydraulically connected, this lowering of head will induce the upward movement of saline water. This situation is believed to exist in several places along the Delaware River, and may be a reason for the increased salinity of ground water pumped from the Potomac-Magothy-Raritan aquifer system.

The actual interface of salt and fresh water lies some distance seaward of the 250-mg/l isochlor, and until recently, it was generally thought that salinity would increase rapidly and approach that of sea water over a distance of a few miles offshore. Recent drilling, coring and testing carried out on the continental shelf indicates that this is not necessarily the case (Hathaway and others, 1976). A series of 19 holes were cored on the continental shelf and slope of the eastern United States from Florida to Georges Bank. Five core holes (Nos. 6011, 6020, 6009, 6010, and 6021) were drilled along a northwest-southeast profile off the New Jersey coast (Figure 25).

Stratigraphic information was obtained from onshore wells and from offshore test wells (COST B2 Well and DSDP Hole 108).

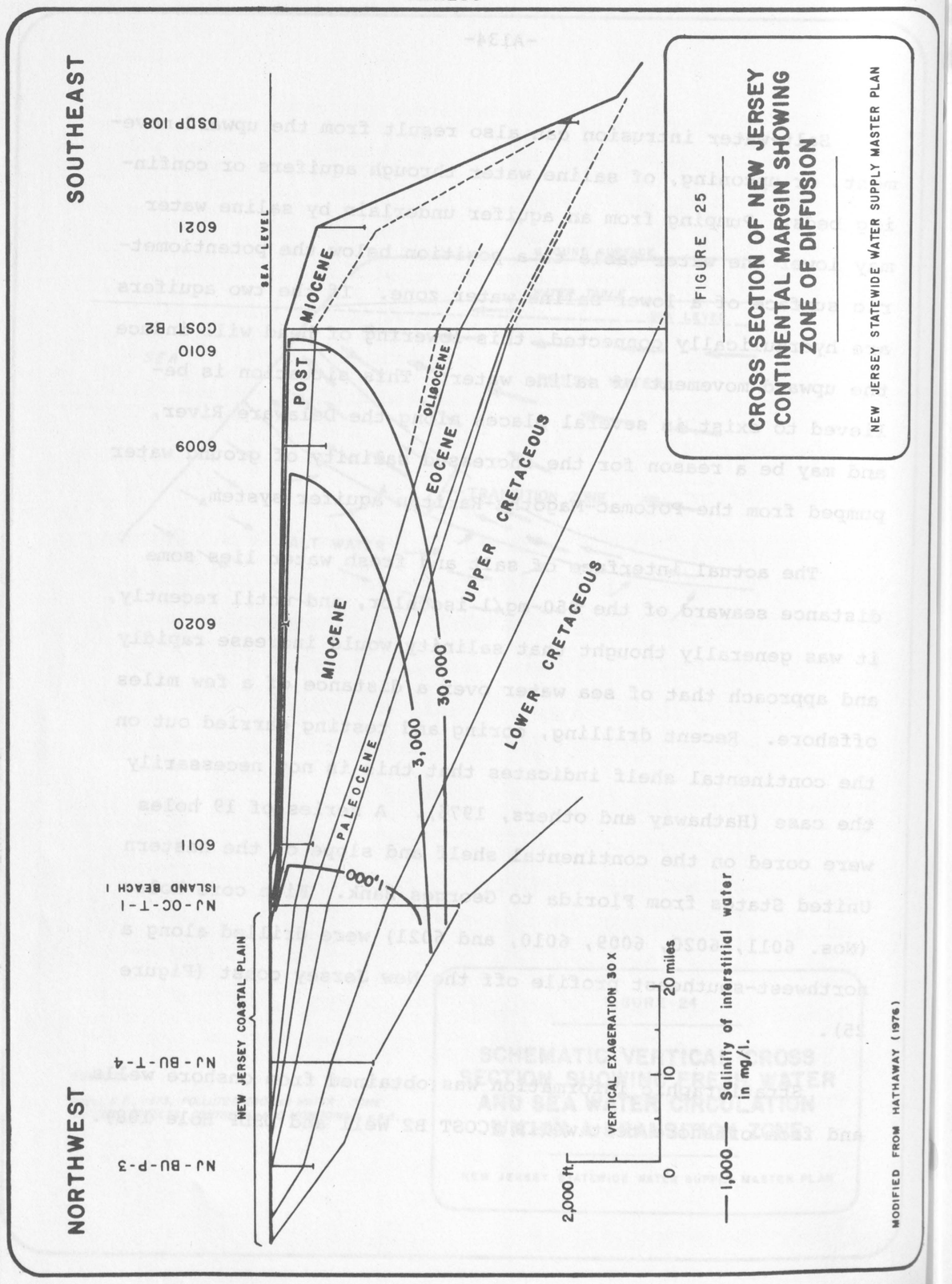


FIGURE 25

CROSS SECTION OF NEW JERSEY CONTINENTAL MARGIN SHOWING ZONE OF DIFFUSION

NEW JERSEY STATEWIDE WATER SUPPLY MASTER PLAN

Examination of interstitial water in cores indicated that relatively fresh water can be found at some distance from the shore. In Hole 6011, located 6 miles offshore, salinities varied from 29,000 mg/l in Pleistocene sand, to 1,500 at 233 feet (Pliocene), and remained in the 2,000- to 3,000-mg/l range to 636 feet in sands and silty clays of Miocene age. The somewhat higher salinity of 15,700 mg/l was found at 735 feet, and water with 5,500 mg/l salinity was found in glauconitic sand.

The presence of relatively fresh water suggests that the fresh-water/salt-water boundary lies considerably farther seaward than 6 miles from shore. This was confirmed in Hole 6020 where salinities decreased rapidly with depth (from 33,000 mg/l at 20 feet to 5,800 mg/l at 143 feet), and in Hole 6009 where salinities remained less than 10,000 mg/l between 112 and 456 feet. The salinity contrast was less at Hole 6010, where values remained between 20,000 to 24,000 mg/l for most of the core length.

Estimated offshore salinity profiles are shown on the cross section. However, it is not known if the relatively fresh-water zone encountered in the core holes extends further downward and is in hydraulic connection with artesian aquifers in the Coastal Plain. This offshore fresh water may be derived from precipitation that occurred in Pleistocene time when the continental shelf was exposed. Since the retreat of

glacial ice and the drowning of the continental shelf, the fresh-water zones which are confined by dense clay beds have not had sufficient time to adjust to the new equilibrium.

The results of the offshore coring programs indicate that a wide transition zone may exist rather than the relatively sharp fresh-water/salt-water interface expected in accordance with the Ghyben-Herzberg principle.

The inland extent of saline water in New Jersey's Coastal Plain aquifers is not completely known. However, where shallow aquifers have been tapped for water supply purposes, chloride data is available and the position of the 250-mg/l isochlor can be determined with reasonable confidence. The precise extent of saline water in deep aquifers is uncertain, but Barksdale and Parker developed maps of the New Jersey Coastal Plain indicating chloride concentrations in the Magothy-Raritan sediments, the Kirkwood Formation, and the Cohansey Sand. These maps locate the 10- and 250-mg/l isochlors and indicate those areas underlain by water containing more than 250 mg/l chloride.

More recent chloride data permit an update of maps indicating chloride concentrations in the Coastal Plain aquifers and in the position of the 250-mg/l isochlor (Figure 26).

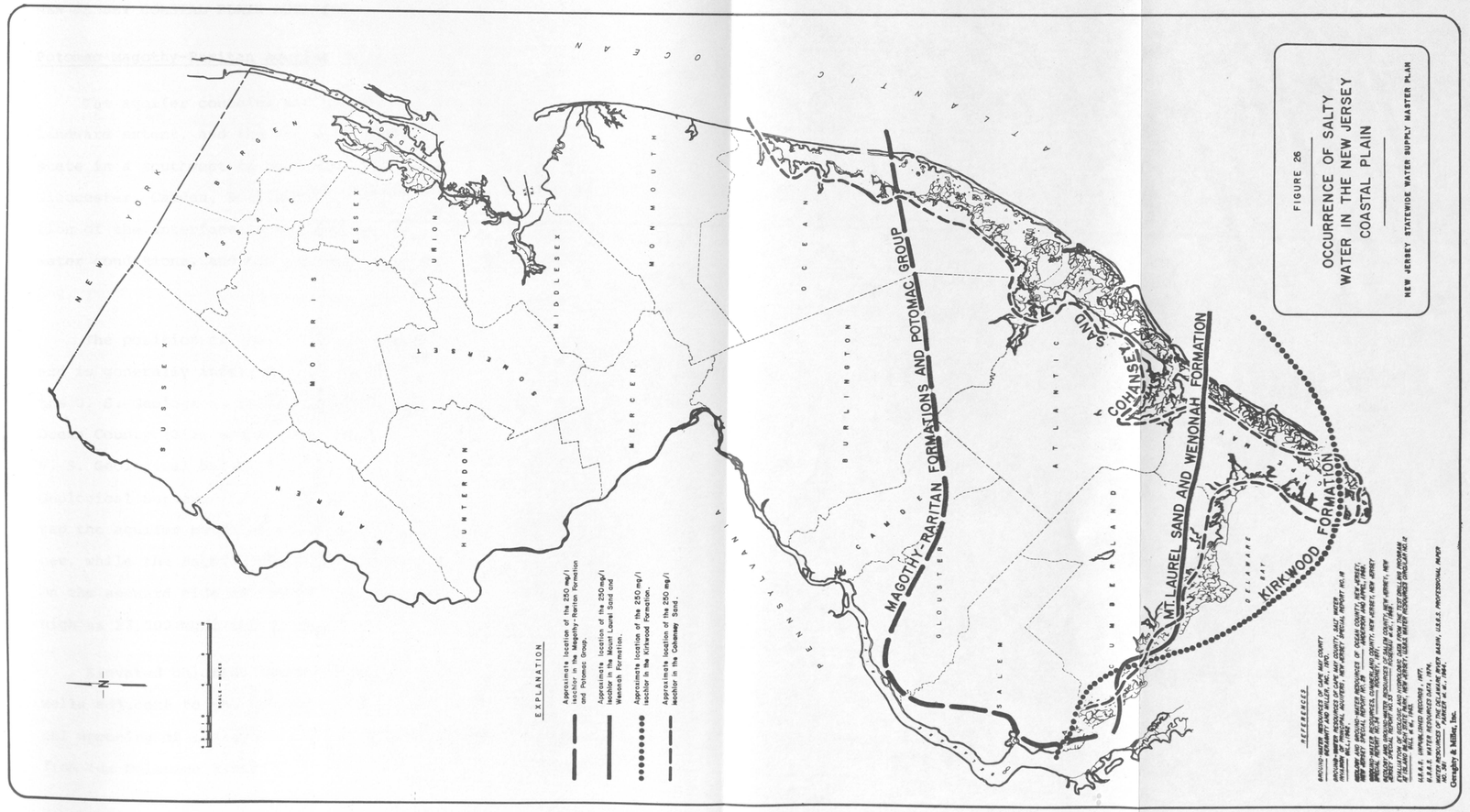


FIGURE 26

OCCURRENCE OF SALTY WATER IN THE NEW JERSEY COASTAL PLAIN

NEW JERSEY STATEWIDE WATER SUPPLY MASTER PLAN

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NEW JERSEY SPECIAL REPORT NO. 29 — CITY OF ATLANTIC CITY, 1968.
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U.S.G.S. WATER RESOURCES DATA, 1970.
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WATER RESOURCES OF THE DELAWARE RIVER BASIN, U.S.G.S. PROFESSIONAL PAPER 381, 1960.

Geraghty & Miller, Inc.

NEW JERSEY COASTAL PLAIN AQUIFERS

Potomac-Magothy-Raritan Aquifer System

The aquifer contains saline water for about half of its landward extent, and the 250-mg/l isochlor cuts across the state in a southwest to northeast direction through Salem, Gloucester, Camden, Burlington, and Ocean Counties. The position of the interface is believed to reflect natural groundwater conditions, and not sea-water intrusion caused by pumping.

The position of the 250-mg/l isochlor is not well defined, and is generally inferred from the results of deep drilling by the U. S. Geological Survey at Island Beach State Park in Ocean County (Gill and others, 1963), chloride data from the U. S. Geological Survey Brooklyn Park observation well (U. S. Geological Survey, 1977), and other wells. Many wells which tap the aquifer north of the interface show low chloride values, while the Ragovin observation well in Cumberland County on the seaward side of the 250-mg/l isochlor shows chloride as high as 27,000 mg/l (U. S. Geological Survey, 1974).

Elevated chloride levels in some Potomac-Magothy-Raritan wells adjacent to the Delaware River appear to be caused by local upconing of saline water, and by the intrusion of water from the Delaware River.

Mount Laurel and Wenonah Formations

Test drilling conducted at Island Beach in Ocean County indicates that the Mount Laurel-Wenonah generally contains low chloride water (Gill and others, 1963). The fresh-water/salt-water interface in the aquifer appears to cross the Coastal Plain beneath Cumberland and Atlantic Counties.

The aquifer yields low-chloride water in its outcrop area, but its water quality further downdip is not known with certainty. Local increases in chloride concentrations are reported from some wells in Salem and Cumberland Counties (Rosenau and others, 1969), and chloride levels in Mount Laurel-Wenonah wells at the City of Salem have been measured at 140 mg/l.

Kirkwood Aquifer

The Kirkwood aquifer contains fresh ground water for almost its entire landward extent on the Coastal Plain. The 250-mg/l isochlor crosses the southern tip of the Cape May peninsula from Wildwood on the Atlantic Ocean, to North Cape May on Delaware Bay (Gill, 1962; Geraghty & Miller, Inc., 1971).

In 1964, Parker and others described a 250-mg/l isochlor crossing Salem and Cumberland Counties near the Delaware Bay shore, however, Rooney (1971) and Rosenau (1969) could not delineate the fresh-water/salt-water front in these counties. The situation is somewhat complex in this region because the

upper Kirkwood aquifer cannot be differentiated from the overlying Cohansey Sand, and is under semiartesian or water-table conditions.

Cohansey Sand

The Cohansey aquifer contains fresh water throughout most of its extent on the Coastal Plain. Saline water has been identified in wells in Cape May County, and scattered cases are reported in Cumberland and Atlantic Counties.

The Cohansey aquifer north of Cape May County is unconfined near the shore with an interface believed to parallel the inland edge of the coastal wetlands (Anderson and Appel, 1969). High chloride levels (13,000 to 14,000 mg/l) have been found in Cohansey wells on the barrier beach near Atlantic City. This may not be caused by regional salt-water encroachment, as the wells are shallow and are located near the natural fresh-water/salt-water interface. Salt-water intrusion of the aquifer has occurred at pumping centers in Cape May City at the extreme tip of the Cape May peninsula, and the 250-mg/l isochlor has been located about one mile inland (Gill, 1962; Geraghty & Miller, Inc., 1971).

Ground-water quality data is incomplete for the Delaware Bay shore in Cumberland County, and the 250-mg/l chloride line is assumed to coincide with the landward limit of the tidal wetlands (Parker and others, 1964).

AREAS AFFECTED BY SALT-WATER INTRUSION

Newark-Passaic River

In 1951, Herpers and Barksdale detected salt-water intrusion in wells completed in the Brunswick Formation near Newark. A large buried valley or ancient stream channel exists in bedrock below Newark, and extends across the Passaic River into Harrison. The depth to rock in the buried valley ranges from 125 feet to more than 190 feet in Newark, and to as much as 300 feet in Harrison. The deposits consist of fine sand and clayey sand in the southwestern part of Newark, and coarse water-bearing sand and gravel in the northeastern part. Several large-capacity wells (600 gpm) reportedly tapped these sand and gravel beds years ago. The Pleistocene cover varies in thickness and consists mostly of till and poorly stratified materials. Most of the region's wells were completed in the underlying sandstones and shales of the Brunswick Formation.

Heavy industrial pumpage in the Newark area lowered water levels and caused infiltration of saline water from the Passaic River. Well records from 1879 indicate that water levels ranged from a few feet above, to 25 feet below land surface, with chloride concentrations ranging from 10 to 25 mg/l. In 1947, water levels had fallen to 125 to 200 feet below land surface, and chloride levels ranged from 250 to 2,500 mg/l. Both the unconsolidated and bedrock aquifers were affected.

Figure 27 indicates that high chloride concentrations could have been associated with areas of heavy industrial pumpage as early as 1942. No detailed ground-water quality investigations have been carried out since that time, but analyses reported by Nichols in 1968 indicate that additional salt-water encroachment has taken place. The Wilbur Drive Company's well along the Passaic River yielded water with 72 mg/l chloride in 1942. In 1961, the chloride level in this well was 330 mg/l. Similarly, chloride concentrations in a well drilled by the Mutual Benefit Life Insurance Company were less than 500 mg/l in 1942 and 1,145 mg/l in 1965.

The major pattern of ground-water development appears to have changed slightly with time, but the potentiometric surface of the Brunswick aquifer lies below sea level over a large area, and hydraulic gradients have steepened considerably. Salt-water encroachment is probably continuing in the Newark area and a new investigation of the problem and its potential impact on ground-water supplies in the region is required.

Sayreville-Raritan River

Salt-water encroachment in the Sayreville and Raritan Rivers area of Middlesex County dates back to the industrial development and increased water demands of the first World War. The duPont Company (1904), the Hercules Powder Company (1920),

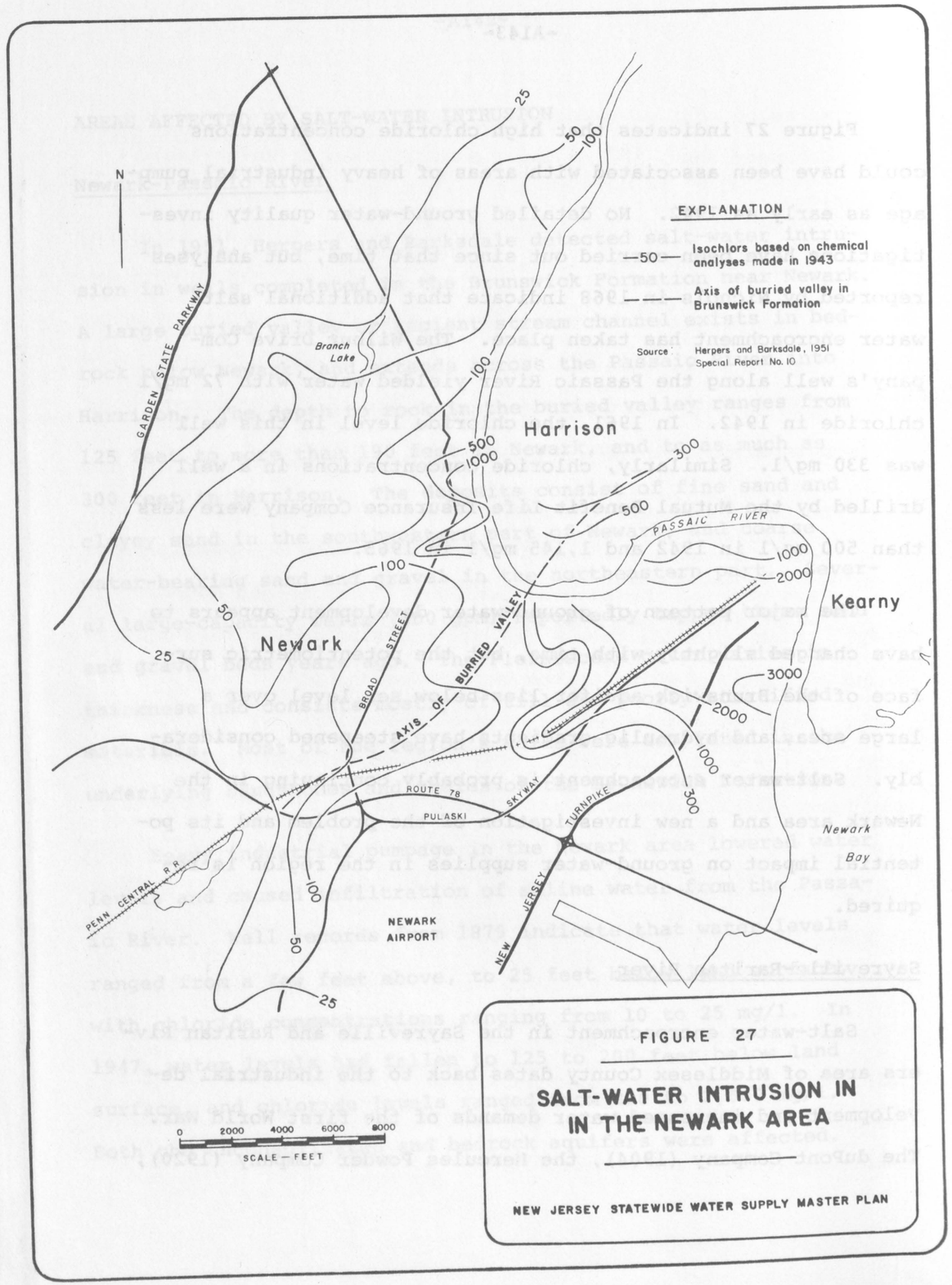


FIGURE 27

SALT-WATER INTRUSION IN IN THE NEWARK AREA

NEW JERSEY STATEWIDE WATER SUPPLY MASTER PLAN

and National Lead Company (1935), developed ground-water supplies from the artesian Farrington Sand. The Perth Amboy Water Works installed wells in the water-table aquifer, the Old Bridge Sand (1902), and the Farrington Sand (1930) at Runyon. During this period, the South Amboy Water Works installed wells in the Old Bridge Sand along the shore of Raritan Bay.

Farrington Sand -

Artesian heads in the Farrington Sand declined in response to industrial and municipal pumpage which reached a peak of 12 mgd in 1936. Salt water began to appear in wells in the City of Perth Amboy and in an area between the Washington Canal and the well fields at Parlin.

Geologic conditions and the construction of the Washington Canal appear to have contributed to salt-water intrusion. The Farrington Sand, which is overlain by the Woodbridge Clay, outcrops in a northeast trending belt north and south of the Raritan River, and a buried diabase ridge of Triassic age underlies the Farrington Sand in the area of the Raritan River between Sayreville and Perth Amboy. The irregular nature of this diabase ridge does not provide a complete seal to groundwater movement in the Farrington Sand, and allows salt water from the Raritan River, the South River, and the Washington Canal to move eastward into the Farrington Sand.

Salt-water encroachment was confirmed by a series of test

wells installed between Parlin and the Washington Canal in 1937 and 1938, and chloride analyses showed that salt water had moved a considerable distance eastward in the Farrington Sand. The position and movement of the salt-water front was observed for about five years, and the data were interpreted by Barksdale and others in 1943.

The historical advance of salt-water encroachment in the Farrington Sand is shown in Figure 28. In 1943, the position of the 10-mg/l isochlor indicated salt-water movement toward Parlin, and major industrial water supplies in the Farrington Sand were abandoned. The duPont, Hercules, and National Lead Companies turned to the Old Bridge Sand to the southwest and had Old Bridge water piped to their plants.

Reduced industrial pumpage from the Farrington Sand slowed salt-water encroachment for some time. However, municipal pumpage increased considerably, and salt water again moved inland. By 1958, the 10-mg/l isochlor had moved inland in places as much as 2/3 of a mile, apparently in response to the increased municipal pumpage from the Farrington Sand south of the Raritan River (5.1 mgd in 1943 to 7.8 mgd in 1958). Moreover, an apparent change in the direction of movement of this salty wedge can be traced to a major reduction in pumpage from the Farrington Sand in Sayreville, and a corresponding increase in pumpage from the Farrington at Madison, East Brunswick, and Spotswood. In 1943, total pumpage in Sayreville

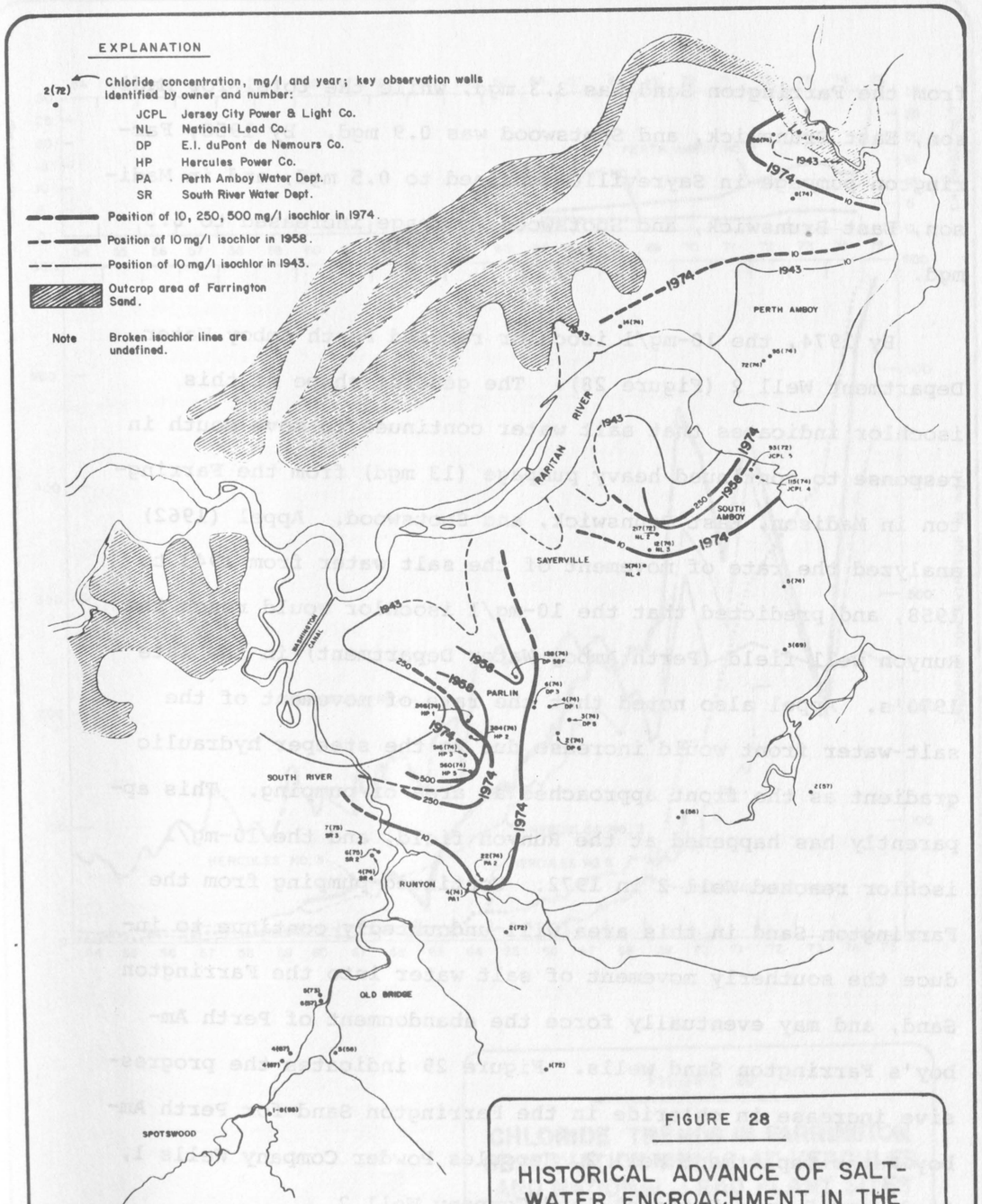


FIGURE 28

HISTORICAL ADVANCE OF SALT-WATER ENCROACHMENT IN THE FARRINGTON SAND

NEW JERSEY STATEWIDE WATER SUPPLY MASTER PLAN

from the Farrington Sand was 3.3 mgd, while the total for Madison, East Brunswick, and Spotswood was 0.9 mgd. By 1958, Farrington pumpage in Sayreville declined to 0.5 mgd, and in Madison, East Brunswick, and Spotswood, pumpage increased to 6.3 mgd.

By 1974, the 10-mg/l isochlor reached Perth Amboy Water Department Well 2 (Figure 28). The general shape of this isochlor indicates that salt water continues to move south in response to continued heavy pumpage (13 mgd) from the Farrington in Madison, East Brunswick, and Spotswood. Appel (1962) analyzed the rate of movement of the salt water from 1943 to 1958, and predicted that the 10-mg/l isochlor would reach the Runyon well field (Perth Amboy Water Department) in the late 1970's. Appel also noted that the rate of movement of the salt-water front would increase due to the steeper hydraulic gradient as the front approached an area of pumping. This apparently has happened at the Runyon field, and the 10-mg/l ischlor reached Well 2 in 1972. Continued pumping from the Farrington Sand in this area will undoubtedly continue to induce the southerly movement of salt water into the Farrington Sand, and may eventually force the abandonment of Perth Amboy's Farrington Sand wells. Figure 29 indicates the progressive increase in chloride in the Farrington Sand for Perth Amboy Water Department Well 2, Hercules Powder Company Wells 1, 2, 3, and 5, and National Lead Company Well 2.

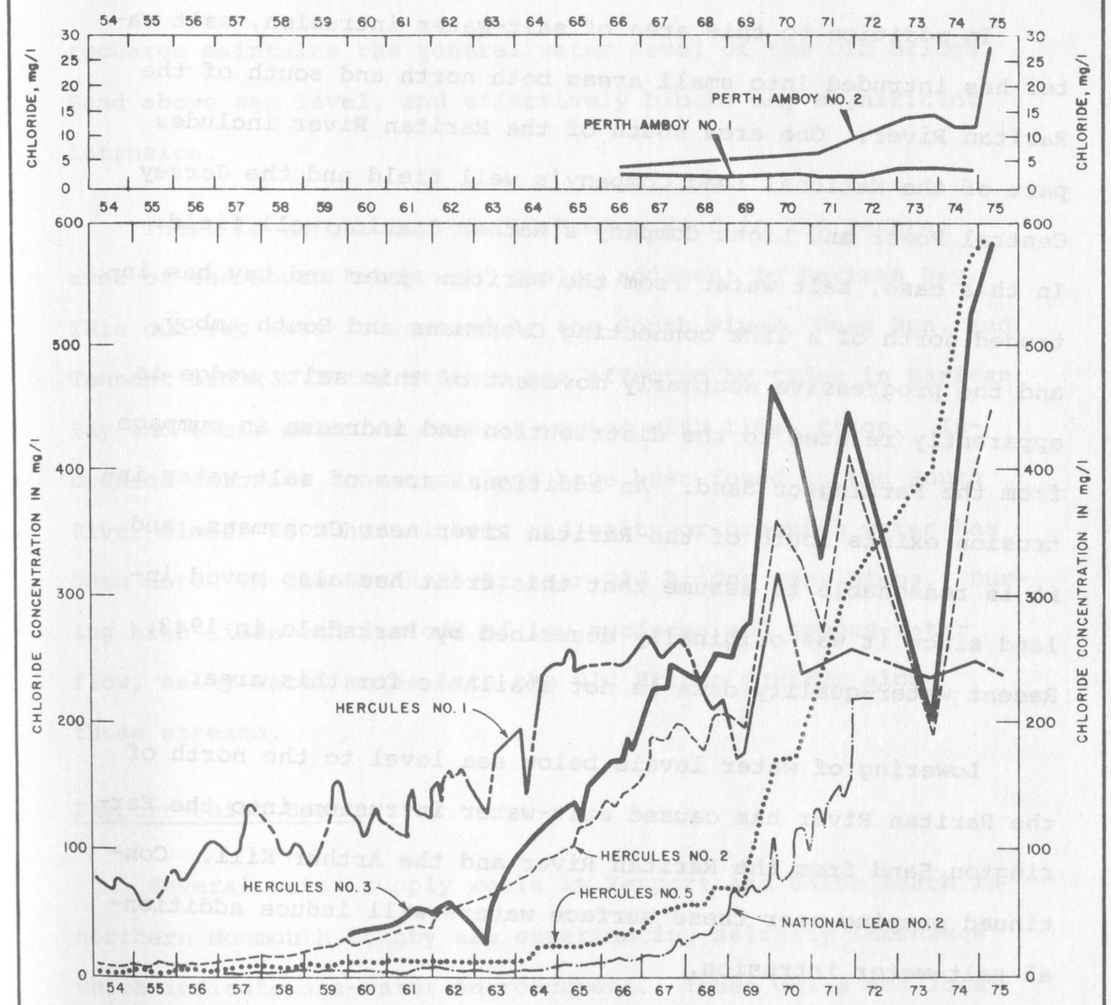


FIGURE 29

CHLORIDE TRENDS IN FARRINGTON OBSERVATION WELLS AT HERCULES AND NATIONAL LEAD PLANT SITES AND IN THE PERTH AMBOY WELLS

NEW JERSEY STATEWIDE WATER SUPPLY MASTER PLAN

In addition to this area of salt-water intrusion, salt water has intruded into small areas both north and south of the Raritan River. One area south of the Raritan River includes part of the National Lead Company's well field and the Jersey Central Power and Light Company's Warner Station well field. In this case, salt water from the Raritan River and bay has intruded north of a line connecting Crossmans and South Amboy, and the progressive southerly movement of this salty wedge is apparently related to the distribution and increase in pumpage from the Farrington Sand. An additional area of salt-water intrusion exists south of the Raritan River near Crossmans, and it is reasonable to assume that this front has also moved inland since it was originally described by Barksdale in 1943. Recent water-quality data is not available for this area.

Lowering of water levels below sea level to the north of the Raritan River has caused salt-water intrusion into the Farrington Sand from the Raritan River and the Arthur Kill. Continued pumping near these surface waters will induce additional salt-water intrusion.

Old Bridge Sand -

No widespread salt-water intrusion problems currently exist in the Old Bridge Sand and, although the Old Bridge aquifer is heavily pumped (30 mgd in 1974), most of this pumpage occurs in outcrop areas where the aquifer is recharged. This

recharge maintains the general water level of the Old Bridge Sand above sea level, and effectively blocks any significant intrusion.

There is an outcrop of Old Bridge Sand in the general area of the South Amboy well field, adjacent to Raritan Bay. This outcrop area is crossed by the South River, Deep Run, and Tennant Brook. These streams are affected by tides in Raritan Bay and their chloride content varies with tidal stage. Increased chloride concentrations have been found in the South River almost to Duhernal Dam, and salty or brackish water has been noted in the South River near Old Bridge many times. During high tides and periods of low surface- and ground-water flow, salty water moves into the Old Bridge aquifer along these streams.

Keyport-Union Beach

Several water supply wells in Keyport and Union Beach in northern Monmouth County are experiencing salinity increases which indicate sea-water encroachment. These wells are located along Raritan Bay and are completed in the Old Bridge Sand at 200 to 250 feet below the land surface. The aquifer is confined, but saline water may enter the sand through outcrop areas beneath Raritan Bay.

Keyport Well 6, located at the shoreline, had a chloride concentration of 66 mg/l in 1975. Keyport Well 5, located 500

feet inland, yielded water with 2 to 3 mg/l chloride in 1949, and 27 mg/l in 1975. The Union Beach wells are located about 2,000 feet inland along a tidal creek, and experienced a considerable increase in chloride since 1973 (Figure 30). Chloride levels in Well 1 increased from 11 mg/l in 1972 to 245 mg/l in 1977, and chloride in Well 2 increased from 3.5 mg/l in 1972 to 660 mg/l in 1977. These rapid increases in salinity indicate that the wells are located in the path of a salt-water tongue which appears to be moving in a southeasterly direction toward a large cone of depression (45 feet below sea level) caused by pumpage at Hazlet Township (Kam, 1977). No detailed studies have been made in this area to determine the lateral extent of encroachment, and further investigation is needed to evaluate the threat of salt-water intrusion on other municipal and industrial well fields serving the Keansburg area.

Atlantic City Region

Salt-water intrusion in the Atlantic City area is limited to the Cohansey Sand. Concern over potential sea-water encroachment in the Kirkwood Formation has lessened and, in spite of large declines in the potentiometric surface of the 800-foot sand, no significant increases in chloride concentrations have been discerned. The Cohansey Sand is salty (10,000 to 14,000 mg/l) at Atlantic City, but contains fresh water on the mainland. The 100- and 200-foot sands of the Cohansey For-

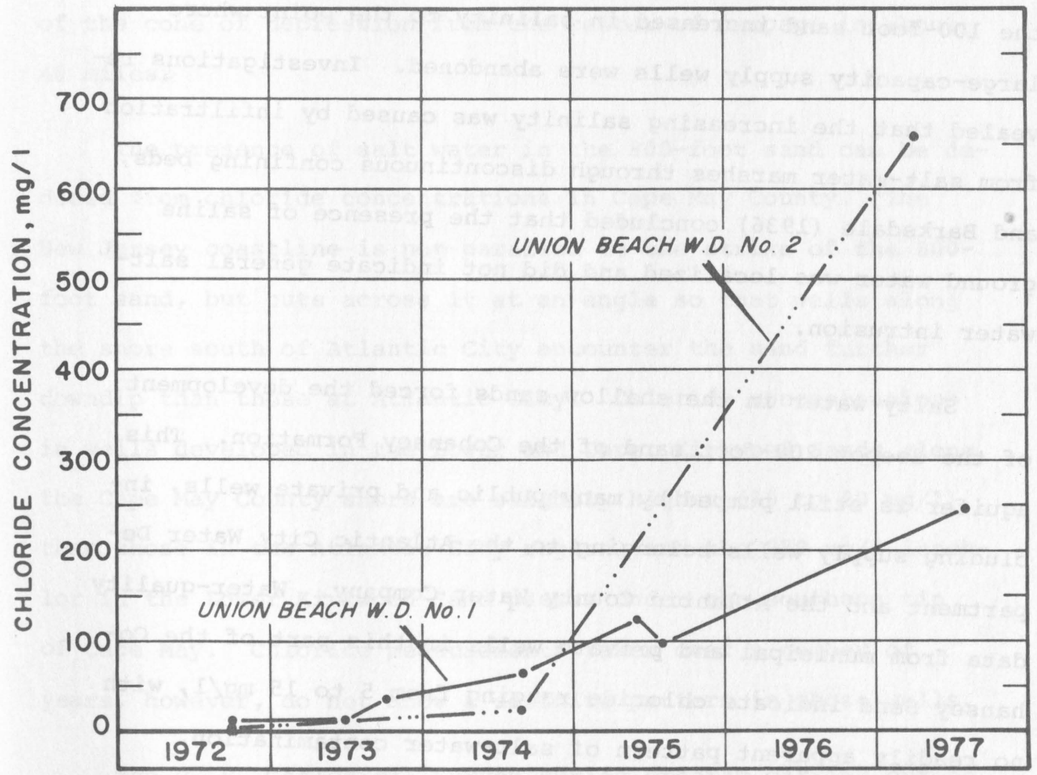


FIGURE 30

CHLORIDE TRENDS IN UNION BEACH WATER-SUPPLY WELLS, MONMOUTH COUNTY

NEW JERSEY STATEWIDE WATER SUPPLY MASTER PLAN

mation on the mainland were developed by the Atlantic City Water Works in the early 1930's; however, water obtained from the 100-foot sand increased in salinity to the point where large-capacity supply wells were abandoned. Investigations revealed that the increasing salinity was caused by infiltration from salt-water marshes through discontinuous confining beds, and Barksdale (1936) concluded that the presence of saline ground water was localized and did not indicate general salt-water intrusion.

Salty water in the shallow sands forced the development of the deeper 200-foot sand of the Cohansey Formation. This aquifer is still pumped by many public and private wells, including supply wells belonging to the Atlantic City Water Department and the Atlantic County Water Company. Water-quality data from municipal and private wells in this part of the Cohansey Sand indicate chloride ranging from 5 to 15 mg/l, with no readily apparent pattern of salt-water contamination. There has not been a detailed water quality study in this area in recent years.

The 800-foot sand of the Kirkwood Formation was originally developed in 1889, and the number of wells and resulting pumpage has increased rapidly. The potentiometric surface of the Kirkwood aquifer in the Atlantic City region declined from almost 25 feet above sea level in 1889, to 55 feet below sea level in 1924, and to 80 feet below sea level in 1934. Figure

31 indicates historical profiles of the cone of depression in the Atlantic City-Cape May County region. The radial distance of the cone of depression from the center of pumpage is about 40 miles.

The presence of salt water in the 800-foot sand can be deduced from chloride concentrations in Cape May County. The New Jersey coastline is not parallel to the strike of the 800-foot sand, but cuts across it at an angle so that wells along the shore south of Atlantic City encounter the sand further downdip than those at Atlantic City. Chloride concentrations in wells developed in the Lower and Upper Kirkwood Sands along the Cape May County shore are slightly higher (10 to 20 mg/l) than those in the Atlantic City region, and the 250 mg/l isochlor in the Lower Kirkwood Sand passes under the southern tip of Cape May. Chloride measurements taken over a number of years, however, do not show a definite pattern in these wells.

The U. S. Geological Survey coring program carried out on the continental margin indicates that relatively fresh ground water is present at a considerable distance offshore, and this might explain the fact that no significant salt-water encroachment has taken place in the 800-foot sand, despite the existence of the large cone of depression in the potentiometric surface of the aquifer.

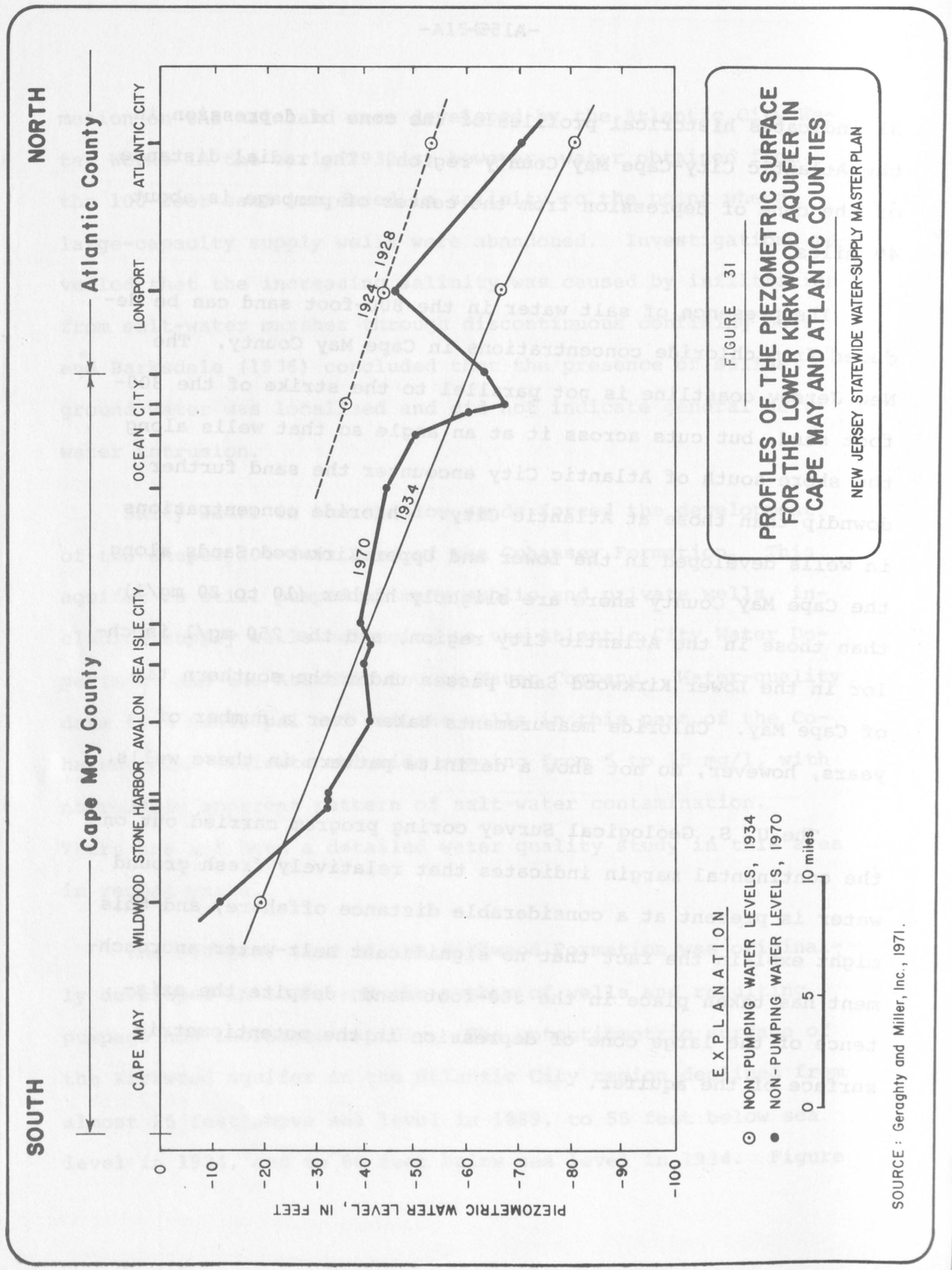


FIGURE 31

PROFILES OF THE PIEZOMETRIC SURFACE FOR THE LOWER KIRKWOOD AQUIFER IN CAPE MAY AND ATLANTIC COUNTIES

NEW JERSEY STATEWIDE WATER-SUPPLY MASTER PLAN

397-31

Cape May County

Cape May County is a peninsula extending into the ocean at the southernmost tip of the state, and its population and pumpage are concentrated along the coast. Five aquifers in the area yield fresh water; the unconfined Holly Beach aquifer, confined aquifers in the Estuarine Sand facies of the Cape May Formation, the Cohansey Sand, and the Upper and Lower Sands of the Kirkwood Formation (the latter of which is equivalent to the 800-foot sand of the Atlantic City region). Most pumpage is from the Cohansey Sand, the Kirkwood Formation, and the Holly Beach aquifer. Gill (1962) studied the stratigraphy and water quality in the principal aquifers and described salt-water encroachment patterns in detail. A later study by Geraghty & Miller, Inc. (1971) updated pumpage, water-level and chloride data, and recalculated the regional fresh-water budget.

The hydrologic regime of the Cape May peninsula is complicated because it is surrounded by salt water, and replenishment occurs through precipitation recharged through the Holly Beach water-table aquifer. The area's artesian aquifers are recharged by vertical leakage, and much of this leakage takes place offshore where the upper beds contain saline water. Fresh ground water can be developed from the artesian aquifers with relatively little salt-water encroachment because a portion of the water pumped originates from natural storage, and not from leakage.

Heads in both the Cohansey and the Kirkwood have declined sharply as a result of pumping. Heads in the Cohansey Sand are below sea level in the southern half of the Cape May peninsula, and reached 15 feet below sea level in the Cape May City-Cape May Point area in 1969. Pumping in the Rio Grande well field at Cape May Point and Cape May City has formed extensive cones of depression, each many miles in diameter. Seasonal low water levels range from 25 to 30 feet below sea level.

Heads in the Lower Kirkwood have been below sea level for over 60 years, with the hydraulic gradient inclined northward and eastward towards the center of pumpage in the Atlantic City region. Water-level trends on hydrographs are trending downward, and a further decline of the potentiometric surface of the Kirkwood may reasonably be expected to occur in the future.

Heads in the Estuarine Sand are above sea level except along the coast at Villas, and at the Rio Grande pumping facility, where summer pumpage causes water levels to decline as much as 5 feet below sea level. This water-level decline may be due, in part, to induced leakage downward from this aquifer into the heavily pumped Cohansey Sand.

The Holly Beach aquifer is pumped by private wells as well as at the Rio Grande well field. The aggregate pumpage, however, is small (2 mgd in 1970), and water levels in the

aquifer are above sea level.

Saline ground water on the Cape May peninsula has been found in both water-table and confined aquifers. Most of these occurrences have been local in nature, and regional salt-water intrusion does not appear to be a cause for immediate concern. The occurrence of saline water in each aquifer is summarized below.

AQUIFERS AFFECTED BY SALT-WATER INTRUSION

Holly Beach Water-Bearing Zone

The Holly Beach is an unconfined aquifer, and is in direct hydraulic contact with surface-water bodies. Lowered heads in the Holly Beach, to a point equal to or lower than heads in surface-water bodies, will induce the infiltration of salty surface waters into the aquifer from Delaware Bay, tidal streams and marshes.

Chloride in excess of 250 mg/l occurs near Bidwell Ditch, Pierces Point, Fishing Creek, and from North Cape May to Cape May Point, where wells tapping the Holly Beach have been installed near salty or brackish surface waters. Chloride contamination appears to be a local problem and indicates that wells were drilled too close to potential sources of salt water. There is no evidence of overall progressive salt-water encroachment in the aquifer.

Estuarine Sand

No changes or trends in chloride concentration in this aquifer have been noted, with the exception of the Fishing Creek drainage area near Del Haven and Villas. Local pumping in this area has lowered the potentiometric head below sea level, and several observation wells show chloride concentrations above 250 mg/l. Further contamination of this area can be expected over time, but current problems are local in nature, and there is no general threat to the aquifer at this time.

Cohansey Sand

Chloride concentrations in wells at Wildwood, West Cape May, Cape May City, and at the Coast Guard Station near Cape May have increased slightly over the years. Salty water was present in the Cohansey near the southern end of the peninsula before any wells were drilled, and when pumping started, wells situated closest to the zone of diffusion were the first to be affected. Figure 32 shows the location of water supply and monitoring wells in the Cohansey Sand near Cape May City, chloride concentrations in 1976, and the position of the various isochlors. These isochlors are generally in the same position as in 1958 (Gill, 1962), indicating that no appreciable saltwater encroachment has occurred.

Chloride trends since 1968 for four wells in the Cape May City and Cape May Point areas are illustrated in Figure 33.

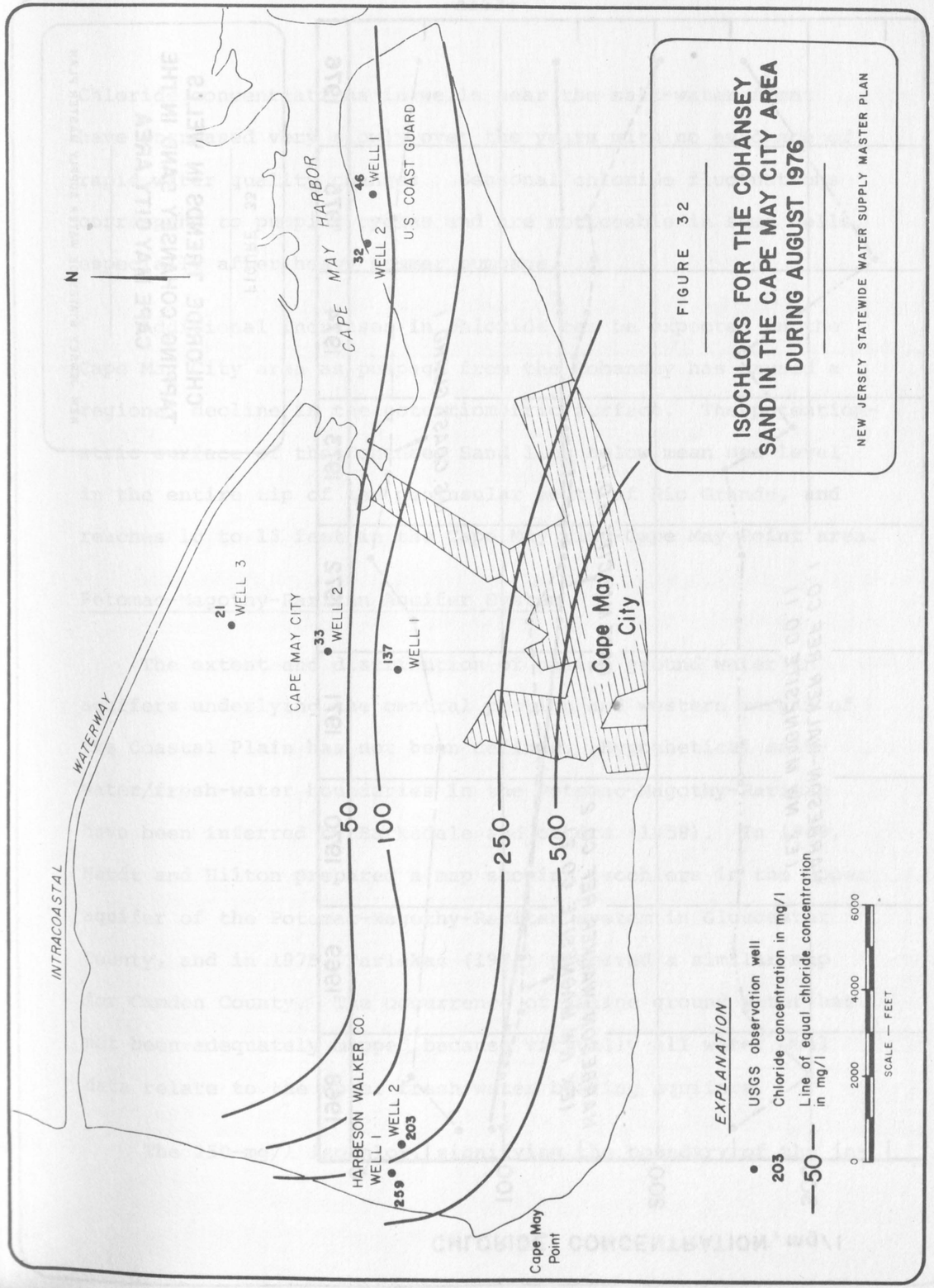


FIGURE 32

ISOCHLORS FOR THE COHANSEY SAND IN THE CAPE MAY CITY AREA DURING AUGUST 1976

NEW JERSEY STATEWIDE WATER SUPPLY MASTER PLAN

397-32

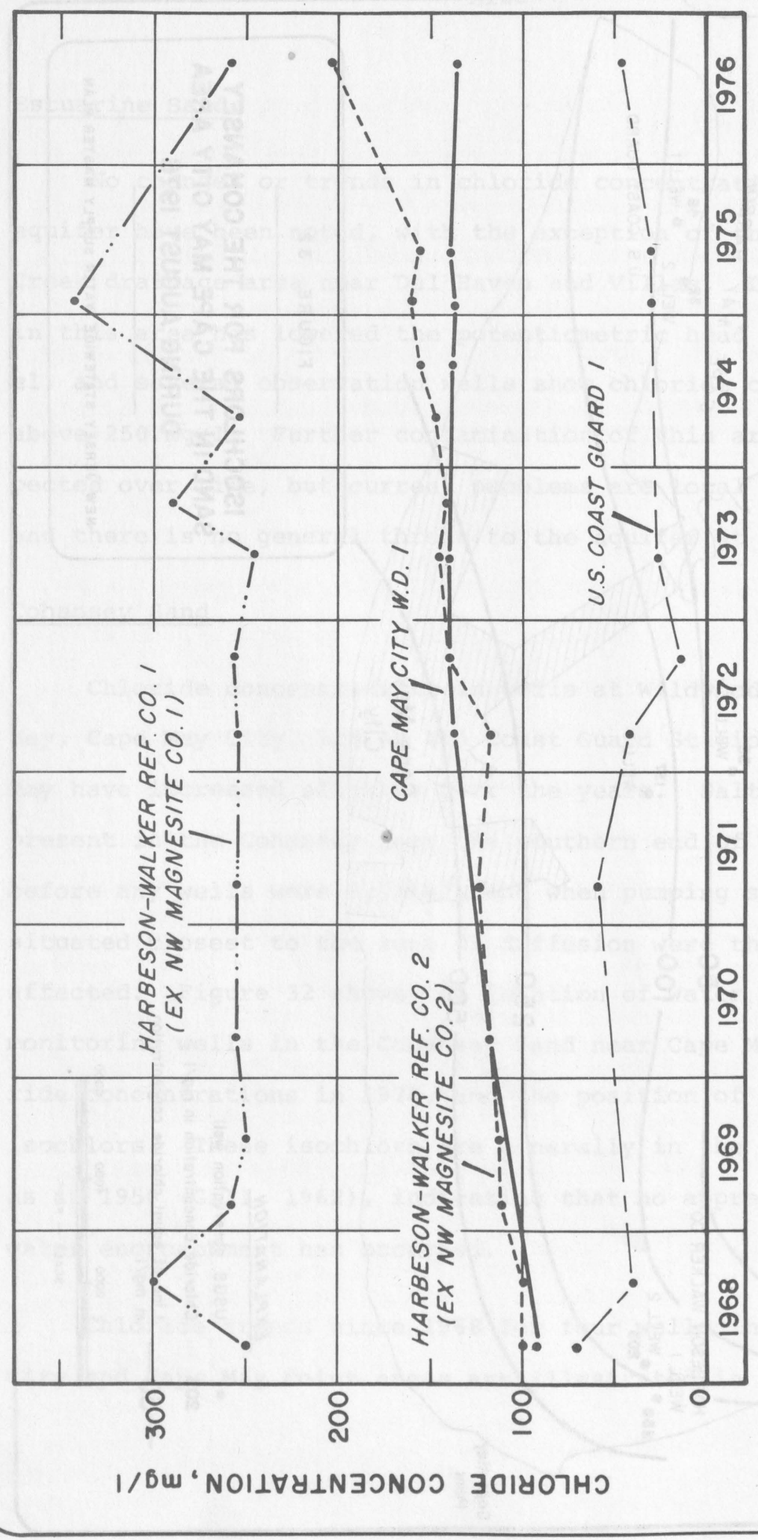


FIGURE 33

CHLORIDE TRENDS IN WELLS TAPPING COHANSEY SAND IN THE CAPE MAY CITY AREA

NEW JERSEY STATEWIDE WATER SUPPLY MASTER PLAN

Chloride concentrations in wells near the salt-water front have increased very slowly over the years with no evidence of rapid water quality changes. Seasonal chloride fluctuations correspond to pumping cycles and are noticeable in some wells, especially after heavy summer pumpage.

Additional increases in chloride can be expected in the Cape May City area as pumpage from the Cohansey has caused a regional decline in the potentiometric surface. The potentiometric surface of the Cohansey Sand lies below mean sea level in the entire tip of the peninsular south of Rio Grande, and reaches 10 to 15 feet in the Cape May City-Cape May Point area.

Potomac-Magothy-Raritan Aquifer System

The extent and distribution of saline ground water in aquifers underlying the central portion and western margin of the Coastal Plain has not been defined. Hypothetical salt-water/fresh-water boundaries in the Potomac-Magothy-Raritan have been inferred by Barksdale and others (1958). In 1969, Hardt and Hilton prepared a map showing isochlors in the upper aquifer of the Potomac-Magothy-Raritan system in Gloucester County, and in 1975, Farlekas (1976) prepared a similar map for Camden County. The occurrence of saline ground water has not been adequately mapped because virtually all water well data relate to the upper fresh-water bearing aquifers.

The 250-mg/l isochlor, signifying the boundary of the in-

terface zone in the non-marine Cretaceous beds, lies along a gently curved line that crosses New Jersey diagonally from the ocean beach near Manasquan to a point on Delaware Bay about 8 miles south of Salem (Figure 26). Salt water underlies about half of the Coastal Plain in the non-marine Cretaceous sediments, and pumpage from wells close to the 250-mg/l line, e.g. in central Salem, Gloucester, Burlington, and Ocean Counties, could cause salt-water intrusion. Well records and chloride data are not sufficient to determine whether any inland migration of the 250-mg/l isochlor has taken place.

The Potomac-Magothy-Raritan system outcrops along the Delaware River in densely populated and industrialized areas and is heavily pumped. The thickness of the combined Potomac-Magothy-Raritan aquifer system is 500 feet in Gloucester County, 840 feet in Camden County, and 2,000 feet in Burlington County, with individual aquifer zones about 50 to 150 feet thick. The aquifer system along the Delaware River is separated into an upper unit consisting mainly of Magothy Formation sands, and middle and lower units consisting of Raritan Formation and Potomac Group sands. The upper aquifer, which is heavily pumped, is generally in hydraulic connection with the overlying Pleistocene deposits, and locally may be under water-table conditions. The lower zone is artesian with a maximum aquifer thickness of 50 feet and is separated from the upper zone by clay. The two aquifer zones are distinct in the outcrop area, but cannot be identified further southeast because the clays and sands are discontinuous. The lower aquifer zone of the Potomac-Magothy-Raritan has not been developed because sufficient fresh water has been available from the upper zone, and there are indications that the lower sand contains brackish water. This saline water may be connate water which is naturally present in the sediments. Saline ground water along the Delaware River is a result of the intrusion of saline surface water into the water-table aquifer, and the upward coning of saline ground water into fresh-water zones.

Chloride concentrations in the Delaware River and its tidal streams fluctuate depending on seasonal flow and climatic conditions. During drought periods the saline front advances far up the Delaware River and then recedes as river flow increases. The chloride concentration of the Delaware River at the Delaware Memorial Bridge ranged from less than 10 mg/l to 4,500 mg/l during the 1955-56 period (Rosenau and others, 1969).

Heavy pumpage of the Potomac-Magothy-Raritan along the Delaware River has resulted in a considerable decline in water levels. For Camden, Gloucester, and Burlington Counties, 24 public supply systems and 28 major industrial facilities pumped 124 mgd in 1975, and virtually all of this pumpage (118 mgd) was derived from the Potomac-Magothy-Raritan system. The

potentiometric surface of the aquifer system has declined to below sea level in the entire Salem, northern Gloucester, Camden, and Burlington Counties region. Moreover, deep cones of depression 80 to 90 feet below sea level have formed in the Camden area southward to the Town of Berlin, westward along the Gloucester-Camden border, and at Mount Holly in Burlington County. Heads along the Delaware River are now well below sea level in many places and provide conditions for the movement of river water into the Potomac-Magothy-Raritan aquifer system.

Pumping test data indicate that some 60 percent of current ground-water pumpage may be induced Delaware River water and, where saline water is present in the Delaware River, salty water will enter the aquifer and begin to move along the hydraulic gradient towards pumping centers.

The full impact of saline river water infiltration on the Potomac-Magothy-Raritan aquifer system is unknown. Water-quality changes have taken place along the Delaware River as indicated by anomalously high chloride concentrations in the Camden area. Langmuir (1969) indicated that large-scale pumpage in Camden County, coupled with reduced pumpage across the Delaware River in Philadelphia, caused polluted ground water to migrate from the Philadelphia area into Camden County. Although this may have taken place, waste disposal practices in Camden County may also be a major cause of degraded water quality there.

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REGIONS WHERE THE GROUND-WATER RESERVOIR IS STRESSED BY PUMPING

Ground water is the most important source of fresh water in the New Jersey Coastal Plain. As the Coastal Plain became urbanized and industrial development increased, the demand for ground water also increased. Ground-water withdrawals from the major aquifers increased steadily, and in some areas, exceeded natural recharge. The impact of ground-water development on the potentiometric surface of each major Coastal Plain aquifer is described below.

COHANSEY SAND

The Cohansey Sand is essentially a water-table aquifer. In some areas it is overlain by a thin veneer of Quaternary deposits which readily absorb and transmit precipitation.

Except for seasonal population increases along the seaside resort areas of Ocean, Atlantic, and Cape May Counties, population densities and industrial water demands in the outcrop area of the Cohansey are light. Total reported pumpage from this aquifer was about 50 mgd in 1976, with Cumberland and Atlantic Counties each pumping about 35 percent of the total (Water Resources Engineers, 1977a and b). The general lack of water-level data makes it very difficult to determine how this pumpage impacts the potentiometric surface, but water-

level declines caused by pumping seem limited to Cape May County.

Water levels in wells tapping the Cohansey aquifer in Cape May County range from a few feet above sea level to about 25 feet below sea level, with most water levels below sea level. A long-term downward trend of 0.4 foot per year is evident in these wells. The trend is indicated by data for the Cape May Canal No. 5 Well which was 8 feet below sea level in December 1957, and had declined to 18.4 feet below sea level in March 1977. Fluctuations in water levels caused by seasonal pumpage range from 5 to almost 20 feet in one year (U. S. Geological Survey, 1977).

KIRKWOOD FORMATION

The Kirkwood Formation is a heavily pumped major aquifer in the southeastern Coastal Plain. Nearly all of the 25-mgd total reported pumpage in 1976 was withdrawn along the shore and barrier beaches in Atlantic, Ocean, and Cape May Counties, and summer pumpage can be as much as three to four times the winter pumpage. Although the upper and lower aquifers of the formation have been developed, there has been extensive pumpage only from the lower aquifer, the 800-foot sand.

The first wells were drilled to the 800-foot sand in the Atlantic City region during the late 1880's. Static water levels at that time were 20 to 25 feet above sea level. In 1924,

however, the water level in an observation well near the center of pumpage was 54 feet below sea level during the summer. Annual average pumpage was slightly over 6 mgd in the 1920's. By 1929, pumpage had increased to about 9.5 mgd, and the water level in the same observation well dropped to 84 feet below sea level during the summer. From 1929 to 1934, pumpage declined to about 7 mgd, and water levels gradually rose, although they were still below sea level over a considerable area (Clark and others, 1968).

Figure 34 presents a long-term hydrograph of an observation well (Galen Hall) in Atlantic City from 1948 (U. S. Geological Survey, 1977). Water levels in this well, located near the center of the cone of depression, were about 50 feet below sea level in the winter and about 65 feet below sea level in the summer during the late 1940's. After a slight decline in the early 1950's, water levels recovered until the onset of a drought in 1963. During this period, water levels during the winter dropped to 60 feet below sea level. Between 1969 and 1972 water levels recovered and reached a high of 50 feet below sea level. Since that time, water levels have declined slightly. Another well in the area (Jobs Point) indicates a general water-level decline through the 1960's which has apparently stabilized (U. S. Geological Survey, 1977).

Rhodehamel (1973) reports that the configuration of the potentiometric surface of the Kirkwood Formation in the Mulli-

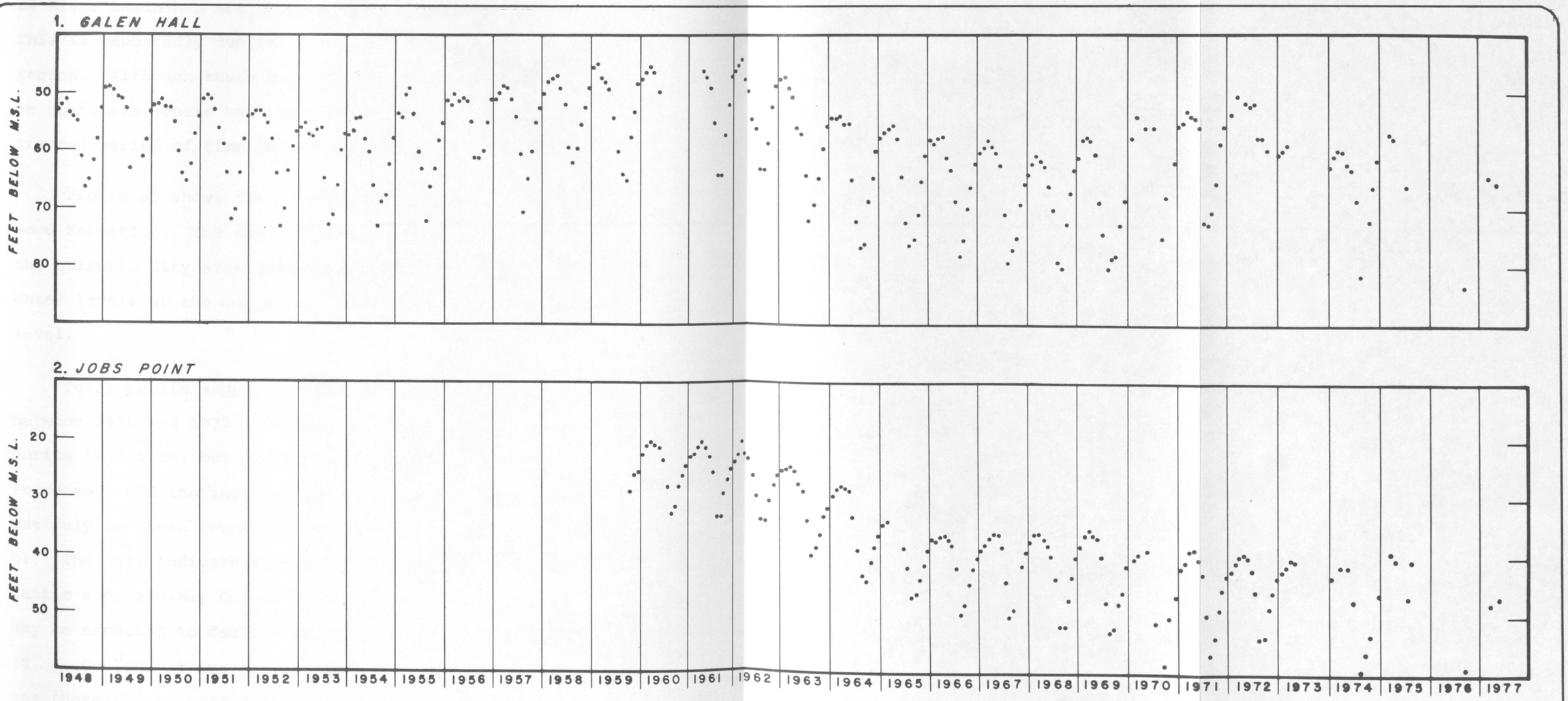


FIGURE 34

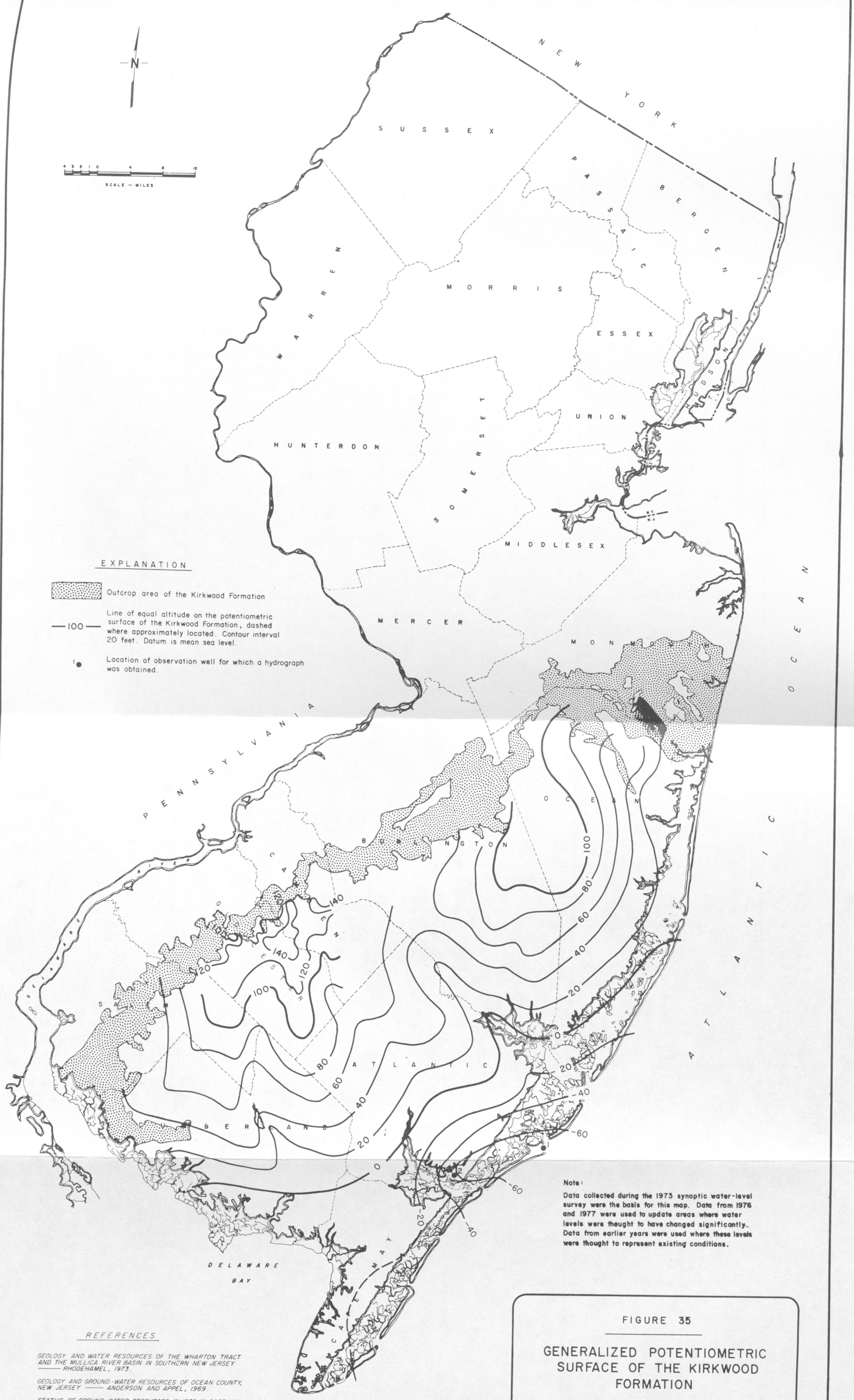
HYDROGRAPHS OF OBSERVATION WELLS
IN THE KIRKWOOD FORMATION

NEW JERSEY STATEWIDE WATER SUPPLY MASTER PLAN

ca River basin has not changed significantly in recent years. This is reportedly due to little variation in pumping in this region. Although there have been no large-scale withdrawals in the basin, there have been small losses in head over a protracted period of time caused (possibly) by artesian flow.

Figure 35 shows the potentiometric surface of the Kirkwood Formation. The map indicates a cone of depression around the Atlantic City area extending southwest to Cape May County. Water levels at the center are more than 70 feet below sea level.

Total public supply pumpage from the Kirkwood increased between 1970 and 1975. Pumpage in Atlantic County decreased during this time, but pumpage in Cape May and Ocean Counties increased, and the increase in total pumpage occurred almost entirely in Ocean County (Water Resources Engineers, 1977a and b). The data indicate that water levels have stabilized in Atlantic and Cape May Counties, but water levels in Ocean County may be expected to decline in response to increased pumpage (U. S. Geological Survey, 1977). Although public supply pumpage increased by nearly 300 percent from 1935 to 1970, water levels along the coast between Atlantic City and Wildwood have remained essentially unchanged (Figure 31) because the pattern of ground-water withdrawal has shifted (Geraghty & Miller, Inc., 1971).



Note:

Data collected during the 1973 synoptic water-level survey were the basis for this map. Data from 1976 and 1977 were used to update areas where water levels were thought to have changed significantly. Data from earlier years were used where these levels were thought to represent existing conditions.

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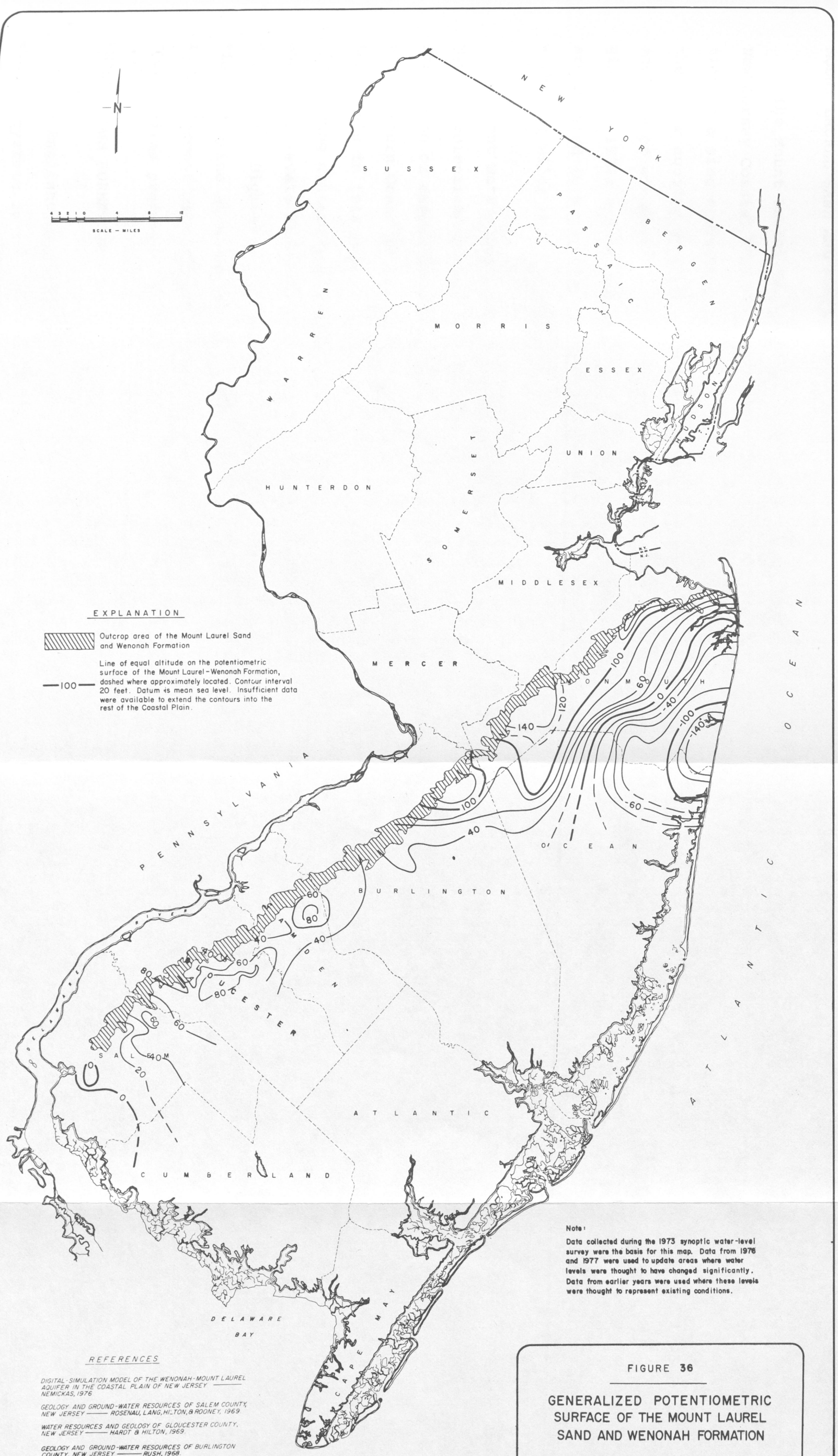
WATER-LEVEL FILES OF OBSERVATION WELLS IN NEW JERSEY —— U.S. GEOLOGICAL SURVEY, 1977.

FIGURE 35

GENERALIZED POTENTIOMETRIC SURFACE OF THE KIRKWOOD FORMATION

NEW JERSEY STATEWIDE WATER SUPPLY MASTER PLAN

Geraghty & Miller, Inc.



Note:

Data collected during the 1973 synoptic water-level survey were the basis for this map. Data from 1976 and 1977 were used to update areas where water levels were thought to have changed significantly. Data from earlier years were used where these levels were thought to represent existing conditions.

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FIGURE 36

GENERALIZED POTENTIOMETRIC SURFACE OF THE MOUNT LAUREL SAND AND WENONAH FORMATION

NEW JERSEY STATEWIDE WATER SUPPLY MASTER PLAN

Geraghty & Miller, Inc.

MOUNT LAUREL SAND AND WENONAH FORMATION

The Mount Laurel Sand and the Wenonah Formation in the New Jersey Coastal Plain are hydraulically connected and function as a single aquifer. It is the least developed of all the major aquifer systems in the Coastal Plain, with an average rate of withdrawal of 3.4 mgd in 1976 (Water Resources Engineers, 1977a and b). Most of the wells tapping this aquifer are located in a northeast-southwest trending belt that lies within 20 miles of the outcrop.

Recent water-level data from various sources were used to map the potentiometric surface (Figure 36), which indicates a large cone of depression along the coast of southern Monmouth and northern Ocean Counties. According to Nemickas (1976), water levels in this area declined by as much as 100 feet near the pumping centers in Monmouth County between 1959 and 1970, and water levels along the coast are now about 140 feet below sea level. Digital simulation models indicate that an additional decline in water levels of some 60 feet may be expected in the deepest part of the cone by 1978, with an additional 20-foot decline predicted for the fringe area (Nemickas, 1976).

ENGLISHTOWN FORMATION

The Englishtown Formation is one of the more important aquifer systems in the northern part of the Coastal Plain. Total withdrawal from this aquifer was 12 mgd in 1976, with most

pumpage occurring in Monmouth and Ocean Counties (5.3 and 6 mgd) (Water Resources Engineers, 1977a and b). Although the volume of water withdrawn from the Englishtown is small compared to other aquifer systems, it is sufficient to stress the aquifer.

The effects of heavy pumping on the Englishtown aquifer have been documented by Nichols (1977), who describes trends in water levels since 1960. Figure 37 indicates that the potentiometric surface prior to heavy pumping was generally above sea level, and above the land surface along coastal areas south of Long Branch, as well as in some inland areas.

Comparing the pre-pumping map to the potentiometric surface of the Englishtown in 1959 (Figure 38), it is evident that pumping has caused significant water-level declines. A decline of more than 100 feet occurred along the coast of southeastern Monmouth County, and the altitude of the potentiometric surface was below sea level over an area from Sandy Hook to west of Lakewood in Monmouth County. The average annual rate of water-level decline along the shore in Monmouth County was over 1.6 feet per year between 1900 and 1959 (Nichols, 1977).

A comparison of Nichols' 1959 potentiometric map with one derived from recent data (Figure 39) indicates a steep decline in water levels with a pumping-related cone of depression cov-

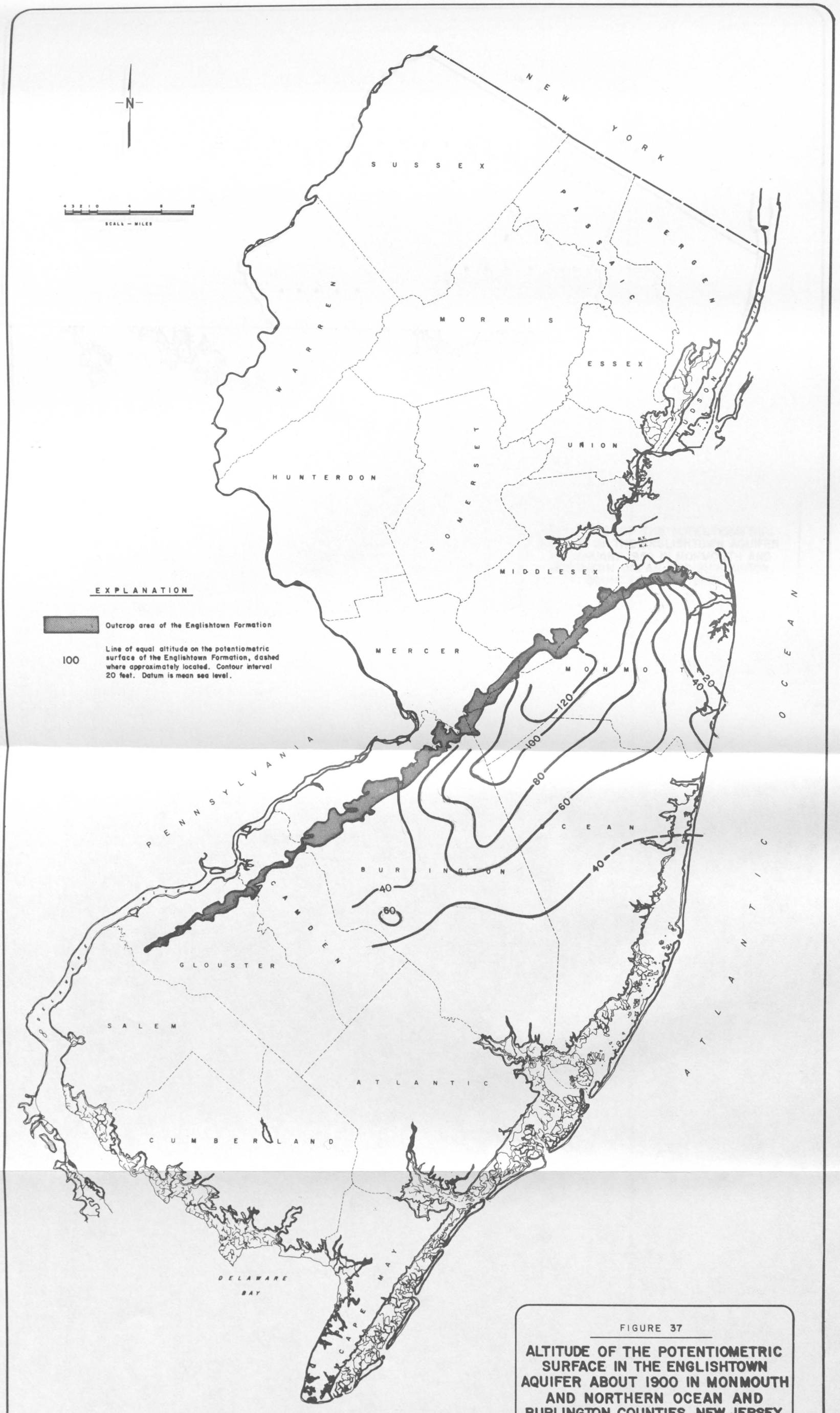


FIGURE 37

ALTITUDE OF THE POTENTIOMETRIC SURFACE IN THE ENGLISHTOWN AQUIFER ABOUT 1900 IN MONMOUTH AND NORTHERN OCEAN AND BURLINGTON COUNTIES, NEW JERSEY

NEW JERSEY STATEWIDE WATER-SUPPLY MASTER PLAN

Geraghty & Miller, Inc.

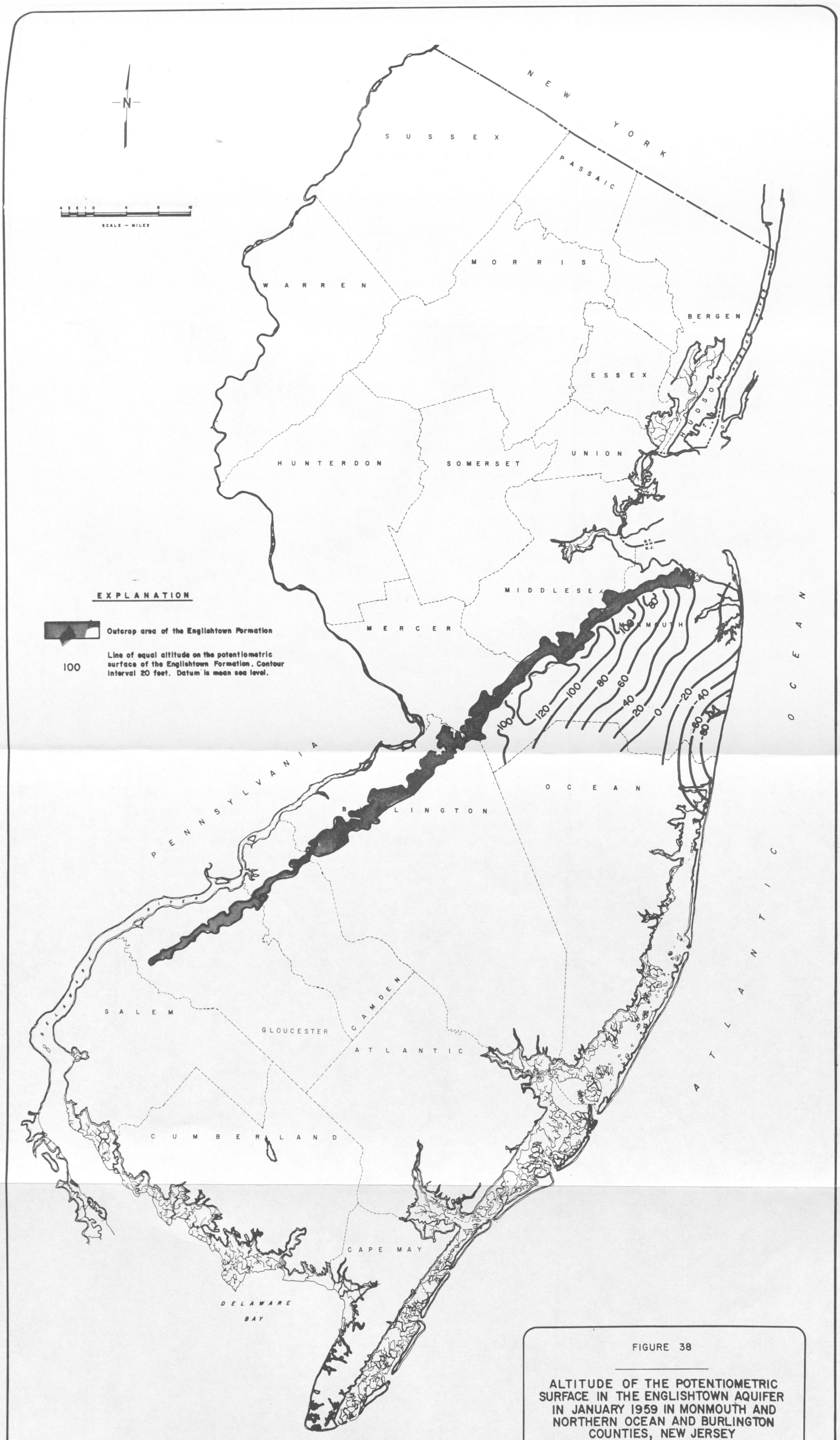
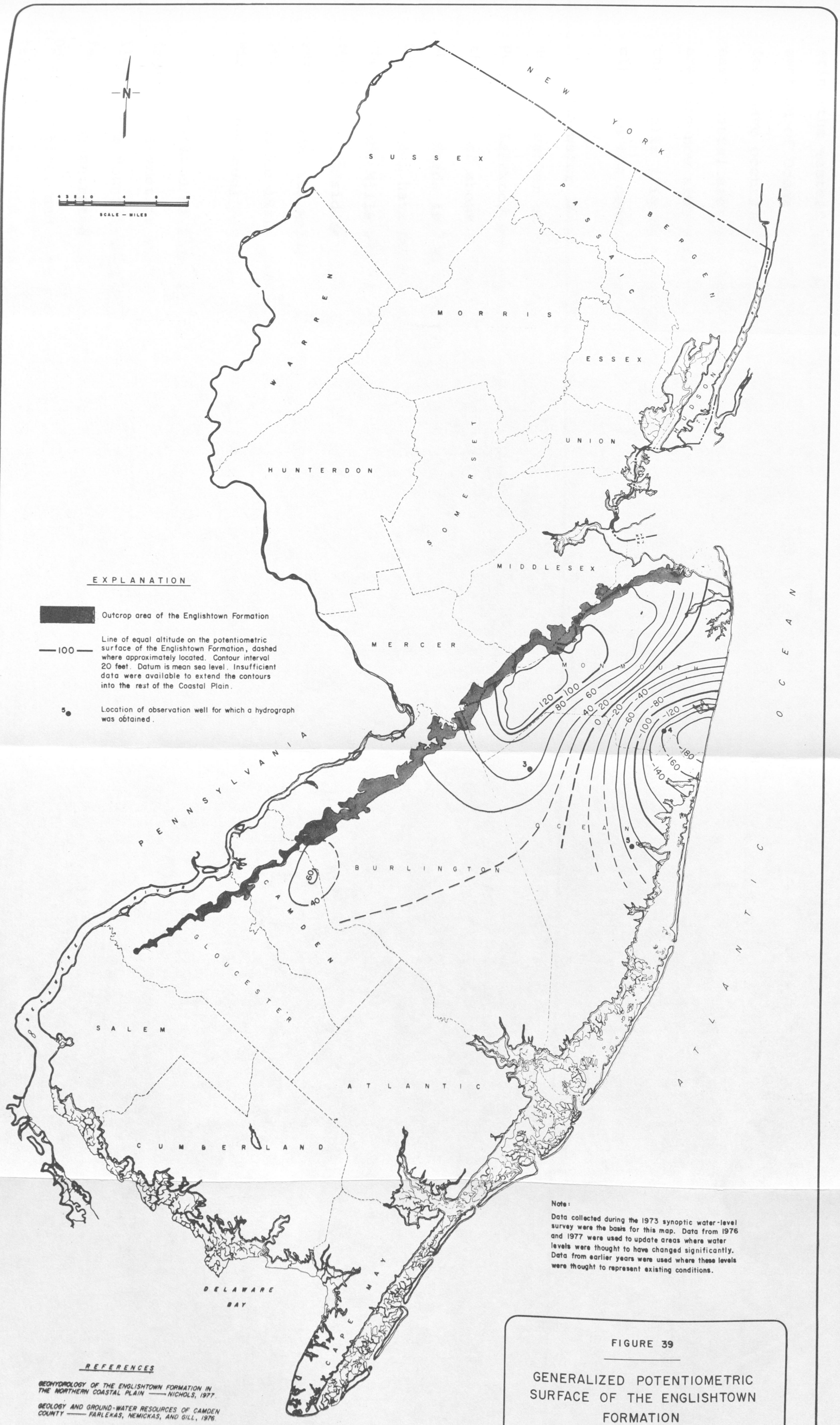


FIGURE 38

ALTITUDE OF THE POTENTIOMETRIC SURFACE IN THE ENGLISHTOWN AQUIFER IN JANUARY 1959 IN MONMOUTH AND NORTHERN OCEAN AND BURLINGTON COUNTIES, NEW JERSEY

NEW JERSEY STATEWIDE WATER SUPPLY MASTER PLAN

Geraghty & Miller, Inc.


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NEW YORK
SUSSEX
PASSAIC
BERGEN
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HUNTERDON
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MERCER
MONMOUTH
OCEAN
PENNSYLVANIA
BURLINGTON
CAMDEN
GLOUCESTER
SALEM
ATLANTIC
CUMBERLAND
DELAWARE BAY
CAPE MAY
ATLANTIC OCEAN
DELAWARE RIVER
EXPLANATION
Outcrop area of the Englishtown Formation
100
Line of equal altitude on the potentiometric surface of the Englishtown Formation, dashed where approximately located. Contour interval 20 feet. Datum is mean sea level. Insufficient data were available to extend the contours into the rest of the Coastal Plain.
5
Location of observation well for which a hydrograph was obtained.
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ering the eastern half of Monmouth County and the northeastern section of Ocean County. Water-level declines of over 100 feet have occurred at the center of the cone along the southeast coastal area of Monmouth County, and water levels in this area are now almost 200 feet below sea level. Hydrographs of three wells (Figure 40) demonstrate significant water-level declines in the cone of depression.

The water level in the Allaire State Park well, located near the center of the cone between the two main centers of pumping (Lakewood and southern Monmouth coast), has declined at a rate of about 9 feet per year since the well was drilled in 1964. Heads in the Toms River well, near the coast in Ocean County, have declined about 3.5 feet per year since 1966. The Colliers Mills well in the northwest corner of Ocean County was not considered located in an area that was impacted by pumping, but its water level has declined more than one foot per year since 1966. Based on extrapolated trends, the area-wide water-level decline can be expected to continue.

Comparison of Figures 36 and 39 indicate that the generalized potentiometric surface of the Englishtown aquifer is similar to the Mount Laurel-Wenonah. Development of both aquifers is concentrated in southeastern Monmouth and northeastern Ocean Counties, and both aquifers show severely depressed water levels in this area. Pumping from the Englishtown aquifer has had a marked effect on water levels in the overlying Mount

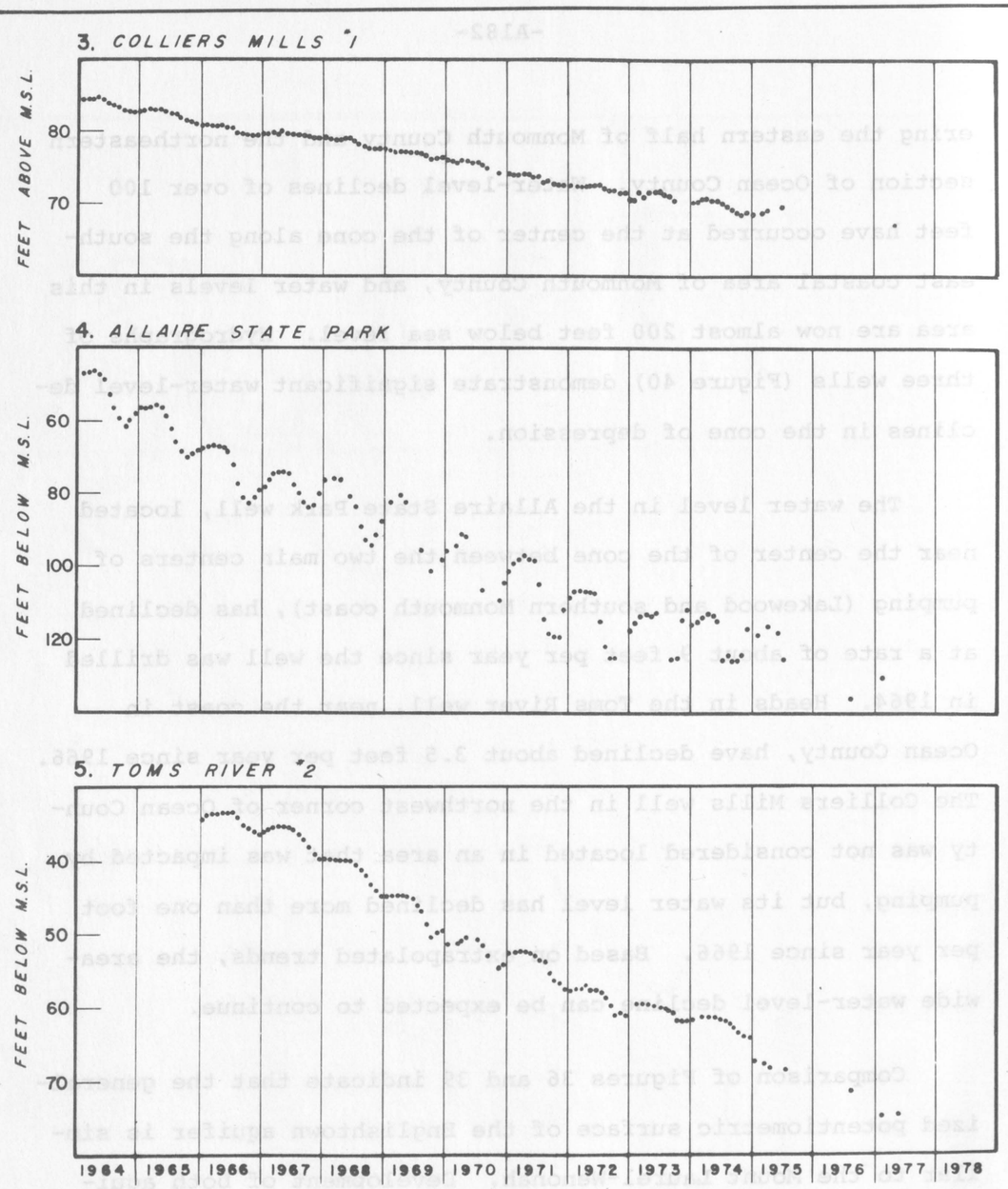


FIGURE 40

HYDROGRAPHS OF OBSERVATION WELLS IN THE ENGLISHTOWN FORMATION

NEW JERSEY STATEWIDE WATER SUPPLY MASTER PLAN

Laurel aquifer, and these effects can be expected to continue as long as water levels in the Englishtown continue to decline.

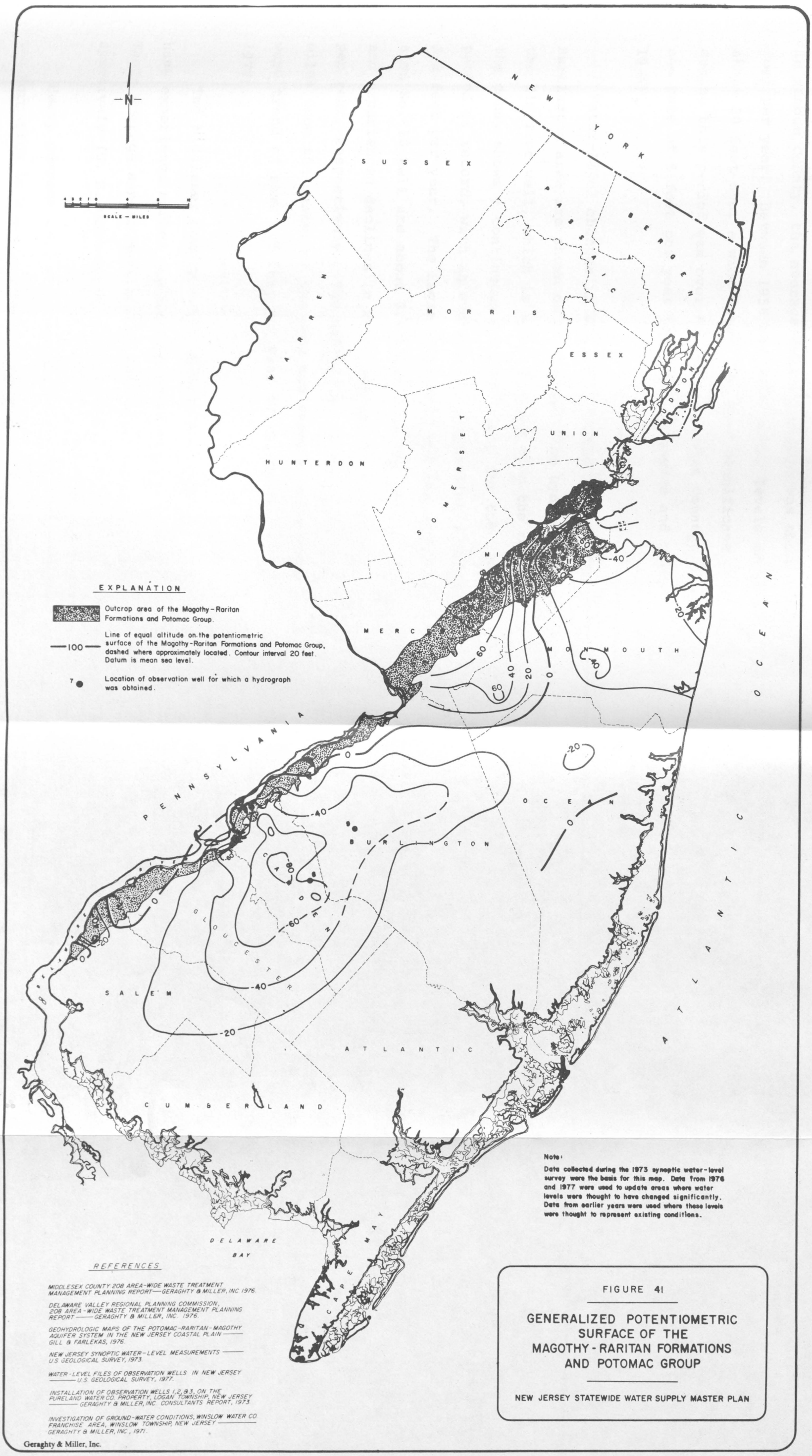
POTOMAC-MAGOTHY-RARITAN SYSTEM

The Potomac-Magothy-Raritan system is the most heavily developed and most widely utilized aquifer in the Coastal Plain with an average annual withdrawal of about 220 mgd in 1976 (Water Resources Engineers, 1977a and b).

According to Gill and Farlekas (1976), ground-water development caused cones of depression in Camden and Gloucester Counties as early as 1956, with water levels 30 feet below sea level. By 1968, the cones of depression widened to include Salem, Gloucester, Camden, and Burlington Counties. The cone of depression has intercepted the salt-water interface in the aquifer, and water levels throughout most of this area are below sea level.

A map of the generalized potentiometric surface of the Potomac-Magothy-Raritan aquifer system in 1973 (Figure 41), indicates cones of depression in areas of major ground-water development with some ground-water levels more than 80 feet below sea level.

Between 1900 and 1956, the ground-water decline in most areas of Salem, Gloucester, Camden, Burlington, Ocean, and Monmouth Counties was over 10 feet, and at the center of pumpage



Note:

Data collected during the 1973 synoptic water-level survey were the basis for this map. Data from 1976 and 1977 were used to update areas where water levels were thought to have changed significantly. Data from earlier years were used where these levels were thought to represent existing conditions.

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Geraghty & Miller, Inc.

FIGURE 41

GENERALIZED POTENTIOMETRIC SURFACE OF THE MAGOTHY-RARITAN FORMATIONS AND POTOMAC GROUP

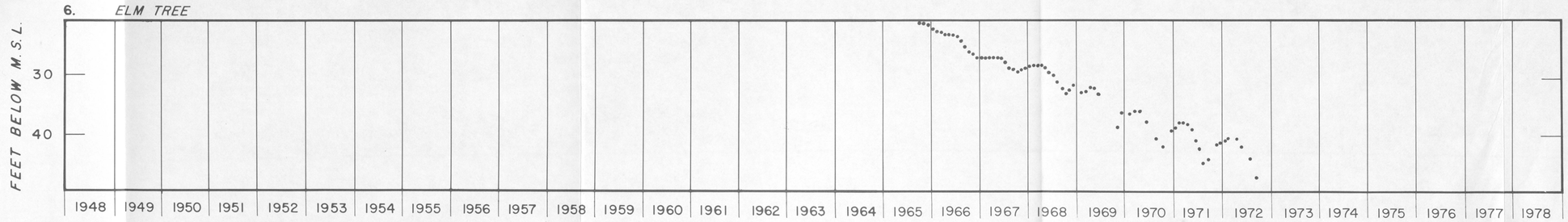
NEW JERSEY STATEWIDE WATER SUPPLY MASTER PLAN

in Camden County, the average rate of decline was about one foot per year. Between 1956 and 1968, water-levels declined about 30 feet over a wide area. The most significant decline during this period was over 60 feet in Camden County, an average rate of 5 feet per year (Farlekas, Nemickas and Gill, 1976).

Water-level changes in six wells in the Camden-Gloucester-Burlington area are shown on Figure 42. The hydrograph for the Elm Tree well, which is about 4 miles from the center of the cone, shows a continuous downward trend for the 12-year period of record, with an average rate of decline of almost 3.5 feet per year. The Eagle Point well and the Camden Division No. 10 Well are about 8.5 miles from the cone's center, and experienced declines in water levels of 0.8 and 0.9 feet per year, respectively. The Medford No. 1 Well is about 11 miles from the center of the cone and shows a continuous downward trend of some 2.5 feet per year (U. S. Geological Survey, 1977).

Two Middlesex County wells, Duhsay 4 and Runyon Old Deep, have experience marked declines in water levels since 1963. Their average annual declines in head were 3 and 4 feet, respectively (U. S. Geological Survey, 1977).

Heavy pumpage from the Farrington Sand Member of the Raritan Formation in Middlesex County has depressed the potentiom-



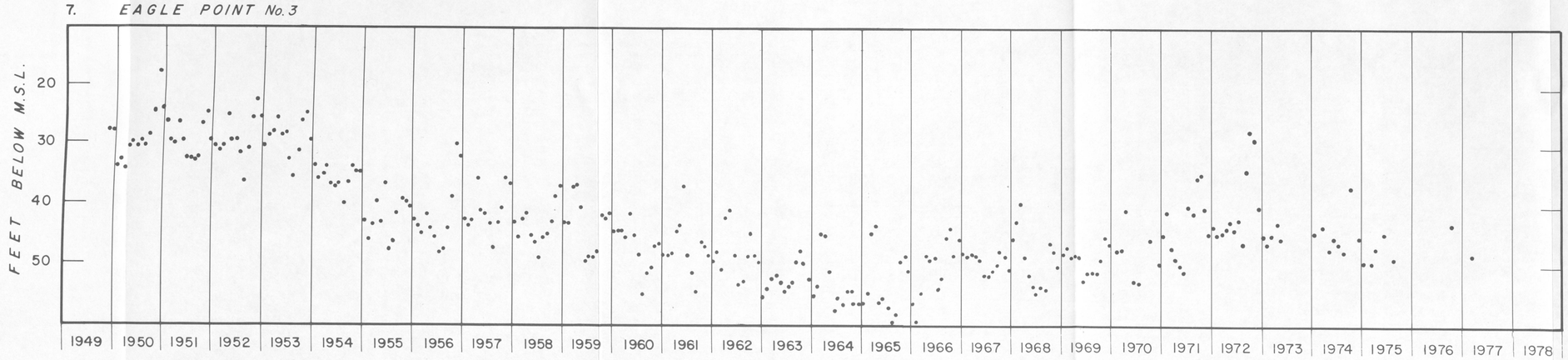
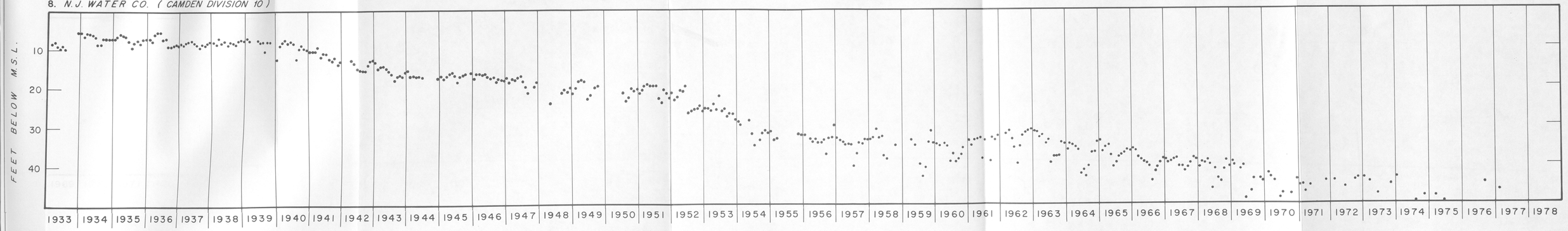


FIGURE 42

HYDROGRAPHS OF OBSERVATION WELLS IN THE MAGOTHY-RARITAN-POTOMAC AQUIFER SYSTEM

NEW JERSEY STATEWIDE WATER SUPPLY MASTER PLAN

8. *N.J. WATER CO. (CAMDEN DIVISION 10)*



9. *MEDFORD No.1*

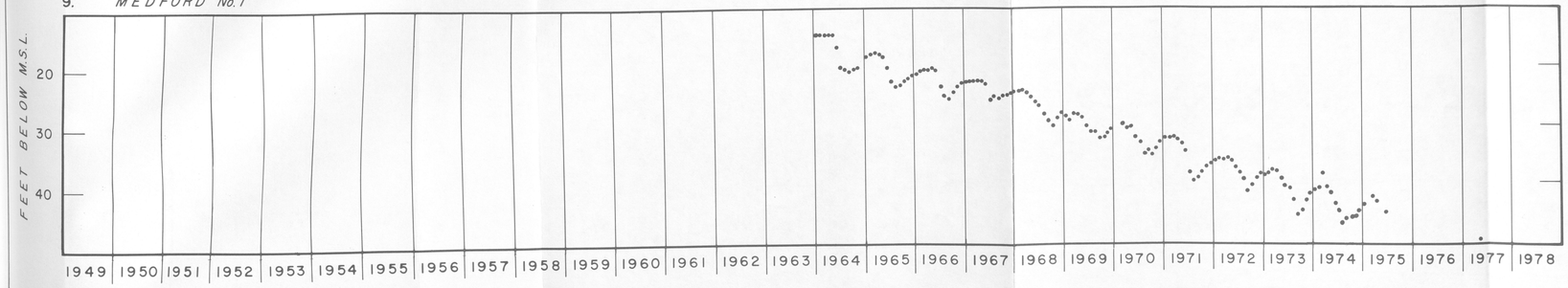
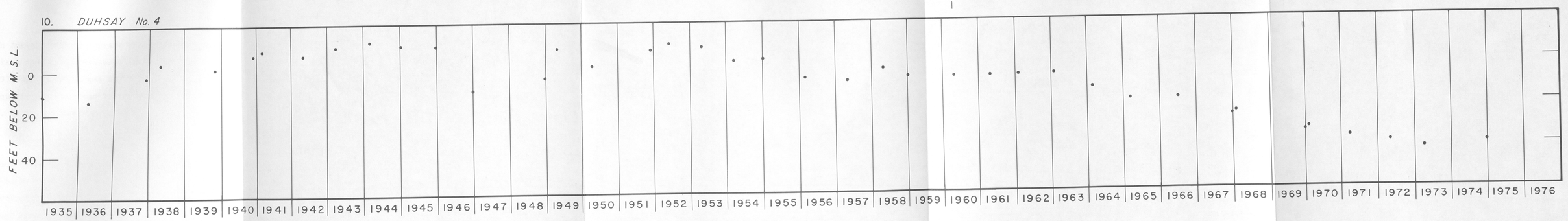


FIGURE 42 / continued

HYDROGRAPHS OF OBSERVATION WELLS IN THE MAGOTHY-RARITAN-POTOMAC AQUIFER SYSTEM

NEW JERSEY STATEWIDE WATER SUPPLY MASTER PLAN

10. *DUHSAY No. 4*



11. *RUNYON OLD DEEP*

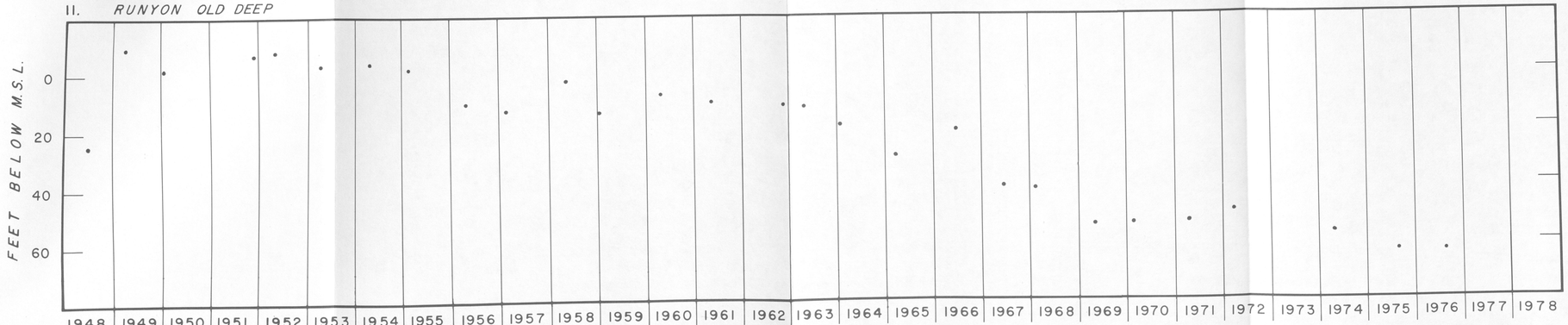


FIGURE 42 / continued

HYDROGRAPHS OF OBSERVATION WELLS IN THE MAGOTHY-RARITAN-POTOMAC AQUIFER SYSTEM

NEW JERSEY STATEWIDE WATER SUPPLY MASTER PLAN

etric surface near South Amboy. Annual average pumpage from the Potomac-Magothy-Raritan system in Middlesex County amounted to over 46 mgd in 1976 (Water Resources Engineers, 1977a and b). Heads in the aquifer near Raritan Bay are about 70 feet below sea level (U. S. Geological Survey, 1977).

Other Aquifers

The impact of pumpage on other Coastal Plain aquifers in New Jersey is too small to be of regional concern. Pumpage is generally low and the historical record cannot support any useful discussion of regional impacts.

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EFFECT OF GROUND-WATER PUMPAGE ON SURFACE WATER IN LOW STREAMFLOW PROBLEM AREAS

In some areas of the state, low streamflow has become a problem during the summer and fall months. Low-flow situations create actual or potential shortages of water for public supply, industrial processes, and for the dilution of municipal and industrial waste water discharged to surface waters. Diversion permits and grandfather rights allow ground-water diversions, and where ground-water withdrawals contribute to low streamflow, the legal rights of surface-water diverters may be infringed upon by ground-water users.

This section indicates the general relationships between ground-water withdrawal and surface-water use. It identifies areas in the state where ground-water withdrawals are known or believed to have a significant effect on streamflow, as well as areas where the future development of large ground-water supplies may be expected to reduce streamflow.

FACTORS AFFECTING STREAMFLOW

Ground-water discharges related to head differences maintain streamflow, supplementing surface runoff from rainfall and snow melt. Where the normal level of the water table is below a stream bed, ground water will not discharge to the stream and streamflow may be intermittent. In maintaining streamflow between precipitation events, ground-water dis-

charges tend to lower the water table which, in turn, decreases ground-water discharge to surface waters; during a drought, the ground water available to maintain streamflow may be diminished.

Streamflow resulting from surface runoff is governed primarily by the length and intensity of precipitation events, the rapidity and volume of snow melt, and the infiltration characteristics of the soil mantle. Given equal rainfall and evapotranspiration for two basins, the basin with poorer infiltration and/or storage characteristics will lose more of the rainfall to surface runoff, with less recharged water available to support streamflow.

Data from the 1969 water year for the Stony Brook gaging station at Princeton and from the Millstone River at Plainsboro indicate the differences in runoff characteristics between basins. The Stony Brook basin is underlain by consolidated Triassic rock, while the Millstone above Plainsboro lies in the Coastal Plain province and is underlain by unconsolidated sediments. These unconsolidated sediments contain large amounts of sand and gravel and have a much greater capacity to absorb and store precipitation than the Triassic rock. Precipitation for the water year 1969 was average, and was virtually identical in both basins. Moreover, the calculated mean runoff per square mile of basin was the same. Hydrographs indicate a low base flow with extreme flood peaks in Stony Brook

compared to Millstone. The capacity of formation materials underlying the Millstone basin to absorb and store rainfall is illustrated by the fact that the ratio of peak discharge to low flow is only 29:1, compared with 17,400:1 in Stony Brook. Topographic relief is greater in the Stony Brook basin, but differences in hydrogeologic characteristics are the governing factor.

Although rainfall is fairly evenly distributed throughout the year in New Jersey, high evaporation and transpiration rates associated with summer and early fall temperatures tend to decrease surface runoff and ground-water recharge. Accordingly, under natural conditions, summer and fall streamflow is normally less than the mean annual flow, with local hydrogeologic conditions dictating the actual difference.

Ground-water withdrawals in a drainage basin decrease the prevailing hydraulic gradient and reduce the volume of ground water discharging to surface waters. In certain situations, the hydraulic gradient may be reversed, and, if the material beneath and along the stream bed is permeable, surface water will be induced into the ground-water reservoir. In many areas of the state, much of the withdrawn ground water is returned to the ground through cesspools and septic systems and eventually discharges to streams; thus, it would appear that no net withdrawal of ground water has occurred, and no significant effect on streamflow should be expected. However,

ground water generally moves very slowly and, if ground water is withdrawn adjacent to a stream and returned to the ground some distance away, it may take a number of months for this water to reach the stream. Therefore, although no net long-term withdrawal is occurring, there is a net short-term withdrawal in the immediate area which may reduce flow.

Sewering may compound low flow problems by decreasing the amount of ground water in storage and lowering the water table through consumptive use. In 1976, Geraghty & Miller, Inc. indicated that the Stony Brook Regional Sewerage Project would have a significant impact on streamflow and, if all pumped ground water were removed from the basin by sewers with no offsetting imports, there would be no ground-water discharge to Stony Brook about 8 percent of the time. Based on projected increases in sewage flow for 1990 and 2010, the expected frequency of no-flow periods would increase to about 10 and 20 percent, respectively, and would occur most frequently during the summer and fall.

Intensive urbanization results in reduced ground-water recharge and lower base flow in streams. Paving increases surface runoff and storm sewers divert this runoff to streams, with a resultant reduction in ground-water recharge.

EXISTING PROBLEM AREAS

Passaic River Basin

Ramapo River Sub-Basin -

The North Jersey District Water Supply Commission diverts an annual average of about 25 mgd from Pompton Lake, except during the period from June through September and during periods when the flow below Pompton Lake falls below 40 mgd. According to Hordon (1976), the mean annual diversion by the North Jersey District Water Supply Commission from both Pompton Lake and Wanaque Reservoir over the period 1968-73 was nearly 109 mgd, or nearly 15 mgd above the "safe" yield (as reported by Hordon).

Quaternary age stratified drift deposits flank the Ramapo River upstream of Pompton Lake to the New Jersey/New York State line. The width and thickness of these deposits varies throughout the valley but, for the most part, the material consists of very permeable sand and gravel with no extensive confining beds of silt or clay.

Vecchioli and Miller (1973) indicate a direct hydraulic connection exists between the river and the associated drift or valley-fill aquifer. Moreover, field measurements indicated that the Ramapo River is a losing stream for at least part of its reach, and that during some periods, it loses water to

the ground over its entire length from the state line to Pompton Lake. This loss extends further downstream as the summer progresses and can be attributed to ground-water withdrawals in the Ramapo Basin which reduce the river's flow and cause river water to recharge the aquifer during the summer and fall. After September of each year, reductions in the Ramapo's flow caused by ground-water pumpage can reduce the North Jersey District Water Supply Commission's ability to divert water from Pompton Lake. The Commission (on the average) exceeds its annual average safe yield, and increased diversions in the Ramapo Basin, especially from the proposed Spring Valley well field, may add to the problem in the future.

Rockaway River Sub-Basin -

Jersey City diverts water for public supply from the Boonton Reservoir on the Rockaway River. Between 1968 and 1975, the mean annual diversion was nearly 65 mgd, which exceeded the safe yield by an average of 7 mgd. The difference between pumpage and safe yield increased from slightly over 1 mgd at the beginning of this period to nearly 15 mgd in 1973. The long-term average flow at the Boonton gaging station upstream of the reservoir is slightly over 140 mgd and, for the 1976 water year, the mean flow was nearly 190 mgd. However, between late August and mid-September 1976, the mean flow was less than 32 mgd on 23 days and was as low as 23 mgd for 11 days. From mid-July through the end of September, the mean daily

flow below the reservoir was less than 12 mgd on 73 of 76 days. A large percentage of the flow below the reservoir consists of effluent from the Rockaway Valley treatment plant that is discharged to the river below the reservoir.

A recent study in the Rockaway River valley (Tetra Tech, 1978) estimated the total ground-water pumpage in the basin at about 20 mgd. Most of this was drawn from stratified drift deposits occurring along the river and its tributaries. Flow measurements were taken above the reservoir in September and November 1977 to determine the exchange of water between the ground-water reservoir and the river. In September, under low flow conditions, the upper reaches of the river (above Wharton) gained, but from Wharton to the reservoir, the river was losing (surface water recharging the ground water). November measurements made under moderately high flow conditions indicated that the river was losing between Randolph and Denville. This reduced streamflow is generally attributed to pumpage, and the decreased length of the river's losing stretch in November may be related to reduced pumping after heavy seasonal demands.

Part of the Rockaway Basin is sewered and there are plans to expand the sewage treatment facilities to handle projected waste water flows of 12 mgd in 1995, and 21 mgd in 2020. This increased waste water flow out of the basin will reduce ground-water recharge and base flow to the Rockaway River above Boon-

ton Reservoir and will complicate an existing problem.

Saddle River Sub-Basin -

The Hackensack Water Company operates a well field with a 2-mgd diversion right along the Saddle River in the Township of Upper Saddle River. The borough diverts water for fire protection from the Saddle River below this well field and an adequate streamflow is necessary to assure that emergency demands can be accommodated whenever they occur. As a condition of the diversion permit issued to the Hackensack Water Company, it must stop pumping its well field when river flow falls below 1.5 mgd. The U. S. Geological Survey made discharge measurements in the Saddle River during October and November 1977 to determine whether there is a connection between the aquifer and the river. The measurements indicated that the river is losing between the upstream and downstream measuring points under both pumping and non-pumping conditions.

POTENTIAL PROBLEM AREAS

In addition to these examples, there are other areas where ground-water pumpage contributes to reduced streamflow. The surface-water resources of several drainage basins in the northeast part of the state are extensively developed for public and industrial supply. All the potable surface supplies in the Hackensack River basin are developed upstream of the New Milford gage, and according to Carswell (1976), about 50

percent of the rainfall in the upper basin is lost to evapotranspiration, leaving a maximum of 113 mgd of surface water for development. Diversions by the Hackensack Water Company, West Nyack, and the Spring Valley Water Company in New York, amounted to an average of 103 mgd during the water year 1976, and resulted in 120 days of no flow below the New Milford gage from early May to mid-September 1976. The surface-water supply problem in the Hackensack basin is magnified by low flow conditions during the summer and fall when upstream reservoirs must release stored water to maintain public supply diversions.

Passaic River Basin

Whippany River Sub-Basin -

In 1976, reported public supply and industrial pumpage in this basin was approximately 11 mgd. If all grandfather rights were exercised in the basin, pumpage could be over 21 mgd. Approximately 40 percent of this basin is sewered and ground-water pumpage may have a significant impact on streamflow under low flow conditions.

Upper Passaic Sub-Basin -

Reported public supply and industrial pumpage was approximately 28 mgd during 1976. Exercise of all grandfather rights would increase the total to over 31 mgd. The northern 60 percent of the basin is sewered, and ground-water pumpage in this

area may have a significant effect on streamflow under low flow conditions.

Lower Passaic Sub-Basin -

Reported public supply and industrial pumpage in this basin is approximately 23 mgd, and exercise of all grandfather rights could increase ground-water pumpage to nearly 40 mgd. Approximately 90 percent of this basin is sewered, so that ground-water pumpage may have a significant effect on streamflow under low flow conditions.

IMPROVED RESOURCE MANAGEMENT IN LOW FLOW AREAS

Additional flow measurements should be made along the entire stretch of the main channel of each basin during each season over a period of several years. These measurements will identify losing stretches of rivers and critical seasonal variations in flow. It may be necessary to curtail additional ground-water diversions along losing stretches of rivers during low flow periods. Applicants for additional ground-water diversions along gaining stretches of the rivers should be required to carry out pumping tests to determine the probable effects of their proposed diversion on streamflow.

Where loss of streamflow appears to be a localized problem, controlled pumping tests could be conducted to determine if the stream is recharging the aquifer, and what percentage of pumped water is actually derived from surface water.

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TASK 7

WATERSHED RESOURCE MANAGEMENT ACTIVITIES

SUBTASK 7.C

GROUND-WATER MANAGEMENT

APPENDIX B

AUGUST, 1979

NEW JERSEY STATE

WATER SUPPLY MASTER PLAN

CONTENTS

	Page
APPENDIX B: GROUND-WATER CONTAMINATION	
INTRODUCTION	B 1
INDUSTRIAL AND MUNICIPAL LANDFILLS	B 2
CASE HISTORIES	B 6
EXTENT OF THE PROBLEM	B16
INDUSTRIAL WASTE WATER IMPOUNDMENTS	B24
CHARACTERISTICS OF CONTAMINANTS	B26
CASE HISTORIES	B26
EXTENT OF THE PROBLEM	B31
SEPTIC SYSTEMS	B36
CHARACTERISTICS OF DOMESTIC SEWAGE	B37
CASE HISTORIES	B38
EXTENT OF THE PROBLEM	B39
MUNICIPAL SEWER LEAKAGE	B43
CASE HISTORIES	B44
EXTENT OF THE PROBLEM	B45
BURIED PIPELINES AND STORAGE TANKS	B46
CASE HISTORIES	B48
EXTENT OF THE PROBLEM	B52
ACCIDENTAL DISCHARGES	B58
CASE HISTORIES	B60
EXTENT OF THE PROBLEM	B62
HIGHWAY DEICING PRACTICES	B69
CASE HISTORIES	B70
EXTENT OF THE PROBLEM	B72
AGRICULTURAL ACTIVITIES	B75
WATER WELLS	B78
DIFFUSION WELLS	B81

CONTENTS (Cont'd.)

	Page
SPRAY IRRIGATION	B82
CASE HISTORIES	B82
EXTENT OF THE PROBLEM	B87
REFERENCES	B88

FIGURES

43.	Approximate Locations of Industrial-Municipal Landfills	B21
44.	Approximate Locations of Industrial Waste Water Impoundments	B35
45.	Density of Housing Units Using On-Site Waste Disposal Systems by County	B41
46.	Approximate Locations of Storage Tank Facilities That Exceed 400,000 Gallons Capacity	B54
47.	Approximate Locations of Major Petroleum Pipelines, Terminals, and Refineries	B56
48.	Approximate Locations of Reported Spills Occurring From January 1976 Through July 1977	B67
49.	Generalized Location of Prime Open Agricultural Lands	B76
50.	Approximate Location of Facilities Utilizing Spray Irrigation of Industrial or Municipal Waste Water	B84

TABLES

4.	Summary of Leachate Characteristics From Municipal Solid Wastes	B 5
5.	Components of Industrial Waste	B 7
6.	Water Quality Analyses in the Vicinity of the Kin Buc Landfill, Edison Township, September 17, 1974	B 9
7.	Water Quality Analyses in the Vicinity of the Kin Buc Landfill, Edison Township, September 30, 1974	B10

TABLES (Cont'd.)

8.	Water Quality Analyses in the Vicinity of the Kin Buc Landfill, Edison Township, February 19, 1976	B11
9.	Summary of Ground-Water Quality in the Vicinity of JIS Landfill, South Brunswick	B17
10.	Summary of Organic Chemical Analyses of Ground-Water Samples From Observation Wells and Other Wells in the Vicinity, South Brunswick	B18
11.	Approximation of Potential Leachate Generation Within Each Geologic Province in New Jersey	B20
12.	Recharge, Pumpage, and Storage Within the Major Aquifer Systems Within New Jersey	B23
13.	Industrial Waste Water Parameters Having or Indicating Significant Ground-Water Contamination Potential	B27
14.	Approximation of the Potential Volume of Leakage From Industrial Waste Water Impoundments to Major Aquifers	B34
15.	Comparison of Housing Units Served by Sewers to Housing Units Served by Septic Systems	B42
16.	Results of Chemical Analyses of Water Samples From Wells Associated With Storage Tank Facilities, Gloucester County	B51
17.	Major Storage Facilities and Geologic Provinces Within New Jersey	B53
18.	Reported Pipeline Failures Within New Jersey From 1972 to 1977	B57
19.	Causes and Volumes of Reported Spills Which Have Occurred Within New Jersey During 1976	B63
20.	Causes and Volumes of Reported Spills Which Have Occurred Within New Jersey During 1977	B64
21.	Causes and Frequency of Reported Spills Potentially Affecting Ground-Water Quality Within New Jersey From January 1976 to July 1977	B65

TABLES (Cont'd.)

		Page
22.	Statistical Summary of the Relationship Between the Frequency of Reported Spills and Geologic Provinces in New Jersey From January 1976 to July 1977	B66
23.	New Jersey State Highway Mileage by Systems as of January 1, 1974	B73
24.	Examples of Conditions Under Which Water Wells Can Cause Ground-Water Contamination	B79
25.	Facilities Using Spray Irrigation to Dispose of Treatment Plant Effluent in New Jersey	B83
26.	Results of Chemical Analyses of Water Samples From Wells Associated With Frozen Food Processing at a Plant in Camden County, New Jersey	B86

APPENDICES

B1. Industrial and Municipal Landfills in New Jersey

B2. Classification Code for Industrial and Municipal Wastes

B3. Industries Reportedly Having Waste Water Impoundments Within New Jersey

B4. Types and Volumes of Waste Water Discharged Into Industrial Waste Water Impoundments Within New Jersey, by Type of Industry

B5. Name and Location of Facilities Complying With Federal SPCC Regulations Within New Jersey

B6. Major Storage Tank Facilities Within the State of New Jersey Complying With SPCC Regulations

B7. Reported Spills Which Have Occurred Within New Jersey During 1976

B8. Reported Spills Which Have Occurred Within New Jersey During 1977 (January-June)

APPENDIX B

GROUND-WATER CONTAMINATION

INTRODUCTION

The following section is an inventory of both actual and potential sources of ground-water contamination. Those activities that pose the greatest threat to ground water, either because of their widespread occurrence or the nature of the contaminants involved, are discussed first with less significant sources discussed later. Case histories were selected to illustrate the type and extent of contamination resulting from the various sources. Locations and listings of potential sources of contamination including landfills, lagoons, pipelines, and spills have been mapped and tabulated to indicate the possible magnitude of the problem.

INDUSTRIAL AND MUNICIPAL LANDFILLS

New Jersey disposes of virtually all of its solid wastes in landfills. New Jersey's landfill facilities run the gamut from closely supervised industrial sites to uncontrolled common dumps.

The typical industrial-municipal landfill covers an area of 50 to 200 acres, and accepts municipal solid waste, construction debris, chemical wastes, sludge, and various liquid wastes. Permit conditions usually restrict the types of waste that a landfill operator can accept and, in view of the high costs of disposing of hazardous wastes and the relatively minor fines imposed for violating landfill operating permits, it is not unusual for landfill operators to accept unauthorized wastes.

Generally, landfills have been located where the land is assumed to have little or no value for other uses. They are often located in wetlands or abandoned sand and gravel pits with little regard for the possible environmental effects of the operation. Badly sited or badly constructed landfills can generate considerabe quantities of leachate that may enter and contaminate the ground-water system, especially those landfills placed below the water table.

Landfills contaminate ground water through leachate generated by precipitation percolating through the waste and de-

composing material. Additional sources of landfill-related contamination include surface runoff from the surrounding land that runs over or through the landfilled material, moisture contained in the materials placed in the landfill, moisture from the decomposition of wastes, and water entering and leaking through the bottom and sides of the fill itself.

Most of the organic compounds in solid and liquid wastes are decomposed or stabilized by aerobic and anaerobic organisms to simple substances, including gases and soluble organic and inorganic compounds. If water is available from precipitation or surface drainage, these compounds may be dissolved and carried off with the water that infiltrates the landfill and recharges the ground water or discharges into surface waters. Solid inorganic materials are slowly dissolved by percolating water, so the leachate contains increased concentrations of metallic ions. Liquid industrial wastes, septic tank wastes, and waste water treatment sludges contribute to an increase in dissolved solids in water percolating through the landfill.

Leachate is a highly mineralized liquid which typically contains chloride, iron, lead, copper, sodium, nitrate, and a large number of organic chemicals. The chemical composition of the leachate will depend on the nature of the material deposited in the landfill. Where industrial wastes are landfilled, the leachate may contain a number of hazardous constituents including toxic metals and chemicals. Leachate, espe-

cially from municipal landfills, may also contain viruses and pathogenic bacteria. However, the concentration of biological and certain chemical pollutants traveling through soil tends to decrease with distance from the source. The effectiveness of soil processes such as adsorption, ion exchange, dispersion, or dilution in attenuating the chemical pollution from a landfill depends on the nature and concentration of the pollutant, the characteristics of the soils underlying the landfill, and the geologic and hydrologic conditions at the site and in the surrounding area.

Landfills continue to generate leachate after they are abandoned. The Pennsylvania Department of Health compared the leachate produced from a landfill abandoned in 1950 to an active landfill, and although there was a hundred-fold difference in BOD and COD concentrations, the differences in specific conductance, ammonia nitrogen, and sulfate indicated that the abandoned landfill was a continuing source of contamination (Geraghty & Miller, Inc., 1977a).

The largest single component in municipal waste is paper, with substantial quantities of kitchen waste, yard wastes, glass, metals, plastics, rubber, and liquids. Many municipal sites also receive industrial residues and pollution control system sludges in addition to septic tank pumpings, sewage sludge, street sweepings, and construction/demolition debris. Table 4 indicates the general chemical make up of leachate gen-

Table 4. Summary of Leachate Characteristics From Municipal Solid Wastes. (Constituents in ppm, where applicable.)

Constituent	Median Value	Ranges of All Values
Alkalinity ($CaCO_3$)	3,050	0 -20,850
Biochemical Oxygen Demand (5 days)	5,700	81 -33,360
Calcium (Ca)	438	60 - 7,200
Chemical Oxygen Demand (COD)	8,100	40 -89,520
Copper (Cu)	0.5	0 - 9.9
Chloride (Cl)	700	4.7 - 2,500
Hardness ($CaCO_3$)	2,750	0 -22,800
Iron, Total (Fe)	94	0 - 2,820
Lead (Pb)	0.75	< 0.1 - 2
Magnesium (Mg)	230	17 -15,600
Manganese (Mn)	0.22	0.06- 125
Nitrogen (NH_4)	218	0 - 1,106
Potassium (K)	371	28 - 3,770
Sodium (Na)	767	0 - 7,700
Sulfate (SO_4)	47	1 - 1,558
Total Dissolved Solids (TDS)	8,955	584 -44,900
Total Suspended Solids (TSS)	220	10 -26,500
Total Phosphate (PO_4)	10.1	0 - 130
Zinc (Zn)	3.5	0 - 370
pH	5.8	3.7 - 8.5

Reference: Geraghty & Miller, Inc., 1977 a.

erated from typical municipal solid wastes.

In addition to the refuse generated by residences and commercial establishments, a wide variety of industrial wastes are landfilled. Some of these materials constitute a severe threat to the public health (e.g., cyanide, arsenic, phenols, chlorinated hydrocarbons, vinyl chloride, chromium, lead) (Geraghty & Miller, Inc. 1977a). Table 5 contains a partial list of potentially hazardous materials found in industrial wastes.

CASE HISTORIES

The following case histories reflect the nature of groundwater contamination from landfill operations.

In March 1971, an industrial firm hired an independent waste hauler to remove drums containing organic solvents and residues from the manufacture of organic chemicals and plastics from one of the firm's plants in New Jersey. In December 1971, about 4,000 of these drums were found on a former farm in Dover Township. The contents of many of the drums had been dumped into trenches, while other drums and chemical wastes were buried in various sections of the property.

In 1974, a number of area residents noticed an unusual taste and odor in their well water. Subsequent analyses of samples from these and other area wells indicated the presence

Table 5. Components of Industrial Waste.

	Metals Mining	Primary Metals	Pharmaceuticals	Batteries	Inorganic Chemicals	Organic Chemicals	Pesticides	Explosives	Paints	Petroleum Refining	Electroplating
Ammonium salts		X									
Antimony	X				X				X		
Arsenic	X	X	X		X					X	
Asbestos					X				X		
Barium	X								X		
Beryllium			X							X	
Biological waste											
Cadmium	X	X		X	X				X	X	X
Chlorinated hydrocarbons					X	X			X		X
Chromium		X	X	X	X				X	X	X
Cobalt									X	X	
Copper	X	X	X	X					X	X	X
Cyanide		X			X					X	X
Ethanol waste, aqueous			X								
Explosives (TNT)								X			
Flammable solvents						X			X		
Fluoride		X			X						
Halogenated solvents			X								
Lead solvents	X	X		X	X				X	X	X
Magnesium	X										
Manganese		X									
Mercury		X	X	X	X				X	X	
Molybdenum										X	
Nickel		X		X	X					X	
Oil		X				X				X	X
Organics, miscellaneous							X				
Pesticides (organophosphates)								X			
Phenol		X								X	X
Phosphorus					X						X
Radium	X										
Selenium	X	X	X							X	
Silver				X						X	X
Vanadium										X	
Zinc	X	X	X	X	X				X	X	X

Reference: Geraghty & Miller, Inc., 1977a.

of petrochemicals. The county Board of Health subsequently issued an order forbidding the use of about 150 wells for any purpose, and an emergency water supply was arranged until a public water supply could be provided (Geraghty & Miller, Inc., 1977a; Office of Special Services, 1977).

The Kin Buc landfill (Edison Township) is located in the Raritan River salt marsh. The landfill accepts all types of wastes including liquids. Only 30 acres of Kin Buc's 220 acres are being used. Disposal is continuous with 175,000 tons of waste deposited in 1972. The site is poorly drained and has a high leachate generation rate. Wastes are essentially mounded in the marsh and now form a 100-foot high pile of refuse. When the water table rises above the bottom of the mound during wet periods, leachate flows into the Raritan River. Leachate from the site penetrates the Old Bridge Sand to recharge the Farrington aquifer. Leachate also affects the quality of Raritan River water in the vicinity of the site. Tables 6, 7, and 8 show the results of analyses of ground- and surface-water samples (Geraghty & Miller, Inc., 1976).

The old Camden City landfill covers approximately 90 acres to a height of 40 feet. It overlies the Potomac-Magothy-Raritan aquifer which is the primary source for the City of Camden. In recent years, the City of Camden has abandoned several public supply wells in the area because of contamination caused by the landfill. The relatively large size of this

Table 6. Water Quality Analyses in the Vicinity of the Kin Buc Landfill, Edison Township, September 17, 1974. (Results other than pH and bacteria analyses given in mg/l. Bacteria are given as Most Probable Number (MPN) per 100 ml.)

Constituents	Raw Leachate	Raritan River at Kin Buc Upstream	Raritan River at Kin Buc Downstream	USPHS [1] Limits (1962)	USEPA [2] Standards (1976)
pH	5.6	7.1	7.3	-	-
Alkalinity	567	62	51	-	-
Nitrate Nitrogen	1	1.5	1.5	10	10
Chloride	2,300	895	535	250	-
Phosphate	5	1	1	-	-
Sulfate	589	126	80	250	-
Dissolved Oxygen	0	4.8	5.3	-	-
BOD	> 1,822	1	14	-	-
COD	9,914	89	93	-	-
Phenols	25.116	ND	0.047	0.001	-
Cyanide	0.013	ND	ND	0.01	-
Total Dissolved Solids	9,323	2,055	1,378	500	-
Chromium, Cr^{+6}	ND	ND	ND	0.05	0.05
Lead	0.003	0.002	0.005	0.05	0.05
Copper	0.152	ND	0.048	1	-
Zinc	3.64	0.10	0.16	5	-
Cadmium	0.008	0.002	0.001	0.01	0.010
Iron	30.6	2.5	3.2	0.3	-
Manganese	0.024	0.010	0.010	0.05	-
Total Hardness	2,200	350	254	-	-
Total Coliform	2,400	490	5,400	1	1
Fecal Coliform	340	20	790	-	-
Streptococci	2,400	240	1,600	-	-
Color	-	-	-	15	-

Note: ND - Not Detected

1) Recommended by U. S. Public Health Service for drinking water on interstate carriers.
2) Proposed by the U. S. Environmental Protection Agency as of May 1976 for drinking water.

Reference: Geraghty & Miller, Inc., 1976.

Table 7. Water Quality Analyses in the Vicinity of the Kin Buc Landfill, Edison Township, September 30, 1974. (Results other than pH given in mg/l.)

Constituents	Raw Leachate	Raritan River at Kin Buc Upstream	Raritan River at Kin Buc Downstream	USPHS Limits (1962) [1]	USEPA Standards (1976) [2]
pH	5.6	6.3	6.9	-	-
Alkalinity	522	38	41	-	-
Nitrate Nitrogen	ND	ND	ND	10	10
Chloride	1,400	75	24	250	-
Phosphate	1	0.5	0.1	-	-
Sulfate	675	28	24	250	-
Dissolved Oxygen	0	7	7.4	-	-
BOD	881	58	12	-	-
COD	19,958	51	24	-	-
Phenols	19.30	0.313	0.061	0.001	-
Cyanide	0.010	ND	ND	0.01	-
Total Dissolved Solids	12,882	197	133	500	-

Note: ND - Not Detected

1) Recommended by U. S. Public Health Service for drinking water on interstate carriers.
2) Proposed by the U. S. Environmental Protection Agency in 1976 for drinking water.

Reference: Geraghty & Miller, Inc., 1976.

Table 8. Water Quality Analyses in the Vicinity of the Kin Buc Landfill, Edison Township, February 19, 1976. (Results other than pH and bacteria analyses given in mg/l. Bacteria are given in MPN per 100 ml.)

Constituents	Raw Leachate	Raritan River at Kin Buc Upstream	Raritan River at Kin Buc Downstream	Ground Water Trench	USPHS Limits (1962) [1]	USEPA Standards (1976) [2]
pH	3.8	6.5	6.9	7	-	-
Alkalinity	4,500	38	59	922	-	-
Total Nitrogen	365	2	3.9	38.1	-	-
Ammonia Nitrogen	300	2	2.5	33.5	-	-
Nitrate Nitrogen	1	1	1.5	ND	10	10
COD	18,348	98	67	94	-	-
Chloride	1,000	26	420	175	-	-
Phosphate	2	0.35	0.42	1	-	-
Sulfate	225	20	110	ND	250	-
BOD	1,751	5	4	201	-	-
Dissolved Oxygen	0	10.7	9	0	-	-
Phenols	0.256	0.008	0.105	0.243	0.001	-
Cyanide	0.041	ND	0.009	ND	0.01	-
Arsenic	ND	ND	ND	ND	-	-
Total Dissolved Solids	1,844	151	888	1,300	500	-
Chromium Cr^{+6}	ND	ND	ND	ND	0.05	0.05
Lead	0.077	0.038	0.026	0.044	0.05	0.05
Copper	ND	ND	ND	ND	1	-
Zinc	4.41	0.072	ND	0.19	5	-
Cadmium	0.026	0.003	0.003	0	0.01	0.010
Iron	18.4	1.82	8	11.6	0.3	-
Manganese	0.15	0.015	0.16	ND	0.05	-
Total Hardness	7,100	120	210	820	-	-
Total Coliform	20	2,400	2,400	2,400	1	1
Fecal Coliform	20	920	540	350	-	-
Streptococci	1,600	2,400	110	49	-	-
Nitrite Nitrogen	0.022	0.028	0.008	0.003	-	-
Color	-	-	-	-	15	-

Note: ND - Not Detected

1) Recommended by the U. S. Public Health Service for drinking water on interstate carriers.
2) Proposed by the U. S. Environmental Protection Agency as of May 1976 for drinking water.

Reference: Geraghty & Miller, Inc.,1976.

landfill and its critical location over the heavily pumped Potomac-Magothy-Raritan aquifer represents a threat to local and regional ground-water quality (Geraghty & Miller, Inc., 1977c).

The L&D landfill is located in Burlington County near the Town of Mount Holly and covers approximately 200 acres. It accepts an average of about 400 tons per day of both municipal and industrial refuse and has operated at current volumes for seven years. Ground-water flow from the site is in the general direction of the developed area. The North Branch of Rancocas Creek is about 200 yards north of the landfill, and serves as a discharge area for leachate contaminated ground water (Geraghty & Miller, Inc., 1977b).

The L&D landfill occupies a sand and gravel pit which over lies the Wenonah-Mount Laurel Formation. This formation is one of the important aquifers in southern New Jersey, and is used both for domestic and public supply. The leachate generation rate at this landfill may be some 150,000 gpd. Some of this leachate migrates into the Wenonah-Mount Laurel aquifer and then discharges into Rancocas Creek. However, during a drought, water levels in the aquifer will decline, possibly below the bottom of the stream bed, and leachate in the aquifer would tend to move in the direction of pumping wells (Geraghty & Miller, Inc., 1977c).

In Gloucester County, one industry operates a landfill located on a 5-acre site adjacent to the Delaware River. The site is used for the disposal of sludges generated at the plant's waste water treatment facility. The landfill overlies the outcrop of the Potomac-Magothy-Raritan aquifer. Extensive river deposits in the area may isolate the landfill from the aquifer and cause the leachate to migrate through shallow sediments directly to the Delaware River. Two plant production wells are located several hundred yards from the landfill and are screened in the aquifer.

Analyses of samples from two observation wells screened in the Potomac-Magothy-Raritan indicate that a leachate plume lies between the landfill and the river. These wells yielded water containing abnormally high concentrations of copper, chloride, magnesium, and iron. Nickel and lead were found in both observation wells, but not in the production wells, and organic compounds were not detected in any of the samples (Geraghty & Miller, Inc., 1977b).

The Kramer landfill is located on a 60-acre site in Mantua Township, Gloucester County. The area is drained by Edward's Run, which is directly east of the landfill, and numerous leachate seeps flow directly into Edward's Run along the toe of the landfill. The landfill accepts municipal waste, sewage and sewage sludge, and non-chemical industrial waste. In the past, it also accepted chemical industrial wastes. The

inactive portions of the landfill are flat and are covered with a sandy material which is not an effective barrier to infiltration.

Water quality analyses of samples from three observation wells located near this landfill indicate abnormal levels of total dissolved solids, with calcium, sulfate, sodium, COD, and detergents (MBAS) all above background levels. Moreover, trace quantities of two electronegative organic compounds were found, possibly indicating the presence of soluble industrial chemicals in the ground water (Geraghty & Miller, Inc., 1977b).

The Kinsley landfill covers some 65 acres in Deptford Township, Gloucester County, and is approximately 50 feet thick. The site is in a relatively flat upland area and is underlain by two confining beds, the Navesink and Hornerstown Formations. The area is drained by several small streams, including Monongahela Brook. This landfill accepts municipal waste, animal wastes from nearby hog farms, sewage sludge, and certain types of industrial waste including some chemicals. The volume of waste currently dumped at the site is reported to be 1,500 tons per day. The landfill has a leachate collection system consisting of a diked channel; water collected in the channel is pumped to the top of the landfill. There are at least eight monitoring wells installed at various depths at the site.

Although the landfill is separated from the deep aquifer by the confining layers, recent water quality analyses indicate that the aquifer has been affected by leachate. Concentrations of iron, chloride, phenols, cadmium, lead, and manganese exceed drinking water standards in at least one of the deep wells, and even though substantial attenuation is occurring, some contaminants appear to be migrating into the deeper aquifer. It has been suggested that the contamination in the deeper aquifer may be caused by an abandoned dump near the Kinsley site. This possibility, however, has not been fully investigated (Geraghty & Miller, Inc., 1977c).

The Newfield landfill is a municipal-industrial waste disposal site of approximately 3 acres owned and operated by the Borough of Newfield. It accepts non-chemical, inert industrial wastes, and brush and leaves from the surrounding area. The landfill is situated on the outcrop of the Cohansey Sand, which is a major aquifer. Analysis of water from a well located at the toe of the landfill indicates that leachate has contaminated the ground water.

The JIS landfill in South Brunswick is a 30-acre pit which is 20 to 30 feet deep. The landfill's configuration tends to direct runoff into the pit, maximizing leachate production. The landfill is located in the Magothy recharge area, and excavation may have exposed the formation to the landfill allowing leachate to enter the aquifer directly. The landfill

accepts all types of industrial wastes. Recently, a domestic well nearby was found to be contaminated. Tables 9 and 10 show chemical analyses from adjacent wells but the actual extent of contamination has not been determined (Geraghty & Miller, Inc., 1976).

EXTENT OF THE PROBLEM

The volume of leachate generated by a particular landfill depends on its absorptive capacity, areal extent, and the amount of infiltrated water. Most landfills are bulldozed to a fairly flat surface and are normally covered with relatively coarse-grained material. In general, there is no attempt to plant vegetation until the site is closed. These practices are conducive to infiltration, and it is reasonable to assume that at least half of the annual precipitation falling on the site will be recharged to the ground after percolating through the landfilled material. The average annual rainfall in the study area is approximately 45 inches, and the more than 10,000 acres of landfill in New Jersey could theoretically generate some 5.7 billion gallons of leachate per year (Karubian, 1974).

All landfill sites in the state were inventoried to assess the potential impact of industrial and municipal landfills on ground-water resources. The inventory was compiled from data obtained from the New Jersey Solid Waste Administra-

Table 9. Summary of Ground-Water Quality in the Vicinity of JIS Landfill, South Brunswick, New Jersey. (Results other than pH and bacteria analyses given in mg/l. Bacteria are given in MPN per 100 ml.)

	Well 1	Well 2	Well 3	Well 4	Private Well Kaler	Private Well Kordus
Sampling Date	11-6-75	12-2-75	11-6-75	11-6-75	12-2-75	12-2-75
Color (Units)	40	5	500	50	30	5
pH	5.8	5.8	-	-	5.9	5.4
Alkalinity	23	19	-	-	21	11
Total Nitrogen	1	1	1	0.56	2	1
Ammonia Nitrogen	ND	ND	ND	ND	ND	ND
Nitrate Nitrogen	ND	12.5	3.8	9	ND	4
Chloride	57	20	190	-	28	35
Phosphate	ND	ND	-	-	ND	0.02
Sulfate	7	23	-	-	8	1
BOD	>29	< 1	< 1	< 1	3	ND
Dissolved Oxygen	2.9	9.3	-	-	0.7	9
COD	108	12	ND	4	28	4
Phenols	2.34	0.022	0.014	0.007	0.136	0.015
Cyanide	ND	ND	-	-	ND	ND
Turbidity (Units)	24	3	-	-	31	2
Total Dissolved Solids	138	147	1,096	368	118	74
Chromium Cr^{+6}	ND	ND	ND	ND	ND	ND
Lead	0.021	0.740	0.040	-	0.007	0.015
Copper	0.070	ND	ND	ND	0.035	0.595
Zinc	0.25	0.40	0.23	0.26	0.55	0.20
Cadmium	ND	ND	0.003	0.002	ND	ND
Iron	3.36	0.52	20	-	4.4	0.38
Manganese	0.31	0.10	-	-	0.02	0.02
Total Hardness	120	86	-	-	40	36
Total Coliform	330	< 2	-	-	7	< 2
Fecal Coliform	< 2	< 2	-	-	< 2	< 2
Streptococci	< 2	< 2	-	-	< 2	< 2

Note: ND - Not Detected

Reference: Geraghty & Miller, Inc., 1976.

Table 10. Summary of Organic Chemical Analyses [1] of Ground-Water Samples From Observation Wells and Other Wells in the Vicinity, South Brunswick, New Jersey. (Results given in mg/l.)

Well	Kaler	Kaler	JIS 1	JIS 2	JIS 3	JIS 4	BSAF
EPA Lab Sample No.	40368	32739	32730	32731	32490	32491	32236
Sampling Date	10-3-75*	10-3-75*	11-6-75	11-6-75	12-2-75	12-2-75	12-3-75
Chloroform	2.6	120	0.6	-	ND	5,710	ND
Toluene	0.39	80	1.8	-	ND	310	-
Xylenes	0.35	190	-	-	ND	150	-
Tri-chloroethane	1.5	160	-	-	ND	30	0.5
Tri-chloroethylene	0.22	660	-	5.2	ND	830	2.9
Dichloroethylene	-	25	-	-	-	-	-
Benzene	-	-	-	-	ND	100	ND
MIBK	-	-	-	-	ND	190	ND
Styrene	-	-	-	-	ND	90	ND

Note: * Date of chemical analysis, not sampling date.

ND - Not Detected

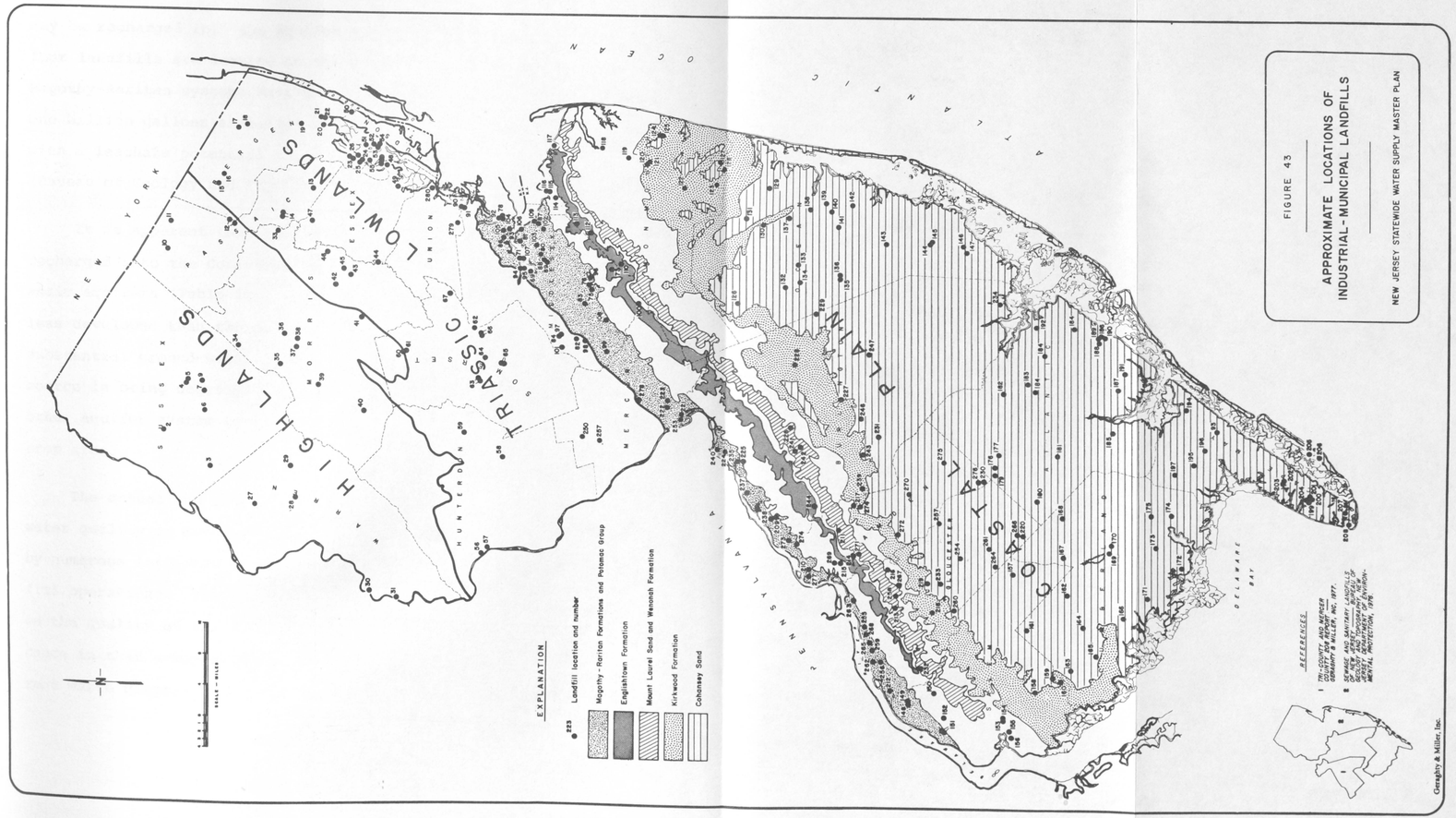
1) No drinking water limits or standards have been set for these compounds by USPHS or USEPA.

tion and the Bureau of Topography and Geology, that describes 280 registered industrial-municipal landfills (Appendix B1), and the type of industrial or municipal wastes that they accept (Appendix B2). The potential impact of unregistered dumps and illegal disposal sites scattered throughout the state is not assessed here (Bureau of Solid Waste Management, 1975; Bureau of Geology and Topography, 1976).

The potential volume of leachate was estimated from average landfill size (area), and the average precipitation. Since the area of each landfill in the state was not known, landfill areas in Gloucester, Camden, Burlington, and Mercer Counties were used as a proxy (Table 11), and the average size of a landfill in these counties (32 acres) was assumed to represent a general statewide average (Bureau of Geology and Topography, 1976). The average precipitation throughout the state was assumed to be 45 inches per year. Based on these estimates, the average landfill may generate approximately 18.7 million gallons of leachate per year. Known landfills were plotted on a generalized geologic map of the state (Figure 43); the number of landfills in each province was multiplied by the estimated volume of leachate generated by a typical landfill to arrive at an estimate of the total potential volume of leachate generated in each outcrop area (Table 11). Eighty-nine registered landfills are located on the Cohansey Formation outcrop, and an estimated 1.7 billion gallons of leachate

Table 11. Approximation of Potential Leachate Generation Within Each Geologic Province in New Jersey.

Geologic Province	Geologic Formation	Number of Landfills	Volume of Leachate Generated per Landfill (million gal./year)	Total Volume of Leachate Generated (billion gal./year)
Highlands	-	27	18.7	504
Triassic Lowlands	Sandstones, shales, etc.	58	18.7	1,083
Coastal Plain	Potomac/Magothy/Raritan	54	18.7	1,009
	Englishtown	6	18.7	112
	Mt. Laurel/Wenonah	7	18.7	130
	Kirkwood	14	18.7	261
	Cohansey	89	18.7	1,664



may be recharged into the aquifer system each year. Fifty-four landfills are located on the outcrop of the Potomac-Magothy-Raritan system, having a leachate potential of some one billion gallons annually; and 58 in the Triassic rocks with a leachate potential of some 1.1 billion gallons per year (Bureau of Geology and Topography, 1976).

It is apparent that substantial volumes of leachate are recharged into the Cohansey, Potomac-Magothy-Raritan, and Triassic aquifers (Table 12). Although the Cohansey aquifer is less developed than the other two, it may be used to provide substantial ground-water supplies in the future. This resource is being degraded by landfill operations more than any other aquifer system in the state by virtue of its large outcrop area.

The actual and potential impact of landfills on ground-water quality in New Jersey is substantial, and is documented by numerous instances of ground-water contamination by landfill operations. The impact of landfill-related contamination on the quality of the Cohansey aquifer is of special significance in that a major future resource is being degraded by current waste disposal activities.

Table 12. Recharge, Pumpage, and Storage Within the Major Aquifer Systems Within New Jersey.

Geologic Province	Geologic Formation	Potential Recharge (mgd)	Potential Recharge (gal./year)	Reported Pumpage (mgd)	Storage (gal.)
Highlands	-			30.76	
Triassic Lowlands	-	335	122.3×10^9	160.92	
Coastal Plain	Potomac/Magothy/Raritan	320	116.8×10^9	218.03	50×10^{12}*
	Englishtown	120	43.8×10^9	12.04	
	Mt. Laurel/Wenonah	130	47.4×10^9	3.41	
	Kirkwood	170	62.0×10^9	24.58	
	Cohansey	2,500	912×10^9	50.40	

*Total for Coastal Plain aquifers.

INDUSTRIAL WASTE WATER IMPOUNDMENTS

Industrial waste water impoundments include lagoons, basins, pits, and ponds. They may be natural depressions or may be constructed by excavation or diking, and may be lined or unlined. Their distribution within the state reflects the concentrated industrial development which extends from Elizabeth to Trenton and along the Delaware River to Paulsboro. Some impoundments are designed to recharge waste liquids into the ground; others are intended for permanent storage and are alledged to be leakproof. Impoundments designed for long-term storage are generally sited in materials with low permeability and may be lined with clay, concrete, asphalt, metal, or plastic sheeting.

Surface impoundments cause ground-water contamination by leaking waste liquids into shallow aquifers by design, accident, or failure. In some heavily industrialized sections of New Jersey, contamination resulting from the leakage of impounded wastes has limited the use of the shallow aquifers. Potential contaminants include the range of organic and inorganic chemicals normally contained in industrial waste water and include phenols, acids, heavy metals, and cyanide. Because industrial impoundments can leak hazardous materials into the ground, they should be considered a major source of ground-water contamination. The contamination potential of an impoundment will be influenced by the nature of the waste mate-

rial, soil permeability, the height of the water table, rainfall, and evaporation.

In general, industrial waste impoundments are not designed to protect ground water, and many were constructed so that waste water will be lost to the ground thereby creating a renewable "storage" space capable of accommodating continuous discharges. Many unlined impoundments are located in geologic settings that are highly susceptible to leakage, e.g., abandoned sand and gravel pits, sinkholes, and swamps overlying permeable unconsolidated deposits. Clay is probably the most widely used lining material, but it is not impermeable. Thus, the leakage potential from lined impoundments can also be significant.

Leakage through the sides of an excavated lagoon (caused by erosion of soil banks or by the rupture of artificial linings on the sides of an impoundment) can occur at a high rate and may be as important as leakage through the bottom, which is often clogged with settled solids and sludges which retard the flow of water. The problem is compounded by the fact that waste discharges into holding ponds, lagoons, and basins are typically not metered, and most impoundments do not have monitoring wells.

CHARACTERISTICS OF CONTAMINANTS

The chemical constituents in industrial waste water can be grouped by major SIC category. Table 13 was prepared from an EPA list of potential ground-water contaminants. Many of these chemicals are not included in standard water quality analyses.

The volume of leakage from an impoundment depends on the self-sealing characteristics of the soil, its permeability, and on the effectiveness and longevity of the lining material. Soil characteristics will generally determine the degree to which contaminants are attenuated as the waste water moves through the unsaturated zone into the ground-water system.

CASE HISTORIES

Documentation of ground-water contamination as a result of leakage from waste water impoundments is not complete because there is a lack of adequate monitoring and a poor historical record. The following examples then, represent only a small part of the overall problem.

An industrial firm, located in the Town of Newfield, Camden County, used a 12-foot deep unlined pond to dispose of sodium hydroxide and sodium chromate for about 20 years. In the early 1970's, water in a local domestic well turned yellow and, about a year later, a public supply well serving the Town of

Table 13. Industrial Waste-Water Parameters Having or Indicating Significant Ground-Water Contamination Potential.

PAPER AND ALLIED PRODUCTS (Pulp and Paper Industry)

Ammonia	Nutrients (nitrogen and phosphorus)	
Chemical Oxygen Demand	pH	
Color	Phenols	Total Dissolved Solids
Heavy Metals	Sulfite	Total Organic Carbon

PETROLEUM AND COAL PRODUCTS (Petroleum Refining Industry)

Ammonia	Iron	Sulfate
Chloride	Lead	Sulfite
Chromium	Mercaptans	Total Dissolved Solids
Chemical Oxygen Demand	Nitrogen	Total Organic Carbon
Color	Odor	Total Phosphorus
Copper	pH	Turbidity
Cyanide	Phenols	Zinc

PRIMARY METALS (Steel Industries)

Ammonia	Iron	Sulfate
Chloride	pH	Tin
Chromium	Phenols	Zinc
Cyanide		

CHEMICALS AND ALLIED PRODUCTS (Organic Chemicals Industry)

Chemical Oxygen Demand	pH	Total Nitrogen
Cyanide	Phenols	Total Organic Carbon
Heavy Metals	Total Dissolved Solids	Total Phosphorus

Reference: Geraghty & Miller, Inc. 1977a.

Newfield and located on the firm's property became contaminated with hexavalent chromium. The well was removed from the public supply system, but is still used by the company as a cooling water supply.

The lagoon was subsequently lined, and an interceptor well was installed and connected to a new treatment facility. Upon investigation, hexavalent chromium concentrations up to 150 mg/l were found in ground water some 700 feet from the lagoon, but the actual extent of this contamination was not determined (Geraghty & Miller, Inc., 1977c).

During 1973, leakage of partially treated waste water from an unlined lagoon contaminated five domestic wells located near an industrial plant in Winslow Township, Camden County. The company agreed to abandon and fill the lagoon, update its treatment process, and install and maintain activated carbon treatment systems for the affected homes (Geraghty & Miller, Inc., 1977c).

The King of Prussia lagoon overlies the outcrop of the Cohansey aquifer in the Pine Barrens region of Camden County. Leaking waste water has killed a large number of trees in the vicinity of the site, and water from observation wells in the area contains high concentrations of contaminants including organic solvents. A plume of contaminated ground water is believed to be migrating away from the site (Geraghty & Miller, Inc., 1977b).

The Monroe Utilities Authority (MUA) operates several public supply wells in Williamstown, New Jersey. Recently, small quantities of mercury were found in Wells 4 and 5 and they were removed from service. While searching for the probable source of this ground-water contamination, an unlined lagoon owned by an industrial firm was discovered approximately 2,000 feet upgradient from the two wells. The plant reportedly discharged wash water from fruit and vegetable packing into the lagoon which was excavated in sandy material (Cape May or Cohansey Formation), allowing rapid percolation of the wash water and pesticide residuals into the ground water. Mercury was a common ingredient in these pesticides until the early 1970's.

While the actual source of the mercury in Wells 4 and 5 was not demonstrated, the lagoon is the suspected point of origin. Mercury was found in concentrations of 0.004 mg/l in Well 4 and 0.001 mg/l in Well 5. Well 6, located several miles away from the plant, showed a mercury concentration of 0.0005 mg/l. The limit on mercury in potable water is 0.002 mg/l (Geraghty & Miller, Inc., 1977b).

An industrial firm, located in Birmingham, manufacturers sulfuric acid, di-vinyl benzene, and ion exchange resins. Waste process water is pumped to two large, unlined ponds as a part of the treatment process. The geology of the site favors the movement of leakage from the lagoons towards Rancocas

Creek. Analyses of water from a monitoring well adjacent to the site indicates abnormally high levels of sulfate, calcium, chloride, and sodium, as well as organic compounds (Geraghty & Miller, Inc., 1977b).

An industrial firm, located in Independence Township, Warren County, manufactures hair dye chemicals and discharges process waste into three lagoons, one of which is unlined. NJDEP indicated that waste water from the lagoon is discharging to a nearby stream. There are no monitoring or production wells in the area, and the extent of any ground-water contamination has not been determined (Harrington, 1978).

An industrial firm, located in Belvidere Township, Warren County, manufactures protective coatings and emulsions. Waste water from its polyvinyl acetate emulsion plant has been treated in three unlined lagoons since 1956. The NJDEP has sampled three observation wells located on the site, and one well is contaminated by mercury. The contamination has migrated approximately 45 feet from the lagoon to the observation well, but its full extent has not yet been determined (Harrington, 1978).

An industrial firm, located in Franklin Borough, Sussex County, manufactures pharmaceutical chemicals. Plant waste water contains chloride, sulfate, and acetic acid, and is discharged to an unlined lagoon which overlies a zinc mine. The

NJDEP found waste water leaking into the zinc mine, but the data were not sufficient to confirm the source of the leakage (Harrington, 1978).

An industrial firm in Howell Township, Monmouth County, reclaims silver from photographic emulsions. A field inspection by the NJDEP in 1976 revealed that the company discharged process sludges into a pond located in back of the plant. Water samples taken in September 1976 from two domestic wells near the site contained 0.06 and 0.07 mg/l of silver, and 0.99 and 0.198 mg/l of phenol. The firm's waste water stream had a phenol level of 40 mg/l. An extensive sampling program was initiated, and analyses by EPA laboratories indicated the presence of several organic compounds in the domestic wells. As of September 1977, 50 private wells in the area were ordered closed due to silver contamination. All but 17 of these wells have been returned to service (Office of Special Services, 1977).

EXTENT OF THE PROBLEM

In general, industrial waste water impoundments are not well regulated. Impoundments are regulated only when they utilize ground recharge as a disposal method; then SPDES permits are required for evaporation ponds and lagoons. The lack of permit data makes it difficult to evaluate their impact on the state's ground-water resources. Information was obtained

primarily from conversations with technicians and engineers, and from general files of the Pollution Control Monitoring, Surveillance and Enforcement Element of NJDEP (1977).

Appendix B3 contains information on the 144 industrial waste water impoundment sites identified. This does not represent the total number of impoundments because many are not permitted, and are essentially unidentified. Appendix B4 indicates the type of waste water discharged to impoundments, rate of discharge, and whether the impoundment is lined or unlined. Most of the impoundments are unlined, but even lined impoundments may eventually leak.

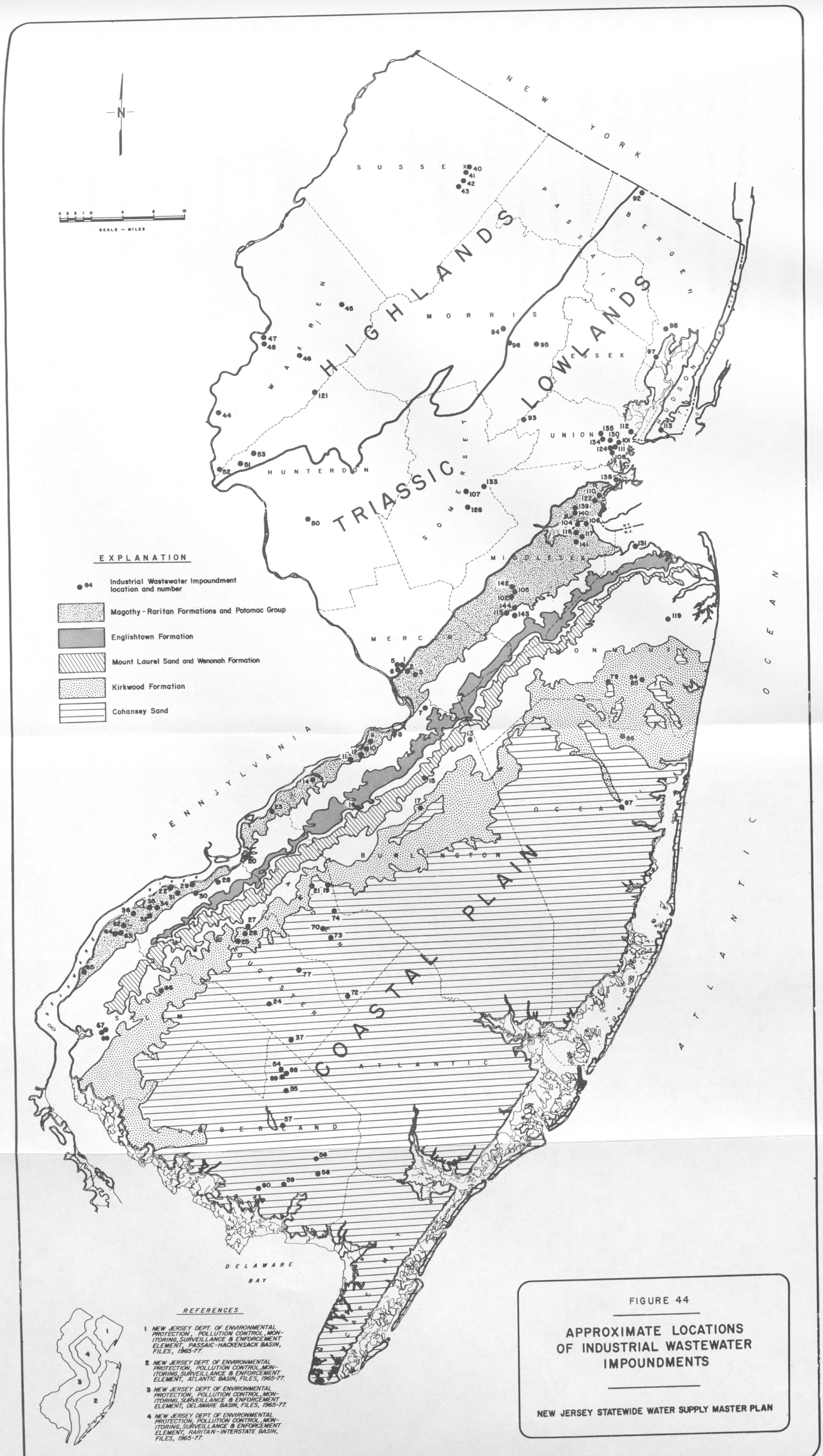
Leakage from an average impoundment was calculated to determine the overall magnitude of potential leakage. The actual volume of leakage at an individual site may vary from the calculated average by one or several orders of magnitude, depending on soil composition and self-sealing capability, the nature of the waste materials, and prevailing hydrogeologic conditions at the site (Karubian, 1974). This calculated leak rate is based on an assumed average retention time of 20 days, a nominal depth of 4 feet, and a seepage rate estimated at 30 inches per year. The calculated leakage rate for all impoundments is 1.6 mgd.

Known impoundments were plotted on geologic maps to identify sites located in aquifer outcrop areas (Table 14 and Fig-

ure 44). The total potential leakage of waste water from industrial impoundments situated on the Potomac-Magothy-Raritan outcrop area is estimated at 760 million gallons per year. Potential leakage into the Triassic and Cohansey aquifers is estimated at 440 and 400 million gallons per year, respectively. Continued large-scale leakage of industrial wastes will degrade local and regional water quality in these aquifers.

Table 14. Approximation of the Potential Volume of Leakage From Industrial Waste-Water Impoundments to Major Aquifers.

Geologic Province	Geologic Formation	Number of Sites With Lagoons	Volume of Leakage From One Lagoon (million gal./year)	Total Volume of Leakage Generated (million gal./year)
Highlands	–	14	20	280
Triassic Lowlands	Sandstones, shale, etc.	22	20	440
Coastal Plain	Potomac/Magothy/Raritan	38	20	760
	Englishtown	1	20	20
	Mt. Laurel/Wenonah	1	20	20
	Kirkwood	8	20	160
	Cohansey	20	20	400



REFERENCES

1 NEW JERSEY DEPT. OF ENVIRONMENTAL PROTECTION, POLLUTION CONTROL, MONITORING, SURVEILLANCE & ENFORCEMENT ELEMENT, PASSAIC-HACKENSACK BASIN, FILES, 1965-77.

2 NEW JERSEY DEPT. OF ENVIRONMENTAL PROTECTION, POLLUTION CONTROL, MONITORING, SURVEILLANCE & ENFORCEMENT ELEMENT, ATLANTIC BASIN, FILES, 1965-77.

3 NEW JERSEY DEPT. OF ENVIRONMENTAL PROTECTION, POLLUTION CONTROL, MONITORING, SURVEILLANCE & ENFORCEMENT ELEMENT, DELAWARE BASIN, FILES, 1965-77.

4 NEW JERSEY DEPT. OF ENVIRONMENTAL PROTECTION, POLLUTION CONTROL, MONITORING, SURVEILLANCE & ENFORCEMENT ELEMENT, RARITAN-INTERSTATE BASIN, FILES, 1965-77.

FIGURE 44

APPROXIMATE LOCATIONS OF INDUSTRIAL WASTEWATER IMPOUNDMENTS

NEW JERSEY STATEWIDE WATER SUPPLY MASTER PLAN

Geraghty & Miller, Inc.

SEPTIC SYSTEMS

Septic tanks and cesspools discharge large volumes of waste water directly into the ground, and are the most frequently reported sources of ground-water contamination. Most septic-system problems are related to surface flooding and/or the recycling of waste liquids through private wells. Except where liquid recycling is so rapid that pathogenic organisms can survive, the major health concern from on-site domestic waste disposal systems is high nitrate concentrations (Geraghty & Miller, Inc., 1977a).

Septic systems are widely used to dispose of wastes from homes, stores, laundries, small office buildings, hospitals, and industrial locations where community or municipal sewer systems are not available. Under normal conditions, septic systems are effective in removing phosphates, but chloride, nitrate, sulfate, bicarbonate, and dissolved solids are not removed and can enter the ground water (Miller, DeLuca and Tessier, 1974). Bacteria, viruses, and other pathogens are normally removed in soils, but under certain conditions, they reach the water table and are transported in ground water. A number of other ground-water contaminants are associated with septic systems including synthetic detergents, water treatment chemicals, and organic compounds used as septic system cleaners and degreasers.

A percolation test is generally required to determine the soil suitability for a septic system at a specific site, and rapid percolation is assumed to indicate efficient performance. Percolation testing, however, conveys a very limited amount of information, and coarse-grained soils that perform well in percolation tests are often the least effective in removing bacteria and bonding chemical pollutants. Moreover, the test cannot indicate the probable long-term impact on ground-water quality from various septic system densities (Miller, DeLuca, and Tessier, 1974).

CHARACTERISTICS OF DOMESTIC SEWAGE

Domestic sewage is about 99.9 percent water by weight, and contains soluble organic and inorganic materials including food wastes, soaps, bacteria, viruses, and other microorganisms. Its composition is not uniform, and varies from hour to hour and from house to house. The constituents in domestic sewage which pose the greatest potential threat to ground-water quality are:

- Excessive concentrations of nitrate produce a bitter taste in drinking water, and may be physically harmful. Water from wells containing more than 45 mg/l nitrate as NO_3 has been linked to methemoglobinemia in infants.
- Ground-water discharges containing high levels of phosphate can accelerate eutrophication in lakes, and high levels of BOD can deplete dissolved oxygen supplies necessary to support aquatic life.
- Lead, tin, iron, copper, zinc, and manganese leached from pipes are toxic in excessive concentrations.
- Sodium, chloride, sulfate, potassium, calcium, and magnesium can pose health hazards to some individuals (Geraghty & Miller, Inc., 1977a).

CASE HISTORIES

Two instances of excessive nitrate concentrations in ground water resulting from domestic septic tank effluent were identified by the NJDEP in Mercer County. Both cases involved nitrate contamination of local supplies which had to be abandoned for public water (Benitente, 1977).

Industrial waste water is sometimes disposed of in septic systems, and can contain constituents that have a high potential for contaminating ground water. An industrial firm located in Wharton, Morris County, discharges waste water to dry wells and a septic system. The plant has been operating at this site for approximately 10 years. Recently, the Borough of Wharton drilled a public supply well near the plant site; the water samples contained 10 mg/l of oil and grease. An investigation by the NJDEP, concluded that the firm's waste water contained high (22 mg/l) concentrations of oil and grease. The company has agreed to install monitoring wells to determine the extent of this contamination, and will install and operate a waste water treatment facility (Pollution Control Monitoring, Surveillance and Enforcement Element, 1977).

EXTENT OF THE PROBLEM

On-site domestic waste disposal systems may cause individual, local, or regional ground-water contamination problems. An individual problem occurs when a system on a particular piece of property contaminates one or more wells in the immediate vicinity. A local problem exists when a number of individual disposal systems contaminate an aquifer segment which is used to supply water in the area. A regional problem is created when many systems contaminate aquifers over a larger area, such as one or more counties. Ground-water contamination from septic system effluent is a regional problem in New Jersey.

The most important factor in the potential regional impact is the number and density of on-site domestic waste disposal systems in an area. Geology, depth to the water table, and climate will affect the nature and severity of the contamination problem, but to a lesser degree (Geraghty & Miller, Inc., 1977a). Regional ground-water quality impacts are extremely difficult to control or abate because many contaminants will persist in the ground-water system long after the septic tanks and cesspools are replaced by community sewer systems.

The regional potential for ground-water contamination is suggested by the relative density of on-site domestic waste disposal units. Three density ranges seem most relevant:

less than 10, 10 to 40, and more than 40 units per square mile. These ranges may be considered as low, intermediate, and high. In areas which are not sewered, housing density is a reasonable proxy for the number and density of individual disposal systems. Figure 45 shows the three housing density ranges with on-site domestic waste disposal facilities mapped on a county-by-county basis (Bureau of the Census, 1972). The high density areas are found in the eastern part of the state, from Monmouth to Bergen County, and in Union County. The remainder of the state has an intermediate density (Table 15). Actual densities in documented problem areas are considerably higher than 40 units per square mile.

The volume of waste water discharged to the ground through septic systems does not necessarily indicate the existence or magnitude of ground-water quality problems. The actual volume of domestic waste water discharged to the subsurface in the high-density areas, however, can be very large, and in some instances, represents a significant part of the recharge to the local aquifers (Office of Hazardous Substances Control, 1977a). The potential impact of the industrial use of septic systems on ground-water quality is significant. There is no inventory of industrial facilities discharging waste water into septic systems and problems are generally identified after wells become contaminated.

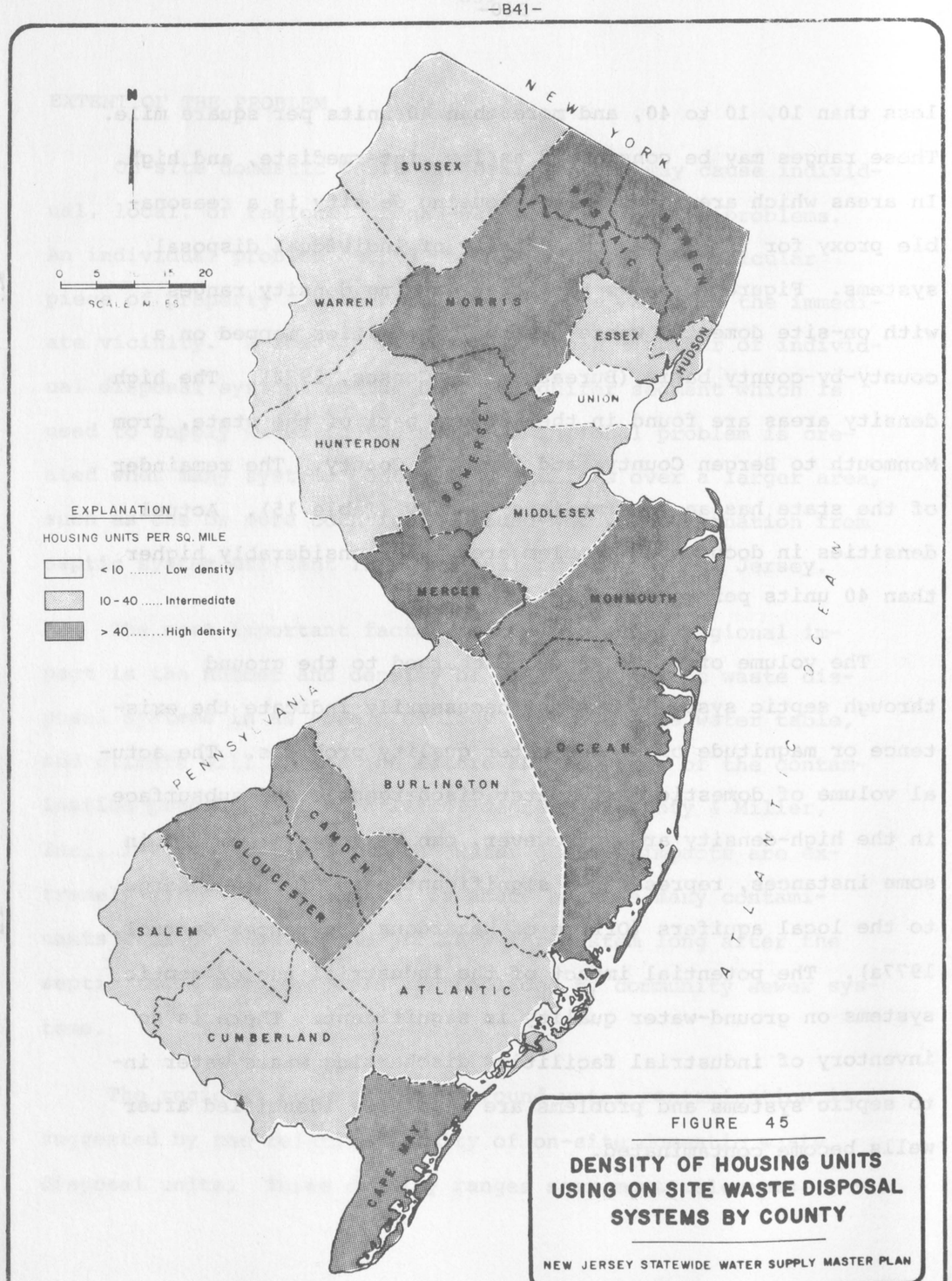


FIGURE 45

DENSITY OF HOUSING UNITS USING ON SITE WASTE DISPOSAL SYSTEMS BY COUNTY

NEW JERSEY STATEWIDE WATER SUPPLY MASTER PLAN

Table 15. Comparison of Housing Units Served by Sewers to Housing Units Served by Septic Systems.

County	Total Housing Units (year-round)	Sewage Disposal: Public Sewer	Sewage Disposal: Septic Tank or Cesspool	Sewage Disposal: Other	Area (sq mi)	Density of Septic Systems (units/sq mi)
Atlantic	67,801	47,526	19,774	501	569	34.7
Bergen	283,575	234,545	48,589	441	234	207.6
Burlington	87,758	69,438	17,614	695	819	21.5
Camden	143,150	131,722	10,820	600	221	48.9
Cape May	28,335	17,305	10,830	239	267	40.5
Cumberland	38,932	22,020	15,853	1,030	500	31.7
Essex	311,566	308,321	2,717	519	130	20.9
Gloucester	51,075	32,652	17,865	566	329	54.3
Hudson	214,665	213,634	676	343	47	14.3
Hunterdon	22,116	5,096	16,653	403	423	39.3
Mercer	96,401	86,233	9,861	306	228	43.2
Middlesex	171,599	160,313	10,956	328	312	35.1
Monmouth	142,927	89,517	52,686	773	476	110.6
Morris	113,033	63,804	48,605	594	468	103.8
Ocean	80,460	33,040	46,973	435	642	73.1
Passaic	151,093	135,124	15,515	407	192	80.8
Salem	19,408	10,631	8,110	679	365	22.2
Somerset	58,149	40,201	17,618	330	307	57.3
Sussex	24,415	4,366	19,739	384	527	37.4
Union	174,328	173,246	958	113	103	9.3
Warren	24,553	12,243	11,829	437	362	32.6

Reference: Bureau of Census, Soical and Economic Statistics Administration, 1970.

MUNICIPAL SEWER LEAKAGE

A sanitary sewer is theoretically watertight, but in practice, some leakage is normal and anticipated. Leakage from gravity sewers is generally caused by the following conditions:

- Poor workmanship, especially where mortar is used as a jointing material.
- Defective pipe.
- Breakage caused by frost heaving, superimposed loads, or differential settling.
- Rupture caused by downhill creep of earth fill materials in hilly terrain and loss of foundation support caused by underground washouts.
- Penetration by tree roots.

Many of the municipal sewer systems in the older urbanized areas of New Jersey were constructed in the early 1900's, and some of the original pipe is still in use. Older sewer systems are characterized by short pipe lengths with as many as 1,000 to 2,000 pipe joints per mile of pipe. These joints were commonly sealed with mortar, giving many opportunities for leakage. Although the leakage from any single joint may be very low in volume, the combined total of many small leaks may have a significant impact on ground-water quality. Sewer construction materials and techniques have improved significantly, and current practice specifies a leakage rate of less than 30 gpd per mile per inch of pipe diameter (Geraghty & Miller, Inc., 1976).

CASE HISTORIES

In March 1971, the NJDEP ordered the Perth Amboy Water Department to discontinue the use of certain suction wells in the Runyon Well Field. Analyses of the well water indicated higher than normal concentrations of aluminum, lead, and zinc in the Old Bridge aquifer. Subsequent investigation by the NJDEP revealed several sources of contamination, including a leaking connection in a municipal sewer line.

An industrial firm, located approximately one-half mile upstream from the Runyon Well Field, produces zinc fluoride and other chemical compounds. The firm's waste water is discharged into a municipal sewer owned by Old Bridge Township. Investigations revealed that a ruptured sewer lateral effectively bypassed the firm's pretreatment facility. Subsequent soil borings taken along the route of the Old Bridge sewer line indicated increasing amounts of contaminants in the direction of the well field (Geraghty & Miller, Inc., 1976).

During a routine analysis of water from the City of Camden's municipal supply, a high concentration of chromium was found in a well and it was removed from service. The chemical was subsequently traced to a number of metal-plating firms with sewer discharges. The full extent of the chromium contamination has not been determined (Geraghty & Miller, Inc., 1977b).

EXTENT OF THE PROBLEM

The age of a sewer system is a major determinant of potential leakage. Age data were assembled for approximately 60 percent of the state's sewer systems. This information is summarized on Figure 19. Sewer systems over 40 years old should be considered leak prone. No age data were available for the rest of the state.

Additional factors must be considered prior to any detailed assessment of potential leakage, including the depth of the sewer line with respect to the water table, the type of sewer (pressure or gravity), soil characteristics, flow rates, and population density. In general, however, systems exceeding 40 years in age are a potential threat to ground-water quality and should be subjected to detailed investigation.

BURIED PIPELINES AND STORAGE TANKS

Leaking or ruptured buried pipes and storage tanks are a threat to ground-water quality. Petroleum and petroleum products are transported and stored in hundreds of miles of transmission pipelines throughout the state, and in thousands of home and gasoline station tanks. Pipelines and tanks are subject to accidental rupture, external corrosion, and structural failure from a wide variety of causes.

The leakage of petroleum and petroleum products from underground pipelines and tanks is more common than is generally realized, particularly in the case of small commercial facilities, home heating oil tanks, and retail gasoline stations because installation, inspection, and maintenance standards may be low or essentially nonexistent.

Storage tanks often develop leaks after 5 to 20 years of service, and these leaks may not be readily detected because evaporation and other normal losses can average 0.5 percent per year of storage and effectively mask low volume leaks (Geraghty & Miller, Inc., 1977c). Over an extended period of time, a single tank or pipeline may leak a large volume of liquid into the ground unnoticed. There may be substantial contamination beneath most storage tank facilities, but no investigations are made unless there is a reported incident. If a leak occurs above the water table, the liquid may remain in

the vicinity of the leak, move within the backfilled materials in the trench or excavation, or migrate downward through the soil under the influence of gravity. The direction and rate of movement of liquids in the soil depends on several factors, including the volume of fluid, the comparative permeabilities of soil materials, and the density, viscosity, and miscibility of the liquid. A large volume of liquid may exceed the soil's adsorptive capacity and may reach the water table. Moreover, rainfall can drive chemicals adsorbed on soil into the saturated zone.

Underground and surface tanks are widely used by commercial establishments and individual residences to store gasoline and heating oil. These tanks are normally coated with a protective paint or corrosion-resistant bituminous material which, after some period of time, begins to break down. The installation, use, maintenance and replacement requirements for these tanks is not well regulated (Geraghty & Miller, Inc., 1976).

Transportation pipelines are used primarily for petroleum products and natural gas. According to the Office of Pipeline Safety, U. S. Department of Transportation (1976), the most common causes of pipeline failures are external corrosion, impacts by vehicles and equipment, and defective welds at seams and joints. Pipeline facilities have leak prevention programs

to prevent or control the escape of combustible, explosive, or toxic chemicals, but these programs are designed to minimize safety hazards and do not stress the protection of groundwater quality.

CASE HISTORIES

An industrial firm located in Waldwick, Bergen County, manufactures pharmaceuticals and stores a variety of chemicals including acetone, N-butyl alcohol, methylene chloride, ampicillin liquors, and spent solvents in underground tanks. Contamination of nearby Allendale Brook and a fish kill at White's Pond which is fed by Allendale Brook, resulted in a site inspection by the NJDEP. The inspection revealed that a storm sewer was discharging contaminated water into the brook; analysis of the water indicated an acetone concentration of 5 mg/l.

A subsequent investigation by the NJDEP and the U. S. Environmental Protection Agency showed that chemicals used in the firm's manufacturing process were entering a storm sewer. In addition, a leak was discovered in a pipe from one underground storage tank. Tests run on the storm sewers indicated no direct connection between the firm's storage tanks and nearby storm sewers, so that the chemicals had traveled via ground water from the leaking pipe to the storm sewer (Pollution Control Monitoring, Surveillance and Enforcement Element, 1977).

The Village of South Orange, Essex County, obtains its water supply from two well fields tapping fractured shale and sandstone bedrock. In March 1977, a gasoline odor was reported in water pumped from a well in the south well field and the well was shut down. All of the wells in the field subsequently developed a gasoline taste and odor and were taken out of service. The well field is not being used for public supply purposes, but several wells are being pumped in an attempt to purge the aquifer of gasoline. The village is now using the north well field supplemented with water purchased from the Commonwealth Water Company.

The well field that was taken out of service is surrounded by intensive residential and commercial development, including 10 gasoline stations. In April and May 1977, the stations pressure tested their tanks and no major leaks were detected. However, since the contamination is occurring at low concentrations, it may be caused by a slow leak which cannot be detected (Office of Special Services, 1977).

In Sewaren, Middlesex County, ground-water contamination caused by gasoline and heating fuel was reported in February 1972. At that time, vapors reached explosive levels, although the problem had been recurring over the previous 25 years. These fuels had apparently entered the Farrington Sand from leaks in one or more of the many storage tanks and pipelines

in the area, or from fuel spills that occurred during World War II, and the fumes were seeping into sewers and nearby basements during periods of high water levels.

Hydrogeologic conditions suggested that the fuel could be escaping from property owned by an industrial firm. The firm did not admit responsibility but did provide technical services during the attempt to remove the fuels from the aquifer. In July 1972, nine pumping wells were in operation, and by October some 1,060,000 gallons of gasoline and fuel oil had been recovered (Geraghty & Miller, Inc., 1976).

A refinery in Paulsboro, Gloucester County, is situated adjacent to the Delaware River, on the outcrop of the Potomac-Magothy-Raritan aquifer. The refinery makes and stores fuel oil, gasoline, and a number of other petrochemicals. Several production wells screened in the Magothy-Raritan-Potomac system supply some of the refinery's water, with the remainder obtained from the Delaware River.

Analyses of water from three of the plant's production wells indicated abnormally high levels of sodium, chloride, sulfate and iron, and a volatile organic compound, possibly trichloroethylene (Table 16). No background ground-water samples were available for comparison, but wells screened in the same aquifer system north and south of the refinery did not yield similar concentrations (Geraghty & Miller, Inc., 1977c).

Table 16. Results of Chemical Analyses of Water Samples from Wells Associated with Storage Tank Facilities, Gloucester County, New Jersey. (Results in milligrams per liter where applicable.)

	Refinery A			Refinery B		
	Well 40	Well 41	Well 45	Well 2	Well 6	Well 9
Date	2-3-77	2-3-77	2-3-77	2-3-77	2-3-77	2-3-77
Depth	267	280	156	?	?	15
pH	3.8	5.4	4.3	7.1	6.9	7.2
Alkalinity	0	16	2	68	58	348
Specific Conductance	1,100	800	2,000	300	280	900
Total Dissolved Solids	700	450	1,370	180	180	570
Chloride	203	107	116	27	26	14
Sodium	140	100	330	39	35	12
Potassium	5.7	4.3	5.8	4.8	5.1	12
Magnesium	13	13	19	3.9	4.8	29
Calcium	50	55	45	25	35	85
Sulfate	230	160	620	30	30	25
Nitrate nitrogen	<0.01	< 0.01	0.19	<0.01	< 0.01	0.02
Phosphate	0.07	0.07	0.05	0.09	0.08	0.33
Cadmium	<0.01	< 0.01	< 0.01	<0.01	< 0.01	< 0.01
Chromium	<0.01	< 0.01	0.01	<0.01	0.01	< 0.01
Copper	0.17	< 0.01	0.04	<0.01	< 0.01	< 0.01
Iron	19	17	38	1.9	2.2	11
Nickel	<0.03	< 0.03	0.07	<0.03	< 0.03	0.28
Lead	<0.03	< 0.03	< 0.03	<0.03	< 0.03	0.05
Zinc	0.59	0.38	0.40	0.04	0.15	3.2
Cobalt	0.05	0.07	0.22	<0.01	< 0.01	< 0.01
Phenol	0.03	0.03	0.06	0.05	1.7	0.04
PCB related compounds	<0.001	< 0.001	< 0.001	<0.001	< 0.001	< 0.001
Halogenated pesticides	<0.001	< 0.001	< 0.001	<0.001	< 0.001	< 0.001
Heavy volatile organics	<0.02	< 0.02	< 0.02	<0.02	< 0.02	< 0.02
Light volatile organics	0.2	0.3	0.3	<0.1	< 0.1	< 0.1

Reference: Geraghty & Miller, Inc., 1977c.

EXTENT OF THE PROBLEM

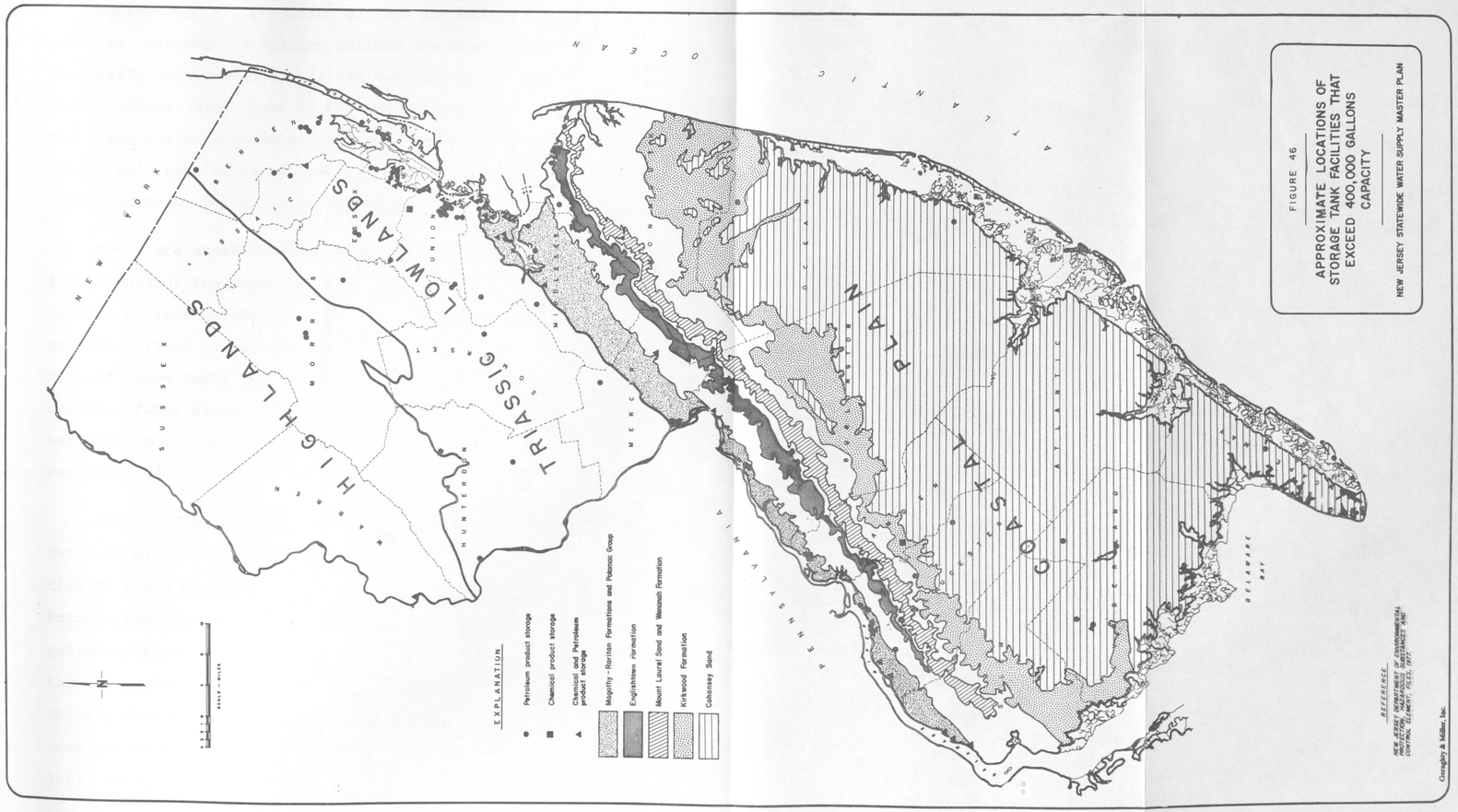
The number of fuel storage tanks in the state is not known. They are used throughout the state and have a wide range in age. Many tanks are not metered properly and receive virtually no maintenance. A large number of storage facilities are located in the Coastal Plain province. Moreover, approximately 25 percent of the petroleum storage facilities, and almost 40 percent of combined storage facilities, are located on the Potomac-Magothy-Raritan outcrop area (Table 17 and Figure 46). Approximately 50 percent of the petroleum storage and 41 percent of the combined facilities are located on the Triassic rocks. Most of the storage facilities in the Triassic basin are located near Elizabeth, and are adjacent to the Potomac-Magothy-Raritan outcrop area.

Storage tank facilities are required to have Federal and/or state permits depending upon the storage capacity of the site; there are approximately 440 permitted sites in the state. Appendix B5 gives the name and location of facilities operating with Federal permits (U.S. Environmental Protection Agency, 1977). The type of product stored at each site may vary from relatively harmless liquids to toxic substances. The location, storage capacity, daily flow, and product type for storage facilities exceeding 400,000 gallons capacity is described in Appendix B6 (Office of Hazardous Substances Control, 1977b). These facilities typically store petroleum products.

Table 17. Major Storage Facilities and Geologic Provinces Within New Jersey.

Geologic Province	Formation	Product Storage Type: Petroleum Storage No.	Petroleum Storage Percent	Chemical or Chemical and Petroleum Storage No.	Chemical or Chemical and Petroleum Storage Percent
Highlands	-	3	3.5	1	2
Triassic Lowlands	Triassic formations	43	50.5	20	41.6
Coastal Plain	Potomac/Magothy/Raritan	21	24.7	19	39.5
	Englishtown	1	1.1	0	0
	Mt. Laurel/Wenonah	2	2.4	0	0
	Kirkwood	1	1.1	1	2
	Cohansey	9	10.5	2	4.1
	Non-aquifer formation	3	3.5	3	6.2
	Facilities not located on map	2	2.3	2	4.1
	TOTAL:	85	99.6	48	99.5

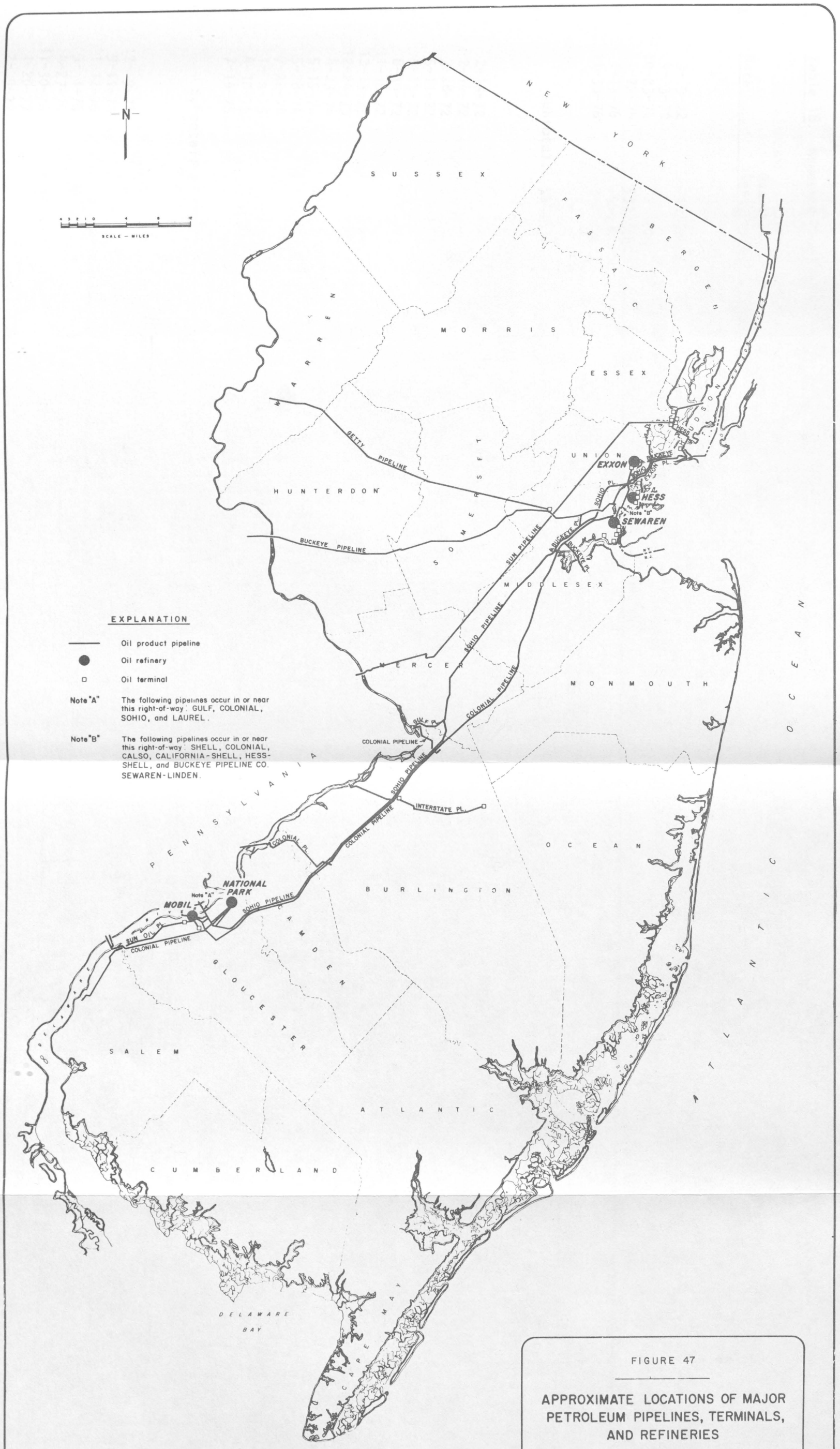
Note: All facilities have a minimum capacity of 400,000 gallons.



Approximately 3.6 billion gallons are stored in these facilities, and some 87 million gallons are transferred through them daily (Appendix B6). If the 0.5 percent of the aggregate stored volume leaks, some 18 million gallons will be lost. The potential ground-water quality impact from leakage at these facilities is significant, and primarily affects the Potomac-Magothy-Raritan aquifer system.

There are about 8,500 gasoline service stations distributed throughout the state (Simon, 1977). Assuming an average on-site storage capacity of 10,000 gallons, approximately 85 million gallons of gasoline may be stored in subsurface tanks. Most of these tanks are tar-coated steel, and are prone to corrosion. Fiber glass tanks, introduced in the early 1960's, do not corrode but may crack under cold temperatures or excessive surface loads.

Major petroleum pipelines extend from Paulsboro along the Delaware River northeastward to Bayonne (Figure 47). The location of these pipelines approximates the outcrop area of the Potomac-Magothy-Raritan, so spills and leakage associated with petroleum pipeline operations must be considered a potential threat to the aquifer. Approximately 900,000 gallons were spilled from pipelines between 1972 and 1977. Pipeline failures are shown on Table 18 (Office of Hazardous Substances Control, 1977c).



REFERENCE

MODIFIED FROM: ENVIRONMENTAL MAP OF NEW JERSEY, ENERGY, (DRAFT COPY), DEPT. OF ENVIRONMENTAL PROTECTION, BUREAU OF GEOLOGY AND TOPOGRAPHY, JUNE 1976

FIGURE 47

APPROXIMATE LOCATIONS OF MAJOR PETROLEUM PIPELINES, TERMINALS, AND REFINERIES

NEW JERSEY STATEWIDE WATER SUPPLY MASTER PLAN

Geraghty & Miller, Inc.

Table 18. Reported Pipeline Failures Within New Jersey From 1972 to 1977.

Date	Quantity (gallons)	Product	Cause	Location
		Colonial Pipeline		
3- 9-72	10,000	Gas	Unknown	Allentown
4- 3-72	-	Kerosene	Pipe leak	Linden
10-23-74	800	Gas	do	Woodbridge
11-22-75	537,684	Kerosene	do	Crosswicks
1-13-76	Sheen	do	do	do
11-30-76	3-6,000	Gas	Tank overfill	Trenton
-	15	do	Leak	West Deptford
Subtotal:	554,499			
		Interstate Storage & Pipeline		
2-13-72	-	JP4	Leak	-
2-14-72	-	do	do	-
2-28-72	-	do	do	-
5-11-72	-	do	do	-
5-13-72	-	do	Corrosion	-
8-10-72	-	do	Leak	-
11-16-72	-	do	do	-
12-13-73	20	do	Corrosion	-
12-24-73	50	do	do	-
4-23-74	-	do	Leak	-
5-15-74	-	do	do	-
5-28-74	5	do	-	-
7-22-74	-	do	-	-
1- 4-75	5-10	do	Gasket failure	Burlington
4-10-75	15-20	do	Leak	do
7-14-75	-	do	do	Jacksonville
Subtotal:	105			
		Getty Pipeline		
12- 9-74	-	No. 2	Pinhole in pipe	-
9-11-75	-	Kerosene	Break	Watchung
1-12-76	4,160	No. 2	Rupture	Bound Brook
3- 1-76	307,661	do	do	Piscataway
4-27-76	-	Oil	-	-
11-30-76	50,000	No. 2	Rupture	Carteret
1-20-77	1,380	do	Break	Edison
2- 9-77	-	do	Rupture	-
Subtotal:	363,201			
TOTAL:	917,805			

Reference: Office of Hazardous Substances and Control, 1977.

ACCIDENTIAL DISCHARGES

Accidental spills and discharges of hazardous chemicals or other materials can introduce contaminants into the ground and degrade ground-water quality. These spills and discharges are caused by poor housekeeping practices at gasoline stations, commercial establishments, industrial facilities, and airports; by the illicit dumping of waste materials; and by storage failures or transportation related accidents.

Ground-water contamination caused by poor housekeeping practices is characteristic of petrochemical production, transportation, and storage. Oil has saturated the soil at several refineries and petroleum storage areas in New Jersey, and oil ponds form on the land surface when the water table is high. Storm sewers in these areas often contain oil-laden ground water that has leaked into them. Although leakage from buried pipes may contribute to the problem of petrochemicals in ground water, it is primarily caused by the long-term buildup of oil from accidental spillage and leakage from surface tanks and pipes (Miller, DeLuca, and Tessier, 1974).

Ground-water contamination also occurs where oil and other materials are purposely discarded on the land surface, especially at gasoline stations, small commercial establishments and at industrial waste piles. A study of the ultimate disposal of waste crankcase oil in Massachusetts revealed that

some 650,000 gallons of oil a year is spilled, dumped, or discarded on the ground at or near service stations throughout the state. Two million gallons was discarded by car dealers, garage owners, construction equipment operators, fleet operators, and by individuals changing the oil in their personal automobiles (Arthur D. Little, Inc., 1969). Although industry disposes of most of its uncollected oil in landfills, at least some lubricating, hydraulic, and cutting oils are discarded on the ground. In many cases, small quantities of oil and other liquids are discarded in open or wooded lands when it is not economical or is inconvenient to store the material in drums or haul it to municipal waste treatment plants or landfills.

Accidental spillage is an inherent problem in the storage and transportation of fluid materials. Although it may not be possible to eliminate accidents, it is possible to achieve a reasonable measure of ground-water protection in the cleanup of spills after they have taken place. Liquids spilled on roadways, for example, are generally flushed from the road surface rather than removed with absorbent materials because the maintenance of traffic flow is considered more important than minimizing ground-water contamination.

All spills and leaks pose some threat to ground-water quality. Although small spills may be absorbed or adsorbed in the unsaturated zone, large volume spills can percolate a substantial quantity of fluid to the water table. Depending on

the density and miscibility of the fluid, it will tend to float on or mix with the ground water. Removing contaminants by pumping is costly and is not always successful.

Very small amounts of chemicals introduced into the soil may give potable water an objectionable taste and odor. In sufficiently high concentrations, the lighter fractions of petroleum products, liquified petroleum gas, and natural gas can seep into basements, excavations, tunnels, and other underground structures with ground water, and constitute a severe explosion and fire hazard.

CASE HISTORIES

In 1945, approximately 350,000 gallons of No. 2 fuel oil spilled when a pipeline ruptured in the Town of Phillipsburg, Hunterdon County. The entire volume of oil migrated into the underlying limestone formation, and virtually none was recovered. A few years ago a number of production wells, owned by an industrial firm and located some 800 feet from the original spill site, became contaminated with a large volume of oil. The full extent of this contamination is not known (Office of Special Services, 1977).

The Runyon Well Field, operated by the municipality of Perth Amboy, yields contaminated water. An investigation by the NJDEP noted that the pollution was caused, in part, by a ruptured sewer. Subsequent study by the NJDEP identified

other sources, including accidental spills of industrial products. The NJDEP report noted that the watershed upstream from the well field, particularly along Pricketts Brook, is heavily industrialized, and that Pricketts Brook was contaminated by BOD, COD, zinc, lead, aluminum, cadmium, and iron as a result of surface runoff from the industrialized areas. Surface runoff in this area flows directly into Tennent Pond and recharges the Old Bridge aquifer in the Runyon Well Field (Geraghty & Miller, Inc., 1976).

During August 1973, a spill of several hundred gallons of methyl isobutyl ketone occurred on property owned by an industrial firm in Paulsboro, Gloucester County. About one year later, a domestic well was contaminated with this chemical and some time later a spring located 435 feet from the spill site became contaminated. After an investigation to define the extent of the pollution, the firm replaced the two contaminated water supplies with deep wells, and upgraded its solvent storage facility to reduce the possibility of future leaks or spills. No direct action was taken to remove the chemical in the aquifer because its low solubility and density would effectively restrict it to the upper portion of the water table, and migration to a deeper aquifer is not likely in the area (Geraghty & Miller, Inc., 1977b).

An industrial firm located in Middlesex County stored containers of chlorinated hydrocarbons and organic phosphate near

the Perth Amboy Water Company. Some of the drums ruptured and released their contents into the local surface-water system. Ground-water sampling indicated abnormally high concentrations of lead, chromate, and phenols of 0.069, 0.064, and 0.45 mg/l, respectively (Geraghty & Miller, Inc., 1976).

EXTENT OF THE PROBLEM

Approximately 70,000 and 82,000 gallons were spilled during 1976 and 1977, respectively (Tables 19 and 20). Spills of petroleum products, including gasoline, totaled approximately 60,000 gallons during 1976, and 66,000 gallons during 1977. Most reported spills resulted from truck accidents and leaking underground storage tanks (Table 21). In 1975, the New Jersey Turnpike Authority reported a total of 545 truck-related accidents on the New Jersey Turnpike in Middlesex County (Geraghty & Miller, Inc., 1976). Although no records were available regarding the nature of the products being transported, the possibility of significant ground-water pollution as a result of truck-related accidents is apparent.

The location of reported spills reflects the extent of urbanization and industrialization in the state. The majority of reported spills occurred in the Triassic basin and on the Potomac-Magothy-Raritan outcrop area (Table 22 and Figure 48). These aquifers have received, and will probably continue to receive, major amounts of petroleum and chemical products.

Table 19. Causes and Volumes of Reported Spills Which Have Occurred Within New Jersey During 1976 (all volumes in gallons).

Cause	Petroleum Products	Gasoline	Industrial Chemicals	Other	Total
Unknown	10,063	1,550	1,920	0	13,533
Truck Accident	6,980	8,700	0	0	15,680
Storage Tank Leak (below ground)	0	2,400	0	0	2,400
Deliberate Dumping	0	0	3,870	0	3,870
Continuous and Intentional Discharge	0	0	500*	0	500*
Storage Tank Leak (above ground)	1,825	25,000	0	0	26,825
Tank Truck Spillage	0	1,000	0	0	1,000
Railroad Tank Car Leak	0	0	3,000	0	3,000
Miscellaneous	2,800	850	20	0	3,670
TOTAL:	21,668	39,500	8,810 + 500*	0	69,978 + 500*

* Discharges in gallons per day.

Reference: Office of Hazardous Substances and Control, 1977a.

Table 20. Causes and Volumes of Reported Spills Which Have Occurred Within New Jersey During 1977 (all volumes in gallons).

Cause	Petroleum Products	Gasoline	Industrial Chemicals	Other	Total
Unknown	43,920	11,410	72	5,000	60,402
Truck Accident	7,640	0	6,000	100	13,740
Storage Tank Leak (below ground)	100	4,475	0	0	4,575
Deliberate Dumping	0	0	3,270	0	3,270
Continuous Discharge	0	0	285*	0	285*
Storage Tank Leak (above ground)	0	0	200	0	200
Tank Truck Spillage	0	0	0	0	0
Railroad Tank Car Leak	0	0	0	0	0
Miscellaneous	0	0	0	30	30
TOTAL:	51,660	15,885	9,542 + 285*	5,130	82,217 + 285*

* Discharges in gallons per day.

Reference: Office of Hazardous Substances and Control, 1977a.

Table 21. Causes and Frequency of Reported Spills Potentially Affecting Ground-Water Quality Within New Jersey From January 1976 to July 1977.

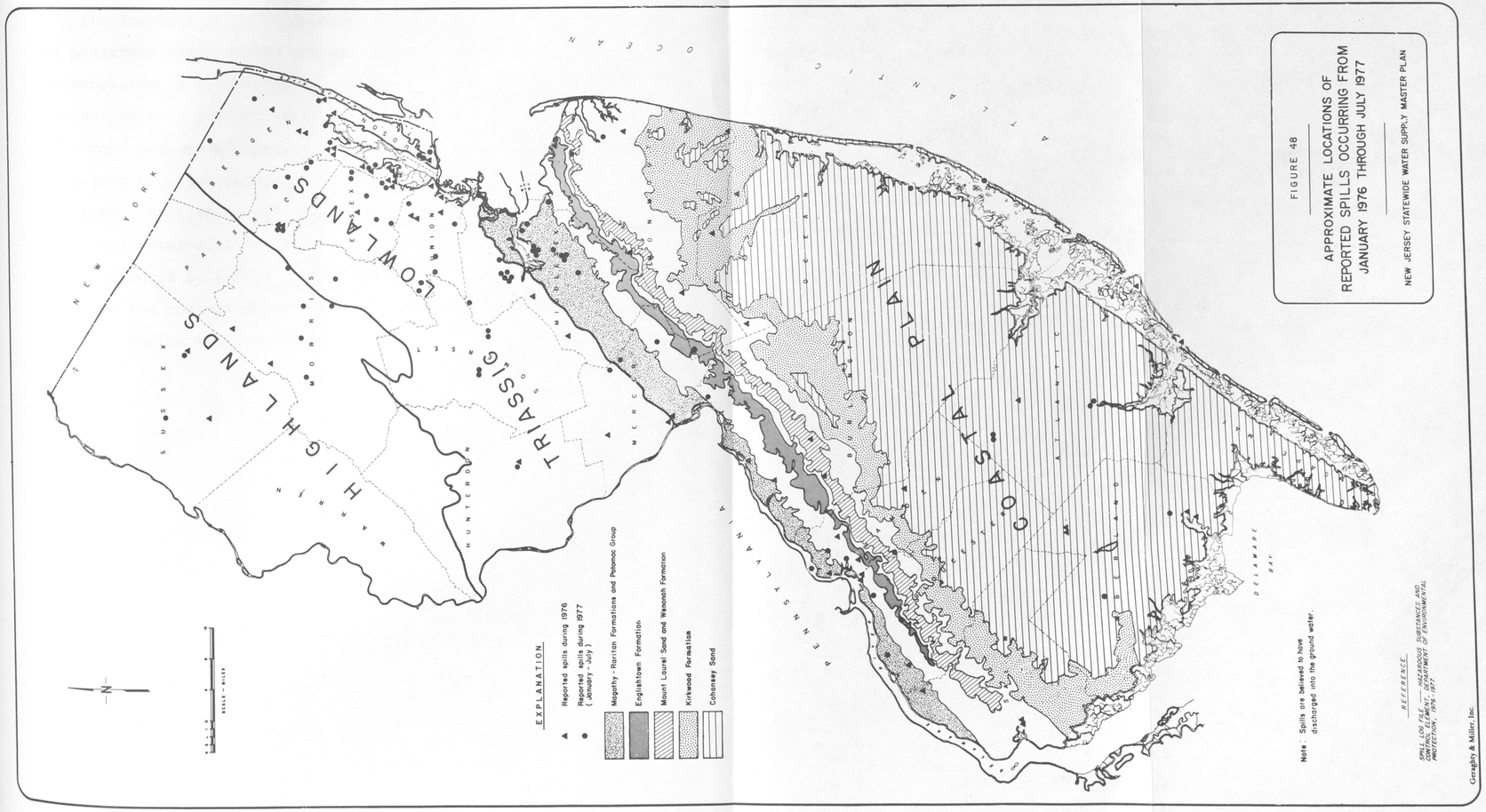
Cause	1976 Number	1976 Percent	1977 Number	1977 Percent
Unknown	39	48.7	45	57.6
Truck Accident	10	12.5	6	7.7
Storage Tank Leak (below ground)	8	10	13	16.6
Deliberate Dumping	8	10	6	7.7
Continuous and Intentional Discharge	3	3.7	1	1.3
Storage Tank Leak (above ground)	3	3.7	1	1.3
Tank Truck Spillage	2	2.5	0	0
Railroad Tank Car Leak	2	2.5	0	0
Miscellaneous	5	6.2	6	7.7
TOTAL:	80	99.8	78	99.9

Reference: Office of Hazardous Substances and Control, 1977a.

Table 22. Statistical Summary of the Relationship Between the Frequency of Reported Spills and Geologic Provinces in New Jersey From January 1976 to July 1977.

Geologic Province	Formation	1976 Number	1976 Percent	1977 Number	1977 Percent
Highlands	-	4	5	7	8.9
Triassic Lowlands	Triassic Formations	30	37	43	55.1
Coastal Plain	Magothy/Raritan/Potomac	15	18.7	6	7.7
	Englishtown	1	1.2	3	3.8
	Mt. Laurel/Wenonah	2	2.5	1	1.3
	Kirkwood	3	3.7	0	0
	Cohansey	9	11.2	8	10.2
	Non-aquifer Formations	11	13.7	7	8.9
	Spills not located on map	5	6.2	3	3.8
	TOTAL:	80	99.2	78	99.7

Reference: Office of Hazardous Substances and Control, 1977a.



The location, type of product, volume, and cause of oil and hazardous waste spills between January 1976 and July 1977 are tabulated in Appendices B7 and B8 (Office of Hazardous Substances Control, 1977a). This inventory is not complete because many accidental spills are not reported to the NJDEP. The extent of under reporting is unknown and cannot be readily estimated. Available evidence indicates that spills generally have local water-quality impacts. Regional ground-water quality is affected by spills, but the impact is generally not as severe as the contamination resulting from impoundments, landfills, or buried storage tanks.

HIGHWAY DEICING PRACTICES

The requirement for unimpeded and safe vehicular travel on highways during winter conditions has led to the increased use of sodium and calcium chloride by state and local agencies. Salt spreading is a popular method of controlling roadway icing because of its ease of handling, efficiency, and relatively low cost. Both the storage and use of large volumes of salt have an adverse impact on surface- and ground-water quality.

The sodium, calcium, and chloride ions in the salt are carried to the water table by snow melt and rainfall. Salt-contaminated water can then move through the saturated zone until it is discharged into a surface-water body, or leaks into an adjacent aquifer. Although both sodium and chloride ions can move through the unsaturated and saturated zones, sodium ions are more readily bound in various types of soils. This accounts for the relatively higher ratio of chloride to sodium found in contaminated ground water as opposed to surface water that receives direct runoff (Miller, DeLuca, and Tessier, 1974).

Salt storage piles are located throughout the state, and in the fall, each may contain from several hundred to several thousand tons of salt. The low solubility of rock salt permits outside storage over relatively long periods of time without hard caking or noticeable loss in volume and many salt

piles are left uncovered on open land. Outside storage is common if the salt has been mixed with sand, since covered storage for large volumes of material would require an expensive structure.

Precipitation falling on the stockpile dissolves a portion of the salt and carries it into the ground water. Salt-spreading trucks are often washed out at these storage areas, and the resulting brine seeps into the soil and compounds the problem. Drainage from salt piles and wash areas is often disposed of in dry wells, and salty water is introduced directly into the ground at the site (Miller, DeLuca, and Tessier, 1974).

Road-salting practices and storage may lead to violations in permissible chloride and sodium concentrations in drinking water. The U. S. Public Health Service Drinking Water Standards of 1962 set a maximum recommended limit of 250 mg/l for chloride, and medical authorities generally discourage the use of water containing more than 20 mg/l of sodium for certain patients. Other problems associated with deicing include accelerated metal corrosion and the addition of anti-caking and corrosion-inhibiting chemicals into the ground-water regime.

CASE HISTORIES

Long-term records of water quality in a number of municipal wells have shown a gradual but significant trend of in-

creasing chloride concentrations in many of the glacial sand and gravel aquifers of northern New Jersey. Some of these aquifers were pumped for decades with no indication of contamination until the early 1960's, when chloride concentrations began to increase. If the present trend continues for another decade, many wells will yield water that exceeds 250 mg/l of chloride and contains high levels of sodium (Miller, DeLuca, and Tessier, 1974).

Few documented cases of ground-water contamination due to salt stockpiling and use have been identified in New Jersey. However, one case is presently being investigated by the NJDEP. The Germany Flats area in Sussex County contains a buried sand and gravel aquifer with a good potential for ground-water supply. There are large, partly uncovered salt stockpiles and a landfill belonging to the Township of Sparta situated on the stratified drift. A resistivity survey conducted during a recent water resource study of the area identified areas of polluted ground water. An area of low resistivity was found near the salt storage section and another near the landfill. The investigation concluded that the salt storage piles and the landfill are "apparently responsible for the highly mineralized water in the adjacent wetlands and the upper parts of the sand and gravel aquifer in that part of Germany Flats" (Harold E. Pellow and Associates, Inc., 1975).

Further investigation by the NJDEP revealed excessive con-

centrations of chloride and sodium in the ground water resulting from leaching of the salt storage piles. The state has recommended that the salt piles be put on bituminous pads to minimize the migration of salt into the aquifer and that swales be constructed to contain surface runoff (Vernam, 1978).

EXTENT OF THE PROBLEM

The impact of road deicing chemicals on ground water depends to a great extent on the severity of icing conditions. Salt spreading varies with location, specific icing conditions, and operator training, and can vary from approximately one ton of salt per lane mile to as many as 10 tons per lane mile during an average snowfall. The average application rate for the state is 4 tons per lane mile. Table 23 indicates the number of state highway miles by county (Dunn, 1977).

The New Jersey Turnpike Authority and the State Department of Transportation application rates are approximately 330 pounds per lane mile (Lewis, 1977). State agencies maintain adequate records of salt use and storage, and its impact can be estimated. Local municipalities, however, frequently do not maintain sufficient records, and the total volume used cannot be determined.

The state's storage facilities have a capacity of 70,000 to 80,000 tons, approximately 80 percent of which is under cover. The New Jersey Turnpike Authority has a number of storage

Table 23. New Jersey State Highway Mileage by Systems as of January 1, 1974.

County	State Roads	County Roads	Municipal Roads	N. J. Turnpike	Garden State Parkway	Atlantic City Expressway	Other Roads	Total Mileage
Atlantic	146	364	1,233	-	20	29	5	1,797
Bergen	101	450	2,166	2	14	-	13	2,746
Burlington	152	496	1,453	30	6	-	1	2,138
Camden	100	385	1,238	9	-	14	3	1,749
Cape May	78	187	542	-	24	-	7	838
Cumberland	84	548	654	-	-	-	-	1,286
Essex	55	211	1,272	6	10	-	-	1,554
Gloucester	132	405	683	17	-	1	-	1,238
Hudson	27	119	431	14	-	-	4	595
Hunterdon	109	253	781	-	-	-	-	1,143
Mercer	86	172	885	12	-	-	1	1,156
Middlesex	133	316	1,546	27	8	-	1	2,031
Monmouth	170	397	1,951	-	29	-	-	2,547
Morris	140	296	1,577	-	-	-	-	2,013
Ocean	131	630	1,343	-	36	-	-	2,140
Passaic	49	236	901	-	7	-	-	1,193
Salem	82	354	403	8	-	-	1	848
Somerset	111	231	897	-	-	-	-	1,239
Sussex	106	297	946	-	-	-	1	1,350
Union	58	157	1,128	7	2	-	1	1,353
Warren	102	260	614	-	-	-	3	979
TOTAL:	2,152	6,764	22,644	132	156	44	41	31,933

State - Forest, Park and Institutional Roads Maintained: 486

Total Mileage All Systems: 32,419

Reference: Thatch, D. W., and S. D. Foss, 1976.

facilities with capacities ranging from 1,000 to 4,000 tons. No data on storage facilities for local municipalities were obtained (Dunn, 1977).

In general, there is a greater potential for both regional and local ground-water contamination from salt storage and use in the northern part of the state. Salt contamination in the southern part of the state is generally the result of inadequate storage, and total covered storage should be required.

AGRICULTURAL ACTIVITIES

There are approximately one million acres in agricultural use in New Jersey. Most agricultural activities are in the southern part of the state on contiguous farms ranging in size from a few hundred to several thousand acres (Figure 49). Farms are generally located a considerable distance from major centers of ground-water development, and are usually served by individual supply wells. A number of agricultural activities, including horticulture and dairy farming, can lead to ground-water contamination from fertilizers, pesticides, herbicides, soil conditioners, and animal wastes. These chemicals are used throughout the state (Office of Special Services, 1977).

There is no reliable data on the potential or actual impact of fertilizers or insecticides on ground-water quality in the state. Based on available case histories, it appears that the use of nitrogen fertilizers may affect ground-water quality in the vicinity of the agricultural areas. Since the major agricultural areas are widely separated from major areas of ground-water recharge or pumping, the threat to regional ground-water quality from this source is minimal.

Although many agricultural chemicals are highly toxic, their recommended application rates are very low, and they are generally adsorbed onto soil particles. The soil provides effective removal of many agricultural chemicals and minimizes

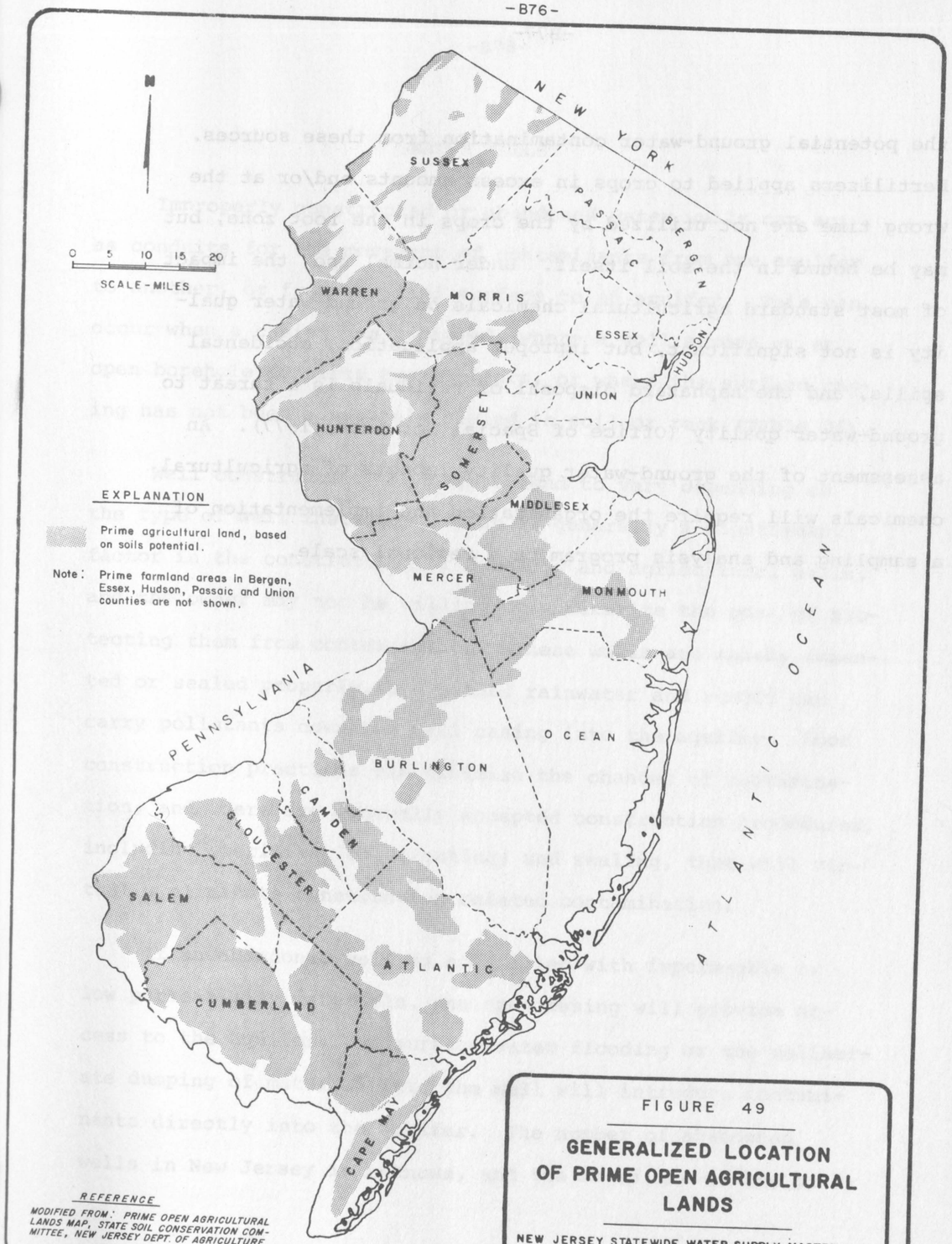


FIGURE 49

GENERALIZED LOCATION OF PRIME OPEN AGRICULTURAL LANDS

NEW JERSEY STATEWIDE WATER SUPPLY MASTER PLAN

the potential ground-water contamination from these sources. Fertilizers applied to crops in excess amounts and/or at the wrong time are not utilized by the crops in the root zone, but may be bound in the soil itself. Under normal use, the impact of most standard agricultural chemicals on ground-water quality is not significant, but improper application, accidental spills, and the haphazard disposal of residuals is a threat to ground-water quality (Office of Special Services, 1977). An assessment of the ground-water quality impacts of agricultural chemicals will require the organization and implementation of a sampling and analysis program on a regional scale.

WATER WELLS

Improperly constructed or abandoned water wells can act as conduits for the movement of contaminants from one aquifer to another, or from the land surface to an aquifer. This can occur when a casing has ruptured, where a well screen or an open borehole connects two aquifers, or where the surface casing has not been adequately sealed in soil or rock (Table 24).

Well construction techniques tend to vary depending on the type of well installed. Cost is generally a significant factor in the construction of domestic and agricultural wells, and the owner may not be willing to underwrite the cost of protecting them from contamination. These wells are rarely cemented or sealed properly, and ponded rainwater and runoff can carry pollutants down the well casing into the aquifer. Good construction practices can minimize the chances of contamination, and there are generally accepted construction procedures, including sterilization, grouting, and sealing, that will virtually eliminate construction related contamination.

If an abandoned well is not filled with impermeable or low permeability materials, the open casing will provide access to the aquifer, and surface-water flooding or the deliberate dumping of material into the well will introduce contaminants directly into the aquifer. The number of abandoned wells in New Jersey is unknown, and the magnitude of the prob-

Table 24. Examples of Conditions Under Which Water Wells Can Cause Ground-Water Contamination.

Imperfect Construction	Inadequate surface protection
	Poor or no grouting
	Well finished at or below land surface
	Open annulus around casing
Illegal Construction	Poor location
	Split screen where prohibited by situation
	Improper abandonment of well
	Improper backfill of test holes
Well Failure	Casing corrosion
	Casing electrolysis (chemical)
	Stray currents in ground
	Accidental holing of casing during construction or maintenance
Well Use	Direct recharge of contaminant
	Movement of contaminants caused by pumping
	Salt-water intrusion

lem is difficult to estimate but it may be significant. There are roughly 1,000 licensed well drillers in New Jersey, but only about 20 of them are licensed to seal wells (Webster, 1978).

Personnel from the Water Allocations Unit of the Bureau of Water Supply Planning and Management are supposed to be present when a well is sealed. This task is frequently assigned to a local health officer who may not be familiar with approved well sealing techniques. In many cases, wells are simply abandoned by the operator without any attempt at sealing. The magnitude of this problem is unknown and would require a significant research effort by the NJDEP.

DIFFUSION WELLS

The temperature of natural ground water at a depth of 30 to 60 feet normally exceeds the average annual air temperature by 2 or 3°F. At greater depths the temperature increases by approximately 1°C per 100 feet. Regional ground-water temperatures in New Jersey are approximately 52 to 57°F (Walton, 1970). The discharge of cooling waters through diffusion wells may raise the temperature of the natural ground water by 10 to 40°F, and may result in thermal loading of the aquifer.

Thermal loading of ground water has been observed in industrial areas of Long Island, New York, where large volumes of heated water are returned to the aquifer (Geraghty & Miller, Inc., 1977d). However, no case histories of thermal loading have been documented in New Jersey and the number of diffusion wells is estimated at under 100 (Webster, 1978).

SPRAY IRRIGATION

Spray irrigation utilizes treatment by soil processes to supplement the secondary treatment of domestic and/or municipal waste water. It is also used to dispose of certain industrial wastes, principally from food processing. A number of facilities dispose of municipal and industrial waste water by spray irrigation, as shown on Table 25 and Figure 50 (Forlini, 1978).

The ground-water quality impacts of spray irrigation depend on a number of factors, including the characteristics of the soils underlying the site, the nature of the waste water applied, the extent of pretreatment, and the geology and hydrology of the site. The following examples illustrate the problems associated with the spray disposal of waste water on the land surface.

CASE HISTORIES

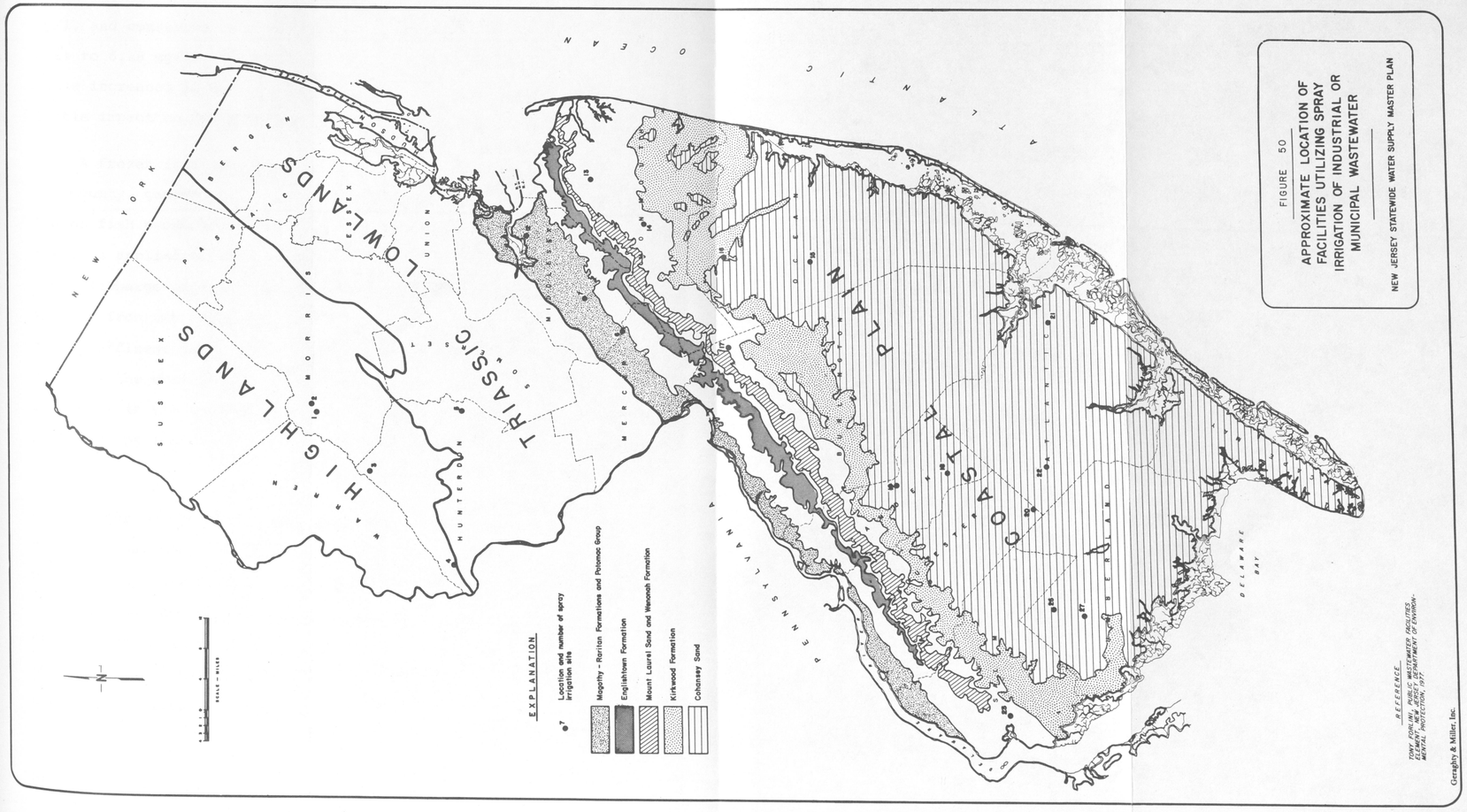
The East Windsor Municipal Utilities Authority presently spray irrigates municipal sewage treatment plant effluent at a rate of 1.9 to 2.3 inches per day. Monitoring at the site has shown that the facility has not substantially degraded ground-water quality. Orthophosphate concentrations were near background levels, and nitrate concentrations ranged from 2.9 to 4 mg/l, with a background level of 2 mg/l. The concentrations of copper, lead, chromium, and zinc increased by 0.05 to 0.11

Table 25. Facilities Using Spray Irrigation to Dispose of Treatment Plant Effluent in New Jersey.

Map No.	Name of Facility	Municipality	County
1	Oakwood Village	Mount Olive	Morris
2	Eagle Rock Village	do	do
3	Lebanon Cheese Company	Lebanon	Hunterdon
4	Riegel Paper Company	Holland	do
5	Durling Farms	Readington	do
6	East Windsor Municipal Utilities Authority	East Windsor	Mercer
7	Monroe Township M.U.A. (Forsgate Sanitation)	Monroe	Middlesex
8	Lincoln Property	do	do
9	Rutgers University	New Brunswick	do
10	-	-	-
11	Firmenich, Inc.	Plainsboro	Middlesex
12	Roxbury Mall	Roxbury	-
13	Western Electric	Holmdel	Monmouth
14	*Monmouth County Battle Field	Freehold	do
15	Crestwood Village 1 and 2	Manchester	Ocean
16	Great Adventure	Jackson	do
17	Hoffman-LaRoche	North Hanover	Burlington
18	Braddock Frosted Foods	Winslow	Camden
19	Owens-Corning	Berlin	do
20	United Poultry	Franklin	Gloucester
21	Stockton State College	Galloway	Atlantic
22	Scott Paper Company	Buena Vista	do
23	Heinz	Salem City	Salem
24	Vineland Live and Dressed Poultry	Pittsgrove	do
25	*Seabrook Farms	Upper Deerfield	Cumberland
26	*Tricounty Vegetable	Deerfield	do
27	Hunt-Wesson Foods, Inc.	Bridgeton City	do

* Not Operational

Reference: Forlini, A., 1978.



mg/l, and concentrations of iron and aluminum increased from 0.14 to 6.18 mg/l, and from 0.075 to 34 mg/l. Except for these increases in metal concentrations, the operation has had little impact on ground-water quality (Forlini, 1978).

A frozen food processor located in Winslow Township, Camden County, generates waste water during the preparation of frozen fish products. Effluent from an on-site treatment plant is applied to two fields by spraying. The fields overlie a recharge area of the Cohansey Formation. Analyses of samples from two observation wells in the irrigated field and of the effluent prior to spraying are shown in Table 26. Water from the observation wells contains levels of certain constituents in the same order of magnitude found in the effluent prior to application.

An industrial firm has disposed of untreated industrial waste water containing latex, acrylics, and glue wastes by spray irrigation for a number of years. Recently, the glue wastes have caused the soil underlying the site to bond together, reducing the percolation capabilities of the soil, and increasing waste water ponding. In addition, one of three monitoring wells at the site has yielded ground water containing acrylics and latex (Forlini, 1978).

An industrial firm, located in Hunterdon County, began a pilot spray irrigation program during 1961 and now discharges

Table 26. Results of Chemical Analyses of Water Samples From Wells Associated With Frozen Food Processing at a Plant in Camden County, New Jersey.

	Well 2A	Well 1B	Effluent
Date	2-1-77	2-1-77	2-1-77
Depth (feet)	20	20	-
pH	7	6.4	10.4
Alkalinity	318	6	198
Specific Conductance	530	1,100	1,220
Total Dissolved Solids	480	360	1,260
Chloride	95	60	135
Sodium	120	66	160
Potassium	23	11	26
Magnesium	11	7.5	5.8
Calcium	75	45	200
Sulfate	16	96	187
Nitrate Nitrogen	0.03	10	0.05
Phosphate	< 0.01	< 0.01	87
Cadmium	< 0.01	< 0.01	< 0.01
Chromium	< 0.01	0.02	0.02
Copper	< 0.01	0.01	0.04
Iron	130	1.3	10
Nickel	< 0.03	< 0.03	< 0.03
Lead	< 0.03	< 0.03	0.06
Zinc	0.14	0.33	0.53
Cobalt	< 0.01	< 0.01	0.01
Phenol	0.01	0.01	0.32

Reference: Geraghty & Miller, Inc., 1977.

about one mgd onto a 56-acre site. Water-quality data indicate that the soil is apparently effective in removing contaminants from the waste water (Forlini, 1978).

EXTENT OF THE PROBLEM

Too little is known about the operation of these facilities and monitoring activities are not sufficient to gauge the extent of the practice or the problem. The disposal of waste water on the land surface through spray irrigation does pose a threat to ground-water quality. It is essential that NJDEP require adequate pre-treatment in all cases where industrial waste water is spread on the land surface.

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APPENDICES B1 THROUGH B8

Appendix B1. Industrial and Municipal Landfills in New Jersey.

No.	Name	Municipality	County
1	Wantage Township	Wantage	Sussex
2	Worthington	Frankford	do
3	Hardyston Township	Hardyston	do
4	Hamms	Lafayette	do
5	Gilman-Demarest	do	do
6	Newton Township	Newton	do
7	Dominic Stomoto	Andover	do
8	Stillwater Township	Stillwater	do
9	Sparta Township	Sparta	do
10	West Milford Township	West Milford	Passaic
11	Ringwood Sanitary Landfill	Ringwood	do
12	duPont (2 locations)	Wayne	do
13	Carrino Contractor Co.	Little Falls	do
14	R&M Reclamation (2 locations)	Wayne	do
15	George Halick	Mahwah	Bergen
16	Zuidema Cesspool Service	do	do
17	Borough of Hillsdale	Hillsdale	do
18	Borough of Westwood	Westwood	do
19	Teaneck Township	Teaneck	do
20	R&M Reclamation	Ridgefield Park	do
21	Bergen County	do	do
22	Ridgefield Park	do	do
23	Bergen County Sanitary Landfill (2 locations)	Kingsland	do
24	C. Egan & Sons	North Arlington	do
25	Sanitary Land Developers	do	do
26	Avon (2 locations)	Kingsland	do
27	Blairstown Township	Blairstown	Warren
28	Hope Township	Hope	do
29	Ashland Chemical	Independence	do
30	Belvidere-White Township	Belvidere	do
31	Baker Chemical Harmony	Harmony	do
32	Baker Chemical Lopatcong	Lopatcong	do
33	Pio Costa	Lincoln Park	Morris
34	Jefferson Township	Jefferson	do
35	Mt. Arlington Borough	Roxbury	do

Appendix B1. (Continued)

No.	Name	Municipality	County
36	Lavine Bros.	Rockaway	Morris
37	Wharton Borough	Wharton	do
38	Doverton	Rockaway	do
39	Frank Fenimore	Roxbury	do
40	Filberto	Washington	do
41	Villa Walsh Church	Morris	do
42	Whippany Paper Board	Hanover	do
43	Metro Ltd.	do	do
44	Florman Park Borough	Florman	do
45	B. Horstman	East Hanover	do
46	Sharkey Farms	do	do
47	Caldwell Trucking	Caldwell	Essex
48	Ottitio	Newark	do
49	D&J Trucking	do	do
50	Thomas Heagney	Bergen	Hudson
51	1947 Corp. Incinerator Assoc.	Secaucus	do
52	1947 Corp. Site 1	do	do
53	1947 Corp. Site 2	do	do
54	Mall Landfill Assoc.	do	do
55	Kearny Municipal Sanitary Landfill Assoc. (4 locations)	Kearny	do
56	Riegel Produce Corp.	Alexandria	Hunterdon
57	Pastore SWDA	do	do
58	Flemington-Raritan Landfill	Raritan	do
59	Readington	Readington	do
60	Bernards Township	Bernards	Somerset
61	Bernardsville Borough	Bernardsville	do
62	Severin	Bridgewater	do
63	Bridgewater Township (2 locations)	do	do
64	Johns-Mansville	Manville	do
65	Hillsborough Township (2 locations)	Hillsborough	do
66	Bound Brook Borough (2 locations)	Bound Brook	do
67	North Plainfield Borough	Plainfield	do
68	E.M. Dreifus Association	Franklin	do
69	Edgeboro Disposal	North Brunswick	Middlesex
70	S.C.G. Industries	East Brunswick	do

Appendix B1. (Continued)

No.	Name	Municipality	County
71	Middlesex County Park Comm.	Sayreville	Middlesex
72	Marisol, Inc.	Middlesex Borough	do
73	R.E. Etsch Landfill	Monroe	do
74	Olbrys	do	do
75	Jamesburg Municipal Landfill	do	do
76	International Disposal	do	do
77	Johnson & Johnson	North Brunswick	do
78	Asarco	Perth Amboy	do
79	Colucci Trucking	Piscataway	do
80	Hercules Powder Corp.	Sayreville	do
81	National Lead Landfill	do	do
82	Spillatore Landfill	South Brunswick	do
83	Jones Industrial Service	do	do
84	CID Landfill	do	do
85	Elizabeth Disposal Inc.	Woodbridge	do
86	Keasby Landfill	do	do
87	Nappi Trucking	Madison	do
88	Sayreville No. 1	South River	do
89	Sayreville No. 2	Sayreville	do
90	Arace Bros.	Carteret	do
91	Borough of West Carteret	do	do
92	A.M. Smelting & Refining Co.	Perth Amboy	do
93	Philip Carey	do	do
94	Kin Buc	Edison	do
95	Edison Township	do	do
96	Princeton Disposal	South Brunswick	do
97	Bellizo Machine	do	do
98	South Brunswick	do	do
99	Plainsboro	Plainsboro	do
100	George Bradford	Monroe	do
101	Princeton Disposal	do	do
102	Global Trucking	Madison	do
103	duPont	Sayreville	do
104	Outerbridge Terminal Inc.	Perth Amboy	do
105	City of Perth Amboy	do	do
106	do	South Amboy	do
107	Industrial Park	Edison	do
108	Cranbury Township	Cranbury	do
109	Delta Excavating	Sayreville	do
110	Englishtown Borough	Englishtown	Monmouth

Appendix B1. (Continued)

No.	Name	Municipality	County
111	Lone Pine	Freehold	Monmouth
112	Al Storer	Marlboro	do
113	Ace Manzo	do	do
114	Atco Chemicals	Keyport	do
115	Union Beach Borough	Union Beach	do
116	Roselle Sinosa	Keyport	do
117	Middletown	Middletown	do
118	Red Bank Borough	Red Bank	do
119	Charles H. Wilson	New Shrewsbury Borough	do
120	Shrewsbury Disposal	Atlantic	do
121	Monmouth Regional Disposal	New Shrewsbury Borough	do
122	Howell Township	Howell	do
123	Roselle Sinola	do	do
124	M&T Dolish	Ocean	do
125	Neptune Township	Neptune	do
126	Ocean Co. Sewerage Authority Colliers Mini Site	Jackson	Ocean
127	James H. James, Inc.	Brick	do
128	Brick Township	do	do
129	Dover Township	Dover	do
130	Ocean Landfill	Manchester	do
131	Lakewood	Lakewood	do
132	American Cyanamid	Manchester	do
133	Sunny Pine	do	do
134	Manchester Township, Ocean Co. Sewerage Authority	do	do
135	WM Site No. 1 Lakewood	do	do
136	WM Site No. 2 Woodmansie	Lacey	do
137	Toms River Chemical	Dover	do
138	South Toms River Borough	South Toms River	do
139	Beach Haven Borough	Beach Haven	do
140	Berkeley Township	Berkeley	do
141	Olsens Septic Service	Lacey	do
142	Lacey Township	do	do
143	Southern Ocean	Ocean	do
144	Stafford Township	Stafford	do
145	Stafford Township Expansion	do	do

Appendix B1. (Continued)

No.	Name	Municipality	County
146	Tuckerton Borough	Eagleswood	Ocean
147	Little Egg Harbor Township	Little Egg Harbor	do
148	National Lead	Oldmans	Salem
149	Cesco Inc.	do	do
150	Harry J. Eckert & Sons	do	do
151	duPont-Chambers Works (2 locations)	Upper Penns Neck	do
152	A. Clemente	do	do
153	Unknown	Mannington	do
154	Mannington Mills	do	do
155	City of Salem	Salem	do
156	Elinsborough Township	Elinsborough	do
157	Carl Garrison	Pittsgrove	do
158	Quinton Township	Quinton	do
159	Quinton Solid Waste Lagoon	do	do
160	L. Alloways Creek Township	L. Alloways	do
161	Alloways Township	Upper Deerfield	Cumberland
162	Deerfield Township	Deerfield	do
163	Shiloh	Stow Creek	do
164	Bridgeton City	Bridgeton	do
165	Hopewell and Greenwich Township	Hopewell	do
166	Fairfield Township	Fairfield	do
167	Vineland City	Vineland	do
168	R. W. DuBois	do	do
169	Millville City	Millville	do
170	Kerr Glass	do	do
171	Downe Township No. 1	Lawrence	do
172	Downe Township No. 2	Downe	do
173	Commercial Township	Commercial	do
174	Maurice River Township No. 1	Maurice River	do
175	Maurice River Township No. 2	do	do
176	Folsom Borough	Folsom	Atlantic
177	Unknown	Hammonton	do
178	Town of Hammonton	do	do
179	Joe Esposito	Folsom	do
180	Borough of Buena	Buena	do

Appendix B1. (Continued)

No.	Name	Municipality	County
181	Hamilton Township	Hamilton	Atlantic
182	Mullica Township	Mullica	do
183	Hornikle	do	do
184	Galloway Township (3 locations)	Galloway	do
185	Estell Manor City	Estell Manor City	do
186	Price No. 1	Egg Harbor	do
187	Price No. 2	do	do
188	Price No. 3	do	do
189	Price No. 4	do	do
190	Price No. 5	Pleasantville City	do
191	Lee's Gravel Pit	Linwood City	do
192	Port Republic	Port Republic	do
193	Dennis Township	Dennis	Cape May
194	Upper Township	Upper	do
195	W. Saduk	Woodbine	do
196	Woodbine	do	do
197	Dennis Township	Dennis	do
198	Sea Isle City	Sea Isle City	do
199	Mar Tee No. 1	Lower	do
200	Mar Tee No. 2	do	do
201	Mar Tee No. 3	do	do
202	Mar Tee No. 4	Middle	do
203	Mar Tee No. 4a	do	do
204	Fillmore Construction Co.	Lower	do
205	North Wildwood City	North Wildwood	do
206	Fillmore Construction Co.	do	do
207	Ed Smith	Lower	do
208	N. W. Magnesite	do	do

Appendix B2. Classification Code for Industrial and Municipal Wastes. (New Jersey Department of Environmental Protection, Bureau of Solid Waste Management)

Classification Number	Type of Waste
10	Municipal (household, chemical)
11	Institutional
12	Dry sewage sludge
13	Bulky waste
14	Construction and demolition
15	Pesticides - dry
16	Hazardous waste containers
17	Hazardous waste - dry
18	Chemical use - dry - nonhazardous
19	Junked autos
20	Tires
21	Dead animals
22	Leaves and chapped tree waste
23	Agriculture vegetative waste
24	Tree stumps
25	Food processing waste
26	Industrial (non-chemical)
70	Waste oil
71	Semi-solid materials and sludge
72	Bulk liquid and semi-liquid
73	Septic tank clean-out waste
74	Liquid sewage sludge
75	Pesticide liquids
76	Hazardous waste liquids
77	Chemical waste liquids

Appendix B2. (Continued)

Map No.	Name	Volume of Waste Tons	Gallons	Type of Waste
1	Wantage Township	6,940	0	10,11,20,22
2	Worthington	1,135	0	10,11
3	Hardyston Township	3,810	0	10,22
4	Hamm Sanitation Inc.	79,277	417,000	14,18,19,20,21,22,23, 24,25,27,73,74
5	Gilman-Demarest	-	-	-
6	Newton Township	8,350	0	10,11,13,27
7	Dominic Stomoto	-	-	-
8	Stillwater Township	312	0	10
9	Sparta Township	13,466	1,509,800	10,13,14,22,24,73,74
10	West Milford Township	-	-	-
11	Ringwood Sanitary Landfill	-	-	-
12	duPont (2 locations)	-	-	-
13	Carrino Contractor Co.	-	-	-
14	R&M Reclamation (2 locations)	-	-	-
15	George Halick	-	-	-
16	Zuidema Cesspool Service	0	1,000,000	73
17	Borough of Hillsdale	-	-	-
18	Borough of Westwood	-	-	-
19	Teaneck Township	7,760	0	10,13,14
20	R&M Reclamation	-	-	-
21	Bergen County	637	-	-
22	Ridgefield Park	9,308	0	10
23	Bergen County Sanitary Landfill (2 locations)	-	0	-
24	C. Egan & Sons	185,922	0	10,11,13,14,18,20,22,24,27
25	Sanitary Land Developers	-	-	-
26	Avon (2 locations)	357,396	0	10,11,13,14,18,20,22,23,24, 25,27
27	Blairstown Township	-	-	-
28	Hope Township	-	-	-
29	Ashland Chemical	-	-	-
30	Belvidere-White Township	-	-	-
31	Baker Chemical Harmony	2,370	-	10,13,14,16,18,20,22,24,27
32	Baker Chemical Lopatcong	-	-	-
33	Pio Costa	-	-	-
34	Jefferson Township	-	-	-
35	Mt. Arlington Borough	-	-	-

Appendix B2. (Continued)

Map No.	Name	Volume of Waste Tons	Gallons	Type of Waste
36	Lavine Bros.	-	-	-
37	Wharton Borough	-	-	-
38	Doverton	-	-	-
39	Frank Fenimore	205,840	0	10,11,13,14,18,20,21,22, 24,25,27
40	Filberto	-	-	-
41	Villa Walsh Church	-	-	-
42	Whippany Paper Board	4,735	0	13,27
43	Metro Ltd.	-	-	-
44	Florman Park Borough	-	-	-
45	B. Horstman	-	-	-
46	Sharkey Farms	-	-	-
47	Caldwell Trucking	-	-	-
48	Ottitio	-	-	-
49	D&J Trucking	-	-	-
50	Thomas Heagney	-	-	-
51	1947 Corp. Incinerator Assoc.	-	-	-
52	1947 Corp. Site 1	1,458	0	14,27
53	1947 Corp. Site 2	-	-	-
54	Mall Landfill Assoc.	352,766	684	10,11,12,13,14,20,21,23,24,26
55	Kearny Municipal Sanitary Landfill Assoc. (4 locations	175,583	0	10,13,14,22,24,27
56	Riegel Produce Corp.	-	-	-
57	Pastore Landfill	3,800	0	27
58	Flemington-Raritan Landfill	14,869	750,000	10,18,22,25,27,74
59	Readington Township SWDA	3,265	0	10
60	Bernards Township	20,497	0	10,11,13,14,20,22,24
61	Bernardsville Borough	11,331	10,100	10,13,22,73
62	Severin	-	-	-
63	Bridgewater Township	-	-	-
64	Johns-Manville	80,160	0	13,20,27
65	Hillsborough Township (2 locations)	13,425	1,100	10,12,13,14,18
66	Bound Brook Borough (2 locations)	-	-	-
67	North Plainfield Borough	-	-	-
68	E. M. Dreifus Assoc. Inc.	-	-	-
69	Edgeboro Disposal	-	-	-
70	S.C.G. Industries	-	-	-

Appendix B2. (Continued)

Map No.	Name	Volume of Waste Tons	Gallons	Type of Waste
71	Middlesex County Park Comm.	-	-	-
72	Marisol, Inc.	-	-	-
73	R. E. Etsch Landfill	-	-	-
74	Olbrys	4,455	0	13,22,24,27
75	Jamesburg Municipal Landfill	-	-	-
76	International Disposal	-	-	-
77	Johnson & Johnson	-	-	-
78	Asarco	-	-	-
79	Colucci Trucking	-	-	-
80	Hercules Powder Corp.	-	-	-
81	National Lead Landfill	-	-	-
82	Spillatore Landfill	-	-	-
83	Jones Industrial Service	13,992	130,126	10,14,16,17,23,27,71,73,74
84	CID Landfill	-	-	-
85	Elizabeth Disposal Inc.	-	-	-
86	Keasby Landfill	-	-	-
87	Nappi Trucking	-	-	-
88	Sayreville No. 1	723,678	10,225	12,13,14,22,71,73
89	Sayreville No. 2	-	-	-
90	Arace Bros.	-	-	-
91	Borough of W. Carteret	-	-	-
92	A.M. Smelting & Refining Co.	-	-	-
93	Philip Carey	-	-	-
94	Kin Buc	554,765	37,122,326	10-15,17,18,20,22-25,27,70-77
95	Edison Township Disposal Area	267,739	400	10,11,13,14,17,18,20,22-27
96	Princeton Disposal	29,568	4,100	10,13-18,20-24,27
97	Bellizio Machine	-	-	-
98	S. Brunswick Sanitary Landfill	55,839	0	10,12-14,19,20,22-27
99	Plainsboro Township	1,125	0	10,13,27
100	George Bradford	-	-	-
101	Princeton Sanitary Landfill	19,454	0	10,11,13,14,16,20,22-24,27
102	Global Trucking	-	-	-
103	duPont	-	-	-
104	Outerbridge Terminal Inc.	-	-	-
105	City of Perth Amboy	-	-	-

Appendix B2. (Continued)

Map No.	Name	Volume of Waste Tons	Gallons	Type of Waste
106	City of South Amboy	-	-	-
107	Industrial Park	-	-	-
108	Cranbury Township	2,785	0	10,11,22-24,27
109	Delta Excavating	-	-	-
110	Englishtown Borough	-	-	-
111	Lone Pine Corp.	124,248	2,228,400	10-14,20,22-24,27,72-74
112	Al Storer	-	-	-
113	Ace Manzo	-	-	-
114	Atco Chemicals	-	-	-
115	Union Beach Borough	-	-	-
116	Rosell Sinosa	-	-	-
117	Middletown	-	-	-
118	Red Bank Borough	1,390	300	10,13,14,20-23,26,77
119	Charles H. Wilson	-	-	-
120	Shrewsbury Disposal	233,450	22,928	10,11,13,14,19-25,27,74
121	Monmouth Regional Disposal	-	-	-
122	Howell Township	-	-	-
123	Roselle Sinola	-	-	-
124	M&T Dolish	-	-	-
125	Neptune Township	31,166	4,000	10,11,13,14,22,24,73
126	Ocean Co. Sewerage Authority Colliers Mini Site	-	-	-
127	James H. James, Inc.	3,024	120,000	13,14,22,24,73
128	Brick Township	116,445	10,378,285	10,11,13,14,16,19,20,22-24
129	Dover Township	150,174	200	10-14,18-20,22-25,27,70,71
130	Ocean Co. Landfill Corp.	18,259	235,100	10,12,13,22,26,70,74
131	Lakewood	132,707	0	10,11,14,15,20,22,24,27,74
132	American Cyanamid	-	-	-
133	Sunny Pine	-	-	-
134	Manchester Township Ocean Co. Sewer Authority	-	-	-
135	WM Site No. 1 Lakewood	-	-	-
136	WM Site No. 2 Woodmansie	-	-	-
137	Toms River Chemical	-	-	-
138	South Toms River Borough	-	-	-
139	Beach Haven Borough	-	-	-
140	Berkeley Township	5,609	0	10,13,14,22,24

Appendix B2. (Continued)

Map No.	Name	Volume of Waste Tons	Gallons	Type of Waste
141	Olsens Septic Service	-	-	-
142	Lacey Township	619	0	10,14,22,24
143	Southern Ocean	38,825	10,108,225	10,11,13,14,20,22,24,27,73,74
144	Stafford Township	23,178	1,089,500	10-14,19,20,24,27,70,73,74
145	Stafford Township Expansion	-	-	-
146	Tuckerton Borough Eagles-wood Township	-	-	-
147	Little Egg Harbor Township	-	-	-
148	National Lead	-	-	-
149	Cesco Inc.	-	-	-
150	Harry J. Eckert & Sons	7,165	135,900	10,14,20,22,73
151	duPont Chambers Works (2 locations)	-	-	-
152	A. Clemente	22,178	128,000	14,20,22,27,73
153	Unknown	-	-	-
154	Mannington Mills	-	0	-
155	City of Salem	7,398	-	10,11,13,14,22,24,27
156	Elinsborough Township	-	-	-
157	Carl Barrison	-	-	-
158	Quinton Township	10,171	173,000	10,11,14,27,73,74
159	Quinton Solid Waste Lagoon	-	-	-
160	L. Alloways Creek Township	-	-	-
161	Alloways Township SWDA	9	0	22
162	Deerfield Township	-	-	-
163	Shiloh	-	-	-
164	Bridgeton City	24,612	0	10,11,13,14,18,20,22-27
165	Hopewell & Greenwich Township	-	-	-
166	Fairfield Township	1,296	0	10
167	Vineland City	168,114	20,302,001	10,11,13,14,18,20,22-25,27, 73,74,77
168	R. W. DuBois	-	-	-
169	Millville City	23,229	30,000	10,13,14,20,22,24,27,70
170	Kerr Glass	-	-	-
171	Downe Township No. 1	-	-	-
172	Downe Township No. 2	-	-	-
173	Commercial Township	-	-	-
174	Maurice River Township No. 1	1,500	0	10
175	Maurice River Township No. 2	-	-	-

Appendix B2. (Continued)

Map No.	Name	Volume of Waste Tons	Gallons	Type of Waste
176	Folsom Borough	-	-	-
177	Unknown	-	-	-
178	Town of Hammonton	-	-	-
179	Joe Esposito	-	-	-
180	Borough of Buena	-	-	-
181	Hamilton Township SWDA	-	-	-
182	Mullica Township SWDA	138	0	10,27
183	Hornikle	-	-	-
184	Galloway Township (3 locations)	-	-	-
185	Estell Manor City	78	0	10
186	Price No. 1	16,562	0	10,11,14,22
187	Price No. 2	58,920	0	10,13,14,19,20,22-24,27
188	Price No. 3	-	-	-
189	Price No. 4	-	-	-
190	Price No. 5	-	-	-
191	Lee's Gravel Pit	88,784	806,000	10,14,19-25,73
192	Port Republic	-	-	-
193	Dennis Township	-	-	-
194	Upper Township	4,543	0	10,13,14,24
195	W. Saduk	-	-	-
196	Woodbine	105,486	2,253,000	10,12-14,73,74
197	Dennis Township	-	-	-
198	Sea Isle City	7,857	0	10,12-14
199	Mar Tee No. 1	10,596	0	10,13,14,22,24
200	Mar Tee No. 2	327,995	656,000	11-14,20,22,24,27
201	Mar Tee No. 3	-	-	-
202	Mar Tee No. 4	-	-	-
203	Mar Tee No. 4a	-	-	-
204	Fillmore Construction Co.	-	-	-
205	North Wildwood City	-	-	-
206	Fillmore Construction Co.	-	-	-
207	Ed Smith	3,355	0	10,13,14,19,20,22,24,27
208	N. W. Magnesite	-	-	-
209	Sanitary Landfill Inc.	-	-	-
210	Camden City	-	-	-

Appendix B2. (Continued)

Map No.	Name	Volume of Waste Tons	Gallons	Type of Waste
211	Haddonfield	-	-	-
212	Monsanto	-	-	-
213	Helen Kramer	92,132	5,728,824	10-14,18,20,22,24-27,70-74
214	Mac Sanitary Landfill Inc.	281,065	200	10,11,13,14,19,20,22-27,70
215	Fazzio	201,399	4,133,959	10-14,18,20,22,24,25,27,70-74, 77
216	Kinsley Landfill Inc.	422,483	2,540,004	10-14,18-20,22-27,72-74
217	Buzby Bros. Materials Corp.	143,405	3,571,945	10-14,17,18,20-25,27,73,74
218	Henry Harris	13,586	1,953,000	10,11,13-15,18,22-25,27,73,74
219	Nick Lipari	-	-	-
220	Newfield	-	-	-
221	Interstate (Duck Island)	-	-	-
222	Interstate Waste Removal Co	10,357	300,000	10,11,13,14,20,22,27,72
223	Hamilton Township	93,571	600,000	10,11,13,14,22-24,27,73
224	Florence Land Recontouring	35,698	50,000	10-15,20-22
225	Burlington City	-	-	-
226	L&D Corp.	-	-	-
227	Big Hill	227,681	20,000	10,13,14,20,22,24,74
228	Fort Dix	-	-	-
229	Pemberton Township	14,449	1,412,000	10,11,13,14,22-24,72-74
230	Winslow Township	12,352	0	10,13,14,22-25,27
231	McElhone	-	-	-
232	Gahrs	-	-	-
233	Glassborough	-	-	-
234	Bass River	-	-	-
235	U. S. Pipe	-	-	-
236	Patsaros SWDA	-	-	-
237	Tenneco Chemical	-	-	-
238	Hoegances	-	-	-
239	Evesham	-	-	-
240	Griffin Pipe Products Co.	4,800	0	10,13
241	Winzinger	-	-	-
242	Lumberton	-	-	-
243	Medford Township SWDA	20,923	0	10-15,20-22
244	Moorestown Township	14,282	0	10,12-14,20,22-24,26,27
245	North Hanover Township	-	-	-

Appendix B2. (Continued)

Map No.	Name	Volume of Waste Tons	Gallons	Type of Waste
246	Tabernacle Township	-	-	-
247	Woodland Township	-	-	-
248	Hainesport	-	-	-
249	Trenton Psy. Hospital	-	-	-
250	Hopewell Township	-	-	-
251	Pennington Borough	-	-	-
252	Princeton Sanitary Landfill	-	-	-
253	Trenton City	-	-	-
254	Almo Anti-Pollution Service	1,500	597,750	26,76
255	Mobil Oil Corp.	-	-	-
256	Logan Township	-	-	-
257	Monroe Township	-	-	-
258	Mantua Township	10,645	0	10,13,14,18,27
259	Greenwich Township	5,264	0	10,14,20,22,24,27
260	Elk	-	-	-
261	Franklin Township	1,810	0	10,13,22,24
262	duPont	-	-	-
263	National Park	-	-	-
264	Raines	-	-	-
265	Hercules	-	-	-
266	Rambine	-	-	-
267	Marvin Jonas Inc.	880	14,000	76,77
268	Paulsboro	-	-	-
269	Audubon	-	-	-
270	New Freedom	-	-	-
271	Matteo	-	-	-
272	Amadei	372,451	2,532,000	10-12,14,17,18,20,23-25,27,73
273	Ward Sand & Materials Co.	282,607	0	10-14,20,22,24-27
274	Pennsauken	-	-	-
275	Ancora Street Hospital	-	-	-
276	King of Prussia	-	-	-
277	Knox Gelatin	-	-	-
278	R&M Nami	-	-	-
279	Rahway City	-	-	-
280	Peter Roselle	-	-	-

Appendix B3. Industries Reportedly Having Waste Water Impoundments Within New Jersey.

* not located

Map No.	Name	Municipality	County	Geologic Province or Formation
1	Sterling Drugs-Glenbrook Labs	Hamilton	Mercer	Triassic
2	Acme-Hamilton	Hamilton	Mercer	Magothy/Raritan
3	American Standard	Hamilton	Mercer	Magothy/Raritan
*4	Anchor Thread	Hamilton	Mercer	-
5	Nafi-Chris Craft	Hamilton	Mercer	Triassic
6	General Electric Co.	Hamilton	Mercer	Triassic
7	Yates	Bordentown	Burlington	Non-Aquifer
8	Roebling Steel	Florence	Burlington	Magothy/Raritan
9	Hooker Chemical	Burlington	Burlington	Magothy/Raritan
10	Hercules	Burlington	Burlington	Magothy/Raritan
11	Tenneco Plastics Division	Burlington City	Burlington	Magothy/Raritan
12	U.S. Pipe & Foundry	Burlington City	Burlington	Magothy/Raritan
13	Hoffman-LaRoche	North Hanover	Burlington	Non-Aquifer
14	Riverside Metal	Riverside	Burlington	Magothy/Raritan
15	Kaufman Minteer	Springfield	Burlington	Mt. Laurel/Wenonah
16	Perry Manufacturing	Hainesport	Burlington	Englishtown
17	Ionac	Pemberton	Burlington	Kirkwood/Cohansey
*18	Air Products	Paulsboro	Camden	-
19	Camden Lime Co.	Voorhees	Camden	Cohansey
20	New Jersey Zinc	Gloucester City	Camden	Magothy/Raritan
21	Lucas Paint	Gibbsboro City	Camden	Cohansey
22	Dupont, Carney's Point Works	Greenwich	Gloucester	Magothy/Raritan
23	Georgia Pacific	Pennsauken	Camden	Magothy/Raritan
24	Pioneer Metals	Franklin	Gloucester	Cohansey
25	Struthers-Dunn	Mantua	Gloucester	Kirkwood
26	CBS Records	Pitman	Gloucester	Kirkwood
27	Inversand	Mantua	Gloucester	Non-Aquifer
28	Pennwalt	West Deptford	Gloucester	Magothy/Raritan
29	Mobil Oil Research	Greenwich	Gloucester	Magothy/Raritan
30	Air Products & Chemicals	Greenwich	Gloucester	Magothy/Raritan
31	Hercules	Greenwich	Gloucester	Magothy/Raritan
32	Rollins Environmental Services	Logan	Gloucester	Magothy/Raritan
*33	Grasso Foods	Woolwich	Gloucester	-
34	Bridgeport Rentals	Logan	Gloucester	Magothy/Raritan
35	Polyrez Co.	Logan	Gloucester	Magothy/Raritan
36	Monsanto	Logan	Gloucester	Magothy/Raritan
37	Shield Alloy	Franklin	Gloucester	Cohansey
*38	United Poultry	Franklin	Gloucester	-
*39	National Fruit	Glassboro	Gloucester	-
40	Accurate Forming	Hamburg City	Sussex	Highlands

Appendix B3.(Continued)

Map No.	Name	Municipality	County	Geologic Province or Formation
41	Ames Rubber	Hamburg City	Sussex	Highlands
42	Northern Fine	Franklin Boro	Sussex	Highlands
43	Metaltec	Franklin Boro	Sussex	Highlands
44	J.T. Baker Chemical Co.	Phillispburg	Warren	Highlands
45	Ashland Chemical Corp.	Independance	Warren	Highlands
46	Oxford Textile	Oxford	Warren	Highlands
47	Hoffman-LaRoche	White	Warren	Highlands
48	Inmont Corp. (Celanese Coatings & Specialty Co.)	Belvidere	Warren	Highlands
*49	Cramer Plating Co.	White	Warren	-
50	Magnesium Elektron	Kingwood	Hunterdon	Triassic
51	Riegel Paper Corp.	Warren Mill	Hunterdon	Highlands
52	Riegel Paper Corp.	Riegelsville	Warren	Highlands
53	Riegel Paper Corp.	Hugesville City	-	Highlands
54	Vineland Chemical Co.	Vineland	Cumberland	Cohansey
55	Owens-Illinois Plant	Vineland	Cumberland	Cohansey
56	Unisyl	Maurice River	Cumberland	Cohansey
57	Wheaton Glass	Millville	Cumberland	Cohansey
58	Owens Illinois	Maurice River	Cumberland	Cohansey
59	Whitehead Bros.	Commercial	Cumberland	Cohansey
60	Pennsylvania Glass & Sand Co.	Downe	Cumberland	Cohansey
*61	Clemment-Pappas Canning Co.	Florence	Cumberland	-
62	B.F. Goodrich	Oldmans	Salem	Magothy/Raritan
63	Browning Ferris Industries	Oldmans	Salem	Magothy/Raritan
64	No-Strip	Oldmans	Salem	Magothy/Raritan
65	Dupont, Chambers Works	Lower Penns Neck	Salem	Magothy/Raritan
66	Richman Ice Cream	Piles Grove	Salem	Kirkwood
67	Mannington Mills	Mannington	Salem	Non-Aquifer
*68	B&B Poultry	Pittsgrove	Salem	-
69	Heinz	Salem City	Salem	Non-Aquifer
70	Johns-Manville	Winslow	Camden	Cohansey
*71	Blue Anchor	Winslow	Camden	-
72	King of Prussia	Winslow	Camden	Cohansey
73	Certain-Teed	Winslow	Camden	Cohansey
74	Owens Corning	Berlin	Camden	Cohansey
*75	Glen Gery	Winslow	Camden	-
*76	M&R Refractories	Winslow	Camden	-
77	Violet Packing Co.	Monroe	Gloucester	Cohansey
*78	Friendly Village	Monroe	Gloucester	-
79	Chemed	Howell	Monmouth	Kirkwood
*80	Bog Creek Farm	Howell	Monmouth	-
*81	Aldrich Laumdromat	Howell	Monmouth	-
*82	Frequency Engineering Labs	Howell	Monmouth	-
*83	IPRC	Howell	Monmouth	-
84	Foster Canning	Farmingdale	Monmouth	Kirkwood
85	I. Rokeach	Farmingdale	Monmouth	Kirkwood

Appendix B3. (Continued)

Map No.	Name	Municipality	County	Geologic Province or Formation
86	Fluid Chemical Co.	Lakewood	Ocean	Kirkwood
87	Toms River Chemical	Dover	Ocean	Cohansey
88	Venice Maid Co.	Vineland	Cumberland	Cohansey
89	Green Giant Co.	Vineland	Cumberland	Cohansey
*90	Everlon Fabrics Corp.	Lower	Cape May	-
*91	Henry Colt Enterprises	-	-	-
92	Ford Motor Company	Mahwah	Bergen	Triassic
93	Reheis Chemical	Berkeley	Union	Triassic
94	Picatiny Arsenal Aradcom Support Activity, U.S. Army	Parsippany	Morris	Highlands
95	Whippany Paper Board	Hanover	Morris	Triassic
96	Airton-Div. of Litton Ind.	Morris Plains	Morris	Triassic
97	C.P. Hull	North Arlington	Bergen	Triassic
98	Diamond Shamrock	Carlstadt	Bergen	Triassic
*99	Harmon Colors	-	-	-
*100	Pfister Chemical	-	-	-
101	GAF	Linden	Union	Triassic
102	BASF	South Brunswick	Middlesex	Magothy/Raritan
*103	GREFCO	South Brunswick	Middlesex	-
104	CPI-Consolidated Polymers Industries	Sayreville	Middlexex	Magothy/Raritan
105	Phelps Dodge	South Brunswick	Middlesex	Magothy/Raritan
106	National Lead	Sayreville	Middlesex	Magothy/Raritan
107	American Cyanamid	Bridgewater (Bound Brook)	Somerset	Triassic
108	American Cyanamid	Linden	Union	Triassic
*109	American Cyanamid	Woodbridge	Middlesex	-
110	Copper Pigment	Woodbridge	Union	Triassic
111	Linden Chlorine	Linden	Union	Triassic
112	Allied Chemical	Elizabeth	Union	Triassic
113	Bayonne Industries	Bayonne	Hudson	Triassic
*114	Air Products	-	-	-
115	Carter Wallace	Cranbury	Middlesex	Magothy/Raritan
116	Hexcel	Sayreville	Middlesex	Magothy/Raritan
117	E.I. duPont	Sayreville	Middlesex	Magothy/Raritan
*118	IBM	New Brunswick	Middlesex	-
119	Metalurgical International	Tinton Falls	Monmouth	Non-Aquifer
*120	Tenneco	Raritan	Middlesex	-
121	Cooper Chemical	Washington	Warren	Highlands
122	Witco	Perth Amboy	Middlesex	Magothy/Raritan
*123	Lily Tulip Cup Corp.	Holmdel	Monmouth	-
124	Exxon	Linden	Union	Triassic
*125	Exxon	Bayonne	Hudson	-

Appendix B3.(Continued)

Map No.	Name	Municipality	County	Geologic Province or Formation
126	Johns-Mansville	Mannville	Somerset	Triassic
*127	Stauffer Chemical Co.	-	-	-
*128	Azoplate	Branchburg	Somerset	-
*129	Merck	Branchburg	Somerset	-
130	Merck	Linden	Union	Triassic
131	International Flavors & Fragrances	Union Beach	Monmouth	Non-Aquifer
*132	GAF	Bridgewater	Somerset	-
133	GAF	South Bound Brook	Somerset	Triassic
134	Chevron	Linden	Union	Triassic
135	Solar Compounds	Linden	Union	Triassic
*136	Resins Inc.	Linden	Union	-
137	Mideast Aluminum Industries	-	-	-
138	Reichhold Chemical Co.	Carteret	Middlesex	Magothy/Raritan
139	Hatco Chemical Co.	Woodbridge	Middlesex	Magothy/Raritan
140	Tenneco Co.	Woodbridge	Middlesex	Magothy/Raritan
141	Hercules Powder	Sayreville	Middlesex	Magothy/Raritan
142	Flint Ink Co.	South Brunswick	Middlesex	Magothy/Raritan
143	Federal Fertilizer Co. (Kaiser Agricultural Chemicals)	Monroe	Middlesex	Non-Aquifer
144	Columbian Carbon Co. (Division of Cities Service)	South Brunswick	Middlesex	Magothy/Raritan

Appendix B4. Types and Volumes of Waste Water Discharged into Industrial Waste Water Impoundments, Within New Jersey, by Type of Industry.

Map No.	Name and Municipality	Type of Waste	Impoundment Volume (gallons)	Impoundment Size (acres)	Rate of Discharge (gpd)	Treatment Plant	Lined or Unlined	Operational
PRIMARY METALS								
82	Frequency Engineering Labs (Howell)	Metal rinsing waste including hydrochloric acid, chromates, caustic soda, arsenic, aluminum, copper, lead, and zinc.	-	-	23,000	-	Unlined	-
37	Shield Alloy Corp. (Newfield)	Wastewater resulting from the smelting, grinding, and milling of ores into alloys, and includes soluble hexavalent chromium.	1,125,000	150,000	-	yes	4 lined treatment ponds	yes
43	Metaltec Corp. (Franklin)	Oil and detergent waste in addition to cooling water.	-	-	5,000	yes	Unlined	-
50	Magnesium Elektron Inc. (Kingwood)	Wastewater resulting from the manufacture of zirconium products including zirconium, sulfates & chlorides.	120,000	-	-	yes	7 unlined sedimentation and neutralization lagoons	-

Note: - Indicates no data

Appendix B4. (Continued)

Map No.	Name and Municipality	Type of Waste	Impoundment Volume (gallons)	Impoundment Size (acres)	Impoundment Rate of Discharge (gpd)	Treatment Plant	Lined or Unlined	Operational
40	Accurate Forming & Finishing Corp. Hamburg City)	Waste water from the plating of metals including chromic acid waste.	20,000	-	30,000	yes	3 lined sludge lagoons 1 unlined acid waste lagoon	yes
49	Cramer Plating Co. (Butzville)	-	15,000	-	-	no	1 unlined	yes
25	Struthers-Dunn (Mantua)	Metal processing waste including spent acid and alkali solutions.	12,000	-	-	yes	1 lined sludge 2 settling	yes
12	US Pipe & Foundry (Burlington)	Manufacture of pipe.	25,300	112,500	-	no	Unlined	-
14	Riverside Metals (Riverside)	Acid bearing waste water.	4,500-6,000	-	-	yes	2 unlined	no
24	Pioneer Metals (Franklin)	Metal plating waste including chrome, cyanide, and nickel.		-	6,000	yes	Swamp	yes
7	Yates (Bordentown)	Metal plating waste including copper waste sludge.	500,000	-	-	yes	3 lined (recently lined)	yes
76	M&R Refractories (Winslow)	Scrubbing and cooling waste water.	-	-	-	-	Unlined	-

Appendix B4 (Continued)

Map No.	Name and Municipality	Type of Waste	Impoundment Volume (gallons)	Impoundment Size (acres)	Impoundment Rate of Discharge (gpd)	Treatment Plant	Lined or Unlined	Operational
105	Phelps Dodge (South Brunswick)	Waste water resulting from the turning of copper and copper alloys.	-	4.0	500,000	yes	2 unlined spoils lagoons	yes
128	Azoplate (Branchburg)	Metal plating waste.	90,000	12,000	-	yes	2 asphalt lined	yes
137	Mideast Aluminum Industries	Wastewater resulting from the anodizing of aluminum.		-		-	9 unlined (removed)	yes
119	Metallurgical International Inc. (Tinton Falls)	Iron oxide waste. Waste water resulting from the manufacture of powdered tungsten carbide.	12,000	-	-	yes	1 lined (torn liner)	yes
96	Airton - Division of Litton Industries (Morris Plains)	Electroplating waste water.		-	600,000	yes	Unlined holding lagoon	yes
97	C.P. Hull (North Arlington)	Waste water resulting from the recycling of metals including lead and tin.	45,560	6,000	-	yes	Unlined holding lagoon	yes

Appendix B4. (Continued)

Map No.	Name and Municipality	Type of Waste	Impoundment Volume (gallons)	Impoundment Size (acres)	Impoundment Rate of Discharge (gpd)	Treatment Plant	Lined or Unlined	Operational
CHEMICALS AND ALLIED PRODUCTS								
86	Fluid Chemical (Lakewood)	Chemical waste. Freon 1,2 (trichlorofluror methane) and Limonene.	6,000	-	-	no	Unlined	yes
31	Hercules (Greenwich)	Wastewater resulting from the manufacture of dicumyl peroxide & cumene (Isopropyl benzene), producing highly caustic wastes.	1,000,000	6,000	-	yes	1 lined	yes
1	Glenbrook Labs Division of Sterling Drugs Inc. (Hamilton)	Waste mixture of water & caustic soda, sodium aciatate, salacylic acid from the manufacture of asprin.		-	2,000	no	Unlined	yes
44	J.T. Baker Chemical Co. (Phillipsburg)	Wastewater from the manufacture of inorganic and organic chemicals.	3,000,000	-	-	yes	1 unlined polishing lagoon 1 cement lined equalization pond	yes

Appendix B4. (Continued)

Map No.	Name and Municipality	Type of Waste	Impoundment Volume (gallons)	Impoundment Size (acres)	Impoundment Rate of Discharge (gpd)	Treatment Plant	Lined or Unlined	Operational
54	Vineland Chemical Co. (Vineland)	Wastewater resulting from the manufacture of herbicides. Wastewater includes arsenic and mercury.	-	.5	-	no	3 unlined	yes
87	Toms River Chemical Corp. (Dover)	Wastewater resulting from the manufacture of synthetic organic dyestuffs, dyestuff intermediates, epoxy resins, & miscellaneous chemicals. Waste water includes chromium, copper, zinc, "chlorinated" solvents and nitrobenzene.	-	-	-	yes	Unlined prior to 1975, equalization, neutralization, & final settling ponds.	-
42	Northern Fine Chemicals (Franklin)	Wastewater resulting from the manufacture of acetamidophen (pharmaceutical product) including chloride, sulfates & acetic acid.	-	-	3,200	no	1 unlined (removal planned)	no

Appendix B4. (Continued)

Map No.	Name and Municipality	Type of Waste	Impoundment Volume (gallons)	Impoundment Size (acres)	Impoundment Rate of Discharge (gpd)	Treatment Plant	Lined or Unlined	Operational
13	Hoffman LaRoche (White Twp.)	-	1,800,000	-	-	yes	-	yes
64	No Strip Chemical Works Inc. (Oldmans)	Wastewater resulting from the manufacture of asphalt additives & emulsifiers.	-	-	-	no	-	yes
36	Monsanto (Logan)	Wastewater resulting from the manufacture of phthalic anhydride and other organic compounds.	1,098,000	-	1,098,000	yes	Lined	yes
62	B.F. Goodrich Co. (Oldman)	Wastewater from the manufacturing of bulk plastics & polymers, principally polyvinyl chloride.	-	-	800,000	yes	1 lined raw waste detention pond	yes
22	DuPont Carneys Point Works	Waste water from the manufacturing of nitrated cellulose products, & explosives. Acidic industrial wastes.	16,000,000	-	2,800,000	yes	1 unlined pond	yes
	Chambers Works		-	-	4,300,000	-	-	yes
45	Ashland Chemical (Independence)	Wastewater from the manufacture of chemicals and resins.	70,000	-	-	yes	1 unlined sludge	yes

Appendix B4. (Continued)

Map No.	Name and Municipality	Type of Waste	Impoundment Volume (gallons)	Impoundment Size (acres)	Impoundment Rate of Discharge (gpd)	Treatment Plant	Lined or Unlined	Operational
10	Hercules, Inc. (Burlington)	Industrial waste water resulting from the manufacture of disumyl peroxide and experimental chemicals.	1,000,000	-	180,000	yes	3 unlined lagoons	yes
28	Pennwalt (Thorofare plant) (West Deptford)	Waste products of muriatic acid (HCL) and small amounts of hyprofluoric acid (HF)	2-300,000		-	yes	2 clay lined settling lagoons	yes
		Manufactures chlorofluoro hydrocarbons.	12,000	-	-			
11	Tenneco (Burlington)	Manufacture of vinyl polymer.	-	-	385,000	yes	1 unlined lagoon 1 clay lined sludge drying lagoon	-
30	Air Product & Chemical Co. (Greenwich)	Waste water resulting from the manufacture of catalytic agents (organic and inorganic).	400,000	-	-	yes	1 holding pond	yes
17	Ionac (Pemberton)	Waste water resulting from the manufacture of organic compounds.	2-1,000,000	-	-	no	2 unlined lagoons	

Appendix B4.(Continued)

Map No.	Name and Municipality	Type of Waste	Impoundment Volume (gallons)	Impoundment Size (acres)	Impoundment Rate of Discharge (gpd)	Treatment Plant	Lined or Unlined	Operational
9	Hooker Chemical (Burlington)	Wastewater resulting from the manufacture of poly vinyl chloride.	2,000,000	-	-	yes	2 unlined lagoons (last used 3-4 years ago)	yes
106	National Lead (Titanium Pigment Division) (Sayreville)	Utilizes TiO_2 in the manufacture of paint base.	-	60.0	-	yes	2 unlined spoils lagoons	yes
			-	20.0	-		1 waste lagoon	
			-	40.0	-		3 neutralization ponds	
109	American Cyanamid (Woodbridge)	Manufacture of industrial chemicals.	270,000	-	-	yes	1 lined	yes
112	Allied Chemical (Elizabeth)	Manufacture of industrial chemicals.	-	-	-	no	Unlined settling ditches	yes
113	Bayonne Industries (Bayonne)	-	64,800	64,800	-	-	Unlined	yes
116	Hexcel Fine Organics (Sayreville)	Manufacture of organic chemicals.	81,000		-	-	Unlined pond	yes
126	Johns-Mannsville (Mannville)	-	2-600,000 2-150,000 1-9,000,000	80,000 20,000 1,200,000	-	-	4 unlined settling basins 1 unlined lagoon	yes

Appendix B4.(Continued)

Map No.	Name and Municipality	Type of Waste	Impoundment Volume (gallons)	Impoundment Size (acres)	Impoundment Rate of Discharge (gpd)	Treatment Plant	Lined or Unlined	Operational
141	Hercules Powder (Sayreville)	-	56,250	-	-	yes	2 unlined	yes
143	Kaiser Agricultural Chemicals (Federal Fertilizer)	Waste water resulting from the manufacture of mixed chemical fertilizers.	-	-	-	yes	Treatment lagoon	yes
130	Merck (Rahway City)	Waste water resulting from the manufacture of Thiobendazole (TRZ) and pharmacutical materials.	-	-	-	yes	Unlined ditch	yes
121	Cooper Chemical (Washington)	Waste water resulting from the manufacture of industrial chemcals.	-	-	1,000	-	1 lined evaporation pond 1 unlined chemical waste lagoon	yes
107	American Cyanamid (Bridgewater)	Waste water resulting from the manufacture of industrial chemicals.	-	-	-	-	Lined and unlined lagoons	yes
108	American Cyanamid (Linden)	Waste water resulting from the manufacture of industrial chemicals.	-	-	-	-	Lined and unlined lagoons	yes

Appendix B4. (Continued)

Map No.	Name and Municipality	Type of Waste	Impoundment Volume (gallons)	Impoundment Size (acres)	Impoundment Rate of Discharge (gpd)	Treatment Plant	Lined or Unlined	Operational
136	Resins Inc. (Linden)	Waste water resulting from the manufacture of resins.	-	-	-	-	Unlined ditch	yes
139	HATCO Chemical Co. (Division of Grace Chemical Co.) (Woodbridge)	Waste water resulting from the manufacture of inorganic chemical products.	-	-	-	-	2 unlined	yes
104	Consolidated Polymers Industries (Sayreville)	Involved in the manufacture of prepolymers. Waste water includes organics, sodium hydroxide and sodium phosphate.	675,000	90,000	-	no	1 unlined settling pond	yes
101	GAF Corp. (Dyestuff & Chemicals Division) (Linden)	Waste water resulting from the manufacture of organic and inorganic chemicals including dyes, pigments and a wide variety of chemical specialties.	7,000,000	3,000,000	-	yes	Lined equalization pond and abandoned lagoons	
111	Linden Chlorine Products (Linden)	Manufactures chlorine, sodium hydroxide, and hydrogen.	562,500	75,000	-	yes	1 unlined mercury sludge pond	yes

Appendix B4. (Continued)

Map No.	Name and Municipality	Type of Waste	Impoundment Volume (gallons)	Impoundment Size (acres)	Impoundment Rate of Discharge (gpd)	Treatment Plant	Lined or Unlined	Operational
144	Columbian Carbon Company Division of Cities Service (South Brunswich)	Waste water includes mineral acids, dissolved iron, oils and suspended solids.	576,000	-	-	yes	Unlined ponds	yes
110	Copper Pigment & Chemical Works (Woodbridge)	Involved in various blending activities utilizing cyanides, flouborates, arsenates, and organic chemicals.	243,000	32,400	-	no	1 unlined lagoon	yes
127	Stauffer Chemical Co.	Utilizes solvents containing such compounds as dichloroethylene, toluene and xylene in the manufacture of agricultural chemicals, insecticides and fertilizers.	-	-	-	-	1 unlined pond	yes
118	IBM (New Brunswick)	Waste water includes chromium cyanide, phenols and organic solvents.	-	-	-	yes	2 ditches	yes

Appendix B4. (Continued)

Map No.	Name and Municipality	Type of Waste	Impoundment Volume (gallons)	Impoundment Size (acres)	Rate of Discharge (gpd)	Treatment Plant	Lagoon Lined or Unlined	Operational
142	Flint Ink Co. (South Brunswick)	Xylene and trichlorethane utilized in the manufacture of inks.	-	-	85,000	-	Unlined ditch and lagoon	yes
131	International Flavors and Fragrances (Union Beach)	Waste water resulting from the manufacture of intermediate essence and essential oils, including myrcene and phenyl ethyl alcohol.	1,777,800	236,640	-	yes	1 clay lined aeration lagoon	yes
			108,000	14,400	-	-	1 sludge lagoon	
			81,000	7,200	-	-	1 unlined treatment lagoon	
117	E.I. duPont (Sayreville)	Waste water resulting from the manufacture of polyester based photographic film.	21,000,000	-	-	yes	Lined	yes
93	Reheis Chemical (Berkeley)	Pharmaceutical waste products including aluminum hydroxide.	10,000,000	-	500,000-1,400,000	yes	Unlined	yes

Appendix B4. (Continued)

Map No.	Name and Municipality	Type of Waste	Impoundment Volume (gallons)	Impoundment Size (acres)	Rate of Discharge (gpd)	Treatment Plant	Lined or Unlined	Operational
98	Diamond Shamrock (Carlstadt)	Waste water resulting from the manufacture of organic chemicals (sulfonated naphthalene formaldehyde compounds) raw materials utilized include, sulfuric acid, caustic soda, oleoin, phenols, creosol and napthalene.	150,000 each	-	-	yes	2 lined	yes
100	Pfister Chemical	Industrial waste water resulting from the manufacture of organic chemicals.	-	-	-	-	2 unlined holding ponds	yes

Appendix B4. (Continued)

Map No.	Name and Municipality	Type of Waste	Impoundment Volume (gallons)	Impoundment Size (acres)	Impoundment Rate of Discharge (gpd)	Treatment Plant	Lined or Unlined	Operational
PAPER AND ALLIED PRODUCTS								
51	Riegel Paper Corp. Warren Mill	Paper manufacturing waste.	2,200,000	-	750,000	yes	2 unlined	yes
52	Riegelsville	Paper manufacturing waste.	700,000	-	-	yes	1 unlined polishing	yes
53	Hugesville City	Paper manufacturing waste.	20,000	-	-	yes	1 unlined	yes
23	Georgia Pacific (Pennsauken)	Paper mill waste.	2,000,000	-	-	yes	1 lined aeration 1 lined sludge	-
123	Lilly Tulip Cup Corp. (Holmdel)	Iron settling.	90,000	18,000	-	-	Lined pond	yes
103	GREFCO (South Brunswick)	Waste water from floor drains containing traces of newsprint, asphalt emulsion, and expanded perlite.	-	-	3,000	yes	Unlined percolation ponds	yes

Appendix B4. (Continued)

Map No.	Name and Municipality	Type of Waste	Impoundment Volume (gallons)	Impoundment Size (acres)	Impoundment Rate of Discharge (gpd)	Treatment Plant	Lined or Unlined	Operational
PETROLEUM AND COAL PRODUCTS								
29	Mobil Oil Research (Greenwich)	Industrial waste water resulting from the fractionation and refining of petroleum products.	-	7	-	yes	Lined	-
FOOD AND KINDRED PRODUCTS								
84	Foster Canning (Farmingdale)	Dog food canning.	-	3.0 - 5.0	-	no	2 unlined lagoons	yes
85	I. Rokeach (Farmingdale)	Fish products.	-	-	-	no	Unlined lagoon	yes
66	Richman Ice Cream (Piles Grove)	Milk waste.	-	-	30,000	no	1 unlined aeration lagoon	yes
88	Venice Maid Co. (Vineland)	Vegetable processing waste water.	-	-	-	no	1 unlined	yes
89	Green Giant Co. (Vineland)	Vegetable processing waste water.	-	-	-	no	Utilizes same lagoon complex as Venice Maid Co.	yes

Appendix B4.(Continued)

Map No.	Name and Municipality	Type of Waste	Impoundment Volume (gallons)	Impoundment Size (acres)	Rate of Discharge (gpd)	Treatment Plant	Lined or Unlined	Operational
61	Clemment-Pappas Canning Co. (Florence)	-	-	-	-	-	-	-
77	Violet Packing Co. (Monroe)	Food processing waste water.	-	3,000	22,500	-	3 lined primary settling lagoon (1 torn liner)	-
			2-675,000	9,000	-	-	2 unlined lagoons	
91	Henry Colt Enterprises Inc.	Food processing waste.		-	50,000	-	1 unlined	-
71	Blue Anchor Foods (Winslow)	Frozen foods processing waste.	200,000	-	-	yes	2 unlined seepage lagoons	-
33	Grasso Foods (Woolwich)	Food processing waste water.	-	-	1,400	no	2 unlined lagoons	-
68	B&B Poultry (Pittsgrove)	Waste water resulting from the slaughter of poultry.	-	-	-	no	2 unlined gravel pits	yes

Appendix B4. (Continued)

Map No.	Name and Municipality	Type of Waste	Impoundment Volume (gallons)	Impoundment Size (acres)	Rate of Discharge (gpd)	Treatment Plant	Lined or Unlined	Operational
TRANSPORTATION EQUIPMENT								
92	Ford Motor Co. (Matawan)	Industrial waste resulting from the assembly of cars and trucks. Wastes include points, solvents, oils, etc.	3,000,000	-	600,000	yes	Lined	yes
STONE, GLASS AND CLAY PRODUCTS								
75	Glen Gery (Winslow)	Cooling water and oils in brick manufacturing.		-	-	-	-	yes
	Pennsylvania Glass & Sand Co. (Donne)	Waste water from sand washing.	-	-	-	no	3 unlined	yes
59	Whitehead Bros. Dividing Creek Plant (Commercial)	Waste water from sand washing.	-	-	-	no	Unlined	yes
57	Wheaton Glass Co. (Millville)	Oil settling ponds and glass manufacturing waste.	20,250	2,700	-	no	10 unlined lagoons	yes
3	American Standard (Hamilton)	-	33,000	-	-	no	2 unlined	yes
27	Inversand (Mantua)	Sand washing and chemical treatment waste water	-	-	700,000	yes	Unlined (proposed liner)	yes

Appendix B4. (Continued)

Map No.	Name and Municipality	Type of Waste	Impoundment Volume (gallons)	Impoundment Size (acres)	Rate of Discharge (gpd)	Treatment Plant	Lined or Unlined	Operational
132	GAF (Bridgewater)	Stone crushing and dyeing operations.	-	-	-	yes	1 polishing lagoon 1 unlined settling pond 2 unlined storage and retention ponds	yes
TEXTILE MILL PRODUCTS								
4	Anchor Thread (Hamilton)	Waste water resulting from the dyeing of cotton and synthetic yarns.	82,000	-	-	yes	2 lined	
46	Oxford Textile Co., Inc. (Oxford)	Waste water resulting from the dying of fabrics.	500,000	-	-	yes	3 unlined settling ponds 1 aeration lagoon	
90	Everlon Fabrics Corp.	Waste water resulting from the dying of fabrics.	4,000,000	-	-	yes	Lined asphalt	yes
95	Whillany Paper Board (Hanover)	Industrial waste water resulting from the manufacture of paper board.	-	-	10,700,000	yes	Unlined sludge holding lagoons	yes

Appendix B4. (Continued)

Map No.	Name and Municipality	Type of Waste	Impoundment Volume (gallons)	Impoundment Size (acres)	Rate of Discharge (gpd)	Treatment Plant	Lined or Unlined	Operational
99	Harmon Colors	Waste water resulting from the manufacture of dyes.	-	-	-	yes	Unlined holding lagoon	yes
RUBBER AND PLASTIC PRODUCTS								
83	IPRC Corp. (Howell)	Plastics waste including, Aluminum Cadmium Chromium Copper Cyanide Lead Zinc Arsenic Phenols	-	-	-	-	Unlined	-
74	Owens Corning (Berlin)	Pipe insulation manufacturing.	1-4,500,000 1- 375,000	- -	- -	yes	2 unlined lagoons	yes
67	Mannington Mills (Mannington)	Waste water from the manufacture of latex paint and vinyl floor covering.	13,500 each	-	50,000	no	7 unlined lagoons	yes
5	Nafi Corp. Division of Chris Craft Industries, Inc. (Hamilton)	Waste water resulting from the manufacture of styrofoam.	-	-	-	no	1 unlined	yes

Appendix B4.(Continued)

Map No.	Name and Municipality	Type of Waste	Impoundment Volume (gallons)	Impoundment Size (acres)	Impoundment Rate of Discharge (gpd)	Treatment Plant	Lined or Unlined	Operational
6	General Electric Co. (Mercer)	Paint refuse.	8,400	-	-	-	-	-
48	Inmont Corp. (Celanese Coatings and Specialty Co.) (Belvidere)	Waste water resulting from the manufacture of protective coatings and emulsions, including waste from the polyvinyl acetate emulsion plant.	675,000 each	30,000 sq.ft.	-	-	3 unlined (prior to 1976)	no
41	Ames Rubber Co. (Hamburg City)	Industrial and domestic waste, including oil and zinc.	-	-	5,000	-	1 unlined	yes
26	Columbia Records (Pitman)	Industrial waste water resulting from the manufacture of plastic recording discs.	2,000,000	-	-	no	3 unlined settling ponds	yes
21	Lucas Paint (Gibbsboro City)	Paint manufacturing waste.	8,000 domestic 16,000 industrial	-	-	-	3 unlined paint waste lagoons	-

Appendix B4.(Continued)

Map No.	Name and Municipality	Type of Waste	Impoundment Volume (gallons)	Impoundment Size (acres)	Impoundment Rate of Discharge (gpd)	Treatment Plant	Lined or Unlined	Operational
70	Johns-Mannsville (Winslow)	Waste water resulting from the manufacturing of fiberglass and containing phenolic resin binder.	4,687,500	625,000	20 gpm		1 unlined 1 lined	yes
73	Certain-Teed (Winslow)	Waste water resulting from the manufacture of fibreglass.	1-1,687,500 1-1,687,500	225,000 225,000	- -	- -	1 unlined 1 lined	no
2	Acme Hamilton (Hamilton)	Waste water resulting from the manufacture of rubber products.	-	-	-	no	Unlined	yes
140	Tenneco (Woodbridge)	Waste water resulting from the manufacture of plastics.	-	15,000	3,000,000	no	4 unlined settling lagoons 1 evaporation lagoon	yes
102	BASF-WYANDOTTE Corp. (South Brunswick)	Waste water resulting from the manufacture of styrofoam.	6,750,000	900,000	-	yes	Unlined lagoons	yes
114	Air Products	Manufactures plastics.	-	-	4-500,000	-	1 unlined	yes

Appendix B4.(Continued)

Map No.	Name and Municipality	Type of Waste	Impoundment Volume (gallons)	Impoundment Size (acres)	Rate of Discharge (gpd)	Treatment Plant	Lined or Unlined	Operational
120	Tenneco Plastics Division (Raritan)	Waste water resulting from the manufacture of plastic bottles.	112,500 each	-	-	no	4 unlined settling basins 1 evaporation lagoon	yes
MISCELLANEOUS MANUFACTURING INDUSTRIES								
81	Aldrich Laundromat (Howell)	Laundry	12,000	-	12,000	no	Unlined	yes
79	CHEMED (Howell)	Protolytic enzymes for striping X-ray film.	2,000-5,000	-	2,000	no	Unlined	no
80	Bog Creek Farm (Howell)	Volatile organics include pentane, acetone, methylene chloride, ethylene.	67,500	-	-	yes	Unlined pond	-
	Matlack Inc. (Woolwich)	Waste water resulting from tanker truck washing.	-	-	-	yes	1 unlined pond	
34	Bridgeport Rentals (Logan)	Mix of oils and metals.	15,000,000	-	-	no	unlined	-

Appendix B4.(Continued)

Map No.	Name and Municipality	Type of Waste	Impoundment Volume (gallons)	Impoundment Size (acres)	Rate of Discharge (gpd)	Treatment Plant	Lined or Unlined	Operational
19	Camden Lime Co. (Voorhees)	Alkaline waste water resulting from the rinsing of mixing trucks.	450,000	60,000	-	-	1 lined	-
15	Kaufman Minteer (Springfield)	Tank truck washings.	1,687,500	135,000	-	no	1 unlined lagoon	yes
13	Hoffman LaRoche (North Hanover)	Animal waste.	2,000,000	-	-	yes	Lined	yes
32	Rollins Environmental Services	Industrial waste treatment facility.	-	-	-	yes	5 unlined final settling ponds 20 lined lagoons	yes
63	Browning-Ferris Industries (Oldmans)	Waste water resulting from the cleaning of chemical vats.	-	7,500	-	no	One lined (torn liner)	yes
129	Merck (Branchburg)	Animal waste.	72,000	-	-	yes	1 lined oxidation ditch and pond	yes
133	GAF (S. Bound Brook)	Waste water resulting from the manufacture of asbestos.	22,500,000	-	-	-	1 lined pretreatment pit 1 unlined settling lagoon	yes

Appendix B4. (Continued)

Map No.	Name and Municipality	Type of Waste	Impoundment Volume (gallons)	Impoundment Size (acres)	Rate of Discharge (gpd)	Treatment Plant	Lined or Unlined	Operational
94	Picatiny Arsenal Aradcom Support Activity U.S. Army (Parsippany)	Industrial waste water resulting from chromate and cyanide treatment.	-	-	17,000	yes	Cyanide and chromate settling lagoon	yes
			-	-	-	-	Unlined	-
16	Perry Manufacturing (Hainesport)	-	-	-	-	-	-	-

Appendix B5. Name and Location of Facilities Complying with Federal SPCC Regulations within New Jersey.

Facility Name	Facility Location
A. Van der Berg & Sons	367 Fairview Ave., Midland Park, NJ
A. Williams & Sons	N. Main St. and Clayton Ave., Williamstown, NJ
A.C. Berwick Transport	Mutton Hollow Rd., Woodbridge, NJ
Accurate Forming Company	Route 94, Hamburg, NJ
Ace Chemical Inc.	185 Foundry St., Newark, NJ
Acme Hamilton Mfg. Corp.	P.O. Box 361, Trenton, NJ
Acro Chemical Products Corp.	20 Parker Road, Longvalley, NJ
Ad Runyon Co.	45 Division Ave., Millington, NJ
Aeroheat Fuel Co., Inc.	444 Mulberry St., Newark, NJ
Affiliated Medical Research	3684 U.S. Highway No. 1, Princeton, NJ
Agway Petroleum Corp.	Route 206, Newton, NJ
Agway Petroleum Corp.	54 Highway 22, Clinton, NJ
Agway Petroleum Corp.	Pine St., Mt. Holly, NJ
Air Products Chemical, Inc.	East Dewey Ave., Wharton, NJ
Albert Camaeri	P.O. Box 317, RD1, Columbia, NJ
Albert Steel Drum Co.	338 Wilson Ave., Newark, NJ
Allied Chemical	Metuchen Works, Metuchen, NJ
Allied Chemical	Route 22 and Chimney Rock Rd., Bound Brook, NJ
Amerada Hess Corp.	238 West Fort Lee Road, Bogota, NJ
Amerada Hess Corp.	Delair, NJ
American Cyanamid Corp.	Tremley Pt. Road, Linden, NJ
American Honda	115 Gaither Drive, Mt. Laurel, NJ
American Oil & Supply Co.	238 Wilson Ave., Newark, NJ
Amoco Oil Co.	Roosevelt Ave., Carteret, NJ
Anchor Thread Co.	Main St., Groveville, NJ
Andersens Equipment Service	10 West Ave., Atlantic Highlands, NJ
Anhyser Busch Inc.	200 U.S. Highway 1, Newark, NJ
Annex Trucking Co.	125 K Factory Land, Middlesex, NJ
Anthony Ferrante & Sons, Inc.	Route 202, Bernardsville, NJ
Anthony Valerio	Waterford Rd., Hammonton, NJ
Arco Terminal	Lamberton Rd., Trenton, NJ
Arkansas Company, Inc.	P.O. Box 210, Newark, NJ
Ashland Chemical Co.	Alfano Road, Great Meadows, NJ
Astro-Pak	235 Forest St., Metuchen, NJ
Atlantic Container	N. Fleet, Elizabeth, NJ
Atlantic Resources Corp.	Horseshoe Rd., Sayreville, NJ
Atlas Refining Corp.	142 Lockwood St., Newark, NJ
Auto Waste Oil Service	P.O. Box 792, 328 Stokes Ave., Trenton, NJ
Ayers & Seely	Main St., Andover, NJ
B&L Oil	472 Frelinghuysen Ave., Newark, NJ

Appendix B5. (Continued)

Facility Name	Facility Location
BD Simmons, Inc.	Main St., Franklin, NJ
Bashlow Realty Co.	400 S. River Rd., Hackensack, NJ
Bayonne Industries, Inc.	Foot of East 22nd St., Bayonne, NJ
Beattle Manufacturing Company	242 Main St., Little Falls, NJ
Beaufort Fuel Company	412 Beaufort Ave., Livingston, NJ
Beecham Laboratories, Inc.	101 Possumtown Rd., Piscataway, NJ
Belford Seafood Corp. Assoc.	Main St., Belford, NJ
Bendix Corp.	Route 35, Eatontown, NJ
Benjamin Moore & Co.	134 Lister St., Newark, NJ
Bennett Bros. Sales Westinghouse	1609 State Hwy. No. 27, Edison, NJ
Bergen Co. Police Fire Academy	Campgaw Rd., Mahway Township, NJ
Best Foods	99 Ave. A., Bayonne, NJ
Betts Heating Co.	Oreard, Newton, NJ
Biocraft Laboratories, Inc.	Industrial Way, Waldwick, NJ
Bird & Son	Amboy Ave., Perth Amboy, NJ
Blackwood Carbon Products Co.	121 Fairmont Ave., Laurel Springs, NJ
Bolkema Fuel Company	Midland Park, NJ
Bonded Oil Company	Ridgewood Ave. & Route 17, Paramus, NJ
Borden Chemical Print Ink Div.	1625 Federal St., Camden, NJ
Borne Chemical Co.	632 South Front St., Elizabeth, NJ
BP Gas & Go	6727 South Cresent Blvd., Pennsauken, NJ
BP Oil Inc.	P.O. Box 268, Linden, NJ
Bradco Supply Corp.	23 Production Way, Avenel, NJ
Brewers Fuel Co.	77 Second St., Somerville, NJ
Brodun Industrial Chemical Service	Box 802 Maple Ave., Mt. Holly, NJ
CJ Raffo Transport, Inc.	561 Broadlawn Terrace, Vineland, NJ
Camp Charles Wood	Fort Monmouth, NJ
Camp Trucking Co. Inc.	175 Rosewood Land, Port Reading, NJ
Campbell and Pratt Oil Co.	P.O. Box 335 M, Morristown, NJ
Canron, Inc.	183 Sitgreaves St., Phillipsburg, NJ
Capitol City Products	River Rd., West New York, NJ
Carpenter Technology	Engelhard Drive, Carnbury, NJ
Cary Page Chemical Co.	Bldg. 433 Raritan Center, Edison, NJ
Castrol Oil Inc.	254 Doremus, Newark, NJ
Celanese Coatings & Specialty	P.O. Box 205, Belvidere, NJ
Central Oil & Heating Co.	267 S. Broadway, Pennsville, NJ
Central Railroad Co. of NJ	1100 Raymond Blvd., Newark, NJ
Chem Ed Recycling, Inc.	U.S. Highway 9, Freehold, NJ
Chemical Control Corp.	23 South Front St., Elizabeth, NJ
Chemical Recovery Corp.	71 Buckingham Ave., Perth Amboy, NJ

Appendix B5. (Continued)

Facility Name	Facility Location
Chemical Disposal, Inc.	19 Emerson Plaza, Emerson, NJ
Chris Industries, Inc.	P.O. Box 367, Matawan, NJ
Christie Industries	766 Route 17, Ramsey, NJ
Claridge Estates	Claridge Dr., Verona, NJ
Clifton Mill	10 North Jefferson Rd., Whippany, NJ
Clinton M. Kandle	Holly Ave., Pitman, NY
Coastal Oil Co.	Clark Terminal, 350 Central Ave., Clark, NJ
Cold Spring Fish & Supply Co.	Cape May Harbor, Cape May, NJ
Colgate Palmolive Co.	909 River Rd., Piscataway, NJ
Commercial Fuel Corp.	3rd and L Streets, Millville, NJ
Con Chem Inc.	Horseshoe Rd., Sayreville, NJ
Congoleum Industries, Inc.	861 Sloan Ave., Trenton, NJ
Conrail Corp.	1 Hudson Place, Hoboken, NJ
Consolidated Cork Corp.	South Randolphville Rd., Piscataway, NJ
Colsolidated Rail	One Hudson Place, Hoboken, NJ
Construction Specialties, Inc.	55 Winans Ave., Cranford, NJ
Consumers Oil Co.	1473 Lamberton Rd., Trenton, NJ
Continental Copper & Steel	Fuller Rd. and Stiles St., Linden, NJ
Cook & Dunn	157-167 Kossuth St., Newark, NJ
Cook Industry	5 N Stiles St., Linden, NJ
Cosmair, Inc.	1154 Westfield Ave., Clark, NJ
CPS Chemical Co.	P.O. Box 162, Old Bridge, NJ
Crystal Ice & Fuel Division	P.O. Box 157, Sommerville, NJ
Cumberland Farms Gas Station	Route 9, Little Egg Harbor Township, NJ
Custom Oil Co.	637 River Dr., Garfield, NJ
DA Stuart Co., Ltd.	P.O. Box 130, Somerville, NJ
D Annunzio Bros.	2435 Plainfield Ave., Scotch Plains, NJ
Decker & Simmons Co.	37 Hamburg Ave., Sussex, NJ
Degan Oil & Chemical Co.	200 Kellogg St., Jersey City, NJ
Delaval Turbine Co.	P.O. Box 251, Trenton, NJ
Delo Remy	Jersey Ave., New Brunswick, NJ
Dept. of Air Force	Belle Mead, NJ
Dept. of Commerce	Administration Services, Hoboken, NJ
Diamond Head Oil Refining Co.	1401 Harrison Turnpike, Kearny, NJ
Dock Watch Quarry Pit, Co.	P.O. Box 245, Martinsville, NJ
Dover Sewerage Authorities	22 Robbins, Toms River, NJ
Dowling Fuel Company	Industrial Ave., Ridgefield, NJ
Dura Loc Chemical Corp.	84 Lister Ave., Newark, NJ
Dynapec Manufacturing Co.	Kelly Place, Stanhope, NJ
Eagle Fuel Oil Co.	260 Culver Ave., Jersey City, NJ

Appendix B5. (Continued)

Facility Name	Facility Location
East Brunswick High School	East Brunswick, NJ
East Rutherford Sewage Treatment	Marietta Parkway, East Rutherford, NJ
Eden Mill	10 North Jefferson Rd., Whippany, NJ
Edwards Waste Oil Service	P.O. Box 511, RD #5, Newton, NJ
EJ Koenig, Inc.	P.O. Box 78, Trenton, NJ
Elmer Brewer, Inc.	P.O. Box 1018 77 Second St., Somerville, NJ
Empire Petroleum	71 Front St., Elizabeth, NJ
Englehard Min. & Chemical Corp.	429 Delancy, Newark, NJ
Erda Forrestal Labs	P.O. Box 102, Princeton, NJ
Essex Chemical Corporation	330 Doremus Ave., Newark, NJ
Ethyl Corp. Visqueen Division	P.O. Box 470, Flemington, NJ
Ethyl Development Corp.	Station & Knowlton Streets, Belvidere, NJ
Exxon Company	NJ Turnpike, Ridgefield, NJ
Federal Oil Company	Camden, NJ
Fisher-Coe, Inc.	38 Diller Ave., Newton, NJ
Fiske Bros. Refining Co.	129 Lockwood St., Newark, NJ
Flemington Block & Supply	Route 31, Flemington, NJ
Flintkote Company	163 Henderson St., Jersey City, NJ
FMC Corporation	Box 171, Route 47, Malaga, NJ
Food Oils	145 Grand St., Carlstadt, NJ
Fort & Hargrove	Maple Ave., Mt. Holly, NJ
Fort Dix	Dept. of the Army, Fort Dix, NJ
Fort Monmouth	Director of Facilities Engineering, Fort Monmouth, NJ
Fortescue Realty Co., Inc.	Fortescue Rd., P.O. Box 500, Fortescue, NJ
Frank D. Smith & Son, Inc.	Rt. 38, P.O. Box 248, Mount Holly, NJ
Fred Heinzelman & Sons, Inc.	790 Washington Ave., Carlstadt, NJ
Fredericks Fuel & Heating Service	225 Oak Ridge Rd., Oak Ridge, NJ
Frits and Cooper Oil Co.	4 Post Lane, Riverdale, NJ
Fuel Oil Supply	600 South Ave. E, Carnford, NJ
G&S Motor Equipment Co., Inc.	1800 Harrison Ave., Kearny, NJ
GAF Corporation	35 Main St., South Bound Brook, NJ
Garden State Paper Co.	950 River Drive, Garfield, NJ
GATX Company	78 Lafayette St., Carteret, NJ
Gayner Glass Works	Salem, NJ
General Cable Corp.	236 West First St., Bayonne, NJ
General Electric Co.	2231 East State St., Trenton, NJ
General Hose Products, Inc.	30 Sherwood Lane, Fairfield, NJ
General Services Administration	Route 206, Belle Mead, NJ
George A. Rossi	Paul St., Vineland, NJ
George O. Stevens, Inc.	111 Grant Ave., Plainfield, NJ

Appendix B5. (Continued)

Facility Name	Facility Location
George Seafield Co., Inc.	831 East Main St., Bound Brook, NJ
George W. Lippincott, Inc.	Mount Holly, NJ
Gibbsboro Air Force Station	Gibbsboro, NJ
Gilchrist Diner & Marina Delta	Atlantic City, NJ
Givaudan Corporation	100 Delawanna Ave., Clifton, NJ
Glenbrook Laboratories	2133 E. State St., Trenton, NJ
Globe Petroleum, Inc.	9 Central Ave., Red Bank, NJ
Goodall Rubber Co.	P.O. Box 631, Trenton, NJ
Gramlich Trucking Co.	141 Elm Ave., Hackensack, NJ
Great Notch Fuel Company	Sindle Ave., Little Falls, NJ
Grignard Chemical Co.	185 Foundry St., Newark, NJ
GSA Somerville Depot	U.S. Highway 206, Somerville, NJ
Gulick Fuel Oil Co.	P.O. Box 128, Hackettstown, NJ
HB Williams Heating Service	Palmyra, NJ
Hangsterfer Laboratories	Ogden Rd., Mantua, NJ
Hanover Mill	10 North Jefferson Rd., Whippany, NJ
Harbison-Walker Refractories	P.O. Box 379, Cape May, NJ
Harrison By Products Company	Foot of Sanford Ave., Harrison, NJ
Harry W. Aumack, Inc.	1 New St., Port Monmouth, NJ
Harshaw Chemical Co.	Foot of Water St., Gloucester City, NJ
Hart & Iliff Fuel Inc.	4 Hampton St., Newton, NJ
Hartz Mountain Industries	305 Broadway, Jersey City, NJ
Harvard Storage & Warehouse Co.	Belleville Turnpike, Kearny, NJ
Haskon, Inc.	Mantua Rd., Paulsboro, NJ
Henoch Oil Co.	5151 Broad St., Clifton, NJ
Henoch Oil Co.	Lincoln Park, NJ
Henry Allen Company	15 Lewis St., Eatontown, NJ
Hess Oil Co.	Route 46 Circle, Little Ferry, NJ
Hexcel Fine Organics	880 Main St., Sayreville, NJ
Hitchner Brothers, Inc.	66 East Ave., Woodstown, NJ
Hoffman-La Roche Inc.	P.O. Box 238, Belvidere, NJ
Holiday City at Berkeley	1433 Hooper Ave., Toms River, NJ
Holland Greenhouse	Hightstown, NJ
Hollyford Ice and Cold Storage	Mount Holly, NJ
Home Fuel Oil Co. Bulk Plant	289 Hamburg Turnpike, Riverdale, NJ
Houdaille Construction Co.	10 Park Place, Morristown, NJ
Hough Fuel	340 Fourth St., Trenton, NJ
Howard Fuel Company	Foot of East 5th St., Bayonne, NJ
Howmet, Inc.	P.O. Box 371, Roy St., Dover, NJ
Hudson Tank Storage Company	Foot of Baldwin Ave., Weehauken, NJ

Appendix B5. (Continued)

Facility Name	Facility Location
Hughesville Mill	Milford, NJ
Humble Oil & Refining	Bayonne, NJ
Hummel Lanolin Corp.	185 Foundry St., Newark, NJ
Hy Pro Feed Inc.	305 Coremus St., Newark, NJ
Hydrocarbon Research, Inc.	P.O. Box 1416, Puritan Ave., Trenton, NJ
ICI America Inc.	Bayonne, NJ
IMC Chemicals, Inc.	100 Lister Ave., Newark, NJ
Imperial Oil Company, Inc.	Orchard Place, Morganville, NJ
Industrial Petrochemical Co.	128 Doremus Ave., Newark, NJ
Inland Chemical Corp.	600 Doremus Ave., Newark, NJ
Inmont Corporation	150 Wagaran Rd., Hawthorne, NJ
Insol Coustic Birma Co.	Jernee Mill Rd., Sayreville, NJ
International Business Machines	Dayton, NJ
International Flavors & Fragrances	800 Rose Lane, Union Beach, NJ
International Recycling Corporation	Horseshoe Rd., Sayreville, NJ
Iron Oxide Corp.	125 Front St., Elizabeth, NJ
JC Johnson, Inc.	15 West Main St., Clinton, NJ
J Landau & Company	214 Washington Ave., Carlstadt, NJ
JM Huber Corp.	Raritan Center, Edison, NJ
J.T. Baker Chemical Company	222 Red School Lane, Phillispburg, NJ
James McTague	P.O. Box 86, Glassboro, NJ
John H. Lore, Jr.	935 Kings Highway, Swedesboro, NJ
John Lucas & Company	Gibbsboro, NJ
John Pflugfelder, Inc.	Walnut St., Williamstown, NJ
Joy Oil Company	1616 S. Second St., Plainfield, NJ
Kaiser Cement & Gypsum Co.	2700 Burlington Ave., Delanco, NJ
Kart Oil & Chemical Co., Inc.	P.O. Box 203, Old Bridge, NJ
Kavanaugh and Van Fleet, Inc.	94 East Main St., Somerville, NJ
Keith Industries	527 Avenue P, Newark, NJ
Keller Engineering Corp.	110 Madison St., East Rutherford, NJ
King Oil Co.	136 Spring St., Trenton, NJ
Klitzner Oil Co.	632 S. Broad St.,Elizabeth, NJ
Koening and Sons Plastics Co.	P.O. Box 1810, Trenton, NJ
Koppers Company	Westfield, NJ
LB Dunham Co.	51 Broad Ave., Fairview, NJ
LE Carpenter Co.	Wharton, NJ
L&L Oil Company	Edwards Industrial Center, Matawan, NJ
Lakehurst Naval Air Station	Technical Sta., PMO, Lakehurst, NJ
Lakeland Regional High School	Wanaque, NJ
Langer Transport Corp.	Rt. 440 & Danforth Ave., Jersey City, NJ

Appendix B5. (Continued)

Facility Name	Facility Location
Laurie Rubber Co.	Canal St., East Millstone, NJ
Lenh and Fink Products Co., Inc.	Route 206, Belle Meade, NJ
Leigh Fuel Corporation	7th and New Brunswick Ave., Alpha, NJ
Lemonde Chemicals	1600 New York Ave., Trenton, NJ
Lever Bros.	101 River Rd., Edgewater, NJ
Lightman Drum Co., Inc.	P.O. Box 22, Berlin, NJ
Lilly Industrial Coatings, Inc.	1991 Nolte Dr., Paulsboro, NJ
Limestone Products Corp.	RD #1, Lafayette, NJ
Liquidnye Corp.	2121 Route 35, Sea Girt, NJ
Lorban Corporation	P.O. Box 75, Plainsboro, NJ
Luv Condominium	Dell Rd., Stanhope, NJ
Mac Andres and Forbes Co.	3rd and Jefferson, Camden, NJ
Mack Trucks	1120 Route 22, Somerville, NJ
Madan Plastics	370 North Ave., Cranford, NJ
Maguillian Heating and Cooling	619 Passaic Rd., Kearny, NJ
Mainland Park Lumber Co.	Lake Ave., Midland Park, NJ
Mantua Chemical Terminal, Inc.	Crown Point Rd., Thorofare, NJ
Mar-Tee Contractors, Inc.	Town Bank Rd., RFD #2, Cold Springs, NJ
Marco Products, Inc.	1400 New York Ave., Trenton, NJ
Martin & Brown Fuel Co.	17 Main St., Matawan, NJ
Marvin Jonas Inc.	Barnridge Rd., Sewell, NJ
Mazzo Oil Co.	139 Van Winkle Ave., Garfield, NJ
McCormack Sand and Gravel	Scotts Corners Rd., Plainsboro, NJ
McGuire Air Force Base	Headquarters 438 Air Base Group, McGuire Air Force Base, NJ
McNulty Heating & Fuel Oil Service	Lincoln & Pulaski Avenues, Riverside, NJ
McWilliams Forge Company, Inc.	Rockaway, NJ
Meenan Oil Co.	30 Fort Ave., New Egypt, NJ
Metaltec Corp.	Hemlock Dr., Franklin, NJ
Metro Oil and Chemical Co.	Ridgefield, NJ
Military Ocean Terminal	Foot of E. 32nd, Bayonne, NJ
Mitchell Supreme Fuel Co.	532 Freeman St., Orange, NJ
MJ Stavola Manufacturing, Inc.	Kingston, NJ
Modern Transportation Co.	75 Jacobus Ave., Kearney, NJ
Monmouth County College	West Long Branch, NJ
Monsanto Commercial Products	P.O. Box 23, Route 130, Yardville, NJ
Moore Fuels Inc.	525 N. High St., Millville, NJ
Mortenson and Coutts	35 First Ave., Atlantic Highlands, NJ
Munyan Fuel Company	725 East Broad St., Paulsboro, NJ
New Jersey Central Power & Light Co.	Milford, NJ
N. Tozzi Fuel Oil and Heating	2 Thompson St., Raritan, NJ

Appendix B5. (Continued)

Facility Name	Facility Location
Nad Earle PWO	Colts Neck, NJ
Nafec Support Services	Atlantic City, NY
National Fuel Inc.	175 Orange St., Newark, NJ
National Gypsum Company	River Rd., Florence, NJ
National Hose Co., Inc.	Richboynton Rd., Dover, NJ
National Sponge Cushion Co.	1936 East State St., Trenton, NJ
National Starch & Chemical	225 Pellville Ave., Bloomfield, NJ
Nestle Co., Inc.	Jersey Ave., Freehold, NJ
New Jersey Steel & Structural	Crossman Rd., Sayreville, NJ
Newfield Oil and Coal Co.	P.O. Box 25, Newfield, NJ
New Jersey Dept. of Transportation	1035 Parkway Ave., Trenton, NJ
New Jersey Dept. of Transportation	Kearney, NJ
NL Industries	Penns Grove, Pedricktown Rd., Pedricktown, NJ
NL Industries	P.O. Box 58, South Amboy, NJ
NL Industires	40 Avenue A, Bayonne, NJ
No. Strip Chemical Works, Inc.	P.O. Box 160, Pedricktown, NJ
Noble Automotive Chemical & Oil	Cramer Road & Route 206, Vincentown, NJ
Noise Unlimited, Inc.	104 South Bridge St., Somerville, NJ
Non Fluid Oil Corp.	298 Delancey St., Newark, NJ
Northern Fine Chemicals, Inc.	93 Main St., Franklin, NJ
Oil Processing and Storage	P.O. Box 61, Bridgeport, NJ
Oil Ways Fuel Corporation	201 Bloomfield Ave., Nutley, NJ
Olin Corp.	Paulsboro, NJ
Olt Bros. Inc.	7745 Maple Ave., Pennsauken, NJ
Owens Corning Fiberglass Corp.	Fiberglass Road, Barrinton, NJ
Oyster Creek Nuclear Plant	Ocean County, NJ
Pabst Breweries	400 Grove St., Newark, NJ
Passaic Concrete Pipe	P.O. Box 348, Pompton Lakes, NJ
Passaic Valley Oil and Supply	1050 Valley Rd., Stirling, NJ
Passaic Valley Water Treatment	Little Falls, NJ
Paulsboro Refinery	Paulsboro Refinery, Paulsboro, NJ
Pedricktown Support Facility	DFAE Fort Dix, Fort Dix, NJ
Petrolene	800 State Rd., Princeton, NJ
Petrolene Inc.	Broemel Place, Pennington, NJ
Petrolene Inc.	441 W. 2nd St., Plainfield, NJ
Petrolene Inc.	119 Harrison Ave., Roseland, NJ
Phelps Dodge Copper Products	720 S. Front St., Elizabeth, NJ
Philadelphia Refining Packaging	821 South 2nd St., Camden, NJ
Picatinny Arsenal	Headquarters, Picatinny Arsenal, Dover, NJ
Pitney Moore Mfg.	Maddock Ave., Trenton, NJ

Appendix B5. (Continued)

Facility Name	Facility Location
Plainfield Lumber & Supply Co.	403 Berckman St., P.O. Box 866, Plainfield, NJ
Plant Food Chemical Co.	Cranbury, NJ
Plessey Inc.	Frenchtown, NJ
Point Bay Fuel Inc.	334 Hawthorne Ave., Pt. Pleasant Beach, NJ
Portside Terminal Warehouse	12 Warren St., Jersey City, NJ
Premium Oil Co.	516 12th St., Hammonton, NJ
President Container Corp.	200 W. Commercial Ave., Moonachie, NJ
Princeton Chemical Research	P.O. Box 652, Princeton, NJ
Process Systems	30 Production Way, Avenel, NJ
Progressive Fuel Oil Co.	South Delsea Dr., Franklinville, NJ
Public Service Electric Gas Co.	Hendricks Causeway, Ridgefield, NJ
RB Whitaker & Son	High and McNeal Streets, Millville, NJ
Reagent Chemical	5 Factory Lane, Middlesex, NJ
Reefer Repair & Service	Foot of Howell, Jersey City, NJ
Regional Petroleum Corp.	Route 23, P.O. Box, Franklin, NJ
Reichold Chemical Company	Middlesex Ave., Carteret, NJ
Reichold Chemicals	P.O. Box 31, Hackettstown, NJ
Renzi Oil Company	212 S. Washington St., Hammonton, NJ
Research Cottrell Mfg. Div.	P.O. Box 750, Bound Brook, NJ
Rhodia Inc.	297 Jersey Ave., New Brunswick
Richards Fuel Oils, Inc.	110 South Bridge Street, Somerville, NJ
Ridgefield Oil and Chemical Co.	Ridgefield Park, NJ
Riegel Products Corp.	Milford, NJ
Riegelsville Mill	Millford, NJ
River Heights Apartments	78 Fox Rd. 2A, Edison, NJ
River Terminal Development	Port Kearny, South Kearny, NJ
Robert H. Hildebrant Oil Service	6th and Mansfield Streets, Belvidere, NJ
Ross Oil Terminal Corp.	Foot of East 5th St., Bayonne, NJ
Ross Oil Co.	511 Paul St., Vineland, NJ
Rovic Construction Co., Inc.	911 Bergen Ave., Jersey City, NJ
Royal Petroleum	Cliff Rd., Sewaren, NJ
Rutgers Oil Company	Meadow Rd., P.O. Box 1332, Edison, NJ
Salmon Oil Co., Inc.	Branchville Borough, Sussex Co., NJ
Sandoz Inc.	Route 10, East Hanover, NJ
Scientific Chemical Processing	216 Paterson Plank Rd., Carlstadt, NJ
Sea Coast Transport Inc.	P.O. Box 97H, Roosevelt Ave., Morganville, NJ
Sea Harvest Inc.	Ocean Dr., Cape May, NJ
Seaboard Manufacturing Labs	P.O. Bix 500 Universal Rd., Paulsboro, NJ
Seaboard Oil Co.	Absecon Blvd., Atlantic City, NJ
Seacoast Products, Inc.	Shore Rd., Port Monmouth, NJ

Appendix B5. (Continued)

Facility Name	Facility Location
SGC Industries	1 Biondi Ave., Cliffwood, NJ
Shell Oil	Dover Chester Rd., Randolph, NJ
Sherwin Williams Co.	Brown St. & Lister Ave., Newark, NJ
Shield Aerosol, Inc.	Turner Place, Piscataway, NJ
Shipps Fuel Company	46 Fairfield Ave., P.O. Box 5246, Trenton, NJ
Ships Inc.	2500 Broadway, Camden, NJ
Sika Chemical Corp.	875 Valley Brook Ave., Lyndhurst, NJ
Simmons Oil Co.	37 Hamburg Ave., Sussex, NJ
Solar Fuel Oil Co.	139 Ryerson Ave., Wayne, NJ
Solar Oil Sussex Inc.	P.O. Box 303, Sussex, NJ
Solvents Recovery Service	1200 Sylvan St., Linden, NJ
Somerset County College	County Rd. 24 and Lamington Rd.
St. Joe Paper Company	89 Levning St., P.O. Box 1988, South Hackensack, NJ
St. Josephs Village	Rockleigh, NJ
Stay Seal Inc.	Kingston, NJ
Staals Oil & Coal Co.	Garfield, NJ
Stabilize & Basic Pigment Co.	P.O. Box 1364, Sawmill Rd., Edison, NJ
Standard Tallow Corp.	61 Blanchard St., Newark, NJ
Staufer Chemical Company	Meadow Rd., Edison, NJ
Sterling Plastics Co., Inc.	P.O. Box 316, Windsor, NJ
Sterners, Inc.	12th Avenue, Belmar, NJ
Suburban Fuel Company	750 Route 17, Paramus, NJ
Sunoco Gas Station	Route 206 & Princeton Ave., Montgomery, NJ
Sunrise Oil Co.	170 S. Dean St., Englewood, NJ
Superior Varnish and Drier Co.	Crescent Blvd., Merchantville, Pennsauken, NJ
Sussex Regional Petroleum Co.	Old Route 23, Sussex, NJ
Swope Oil & Chemical Company	8281 National Highway, Pennsauken, NJ
Tankport Terminals	35 Caven Point Rd., Jersey City, NJ
Taylor Oil Co., Inc.	20 Franklin St., Somerville, NJ
Ted Wasky	Foot of Broad St., Pompton Lakes, NJ
The Tattersall Co.	2721 Lamberton Rd., Trenton, NJ
Thiokol Chemical Division	780 N. Clinton Ave., P.O. Box 1296, Trenton, NJ
Thomasset Colors Inc.	120 Lister St., Newark, NJ
Thompson Fuel Company	10 Memorial Dr., Neptune, NJ
Thunderhead Asphalt Plant	Box 349, Sewell, NJ
Toms River Chemical Co.	Toms River, NJ
Township of Willingboro	Dept. of Public Works, Willingboro, NJ
Transcontinental Towing Co.	335 Paterson Plank Rd., Carlstadt, NJ
Transport of New Jersey	180 Boyden Ave., Maplewood, NJ
Trap Rock Hauling	141 Central Ave., Westfield, NJ

Appendix B5. (Continued)

Facility Name	Facility Location
Trap Rock Industries Inc.	Dean Myers Mgr., Kingston, NJ
Trenton Air Propulsion Center	Trenton, NJ
Trenton Lehigh Fuel Co.	430 New York Ave., Trenton, NJ
Tri County Asphalt Corp.	311 West Main St., Rockaway, NJ
Tri Terminal Corp.	309 River Rd., Edgewater, NJ
Trodyne	39 Industrial Ave., Teterboro, NJ
Troy Chemical Corporation	One Avenue L, Newark, NJ
United Precasting Corp.	Pancoast Mill Rd., Buena, NJ
U.S. Coast Guard Training Center	U.S. Coast Guard Training Center, Cape May, NJ
U.S. Gypsum Company	P.O. Box 978, 1255 Raritan Rd., Clark, NJ
U.S. Naval Station	Leonardo, NJ
U.S. Pipe and Foundry Co.	East Pearl St., Burlington, NJ
U.S. Gypsum Co.	600 New Market Ave., South Plainfield, NJ
U.S. Pipe and Foundry	Burlington, NJ
Universal Container Corp.	Universal Rd., P.O. Box 500, Paulsboro, NJ
Universal Foods Corporation	800 Mill St., Beyleville, NJ
Universal Terminals	Port Newark, NJ
U.S. Air Force	Belle Meade, NJ
U.S. Air Force	McGuire AFB, McGuire, NJ
U.S. Air Force	Gibbsboro AFB, Gibbsboro, NJ
U.S. Army	Deputy Installation Officer, Fort Monmouth, NJ
U.S. Coast Guard	Gloucester, NJ
U.S. Mineral Products	Furnace St., Stanhope, NJ
U.S. Navy	Trenton Air Propulsion Center, Trenton, NJ
U.S. Poastal Service Meadows Bulk Mail Facility	850 Newark Turnpike, Kearny, NJ
Utsches Marine	U.S. Highway 9, Cape May, NJ
V&H Oil Company	Route 206 North, Newton, NJ
VA Hospital	Tremont Ave., East Orange,NJ
VA Hospital	Lyons, NJ
Van Savir's Fuel	311 Pennsylvania Ave., Mt. Holly, NJ
Van Varick & Sons	1067 Route 23, Wayne, NJ
WAS Terminals, Inc.	126 Passaic St., Newark, NJ
WL Rife Inc.	907 Marine Highway, Hairsport, NJ
Warren Glen Mill	Milford, NJ
Washington Polyols Basf Wyando	Pleasant View and Pershing, Washington, NJ
Welch Holmes Clark Co., Inc.	7 Avenue L, Newark, NJ
Wellen Oil Inc.	Foot of Howell St., Jersey City, NJ
Welsh Farms, Inc.	65 Fairview Ave., Long Valley, NJ
Wenzcel Tile Corporation	Klag Ave. - P.O. Box 5308, Trenton, NJ
Western Electric Co.	650 Liberty Ave., Union, NJ

Appendix B5. (Continued)

Facility Name	Facility Location
Whippany Paper Board Co., Inc.	10 North Jefferson Rd., Whippany, NJ
Winner Chemicals, Inc.	Mantua Ave., Paulsboro, NJ
Witco Chemical Corporation	1000 Convery Blvd., Perth Amboy, NJ
Witco Chemical Corporation	2 Woods St., Paterson, NJ
Worthington Pump Corporation	270 Sheffield St., Mountainside, NJ
WR Grace & Company	Nolte Dr., Paulsboro, NJ
Wtckoff Fuel Oil Co.	Route 10, Whippany, NJ
Zagorin and Son	South Park Ave., Lakewood, NJ
Zinchem, Inc.	Front & Broad Streets, Perth Amboy, NJ

Appendix B6. Major Storage Tank Facilities Within the State of New Jersey Complying With SPCC Regulations.

Product Type: 1) Petroleum; 2) Chemical; 3) Both

Name	Location	Storage Capacity (gallons)	Daily Throughput (gallons)	Product Type
Texaco	Linden	11,832,000	124,000	1
Eastern Sterling Plastics	Windsor	430,000	12,000*	3
Texaco	Newark	75,000,000	1,260,000	1
Texaco	Little Ferry	2,232,000	88,200	1
Pitt-Consol Chemicals (Conoco)	Newark	12,000,000	35,000	3
American Cyanamid	Linden	3,482,000	588,000	3
Buckeye Pipeline	Linden	88,038,000	12,843,000	1
Merck Chemical	Rahway	1,035,000	200,000*	3
duPont Chambers Works	Deepwater	22,436,000	665,280	3
Texaco	Pennsauken	49,528,000	874,679	1
Texaco, Eagle Point	West Deptford	399,000,000	3,696,000	1
Atlantic City Electric Co.	Lower Penns Neck	761,500	390,000	3
B.L. England Station	Upper Township	12,600,000	147,000	3
Middle Station	Middle Township	750,000	-	1
Cedar Station	Stafford Township	550,000	-	1
Carls Corner Station	Upper Deerfield	635,000	-	1
Mickelton Station	East Greenwich	1,680,000	-	1
Shell Oil Company	Sewaren	126,000,000	3,276,000	3
Golden Terminal	Bayonne	40,000,000	300,000	3
duPont-Repauno Plant	Greenwich	5,005,700	-	3
Shell Chemical	West Deptford	1,477,800	205,830	3
G&W Natural Research Group	Gloucester	983,000	-	3
		910,000*		
Boynton Oil	Plainfield	-	-	-
United Oil Company	Elizabeth	800,000	45,000	1
Mongan's Inc.	Sicklerville	1,100,000	3,000	1
Colonial Pipeline	Woodbury	71,400,000	2,790,744	1
Colonial Pipeline	Pennsauken	8,400,000	469,350	1
Colonial Pipeline	Linden	124,320,000	14,801,304	1
Q Petroleum	Newark	1,805,000	55,000	1
D.C. Inc.	Dover	600,000	12,000	1
Minnisink Oil Company	Whippany	1,260,000	15,000	1
Crown Central Petroleum	Elizabeth	14,656,000	445,200	2

Note: All facilities have a minimum of 400,000 gallons storage capacity.

* Pounds

Appendix B6. (Continued)

Name	Location	Storage Capacity (gallons)	Daily Throughput (gallons)	Product Type
Linden Chlorine	Linden	8,447,000 800,000*	1,600,000*	3
Cities Service	Petty I.	48,846,000	546,000	1
Mobil	Paulsboro	350,248,270	4,200,000	3
Petrolene (Amoco)	North Brunswick	570,000	15,000	1
Texaco	Bayonne	77,406,000	2,016,000	1
duPont-Grasseli Plant	Linden	2,479,200	44,100	3
Northern N.J. Oil	Newark	2,000,000	100,000	1
Charles J. McNulty, Inc.	Burlington	2,600,000	50,000* 200,000	1
Duell Fuel Company	-	1,600,000	16,000	1
Gulf Oil	Trenton	9,682,638	147,945	1
Reichhold Chemical, Inc.	Elizabeth	926,000	475,000*	2
Kelways Inc.	East Rutherford	4,200,000	30,000	1
Midland Glass	Matawan Township	1,022,875	26,291	1
Exxon, Bayway Refinery	Linden	425,664,540	201,470	3
Exxon	Hackensack	3,208,657	87,000	1
Exxon	Paulsboro	67,389,789	1,963,960	1
Exxon	Flemington	2,964,948	127,000	1
Exxon	Atlantic Highlands	3,645,379	25,000	1
Monsanto	Bridgeport	4,300,000	228,000	3
Colgate-Palmolive Company	Jersey City	2,513,000	87,690	3
Metropolitan Petroleum Co., Tankport	Jersey City	54,600,000	550,000	1
Ashland Chemical Company	Newark	7,250,000	430,900*	3
Mobile Pipeline	Plainfield	Minor storage (Paulsboro)	2,714,250	1
Exxon	Bayonne	315,000,000	5,334,000	3
Exxon	Interplant Pipeline	-	Transfer only	1
Hercules Inc.	Parlin	3,530,109	93,970*	3
Arco	Newark	27,636,000	442,000	1
Woodruff Oil	Bridgeton	2,000,000	40,000	1
Reinauer Bros.	Mahway	410,000	6,000	1
Tenneco	Fords	1,802,500	100,000	3
Jersey Central P&L	Milford	25,613,000	210,900	1
Jersey Central P&L	Lebanon	1,152,000	15,700	1
Jersey Central P&L	Sayreville	16,303,000	343,600	1

Appendix B6. (Continued)

Name	Location	Storage Capacity (gallons)	Daily Throughput (gallons)	Product Type
Jersey Central P&L	South Amboy	6,881,000	78,000	1
Ashland Chemical Company	Fords	1,514,524	230,000*	3
BP Oil	Linden	74,038,650	2,090,298	1
Ingersol Rand Company	Phillipsburg	1,222,782	-	3
FMC	Carteret	714,550	28,400	3
Crown Oil	Chatham	710,000	24,000	1
Essex Chemical Corp.	Clifton	900,000	54,600	2
L.S. Riggins Oil Company	Millville	673,800	6,062	1
Rutgers Oil Company	Edison	897,635	18,000	1
Ashland Chemical	Newark	406,113 4,000*	-	3
Croda Storage	-	3,500,000	-	3
Western Electric	Kearney	840,000	-	3
Gatx Terminal Corp.	Carteret	195,132,000	2,499,000	3
Gatx N.J. Terminal Corp.	Carteret	44,520,000	441,000	3
Union Carbide	Bound Brook	11,817,000	180,000*	3
Chevron	Perth Amboy	336,000,000	7,056,000	3
Spartan Terminal Co.	Dover	4,000,000	31,022	1
Chevron Marketing	Perth Amboy	8,316,000	46,000	1
Stepan	Fieldsboro	695,000	500,000*	3
duPont	Carney's Point	1,093,000	43,260	3
Grace Oil Company	Wildwood	942,000	27,900	1
Owens Illinois	Bridgeton	1,742,000	-	3
Personal Products	Milltown	708,000	10,000	3
Gulf Oil Refining & Market.	Linden	81,614,289	703,000	1
Allied Chemical	Elizabeth	3,415,475	1,383,954	3
Shotmeyer Bros.	Hawthorne	2,310,000	18,000	1
BP Oil Company	Paulsboro	13,497,960	357,000	3
Central Bergen Heating & Air Conditioning	Hackensack	840,000	4,600	1
Celanese Chemical Co.	Newark	9,000,000	2,000,000*	2
duPont	Parlin	555,700	40,236	3
B.F. Goodrich	-	783,000	30,000	3
Gibersons Inc.	Atlantic City	600,000	10,000	1
Mantua Chemical Term.	Paulsboro	13,440,000	322,200	3
Mobil	Linden	12,554,094	621,600	1
Mobil	Trenton	4,356,000	182,000	1

Appendix B6. (Continued)

Name	Location	Storage Capacity (gallons)	Daily Throughput (gallons)	Product Type
Mobil	Atlantic City	2,145,000	28,000	1
Mobil	Paulsboro	2,856,000	483,000	1
Pt. Bay Fuel Company	Lakewood	685,000	11,583	1
Nassau Oil Company	Princeton	540,000	29,000	1
Pedroni Fuel Company	Vineland	1,370,000	20,000	1
Phillips Fuel Company	Hackensack	1,850,000	70,000	1
Sun Oil	Hackensack	577,500	16,000	1
Sun Oil	Newark	27,287,400	3,150,000	1
Sun Oil	Piscataway	3,990,000	292,000	1
PSE&G	Newark	9,748,882	-	3
PSE&G	Jersey City	6,417,925	-	3
PSE&G	Burlington	10,000,000	-	3
PSE&G	National Park (not a major facility)	212,560	-	1
PSE&G	Bayonne	424,000	-	1
PSE&G	Jersey City (Marion generator)	Satelite Station minor storage	126,000	1
PSE&G (gas plant)	Jersey City	6,315,400	706,500	1
PSE&G (gas plant)	Edison	7,132,500	859,900	1
PSE&G	Sewaren	9,240,000	-	-
PSE&G	Edison	5,250,000	-	-
PSE&G	Salem	1,279,195	-	-
PSE&G	Linden	12,516,000	-	-
PSE&G	Kearny	11,550,000	-	-
PSE&G	Ridgefield	14,200,000	-	3
PSE&G (gas)	Harrison	15,919,907	1,216,402	-
PSE&G (gas)	Paterson	2,614,300	482,300	1
PSE&G	Trenton	2,165,000	-	-
PSE&G (gas)	Trenton	1,924,000	295,000	1
PSE&G	Linden	6,334,500	-	1
Outerbridge Terminal	Perth Amboy	46,200,000	252,000	3
White Meadow Petroleum	Rockaway	3,200,000	30,000	1
Schering-Plough	Union	527,000	-	3
U.S. Metals Refinery	Carteret	1,800,000	-	3
Cities Service	Linden	3,371,000*	100,000*	1
	TOTALS:	3,611,298,971 5,085,000*	87,141,310 5,741,910*	

Appendix B7. Reported Spills Which Have Occurred Within New Jersey During 1976.

Date	Location	Name	Product	Approximate Amount (gallons)	Cause
1- 5	Hopatcong	White Meadow Petroleum Co.	Fuel oil	500	Truck accident
1- 7	Bayonne	Preus & Sons	Waste oil	Truck load	-
1-12	224 W. Hanover, Trenton	Koening Oil Co.	#2 fuel oil	20	-
1-19	Sayreville	Crajack Truck	Ethylene dichloride	500	-
		Hexcel Co.	Sodium hydroxide	100	-
1-20	Westville	Texaco Service Station	Slop oil	100*	-
1-28	West Orange	-	#2 fuel oil	300	Truck accident
1-31	Atlantic City	Coraluzzo Fuel Co.	#2 fuel oil	25	-
2- 4	Union	Sunoco Service Station	Gasoline	50	-
2- 6	Berlin	Enterprise Container Co.	90% caustic; 10% other chemicals	500	Continuous and intentional discharge
2-13	Lake Hopatcong	Minnisink Oil Co.	#2 fuel oil	150-175	-
2-24	Rt 130 and Washington Avenue, No.Brunswick	Gulf Service Station	Gasoline	20	-
2-27	Salem	PSE&G Salem Generating Station	Lube oil	20- 25	-
3- 1	New Egypt, Plumsted	Meenan Oil Co.	#2 fuel oil	1,500-1,800	Storage leak (above ground)
3- 7	Lakewood Township	Fluid Chemical	Cosmetic waste	-	-
3- 9	Englewood, Hackensack	Sunrise Oil	Diesel	30	Truck accident
3-19	Sayreville	Northern Fine Organic	#2 fuel oil	25	Storage leak (above ground)
	West Deptford	Texaco Eagle Point Station	-	-	Continuous and intentional discharge
3-26	88 Main St., Sayreville	Hexcel Chemical Co.	Ethylene dichloride	20	Transfer hose leak
4- 6	West Deptford	Texaco Eagle Point Station	#6 fuel oil	40- 50	-
4-24	Old Waterworks Rd., Old Bridge	CPS Chemical	Triethylene glycol	3,000	Railroad tank car spill
	Old Bridge	Kart Oil & Chemical Co.	Waste oil	15	-
4-30	Flemington	Boss Ginco Truck Lines	Diesel	75	-

Appendix B7. (Continued)

Date	Location	Name	Product	Approximate Amount (gallons)	Cause
5-17	Kearney	Nicholas Inc.	Gasoline	8,500	Truck accident
5-22	Main and Artur Streets, Sayreville	Shell Oil Service Station	Gasoline	1,000	Tank truck spillage
5-24	Rt. 526, Jackson Township	-	Oil or chemical wastes	3,850	Deliberate dumping
6- 3	Ridgefield	PSE&G Exxon Service Station	#6 fuel oil	500	Truck accident
6-12	N.J.Turnpike Exist 11, Elizabeth	Exxon Service Station	Gasoline	100	-
6-14	Salem and Rancoccas Road, Willingboro	Getty Service Station	Gasoline	-	Storage tank leak (below ground)
6-17	Newman and Spring Streets, Red Bank	Exxon Service Station	Gasoline	50	-
	Baird and Kings Highway, Mt. Ephraim	-	-	-	Transfer pipe leak
6-22	Milton	Lake Tepero Service Station	Gasoline	-	Storage tank leak (below ground)
6-23	Rt. 4, Fort Lee	Exxon Service Station	Gasoline	600	-
6-25	Trenton State Hospital,	Kaufman-Minteer Truck	#6 fuel oil	100	-
7- 8	Murray Hill Pky. and Madison Circle Drive, East Rutherford	-	Drums of Mobil solvent	20	Deliberate dumping
7- 9	Mays Landing Rd. (Broad St.), Vineland	Major Petroleum	#2 fuel oil	100-150	Truck accident
7-14	Rt. 36 and Wilson Avenue, Fort Monmouth	Gulf Service Station	Gasoline	-	Storage tank leak (below ground)
7-15	Brielle	Exxon Service Station	Gasoline	-	-
7-16	Croxton Yards, Secaucus	Conrail Tank Car	Chlorosulponic acid	5- 10	-
7-18	Kearney	BASF	Dioctal phthalate	20	-
8-17	Lumberton	Bernico Co.	Heating oil	200	-
8-20	Pennington	E. Oostdyk Trucking Co.	Acrysol ASE-60	200	-
8-26	Logan	Rollins Environmental Serv.	Waste chemicals	-	-

Appendix B7. (Continued)

Date	Location	Name	Product	Approximate Amount (gallons)	Cause
9- 2	Pedricktown	-	Waste oil	-	Deliberate dumping
9- 3	Rt. 47, Dorchester	Getty Service Station	do	-	do
9- 7	9th and Bay St., Ocean City	Exxon Service Station	Gasoline	-	Storage tank leak (below ground)
	Englishtown	Meenan Oil Co.	Fuel oil	1,650	do
9-15	Rt. 20, Cherry Hill	Taylor Rental	Waste oil	-	Deliberate dumping
9-20	Bay Shore Rd., Cape May	Sunoco Service Station	Gasoline	2,000	Storage tank leak (below ground)
9-22	Front Street, Camden	RCA	PBC	190	-
9-29	Westhampton Township	B.P. Oil Co.	Gasoline	200	Truck accident
10- 4	Dumont	Sun Oil Co.	Gasoline	30	-
10- 7	Newark	Chemtrol Inc.	Waste chemicals	-	Deliberate dumping
10-14	Garden State Pky., South Amboy	Cheesequake Service Station	Gasoline	400-500	-
	2215 N. Delsea Drive, Vineland	D&B Auto Body	#2 fuel oil	200	-
10-15	White Horse Pike, Elwood	Exxon Service Station	Gasoline	400	Storage tank leak (below ground)
10-19	Linden	Kart Oil	#6 fuel oil	5,500	Truck accident
10-22	Rt. 1, South Brunswick	Oakdale Village	Kerosene	300	-
10-23	436 Doremus Ave., Newark	Sun Oil	Gasoline	25,000	Storage tank leak (below ground)
10-26	Rt. 1 and Finnigans Lane, South Brunswick	Shell Service Station	Gasoline	300	-
10-30	Mt. Laurel	Hanover Trail Steak House	#2 fuel oil	7,000	-
11- 3	Spotswood	Inland Container Corp.	-	-	Continuous and intentiona discharge
11- 5	Rt. 23, Wayne	Archie Metal Industries	Acid	500	-
11-22	Rt. 31, Readington	Seaboard Tank Lines	Hot tar	3,000	-

Appendix B7. (Continued)

Date	Location	Name	Product	Approximate Amount (gallons)	Cause
11-27	Leesburg	Leesburg State Prison	#6 fuel oil	2,800	Overfill of underground tank
11-30	Rt. 526, Clarksburg	Private home	Gasoline and oil	250	Citizen dumped oil and gas into excavation
	Bergen	Exxon Co.	#2 fuel oil	400	-
12- 6	Rt. 23, Franklin	Exxon Service Station	Gasoline	-	Storage tank leak (below ground)
12- 7	285 Highland Cross Rd. Rutherford	-	Chemicals	-	Deliberate dumping
	Elizabeth	Conrail track	LPG	-	Railroad tank car leak
12- 9	Orchard Street, Newton	Shippers Service	#2 fuel oil	275	-
12-15	Old Bridge	Board of Education	Waste oil	250	Tank truck spillage
12-22	Phillipsburg	Erie Lackawanna Railroad	Diesel	50	Leak in transfer pipe valve
12-23	Little Egg Harbor Township	Cumberland Farms Service Station	Gasoline	50-100	-
	Wayne	Hess Service Station	Gasoline	50- 75	-
12-24	Newark	-	#2 fuel oil	1,000	-
12-28	436 Doremus Avenue, Newark	Sun Oil Co.	Gasoline	75	-
12-29	Lebanon Township	Jersey Central Power	Hydrochloric acid	400	-
12-30	100 Bergen Street, Newark	College of Medicine and Dentistry	#6 fuel oil	3	-

Appendix B8. Reported Spills Which Have Occurred Within New Jersey During 1977 (January-June).

Date	Municipality	Name and Location	Product	Approximate Amount (gallons)	Cause
1- 3	South Amboy	Exxon Service Station Route 35	Gasoline	1,500	-
1- 6	Moonachie	Helm Express -	Ethylamine	55	-
1-10	Hammonton	Agway Petroleum -	#2 Fuel oil	10	-
1-11	Patterson	Sunoco Service Station -	Gasoline	20	-
1-14	Newark	Northern N.J. Oil Co. 2150 McCarter Highway	#2 Fuel oil	20	-
1-15	Hillside	United Oil Co. 100 Central Avenue	#4 Fuel oil	200	-
1-19	Bellville	Northern N.J. Oil Co. -	#6 Fuel oil	25	-
1-19	Pennsauken	Cities Service Oil Co. Petty Island	#2 Fuel oil	42,000	-
1-21	Bellville	Mitchell Supreme Fuel Oil Co. -	#2 Fuel oil	100	-
1-25	Port Monmouth	Homeowner -	#2 Fuel Oil	200	Homeowner disconnected line
1-26	Kearney	- Schyler Avenue	Butyl Terylate Hexyl Acrylate	3,500 2,500	Truck accident

Appendix B8. (Continued)

Date	Municipality	Name and Location	Product	Approximate Amount (gallons)	Cause
1-27	Gibbstown	-	Oil of aniline	5,000	-
1-31	Hammonton	A. Berenato Premium Oil -	Gasoline	50-60	-
2-2	Newark	United Oil Co. Fort Street	#2 fuel oil	900	-
2-3	Berkeley Heights	- -	Chrome, zinc chloride	1,000 - 2,000 per week	Continuous and intentio discharge
2-4	West Windsor	Strickland Transfer Co. -	Acid and chlorine	-	Truck accident
2-4	Allentown	Sun Oil -	Gasoline	1 - 15	-
-	Rahway	Merck -	PCB	30	Transformer failure
2-8	Raritan	Agway Oil Co. Route 523	#2 fuel oil	500	-
2-9	Mays Landing	- Cologne Rd. and Black Horse Pike	Ink, paint, acids, and weed herbicides	55 gal. drums	Deliberate dumping
2-10	South Orange	Gulf Oil Corp. -	Gasoline	800	-
2-11	Flemington Junction	Agway Oil Co. Route 523	#2 fuel oil	100	Underground tank leak

Appendix B8. (Continued)

Date	Municipality	Name and Location	Product	Approximate Amount (gallons)	Cause
2-11	East Orange	Exxon Service Station Central and Cambridge Street	Gasoline	-	Underground tank leak
2-17	Ship Bottom	Exxon Service Station Long Beach Blvd. and 9th Street	Gasoline	450	Underground tank leak
2-22	Wayne	Chevron Service Station Hamberg Turnpike	Gasoline	2,500	-
2-28	Kearney	- -	Asphalt	6,500	Truck accident
3-29	Matawan	- Route 3 and Juniper Place	Asphalt	200 - 300	-
3-10	Franklin	- 534 Hamilton Avenue	Trichloroethane and Perchloroethane	Twelve 55 gal. drums	Deliberate dumping
3-10	South Gouldtown	- -	MCN 250	300 - 500	Deliberate dumping
3-13	Bayonne	Howard Oil Co. Foot of 5th Street	#6 fuel oil	2,000	-
3-14	Eatontown	Diva Inc. 607 Industrial Way West	Copper chloride, sodium hydroxide, potassium hydroxide sulphuric acid, and ammonia persulfate	-	Deliberate dumping
3-15	Raritan	Roche Clinical Labs South Johnson Drive	Gasoline	100	-

Appendix B8. (Continued)

Date	Municipality	Name and Location	Product	Approximate Amount (gallons)	Cause
3-17	West Windsor	Getty Service Station Route 571 and Cranbury Road	Gasoline	-	-
3-18	Edison	Coastal Tank Lines -	Gasoline	1,500	-
3-22	Whippany	- Holmstead Road	#2 fuel oil	142	Storage tank leak (bel ground)
3-22	Bordentown	- -	Diesel oil	40	Truck accident
3-23	Oaklyn	Rite Aid Pharmacy Route 30 and Cedar Avenue	#2 fuel oil	-	-
3-23	Patterson	Exxon Service Station Straight and Morton Streets	Gasoline	-	-
3-29	Edison	Railroad Raritan Center	Turpentine	-	-
3-31	Blenheim	Exxon Service Station Black Horse Pike	Gasoline	-	Storage tank leak (bel ground)
4-1	Middletown	Hess Service Station Route 35	Gasoline	4,400	-
4-9	Edison	- -	Gasoline	225	Storage tank leak (bel ground)
4-13	Haledon	N. J. Sak Chemical Co. (Sibron Corp.)	Ethyl acrylate	2	-

Appendix B8. (Continued)

Date	Municipality	Name and Location	Product	Approximate Amount (gallons)	Cause
4-16	Mays Landing	- Black Horse Pike	Waste chemicals	Thirty-five 55 gal. drums	Deliberate dumping
4-18	Ledgewood	Goodyear Tire Store 1014 Route 46	Waste oil	75	-
4-19	Berkeley Township	Denzer & Schaeffer (Berkeley Photo)	Silver, zinc, chrome, and phenols	1,000 - 2,000 per week	Discharge into an abandoned well
4-20	Montville	Fairclough Oil Co. Route 202	#2 fuel oil	-	Sloppy operations
4-26	Edison	- -	Sludge, paint waste	8,000	-
4-27	Clifton	Peoples Auto Service 1313 Main Avenue	Gasoline	1,100	Storage tank leak (below ground)
4-29	Windsor	Eastern Sterling Plastics Corp. Main Street	Styrene	400	-
5-2	Wayne	Wayne Diagnostic Center -	Gasoline	-	Storage tank leak (below ground)
5-5	Dover	- -	Phenols	Concentration 3 ppm	Detected in private well
5-6	Bayonne	Beacon Oil Co. 654 Broadway	#2 fuel oil	25	-
5-10	Bound Brook	- -	Fuel oil	50	-

Appendix B8. (Continued)

Date	Municipality	Name and Location	Product	Approximate Amount (gallons)	Cause
5-11	Closter	Getty Service Station -	Oil	Bubbling out of ground	Storage tank leak (below ground)
5-14	Pennsauken	Matlack Truck -	#2 fuel oil	15	-
5-17	Maplewood	Shell Gas Station 1611 Springfield Avenue	Gasoline	1,000	Storage tank leak (below ground)
5-20	Clarksboro	- -	#2 fuel oil	-	-
5-23	Bayonne	Bayview Exxon Kennedy Blvd.	Gasoline	200	Storage tank leak (below ground)
6-1	Dunellen	National Starch & Chemical Co. -	Water-soluble latex	30	-
6-2	Scotch Plains	Shell Station Route 2 and Scotland Road	Gasoline	500	Storage tank leak (below ground)
-	West Deptford	Colonial Pipeline -	Gasoline	3 - 400	-
6-10	Westfield	Tuscan Dairies -	Diesel fuel	25	-
6-15	Fort Lee	Shell Station Route 5	Gasoline	30	-
6-16	Little Ferry	Olympic Freight Bellview, Washington	Alcohol	100	Truck accident

Appendix B8. (Continued)

Date	Municipality	Name and Location	Product	Approximate Amount (gallons)	Cause
6-17	Montvale	Montvale Shell Kindea Kamack and Magnolia Rds.	Gasoline	500	Storage tank leak (below ground)
6-20	Roxbury	Hercules Inc. -	60 percent sulfuric acid	-	-
6-20	Waretown	Sunoco Station South Main St. and Route 9	Gasoline	50 - 100	-
6-22	Old Bridge	Gold Leaf Transport -	PCB oil	185	Deliberate dumping
6-22	Edison	Shell Station Route 27 and Plainfield Avenue	Gasoline	500	Storage tank leak (below ground)
-	Branchville	State Highway Dept. Storage Facility, Route 206	NaCl	-	Runoff from NaCl piles at garage and facilities
6-22	Metuchen	ConRail Main Street Station	Caustic soda	-	-
6-27	Denville	- Garden State Road	Asphalt, AC-20	1,100	Truck accident
6-28	Carlstadt	Arsynco Industries Foot of 13th Street	Toluene	200	Storage tank leak (above ground)
7-1	Bound Brook	B.G. Pratt Co. Div. of Gabriel Chemical -	Vapam	10	-

Appendix B8. (Continued)

Date	Municipality	Name and Location	Product	Approximate Amount (gallons)	Cause
7-6	Morris Plains	Brouan Transfer Co. -	Gasoline	100	-
7-9	Port Elizabeth	Maher Chemical -	Monochloroacetaldehyde	65 kilograms	-
7-11	Newark	PSE&G -	Mineral oil	3,900	-
7-12	Clifton	Beecham Products -	Cyclopool 3BS A-30 (detergent)	15	-